National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Monitoring Freshwater Systems in the Southwest Alaska Network

Standard Operating Procedures

Natural Resource Report NPS/SWAN/NRR—2015/925.1

ON THE COVER
Photograph of Upper Twin Lake in Lake Clark National Park and Preserve, Alaska.
Photograph courtesy of Kent Miller

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Contents

[1] Pages in the SOP document are numbered as SOP#-# (e.g. SOP1-1, SOP1-2, SOP1-3, etc.).

Executive Summary

The Southwest Alaska Network (SWAN) is one of four networks established within Alaska as part of the National Park Service (NPS) Inventory and Monitoring (I&M) Program. It consists of five units of the NPS (Figure 1): Alagnak Wild River (ALAG), Aniakchak National Monument and Preserve (ANIA), Katmai National Park and Preserve (KATM), Kenai Fjords National Park (KEFJ), and Lake Clark National Park and Preserve (LACL). Collectively, these units comprise 3.8 million hectares (9.4 million acres) and extend over 650 km (400 miles) of the Alaska and Kenai Peninsulas.

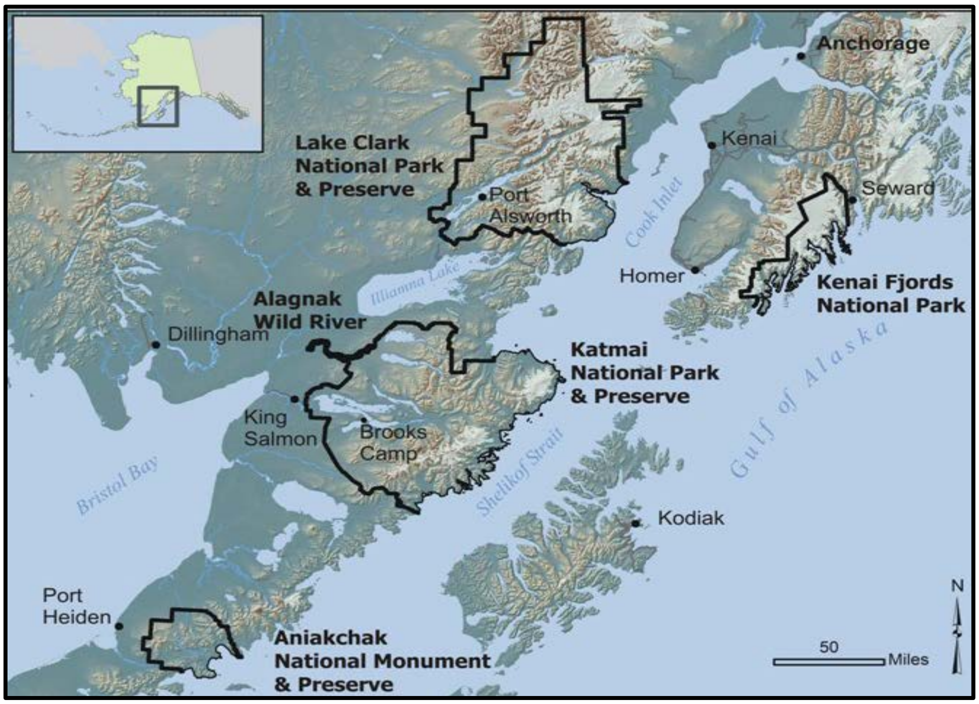

Figure 1. Map of park units included within the Southwest Alaska Network.

The Vital Signs Monitoring Program was established in 2001 to assess the status and trends in selected resources representing the overall health of the park. These resources are considered especially vulnerable to alteration by stressors, or they have important human values. Understanding the range of natural variation in park ecosystems serves as a basis for detecting long-term changes to park resources, and informs management decisions towards maintaining the integrity of park ecosystems. During monitoring development workshops, scientists from universities and state and federal agencies identified surface hydrology and freshwater chemistry as two resources of aquatic systems that warranted long-term monitoring in SWAN park units (Bennett et al. 2006).

These standard operating procedures (SOPs), and the associated protocol narrative (Shearer et al. 2015), provide in-depth information on monitoring water quantity (surface hydrology) and water quality (freshwater chemistry) in aquatic systems within the SWAN. The SOPs are meant to provide step-by-step instructions for all tasks associated with field preparation and safety, instrument programming and use, data collection, processing, and management, quality control, analyses, and reporting.

Acknowledgments

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SOP1: Field Season Preparation and Safety

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

Suggested Reading

Lane, S. L., and R. G. Fay. 1997. Safety in field activities. Chapter A9 *in* National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9.

National Park Service. 2008. National Park Service Occupational Safety and Health Program, reference manual 50B. U.S. Department of the Interior, Washington D.C.

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Introduction

This standard operating procedure (SOP) summarizes activities needed to prepare for the field season, as well as safe conduct during the field season. Pre-season activities include obtaining research permits for each park, scheduling field trips, assembling equipment and supplies, preparing field folders, and completing required and recommended training. Conducting field activities in remote areas, such as SWAN parks, poses many challenges. Safe and effective protocol implementation depends on the expertise and care of project personnel, and on familiarity with and adherence to standard operating procedures. Safety is the first priority in all field activities, and is best ensured through a proper mental attitude, adequate training, and ongoing attention to potential safety issues.

Field Season Preparation

This section outlines tasks, in approximate chronological order, required in preparation for the field season. Field season preparation starts with completion of the previous field season when SOPs and data collection techniques are evaluated, and extends through proper training of field crew staff. Table 1.1 provides a summary of these tasks and a general timeline for their completion.

Protocol and Data Review

The first step in planning for the upcoming season is reviewing the previous year's activities and data, including laboratory results and field notes, to identify any potential problems. This should include plotting water quality data to identify suspect data points that may indicate equipment instability or contamination. It should also include reviewing SWAN-specific Job Hazard Analyses (JHAs) to ensure that, as SOPs change, hazards are still mitigated. Identified potential problems with the SOPs or data can be addressed with increased training or supervision, or through procedural changes.

Research Permit Acquisition

A Scientific Research and Collecting Permit must be obtained for each project and from each park in which field work will be conducted. The permit must be issued before any work can be done within a park unit. The permit process can be initiated through the Research Permit and Reporting System website at https://irma.nps.gov/rprs/Home. Investigators will be asked to choose a username and password. The username and password should be retained for future use.

Unless the project is new, the Principal Investigator (PI) will simply apply to renew the permit. If the project is new, a new permit request must be filed. The website provides instructions for applying for a new permit and renewing an existing permit. To satisfy the conditions of the research permit, the PI must complete an Investigator’s Annual Report (IAR) through the permit website. This report must be written annually upon completion of the field season. Permit renewals will not be issued until the IARs are completed.

Field Trip and Training Schedule

Field trip scheduling must be coordinated with park staff well in advance of the field season to ensure availability of quarters for crew, availability of park vehicles for transportation, and availability of park staff for assistance. The project leader also should make advance arrangements with charter aircraft companies and those conducting training activities (Table 1.2).

Table 1.1. Approximate timeline of tasks to prepare for field work.

Time Period	Task	Person Responsible for Task
Fall / Winter	Review SOPs and datasets, and revise SOPs as needed.	Project leader
February	Obtain Scientific Research and Collecting Permit(s) from each park unit where field work is planned.	Project leader
March	Create a preliminary schedule of field trips and training activities with approximate sampling dates.	Project leader
March	Order necessary supplies, such as water quality instrument calibration solutions.	Hydrologic technician
March / April	Check equipment for proper working order and make repairs as needed.	Hydrologic technician
April / May	Complete all required and recommended safety training.	Project leader and hydrologic technician
April / May	Confirm draft schedule of field activities with park staff and revise if necessary.	Project leader
April / May	Submit lodging and flight requests with each park unit where field work is planned.	Project leader and hydrologic technician
May	Assemble field folder containing maps, datasheets, site lists, copies of research permits, etc.	Hydrologic technician
Late May / Early June	Complete operational training for water quality and hydrology sampling.	Project leader and hydrologic technician
Fall	Inventory supplies and equipment and make a list of anticipated repairs.	Hydrologic technician

Supplies and Equipment Inventory

Supplies and equipment should be inventoried well in advance of the field season. Consult the checklists found in the SOPs while performing the pre-season inventory (Table 1.3). All equipment should be checked for wear and repaired or replaced as necessary. Calibrate multiparameter sondes as described in SOP3, and measure core parameters from a fresh bucket of lake water. If any reported parameters are outside the expected range, determine the cause of the erroneous readings and return the instrument to its manufacturer for repair, if necessary. If time permits, conduct a post-season inventory in the fall before storing supplies and equipment for the winter.

Table 1.2. Trainings activities required and recommended for SWAN personnel.

Training	Duration	Renewal	Location
Basic aviation	8 hours	Every 3 years	Check with park pilots
Dunker	8 hours	Once	KATM
Bear safety / firearms	8 hours	Annually	KATM / LACL / AKRO
Boat operator (MOCC)	32 hours	Every 3 years	KATM / LACL
Defensive driving	8 hours	Every 3 years	
Cardiopulmonary resuscitation (CPR)	8 hours	Every 3 years	See http://www.redcross.org/take-a-class
Wilderness first aid	2–10 days	Every 3 years	See http://www.redcross.org/take-a-class

Field Folder Assembly

Important reference information for each sampling station is kept in a field folder that is taken on every field trip. Field folders will contain at a minimum the following:

- A map of the location(s) to be sampled with sampling site coordinates. Include a bathymetric map if available.
- A field laptop with updated software, digital datasheets, and sampling site coordinates.
- A hard copy of any relevant datasheets, printed on "write-in-the-rain" paper, to be used as back-up.
- A hard copy table of sampling site coordinates.
- All SOPs relevant to field data collection (SOPs 1, 3–8).
- The field notebook maintained by the field crew leader.
- A copy of the Research and Collection permit.
- A list of emergency phone numbers (e.g., for office contacts, medical facilities).

Operational Training

Operational training in field methods will consist of review of SOPs 3–9 and freshwater JHAs, and practical exercises in sampling and data collection. Quality control procedures will be emphasized at every step in training. Training will be conducted by the SWAN aquatic ecologist and hydrologic technician, with the assistance of KATM and LACL fisheries biologists during the first week of field activities. Most often, these personnel will comprise the field crew. As such, operational training will provide an opportunity to refresh methodologies and techniques used during the previous field season. During this training, personnel should run through procedures for water quality instrument calibration, vertical lake profiles and in-situ sample collection, and wadeable and non-wadeable discharge measurement.

Table 1.3. Equipment checklists found in various SOPs.

SOP	Equipment List	Location
SOP1	Checklist of safety gear for freshwater monitoring activities	Table 1.4
SOP3	Checklist of equipment and supplies for calibrating multiparameter sondes	Table 3.2
SOP4	Checklist of field equipment and supplies for water quality monitoring	Table 4.1
SOP5	Checklist of field equipment and supplies for wadeable discharge measurement	Table 5.1
SOP6	Checklist of field equipment and supplies for boat-based discharge monitoring	Table 6.1
SOP7	Checklist of equipment needed to install level loggers and barologgers	Table 7.2
SOP8	Supplies needed to build a moored temperature array	Table 8.2
SOP8	Checklist of tools needed to assemble a moored temperature array	Table 8.3
SOP8	Checklist of equipment needed to deploy a moored temperature array	Table 8.4
SOP9	Checklist of equipment for decontamination of AIS at remote and non-remote locations	Table 9.2

Safety

Conducting safe field sampling trips is best assured through compliance with Federal and Park safety regulations and adequate trip planning, which includes filing a trip plan and developing contingency plans to identify and handle potential hazards. Most of all, safety in the field is best assured by all field crew members maintaining a positive mental attitude.

Safety Procedures

The project leader is responsible for ensuring that all activities are conducted in compliance with the Department of Interior and the Occupational Safety and Hazard Administration safety procedures. Additionally, the project leader will ensure that all employees understand and follow safety policies and procedures, and that all field personnel have completed emergency contact forms.

The trip plan is an important tool in the overall trip planning process. It also contains valuable information for others who may need to provide assistance in the event of an emergency. SWAN currently uses a trip plan form developed by the Alaska Region Communications Center (ARCC) ─ a.k.a. “Denali Dispatch” or “Denali Comm. Center” (Figure 1.1). Blank forms and instructions are located on the T Drive (T:_Program_Management\Field_Operations\Emergency_Plans\ Blank_Forms_Instructions\2014). Copies of completed forms should be emailed to dena_commcenter@nps.gov (if in LACL), katm_dispatch@nps.gov (if in KATM), the SWAN project and program leaders, and any other interested staff in the park where field activities will be conducted.

Clear Form

ARCC
AK Region Float Plan

Dates of Mission	Check-In Times	Park:	Radio Identifier:
to	AM Check-In: PM Check-In:		(Use when contacting 700.)

Leader

Trip Leader Name:	Supervisor Name:
Trip Leader Phone:	Supervisor Phone:
Trip Leader Sat:	SPOT, PLB or EPIRB (Serial or Name): (#)

Party Information

Party Member Name:	Party Member Clothing Color:

Vessel Information

Vessel

Name:	Length:
Color:	Make:
Additional Markings:	Type:
	Days of Food:
	Gallons of Fuel:

Additional Transport.

☐ Aircraft
(You MUST file a flight plan.)
N-Number:

☐ Additional Watercraft
(You MUST file separate float plan.)
Name:

☐ Car or Truck
Make:
Model:
Color:
Plate:
Location:

Additional remarks:

Mission

Mission purpose and objectives:

Equipment

☐ Compass	☐ Space Blanket	☐ Marine VHF Radio	☐ USCG Req. Equip.
☐ Signal Mirror/Flares	☐ PFD	☐ NPS Radio	☐ Vessel Mounted EPIRB
☐ Whistle	☐ Survival Kit	☐ Maps or Charts	☐ Weapon(s):
☐ Immersion Suit	☐ Sat Phone:		

Description of additional clothing and equipment (jacket, tent, pack, etc.).

Detailed Itinerary/Comments

Include detailed route information, via points, etc.

Dispatch

Primary Dispatch	Dispatch Transfer Information		Brief Comment (Use box above for additional details):
ARCC	Transfer To ARCC: Date: *Time:	Transfer From ARCC: Date: *Time:	

PHONE: (907) 683-9555 **EMAIL: DENA_CommCenter@NPS.GOV** **FAX: (907) 683-9640**

Sat Phone: 8816-3145-8390 Mobile Phone: (907) 378-5751

Figure 1.1. Blank trip plan form, developed by the Alaska Region Communications Center (ARCC) and required for all SWAN freshwater monitoring activities.

Field trip planning should include checking the weather for potential storms and remaining alert for changing weather conditions, querying personnel at the Parks for information on potential hazards in the area to be sampled, and ensuring that all safety equipment in the Safety Checklist (Table 1.4) is taken to the field.

Safety Hazards

The greatest hazards encountered in sampling SWAN lakes and rivers are those associated with boat and plane transport, which are addressed in the required boating safety and aircraft training (Table 1.2). Other important hazards include wildlife encounters and severe weather, and lesser hazards associated with chemicals and drinking water.

Table 1.4. Checklist of safety gear for freshwater monitoring activities.

Personal Gear	
☐	Appropriate footwear (rubber boots and/or waders)
☐	Hat, gloves
☐	Insect repellent and/or bug headnet
☐	Extra clothing (wool or synthetic) and rain gear
☐	Sunglasses, sunscreen
☐	Food
Crew Gear	
☐	Field folder (see bulleted list above for contents)
☐	Satellite phone and/or Park radio
☐	Means to start a fire
☐	Space blanket(s)
☐	Compass
☐	Well-stocked first aid kit and manual
☐	Flares
☐	Flashlights (including fresh batteries)
☐	Personal floatation devices (PFDs)
☐	Mustang suits, if appropriate
☐	Aircraft emergency vests, if appropriate
☐	Emergency food
☐	USGS NFM Ch.A9. Safety in Field Activities

Wildlife

SWAN parks are home to large numbers of brown bears (*Ursus arctos*), black bears (*Ursus americanus*) and moose (*Alces alces*). Bear encounters are especially likely in riparian areas, where bears spend much of their time and stream noise frequently masks human presence. Field personnel are required to obtain National Park Service bear safety training (Table 1.2). Firearms training is required for staff who will be handling and carrying firearms. However, all staff should be familiar with and obtain training in the safe handling and use of bear deterrent spray. Electric fences and bear resistant food containers are required for any field camps. Additionally, SWAN park units may have policies that govern camp practices in specific areas of a park that must be observed. The field trip leader should consult with Park Resource Management staff about any known problem animals or special areas of concern in the areas to be visited.

No animal-transmitted diseases are known to occur in Alaska. Current information on animal-transmitted diseases is available from the Alaska Department of Epidemiology and the USGS National Wildlife Health Center (http://www.nwhc.usgs.gov/).

Weather and Environmental Conditions

SWAN parks experience severe and unpredictable weather. Conditions may make traveling via boats and float planes hazardous or impossible. Field trip leaders should exercise caution in undertaking trips in deteriorating weather conditions and should consult with Park personnel about local conditions before departing. Be prepared to wait several days in the field for weather to clear enough for boat or float plane transport to be conducted safely. This requires taking extra clothing and food along on all field trips.

Most sampling takes place on lakes and rivers where water temperatures are usually below 14 °C (even colder on glacial rivers). Additionally, air conditions are often cool and damp. Hypothermia is a very real concern, especially when operating boats on open water. Mustang suits or similar protective clothing should be worn in early spring and late fall, or when otherwise appropriate. All personnel should be vigilant for signs of hypothermia in themselves and other crew members.

Drinking Water

Giardia is known to exist in SWAN parks. Therefore, all water should be obtained from a known safe source or filtered prior to drinking. Personnel should avoid obtaining water from sources with high geothermal inputs (e.g., the Battle Lake area of KATM) or large amounts of recent volcanic ash, as both may contain toxic concentrations of heavy metals and other chemicals that may not be removed by water filters.

SOP2: GRTS Point Development

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

Suggested Reading

Stevens, D. L., Jr. and A. R. Olsen. 2004. Spatially-balanced sampling of natural resources. Journal of American Statistical Association 99: 262–278.

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Introduction

This standard operating procedure (SOP) describes a 14-step procedure for generating a grid of lake water quality sampling points from which a subset is selected through a generalized random tessellation stratified (GRTS) analysis. In Steps 1–6, ArcMap geographic information systems (GIS) software is used to overlay a lake basin data layer with a grid system comprised of 1-km^2 or 0.25-km^2 cells. A point is assigned to the center of each grid cell, and latitude and longitude coordinates are generated for each point. In Steps 7–12, a GRTS analysis is applied to the coordinate list using SAS and S-DRAW software. The result is a set of randomly selected, spatially balanced points with corresponding location coordinates (Stevens and Olsen 2004). In Steps 13–14, the GRTS points are uploaded into a global positioning system (GPS) unit using DNRGPS software, which allows the transfer of data between ArcMap GIS software and Garmin GPS units.

This SOP was developed in 2009 using software versions that have since evolved. For example, ArcMap 9.3, DNRGarmin, Excel 2003, SAS 9.2, and S-DRAW 1.0 have been updated to ArcMap 10.1, DNRGPS, Excel 2010, SAS 9.4, and S-DRAW 5.0, respectively. Users of the SOP who are operating updated versions will need to adapt the steps below accordingly.

Before beginning the steps, ensure that the X Drive is accessible, as it is the repository for the initial GIS data layers used. Also, create a working folder for the project on the T Drive. Consult with the data manager to verify where GIS project folders should be stored. If working remotely, create a local project folder for storing project files. Finally, ensure that NPS Theme Manager and AlaskaPak are loaded. Theme Manager is a tool for organizing and delivering data layers to GIS users. AlaskaPak is a set of simple tools for many common GIS tasks performed by resource managers. Directions for accessing Theme Manager and AlaskaPak within ArcMap are located on the T Drive (T:\SWAN\Vital_Signs\Water_Fish\GIS\ArcMap\Tools) in a file called 20130827_Accessing_TM_AKPak_10.2.pdf.

Steps in GRTS Point Development

Step 1: Develop the Base Lake Map

First, create a new buffered layer of a lake or lake system selected from the master “SWAN Lakes” shapefile.

1. Open ArcMap to a new blank workspace. Then, open Theme Manager and use this source to add files from the X drive to the workspace. Specifically, navigate to Alaska Regional Theme List \ SWAN Themes \ Land / Water \ SWAN Lakes in Theme Manager and add it to your workspace. This layer will show all the lakes in the SWAN network. Zoom in to the lake area of interest, e.g., Lake Brooks (Figure 2.1).

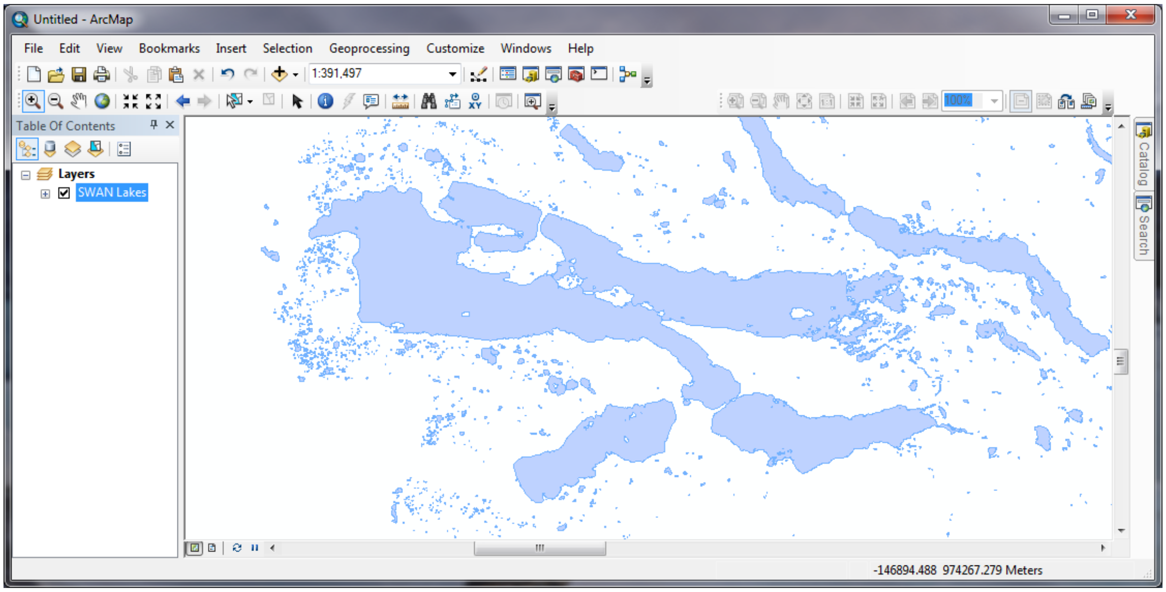
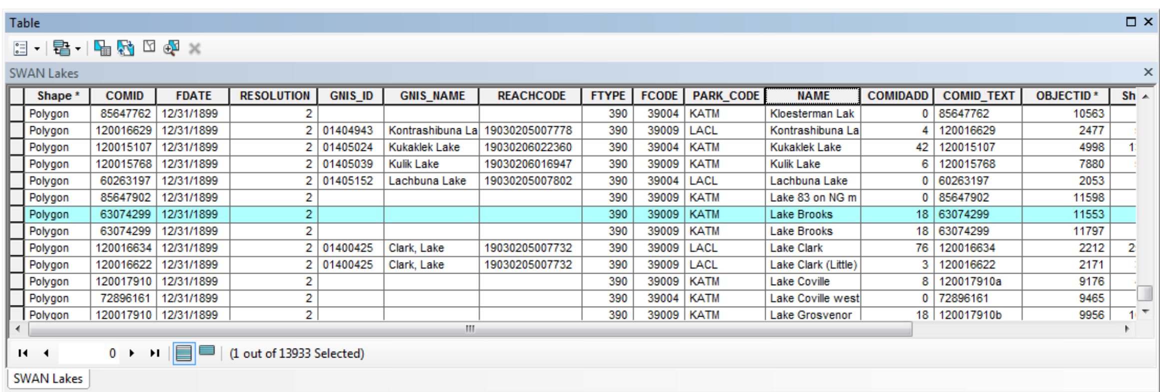


Figure 2.1. Screen shot of the "SWAN Lakes" shapefile.

2. Right click on the data layer in the Layers pane on the left and select Open Attribute Table. If the lake of interest has a name, right click on the Name column heading and select Sort Ascending to group the named lakes in alphabetical order. Scroll down to find the lake of interest and select that line of data, highlighting the line in the attribute table as well as the lake in the main View pane (Figure 2.2).



Table

SWAN Lakes

Shape *	COMID	FDATE	RESOLUTION	GNIS_ID	GNIS_NAME	REACHCODE	FTYPE	FCODE	PARK_CODE	NAME	COMIDADD	COMID_TEXT	OBJECTID *	Sh
Polygon	85647762	12/31/1899	2				390	39004	KATM	Kloesterman Lak	0	85647762	10563	
Polygon	120016629	12/31/1899	2	01404943	Kontrashibuna La	19030205007778	390	39009	LACL	Kontrashibuna La	4	120016629	2477	
Polygon	120015107	12/31/1899	2	01405024	Kukaklek Lake	19030206022360	390	39004	KATM	Kukaklek Lake	42	120015107	4998	1
Polygon	120015768	12/31/1899	2	01405039	Kulik Lake	19030206016947	390	39009	KATM	Kulik Lake	6	120015768	7880	
Polygon	60263197	12/31/1899	2	01405152	Lachbuna Lake	19030205007802	390	39004	LACL	Lachbuna Lake	0	60263197	2053	
Polygon	85647902	12/31/1899	2				390	39009	KATM	Lake 83 on NG m	0	85647902	11598	
Polygon	63074299	12/31/1899	2				390	39009	KATM	Lake Brooks	18	63074299	11553	
Polygon	63074299	12/31/1899	2				390	39009	KATM	Lake Brooks	18	63074299	11797	
Polygon	120016634	12/31/1899	2	01400425	Clark, Lake	19030205007732	390	39009	LACL	Lake Clark	76	120016634	2212	2
Polygon	120016622	12/31/1899	2	01400425	Clark, Lake	19030205007732	390	39009	LACL	Lake Clark (Little)	3	120016622	2171	
Polygon	120017910	12/31/1899	2				390	39009	KATM	Lake Coville	8	120017910a	9176	
Polygon	72896161	12/31/1899	2				390	39004	KATM	Lake Coville west	0	72896161	9465	
Polygon	120017910	12/31/1899	2				390	39009	KATM	Lake Grosvenor	18	120017910b	9956	1

0 (1 out of 13933 Selected)

SWAN Lakes

Figure 2.2. Screen shot of the attribute table for the "SWAN Lakes" data layer.

3. With the SWAN lakes layer highlighted in the Layers pane, right click and scroll to the Selection option. In the window that opens, select Create Layer from Selected Features. This will create a layer with only the selected lake, entitled "SWAN Lakes Selection."

4. Double click this layer in the Layers pane to open the Layer Properties window. Under the General tab, rename the layer with the lake name (e.g., Lake_Brooks, for this example). If the lake is unnamed, rename the layer based on the park and the lake number (PARK_CODE and COMID, respectively) from the attribute table.

5. Uncheck the SWAN Lakes layer in the Layers pane to speed map redrawing. Only the single lake or lake system in the new Lake_Brooks layer should be visible. Save your work in the project folder using the following naming convention: 4-letter park code_5-letter waterbody code_GRTS_points.mxd (e.g., KATM_lbroo_GRTS_points.mxd).
6. To ensure that lentic sampling points are far enough away from shore, add a 100 meter buffer. Open the Toolbox and select Analysis Tools / Proximity / Buffer.
7. In the Buffer Tool window, add the Lake_Brooks layer as the Input Feature by selecting it from the pull-down menu, which shows the layers that can be buffered.
8. ArcMap will assign a default name and file path (possibly on the X Drive) to the output layer. Do not attempt to store new files on the X drive. Instead, select the browse folder icon to the right and browse to the project folder. Name the layer (e.g., LakeBrooks_100m_buffer).
9. The next field requires a buffer width. Be sure that meters are selected from the unit options. Enter -100 in the distance box. **Note:** be sure to add the negative (-) sign in front of the 100, otherwise 100 m will be added to the outside of the lake boundary, instead of being subtracted from the inside.
10. Click OK. A window will appear indicating that the new layer is being drawn. Then the buffer layer will be added above the lake layer in the Layers pane. If the two layers are similar in color, change the color of the buffer layer by clicking on the color square below the layer name and selecting a different fill color.
11. Your project should now consist of three layers (Figure 2.3): 1) SWAN Lakes, 2) the selected lake (Lake_Brooks), and 3) the buffer layer (Lake_Brooks_100m_buffer).

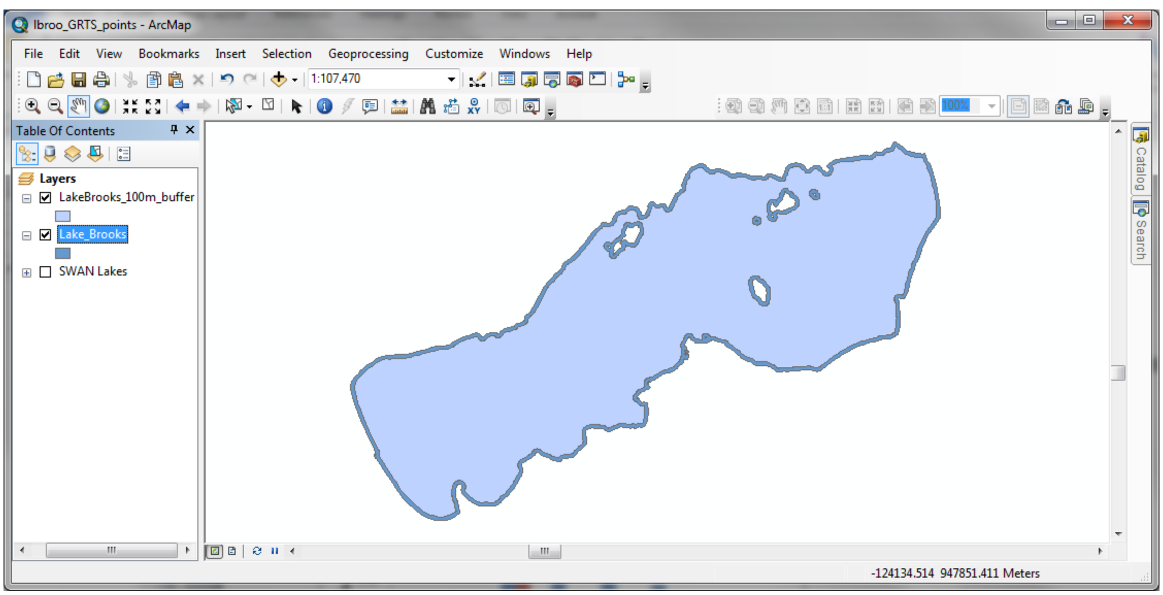


Figure 2.3. Screen shot of the buffer layer (Lake_Brooks_100m_buffer) overlaid on the selected lake layer (Lake_Brooks).

Step 2: Set the Grid

Next, use the AlaskaPak toolbar to place a grid over the lake and assign a center point in each grid cell. The dimensions of the grid — and thus the spacing of the points — will be dictated by the size of the lake and by the perceived minimum distance required to minimize dependency of measurements among water quality samples. For instance, grid points on Lake Clark are spaced 1 km apart, whereas they are spaced 0.25 km apart on Lake Kontrashibuna.

1. If the AlaskaPak toolbar is loaded but not visible, select Customize / Toolbars and check NPS Alaska.
2. Select the grid icon next to the AlaskaPak menu and draw a box surrounding the lake boundary to include the entire lake or lake system. Keep the box as small as possible while still including the entire lake. If the box does not cover the entire lake, click Cancel in the new Generate Grid window and try again.
3. In the Generate Grid window, enter 1000 for the width and height of the cell, and set the grid units to meters. This will form a grid of cells with areas of 1 km^2. The number of cells (horizontally and vertically) will need to be adjusted iteratively by previewing until the grid covers the lake. Name the output (e.g., LakeBrooks_grid) and save it to the project folder.
4. If, for whatever reason, the newly generated grid layer is inadequate (e.g., the cells have the incorrect size), right click on the layer in the Layers pane and remove it. Redraw the box and repeat the steps above.
5. Open the AlaskaPak menu and select Grids / Generate Grid Points to place a grid point in the center of each cell. In the Feature To Point window, select the input layer (LakeBrooks_grid). Then name the output layer (e.g., LakeBrooks_grid_points) and save it to the project folder. Click OK. The output layer will be drawn automatically in the main View pane (Figure 2.4).

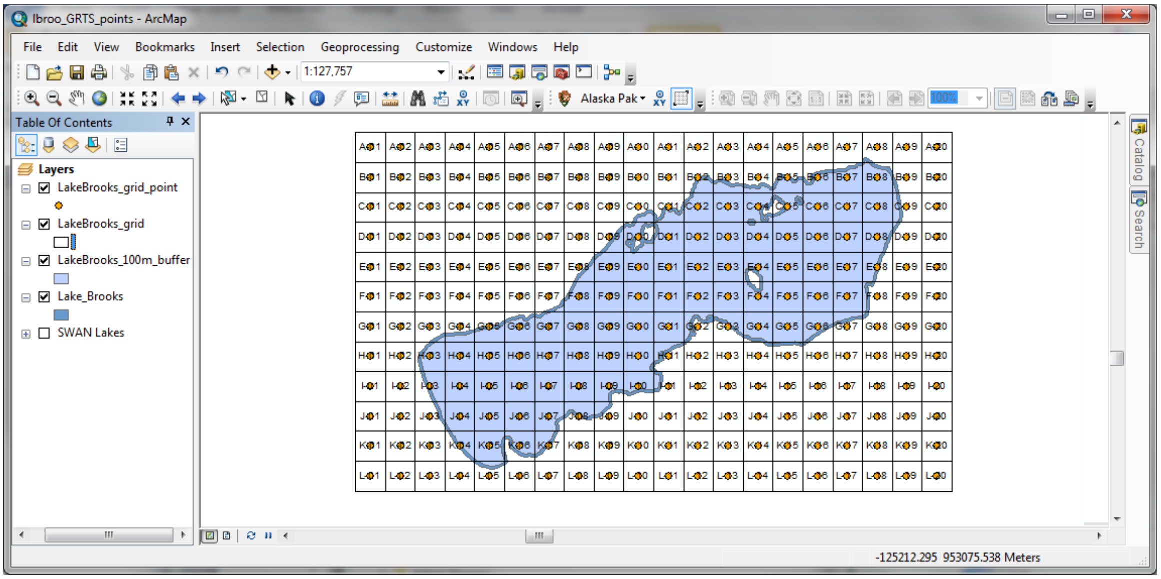


Figure 2.4. Screen shot of grid points (in orange) added to the center of each 1-km^2 cell.

Step 3: Clip the Grid

At this point, a grid layer with a point in each grid cell overlies the lake layer. Next, clip the grid to the extent of the buffer layer so that the resulting points will all be at least 100 m from shore

1. Select Analysis Tools / Extract / Clip from the Toolbox.
2. In the Clip window, select the grid points (LakeBrooks_grid_points) as the Input Feature. Select the buffer layer (LakeBrooks_100m_buffer) as the Clip Feature. Browse to the project folder and save the feature class (e.g., as LakeBrooks_clip_points). Click OK.
3. Once the Clip tool runs, the new feature class will be added to the map. Turn off the grid and the grid_points layers so all that remains is a series of points in a grid across the lake (Figure 2.5).
4. Use Arc Toolbox to define the projection of the newly created clip points layer (e.g., LakeBrooks_clip_points). Select Data Management Tools / Projections and Transformations / Define Projection. Add the clip points layer as the Input Dataset. Import the coordinate system from the SWAN Lakes layer (NAD_1983_Alaska_Albers). Click OK.
5. Save the project (File / Save) to ensure that the above steps are part of the project.

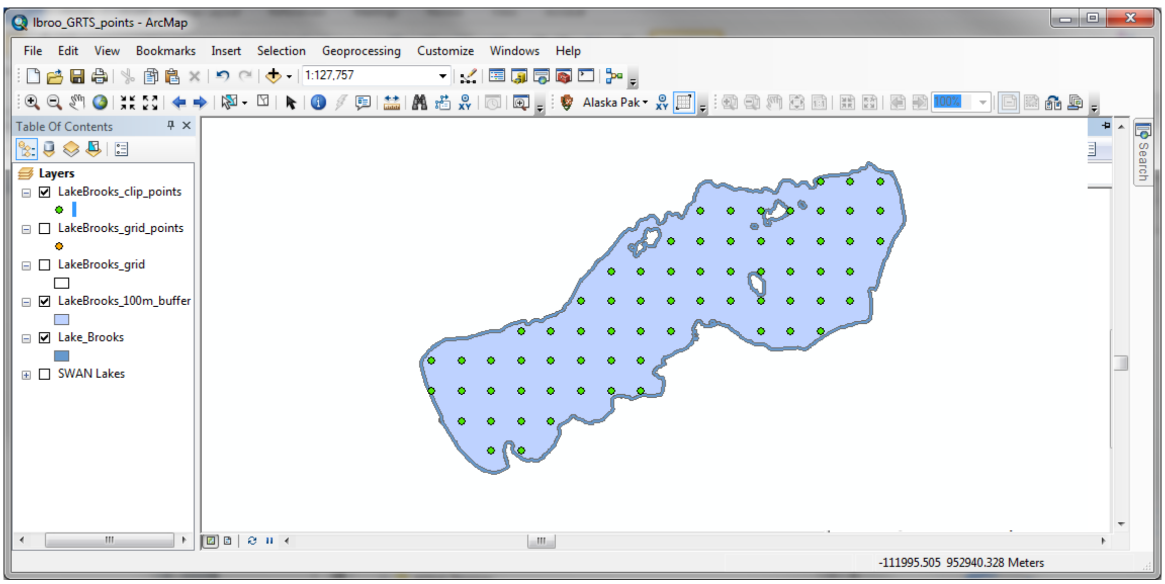


Figure 2.5. Screen shot showing the grid points clipped to the extent of the buffer layer.

Step 4: Label the Grid Points

Now that the grid points are clipped to the boundary of the buffered lake, assign unique IDs and coordinates.

1. Open AlaskaPak and select Add Attributes / Add ID. In the Add Unique ID window that opens, use the folder icon to navigate to the newly created clip points layer (e.g., LakeBrooks_clip_points). Click OK. After the tool finishes running, close the pop-up window, right click on the clip points layer, and open the attribute table. Scroll to the right to view the new UniqueID attribute containing a number assigned sequentially to each point.

2. Next, assign coordinates in decimal degrees. Open AlaskaPak and select Add Attributes / Add XY coordinates. Be sure that the clip points layer is listed in the Point Feature Class box, and Decimal Degrees is listed in the Coordinate Format box. Lon_DD and Lat_DD should be listed for the X and Y field names, respectively. If not, change them so they are. Under the Formatting Options drop-down menu, uncheck Show Direction. Click OK.
3. Open the attribute table for the clip points layer. Two columns with the Lat_DD and Lon_DD headers and the coordinate data should be visible on the far right. Note that the longitude data will appear as negative values.

Step 5: Convert to UTM

Decimal degree coordinates are helpful when using GPS units (e.g., Garmin). However, Universal Transverse Mercator (UTM) coordinates are required for the GRTS analysis. Therefore, change the projection to UTM in order to generate a set of UTM coordinates.

1. Right click in the main View pane and select Data Frame Properties. Under the Coordinate System tab, note that the projection is set to Alaska Albers. Select the Predefined folder then Projected Coordinate System / UTM / NAD 83 / NAD 83 UTM Zone 5N. Click Apply. The grid points will shift slightly as the map is reprojected. Click OK.
2. Right click the map to show the data frame properties and make sure that the projection is now Transverse_Mercator.
3. Open AlaskaPak and select Add Attributes / Add XY coordinates. Be sure that the clip points layer is listed in the Point Feature Class box. Set the Coordinate Format to Data Frame Coordinates. Label the X and Y field names with _UTM5 extensions (e.g., X_UTM5). Click OK.
4. Open the attribute table for the clip points layer and scroll to the right. Another set of XY data in columns labeled X_UTM5 and Y_UTM5 should be visible, representing easting and northing, respectively.

Step 6: Export the Data Table

All the information necessary to begin a GRTS analysis is now contained in the clip points attribute table. Next, export the table from ArcMap and import it to Excel for processing.

1. Open the attribute table for the clip points layer and select the Options button in either the lower right or upper left corner, depending on the ArcMap version.
2. Select the Export command. In the Export Data window, select All Records as the export option. Browse to the project folder and save the export file as a text file named lakename_grts_points_all (e.g., LakeBrooks_grts_points_all.txt). Click OK.
3. Save your map project in ArcMap. Minimize ArcMap.
4. Open Excel and import the comma-delimited lakename_grts_points_all.txt file. Follow the steps of the Text Import Wizard, selecting Comma and ° as delimiters, and view the file in Excel. Align the rightmost three column headings with the data below. Then, delete all columns except those containing the necessary GRTS data: UniqueID, Lat_DD, Lon_DD,

X_UTM5, and Y_UTM5. Save the file as an Excel workbook (e.g., LakeBrooks_grts_points_all.xls) or one of the file types described in Step 9.

Step 7: Create Folders

Create a folder structure on the C Drive or other relevant location that will house the various data files used or generated from the GRTS analysis. The key folders are:

- DBF_results: *.dbf file(s) with the coordinates of the GRTS sample points
- Raw_data: file(s) of grid points created in Step 6.
- SAS_data: SAS data files (*.sas7bdat)
- Txt_input: text file in S-DRAW input format
- Txt_results: text file(s) outputted by S-DRAW that contain(s) the GRTS selected points.

The user can name these folders whatever he/she wishes, but should create them for each lake sampled (e.g., Brooks Lake, Lake Kontrashibuna) and, if desired, by the year the GRTS sample is chosen (Figure 2.6).

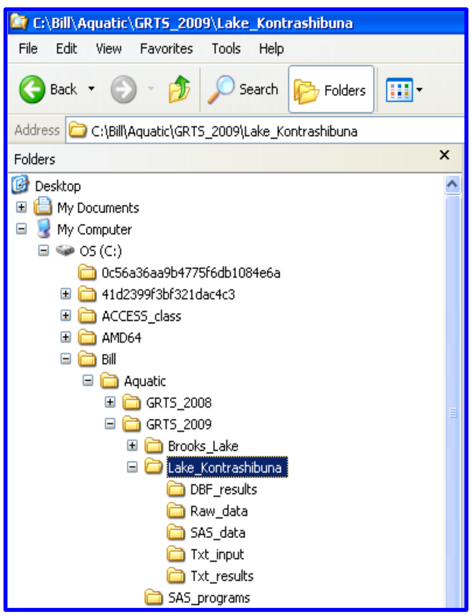


Figure 2.6. Screen shot of the desired folder structure.

Step 8: Create a SAS Library

Create a SAS library to house the SAS files generated in Steps 9–12. These steps were written based on SAS 9.2 Windows XP Professional x64 edition (http://www.sas.com/en_us/home.html). SAS is a commercial software package used to manipulate the raw data file of all grid points into input and file formats that can be read by S-DRAW, and to manipulate the files outputted by S-DRAW into *.dbf files that can be easily read by ArcMap.

1. Double-click on the SAS icon to start the program. Click on the Add New Library button in the top tool bar and a New Library pop-up window appears.

2. Enter a name for the SAS library ("grtslake" in this example). Click on the box to the left of Enable at Startup, click on the Browse button, navigate to the place on the C Drive or relevant drive where the SAS_data subfolder is located, select it, and click OK (Figure 2.7). SAS library names are limited to a maximum of 8 characters.

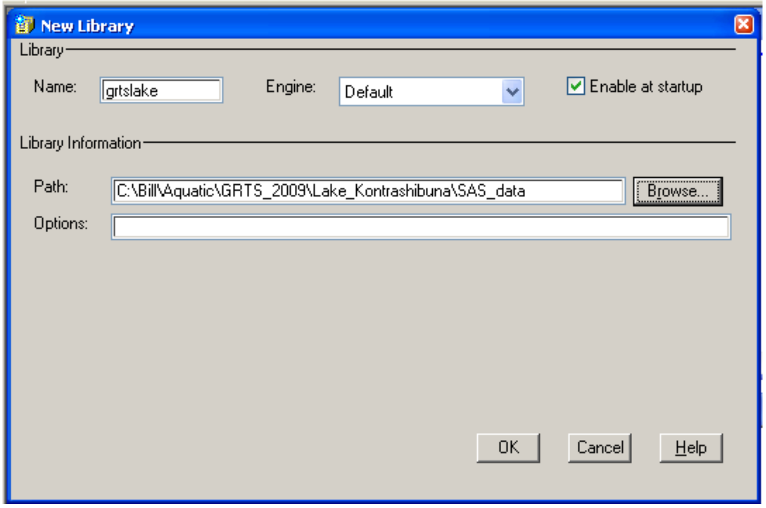


Figure 2.7. Screen shot of the New Library pop-up window in SAS.

Step 9: Import the Data Table to SAS

Import the file(s) created in Step 6 into SAS to convert it/them to the input format and file format required by S-DRAW. **Note:** SAS v. 9. 2 Windows XP Professional x64 edition will import various file formats, such as *.dbf, *.csv, *.txt, *.wkn, *.jmp, *.sav, *.dta, *.db, and *.xls if using MS Excel 4, 5 or 95. The only file formats that are not supported by the x64 edition Import/Export wizards are the ones that use the MS Jet data provider (MS Excel 97 or MS Access 97 and higher; see http://support.sas.com/kb/17/075.html for details). These file formats still can be imported into and exported from the 64-bit version of SAS, but they require a separate procedure (see Step 9 #2). Alternatively, these later file formats can be saved in an earlier file format, e.g., an Excel 97 file can be saved as an Excel 95 file. The SAS Import Wizard then can be used to import the earlier format (see Step 9 #1).

1. For file formats except MS Excel 97 and later or MS Access 97 and later, use the Import Wizard in SAS to import the file(s) created in Step 6, convert it/them to SAS file format(s), and assign it/them to a SAS library.

    a. Double-click on the SAS icon to start the program if it is not already running. Select Import Data from the File drop-down menu.

    b. Select the relevant file format from the drop-down list in the middle of the pop-up window and click on the Next button. In this example, we will be importing .dbf files (Figure 2.8).

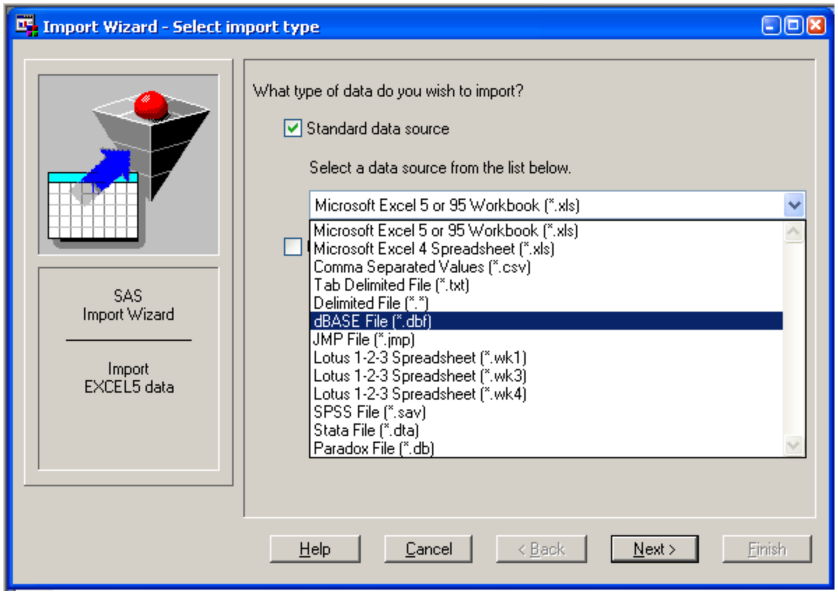


Figure 2.8. Screen shot of the SAS Import Wizard for selecting a file type.

c. The next pop-up window asks you to browse to the drive location containing the file you would like to import. Click on the Browse button, navigate to the file's location on the drive, select the file, and click on the Next button.

d. The next pop-up window allows the user to name the imported file and select a SAS library in which to store this file in SAS file format. Select the SAS library created in Step 8 by clicking on the down arrow button next to the Library box and clicking on the library name (Figure 2.9). **Note:** the list of libraries to choose from will vary depending on how many have been previously created.

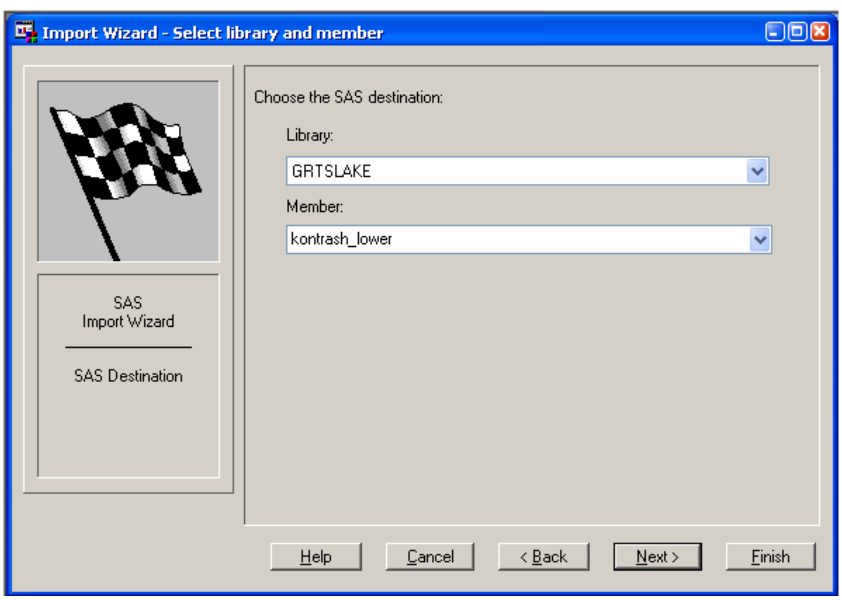


Figure 2.9. Screen shot of the SAS Import Wizard for selecting a library.

e. Click in the box under Member, enter a name for the imported file (e.g., "kontrash_lower" in Figure 2.9), and click the Finish button.

f. For importing additional files, repeat Step 9 #1a–e above.

2. For file formats MS Excel 97 and later or MS Access 97 and later, use SAS PC files server to import them. Perform the following steps to install the PC files server.

   a. Download the PC files server program from the following location to your choice of directory on your PC/laptop that is going to run this application: ftp://ftp.sas.com/techsup/download/blind/zqjpcfileserver.zip.

   b. Unzip the zqjpcfileserver.zip file on your pc, it will unzip to the pcfilesrv__9210__prt__xx__sp0__1 subdirectory where you stored the zip file.

   c. In the unzipped directory pcfilesrv__9210__prt__xx__sp0__1, double click on the setup.exe. This will start the install.

   d. The setup.exe will install the PC files server in the C:\ProgramFiles\SAS\PCFilesServer directory.

   e. Start the PC files server in one of two ways:

      i. Select START / Programs / SAS / PC files server

      ii. Go to the C:\Program Files\SAS\PCFilesServer\9.2 directory and double click on the pcfileserver.exe program.

   f. After starting up the *.exe, the PC Files Server window will pop up (Figure 2.10). This window contains the server name (e.g., 'inplacl37102' for the laptop above) and Port Number (e.g., 8621) that will be needed in the SAS code in Step 12. **Note:** do not close the PC Files Server window during the import/export procedure ─ it has to be running for the code in Step 9 #2g (below) to work.

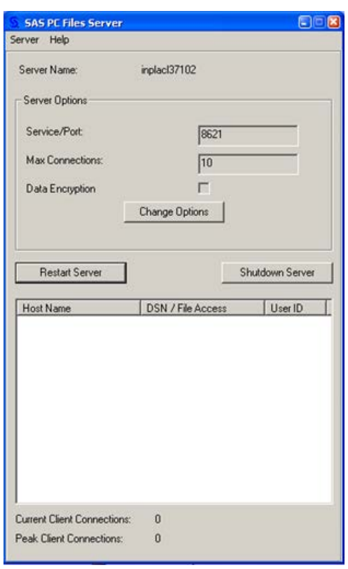


Figure 2.10. Screen shot of the SAS PS Files Server window.

g. To use the PC files server to import an MS Excel file, copy the following SAS code into the SAS Editor window, modify as needed, and click on the Run button in the top toolbar:

```
proc import dbms=excelcs
out=yoursasdata
datafile="yourdirectory\yourfile.xls" replace;
port=8621;
server="yourpcname";
sheet="yoursheet";
run;
quit;
```

The “out=” statement specifies the SAS library name (if relevant) and SAS data file name. The “datafile=” statement indicates the name of the MS Excel file that is being imported and its location on the drive. The “sheet=” statement specifies the name of the particular sheet that is to be imported from the MS Excel spreadsheet. Below is example SAS code, where the sheet "freq_toSAS" in the MS Excel file "LACL_GRTS_2007_2008_CoverFreq_SAS_080923.xls" is converted to a SAS data file "freqdata" and saved to the SAS library "laclfreq":

```
proc import dbms=excelcs
out=laclfreq.freqdata
datafile="C:\Bill\LACL_GRTS_2007_2008_CoverFreq_SAS_080923.xls" replace;
server="inplacl37102";
port=8621;
sheet="freq_toSAS";
run;
quit;
```

Note: the names above should be in double quotes; SAS will return an error in the log window if they're placed within single quotes. Also, if the server name is longer than 31 characters, you will receive a “Failed to connect to the Server” error message in the SAS log window. If this occurs, you will need to replace the server name with your computer’s IP address. You can find the IP address by typing in “cmd” (without quotes) in the START / RUN window and clicking OK. This will bring up a DOS window. Type in “ipconfig” (without quotes) after the DOS prompt and hit return. The IP address should be listed in a DOS window similar to that in Figure 2.11. Close down the DOS window by clicking on the “x” in the upper right corner.

Use the following SAS code to import an MS Access file.

```
proc import dbms=accesscs
out=yoursasdata
datatable=youraccesstable;
database="yourdirectory\yourfile.mdb";
server="yourpcname";
port=8621;
```

```
run;
quit;
```

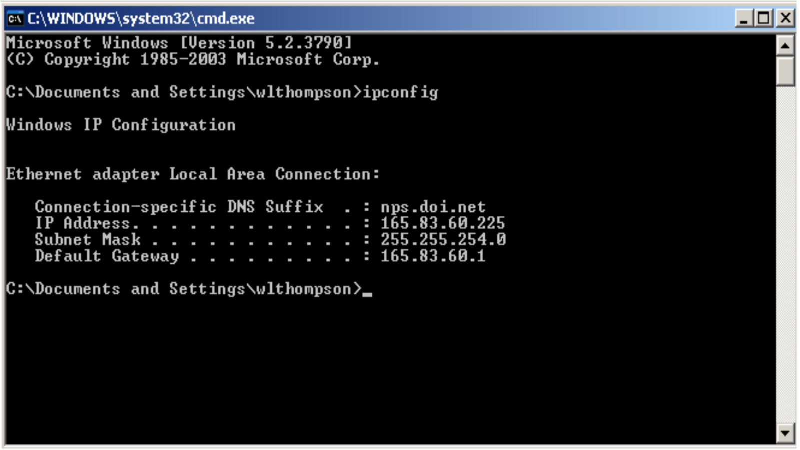


Figure 2.11. Screen shot of the DOS window that lists the IP address.

3. Convert the SAS file(s) created in Step 9 #1 or #2 to generate input formats that can be read by S-DRAW and save them to the SAS library created in Step 8. **Note:** this example uses the "UTM_x-coordinate UTM_y-coordinate Sample_Point_ID" style input format in S-DRAW but other input formats are available depending on how the sample is chosen; see the S-DRAW User's Guide (SDRAW_users_guide.pdf) in http://www.west-inc.com/programs/S-Draw1b.zip for details.

    a. Click the SAS Explorer icon on the top tool bar to view the file(s) created in Step 9 #1 or #2 to ensure data are correct and to check the column variable names, which will be used in SAS code below.

    b. Copy and paste the following lines of SAS code into the SAS Editor window, modify as needed, and click the Run button in the top toolbar. The only modifications will be to the top lines of code beginning with "%let"; see the instructions after the asterisk on each line. **Note:** text between an asterisk and a semi-colon is treated as a comment by SAS and hence will be ignored.

```
%let inpfile=grtslake.kontrash_lower;    * to the right of the equal sign,
                                           specify the name of SAS library
                                           (before the period) and the name of
                                           SAS file containing grid points
                                           (after the period);
%let id=uniqueid;                        * to the right of the equal sign,
                                           specify the variable name containing
                                           the unique id of each grid point.
                                           If there is not a variable for this,
                                           specify "_N_" (without quotes);
%let utm_x=xcoord_utm;                   * to the right of the equal sign,
                                           specify the variable name containing
                                           the UTM x-coordinate of each grid
                                           point;
%let utm_y=ycoord_utm;                   * to the right of the equal sign,
```

```
                                            specify the variable name containing
                                            the UTM y-coordinate of each grid
                                            point;
%let outfile=grtslake.kontr_low_SDRAW; *  to the right of the equal sign,
                                            specify the name of SAS library
                                            (before the period) and the name of
                                            SAS file of grid points in the input
                                            format of S-DRAW (after the period);

***** DO NOT CHANGE ANYTHING BEYOND THIS POINT ***
***** UNLESS YOU KNOW WHAT YOU ARE DOING.      ***;

data &outfile;
  set &inpfile;
  id=&id;
  keep &utm_x &utm_y id;
run;
```

4. This code should be rerun for each file of grid points, with file names modified accordingly.

Step 10: Export Files from SAS

Export the SAS file(s) created in Step 9 as space-delimited text files so they can be read into S-DRAW.

1. Select Export Data from the File drop-down menu to open the Export Wizard (Figure 2.12).
2. Use the drop-down arrow buttons next to the Library box to select the SAS library produced in Step 8, and next to the Member box to select the SAS file produced in Step 9. Click the Next button.

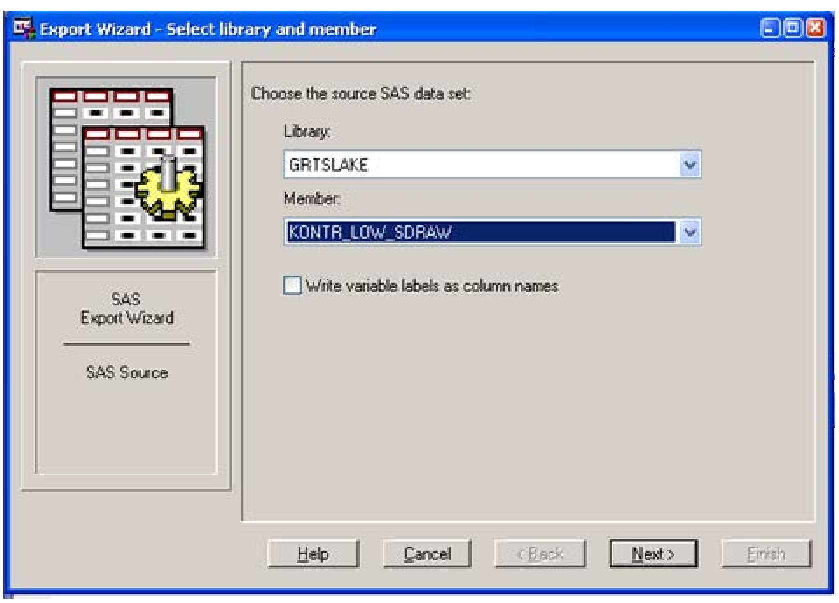


Figure 2.12. Screen shot of the SAS Export Wizard for selecting a library and file.

3. Select Delimited File (*.*) from the drop-down menu (Figure 2.13). Click the Next button.

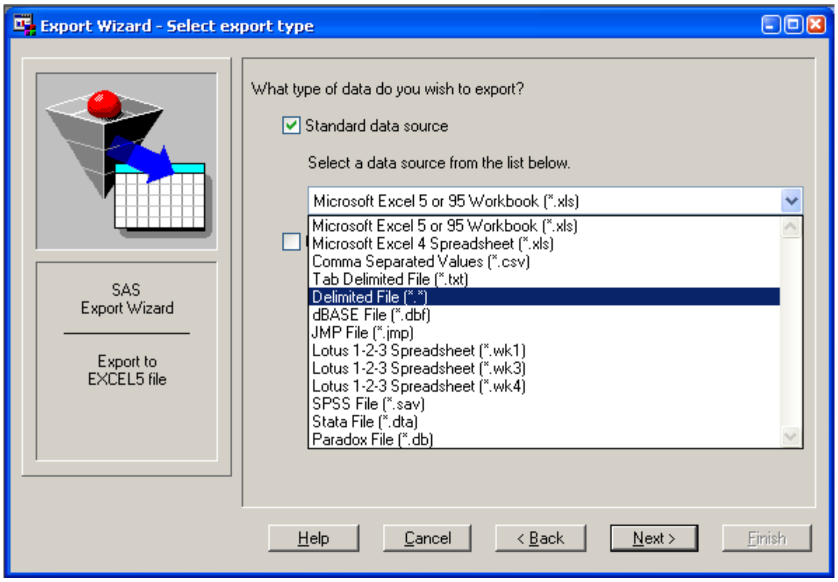


Figure 2.13. Screen shot of the SAS Export Wizard for selecting the export file type.

4. Click the Browse button, navigate to the Txt_input folder (Step 7) on the drive, type in the name of the text file (e.g., kontrash_lower.txt) in the File Name box, and click Save.
5. Click the Finish button to export the file.
6. The *.txt file produced above will need to have the header information (variable names) removed from the file before it can be read into S-DRAW. Use Windows Explorer or other means to navigate to the Txt_input folder on the drive. Use Notepad or other word processor to open the *.txt file, highlight the variable names in the header (Figure 2.14), delete them, and save the file in its original *.txt format.

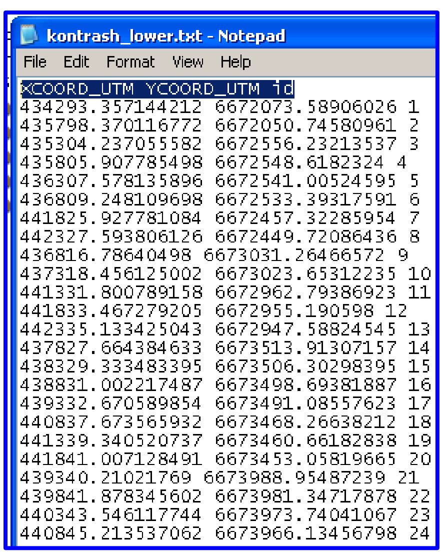


Figure 2.14. Screen shot of the*.txt file exported from SAS with the headers highlighted.

Step 11: Select GRTS Samples in S-DRAW

Use S-DRAW to select GRTS samples of grid points from each *.txt file created in Step 10. S-DRAW is a freeware program used for choosing GRTS samples. See the S-DRAW 1.0 User's Guide (SDRAW_users_guide.pdf) in http://www.west-inc.com/programs/S-Draw1b.zip for details.

1. Place the S-Draw.exe file in the Txt_input folder on the relevant drive. Double-click on S-Draw.exe to initiate the program.

2. The S-DRAW GRTS Sampler window pops up (Figure 2.15). Check the boxes for 2-dimensional, Coordinates, and ID's. Type in the correct values for Sample Size (= 12 in this example), Pixel Size (= 1 as default) and Random Seed (choose a number between -2 billion and +2 billion, or use the default of -1). Use the default settings for Randomize and Output Sample in Reverse Hierarchical Order. The user can enter the total grid points in the input file into Population Size or leave this box blank and allow the program to enter this value. A Random Seed value of -1 draws a random number from the computer's clock. A GRTS sample can be replicated by using the same random number seed.

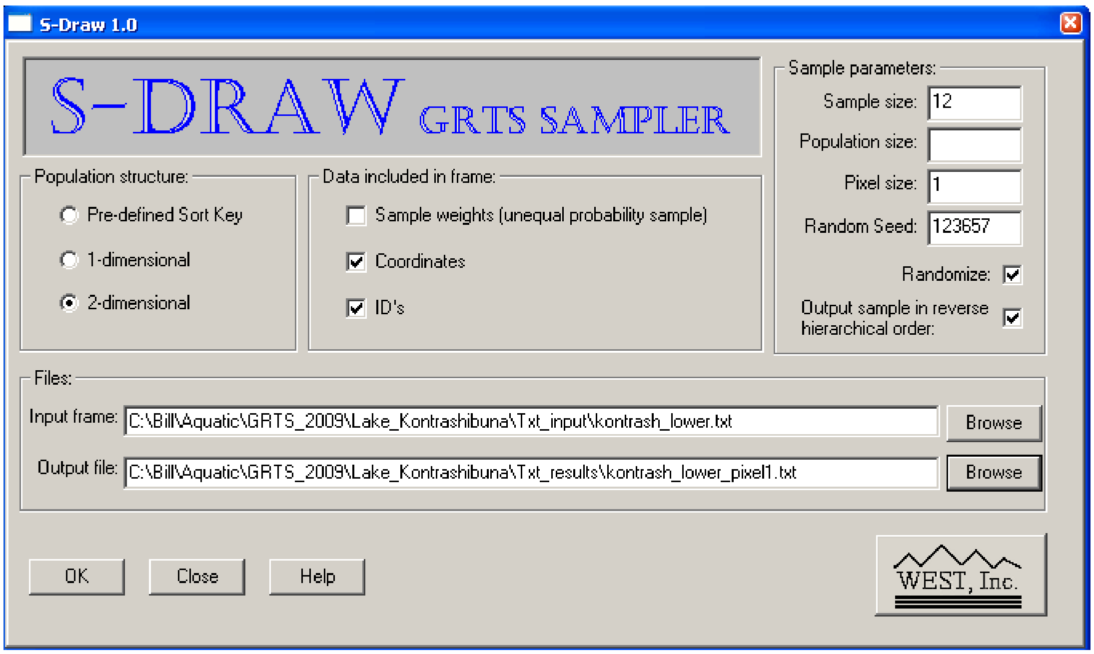


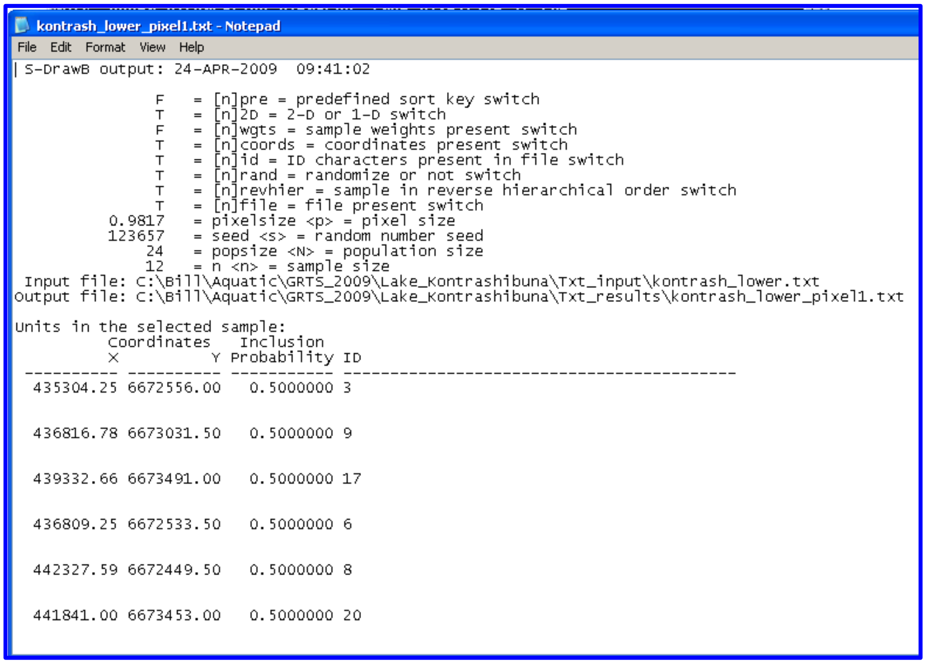
Figure 2.15. Screen shot of the S-DRAW GRTS Sampler window.

3. Click the Browse button next to the Input Frame box (Figure 2.15), navigate to the *.txt file created in Step 10 (e.g., kontrash_lower.txt), single click on the file, and click the Open button.

4. Click the Browse button next to the Output File box (Figure 2.15), navigate to the folder where you would like to save the output file (e.g., Txt_results from Step 7), type in the name of the output file (e.g., kontrash_lower_pixel1.txt), and click the Save button.

5. Click the OK button to run the program and generate an output file containing the GRTS sample of grid points.

6. S-DRAW creates an output *.txt file containing the GRTS sample of grid points (Figure 2.16). In this output file, the UTM coordinates are rounded to 2 decimal places. **Note:** selecting the best pixel size to produce a spatially balanced sample is not straightforward. The default value of 1 will usually suffice, but it is recommended to reselect GRTS samples at other pixel sizes (e.g., 0.01, 10, and 25) for each input file in order to provide alternatives in case a pixel size of 1 is insufficient. Hence, the pixel size should be included in the name of the output file (i.e., kontrash_lower_pixel1.txt for a pixel size of 1 or kontrash_lower_pixel01.txt for a pixel size of 0.01).



```
kontrash_lower_pixel1.txt - Notepad
File  Edit  Format  View  Help
| S-DrawB output: 24-APR-2009  09:41:02

              F    = [n]pre = predefined sort key switch
              T    = [n]2D = 2-D or 1-D switch
              F    = [n]wgts = sample weights present switch
              T    = [n]coords = coordinates present switch
              T    = [n]id = ID characters present in file switch
              T    = [n]rand = randomize or not switch
              T    = [n]revhier = sample in reverse hierarchical order switch
              T    = [n]file = file present switch
         0.9817    = pixelsize <p> = pixel size
         123657    = seed <s> = random number seed
             24    = popsize <N> = population size
             12    = n <n> = sample size
 Input file: C:\Bill\Aquatic\GRTS_2009\Lake_Kontrashibuna\Txt_input\kontrash_lower.txt
Output file: C:\Bill\Aquatic\GRTS_2009\Lake_Kontrashibuna\Txt_results\kontrash_lower_pixel1.txt

Units in the selected sample:
         Coordinates    Inclusion
         X            Y Probability ID
 ---------- ---------- ----------- -----------------------------------------
  435304.25 6672556.00   0.5000000 3

  436816.78 6673031.50   0.5000000 9

  439332.66 6673491.00   0.5000000 17

  436809.25 6672533.50   0.5000000 6

  442327.59 6672449.50   0.5000000 8

  441841.00 6673453.00   0.5000000 20
```

Figure 2.16. Screen shot of the output *.txt file generated by S-DRAW.

7. Repeat #2–6 (above) for each input file and pixel size.

Step 12: Process Output Files from S-DRAW in SAS

Use SAS to import the S-DRAW output files produced in Step 11, remove the header information from these files, and export them as *.dbf files that can be read into ArcGIS.

1. Copy and paste the following lines of SAS code into the SAS Editor window, modify as needed, and click on the Run button in the top toolbar. The only modifications will be to the top lines of code beginning with "%let" and to the directory path/file name inserted in double quotes after the “infile” statement farther down the program. See the instructions after the asterisk on each line. This SAS code should be modified accordingly and rerun for each S-DRAW output file produced in Step 11.

```
%let outpfile=grtslake.kontr_low_pix1; * to the right of the equal sign,
                                         specify the name of the SAS library
                                         (before the period) and the name of
                                         of the SAS-formatted file
                                         containing the GRTS sample of grid
```

```
                                         points (after the period);
%let inpfile=grtslake.kontr_low_SDRAW; * to the right of the equal sign,
                                         specify the name of SAS library
                                         (before the period) and the name of
                                         SAS file of grid points in the input
                                         format of S-DRAW (after the period)
                                         that was created in Step 9 #3;
%let utm_x=xcoord_utm;                 * to the right of the equal sign,
                                         specify the variable name containing
                                         the UTM x-coordinate of each grid
                                         point;
%let utm_y=ycoord_utm;                 * to the right of the equal sign,
                                         specify the variable name containing
                                         the UTM y-coordinate of each grid
                                         point;

options noxwait noxsync;               * do not modify this code;

data a;                                * do not modify this code;
  %let _EFIERR_=0;                     * do not modify this code;


**** After the infile statement and within the double quotes, insert the
**** directory path and relevant S-DRAW output text file name produced in
**** Step 11. Do not modify the "delimiter" statement or any code following
**** it.;

infile

"C:\Bill\Aquatic\GRTS_2009\Lake_Kontrashibuna\Txt_results\kontrash_lower_pixe
l1.txt"


delimiter = ' ' MISSOVER DSD lrecl=32767 firstobs=21 ;

*********************************************************
**** DO NOT CHANGE ANYTHING BEYOND THIS POINT UNLESS ****
**** YOU KNOW WHAT YOU ARE DOING.                   ****
*********************************************************;

informat VAR1 $8. ; informat S_DrawB $13. ; informat XCoord 14.2 ;
informat YCoord 14.2 ; informat VAR5 $55. ; informat _3_55_41 $1. ;
informat Inclprob 9.8 ; informat ID 10. ; informat VAR9 $1. ;
informat VAR10 $1. ; informat VAR11 $14. ; informat VAR12 $1. ;
informat VAR13 $1. ; informat VAR14 $12. ; informat VAR15 $12. ;
informat VAR16 $4. ; informat VAR17 $1. ; informat VAR18 $13. ;
informat VAR19 $5. ; informat VAR20 $12. ; informat VAR21 $4. ;
informat VAR22 $14. ; informat VAR23 $13. ; informat VAR24 $9. ;
informat VAR25 $15. ; informat VAR26 $6. ; informat VAR27 $6. ;

format VAR1 $8. ; format S_DrawB $13. ; format XCoord 14.2 ;
format YCoord 14.2 ; format VAR5 $55. ; format _3_55_41 $1. ;
format Inclprob 9.8 ; format ID 10. ; format VAR9 $1. ; format VAR10 $1. ;
format VAR11 $14. ; format VAR12 $1. ; format VAR13 $1. ; format VAR14 $12. ;
format VAR15 $12. ; format VAR16 $4. ; format VAR17 $1. ; format VAR18 $13. ;
format VAR19 $5. ; format VAR20 $12. ; format VAR21 $4. ;format VAR22 $14. ;
format VAR23 $13. ; format VAR24 $9. ; format VAR25 $15. ; format VAR26 $6. ;
```

```
format VAR27 $6. ;

input VAR1 $ S_DrawB $ XCoord YCoord VAR5 $ _3_55_41 $ Inclprob ID VAR9
$ VAR10 $ VAR11 $ VAR12 $ VAR13 $ VAR14 $ VAR15 $ VAR16 $ VAR17 $ VAR18
$ VAR19 $ VAR20 $ VAR21 $ VAR22 $ VAR23 $ VAR24 $ VAR25 $ VAR26 $ VAR27 $ ;
if _ERROR_ then call symputx('_EFIERR_',1);
&utm_x=xcoord;
&utm_y=ycoord;
keep &utm_x &utm_y ID;
run;

data b;
  set a;
  pt_order=_N_;
run;
data b1;
  set b;
  id_drop=1;
  keep pt_order id id_drop;
  proc sort;
     by id;
run;
data &outpfile;
  merge &inpfile b1;
    by id;
  if id_drop=1;
  drop id_drop id;
  proc sort;
    by pt_order;
run;
```

2. Use the Export Wizard in SAS to convert the SAS-formatted output files containing GRTS-chosen points that were generated in Step 12 #1 to *.dbf formats and place them in the DBF_results folder (Step 7).

    a. Select Export Data from the File drop-down menu.

    b. Use the drop-down arrow buttons next to the Library box to select the SAS library (Step 8) and next to the Member box to select the SAS file produced in Step 12 #1. Click the Next button.

    c. Select the file format (*.dbf) for the export file from the drop-down list (Figure 2.13) and click on the Next button.

    d. Click on the Browse button, navigate to the DBF_results folder (Step 7) on the drive, type in the name of the text file (kontrash_lower_pixel1.dbf in this example) in the File Name box, and click the Save button.

    e. Click the Finish button to export the file. The resulting *.dbf file will contain the UTM x-coordinate, UTM y-coordinate, and sample order of GRTS points (pt_order).

Step 13: Import and Process the GRTS Points

The GRTS analysis produces a file containing the UTM coordinates and unique IDs (pt_order) of the randomly selected, spatially balanced GRTS points. This file needs to be imported back into ArcMap and processed, after changing the pt_order field in Excel from a numeric plot ID value to a truly unique ID.

1. Using Excel, open the file produced by the GRTS analysis (e.g., kontrash_lower_pixel1.dbf in Step 12). Rename the pt_order numbers by adding a prefix consisting of the first two letters of the lake or basin name, followed by a hyphen and '00' before numbers less than ten or '0' before numbers ten and above. For example, GRTS points for Lake Brooks are assigned a unique ID as follows: BR-001, BR-002…BR-010, BR-011, etc. This will allow the points to appear sequentially in the waypoint list on the Garmin.
2. Check to make sure that the UTM columns are formatted as numbers with 6 decimal places and that the pt_order column is formatted as text. Save as a *.xlsx file (for ArcMap version ≥10.1) or as a *.dbf file (for older versions of ArcMap and Excel).
3. If using ArcMap version 10.1 or higher, select File / Add Data / Add XY Data in ArcMap. Navigate to the *.xlsx file created in Step 13 #2 (above) and ensure that the correct UTM columns are assigned to the X and Y Fields. Click OK. Right click on the newly added "_$Events" file name in the Layers pane and select Data / Export Data. In the Export Data window, select All Features as the export option. Use the same coordinate system as the data frame. Browse to the project folder and save the file (e.g., xy_LakeBrooks_pixel25.shp). Click OK.
4. If using an older version of ArcMap, open ArcCatalog and navigate to the *.dbf file. Right click on the file and select Create Feature Class to generate a shapefile. Set the projection to NAD 83 UTM Zone 5N. Save the file as the default file name (xy_LakeBrooks_pixel25.shp) in the project folder. Select the Add Data icon, browse to the newly created shapefile, and click Add. The points should appear on the map as a subset of the original set of grid points (Figure 2.17).
5. Open the attribute table of the newly created shapefile and select the first 15 points. Right click the layer name in the Layers pane and select Selection / Create Layer From Selected Features. Rename the new layer 5-letter waterbody code_grts_final (e.g., lbroo_grts_final).
6. Change the projection back to Alaska Albers. Select View / Data Frame Properties / Coordinate System / Predefined / Projected Coordinate System / Continental / North America / Alaskan Albers Equal Area Conic. The map will shift slightly when the new projection is applied.
7. Now that the projection has been reset to Alaska Albers, the decimal degree coordinates can be assigned using the AlaskaPak toolbar. Open AlaskaPak and select Add Attributes / Add XY coordinates. Be sure that the lake name_grts_final layer is listed in the Point Feature Class box. Select Decimal Degrees from the Coordinate Format pull down menu. Lon_DD and Lat_DD should be listed for the X and Y field names, respectively. If not, change them

so they are. Under the Formatting Options drop-down menu, uncheck Show Direction. Click OK. Open the attribute table to verify that the Lat_DD and Lon_DD were added.

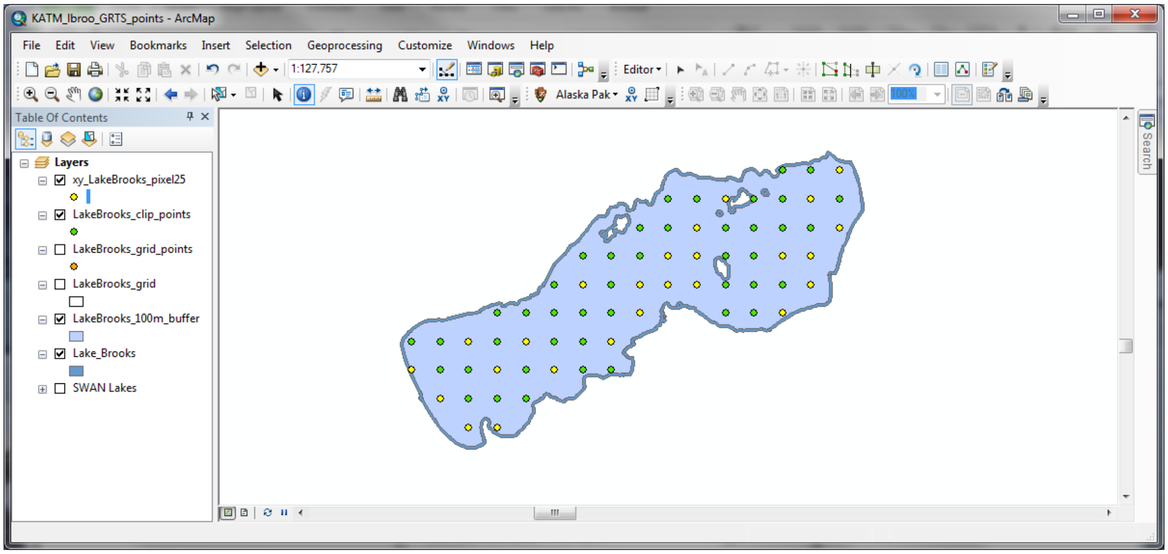


Figure 2.17. Screen shot of GRTS points (in yellow), as a subset of the original set of grid points (in green).

8. Right click on the new layer and select Properties. Open the Labels tab. Check the Label Features in this Layer box and select pt_order from the drop-down menu in the Label Field. Click OK.

9. Add a 1:63,360-scale topographic base layer to the project using Theme Manager (e.g., Alaska-wide / Multi Park Themes / Topography / Alaska USGS Topo Shaded Relief 63K). Insert a scale bar and north arrow in Layout View and export the map to the project folder by selecting File / Export Map (Figure 2.18). Name the file 5-letter waterbody code_grts_final_date (YYYYMMDD) (i.e., lbroo_grts_final_20100301).

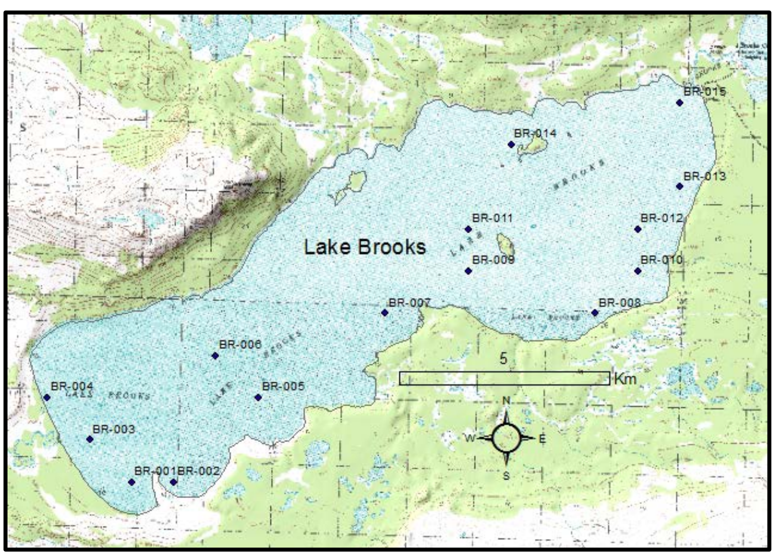


Figure 2.18. Map of GRTS points overlayed on a 1:63,360-scale topographic map.

Step 14: Upload the GRTS Points to the GPS Unit

Now that the GRTS points have been imported and processed, they are ready to be uploaded to a GPS unit. Before uploading, ensure that the coordinate system for the final shapefile created above (i.e., lbroo_grts_final) is set to NAD83 Alaska Albers by checking the Data Frame Properties. Next, upload this shapefile to a GPS unit. The process below is based on the use of a Garmin GPSmap 76CSx unit with DNRGPS software. DNRGPS is an open source update to the DNRGarmin application used by SWAN in 2009. For additional details, see the documentation bundled with the downloaded software (Minnesota DNR 2012).

1. Connect the Garmin to the computer and turn on the unit.
2. Open DNRGPS. The software should establish communication with the Garmin.
3. From the DNRGPS File menu, select Load From / File. Browse to the shapefile in the project folder (e.g., lbroo_grts_final). Highlight the file name and select Open. In the Select IDENT Field window, highlight the pt_order field. Click OK. The file will load into DNRGPS (Figure 2.19).

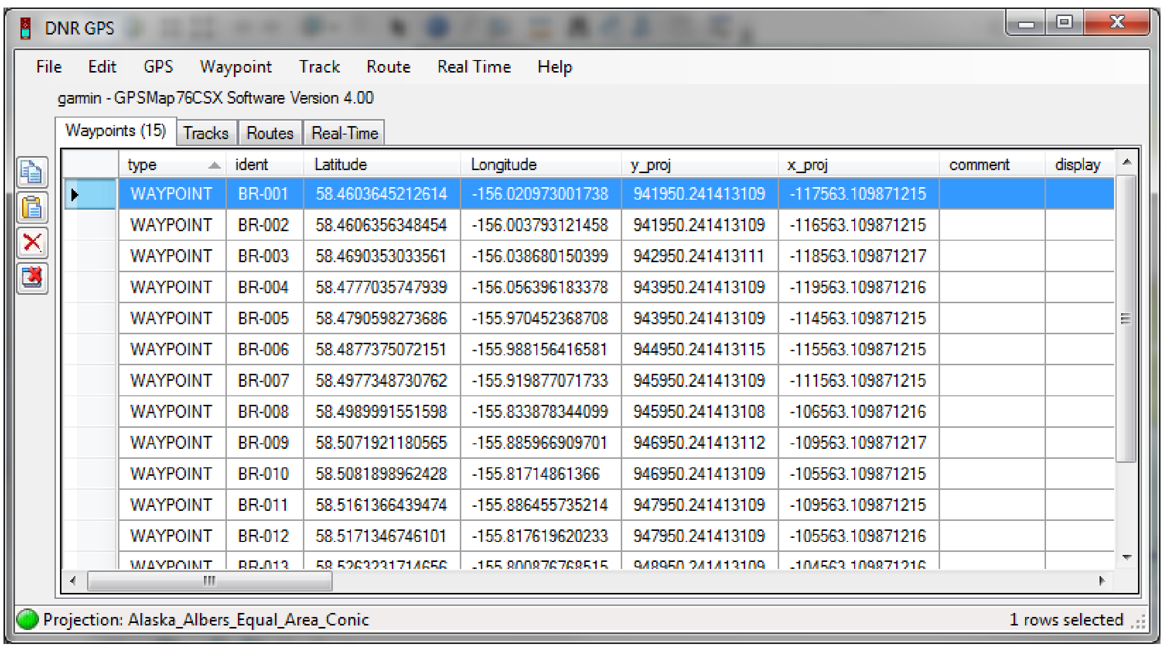


Figure 2.19. Screen shot of the GRTS points loaded into DNRGPS.

4. Verify that the coordinates loaded correctly by comparing the Latitude and Longitude fields in DNRGPS with the Lat_DD and Lon_DD fields in ArcMap. If the lat and lon values do not match, there is likely a problem with the projection. Contact the GIS team for assistance if projection problems cannot be resolved.
5. If the coordinates loaded correctly, select Waypoint / Upload. The data points will be uploaded into the Garmin. A success message will appear upon completion.
6. Disconnect the GPS from the computer. Navigate to the Waypoints directory using the Find button, and pull up a sample point from the file you just loaded. Move the cursor to the Map

feature and select Enter. The point should appear on the map in the correct location, although it may be necessary to zoom in or out to get a good view of the point on the lake.

7. Close DNRGPS.

Status of GRTS Point Development

GRTS points have been developed for all Tier 1 lakes in KATM and LACL. In order to maintain randomness over time, SWAN will assess the need to redo the GRTS draw occasionally (e.g., every 10–20 years), as discussed by Irwin (2008).

The establishment of GRTS points for Tier 2 lakes was ongoing until 2012, when a study of lake water quality sampling design evaluated the necessity of measuring 10 spatial replicates on relatively small lakes with uniform basins (Wilson and Moore 2013). Results indicated that water quality estimates in these lakes were well represented by a single measurement, collected near the lake center. Thus, GRTS analysis was deemed unnecessary.

Literature Cited

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Minnesota Department of Natural Resources (DNR). 2012. DNRGPS documentation: release 6.0.0.8. Available at http://www.dnr.state.mn.us/mis/gis/DNRGPS/DNRGPS.html.

Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially-balanced sampling of natural resources. Journal of American Statistical Association 99: 262–278.

Wilson, T. L., and C. Moore. 2013. A review of lake vertical profile monitoring in the Southwest Alaska Network: recommendations for future efforts. Natural Resource Technical Report NPS/SWAN/NRTR—2013/689. National Park Service, Fort Collins, Colorado.

SOP3: Sonde Calibration, Error Checking, and Maintenance

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

Suggested Reading

Carney, J., and T. Faber. 2002. Standard operating procedure for calibration and field measurement procedures for the YSI Model 6-series sondes (including: temperature, pH, specific conductance, turbidity, and dissolved oxygen). U.S. Environmental Protection Agency Office of Environmental Measurement and Evaluation, North Chelmsford, Massachusetts. Available at http://www.epa.gov/region1/lab/reportsdocuments/wadeable/methods/Sonde.pdf.

Gibs, J., F. D. Wilde, and H. A. Heckathorn. 2007. Use of multiparameter instruments for routine field measurements (ver. 1.1): U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chapter A6, Section 6.8. Available at http://pubs.water.usgs.gov/twri9A/.

Wagner, R. J., R. W. Boulger, Jr., C. J. Oblinger, and B. A.Smith. 2006. Guidelines and standard procedures for continuous water-quality monitors: station operation, record computation, and data reporting. Techniques and Methods 1-D3. U.S. Geological Survey, Reston, Virginia. Available at http://pubs.usgs.gov/tm/2006/tm1D3/pdf/TM1D3.pdf.

Yellow Springs Instruments, Inc. (YSI). 2011. 6-series multiparameter water quality sondes: user manual. Yellow Springs Instruments, Yellow Springs, Ohio. Available at http://www.ysi.com/media/pdfs/069300-YSI-6-Series-Manual-RevJ.pdf.

SOP3 - Contents

SOP3 - Contents (continued)

SOP3 - Figures

SOP3 - Tables

Introduction

This standard operating procedure (SOP) covers steps for the calibration, error checking, and maintenance of Yellow Springs Instruments, Inc. (YSI) "6-series" multiparameter sondes (models 600QS, 6600, and 6920). The sondes are used alongside YSI multiparameter display units (model 650) to measure water temperature, specific conductivity, pH, and dissolved oxygen (DO). These variables are basic measures of water quality and are designated as required "core" parameters for aquatic monitoring by the National Park Service Water Resources Division (WRD) (NPS 2002). Given the influence of glacial silt and volcanic ash on many SWAN waterbodies, turbidity is another parameter of interest. Currently, water clarity (Secchi depth) readings are taken as surrogates for turbidity (SOP4). In the future, turbidity might be measured directly via sonde, thus its inclusion in this SOP.

Electronic instruments greatly facilitate collection of physical water quality data. However, they also may be a source of frustration and lost data, especially when used in remote locations, if proper calibration, operation, and maintenance procedures are not followed. Collecting reliable data requires diligent attention to sensor calibration, periodic calibration checks, and proper storage and handling of sensors. The sonde calibration and error checking procedures discussed below are based on recommendations set by the WRD. Adherence to these procedures should aid in the collection of accurate and precise data. Additionally, these procedures enable NPS-wide consistency in quality assurance/quality control (QA/QC) measures for sonde calibration.

A basic understanding of the configuration of sensors (or "probes") on multiparameter sondes is important to develop prior to calibration, error checking, and maintenance (Figure 3.1). While a variety of sensors are available, the instruments used to measure core water quality parameters should meet the minimum specifications presented in Table 3.1. Table 3.2 lists equipment and supplies necessary for routine sonde calibration and maintenance. For additional information, see the YSI 6-series sonde operation manual (YSI 2011).

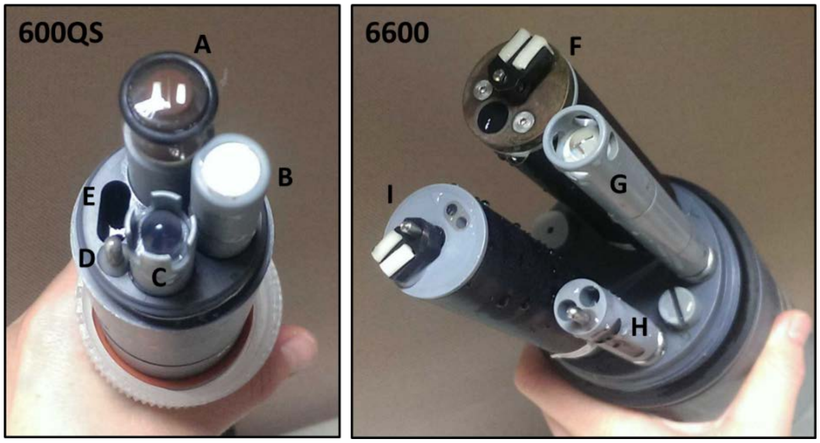

Figure 3.1. Sensor configurations on the "bulkheads" of the two YSI sonde models owned by SWAN (600QS and 6600). Sensors are as follows: A) DO ("Rapid Pulse"); B) pH (reference); C) pH; D) temperature; E) conductivity; F) DO ("ROX Optical"); G) pH; H) conductivity/temperature; and I) turbidity.

Table 3.1. Stabilization criteria and recommended instrument specification criteria for recording field measurements, adopted from Wilde 2008 and Penoyer 2003, respectively.

Standard Direct Field Measurement	Measurement Stabilization Criteria [a]	Recommended Instrument Specifications		
		Range	Resolution/ Sensitivity [b]	Accuracy [c]
Temperature [d]		-5 to +45 °C	0.01 °C	± 0.15 °C
Thermistor thermometer	± 0.2 °C			
Liquid-in-glass thermometer	± 0.5 °C			
Specific conductivity [e]		0 to 10^5 μS/cm	1 to 100 μS/cm (range dependent)	± 0.5% of reading + 1 μS/cm
When ≤ 100 μS/cm	± 5 %			
When >100 μS/cm	± 3 %			
pH [f]		0 to 14 pH units	0.01 pH unit	± 0.2 pH unit
Meter displays to 0.01	± 0.1 pH unit			
Dissolved oxygen [f]		0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ± 2% of reading or 0.2 mg/L, whichever is greater
Amperometric method in mg/L	± 0.3 mg/L			
Turbidity [e]		0 to 1000 NTU	0.1 NTU	± 5% of reading or 2 NTU, whichever is greater (depth limit of 200 ft)
Turbidometric method in NTU	± 10 %			

[a] Variability/repeatability should be within the value shown. Measurement stabilization criteria are not the same as the Measurement Quality Objectives (MQOs) listed in the “Core Water Quality (Vital Signs) Monitoring Parameters for Marine and Coastal Parks” produced by the marine work group.

[b] These are manufacturer specifications for sensor resolution. As such, they are likely too narrow to be achieved in the field as a quality control check for sensitivity (i.e., AMS+), but they can be used as a starting point until more realistic AMS+ goals can be developed.

[c] In the case of field probes, accuracy is typically a “best case” maximum deviation from known correct values (typically based on comparisons with known NIST-certified reference materials or standards). True accuracy is a combination of high precision and low bias (see Irwin 2004 for details). Accuracy specifications reflect only the uncertainty in measurements of the instrument and sensor in combination, and not other factors that can affect accuracy, such as environmental factors or field personnel’s ability to calibrate and operate using good measurement protocols.

[d] Recommended “calibration check” is quarterly. The sensor must be calibrated by the manufacturer.

[e] Recommended sensor calibration is daily.

[f] Recommended sensor calibration is at the beginning and end of sampling at each station (twice a day, minimum).

Table 3.2. Checklist of equipment and supplies for calibrating multiparameter sondes.

- ☐ YSI "6-series" multiparameter sonde (YSI 6600, 6920, or 600QS) [a]
- ☐ YSI multiparameter display system (MDS; YSI 650)
- ☐ Field cable
- ☐ Communications cable (YSI 6095B MS-8/DB-9 adapter)
- ☐ Field laptop (e.g., Panasonic CF-18 Toughbook) with 2 fully charged batteries
- ☐ Instrument log book and pencil
- ☐ Water bath, aquarium pump, hose, and air bubbler
- ☐ National Institute of Standards and Technology (NIST)-certified or -traceable thermometer
- ☐ pH Standards (4, 7, and 10 standard units)
- ☐ Conductivity standard (100 and 1,413 µS/cm)
- ☐ 8 C-size alkaline batteries
- ☐ YSI 6570 maintenance kit and YSI 6035 reconditioning kit [b]
- ☐ Replacement DO membrane and KCl electrolyte solution
- ☐ 9/64" hex screwdriver for battery compartment lid
- ☐ Stopcock grease or equivalent (e.g., Vaseline)
- ☐ Deionized water
- ☐ Hydrochloric acid (1 M)
- ☐ Dishwashing detergent
- ☐ Compressed air
- ☐ Squirt bottles
- ☐ 1000-mL beaker
- ☐ Ring stand and clamp
- ☐ Lab gloves
- ☐ Sink
- ☐ Disposable wipes, lens cleaning tissues, cotton swabs, and/or a soft cloth

[a] Equipped with probes to measure conductivity/temperature (YSI 6560), pH (YSI 6561), dissolved oxygen ("Rapid Pulse" probe: YSI 6562; ROX optical probe: YSI 6150), and turbidity (YSI 6136).

[b] The maintenance kit includes two types of O-rings (for probes and cable connector), O-ring lubricant, probe installation/replacement tools, two cleaning brushes for the conductivity sensor, and a syringe for cleaning the depth sensor port.

Calibration and Error Checking

Sensors must be calibrated before each field trip. Error checks before and after each field trip are also required as part of the QA/QC process to ensure reliable data collection. Post-trip error checks indicate whether sensor calibration has drifted outside of an acceptable range and if data must be flagged for drift correction. If field trips occur on back-to-back days, an error check can substitute for a full calibration on the morning of the second day, provided that sensor calibration remained within the acceptable range on the first day.

Before performing any calibration or error checking procedures, the sonde and display unit must stabilize (warm-up) for at least 15 minutes. During the warm-up period, check the battery level in the display. Also record the expiration date, catalog number, lot number, and manufacturer of each calibration solution used. Probes must be cleaned by rinsing with deionized water before and after immersion in calibration solution. Specific conductivity and pH are temperature-dependent. Thus, the temperature thermistor, located on the conductivity probe on the 6600 sonde, must be submersed in solution during calibration of the conductivity and pH probes. Dissolved oxygen is also temperature-dependent; however, this parameter is calibrated with a water-saturated air procedure, so the probe must not be immersed in solution.

All calibration and error checking information should be recorded in one of two electronic forms. The choice of form depends on the data type. For vertical lake profile and in-situ data, use the "MP_WQMeter_Calibration" worksheet (Figure 3.2) in the file called SWAN_MPSonde_calibrationforms_MASTERCOPY.xlsx. For continuous water quality data, use the "Pre_Deployment_Calibration" worksheet in the file called SWAN_Continuous_Calibration_Drift_Corrections_MASTERCOPY.xlsx. Blank forms are located on the T Drive at T:\Vital_Signs\Water_Fish\Electronic_Field_Forms\SWAN_Master_Copies. The naming convention for these files is: 4-letter park code_5-letter waterbody code_'sonde'_'calibration'_date of calibration in YYYYMMDD format (e.g., LACL_lclar_sonde_calibration_20090604).

Depth

The depth sensor is factory calibrated, but it is necessary to zero the absolute sensor relative to the local barometric pressure at or adjacent to the waterbody being monitored, prior to submergence of the sonde. The depth sensor should also be zeroed after any aircraft flight.

<u>Calibration</u>

1. Make certain that the depth sensor module is in air and not immersed in any solution.
2. On the sonde display, select Sonde Menu / Calibrate / Pressure-Abs (or Pressure-Gage if you have a vented level sensor) to access the depth calibration procedure.
3. Input 0.00 and press Enter
4. When no significant change ($\leq$ 0.1 mm Hg) occurs for approximately 30 seconds, press Enter to confirm the calibration. This zeros the sensor with regard to current barometric pressure.
5. Press Enter again to return to the Calibrate menu.

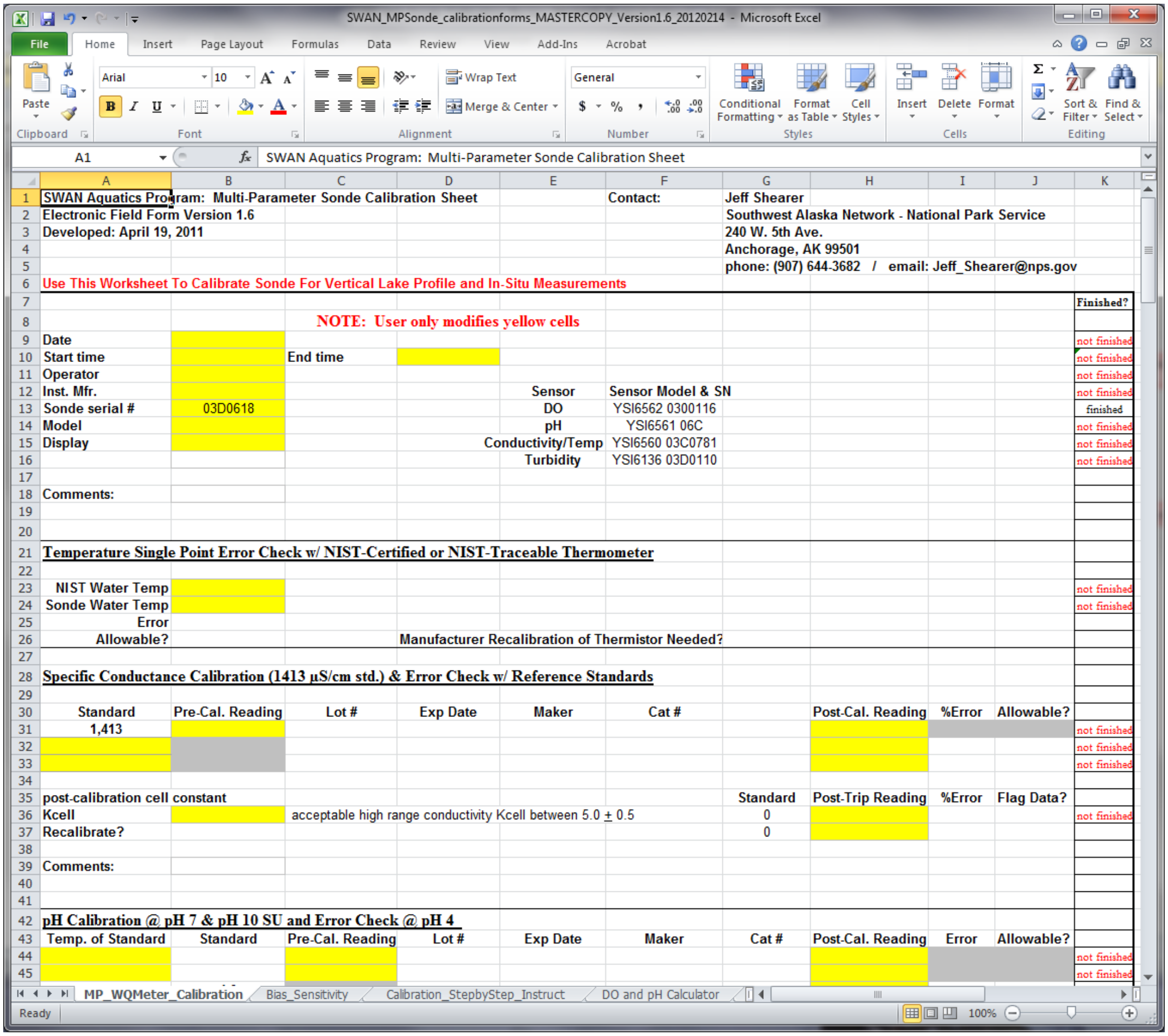

Figure 3.2. The "MP_WQMeter_Calibration" worksheet for inputting sonde information, and calibration and error checking data. Yellow cells in the worksheet indicate input locations.

Troubleshooting

The YSI "6-series" sondes are equipped with depth sensors that are functional to 61 m (200 feet). These depth sensors operate based on pressure differences and are assumed to be long-lived and accurate to ± 0.1 m. Little trouble should be experienced with the depth sensors on these sondes. However, marked depth increments on the sonde field cable should be used as a comparison to ensure that depth readings are accurate. Factory servicing is required to correct problems if large discrepancies between depth sensor readings and a known depth marker (e.g., tape measure) occur.

Temperature

Several probes (specific conductivity, pH, dissolved oxygen) rely on temperature readings for accurate measurements; therefore, this sensor should be "calibration checked" before calibrating the temperature-dependent sensors. The sonde temperature sensor is very reliable but should be error-checked against a National Institute of Standards and Technology (NIST)-certified or –traceable thermometer with 0.1 ºC divisions before each field trip. **Note:** only the manufacturer can perform temperature sensor calibrations, if sensor calibration checks against a NIST-certified or -traceable thermometer have identified that the sensor is out-of-specification.

Calibration and Error Checking

1. Prepare a container filled with water and allow the water to stabilize at room temperature.
2. Next, place the NIST thermometer and sonde into the water, wait for both temperature readings to stabilize, and record the temperature values.
3. Compare the two measurements. The sonde's temperature sensor must agree with the reference thermometer within $\pm$ 0.3 °C. If the measurements do not agree, the instrument may not be working correctly and the manufacturer should be contacted.

Troubleshooting

Similar to the depth sensor, the temperature sensor should be relatively trouble-free. If a discrepancy between a NIST thermometer and the sonde temperature sensor in liquid exceeds 0.3 °C, the cause must be investigated. On the YSI 6600 and 6920 sondes, remove the 6560 temperature / conductivity probe. The sonde display should read -9.99 °C with the probe removed. If the display reads any number other than -9.99 °C, contamination of the port or circuit malfunction is the most likely cause. Follow the sonde port cleaning procedure outlined in the Maintenance section (below). If cleaning the sonde port connector does not solve the problem, factory servicing is needed.

Specific Conductivity

Conductivity is a measure of the ability of an aqueous solution to carry an electrical current. Specific conductivity is the conductivity value corrected at 25 °C. It is important to understand the difference between conductivity and specific conductivity, especially when profiling lakes where water temperatures change with depth, as many sondes will display both readings. Typically, increases in ionic strength with depth, as estimated by specific conductivity, would be offset by the corresponding decrease in conductivity due to decreasing water temperatures. Thus, the differences between specific conductivity and conductivity would confound analyses of seasonal patterns of dissolved ions since water temperatures fluctuate seasonally. In the event that an uncompensated sensor recording only conductivity must be used, specific conductivity can be calculated from conductivity and water temperature as follows:

$$C_{25} = \frac{C_m}{1 + 0.019(T_m - 25)}$$

where, C_{25} = corrected conductivity value (in µS/cm) adjusted to 25 °C; C_m = actual conductivity value (in µS/cm) measured before correction; and T_m = water temperature (in °C) at the time of C_m measurement.

Calibration and Error Checking

1. Triple rinse all probes with deionized water. Shake off excess water.

2. Pour a small amount (~25 mL) of 1,413 µS/cm solution in the calibration cup, thread the cup onto the sonde, shake the sonde rinsing the sensors with solution, then discard the solution. Repeat this step two more times. Expired or recycled solution is acceptable for the rinsing steps of calibration.
3. Place the cleaned probes into the 1,413 µS/cm solution. **Note:** ensure that no air bubbles are trapped inside the conductivity cell.
4. From the sonde display main menu, select Sonde Menu / Calibrate / Conductivity / SpCond, and press Enter.
5. Enter the standard concentration 1,413 mS/cm and press Enter. **Note:** double check that the concentration is entered as milli-Siemens per cm (mS/cm), not micro-Siemens per cm (µS/cm).
6. After the specific conductivity reading has stabilized, record the value in the relevant worksheet ("Pre_Deployment_Calibration" or "MP_WQMeter_Calibration") as the "Pre-Cal. Reading." Press Enter, wait for the "Calibrated" message to appear, and record the value as the "Post-Cal. Reading."
7. Record the "K cell constant" by selecting Sonde Menu / Advanced / Cal Constant.
8. Repeat Steps 1–3, substituting 100 µS/cm solution for 1,413 µS/cm solution.
9. From the sonde display menu, select Sonde Menu / Run / Discrete Sample / Start Sampling.
10. Once the readings have stabilized, record the value of the specific conductivity 100 µS/cm solution as the "Post-Cal. Reading." The value should be within 5 µS/cm of 100 µS/cm. If so, proceed to the steps for pH calibration. If not, clean the probes and conduct the calibration procedure again, beginning with Step 1.

<u>Troubleshooting</u>

The conductivity K cell constant generated during calibration can be used as an indicator of potential problems. The K cell constant should read 5.0 ± 0.5. Any significant change in this number between readings of different conductivity solutions suggests a possible problem. First, check to make sure proper calibration procedures were followed and that the conductivity solutions are not expired. The conductivity value should read 0.00 (or very close to it) when either in distilled water or when dried and in air. If the probe reports a conductivity value when placed in a non-conductive medium, remove the 6560 temperature/conductivity probe. With the probe removed, the sonde display should read -9.99 °C for temperature and 0.00 ± 10 µS/cm for conductivity. If the conductivity immediately drops when the probe is removed, then the probable cause is water leakage into the sensor. If the conductivity reading remains, clean the probe and port as described in the Maintenance section (below).

pH

The pH of a sample is determined electrometrically using a glass electrode. Choose the appropriate standards that will bracket the expected values at the sampling locations. For SWAN lakes and rivers, most expected values fall between pH 7 and pH 10. The steps below outline a 2-point calibration procedure with pH 7 and pH 10 and an error check using pH 4 solution. Since pH is a temperature-dependent value, we will use the temperature-adjusted pH value for calibrations. Whether performing a 2-point or 3-point calibration, always calibrate with pH 7 first.

Calibration and Error Checking

1. Triple rinse all probes with deionized water. Shake off excess water.
2. Pour a small amount (~25 mL) of pH 7 buffer in the calibration cup, thread the cup onto the sonde, shake the sonde to rinse the sensors with solution, then discard buffer. Repeat this step two more times.
3. Place the sonde probes into the pH 7 buffer. Be certain to use enough pH buffer to cover the temperature probe as well.
4. Select Sonde Menu / Run / Discrete Sample / Start Sampling. Once the sensors have stabilized, note the temperature of the pH 7 buffer solution. Next enter the pH buffer solution temperature in the “DO_and_pH_Calculator” worksheet of the instrument calibration form to obtain the temperature-adjusted pH value.
5. Select Sonde Menu / Calibrate / ISE1 pH / 2 point. Input the temperature-adjusted pH value from the “DO_and_pH_Calculator” worksheet (e.g., 7.03) and press Enter.
6. Wait for the pH value to stabilize, record it as the “Pre-Cal. Reading” in the relevant worksheet (“Pre_Deployment_Calibration” or “MP_WQMeter_Calibration”). Record the pH mV value and solution temperature, and press Enter.
7. Wait for the "Calibrated" message and record the pH value as the “Post-Cal. Reading.” If an "Out of Range" message appears, do not accept. Check the probe and refer to operator’s manual.
8. Triple rinse all probes with deionized water, and shake off excess water, as in Step 1.
9. Triple rinse the sensors with pH 10 buffer, similar to Step 2.
10. Place the pH probe into the pH 10 buffer. Note the temperature of the solution, and press Enter. It is very important to record the temperature of the pH 10 buffer before pressing Enter. If you press Enter without noting the temperature, you will have to start over.
11. When prompted, enter the temperature-adjusted pH 10 value as the pH of the second buffer. Record the pH value as the “Pre-Cal. Reading.” Record the pH mV value and solution temperature.
12. Wait for the "Calibrated" message, record the pH value as the “Post-Cal. Reading,” and press Enter to continue.
13. Repeat the triple rinse with deionized water, shaking off excess water.
14. Triple rinse the sensors with pH 4 buffer, similar to Step 2.
15. Place the pH probe into the pH 4 buffer and on the sonde display, select Sonde Menu / Run / Discrete Sample / Start Sampling.

16. Once the readings have stabilized, record the value of the pH 4 buffer as the “Post-Cal. Reading.” The value should be within 0.3 standard units of 4.0. If so, proceed to Step 17. If not, clean the probes and conduct the calibration procedure again, beginning with Step 1.
17. Rinse the probes with deionized water and shake off excess water.

Troubleshooting

Use the “slope” (or the difference) between the pH millivolt readings for two calibrations points as a diagnostic key (YSI 2011). Millivolt (mV) readings should be as follows: pH 4 = 180 ± 50 mV; pH 7 = 0 ± 50 mV; pH 10 = -180 ± 50 mV. The acceptable range for the difference between two readings (e.g., between pH 7 and 10) is 165 to 180 mV. If the difference drops below 160 mV, the sensor should be taken out of service.

pH standards are highly buffered and provide optimal pH measurement conditions, unlike poorly buffered environmental waters. Low ionic strength waters with specific conductivity < 50 µS/cm may cause pH measurement stability problems with some probes, in which the measurement drifts slowly in one direction, up to several hundredths of a pH standard unit per minute. If this situation occurs, a low ionic strength sensor must be used. Often, probes will calibrate well in high ionic strength buffers, but will not read accurately in lower ionic strength waters. Using low ionic strength buffers can remedy this problem.

Dissolved Oxygen

Dissolved oxygen content in water is measured using either a “Rapid Pulse” (YSI 6562) or “ROX Optical” (YSI 6150) sensor. The ROX optical sensor has a puncture-proof membrane that does not require electrolyte solution or maintenance. The Rapid Pulse probe’s membrane and electrolyte solution should be inspected for damage or air bubbles prior to calibration. If air bubbles or damage are present, replace the membrane according to guidance in the Maintenance section (below). If possible, perform the inspection 1-2 days before using the sonde, because YSI recommends an 8-12 hour equilibration period after membrane replacement. Inspecting the membrane during post-sampling error checks is also a good habit, as it allows time for overnight equilibration if membrane replacement is needed.

The DO probe must be calibrated using the calibration cup provided with the sonde or a wet, white towel wrapped around the sensor guard. Calibration of the DO probe requires inputting the current barometric pressure. The YSI 650 MDS display has an internal barometer and automatically provides this value during the calibration procedure.

Error checking requires that a water bath with air bubbler be set up and running at least 8 hours prior to calibration. It is best to allow the air bubbler to run overnight to bring the DO saturation percent as close to 100% as possible. True 100% saturation may not be achieved, especially if calibrating at elevations above sea level.

Calibration and Error Checking

1. Before calibrating the DO probe, perform the “hi/low” DO warm-up check. This step should be performed with the auto sleep functions enabled, while the sonde is not submersed in

water. **Note:** if calibrating a sonde with a 6150 ROX Optical DO probe, proceed directly to Step 6.

2. Select Sonde Menu / Report and enable DO Charge. Next, go to Sonde Menu / Run / Discrete Sample and allow the sonde to run for 10 minutes at a 4-second sample interval. After 5 minutes, record the DO Charge. This value should be 50 $\pm$ 25.
3. After the sonde has run for 10 minutes, go to Sonde Menu / Advanced / Setup and confirm that the RS-232 and SDI-12 auto sleep functions are enabled. Wait 60 seconds before proceeding to Step 4.
4. Place the sonde in the Discrete Sample mode (Sonde Menu / Run / Discrete Sample), select a 4-second interval, and record the first 10 DO% values on paper. The numbers should start high and drop with each four-second sample (e.g., 110, 108, 106, 105, 103, 102.5, 102.1, 101.8, 101.3, and 101). It does not matter if all the numbers are above 100%; it is only important that the numbers decline. If the values start low and then climb, the probe must be replaced. **Note:** initial power up can cause the first two DO% numbers to read low, so those values can be disregarded. The probe is now ready to calibrate.
5. Clean all probes on the sonde with tap water. Shake off excess water.
6. Place approximately 3 mm of water in the calibration cup. Engage the cup threads one turn only to ensure the DO probe is vented to the atmosphere. Alternatively, use a wet towel wrapped around the sensor guard in place of the calibration cup. Do not allow water to touch the DO membrane or temperature sensor and ensure the sonde is not in direct sunlight. Allow the sonde to sit at least 10 minutes prior to proceeding so the air around the DO membrane becomes saturated with water vapor. Do not have the sonde in the Run mode during this time.
7. Go to the Sonde Menu / Advanced / Setup and set the RS-232 and SDI-12 auto sleep functions to the intended application: “On” for unattended samples; “Off” for vertical lake profiles and spot samples.
8. Next, select Sonde Menu / Calibrate / Dissolved Oxy / DO sat%. **Note:** calibration of dissolved oxygen by the DO% procedure also results in the calibration of the DO mg/l mode and vice versa.
9. Enter the current barometric pressure (in mm Hg) into the sonde display. The correct pressure will often be provided but double check with the reading found in the lower right hand corner of the sonde display.
10. Press Enter and wait for the DO% reading to equilibrate.
11. If calibrating the sonde for unattended samples (i.e., auto sleep functions enabled), the sonde will automatically calibrate. Record the DO concentration (mg/L) as the “Post-Cal. Reading” in the relevant worksheet (“Pre_Deployment_Calibration” or “MP_WQMeter_Calibration”). Also record the DO Charge.
12. If calibrating the sonde for spot samples (i.e., auto sleep functions disabled), the sonde will provide a “Pre-Cal. Reading” after equilibrating. Enter the DO concentration (mg/L) as the

"Pre-Cal. Reading" and record the DO Charge.

13. Enter the temperature and barometric pressure into the "DO_and_pH_Calculator" worksheet to obtain the "Calculated DO Level." Next, wait 3 minutes, press Enter to accept the calibration, and record the DO concentration (mg/L) as the "Post-Cal. Reading." Press Enter to return to the calibration menu.
14. To begin error checking, place the sonde in the water bath, and select Sonde Menu / Run / Discrete Sample / Start Sampling. Once the readings have stabilized, enter the water bath temperature and barometric pressure in the "DO_and_pH_Calculator" worksheet. Paste the calculated DO Level (mg/L) from this worksheet into the relevant worksheet ("Pre_Deployment_Calibration" or "MP_WQMeter_Calibration"). Record the "Probe Reading" DO concentration (mg/L) from the sonde in the same location. Also record the DO Gain by selecting Sonde Menu / Advanced / Cal Const.
15. Fill the calibration cup half way with tap water and thread it onto the sonde. The sonde is now ready for use.

Troubleshooting

Four potential problems may arise when calibrating the Rapid Pulse DO sensor: 1) a high DO Charge reading; 2) a hi/low DO warm-up failure; 3) a high or low DO Gain reading; and 4) a puncture in the DO membrane.

If a high DO Charge is experienced (normal range 50 $\pm$ 25), remove the DO probe from the sonde and confirm that the DO Charge drops to a range of -0.8 to +1.2. Values greater than 1.2 indicate the DO port is contaminated or wet. See the port cleaning instructions for corrective actions. If the DO Charge is within an acceptable range with the probe removed, then the problem is in the probe. Remove the electrolyte from the sensor, rinse the electrolyte well with deionized water, and dry it with a Kimwipe. Then, reinstall the probe and retest. If the charge remains outside the acceptable range, then the probe has internal leakage or contamination. The last option before replacing the probe is to soak it per the cleaning instructions and recondition it with the provided maintenance kit.

The first step in isolating the cause of a hi/low DO warm-up failure is to test the sonde with the DO probe removed. With the probe removed, the DO Charge should range between -0.8 and +1.2. If the charge exceeds 1.2, clean both the probe and sonde bulkhead connector per the cleaning instructions in the Maintenance section below. After cleaning, run the DO probe for 15 minutes in the Discrete Sample mode, and then retest probe function. Let the sonde sit idle for at least 60 seconds before beginning the hi/low warm-up test. If the probe still fails the test, it must be replaced.

The DO Gain number is a multiplier and should range between -0.7 and +1.4. The DO Gain is usually out of the acceptable range as a result of a poor DO Charge reading or a failed hi/low warm-up test. Corrective actions are the same as those discussed above for the DO Charge and hi/low test.

To test the DO membrane for punctures, fill a 1,000 mL beaker with tap water. Use the aquarium pump to saturate the water with oxygen for approximately 30 minutes. After calibrating the sonde, run it in the Discrete Sample mode in water-saturated air (i.e., inside the calibration cup) and record the value once stable. The value will read less than 100% if the sonde was calibrated for unattended samples. Now place the sonde in the beaker and watch the DO% value. If it reads, for example, 98.2% in water-saturated air and the readings go up by 1-2%, then the membrane is compromised. The leak could be a small puncture in the Teflon membrane or a loose fitting O-ring. Replace both the membrane and O-ring when a leak is detected.

Turbidity

The turbidity reading is based upon a comparison of intensity of light scattered by a sample under defined conditions with the intensity of light scattered by a standard reference solution. Critical to the sonde's operation is that the lens covering the turbidity probe is kept clean both during calibration and field use. The turbidity probe includes an automated optic wiper which can be activated using the sonde display. **Note:** calibration procedures apply to YSI 6136 turbidity probes fitted to YSI 6600 or 6920 sondes; YSI 600QS sondes do not support turbidity probes. Other probe brands or models might report units of FNU or FTU, not NTU. For guidance on the topic of turbidity probes and appropriate units, see Anderson 2005.

Calibration and Error Checking

1. Triple rinse all probes with deionized water. Shake off excess water.
2. Place a small amount (~ 25 mL) of 0 NTU standard in the calibration cup, thread the cup onto the sonde, and shake the sonde covering the probes with solution. Discard the solution and repeat this step twice. **Note:** do not shake the turbidity solution container as this will trap air bubbles in the solution. Always calibrate with 0.0 NTU solution first to prevent cross-contamination of higher turbidity solutions.
3. Pour the turbidity standard into the calibration cup slowly, ensuring no air is bubbled into the solution. If air bubbles are present, tap the cup until bubbles are removed. **Note:** using the YSI calibration cup is strongly recommended. If glassware must be used, install the sensor guard first. Plastic beakers or containers can reflect the infrared light beam of the optical sensor and cause errors.
4. From the sonde display, select Sonde Menu / Calibrate / Turbidity / 2-point, and press Enter.
5. Input "0.0" as the first calibration standard and press Enter.
6. Select the "Clean Optics" option to activate the automated wiper. Once the cleaning process is complete, wait for the turbidity measurement to equilibrate. Then record the value as the "Pre-Cal. Reading" for 0 NTU in the relevant worksheet ("Pre_Deployment_Calibration" or "MP_WQMeter_Calibration") and press Enter. Record the updated value as the "Post-Cal. Reading.
7. Place the probe in the 100 NTU standard. Provided 0 NTU solution was used for the first calibration step, it is not necessary to clean the probes before immersing in 100 NTU solution.
8. Press Enter to continue calibration.
9. Enter "100.0" as the second calibration standard and press Enter.

10. Again, select the “Clean Optics” option to activate the automated wiper. Once the cleaning process is complete, wait for the turbidity measurement to equilibrate, record the value as the “Pre-Cal. Reading,” press Enter, and record the updated value as the “Post-Cal. Reading.”
11. Clean all probes on the sonde with deionized water. Shake off excess water.

Troubleshooting

The turbidity probe used on YSI 6600 and 6920 sondes is equipped with a wiper that cleans biofouling from the optical lens. Ensure that the wiper is parking approximately 180° from the lens. Do not turn the wiper manually as this will damage the internal gears and void the probe warranty. If the wiper is not parked approximately 180° from the optic lens, select Sonde Run / Clean Optics. The wiper will turn in each direction and park in the correct position. Occasionally the Clean Optics option may need to be selected two or three times to get the wiper to park correctly.

If a calibration error occurs, there are several possible causes, including 1) air bubbles on the optical surface, 2) contamination of the 0 NTU and higher standards, and 3) internal malfunction of the probe optical system. Whatever the problem, do not override the calibration error message. With the sonde in the Run mode, remove the sensor guard or calibration cup and place a thumb or finger over the probe optics. If no response is reported, the probe must be returned for servicing. If the probe is functioning properly, a high (>1,000 NTU) reading should be reported. In that case, return the probe to the 0 NTU solution, activate the wiper, and perform a 2-point calibration. Observe the readings in the 0 NTU solution. If a value of >5 NTU is reported, then the solution might be contaminated from debris on the probe(s) or sensor guard carried over from previous field use. Discard the solution, rinse the sonde, and try again with fresh solution. If the new reading is <5 NTU, proceed to the second calibration point. If not, contact YSI customer service for further assistance. If a calibration error occurs on the second point, use a new source of standard and perform the calibration again. Contact YSI customer service if an error still occurs after using a new standard source.

Occasionally slightly negative turbidity readings may be experienced in very clear waters, as may be encountered in non-glacial lakes within the SWAN. Negative readings are usually due to either contaminated 0 NTU turbidity solution, or interference from the calibration cup during the 0 NTU calibration. Avoid contaminated turbidity solutions by thoroughly cleaning all probes and the calibration cup prior to calibration procedures. Interference from the calibration cup may be a result of: 1) using a calibration cup with a gray (rather than black) bottom; 2) using a calibration cup with a black bottom contaminated with impurities; or 3) having the probe too close to the calibration cup bottom. To overcome these problems, use a clean, black cup and only thread the cup one turn onto the sonde to keep the cup as far from the probe as possible.

Additional Troubleshooting Procedures

Occasionally problems encountered during calibration require that the instrument be uncalibrated and returned to its factory settings. Uncalibration can be performed by following these steps:

1. Access the desired parameter to uncalibrate in the calibrate menu.
2. When prompted to input a number for a standard, hold down the Enter key and press Escape. Then highlight “Yes” and press Enter.

3. For additional troubleshooting, refer to the YSI Operations Manual or call YSI technical support at 1-800-897-4151.

Post-Trip Error Checking and Data Evaluation

Instrument probes experience "drift" during use in the field. As a result, they may operate outside the accepted range. To determine the amount of drift, the probes must be checked against their calibration standards.

Specific Conductivity, pH, and Turbidity

1. Allow the standards to equilibrate to the ambient temperature.
2. Rinse all probes on the sonde with deionized water. Shake off excess water.
3. Place probes in the standard solution for a given parameter (e.g., the 100 µS/cm solution or the pH 4 buffer).
4. From the display main menu, select Run and press Enter. Allow measurements to equilibrate, and then record the reading in the corresponding "Post-Trip Error Check" cell in the relevant worksheet ("Pre_Deployment_Calibration" or "MP_WQMeter_Calibration").
5. Results should be compared with the quality control criteria listed in Table 13.2 of SOP13. Data not meeting these criteria should be processed as described in SOPs 11 and 13.

Dissolved Oxygen

Ideally, the dissolved oxygen probe should be checked in the field at least twice a day. In reality, this is difficult because DO error checking requires an air-saturated water bath.

1. Set up a water bath with an air bubbler at least 8 hours prior to error checking. It is best to allow the air bubbler to run overnight to bring the DO saturation percent as close to 100% as possible. To begin error checking, place the sonde in the water bath, and select Sonde Menu / Run / Discrete Sample / Start Sampling.
2. Once the readings have stabilized, record the temperature, barometric pressure, and DO probe (in mg/l and %) readings in the relevant worksheet ("Pre_Deployment_Calibration" or "MP_WQMeter_Calibration"). The DO probe reading should be within 0.3 mg/l of the calculated DO level (which is based on barometric pressure and temperature and computed in the "DO_and_pH_Calculator" worksheet). If the DO data do not meet this requirement, they should be processed as described in SOPs 11 and 13.

Maintenance

Cleaning Probes and Ports

To remove contamination ─ including O-ring grease, saltwater electrolyte, and calibration solutions ─ the probes and their ports on the sonde bulkhead can be submerged in hot tap water with dishwashing detergent added (Dawn® or similar product with a degreasing agent is preferred). The water temperature should be at least 35 to 40 °C. Use a lab rinse bottle to flush the ports with soapy water. Soak the affected probe(s) and sonde connector(s) for one hour. Rinse thoroughly with deionized water and allow to dry overnight after the majority of water has been shaken off or blown dry.

Replacing Batteries

The battery lid for the 6600 and 6920 sondes is located on top of the sonde. Use a 9/64” hex screwdriver to remove the battery lid screws. Replace depleted batteries with 8 C-size alkaline batteries, being careful to observe correct polarity. Clean the O-ring on the outside of the battery compartment, and apply a thin coating of stopcock grease to the O-ring. Do not over-tighten the hex screws when replacing the battery compartment lid as this may result in flooding of the battery compartment. The 600QS sonde is powered by the 650 MDS display and, therefore, has no batteries.

Reconditioning Rapid Pulse DO Probes

Reconditioning of the silver electrodes on the 6562 Rapid Pulse DO probe is needed if the electrodes appear black in color. Only use the fine sanding disk provided in the YSI 6035 reconditioning kit for this procedure. First, remove the membrane, rinse the probe with DI water, and dry it with a Kimwipe. Next, hold the probe in a vertical position and with the sanding disk between your thumb and finger, strike the disk against the probe face as if striking a match. It is important to stroke the probe face in the same direction as the gold electrode located between the two silver electrodes. Ten to 15 strokes is usually sufficient to remove discoloration of the silver electrodes. After sanding, rinse the probe face with deionized water to remove any grit left from the sanding. Finally, add new KCl solution and a membrane.

Replacing Rapid Pulse DO Membranes

The KCl solution and Teflon membrane of the 6562 Rapid Pulse DO probe should be replaced before each long-term deployment, or at least once every 30 days when used for lake profiles and spot sampling. Following replacement, DO membranes must equilibrate for 8 to 12 hours before use. The procedure for membrane replacement is detailed below. For additional information, see Figures 8–13 in Section 2 of YSI 2011.

1. Secure the sonde in an inverted vertical position, with the probes facing up.
2. Remove the old DO membrane and clean the probe tip with water and lens cleaning tissue. Make sure to remove any debris or deposits from the O-ring groove.
3. Using the dropper bottle of KCl electrolyte supplied by YSI, place electrolyte on the DO probe tip until a high meniscus is formed.
4. Next, stretch a Teflon membrane tightly over the face of the DO probe and KCl meniscus, being certain no air bubbles are trapped underneath.
5. Holding the tightly stretched membrane in place, slip an O-ring over the membrane and into the groove along the sides of the probe.
6. Neatly trim away excess membrane that is sticking out beyond the O-ring.

Cleaning Conductivity Probe and Depth Sensor Openings

The cleaning brush and syringe provided with the 6570 YSI maintenance kit should be used for keeping the openings on the conductivity probe and depth sensor clean. Fifteen to 20 swabs with the brush rinsed in clean water should be sufficient to remove any biofouling or sediment that may become trapped in the conductivity probe opening. Only the provided syringe should be used to flush the depth sensor opening with water. Use of other objects, such as a pipe cleaner, may damage the sensor.

Cleaning pH Probes

In order for the 6561 pH probe to function properly, the glass bulb on the probe face must be kept clean of sediment and biofouling. First, remove the probe from the sonde. Initially, simply clean the bulb with clean water and a soft cloth, lens cleaning tissue, or cotton swab. If using a cotton swab, be careful not to wedge the swab between the glass sensor and the guard. If additional cleaning is required, soak the probe for 10 to 15 minutes in clean water containing commercial dishwashing liquid. After soaking, rinse the probe with clean water, wipe with a cotton swab, and re-rinse. If additional cleaning is still required, soak the probe for 30 to 60 minutes in 1 M hydrochloric acid (HCl). Then rinse the probe with clean water, wipe with a cotton swab, and re-rinse. Dry the probe and probe port with compressed air and apply a thin coating of O-ring lubricant to all O-rings before re-installing onto the sonde.

Replacing DO and Turbidity Probe Wipers

The 6150 DO and 6130 turbidity probes are equipped with wipers that can be activated manually or automatically to clean the sensor lenses. Wiper sponges will need to be replaced periodically. Replacement of the wiper sponge requires the hex wrench provided with the sensor. It is important to ensure that a small gap (~0.5 mm) is left between the wiper and the sensor face. This prevents the plastic wiper from making contact with and damaging the sensor lens.

Sonde Pre-Season Review

Careful inspection of the sonde and its components is required prior to field use. Inspect the sensor ports and battery compartment for water damage, corrosion, and stripped threadings. Calibrate the sensors to check for basic function and ability to sample within the minimum data quality objectives. Program a “test deployment” of unattended logging prior to actual deployment to ensure that equipment will perform in the field.

Sonde Post-Season Storage

Proper storage of the sonde will ensure readiness for use and extended life of the equipment. The procedure for short-term (several hours to several weeks) storage is the same for all sondes. Regardless of what sensors are installed on the sonde, it is important to keep them moist without immersing them in water. Place 100 mL of tap water or a wet sponge in the calibration or storage cup, and thread the cup onto the sonde to prevent evaporation. This procedure should be adequate for ensuring the air humidity is near 100% at all times during storage.

The procedure for long-term (> 4 weeks) storage depends on the sonde model. For 6600 and 6920 sondes, keep the conductivity/temperature and Rapid Pulse DO probes in the sonde, and leave the membrane and electrolyte solution on the DO sensor. Place enough water (deionized, distilled, or tap water) in the calibration cup to cover the sensors, thread the cup onto the sonde, and tighten to ensure a good seal and to minimize evaporation. If the sonde has an optical DO sensor, it is imperative that the internal sensor membrane be kept moist. If the optical DO sensor is removed from the sonde body, use the small sponge and rubber cap included with the sensor to keep the membrane moist during storage. The key for storing the pH probe of the 6600 and 6920 sondes is ensuring that the electrode junction does not dry out. Use KCl solution to store the pH probe in the storage bottle provided during shipping. Remove batteries during long-term storage of the 6600 and 6920 sondes because they may leak and corrode. For the 600QS sonde, make certain the DO probe has an undamaged membrane and that electrolyte solution is in place. Place approximately 100 mL of tap water in the storage cup, insert the sonde, and seal the cup with the cap and O-ring. Do not use deionized or distilled water for long-term storage of the 600QS sonde as it may damage the pH glass sensor. Be sure to insert port caps for any probes that are removed during storage.

Health and Safety Warnings

Standard solutions do not contain substances that are hazardous under normal usage (Table 3.3). However, precautions include avoiding inhalation, skin contact, eye contact, or ingestion. If skin contact occurs, remove contaminated clothing immediately and wash the affected areas with large amounts of water. Consult Material Safety Data Sheets (MSDS) for further action. MSDS are located on the T Drive at T:\Vital_Signs\Water_Fish\Equipment\Calibration_Standards.

Table 3.3. Compounds contained in calibration standards.

Standard	Compounds
Conductivity	Iodine, potassium chloride
pH 4	Potassium hydrogen phthalate, formaldehyde
pH 7	Sodium phosphate, potassium phosphate
pH 10	Potassium tetraborate, potassium carbonate, potassium hydroxide, disodium EDTA
Turbidity	Styrene divinylbenzene

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SOP4: Water Quality Measurement

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

Suggested Reading

Gibs, J., F. D. Wilde, and H. A. Heckathorn. 2007. Use of multiparameter instruments for routine field measurements (ver. 1.1): U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chapter A6, Section 6.8. Available at http://pubs.water.usgs.gov/twri9A/.

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Introduction

This standard operating procedure (SOP) provides the step-by-step instructions needed to monitor water quality parameters in lakes and rivers within the Southwest Alaska Network (SWAN). Core parameters for monitoring water quality, as defined by the National Park Service Water Resources Division (WRD), are water temperature, specific conductivity, dissolved oxygen, and pH (NPS 2002). SWAN added a measure of water clarity (either turbidity or Secchi depth) to this list, given the influence of glacial silt and volcanic ash on many SWAN waterbodies.

A primary objective of SWAN water quality monitoring is to identify the status and trends of core parameters in large lake systems during summer months (approximately June through September). Three different sampling schemes are used to accomplish this objective: vertical lake profiles, continuous monitoring, and in-situ monitoring. Vertical lake profiles are collected at random, spatially-balanced sites selected through a Generalized Random Tessellation Stratified (GRTS) process (Stevens and Olsen 2004). This sample design enables broad spatial coverage of large lake basins that experience both glacial and non-glacial inputs. It also provides a synopsis of the vertical water column profile. Continuous monitoring is conducted at lake outlets to provide an estimate of water quality variability over diel or multi-day scales. In-situ monitoring is conducted in conjunction with water level and discharge measurements at lake outlets to provide a snapshot of water conditions leaving the lake system. Additionally, in-situ monitoring is conducted to correct for sensor drift on continuously deployed instruments.

To achieve accurate and reliable estimates, field measurements must represent, as closely as possible, the natural condition of surface water at the time of sampling. Knowledge of and experience with sampling equipment and collection procedures are required to ensure that high quality data are collected. The following steps must be taken if high quality data are to be collected:

1. Establish and follow proper instrument calibration and error checking techniques (SOP3).
2. Maintain a permanent record (i.e., a log book) for each field instrument for recording calibrations and manufacturer repairs.
3. Have a back-up instrument readily available and in good working condition.
4. Become familiar with new instruments and techniques before collecting data. The “Record of Bias” file developed by WRD (NPSWRD_Record_of_bias_080428.xlsx) should be used as a quality assurance/quality control (QA/QC) check to ensure that new and old instruments/ methods produce comparable data. The worksheet is located on the T Drive at T:\Vital_Signs\Water_Fish\Electronic_Field_Forms\SWAN_Master_Copies\Record_of_Bias_Form.
5. Follow all QA/QC procedures (SOP13). Make field measurements in a manner that minimizes operator error and bias. Check field measurement precision and accuracy (variability and bias).

Equipment and Supplies

A list of equipment and supplies needed for field sampling is provided below (Table 4.1). This list should be checked each day prior to leaving the boat dock.

Table 4.1. Checklist of field equipment and supplies needed for boat-based water quality monitoring. Some items listed will be unnecessary if sampling from a float plane.

- ☐ Multiparameter instrument (e.g., YSI 600QS sonde)
- ☐ Sonde display (e.g., YSI 650 MDS)
- ☐ Field cables for sonde (200 ft- and 8 ft-long)
- ☐ Field laptop (e.g., Panasonic CF-18 Toughbook) with 2 fully charged batteries
- ☐ Adapter to power laptop via boat battery
- ☐ Data port cable for connecting sonde display to field laptop
- ☐ External memory drive (e.g., USB jump drive) and hard copy of electronic field forms
- ☐ Calibration information for sonde (in an electronic worksheet and/or log book)
- ☐ Sonde maintenance kit (YSI 6570)
- ☐ Secchi disk with rope, tape measure, and weights
- ☐ Global Positioning System (GPS) device with GRTS sample sites loaded
- ☐ Hard copy list of GRTS sample sites with lat / long coordinates
- ☐ NIST-traceable thermometer with protective metal tube
- ☐ Depth finder or flasher
- ☐ Digital camera
- ☐ Extra batteries (at least 8 C-cell batteries for YSI equipment and 4 AA for GPS)
- ☐ Field notebook, pencils, pens (indelible ink)
- ☐ Field trip itinerary
- ☐ Park radio and fully-charged spare battery
- ☐ Extra gas can filled with gas
- ☐ Boat emergency supply kit (e.g., flares, whistle, fire starter, space blanket, etc.)
- ☐ Tool kit for boat motor and equipment (e.g., screw drivers, spark plug wrench, pliers, etc.)
- ☐ Personal flotation devices (1 per person)
- ☐ Knife or multi-tool (1 per person)
- ☐ Personal gear (water, food, extra clothing/hat, sunglasses, sun screen, rain gear, etc.)

Vertical Lake Profiles

Vertical lake profiles are collected during a summer index period (late July to late August) to document vertical gradients in core water quality parameters, especially thermoclines. Thermoclines are the portion of the water column where the maximum rate of temperature change occurs in relation to depth, usually defined as >1°C per meter. The differences in water density above and below a thermocline can also lead to differences in dissolved oxygen levels and other parameters, all of which heavily influence lake productivity.

While traditional vertical lake profiles are measured from the surface to the lake bottom, we are limited by the maximum submersible depth of our instruments (61 m for YSI "6-series" sondes) relative to the maximum depth of the lakes (e.g., ~280 m in Lake Clark). Thus, we will conduct vertical lake profiles down to 50 m. Continuous water temperature monitoring on Lake Clark since September 2006 has not shown the formation of a thermocline below 50 m.

To ensure a complete sample set (10 GRTS points per lake basin), a minimum of 8 days and 12 days should be scheduled for Lake Clark and Naknek Lake, respectively. This large window will allow for weather delays and other issues that may come up. Maps of vertical lake profile sites for Tier 1 lakes are provided in Figures 4.1 and 4.2. Location coordinates for each site are provided in Appendix 4.1.

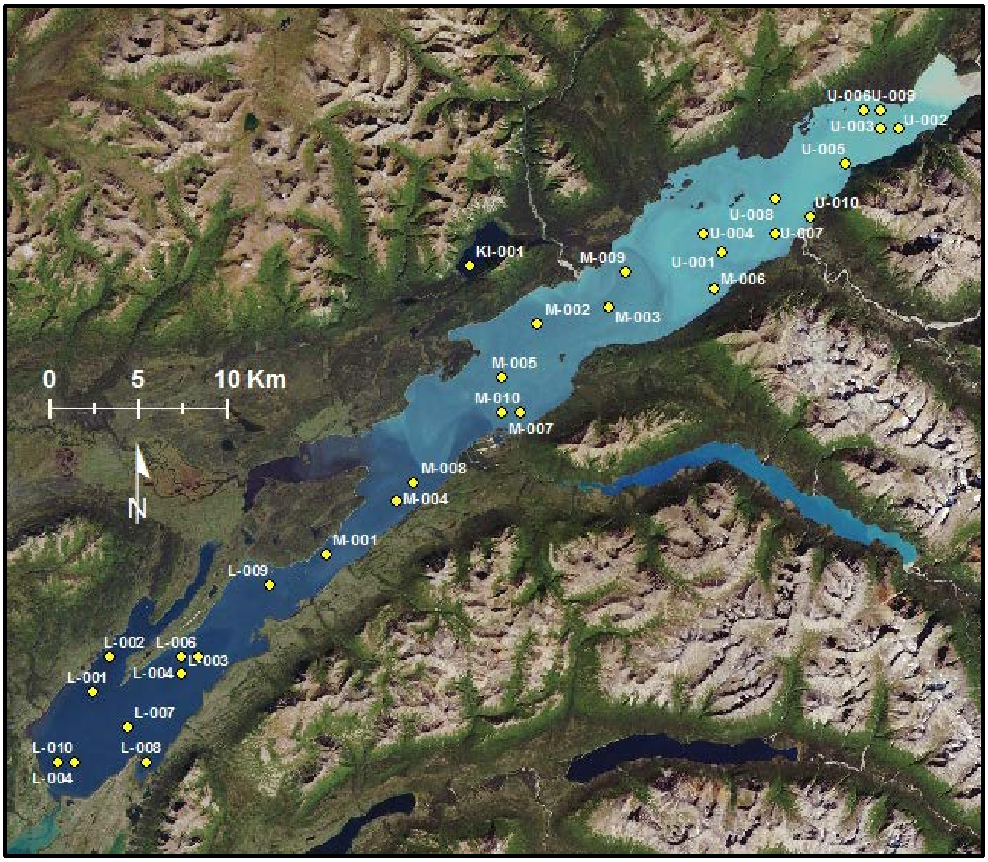

Figure 4.1. Current LACL Tier 1 GRTS sites for vertical lake profile monitoring.

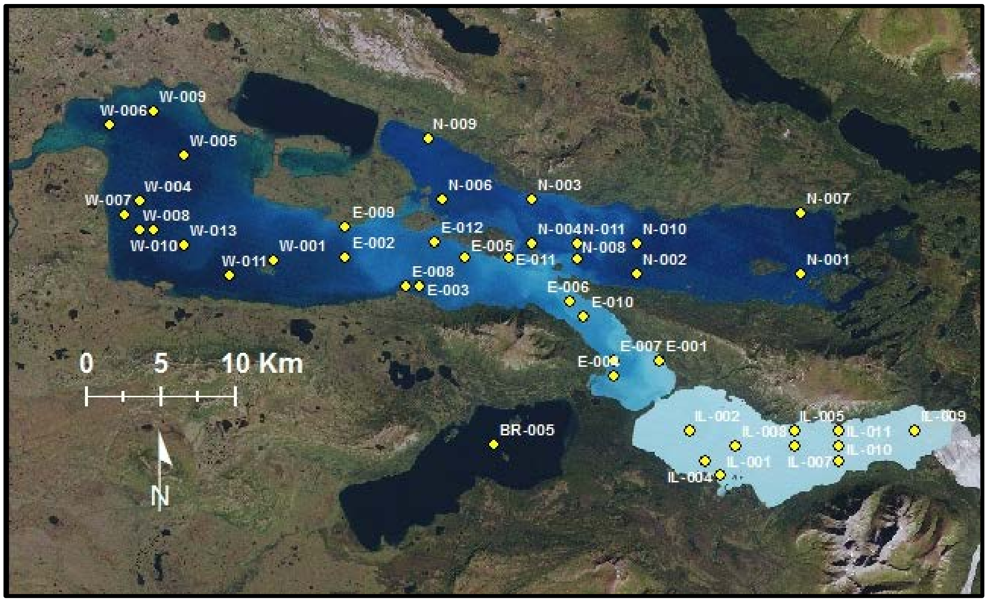

Figure 4.2. Current KATM Tier 1 GRTS sites for vertical lake profile monitoring.

Data Recording

Vertical lake profile data can be recorded manually on electronic or paper field forms, or automatically on the YSI 650 MDS sonde display (hereafter the “sonde display”). Until 2012, data were recorded both ways; then manual recording was discontinued in the interest of saving time. As long the data are double-checked on the sonde display after each profile, and then downloaded from the display after each day in the field, the risk of losing data is minimized. The electronic field form, SWAN_VertLakeProfile_fieldforms_MASTERCOPY, is still used to record metadata (i.e., location, date, weather) and Secchi depths (Figure 4.3). Blank forms are located on the T Drive at T:\Vital_Signs\Water_Fish\Electronic_Field_Forms\SWAN_Master_Copies\Vertical_Lake_Profile_Field_Form. Naming conventions for both the electronic field forms and the sonde display files are provided in Appendix 4.2.

Field Measurements

SWAN field measurement methods have evolved over time. For example, one replicate site was included per lake basin until 2011, and two measurements were taken per depth (i.e., down and up the profile) until 2012. For a detailed description of methodological changes, see Moore et al. 2012 and Wilson and Moore 2013.

1. After navigating to the sample site (Appendix 4.1), save the electronic field form with the correct file name (Appendix 4.2) and record the sample site information (Figure 4.3).
2. Set up the portable depth finder and record the depth of the site on the electronic field form. If conducting Tier 1 sampling on a boat with a built-in depth finder, use it rather than the portable depth finder to measure site depth. Use this information to determine how deep to lower the sonde. It is important to avoid contacting the lake bottom.

3. Connect the sonde to the sonde display with the 200’ field cable and power up the sonde display.

4. Lower sonde sensors just under the water surface and hold in position while sensors acclimate to water conditions. **Note:** placing sonde sensors in a bucket of lake water when moving between sites reduces the acclimation time.

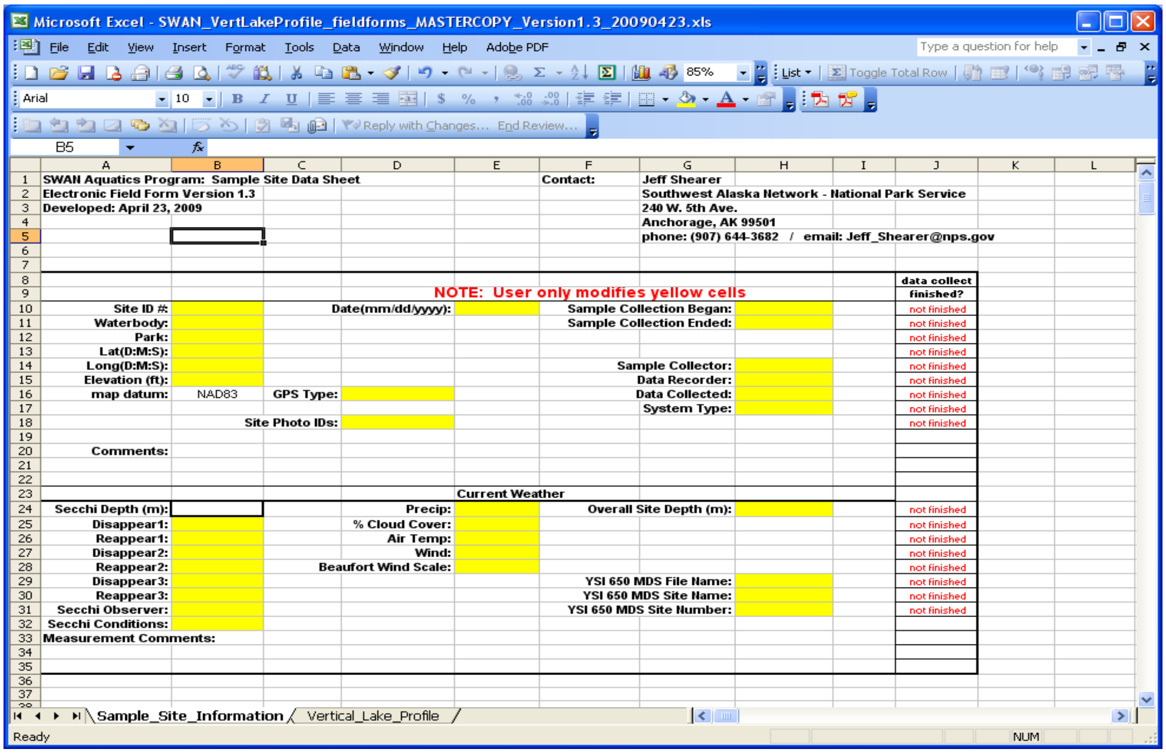

Figure 4.3. Electronic field form for recording site information and Secchi depth during vertical lake profile monitoring.

5. On the sonde display, select Logging Setup and ensure that Use Site List is selected. Next, select Edit Site List. Create a File Name based on the naming convention in Appendix 4.2.

6. Select Sonde Menu / Report and ensure that Date, Time, Temp (°C), SpCond (uS/cm), DOsat (%), DO (mg/L), DOchrg, Depth (m), pH, and pH mV are selected for reporting.

7. Return to the main menu and select Sonde Run. In well-mixed, oxygen saturated waters (typical of SWAN lakes), water temperature will often have the largest vertical gradient compared to dissolved oxygen (DO), pH, and specific conductivity. Thus, wait for temperature readings to stabilize. Because temperature often takes the longest to stabilize, this assures all other parameters have equilibrated. **Note:** pH readings might not “lock” onto a fixed number. Before recording a value, ensure that the pH readings are “dancing” around a mean and not “drifting” in one direction. If readings are drifting, the sonde has not equilibrated yet.

8. Once sensor readings have stabilized, select Log One Sample on the sonde display (upper left corner of screen display) and record data to the appropriate File Name. The sonde display

will indicate Sample Logged. Lower the sonde to the next depth interval (1 m) using the depth shown on the sonde display as a guide.

9. When sensor readings have stabilized at the 1 m depth interval, repeat Step 7. **Note:** the sonde display will automatically default to the last file name where data were saved when Log One Sample is selected. Continue lowering the sonde and logging samples until 50 m or the lake bottom is reached. The recording depth intervals for vertical lake profiles are the surface, 1 m, 2 m, 3 m, 4 m, 5 m, 10 m, 15 m, 20 m, 25 m, 30 m, 35 m, 40 m, 45 m, and 50 m.
10. Repeat Step 7 until 50 m or the lake bottom is reached, whichever comes first. **Note:** if the sonde makes contact with the lake bottom, sensor readings may be influenced by anaerobic sediment conditions. Sharp declines in dissolved oxygen and pH readings when the field cable becomes slack may be an indication of this occurrence. In such cases, raise the sonde 1 or 2 m above the lake bottom, pull up and down repeatedly on the field cable to flush water over the sensors, and wait for sensor readings to stabilize (this may take several minutes).
11. Once all depth intervals have been logged, double check to ensure that the sonde display recorded data at each depth interval. If so, select Stop Logging and power off the sonde display. Check to make certain all required site information is recorded on the electronic field form, then save and close the file.
12. Be certain to conduct post-trip error checks once sampling is completed for the day to ensure sensor calibrations have not drifted outside an acceptable range. See SOP3 for details.

Secchi Depth

Secchi disc depth is a simplistic measure of water transparency to light and has been widely used in limnological studies (Wetzel 2001). The depth at which the colored disc disappears from view (the depth of interest) is influenced by the absorption characteristics of the water as well as dissolved and suspended particulate matter (e.g., sediments, algae, etc.). Secchi depth should be recorded at each site following collection of vertical lake profile data.

1. Measure Secchi depth on the shaded side of the boat using a 20-cm black and white Secchi disc. Be sure to remove sunglasses. **Note:** a 30-cm Secchi disc may be needed in exceptionally clear waters (e.g., Secchi depths greater than 20 m).
2. Slowly lower the disc until it just disappears and record the depth to the nearest 0.1 m on the electronic field form (Figure 4.3). Be certain the disc is suspended vertically. Heavy current or waves may require adding more weight to the Secchi disc or setting drift anchors.
3. Lower the disc farther so that it is completely out of sight and slowly raise it until it just reappears, then record that depth on the field form.
4. Repeat Steps 2 and 3 two more times. Secchi depth will be the average of all six readings. Record the Secchi observer and Secchi observation conditions (e.g., 1 = clear skies, calm winds; 2 = partly cloudy, choppy waves; 3 = dark skies, heavy chop, strong drift) as well.

Continuous Monitoring

The objective of continuous monitoring of core parameters at lake outlets is to document variability in water quality over diel or multi-day temporal scales that otherwise may be missed with in-situ sampling. Of particular interest are the short-term temporal fluctuations in core parameters within glacial and non-glacial systems, as well as changes in water quality associated with the seasonal hydrograph.

Continuous monitoring is limited by the number of sondes with internal memory that SWAN has in inventory ─ currently only two. As a result, it is not possible to continuously monitor inflowing tributaries, or even the outflows of smaller Tier 1 lakes. Sampling during the full range of the open water period at Lake Clark and Naknek Lake has been prioritized.

Data Recording

Continuous water quality data are logged only to the sonde's internal memory due to the unattended deployment technique used to collect data. Files should be saved following the naming conventions outlined in Appendix 4.2 and SOP10.

Field Measurements

<u>Sonde Programming</u>

1. Connect the YSI 6600 or 6920 multiparameter sonde to the YSI 650 MDS sonde display and program the sonde to automatically record by selecting Sonde Menu / Run / Unattended Sample.
2. In the Unattended Set-up menu, set the interval to 01:00:00 (i.e., 1 hour), the start date to the day after deployment, the start time to 00:00:00 (i.e., midnight), and the duration days to 365. Be sure to note the battery life and free memory, which is based on battery voltage and sampling frequency. Battery life and free memory should extend several weeks to a month or more beyond the anticipated deployment duration to ensure the instrument remains operational in case of inability to access the site at a later date. **Note:** the sonde display will indicate battery life even when there are no C batteries installed in the sonde, due to a much smaller internal battery built into the sonde. It is important to physically check for the presence and condition of C batteries.
3. Double check that all intended parameters are being recorded by selecting View Parameters to Log. The sonde should be programmed to record date, time, depth (m), temperature (°C), conductivity (µS/cm), specific conductivity (µS/cm), DO sat (%), DO (mg/L), DO charge, pH, pH millivolts (mV), battery level, and barometric pressure (mm Hg). If one or more parameters must be added, go to Sonde Menu / Report to select the appropriate parameter(s).
4. When all parameters are set, select Start Logging. The sonde is now programmed to start logging at the set date and time. Power off the sonde display and disconnect the field cable from the sonde.

<u>Sonde Deployment</u>

1. Deployment should begin as soon as a site becomes ice-free and accessible. It should continue throughout the open water period (June–September).

2. If possible, sondes should be deployed in reaches with low turbulence and uniform cross section, in a relatively straight portion of the stream located as close to the mouth of the lake as is safe and practical. Attention must be given to channel features. Do not place the sonde on an inside river bend or in a deposition zone where shifting bed loads and glacial silt will bury it.
3. For protection of the sonde, a sensor guard should be installed and the sonde should be housed inside a heavy duty polyvinyl chloride pipe (e.g., Schedule 80 PVC; Figure 4.4), with the sensors at the open end and a 3/8" lag bolt keeping the sonde in place.
4. Affix the sonde and housing unit securely to a heavy anchor (onsite rock or concrete block) that will not move during high flow events (Figure 4.4). Ideally, the sonde and housing unit are connected with a stainless steel cable to a secure object outside the river channel as well, in case of anchor failure during flood events. The cable will also aid in recovery of the sonde in the event the unit becomes buried due to sediment deposition.
5. The sonde should be placed within the centroid of flow. However, given the non-wadeable nature of most lakes outlets, placing the sonde in the centroid of flow may not be possible. No bridge foundations or other manmade structures (which would provide ideal attachment points) exist at monitoring sites in SWAN parks. Individual site conditions will dictate specific locations where the sonde can be safely deployed. Regardless of site conditions, always position sonde with sensors oriented downstream.
6. If possible, return to the deployment site within a day or two of deployment to ensure that the sonde is logging data.

Figure 4.4. For continuous monitoring, the sonde is placed in a PVC housing moored via hose clamps cast in concrete (panel A) or line secured to a metal anchor (panel B).

<u>Sonde Maintenance, Inspection, and Downloading</u>

Periodic site visits serve to provide an ending point for the water quality measurements since the last site visit, to provide a starting point for the next set of water quality measurements, and perhaps most importantly to verify that sensors are recording properly and have not drifted outside the range of acceptable differences from calibration standards. Multiparameter sonde sensors will drift from their calibrated condition with time for two primary reasons: 1) fouling due to algal, sediment, and other material build-up on the sensors, and 2) electronic calibration drift. Specific environmental and hydrologic conditions at a site coupled with sensor type will dictate the degree of sensor drift, and thus the frequency of site visits needed for sonde maintenance (Wagner et al. 2006). In general, sondes should not be deployed longer than four to six weeks between site visits. The following steps are provided to guide field crews through site inspection procedures.

1. Using an independent, freshly calibrated sonde (hereafter, the "field meter"), record seven consecutive core water quality parameter readings as close to the deployment sonde (hereafter, the "monitor") as possible. Record the seven readings in the Site_Visit_Measurements worksheet of the Excel file called SWAN_Continuous_ Calibration_Drift_Corrections_MASTERCOPY (Figure 4.5). Find blank forms on the T Drive (T:\Vital_Signs\Water_Fish\Electronic_Field_Forms\SWAN_Master_Copies \Continuous_Calibration_and_Drift_Correction_Form) and save them with the following naming convention: 4-letter park code_5-letter waterbody code + "o" for outlet_continuous_calibration_date (YYYYMMDD).
2. Next, retrieve the PVC housing unit containing the monitor. Carefully remove the monitor from the housing and attach the sonde display with the field cable.
3. Power up the sonde display and select Sonde Menu / Run / Unattended Sample / Stop Logging.
4. Return the monitor to its deployment location and select Sonde Run on the sonde display. Once readings have stabilized, record seven consecutive core water quality parameter readings in the Site_Visit_Measurements worksheet. Power off the sonde display when finished.
5. Next, clean the monitor sensors as per instructions in the Maintenance section of SOP3.
6. Return the monitor to the deployment location and again record seven consecutive core water quality parameter readings onto the SWAN Site_Visit_Measurements worksheet.
7. Return the field meter to the deployment location, connect it to the sonde display, and once sensor readings have stabilized record seven consecutive core water quality parameter readings in the Site_Visit_Measurements worksheet.
8. This process will provide four different sets of sonde readings: before and after cleaning readings with the field meter, and before and after cleaning readings with the monitor. The difference between the before and after sonde cleaning reading of the monitor (once corrected for site condition changes with the field meter readings) is the amount of drift due to sensor fouling. See Wagner et al. 2006 for details.
9. Lastly, conduct the post-trip error checks for the specific conductivity, pH, dissolved and oxygen sensors as per instructions in SOP3. Record error check values in the Post_Deployment_Error_Checks worksheet of the same file (Figure 4.6). Sonde recalibration is conducted either after every download (a more conservative option), or only if post-trip

error check values differ from calibration standards more than the values listed in Table 4.2 (a less conservative option). Sensor drift correction procedures are outlined in SOP11.

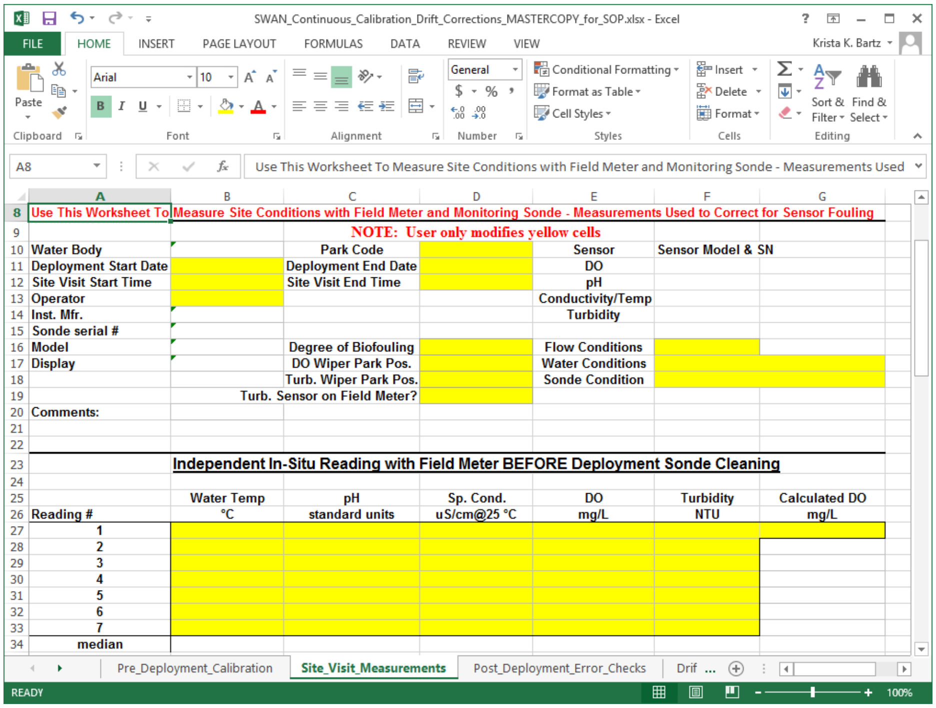

Figure 4.5. SWAN Site_Visit_Measurements worksheet used to record four sets of sonde readings during periodic site visits.

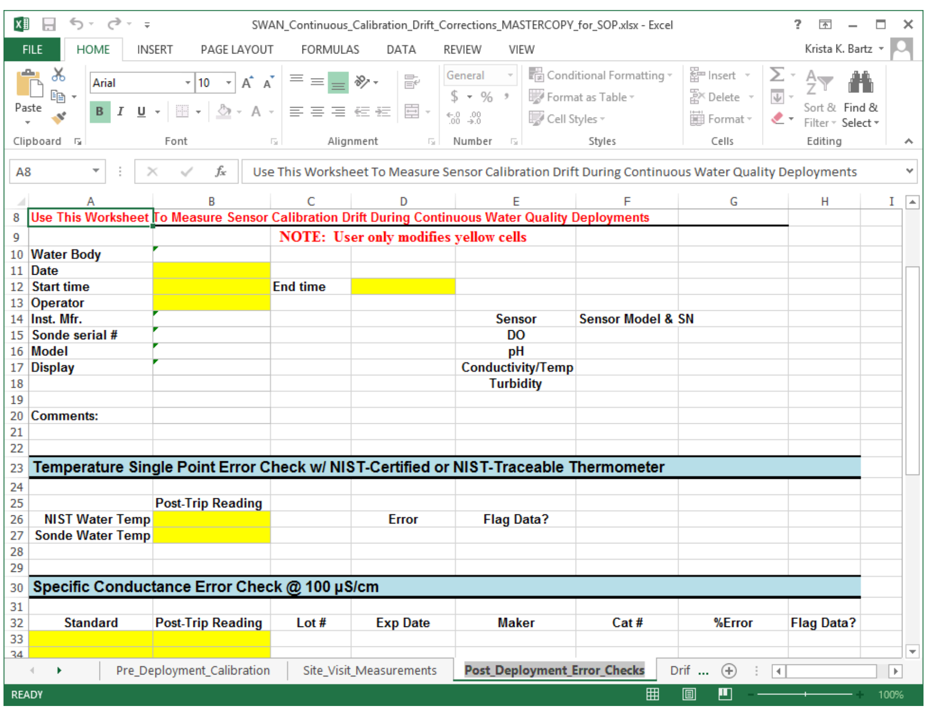

Figure 4.6. SWAN Post_Deployment_Error_Checks worksheet used to record sensor calibration drift during periodic site visits.

Table 4.2. Calibration criteria for water quality data corrections (adopted from Wagner et al. 2006). Variations outside the criteria listed require sonde recalibration.

Parameter	Calibration Criterion
Temperature	± 0.2 °C
Specific conductivity	± 5 µS/cm or ± 3% of the measured value, whichever is greater
pH	± 0.2 standard pH unit
Dissolved oxygen	± 0.3 mg/L

In-Situ Monitoring

In-situ measurements of core water quality parameters are taken at lake outlets in conjunction with discharge measurements (SOPs 5 and 6) and during site visits to inspect continuously deployed sondes. The objective of in-situ monitoring is to obtain an integrated snapshot of conditions at the time of sampling. Thus, it is important to sample a location that is representative of the entire channel cross section. Sampling sites should be located in reaches with low turbulence and uniform cross section in a relatively straight portion of the stream, if possible. A single measurement taken at the centroid of flow (typically mid-width and mid-depth in a riffle or a section of stream where flow appears uniform) should be adequate if water at the sample site is well-mixed. To determine if water is well-mixed, follow the "equal-width increments" method, in which the stream cross section is broken into at least 10 increments of equal width, and core parameters are recorded in the center of each increment half way between the water surface and stream bottom on the vertical axis (Wilde 2008). If the range of measurements for each parameter does not vary outside the stabilization criteria (Table 4.3), then water conditions are considered well-mixed. If water conditions are not well-mixed, then in-situ measurements are reported as the integrated range of values recorded from each increment (see Wilde 2008 for more details).

Data Recording

As with the vertical lake profiles, in-situ data were recorded both manually (via electronic field forms) and automatically (via the sonde display) until 2012. From 2012 onward, data have been recorded only automatically. Naming conventions for in-situ and cross sectional profile data for electronic field forms and sonde display file names. Naming conventions for both the electronic field forms and the sonde display files are provided in Appendix 4.2.

Field Measurements

1. Connect the sonde to the sonde display with the field cable and power up the sonde display. The 8-foot field cable should be long enough for most sites.
2. On the sonde display main menu, select Logging Setup and ensure that Use Site List is selected. Next, select Edit Site List and create a File Name with the correct naming convention (see Appendix 4.2).

Table 4.3. Stabilization criteria and recommended instrument specification criteria for recording field measurements, adopted from Wilde 2008 and Penoyer 2003, respectively.

Standard Direct Field Measurement	Measurement Stabilization Criteria [a]	Recommended Instrument Specifications		
		Range	Resolution/ Sensitivity [b]	Accuracy [c]
Temperature [d]		-5 to +45 °C	0.01 °C	± 0.15 °C
Thermistor thermometer	± 0.2 °C			
Liquid-in-glass thermometer	± 0.5 °C			
Specific conductivity [e]		0 to 10^5 µS/cm	1 to 100 µS/cm (range dependent)	± 0.5% of reading + 1 µS/cm
When ≤ 100 µS/cm	± 5 %			
When >100 µS/cm	± 3 %			
pH [f]		0 to 14 pH units	0.01 pH unit	± 0.2 pH unit
Meter displays to 0.01	± 0.1 pH unit			
Dissolved oxygen [f]		0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ± 2% of reading or 0.2 mg/L, whichever is greater
Amperometric method in mg/L	± 0.3 mg/L			
Turbidity [e]		0 to 1000 NTU	0.1 NTU	±5% of reading or 2 NTU, whichever is greater (depth limit of 200 ft)
Turbidometric method in NTU	± 10 %			

[a] Variability/repeatability should be within the value shown. Measurement stabilization criteria are not the same as the Measurement Quality Objectives (MQOs) listed in the “Core Water Quality (Vital Signs) Monitoring Parameters for Marine and Coastal Parks” produced by the marine work group.

[b] These are manufacturer specifications for sensor resolution. As such, they are likely too narrow to be achieved in the field as a quality control check for sensitivity (i.e., AMS+), but they can be used as a starting point until more realistic AMS+ goals can be developed.

[c] In the case of field probes, accuracy is typically a “best case” maximum deviation from known correct values (typically based on comparisons with known NIST-certified reference materials or standards). True accuracy is a combination of high precision and low bias (see Irwin 2004 for details). Accuracy specifications reflect only the uncertainty in measurements of the instrument and sensor in combination, and not other factors that can affect accuracy, such as environmental factors or field personnel’s ability to calibrate and operate using good measurement protocols.

[d] Recommended “calibration check” is quarterly. The sensor must be calibrated by the manufacturer.

[e] Recommended sensor calibration is daily.

[f] Recommended sensor calibration is at the beginning and end of sampling at each station (twice a day, minimum).

3. Return to the main menu and select Sonde Run. Place the sonde in the water and wait for the sensor readings to stabilize.
4. Once sensor readings have stabilized, select Log One Sample (upper left on sonde display screen); do not log data to the sonde's internal memory. Select the appropriate File Name under the Site List and press Enter. The sonde display will indicate Sample Logged.
5. If recording a cross-sectional profile (i.e., to assess whether water at a sample site is well-mixed), proceed to the next increment and repeat Step 4 until all increments have been measured. Cross-sectional profile measurements should be taken at the monitor site first, then at each increment, and last at the monitor site again (Wagner et al. 2006). If discharge is measured at the site, the cross-sectional increments should correspond to the discharge increments (cells).
6. If taking an in-situ measurement, repeat Step 4 six more times. The seven readings should be recorded consecutively, one right after another. Recording seven consecutive readings enables the calculation of "Alternative Measurement Sensitivity Plus" (AMS+), a quality control step that provides an estimate of instrument noise and natural heterogeneity (Thoma et al. 2012, Irwin 2008). See SOP13 for details.

Appendix 4.1

Table 4.4. Vertical lake profile site IDs, sonde display file names, and approximate coordinates currently monitored on Tier 1 and Tier 2 lakes. Additional information (e.g., past sites) can be found on the T Drive at T:\Vital_Signs\Water_Fish\Data\Sample_Locations or T:\Vital_Signs\Water_Fish\GIS\Sampling_sites.

Park	Tier	Lake and basin	Site ID [a]	Latitude	Longitude
LACL	1	Lake Clark - Lower	lclarl001	60.07365	-154.72287
LACL	1	Lake Clark - Lower	lclarl002	60.09163	-154.70523
LACL	1	Lake Clark - Lower	lclarl003	60.08305	-154.63290
LACL	1	Lake Clark - Lower	lclarl004	60.03768	-154.75810
LACL	1	Lake Clark - Lower	lclarl005	60.09199	-154.63307
LACL	1	Lake Clark - Lower	lclarl006	60.09207	-154.61503
LACL	1	Lake Clark - Lower	lclarl007	60.05596	-154.68644
LACL	1	Lake Clark - Lower	lclarl008	60.03816	-154.66806
LACL	1	Lake Clark - Lower	lclarl009	60.12815	-154.54347
LACL	1	Lake Clark - Lower	lclarl010	60.03779	-154.74010
LACL	1	Lake Clark - Middle	lclarm001	60.14430	-154.48615
LACL	1	Lake Clark - Middle	lclarm002	60.26115	-154.27029
LACL	1	Lake Clark - Middle	lclarm003	60.27022	-154.19782
LACL	1	Lake Clark - Middle	lclarm004	60.17137	-154.41422
LACL	1	Lake Clark - Middle	lclarm005	60.23425	-154.30630
LACL	1	Lake Clark - Middle	lclarm006	60.27928	-154.08901
LACL	1	Lake Clark - Middle	lclarm007	60.21637	-154.30614
LACL	1	Lake Clark - Middle	lclarm008	60.18037	-154.39624
LACL	1	Lake Clark - Middle	lclarm009	60.28813	-154.17978
LACL	1	Lake Clark - Middle	lclarm010	60.21641	-154.28803
LACL	1	Lake Clark - Upper	lclaru001	60.29807	-154.08157
LACL	1	Lake Clark - Upper	lclaru002	60.36065	-153.89985
LACL	1	Lake Clark - Upper	lclaru003	60.36066	-153.91804
LACL	1	Lake Clark - Upper	lclaru004	60.30700	-154.09975
LACL	1	Lake Clark - Upper	lclaru005	60.34280	-153.95444
LACL	1	Lake Clark - Upper	lclaru006	60.36961	-153.93621
LACL	1	Lake Clark - Upper	lclaru007	60.30704	-154.02712
LACL	1	Lake Clark - Upper	lclaru008	60.32492	-154.02714
LACL	1	Lake Clark - Upper	lclaru009	60.36961	-153.91802
LACL	1	Lake Clark - Upper	lclaru010	60.31598	-153.99080
LACL	1	Kijik Lake	kijil008	60.29752	-154.32749
LACL	2	Crescent Lake	cresl002	60.37343	-152.96559
LACL	2	Hickerson Lake	hickl001	59.93532	-152.92641
LACL	2	Twin Lake - Upper	utwil001	60.63953	-153.85695
LACL	2	Tazimina Lake - Upper	utazl001	60.04860	-154.15576
LACL	2	Two Lakes	twol001	61.13037	-153.78816
LACL	2	Turquoise Lake	turql001	60.78791	-153.89409
LACL	2	Telaquana Lake	telal001	60.95232	-153.80440
LACL	2	Snipe Lake	snipl001	60.61790	-154.29907

Park	Tier	Lake and basin	Site ID [a]	Latitude	Longitude
LACL	2	Portage Lake	portl001	60.50484	-153.86165
LACL	2	Twin Lake - Lower	ltwil001	60.63577	-153.95159
LACL	2	Tazimina Lake - Lower	ltazl001	59.99332	-154.48237
LACL	2	Little Lake Clark	llcla001	60.41258	-153.68953
LACL	2	Lachbuna Lake	lachl001	60.48971	-154.00272
LACL	2	Kontrashibuna Lake [b]	kontl001	60.17845	-154.01776
LACL	2	Fishtrap Lake	fishl001	60.48694	-154.34905
KATM	1	Naknek Lake - East	naknle001	58.57230	-155.69742
KATM	1	Naknek Lake - East	naknle002	58.62959	-156.06311
KATM	1	Naknek Lake - East	naknle003	58.61306	-155.97576
KATM	1	Naknek Lake - East	naknle004	58.56266	-155.74868
KATM	1	Naknek Lake - East	naknle005	58.63174	-155.92499
KATM	1	Naknek Lake - East	naknle006	58.60666	-155.80272
KATM	1	Naknek Lake - East	naknle007	58.57160	-155.74914
KATM	1	Naknek Lake - East	naknle008	58.61280	-155.99302
KATM	1	Naknek Lake - East	naknle009	58.64748	-156.06419
KATM	1	Naknek Lake - East	naknle100	58.59796	-155.78500
KATM	1	Naknek Lake - Iliuk	naknli001	58.50477	-155.62352
KATM	1	Naknek Lake - Iliuk	naknli002	58.53116	-155.65922
KATM	1	Naknek Lake - Iliuk	naknli003	58.53329	-155.48703
KATM	1	Naknek Lake - Iliuk	naknli004	58.51350	-155.64115
KATM	1	Naknek Lake - Iliuk	naknli005	58.53267	-155.53869
KATM	1	Naknek Lake - Iliuk	naknli007	58.52373	-155.53829
KATM	1	Naknek Lake - Iliuk	naknli008	58.52288	-155.60715
KATM	1	Naknek Lake - Iliuk	naknli009	58.53426	-155.40093
KATM	1	Naknek Lake - Iliuk	naknli010	58.51539	-155.48626
KATM	1	Naknek Lake - Iliuk	naknli011	58.52434	-155.48665
KATM	1	Naknek Lake - West	naknlw001	58.62615	-156.14606
KATM	1	Naknek Lake - West	naknlw004	58.65922	-156.30379
KATM	1	Naknek Lake - West	naknlw005	58.68697	-156.25372
KATM	1	Naknek Lake - West	naknlw006	58.70330	-156.34139
KATM	1	Naknek Lake - West	naknlw007	58.64997	-156.32047
KATM	1	Naknek Lake - West	naknlw008	58.64134	-156.30259
KATM	1	Naknek Lake - West	naknlw009	58.71318	-156.29009
KATM	1	Naknek Lake - West	naknlw010	58.64165	-156.28533
KATM	1	Naknek Lake - West	naknlw011	58.61633	-156.19727
KATM	1	Naknek Lake - West	naknlw013	58.63331	-156.25020
KATM	1	Naknek Lake - North	naknln001	58.62677	-155.53568
KATM	1	Naknek Lake - North	naknln002	58.62436	-155.72560
KATM	1	Naknek Lake - North	naknln003	58.66739	-155.84884
KATM	1	Naknek Lake - North	naknln004	58.64056	-155.84740
KATM	1	Naknek Lake - North	naknln006	58.66585	-155.95254
KATM	1	Naknek Lake - North	naknln007	58.66255	-155.53728

Park	Tier	Lake and basin	Site ID [a]	Latitude	Longitude
KATM	1	Naknek Lake - North	naknln008	58.63235	-155.79512
KATM	1	Naknek Lake - North	naknln009	58.70136	-155.97188
KATM	1	Naknek Lake - North	naknln010	58.64225	-155.72649
KATM	1	Naknek Lake - North	naknln011	58.64129	-155.79558
KATM	1	Lake Brooks	lbroo005	58.51986	-155.88560
KATM	2	Battle Lake	battl001	59.06150	-154.91830
KATM	2	Lake Coville	lcovi001	58.74882	-155.60104
KATM	2	Lake Grosvenor	lgros001	58.68909	-155.27884
KATM	2	Hammersly Lake	hamml001	58.82919	-155.11986
KATM	2	Idavain Lake	idavl001	58.78378	-155.98063
KATM	2	Jojo Lake	jojol001	58.60897	-155.21377
KATM	2	Kukaklek Lake	kukal001	59.17590	-155.27580
KATM	2	Kulik Lake	kulil001	58.97640	-155.02240
KATM	2	Mirror Lake	mirrl001	59.23680	-154.76010
KATM	2	Murray Lake	murrl001	58.78400	-155.06960
KATM	2	Nonvianuk Lake	nonvl001	58.97740	-155.18730
KATM	2	Pirate Lake	piral001	59.00346	-154.71668
KATM	2	Spectacle Lake	specl001	59.20780	-154.86260
KATM	2	Devil’s Cove Lake	decol001	58.35128	-154.24333
KATM	2	Hallo Glacier Lake	hagll001	58.39847	-154.178
KATM	2	Dakavak Lake	dakal001	58.11549	-154.69270
KEFJ	2	Delight Lake	delil001	59.55086	-150.28031
KEFJ	2	Desire Lake	desil001	59.59504	-150.25693

[a] 5-letter waterbody code + 1-letter basin ID + 3-digit site number.

[b] From the lower basin of Kontrashibuna Lake.

Appendix 4.2

Table 4.5. Naming conventions for recording water quality data using electronic field forms and sonde display files. As of 2014, many water quality files (at T:\Vital_Signs\Water_Fish\Data\Water_Quality) do not adhere to these conventions.

Sampling Scheme	Data Recording Device	Naming Convention	Example
Vertical lake profile	YSI 650 MDS file	4-letter park code_5-letter waterbody code + 1-letter basin ID + 3-digit site number_'profile'_date + 'raw'	KATM_naknle003_profile_20090814raw
Vertical lake profile	Electronic field form	4-letter park code_5-letter waterbody code + 1-letter basin ID + 3-digit site number_'fieldform'_date + 'metadata'	LACL_lclarm008_fieldform_20140717metadata
Continuous monitoring	YSI 650 MDS file	4-letter park code _5-letter waterbody code + 'o'_ 'continuous'_'wq'_date + 'raw'	KATM_naknlo_continuous_wq_20140904raw
In-situ monitoring	YSI 650 MDS file	4-letter park code_5-letter waterbody code_ 'insitu'_date + 'raw'	LACL_chulr_insitu_20090718raw
Cross sectional profile	YSI 650 MDS file	4-letter park code_5-letter waterbody code_ 'xsect'_'wq'_ date + 'raw'	LACL_lclar_xsect_wq_20140913raw

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SOP5: Discharge Measurement in Wadeable Waters

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

SOP5 - Contents

SOP5 - Figures

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Introduction

Stream discharge is the volume of water passing a given point on a stream bank per unit of time. Discharge is a key parameter, both in understanding hydrologic cycles and in relating standing concentrations of nutrients, ions, and contaminants to their movement through aquatic environments. Many streams within SWAN park units are large and unwadeable, requiring boat-based techniques for obtaining discharge values. However, other streams of interest within SWAN are wadeable, which enables the use of a different set of techniques. This standard operating procedure (SOP) describes the methods for determining discharge in wadeable streams, from site selection and equipment set-up, to data collection and analysis.

Discharge (ft^3/s or m^3/s) is fundamentally related to velocity (ft/s or m/s). To calculate discharge (Q), a cross-section of the stream is selected and then divided into evenly spaced "cells." Cell width (W), water depth (D), and velocity (V) measurements are recorded for each cell at the cell midpoint. Discharge (Q) is then computed from these measurements, as shown in Figure 5.1.

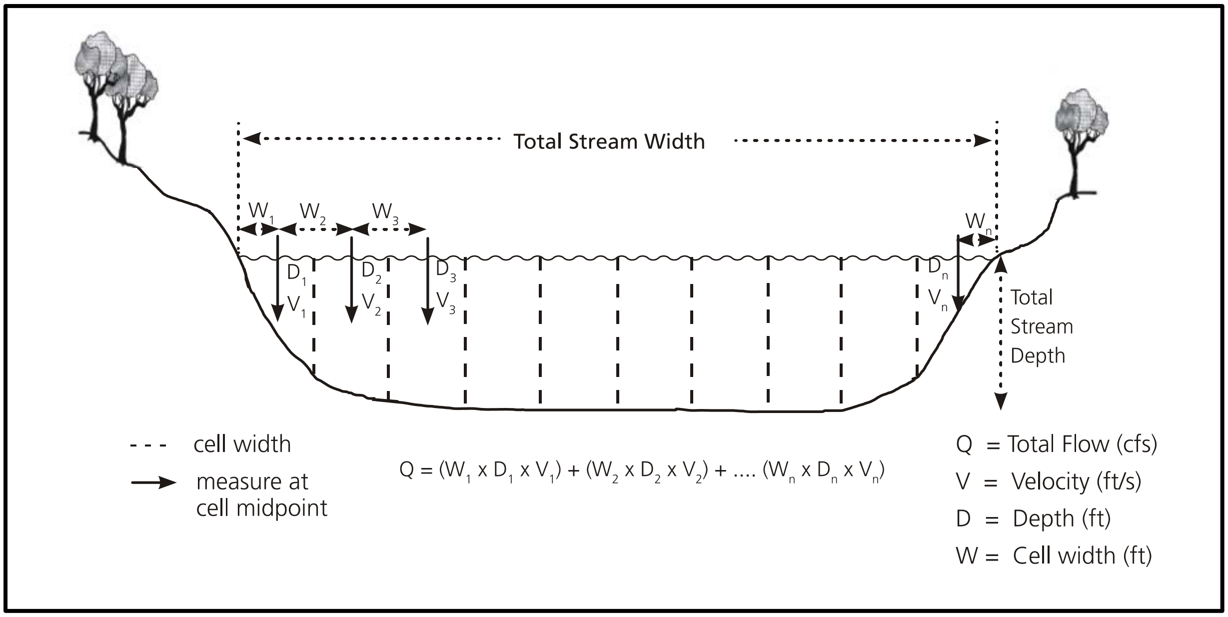


Figure 5.1. Simplified illustration of the technique for discharge calculation presented in this SOP.

In wadeable streams, velocity measurements are made using a hand-held flowmeter connected to a top setting wading rod. Many types of flowmeters are on the market (e.g., Marsh-McBirney, Pygmy, Price AA, Acoustic Doppler Velocimeter). Because SWAN has two Marsh-McBirney flowmeters in its inventory, and because acoustic Doppler technology is highlighted in SOP6, this SOP focuses on the Marsh-McBirney Flo-Mate portable flowmeter.

This procedure is conducted with a two-person crew ─ a data recorder and an observer who operates the flowmeter. Both crew members should be familiar with the field methods for obtaining accurate velocity readings and the calculations required to convert velocity readings to discharge.

Marsh-McBirney Flo-Mate

The Marsh-McBirney Flo-Mate (Model 2000) is a portable flowmeter that uses an electromagnetic sensor to measure velocity in a conductive liquid, such as water. As water moves through the magnetic field, a voltage is produced. The magnitude of the voltage is proportional to the velocity at which the water moves through the magnetic field (Marsh-McBirney 1990). This protocol is meant to highlight the operational features of the digital flowmeter. Personnel should be familiar with the basic operation of the meter, and should carry a laminated copy of the operating manual in the field.

Features

- The sensor uses digital filtering to remove electrical noise that may be present in the flow.
- A "noise" flag is displayed if electrical noise interferes with normal operations.
- A "conductivity lost" flag will be displayed and velocity readings are blanked out when conductivity is lost. This occurs when the sensor is out of the water, and may occur when the batteries are low.
- If conductivity is lost for more than 5 seconds, the emission of the electromagnetic current is turned off. The entire unit will power down if the sensor remains dry for more than 5 minutes.
- A "low battery" flag is displayed when the battery voltage is getting low. Battery life varies from 1 hour (alkaline) to 15 minutes (NiCad) once the low battery flag is displayed. If the voltage is too low, the unit will turn off. The unit operates on 2 D-cell batteries. Consult the manual for other battery options.
- There are 19 data storage locations in which velocity readings can be saved and recalled.

Calibration

The Flo-Mate sensor must be free of any oil or grease build-up to work properly. If the sensor appears to have a grimy film, wash it using warm water and a mild soap. Unless the sensor is used in highly contaminated liquids, the sensor generally should remain free of oil/grease build-up. The sensor is calibrated by conducting the "zero adjust check" in a 5 gallon bucket of clean water, according to the following steps.

1. Secure the cable to a rod (i.e., broom stick, rebar) lying across the top of the bucket.
2. Place the sensor in the bucket, positioning it at least 3 inches from the sides and bottom of the bucket.
3. Let the sensor sit in the bucket for 5–10 minutes to allow all water movement to cease.
4. Set the filter value to 5 seconds.
5. Initiate the zero start sequence by pressing the STO and RCL button at the same time. The number 3 will appear on the screen.
6. Decrement to zero with the down arrow button. The number 32 will appear.

7. The unit will decrement itself to zero and turn off. The unit is now zeroed and ready for field use.
8. Zero stability equates to a ±0.05 ft/s (±0.012 m/s) reading.
9. **Note:** each button in this sequence must be pressed within 5 seconds of the previous one. If the time between button entries is longer than 5 seconds or an incorrect button is pressed during the sequence, the unit will display an ERR 3 reading. Turn the unit off and on and start the sequence again.

Operation

The Flo-Mate has two operating modes: Real-Time and Recall. In the Real-Time mode, current velocity readings are displayed and the "period bar" is dynamic based on the set filter time (Figure 5.2). In the Recall mode, velocity readings are displayed from memory and the period bar is static.

The meter always powers up in Real-Time mode, and proceeds through the sequence shown in Figure 5.2. The software version is displayed first, and then the meter runs through a segment test. When the test is complete, the unit displays the current velocity reading. If the sensor is out of the water, a "conductivity lost" flag appears and there is a dashed line in place of the velocity reading. If the battery is low, a "low battery" flag is displayed. If the battery voltage is adequate, no flag appears. Be sure to carry extra batteries in the field.

In Real-Time mode, the user can select or change various settings, including units (English / metric), filter time (set time period for integrated reading), and type of integrated reading (Fixed Point Averaging or Time Constant Filtering). The user also can control the beeper and store readings in memory.

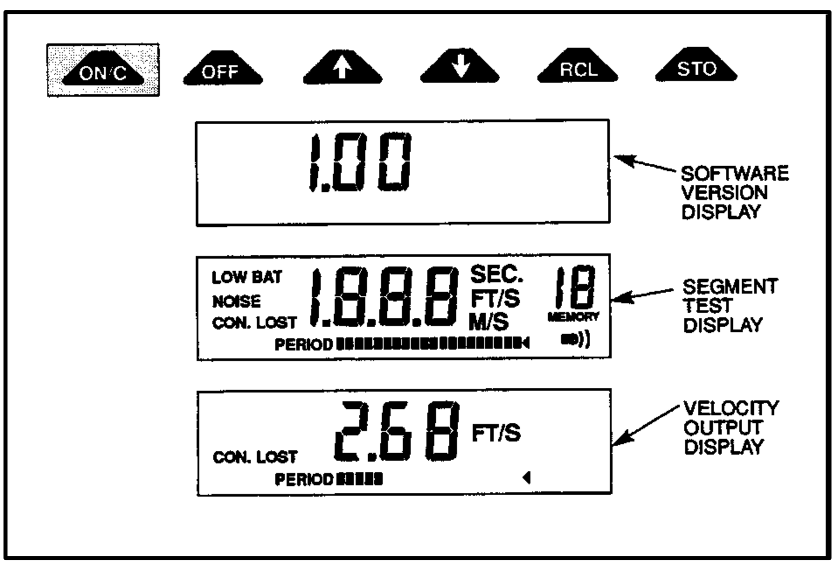


Figure 5.2. Start-up sequence display for the Marsh-McBirney Flo-Mate flowmeter. Once the unit has completed a segment test, the current velocity reading and units will be displayed. The period bar will be dynamic based on the filter time entered in seconds.

Although most SWAN data are recorded using the metric system, discharge measurements are an exception. Discharge (Q) is calculated in cubic feet per second (ft^3/s or cfs), therefore, all associated measurements should be in English units to avoid confusion and unnecessary conversions that can introduce error during the Q calculations. To set the flowmeter to record velocity in English units (ft/s), press the OFF and ON buttons simultaneously and scroll through the settings to ft/s. **Note:** two beeper options (with and without the beeper) are available. Unless there is a reason to use the beeper, conserve battery power by selecting the ft/s setting without the beeper.

The fluid dynamics surrounding the sensor often cause velocity readings to fluctuate, making it difficult to assign a single true reading. The flowmeter offers two methods of stabilizing velocity readings: Fixed-Point Averaging (FPA) and Time Constant Filtering (rC). These methods dampen the velocity readings based on a filter time period (FPA: 2-120 seconds; rC: 2-30 seconds). Press the up and down arrow buttons simultaneously to move between these two settings.

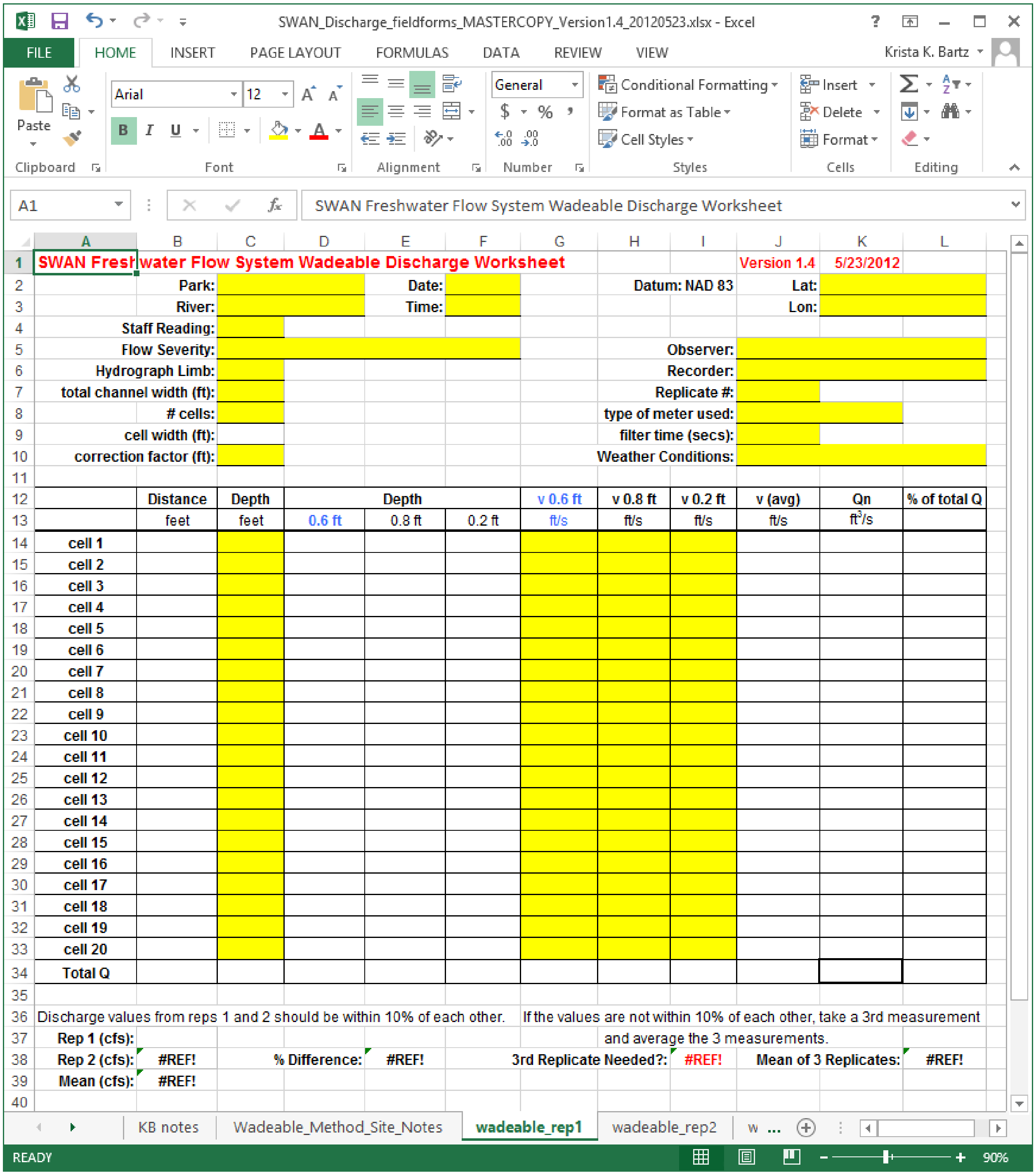
The FPA method is the preferred setting for SWAN velocity measurements. When switched to that setting, the display will read FPA and the velocity output will be updated at the end of each averaging period, based on the set filter time. The filter time should be set based on the type of flow. If the flow is relatively calm and uniform, set the filter to 45 seconds. If the flow is more irregular, set the filter time to 90 seconds or higher. Set the filter time to the greatest time required for the stream conditions. While it is possible to reset the filter time as needed in the midst of a channel cross-section, it is easier and safer to select a filter time that accommodates the range of channel conditions before beginning the cross-section profile. The user may decide to adjust the recommended filter times (above) as needed.

To set the filter time, press the up arrow button and then use the up or down arrow to set the time in seconds. Be sure to record the filter time on the data sheet. **Note:** filter times may vary on the same reach based on the seasonal hydrograph. The rising limb of the hydrograph may require a longer filter time, whereas low flow or base flow conditions may require a shorter filter time.

Wadeable Discharge Datasheet

The master datasheet for wadeable discharge measurement is an Excel file called SWAN_Discharge_fieldforms_MASTERCOPY (Figure 5.3), located at T:\Vital_Signs\Water_Fish\Electronic_Field_Forms\SWAN_Master_Copies\Discharge_Field_Form. Before leaving for the field, this file should be opened and renamed using the “save as” option and the following naming convention: the 5 letter waterbody code_Q_date (yyyymmdd). For example a discharge measurement made at Lake Brooks outflow on June 30, 2008 would be saved in a file named: lbroo_Q_20080630. If an unnamed tributary is measured, use the hydrologic unit code (HUC). If the HUC is not identified, use the following convention: five letter lake code and cardinal orientation (e.g., lclar_westtrib_Q_date (yyymmdd)).

This file contains three relevant worksheets ─ wadeable_rep1, wadeable_rep2, and wadeable_rep3 ─ one for each set of cross-section measurements (see below). Although the worksheets can be printed on write-in-the-rain paper and included in the field gear, the electronic versions are populated with various parameters automatically, making field calculations unnecessary. Therefore, consider entering the data directly using the field laptop.



SWAN_Discharge_fieldforms_MASTERCOPY_Version1.4_20120523.xlsx - Excel

	A	B	C	D	E	F	G	H	I	J	K	L
1	SWAN Freshwater Flow System Wadeable Discharge Worksheet									Version 1.4	5/23/2012	
2		Park:			Date:			Datum: NAD 83		Lat:		
3		River:			Time:					Lon:		
4		Staff Reading:										
5		Flow Severity:							Observer:			
6		Hydrograph Limb:							Recorder:			
7		total channel width (ft):							Replicate #:			
8		# cells:							type of meter used:			
9		cell width (ft):							filter time (secs):			
10		correction factor (ft):							Weather Conditions:			
11												
12		Distance	Depth		Depth		v 0.6 ft	v 0.8 ft	v 0.2 ft	v (avg)	Qn	% of total Q
13		feet	feet	0.6 ft	0.8 ft	0.2 ft	ft/s	ft/s	ft/s	ft/s	ft³/s	
14	cell 1											
15	cell 2											
16	cell 3											
17	cell 4											
18	cell 5											
19	cell 6											
20	cell 7											
21	cell 8											
22	cell 9											
23	cell 10											
24	cell 11											
25	cell 12											
26	cell 13											
27	cell 14											
28	cell 15											
29	cell 16											
30	cell 17											
31	cell 18											
32	cell 19											
33	cell 20											
34	Total Q											
35												
36	Discharge values from reps 1 and 2 should be within 10% of each other.						If the values are not within 10% of each other, take a 3rd measurement					
37	Rep 1 (cfs):							and average the 3 measurements.				
38	Rep 2 (cfs):	#REF!		% Difference:	#REF!		3rd Replicate Needed?:		#REF!	Mean of 3 Replicates:		#REF!
39	Mean (cfs):	#REF!										
40												

KB notes | Wadeable_Method_Site_Notes | wadeable_rep1 | wadeable_rep2

Figure 5.3. Electronic field form for calculating discharge. Most unhighlighted cells in the form are populated automatically when the highlighted cells are filled in.

Measurement Techniques

The measurement techniques presented in this section are based on methods described by USGS (Rantz 1992). As stated above, a cross-section of the stream is selected and then divided into evenly spaced "cells." Cell width (W), water depth (D), and stream velocity (V) are then recorded for each cell at its midpoint (Figure 5.1). These techniques require a Marsh-McBirney Flo-Mate digital flowmeter, a top-setting wading rod, and a measuring tape or range finder. Table 5.1 lists additional field gear needed to conduct a wadeable discharge measurement.

Table 5.1. Checklist of field equipment and supplies needed for wadeable discharge measurement.

☐	Top-setting wading rod
☐	Marsh-McBirney Flo-Mate digital flowmeter
☐	Open reel measuring tape
☐	Stakes (for anchoring tape to each bank)
☐	Range finder
☐	Calculator
☐	Extra D-cell batteries (4)
☐	Hard copy datasheets (3 per site) and/or field laptop with electronic datasheets
☐	Rating curve (if available)
☐	4-ft long piece of rebar and a mallet (for creating a reference point, if necessary)
☐	Floating objects
☐	Stopwatch / timer
☐	Park radio w/ extra batteries
☐	First aid kit
☐	Personal floatation device (1 / person)
☐	Personal gear for field team

Field personnel are required to wear personal floatation devices (PFDs) while conducting the discharge measurements. If conditions appear to be unsafe or deteriorating, do not attempt a stream crossing. Instead, try to obtain velocity readings using the alternative techniques described below. All safety precautions should be followed, including filing a plan with Park dispatch to inform them of your location and intended field work. Additional safety information and guidelines can be found in SOP1.

Selecting a Site

<u>If a Rating Curve Already Exists</u>

If a rating curve has been developed, make an observation near the staff gage site. Read the staff gage and estimate the discharge for the reach using the known rating curve equation. Use this as a guide to determine how many cells are needed to adequately sample the river. Each cell should represent approximately 5% to 10% of the total flow. As a rule, 20-25 cells will be required.

The selected cross-section should be in reasonable proximity to the staff gage to avoid the need for adjusting measured discharge based on the rating curve developed for the gage site. However, a distance of 0.5 mi (approximately 1 km) between the gage and measuring section is acceptable if necessary to provide both a good stage-measurement site and a good discharge-measurement site (Rantz 1992).

<u>If a Rating Curve Does Not Exist</u>

If the measurement is to be obtained from a site where there is no pre-existing rating curve, the selected channel cross-section should be fairly uniform in depth, and flow should be parallel to the banks and fairly uniform throughout the cross-section.

General guidelines for site selection, from Rantz 1992, suggest that:

- the general course of the stream should be straight for about 300 ft (approximately 100 m) upstream and downstream from the site (i.e., not on the inside or outside of a river bend);
- total flow should be confined to one channel at all stages, and no flow should bypass the site as subsurface flow;
- the streambed should be free of aquatic plants, and not subject to scour and fill;
- the banks should be permanent, high enough to contain floods, and free of brush;
- unchanging natural controls should be present in the form of a bedrock outcrop or other stable riffle for low flow and a channel constriction for high flow; and
- reaches with obvious bed irregularities, such as large boulders or changes in depth, should be avoided.

Many Alaskan rivers do not conform to these guidelines. Glacial streams offer many challenges, as most guidelines are violated. In highly braided streams, select a uniform cross-section with a stable bottom and conduct discharge measurements in each braid. These separate discharge values can be summed to estimate total discharge.

Dividing the Cross-Section Width into Cells

After selecting the best site within the sample area, measure the wetted width of the channel at the site.

- If the channel is narrow and the flow is calm, use a measuring tape to determine the channel width. Stretch the tape across the channel and secure it on each bank. Record the channel width, accounting for any wrap on the tape to get an accurate measurement.

- If the channel and flow conditions make measuring by tape unfeasible, use a range finder to determine the channel width. If no obvious markers exist at the waterline, sight on objects that are on shore, but be sure to subtract the extra distance from the total width. Failure to do so will result in an overestimation of discharge.

Next, divide the total width into 20-25 evenly spaced "cells" (Figure 5.1). **Note:** in a channel with an irregular depth profile, cell width may vary as deeper cells should be sampled more frequently.

Measuring Cell Depth and Velocity

All velocity measurements are based on the total depth within each cell. Therefore, the depth must be measured and recorded first. Velocity is measured by the flowmeter at a single point. However, discharge is based on the "mean vertical velocity" within each measured cell. Mean vertical velocity is derived from depth-integrated measurements within the vertical profile. It can be estimated from several velocity measurements using established quantitative relationships.

Estimating Mean Vertical Velocity

The USGS recognizes six methods for estimating mean vertical velocity using these relationships. The "vertical-velocity curve method" is the most labor intensive and is the basis for coefficients used by other methods that are more common and less labor intensive. The "two-point method" involves recording velocities at 0.2 and 0.8 of the total depth in a given cell. These values are averaged to estimate the mean vertical velocity. This method provides the most consistent and accurate results (Buchanan and Somers 1968) and is the one used most frequently by USGS. This method is not used in waters less than 2.5 ft (0.76 m) because the sensor is too close to the surface and the bottom to provide accurate readings. In these conditions, the "six-tenths-depth method" is used. The other three methods used by the USGS are for measuring velocity in less than ideal conditions. SWAN staff will measure velocities under conditions in which the two-point or six-tenths-depth methods can be accurately and safely obtained. Use the two-point method whenever possible.

Two-Point Method

The two-point method requires three measurements per cell: the total depth in the cell, and the velocities at 0.2 and 0.8 depths from the water surface. For example, if the total depth measurement was 5 ft, velocity would be recorded 1 ft and 4 ft below the surface. The two velocity values are then averaged to estimate mean vertical velocity. This method is based on both field observations and mathematical theory (Buchanan and Somers 1968).

Six-Tenths Depth Method

The six-tenths depth method requires two measurements per cell: the total depth in the cell, and the velocity at 0.6 depth from the water surface. This method is used when the total depth is less than 2.5 ft, or the water depth is changing rapidly and there is not enough time to measure velocity accurately using the two-point method.

Using the Wading Rod to Determine Various Depths

The top-setting wading rod consists of a sliding rod incremented in feet and a depth gage rod incremented in tenths of feet (Figure 5.4). The top of the depth gage rod has a plate with a tenths scale from 0 to 10. The double lines on the body of the depth gage rod indicate half foot increments and the single lines represent tenths of feet. Each fractional depth (0.6, 0.2 and 0.8) can be determined based on the total depth by moving the sliding rod as described below. **Note:** the wading rod and flowmeter can be unwieldy to carry, even in calm channel conditions. Therefore, in the interest of safety, the recorder should follow along behind the observer, carrying the calculator, making the calculations, and calling out the distance values.

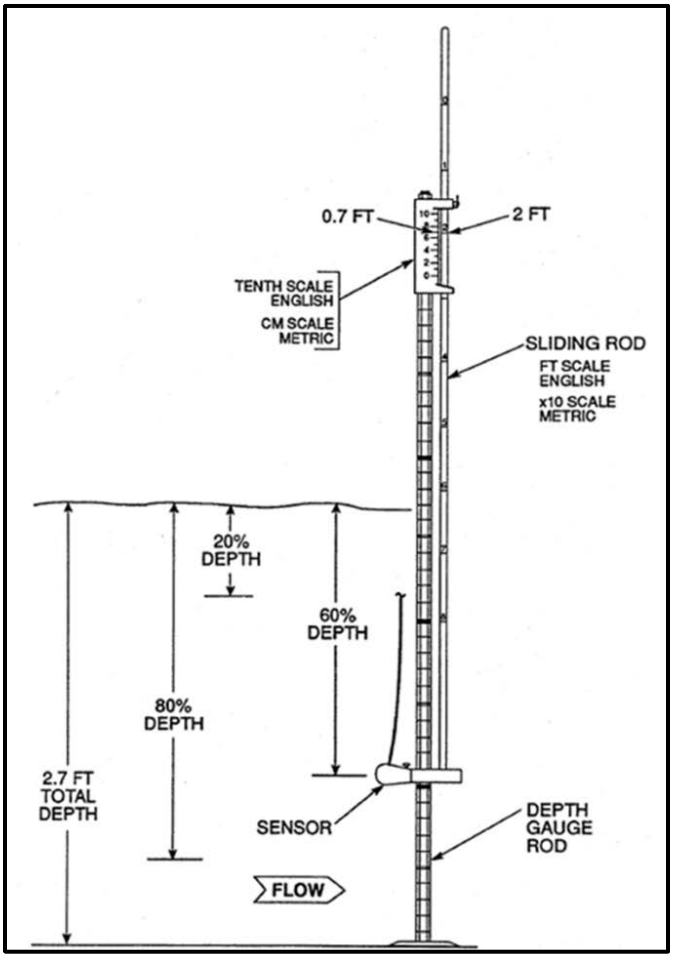


Figure 5.4. Top setting wading rod, illustrating the technique for setting the flowmeter sensor at 0.6 (60%) of the total depth (0.2 and 0.8 depths are also shown).

Total Depth

Place the depth gage rod firmly on the substrate. Holding the rod upright, use the double and single lines on the depth gage rod to measure the total water depth (e.g., 2.7 ft in Figure 5.4).

0.6 Depth

Line up the foot scale of sliding rod with the tenths scale on the top of the depth rod, to match the total depth value. For example, if the total depth is 2.7 ft, align the 2 ft mark on the sliding rod with the 7 tenths mark on the top of the depth rod.

0.2 Depth

Multiply the total depth by 2 and repeat the above process with that value. For example, if the total depth is 2.7 ft, then 2 x 2.7 = 5.4. Match the 5 ft mark on the sliding rod with the 4 tenths mark on the top of the depth rod.

0.8 Depth
Divide the total depth by 2 and repeat the above process. For example, if the total depth is 2.7 ft, then 2.7 / 2 = 1.35. Match the 1 ft mark on the sliding rod to a point half way between the 3 and 4 tenths marks on the top of the depth rod.

<u>Measuring Velocity</u>
The recorder should complete the informational section of the datasheet (Figure 5.3). Noting the hydrographic limb and weather conditions will be helpful for comparing readings over time at a given site. If the team is using a range finder, the recorder will operate the range finder and guide the observer to the next cell midpoint.

The observer should check to see that the flowmeter is ready to operate (i.e., the sensor is connected to the wading rod; the batteries are adequate; the units are set to ft/s; fixed-point averaging is selected; and the filter time is adequate for the conditions).

1. Starting on the near shore, determine the midpoint of the first cell. For example, if the wetted width is 100 ft and the number of cells is 20, then each cell width is 5 ft and the first observation point is 2.5 ft from shore. Each subsequent measurement is 5 ft from the previous point. This will place the observation points at the center of each cell (Figure 5.1). **Note:** the most recent version of the electronic datasheet calculates the observation points automatically, given the wetted width and the number of cells.
2. If the observer is using a measuring tape, follow the tape out to the proper position. If the recorder is guiding the observer with a range finder, have the observer move out into the cross-section so that the recorder can sight off the observer and guide him/her to the appropriate location.
3. The observer positions the wading rod to measure the total depth of the cell and calls out the value to the recorder. Based on this depth, decide which method to use.
4. If the six-tenths method is used, no calculations are required. The observer can simply position the sensor by moving the sliding rod as described above, take a velocity reading, and call out the value to the recorder. **Note:** prior to taking the reading, orient the sensor so it faces upstream, and stand downstream and to the side of the sensor to avoid inhibiting the flow.
5. If the two-point method is used, the recorder should calculate the 0.8 depth using the method described above and call out that depth to the observer. The observer adjusts the wading rod, makes a 0.8 reading, and calls out the velocity to the recorder. The recorder then calls out the 0.2 depth and the observer again adjusts the wading rod, makes a second velocity reading, and calls out the value.

6. Once the reading(s) have been made, the observer moves on to the midpoint of the next cell using either the tape or the range finder as a guide.
7. Repeat Steps 2 through 6 until the river cross-section is completed.
8. The recorder can use the time between velocity readings to calculate the area and discharge for each cell so that an estimated total discharge can be determined (see Figure 5.1). This will enable a prompt comparison the two discharge values to determine if an additional (i.e., third) set of measurements is necessary (see Step 11). **Note:** if the velocity readings are entered directly into the electronic datasheet on the field laptop, calculations will be done automatically.
9. If the site has a staff gage, take a staff reading after completing each channel cross-section. If a datum measurement is required, be sure to record those readings on the datasheet.
10. If the site is not a gaged site, select a permanent object (large tree, boulder, etc.) and record its lat/long coordinates. Measure the shortest distance between the object and the edge of the water line. This will serve as a reference for future discharge measurements. If a large permanent object is not available, install a 4-ft long rebar stake at least 3 ft into the ground above the highest observable water line, in order to set a reference point. If this site will become a regular measurement site, it should be surveyed to accurately document changes in datum points over time (see SOP7).
11. If conditions have remained unchanged (i.e., the river isn't rising rapidly, wave action remains low), repeat the cross-section to obtain a second set of measurements. Check to see whether the discharge values resulting from the two sets of measurements differ by less than 10%. If so, the two discharge values can be averaged. If not, consider increasing the filter time. Take a third set of measurements and average the three discharge values.
12. Establish a permanent photo point of the cross-section and photograph the site. As a rule of thumb, fill 80 - 90% of the frame with the channel cross-section and 10–20% with the horizon. Photograph the staff gage or permanent marker and any additional points of reference or flow conditions that should be documented.

Using Alternative Techniques

Quantitative measurements cannot always be obtained using the techniques described above. Equipment limitations and safety considerations may hinder wadeability. This usually occurs during storm events and seasonal runoff when discharge is too high to safely obtain cross-section measurements. However, peak discharge is a key data point. In these situations, it may be possible to estimate discharge by alternative means. Examples include the "float velocity method," in which an object is timed as it floats downstream, and the "dilution method," in which a dye or salt plug is injected into the stream and a reading is made downstream of the injection site. The float velocity method is simple to employ and is, therefore, described below. Additional information regarding the dilution method can be found in Rantz 1992.

Float Velocity Method

If a channel is not safe or suitable to conduct wadeable measurements, the float velocity method provides a reasonable estimate of discharge if the channel is not too wide or too deep (Rantz 1992, Harrelson et al. 1994). A team of two and a known cross-section area (see below) is required. Other requirements include a measuring tape, a timer, and 5-10 floats made from natural material that will sink at least half way into the water (e.g., small wooden blocks that have been soaked in water). Inorganic objects (e.g., half-full water bottles) should be avoided as it may not be possible to retrieve them. For this reason, objects should be biodegradable and expendable.

1. Select a start and a finish point in a reach with good stream channel visibility. The distance between the points should be at least three times the wetted width.
2. Person A, stationed upstream of the start point, tosses the object into the thalweg, moves to the start point, and calls out when the object crosses the point.
3. Person B, located downstream at the finish point, starts the timer when the object crosses the start point, stops the timer when the object crosses the finish point, and records the total time elapsed between points. Person B then retrieves the object.
4. Repeat the above two steps 5–10 times.
5. For each run, calculate a velocity (ft/s) by dividing the start-to-finish distance (ft) by the time (s). Take an average of the 5–10 velocity values.
6. Multiply the average velocity by 0.85 (the velocity adjustment coefficient). This coefficient converts a surface velocity into a corrected, depth-integrated velocity (Rantz 1992).
7. Finally, multiply the corrected velocity by the known cross-section area (i.e., start-to-finish distance x wetted width; ft^2) to estimate the discharge (ft^3/s). This technique can be accurate to ± 10% when conducted with attention to detail, under the right conditions. Accuracy decreases in deep streams and/or high winds.

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Rantz, S. E. et al. 1992. Measurement and computation of streamflow: Volume 1. Measurement of stage and discharge. U.S. Geological Survey Water-Supply Paper 2175. U.S. Government Printing Office, Washington D.C.

SOP6: Discharge Measurement in Unwadeable Waters

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

Suggested Reading

SonTek. 2013. RiverSurveyor S5/M9 system manual firmware version 3.00. SonTex, a Xylem Brand, San Diego, California.

SonTek. 2012. RiverSurveyor Live 3.01: Collecting data – step by step guide. Version 2012.04.13.

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Introduction

One of the primary objectives of the Southwest Alaska Network (SWAN) freshwater monitoring program is to determine the timing, magnitude, and duration of summer flows leaving select lake systems. In order to accomplish this objective, accurate discharge measurements must be taken throughout the ice-free period. Most lake outlets monitored by SWAN are unwadeable during this time of year, requiring discharge measurements to be collected from a motorized boat. This is due to the large volume of water at our primary sampling sites: the Lake Clark outlet in Lake Clark National Park and Preserve (LACL), and the Naknek Lake outlet in Katmai National Park and Preserve (KATM). Acoustic Doppler current profiling technology provides an ideal platform to measure discharge from a moving boat at these sites. Sites with smaller catchment basins, such as the outlets of Kijik Lake and Lake Brooks, may warrant the implementation of wadeable discharge techniques.

An acoustic Doppler current profiler (ADCP) ─ such as the Sontek/YSI M9 RiverSurveyor ADCP used by SWAN ─ is an instrument utilized to measure water velocity, water depth, and boat speed. Volumetric discharge is calculated from these parameters and automatically logged both internally by the acoustic Doppler profiler (ADP) unit and through wireless communication with a portable computer device. Water velocity measurements are made through transmission of sound at several frequencies from the ADP and a resultant Doppler shift off water particles. Discharge measurements completed with an ADCP unit hold several advantages over traditional current meter based methodology. These include reduced time required to complete a channel transect, continuous data collection throughout the transect, and deployment in the near-surface section of the water column (Oberg et al. 2005).

This standard operating procedure (SOP) outlines guidelines and procedures essential for the safe and successful completion of discharge measurements in unwadeable waters. It should be used in conjunction with available literature, including the RiverSurveyor S5/M9 System Manual and RiverSurveyor Live 3.01 data collection guide, which provides a fairly comprehensive guide for data collection and is recommended as a supplement to the protocol outlined here. An additional resource for developments on the use of ADCP technology for surface hydrology is the U.S. Geological Survey's (USGS) hydroacoustics working group website (http://hydroacoustics.usgs.gov/).

Field Work Preparation and Equipment Setup

A minimum crew of two people is required for completion of this field activity. Ideally, one person handles data collection and system maintenance while the second person serves as boat operator. Each role requires specific skill sets, such as experience running the RiverSurveyor Live software, or handling and maintaining position in swift currents with a motorized water craft.

Sampling sites are often remote in nature, emphasizing the need for thorough preparation and maintained communication with park or regional dispatch operations. A checklist of items to prepare for transport into the field is included below (Table 6.1).

Table 6.1. Checklist of field equipment and supplies needed for boat-based discharge monitoring.

☐	M9 RiverSurveyor Acoustic Doppler Profiler (ADP) core unit
☐	Power and Communications Module (PCM) unit
☐	Differential Global Positioning Satellite (DGPS) external antennae
☐	Connection cables for M9 ADP – PCM and DGPS antennae
☐	PCM Bluetooth dongle
☐	Panasonic Toughbook laptop computer
☐	Backup battery packs (fully charged) for the Toughbook and PCM
☐	Ocean Science Riverboat ST trimaran
☐	Rangefinder
☐	Calculator
☐	Park radio with extra batteries
☐	Satellite phone with charged battery
☐	Handheld Global Positioning System (GPS) unit with extra batteries (if the boat is not GPS-equipped)
☐	Emergency fuel for boat
☐	Personal flotation device (1 per person)
☐	Personal gear for field team (food, water, clothing)
☐	Standard tool kit or multi tool knife
☐	First aid kit

Boat-Based Equipment Setup

While traveling to the field site, all equipment should be placed in proprietary storage cases and secured within the vehicle or boat to prevent damage during transport. Upon arrival begin the process of securing the ADCP to the Riverboat ST trimaran.

1. Loosen the adjustable security fasteners on each side of the instrument mounting plate centrally located on top of the center float of the trimaran (Figure 6.1). Place the M9 ADP core unit in the cylindrical opening within the center hull. Work the unit in by rotating it back and forth while applying steady downward pressure. Once in place, tighten the two fasteners until secure. The depth of the ADP will be readjusted and noted once placed in water.
2. Attach the PCM unit to the rectangular surface on the back-end of the instrument mounting plate by tightening the two fasteners located beneath the mounting plate into screw holes located on the bottom of the PCM.
3. Secure the mounting rod for the DGPS in the screw hole located on top of the PCM. Attach the DGPS antennae to the top of the mounting rod.

Figure 6.1. Partly assembled ADCP-Trimaran unit, including the instrument mounting plate (A), M9 ADP core unit (B), connection cable (C), attachment point for the DGPS mounting rod (D), and PCM unit (E).

4. Plug the 8-pin male Bluetooth dongle into the 8-pin female port on the PCM. Connect the 8-pin male end of the connection cable into the M9 ADP and 8-pin female end of the cable into the remaining 8-pin port on the PCM.
5. Connect the DGPS antennae to the PCM by tightening the connecting cable ends into respective ports on each unit (Figure 6.2).
6. Double check to ensure cable connections are flush with ports and secured with threaded fasteners.
7. Prepare the line for securing of the ADCP-Trimaran unit to the boat. The bow line of the boat works well in this situation. Prepare a double-backed and dressed figure-eight loop on the line and clip the newly created loop into the locking carabiner located on the end of the wire rope bridle on the trimaran (Figure 6.2). Tighten down the locking mechanism on the carabiner to secure the ADCP-Trimaran unit to the line. Double check the security of the line at attachment points on the boat and create additional points of security as needed.
8. Place the ADCP-Trimaran unit into the water and position the unit roughly ⅔ the length of the boat as measured from the stern. Once the unit is deemed secure, carefully readjust the ADP core unit to a desired transducer depth (approximately 10 cm below the water surface).
9. Press the power button located on top of the PCM. The LED status light should toggle on for "Radio."
10. Ensure that Bluetooth connectivity is enabled by navigating to Bluetooth Settings within the Bluetooth folder in the Start menu programs list. Click the Bluetooth dropdown menu and

select Options. The power icon under Bluetooth Status will indicate the current functionality of the Bluetooth configuration.

Figure 6.2. Assembling the ADCP-Trimaran unit on the lower Brooks River, Katmai National Park and Preserve. The DGPS mounting rod and antenna and pictured in the foreground.

11. Open the RiverSurveyor Live software. Click Connect to a RiverSurveyor System under Connection Options in the main window. Select COM40 as the port for connecting the Toughbook to the PCM. If the COM40 port is unavailable, restart the laptop.
12. Once connected, the Smart Page will be displayed. The Smart Page is the location within RiverSurveyor where all system and sampling settings are entered and reviewed and site-specific information is added prior to data collection.

RiverSurveyor Live System Setup

Once communications are functional between the ADCP unit and Toughbook computer, proceed to set up the system for your specific sampling location and situation. Additional details regarding this component of equipment setup are provided in the RiverSurveyor Live 3.01 document called "Collecting Data – Step by Step Guide" (in T:\Vital_Signs\Water_Fish\Equipment\ADCP).

1. From the Smart Page Setup window, select Set Units and English. Select Set Time and align the ADP unit's time with the computer's time.
2. Select System Test and run a system test. This is an important step towards the establishment of a connection between the PCM, DGPS, and computer. Both the radio and GPS LED status lights will be green and solid when PCM-computer and PCM-DGPS communications are established.
3. Open Site Information and fill in the categories as shown in Figure 6.3. Ensure that location names (Table 6.2) match those found in the Aquarius database; a mismatch in location information will result in a failure to append discharge data through the Field Visit function on the Aquarius Springboard platform.

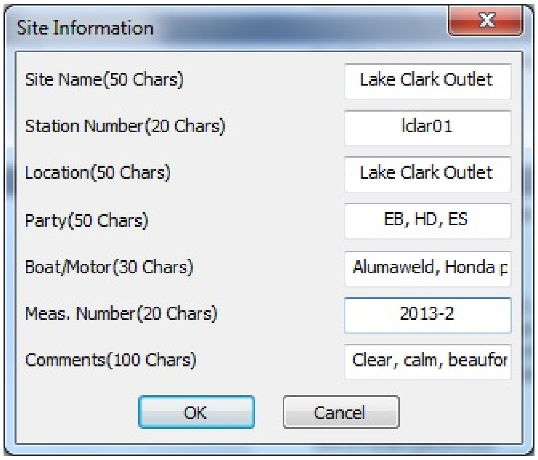

Figure 6.3. Site Information window in RiverSurveyor Live software.

Table 6.2. Location names, waterbody codes, and approximate coordinates for SWAN discharge sampling sites (2006-2014).

Park	Location Name	Waterbody Code	Latitude	Longitude
LACL	Lake Clark Outlet [a]	lclar	60.017036	-154.755119
LACL	Kijik Lake Outlet [a]	kijil	60.30716	-154.29060
LACL	Tanalian River	tanar	60.196831	-154.341842
LACL	Chulitna River	chulr	60.204333	-154.702222
LACL	Telaquana River [b]	telal	60.963975	-154.032642
LACL	Chilikadrotna River [b]	ltwil	60.664589	-154.047931
KATM	Naknek Lake Outlet [a, b]	naknl	58.673031	-156.455317
KATM	Lake Brooks Outlet [a, b]	lbroo	58.547800	-155.795322
KATM	Savanoski River	savor	58.552528	-155.088806
KEFJ	Exit Creek	exitc	60.188469	-149.636244

[a] Sampling sites where SWAN currently (as of 2014) measures discharge.

[b] Sampling sites with USGS rating curves.

4. Select System Settings and enter values for transducer depth and magnetic declination as follows:
    a. Transducer Depth: Position the ADP core unit to the desired depth in the water column. A high degree of draft is desirable to mitigate potential air entrainment, which can interfere with the sonar pulse coming from the sounder. Measure the distance between the bottom edge of the sounder and the water level on the trimaran boat to obtain the transducer's depth below water surface (usually approximately 6 cm.)
    b. Magnetic Declination: Before each field trip, look up the magnetic declination for the sampling location and date/time online. If unable to obtain magnetic declination

information ahead of time, use the approximate values shown below (from http://www.ngdc.noaa.gov/geomag-web/); then post-process the discharge files later using actual magnetic declination values.

i. Lake Clark Outlet (LACL): 16° 12' E changing by 0° 16' W/year

ii. Naknek Lake Outlet (KATM) 15.03° E changing by 0.25° W per year

iii. Lake Brooks Outlet (KATM) 15.27° E changing by 0.25° W per year

5. Select Edge Settings, enable Auto-Edge Profiles, and set the measurement count for 10 values. This setting helps streamline the sampling process and prevent user error by automatically taking 10 edge samples once the data collector ends the measurement along the main channel transect. Make sure to note which bank you plan to begin the first transect from in this section, either river-left or river-right. **Note:** the discharge measurement process partitions the river into three distinct sections: a main transect and two edge distances. An edge distance is the length between the ADCP-Trimaran and the channel bank at each end of the main transect (Figure 6.4). These near-shore sections of river cannot be traversed and measured from a motor boat.

6. Estimate edge distances for river-left and river-right by evaluating channel width, depth, and structure. These values will be adjusted in real time by measuring edge distance with a range finder during data collection.

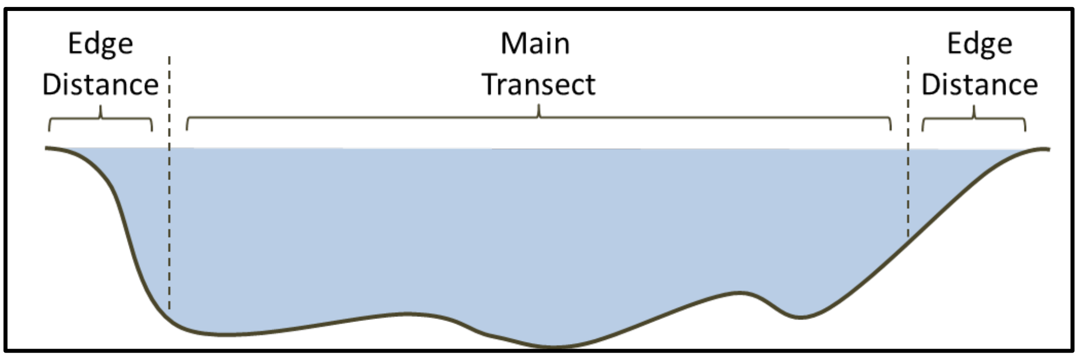

Figure 6.4. Channel cross-section partitioned for a boat-based discharge measurement.

Compass Calibration

A compass calibration must be conducted prior to collection of channel discharge transects. This process allows the unit to detect local magnetic distortion and make internal adjustments to compensate for magnetic interference in close proximity to a given sampling location. Accurate velocity-readings during channel transects are dependent on the ability of the ADP to determine direction. The attainment of a PASS score on the compass calibration is a crucial step towards the collection of accurate hydrologic data with the ADCP.

1. Ensure the ADCP-Trimaran unit is secured alongside the boat. On the computer, open up the Compass Calibration tab on the Smart Page in RiverSurveyor Live.

2. Begin rotating the boat in a tight, counter-clockwise direction. Each complete circle should take around 1 minute.
3. Once the boat is in motion, select Begin Compass Calibration on the computer screen.
4. While the boat operator maintains circular motion, the data collector should begin pitching and rolling the entire ADCP-Trimaran unit. Grab hold of the cross bar on the trimaran boat with both hands and rotate the unit back-and-forth in all directions to angles from 10° to 15°. Use caution when extending one's self out from and across the gunwale of the boat.
5. Sontek recommends compass calibrations be conducted between 60 and 120 seconds. Once this time requirement is met, the data collector may cease pitching and rolling the ADCP-Trimaran unit and select Stop to end the compass calibration process. The boat operator should stop rotating the boat only after confirmation of completion of the activity is reported on the computer.
6. Results of the calibration should fall within the following thresholds: M score < 10; Q score > 3 (as close to 10 as possible). If the score results in "FAIL" or "PASS (CAUTION)," attempt the calibration process again. If a "PASS (CAUTION)" score is attained but cannot be improved, take note of the potential compass heading issues and continue with pre-sampling activities. If a compass calibration cannot be successfully completed, do not continue with data collection.

Loop Moving Bed System Test

A loop moving bed test should be conducted prior to primary discharge measurement activity. This test estimates the physical state (stationary vs. mobile) and velocity of the channel substrate within a selected reach of stream.

1. Maneuver the boat towards the near bank where you plan to begin taking channel discharge transects.
2. Hold the boat in position and begin the loop method test by switching to the System tab on the bottom of the computer screen. Select Loop Method, wait for the system to initialize and then select Start.
3. Once the test has begun, maneuver the boat along your pre-selected channel transect and continue moving until the boat has reached the opposite river bank edge. Consistent speed across your test transect is important during this process. Once this position has been attained, bring the boat back to the same location from which the test began, thus "closing the loop." Ensure the boat is facing the same direction as it was upon initiation of the test.
4. When back in the original near-bank position select Stop on the computer screen. A message will appear with the results of the test and an option to proceed with the first discharge transect. If ready to begin sampling, select Yes and proceed with the first measurement. If any pre-sampling adjustments are deemed necessary, select No and make system changes as needed.

Discharge Measurement Techniques

Although most SWAN data are collected using the metric system, discharge measurements are an exception to that general rule. Discharge is calculated in cubic feet per second (ft^3/s or cfs), therefore, all associated measurements should be in English units to avoid confusion and unnecessary conversions that can introduce error during transect and edge measurements.

Site Selection

1. If there is a staff gage and a developed rating curve for the river (Table 6.2), make an observation in the proximity of the staff gage. Read the staff gage and estimate the discharge for the reach using the known rating curve equation.
2. The selected cross section should be in reasonable proximity to the staff gage (if one exists) to avoid the need for adjusting measured discharge based on the rating curve developed for the gage site. However a distance of 0.5 mi (approximately 1 km) between the gage and measuring section is acceptable if such a distance is necessary to provide both a good stage-measurement site and a good discharge-measurement site (Rantz 1982).
3. If the measurement is to be obtained from a site where there is no staff gage, the selected channel cross-section should be fairly uniform in depth, and flow should be parallel and fairly uniform in velocity throughout.
4. General guidelines for site selection (from Rantz 1982) include choosing a location where:
    a. the stream is straight for about 300 ft (approximately 100 m) upstream and downstream of the site;
    b. the total flow is confined to one channel at all stages, and no flow bypasses the site as subsurface flow;
    c. the streambed is not subject to scour and fill and is free of aquatic growth;
    d. banks are permanent, high enough to contain floods, and are free of brush; and
    e. unchanging natural controls are present in the form of a bedrock outcrop or other stable riffle for low flow and a channel constriction for high flow.
5. Avoid reaches with obvious bed irregularities, such as large boulders or changes in depth, and inside or outside river bends.
6. If there are no obvious markers at the waterline, you can use objects on shore to estimate edge distances. Be sure to subtract any extra distance from the edge width, since failure to do so will increase the estimated area of the channel and result in potential over-estimation of discharge values.

Channel Discharge Transects

1. If no staff gage exists for the site, select a permanent object (large tree, boulder, etc.) and collect the lat/long data for that point. Measure the shortest distance between the object and the edge of the water line. This will serve as a reference for future discharge measurements. If a large permanent object is not available, install a 4-ft rebar stake at least 3 ft into the

ground above the highest observable water line to set a reference point. If this site will become a regular measurement site, it should be surveyed to accurately document changes in datum points over time.

2. Align your vessel with a reference point and hold position in the near-bank area at the edge of the selected channel cross section. Once the boat operator is ready, the data collector selects Start a Measurement [F5] and Start Edge [F5]. The data collector then measures the distance from the ADCP unit to water's edge with the rangefinder and enters that value into the distance field. After the data collector clicks on the OK button, the program will automatically log 10 edge measurements. Once the start edge is complete, the unit will prompt the user to begin moving the boat. The Data collector communicates this to the boat operator, who begins to move the boat slowly across the transect.
3. If a staff gage exists at the site (Table 6.2) and water levels permit it, take a reading of the gage after each channel cross section is completed. If a datum measurement is required, be sure to include those readings.
4. Drive the boat slowly across the transect until the opposite bank is reached. When in position, the data collector selects End Transect and repeats the process of shooting the edge-to-water distance with the range finder and entering that information into the edge value field. After 10 edge samples, the transect will complete itself. Repeat Steps 2–4 (above) three additional times to get four transects, in total, across the cross-section. Four discharge values that fall within 5% of each other are, together, considered a valid measurement of stream discharge when averaged.
5. Once data collection is complete, navigate back to the area where initial setup of the ADCP-Trimaran occurred. Disassemble the ADCP-Trimaran unit by reversing Steps 1–9 of the "Boat-Based Equipment Setup" section (above).
6. After returning from the field, dry the equipment by opening the travel case and removing the battery pack from the PCM. Let the PCM and ADP units dry in the opened case overnight.
7. **Note:** discharge measurements taken during base and peak flow portions of the hydrograph are ideal, but any measurements collected are beneficial. If a staff gage and rating curve exist at a given site, new discharge measurements will provide an indication of rating curve stability. Specifically, new stage and discharge measurements should be added to the rating curve dataset, and the rating curve equation should be adjusted as necessary for that "rating" period, before converting the seasonal water level data into discharge (SOPs 7 and 11).

Safety

Several safety points need to be considered before leaving the dock. First, always file a float plan with the park dispatch or the Alaska Region Communications Center (ARCC). If the duration of field work is anticipated to extend beyond park dispatch hours of operation, submit a float plan with ARCC before entering the field. An ARCC float plan form is included in SOP1. It contains the following information, among other things:

- Number of people on board

- Type of and/or name of boat
- Location of work site
- Expected time out
- Amount of fuel on board (estimated hours or measured volume)
- Call-in schedule (hourly, upon arrival and departure, etc.)

Notify dispatch to close the float plan when you have returned to your starting point.

Be sure that the boat is in proper working order, that it has enough fuel on board for the duration of the work, and that the boat operator is familiar with the boat capabilities and water body. If the boat is not equipped with a Global Positioning System (GPS), carry a portable GPS with extra batteries. All persons on board are required to wear a personal floatation device (PFD). This can be a life jacket, float coat, or mustang survival suit. Extra food, warm clothing, and fluids should be included as part of personal gear on board. A first aid kit also should be on board. Additional information on field safety can be found in SOP1.

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SOP7: Water Level Measurement

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

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Introduction

This standard operating procedure (SOP) describes the methods used to program and deploy non-vented pressure transducers, or water level loggers, to monitor water quantity continuously at lake outlets within the Southwest Alaska Network (SWAN).

Non-vented pressure transducers are self-contained units that are programmed to record level data continuously in unattended settings. Unlike vented pressure transducers, absolute pressure transducers do not self-correct for the effects of barometric pressure, and therefore need to be deployed with a companion barometric pressure transducer, or barologger, which is used to compensate the level logger data by removing the effects of changes in air pressure on the water level readings. This step is completed after the data are downloaded (see SOP10). The barologger should be placed within 48 km of the level logger to provide the most accurate data correction.

Level loggers and barologgers are deployed in spring after ice-out when monitoring locations can be accessed safely, and then removed in fall before freeze-up (approximately April–September). Monitoring locations are limited currently to the outlets of Tier 1 lakes in Lake Clark (LACL) and Katmai (KATM) National Parks and Preserves (Table 7.1). Additional loggers may be deployed seasonally to estimate inflow into Tier 1 lakes, and/or outflow from Tier 2 lakes. Site locations will be determined by the aquatic ecologist during preseason planning.

Table 7.1. Locations of level loggers and barologgers currently used to gage lake level.

Park	Lake	Level Logger Location	Barologger Location	Latitude [a]	Longitude [a]
LACL	Lake Clark	At the LACL tape-down station in Hardenberg Bay	Outside of park headquarters in Port Alsworth	60.20454	-154.30668
LACL	Lake Clark	At the lake outlet, near the left bank	On a white spruce adjacent to the level logger (left bank)	60.01704	-154.75512
LACL	Kijik Lake	In Little Kijik River, near the right bank	On a white spruce adjacent to the level logger (right bank)	60.30716	-154.29060
KATM	Naknek Lake	At Lake Camp on “To Go Rock,” just upstream of park dock	At Lake Camp above door of restroom at boat ramp parking lot	58.68184	-156.43503
KATM	Lake Brooks	Mounted on a bracket on the left bank, at the lake outlet	On adjacent housing unit (number BL-3)	58.54758	-155.79548

[a] Coordinates pertain to the level logger locations only.

SWAN currently uses In-Situ LT500 transducers with a 30 psi range, which can be deployed to a maximum depth of 10.9 m, and Solinst 3001 Levelogger Gold F30/M10 transducers with a maximum depth of 10.0 m. Barologgers monitor atmospheric pressure changes and have a lower psi tolerance. They are not designed to handle water pressure and should never be used underwater. These transducers are powered by lithium batteries with five- and ten-year lifespans, respectively for In-Situ and Solinst, and cannot be attached to an external power source. As self-contained devices that are vacuumed sealed, no field maintenance can be performed. Some calibrations checks are possible from the field; however, the devices will need to be sent to the factory for recalibration and inspection.

This SOP describes the basic procedures for programming and operation of In-Situ and Solinst level loggers and barologgers. Although the equipment for both brands follow the same basic premise for programming and operation, the steps will be outlined separately here. Consult the equipment manuals for more detailed information on the software and specifications. Both manuals can be accessed through the help menu within the software.

Win-Situ, the In-Situ software, adds a sub-folder to the “Documents” folder during installation (e.g., C:\Users\KKBartz\Documents\WinSitu Data). This sub-folder is where all raw data files and exported files are automatically stored when downloaded. Solinst automatically stores files in the “Program Files” directory (e.g., C:\Program Files\Solinst\Levelogger3_4). This default directory will need to be changed to prevent data loss in the event of a program reinstall (detailed below). For both brands, this folder structure serves as interim storage until the files are processed and moved to their permanent locations (see SOPs 10 and 11).

Software upgrades and other product information can be found at www.solinst.com and www.in-situ.com. Check with the technical staff of the manufacturer to determine if a software and/or firmware upgrade is necessary. Be sure that any upgrades are back-compatible so that communication with older devices remains possible.

Getting Started with In-Situ

Win-Situ (currently version 5.6.21.0) is the software used to communicate with the LevelTroll (LT) and BaroTroll (BT) pressure transducers. Win-Situ BaroMerge is the software used for the post-processing water level correction and will be discussed in SOP10 as part of the data downloading procedure. A TrollCom provides the communication interface between the Level/BaroTroll and the computer or RuggedReader handheld PC. It consists of a rugged cable with a twist lock at one end to attach to the LT or BT device, and a serial port at the other end to attach to the computer. Alternatively, a serial adapter can be used to communicate with a computer through a USB port. Be sure that the drivers for the serial adapter have been loaded before connecting an LT or BT unit.

Adjusting the General Settings

Before communicating with a device, check the general settings to ensure that they are correct (Figure 7.1). Settings will remain fixed until the software is updated or reinstalled, or until they are adjusted as described below.

1. From the menu tabs, select Preferences and then General Settings.
2. Under Time Format, select Export Two Columns for Date and Time. This feature is used during the export process and will facilitate data processing by exporting the date and time to separate columns.
3. Water level monitoring occurs during the summer season, thus date and time settings should be set to Alaska Daylight Time (AKDT). Under Time Zone Application, set the Current Time Zone to AKDT and enable the Daylight Saving Time (DST) option by leaving the Ignore DST box unchecked (otherwise the time will not be adjusted to AKDT).
4. Under Export Delimiter Character, select Comma as the delimiter.

5. Under Parameter Defaults, set the Significant Decimal Digits to 3 and leave the other boxes in the default configuration.

6. Accept and save any changes to settings by clicking the check mark in the lower right corner.

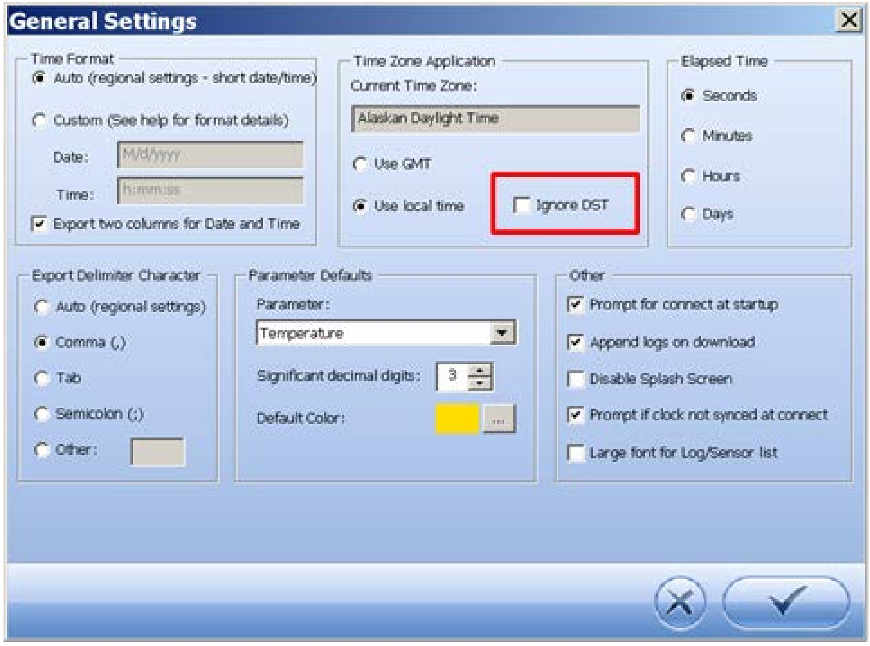

Figure 7.1. Screen shot of the Win-Situ General Settings window with the Ignore DST option unchecked.

Establishing a Connection

1. Remove the twist lock cap from the transducer and fit the connection into the twist lock end of the TrollCom rugged cable. Be sure to match the pins and flat side correctly to avoid damaging the unit.

2. Attach the serial port to the computer directly or through a serial adapter.

3. Start Win-Situ. A window will open asking if you want to connect to a device now. Select Yes. This will establish communication with the device.

4. Another window likely will appear, stating that the time shown on the device is out of sync with the time shown on the computer. Check the upper right part of the screen to see the time for both the device and the computer. The device time is shown in red when it is out of sync with the computer time. Generally, they will differ by less than 60 seconds. Click to sync the times; afterward, both times will show in green.

5. Once communication is established, the screen will default to the Home tab and display the real-time readings from the device (Figure 7.2). At this point, the plugs pictured in the lower right corner of the screen are connected, indicating that communication has been established. Prior to connection, the plugs are shown as disconnected and are highlighted in a yellow background.

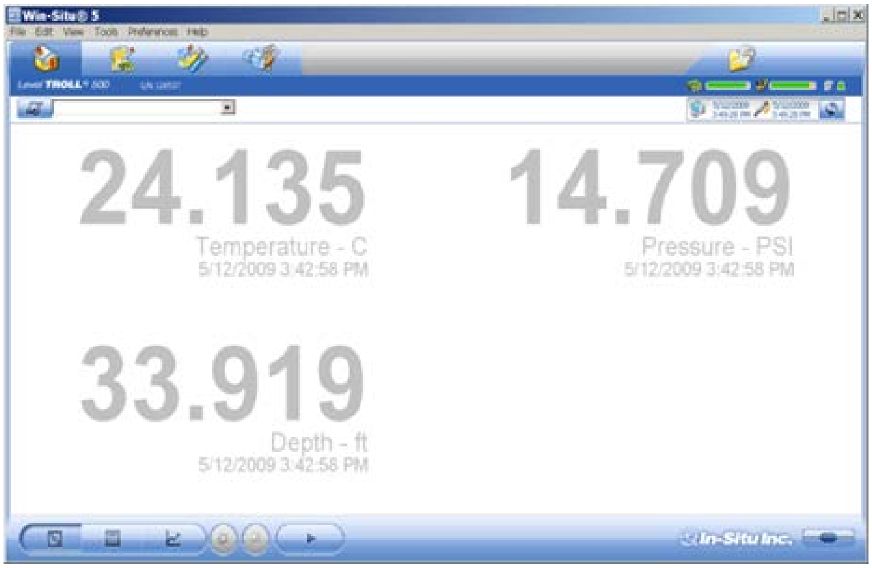

Figure 7.2. Screen shot of the Win-Situ Home tab view showing real-time readings.

6. Select the hammer and screwdriver icon to reach the Device Setup tab view (Figure 7.3). If a new device is connected, the name will be blank. Input the serial number as the name with an LT or BT prefix. This screen will also show which firmware and hardware versions are currently installed on the device. Firmware updates can be performed by selecting the Update Device button. **Note:** always check with an In-Situ technical representative before upgrading firmware. Not all units can support the newest firmware version.

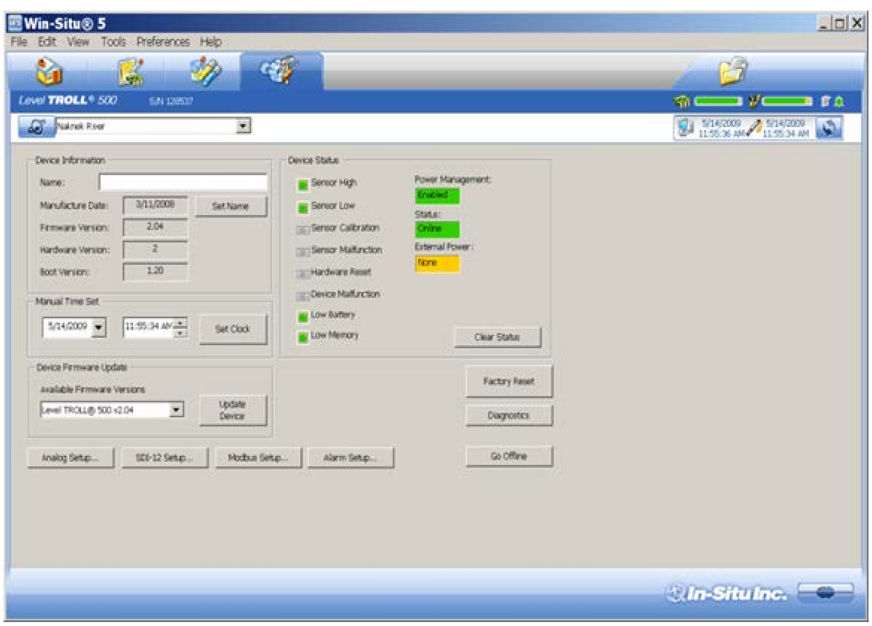

Figure 7.3. Screen shot of the Win-Situ Device Setup tab view.

7. Use the Device Setup tab to check the logger status (Figure 7.3). The green boxes indicate that the logger is performing correctly. If the boxes are yellow or red, contact an In-Situ

technical support representative. **Note:** yellow color appears in the external power box because these devices do not support external power.

8. To troubleshoot problems communicating with a device, select Preferences from the menu tabs and then view the Communication Settings. Compare the com port setting in the Communication Settings in Win-Situ with the USB port setting for the serial converter in Device Manager (Figure 7.4). They should match. If they do not, change the com port setting in the Communication Settings in Win-Situ to match the USB port setting listed under Device Manager. If they do match but communication cannot be established, attempt to connect another LT or BT to rule out a problem with the device. If problems with establishing a connection persist, contact an In-Situ technical representative.

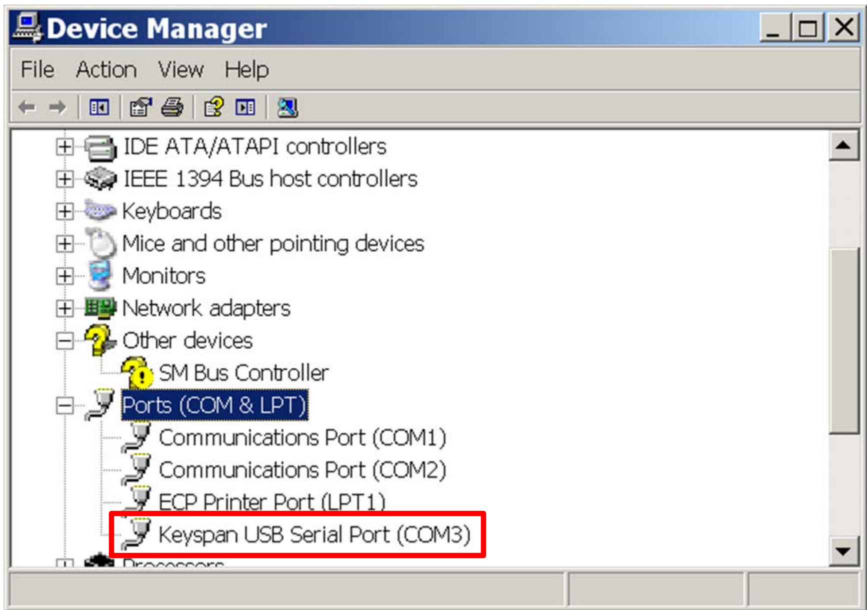

Figure 7.4. Screen shot of the Device Manager window.

Programming a Logger

1. Select the clipboard icon (second from the left) to program a LevelTroll logger to record data. If the logger has not yet been deployed, the screen will be blank. Select a site name for the logging session from the drop-down menu next to the blue globe. Then select the New button in the lower left part of the screen to set up a new logging program.

2. The Logging Setup Wizard window will open (Figure 7.5). The site name can be selected from this window as well. Use the following naming convention to name the program: 4-letter park code + 5-letter water body code + site ID + lvl (e.g., KATM_naknl01_lvl). This log name will be part of the file name when the data are downloaded; the offload date and time will be added to the file name at that time. Click the forward arrow button on the lower right part of the screen.

Figure 7.5. Screen shot of the initial Win-Situ Logging Setup Wizard window.

3. The next window in the Logging Setup Wizard determines which parameters and units will be logged (Figure 7.6). If the unit settings are incorrect, highlight the parameter from the list on the right and change the units using the pull-down menu. Although most parameters are recorded using SI units, depth is recorded in feet so the data can be used in the rating curve equations. Click the forward arrow.

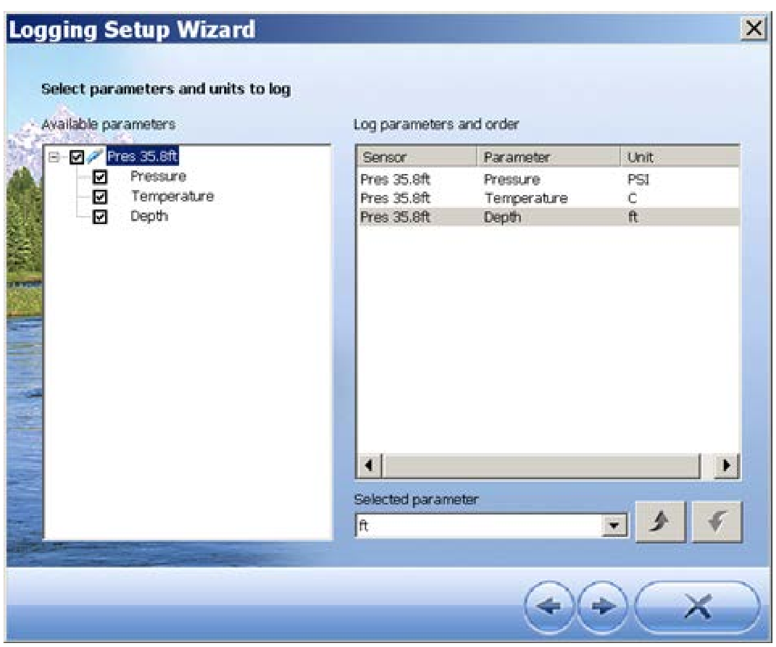

Figure 7.6. Screen shot of the second Win-Situ Logging Setup Wizard window showing three parameters to be logged: pressure (in PSI), temperature (in °C) and depth (in ft).

4. In the next window, select the Linear Method under long-term monitoring. Click the forward arrow.
5. In the next window, set the logging interval to 1 hour. Click the forward arrow.
6. The next window displays options for starting and stopping the logger (Figure 7.7). Set the logger to a scheduled start time by changing the default values to a date and time that coincide with the deployment schedule. Set the Start Time for 12:00 AM. The start date may be set several days in advance if you are traveling to a remote location. Set the Stop Condition to “None” and leave the Wrap Condition box unchecked. Click the forward arrow.

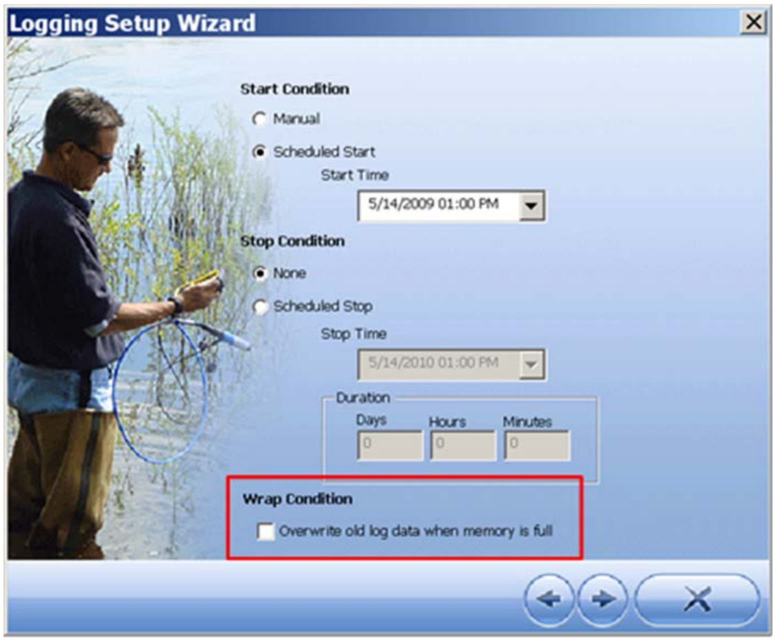

Figure 7.7. Screen shot of the Win-Situ Logging Setup Wizard window that contains options for starting and stopping a logger.

7. The next window displays the depth settings. Under the Water Surface category, select Depth. Click the forward arrow.
8. The next window displays the specific gravity settings. Select Freshwater and leave the default setting of 0.999000 unchanged. Click the forward arrow.
9. The last window displays a summary of the settings programmed during the previous steps (Figure 7.8). Review the selections. Click the check mark icon to accept and save the settings, or use the back arrow to edit previous windows if errors are found. There will be another opportunity to edit the settings before the logger is deployed (see Step 11).
10. Once the program has been saved, it will appear as a row on the main screen with a clock icon (on the left side). The status will be listed as pending, indicating that the program is ready but not running. When the scheduled start date and time occur, the logger will begin to record data. Subsequently, if a status check is performed in the field with the Rugged Reader,

a running icon will appear to the left of the program name, indicating that the program is in logging mode.

Figure 7.8. Screen shot of the final Win-Situ Logging Setup Wizard window that summarizes the selected settings.

11. If the program needs to be edited, highlight it and select the Edit Log button at the bottom of the screen (Figure 7.9).

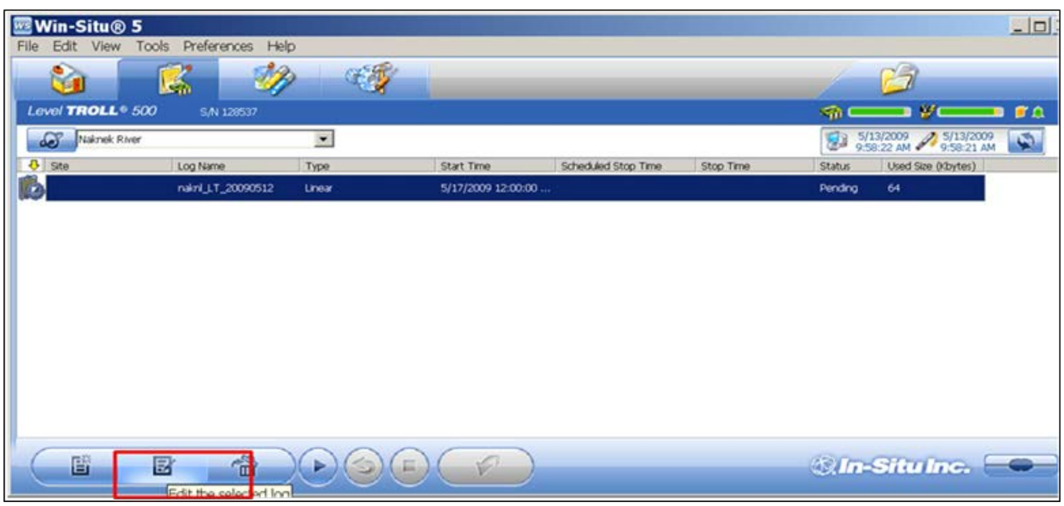

Figure 7.9. Screen shot depicting steps in Win-Situ for editing a saved program.

12. Disconnect the logger by clicking on the plug icon in the lower right part of the screen. Disconnect the device from the TrollCom, and replace the twist lock cap on the device. Be sure that the gasket inside the twist lock cap is still in place. It can fall out when loose.

13. Repeat Steps 1–12 (above) to program a BaroTroll logger after establishing communication. Use the same site name. Replace the “lvl” suffix in the log name with “baro,” leaving the rest of the log name identical. Use the same settings for the barologger program as those in the level logger program. Make sure that the start date and time are identical to ensure that the barometric compensation can be completed using the BaroMerge program.
14. After programming the BT device, disconnect it by clicking the plug icon and close Win-Situ. Disconnect the device from the TrollCom, and replace the twist lock cap on the device. Be sure that the gasket inside the twist lock cap is still in place.

Getting Started with Solinst

Solinst Levelogger (currently version 3.4.1) is the software used to communicate with the Levelogger and Barologger pressure transducers. A Levelogger Optical Reader provides the communication interface between the Level/Barologger and the computer via a USB connection.

Adjusting the General Settings

1. As described in the Introduction, the Solinst software automatically stores files in the “Program Files” directory upon installation. To change this default directory, create a Solinst sub-folder in the “Documents” folder (e.g., C:\Users\KKBartz\Documents\Solinst), and change the default directory in Solinst Levelogger by selecting the Configuration tab and choosing Application Setting. Then, browse to the new Solinst sub-folder and click OK.
2. Set the default file name by selecting the Configuration tab and choosing Default File Name Setting. Check the Location and Last Date boxes. Uncheck Start Date and Serial Number.
3. These settings should become the default once the program closes. If questions arise, check the software settings when the program opens.

Establishing a Connection

1. Before opening the program, place the Levelogger in the Optical Reader and connect it to the computer through a USB port. Open the Solinst Levelogger software. Select the correct com port setting (Figure 7.10). It is handy to have the com port setting labeled on the Optical Reader cable.
2. On the second tier of icons, click the leftmost tab showing a logger with the green arrow (Figure 7.10). Once a connection is established, a small window that states “Retrieving” will appear, and then the logger information will be displayed on the screen.
3. Before programming a logger, check the Levelogger Status on the right side of the screen (Figure 7.10). The firmware version is shown; check with the Solinst technical representative to determine if an upgrade is needed. The battery power should be > 90% for a summer deployment. The amount of free memory is displayed as a number of readings (the maximum number is 40,000). The status should say Stopped. If not, stop the logger and retrieve the data (SOP10) to make sure all data are saved. Finally, verify that the date and time are correct, as sensor drift can occur. Enable Time Synchronization by checking the box.

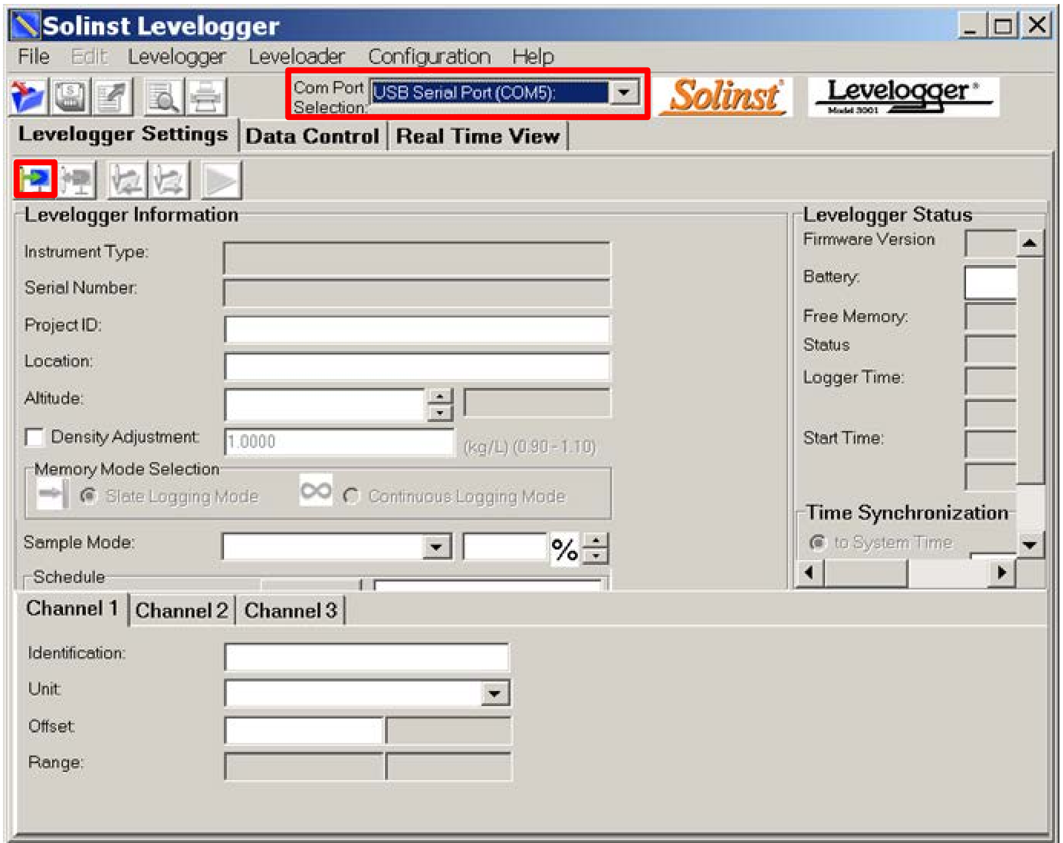

Figure 7.10. Screen shot of Solinst Levelogger software, highlighting the com port selection and "green arrow" tab.

4. To troubleshoot problems communicating with a device, compare the com port setting in Solinst Levelogger (Figure 7.10) with the USB port setting for the serial converter in the Device Manager (Figure 7.4). They should match. If they do not, change the com port setting in the Configuration Setting window of Solinst to match the USB setting listed in the Device Manager. If they do match but communication cannot be established, attempt to connect another Levelogger to rule out a problem with the device. If you continue to have problems establishing a connection, check with an IT administrator as you may not have administrative rights to your computer. If problems with establishing a connection persist, contact a Solinst technical representative.

Programming a Logger

1. Give the Project ID a relevant name, such as "SWAN water quantity" or "SWAN surface hydrology" (Figure 7.11). The Project ID is stored as a set of choices, so if the loggers are used for other projects (e.g., nearshore, salt marsh, etc.), the Project ID might need to be renamed.

2. Name the location using the 4-letter park code +_5-letter water body code + site ID + _lvl or _baro (e.g., KATM_naknl01_lvl). If the logger is located on a temperature array (as is sometimes the case with Solinst devices), include the depth in the location name. The download date will be added to the location name when the logger is downloaded.

3. Depth and temperature are logged on different channels, shown at the bottom of the sreen. Channel 1 records depth. Set the units to feet; leave the offset at 0.0 and the range on the default setting, which is determined by the device model. Channel 2 records temperature. It logs in Celsius by default.
4. Once the depth is set to record in feet, the altitude at which the logger will be deployed can be entered.
5. Under the Memory Mode, select Slate Logging Mode. This ensures that the logger will stop when full and not overwrite data.
6. Under the Sample Mode, select Linear and set the time interval to 1 hour.
7. After completing Steps 1–6, click the second tab from the left (with the red arrow) on the second tier of icons (Figure 7.11). This will upload the program to the levelogger. When the program has uploaded, the rightmost tab (green arrow) will become active.

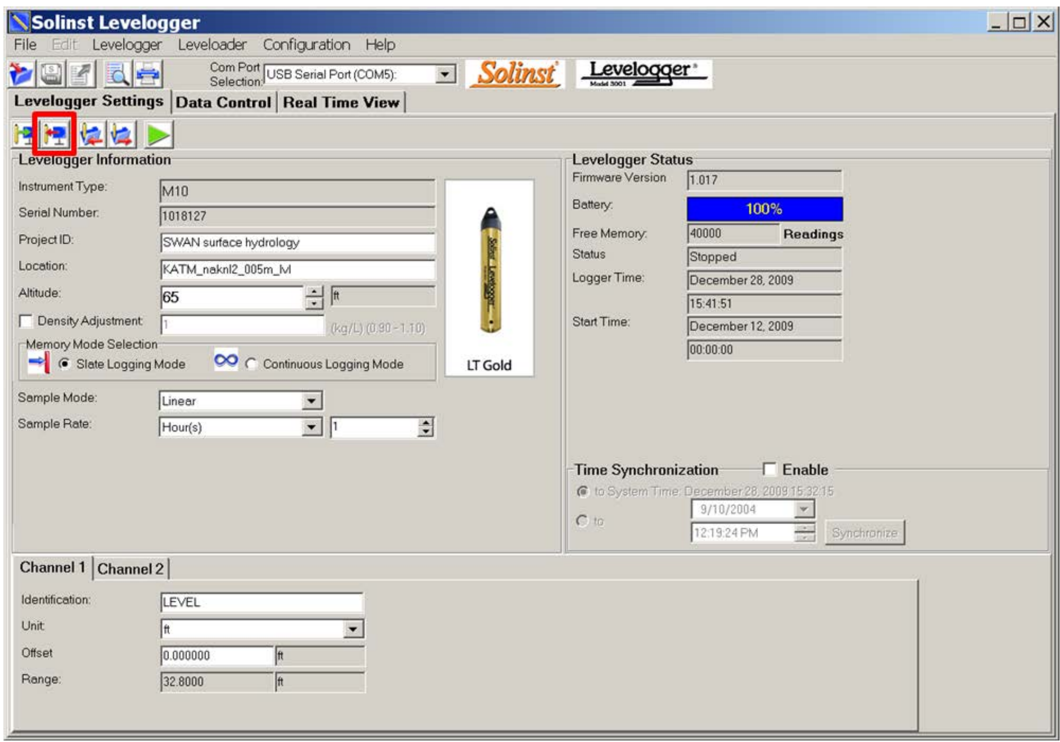

Figure 7.11. Screen shot of Solinst Levelogger software, highlighting the "red arrow" tab.

8. Click the rightmost green arrow tab to set the logging schedule. Two windows will appear. The first states that all data will be erased from the logger. Click yes if all previously recorded data have been downloaded and verified (see SOP10). The second window asks whether or not to synchronize the time. Select yes.
9. The next window programs the start time. Set the start time for 12:00 AM on the morning when the logger is scheduled to be deployed (Figure 7.12). Click OK.

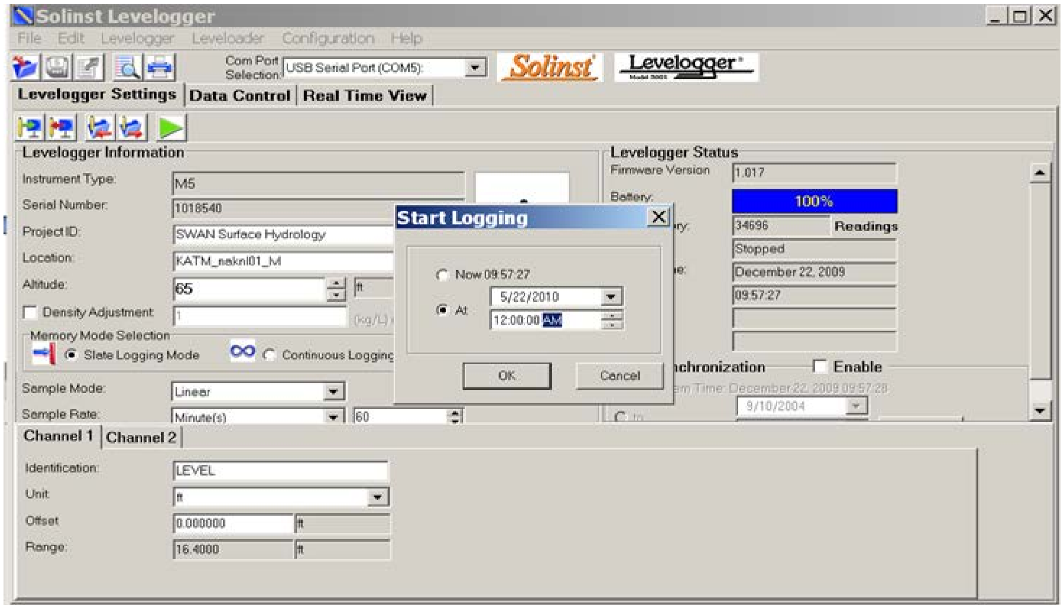

Figure 7.12. Screen shot of Solinst Levelogger window used to set a logger's start time.

10. The green arrow icon will become a red stop sign. The Levelogger Status settings (on the right side of the screen) will change. Specifically, the Status will shift from Stopped to Future Started and the Start time will display the date and time entered.
11. The logger is now programmed for deployment with a delayed start time. There is no disconnect button. Simply remove the device from the Optical Reader. Place the barologger into the Optical Reader and repeat Steps 1–10. Begin by clicking the green arrow in the second tier of icons to establish communication with the barologger. Substitute _baro for _lvl in the location name.
12. When the barologger has been programmed with the delayed start time, remove it from the Optical Reader and close the program.

Installing Loggers

Loggers should be deployed in late spring after ice-out. Program them following the above instructions and place them in their protective housings. When planning travel to and from these sites, schedule enough time to measure discharge during the site visit (SOPs 5 and 6). Field equipment is listed in Table 7.2.

Permanent Sites

Permanent logger sites were established previously at Tier 1 lakes in KATM (Table 7.1). These sites have a bracket and set screw in place. Slide the logger housing into the set screw and tighten the screw to a hand tight position. Record a "tape-down" reading by measuring the distance from the site reference point to the current water level, and record the time and water level height (Figure 7.13). The benchmark and reference points should be resurveyed and recorded in the field notebook. These values are important to document shifts in the rating curve.

Figure 7.13. Reference point for conducting the “tape down” measurements at Lake Camp, located just upstream of the Naknek Lake Outlet boat dock (KATM).

Table 7.2. Checklist of equipment needed to install level loggers and barologgers at permanent or temporary sites.

- ☐ Programmed levelogger
- ☐ Programmed barologger
- ☐ Metal pipe housing
- ☐ Rebar and bracket for temporary installations
- ☐ Mallet or sledge hammer
- ☐ Zip tie or wire to mount barologger
- ☐ Hammer and nails or impact driver and screws
- ☐ Bucket with holes in the bottom
- ☐ Surveying gear (level and stadia rod)
- ☐ Measuring tape
- ☐ Reference site location
- ☐ Field notebook and pencil

Temporary Sites

It is impossible to establish permanent monitoring sites for all lake inflows and outflows of interest within SWAN. Therefore, water level data are collected on a temporary basis at select sites. For temporary water level monitoring sites, a surveyed benchmark point and several reference points will need to be established. Survey points will be important for retaining a consistent location from year to year, since no permanent installation exists at these sites.

Select a location that is safely accessible and not in the way of boat traffic. Place the level logger in its protective housing and attach it to a piece of rebar ~ 1 m long, which has been driven into the stream bed so that only ~10 cm is visible underwater. After installing the level logger, its relative elevation needs to be established using differential leveling. The steps below briefly outline this procedure for a new temporary site. For additional details, see Kennedy 1990 or Harrelson et al. 1994.

1. Select a benchmark (BM) and two reference points (RP1 and RP2) near the level logger location. These points should be easily identifiable objects that will remain in place for the foreseeable future (e.g., large boulders, mature trees, and large stumps). If trees or stumps are selected, install a screw or large nail near the base of the tree so that the exact point can be easily relocated. Pictures, GPS coordinates, and detailed descriptions also help ensure relocation of reference points in subsequent years.
2. Assign an arbitrary elevation (e.g., 100 ft) to the benchmark.
3. Set up the tripod in a location with a clear view of the benchmark, reference points, and channel cross-section. Stomp the legs into the ground to create a stable platform for the transit level. Attach the transit level to the tripod and use the adjustment knobs to center the bubble on the built-in bull's-eye level.
4. With one person holding the stadia rod at the benchmark and the other operating the level, take an elevation reading on the benchmark. Record this value as the "backsight" (BS) measurement for the benchmark on the data sheet. Add this backsight to the arbitrary elevation assigned to the benchmark. The result of this addition establishes the height of instrument (HI).
5. Take a reading with the rod at the water's surface. Record this value as the foresight and subtract it from the HI to obtain the elevation of the water surface. If wind or current is creating a disturbance on the water surface, a bucket with holes in the bottom can be used to create an area of calm water around the stadia rod.
6. Place the rod on top of the level logger and take a measurement with the transit level. Record this measurement as a foresight and subtract it from the HI to obtain the elevation of the level logger. This elevation may have to be adjusted if the "logging end" of the level logger is at the bottom, not the top. For example, if the logger is installed vertically and it records at its bottom end, then the length of the logger housing can be subtracted from the elevation of the top of the housing to obtain the elevation of the logging end.

7. Place the stadia on top of each of the two reference points (RP1 and RP 2) and take readings with the transit level. Record these readings as foresights on the data sheet and subtract each from the HI to establish the elevations of the reference points.
8. In order to complete the survey, a turning point must be created to check for measurement or recording errors. Throughout the differential leveling process, it is imperative that either the stadia rod or the transit level are at a location of known elevation at all times. When preparing to move the transit level, a turning point (TP) establishes a location of known elevation that can be used to determine a new HI after the transit level is moved. Any of the previously measured points can serve as the TP, but the TP information should be recorded on a separate line. Place the stadia rod on the selected TP and take a measurement with the transit level. Record this measurement as a foresight and subtract it from the HI. This establishes the TP as a point of known elevation. While keeping the stadia at the TP, Move the tripod to a new location and re-center the bubble on the bull's-eye level.
9. Take a measurement from the new transit location back to the TP. Record this measurement as a backsight and add it to the elevation of the TP to obtain a new height of instrument (HI).
10. Move the stadia rod back to the BM and take a measurement. Record this measurement as a foresight and subtract it from the HI to obtain the elevation of the benchmark. This value should be the same (or very close) to the arbitrary elevation assigned to the benchmark at the beginning of the survey. Arithmetic errors are the most common errors during differential leveling. If a closure error is found, check all calculations before redoing the survey
11. The above protocol describes the minimum survey that should take place during a level logger deployment. The above principles can be used to collect other elevation information about the deployment site. A tape-down station should be surveyed in at new deployment locations to correlate discharge measurements with stage information. If practical, a detailed cross-section survey should be completed as well.

Removing Loggers

All loggers should be removed at the end of the open water season as they are not designed for deployment in sub-zero temperatures. Most monitoring locations are out of the water during the winter, and spring low-flow conditions expose the loggers to potential damage from ice and extreme cold. Be sure to retrieve both the level and barologgers from the field so that the water level data can be compensated for barometric pressure (see SOP10).

Literature Cited

Harrelson, C. C, C. L. Rawlins, and J. P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. General Technical Report RM-245. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Kennedy, E.J. 1990. Levels at streamflow-gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A.

SOP8: Water Temperature Measurement:

Vertical Temperature Arrays

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

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Introduction

This standard operating procedure (SOP) describes the construction, installation, and maintenance of moored all-season vertical temperature arrays in Tier 1 lakes within the Southwest Alaska Network (SWAN). The array layout (Figure 8.1) follows that of commercial long-line fishing gear, except that the horizontal rope is stretched between the two vertical ropes at 5 m below the lowest known or estimated lake surface, instead of across the lake bottom, and submersible buoys are attached to the vertical lines just above this point, allowing the array to reside safely under the ice.

In spring, the instrument line (the vertical rope with the temperature data loggers attached) is retrieved for data download by catching the bridle line (the horizontal rope) with a grappling hook. The data loggers are either read or replaced, and a surface float, with another logger between 0 m and 1 m depth, is attached to the instrument line before it is returned to the lake. The surface float is removed when the data loggers are tended in the fall. Once the array is deployed, the anchor line (the second vertical rope without instruments) remains in place unless the entire array is replaced. Currently, six temperature arrays are deployed in SWAN lakes. Locations are listed in Table 8.1.

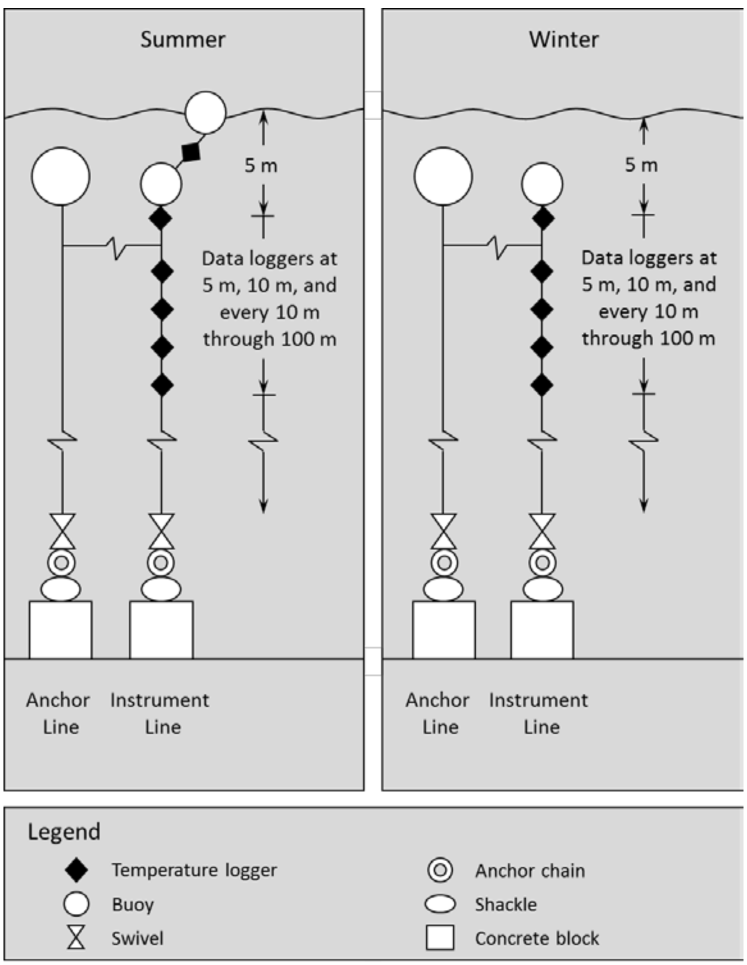

Figure 8.1. Schematic of the temperature array layout during summer and winter.

Table 8.1. Temperature array site information. Latitude and longitude represent approximate locations in decimal degrees (NAD 83) for instrument lines. Actual coordinates change over time as the lines are retrieved, downloaded, and redeployed.

Park	Lake	Basin (Basin #)	Installation Year	Latitude	Longitude
LACL	Lake Clark	Middle (01)	2006	60.26228	-154.23886
LACL	Lake Clark	Lower (02) [a]	2009	60.03848	-154.74194
LACL	Kijik Lake	[b]	2010	60.29748	-154.32933
KATM	Naknek Lake	North (01)	2008	58.63842	-155.63687
KATM	Naknek Lake	West (02)	2008	58.61661	-156.03706
KATM	Naknek Lake	Iliuk (03)	2011	58.52285	-155.60542
KATM	Lake Brooks	[b]	2010	58.53001	-155.85043

[a] This array was lost some time during the winter of 2009-2010.

[b] Kijik Lake and Lake Brooks have only one basin each.

Temperature Array Construction

The supplies needed for temperature array construction depend, in part, on the site selected for deployment. Site selection is somewhat subjective. Criteria for selection should include: (a) bathymetric information ─ the site should have a bottom profile with a low-gradient slope; and (b) a minimum depth of 125 m (where possible) to ensure data collection to 100 m. Select the site on the lake using existing bathymetric maps, park staff knowledge, and a coarse grain survey with a fathometer. The deployment site may not be the deepest location on the lake, but may be selected due to interest in lake basin mixing, prevailing winds, or other factors (e.g., comparing glacial versus non-glacial lake basins). Once a deployment site is determined on a lake map, an on-site visit is recommended to record the location with a GPS and actual depth with sonar or flasher. Then purchase line accordingly, allowing for up to 10–15 m surplus for the two vertical lines (Figure 8.1). Twelve-strand hollow core line, ½ inch in diameter, is recommended for durability and ease of splicing (Table 8.2).

Table 8.2. Supplies needed to build a moored temperature array.

Category	Quantity	Item Description [a]
Rope Framework	2	½ in. 12-strand hollow core polypropylene-polyethylene Lugger line [b, c]
	1	61 m length of ½ in. 12-strand hollow core polyester sinking line [c]
	1	10 m length of ⅜ in. nylon rope for the surface float
	6	½ in. plastic thimbles
	2	13 in. diameter (or similar size) submersible floats [d]
	1	Surface float (flagged shrimp pot buoy float)

Category	Quantity	Item Description[a]
	1	Large spring clip or carbineer for attaching horizontal line to instrument line
	1	Small radio transmitter[e]
	(as needed)	Whipping cord (for securing the splices)
	(as needed)	Electrical tape
Anchor System	2	Sets of anchors of sufficient weight to hold submersible floats in place
	2	1.5 m lengths of $^5/_{16}$ in. stainless steel chain[f]
	2	4.5 m lengths of $^5/_{16}$ in. stainless steel chain[f]
	4	⅞ in. stainless steel shackles[f]
	2	⅜ in. stainless steel swivels[f]
	8	⅜ in. stainless steel shackles[f]
	(as needed)	Stainless wire or electrical cable ties for securing shackle pins[f]
Data Loggers	1 per depth	Onset Water Temp Pro v2; 1 ea. at surface, 5 m, 10 m, and every 10 m to 100 m
	1 per depth	Onset HOBO Pendant light/temperature; 1 ea. at surface, 5 m, 10 m and 15 m
	1	Water level logger at 5 m
	1	Onset HOBO waterproof shuttle
	1 per logger	#70 nylon Gagnon cord; ~30 cm long
	3 per logger[g]	Appropriately marked plastic tags for indicating depth[h]

[a] English units are used for products that are commonly described that way (e.g., ropes, shackles, swivels); otherwise, metric units are used.

[b] Length varies with lake depth, but must accommodate both the instrument and anchor lines.

[c] Available from Machovec (763-263-9835; http://www.machovec.com/) or Arctic Wire Rope and Supply, Inc. (907-562-0707; http://arcticwirerope.com/).

[d] Floats >16 in. should be avoided due to excessive amount of weight required to overcome buoyancy. Commercial trawl floats work well due to heavy duty construction and ability to withstand deep working depths.

[e] Such as Lotek MCFT2-3L series radio transmitters with a 5 second burst interval.

[f] Galvanized hardware can also be used, but will not last as long. Mixing metals of different specific electric potentials, such as stainless and galvanized, should be avoided since it will result in increased (galvanic) corrosion of the metal with a higher position in the galvanic series, in this case galvanized, unless protected by paint or some other coating.

[g] One tag marks the line, another labels the data logger, and the third is used when data loggers are replaced.

[h] Available from Floy Tag & Mfg., Inc. (800-843-1172; http://www.floytag.com/).

Assembling the Anchor System

The anchor system (Table 8.2) is set up in the following order:

1. First, a $\frac{7}{8}$ in. shackle fits over the rope thimble and connects a $\frac{3}{8}$ in. swivel.
2. The $\frac{3}{8}$ in. shackle attaches the swivel to the 1.5 m of $^{5}/_{16}$ in. chain.
3. Next a $\frac{3}{8}$ in. shackle attaches the chain to the anchor.
4. If multiple anchors are used, attach the remaining anchors to one end of a 4.6 m piece of $^{5}/_{16}$ in. chain with a $\frac{3}{8}$ in. shackle and the other end of the chain to the first anchor.
5. Wait for the entire temperature array to be constructed before using stainless steel wire or electrical cable ties to secure the shackle pins in place so they are not able to turn and work themselves loose over time.

Two or three smaller anchors (approximately 27–37 kg, total) are easier and safer to handle before and during installation than one larger anchor. The effective underwater weight of concrete is about 45% less than its weight in air, while metals weigh 10–15% less underwater. Therefore, although concrete anchors can be easily and cheaply made, they are not ideal due to their additional bulk and weight. Pyramid-shaped lead drift boat anchors are available in a range of weights and have worked well on past temperature array deployments. The bottom 1.5 m of chain is not strictly necessary, but adds weight and elevates the rope and swivel above much of the soft sediment and sediment-water slurry that occurs at the bottom of glacial lakes.

Assembling the Instrument and Anchor Lines

Assembling a temperature array involves creating six "eye-splices" or loops: four end loops at the upper and lower ends of the instrument and anchor lines, and two attachment loops for connecting the bridle line. Splicing instructions are available online or on the T Drive at T:\Vital_Signs\Water_Fish\Equipment\Temp_array\Splice_Instructions. Whenever a loop is spliced, use a plastic thimble (a grooved teardrop shaped ring; Figure 8.2 and Table 8.2) to prevent chafing of the line. Wrapping the last 5–7 cm of line with electricians tape stiffens the end sufficiently so that, in some cases, it may be used instead of a fid (a large needle used in splicing; Figure 8.2 and Table 8.3) once it has been inserted into the hollow core.

Hollow core rope strands relax when pushed from opposite directions, thus a push-pull technique works well for working the splicing end into the hollow core of the main line. Insert the fid full length into the hollow core of the main line, with the splicing end of the rope tucked into the hollow end of the fid. Hold the main line, splicing end and fid tightly in your left hand, and use your right hand to pull the main line toward you, bunching the rope up on the fid. Carefully loosen your left hand while gripping tightly with your right, allowing the fid and splicing rope to slide forward in the hollow core of the line. If necessary, use the pusher (Figure 8.2 and Table 8.3) to hold the splicing end into the hollow end of the fid. Bracing the end of the pusher against your body leaves both hands free to work the line.

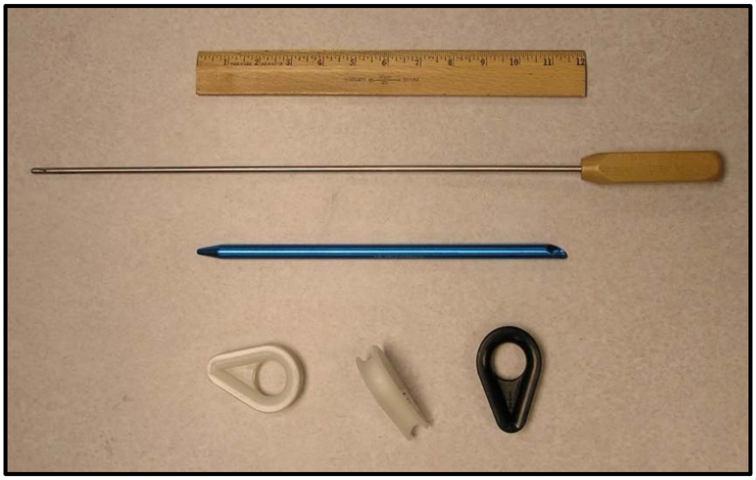

Figure 8.2. Tools used for splicing line (from bottom to top): thimbles, fid, and pusher. A ruler is shown for scale.

Table 8.3. Checklist of tools needed to assemble a moored temperature array.

☐	Rope counter
☐	Rope cutter
☐	Fid, appropriately sized for the rope diameter
☐	Pusher for splicing, large
☐	Whipping needle or blunt end #13 yarn needle

Assembling the instrument and anchor lines is best done outside, or in a large, open space where the line can be spread out in a linear manner. The anchor line and instrument line are assembled similarly. The only difference is that the instrument line has the added steps of attaching the data loggers. The following steps outline the process of line assembly and data logger attachment.

1. Use the following formula to determine the amount of line needed for each anchor and instrument line: (water depth in m at deployment site) - (1.5 m anchor chain + 5 m for submersible float depth) + (1 m to account for splices).
2. Using the rope counter (Figure 8.3 and Table 8.3), measure off the amount of rope calculated in Step 1. Cut the rope with the rope cutter (Figure 8.3 and Table 8.3).
3. Next, splice in a thimble that will be connected with a ⅞ in. shackle to the ⅜ in. swivel near the anchor chain (Figure 8.4). For splicing instructions, see the documents at T:\Vital_Signs\Water_Fish\Equipment\Temp_array\Splice_Instructions.
4. At the other end of the line, run the line through the submersible buoy and splice in a thimble as described above.
5. Follow Steps 1–4 for both the anchor and the instrument lines.

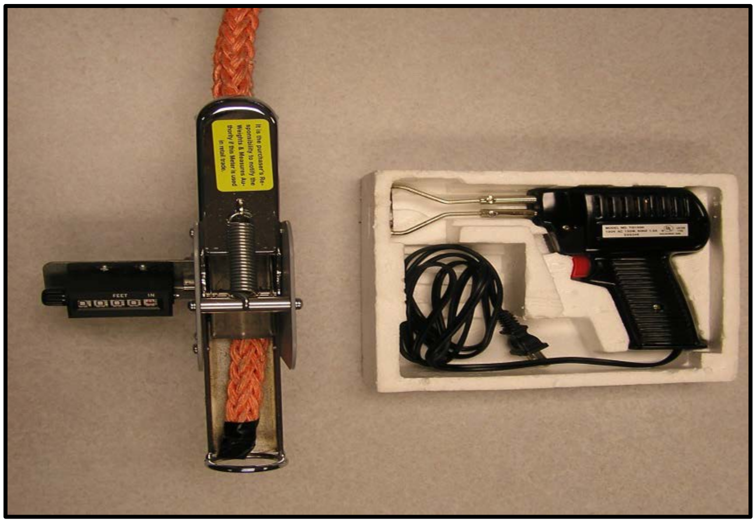

Figure 8.3. Rope measuring and cutting tools. Rope counter (left) with rope positioned for measurement, and rope cutter (right).

Figure 8.4. Thimble spliced into the lower end of the instrument line. The shackle and anchor chain are attached. The swivel described in Step 3 (above) is not pictured.

6. On the anchor line, approximately 1 m below the top thimble (and below the submersible buoy), splice the 61-m bridle line directly into the main line.
7. On the instrument line, approximately 1 m below the top thimble (and below the submersible buoy), splice a horizontal 1-m long piece of ½ in. 12-strand hollow core line into the main line (Figure 8.5).
8. Splice a thimble into the other end of the horizontal 1-m long line (Figure 8.5). This thimble will serve as the attachment point for the bridle line.
9. On the bridle line, splice a thimble into the end that will be attached to the instrument line. After the instrument line has been deployed, use a large spring clip or carabineer to connect the bridle line to the short piece of line spliced in Step 7 above.

Figure 8.5. Instrument line with submersible buoy and horizontal 1-m long attachment point.

10. Immediately below the top thimble on the instrument line, use the pusher to thread a 30 cm piece of #70 nylon Gagnon cord through the center of the main line and secure one end with a bowline knot. Tape the knot with electricians tape.
11. Slip the free end of the Gagnon cord through the mounting hole on the end of a HOBO data logger, secure that end with a bowline knot, and tape the knot with electricians tape. The Gagnon cord will allow the 5-m temperature data logger to hang freely while the main line is wrapped around the winch pulley during deployment and retrieval.
12. Measure 5 m further down the main line from the 5-m data logger attachment point and thread in another 30 cm piece of Gagnon cord. This point will be the 10 m mark. Repeat Step 11 every 10 m, from the 10 m mark until the 100 m mark or the anchor chain is reached, whichever comes first. A 30 cm piece of Gagnon cord will be threaded in to secure a data logger at each measurement point (Figure 8.6).

Figure 8.6. Gagnon cord threaded into the instrument line serves as an attachment point for a data logger. Initially, a stainless steel split ring (shown at the distal end of the cord) was used to attach the cord to the logger, but these rings corroded over time so they were omitted from the SOP.

13. HOBO Water Temp Pro v2 data loggers are only waterproof to 120 m. If, in the future, there is interest in monitoring below 100 m, TidbiT data loggers should be used below 120 m, as TidbiTs are designed to operate at these depths.
14. **Note:** lake conditions in the SWAN are uncertain, with bottom bathymetry only crudely known, and lake currents a data gap. It is prudent to attach a small radio transmitter to the array, if feasible, to aid in relocation (details provided below).
15. **Note:** Solinst water level loggers are attached at a depth of 5 m on temperature array instrument lines in Lake Clark and Naknek Lake. These loggers provide a year-round record of lake level, which could be used to estimate annual flux in lake volume and over-winter base flow of the Lake Clark and Naknek Lake systems. They also could help understand the amount of year-round variation in the actual depths of the temperature loggers relative to their intended depths (e.g., 5 m, 10 m, 20 m, etc.), since the intended depths are measured from the lake bottom, where the lines are anchored.

Data Logger Programming

The temperature arrays currently use HOBO Water Temp Pro v2 loggers made by Onset. Loggers are attached year-round at depths of 5 m, 10 m, then every 10 m to 100 m (or the lake bottom). During the open water season, an additional logger is attached to the surface float line between 0 m and 1 m depth. HOBO Pendant Temperature/Light data loggers were co-located with HOBO Water Temp Pro v2 loggers at depths of 5 m, 10 m, and 15 m until 2012, when they were removed due to issues with fouling.

HOBO loggers require HOBOware Pro software, an optical reader, and a coupler to communicate with the computer. Two types of optical readers are available: 1) the Optic USB Base Station, which requires a computer connection, and 2) the Waterproof Shuttle, which can be used in the field to download remotely without a computer connection, or connected to the computer with a portable cable (Figure 8.7). Programming steps for HOBO Water Temp Pro v2 loggers are detailed below. Comparable steps for HOBO Pendant Temperature/Light loggers are also included, in case fouling issues are resolved in the future.

Figure 8.7. Optical readers for Onset HOBO Water Temp Pro v2 loggers: the Optic USB Base Station (bottom) and the Waterproof Shuttle (top).

Temperature Data Loggers

1. Open HOBOware Pro software on the computer.
2. Connect the optical reader (Figure 8.7) to the computer using the USB connection.
3. If any loggers are housed in protective boots, the boots must be removed before the loggers can communicate with the computer.
4. HOBO Water Temp Pro v2 loggers fit into Onset 2-C couplers. Match the arrows on the logger with the arrows on the coupler to ensure a proper connection with the optic reader. Press the lever on the coupler to make the connection. A green light will appear if the contact is correct. If no green light appears (on the USB Base Station) or the red “fail” light appears (on the Waterproof Shuttle), twist the logger in the coupler slightly and try again.
5. In the main menu of HOBOware Pro, select Device / Launch. A window will appear with the logger model and serial number. Click OK to select the logger.
6. Next, a Launch Logger window will display the logger’s serial number and battery status (Figure 8.8). In the space for the Description, type in the 4-letter park code, the 5-letter waterbody code plus 2-digit site ID, and the 3-digit deployment depth plus “m_temp” (e.g., LACL_lclar01_005m_temp). Set the logging interval to 1 hr. Be sure to check this as new loggers are set to a default of 1 min. Select the launch options based on when the logger will be deployed. For initial deployments, use a delayed start time of 00:00 AM for the day after the deployment date. If replacing loggers in the field, program a delayed start date and time that will minimize the sampling gap that may occur during sampling site visit activity. Click Delayed Start when all the programming information is complete.

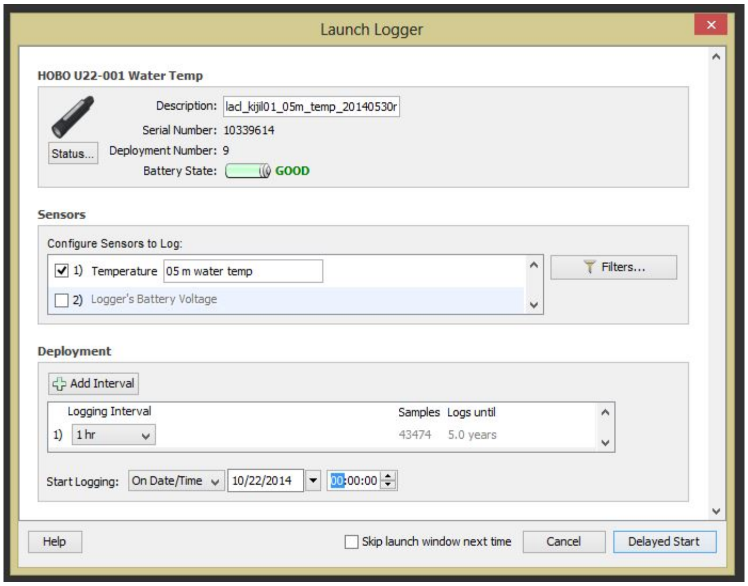

Figure 8.8. Screen shot depicting the Launch Logger window in HOBOware Pro software.

7. A Launching Logger window will appear for several seconds to display programming progress. Below the main window in the lower left corner, a report will appear indicating the launching result. If a “Launch successful” result occurs, remove the logger from the coupler.
8. For an initial deployment, attach the appropriate depth tag to the eye of the logger, or mark the programmed depth on the logger using permanent ink, so the logger can be placed at the correct location on the array.
9. Repeat Steps 2–8 until all loggers are programmed and marked. Close HOBOware Pro when finished.
10. **Note:** loggers programmed to measure temperatures at depths of 5 m or greater should be fit with protective boots and caps. Near-surface (0–1 m depth) loggers should be deployed with a cap that fits over the face to protect it from bio-fouling. These caps are smaller than the ones that come with the protective boot and allow the user to perform a download without having to remove the logger from the instrument line.

Light Data Loggers

HOBO Pendant Temperature/Light data loggers are programmed using HOBOware Pro software and an Optic USB Base Station or Waterproof Shuttle, connected to a 2-A coupler.

1. Connect the light logger to the optical reader with the 2-A coupler and open HOBOware Pro. Press the coupler lever to establish communication. Be sure that the coupler face is flush with the optical reader.
2. From the menu select Device / Launch. Find the pendant listed and select OK. The Launch Logger window will appear (Figure 8.8). Change the default site description to the 4-letter park code, the 5-letter waterbody code plus 2-digit site ID, and the 3-digit deployment depth plus “m_light” (e.g., LACL_lclar01_005m_light).
3. Select all three channels for logging (temperature, light, and battery voltage).
4. Set the logging interval to 1 hour. Be sure to check this as the default is 1 minute. Set the launch options to delayed start with a date that corresponds to the date following the deployment date and a start time of 12:00 am.
5. Click Launch. The program will be loaded onto the device. Close HOBOware Pro and disconnect the optical reader.

Temperature Array Operations

This section outlines the steps necessary to safely deploy and retrieve temperature arrays for data collection and downloading. Hazards are inherent any time a temperature array is raised or lowered. Therefore, it is absolutely critical that all crew members read the safety guidelines below and the relevant Job Hazard Analysis. Crew members must also communicate with each other during operations, and place personal safety above all other tasks.

Crew Safety Guidelines

<u>Extreme care and attention must be used by all crew members during deployment and retrieval of any temperature array</u>! The following safety guidelines must be observed at all times:

1. Never stand between the coiled array line and the working side of the boat (i.e., the side over which line is being raised or lowered), often referred to as the ‘line bite.’ All crew members must remain behind the line at all times in the event that the line breaks free and sinks under the weight of the anchors.
2. Always carry a stout, fixed-blade knife in an easily accessible location in the event of accidental entanglement with the array line.
3. Always use cleats and tie-offs as safety control points in the event that the array line slips free from the pulley.
4. Hand and eye protection should be worn while the array line is actively being retrieved and deployed. If the capstan winch is being used, hearing protection is required.

Temperature Array Deployment

Calm wind conditions are ideal for temperature array deployment and maintenance. Even with an experienced crew, minimal wind or wave action may be required. Three people work best for deployment, with one person operating the boat and two people working with the array. The boat operator can reposition the boat if needed, or lend a hand for the more labor intensive tasks, such as lifting the anchor(s) over the side of the boat. Equipment required for array deployment is listed in Table 8.4, and the steps involved are summarized below.

Table 8.4. Checklist of equipment needed to deploy a moored temperature array.

☐	Light commercial winch or pot puller
☐	Gas / oil for winch operation
☐	Large boat with davit
☐	Two 15 m lengths of rope
☐	1 m of scrap rope
☐	One small surface float
☐	Grappling hook and rope
☐	Global positioning system (GPS) unit
☐	Personal protective gear (i.e., gloves, ear and eye protection)

1. Organize the anchor, instrument, and bridle lines into separate bins or tubs. Ready them for deployment, but situate them outside the immediate workspace of the boat deck. The anchor line will be the first deployed piece of line.
2. Using a piece of spare rope (approximately 2 m long), thread the rope through the shackles attached to the anchors and tie the loose ends to form a loop.
3. Hook the spare rope loop onto the davit and lift the anchors up and over the side of the boat.

4. Before lowering the anchors into the water, wrap the anchor line around the pot puller or winch pulley so that it is ready to bear the weight of the anchors.
5. With the rope on the pulley and secure, lower the anchors with the davit into the water low enough so that the anchor weight is now transferred to the pot puller or capstan winch.
6. Now that pressure is relieved from the davit, unhook the spare rope, untie the loop, and pull the rope free from the anchor shackles.
7. Next, lower the array line using the capstan winch. **Note:** be certain to pass the array line through a boat cleat or tie-off point before it passes through the pulley as a safety precaution.
8. Several meters before the subsurface float reaches the pulley, secure the array line to a cleat and stop lowering the line. Attach the bridle line to the anchor line with a springloaded carabiner connecting spliced end loops. Tie off the bridle line, allowing enough extra line to account for the distance from the current anchor depth to the lake bottom.
9. At this point, two crew members can hold the weight of the array line below the pulley while the third crew member frees the line from the pulley and places the subsurface float over the side of the boat.
10. Reposition the boat in the desired location for deployment of the instrument line. Repeat Steps 2–8 for the instrument line. **Note:** ensure all data loggers are launched prior to deployment.
11. Reposition the boat to "stretch out" the amount of bridle line. The bridle line will be easier to retrieve in later site visits if some tension is created between the anchor and instrument lines. Repeat Step 9.
12. Ensuring that all hands and feet are free from the line, the two crew members holding the weight can release the line. The subsurface float should sink to a depth of approximately 5 m.
13. Record a GPS waypoint.

Temperature Array Relocation

Finding and retrieving temperature arrays, in some years and locations, has been challenging. The positions of instrument lines have shifted as much as 0.4 km, according to GPS waypoints taken during consecutive fall and spring site visits. The temperature array located in the lower basin of Lake Clark was last maintained in 2009 (Table 8.1). It was never again located despite several extensive search operations. To provide an extra tool for array relocation, Lotek radio tags have been installed on several instrument lines (Table 8.5). Steps for installing Lotek radio tags on temperature arrays are listed below.

1. Activate the radio transmitter by removing the magnet from the tag.
2. Record the radio tag specifications, including the frequency. For example, radio tags installed in 2014 had the following specifications: brand = Lotek; model = Tadiran; frequency = 162.494 MHz; code = 12; burst interval = 5.0 seconds.

3. Place the transmitter inside the hollow core of the instrument line below the 5 m submersible buoy.

Table 8.5. Temperature arrays in SWAN lakes with active radio tags.

Temperature Array ID	Park	Lake	Basin	Tag Installation Year	Serial Number
LCLAR01	LACL	Lake Clark	Middle	2011	[a]
KIJIL01	LACL	Kijik Lake	Lower	2014	MC002506
NAKNL01	KATM	Naknek Lake	North	2014	[a]
NAKNL02	KATM	Naknek Lake	West	2014	MC002508

[a] Serial number not recorded prior to deployment.

Temperature Array Maintenance and Data Collection

Ideally, temperature arrays should be retrieved for data downloading and maintenance twice per year, in early summer and in early fall. However, site access logistics may allow data downloads only once per year. A surface buoy with approximately 8–10 m of ⅜ in. nylon rope is attached to the instrument line submersible float during the spring retrieval and removed during the fall retrieval. A HOBO Water Temp Pro v2 data logger is attached to the surface buoy using Gagnon cord or zip ties, so that the logger is suspended < 1 m below the water surface. **Note:** once the temperature array has been deployed, only the instrument line is retrieved for data downloading. Retrieve the anchor line only if the entire temperature array is to be replaced or moved.

1. During the spring retrieval, use a GPS and/or radio receiver to relocate the general area of the temperature array, and a grappling hook to catch the bridle line. During the fall retrieval, use a boat hook to grab the surface buoy.
2. Pull the instrument line into the boat until the submersible float is past the winch or pot puller pulley. With two crew members holding the weight of the instrument line, the third crew member should wrap the loose line around the pulley and secure the end to a boat cleat.
3. Start the winch and retrieve the instrument line to the depth of the bridle line (Figure 8.9).
4. Turn off the winch and disconnect the bridle line clip from the instrument line. Attach the bridle line to the boat. This will hold the boat in place while the instrument line is raised and lowered.
5. Use the capstan winch to retrieve the instrument line. Care should be taken so that the data loggers hang free and are not bound as the instrument line wraps around the pulley.
6. **Note:** the capstan winch retrieves the instrument line best if two complete wraps of the rope are used on the winch pulley, and one or two crew members apply pressure by pulling the rope slightly (Figure 8.10). Additional wraps of line around the pulley, although providing more friction, tend to bind causing delays in the retrieval process.

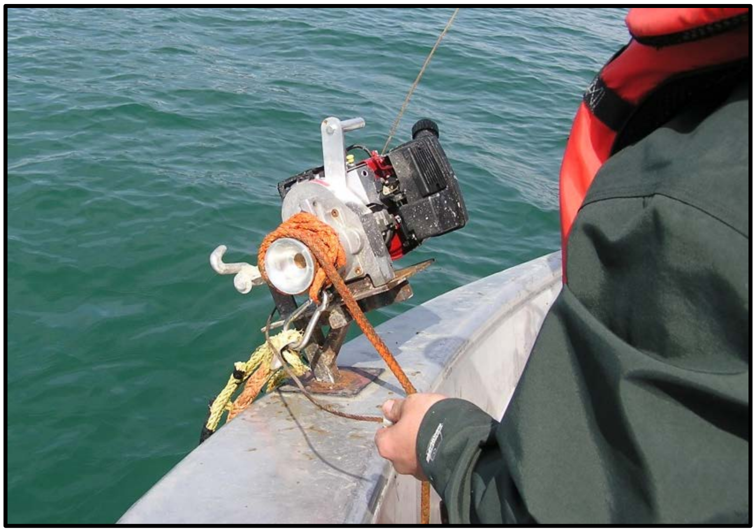

Figure 8.9. The captsan winch is used to retrieve the instrument line to the depth of the bridle line. Although not worn in this photo, gloves are strongly encouraged.

7. As the instrument line is retrieved, quickly check the line for wear, excessive abrasion, or cuts. Do not attempt to make any repairs until the entire line has been retrieved and secured. A more thorough check is conducted later (see Step 11, below).

8. After the last data logger has cleared the pulley, but before the anchor chain reaches the pulley, stop the winch and secure the instrument line to a boat cleat or tie-off.

9. Prior to downloading the data in the field, create a temporary folder on the field laptop with the lake name, site ID, and download date included in the folder name (e.g., lclar01_20080530). Save the raw data files in this temporary field folder using the following naming convention: 4-letter park code + _5-letter water body code + _2-digit site ID +_3-digit depth interval + 'm' _download date (YYYYMMDD) + 'raw.' For example, data downloaded from the mid Lake Clark temperature array at 5 m on May 30, 2008 would be saved as "LACL_lclar01_005m_20080530raw." See SOP10 for guidance on data downloading.

10. Check the battery status of each logger as it is downloaded. Because the loggers run on lithium ion batteries, voltage alone will not indicate remaining logger lifetime. Loggers that fail to communicate/download, or that indicate a battery status of "low" or "bad," should be replaced immediately. If the loggers are downloaded to a laptop, quickly view the data to look for anomalous readings that may indicate the logger is malfunctioning. Replace any loggers with low batteries or questionable data.

11. After the loggers are downloaded, inspect the condition of the instrument line. Although the line is built for strength and durability, it is susceptible to degradation over time. Pay particular attention to the splices at the junction of the bridle line and instrument line, as this junction is often the most stressed due to the nature of the retrieval process. If these splices are at all suspect, tie a butterfly loop (or similar) below the splices on the bridle line and instrument line. Use a new piece of line, 4.5–6 m in length, to connect the two loops. This

line will maintain a connection between the bridle and instrument lines in case of a splice failure.

12. Lower the instrument line following Steps 6–9 outlined in the Temperature Array Deployment section above.

Figure 8.10. Capstan winch and the best position of line with two wraps and slight pressure applied during retrieval.

Data Logger Error Checks

Pre-Deployment Check

Prior to the initial deployment, data logger accuracy should be checked over a range of temperatures that encompass those expected to be encountered in the field. Various protocols exist for conducting an accuracy check. The steps below follow those described by Mauger (2008). A National Institute of Standards and Technology (NIST) certified calibration thermometer (accurate to ±0.2 °C) is required.

1. Open HOBOware Pro software on the computer.
2. Connect the optical reader (Figure 8.7) to the computer using the USB connection.
3. Connect a HOBO Water Temp Pro v2 logger to the optical reader using a 2-C coupler. Press the lever on the coupler to make the connection.
4. In the main menu of HOBOware Pro, select Device / Launch. A window will appear with the logger model and serial number. Click OK to select the logger.
5. Next, a Launch Logger window will display the logger’s serial number and battery status (Figure 8.8). Verify the battery health. In the space for the Description, type in the logger’s serial number. Program the logger to record at short (e.g., 5 minute) intervals. Select the Start Logging date/time. Click Delayed Start when all the programming information is complete.

6. A Launching Logger window will appear for several seconds to display programming progress. Below the main window in the lower left corner, a report will appear indicating the launching result. If a “Launch successful” result occurs, remove the logger from the coupler.
7. Repeat Steps 1–6 for a batch of loggers.
8. Submerge loggers in an ice water bath in an insulated container (e.g., a cooler), ensuring that the loggers are completely surrounded by water, not floating at the surface or sitting on the bottom.
9. Allow loggers to equilibrate to the temperature of the bath for at least 1 hour, stirring the water periodically.
10. Stir the water, and then measure and record the water bath temperature with the NIST thermometer as close as possible to the time when the loggers are programmed to record.
11. Repeat Step 10 at least two more times.
12. Once the ice water bath temperature measurements have been recorded, place the loggers in the second (room temperature) bath and repeat Steps 9–11.
13. Connect the loggers to the computer and download the data as described in SOP10.
14. Compare each logger’s data to the NIST thermometer data recorded for the same time point. If the difference between the logger and the NIST thermometer exceeds 0.3° C, retest the logger. If the logger fails the calibration check a second time, do not deploy it.

Post-Deployment Check

After the data loggers have been deployed and the data downloaded, visually inspect the data plot from each logger using HOBOware Pro. Check for anomalous readings or groups of readings that may indicate, for example, the failure of a thermistor, the mislabeling of logger depth, or the recording of air rather than water temperature. Note these readings in a field notebook until the erroneous readings have been verified. One way to check potentially erroneous readings is to review corresponding data from depths above and/or below. For Naknek Lake and Lake Clark, any readings below -1 °C should be considered suspect, as should readings above 20 °C. An hourly rate of change of greater than 2 °C per hour or a daily mean change of greater than 2 °C between two successive days warrants additional scrutiny ─ although wind-driven upwelling can cause legitimate thermal variation of this magnitude (Lisi 2014). Below 10 m, a rate of change of 1 °C would be more appropriate. Temperature array time series data will be processed using AQUARIUS software, as outlined in SOP11. Finally, upon retrieval (i.e., when a logger is removed from the temperature array), the pre-deployment check described above should be repeated.

Future Arrays

Installing additional arrays in lakes without access to large boats with davits like those available in Lake Clark and Naknek Lake will present different challenges. Use of a cata-raft with a capstan winch mounted so as to pull through the center of the raft frame may be an option, although it would require significant aircraft support and several hours to assemble and disassemble the raft.

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SOP9: Decontamination of Field Equipment

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

Suggested Reading

Elias, J. 2005. Standard Operating Procedure #5, Decontamination of equipment to remove aquatic exotic species. *in* S. Magdalene, D. R. Engstrom, and J. Elias. Large rivers water quality monitoring protocol, version 1.0. National Park Service, Great Lakes Network, Ashland, Wisconsin.

Starkey, E. N., L. K. Garrett, T. J. Rodhouse, G. H. Dicus, and R. K. Steinhorst. 2009. Standard Operating Procedure #8, Decontamination of equipment for aquatic invasive species. *in* E. N. Starkey, L. K. Garrett, T. J. Rodhouse, G. H. Dicus, and R. K. Steinhorst. Integrated water quality monitoring protocol standard operation procedures, Upper Columbia Basin Network. Natural Resource Report NPS/PWR/UCBN/NRR—2009/00xx. National Park Service, Fort Collins, Colorado.

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Introduction

Aquatic invasive species (AIS) are a serious ecological and socio-economic threat to freshwater systems throughout North America. AIS have the potential to out-compete native flora and fauna, alter habitat conditions, and cause billions of dollars in infrastructure repairs and mitigation. The introduction and subsequent spread of zebra mussels (*Dreissena polymorpha*) in the Great Lakes Region is a classic example. The U.S. General Accounting Office (2001) reports that from 1989 to 1995 $70 million was spent on control of zebra mussels by municipalities and industry in the Great Lakes region. New Zealand mudsnails (*Potamopyrgus antipodarum*), silver carp (*Hypophthalmichthys molitrix*), and Eurasian watermilfoil (*Myriophyllum spicatum*) are just a few other notable examples in a long list of species whose introduction and spread throughout U.S. waters have resulted in ecological and economic impacts. However, relatively few AIS have been introduced to the waters of Alaska. Reasons for Alaska's fortunate status include geographic isolation, strict plant and animal transportation laws, relatively low human population, and northern climate (Fay 2002).

To date, we are unaware of any AIS populations established within SWAN lakes and rivers. Pursuant to its mission, the National Park Service has a responsibility to take a proactive role in maintaining the ecological integrity that characterizes SWAN aquatic systems and prevent the introduction and spread of AIS within park waters. This standard operating procedure (SOP) identifies the most likely AIS threats to southwest Alaska lakes and streams and provides general decontamination procedures for field crews to minimize the risk of accidental transport of all species, native and AIS, between water bodies during water quality, water quantity, and fisheries monitoring activities. This SOP does not address terrestrial or marine invasive species that may be encountered in upland or coastal areas.

Existing and Potential Threats to Alaska

Aquatic invasive species not found within the SWAN but considered high priority threats within the state of Alaska are listed in Table 9.1. This list is not meant to be all inclusive. Information on species introductions is limited and anecdotal due to the lack of an AIS monitoring program (Fay 2002).

Procedures

The following procedures must be followed before entering any waterbody for sampling purposes. Additionally, these procedures must be followed when sampling is complete on one waterbody but before sampling begins on a different waterbody. Equipment needed to follow the procedures is listed in Table 9.2.

As stated previously, we are unaware of any established AIS populations within SWAN waters. However, without an active AIS monitoring program in place, we will take a proactive approach and treat all equipment when moving between waterbodies. The following procedures were directly adapted from three other networks' SOPs: 1) the Great Lakes Network Standard Operating Procedure #5: Decontamination of Equipment to Remove Exotic Species (Elias 2005), 2) the Upper Columbia Basin Network Standard Operating Procedure #8: Decontamination of Equipment for Aquatic Invasive Species (Starkey et al. 2009), and 3) the Sierra Nevada Network Standard Operating

Procedure #7: Equipment Disinfection (Schweizer 2007). These procedures may need to be modified in the event AIS are detected within SWAN waters.

Table 9.1. Aquatic invasive species considered high priority threats to freshwaters and riparian areas of Alaska (Fay 2002, McClory and Gotthardt 2008).

Functional Group	Scientific Name	Common Name
Plants	*Elodea Canadensis*	Canadian pondweed
	Polygonum cuspidatum	Japanese knotweed [a]
	Phalaris arundinacea	Reed canary grass [a]
	Hydrilla verticillata	Hydrilla
	Landoltia punctata	Dotted duckweed
	Lythrum salicaria	Purple loosestrife [a]
	Myriophyllum spicatum	Eurasian watermilfoil [a]
	Spartina alterniflora	Salt marsh cordgrass
	Spartina densiflora	Dense-flowered cordgrass
	Utricularia inflate	Swollen bladderwort
Invertebrates	*Potamopyrgus antipodarum*	New Zealand mudsnail
	Eriocheir sinensis	Chinese mitten crab
	Dreissena polymorpha	Zebra mussels
	Pacifastacus leniusculus	Signal crayfish [a]
	Bythotrephes cederstroemi	Spiny water flea
Vertebrates	*Salmo salar*	Atlantic salmon [a]
	Perca flavescens	Yellow perch [a]
	Esox lucius	Northern pike [b]
	Rana aurora	Red-legged frog [a]
	Pseudacris regilla	Pacific chorus frog
Viruses	*Myxobolus cerebralis*	Whirling disease

[a] Present or previously documented in Alaska

[b] Present and native in Bristol Bay drainages of LACL, KATM, and ALAG; considered invasive to Cook Inlet and Resurrection Bay drainages, including KEFJ.

Procedure at Non-remote Locations where Tap Water is Available

1. Remove and rinse all visible organic material (mud, plant material, etc.) from boats, paddles, waders, boots, and sampling equipment.
2. Soak all nets, waders, and boots in a 2% Sparquat 256 solution for 10 minutes or spray a 10% Sparquat 256 solution on equipment and let stand for 5 minutes. Sparquat is preferred over bleach since it is less harsh on nets and wader material.
3. Thoroughly rinse disinfectant solution off sampling equipment.
4. If possible, let equipment dry for 10 days; if not, proceed to the next step.
5. Use a scrub brush and a hose with a spray nozzle to scrub and rinse boats, paddles, waders, boots, and sampling equipment. Perform this task on vegetated land away from impervious surfaces and slopes where rinse water may run directly into a nearby waterbody.
6. Use a bottle brush or toilet brush to clean the inside of PVC housing units for multiparameter sondes.
7. Pay particular attention to ropes, cracks, and crevices in equipment. Rinse well.
8. Visually inspect all gear to verify that it has been cleaned and rinsed.

Table 9.2. Checklist of equipment for decontamination of AIS at remote and non-remote locations.

☐	2% and/or 10% Sparquat 256 solution
☐	Bucket or large container (to hold the 2% Sparquat 256 solution)
☐	Spray bottle (to hold the 10% Sparquat 256 solution)
☐	Scrubbing implements (scrub brush, bottle brush, toilet brush)
☐	Hose with a spray nozzle
☐	56% dry chlorine bleach
☐	Collapsible bucket

Procedure at Remote Locations where Tap Water is Unavailable

This procedure uses dry, granular chlorine bleach as a disinfectant instead of Sparquat 256. Dry chlorine bleach is readily available at pool / spa supply stores and is easy to pre-measure and transport to remote field sites rather than a liquid disinfectant (Schweizer 2007). One cup of 56% dry chlorine bleach mixed with 2 gallons of water will yield a 2% bleach solution that can be used to disinfect equipment.

1. Remove all visible organic material (mud, plant material, etc.) from boats, paddles, waders, boots, and sampling equipment. Run hand up and down ropes attached to all equipment and anchor to dislodge remaining organic material.
2. Rinse all gear. Pay particular attention to cracks and crevices in equipment when rinsing.

3. Visually inspect all gear to verify that it has been cleaned and rinsed.
4. If possible, let equipment dry for 10 days; if not, proceed to the next step.
5. Measure 1 cup of dry chlorine bleach into a collapsible bucket containing 2 gallons of water.
6. Allow equipment to soak in bleach solution for a minimum of 2 minutes.
7. Rinse equipment with water from the new survey site. Do NOT rinse equipment with water from old survey site; this will re-contaminate the equipment.
8. For large equipment that cannot be soaked in the bucket, fill a spray bottle with 2% bleach solution and spray all surfaces. Allow equipment to air dry, then rinse with water from the new survey site.
9. Dispose of bleach solution at least 100 meters from any surface waters.
10. Visually inspect all gear to verify that it has been cleaned and rinsed.

General Best Practices Regardless of Remoteness

1. If an AIS becomes established in SWAN waters, the contaminated waterbody should be sampled last during the field season, to the extent possible.
2. Again, to the extent possible, sampling should start at the most upstream sites within a watershed and proceed downstream.
3. Finally, to the extent possible, avoid using boats and other equipment in different waters. Generally speaking, logistics prevent the use of any hard-sided (i.e., non-inflatable) boat on more than one lake system within the SWAN. However, inflatable rafts and small motors will be transported between lakes. SWAN will work towards obtaining a set of field equipment for each park unit, but within each park unit equipment will be used in different watersheds.

Literature Cited

Elias, J. 2005. Standard Operating Procedure #5, Decontamination of equipment to remove aquatic exotic species. *in* S. Magdalene, D. R. Engstrom, and J. Elias. Large rivers water quality monitoring protocol, version 1.0. National Park Service, Great Lakes Network, Ashland, Wisconsin.

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SOP10: Data Download and Export

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

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Introduction

This standard operating procedure (SOP) describes the protocol for using proprietary software to download and export data collected with and stored on electronic equipment, prior to data processing and analysis. SWAN employs various types of electronic equipment and the associated proprietary software for freshwater monitoring (Table 10.1). Future software upgrades may not be compatible with older file versions. To address this problem, all raw proprietary software data files must be exported to a non-proprietary format, such as comma separated value (*.csv) or text (*.txt), prior to analysis.

Table 10.1. Electronic equipment and associated software used for SWAN freshwater monitoring.

Equipment Used [a]	Software [a]	Parameters Measured
YSI 6600 multiparameter sonde	EcoWatch, Streamline	Core parameters [b]
YSI 6600V2 multiparameter sonde	EcoWatch, Streamline	Core parameters [b]
YSI 600QS multiparameter sonde	EcoWatch, Streamline	Core parameters [b]
SonTek RiverSurveyor M9	RiverSurveyor Live	Discharge
In-Situ Level TROLL 200 or 500	Win-Situ	Water level pressure, temperature
In-Situ Baro TROLL	Win-Situ	Atmospheric pressure
Solinst LT Levelogger Gold M5/F15	Solinst Levelogger	Water level pressure, temperature
Solinst LT Barologger Gold M1.5/F5	Solinst Levelogger	Atmospheric pressure
Onset HOBO Water Temp Pro v2	HOBOware Pro	Water temperature
Onset TidbiT v2	HOBOware Pro	Water temperature
Onset HOBO Pendant Temperature/Light	HOBOware Pro	Light intensity, temperature

[a] Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

[b] Core parameters: water temperature, pH, dissolved oxygen, and specific conductivity

Naming Data Files

The use of electronic equipment and proprietary software for data collection requires that users be especially cognizant of proper data management procedures while downloading, exporting, and processing data. These steps generate multiple files of differing formats and extensions containing the same data. For example, raw water temperature data from an Onset HOBO Water Temp Pro v2 logger are saved as a *.hobo file when downloaded, as a *.csv file when exported, and as another *.csv file when processed for quality assurance/quality control (QA/QC). Saving data files with the proper file naming convention is a critical step in the data management process. Table 10.2 provides the correct file naming convention for all files generated from electronic equipment used for SWAN freshwater monitoring. All file names should, at a minimum, contain the 4-letter park code, 5-letter waterbody code, site ID number, date recorded or downloaded (YYYYMMDD), and data format version (e.g., raw, export, or qaqc). Data files downloaded from proprietary software should have names ending in “raw.” Comma separated value (csv) files exported from proprietary software should end in "export." Files processed for quality assurance/quality control (QA/QC) and saved in various formats should end in "qaqc."

Vertical Lake Profile, Continuous, and In-situ Water Quality Data

The objective of vertical lake profile monitoring is to document the spatial variability of core water quality parameters occurring within and among lake basins during the summer index period. The objective of continuous monitoring is to document temporal variability of core parameters over diel or multi-day scales. The objective of in-situ monitoring is to obtain a snapshot of water quality conditions at lake outlets at the time of sampling. A multiparameter sonde is used to record core parameters for all vertical lake profile, continuous, and in-situ water quality measurements. Instructions for recording core parameters in the field are provided in SOP4. This SOP provides instructions for retrieving data files stored on the sonde display, and then exporting the files for data archiving using either EcoWatch or Streamline software.

Downloading Data from the Sonde or Sonde Display

Data can be recorded manually on field data sheets, stored on the sonde display (YSI 650 MDS), or saved in the sonde memory (on 6600 series sondes). For continuous water quality monitoring, data must be recorded to the internal memory of the sonde. For vertical lake profile and in-situ monitoring, data are typically stored on the sonde display. To download data from the sonde or sonde display, follow the steps below.

1. To retrieve files from YSI 6600 series sondes following continuous deployment, connect the sonde to the sonde display with the field cable. Select Sonde Menu / File / Upload on the sonde display, choose the appropriate file, and press Enter. Upload the file in PC6000 format. Once the file upload process is complete, follow Steps 2–7 below to download files from the sonde display to the computer.
2. Connect the display to a desktop computer or field laptop with the 9-pin serial port cable and power up the sonde display.
3. Open the EcoWatch software program. Select Comm / Sonde (Figure 10.1). Highlight the correct Com Port and select OK. A '#' sign will appear when EcoWatch has connected to the sonde display.
4. On the sonde display, select File / Upload to PC. Choose the appropriate files for transfer (Figure 10.2).
5. The data file upload process will appear on the EcoWatch window as well as the sonde display. When finished, power off the sonde display and disconnect from the computer.
6. Once file transfer is complete, navigate to the default data directory for EcoWatch (C:\ecowwin\Data) and open the recently uploaded files to ensure data transferred properly.
7. Copy each recently uploaded raw data file in C:\ecowwin\Data to the appropriate data folder on the T Drive: T:\SWAN\Vital_Signs\Water_Fish\Data\Water_Quality\.

Table 10.2. File naming conventions for aquatic monitoring data collected with electronic data loggers and other equipment.

Monitoring Technique	Parameter	File Naming Convention	File Name Example
Vertical lake profiles	Core parameters	park code_5-letter waterbody code + 1-letter basin ID + 3-digit site ID #_'profile'_YYYYMMDD + format	KATM_naknle003_profile_20090814export
Continuous water quality	Core parameters	park code_5-letter waterbody code + 'o'_'continuous'_'wq'_YYYYMMDD + format	KATM_naknlo_continuous_wq_20140904raw
Cross sectional water quality	Core parameters	park code_5-letter waterbody code_'xsect'_'wq'_YYYYMMDD + format	LACL_lclar_xsect_wq_20140913raw
In-situ water quality	Core parameters	park code_5-letter waterbody code_'insitu'_YYYYMMDD + format	LACL_chulr_insitu_20090718qaqc
Acoustic Doppler profiler	Discharge	park code_5-letter waterbody code + 'o'_'Q'_YYYYMMDD + format	LACL_kijilo_Q_20140916export
Water / atmospheric pressure	Water level / barometric pressure	park code_5-letter waterbody code + 'o'_'lvl' OR 'baro' OR 'lvl_compensated'_YYYYMMDD + format	KATM_lbrooo_baro_20080930export
Temperature array	Water temperature	park code_5-letter waterbody code + 2-digit site ID #_3-digit depth + 'm' _'temp'_YYYYMMDD + format	LACL_lclar01_020m_temp_20090613raw
Temperature array	Light intensity	park code_5-letter waterbody code + 2-digit site ID #_3-digit depth + 'm'_'light'_YYYYMMDD + format	LACL_lclar01_010m_light_20090613qaqc
Temperature array	Water level	park code_5-letter waterbody code + 2-digit site ID # _ 'array'_'lvl'_YYYYMMDD + format	LACL_lclar01_ array_lvl_20090613export

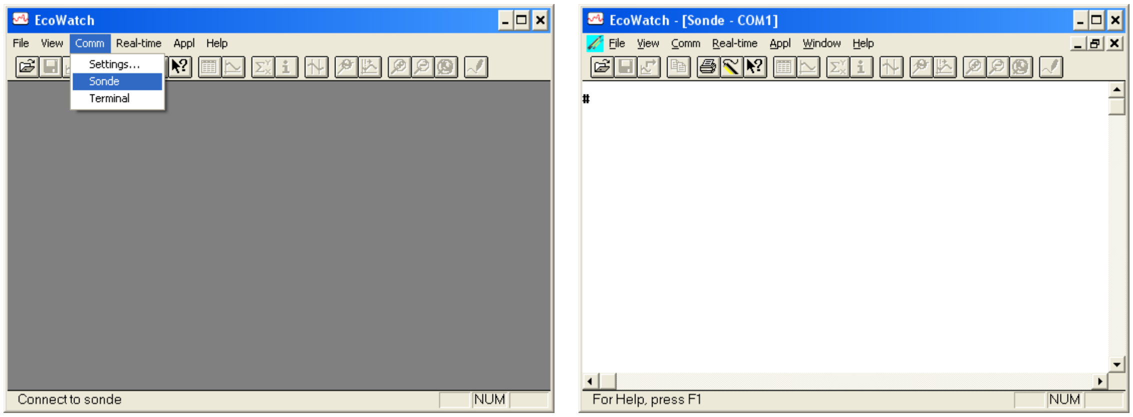

Figure 10.1. Screen shots of initial steps in connecting EcoWatch to the sonde display.

8. Name files according to the relevant conventions provided in Table 10.2.
9. After <u>all</u> files have been uploaded from the sonde display, the display memory can be cleared by selecting File / Delete All Files. **Note:** the YSI 650 MDS sonde display has a flash memory which prevents files from being lost when batteries are depleted or changed. However, the flash memory prevents individual files from being deleted; either all files are deleted or none are deleted. Once files have been deleted from the sonde memory, they cannot be recovered.

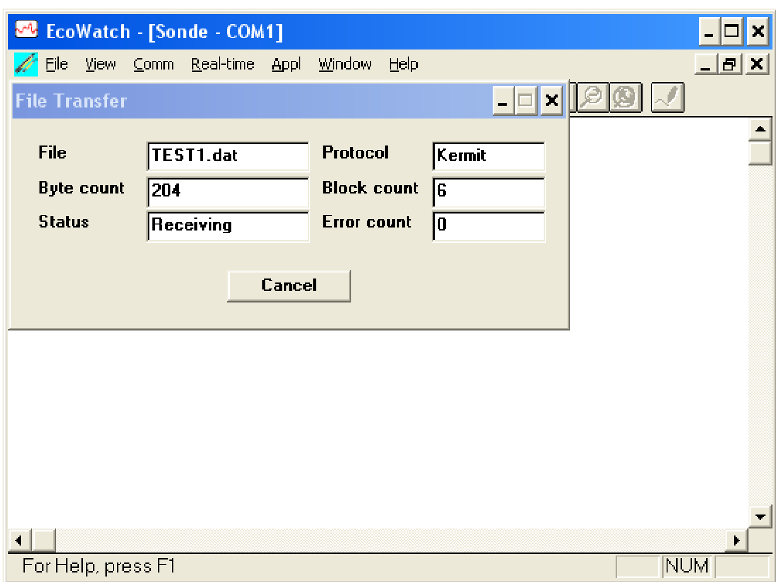

Figure 10.2. Screen shot of the File Transfer window in EcoWatch.

Exporting Data Downloaded from the Sonde or Sonde Display

Raw data files downloaded from YSI 6-series equipment exist in a proprietary DAT format that is only viewable through software such as EcoWatch. It is imperative that files are stored in a format that is usable beyond the lifespan of a given data collection platform (e.g., YSI 6-series sonde platform). Therefore files must be exported from *.dat to *.txt or *.csv format. The steps below outline the procedure for exporting raw YSI DAT files using either YSI's EcoWatch software or Interactive Oceanographic's Streamline software.

<u>Exporting Data with EcoWatch</u>

1. Open EcoWatch and select File / Open.
2. Navigate to C:\ecowwin\Data and select the data file of interest.
3. To facilitate file import to AQUARIUS during subsequent data processing steps (SOP11), always export data from EcoWatch in the following order with the corresponding units: DateTime (M/D/Y) / Temperature (°C) / pH / Specific Conductivity (µS/cm) / Dissolved Oxygen Concentration (mg/L) / Dissolved Oxygen Saturation (%) / Turbidity (NTU).
4. To select parameters for export, go to Setup / Parameters / Add/Remove (Figure 10.3).
5. To change the order in which parameters are displayed, use the Up and Down buttons on the left side of the Add/Remove Parameters window (Figure 10.3).
6. Next, select File / Export and export the file in Comma Delimited Format (CDF/WMF) as a *.txt file (Figure 10.4).

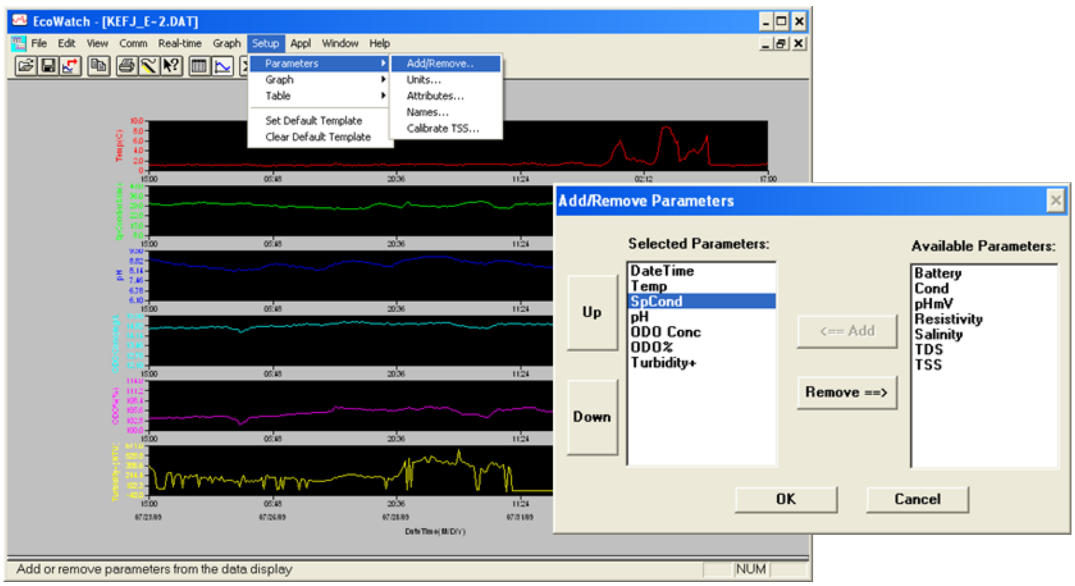

Figure 10.3. Screen shot of the procedure for selecting parameters to export from EcoWatch.

<u>Exporting Data with Streamline</u>

1. Open Streamline and select File / Export.
2. Click Browse and navigate to the appropriate source data folder on the T Drive: T:\SWAN\Vital_Signs\Water_Fish\Data\Water_Quality\. Select the raw data file of interest. A message in blue will indicate the number of YSI DAT files available within the folder for export. Click Next to continue.

3. Click Browse and navigate to the appropriate destination folder on the T Drive: T:\SWAN\Vital_Signs\Water_Fish\Data\Water_Quality\. This is the location to which processed DAT files will be exported. Click Next to continue.

4. Select the Comma-delimited (*.CSV) radio button as the format for exported files and click Next.

5. Click Process. A list of processed files will be created along with a Success message. A message in blue will indicate the number of files processed. Click Close.

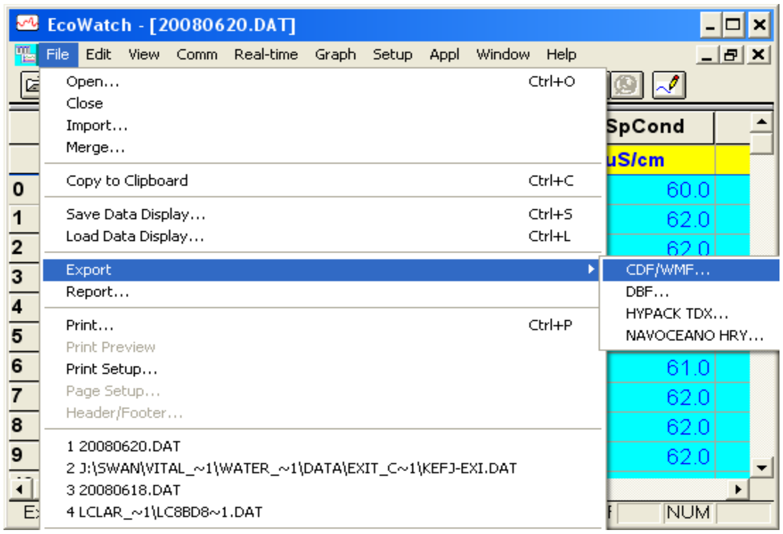

Figure 10.4. Screen shot of the procedure for exporting comma delimited *.txt files from EcoWatch.

Stream Discharge Data

Discharge data are required to develop a relationship between water level (stage) and volumetric flow. SWAN measures discharge primarily with a Sontek M9 River Surveyor acoustic Doppler current profiler (ADCP), as described in SOP6. Certain situations may call for measuring discharge with a flowmeter and top-setting wading rod (SOP5), in which case downloading and exporting are unnecessary because the data are recorded in a non-proprietary format.

Downloading Data from the ADCP

Data collected during channel transects with the M9 are stored both internally in the ADP unit and externally on a portable computer used for communication with the M9 during sampling events. As such, the raw discharge data files (*.rivr) are already downloaded to from the ADCP to the field computer; no additional steps are required.

Exporting Data Downloaded from the ADCP

The steps below outline the process for exporting raw discharge data files (*.rivr) to summary files (*.dis) using Sontek River Surveyor Live software.

1. Open River Surveyor Live software. Click Open File and navigate to the desired source file located within T:\SWAN\Vital_Signs\Water_Fish\Data\Surface_Hydrology\. Each channel

transect is stored as a stand-alone *.rivr file. Highlight all transects desired for export and click Open.

2. Click the Show/Hide Discharge Summary icon (fourth from left at the top). This summary displays parameters of each discharge transect as well as summary statistics based on open files.
3. Ensure all transect files have a box checked at the left hand side of each row. Click Export Discharge Summary To ASCII. The export folder location will default to the source folder of the *.rivr files. Name the file following conventions in Table 10.2 and click Save.
4. The resulting Sontek discharge summary files with the format *.dis can be uploaded directly to AQUARIUS or opened in Excel and saved as *.csv files.

Water Level Data

The objectives for monitoring surface hydrology are to identify trends in the timing and magnitude of peak lake discharge and to estimate the effects of glacial basins on lake systems. As described in SOP7, emphasis currently is placed on monitoring the outflows of Tier 1 lake systems: Naknek Lake and Lake Brooks (KATM), and Lake Clark and Kijik Lake (LACL). In the future, additional water level measurements could be collected on Tier 2 lake systems as time and resources permit.

SWAN monitors water levels with non-vented pressure transducers, thus water level readings must be corrected for barometric pressure. This section addresses downloading and exporting data from In-Situ and Solinst water level and barometric pressure loggers, and compensating (or correcting) water level data for barometric pressure. In-Situ and Solinst procedures are presented separately sections. **Note:** in the In-Situ-related sections, downloading and exporting procedures are combined.

In-Situ Level Loggers

Downloading Data to a Computer and Exporting Files

1. Connect the level logger to the TrollCom rugged cable and connect the cable to the computer via a USB port.
2. Open Win-Situ and click Yes to connect to the device. If an error message arises, check the com port setting in the control panel under System \ Device Manager. Change the com port setting in Win-Situ to match the com port on the system. Click the connect plug in the lower right screen. If you don’t have administrative rights, contract an administrator to set the com port.
3. Once the logger is connected, the program will verify that the time on the device matches the time on the computer. If they do not match, a window will appear, providing an opportunity to reset the device time to match the computer time. Select Yes to reset the time on the logger. The screen then defaults to the Home tab, which displays real-time readings of temperature, pressure, and depth (Figure 10.5).
4. Select the “Logger” icon to display the files stored on the logger and their status. Select the file that is logging and click the stop button (Figure 10.6).

5. A dialogue box will appear stating that the log cannot be restarted and requesting confirmation to continue. Click Yes. The status will change from “running” to “stopped.”

Figure 10.5. Screen shot of real-time temperature, pressure, and depth readings in Win-Situ.

6. With the file still highlighted, click the download button to begin the download process (Figure 10.6). In the subsequent Download Options window, select the Download All Data radio button and click the check mark button to proceed. The file will automatically download to the site directory established in Win-Situ, with a default file name that includes the programmed site ID and the current date (YYYY-MM-DD) and time (HH-MM-SS) (e.g., naknl_lvl_2009-08-23 11-32-16.wsl; see SOP7).

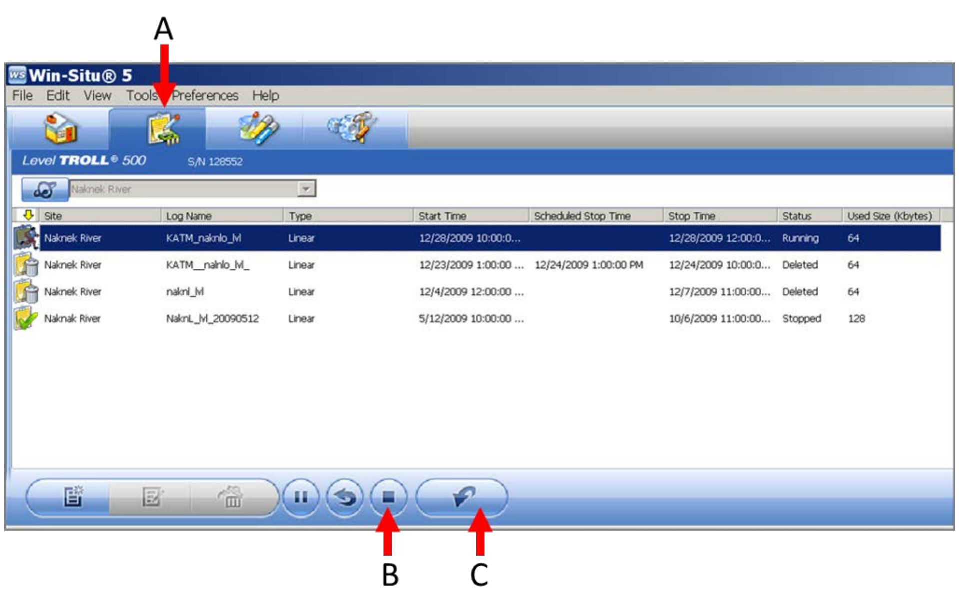

Figure 10.6. Screen shot showing Win-Situ’s “Logger” icon (A), and the stop and download buttons (B and C, respectively).

7. Click Yes to view the data. Detailed metadata are included at the top of the file. Scroll down to view the water level data. Check to ensure that the recorded data values appear reasonable for site.
8. To export the file, select File / Export to CSV. The file will automatically be exported to the corresponding site in the Exported Data folder. The file name will be retained (as exemplified above); however, the file extension of *.wsl will be replaced by *.csv.
9. Disconnect the logger and repeat the file download and export process for the barologger. Close out the program.

Downloading Data to a Rugged Reader

Level loggers and barologgers typically will be collected from the field, taken indoors, and downloaded to a computer, as described above. However, In-Situ loggers may also be downloaded in the field using the Rugged Reader. The Rugged Reader is a personal digital assistant (PDA) equipped with Windows Mobile and Win-Situ Mobile software. It can be used to access and download LevelTroll and BaroTroll loggers in remote locations. Downloaded files are then transferred to a computer using MS ActiveSync and Win-Situ Sync software. These programs should be installed on the computer prior to transferring data files.

Users should review the Rugged Reader manual to become familiar with the basic operation and power needs of the unit before using it in the field. If the unit has not been used during the winter, check the battery power and visit the In-Situ website for software updates.

1. Connect the LevelTroll to the rugged TrollCom, and connect the serial cable to the Rugged Reader (Figure 10.7).
2. Select Start \ Programs \ Win-Situ Mobile on the Rugged Reader. You may need to scroll down through the program icons to see the Win-Situ Mobile icon.
3. Select the Connect button. The display will show a real time reading from the LevelTroll.
4. Use the up arrow to select the Logging icon (Figure 10.7). This will bring up the list of files on the logger. Highlight the active file and select Download. Select the All radio button, and then click the check mark button to initiate downloading. When the download is completed, the file can be viewed. **Note:** the file can be downloaded without stopping the log program. Unless there is a reason to stop and restart the program, complete the download process with the logger in run mode.
5. Select the check mark button to close out the Download feature.
6. Select File \ Disconnect. Remove the LevelTroll and connect the BaroTroll. Select File \ Connect and repeat Steps 3–5.
7. Select File \ Exit.

Figure 10.7. The Rugged Reader connected to the LevelTroll via the TrollCom and serial cable (A). Downloading is initiated by selecting the Logging icon (inset), and then highlighting the active file and clicking the Download button (B).

Transferring Data from a Rugged Reader to a Computer and Exporting Files

1. Upon returning to the office, connect the Rugged Reader to the computer. Turn on the Rugged Reader. Active Sync and Win-Situ Sync will open automatically, and file transfer from the Rugged Reader to the computer will begin (Figure 10.8). The *.wsl files will be stored in Win-Situ's Site Data folder.

Figure 10.8. Screen shot of steps in the file transfer process using Win-Situ Sync.

2. A window will pop up asking which files should be copied from the computer to the Rugged Reader. Click the X button to proceed. No files need to be copied.
3. The final step in the file transfer process exports the *.csv file from the Rugged Reader. Browse to the appropriate folder to store the *.csv file. The default folder is \My Documents\WinSitu Data\Exported Data\Site ID name. Click the check mark button to finish the process.
4. Close Win-Situ Sync and ActiveSync and open Win-Situ on the computer. Open the Site Data and Exported Data folders on the left side of the screen, and select the site name for the data transferred from the Rugged Reader (Figure 10.9). Ensure that the *.wsl and *.csv files now reside in these folders.
5. Close Win-Situ and follow the steps outlined below to compensate the level data.

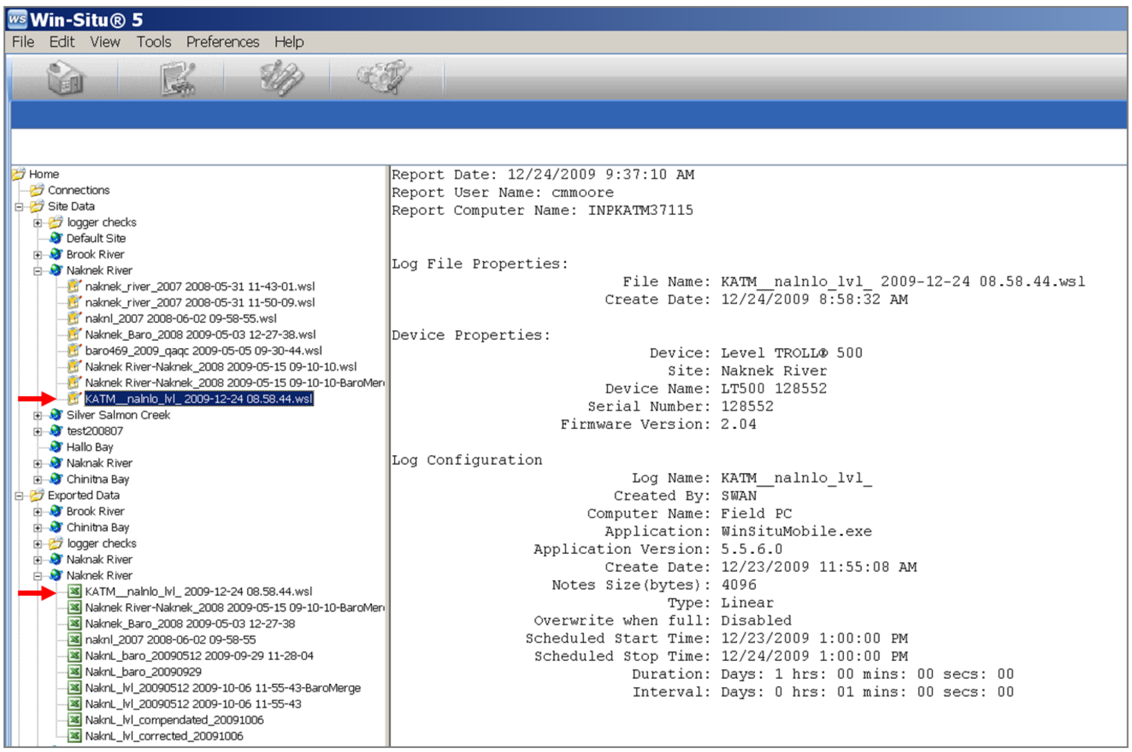

Figure 10.9. Screen shot of the folder structure in Win-Situ. Red arrows indicate paired *.wsl and *.csv files in the Site Data and Exported Data folders, respectively.

<u>Compensating Data</u>

Level data need to be compensated to correct for the effects of barometric pressure prior to analysis. Win-Situ BaroMerge, a stand-alone program used to compensate *.wsl level data files, offers three basic compensation methods: 1) entering a fixed correction; 2) entering manual values; or 3) using a BaroTroll file. In most instances, a BaroTroll file will be used to compensate the level data. There may be instances in which a fixed correction can be applied to a short dataset; however, this SOP only covers the steps required to compensate a file using BaroTroll data.

1. Click the Use BaroTroll File radio button and browse to the location of the BaroTroll file you want to select. Click the forward arrow button. The next window shows the tabular data for

the BaroTroll file (Figure 10.10). Although records can be deleted, it is not necessary to change the file as BaroMerge will match the date and closest time to the date and time in the level file.

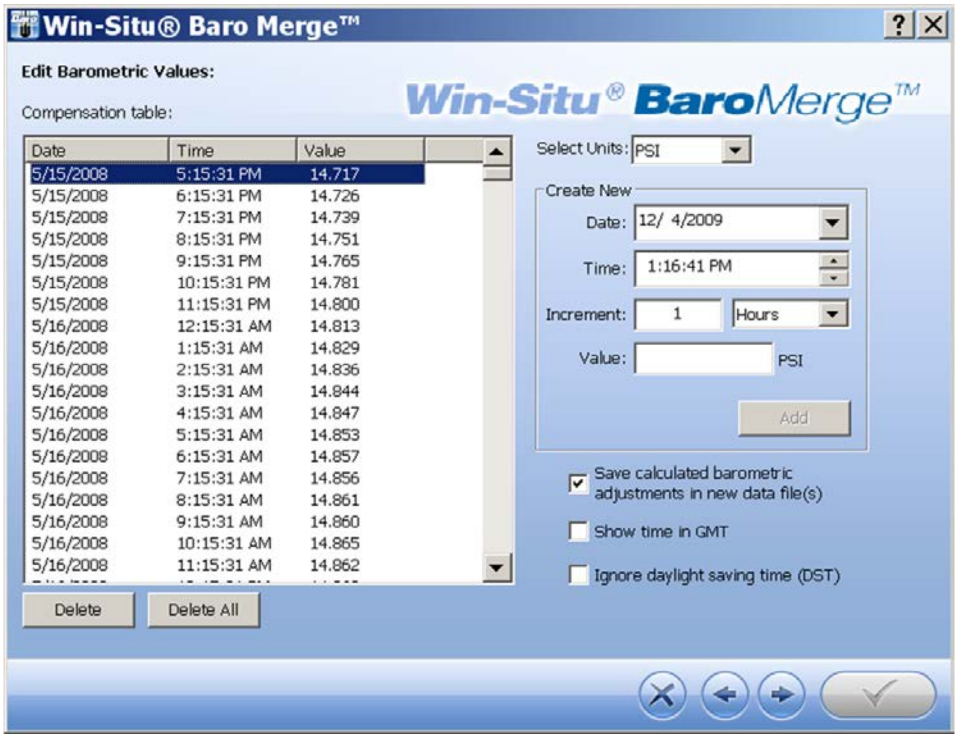

Figure 10.10. Screen shot of barometric pressure options in Win-Situ BaroMerge.

2. Verify that the selected units match the data in the table. Air pressure should be recorded in pounds per square inch (PSI). If it was recorded in another unit, adjust the Select Units dropdown menu to make sure the correct compensation is applied (Figure 10.10).
3. Set the Increment to 1 hour (Figure 10.10). The date and time default to the current date and time, which will be recorded in the new file.
4. Check the box to save the calculated barometric adjustments in a new file (Figure 10.10). Click the forward arrow.
5. Select the corresponding water level file from the Site Data folder (Figure 10.11). Click the check mark button to begin the data compensation. Click the check mark button to finalize the process. Close the program. **Note:** there is no opportunity at this point to name or save the resulting file.
6. Open Win-Situ. Click No when prompted to connect to a device. Navigate to the station site and open the folder. The baro compensated file will maintain the naming convention for that file and will add “BaroMerge” to the *.wsl file name (e.g., naknl_lvl_2009-08-23 11-32-16-BaroMerge.wsl).

Figure 10.11. Screen shot of the water level data folder structure, viewed from Win-Situ BaroMerge.

7. Review the compensated file. Notice that there are now five columns of data, in addition to those pertaining to date, time, and elapsed seconds (Figure 10.12). The two rightmost columns (with Baro-Adj in the headings) show the uncorrected baro logger data values. The remaining columns show the corrected level data (pressure and depth), as well as the uncorrected water temperatures.

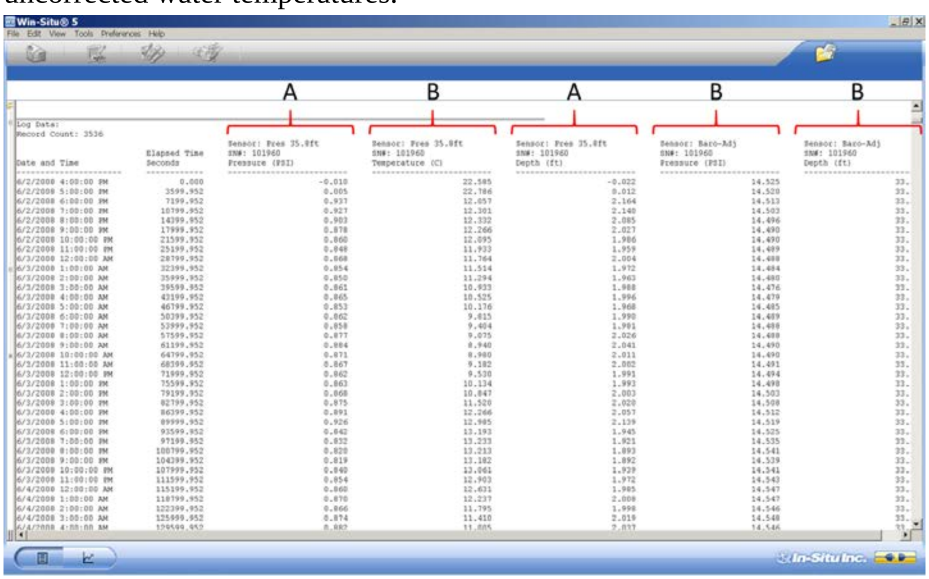

Figure 10.12. Screen shot of a compensated Win-Situ file with corrected (A) and uncorrected (B) data.

8. Export the compensated file by selecting File / Export to CSV. The exported file will include "BaroMerge" in the default name assigned (e.g., naknl_lvl_2009-08-23 11-32-16-BaroMerge.csv).

9. Close Win-Situ.

10. Copy the *.csv files into the working folders on the T Drive (T:\Vital_Signs\Water_Fish\Data\Surface_Hydrology\Level_and_Baro_Logger_Data) as outlined above and rename the files following the naming convention specified in Table 10.2.

Solinst Level Loggers

Downloading Data to a Computer

1. Insert the Barologger into the Optical Reader and connect the cable to the computer via an open USB port. Open Solinst Levelogger software and check the com port setting (Figure 10.13). Select the correct com port to establish communication. **Note:** be sure to connect the Optical Reader to the computer prior to opening the software so that the program can load the com port settings.

2. To end the logging session, click the Stop Sign icon (Figure 10.13) and then select Yes. The stop sign will change to a green arrow.

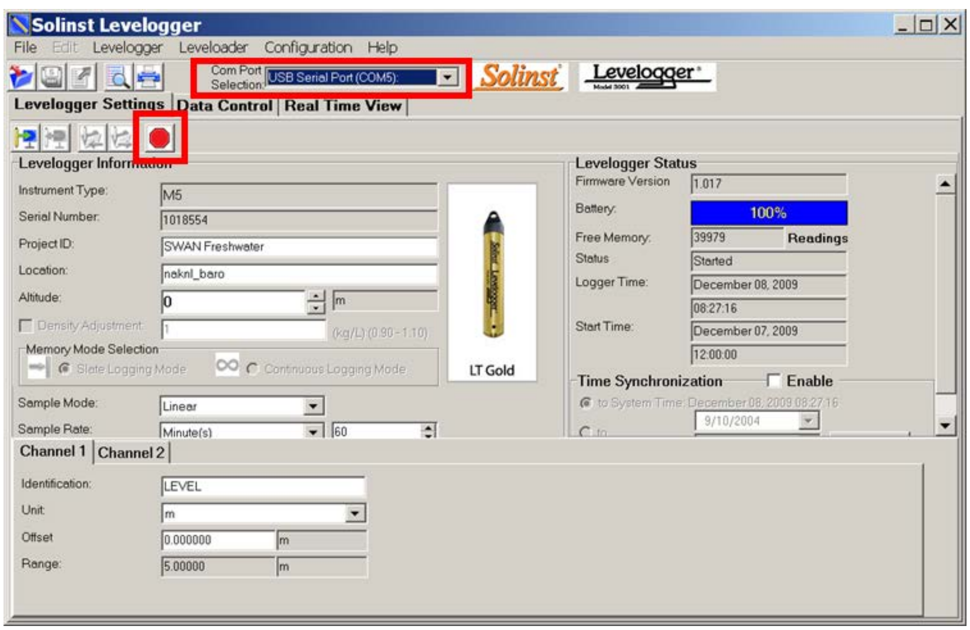

Figure 10.13. Screen shot highlighting the com port selection menu and "stop logging" icon in Solinst Levelogger.

3. Select the Data Control tab and click the red down arrow. Select All Data to begin downloading. When downloading is complete, the data will display in tabular and graphical format (Figure 10.14).

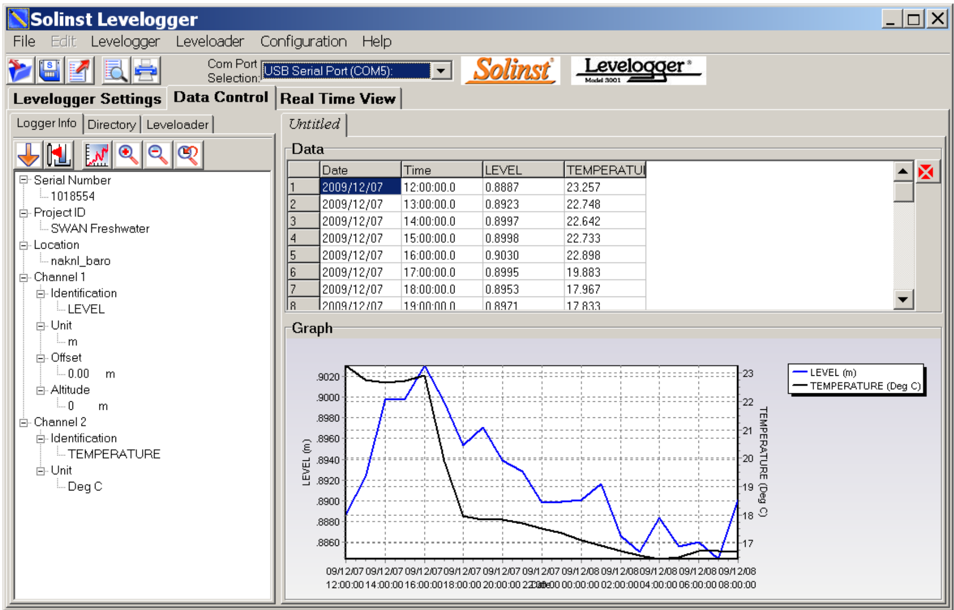

Figure 10.14. Screen shot of downloaded data displayed in Solinst Levelogger.

4. Save the data by clicking the Save icon and navigating to the appropriate folder ─ either in a temporary folder on the field laptop, or on the T Drive at T:\Vital_Signs\Water_Fish\Data\Surface_Hydrology\Level_and_Baro_Logger_Data. Change the default file name (if necessary) to match the naming conventions in Table 10.2 (e.g., KATM_naknlo_baro_20091208raw.lev)

5. Remove the Barologger and download the Levelogger following the Steps 1–4.

<u>Compensating Data</u>

1. Select the Data Control tab in the Solinst Levelogger software (Figure 10.15) and use the file menu to open the level file to be compensated (i.e., File \ Open).

2. Click the Level Compensation icon (Figure 10.15) and then select the radio button corresponding to the file type that is open ─ Levelogger or Barologger. Click Next.

3. The Level Compensation module has four options for correcting level data: 1) barometric compensation, 2) manual data adjustment, 3) density adjustment, and 4) barometric efficiency adjustment. Check the box beside the Barometric Compensation option and click Next.

4. A window will appear allowing the user to browse to the barometric file for the data compensation. If both files are already open, this step will be skipped.

5. The compensated file will be generated automatically and the Save As window will appear. The default file name will match that of the level logger file, with “Compensated” added to the end (e.g., KATM_naknlo_lvl_20091208_compensated.lev).

6. Leave the files open to export them.

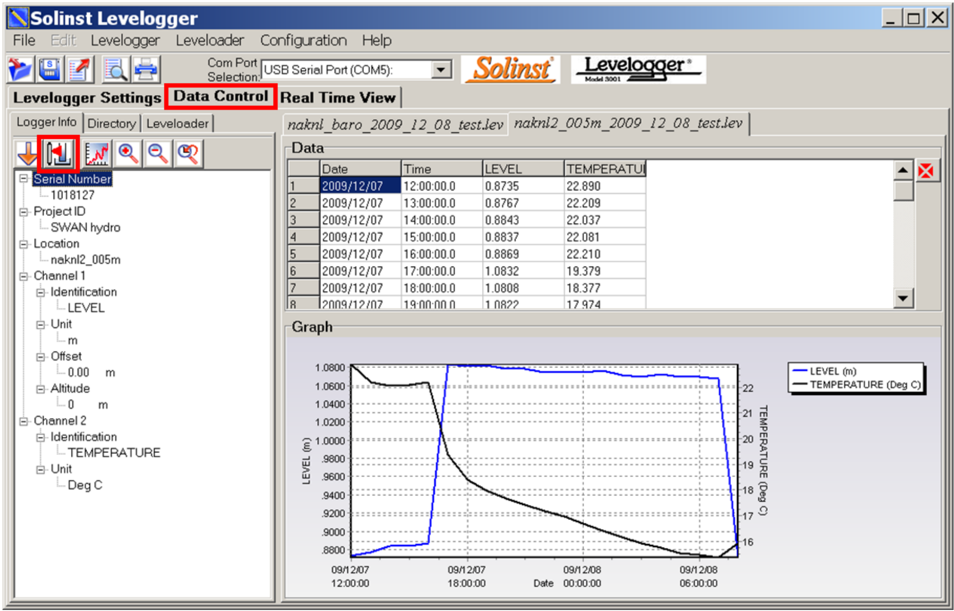

Figure 10.15. Screen shot highlighting the Data Control tab and Level Compensation icon in Solinst Levelogger.

<u>Exporting Data</u>

1. If Solinst Levelogger has been closed, first open the software. Then, open a file for export (via File \ Open).
2. Select a file from the tabs shown above the tabular data. The selected file will have a dashed box around it to indicate that it is the active file. Select File \ Export \ Data.
3. A Save Graph As window will appear. Navigate to the directory where the exported *.csv file will be stored. The default path is My Documents \ Solinst \ Export\. If the files are being managed from a field laptop, navigate to the temporary field folder. Follow the procedures outlined above if files are to be stored on the T Drive.
4. Repeat Steps 1–3 to export the remaining types of data (level logger, barologger, level_compensated) as all three types should be exported to csv format. Close the program.
5. Open Windows Explorer and navigate to the folder where the files are stored. If necessary, rename *.lev and *.csv files following the naming conventions presented in Table 10.2.

Water Temperature Data

The objective of monitoring water temperature in lakes is to document thermocline development and duration, understand lake stratification patterns, and examine inter-annual trends in lake warming or cooling. Water temperature loggers are arranged in a vertical array at fixed depth intervals and programmed to record temperature every hour year-round.

The temperature arrays have employed two models of Onset water temperature loggers since their inception: HOBO Water Temp Pro v2 loggers, which have been most frequently deployed, and TidbiT v2 loggers, which have been deployed at depths exceeding 120 m (Table 10.3). Each of these models uses HOBOware Pro software and an optical reader to communicate with the computer. Two types of optical readers are available: 1) the Optic USB Base Station, which requires a computer connection for power, and 2) the Waterproof Shuttle, which downloads data and resets the logging schedule remotely. The Waterproof Shuttle can also be connected to the computer. If connected, it will function like the Optic USB Base Station.

Table 10.3. Specifications for Onset temperature loggers used for the SWAN temperature arrays.

Logger Type	Model	Operational Range	Accuracy [a]	Waterproof Depth	Coupler
HOBO Water Temp Pro v2	U22-001	-20 – 70 °C	± 0.2 °C	120 m	2-C
TidbiT v2	UTBI-001	-20 – 70 °C	± 0.2 °C	300 m	2-D

[a] Manufacturer specifications for temperatures ranging from 0 to 50 °C. Specifications will not be checked independently by SWAN in the field.

Methods for monitoring water temperature are provided in SOP8. Data collected via these methods are time series of dates, times, and water temperatures (°C). Instructions below provide a step-by-step process for downloading time series from temperature loggers and exporting the files to create archives.

Downloading Data from Temperature Loggers

Temperature loggers generally will be downloaded in the field and then redeployed on the temperature array. If loggers are to be downloaded in the field and redeployed, create two nested folders in My Documents on the field laptop to store the raw data files. Name the parent folder with the five-letter waterbody code plus the 2-digit site ID number, and name the child folder with the download date (e.g., \lclar01\20100612). If loggers are to be downloaded in the office, save the data files to the following directory: T:\Vital_Signs\Water_Fish\Data\Water_Quality\Temperature\SWAN_Temp_Arrays\.

Be sure to have extra temperature loggers packed with the field gear in case a logger is missing or communication cannot be established. Include the correct couplers for the Water Temp Pro v2 (Coupler2-C with blue label) and TidbiT v2 (Coupler2-D with orange label). For a complete checklist of equipment needed to download temperature loggers following array retrieval, see Table 10.4.

Table 10.4. Equipment checklist for downloading temperature loggers.

Equipment Needed	
☐	Extra Water Temp Pro v2 and/or TidbiT v2 loggers
☐	Onset HOBO Optic Base Station or Waterproof Shuttle with two extra AA batteries
☐	Coupler2-C for Water Temp Pro v2 (blue label); Coupler2-D for Tidbit v2 (orange label)
☐	Panasonic Toughbook laptop computer
☐	Bucket for cleaning

The steps below present the two methods for downloading data from the temperature loggers: one for each type of optical reader (i.e., the Optic USB Base Station and the Waterproof Shuttle).

Downloading Data with the Optic USB Base Station

1. Connect the Optic USB Base Station to the computer via an open USB port and open HOBOware Pro.
2. If the logger is housed in a protective boot or cap, remove it and clean any biofouling from the face of the logger. Place it into the coupler, aligning the arrows on the logger and the coupler. Press the lever and look for the green light to signal a connection. If establishing a connection is problematic, skip to Step 8.
3. Select Device / Readout. The logger will be identified by its serial number in a Select Device window (Figure 10.16). Click OK to select the logger. Click No when prompted to stop logging. This will allow the logging to continue on the previously programmed schedule.

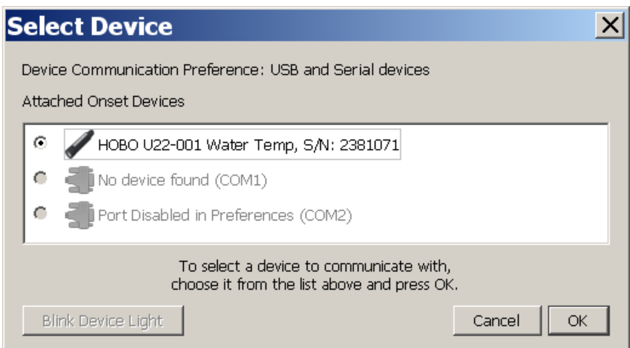

Figure 10.16. Screen shot of the Select Device window in HOBOware Pro.

4. If downloading in the field, save the files to the directory created on the field laptop as noted above (e.g., \lclar01\20100612). The file name will default to the description entered when the logger was programmed (see Figure 8.8 in SOP8). Add the download date (YYYMMDD) and the data type (raw) to the end of the file name (e.g., LACL_lclar01_005m_ temp_20091204raw; Table 10.2). Make sure that a depth value is included in the plot title and that it corresponds to the correct depth on the temperature array.
5. The Plot Setup window will pop up next (Figure 10.17). Plot the temperature in Celsius and include the battery voltage, if recorded, as this can highlight potential errors in the data. Uncheck the boxes related to Internal Logger Events. Click Plot in the lower right corner.
6. The data will be plotted and the tabular data will appear in the upper left part of the screen (Figure 10.18). Close the plot by clicking the X in the tab with the file name.
7. Continue downloading temperature loggers from the array by repeating Steps 2–6.

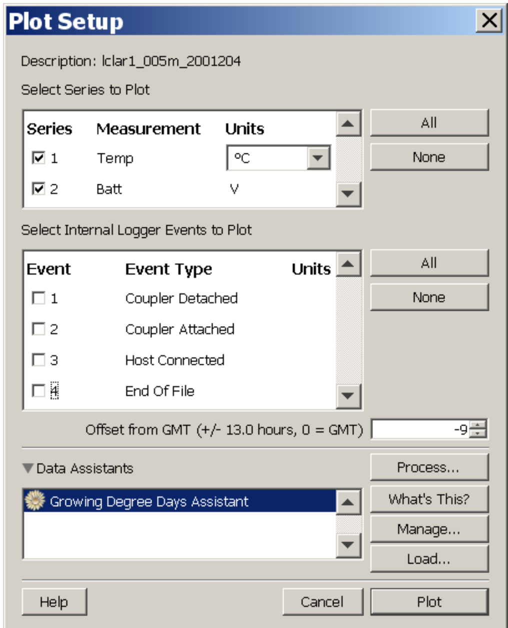

Figure 10.17. Screen shot of the Plot Setup window in HOBOware Pro.

8. If communication cannot be established with a logger, replace the faulty logger with a new one. Launch the new logger following the steps listed in SOP8. Note the serial numbers of both loggers and the depth in a field notebook. Try to establish communication with the faulty logger when back in the office. If communication still cannot be established, return the logger to Onset for data retrieval.

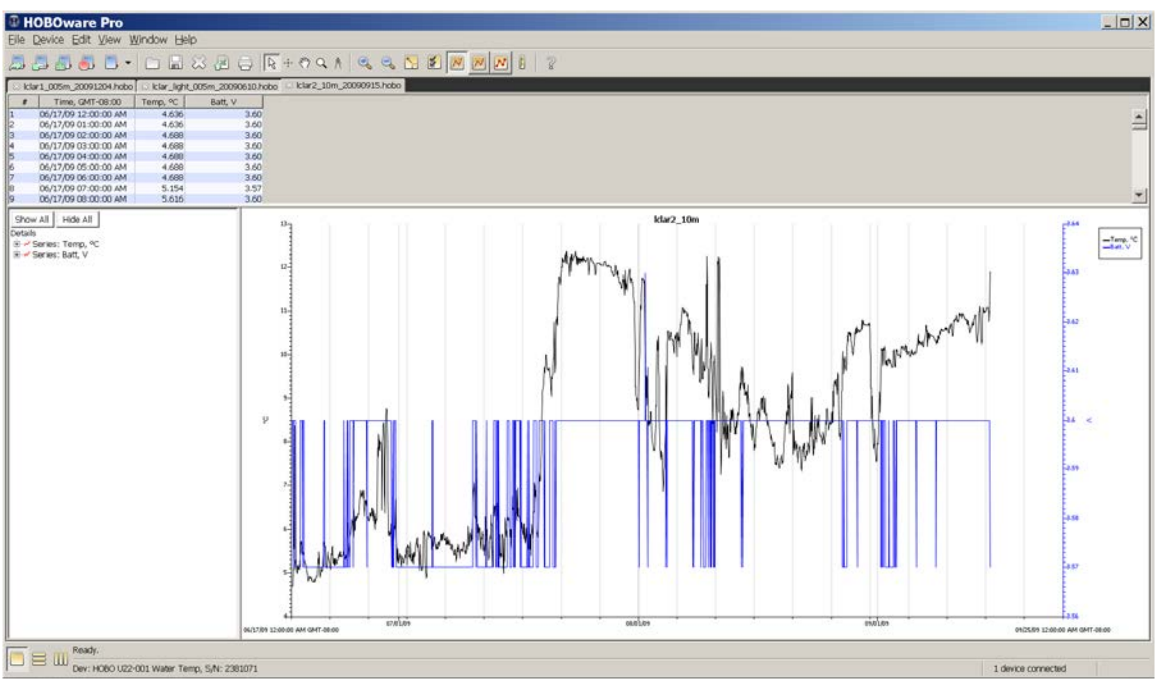

Figure 10.18. Screen shot of temperature data in graphical and tabular forms in HOBOware Pro.

Downloading Data with the Waterproof Shuttle

When using the Waterproof Shuttle to download files, temperature loggers will continue to log hourly data. Logging cannot be stopped unless the shuttle is connected to a computer and communicating through HOBOware Pro. If loggers are operating properly, there is no need to stop and restart their logging programs.

1. The Waterproof Shuttle will not establish communication with a logger if the shuttle's battery power is low. Therefore, check the battery life of the shuttle before going into the field if you plan to download temperature loggers remotely. First, open HOBOware Pro. Connect the shuttle to the computer using the portable cable. Select Device \ Manage Shuttle. The battery level is reported in this window (Figure 10.19).

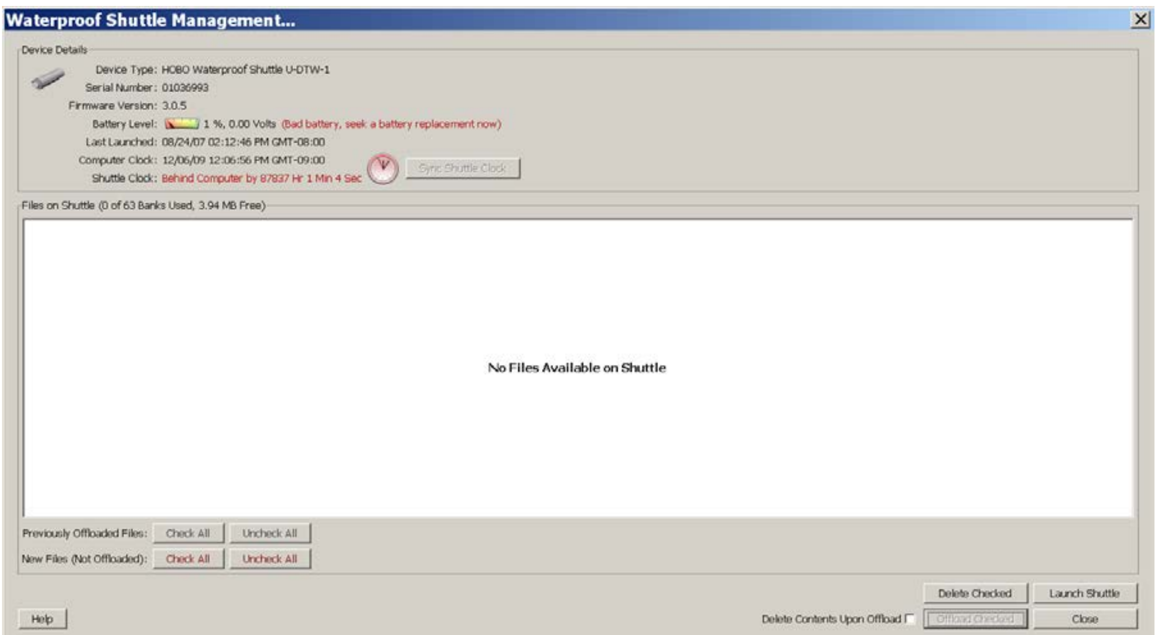

Figure 10.19. Screen shot showing a low battery reading in the Waterproof Shuttle Management window of HOBOware Pro.

2. If the batteries need changing, a warning message will appear. Change the batteries following directions printed on the shuttle. Two AA batteries are required.
3. After the batteries are changed, the shuttle will need to be launched to set the proper date and time. This step is important following a battery change because the shuttle settings will be transferred to any loggers subsequently downloaded, resetting their internal date and time stamps. Reconnect the shuttle to the computer and select Device \ Manage Shuttle. The battery level should now be reported as good. Click Launch Shuttle.
4. Once in the field, place the logger into the coupler, align the arrows, and press the lever. A yellow light will blink during the data transfer process. When the download is complete, the green OK light will be displayed until the lever is pressed to turn it off. Remove the logger and reattach it to the temperature array.

5. Continue downloading loggers until all are downloaded. If there is a problem with a logger, the red Fail light will be displayed. Twist the logger slightly and try again. If the red light persists, check the logger using the Optic USB Base Station to see if communication can be established. If communication cannot be established, replace the logger with a new one. Program the new logger following steps outlined above. Make a note of the old and new logger serial numbers and the depth in a field notebook.

6. Upon returning to base camp or the office, attach the shuttle to the computer with the remote cable. Open HOBOware Pro and select Device \ Manage Shuttle. When the shuttle is connected, files that were downloaded in the field will be displayed in the window. The status will read “not offloaded” and the boxes will be checked (Figure 10.20).

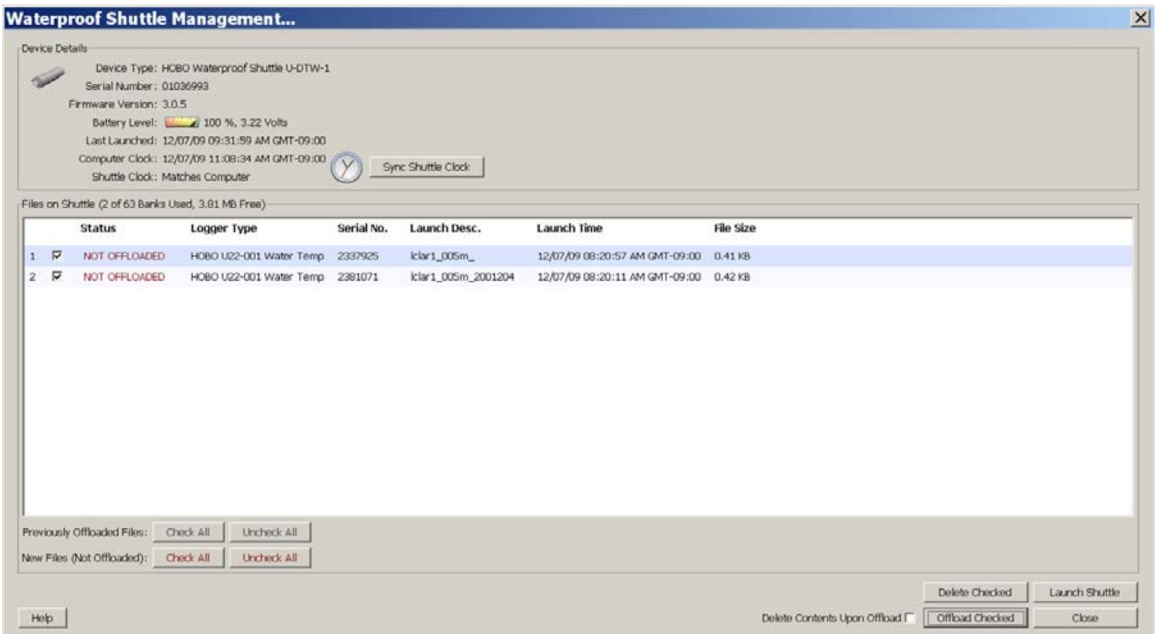

Figure 10.20. Screen shot of HOBOware Pro’s Waterproof Shuttle Management window, depicting files downloaded to the shuttle.

7. Click Offload Checked in the lower right. Do not check the Delete Contents Upon Offload box in case of problems. The files can be deleted later, after the data have been viewed.

8. The offloaded files will appear in a new window, with an option to save them in the lower right corner (Figure 10.21). The directory will default to the last folder in which data were saved, and a new child folder will be created based on the download date and time (e.g., \ShuttleReadout12_07_09_08_43_11_AM_AKST). The folder name indicates that the files were loaded from a shuttle with the current date and time relative to the time zone and standard or day light saving time. Note that the file names cannot be edited at this point; they can be edited in Windows Explorer after the download process is complete.

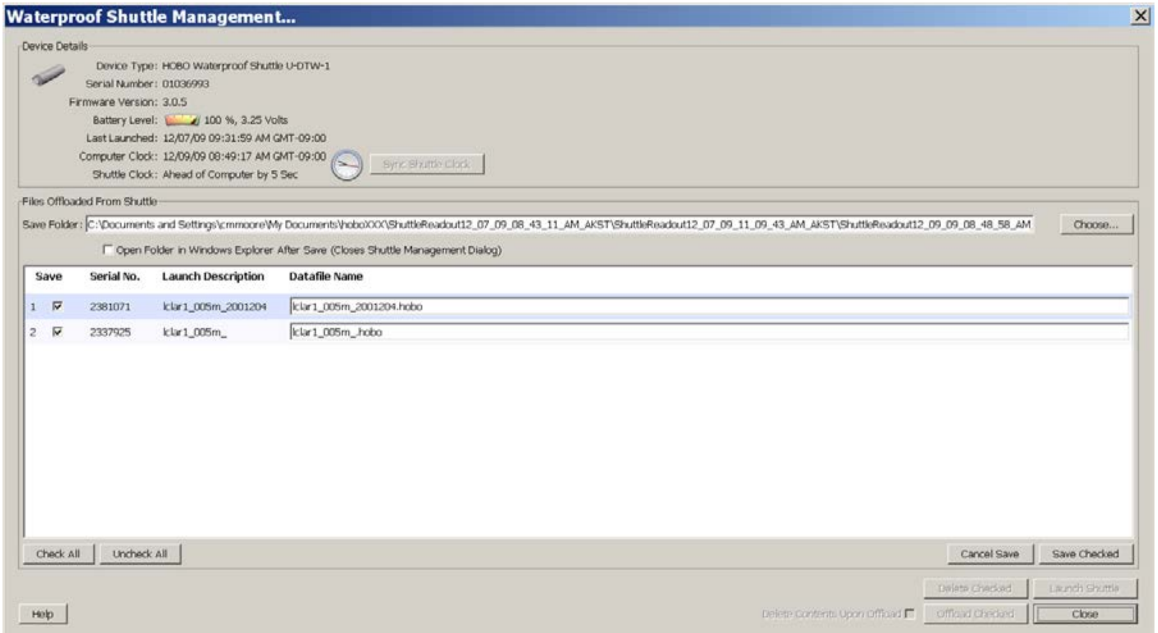

Figure 10.21. Screen shot of HOBOware Pro's Waterproof Shuttle Management window, depicting files offloaded to a default directory.

9. If operating in the field, browse to the temporary temperature array folder on the laptop and save the files there until they can be moved to the T Drive. If the default path is changed in the above step, the selected folder will not have the default shuttle folder name shown above. Click Save Checked in the lower right.
10. Close the shuttle window and use HOBOware Pro to check the downloaded files for valid data. Select File \ Open Data File and navigate to the folder where the files were saved. Once the files have been reviewed, close them and return to the shuttle manager.
11. If data are missing from the files or are otherwise irregular, re-download the files from the shuttle. Select Device \ Shuttle Manager. When the Waterproof Shuttle Management window opens, the status will appear as "offloaded." Check the box(es) of the file(s) to be re-downloaded, and click Offload Checked in the lower right. A new default shuttle folder with the date and current time will be created. If the data still appear irregular, make a note in the field notebook to replace that logger and send it to Onset for data retrieval.
12. To delete the files on the shuttle, select Device \ Shuttle Manager. Check the boxes by each offloaded file and then select Delete Checked in the lower right. Select Yes to delete the files from the shuttle. Once the files have been deleted, the list of files on the shuttle (displayed in the Waterproof Shuttle Management window) will be cleared.
13. Open Windows Explorer and navigate to the folder in which the files were saved. Rename the files following the naming conventions in Table 10.2.

Exporting Data Downloaded from Temperature Loggers

The purpose of this section is to outline the steps needed to convert proprietary software files containing raw data into a universal format for long-term data archiving. These steps will ensure that datasets are available for future use, even as software expiration or upgrades prevent opening old files. All proprietary software files containing raw data should be exported and saved in *.csv format. If *.csv format is not an export option for particular software, export the raw data in *.txt format and then convert the *.txt file to *.csv format in Microsoft Excel.

1. If the software has been newly installed or recently upgraded, open HOBOware Pro and verify that your export settings match those shown in the HOBOware Preferences window in Figure 10.22. To reach this window, select File / Preferences from the drop-down menu, and then General from the left side panel. Expand the Export Settings and set the following:
    - Column separator – Comma
    - Column separator – check the box for "separate date and time into two columns"
    - Column header – check the box for "include logger serial number"
    - Date format – M D Y
    - Date separator – Slash
    - Time format – 24 hour
2. Leave the remaining defaults as set. Click OK at the bottom right. Close the Export Settings and the HOBOware Preferences window.

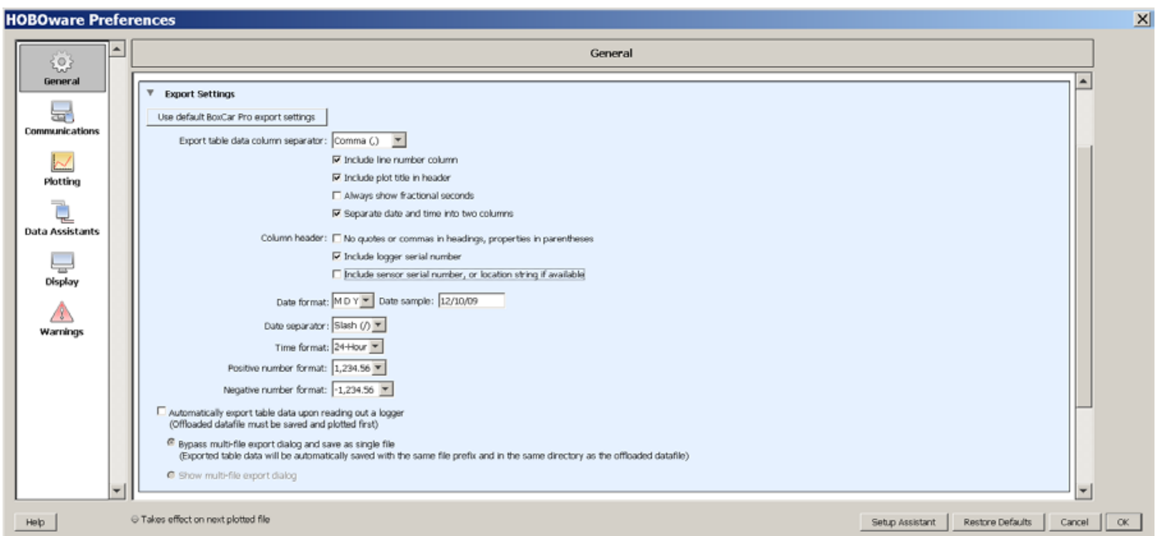

Figure 10.22. Screen shot of the HOBOware Preferences window in HOBOware Pro.

3. Open a raw data file and select File / Export Table Data. Make sure "Temp" and "Batt" are checked, and then click the Export button.

4. Using the naming conventions in Table 10.2, save the exported file as a *.csv file in the following directory: T:\Vital_Signs\Water_Fish\Data\Water_Quality\Temperature\ SWAN_Temp_Arrays\.

5. Continue to export files following the steps above until all HOBO files have been exported to *.csv files. Close the software.

Light Intensity Data

HOBO Pendant Temperature/Light data loggers (model UA-002-64) were co-located with HOBO Water Temp Pro v2 loggers at depths of 5 m, 10 m, and 15 m on moored temperature arrays until 2012. These loggers record light intensity in units of lux, with a measurement range of 0–320,000.

Light intensity measurements were intended to monitor water clarity in SWAN lake systems, and to assess, indirectly, the depth of the euphotic zone ─ the area in which sufficient light penetration occurs to support photosynthesis. However, fouling made the data difficult to interpret (e.g., the light intensity at 10 m exceeded that at 5 m). If the fouling issue could be resolved, turbidity pulses associated with glacial runoff and/or volcanic activity could be tracked spatially and temporally using these loggers in conjunction with in-situ Secchi depth measurements and satellite imagery. In addition, changes in the timing of snowpack runoff could be tracked by monitoring light intensity.

Downloading Data from Light Loggers

The light loggers will be downloaded as part of the moored temperature array download process. HOBO light loggers, like HOBO temperature loggers, use HOBOware Pro software and an optical reader to communicate with the computer. Two types of optical readers are available: the Optic USB Base Station and the Waterproof Shuttle. Both optical readers require a 2-A coupler to connect with a light logger. Much of the information from the “Downloading Data from Temperature Loggers” section above also applies when downloading light loggers.

Downloading Data with the Optic USB Base Station

1. Connect the Optic USB Base Station to the computer via an open USB port and start HOBOware Pro.
2. Connect the light logger to the optical reader with the 2-A coupler. Press the coupler lever to establish communication.
3. Select Device / Readout from the menu. The logger will be identified by its serial number in a Select Device window (Figure 10.16). Click OK to select the logger. Click No when prompted to stop logging.
4. A Save window will appear. Add the download date to the default file name (i.e., the description entered during programming) and save the *.hobo file (e.g., lclar01_005m_light_20100304.hobo) in the temporary project directory.
5. Reattach the light pendant to the temperature array line.
6. **Note:** the battery life on these light sensors is about one year. Therefore, batteries should be replaced after each download process. If a battery has died during logging, change it first and then download the data. Each time a battery is changed, the light logger will need to be re-launched, following instructions in SOP8.

Downloading Data with the Waterproof Shuttle

1. Place the light logger into the 2-A coupler and press the coupler lever. A yellow light will blink during data transfer. When transfer is complete, the light will turn green. Press the lever

again to break communication. Replace the logger’s batteries (Step 6 in the section above) and redeploy.

2. Follow the procedures for downloading temperature data from the “Downloading Data from Temperature Loggers” section above. Use the file naming conventions listed in Table 10.2.

Exporting Data Downloaded from Light Loggers

Export the *.hobo file to a comma separated format (*.csv) following the steps outlined in the “Exporting Data Downloaded from Temperature Loggers” section above. Use the file naming conventions listed in Table 10.2.

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Wagner, R. J., R. W. Boulger, Jr., C. J. Oblinger, and B. A. Smith. 2006. Guidelines and standard procedures for continuous water-quality monitors: station operation, record computation, and data reporting. Techniques and Methods 1-D3. U.S. Geological Survey, Reston, Virginia.

SOP11: Data Processing

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

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Introduction

This standard operating procedure (SOP) describes the protocol for using AQUARIUS Time-Series software (hereafter "AQUARIUS") to process and store exported data files, and to make them publicly available. AQUARIUS has two user interfaces ─ Whiteboard and Springboard ─ with differing functionalities. Detailed information on using each interface is posted at http://nrdata.nps.gov/Programs/Water/Aquarius/AquariusVideos.htm. The customer support website for the company that designs AQUARIUS (Aquatics Informatics; http://aquaticinformatics.com/support/support-login/) also provides many short "how to" videos. Access to this website requires a username and password, obtainable via email request to support@aquaticinformatics.com.

AQUARIUS documents all changes to a raw uploaded dataset, creates a corrected data file, and stores this information in a csv file that can be exported for metadata purposes. This feature standardizes the way in which changes to raw data are tracked. The resulting metadata provides important documentation required as part of the SWAN data management protocol (SOP12).

Because Springboard was unveiled later than Whiteboard, after this SOP was initially drafted, the SOP focuses on processing data in Whiteboard. In Whiteboard, data are processed by dragging a series of toolboxes onto the whiteboard workspace. Toolboxes are then joined or "wired" to each other in various ways to provide a simple yet powerful work environment. Wiring occurs through input ports located on the left side of the toolbox and output ports located on the right side of the toolbox. Toolboxes are categorized by topic (e.g., data input, correction, data output) in the Toolboxes pane on the left side of the screen. The user should be familiar with these toolboxes prior to processing SWAN data.

This SOP describes how to use AQUARIUS Whiteboard to process water quality and water quantity time series data. Although each type of data has specific processing steps, the general workflow is as follows:

1. Conduct any requisite data pre-processing in Excel
1. Import data into AQUARIUS
2. Correct data for erroneous readings, sensor fouling, and/or calibration drift
3. Grade data based on calculations in Excel
4. Flag data based on identified threshold values
5. Compute summary statistics
6. Export corrected and/or summarized data sets

These steps are described in detail below. While some (e.g., Steps 4 and 7) are detailed for only one data type, they are equally applicable to other types of data.

Continuous Water Quality Data from Sondes

This section explain the steps involved in processing continuous water quality data. SWAN currently uses YSI 6600 series multiparameter sondes for unattended deployments. Multiparameter sondes are calibrated (see SOP3) and deployed (see SOP4) at the outlets of Tier 1 lakes to monitor temporal variability in core water quality parameters. Proper use of multiparameter sondes during unattended deployments requires checking the sensors periodically for fouling and calibration drift (and re-calibrating if necessary). Procedures for checking for sensor fouling and calibration drift using an independent, freshly calibrated field meter are covered in SOP4.

The following section is based on the assumption that the SWAN Site_Visit_Measurements (SOP4; Figure 4.5) and Post_Deployment_Error_Checks (SOP4; Figure 4.6) worksheets have been filled out. Blank worksheets are contained in an Excel file called SWAN_Continuous_ Calibration_Drift_Corrections_MASTERCOPY, located on the T Drive at T:\Vital_Signs\Water_Fish\Electronic_Field_Forms\SWAN_Master_Copies\Continuous_ Calibration_and_Drift_Correction_Form. Users should be familiar with the data processing procedures listed in Wagner et al. 2006. They should also have an understanding of general water quality parameter cycles and local site conditions (e.g., via compiling discharge data and weather data from the nearest Remote Automated Weather Station (RAWS) site).

Data Pre-Processing in Excel

Using the "Fouling_and_Drift_Corrections" Worksheet

SWAN uses data correction and grading criteria established by the U.S. Geological Survey (Wagner et al. 2006). Data corrections and grades are calculated in the Fouling_and_Drift_Corrections worksheet of the file called SWAN_Continuous_Calibration_Drift_Corrections_MASTERCOPY (Figure 11.1). This Excel file is a modification of versions discussed by Wagner et al. (2006) and the Upper Columbia Basin Inventory and Monitoring Network (Starkey et al. 2009). The Fouling_and_Drift_Corrections worksheet was developed to assist in assessing and correcting data for sensor fouling and calibration drift.

Assessing Fouling Error and Calibration Drift

Fouling error occurs when algae, sediment, or other materials affect the reading of a sensor. Fouling error is assessed by collecting measurements with a deployed sonde (the "monitor") and an independent, freshly calibrated sonde (the "field meter"), as described in the "Sonde Maintenance, Inspection, and Downloading" section of SOP4. Those measurements are recorded in the Site_Visit_Measurements worksheet (SOP4; Figure 4.5) and are summarized in the Fouling_and_Drift_Corrections worksheet (blue box in Figure 11.1).

Calibration drift is the error in measurement of an electronic sensor departing from its calibrated condition over time. The degree of calibration drift is assessed by comparing measurements taken with cleaned sensors on the monitor following deployment to expected readings of calibration solutions. These measurements are recorded in the SWAN Post_Deployment_Error_Checks worksheet (SOP4; Figure 4.6) and are summarized in the Fouling_and_Drift_Corrections worksheet (red box in Figure 11.1).

Corrections will be applied to the continuous dataset only when sum of the absolute values for fouling and drift (green box in Figure 11.1) exceeds the criteria listed in Table 11.1. However, this does not mean that continuous datasets will be corrected automatically every time fouling and drift errors exceed calibration criteria. A degree of professional judgment is needed to determine whether corrections are warranted. Field notes must be consulted to assess the degree of visible fouling on the sensors during site visits. Additionally, sensor diagnostic information (e.g., DO charge for rapid pulse membrane sensors, wiper parking position for optical sensors, and voltage for pH sensors) will help determine whether fouling or a faulty sensor was the cause of the instrument error.

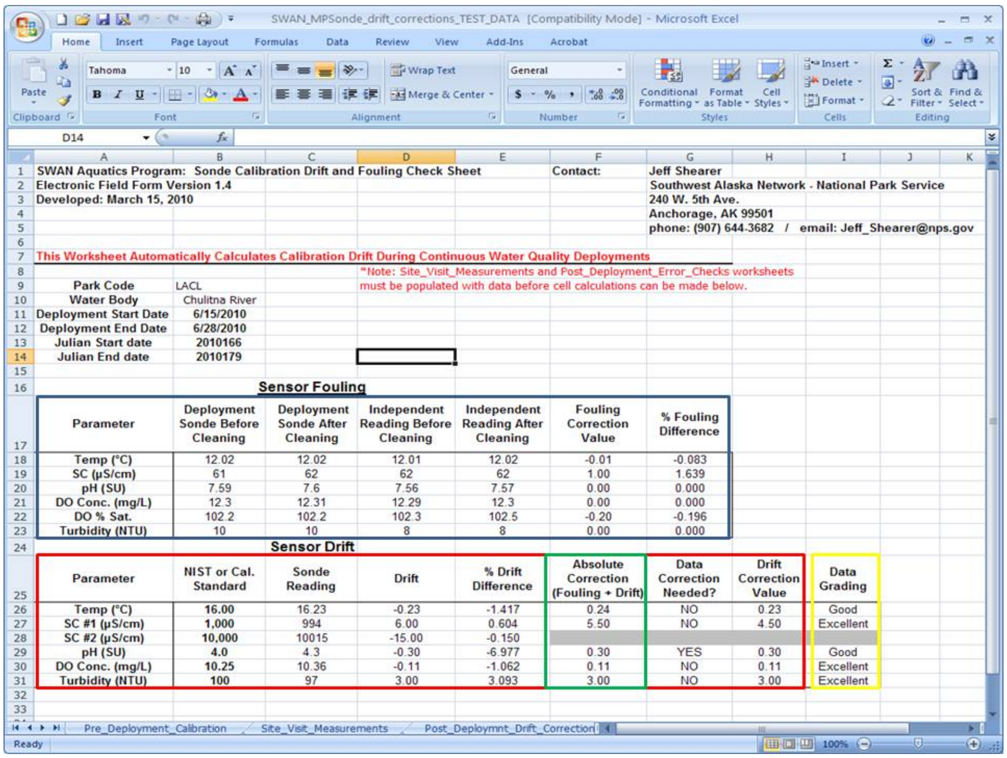

Figure 11.1. Fouling_and_Drift_Corrections worksheet used to aid in the correction of continuous water quality datasets collected using multiparameter sondes.

Table 11.1. Criteria for water quality data corrections, modified from Wagner et al. 2006.

Parameter	**Data Correction Criterion** [a]
Temperature	+ 0.2 °C – if checked with another meter (i.e., an independent sonde)
Temperature	+ 0.5 °C – if checked with a NIST thermometer
Specific conductivity	+ 5 µS/cm or + 3% of the measured value, whichever is greater
pH	+ 0.2 pH units
Dissolved oxygen	+ 0.3 mg/L
Turbidity	+ 0.5 turbidity units or + 5% of the measured value, whichever is greater

[a] Apply the correction when the sum of the absolute values for fouling and calibration drift error exceed the values listed.

Determining Data Grades

Data grades are applied to continuous water quality records (i.e., from unattended sonde deployments) based on the degree of sensor fouling and calibration drift before data corrections are applied. These grades provide the user with a qualitative rating of data accuracy, based on criteria developed by Wagner et al. (2006) (Table 11.2). Data grades are calculated in the Fouling_and_Drift_Corrections worksheet in Excel (yellow box in Figure 11.1). Grades are then assigned using AQUARIUS (discussed below). It is important to note that professional judgment be used when deciding upon the final data grade. Users must record accurate before and after sensor cleaning readings with an independent, freshly calibrated field meter and consult with field notes recorded during site inspections. For example, a change in a water quality parameter, such as turbidity, during sensor cleaning may indicate artificially high sensor fouling and thus a "Poor" data grade, when in fact site conditions changed and data recorded by the sensor were "Good" or "Excellent."

Table 11.2. Data grades for continuous water quality records, developed by Wagner et al. (2006).

	Data Grade [a]			
Parameter	**Excellent**	**Good**	**Fair**	**Poor**
Temperature	< ± 0.2 °C	> ± 0.2 – 0.5 °C	> ± 0.5 – 0.8 °C	> ± 0.8 °C
Specific conductivity	< ± 3%	> ± 3 – 10%	> ± 10 – 15%	> ± 15%
pH	< ± 0.2 units	> ± 0.2 - 0.5 units	> ± 0.5 – 0.8 units	> ± 0.8 units
Dissolved oxygen	< ± 0.3 mg/L or < ± 5%, whichever is greater	> ± 0.3 – 0.5 mg/L or > ± 5 – 10%, whichever is greater	> ± 0.5 – 0.8 mg/L or > ± 10 – 15%, whichever is greater	> ± 0.8 mg/L or > ± 15%, whichever is greater
Turbidity	< ± 0.5 NTU or < ± 5%, whichever is greater	> ± 0.5 – 1.0 NTU or > ± 5 – 10%, whichever is greater	> ± 1.0 – 1.5 NTU or > ± 10 – 15%, whichever is greater	> ± 1.5 NTU or > ± 15%, whichever is greater

[a] Data grades are based on the combined fouling and drift corrections applied to the record.

Data Processing in AQUARIUS

Importing Comma Delimited Files

1. Open AQUARIUS, select the Data Input tab on the left, and drag Import from File toolboxes into the central whiteboard pane. Add one Import from File toolbox for each deployment period that year. Double click the first toolbox to begin loading data.
2. In the Import from File toolbox that opens, navigate to the appropriate data folder by clicking the "…" button next to the Import File(s) line. Select the *.csv file for the deployment period of interest, and then click Open.
3. If no configuration file is available, click the Config Settings button. The Import from File Wizard Step 1 window should appear (Figure 11.2). Select the Time Series radio button and the default option (Text File (CSV, etc.)) on the drop-down menu. Click Next.

Figure 11.2. Step 1 of the Import from File Wizard in AQUARIUS.

4. In Step 2 of the Import from File Wizard, the user specifies which rows of data to import (Figure 11.3). Use the Start Import at Row option to skip the metadata header rows that precede the raw data. Set the Delimiters to Comma and select Next.

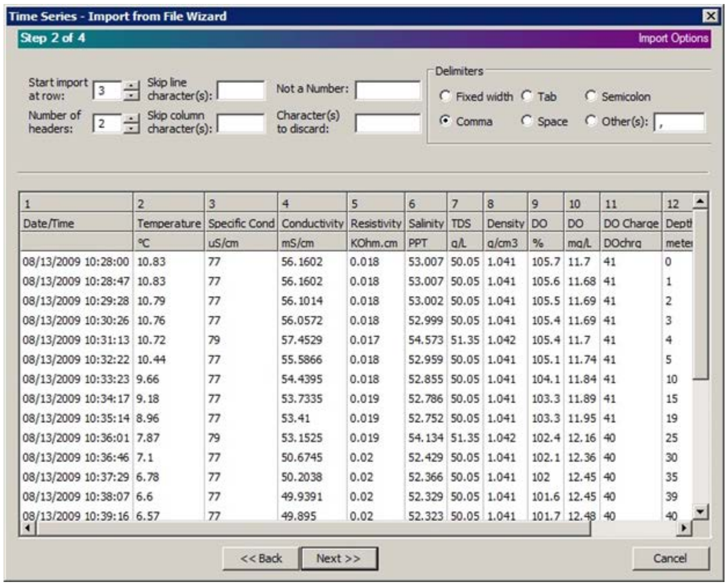

Figure 11.3. Step 2 of the Import from File Wizard in AQUARIUS.

5. In Step 3 of the Import from File Wizard, the user formats each data column and identifies which columns of data to skip (Figure 11.4). The first column is the date. Click the Date/Time radio button and type in "mm/dd/yyyy." Select the Alaska Daylight Time zone (AKDT; UTC-08:00). Select the time column and click the Date/Time radio button and type in "HH:MM:SS." AQUARIUS is case-sensitive for these commands. The date must be lower case and the time must be upper case.

6. Continue selecting the remaining data columns, highlighting the Data radio button for each “Raw” data column. Match each column with its correct category from the Parameter drop-down menu. Change the Int. Type to “1 – Inst. Values.” Repeat this process for the parameters listed in Table 11.3, as well as any other parameters of interest. For all other columns, select the Do Not Import Column (Skip) radio button. Select Next.

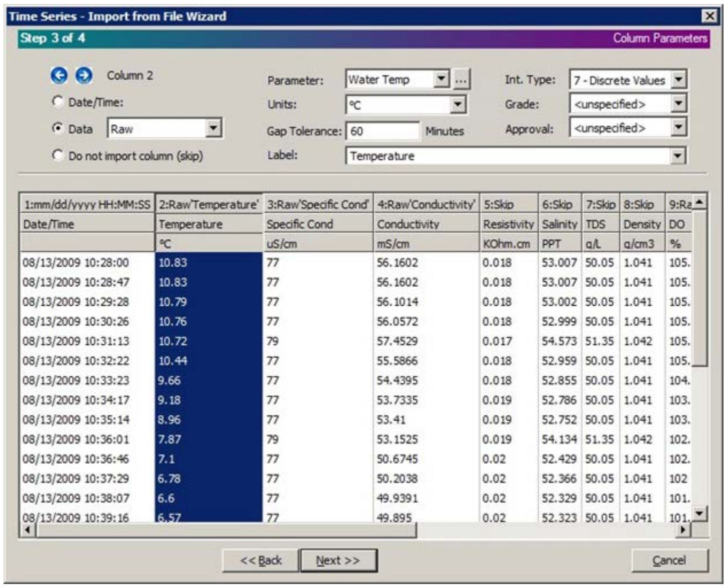

Figure 11.4. Step 3 of the Import from File Wizard in AQUARIUS.

Table 11.3. Water quality parameters and corresponding units currently imported to AQUARIUS.

Parameter	Units
Temperature	°C
Specific conductivity	µS/cm
Conductivity (uncompensated)	µS/cm
Dissolved oxygen	mg/L
Dissolved oxygen saturation	%
Dissolved oxygen charge	(unitless)
Depth	m
pH	(unitless)
pH voltage	mV

7. In Step 4 of the Import from File Wizard, the user can save the configuration (*.cfg) file (Figure 11.5). Configuration files are small scripts that can be used to import additional *.csv files with the exact same layout. If the *.csv files differ at all, an error message will appear during file import or incorrect data columns will be imported. Under Time Series Import Options, select No Gap Processing. Click the Save Configuration box and name the *.cfg file

with a title that is intuitive and helpful (e.g., LACL_chulr01_continuous_wq_2009_cfg). Click Finish.

8. The Import from File toolbox window should be visible, with the Output Ports column populated with the selected parameters. Delete parameters that are not of interest by highlighting the parameter and pressing Delete on the keyboard. The order in which the parameters are displayed can also be changed at this time.

Importing Comma Delimited Files Using Existing Configuration Files

1. Open the Import from File toolbox.
2. Navigate to the appropriate data folder by clicking the "…" button next to the Import File(s) line. In the subsequent Load window, select the *.csv file for the deployment period of interest, and then click Open.
3. In the Import from File toolbox window, click the "…" button next to the Use Configuration File heading line. In the subsequent Open Configuration window, browse to and select the *.cfg file of interest. Click Open.
4. The Import from File toolbox window should be visible, with the Output Ports column populated. Delete parameters that are not of interest by highlighting the parameter and pressing Delete on the keyboard. The order in which the parameters are displayed can also be changed at this time. Click Done.

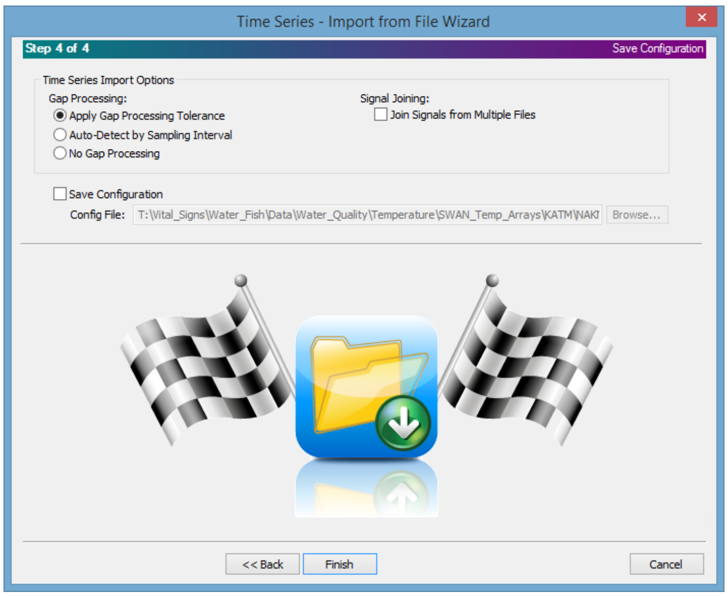

Figure 11.5. Step 4 of the Import from File Wizard in AQUARIUS.

Making Data Corrections

This section focuses on the steps needed to adjust continuous water quality data for fouling and drift errors. As stated previously, applying data corrections for fouling and drift requires a degree of professional judgment. Weather, discharge, and deployment site knowledge will aid in determining if anomalous data are due to false outliers or true data spikes (e.g., following a weather event). Additionally, comparing two parameters side by side may aid in applying data corrections.

1. Select the Correction tab in the Toolboxes pane on the left, and drag a Data Correction toolbox for each parameter of interest into the whiteboard. Wire the output port for the parameter of interest on the Import from File toolbox to the input port on the Data Correction toolbox (i.e., by dragging and dropping). If surrogate data, such as battery power or DO charge (for rapid pulse membrane sensors), are being used to assist with data corrections, wire the surrogate data output port to the surrogate signal input port (input port labeled with an "O").
2. Open the Data Correction toolbox by double clicking on it. The parameter of interest will be graphed in the Target Signal display and the Surrogate Signal display will show any surrogate data, if loaded.
3. Next, examine the data and determine which measurements may be erroneous. Examples of erroneous data include:
    a. battery power = 0%,
    b. specific conductivity = 0 µS/cm, indicating that the sonde was out of water,
    c. DO charge <25, if collected with a Rapid Pulse DO sensor (YSI 6562),
    d. non-data numbers for any parameter (e.g., -9999), and
    e. exceptionally high values of DO or turbidity, suggesting that the optical sensor wiper parked over the optical lens.
4. To correct erroneous data, follow the steps outlined in the comparable section for water temperature data, later in this SOP. Be certain to provide a comment when any data are deleted. Correct all data spikes and erroneous data before applying correction values for sensor fouling and drift.
5. Next, open the Fouling_and_Drift_Corrections worksheet that corresponds to the continuous water quality dataset. This worksheet will indicate if drift corrections are needed based on the absolute value of fouling and drift error. Check the Data Correction Needed box (G25:G31 in Figure 11.1) to determine if corrections are necessary.
6. Drift corrections are applied to the entire dataset. AQUARIUS will prorate the correction based on the length of the time series data set. Highlight the entire deployment period using the Mark Region icon (Figure 11.6). In the Correction Control panel, select Drift Correction from the Action pull-down menu. Enter the drift value (H25:H31 in Figure 11.1) for the appropriate parameter in the Calibration Drift box and the fouling value (F17:F23 in Figure 11.1) in the Fouling Drift box. Be sure that negative signs are entered if any corrections are negative. The Adjust Step box can be used to incrementally increase or decrease the correction values, but it is faster to simply enter the values manually. Click Apply.

7. The Apply Correction window will appear. The default comment logs the sensor and drift correction information, which will be carried through in the metadata. Do not add this to the comment list as the correction values change with each deployment. Click OK.

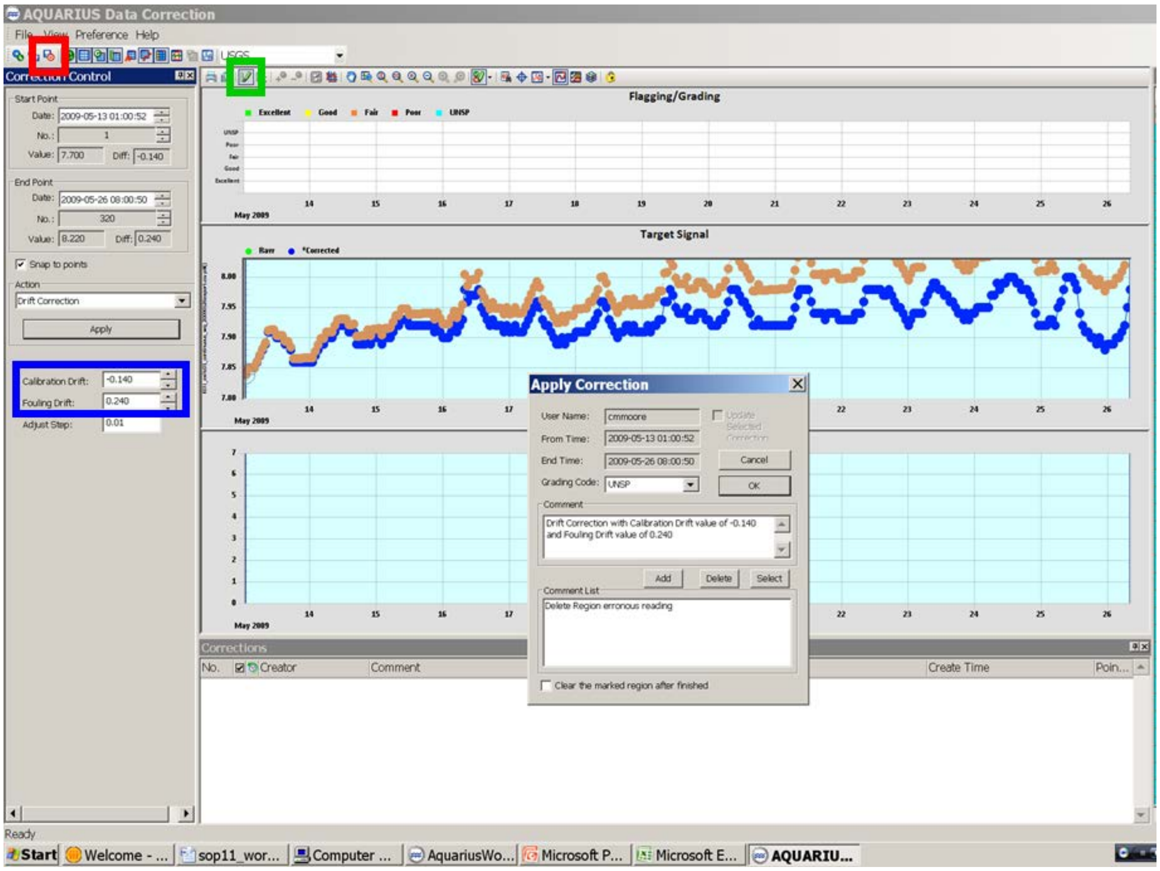

Figure 11.6. Screen shot of the AQUARIUS Data Correction toolbox and Apply Correction window (inset). The Mark Region icon, Save and Exit icon, and Calibration and Fouling Drift boxes are highlighted (green, red, and blue boxes, respectively).

8. Notice that both the corrected and raw signals are now displayed in the Target Signal graph. Select the Save and Exit icon to close the Data Correction toolbox. An active output port should now be visible on the Data Correction toolbox.

Assigning Data Grades

1. Open the Data Correction toolbox (added in Step 1 above). In the Correction Control panel, select Set Grade from the Action pull-down menu. Highlight the entire deployment period using the Mark Region icon (Figure 11.6).
2. Select the Grade from the drop-down menu corresponding to the grade assigned on the Fouling_and_Drift_Corrections worksheet (yellow box in Figure 11.1). Data grades are assigned based on criteria listed in Table 11.2. Click Apply.
3. The Set Grade window will appear. Add any necessary notes to the Comment field.

4. After verifying that the correct data grade was assigned, select the Save and Exit icon. An active output port should now be visible on the Data Correction toolbox.

Flagging Thresholds

Threshold flagging allows the user to flag values that exceed certain limits, such as state surface water quality criteria. SWAN will apply surface water quality criteria developed by the state of Alaska based on standards for "growth and propagation of fish, shellfish, and other aquatic life and wildlife" in fresh waters (ADEC 2012; Table 11.4). However, the state's criteria for turbidity are based on limits above "natural background conditions." Natural background conditions have not yet been determined for SWAN glacially-fed lakes. Until those conditions are known, continuous water quality values will not be flagged based on turbidity levels.

Table 11.4. State surface water quality standards adopted as flagging thresholds for SWAN continuous water quality data (based on ADEC 2012).

Water Quality Parameter	State Surface Water Criteria [a]
Water temperature	$\leq$ 20 °C at any time; $\leq$ 15 °C along migration routes; $\leq$ 13 °C in spawning areas; $\leq$ 15 °C in rearing areas; $\leq$ 13 °C in egg and fry incubation areas
pH [b]	$\geq$ 6.5 and $\leq$ 8.5; may not vary more than 0.5 pH units from natural conditions
Dissolved oxygen	> 7 mg/L for waters used by anadromous or resident fish; $\geq$ 5 mg/L for waters not used by anadromous or resident fish; $\leq$ 17 mg/L and < 110% saturation for all waters
Turbidity	$\leq$ 25 NTU above natural conditions; $\leq$ 5 NTU above natural conditions for lakes

[a] Criteria should be read with the following prefix: "Surface waters must be…"

[b] Several SWAN waterbodies have naturally low pH levels due to geothermal inputs.

Note: surface water quality criteria are subject to change based on regulatory review by the state of Alaska and so should be checked annually. Up-to-date water quality criteria can be found at http://dec.alaska.gov/commish/regulations/.

1. Open the Data Correction toolbox. In the Correction Control panel, select Threshold Correction/Flagging from the Action pull-down menu. Highlight the entire deployment period using the Mark Region icon (Figure 11.6).
2. Under Action Type, select the Flag Points radio button. Then select the Threshold radio button, click on High or Low, and enter the relevant water quality criterion from Table 11.4 in the Value field. Select Apply.
3. In the Set Flag window that opens, add a brief description of the criterion (e.g., "ADEC criteria for pH $\geq$ 6.5 and $\leq$ 8.5 units") in the Comment field. Select OK and then Save and Exit.
4. Flagged data points will not be visible until the data are graphed and the Show/Hide Flags icon (located above the Target Signal window) is selected.

Water Level Data

For sites with existing rating curves (i.e., Naknek and Brooks), level data will go through a four-stage process to produce an end product of mean daily discharge. These stages include: 1) compensating level data for barometric pressure; 2) calculating mean daily level; 3) applying USGS datum corrections; and 4) using the rating curve to compute mean daily discharge from the datum-corrected mean daily level. Stage 1 ─ barometric pressure compensation ─ is described in SOP10. Stages 2–4 are explained below. Level data collected from sites without existing rating curves will be processed only through Stage 2.

Data Pre-Processing in Excel

Extensive metadata are associated with the water level *.csv files exported from the In-Situ and Solinst proprietary software. It is easier to modify these *.csv files in Excel, prior to importing them into AQUARIUS. For example, a *.csv file exported from Win-Situ contains 44 rows of metadata above the relevant data and column headings (Date and Time, Pressure, Temperature). These 44 rows should be deleted and the resulting file saved with an intuitive name similar to the exported file name (e.g., KATM_lbroo01_lvl_compensated_20080930export_no_metadata.csv).

Data Processing in AQUARIUS

Calculating Mean Daily Level

1. Open AQUARIUS and add an Import from File toolbox to the whiteboard. Load the compensated *.csv file to be summarized and corrected. Then add a Descriptive Statistics toolbox and wire the level data output port to the Descriptive Statistics input port. Double click the Descriptive Statistics toolbox to open it (Figure 11.7).

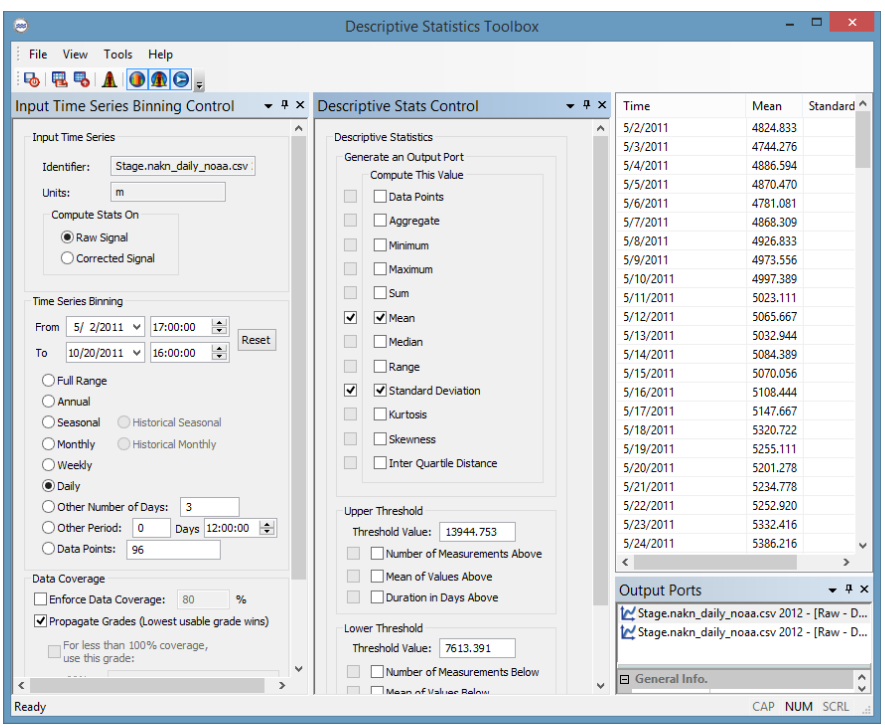

Figure 11.7. Screen shot of the Descriptive Statistics toolbox in AQUARIUS.

2. In the Input Time Series Binning Control pane, select the Raw Signal radio button to compute statistics on the raw data. Allow the summary to be performed on the entire dataset by using the default dates under Time Series Binning. Select the Daily radio button.
3. In the Descriptive Stats Control pane, check both boxes for the Mean and Standard Deviation (SD) values. The right check computes the value and the left check will allow the values to be saved to an output port. Click the Compute button.
4. Daily mean and SD values will be generated and displayed on the right side of the Descriptive Statistics toolbox. Select the Save Data to Output Ports and Exit icon.
5. If processing level data with a rating curve, proceed to the next step. Otherwise, drag an Export to File toolbox into the whiteboard. Wire the Descriptive Statistics toolbox to the Export to File toolbox, and then export the daily mean and standard deviation data.

Applying USGS Datum Corrections

Rating curve equations developed by the USGS Water Resources Division for the Naknek and Brooks sites share a similar format:

$$y = a(x + b) - c$$

in which *y* is discharge (cfs) measured at a given date and time, *x* is compensated lake level (ft) recorded at that date and time, *a* and *c* are constants, and *b* is the datum correction (ft). The datum correction is the average difference between the recorded staff gage height (ft) and the compensated lake level (ft) for several readings collected during a given water year. As such, the datum correction value varies from year to year (Table 11.5). For sample calculations, see Excel files in the subfolders at T:\Vital_Signs\Water_Fish\Data\Surface_Hydrology\Level_and_Baro_Logger_Data\USGS_Rating_Curves.

Table 11.5. Datum corrections for 2006-2012 at two sites with existing rating curves. Corrections are averages of differences in 1–5 readings (n) collected during a given water year.

	Naknek Lake Outlet		Lake Brooks Outlet	
Year	**Datum Correction (ft)**	**n**	**Datum Correction (ft)**	**n**
2006	33.94	4	2.79	4
2007	33.64	4	2.67	4
2008	33.94	1	2.77	1
2009	33.94	1	2.82	1
2010	33.68	1	2.77	[a]
2011	33.68	2	2.78	3
2012	33.73	3	2.77	5

[a] Data not shown in the relevant Excel file (usgs_Brooks 2006.2007 visits.xls).

1. Open the Math and Statistics tab in the Toolboxes pane on the left. Drag a Math toolbox into the whiteboard. Wire the Descriptive Statistics output port to the Math input port. Double click the Math toolbox (Figure 11.8).

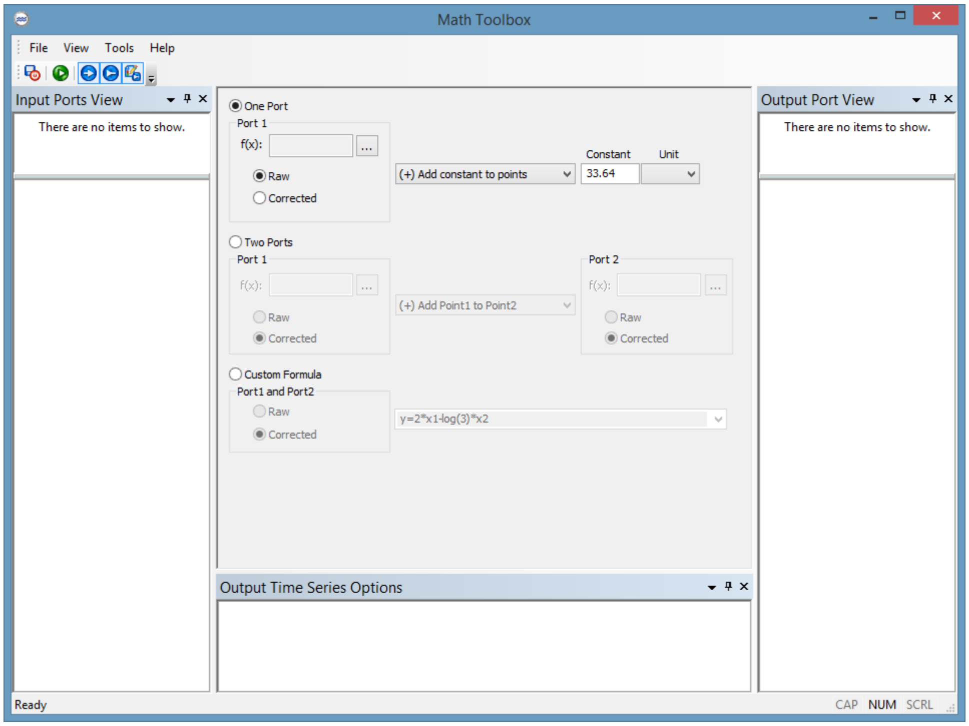

Figure 11.8. Screen shot of the Math toolbox in AQUARIUS, used in applying datum corrections.

2. Select the One Port radio button. Select Add Constant to Points from the pull down menu. If processing Naknek Lake outlet data, enter 33.64 as the Constant value. If processing Lake Brooks data, enter 2.67. **Note:** this correction relates the level data to the station datum, which was established by the USGS when the site was installed. The correction is a crucial step to ensure accurate discharge output when applying the rating curve. For reporting purposes, the uncorrected level data should be used as they represent the true water level.
3. Click the Save Output Port and Exit icon to close the Math toolbox window. The resulting level data are now corrected for the station datum and ready for use in the AQUARIUS Rating Curve Development toolboxes.
4. Add an Export to File toolbox. Export the uncorrected lake level daily mean and standard deviation data.
5. Save the whiteboard and close AQUARIUS.

Computing Mean Daily Discharge Using a Rating Curve

The methods for carrying out Stage 4 are currently in flux. In the past, the AQUARIUS Math toolbox was used to calculate mean daily discharge from the datum-corrected mean daily level values. The rating curve equation was entered after selecting the Custom Formula radio button (Figure 11.9). In the future, however, the Rating Development toolbox should be explored and (potentially) used since it was designed with this specific purpose in mind.

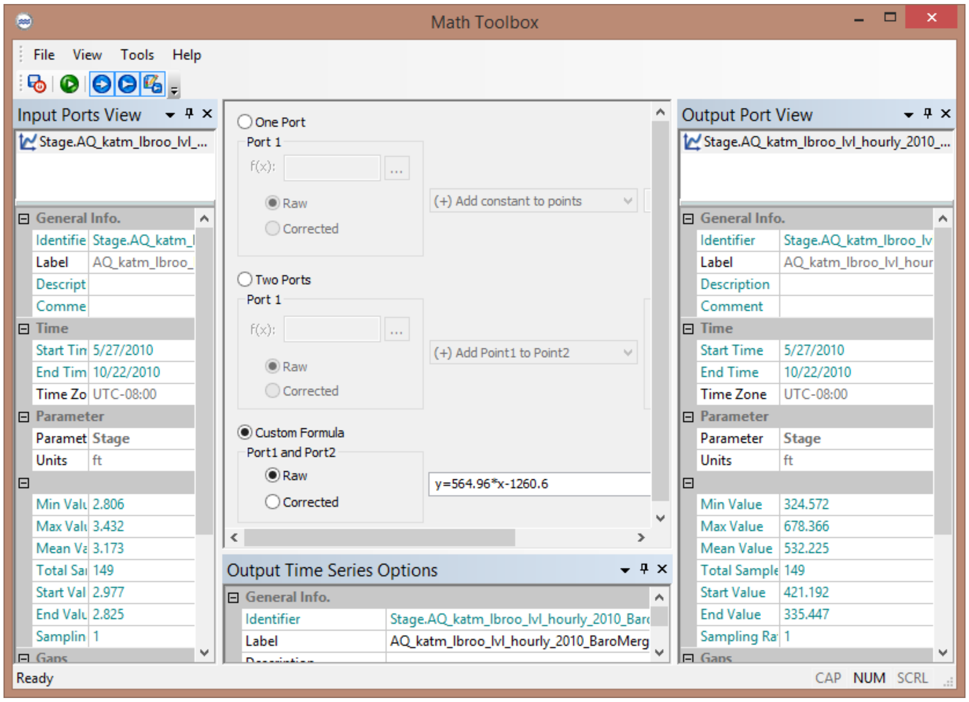

Figure 11.9. Screen shot of the Math toolbox in AQUARIUS, used in applying rating curves.

Water Temperature Data

Moored temperature arrays are deployed in Tier 1 lakes for the purpose of continuous lake temperature monitoring. Each temperature array produces one or two files per year per depth interval ≥ 5 m. For temperature arrays that are easy to access, there will be an early season download (May – June) when the surface buoy and logger are attached, and a late season download (September – October) when the surface buoy and logger are removed.

Downloading data from temperature array loggers can generate >20 data files per year. To simplify file management, create a temporary working folder with an intuitive name (e.g., aquarius_lclar01_2014) and copy all *.csv files for the AQUARIUS session into that folder. Once the final products have been completed, the files can be moved to a permanent location and the temporary folder can be deleted.

To help with toolbox management in complex whiteboards, rename the toolboxes as data are imported and functions are carried out. These toolboxes can be copied and pasted into other whiteboards for additional analysis. To rename toolboxes, right click on the toolbox with the loaded data and select the Properties Pane from the pick list. The properties box will appear. Toolbox naming is left to the user's discretion. A helpful naming convention would include the 5 digit water body code + site ID + the month and year of the offload date (mm/yy) + other useful file ID information (e.g., naknl01 09/09 5m-20m).

Data Pre-Processing in Excel

Unlike the water level *.csv files exported from the In-Situ and Solinst software, water temperature *.csv files exported from Onset software have no extensive metadata. They can be imported to AQUARIUS without modification.

Data Processing in AQUARIUS

<u>Importing Comma Delimited Files</u>

This section will cover importing temperature data collected from loggers deployed year-round at depths $\geq$ 5 m. The surface (0–1 m) logger is deployed on the temperature array only during the open water season. Typically, only one surface temperature data file is collected per field season from a given array. These data are analyzed using similar processes in a separate (or identical) whiteboard.

1. Open AQUARIUS, select the Data Input tab, and drag the Import from File toolbox into the whiteboard. To simplify the number of toolboxes that are managed in the whiteboard, three to four depths can be added to each toolbox. Three toolboxes will accommodate data for depths ranging from 5 m to 100 m for each download period.
2. Double click the first toolbox to begin loading data. In the Import from File toolbox that opens (Figure 11.10), navigate to the appropriate data folder by clicking the "…" button next to the Import File(s) line. Set the file type to *.csv in the subsequent Load window to remove other files from view. Select the first file to import (e.g., KATM_naknl01_005m_20090923export.csv) and click Open.

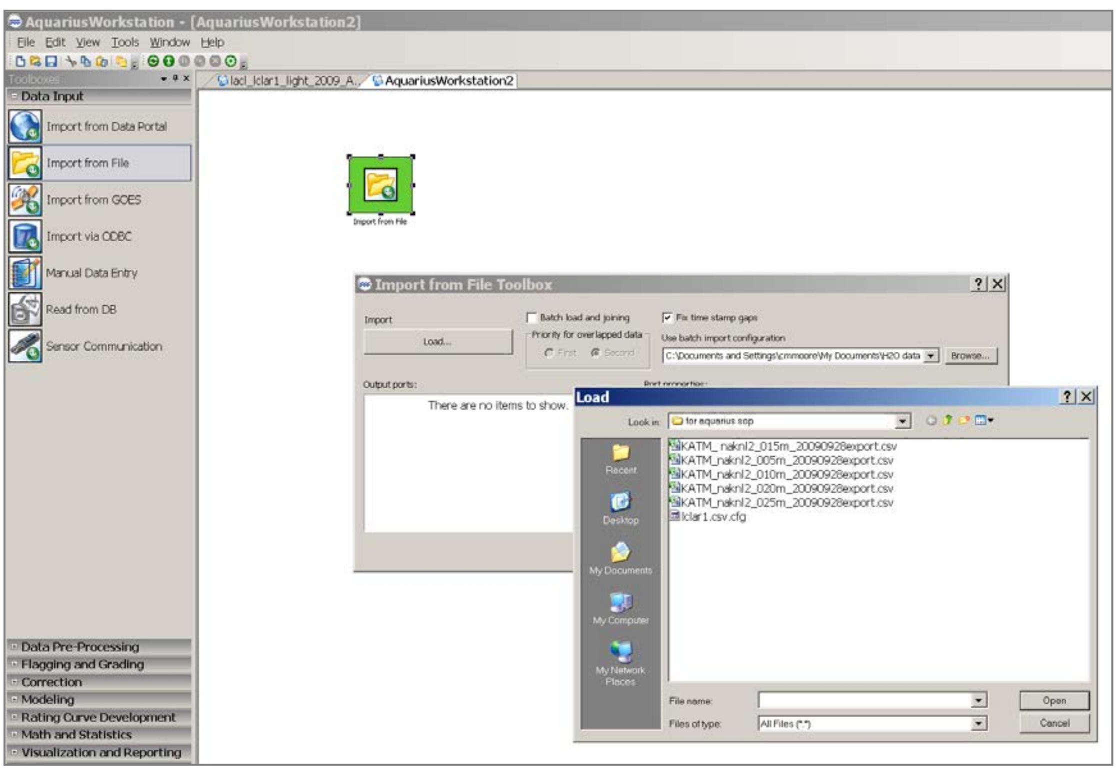

Figure 11.10. Screen shot of the Import from File toolbox and Load window in AQUARIUS.

3. If no configuration file is available, click the Config Settings button. Step 1 of the Import from File Wizard should appear. Select the default Time Series radio button. Click Next.
4. In Step 2 of the Import from File Wizard, the user specifies which rows of data to import (Figure 11.11). Set the Start Import at Row box to “4” and the Number of Headers box to “3” in order to skip the metadata header rows that precede the raw data. Leave the Delimiters on Comma (the default setting) and select Next.

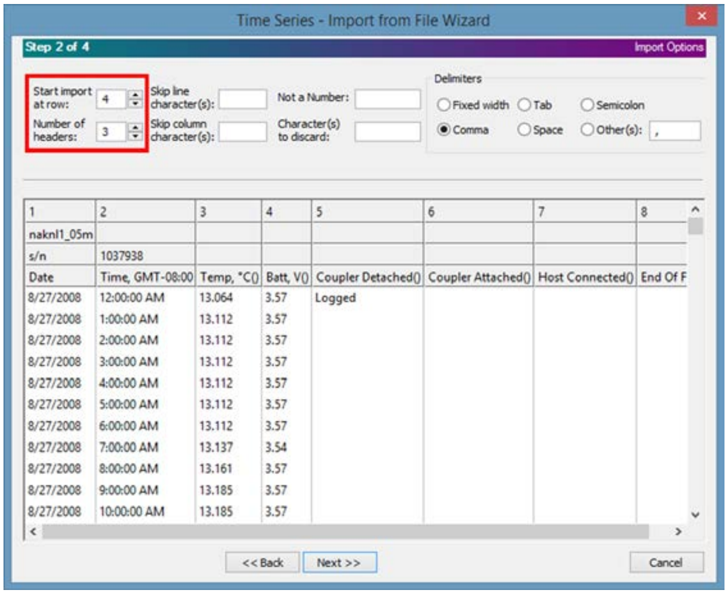

Figure 11.11. Step 2 of the Import from File Wizard in AQUARIUS. The Start Import at Row and Number of Headers boxes are highlighted.

5. In Step 3 of the Import from File Wizard, the user formats each data column and identifies which columns of data to omit (Figure 11.12). The first column is the date. Click the Date/Time radio button. Type “mm/dd/yyyy” in the Date/Time Format window and choose Alaska Daylight Time (AKDT; UTC-08:00) for the Time Zone. Select the time column and click the Date/Time radio button and type in “HH:MM:SS PM.” AQUARIUS is case-sensitive for these commands. The date must be lower case and the time must be upper case.
6. Select the temperature column. Notice that the Data radio button is selected. Fill in the Parameter and Units and add a Label such as “temp_+3-digit depth+m” (e.g., temp_005m). Select the battery column and click the Do Not Import Column radio button. Select any additional columns that may be part of the *.csv file (Coupler Detached, etc.) and click the Do Not Import Column radio button. Notice that only the columns selected for import have meaningful headers (Figure 11.12). Click Next.
7. Step 4 of the Import from File Wizard allows the user to save the configuration (*.cfg) file. This is a small script that can be used to import additional *.csv files with the exact same layout. If the *.csv files differ at all, an error message will appear during file import or incorrect data columns will be imported. Click the Save Configuration box. Select Browse to save the *cfg file in a relevant location with a file name that is useful and intuitive (e.g.,

naknl01_2009_import). Click Save to close the Save Configuration window, and then click Finish to complete the import process.

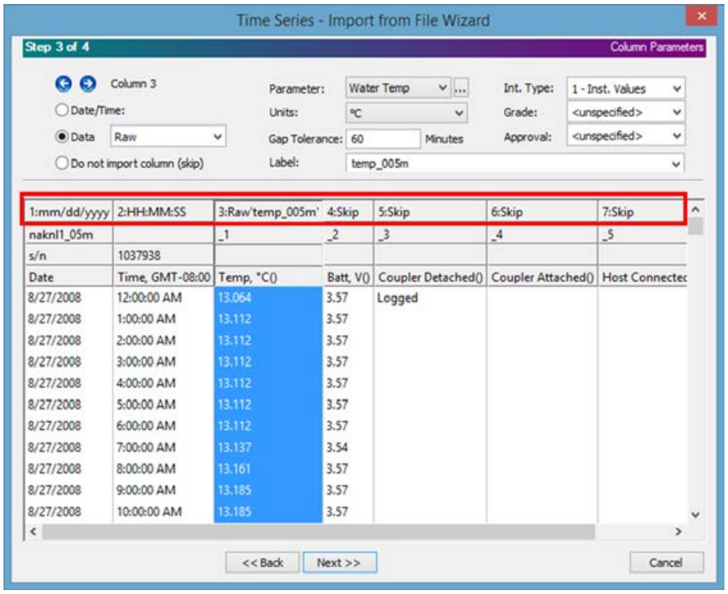

Figure 11.12. Step 3 of the Import from File Wizard in AQUARIUS. Headers are highlighted.

8. When the file has been imported, a new window will appear (Figure 11.13). The Output Ports panel displays the name of the imported file and the Port Properties panel provides information about the file. Scroll down through the properties to view the number of records that were imported. Each file should include the same number of records as the raw *.csv file. If the file did not import correctly, this value is the first indication.

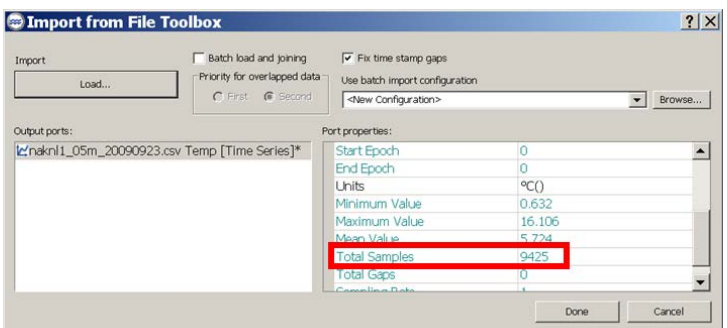

Figure 11.13. Screen shot of the Import from File toolbox in AQUARIUS. The “Total Samples” row in the Port Properties panel (highlighted) indicates the number of records imported.

9. Import the remaining temperature files in sequence, starting with the 10 m depth, by repeating Step 2 above. The configuration file saved in Step 7 can now be used to import remaining files. Select the “…” button to the right of the Use Configuration File window, and navigate to the folder where the *.cfg file was saved. Select the *.cfg file and click Open. Click the Load File(s) button to import the 10 m depth data. The file will load automatically and appear in the Output Ports window. Check the Total Samples.

10. Import the 20 m depth data by repeating Step 9 above. Three files are now loaded into the Import from File toolbox. They should be displayed in the left panel (Figure 11.14).

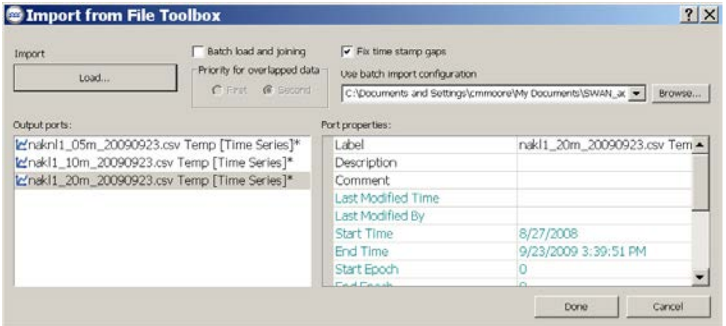

Figure 11.14. Screen shot of the Import from File toolbox in AQUARIUS, with data from three depths (5, 10, and 20 m) in the Output Ports panel.

11. Click Done and notice that the Import from File toolbox now has three active output ports on the right side, represented by khaki colored triangles. Each port corresponds to a depth dataset. Right click on any port to display a Quick View graph of the data (Figure 11.15). The tabular data appear to the right. Close the Quick View image. **Note:** do not simply minimize the view. When screen views are minimized in AQUARIUS, the program becomes inactive, appearing frozen. Check for minimized screens in the left corner if the whiteboard becomes inactive.

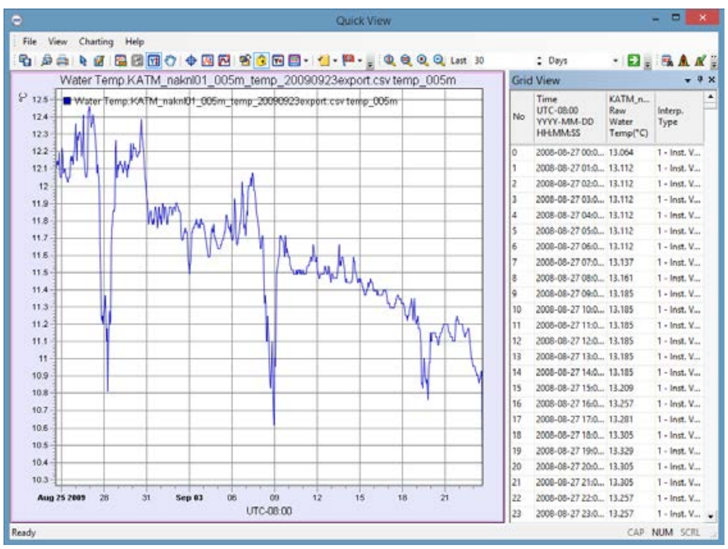

Figure 11.15. Screen shot of the Quick View window in AQUARIUS, with graphical data on the left and tabular data on the right.

12. Repeat Steps 1–11 to import the temperature data for the remaining depths. Load three to four *.csv files into each toolbox. **Note:** it is helpful to keep the depths in order in the toolboxes (i.e., load the depths sequentially from the surface to the bottom). If an incorrect depth is loaded into a toolbox or the depths are out of order, files can be deleted or reordered to maintain consistency. Double click on the toolbox to bring up the Import from File

window. In the Output Ports panel, select the file that is out of sequence. To delete the file, right click and select Delete. To reorder the file, drag and drop it in the proper location.

<u>Making Data Corrections</u>

Once imported, the data need to be corrected. This involves deleting erroneous data created during battery failure or servicing (i.e., when the array was removed from the water). Each data correction is recorded in the Change List in AQUARIUS. Corrections can be undone easily if necessary. If only one file exists for the year and the temperature array was not retrieved for service, there will be no corrections applied to the dataset. If no corrections are needed, proceed to the Flagging Thresholds section.

1. Open the Correction tab in the Toolboxes pane and drag a Data Correction toolbox into the whiteboard for each depth. Wire the output port for the depth of interest on the Import from File toolbox to the input port on the Data Correction toolbox (i.e., by dragging and dropping).
2. Double click the Data Correction toolbox and review the data. The toolbox window features four main areas (Figure 11.16). The Correction Control (on the left) shows the corrections that can be applied to the data. The Time Series Grid (on the right) and the Target Signal (in the upper center) show the raw and corrected data in tabular and graphical format, respectively. Finally, the Change List (in the lower center) records all changes to the raw data and can be exported as a metadata *.txt file.

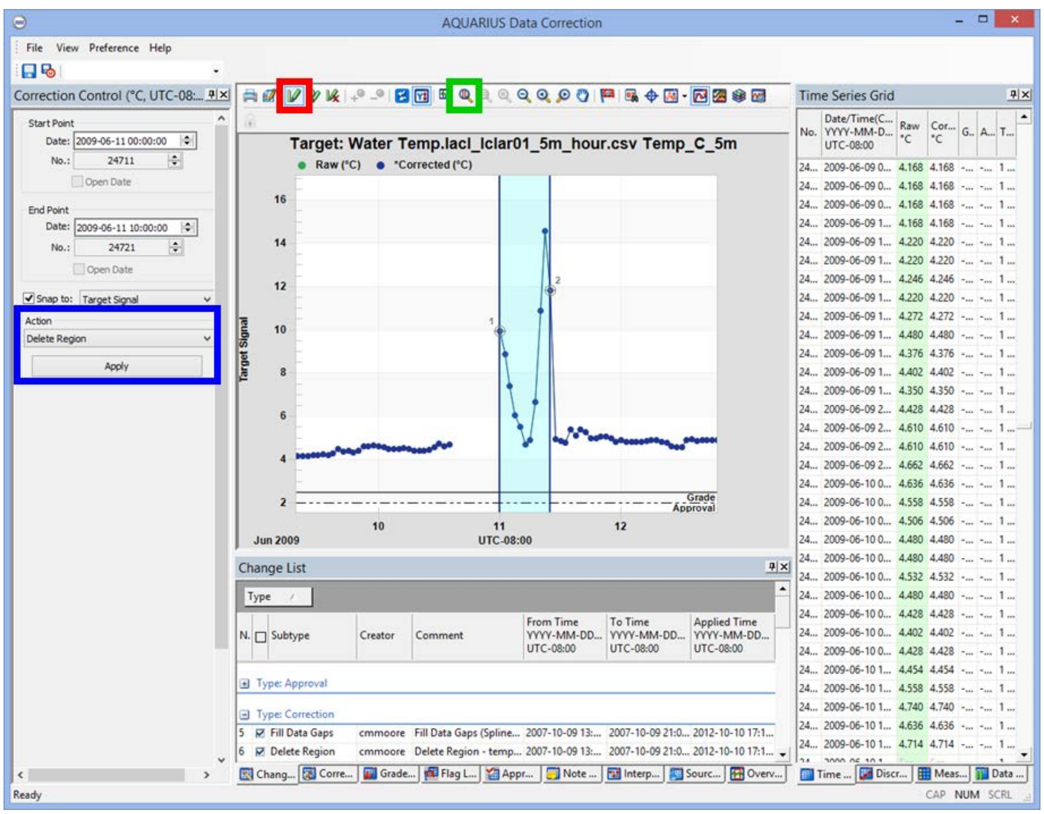

Figure 11.16. Screen shot of the Data Correction toolbox in AQUARIUS. The Mark Region icon, Zoom in Horizontally icon, and Delete Region tool are highlighted (red, green, and blue boxes, respectively).

3. Known data corrections will include periods when the temperature array was out of the water for servicing, creating gaps and erroneous air temperatures in the dataset. Start the correction process by deleting an obvious spike in the data. Use the Zoom in Horizontally icon to zero in on the erroneous data; and then use the Mark Region icon to select the data to be corrected (Figure 11.16).

4. In the Correction Control panel, select Delete Region from the Action pull-down menu. Click Apply. A window will pop up showing information related to the Delete Region action (Figure 11.17). In the Comment field, Delete Region already will be entered. Type in an additional statement explaining that the erroneous data is associated with the data download or battery failure. Keep these statements brief. Use the blue downward pointing arrow to add the revised statement to the Saved Comments field. This feature allows the user to pick comments from a list, standardizing the statements and reduce typing during subsequent deletions. Click OK.

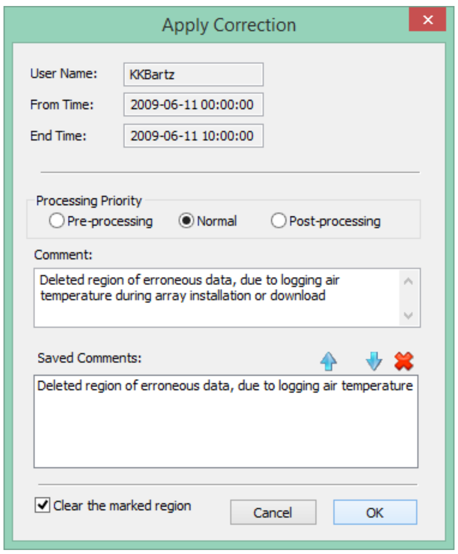

Figure 11.17. Screen shot of the Apply Correction window in AQUARIUS.

5. Notice how the Data Correction toolbox changes. In the Target Signal pane, the deleted points switch from blue (corrected) to green (raw), indicating their removal from the corrected dataset (Figure 11.18). This removal is also visible in the “Corrected °C” column of the Time Series Grid. Also, a new Delete Region row is added to the Change List under the Type: Correction field. If the deleted points need to be restored, unclick the box on the left side of this row. To permanently restore the points, right click on the row and select Delete.

6. Select the Reset Axis icon to show the full dataset. The large data spike that was obvious earlier is now removed. Select the Save and Exit icon.

7. Two data files generally exist per depth for each year. If the temperature array was serviced during the summer, additional time periods may require corrections. Consult the field notebook to identify other time periods in which erroneous data may have been recorded.

8. Repeat Steps 1–7 to correct data for all depth intervals. Save the whiteboard.

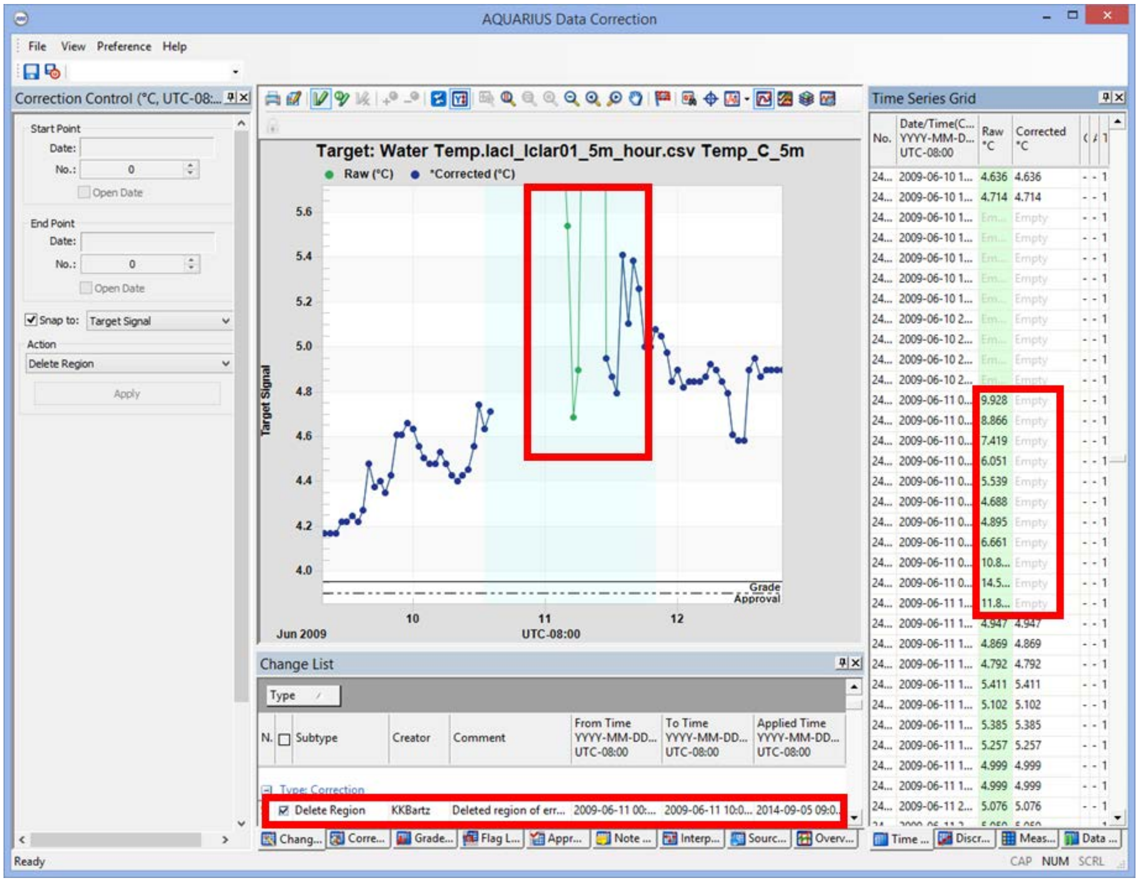

Figure 11.18. Screen shot of the Data Correction toolbox in AQUARIUS. Red boxes highlight the changes that occur after a region of erroneous data has been deleted.

<u>Flagging Thresholds</u>

Threshold flagging allows the user to flag values that exceed certain limits, such as state surface water quality criteria. SWAN will apply surface water quality criteria developed by the state of Alaska based on standards for "growth and propagation of fish, shellfish, and other aquatic life and wildlife" in fresh waters (ADEC 2012; Table 11.4). According to these criteria, water temperatures may not exceed 20 °C at any time; migration routes and rearing areas may not exceed 15 °C; and spawning areas and egg and fry incubation areas may not exceed 13 °C (ADEC 2012). Moored temperature arrays are located the pelagic zone of lakes. As such, threshold flagging will be applied to temperature data collected at the 5 m depth based on the statewide limit of 20 °C and the migration and rearing area limit of 15 °C.

1. Open the Data Correction toolbox. In the Correction Control panel, select Threshold Correction/Flagging from the Action pull-down menu (Figure 11.19). Highlight the entire deployment period using the Mark All Region icon.
2. Under Action Type, select the Flag Points radio button. Then select the Threshold radio button, click High, and enter the relevant water temperature criterion (e.g., 15.00) in the Value field. Select Apply. In the Set Flag window that opens, add a brief description of the

criterion (e.g., “ADEC criteria for temperature in migration and rearing areas”) in the Comment field. Select OK and then Save and Exit.

3. Flagged data points will not be visible until the data are graphed and the Show/Hide Flags icon is selected (Figure 11.19).

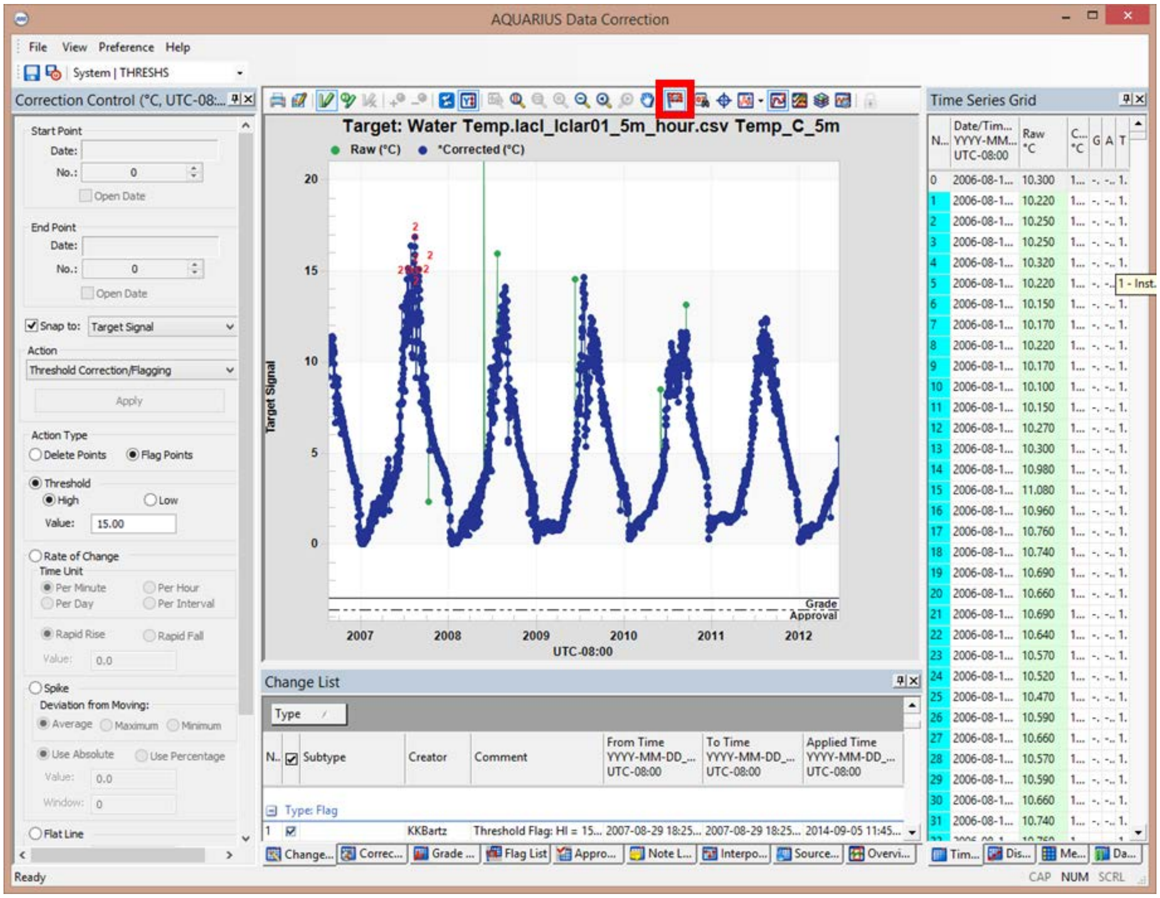

Figure 11.19. Screen shot of the Data Correction toolbox in AQUARIUS, displaying the results of threshold flagging. Flagged data points are visible (red “2’s” in the Target Signal pane) because the Show/Hid Flags icon is selected (red box).

<u>Computing Descriptive Statistics</u>

Preliminary data analysis involves computing basic summary statistics for each depth, using a variety of time frames (i.e., daily, weekly, monthly, annually). Although seasonal time frames would also be appropriate, no hydrological seasons have been defined for Southwest Alaska (Tim Brabets, USGS WRD, personal communication). Basic summary statistics include:

- Hottest day of the year: the maximum average temperature for a 24-hour day;
- Hottest week of the year: the maximum average temperature for a 7-day period;
- Maximum average daily temperature, by month;
- Minimum average daily temperature, by month.

- Monthly degree days: cumulative total degree days for each month;
- Annual degree days: cumulative total degree days from 1 January to 31 December; or
- Frequency and duration of any hard thermoclines ($\geq$1 °C change per m of depth).

Most if not all of these summary statistics could be calculated in AQUARIUS. A step-by-step explanation is beyond the scope of this SOP. However, the steps below offer a basic introduction for computing daily mean temperature at the 5 m depth, which is necessary for identifying the hottest day of the year (first bullet above).

1. Open the Math and Statistics tab in the Toolboxes pane on the left. Drag a Descriptive Statistics toolbox into the whiteboard. Wire the output port for the 5 m Data Correction toolbox to the input port for the Descriptive Statistics toolbox.
2. Double click the Descriptive Statistics toolbox. In the Input Time Series Binning Control pane, select the Corrected Signal radio button to compute statistics on the corrected data. Allow the summary to be performed on the entire dataset by using the default dates under Time Series Binning. Select the Daily radio button (or whichever bin is of interest).
3. In the Descriptive Stats Control pane, check boxes for summary statistics of interest (e.g., Minimum, Maximum, Mean, and Standard Deviation (SD)). The right check computes the value and the left check will allow the values to be saved to an output port. Click the Compute button.
4. Summary statistics will be calculated and displayed on the right side of the Descriptive Statistics toolbox. Select the Save Data to Output Ports and Exit icon.
5. Repeat Steps 1–4 for each additional depth.

<u>Exporting Data</u>
When processing of water temperature data is complete, the files are ready for export from AQUARIUS.

1. Select the Data Output tab in the Toolboxes pane and drag an Export to File toolbox into the whiteboard. Right click the toolbox to open the Properties Pane. Change the number of input ports to the number of files that are to be imported. If the depths range from 5 m to 100 m and one or fewer descriptive statistics have been computed, 11 ports will be needed (Figure 11.20). Wire the output ports from the Data Correction or Descriptive Statistics toolboxes to the input ports on the Export to File toolbox. **Note:** it is helpful to keep the depths in order (i.e., wire the depths sequentially from top to bottom).
2. Double click the Export to File toolbox. All the files connected to an input port will be listed in the Input Ports pane under the Time Series tab. Leave the default Output Options (Save Time Series in CSV Format) and click Export.

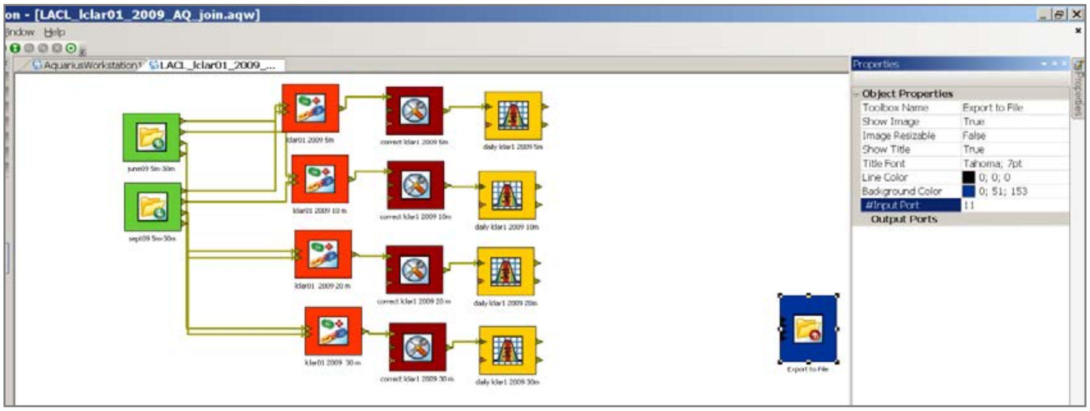

Figure 11.20. Screen shot of the Properties Pane for an Export to File toolbox in AQUARIUS,

3. An Export to CSV window appears containing various options (Figure 11.21). Use the default Time Range (Entire Range).
4. Highlight a single input file on the left, select an Available Column (either raw or corrected) from the center field, and then click Add. Repeat this step until all desired Output Columns are listed. Click Export.
5. In the Save As window that appears, navigate to an appropriate location (i.e., the working folder) and save the file using the following naming convention: 4-letter park code_5-digit water body code + site ID_ temperature_ year + qaqc (e.g., LACL_lclar01_temperature_ 2012qaqc). Click Save.

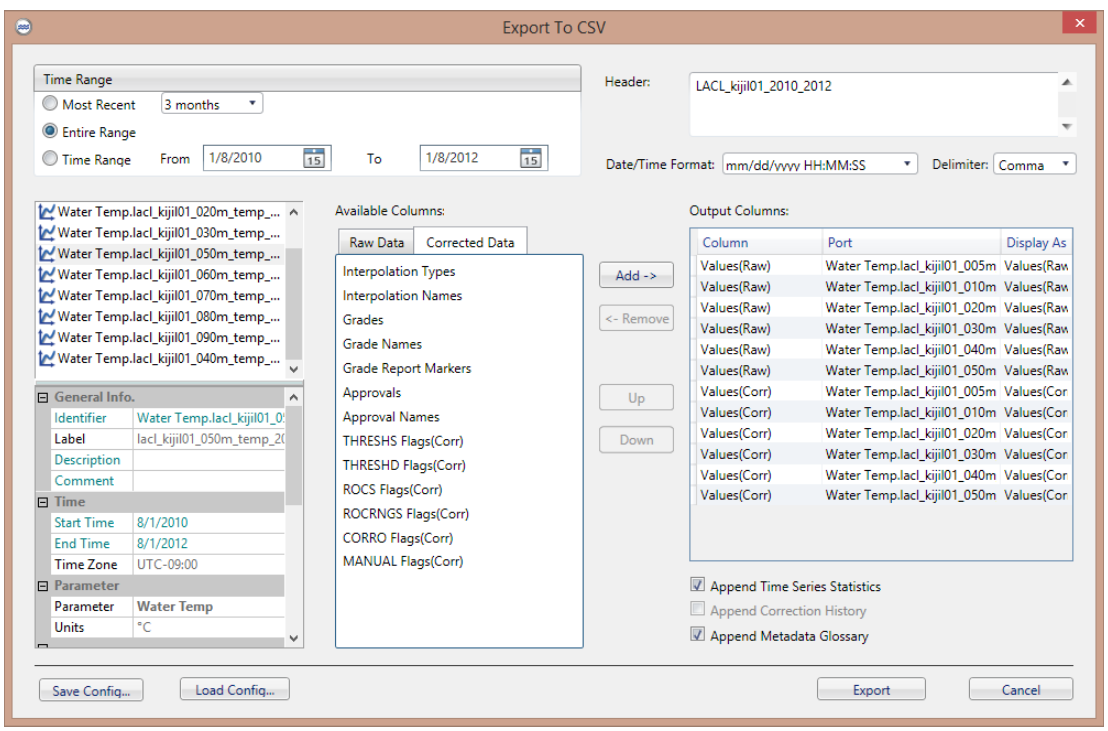

Figure 11.21. Screen shot of the Export to CSV window in AQUARIUS,

Light Intensity Data

Light intensity data loggers were co-located with water temperature data loggers at depths of 5 m, 10 m, and 15 m on moored temperature arrays until 2012. Light intensity measurements were intended to monitor water clarity and euphotic zone depth in SWAN lake systems. However, fouling made the data difficult to interpret (e.g., the light intensity at 10 m exceeded that at 5 m). If the fouling issue could be resolved, light intensity monitoring could resume. The procedures for processing light intensity data are similar to those for processing temperature data (above). The *.csv files can be imported into AQUARIUS directly, without additional modification.

1. Open a new AQUARIUS whiteboard and add one Import from File toolbox for each collection period.
2. Load the light intensity files for all depths for a given collection period into one toolbox. The data will need to be corrected and data gaps associated with data downloads removed.
3. Add a Data Correction toolbox to the whiteboard. Wire the output port for the 5 m Import from File toolbox to input port for the Data Correction toolbox. Follow the steps in the Data Correction section for Water Temperature Data. Repeat this step for each additional depth.
4. Add a Descriptive Statistics toolbox to the whiteboard. Wire the output port for the 5 m Data Correction toolbox to the input port for the Descriptive Statistics toolbox. Compute the minimum, maximum, mean, and SD for each time series bin of interest (e.g., daily), as described for water temperature data (above). Repeat this step for each additional depth.
5. Add an Export to File toolbox. Right click the toolbox, select the Properties Pane and change the input ports to 4 times the number of depths. Wire these input ports to the minimum, maximum, mean, and SD output ports from the Descriptive Statistics toolbox.
6. Double click the Export to File toolbox. All the files connected to an input port will be listed in the Input Ports pane under the Time Series tab. Leave the default Output Options (Save Time Series in CSV Format) and click Export. Select the Corrected Data tab and add parameters from the Available Columns window to the Output Columns window, for each file in the Input Ports pane. Click Export and name the file according to the conventions in SOP10: 4-letter park code_5-letter waterbody code + site ID_ light_YYYYMMDD + qaqc (e.g., LACL_lclar01_light_daily_20090923qaqc). Save and close the whiteboard. Close AQUARIUS.

Literature Cited

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Starkey, E.N., L.K. Garrett, T.J. Rodhouse, G.H. Dicus, and R.K. Steinhorst. 2009. Integrated water quality monitoring protocol standard operating procedures, Upper Columbia Basin Network. Natural Resources Report NPS/PWR/UCBN/NRR-2009/. National Park Service, Fort Collins, Colorado.

Wagner, R. J., R. W. Boulger, Jr., C. J. Oblinger, and B. A. Smith. 2006. Guidelines and standard procedures for continuous water-quality monitors: station operation, record computation, and data reporting. Techniques and Methods 1-D3. U.S. Geological Survey, Reston, Virginia.

SOP12: Data Management

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

SOP12 - Contents

SOP12 - Figures

Introduction

This standard operating procedure (SOP) summarizes the data management tasks and responsibilities necessary to ensure that data collected according to other SOPs in the SWAN freshwater monitoring protocol support the fundamental goals of Southwest Alaska Network's Data Management Plan. These fundamental goals are to obtain high quality data that are readily available, easily interpretable, and secure for the long term (Mortenson 2006). The intended audience of this data management SOP is primarily SWAN staff directly involved with freshwater monitoring. The intended use of this SOP is as a general guide, not as an in-depth, step-by-step process. Any conflicts between the content of this SOP document and other SOPs in the SWAN freshwater monitoring protocol are to be reconciled by the principal investigator.

This data management SOP consists of two sections; the first discusses data stewardship roles and responsibilities, while the second discusses the typical flow of data, from creation to dissemination.

Data Stewardship Roles and Responsibilities

Following the data stewardship roles and responsibilities provided in this document ensures that the goals of the SWAN Data Management Plan (described above) are achieved through a collective team effort. In support of these goals, Inventory and Monitoring Program managers expect that at least 30% of staff time will be spent on data management-related tasks. Thus, providing clear and concise data stewardship roles and responsibilities will ensure that data management tasks are properly assigned to appropriate staff and accomplished in an efficient and timely manner.

The SWAN aquatic ecologist serves as project manager for freshwater monitoring. The project manager will supervise data collection, provide project oversight, direct field data collection and acquisition, and provide cohesive links among data collection, synthesis, interpretation, and reporting. The project manager is also responsible for all other data management tasks not specifically mentioned in this SOP. The project manager is encouraged to delegate these duties to appropriate staff members, based on availability and expertise. While the project manager must act as the primary steward for freshwater monitoring data for the Network, other project and SWAN personnel are also accountable for specific data management tasks. The subsections below outline the data stewardship responsibilities of different project personnel. To ensure that all project data are managed properly, individuals must understand their responsibilities, communicate with one another, and assist each another, as needed.

SWAN Aquatic Ecologist

The aquatic ecologist is responsible for all project operations and results, and may also participate in field operations. The aquatic ecologist ensures that data management activities are conducted according to established procedures and is responsible for data certification: approving the data content, quality, and documentation, as well as making decisions about data sensitivity and distribution. The aquatic ecologist is responsible for evaluating project data at specified intervals, analyzing data for trends, and following reporting requirements.

SWAN Hydrologic Technician(s)
The hydrologic technician works closely with the project manager in all aspects of data management. The hydrologic technician's primary responsibility is to ensure that field data are collected and recorded in a manner consistent with Standard Operating Procedures. The hydrologic technician is also responsible for uploading field data into the appropriate database (AQUARIUS or NPSTORET) and verifying and validating the data.

SWAN Data Manager
The data manager ensures that freshwater monitoring data are organized, useful, compliant, available, and safe. The data manager provides the most current production version of the NPSTORET and AQUARIUS standards and ensures network data are received by WRD. The data manager oversees activities related to information technology acquisition and development, user support, quality assurance, documentation, backups, archiving, and data maintenance and distribution. The data manager reconciles exceptional network specific database needs with standard database architectures. The data manager may work in a coordinator capacity in order to obtain external input and designs needed for custom database development. The data manager is also tasked with project planning detailing database product deliverables.

SWAN Assistant Data Manager
Harnessing guidelines established by the data manager, the assistant data manager identifies specific tools needed to implement the realization of freshwater monitoring database products. In many cases, the assistant data manager may be tasked with implementation of software applications.

Data Flow
Data flow describes the handling of data from time of collection and acquisition through to reporting and archiving; in other words, its "life cycle." The SWAN freshwater monitoring data flowchart summarizes the recommended handling of data during a standard data life cycle (Figure 12.1). This flowchart and the subsequent numbered descriptions are based on content found in the Sierra Nevada Network Lake Monitoring Protocol Data Flow figure (Heard 2007). The flowchart illustrates that data and metadata are collected at various stages throughout the monitoring process, not just during collection and acquisition of data. For example, critical metadata ─ that capture the spatial and temporal circumstances about where water quality data are collected, which water quality instruments are used, the instruments' characteristics (e.g., calibration information, firmware version, serial number, model information, etc.) and deployment information, and the data collection methods employed ─ are all produced at the time of deployment. Capturing metadata at the appropriate time is critical to its usefulness, since obtaining metadata after the fact makes metadata generation difficult, if not impossible.

Other SOPs found within the SWAN freshwater monitoring protocol should be consulted to determine what data and metadata are collected. For example, most data for site establishment are generated during project planning and are supplemented with, and may be revised by, field observations. Metadata for data collection methods are specified in SOPs 2–8 and stored in AQUARIUS, and potentially ported into the legacy NPSTORET database.

It is important to note that this flowchart approaches data flow from a macroscopic view. It is not intended to guide the reader throughout the entire process; rather, it serves as a reminder for various "big picture" steps, and provides a context for data management throughout the life cycle of the project.

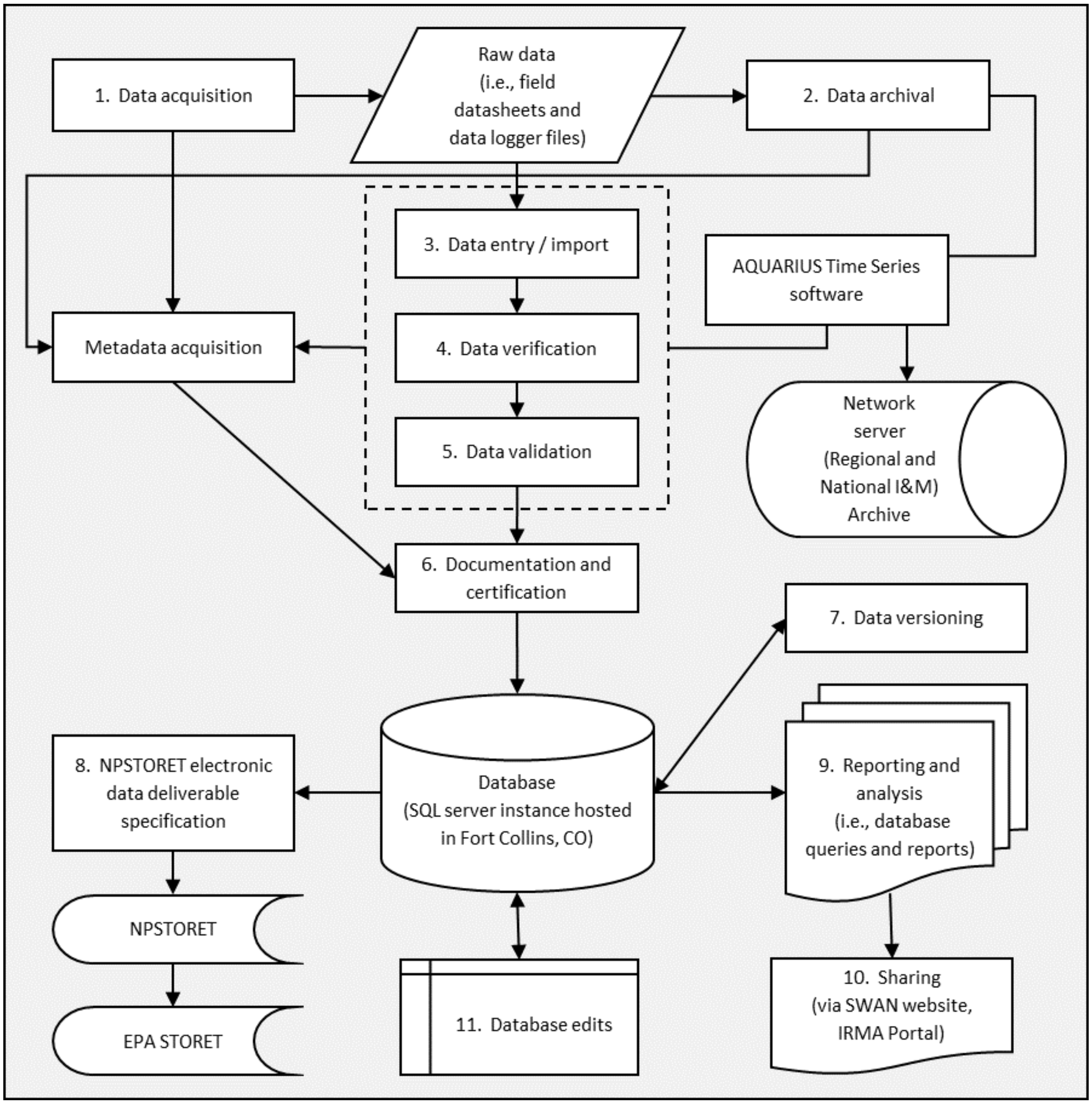

Figure 12.1. SWAN freshwater monitoring data flowchart. Each numbered item within the flowchart has a corresponding description below. For a legend, see Figure 12.2.

Although not indicated with a number in the data flowchart, an integral part of the data life cycle is the use of AQUARIUS Time-Series software. AQUARIUS is a software platform designed to simplify the management and analysis of time-series (i.e., continuous) data. Additional information on use of the software can be found in the user manual or training videos, which can be accessed online at http://aquaticinformatics.com/support/support-login/ or through the help menu. Access to this website requires a username and password, obtainable via email request to support@aquaticinformatics.com. A key feature of the software is the way in which data processing is tracked. The software tracks all changes to the raw dataset, creates a corrected data file, and stores this information in a csv file that can be exported for metadata tracking purposes. This feature standardizes the way in which changes to raw data are tracked. Metadata files provide important documentation on these datasets and are required as part of the SWAN data management protocol.

The descriptions below correspond with the numbered processes in Figure 12.1. Figure 12.2 provides another perspective on the data life cycle, with more emphasis on expected file types at various stages.

1. Data Acquisition

Field data are acquired from both written and electronic sources. Written data sources include (but are not limited to) field descriptions, observation notes, and hard copy datasheets. Likewise, electronic data sources include (but are not limited to) data logger files, GPS location information, and photographs. It is helpful to capture field data electronically whenever practical (e.g., entering data directly into an Excel spreadsheet on the field laptop, rather than filling out a printed field form). At the time of data acquisition, whether written or electronic, associated metadata should be captured as well. Refer to SOPs 2–8 for data and metadata collection guidelines.

2. Data Archival

All raw data, whether written or electronic, should be archived in electronic form on a network server that is backed up regularly. Raw digital data files should be in a uniform, common, and easily accessible data format such as *.txt, *.csv, or *.xml. The original data structure and supporting metadata should be maintained as much as possible; however, it is imperative that this raw, electronic data not be archived in a manufacturer's proprietary format. Access to this data will become difficult if left in the manufacturer's proprietary format, as proprietary formats typically have limited life spans.

Written field datasheets, supporting documentation, and any notes should be converted to digital format ─ preferably to a standard format, such as pdf (Portable Document Format) ─ and then archived to electronic storage, unless they are already captured somewhere else in an electronic file in the archive. It is redundant to have both a scanned document and an electronic file containing the same information.

The file naming of archived records should follow accepted SWAN file naming standards. Metadata about the electronic archive files (file name, file location, etc.) should be captured and made accessible. All data should be traceable back to their original, archived source. This ability to trace the path of data is handled primarily through metadata.

3. Data Entry/Import

Written field data should be entered manually into an electronic format amenable to the input requirements of the database. Written metadata also should be captured in electronic format. The link between the data and metadata should be preserved, such that any single datum is associated with appropriate metadata that describes its acquisition source, conditions, and other attributes. See SOP10 for the specific input requirements for both data and metadata, as well as the appropriate input forms that should be used. Logger data already in electronic format should be put in a format amenable to uploading to AQUARIUS. See SOP10 for these requirements. It is important that data, whether written or electronic, be promptly entered and imported into AQUARIUS for verification and validation purposes (see below). Prompt input minimizes the chances of accidental loss and allows the project leader to identify problems early on.

4. Data Verification

Verification of handwritten field data consists of checking both the original written and subsequent electronic forms for accuracy and completeness. Spot checking for consistency between the written field data and the input, electronic version of the same data (e.g., Excel spreadsheets) should be performed as part of the verification process. The project leader and project staff should perform this check as a routine step in the process of data entry and importation. Metadata contained on both handwritten field forms and Microsoft Excel spreadsheet field forms should be verified in a similar fashion. Verification is also performed using AQUARIUS. It is important to note that all data, both written and electronic, should pass through the verification checks provided, or specifically invoked, in AQUARIUS.

5. Data Validation

Whereas data verification primarily involves catching transcription errors, data validation involves assessing whether or not “Measurement Quality Objectives” are met (see SOP13). Data validation includes, but is not limited to, checking for out-of-bound values (domain checking), expected rates of change, missing or erroneous values, bias or drift, and outliers. Due to the large volume of continuous data that will pass through the validation stage of the data life cycle, the primary validation methods are handled in AQUARIUS (see SOP11), in association with random spot checks, administered by project staff. Random spot checks should be performed by the project leader or project staff on approximately 10% of the gathered values, to assure that data are of high quality. If errors are discovered, the group of data associated with the suspect data should be scrutinized and the source of the anomaly should be determined. Note that outliers which seem extreme but possible will not be deleted since they might, in fact, be real and very important.

6. Documentation and Certification

Documentation involves the consolidation of metadata created up to this point in the data life cycle. All metadata, whether created before, during, or after field data acquisition, should be captured in the appropriate location within AQUARIUS. The next step, certification, cannot occur until all metadata are captured and documented, and all data values have been entered, verified, and validated. In other words, certification is a confirmation by the project leader that the data have passed all existing import, verification, and validation checks, and the data are complete and well-documented (e.g., complete metadata). Data should not be imported into the project database until documentation and certification are complete. The project leader should be responsible for determining certification and documentation, with the assistance of the data manager, if necessary. This is a critical component to the process, as the reliability of the database as a repository for high-quality and well-documented freshwater monitoring data will be compromised if this step is not completed.

7. Data Versioning

AQUARIUS keeps an unaltered raw copy of all data uploaded to it. Subsequent changes to the data are tracked in the database as a "change history." Because the history of all data alterations is maintained within AQUARIUS (along with the instigator of and the rationale for each alteration), SWAN will not create separate archival versions of the data.

8. NPSTORET Electronic Data Deliverable Specification

A subset of the SWAN water quality database will be used to satisfy the Natural Resource Challenge Water Quality STORET reporting requirement (NPS 1999) on an annual basis. However, due to differences in the temporal scale of continuous water quality being stored in AQUARIUS versus the current point/site discrete nature of NPSTORET and STORET, it will be necessary to transform the dataset to match the NPS STORET Electronic Data Deliverable File Specifications v.1.1 (March 15, 2007) as much as reasonably possible. Since there is not a direct, one-to-one relationship between many of the fields in AQUARIUS and the fields found in the NPSTORET/STORET system, this transformation will reduce the dataset delivered to NPSTORET, with the majority of the reduction occurring in how attributes are summarized.

9. Reporting and Analysis

Certified data should be used in all reporting and analysis duties. A basic set of queries and reports should be developed by the data manager, based on input from the project staff. This basic set of queries and reports should assist in standard water quality reporting and analysis responsibilities. More complex queries, reports, or custom, one-time queries and reports, should be created on an ad-hoc basis after consensus between the data manager and project leader is reached. See SOP14 for more on reporting and analysis.

10. Sharing

When available, information should be shared with both the NPS and the public. Certified data should be shared via the AQUARIUS web portal (https://irma.nps.gov/aqwebportal/), hosted in Fort Collins. Summary reports, maps, and basic statistics should be disseminated through the SWAN website, IRMA portal, or other NPS-based report and data sharing sources. Requests for specific products will be handled on an ad-hoc basis by the project leader. Freedom of Information Act (FOIA) requests should be handled by the project leader, in consultation with the data manager. See SOP14 for more information on reporting and analysis.

11. Database Edits

All changes to certified data are documented in a "change history" stored in AQUARIUS. Requests for changes to data and metadata contained within the SWAN water quality database should come from the project leader and should be reviewed and approved by the data manager. Depending on the significance and impact of the requested edits on existing data, revised project data may need to be reposted to various stakeholders.

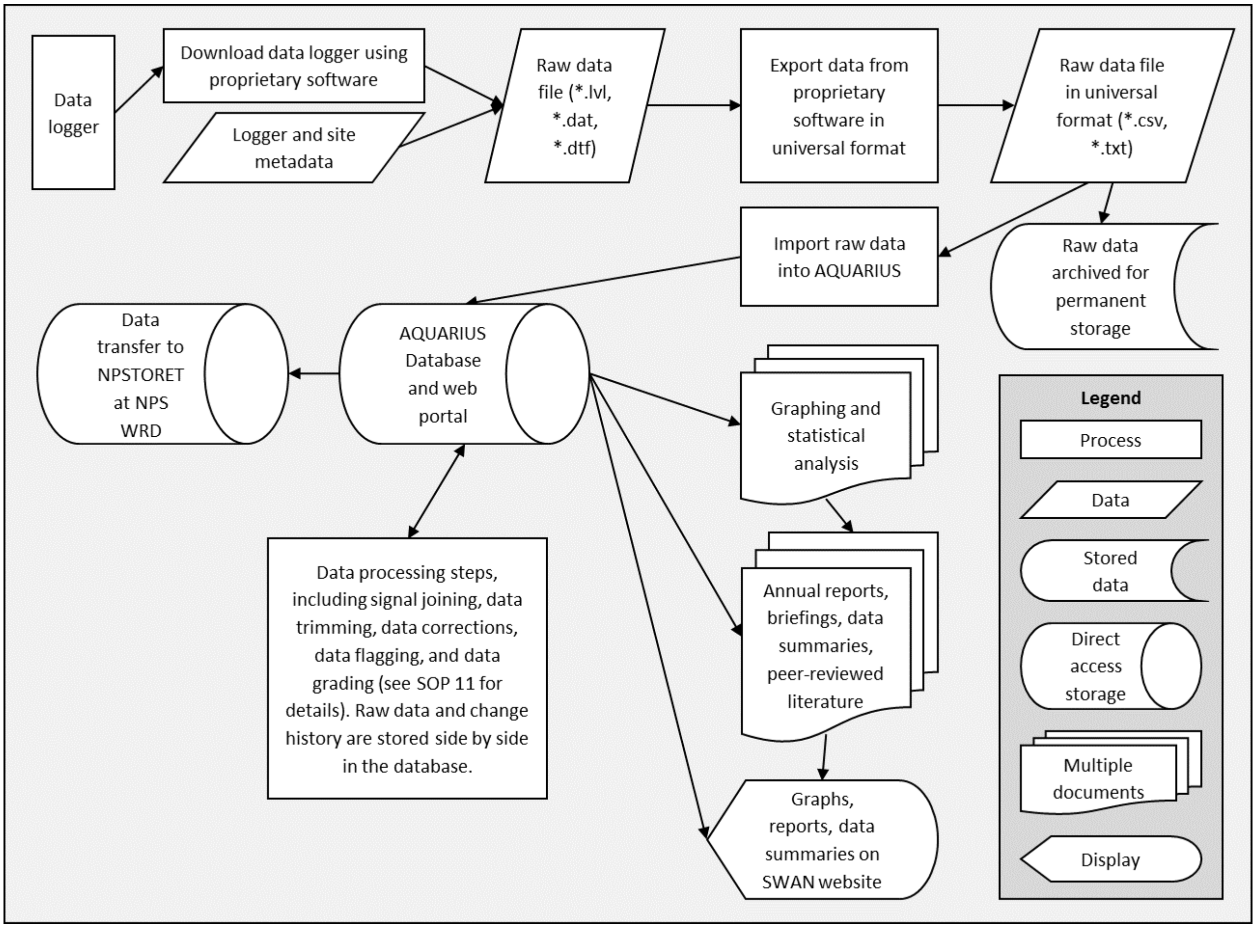

Figure 12.2. Alternate view of life cycle for freshwater monitoring data.

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SOP13: Quality Assurance/Quality Control

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

Suggested Reading

Irwin, R. J. 2008. Draft part B lite QA/QC review checklist for aquatic vital sign monitoring protocols and SOPs. National Park Service, Water Resources Division, Fort Collins, Colorado. Available at: http://www.nature.nps.gov/water/vitalsigns/assets/docs/PartBLite.pdf.

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SOP13 - Contents

SOP13 - Tables

Introduction

This standard operating procedure (SOP) defines procedures for quality assurance and quality control to be used with the Southwest Alaska Network (SWAN) protocol for freshwater monitoring. Quality assurance is the planned and systematic pattern of all actions necessary to guarantee that a project outcome optimally fulfills expectations. Quality control is the systematic evaluation of the various aspects of a project to ensure that the standards of quality are being met. Quality control includes quantifiable performance indicators like measurement precision, measurement bias, and measurement sensitivity; whereas, most quality assurance measures are qualitative aspects such as staff training and qualifications. Together, quality assurance/quality control (QA/QC) is a substantial part of any monitoring program. The objective of QA/QC is to ensure that the data generated by a project are meaningful, representative, complete, precise, comparable, scientifically defensible, and reasonably free from bias (Irwin 2008).

The overall goal of SWAN freshwater monitoring is to provide park managers with information needed to make management decisions that will maintain the ecosystem integrity that characterizes the large lake systems within southwest Alaska park units. Specific monitoring objectives are to answer the following questions:

- What are the status and trend of core parameters (temperature, specific conductivity, pH, and dissolved oxygen) throughout the water column during the mid-summer index period for high-priority lake systems?
- What are the status and trend of the core parameters and turbidity at select high-priority lake outlets during the ice-free period (approximately late May through September)?
- What are the status and trend of lake temperature, duration and depth of thermocline, stratification patterns, and warming and cooling patterns in high-priority lake systems?
- What are the status and trend of the timing, duration, and magnitude of peak summer discharge at the outlets of high-priority lake systems?
- What are the status and trend of the timing, duration, and magnitude of peak summer lake levels at the outlets of high-priority lake systems?

This SOP describes the step-by-step QA/QC procedures for ensuring that SWAN freshwater monitoring data are of known quality, pertinent to monitoring objectives, and useful for future investigations. The general content and formation of this SOP are based on U.S. EPA 2001 and Irwin 2008. The majority of the SOP pertains specifically to quality control for continuous water quality data collected from lake outlets (second bullet above) using YSI 6-series multiparameter sondes. The range, accuracy, and resolution of each sonde sensor used by SWAN are listed in Table 13.1.

Table 13.1. Range, accuracy, and resolution of YSI 6-series sonde sensors used by SWAN for core water quality parameter measurement.

Sensor	Sensor Model	Range	Resolution	Accuracy
Temperature	6560	-5 to +50 °C	0.01 °C	± 0.15 °C
Specific Conductivity	6560	0 to 10^5 μS/cm	1 to 100 μS/cm (range dependent)	± 0.5% of reading + 1 μS/cm
pH	6561	0 to 14 pH units	0.01 pH unit	± 0.2 pH unit
Dissolved Oxygen (mg/L) Rapid Pulse Sensor	6562	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ± 0.2 mg/L or ± 2% of reading, whichever is greater; 20 to 50 mg/L: ± 6% of reading
Dissolved Oxygen (% saturation) Rapid Pulse Sensor	6562	0 to 500%	0.1%	0 to 200%: ± 2% air saturation or ± 2% of reading, whichever is greater; 200 to 500%: ± 6% of reading
Dissolved Oxygen (mg/L) Optical Sensor	ROX 6150	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ± 0.1 mg/L or ± 1% of reading, whichever is greater; 20 to 50 mg/L: ± 15% of reading
Dissolved Oxygen (% saturation) Optical Sensor	ROX 6150	0 to 500%	0.1%	0 to 200%: ± 1% air saturation or ± 1% of reading, whichever is greater; 200 to 500%: ± 15% of reading
Turbidity	6136	0 to 1,000 NTU	0.1 NTU	± 0.3 NTU or ± 2% of reading, whichever is greater
Depth	Deep Medium Shallow Vented Level	0 to 656 ft (200 m) 0 to 200 ft (61 m) 0 to 30 ft (9.1 m) 0 to 30 ft (9.1 m)	0.001 ft (0.001 m) 0.001 ft (0.001 m) 0.001 ft (0.001 m) 0.001 ft (0.001 m)	± 1 ft (0.3 m) ± 0.4 ft (0.12 m) ± 0.06 ft (0.02 m) ± 0.01 ft (0.003 m)

Measurement Quality Objectives (MQOs)

This section, adapted from Sharrow et al. 2007, is intended to demonstrate how this project (i.e., SWAN freshwater monitoring) generates data of known and documented quality, resulting in complete, accurate, and transferable information. Data credibility necessary for the intended uses will be achieved when data are:

1. Consistent over time and consistent between staff members;
2. Collected and analyzed using standardized and acceptable techniques;
3. Comparable to data collected in other assessments using the same methods; and
4. Used appropriately to make decisions based on sound statistics.

Data Quality Objectives (DQOs)

Data quality objectives (DQOs) are quantitative and qualitative performance and acceptance criteria that describe how good data need to be in order to meet project objectives. DQOs for measurement data (referred to here as data quality indicators) are discussed in detail below but are listed by the NPS Water Resources Division (Irwin 2008) as:

1. Target population
2. Representativeness
3. Completeness
4. Data comparability
5. Measurement sensitivity and detection limits
6. Measurement precision as repeatability
7. Measurement systematic error/bias

Target Population

The initial target population for the freshwater monitoring protocol was defined as representative SWAN waterbodies. Logistical and budgetary constraints prevent sampling of all SWAN waterbodies. Thus, the sample population is defined as lakes and lake outlets selected through a priority ranking process by park resource managers, SWAN staff, and invited subject matter experts. Selected waterbodies and the sampling design are justified in the protocol narrative (Shearer et al. 2015).

Representativeness

We seek to characterize lake-wide conditions by profiling water quality parameters at randomly selected, spatially balanced sample sites during a synoptic survey. The general random tessellation stratified (GRTS; Stevens and Olsen 2004) survey design allows us to extrapolate sample site patterns throughout a lake basin (see SOP2). We will monitor water quality parameters at lake outlet sites selected primarily based on site accessibility considerations (see SOP4 and Wagner et al. 2006 for further details). We will select those monitoring sites with low cross-sectional variability so that sample point conditions are better representative of the entire channel cross-sectional profile.

We recognize that water quality and quantity conditions vary at multiple temporal scales (i.e., annually, seasonally, daily). To account for this temporal variability, we will implement two approaches: 1) conduct synoptic surveys during an index period (late July through late August); and 2) use automated data loggers to record frequent observations that capture diel and seasonal variation. Vertical lake profiles will be collected during the same index period each year to reduce the confounding influence of seasonal variation when making comparisons between years.

Completeness

Every attempt will be made to sample all sites as scheduled each year, but weather conditions — especially winds — may limit the ability to access sites safely. Therefore, 100% of sites may not be sampled as scheduled each year. However, sampling within an index period provides some flexibility in scheduling follow-up trips to relatively accessible lakes (Lake Clark and Naknek Lake) to sample sites that may have been missed due to inclement weather. Follow-up trips to other, less accessible lakes may not be possible due to logistical and budgetary constraints on acquiring float plane services. Sites that are sampled with automated data loggers are not as affected by inclement weather, although sensor failure is possible. Multiparameter sondes will be inspected approximately once per month to reduce the chance of battery or sensor failure.

Data Comparability

Data comparability through time — even when sensors, instruments, and staff change — is ensured by following guidelines set forth in the SWAN freshwater monitoring protocol. Changes in equipment or methods will be recorded in the appropriate SOP. This protocol emphasizes the use of multiparameter sondes to record core water quality parameters. Pre- and post-deployment calibration information is recorded in spreadsheets of files called SWAN_MPSonde_ calibrationforms_MASTERCOPY.xlsx (for vertical lake profile and in-situ data) and SWAN_Continuous_Calibration_Drift_Corrections_MASTERCOPY.xlsx (for continuous data) located on the T Drive at T:\Vital_Signs\Water_Fish\Electronic_Field_Forms\SWAN_Master_ Copies (see SOP3). These spreadsheets have built-in quality control checks that calculate sensor error and bias based on observed (i.e., instrument readings) and expected (i.e., calibration standards) values and report whether data meet data quality objectives. Additionally, these spreadsheets allow for the recording of sensor calibration constants, slope, and offsets, providing a tracking record of sensor performance and an indication of expected replacement. Finally, the “Record of Bias” file developed by the NPS Water Resources Division (NPSWRD_Record_of_bias_080428.xlsx) should be used to ensure that new and old instruments or methods produce comparable data. The worksheet is located at T:\Vital_Signs\Water_Fish\Electronic_Field_Forms\SWAN_Master_Copies\Record_of_ Bias_Form.

Measurement Sensitivity and Detection Limits

The low-level method detection limit (MDL) and minimum level of quantitation (ML) are the terms used to describe, respectively, the smallest presence that can be observed and the accurate quantity of an analyte of interest. They are important concepts in water quality data reporting and analysis for many reasons especially when considering chronic low-level pollution that is near detection limits of analysis methods (Irwin 2008). These values will be updated/reported at least once per year or when methods change, and they will become part of the permanent data record (Sharrow et al. 2007). Values below the MDL and ML will be reported as “present less than quantitation limit” or as “non-detectable.” The only core water parameter that occurs at levels near the lower detection limit in SWAN waters is turbidity.

Because values for core water quality parameters are expected to be in the quantitative range or well above the detection limits of the sensor, detection limits are not reported. For this reason, we will not determine MDL and ML for temperature, specific conductivity, pH, or dissolved oxygen. Instead, post-calibration laboratory sensitivity will be evaluated using Alternative Measurement Sensitivity (AMS) first described by Irwin (2008). AMS uses seven replicate measurements made in a controlled environment (e.g., a stabilized water bath) in quick succession to determine instrument noise. Field-measured sensitivity for core parameters will be evaluated using Alternative Measurement Sensitivity Plus (AMS+) (Irwin 2008). AMS+ is based on seven field measurements conducted in-situ and provides an estimate of both instrument noise and very short term natural heterogeneity.

Method Detection Limit

The method detection limit (MDL) is the lowest value that can be distinguished from zero. SWAN will document MDL for turbidity at least once per year and more frequently as personnel and method changes dictate. MDL will be based on seven measurements of a very low concentration sample (near 0.1 NTU). To determine the MDL, at least seven replicate samples with a concentration of the constituent of interest near the estimated detection capabilities of the method are analyzed. The standard deviation among the replicate measurements is determined and multiplied by the upper (one-sided) t-value for n-1 degrees of freedom (df). In the case of 7 replicates (n), the multiplier is 3.143, which is the one-sided t-value for 6 df and an α level of 0.01 (i.e., a confidence interval (CI) of 99%; Irwin 2008). MDLs for each sonde’s turbidity sensor will be reported when data are uploaded into the AQUARIUS database.

Minimum Level of Quantitation

The minimum level of quantitation (ML) is the lowest value that can be reliably measured (Sharrow et al. 2007). Within NPSTORET, ML is synonymous with “lower quantitation limit” (LQL). ML will be determined by multiplying the MDL by 3.18 (Irwin 2008). The ML will be calculated annually for turbidity only, as other core water quality parameters do not approach lower detection limits in SWAN waters. MDLs for each multiparameter sonde will be reported when data are uploaded into the AQUARIUS database.

Alternative Measurement Sensitivity Plus

Alternative Measurement Sensitivity Plus (AMS+) is a way of evaluating the variability of repeated measurements on a single, in-situ environmental sample that is above the low-level MDL. Over time, AMS+ can be used to bound field measurement uncertainty. It includes instrument noise and short term, natural heterogeneity inherent in measurement of water in-situ, particularly flowing water (Sharrow et al. 2007). It is calculated as:

$$SD \times t$$

where *SD* is the standard deviation of 7 measurements obtained in-situ, and *t* = 3.707, the two-sided t-value for n = 7, df = 6, α level = 0.01, and CI = 99%. SWAN will determine AMS+ based on 7 measurements of nearby, but not identical, samples recorded in the field with a multiparameter sonde (Irwin 2008). In flowing water, these measurements can be recorded in rapid succession; however, it is critical that sensors have adequate time to acclimate and readings stabilize prior to recording measurements. These seven measurements will be recorded at the start and end of each operational period when a multiparameter sonde is deployed for unattended sampling and when in-situ samples are collected during site visits. The seven readings are recorded in the Site_Visit_Measurements worksheet of the file called SWAN_Continuous_Calibration_Drift_Corrections_MASTERCOPY (see SOP4). Blank forms are available on the T Drive (T:\Vital_Signs\Water_Fish\Electronic_Field_Forms\SWAN_Master_Copies\Continuous_Calibration_and_Drift_Correction_Form).

Measurement Precision as Repeatability

Relative Percent Difference

Relative Percent Difference (RPD), or "Precision Plus," is the variability of repeated measures of two samples collected in close proximity (Starkey et al. 2009). It is a less rigorous measure of sensitivity than the AMS+ statistic because of its smaller sample size (RPD n = 2; AMS+ n = 7), but it is used more frequently to ensure measurements are "in control," especially in laboratory analyses where seven replicates are not always practical (Sharrow et al. 2007). RPD is calculated as:

$$\left[\frac{(S_1 - S_2)}{\left(\frac{(S_1 + S_2)}{2}\right)}\right] \times 100$$

where S_1 is the larger test result value and S_2 is the smaller test result value.

SWAN will calculate RPD based on data obtained during sonde calibration and error checks (as outlined in SOP3). Immediately after each sensor is calibrated, it is placed in a standard solution to verify calibration success. This measurement is recorded as the "Post-Cal. Reading" on the instrument calibration form (SWAN_MPSonde_calibrationforms_MASTERCOPY.xlsx or SWAN_Continuous_Calibration_Drift_Corrections_MASTERCOPY.xlsx). Then, after all sensors are calibrated and error-checked, each is placed in its corresponding calibration solution for a duplicate reading (see SOP3). These post-cal. and duplicate readings provide the S_1 and S_2 values used in the RPD calculation.

Measurement Systematic Error/Bias

Systematic error/bias is the persistent distortion of a measurement process that causes errors in only one direction (usually high or low). For historical comparisons, results for lab determination of systematic error/bias are usually expressed in terms of % recovery, with the correct or expected result considered to be 100%, and an acceptable range (used herein) between 90 and 110% for core parameters (Irwin 2008, Sharrow et al. 2007). During each site visit to (or calibration of) multiparameter sondes, SWAN will determine the amount of error caused by fouling and calibration drift as described in SOPs 4 and 11. For continuous monitoring (i.e., unattended sonde deployments), the raw values for systematic error/bias will be recorded in the corresponding Fouling_and_Drift_Corrections worksheet of the SWAN_Continuous_Calibration_Drift_Corrections_MASTERCOPY.xlsx file as "fouling correction" and "drift correction." For each parameter, the percent difference (*PD*) will be calculated from these raw values as:

$$PD = \left[\frac{(Y - X)}{X}\right] \times 100$$

where X and Y depend on whether the calculation is intended for fouling or drift correction. If PD pertains to fouling, X and Y represent the parameter values after and before sensor cleaning (respectively) during the site visit. If PD pertains to drift, X is the known value of the calibration standard, and Y is the measured parameter value when placed in the calibration standard.

When data from multiparameter sondes are processed for analysis, before they are uploaded into the AQUARIUS database, they will be corrected and graded to account for fouling and drift error. Data corrections will be applied if the sum of the absolute *PD* values for fouling and drift error exceeds the criteria listed in Table 13.2. Data grades (i.e., accuracy ratings) will be based on the data corrections needed to account for the combined fouling and drift error, and will be applied for each period of deployment (Table 13.3). Correction criteria and data grades are based on USGS standards outlined in Wagner et al. 2006. For additional details, see SOP11.

Table 13.2. Criteria for applying water quality data corrections (modified from Wagner et al. 2006).

Parameter	Data Correction Criteria
Temperature	± 0.2 °C if checked with a meter from the same manufacturer; ± 0.5 °C if not
Specific Conductivity	± 5 µS/cm or ± 3% of the measured value, whichever is greater
pH	± 0.2 pH units
Dissolved Oxygen	± 0.3 mg/L
Turbidity	± 0.5 turbidity units or ± 5% of the measured value, whichever is greater

Table 13.3. Data grades for continuous water quality records (developed by Wagner et al. 2006). Data grades are based on the combined fouling and drift corrections applied to the record.

	Data Grade			
Parameter	**Excellent**	**Good**	**Fair**	**Poor**
Temperature	< ± 0.2 °C	> ± 0.2–0.5 °C	> ± 0.5–0.8 °C	> ± 0.8 °C
Specific Conductivity	< ± 3%	> ± 3–10%	> ± 10–15%	> ± 15%
pH	< ± 0.2 units	> ± 0.2–0.5 units	> ± 0.5–0.8 units	> ± 0.8 units
Dissolved Oxygen	< ± 0.3 mg/L or < ± 5%, whichever is greater	> ± 0.3–0.5 mg/L or > ± 5– 0%, whichever is greater	> ± 0.5–0.8 mg/L or > ± 10–15%, whichever is greater	> ± 0.8 mg/L or > ± 15%, whichever is greater
Turbidity	< ± 0.5 NTU or < ± 5%, whichever is greater	> ± 0.5–1.0 NTU or > ± 5–10%, whichever is greater	> ± 1.0–1.5 NTU or > ± 10–15%, whichever is greater	> ± 1.5 NTU or > ± 15%, whichever is greater

Pre- and post-deployment calibration and error checks will be conducted prior to vertical lake profile and unattended continuous sampling to ensure all sensors are functional and to minimize bias (see SOP3). During pre- and post-deployment calibrations, all sensors must calibrate and remain within the calibration criteria during error checks as defined in Table 13.2 and SOP3. All calibration data are recorded in the worksheets of SWAN_MPSonde_calibrationforms_MASTERCOPY.xlsx or SWAN_Continuous_Calibration_Drift_Corrections_MASTERCOPY.xlsx, and are then archived as metadata in AQUARIUS. During unattended deployments, sondes will be inspected, error-checked, and recalibrated approximately once per month (as outlined in SOPs 3 and 4). All calibrations and error checks are currently conducted in a controlled environment at an NPS facility within 8 hours of deployment or retrieval (often within 2 hours). In the future, we will explore the possibility of conducting calibrations and error checks adjacent to the deployment site to reduce the amount of time instruments sit idle between calibration and operation. All calibrations and error checks are preformed according to guidelines listed in the YSI 6-series sonde manual (YSI 1999) and Wagner et al. 2006.

Summary of Metrics Applied to Water Quality Parameters

Below (and in Table 13.4) is a summary of the various metrics SWAN uses for quality control of water quality data. All metrics should be recorded in the worksheets of either SWAN_MPSonde_calibrationform_MASTERCOPY.xlsx or SWAN_Continuous_Calibration_Drift_Corrections_MASTERCOPY.xlsx, and then archived as metadata in AQUARIUS.

1. Method Detection Limit (MDL): for turbidity sensors on YSI 6600 or 6920 multiparameter sondes. MDL is determined in the lab/office each year using a low signal standard (e.g., near 0.1 NTU). **Note:** turbidity sensors are not available on the YSI 600QS sondes used for vertical lake profiles.
2. Minimum Level of Quantitation (ML): for turbidity sensors on YSI 6600 or 6920 multiparameter sondes. ML is calculated from MDL.
3. Alternative Measurement Sensitivity Plus (AMS+): for all core parameters except turbidity during unattended deployments.
4. Relative Percent Difference (RPD) or precision: based on data collected following each calibration using standard solutions and calibrated sensors.
5. Percent Difference (PD) or bias: based on data collected during each calibration and error-check, before and after unattended sonde deployment and vertical lake profile measurements. Two PD values will be recorded for unattended sonde deployments: one to account for % fouling, and another to account for % drift.

Table 13.4. Comparison table of QC data quality indicators used by the SWAN (modified from Irwin 2008).

Acronym	Metric	Description	Purpose	Sample Size	Equation	Minimum Frequency of Reporting	STORET Note
MDL	Method Detection Level	Represents the lowest value that can be differentiated from zero; the lower semi-quantitative type of detection limit	Control of very low level sensitivity (usually for lab measurements)	7	Obtain MDL from lab; for field samples, calculate as 3.134 * SD of a blank or low signal solution	Once per year or when methods change	Record in "Detection Limit" field. If the result is <MDL, STORET Detection Condition is "Not Detected"
ML	Minimum Level of Quantitation	Represents the lowest quantitative value	Quantitative sensitivity as detection limit (usually for lab measurements)	1 (based on single MDL)	MDL * 3.18	Once per year or when methods change	Record in "Lower Quantitation Limit" field
AMS	Alternative Measurement Sensitivity	Provides an estimate of instrument noise – i.e., how big of a change is real	Sensitivity (usually for lab measurements)	7 measurements in a controlled environment	SD * 3.707	Beginning and end of field seasons	Record in "Analytical Procedure Description" field
AMS+	Alternative Measurement Sensitivity+	Provides an estimate of instrument noise and natural heterogeneity	Total variability of close replicates (usually for field measurements, or whenever MDL is NA)	7 measurements of nearby but not identical samples, in-situ for sondes only	SD * 3.707	Beginning and end of field seasons	Record as stated above for AMS, if no other form of AMS is reported
RPD	Relative Percent Difference	Represents the variability of repeated measures	Precision (for lab or field measurements)	1 comparison of 2 measurements collected in close proximity	$[(S_1 – S_2) / ((S_1 + S_2)/2)] * 100$	1 for every 20 samples	Record as stated above for AMS, if no other form of precision is reported
PD	Percent Difference	Represents the difference between measured result and expected result, based on a reference sample standard or spike	Bias (for lab or field measurements)	1 comparison of 2 values (the measured result and the expected result)	$[(Y – X)/X] * 100$, where X is the expected value and Y is the measured value	1 for fouling bias and 1 for drift bias, for each parameter, every deployment period	Record both values on which PD was based; could also include PD as a comment - choose Reference Sample and Field Spike

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SOP14: Data Analysis and Reporting

Version 1.00, January 2015

Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #

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Introduction

This standard operating procedure (SOP) provides general guidance for analyzing and reporting water quality and quantity data collected as part of the SWAN freshwater monitoring protocol. Data analysis refers to the summarization and transformation of environmental observations into meaningful information, whereas data reporting is the written and graphical presentation of that information to park managers, the scientific community, and the general public. Before data analyses are performed, data processing, quality assurance/quality control and management procedures must be followed, as outlined in SOPs 11–13.

Data analysis methods should be linked directly to the monitoring objectives (see the protocol narrative; Shearer et al. 2015), as well as the temporal and spatial aspects of the sampling design, and the expected uses of the data (MacCluskie et al. 2005, Bennett et al. 2006). The data analysis procedures described in this SOP include 1) summary statistics generated each year for inclusion in annual summary reports, and 2) trend analyses conducted every five years for inclusion in five-year synthesis reports. Annual summary reports provide a descriptive synopsis of field observations. Five-year synthesis reports provide an in-depth examination of trends, a power analysis of pilot data, and an opportunity to integrate water quality and quantity data with datasets from other vital signs, as well as provide an assessment of power analysis as pilot data are collected.

A wide variety of statistical and graphical analysis software is available to natural resource professionals. Summary statistics will be generated in Microsoft Excel or AQUARIUS Time-Series software (http://aquaticinformatics.com/products/aquarius-time-series/), while graphical displays will be produced with AQUARIUS, SigmaPlot (http://www.sigmaplot.com/), or R (http:www.r-project.org/). SWAN will also use R as its primary platform for trend analysis. Mention of trade names or commercial products within this SOP does not constitute endorsement or recommendation for use by the National Park Service.

Annual Data Analysis and Reporting

Data Preparation

The processing of raw data for analysis and reporting involves several steps that are detailed in SOP 11. Processing steps include trimming erroneous data points (e.g., air temperature readings from thermistors during data downloading), applying data corrections due to biofouling or calibration drift, and assigning qualitative data grades. Data transformations represent another step that may be needed prior to analysis of monitoring data.

The objective of data transformation is to improve the variance, linearity, or symmetry of the data (Helsel and Hirsch 2002). Logarithmic transformations are often applied to parameters that span several orders of magnitude or a broad range, such as discharge. Flow-adjusting or flow-weighting is another common type of transformation for parameters influenced by discharge, such as turbidity. Flow-adjusting simply involves dividing the concentration of the parameter by the discharge at the time the parameter was collected in order to make the data more symmetrical. Data transformation does not change the median or interquartile range (IQR); however it does change the mean and standard deviation (SD) (Helsel and Hirsch 1992). Therefore, all four statistics (mean, median, SD, and IQR) are reported for parameters that are typically non-parametric. SWAN is developing stage/discharge rating curves for several lake outlets (i.e., Lake Clark). Until these rating curves are developed and discharge can be estimated, flow-adjustments of parameters collected at these outlets will not be possible.

Data Analysis

The SWAN freshwater monitoring sample design covers both targeted and probabilistic sampling with four primary areas of focus: 1) a spatially balanced snapshot of lake water quality along a vertical profile during the mid-summer index period, 2) continuous monitoring of lake temperature at targeted locations year-round, 3) continuous monitoring of water quality at targeted lake outlets during open water periods, and 4) monitoring of lake level and discharge at targeted lake outlets. The annual data analysis procedures for each monitoring component are described separately below.

Annual Summary of Vertical Lake Profile Data

Lake profiles are measured to provide an assessment of the vertical range of core water quality parameters from the lake surface to 50 m depth or the lake bottom. Lake profile data will be summarized to provide a spatial synopsis of lake-wide conditions or compared among basins within a lake (e.g., Iliuk Arm vs. North Arm of Naknek Lake). Summary statistics for lake profile data will consist of the mean, SD, maximum, and minimum for each parameter at a given depth, among sites. Additional summary statistics might also be calculated. Graphical displays will primarily consist of the depth profiles (Figure 14.1), although boxplots (Figure 14.2) and bar graphs (Figure 14.3) could be used to depict differences in water quality among basins or changes in water quality due to environmental events.

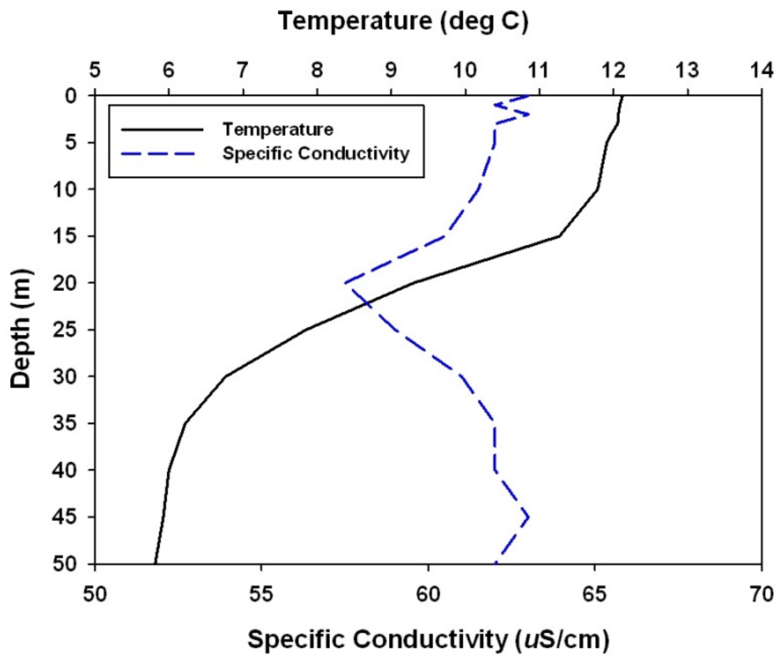

Figure 14.1. Depth profile of water temperature and specific conductivity for a sample location in the upper basin of Lake Clark.

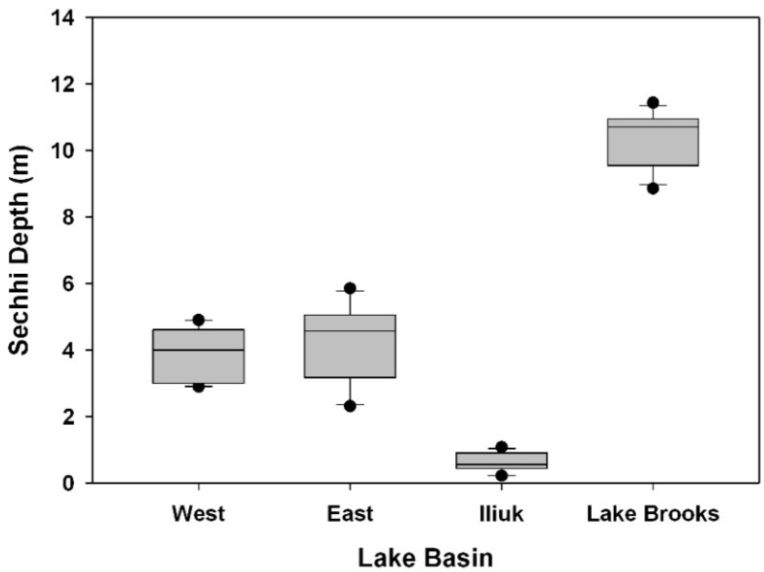

Figure 14.2. Boxplot illustrating the range of Secchi depths recorded in three Naknek Lake basins and Lake Brooks.

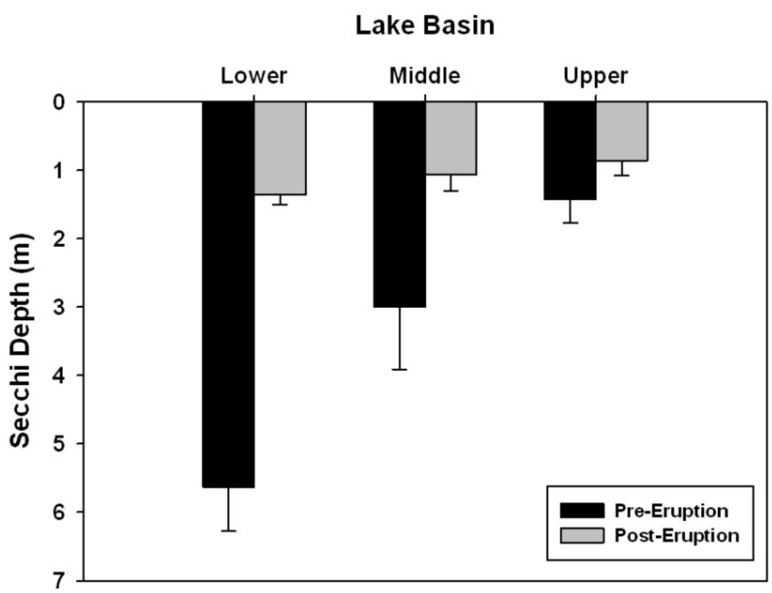

Figure 14.3. Bar plot of Secchi depths recorded in three Lake Clark basins before and after the March 2009 eruption of the Redoubt Volcano.

Annual Summary of Lake Water Temperature Data

Water temperature within Tier 1 lakes is monitored year-round to provide an assessment of seasonal warming and cooling patterns, lake stratification, and periods of isothermy. Water temperature is recorded on a 1-hour interval year-round at depths of 5 m, 10 m, and every 10 m to the lake bottom or 100 m. For each depth, we will first calculate the daily (24-hour) mean and SD for each day of record since our primary interests are monthly and seasonal rather than diel patterns. We will then focus on the 5 m dataset of daily means for the annual summary, as it provides a continuous record of near-surface water temperatures. For each month, maximum and minimum average daily temperatures (and SDs) will be reported, along with the warmest day and 7-day period (dates, mean temperatures, and SDs reported) for the year. Additionally, monthly degree days — the cumulative difference between the daily mean and 0 °C for each month — will be reported. See Table 14.1 for an example. Additional summary statistics might also be computed.

Graphical presentations of lake water temperature data will primarily consist of bivariate plots and isotherms. Bivariate, or time series, plots provide a visual assessment of water temperature versus time (Figure 14.4). These plots are especially useful for illustrating abrupt changes in temperature that may indicate lake freeze-up, major wind events, or some other environmental influence. Isotherms provide a two-dimensional view of three-dimensional data — for our purposes, water temperature versus depth and time (Figure 14.5). Isotherms are useful for visualizing lake stratification patterns. It should be noted that multiple bivariate plots (e.g., water temperature from multiple depth intervals plotted against time) provide the same information as an isotherm, but the option to fill gradients between depth intervals with color aids in visual interpretation. Contour plots, also referred to as isopleth plots, provide a visual assessment of lake stratification patterns between depth intervals (Figure 14.6), but they lack the continuous gradient of temperature change illustrated in isotherms.

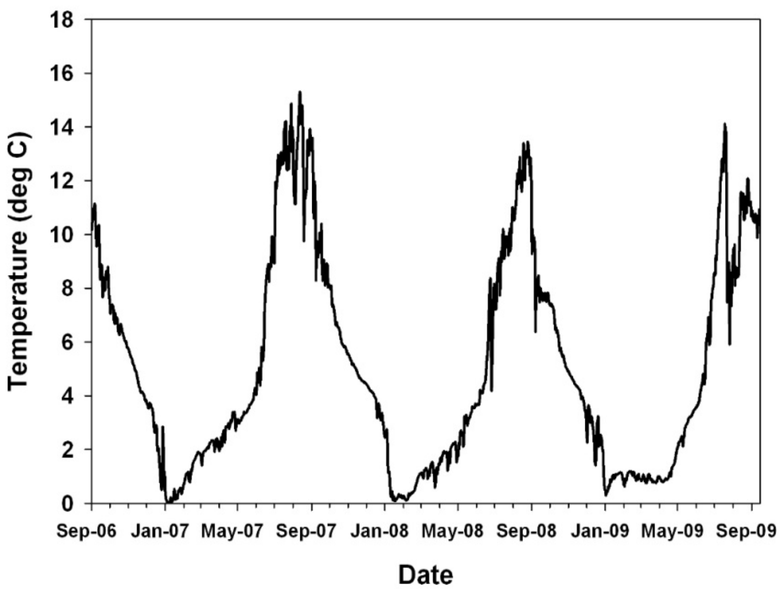

Figure 14.4. Bivariate plot of near-surface (5 m) water temperature data for Lake Clark between September 1, 2006 and September 1, 2009.

Table 14.1. Example summary of near-surface (5 m) water temperature data for Lake Clark between January 1, 2007 and September 1, 2009.

	Max. Avg. Daily Temperature [a] Mean (1 SD [d]); °C			Min. Avg. Daily Temperature [b] Mean (1 SD [d]); °C			Monthly Degree Days [c]		
Month	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
January	0.7 (0.1)	2.7 (0.0)	1.1 (0.0)	< 0.1 (0.0)	0.1 (0.0)	0.3 (0.1)	8	22	27
February	1.9 (0.1)	1.1 (0.1)	1.2 (0.0)	0.7 (0.1)	0.1 (0.0)	0.6 (0.0)	38	14	28
March	2.4 (0.0)	1.5 (0.1)	1.1 (0.0)	1.4 (0.2)	0.6 (0.1)	0.8 (0.0)	65	37	28
April	3.4 (0.5)	2.3 (0.1)	2.0 (0.1)	2.0 (0.1)	1.2 (0.3)	0.8 (0.0)	83	56	34
May	4.3 (0.1)	3.7 (0.1)	3.6 (0.1)	3.0 (0.2)	1.8 (0.3)	2.1 (0.1)	108	92	89
June	9.9 (0.5)	8.4 (0.9)	8.5 (0.7)	4.0 (0.0)	3.6 (0.0)	3.6 (0.0)	204	155	160
July	15.0 (0.9)	11.0 (0.5)	14.1 (0.2)	8.9 (0.3)	7.2 (0.3)	5.9 (0.5)	395	285	321
August	15.9 (0.4)	13.5 (0.5)	12.1 (0.1)	10.3 (1.2)	10.5 (0.3)	8.1 (0.5)	403	378	320
September	13.5 (0.3)	10.2 (0.2)		7.9 (0.5)	6.4 (0.6)		292	236	
October	8.1 (0.1)	7.4 (0.1)		5.5 (0.0)	4.9 (0.0)		204	190	
November	5.6 (0.0)	4.9 (0.0)		4.5 (0.0)	3.2 (0.2		148	127	
December	4.4 (0.0)	3.6 (0.1)		2.5 (0.1)	0.5 (0.1)		116	76	

Year	Warmest Day Date	Warmest Day 24-hr mean (1 SD); °C	Warmest 7-Day Period Dates	Warmest 7-Day Period 7-day mean (1 SD); °C
2007	August 13th	15.9 (0.4)	August 10th – 17th	14.7 (0.8)
2008	August 18th	13.5 (0.5)	August 22nd – 29th	13.0 (0.5)
2009	July 18th	14.1 (0.4)	July 14th – July 20th	13.4 (0.6)

[a] Based on highest 24-hour average.

[b] Based on lowest 24-hour average.

[c] Difference between daily mean temperature and 0 °C summed for each month.

[d] Standard deviations < 0.05 are reported as 0.0.

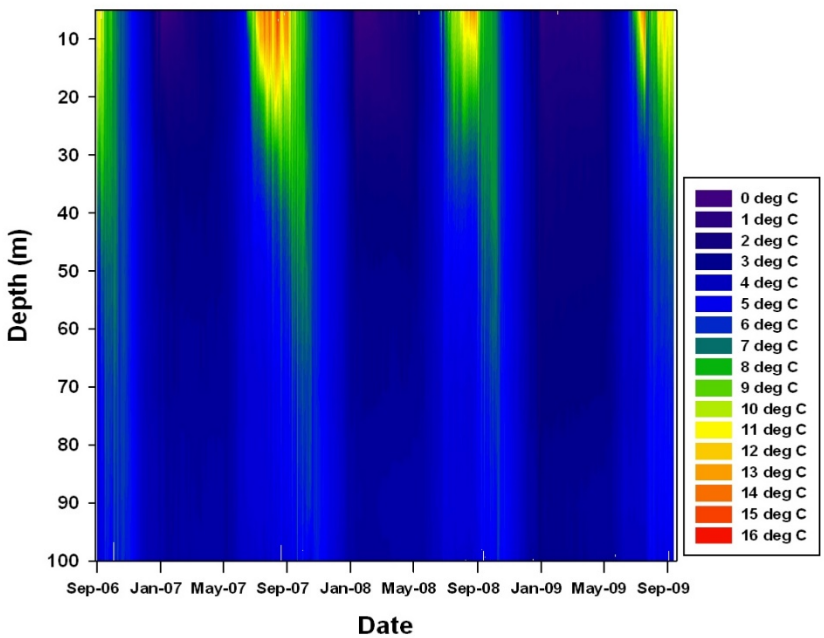

Figure 14.5. Isotherm of water temperature for Lake Clark between September 1, 2006 and September 1, 2009.

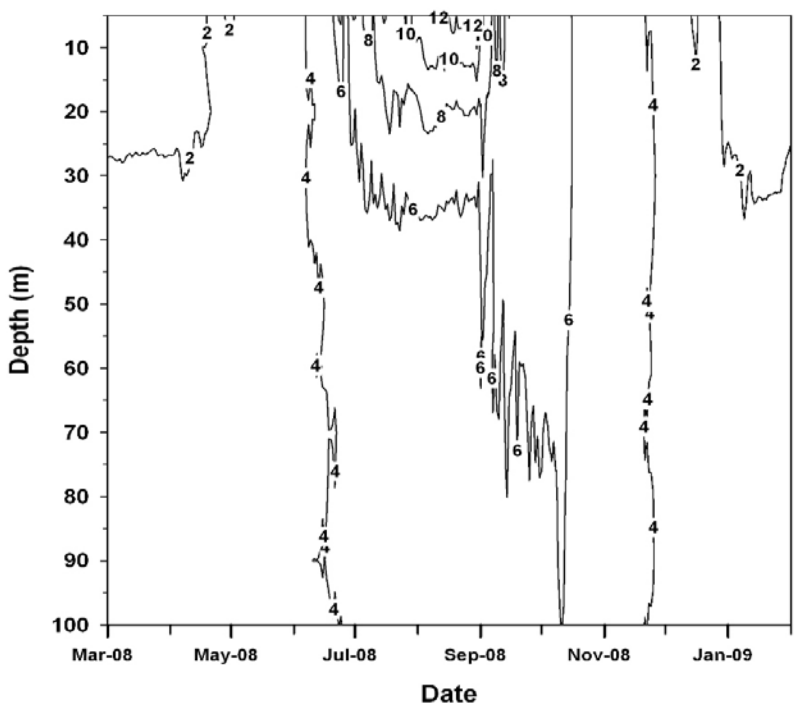

Figure 14.6. Contour plot of water temperature data for Lake Clark depicting summer stratification in 2008. The temperature interval (°C) is listed for each isopleth.

Annual Summary of Continuous Water Quality Data
Core water quality parameters are monitored continuously during the open water season at select Tier 1 lake outlets to provide an assessment of short-term (e.g., diel and weekly) temporal fluctuations that synoptic monitoring may miss. Since continuous water quality monitoring only takes place during the open water season (typically May – October), reporting intervals for data may be categorized by month or hydroperiod (e.g., rising, peak, falling). Tabular data will be summarized by the mean and variance of each reporting interval. Summary statistics will include (at a minimum) the mean, SD, median, maximum, minimum, coefficient of variation, and percent exceedance of defined water quality criteria. Bivariate plots will be used to show parameter patterns during reporting intervals, whereas boxplots may be used for comparisons among reporting intervals.

Annual Summary of Water Level and Discharge Data
Water level and discharge are monitored at select Tier 1 lake outlets in order to build stage-discharge rating curves with which to estimate the timing and magnitude of various streamflow metrics. For locations where rating curves exist, we will calculate the mean, maximum, and minimum discharge for each month on record, as well as the SD for the mean. The date and magnitude of peak (maximum) discharge among all months will be reported, as will the dates and magnitude of peak 7-day average discharge. Graphical presentations will primarily consist of bivariate plots depicting estimated discharge over time (Figure 14.7).

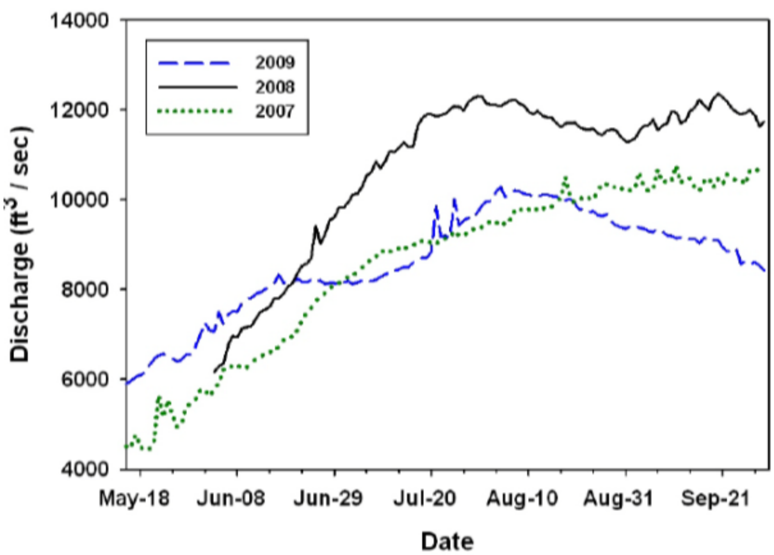

Figure 14.7. Estimated discharge at the Naknek Lake outlet during the ice-free period of 2007–2009.

Annual Summary Reports
Annual summary reports will be formatted following the NPS Natural Resource Technical Report series standards (http://www.nature.nps.gov/publications/NRPM/index.cfm). Annual summary reports will summarize monitoring data and observations and describe within-year patterns observed for water quality and quantity vital signs. Annual summary reports will include five sections:

- Introduction—describing the importance of the vital sign(s) being monitored.

- Study Area Description—including maps of lakes and monitoring sites.
- Methods—detailing field measurement techniques for vertical lake profiles, continuous water temperature, continuous water quality, and lake level / discharge monitoring.
- Results and Discussion—including data summaries, graphical displays, and interpretation of results, categorized by data type / monitoring method (e.g., vertical lake profiles).
- Conclusion and Recommendations—discussing suggested changes to protocol(s), planned activities for the upcoming field season, and future monitoring suggestions to incorporate into program activities to improve our understanding of park resources.

Five-Year Data Analysis and Reporting

Data Preparation

Graphing can be a useful visual tool to aid in identifying trends in data and should be considered as a first step in exploratory trend analysis. Bivariate plots, for example, that compare a water quality parameter (plotted on the y-axis) against time (plotted on the x-axis) can assist in identifying gradual or step trends. It may be important to graph the parameter maximum, minimum, range, or number of water quality exceedances, in addition to the parameter mean, to detect possible trends.

Data Analysis

The objective of trend analysis on water quality and quantity data is to detect changes in parameters over time at a given depth strata and location (e.g., site, lake basin, or entire lake). Trends may be gradual, such as the slow warming of a lake, or abrupt, perhaps resulting from a shift in best management practices. Regardless, trend detection is a function of sample size, data variance, and the responsiveness of the parameter being tested (Irwin 2008). The temporal resolution of the trend analysis (e.g., annual vs. seasonal) will depend on how frequently data are collected. For example, water temperature data are recorded every hour year-round at temperature array locations, whereas vertical lake profile data are measured once per year during an index period at Tier 1 lakes and less frequently (three times per five years) at Tier 2 lakes. Thus, seasonal or monthly trends may be analyzed for temperature array data, while only inter-annual trends can be analyzed for vertical lake profile data.

<u>Trends in Vertical Lake Profile Data</u>

The seasonality of water quality parameters in lakes reflects cyclic physical, chemical, and biological processes (Wetzel 2001). This seasonality must be taken into account to reduce the risk of intra-annual variability masking long-term inter-annual trends. We will attempt to reduce intra-annual variability in water quality parameters measured during lake profiles by sampling only one time per year during a mid-summer index period.

For Tier 1 lake systems where vertical lake profile monitoring occurs annually, we anticipate either no trends or “monotonic trends,” where gradual, continuous change is assumed (although exploratory data analysis may reveal otherwise). To detect monotonic trends in water quality parameter means between years, we will employ a non-parametric Mann-Kendall test. The Mann-Kendall is a rank-based test, which is a derivative of the Kendall’s tau correlation coefficient where one variable is time (Jassby 1996). The Mann-Kendall test does not assume data normality, is resistant to outliers, and is able to incorporate censored or flagged data since only ranks are used.

For Tier 2 lakes, where vertical lake profile monitoring is conducted less frequently (three times every five years), testing for a "step trend" may be more appropriate. A two-sample t-test is among the most common and simple tests to examine difference between two groups of data, however, given the non-normal nature of many water quality data (Hirsch et al. 1982, Hirsch 1988), a rank-sum test may be more appropriate. Similar to the Mann-Kendall test, the rank-sum test has a variant, called the seasonal rank-sum test, which can account for seasonality in data. Helsel and Hirsch (1992) suggest that a step trend may be appropriate when a dataset is naturally broken into two distinct periods and the gap between those data is relatively long. They further suggest the gap should be more than one third the period of record. Testing for a step trend would also be appropriate to examine "before" and "after" differences in response to a change in policy, management, or land use that is anticipated to affect the parameters being monitored.

Trends in Water Temperature, Water Level, and Discharge Data

For data that are partitioned among months or seasons, a seasonal Kendall test will be used (Helsel and Hirsch 1992).The seasonal Kendall test is essentially a Mann-Kendall test conducted on each season or month separately then summed, thus only similar seasons or months are compared across time (Helsel and Hirsch 1992). The seasonal Kendall test has the advantage of removing short-term variability caused by seasonality in data that may otherwise mask trends across the entire time series if using the Mann-Kendall test. Additionally, a seasonal Kendall test can be used to examine trends across an entire lake or lake basin by substituting individual sample sites for seasons. However, the seasonal Kendall test is affected by opposite trends between seasons or months (Jassby 1996). For example, a positive trend during January may be cancelled by a negative trend during February.

Trends in Continuous Water Quality Data

Continuous water quality data collected at lake outlets may by adjusted for river flow, provided discharge data are available, prior to trend analysis. Locally weighted scatterplot smoothing (LOWESS) is a common flow-adjustment technique for trend analysis. The LOWESS curve represents a nonlinear, smoothed relation between two variables (instantaneous discharge and each water quality parameter). The method uses a series of weighted least squares regressions; observations are weighted by both distance from the fitted line and the magnitude of residuals from the previous regression. LOWESS is more desirable than simple regression because it makes no assumptions of data linearity or normality (Cooprider 2005).

Five-Year Synthesis Reports

Five-year status and trend reports will be similar to annual summary reports but will involve a more in-depth statistical analysis of data to examine regional-scale relationships with other data sources (e.g., weather and climate) and will integrate data for other vital signs, such as landscape processes and glacial extent. Five-year synthesis reports will also follow the NPS Natural Resource Technical Report series standards (http://www.nature.nps.gov/publications/NRPM/index.cfm).

Other Types of Reporting

An overarching goal of SWAN is to ensure that information derived from monitoring is delivered to park managers in a meaningful context so that data can be incorporated into relevant management decisions. Additionally, it is important that information is shared with other stakeholders, such as state and federal agencies, native corporations, and the general public, to facilitate continued collaboration and support for nature resource monitoring. To disseminate information across a broad array of audiences with both technical and non-technical backgrounds, it is critical that a variety of reporting formats (e.g., briefs, newsletters, symposia) be made available, in addition to the annual and five-year reports described above. Table 14.2 itemizes the reporting formats used by SWAN to share monitoring information with diverse audiences.

Table 14.2. Reporting formats for SWAN monitoring activities, organized by timing during the calendar year.

Reporting Format	Description	Timing	Frequency	Audience Type	Audience [a]	Assigned to	Priority
Annual Administrative Reports and Work Plans (AAWRP)	Short summary of progress made during the last year for each project	September	Annual	Grazer	WASO, AKRO, SWAN, Parks	All SWAN staff, Network Coordinator	Mandatory
Field Season Highlights	1-page snapshot of field work	October	Annual	Sprinter	Parks, other NPS	All SWAN staff, Network Coordinator	High
Technical Committee (TC) Meetings	Briefing on each SWAN project	Spring/Fall	Biannual	Browser/ Grazer	TC, SWAN	SWAN Project Leaders, Network Coordinator	High
Superintendent Reports	Information from AARWP by park	Winter	Annual	Grazer	Superintendents, AKRO	Network Coordinator	Medium
Annual Reports	Annual technical report	January – March	Annual	Grazer	TC, SWAN , Parks, others	SWAN Project Leaders	Mandatory
Resource Briefs	1-page summary for each vital sign	December – February	Biennial	Sprinter/ Browser	Board of Directors, WASO, public	SWAN Project Leaders, Network Coordinator	Mandatory
E-Bulletins	Half-page email of SWAN facts	Winter	2–3 times per year	Sprinter	Parks, other NPS groups	Network Coordinator	Medium
Science Symposia	Presentation documenting project results/ progress	Late winter	Biennial	All	All	SWAN Project Leaders, Network Coordinator	High
SWAN Newsletters	2-page newsletter with information from AARWP and annual reports	Spring	Annual	Sprinter	Parks, public	SWAN Project Leaders for featured vital signs, outreach staff	Medium

Reporting Format	Description	Timing	Frequency	Audience Type	Audience [a]	Assigned to	Priority
Ecological Profiles	Revised Ecological Profiles for each park [b]		Every 3 years	Grazer	AKRO, SWAN, Parks, public	Park staff, SWAN Project Leaders, Network Coordinator	Medium
Park Newsletters	Information to park newsletter as requested	Varies	As needed	Sprinter	Parks, public	SWAN Project Leaders	Medium
Short Articles	Periodic requests for publications such as Alaska Park Science	Varies	As needed	Grazer	Public	SWAN Project Leaders, Network Coordinator	Medium
Professional Meetings	Abstracts, papers, posters, power points, etc. for subject professional meetings	Varies	As needed	Grazer	Scientific community, public	SWAN staff	Medium
Brochures, DVDs, other guides	Update as needed	Varies	As needed	All	All	As appropriate	Low

[a] WASO = Washington Support Office; AKRO = Alaska Regional Office; TC = Technical Committee.

[b] Ecological Profiles as used in Appendix II of the SWAN Vital Signs Monitoring Plan (Bennett et al. 2006).

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The Department of the Interior protects and manages the nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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U.S. Department of the Interior

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