



# MassDEP

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**Massachusetts Department of Environmental Protection  
Bureau of Water Resources  
Division of Watershed Management  
Watershed Planning Program**

## **STANDARD OPERATING PROCEDURE**

Water Quality Data Validation Procedures  
for DISCRETE PROBE DATA

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**Prepared and  
Approved by:**

/s/ Kari Winfield

Kari Winfield, Environmental Analyst

**Date:** 6/12/2025

**Approved by:**

[Signature]

Jasper Sha, QA Analyst

**Date:** 6/17/25

**Approved by:**

[Signature]

Richard Chase, Section Chief, Data Management  
and Water Quality Assessment

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## I Applicability

These procedures apply to discrete (“attended”) water quality probe data generated by MassDEP’s Watershed Planning Program (WPP). Each year, WPP monitoring staff collect discrete probe readings for temperature (T), pH, specific conductance (SpCond), and dissolved oxygen (DO) at selected locations (rivers and lakes) using multiprobe sondes and loggers or hand-held temperature probes. Auxiliary measurements may include total dissolved solids (TDS) and dissolved oxygen saturation (DOsat). In many cases, discrete probe data are collected for quality control (QC) purposes to compare simultaneous, “side-by-side” readings with deployed probes.

## II Overview

These procedures document WPP’s approach to collating, processing, validating, and finalizing discrete probe data files generated via water quality monitoring surveys (either in conjunction with bottle sample collection or as part of a continuous probe deployment). These procedures involve both automated and manual steps applied to individual-year data sets by WPP data management and quality assurance (QA) staff. Essentially, raw probe data files are assembled, checked for completeness, pre-processed to select “best lines” and assess reading stability, linked to field sheet metadata, checked against laboratory calibration data, then output to standard format for further review. Based on checks against acceptance criteria, data are either accepted “as is”, qualified, or censored. Following review by the Principal Investigators (or assigned staff), reports are provided to staff in a standardized format.

## III Prerequisites for Initiating Procedures

The following information is required in order to initiate processing and validation steps:

- 1) Raw discrete probe data files (.csv or .xls/.xlsx formats)
- 2) Laboratory QC summary reports (documented in the Instrument Lab Workbook “ILW”)
- 3) Proofed electronic field sheet files (entered in relational database, such as the Water Quality Database “WQD” or EDGE/EQuIS)
- 4) Validation Decision Criteria tables for each probe parameter (see Appendix A)
- 5) Program software/languages (MS Windows based): MS Excel, Visual Basic for Applications (VBA), Visual Basic Script (VBScript)

Working files are managed using MS Excel Data management and QA staff should be well-versed in MS Excel, VBA and VBScript coding, and process documentation.

## IV Assumptions

These procedures have the following underlying assumptions:



- 1) Proofed field sheet files are accurate (based on 100% data entry QC), until shown to be inaccurate. Any required changes to field sheet information are documented and transferred to other databases as needed.
- 2) Any decision applied to DO applies automatically to DO saturation (DOsat) and any decision applied to SpCond applies automatically to total dissolved solids (TDS).
- 3) SpCond data represent temperature-compensated values (typically referenced to 25°C)

## V Roles and Responsibilities

**Field Staff** are responsible for conducting water quality surveys (under pre-defined project names) where discrete probe measurements are collected, following appropriate SOPs for field methods. They are responsible for accurately filling out field sheets that track probe serial numbers, dates/times of measurements, sample IDs (OWMIDs), and noting any field issues either on the field sheet directly or by emailing the Data Manager, Quality Assurance Officer, and/or Field & Lab Operations Coordinator. Each **Principal Investigator** in charge of a water quality project should submit Probe Request forms to the Field & Lab Operations Coordinator in advance of the monitoring season for planning and calibration purposes.

The **Field & Lab Operations Coordinator** is responsible for preparing probes and loggers for field use, calibrating probes prior to surveys, and completing probe request forms with serial numbers assigned to projects for specific dates/locations. Data files from data loggers are also downloaded and stored in a commonly accessible file-sharing space

The **Data Manager** compiles field sheet information from appropriate data bases, runs automated scripts to process/check probe data files, and prepares files for review by the QA Officer.

The **QA Officer** performs manual quality assurance checks on probe data and overrides automated decisions where necessary.

## VI Discrete Probe Data Validation Procedures

1. Multiprobe data file pre-processing steps (manual) Role: Data Manager
  - a. Collect all raw attended data files in .xlsx or .csv format (**Field & Lab Operations Coordinator** is responsible for downloading data files from data loggers and storing in a commonly accessible file-sharing space)
  - b. File location: place files in AttendedData\_PreProcess folder by data year and probe type or format type
  - c. File formats:
    - i. Multiprobe files
      1. Hydrolab™
        - a. Should be comma-delimited (.xmd, .csv) or Excel (.xlsx, .xls)



- b. Must follow the native Hydrolab format (.xmd) in terms of header placement and column spacing; date and time in separate columns
- c. OWMIDs are included as annotation rows followed by dates/times on individual rows
- d. Must include the logger serial number in the header block after "Log File Name:"

2. YSI™

- a. Should be comma-delimited (.csv) or Excel (.xlsx,.xls)
- b. must include the date and time in separate columns
- c. must include the logger serial number in separate column "Unit ID"
- d. Correct file formats as necessary (e.g. split out files with multiple probe serial numbers included for each parameter, add "T" if missing from header)
- e. Add columns to allow identification of "best" line for stability in all analytes (T, DO, SpCond, pH) and to apply qualifiers for stability ("u"), making sure not to overlap new columns with any existing data or comment columns (those reserved for "no data" or no probe on board); save files in xlsx format

1. Identify stable best lines in probe files (see Appendix C for full description) (manual) Role: QA Officer or Principal Investigators

- a. Data blocks are identified by unique OWMIDs, date/time differences, latitude/longitude, or depth differences between adjacent rows in the data file
- b. Identify best line for each data block, adding Y to column labeled "'Best' Line? (Enter Y)" and highlighting the line
- c. For each best line, evaluate stability of each analyte (T, DO, SpCond, pH) and apply Accept/Qualify/Censor to each analyte's qualifier column
- d. Place files that have been reviewed for best line into either the folder called "pre-processed only" under attended/yyyy, or pass the files back to the Data Manager. Data Manager will review and add "qcd" to file name.

2. Collect temperature and/or other manually recorded QC data (manual) Role: Data Manager

- a. Using the Excel field sheet meta data file (e.g. MetaDataYYYY.xlsx, where YYYY is the data year), identify all temperature survey OWMIDs:
  - i. Filter field sheet by SmpGearName = "Temperature Logger", make list of FSLOGs
  - ii. Remove filters, Filter field sheet by FSLOG from 3ai
  - iii. Copy all visible rows from 3aii to a new sheet called "MetaDataYYYY (T only)" in file called "YYYY Temperature QC data.xlsx" (YYYY is data year)
  - iv. Copy all columns to a new sheet called "Field Sheet + TempQC"



1. Immediately following field sheet columns, insert columns for temperature QC:
  - a. T deployment?
  - b. QC OWMID
  - c. QC Date
  - d. QC Time
  - e. QC Temp
  - f. QC Depth
  - g. QC Comment
- b. Extract temperature QC data from sample Comments field (Format should be similar to [Time HHMM, Temp XX.XX, Depth XX], with square brackets surrounding the temperature QC data and values comma-separated)
  - i. Filter column SmpTypName by In-situ: QC Cal Check
    1. Copy OWMID values to QC OWMID column
    2. Copy StartDate values to QC Date column
    3. Extract QC Time from Comments column using a formula that searches for Time and the first comma after Time
    4. Extract QC Temp from Comments column using a formula that searches for Temp and the second comma after Temp
    5. Extract Depth from Comments column using a formula that searches for Depth and the second comma after Temp
  - c. Populate T deployment? column:
    - i. Mark all discrete probe QC rows with Y
    - ii. Mark all continuous probe deployment rows with N
    - iii. Mark any air temperature deployments (both unattended and attended rows) with N

### 3. Process raw discrete probe data files (automated) Role: Data Manager

- a. Run visual basic script called **Att\_QCProcRawFiles.wsf** (.wsf = Windows script host file)
  - i. Generates *Year\_attended\_QC1.xlsx* file, containing data from all individual probe files
  - ii. Adds OWMIDs from pre-processed raw data files (rows identified as best lines only), including “u” qualifiers for DO, pH, T, SpC assigned during best line review.
  - iii. Adds all temperature QC OWMIDs from separate data file, applies “s” qualifier to “FS Data Used” column and “X” flag to indicate “NO DATA” for pH, SpCond, TDS, DO, DOsat
  - iv. Adds “m” qualifiers based on time difference between first and last line of each OWMID (or OWMID and depth) data block (see **Validation Decision Criteria Tables**, Appendix A)



v. Converts TDS values to mg/l

4. Cross-reference compiled probe data against field sheet meta data (automated/manual) Role:  
Data Manager

- a. Run visual basic script called **Att\_XREF.wsf** (automated)
  - i. Matches all OWMIDs from compiled probe data file (*Year\_attended\_QC1.xlsx*) to OWMIDs in electronic field sheet for year in question
  - ii. Generates list of “Unmatched FS OWMID”s—those OWMIDs in electronic field sheet not found in any data file
  - iii. Generates list of “Unmatched Att OWMID”s—those OWMIDs in the compiled probe data file not found in the electronic field sheet file
  - iv. Adds OWMIDs marked as not collected in electronic field sheet file to QC1 sheet (MISSING added to all *\_SS* columns)
  - v. Adds column for QC Type (Drop off, Pick up, Intermediate, Unknown, N/A) to QC1 worksheet based on sample type to aid in identifying date/time issues
  - vi. Standardizes reporting units as needed
- b. Reconcile “unmatched” OWMIDs from field sheet or compiled probe data file (manual)
  - i. Identify any data not to be validated and move to separate Excluded Data worksheet (e.g. special projects, non-WPP data, air temperature readings)
  - ii. Check for incorrect OWMID formats (incorrect project prefixes, transposed numbers)
  - iii. Check for OWMIDs with incorrect sonde/logger serial numbers, OWMIDs without best line indicators in probe files
- c. Do the following checks by filtering the resulting QC1 spreadsheet (see also Appendix D) (manual)
  - i. Check for sample types (*SmpTypeName*) not equal to “In-situ: Attended” or “In-situ: QC-Cal Check”
  - ii. Check for OWMIDs with incorrect date/time in data file
  - iii. Check for OWMIDs with incorrect date/time in field sheet
  - iv. Check for duplicate OWMIDs in data file (including duplicated depths for vertical profiles)
  - v. Check for time differences between data file best line and field sheet start date/time, focusing on differences > 30 minutes
  - vi. Check cases where *QCType* = Unknown (*QCType* could not be determined based on dates/times on field sheet)
  - vii. Check cases where probe file serial number does not match serial number from field sheet
  - viii. Check cases where TDS units are not reported in mg/l
- d. Resolve items found in 5b) and 5c) by checking electronic field sheet, paper field sheet, etc., and making changes to pre-processed data files and electronic field sheet as necessary, based on identified errors





- e. Rerun program in 4a) and then 5a) for each year as necessary until items in 5b) and 5c) appear to have been completely addressed
- f. Manually add any measurements not found in probe data files using values from original field sheets (for OWMIDs added in 5av)

5. Compile probe calibration information and associated probe request information  
(automated/manual) Role: Data Manager/ Field & Lab Operations Coordinator

- a. Gather probe request worksheets from Field & Lab Operations Coordinator
- b. Compile probe calibration information by project name, calibration date, pre-survey calibration date, post-survey calibration date, and serial numbers, including:
  - i. Identification of sondes calibrated for particular analytes only (for later application of “NO CAL” flag and “- -” to indicate no data)
  - ii. Calibration standards used for pH and SpCond (for later use in applying “c” qualifier; see Appendix A, **Validation Decision Criteria Tables**)
  - iii. Identification of analytes that violated inaccuracy (“i”) criteria (see Appendix A, **Validation Decision Criteria Tables**)
- c. Run visual basic script called **ILW\_QC\_Summary.wsf** to compile individual instrument calibration files and probe request files

6. Produce QC2 file for QA review (automated) Role: Data Manager

- a. Run visual basic script called **Att\_QC2.wsf**
  - i. Generates *Year\_attended\_QC2.xlsm* file based on QC1 file
  - ii. Creates “QC2 attended working” sheet:
    - 1. Based on decisions/exceptions in lab QC file:
      - a. Adds “NOT USED” flag to analyte-comment (“\_SS”) columns to indicate no calibration (intentionally)
      - b. Adds “NO CAL” flag to analyte-comment (“\_SS”) columns to indicate calibration was incomplete
      - c. Adds “c” qualifier for standards exceptions (see Appendix A, **Validation Decision Criteria Tables**)
      - d. Adds “i” qualifier for pre/post survey accuracy exceptions (see Appendix A, **Validation Decision Criteria Tables**)
    - 2. Adds other qualifier columns by analyte (for “t”, “m”, “u”)
    - 3. Adds flags to analyte-comment “\_SS” columns for “NO DATA” or “MISSING”
  - iii. Imports vba module file called **FinalizeAttData.bas**, used for later data finalization

7. Review results in QC2 file in preparation for QC3 review by Principal Investigators (Manual) Role: QA Officer



- a. Make necessary manual changes to “QC2 attended working” sheet. Highlight changes, and document reasoning in QC2 comments column; include your initials and the date in *each* comment
  - i. Review **Field Sheet (FS) comments (columns BR and BS) for any decisions affecting data** that were not accounted for in automation, including:
    1. Stagnant conditions or beaver impoundment noted: apply “r” qualifier to all data except depth and note “stagnant” in NewFlowStat column if it is not already noted in the FlowStat column.
    2. Stream dry: apply “r” qualifier (if there is any data). “NewFlowStat” column can be used to indicate dry conditions (“No Water”) if that was not already on the field sheet.
    3. Tidal influence noted: apply “t” qualifier.
    4. Add “s” flag for any data where the field sheet data were used in place of electronic data (i.e., no electronic records available)
  - ii. Check the flow status on EACH deployed probe field sheet (any FSLOG with trips in the 500s, like G501) to check for changes to flow status for the intermediate and pick up QC visits because flows at the intermediate and pick-up QC visits are not captured currently in the WQD database. Filter by FS\_Type (col. CL) for “Probe” and then check the QC Type (col. BO) not equal to “Drop off QC” to get the OWMIDs of the QC visits that need to be checked.
  - iii. Check all emailed comments (keep a file of the comments over the year) for any issues potentially affecting data. Many issues are resolved in the initial data processing – e.g. logging data under the wrong OWMID.
  - iv. Check autogenerated “t” qualifiers. For sites with conductivity readings >1500 uS/cm, all results are automatically flagged “t” as potentially tidally influenced, but winter readings may exceed 1500 in freshwater streams and some lakes. Check the site location (ask for GIS shapefile of the current stations) if in doubt.
  - v. Check for **blank records** in any analyte columns. Date/time cells are blank or -1 if data are missing.
  - vi. Review each qualifier column for **3 or more qualifiers**. This may indicate the need for censoring if the datum was not already (automatically) censored.
  - vii. Review each data column (e.g. filter the result column and look at the range of results) for obviously **high/low value outliers** that may be erroneous or non-representative (qualify or censor as needed).
  - viii. Check all **lab QC decisions** (should only require cursory checks on lab QC decisions because all lab QC decisions are entered into the Instrument Lab Workbook (ILW) files, complete with associated OWMIDs, which should eliminate most error associated with using the Sonde QC summary file)
  - ix. Make sure each analyte with “Accept” status has no qualifiers listed



- x. Make sure all analytes listed as MISSING (“\*\*\*”), NO DATA (“- -”), NO WATER (“^^”) have **no** qualifiers
- xi. Make sure all cases where Flow Condition = No Water also have the NO WATER symbol (“^^”) in the data columns for all analytes
- xii. Note that depths with values between 0 and 0.049 m (on final sheet appear as 0 due to reporting rules): have an “i” to qualifier applied.
- xiii. Recover auto-censored data using **FS estimates**, when available. Example: negative depth data due to a faulty depth sensor and FS comment notes that depth was X. (optional)
- xiv. **Random QC checks** (optional)
- b. Make final manual changes to “QC2 attended working sheet” based on miscellaneous information, email correspondence and best professional judgment. Pass the file back to the Data Manager.
- c. Check off items in the “Attended validation action items” Excel file maintained by Data Manager.
- d. Update the QC2 “read me” Excel file for changes in processes (by data year).

**8. Finish QC2 Review and generate final files for Principal Investigator review (manual/automated)**  
Role: Data Manager

- a. Check that all QC2 changes by QA Officer have been documented with comment in the QC2 Comment column (with initials and date) and highlight the actual change.
- b. After all changes have been made to “QC2 attended working” sheet, run vba macro called **FinalizeAttData**
  - i. Creates “QC2 attended final” sheet based on “QC2 attended” sheet
  - ii. Adds station information (Watershed, Water Body, Station Description, Mile Point, Latitude, Longitude) from separate Excel file
  - iii. Applies formatting and reporting rules (see **Appendix B**)
  - iv. Creates “Data summary” sheet with qualifier counts/percentages
  - v. Creates individual project files for each project
    - 1. Adds QC2 “read me” tab imported from separate Excel file
    - 2. Adds “attended probe data” sheet with final data formatting
    - 3. Adds “Data summary” sheet with qualifier counts/percentages
- c. Review “QC2 attended final” sheet and “Data summary” sheet
  - i. Compare **statistics on qualifiers and censorings** for each analyte. Weigh against expected/historical percentages. (optional) Note: these statistics helpful in reviewing decision criteria.
  - ii. Check for blank cells (qualifier columns and Mile Point are the only columns that can have blanks).
  - iii. Check that reporting rules have been applied to all data
  - iv. Random QC checks (optional)



- d. Run visual basic script **Att\_QC3.wsf**
  - i. Generates separate QC3 file based on the QC2 file format to track QC3 review changes
- e. Provide files by project to Principal Investigators for QC3 review

#### 9. QC3 Review Process (manual) Role: Principal Investigators for each project

- a. Staff principal investigators review QC2 FINAL files for issues/errors
  - i. Examine project file for completeness (are all data that were collected present; if not, why? Do any data appear to be missing?)
  - ii. Are data presented reasonable based on field conditions and professional judgment (e.g., are there outlier data that are not “real”)?
  - iii. Examine project file for any errors and inaccuracies you may find
  - iv. Other “problems”
- b. Staff principal investigators submit their QC3 review comments to QA Officer

#### 10. Review comments received during QC3 review (manual) Role: QA Officer/Data Manager

- a. QA Officer makes necessary changes to “QC3 attended working” sheet in the QC3 Excel file, including QC3 changes sheet (where needed, for general changes that apply to all projects)
- b. In collaboration with Data Manager, write a response to the QC3 comments for the Principal Investigators.
- c. Update the QC4 “read me” Excel file for changes in processes (by data year).

#### 11. Produce final QC4 data files (automated) Role: Data Manager

- a. Run vba macro **FinalizeAttData\_QC4** in QC3 Excel file
  - i. Creates “QC4 attended final” sheet based on “QC3 attended working” sheet
  - ii. Applies formatting and reporting rules (see **Appendix B**)
  - iii. Creates “Data summary” sheet with qualifier counts/percentages
  - iv. Create individual project files for each project
    - 1. Adds “read me” tab imported from “read me” QC4 Excel file
    - 2. Adds “attended probe data” sheet with final data formatting
    - 3. Adds “Data summary” sheet with qualifier counts/percentages
- b. Review “QC4 attended final” sheet and “Data summary” sheet
  - i. Compare **statistics on qualifiers and censorings** for each analyte. Weigh against expected/historical percentages. (optional) Note: these statistics helpful in reviewing decision criteria.
  - ii. Check for blank cells (qualifier columns and Mile Point are the only columns that can have blanks).
  - iii. Check that reporting rules have been applied to all data
  - iv. Random QC checks (optional)



## 12. Check "QC4 attended final" data files (Manual) QA Officer

- a. Look for any missing information
- b. Filter the data columns to look at range of reported values, missing values, or other issues
- c. Review the summary of qualifiers



## APPENDIX A: Validation Decision Criteria

### Temperature (T)

Qualifier		Acceptance Criteria			Notes
		Accept	Qualify	Censor	
Stability ("u")	Limits (°C)	<0.3 °C	0.3-0.6 °C	>0.6 °C	Compare 5-minute RANGE of probe readings from 1st stable reading to "best line"
	Lake Metalimnion* Limits (°C)	<0.6 °C	0.6-1.2 °C	>1.2 °C	<i>*If the temperature difference from the reading 1m above is &gt;1.0 deg C., then the readings are within the thermocline</i>
	Other criteria			Erratic readings; probe damage	
Accuracy ("i")	Limits (°C)	<0.2 °C	0.2-0.45 °C	>0.45 °C	Compare probe to NIST Thermometer (semi-annually or as needed)
	Other criteria	$T \geq 0.1 \text{ °C}$	$-0.5 \text{ °C} \leq T < 0.1 \text{ °C}$	$T < -0.5 \text{ °C}$	
Tidally-influenced ("t")	Other criteria		SpCond qualified for "t"		
Method not followed ("m")	Time Difference (min.)	$\geq 2 \text{ min.}$	1-2 min.	<1 min.	Compare probe start time to end time (usually same as stable best line) <i>*for lakes, evaluate each depth separately</i>
Representativeness ("r")	Other criteria		Stagnant conditions or beaver impoundment noted on field sheet		
Manual data ("s")	Other criteria		field sheet data were used in place of electronic data (i.e., no electronic records available)		



## Dissolved Oxygen (DO)

Qualifier		Acceptance Criteria			Notes
		Accept	Qualify	Censor	
Stability ("u")	Limits (mg/l)	<0.4 mg/l	0.4-0.8 mg/l	>0.8 mg/l	Compare 5-minute RANGE of probe readings from 1st stable reading to "best line" <i>DOsat QC Result follows decision for DO</i>
	Lake Metalimnion* Limits (mg/l)	<0.8 mg/l	0.8-2.4 mg/l	>2.4 mg/l	<i>*If the temperature difference from the reading 1m above is &gt;1.0 deg C., then the readings are within the thermocline</i>
	Other criteria		T censored for "u"	Erratic readings; probe damage	
Accuracy ("i")	Limits (mg/l)	<0.2 mg/l	0.2-0.5 mg/l	>0.5 mg/l	Compare probe reading to theoretical 100% saturation value at post-survey check <i>DOsat QC Result follows decision for DO</i>
	Other criteria		T censored for "i"; no post-survey calibration check	Erratic readings; probe damage	
Tidally-influenced ("t")	Other criteria		SpCond qualified for "t"		
Method not followed ("m")	Time Difference (min.)	≥2 min.	1-2 min.	<1 min.	Compare probe start time to end time (usually same as stable best line) For lakes, evaluate each depth separately
Representativeness ("r")	Other criteria		Stagnant conditions or beaver impoundment noted on field sheet		
Manual data ("s")	Other criteria		field sheet data were used in place of electronic data (i.e., no electronic records available)		



## Specific Conductance (SPCOND)

Qualifier		Acceptance Criteria			Notes
		Accept	Qualify	Censor	
Stability ("u")	Limits (%)	<2 %	2-5 %	>5 %	Compare 5-minute RANGE of probe readings from 1st stable reading to "best line" <i>TDS QC Result follows decision for SpCond</i>
	Lake Metalimnion* Limits (%F)	<2 %	2-5 %	>5 %	<i>*If the temperature difference from the reading 1m above is &gt;1.0 deg C., then the readings are within the thermocline</i>
	Other criteria		T censored for "u"	Erratic readings; probe damage	
Accuracy ("i")	Limits (%)	<2 %	2-5 %	>5 %	Compare probe reading to post-survey check value <i>TDS QC Result follows decision for SpCond</i>
	Other criteria		T censored for "i"; no post-survey calibration check	Erratic readings; probe damage	
Calibration Range ("c")	Limits (µS/cm)	<= High Standard	> High Standard to <= 2 * High Standard	> 2 * High Standard	Compare probe value to highest standard used <i>TDS QC Result follows decision for SpCond</i>
	Other criteria		relatively low value compared to a very high standard (e.g., 1200 result after calibration standard 58640 used)		
Tidally-influenced ("t")	Limits (µS/cm)	<1500 (µS/cm)	>=1500 (µS/cm)	None	
	Other criteria		Field sheet comment; proximity to coast; lack of tidal restrictions		<i>*verify location and lack of tidal restrictions (e.g., dams) in GIS</i>
Method not followed ("m")	Time Difference (min.)	≥2 min.	1-2 min.	<1 min.	Compare probe start time to end time (usually same as stable best line) For lakes, evaluate each depth separately





Qualifier		Acceptance Criteria			Notes
		Accept	Qualify	Censor	
Representativeness ("r")	Other criteria		Stagnant conditions or beaver impoundment noted on field sheet		
Manual data ("s")	Other criteria		field sheet data were used in place of electronic data (i.e., no electronic records available)		

## pH

Qualifier		Acceptance Criteria			Notes
		Accept	Qualify	Censor	
Stability ("u")	Limits (SU)	<0.4	0.4-0.6	>0.6	Compare 5-minute RANGE of probe readings from 1st stable reading to "best line" <i>DOsat QC Result follows decision for DO</i>
	Lake Metalimnion* Limits (SU)	<0.4	0.4-0.6	>0.6	<i>*If the temperature difference from the reading 1m above is &gt;1.0 deg C., then the readings are within the thermocline</i>
	Other criteria		T censored for "u"	Erratic readings; probe damage	
Accuracy ("i")	Limits (SU)	<0.2	0.2-0.4	>0.4	Compare probe reading to post-survey check value
	Other criteria		T censored for "i"; no post-survey calibration check	Erratic readings; probe damage	
Calibration Range ("c")	Limits (SU)	Low Standard to High Standard	< Low Standard or > High Standard	None	Compare probe value to highest and lowest standards used
Tidally-influenced ("t")	Other criteria		SpCond qualified for "t"		



Qualifier		Acceptance Criteria			Notes
		Accept	Qualify	Censor	
Method not followed ("m")	<b>Time Difference (min.)</b>	≥2 min.	1-2 min.	<1 min.	Compare probe start time to end time (usually same as stable best line) For lakes, evaluate each depth separately
Representativeness ("r")	<b>Other criteria</b>		Stagnant conditions or beaver impoundment noted on field sheet		
Manual data ("s")	<b>Other criteria</b>		field sheet data were used in place of electronic data (i.e., no electronic records available)		

## Depth

Qualifier		Acceptance Criteria			Notes
		Accept	Qualify	Censor	
Accuracy ("i")	<b>Limits (m)</b>	>0 m	0 m	<0 or >100 m	Analyze probe reading <i>*Criteria applied after reporting rules applied (depth rounded to 1 decimal place)</i>
	<b>Other criteria</b>		faulty sensor	Erratic readings; faulty sensor	
Tidally-influenced ("t")	<b>Other criteria</b>		SpCond qualified for "t"		
Method not followed ("m")	<b>Time Difference (min.)</b>	≥2 min.	1-2 min.	<1 min.	Compare probe start time to end time (usually same as stable best line) For lakes, evaluate each depth separately
Manual data ("s")	<b>Other criteria</b>		field sheet data were used in place of electronic data (i.e., no electronic records available)		Qualifier also applies to hand-held probes where no logger is used



## APPENDIX B: Reporting rules for Discrete Probe Parameters

### Reporting rules for typical probe results

Probe Parameter	Rounding rule	Raw QC0 Result	Final QC4 Result
Dissolved Oxygen	10 <sup>th</sup> decimal	0.25111	0.3
Dissolved Oxygen saturation	Whole number	105.27	105
Specific Conductance	Whole number	25037.577	25038
Temperature	10 <sup>th</sup> decimal	31.333	31.3
pH	10 <sup>th</sup> decimal	5.62	5.6

### Reporting rules for Instrument Detection Limits

Probe Parameter	Rounding rule	Raw QC0 Result	Final QC4 Result
Dissolved Oxygen	10 <sup>th</sup> decimal	0.097	<0.2
Dissolved Oxygen saturation	Whole number	1.97	<2
Specific Conductance*	Whole number	25037.577	25038
Temperature	10 <sup>th</sup> decimal	-0.23	<0.1
pH*	10 <sup>th</sup> decimal	5.62	5.6

\*no lower limit (IDL) currently applies



## APPENDIX C: Procedures for “Best Line” and Stability review

### Objective:

The raw data files for attended multiprobes are reviewed to select the “best line” of data to associate with each unique sampling event (or OWMID). The multiprobe file formats used are either for Yellow Springs Instrument™ (YSI) or Hydrolab™. The only quality control (QC) check performed at this stage is for stability of readings. For each analyte (dissolved oxygen (DO), pH, specific conductance (SpCond), and temperature (T), as applicable) in each selected “best line”, apply stability qualifier (qualify or censor) if necessary.

### Steps:

- 1) Open a raw data file for year being pre-processed
- 2) Scroll down to 1<sup>st</sup> OWMID annotation.
  - a. For YSI files, the OWMID is listed for each record in Site column.
  - b. Other annotations in the “Site” column include CALxxxx, PRELISxxx, and POLISxxx, which are records from instrument calibration steps, pre-field check of the Low Ionic Strength (LIS) buffer, and post-field check of the LIS respectively.
  - c. For Hydrolab files, the data contained in the rows following each Annotation/OWMID# pertain to that OWMID.
- 3) Determine data blocks where the sites or depths change; marked by a change in OWMID and/or change in depth readings for lake profiles. Latitude/longitude values (YSI only) should be the same for the entire block. Watch for occasions where data is logged before the OWMID is changed or is logged under the wrong OWMID. Because only 1 OWMID is used for lake depth profiles, separate each depth data block with a blank line.
- 4) Review the data blocks for each OWMID and select the “best line” (row) that appears to best represent the pH, DO, T and SpCond data (as applicable) at that station and time, in terms of stability of the data record. “Best line” will typically be within the last 3 data rows. Only one row should be selected per OWMID/depth.
- 5) Once you decide on the “best line”, shade the entire row in green (“GOOD”) and mark the row with a “Y” for “YES” in the column called “BEST LINE?”
  - a. For Hydrolab files, copy/paste the associated OWMID (column A , upper left of each data block) in the “copy annotated OWMID” column in the same row and to the right of the “best line”.
- 6) Once the “best line” is selected, apply the following “stability” decision criteria (see table below) to each data block that has an associated field OWMID#. Use the columns to the right of the readings to choose the proper decision from the pick list for each analyte. Visually check the value ranges or calculate the difference (or relative percent difference (RPD) for SpCond) from the beginning of the block to the selected best line and compare with the criteria listed below. For each analyte, a stability decision (ACCEPT, QUALIFY, CENSOR, OR N/A) must be selected. NOTE for Hydrolab files: some analytes had no probe on-board the sonde (“X” or “N”) or were not calibrated (“\*”) — these symbols represent NO DATA for that analyte and get “N/A”.



- 7) Reading stability around the metalimnion in stratified lake: because dissolved oxygen and temperature are naturally more variable within the metalimnion of a stratified lake, broader criteria (see table below) should be used to guide reading-stability decisions.
- IDENTIFY THE THERMOCLINE: If the temperature difference from the reading 1 meter above is >1.00 then the readings are likely within the thermocline.
  - Make sure that the other readings in the data set are stable (i.e. the meter is not having a problem).
  - Use the “metalimnion” criteria to make the stability decisions for T and DO. For pH and SpCond use the regular criteria.

	3-minute RANGE of readings from 1 <sup>st</sup> <i>stable</i> reading to “best line” near the end		
Analyte	ACCEPT	QUAL *	CENSOR *
T (deg. C)	<0.3	0.3-0.6	>0.6
T (°C) within metalimnion	<0.6	0.6-1.2	>1.2
DO (mg/l)	<0.4	0.4-0.8	>0.8
DO (mg/L) within metalimnion	<0.8	0.8-2.4	>2.4
pH (SU)	<0.4	0.4-0.6	>0.6
SpCond (uS/cm) RPD	<2%	2-5%	>5%

\* also look for very erratic, jumpy readings, and significant, continuous movement in one direction without stabilizing

*DO % saturation and TDS stability are calculated parameters (from DO and SpCond, respectively) and so the stability decisions are transferred from DO and SpCond.*

- 8) Hydrolab files: For cases where an annotation appears to have been missed (e.g. analyte data values are substantially different between adjacent rows, date/time differs between adjacent rows):
- Add blank line separating the two data blocks
  - Add “Annotation” to column 1 on the row where you added the blank line
  - If “new” data block appears to contain good data, follow above directions for determining best stable line (note: for lake surveys with missed annotations, repeat known OWMID by adding “Annotation at: OWMID” to “Annotation Copy” column)
- 9) Once all “best lines” have been selected and stability qualifiers imposed as necessary, review file for completeness and errors. If satisfied, save file with same name and in same location.

#### Things to look for:

- “Outliers” at beginning, middle or end of data block. If at beginning, disregard and start with the 1<sup>st</sup> stable row. If in middle, disregard if one aberrant reading, but not if several “outliers”. If at end, do not select the last line.



- Readings that never really stabilize and change unidirectionally in big jumps (i.e., not naturally-occurring variation)
- Missing OWMIDs



## APPENDIX D: Checks on electronic field sheets/data entry

1. Make sure comment fields are not truncated due to having more than 255 characters (FSComment, Comments); re-export from Access if possible, or add complete entries back into Excel field sheets
2. Identify Temperature QC OWMIDs and assign new OWMIDs if necessary; add to electronic field sheet; enter date, time, temperature data into a separate Excel workbook
3. Check for duplicate In-situ: Un-attended
  - a. make sure duplicate is not due to error in data entry (e.g. incorrect SmpTypName)
  - b. if duplicate is recorded on same field sheet as original, then QC Cal checks apply to both unattended OWMIDs
  - c. if duplicate is recorded on separate field sheet with no QC Cal checks, then create new QC Cal Check OWMIDs and copy original QC OWMID data to new OWMIDs; this ensures that each unattended OWMID has a pair of QC Cal Check OWMIDs (for automating trimming of unattended files; later we can decide which duplicate unattended OWMID should be kept)
4. Check for missing sonde and logger IDs for SmpTypName = In-situ: Attended and In-situ: QC Cal Check where SmpGearName = Data Sonde/Logger Combo
  - a. exclude temperature loggers (SmpGearName = Data Probe (Single))—these don't matter because temperature isn't QC'd using loggers
  - b. check that unattended OWMIDs (SmpTypName = In-situ: Un-attended) do not report logger ID for SN2SampGear (could indicate incorrect SmpTypName)
5. Include missing OWMIDs that were omitted from electronic field sheet entry because the sonde wasn't used (usually due to no water, stagnant, low flow, or ice conditions; sometimes due to probe malfunction, battery issues, or site accessibility)
  - a. look for OWMIDs already assigned on paper field sheets and add all sample info to electronic field sheet
    - i. make sure OWMID hasn't been used for another survey/field sheet
  - b. assign new OWMIDs for cases where no OWMID is recorded on paper field sheet
6. Make sure OWMIDs fall under correct SmpTypName
  - a. field sheets where the first digit following the basin letter code is zero are attended
  - b. field sheets where the first digit following the basin letter code is 5 are deployed (In-situ: Un-attended or In-situ: QC Cal Check)
  - c. make corrections as necessary
7. Check that all deployed field sheets have at least 1 un-attended OWMID and 2 QC Cal Check OWMIDs
  - a. sort electronic field sheet by FSLOG, then by SmpTypName descending order
  - b. apply conditional formatting where text = "un" in SmpTypName column, highlight cells a color
  - c. select SmpTypName = blanks, In-situ: Un-attended, In-situ: QC Cal Check



- d. scan through file to make sure that all blanks have been addressed (should have been found by checking for missing OWMIDs) and that each field sheet has at least 1 un-attended and 2 QC Cal checks)
- e. add missing OWMIDs and the associated sample info to electronic field sheet