Region 4 U.S. Environmental Protection Agency Laboratory Services and Applied Science Division Athens, Georgia	
Operating Procedure	
Title: Hydrological Studies	**ID: FSBPROC-501-R7**
Issuing Authority: Field Services Branch Supervisor	
Effective Date: August 20th, 2024	**Next Review Date: August 20th , 2028**
Method Reference: NA	**SOP Author: Derek Little**

Purpose

This document describes general and specific procedures, methods, and considerations to be used and observed when completing Hydrological Studies. While this SOP may be informative for other businesses, it is not intended for and may not be directly applicable to operations in other organizations. Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use.

Scope/Application

This document describes both general and specific methods to be used by field personnel when obtaining hydrological data during water quality surveys. On the occasion that LSASD field investigators determine that any of the procedures described in this section are inappropriate, inadequate or impractical and that another procedure must be used to obtain a hydrological measurement, the variant procedure will be documented in the field logbook, along with a description of the circumstances requiring its use.

Note: LSASD is currently migrating to a paperless organization. As a result, this SOP will allow for the use of electronic logbooks, checklists, signatures, SOPs, and forms as they are developed, which will also be housed on the Local Area Network (LAN) and traceable to each project.

Table of Contents

1. Procedural Information

1.1. General

1.1.1. Hydrological studies are an important component of many branch field studies and include activities such as flow measurement and stage/discharge relationship development. Stage measurement and the determination of stage-discharge relationships are also important hydrological data collected by the branch. For example, stage-discharge studies are extremely useful for determining flow in conjunction with Total Maximum Daily Load (TMDL) storm event sampling efforts. As much attention and care should be given to hydrological measurements in the design of a sampling program as to the collection of water quality samples and subsequent laboratory analysis.

1.1.2. The techniques and equipment described in this procedure are designed to provide representative measurements of specific hydrologic parameters and rates. Care should be applied in the selection of measurement sites and/or reaches to ensure personnel and equipment safety. For example, bridge-based flow measurements may be required when stream velocities preclude wading. Unattended monitoring equipment or samplers should be located outside of navigation channels in large river/estuary surveys and above anticipated water levels during stream-bank deployments.

1.2. Equipment Considerations

1.2.1. The type and size of the water body under investigation will often dictate the equipment required for flow measurement. Wadeable streams will be measured using an acoustic Doppler velocimeter (ADV) affixed to a wading rod. Deeper swifter rivers may require a bridge rig or remote-controlled acoustic Doppler current profiler (ADCP).

1.2.2. Water level/stage measurements can be made using a transducer logger, vented data sonde, or a staff gauge.

1.3. Field Demonstration of Competency

1.3.1. On the job training (OJT) will be supplied for each method (Surface Water Stage and Tape Down, Bucket Flow, Surface Water Flow, and Current Measurement) by the Subject Matter expert or a Competent Staff member.

1.3.2. Three documented OJTs are required before completing an Initial Demonstration of Competency for each method.

1.3.3. Documentation shall follow the process outlined in LSASDPROC-1003 Training and Demonstration of Competency Section 1.2.

1.4. Surface Water Stage and Tape Down

1.4.1. Water level recorders provide a time series record of water levels. When possible, these instruments should be referenced to National Geodetic Vertical Datum (NGVD). All notes on water level tracings should include beginning and ending date and time, site location, stage scale, time scale and the name of the field investigators responsible for the data. Standard United States Geological Survey (USGS) staff gauges may be employed at each water level recorder site to provide a reference and check on the recorder trace. Water stage should be recorded to the nearest 0.01 foot, where possible.

1.4.2. Tape downs provide instantaneous water stage as referenced to a known elevation. An engineering tape is fashioned with a plumb bob to measure from a bridge deck or other reference point to the water surface. The plumb bob provides weight for the tape as well as providing a discernible contact with the water surface. All measurements should be to the nearest 0.01 foot accompanied by a date, time, and station location. The exact reference or point from which a tape down is measured should be permanently marked on the reference (wing wall or bridge rail by etching a reference with a chisel, etc.) and a complete description of the reference should be made in the field records. Photographs are also helpful for referencing a site.

1.4.3. Both procedures (water stage and tape downs) are predicated upon accurate references to established measuring points. As mentioned above, the NGVD is an established datum that provides correlation of water surface recordings to engineering structures (bridge, wing walls, sea wall caps, clarifier cat walks, etc.). When recording water-level dynamics in relation to a specific flow device, the datum is established in relation to the flow device reference point. The flow through rectangular and V-notch weirs, for instance, is proportional to the water level referenced to the weir crest or, in the case of partially filled pipes, the flow rate is proportional to the depth of flow. Therefore, when employing a water-level recorder or tape down on primary flow devices, the reference or datum is the weir crest, or in the case of pipes, the invert. Be sure to record the established flow device reference point.

1.5. Bucket Flow Method

1.5.1. The bucket flow test is a simple but effective way to calculate a flow rate when the above three methods are not appropriate due to field limitations. The equipment required to complete the test is a bucket with known volumetric graduations and a device to record elapsed time (stopwatch). Place the bucket underneath the water flow and time how many seconds it takes to fill the bucket to a chosen volume. Dividing the volume of water collected by the elapsed time will provide the flow rate for that location.

1.6. Surface Water Flow

1.6.1. Surface waters are open channels for flow measurement purposes. Flow measurements shall be made using stream gaging or acoustic Doppler techniques.

1.6.2. Stream Gaging

1.6.2.1. Where available, flow data and/or rating curves may be obtained from existing permanent stream gaging stations maintained by the USGS, United States Army Corps of Engineers or other federal or state agencies. Where permanent stations do not exist, flow may be measured using stream gaging techniques. In making stream gaging measurements and calculating flow, personnel shall utilize the procedures outlined in the USGS publications General Procedures for Gaging Streams (Carter RW, 1968) and Discharge Measurements at Gaging Stations (Turnipseed P, 2010). If a station is to be used more than one time during a water quality survey, a rating curve may be developed for that station. A rating curve is constructed by making a series of independent flow measurements and simultaneous tape down or staff gauge measurements for the same section of a station at different water levels and plotting the resulting data pairs on a semi-log graph. At least two (preferably three spanning multiple seasons) flow measurement-tape downs shall be made to develop a rating curve.

1.6.2.2. For wadeable streams, Acoustic Doppler Velocimeters may be deployed using a top setting wading rod. For non-wadeable or inaccessible streams, a meter may be deployed on a weighted line using a bridge rig system or by using an extended length top-setting rod from a bridge. Depth may be determined from a standard top-setting wading rod, or by taking the difference of tape down or bridge rig measurements of the river bottom and surface.

1.6.3. Cross Section Selection

1.6.3.1. The section of reach where the flow measurements will be made should be selected using the following criteria:

1) A straight reach with the threads of velocity parallel to each other.

2) Stable streambed free of large rocks, weeds, and protruding obstructions such as piers which would create turbulence.

3) A flat streambed profile to eliminate vertical components of velocity.

1.6.3.2. Natural conditions rarely exhibit a reach that satisfies all of these criteria, but a section should be chosen that meets criteria as best as possible. Rocks and other debris within a desired cross section and upstream may be removed prior to any measurements to improve conditions.

1.6.4. Stream Width/Depth

1.6.4.1. After the cross section has been selected the width of the stream must be determined. For wading conditions width measurements may be made using a Lee-Au galvanized steel tag line segmented into equal lengths, steel tapes or cloth tapes. For non-wading conditions, total width may be determined by using a laser range finder. Width should be taken from the edges of the water and bank directly perpendicular to flow. Record the depth by holding the wading rod in a vertical position.

1.6.4.2. For a bridge measurement, lower the tow body to the water surface and set the counter to "Ø". Lower the tow body to the bottom of the water body to determine total depth. Adjust the Ø every 2-3 measurements to account for a bridge crown or slope.

1.6.5. Measurement Spacing

1.6.5.1. Division of measurements should be made such that no partial flow section contains more than 10% of the total discharge. On average there should be 25 to 30 partial sections. For a cross section with a smooth level bottom and good velocity distribution fewer partial sections can be used. A uniform partial section size is not required. Partial section sizes may be adjusted, where needed, to ensure that 10% of the total discharge is not exceeded.

1.6.6. Velocity Measurement

1.6.6.1. When recording velocity, the operator should stand in a position that least affects the velocity of water passing the current meter, usually facing upstream behind the rod and meter. In low flow conditions measurements should be made after ample time has passed that any eddy created by moving has passed. Bridge measurements should be made on the upstream side where feasible.

1.6.6.2. Data quality objectives (DQO) determine the degree of procedures for the measurement. DQOs for the measurement can be divided into two general categories: low and high. Examples of low and high DQO scenarios and their corresponding measurement method cutoff recommendations are provided below. Determination of the DQO level is determined by the project leader.

- Low DQO measurements:
  - Reconnaissance
  - Generalized Loading Calculations
- High DQO:
  - Rating Curves
  - High Priority Loadings Calculations

Table 1: Low and High DQO Scenarios

	Measurement Method		**Averaging Time (seconds)**
DQO Level	0.6 Depth	0.2 and 0.8 Depth	
Low	Total Depth ≤ 2.5 ft	Total Depth > 2.5 ft	30
High	Total Depth ≤ 1.5 ft	Total Depth >1.5 ft	40 to 60

1.6.6.3. A signal to noise ratio of greater than 10 dB is recommended by the manufacturer of the SonTek FlowTracker2® but can be operated as low as 2-3 dB.

1.6.7. Calculating Flow

1.6.7.1. A current meter measurement for discharge is the summation of the products of the partial areas of the stream cross section and their respective average velocities.

$$Q = \sum_{0}^{i=n} \left(a_n v_n \right)$$

Where:

Q is the total discharge, and is the partial cross-section area for partition n,

v_n is the mean velocity of the flow normal to the corresponding partial area.

1.6.7.2. A midsection method is used in calculating total discharge where each measured velocity is assumed to equal the mean velocity for that cross-sectional division area. The area extends laterally half the distance for the preceding meter location to half the distance to the next and vertically from the water surface to the sounded depth.

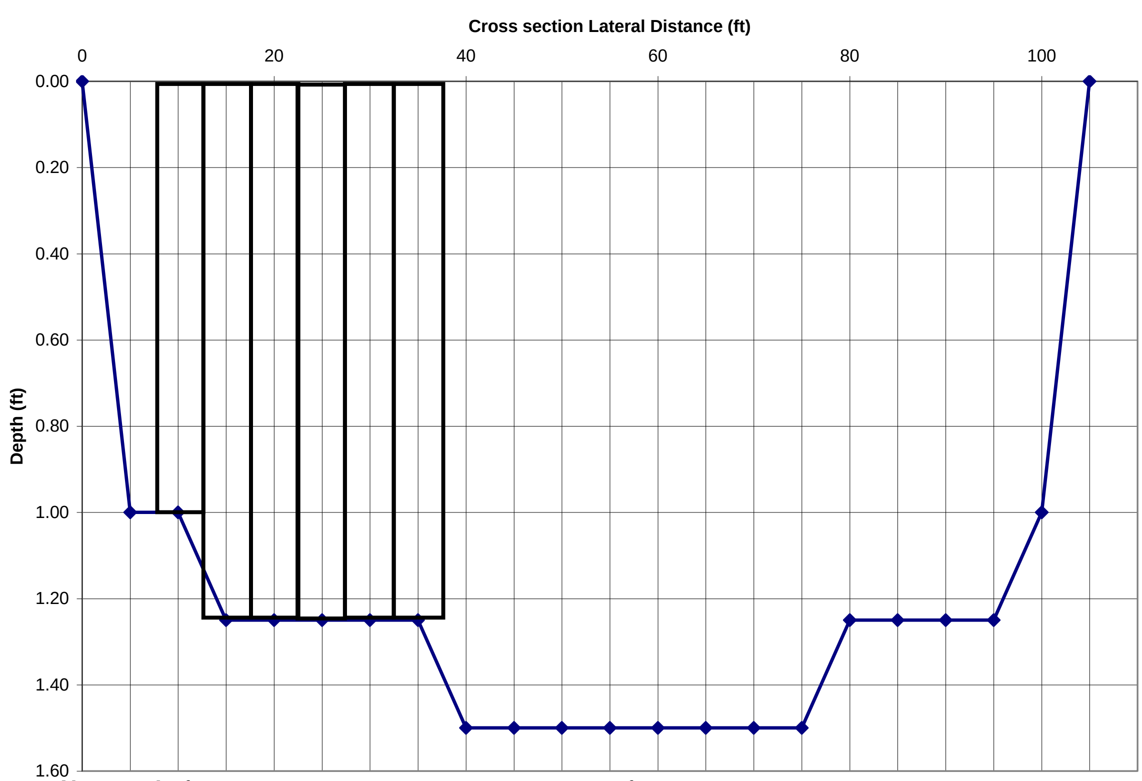
1.6.8. Example Flow Calculation

1.6.8.1. Table and **Error! Reference source not found.** detail an idealistic cross section and its corresponding velocity measurements. The bold boxes in **Error! Reference source not found.** represent the midpoint area for the first two measurements. Velocity measures at those distances are assumed to be throughout the highlighted box.

Table 2: Example Sample Measurements

Dist (ft)	Width (ft)	Depth (ft)	V (fps)
0	0	0.00	0.00
5	5	1.00	1.00
10	5	1.00	1.40
15	5	1.25	1.20
20	5	1.25	1.50
25	5	1.25	1.80
30	5	1.25	1.50
35	5	1.25	1.50
40	5	1.50	1.60
45	5	1.50	1.50
50	5	1.50	1.60
55	5	1.50	1.50
60	5	1.50	1.50
65	5	1.50	1.50
70	5	1.50	1.50
75	5	1.50	1.50
80	5	1.25	1.50
85	5	1.25	1.40
90	5	1.25	1.50
95	5	1.25	1.50
100	5	1.00	1.20
105	5	0	0

Figure 1: Example Cross Section Division



1.6.8.2. For each velocity a corresponding area and flow are calculated. The area is calculated as:

$$a_x = \left[\frac{b_{(x+1)} - b_{(x-1)}}{2}\right] d_x$$

Where:

a_x = location of measurement point
$b_{(x-1)}$ = distance from the measurement point to the preceding location, x-1
$b_{(x+1)}$ = distance from the measurement point to the next location, x+1
d_x = depth of water at location x

For location at 10 feet a10 is calculated as:

$$a_{10} = \left[\frac{15-5}{2}\right]1 = 5\,ft^2$$

Therefore, the flow at distance x (q_x) can be calculated as:

$$q_x = v_x a_x$$

Where:

v_x = the measure velocity at location x

For location at 10 feet q_{10} is calculated as:

$$q_{10} = 1.4\,fps \times 5\,ft^2 = 7cfs$$

1.6.8.3. Total flow can then be calculated by the summation of the individual flows at all points x. Table provides a summary of the results for Table .

Table 3: Results

Dist (ft)	Width (ft)	Depth (ft)	V (fps)	Area (ft2)	Flow (cfs)
0	0	0.00	0.00	0.00	0.00
5	5	1.00	1.00	5.00	5.00
10	5	1.00	1.40	5.00	7.00
15	5	1.25	1.20	6.25	7.50
20	5	1.25	1.50	6.25	9.38
25	5	1.25	1.80	6.25	11.25
30	5	1.25	1.50	6.25	9.38
35	5	1.25	1.50	6.25	9.38
40	5	1.50	1.60	7.50	12.00
45	5	1.50	1.50	7.50	11.25
50	5	1.50	1.60	7.50	12.00
55	5	1.50	1.50	7.50	11.25
60	5	1.50	1.50	7.50	11.25
65	5	1.50	1.50	7.50	11.25
70	5	1.50	1.50	7.50	11.25
75	5	1.50	1.50	7.50	11.25
80	5	1.25	1.50	6.25	9.38
85	5	1.25	1.40	6.25	8.75
90	5	1.25	1.50	6.25	9.38
95	5	1.25	1.50	6.25	9.38
100	5	1.00	1.20	5.00	6.00
105	5	0	0	0	0

1.6.9. Acoustic Doppler Current Profiler (ADCP)

1.6.9.1. Acoustic Doppler Current Profiler (ADCP) meters used in flow measurements may be deployed via a boat-mounted configuration for larger river/estuarine systems or mounted on a tethered float for smaller stream measurement applications. The ADCP provides velocities at several depths along a cross-section of the river. Also, ADCP meters may be used to determine depth and width in conjunction with a laser range finder or other means for determining edge distances. The USGS publication "Discharge-Measurement System Using an Acoustic Doppler Current Profiler with Applications to Large River and Estuaries" (Simpson MR, 1993) provides guidance in the use of ADCP for flow measurement.

1.6.9.2. When using an ADCP in a steady flow system, flow should be measured a minimum of four times along a transect, preferably twice in each direction, and an average of the flows determined. If the four measurements vary by >10%, two to four additional measurements should be made to improve the average flow determination. In unsteady flows or when other field demands limit available time, a flow can be determined from fewer than four transects. In some instances (e.g., tidal river), measurements may be limited to a single transect.

1.6.9.3. ADCP flow is calculated by the manufacturer's software. Adjustments to the resulting flow calculations may be made by the field investigator following data collection based on professional judgment in concert with manufacturer and USGS guidance.

1.7. Current Measurement

1.7.1. Current measurements may be made by several different instruments. Available equipment includes Acoustic Doppler Current meters.

1.7.1.1. Each meter may be programmed via appropriate connection to a computer prior to deployment, deployed in an unattended mode, and interrogated for data download by computer following data collection. Likewise, the meters may be used for real-time data collection in profiling applications. For unattended applications, deployment in and out times/dates should be recorded in the field record. The field record should also include the location and depth(s) of the deployment and serial number or other appropriate identifier of the meter(s) used in the deployment.

1.7.1.2. For unattended applications, the meters may be deployed on a weighted tether line with a subsurface float to keep the tether line taut and a surface float for locating the meter. Multiple meters can be deployed at any depth(s) on the tether. Meters should be deployed in a way that minimizes potential equipment damage or interference from ship traffic or other obstructions.

1.7.1.3. Doppler current meters may be deployed in a variety of ways. For unattended current measurements, these meters may be mounted to a weighted platform specifically designed to minimize potential impacts from drag lines or nets; or in a protective load cage attached to a tether line at a specific depth. It is recommended to attach at least one pinger or locating beacon to the mounting device for unattended measurements. The meter may also be boat mounted for real-time data collection and profiling.

2. General Precautions

2.1. Safety Precautions

2.1.1. Proper safety precautions must be observed when performing hydrological studies. Refer to the LSASD Safety and Occupational Health Manual and any pertinent site-specific Health and Safety Plans (HASPs) and Job Hazard Assessments for guidelines on safety precautions. These guidelines should be used to complement the judgment of an experienced professional. For additional safety information see the Region 4 Safety & Occupational Health SharePoint Site at:

https://usepa.sharepoint.com/sites/r4-safety-occup-health

2.2. Procedural Precautions

2.2.1. The following precautions should be considered when conducting hydrological studies:

- All instrumentation should be in good condition and operating within the manufacturer's recommended tolerances.

- All instrumentation should be calibrated and deployed in accordance with the manufacturer's requirements.

References

Carter RW, D. J. (1968). General Procedure for Gaging Streams U.S. Geological Survey, Techniques for Water-Resources Investigations, Book 3, Chapter A6. USGS.

Kilpatrick FA, W. J. (1989). Measurement of time of travel in streams by dye tracing, Chapter A9. Techniques of Water-Resources Investigations of the United States Geological Survey. United States Geological Survey.

Simpson MR, O. R. (1993). Discharge-measurement system using an acoustic Doppler current profiler with applications to large rivers and estuaries. USGS.

Turnipseed P, S. V. (2010). Discharge measurements at gaging stations Techniques and Methods 3-A8. USGS.

U.S. EPA. (1991). Technical Support Document for Water Quality-based Toxic Controls 505/2-90-001. Office of Water, EPA.

Wilson JF, C. E. (1986). Fluorometric Procedures for Dye Tracing U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 3, Chapter A12. United States Geological Survey.

Revision History

Revision History	Date
FSBPROC-501-R7, *Hydrological Studies*, replaces LSASDPROC-501-R6 Updated Health & Safety web address. Removed “Electromagnetic Current meters” from Section 1.9.1 (FSB no longer has these). Minor edits made throughout.	May 31, 2024
LSBPROC-501-R6, *Hydrological Studies*, replaces SESDPROC-501-R5 SOP put in the new format. SOP revised to include dye tracer procedures.	December 3, 2021
LSBPROC-501-R5, *Hydrological Studies*, replaces SESDPROC-501-R4 Update SESD to LSASD Update to new Divisional format Added Definitions Section **Section 1.5** Dilution: removed statement:”State-of-the-art fluorometers make the dilution study methods valuable assessment tools.” **Section 1.6.5** removed statement: “At a minimum the following information should be recorded in logbooks in addition to those required according to SESD Operating Procedure (SESDPROC 010): Total Discharge, Total Width, Total Area	June 26, 2020
SESDPROC-501-R4, *Hydrological Studies*, replaces SESDPROC-501-R3. **Cover Page:** Changed Author from Stacey Box to Derek Little. Changed Ecological Assessment Branch Chief to Field Services Branch Chief. Changed the FQM from Bobby Lewis to Hunter Johnson. **References 1.4:** Updated References **Section 3.2:** Removed reference to Turner Scuffa units **Section 7.1:** Removed “Available current meters for conducting stream gaging include various acoustic Doppler velocimeters and vertical-axis mounted Price AA and Price pygmy meters.” **Section 7.1.4:** Revised recommendations for minimum logbook recordings. Removed references to Price/Pygmy meters. Removed 3rd paragraph and replaced with table of recommendations along with data quality objectives considerations.	September 26, 2016
SESDPROC-501-R3, *Hydrological Studies*, replaces SESDPROC-501-R2.	August 15, 2012
SESDPROC-501-R2, *Hydrological Studies*, replaces SESDPROC-501-R1.	November 6, 2009
SESDPROC-501-R1, *Hydrological Studies*, replaces SESDPROC-501-R0.	November 1, 2007
SESDPROC-501-R0, *Hydrological Studies*, Original Issue	February 05, 2007