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Surface–Water Quality–Assurance Plan for the U.S. Geological Survey Washington Water Science Center

Open–File Report 03-490
Version 2.0, May 2011

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Surface-Water Quality-Assurance Plan for the U.S. Geological Survey Washington Water Science Center

David L. Kresch and Stewart A. Tomlinson

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U.S. Department of the Interior
U.S. Geological Survey

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Surface-Water Quality-Assurance Plan for the U.S. Geological Survey Washington Water Science Center

By David L. Kresch and Stewart A. Tomlinson

Abstract

This Surface-Water Quality-Assurance Plan documents the standards, policies, and procedures used by the U.S. Geological Survey's Washington Water Science Center (WAWSC) for activities related to the collection, processing, storage, analysis, and publication of surface-water data. This plan serves as a guide to all WAWSC personnel involved in surface-water data activities, and changes as the needs and requirements of the WAWSC change. Regular updates to this Plan represent an integral part of the quality-assurance process. In the Washington Water Science Center, direct oversight and responsibility by the hydrographer(s) assigned to a surface-water station, combined with team approaches in all work efforts, assure high-quality data, analyses, reviews, and reports for cooperating agencies and the public.

Introduction

Congress established the U.S. Geological Survey (USGS) on March 3, 1879, to provide a permanent Federal agency to perform the systematic and scientific "classification of the public lands, and examination of the geologic structure, mineral resources, and products of the national domain." Six mission areas in the USGS exist—Ecosystems; Climate and Land-Use Change; Natural Hazards; Energy and Minerals and Environmental Health; Core Science Systems; and Water. The Water mission area includes surface-water activities in Washington State. Federal, State, and local agencies use surface-water information, including streamflow, stage, and sediment data, for resources planning and management throughout the State. The general public uses stage and discharge data for informational purposes such as flood monitoring and recreation.

Purpose and Scope

The purpose of the USGS Washington Water Science Center's (WAWSC) Surface-Water Quality-Assurance (QA) Plan is to document the standards, policies, and procedures used by the WAWSC for activities related to the collection, processing, storage, analysis, and publication of surface-water data. This plan identifies responsibilities for ensuring that stated policies and procedures are carried out. The plan also serves as a guide for all WAWSC personnel involved in surface-water activities and as a resource for identifying memorandums, publications, and other literature that describe in more detail associated techniques and requirements. Also, the QA Plan provides information and guidelines for cooperating agencies and to agencies that furnish data to the WAWSC.

The scope of the QA Plan encompasses discussions of the policies and procedures followed by the WAWSC for the collection, processing, analysis, storage, and publication of surface-water data. Primary types of surface-water data collected by Field Offices in the WAWSC include stage (water-surface elevation) and streamflow data. Other related data collected by the Field Offices and projects in the WAWSC, that are not specifically addressed herein, include sediment data, drainage basin characteristics, meteorological data, snowpack data, and evapotranspiration data. The Plan also presents issues related to the management of the computer database and employee safety and training. Although procedures and products of surface-water data collected for interpretive projects are subject to the criteria presented in this report, Project Chiefs must develop a separate and complete quality-assurance plan for their interpretive projects for specialized surface-water data not addressed herein. Project Chiefs should consult USGS publications for guidelines on QA and work plans (Green, 1991; Schroder and Shampine, 1992; Shampine and others, 1992). The WAWSC Surface-Water Specialist reviews the WAWSC QA Plan at least once every 3 years in order that responsibilities and methodologies are kept current and in order that the ongoing procedural improvements can be effectively documented.

This QA Plan does not address some topics, and addresses other topics only briefly. The Plan does not discuss proposed policy and issues for archiving data on permanent media. Nor does the Plan address sediment data in detail. Field Office personnel and Project Chiefs involved with the collection and analysis of sediment data should refer to the published USGS Sediment QA plan and guidelines (Knott and others, 1993; Knott and others, 1992; Porterfield, 1972).

Acknowledgments

The WAWSC Surface-Water QA Plan utilizes the basic framework presented in "A Workbook for Preparing Surface-Water Quality-Assurance Plans for WAWSCs of the U.S. Geological Survey, Water Resources Discipline" (Arvin, 1995), released by Office of Surface Water (OSW) memorandum 95.03. Differences between the Workbook and the WAWSC's QA Plan include text additions and deletions, rewording of the text, reorganization of some sections, and inclusion of figures for quick reference. The section of the QA Plan that addresses the quality assurance of real-time data follows the guidelines given in an addendum to the Workbook, released by OSW memorandum 99.07.

Responsibilities

Quality assurance involves actively maintaining and improving high standards at all levels of responsibility. Achieving and maintaining high-quality standards for all data remain key to the integrity of the USGS. Clear delineations of responsibility sometimes become difficult to determine because of varying levels of expertise and duties in an office, combined with numerous types of gaging activities and instruments. Although the WAWSC Director takes responsibility for overseeing the entire WAWSC program, which includes surface-water data collection and analysis, ultimately the person having the most impact on the quality assurance of the collected data is the person who collects the data. Just as the author of a report in the WAWSC oversees the report through completion (WAWSC Report-Review Process, Evaluation, and Improvement Plan, 1995, internal publication), it is the hydrographer who must ensure that accurate, timely data are collected and processed up to the point of final review. Co-workers, supervisors, and managers in the WAWSC organization (fig. 1) serve as resources for the hydrographer to utilize to accomplish the goal of quality-assurance in data. Teamwork and excellent communication between fellow hydrographers and employees in collecting, analyzing, and reviewing data are critical to an effective QA Plan.

Responsibilities of individual WAWSC personnel for ensuring that specified surface-water QA requirements are as follows.

Washington Water Science Center Director

1. Managing and directing the WAWSC program, including all surface-water activities.
2. Ensuring that surface-water activities in the WAWSC meet the needs of the Federal Government, the WAWSC, State and local agencies, other customer agencies, and the public.
3. Ensuring that all aspects of this QA Plan are understood and followed by WAWSC personnel. This is accomplished by the WAWSC Director's direct involvement or through clearly stated delegation of this responsibility to other personnel in the WAWSC.
4. Providing final resolution of any conflicts or disputes related to surface-water activities within the WAWSC.
5. Keeping subordinates briefed on procedural and technical communications from Regional offices and Headquarters.
6. Performing or facilitating periodic reviews of all surface-water programs.
7. Ensuring that all publications and other technical communications released by the WAWSC are accurate and in accord with USGS policy.

Washington Water Science Center Assistant Director for Hydrologic Data (Data Chief)

1. Advises WAWSC Director on all matters related to surface-water networks and data-collection in the WAWSC.
2. Has responsibility for implementing the WAWSC Surface-Water QA Plan in the Hydrologic Data Program and coordinates quality-assurance activities between Field Offices and other units in the Data Program and WAWSC.
3. Ensures that surface-water projects within the Data Program satisfactorily address quality-assurance issues.
4. With the WAWSC Director, coordinates surface-water quality-assurance issues with WAWSC, Regional, and Headquarters staff specialists.

Washington Water Science Center Associate Director for Hydrologic Studies (Studies Chief)

1. Reviews individual ongoing investigations that have surface-water data requirements and ensures that WAWSC surface-water quality-assurance procedures, including appropriate data archiving, are being followed.
2. Coordinates and reviews any surface-water quality-assurance issues with the Surface-Water Specialist.
3. Advises the WAWSC Director and Data Chief on current surface-water projects within the WAWSC.

Updated 01-5-11

	Studies	Data	Support	Total
Permanent	41	29	13	83
Contract	0	0	0	0
OTP	4	2	0	6
Vacant	0	1	2	3
Total	45	32	15	92

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Carlson, C.T., Geographer-12, WA GIO Liaison

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2 - Field Services Unit and Hazard Waste Coordinator/QW DBA
3 - GW DBA
4 - WU DBA
5 - SW DBA
6 - Lakewood Facility Coordinator
7 - GIS Specialist
8 - Information Officer

Key

Names in bold are supervisors.
Employees whose names are indented are supervised by the employee shown above them.

Figure 1. Organization of the U.S. Geological Survey Washington Water Science Center.

Washington Water Science Center Surface-Water Specialist

1. Advises WAWSC Director, Data Chief, and Studies Chief of current surface-water quality-assurance policy and procedures and has responsibility for developing and updating the WAWSC Surface-Water QA Plan.
2. Keeps abreast of current Water Resources Discipline policies, procedures, and practices regarding the quality assurance of surface-water data.
3. Reviews and certifies International Gaging Station records, project surface-water records, and all WAWSC indirect measurements; participates in the WAWSC QA review of network station records.
4. Reviews project proposals involving surface-water data collection and analysis, and ensures that projects include a quality-assurance element.
5. Reviews surface-water elements of WAWSC investigative and data-collection projects and serves as advisor to WAWSC staff on technical matters concerning surface-water hydrology and hydraulics.
6. Reviews surface-water reports produced by the WAWSC and ensures that proper adherence to quality-assurance guidelines and procedures has been maintained in data collection and analysis.
7. Makes recommendations to WAWSC Director, Studies Chief, and Data Chief for improvements in WAWSC surface-water quality-assurance programs and procedures.
8. Develops and(or) arranges training in surface-water techniques and principles for WAWSC staff.

Washington Water Science Center Hydroacoustic Specialist

The WAWSC has a designated Hydroacoustic Specialist. The Hydroacoustic Specialist is responsible for:

1. Advising the Data Chief, the Center's Surface-Water Specialist, and Project Chiefs about all aspects of the use of hydroacoustic instruments.
2. Updating users of hydroacoustic instruments about new policies and recommended procedures pertaining to the use of those instruments.
3. Updating users of hydroacoustic instruments about instrument software and hardware upgrades.
4. Helping users of hydroacoustic instruments to troubleshoot malfunctions and take corrective actions.
5. Reviewing data, procedures, methods, and documentation regarding hydroacoustics.
6. Updating hydroacoustic quality-assurance documents.
7. Advising the Data Chief on personnel training.
8. Tracking trained Center personnel as qualified users of hydroacoustic instruments.

Field Office Chiefs

1. Responsible for ensuring that Field Office personnel follow the WAWSC Surface-Water QA Plan.
2. In consultation with the Data Chief and Surface-Water Specialist, implements procedures to improve Field Office surface-water data-collection methods when needed.
3. Coordinates surface-water quality-assurance activities between Field Office employees and other staff within the Data Section and other units in the WAWSC.
4. Provides input to Data Chief on surface-water quality-assurance procedures used by Field Office personnel.

Project Chiefs

1. Responsible for ensuring that Project personnel follow the WAWSC Surface-Water QA Plan.
2. In consultation with the Surface-Water Specialist, implements procedures to improve surface-water data-collection methods when needed.
3. Coordinates surface-water quality-assurance activities between Project staff and personnel in other units in the WAWSC.
4. With the Surface-Water Specialist, develops quality-assurance plans for issues not addressed in this plan.

Field Personnel

1. Responsible for following the guidelines and procedures outlined in the WAWSC Surface-Water QA Plan for all surface-water data-collection activities.

2. Notify supervisor of any issues that make it difficult or impossible to follow the WAWSC's QA plan at stations in their field trip, and recommend corrections.

3. Regularly review real-time data to detect potential problems with the gage-height record.

Washington Water Science Center Surface Water Database Administrator

1. Responsible for ensuring that data disseminated from the National Water Information System (NWIS) have been quality-assured before release to the public.

2. Makes recommendations to the WAWSC Data Chief for improvement of surface-water quality-assurance procedures regarding NWIS and real-time surface-water data.

Collection of Surface-Water Data

Planning and resource management require reliable surface-water data because many of society's daily activities, including industry, agriculture, energy production, waste disposal, habitat protection, and recreation, link closely to streamflow and water availability. A primary component of operating streamflow-gaging stations (referred to as gaging stations in this report) and conducting other water-resource studies performed by the USGS in the WAWSC is the collection of stage and discharge data.

Most gaging stations operate with the objective of obtaining a continuous record of stage and discharge at the selected site (Carter and Davidian, 1968). A system of instruments that sense and record water-surface elevation in the stream provide a continuous record of stage. Hydrographers periodically make discharge measurements to define or verify the stage-discharge relation and to define the time and magnitude of variations in that relation.

In the WAWSC, all personnel follow established USGS guidelines on the collection of stage and discharge data. Several USGS publications, such as Water-Supply Paper 2175 (Rantz and others, 1982) and many chapters of Book 3 of the USGS report series "Techniques of Water-Resources Investigations", rigorously discuss USGS guidelines on surface-water data collection. Technical memorandums of the USGS's Office of Surface Water (OSW) provide detail on some of these guidelines (appendix A).

At a few sites in Washington simple stage-discharge relations cannot be developed because of the effect of tides or backwater from downstream dams. In those situations a discharge rating is developed by using a velocity index and a stage-velocity-discharge relation.

New conditions and the development of new technology sometimes involve the collection of surface-water data with alternative equipment, some of which have not been fully accepted by USGS. To demonstrate the quality of surface-water data collected with alternative equipment, Field Offices must thoroughly document procedures and observations.

In other cases, the WAWSC may cooperate or contract work with another agency that uses alternative equipment, such as Swoffer current meters. Quality-assurance programs between alternative meters and USGS approved meters will be developed between the USGS and the other agency or contractor to assess whether the alternative meter can be used regularly. Such a program would entail testing both types of meters under controlled and field conditions under an array of stream discharges to validate or invalidate use of the alternative meter. In addition, the other agency or contractor must provide the WAWSC with the procedures they use for ensuring proper calibration of their current meters.

The WAWSC constantly seeks to improve current standards of equipment, and sometimes purchases newly developed Electronic Data Loggers (EDLs), Data Collection Platforms (DCPs), pressure transducers, or other equipment. Before alternative equipment is permanently installed, the WAWSC tests the equipment against standards tested and approved by the Hydrologic Instrumentation Facility (HIF) to meet USGS guidelines. The Field Office or Project Chief ensures that WAWSC personnel correctly use alternative equipment and comprehensively document the equipment's use.

Gage Installation and Maintenance

Critical activities for ensuring quality in streamflow-data collection and analysis include proper installation and maintenance of gaging stations. Effective site selection, correct design and construction, and regular maintenance of a gage are of paramount importance to the efficient collection of accurate streamflow data.

Site selection for a gaging station depends on several criteria, including the purpose of the gage, hydraulic conditions, and access. Criteria that describe the ideal gaging-station site (Rantz and others,1982, p. 5) include unchanging natural controls that promote a stable stage-discharge relation, a satisfactory reach for measuring discharge throughout the expected range of stage, and a means for efficient access to the gage and measuring location. Other aspects of controls considered by WAWSC personnel when planning gage-shelter installations include physical features such as rock riffles, overflow dams, and channel characteristics (Kennedy, 1984, p. 2).

The Field Office Chief or Project Chief, in conjunction with input from field personnel familiar with the area, the construction crew, and the Data Chief and (or) Surface-Water Specialist, selects sites for new gaging stations and oversees the gage construction through to completion. Factors considered in site selection include (1) purpose of the gage, (2) hydraulic and hydrologic considerations, and (3) cost and accessibility. Selecting a new site includes several steps, such as consulting with the cooperating agency, checking terrain and drainage area on a topographic map, field reconnaissances, and a search for data for previous sites on the selected or nearby streams. The Field Office Chief or Project Chief ensures that agreements with property owners are properly documented and that all necessary permits have been obtained. In Washington, permits are required from the land owner (private, local, State, or Federal agency) and the Washington Department of Fish and Wildlife (Hydraulic Project Approval). Other permits may also be required at some sites. The Field Office Chief or Project Chief approves the site design, in conjunction with input from the hydrographer who will be servicing the site, the construction crew, and the Data Chief and(or) Surface-Water Specialist. The Field Office Chief or Project Chief approves the final gaging station product.

A program of careful inspection and maintenance of gages and gage shelters promotes the collection of reliable and accurate data. Allowing the equipment and structures to fall into disrepair may result in unreliable data and unsafe conditions. WAWSC field personnel conduct basic gaging station maintenance on a regular basis. To prevent the buildup of mud or the clogging of intakes, hydrographers flush intakes to stilling wells during each visit (unless weather is below freezing) and de-silt the wells as needed (every 2-15 years) or after a major flood event. Other maintenance activities performed by hydrographers on a regular basis include checking all inside and outside staff gages, checking the bubbler rate and volume of gas left in the nitrogen tank, removing debris and silt from the pressure transducer, purging the transducer orifice line, checking/maintaining the battery voltage, noting outside high-water marks, and maintaining a log of gage inspection information in the gage shelter (fig. 2).

The hydrographer ensures that gages and gage shelters are kept in good repair. To ensure these responsibilities are carried out, hydrographers report any deficiencies that they cannot immediately repair to the Field Office Chief. Annual cableway inspections are documented on cableway inspection sheets (appendix B1). The hydrographer should work with the Field Office Chief or Project Chief to remedy the noted deficiencies or hazards. The hydrographer should never compromise safety for any reason and must accurately document station safety deficiencies to the Field Office Chief or Project Chief. In addition to the annual inspections by the hydrographer regularly servicing the gage, the Field Office Chief or their designee inspects each gaging site at least once every 3 years.

Measurement of Stage

Many types of available instruments measure the water level, or stage, at gaging stations. Gage types include nonrecording gages (Rantz and others, 1982, p. 24) and recording gages (Rantz and others, 1982, p. 32). Because stage data may be used in a variety of ways, OSW policy requires that field personnel collect surface-water stage records at stream sites with certain procedures and instruments of specified accuracy (OSW memorandum 93.07). These instruments and procedures provide sufficient accuracy to support computation of discharge from a stage-discharge relation, unless greater accuracy is required.

Gaging stations usually operate for the purpose of determining daily discharge, instantaneous stage or discharge, or annual extremes in stage and discharge. This includes the goal of collecting stage data at the accuracy of 0.01 ft (foot) or 0.2 percent, whichever is less restrictive for the stage being measured (OSW memorandums 89.08, 93.07 and 96.05). In some cases, however, such accuracy remains impossible. For example, in the WAWSC, stage at some large river stations surges as much as ±0.10 ft, and at some turbulent mountain streams, hydrographers cannot read staff gages more accurately than ±0.10 ft. In these instances, comments in the station analysis alert the data user to such irregularities. In the WAWSC, depending on the size of the stream, these irregularities do not necessarily result in downgrading of the data. For example, at some gages on the Columbia River, stage can vary by several hundredths of a foot, but the difference amounts to less than 5 percent of the flow. OSW memorandum 93.07 provides an explanation of USGS policy on stage-measurement accuracy as it relates to instrumentation.

The types of instrumentation installed at any specific gage shelter operated by the WAWSC depend on a number of factors. These factors include the needs of the cooperating agency, availability of utility lines, terrain—including slope and aspect, configuration of the stream and its banks, and the expected range in stage. Types of continuous water-level recorders operated by personnel in this WAWSC include various manufactures of Electronic Data Loggers (EDLs) and Data Collection Platforms (DCPs) connected to stage sensors. Strip-chart recorders sometimes are used to supplement the EDL or DCP. Analog-to-digital (ADR) punched-paper tape recorders were phased out of operation in 1999. Sensors used to monitor stage include float and tape assemblages driving shaft encoders, submersible and nonsubmersible pressure transducers, and radar sensors. Instruments used for the manual observation of stage (reference gages) include steel tapes in conjunction with fixed reference marks, staff gages, wire-weight gages, and electric-tape gages. The Field Office

GAGING STATION OPERATION AND MAINTENANCE

- Gage inspection information must be on USGS measurement form 9-275F (appendix B6) or substitute, and include:
  - Name of field person or observer
  - Date of visit and times of readings
  - Outside staff gage readings
  - Inside staff gage, tape gage, EDL, transducer, or radar readings
  - Station number and station name
- Check bubbler system at pressure transducer sites
  - Read and record remaining pressure in nitrogen tank
  - Replace tank if less than 200 pounds remaining
  - Check for leaks in system if tank has been replaced more than twice a year
- Flush intakes and purge orifice lines
  - Make sure water runs nearly clear from stilling well
  - For submersible pressure transducers, remove and clean transducer; for non-submersibles, purge orifice line
- Take corrective action if stages differ by more than 0.02 feet
  - Adjust and note data logger offsets
  - Adjust and note tape stage indicator
  - Run levels (later) to resolve reference-gage accuracy issues
  - Establish temporary reference point for damaged gages
- Check battery voltage, regulator/charger, and solar panel
  - Replace battery if voltage below 12.1 volts (use volt meter)
  - Check solar panel for cracks, bullet holes
- Check data logger; download data with field computer
  - Replace data logger if it does not pass system
  - Maintain computer battery in charged condition
  - Keep spare battery pack with computer
  - Keep log of programs for stations in field trip
  - Keep hard copies of programming sheets in field folder or gage shelter
- Cut grass, brush, and tree limbs around gage and lines as needed
- Check cableway, anchors, and cable car, if applicable
  - Check footings, U-bolts, clamps, cable car for rust, wear
  - Keep footings clear of brush, soil
  - Keep extra cablecar puller in field vehicle
  - Inspect cableway system thoroughly once a year
- Make discharge measurement at site as scheduled
  - Read gage heights before and after measurement and record on form; record logged gage heights
  - Record location of measuring section, control, and flow conditions

Figure 2. Activities for gaging station operation and maintenance.

or Project Chief, in consultation with the cooperating agency, the hydrographer to be assigned the station, the WAWSC electronics specialist, and the Data Chief and (or) Surface-Water Specialist, determines the type of water-level recorders and sensors to be installed and operated at each gaging station.

Accurate stage measurement requires not only accurate instrumentation but also proper installation and continual monitoring of all system components to ensure that the accuracy does not deteriorate with time (OSW memorandum 93.07). Hydrographers observe reference and primary gages to ensure that gage-shelter instruments accurately record the water levels of the body of water being investigated. The primary gage should not be confused with a “base gage,” which exists at a slope station and is used in conjunction with an auxiliary gage some distance away (Kennedy, 1983, p. 10). The reference gage is a nonrecording gage used to set the primary gage. The main purpose of the reference gage is to furnish periodic independent water-surface elevations to monitor the accuracy of the primary gage and other gages (Kennedy, 1983, p. 10). The primary gage records the continuous or near-continuous record of surface-water elevations. For example, at stations with stilling wells, hydrographers usually check the float recorder (the primary gage) against the inside staff gage or electric-tape gage (the reference gage). At a station with a pressure transducer, the transducer (the primary gage) is checked against a wire-weight gage or outside staff gage (the reference gages). In eastern Washington, reference points (for taping down to the water surface) may serve as reference gages because outside staff gages would be destroyed regularly by ice in the river. The relation between the reference gage and the primary gage can change as the gage height increases, and hydrographers document these changes. Because of the potential differences, the primary gage should not be adjusted to the reference gage during high flows, except when there is clearly an equipment malfunction that must be remedied. Stage-discharge rating curves should be drawn on the basis of data from the primary gage.

The hydrographer ensures that the instrumentation installed at gaging stations is properly serviced and calibrated. They accomplish this task by visiting the site and observing any deficiencies. If observed deficiencies are minor, the hydrographer should repair them on the spot using spare parts carried in the field vehicle. If the deficiencies are major, then the hydrographer consults with the construction crew, Field Office Chief, or Project Chief to formulate a corrective plan of action. The nature of the observed problem will dictate which person(s) should be consulted. Individuals who have questions related to the calibration and maintenance of water-level recorders should contact the Field Office Chief or Project Chief. Pressure-sensor calibration data will be entered (logged) into the Hydrologic Instrumentation Facility (HIF) National Instrument Testing & Calibration Database (NITCAD), as recommended by the USGS Instrumentation Committee (ICOM).

Secondary methods of data verification remain one of the key elements of quality-assured data. These methods become particularly important with extremes in stage data and data collected with pressure transducers. For gages using stilling wells, maximum and minimum clips on the float tapes record the maximum and minimum stage recorded by the tape and float system. High water marks (HWM’s) inside (from ground cork or debris) and outside the well supplement and verify the maximum recorded stage. For stations with pressure transducers, crest-stage gages (CSGs) record the maximum water levels. Field personnel install CSGs in the same cross section and gage pool that is measured by the transducer. For critical stations, backup recorders help assure a complete and accurate stage record at the gage. For example, a gaging station with a stilling well might contain two float-tape systems, one for the EDL, and one for the strip-chart recorder.

Measurement of Velocity

The WAWSC uses acoustic Doppler velocity meters (ADVM) installed at gaging stations to index mean channel velocities for the computation of a record of discharge.

Personnel who use ADVM instruments for the computation of discharge records should obtain training by attending the Office of Surface Water class “Streamflow Records Computation using ADVM’s and Index-Velocity Methods” that is offered periodically.

As of early 2010, no USGS technical memorandums provide guidance on the installation and operation of index-velocity sites; however, the OSW Hydroacoustics web page for Index-Velocity (http://hydroacoustics.usgs.gov/indexvelocity/index.shtml) is a useful resource that will provide the most up-to-date information. At the time this addendum was prepared (April 2010), the Index-Velocity website includes a list of USGS publications on the topic, best practices, and technical quick sheets.

Installation

1. A thorough site reconnaissance is required prior to installation of an index-velocity meter at an existing gaging station or establishment of a new index-velocity-meter station. The site reconnaissance may include channel surveys and the collection of velocity and temperature profiles. The channel bed is characterized for stability. The site hydraulics are analyzed carefully for factors that potentially could cause rating instabilities. Other considerations include protection of the instrument,

power/communications cable-length limitations, and adequate power supply. The data collected from the reconnaissance are used to ascertain the success of using an index-velocity meter. For ADVMs, aspect ratios (range/depth) and bridge-pier wake-turbulence zone can be computed to determine if the ADVM sample volume will reach a zone of stable velocities. ADVM installation considerations are documented in Morlock and others (2002, p. 8–10).

2. Gage-site-selection criteria documented in Rantz and others (1982, p. 5–9) remain applicable for index-velocity sites.
3. The index-velocity-meter deployment program is recorded and archived. If the index-velocity-meter deployment program can be saved, the deployment program is archived. Some index-velocity-meter programs cannot be saved directly. In these instances, a screen capture of the instrument deployment can be used to save the program parameters. A paper copy of the pertinent parameters is placed in the gage-house folder.

Field Procedures

The following procedures are followed during visits to gaging stations equipped with index-velocity meters:

1. A temperature reading from an independent source, such as a digital thermometer, is taken near the instrument. The temperature and the time of the reading is recorded in the field notes.
2. For ADVMs, a beam-amplitude diagnostic test is run and logged in a file. All files are ultimately archived on the WAWSC server. Beam-amplitude checks are valuable diagnostic and quality-assurance tools. The beam-amplitude checks must show that the ADVM sample cell is free of obstructions and is sized so beam amplitudes at the end of the sample cell are a minimum of five counts above the instrument noise level. If these criteria are not met, the ADVM sample cell must be adjusted until the requirements are met. All sample-cell changes must be noted on the station log and in field notes before saving the new instrument deployment. If the sample-cell size changes significantly, a new index-velocity rating likely is needed.
3. If the gage does not have data telemetry or if all logged parameters are not transmitted, the data logger is downloaded during each site visit and the data are entered into NWIS at the office.
4. At least once annually, the standard cross section is checked to ensure that the channel geometry has not changed significantly. For channels with known scour or fill potential or for channels with the potential for dredging, the standard cross section may need to be checked more frequently. If possible, discharge measurements can be made at the standard cross-section location. The advantage of this approach is that for every measurement, the standard cross section is checked.
5. The frequency of discharge measurements is dictated by stability of the stage-area and index-velocity ratings and by the range of measurements used to define the ratings. Changes in index-velocity instrumentation or changes to existing instrument program parameters (for example, ADVM sample-cell-size changes) likely necessitate the need for a new index-velocity rating and, hence, more-frequent measurements to establish the new rating. It may be possible to reduce measurement frequency once stable ratings have been established for a wide range of flows. All sites, however, must be measured at least four times a year.

Data Quality Assurance

All data-quality parameters available are used to assess the quality of the velocity (and stage) record used to generate discharge records. For ADVMs, these parameters can include cell end, velocity standard deviation, velocity y-component, water temperature, and signal strength (average backscatter amplitude). Unit-value plots are valuable for examining these quality-assurance parameters.

Discharge Computation

The same general USGS policies and recommendations that apply to stage-discharge methods used to produce discharge records apply to index-velocity methods. Therefore, guidelines for the production of streamflow records presented in the section Processing and Analysis of Surface-Water Data apply to index-velocity methods. Polices and recommendations regarding stage data, such as the editing or deleting unit values, also apply to velocity unit values. Likewise, guidelines for records documentation, including the station analysis, daily-values tables, and other supporting materials, are applicable to index-velocity records.

Collection of Precipitation Data

The Office of Surface Water Technical Memorandum No. 2006.01, revised December 2009 thoroughly describes the collection, quality assurance, and presentation of precipitation data (http://water.usgs.gov/admin/memo/SW/OSW_2006-01_Revised_02122010.pdf).

Most of the precipitation gages operated by the Washington Water Science Center provide “temporary” data and are maintained only as an aid in operations for the cooperator. Temporary data are not intended for publication, although the data will remain in the National Water Information System (NWIS) database as provisional data.

“Permanent” precipitation data are those data published in the annual data report and archived. Requirements for these data include annual calibration of the gage, archival of station descriptions, annual station analysis, calibration forms, and original filed inspection notes. More information is available in OSW Technical Memorandum No. 2006.01.

Gage Shelter Documents

WAWSC procedure dictates that hydrographers maintain certain documents in each gage shelter for the purpose of keeping an on-site record of observations, equipment maintenance, structural maintenance, and other information helpful to field personnel (fig. 3). Documents maintained at each gage shelter will include a log of site visits, updated by field personnel during each visit, which describes control conditions and lists gage readings, gage-shelter maintenance, equipment maintenance, and discharge measurements (appendix B2); copies of the most current rating curve and rating table; a copy of the most recent station description, which describes all the gages, reference marks, and measurement locations; a copy of the programming sheet for the EDL or DCP; brief instructions on how to access and program the EDL or DCP; corrections to determine the maximum and minimum stage from clip readings; a calendar; any important telephone numbers; notes on any special procedures or characteristics at the gage; a traffic control plan; and job hazard analyses (JHAs) concerning potentially hazardous conditions at the gage. At cableway stations, cableway documentation forms (appendix B1), which list the maximum stage at which to measure discharge and the design cableway sag, should also be maintained in the gage shelter. An optional document to include in the gage shelter is a hydrograph of the previous year’s daily mean flows or a hydrograph of mean daily flows for the period of record at the gage. All documents should be kept in a sealed plastic bag to protect them from moisture.

The hydrographer assigned to the gaging station ensures that outdated gage documents are regularly updated. When field personnel visit a gage shelter and identify a need to update one or more of the documents, they should replace documents as needed or make a note to replace them on the next visit. Individuals having questions related to which documents should be kept in a gage shelter, when the documents should be replaced with newer documents, or how existing documents should be maintained, should contact their Field Office Chief or Project Chief.

Determination and Confirmation of Gage Datum

The various gages at a gaging station are set to register the elevation of a water surface above a reference level called the gage datum. The gage’s supporting structures—stilling wells, backings, shelters, bridges, and other structures—tend to settle or rise as a result of earth movement, static or dynamic loads, vibration, ice-heaving, or damage by floodwaters and flood-borne ice or debris. Vertical movement of a structure makes the attached gages read too high or too low and, if the errors go undetected, may lead to increased uncertainties in streamflow records. Hydrographers use leveling, a procedure that uses surveying instruments to determine elevation differences between two points, to determine the gage datum and periodically check the gage for vertical movement (Kennedy, 1990, p. 1). Running levels periodically to all benchmarks, reference marks, reference points, and gages at each station reveals if any datum changes have occurred (Rantz and others, 1982, p. 545). Three widely dispersed independent reference marks need to be established at every gage, to minimize the chance that all of them would not be lost during a flood. At sites with pressure transducers, levels are run to the orifice whenever possible.

WAWSC procedure requires that levels are run periodically at all gages. Field personnel should run levels at newly installed gaging stations when the gages are established. Levels at established gaging stations should be run once every 3 years, after any major flood event, after any type of earth movement in the area, or any time unresolved gage-height discrepancies exist between the various gages at a station (Kennedy, 1990, p. 14). Field notes are checked for satisfactory closure and arithmetic error before the hydrographer leaves the station. Hydrographers reset gages to agree with levels when levels show greater than a 0.02 ft vertical change. When gages are reset, field personnel document what they did on a Summary and Adjustments of Gaging Station Levels sheet and(or) a Level Notes sheet (appendix B3 and appendix B4). For all levels at new stations, along with routine 3-year levels or levels used to reset a gage datum or establish reference points, field personnel use an engineer’s level. For other checks when less accuracy is required, other types of levels, such as a laser level, are acceptable. The elevation of the outside water surface should always be shot when levels are run.

Kennedy (1990) describes field and documentation methods used to run levels. Kennedy (1990) and OSW memorandum 93.12 detail level procedures pertaining to circuit closure, instrument reset, and repeated use of turning points. Field personnel maintain the level instruments in proper adjustment by running a fixed-scale test and(or) a peg test (Kennedy, 1990, p. 12-14). The WAWSC requires a two-peg test before each levels trip. Personnel document these tests on a Peg Test of Engineer’s Level sheet (appendix B5) that is kept with the level notes. A copy of the two-peg test note sheet is stored in the instrument case for the level that was tested.

The hydrographer ensures that all field level notes are checked and that levels are run at the appropriate frequency. The hydrographer enters the level information on the historical level-summary form within 2 weeks after the levels are completed. The summary should include changes in elevation of reference marks and the orifice, and corrections to be applied to the inside and outside staff gages. The Field Office Chief ensures that levels are run correctly and that all level notes are completed correctly.

FIELD DOCUMENTS

- Gage-shelter documents
    - Maintain a log of gage-inspection information using Form P-19 (appendix B2) or substitute, include
        - Servicing party and date
        - Outside gage reading
        - For stilling well sites, inside staff and tape readings
        - For transducer sites, N_2 tank and regulator pressure, and bubble rate as appropriate, radar and EDL readings
        - Battery voltage
        - Measurement information
            - Where measured
            - Equipment used
            - Maximum depth and velocity
        - Remarks on control, PZF, HWM, max and min clips, etc.
        - Comments on flushing intakes or cleaning transducer
    - Copy of EDL or DCP programming
    - Special gage notes
        - Special attention items
        - Max and min clip corrections
        - Telephone contacts
    - Copy of most recent station description
    - Copy of current rating and rating table
    - Station job hazard analysis
- Field folder documents
    - Map with instructions on getting to site
    - Copy of most recent station description
    - Copy of current rating, rating table, and shift diagram
    - List of discharge measurements and preliminary shifts
    - Pertinent notes, letters regarding gages at site
    - Traffic control plan
    - Station job hazard analysis

Figure 3. Field documents.

Site Documentation

Site documentation requires thorough qualitative and quantitative information describing each gaging station. This documentation, in the form of a station description and photographs, provides a permanent record of site characteristics, structures, equipment, instrumentation, altitudes, location, and changes in conditions at each site. These documents also provide a history of past flood events, nearby construction, or any unusual occurrences at the site.

Station Descriptions

A station description outlining basic gage information becomes part of the permanent record for each gaging station. WAWSC procedure dictates that the station description for a new gage is written at the time the first year's records are computed. The hydrographer assigned to service the gaging station ensures that station description is prepared correctly and in a timely manner. Hydrographers should obtain assistance from the Field Office Chief if they have a question on preparing and completing station descriptions. The hydrographer reviews station descriptions every year and updates them if necessary. The Field Office Chief reviews all station descriptions to ensure that they are updated and complete.

Station descriptions outline specific types of information in a consistent format (Kennedy, 1983, p. 2). The station description includes information such as location of the station, date of establishment, drainage area above the site, a description of the gages, history of activities at the station, reference and benchmarks, channel and control characters, floods, point-of-zero-flow (PZF) data, site maps, and road logs to the site. Other items hydrographers should include are details on discharge measurement locations, extreme stage and discharge, regulations and diversions, cooperative agencies, local observers, and other site-specific information (Kennedy, 1983, p. 3-5).

Drainage areas determined using Geographic Information System (GIS) methods should be checked against the original drainage-area maps for consistency. The accuracy of drainage areas determined from digital elevation models (DEMs) will likely improve as the resolution of the DEMs increases.

The hydrographer maintains paper copies of the station description in the station folder and field folder and at the site, as well as electronic copies on the USGS computer. For new sites, hydrographers obtain latitude, longitude in the field using a GPS. Historical information is obtained from a variety of sources such as annual reports, investigative or open-file reports, or USGS and other-agency files. The surface-water database administrator for the WAWSC assigns the station number.

Photographs

Field personnel photograph gage shelters, station controls, channel conditions, reference marks, flood damage, indirect-measurement sites, vandalism, and other important conditions to document activity and conditions at the gaging station. Field personnel should carry digital cameras in their field vehicle to take photographs when they might be needed. The WAWSC office maintains a few cameras that can be checked out for more extensive photographic needs. The back of each photograph that is included with the station folder should be marked with a permanent-ink marker to document the station number, station name, date, gage height, and any other information needed to interpret the photo. Digital photographs are archived in the appropriate folder on the field office server.

Direct Measurement of Discharge Using a Current Meter

Hydrographers make direct measurements of discharge using any one of a number of methods approved by USGS, the most common of which is the current-meter method. In the current-meter measurement, the sum of the products of the subsection areas of the stream cross section and their respective average velocities determines the discharge (Rantz and others, 1982, p. 80). Rantz and others (1982, p. 139), Carter and Davidian (1968, p. 7), and Buchanan and Somers (1969, p. 1) describe procedures used for current-meter measurements.

When personnel make measurements of stream discharge, they attempt to minimize errors. Sauer and Meyer (1992) identify sources of errors, which include random errors such as depth errors associated with soft, uneven, or mobile streambeds and uncertainties in mean velocity associated with vertical-velocity distribution errors and pulsation errors. Velocity distribution errors also include systematic errors, or bias, associated with improperly calibrated equipment or the improper use of such equipment.

To reduce systematic errors in direct-discharge measurements, Field Office Chiefs rotate most field trips every 3 years, or include informal check-measurement programs on all field trips. Because of complex, varied instrumentation and remote station locations, some field trips tend to be matched to expertise and physical capabilities, and thus are rarely rotated.

WAWSC practices related to the measurement of discharge by use of the current-meter method, in accordance with USGS policies, include such topics as depth criteria, number of measurement subsections, computation of mean gage height, check measurements, and corrections for storage (fig. 4).

GUIDELINES FOR DIRECT MEASUREMENT OF DISCHARGE USING A CURRENT METER

- Ideal cross-section selection criteria
  - Ideally, a nearly uniform bottom across section
  - Average velocity greater than 0.5 ft/sec, depth greater than 0.5 ft
  - Straight channel whenever possible to avoid angles
  - Uniform flow, free of eddies, slack water, and excessive turbulence
  - Cross section is close to gage to avoid storage/inflow adjustment
- Meter selection criteria
  - Depth of water
    - If greater than 1.5 ft, choose Price AA meter
      - Use low-flow AA meter for cross sections with average velocity below 1 ft/sec
    - If less than 1.5 ft, choose pygmy meter
- Current-meter quality assurance/maintenance
  - Perform spin test before each trip and log, or perform each day
    - For Price AA meter, 1.5 minutes is acceptable, 4 minutes is ideal
    - For Price pygmy meter, 0.5 minutes is acceptable, 1.5 minutes is ideal
  - Check meter and repair or replace bent cups and worn pivots
  - Clean and oil meter daily, or after each measurement in sediment-laden water
- Measurement notes include
  - Date, party, meter type, suspension, and meter number
  - Name of stream and station number, or location for misc. measurement
  - Stage readings and times before, during, and after measurement
  - Time measurement started and ended, with intermediate times
  - Bank of stream that measurement was started from
  - Control and flow conditons
  - Other pertinent information regarding conditons
- Number of measurement subsections
  - Ideally, about 25-30 stations
  - Target for no more than 5 percent of flow in each section
  - Use fewer stations for rapidly changing stage, floods with lots of debris, and narrow channels
- Stopwatch
  - Periodically test with regular watch or another stopwatch
  - Allow 40–70 seconds for each vertical measurement
    - 1/2 counts OK in rapidly changing stage—record as 1/2 counts
- Check measurements
  - Perform second measurement if first is more than 5 percent from current rating or shift
  - Change meter and stopwatch
  - Use different stationing, or change cross sections
- Work measurement in field whenever possible

Figure 4. Guidelines for direct measurement of discharge using a current meter.

Depth Criteria for Meter Selection

WAWSC personnel select the type of current meter to be used for each discharge measurement on the basis of criteria presented in OSW memorandum 85.07. Generally speaking, a Price AA meter should be used at depths greater that 1.5 ft, and a Price pygmy meter for depths less than 1.5 ft. However, there are also velocity considerations. The reverse side of the pygmy meter rating table details all the specific information. Personnel should use current meters with caution when a measurement must be made in conditions outside of the ranges of the method presented in OSW memorandum 85.07, and they should downgrade the measurement accuracy accordingly.

Frequently, stream conditions fit guidelines between those for a pygmy-meter measurement and AA-meter measurement. In these instances, the meter most suited for most of the channel flow should be used. For example, if the cross section varies from depths of 0.7 ft for 10 ft of the cross section, then slowly increases to 2.5 ft for 30 ft of cross section, then gradually decreases to 1 ft of depth over 10 ft, a Price AA meter is probably the best meter to use because most of the flow will most likely be in the deeper part of the cross section. The hydrographer should recognize, however, that there will be some greater error in those parts of the measurement where the water is shallower than 1.5 ft. Ideally, a pygmy meter would be used for the parts of the cross section shallower than 1.5 ft and a Price AA meter for areas deeper than 1.5 ft; however, this is generally not practical and probably not worth the perhaps slight gain in measurement accuracy. It is recommended that a change of meters is not made during a measurement in response to the occurrence of two or more subsections in a single measurement cross section that exceed the stated ranges of depth and velocity. In cases where two channels exist, one deep and one shallow, then changing meters becomes more practical and reasonable. Personnel who have questions concerning the appropriate procedures for making stage and discharge measurements should address their questions to more experienced hydrographers or to the Field Office or Project Chief.

Criteria for Sounding-Weight Selection

When a measurement must be made from a bridge, cableway, or boat, hydrographers must consider depth and velocity in choosing the correct weight to use. A general rule of thumb is to use a weight (in pounds) at least as heavy as the product of the fastest velocity (in feet per second) and deepest depth (in feet) in the cross section (Rantz and others, 1982, p. 146-147). However, heavier weights may need to be used in shallow, fast streams. If the weight is insufficient, the stream will drag the meter and weight assembly downstream and an air and wet-line correction for depth may need to be used (Rantz and others, 1982, p. 159-168).

Number of Measurement Subsections

The spacing of observation verticals in the measurement section can affect the accuracy of the measurement (Rantz and others, 1982, p. 179). USGS criteria state that hydrographers observe depth and velocity at a minimum number of about 30 verticals, which is normally necessary to ensure that no more than 5 percent of the total flow is measured in any one vertical. Even under the worst conditions the discharge computed for each vertical should not exceed 10 percent of the total discharge and ideally not exceed more than 5 percent (Rantz and others, 1982, p. 140). Exceptions to this policy prevail in circumstances where accuracy would be sacrificed if this number of verticals were maintained, such as for measurements during rapidly changing stage (Rantz and others, 1982, p. 174). Hydrographers sometimes use fewer verticals than are ideal for very narrow streams (about 12 ft wide when an AA meter is used and about 5 ft wide when a pygmy meter is used). Because measurement of discharge is essentially a sampling process, the accuracy of sampling results often decreases markedly when the number of samples is less than about 25.

Computation of Mean Gage Height

WAWSC personnel use procedures presented in Rantz and others (1982, p. 170) for computing mean gage height during a discharge measurement. Methods used to determine the mean gage height involve discharge-weighting or time-weighting the stage readings during the measurement. Mean gage height is used when plotting a discharge measurement on a stage-discharge rating curve.

Check Measurements

USGS policy states that if a discharge measurement plots more than 5 percent from the rating or shift currently in place, then hydrographers should make a second discharge measurement to check it. In the WAWSC, however, because many sites have either only fair to poor measurement conditions or highly unstable channels and controls, consideration of unique site characteristics is a major factor in deciding under what criteria a check measurement is made. These characteristics include control stability, bed movement, and growth of vegetation in the channel during summer. During recessions after peak flows, changes of 5 percent or more from the rating are common. During low flows, this criterion may also be too stringent, and perhaps a shift difference of plus or minus 0.02 ft becomes acceptable. Hydrographers should consult with the Field Office Chief or Project Chief to determine stations where a criterion other than 5 percent should be used, and should document this in the Station Description and Station Analysis.

When making a check measurement, hydrographers change or check as much of the instrumentation and conditions as possible. These changes and checks include using a different current meter, changing stopwatches or checking the stopwatch with a regular timepiece, selecting different vertical sections in the cross section, or choosing a new cross section altogether (Rantz and others, 1982, p. 346). In cases where the second measurement verifies neither the original rating nor shift nor the first measurement, a third measurement might be made and the closest two out of three used.

Corrections for Storage

Rantz and others (1982, p. 177) and OSW memorandum 92.09 discuss corrections for storage applied to measured discharges for the purpose of defining stage-discharge relations. These corrections involve an adjustment to the measured discharge that is based on the channel surface area and average rate of change in stage in the reach between the gage and point of measurement. Storage corrections generally apply only if the discharge measurement is made at some distance from the gaging-station location.

Field Notes

A necessary component of surface-water data collection and analysis includes thorough documentation of field observations and data-collection activities. To ensure that clear, thorough, and systematic notations are made during field observations, field personnel record discharge measurements on standardized USGS discharge measurement notes (Form 9-275 series, appendix B6). If these forms are not available, any substitute can be used, even a regular sheet of paper, as long as the field person includes all the necessary information in the notes (fig. 5). Field notes are considered original legal documents, and thus, hydrographers should not erase original observations, once written on the note sheet. They make corrections to original data by crossing the value out, then writing the correct value. Some examples of original data on a discharge-measurement note sheet include gage readings, depths, measurement stations, current-meter counts or clicks, and time notations. Hydrographers can erase derived or computed data, such as computed widths, velocities, section and total discharges, and mean gage height.

Generally, discharge measurements made during field site visits will be calculated on site after the measurement is made. This allows check measurements to be made without having to make another station visit. During floods or other emergency situations, hydrographers should calculate discharge measurements as soon as possible and phone results into the office for informational purposes. This is particularly important during major floods so that discharges the WAWSC presents to the public and the media reflect the most current data possible.

Information that should be documented by field personnel on the measurement note sheet includes, at minimum, the initials and last name of all field-party members, date, times associated with gage readings and other observations, station name and number, control and channel conditions, outside and inside (if applicable) staff-gage readings, readings from the EDL or DCP, condition of the battery and nitrogen tank (if applicable), type of instrument used for any discharge measurements, any observed HWMs and (or) maximum and minimum clip readings, crest-stage gage readings, PZF estimates, and any other pertinent information regarding unusual gage or streamflow conditions. Points of zero flow should be collected at wadeable streams whenever feasible and included on the form 9-207 as well as the measurement notes. Mathematics for maximums and minimums from clip readings, PZF estimates, reference-point elevations, and similar calculations should be shown on the measurement note sheet.

Hydrographers document notations associated with miscellaneous surface-water data-collection activities on miscellaneous field note forms (9-275-D, appendix B7) or any other sheet of paper, as long as the necessary information are included (fig. 5). All miscellaneous notes include, at minimum, station number and name, initials and last name of field-party members, date, time associated with observations, purpose of the site visit, and pertinent gage-height readings or other information.

Besides the 9-275 series of discharge measurement notes, other types of field notes used in the WAWSC include crest-stage gage notes (T-9335, appendix B8), snow survey notes (T-9334, appendix B9), and level notes (9-276, appendix B4). A variety of pertinent station and conditions information, readings, observations, and calculations are required in filling out these notes (fig. 5).

The degree of review and checking of field note sheets depends on the experience and demonstrated performance of the hydrographer. For new hydrographers, fellow hydrographers check every measurement or field note right after the site visit to ensure that all required information and observations are made and noted correctly, and that discharge measurements are being completed according to standards and are correctly computed. Experienced hydrographers with demonstrated competence need to have only periodic reviews of the measurements and field notes, unless measurements or observations entail unusual conditions. In the event of unusual conditions, the measurement should be thoroughly reviewed and checked. Reviewers finding deficiencies in the content, accuracy, clarity, or thoroughness of field notes notify the hydrographer of these facts by communicating USGS standards and requirements directly with them. Reviewers that find continued deficiencies in another hydrographer's measurement notes notify the Field Office Chief or Project Chief, who will then reemphasize USGS measurement notes standards with the hydrographer.

FIELD-MEASUREMENT NOTES

- Use 9-275 series notes for inspections and measurements
- Station inspection notes include
  - Date and party
  - Name of stream and USGS station number
  - Outside and inside (stilling well) stage readings
  - Electronic data logger/data-collection platform stages and times
  - Readings and times for other sensors
  - Control and flow conditions
  - Observed high-water marks and max. and min. clip readings
  - Condition of battery and nitrogen tank, if applicable
  - Other pertinent information regarding equipment and conditions
- In addition to the above, measurement notes include
  - Meter type, suspension, and meter number
  - Stream location for miscellaneous measurement
  - Stage readings and times before, during, and after measurement
  - Time measurement started and ended with intermediate times
  - Bank of stream that measurement was started from
- Miscellaneous field notes
  - Used for almost anything
  - Include party, date, station name and number, and observations
- Crest-stage gage notes
  - For crest-stage gage inspections and service
  - Include party, date, time, station name and number, stick readings, quality of marks, HWMs, and other observations
- Snow survey notes
  - For snow depth, water content, and density
  - Include party, date, time, snow-course, readings, weather, snow conditions, and remarks
- Level notes
  - For running levels at stations
  - Include station number, party, date, and level observations
- Information on all notes should be written as completely and legibly as possible—ask yourself if someone else could understand the notes completely in 10 years' time—the answer should be yes
-

Figure 5. Field-measurement notes.

Acceptable Equipment

The WAWSC uses equipment for the measurement of surface-water discharge that has been found acceptable by the USGS through use and testing. Usually, this equipment has been rigorously tested and calibrated by the USGS Hydrologic Instrumentation Facility (HIF). An array of acceptable equipment for measuring discharge includes current meters, timers, wading rods, bridge cranes, tag lines, and others (Rantz and others, 1982, p. 82; and Smoot and Novak, 1968). Although an official list of acceptable equipment is not available, Buchanan and Somers (1969), Carter and Davidian (1968), and Edwards and Glysson (1988) discuss the equipment used by the USGS.

WAWSC personnel most commonly use the Price AA current meter and the Price pygmy current meter for measuring surface-water discharge. The HIF, who test a percentage of all new meters received to assure they meet USGS standards, supplies these current meters to the WAWSC. Hydrographers may use other current meters, provided that those meters have been fully tested, calibrated, and field-checked against the appropriate Price meter. Generally, the use of other meters will require an ongoing quality-assurance program to validate their regular use. Methods followed by WAWSC personnel for inspecting, repairing, and cleaning these meters are described in Smoot and Novak (1968, p. 9), Rantz and others (1982, p. 93), and Buchanan and Somers (1969, p. 7).

The ultimate responsibility for the good condition and accuracy of a current meter rests with the field person who uses it (OSW memorandum 89.07). A timed spin test made a few minutes before a measurement does not ensure that the meter will not become damaged or fouled during the measurement. Field personnel must assess apparent changes in velocity or visually inspect the meter periodically during the measurement to ensure that the meter continues to remain in proper operating condition. If there is any question regarding the performance of a meter, an immediate spin test may provide the answer.

Spin Tests

WAWSC procedure requires spin tests prior to each field trip. Hydrographers document spin-test results in a log that is maintained for each instrument. Field Office files contain these logs in chronological order by meter number. Archived surface-water data include this log (OSW memorandum 89.07). Spin tests and visual inspections may identify needed repairs to meters. Field personnel note these repairs on the log for the particular meter being serviced. The Field Office or Project Chief reviews the logs semiannually to assure that personnel perform regular spin tests, maintenance, and repairs to current meters. If deficiencies are observed during this review of the log, the Field Office or Project Chief orally communicates the noted problems to the hydrographer, who should immediately take the recommended corrective actions.

In addition to the timed spin tests performed prior to field trips, field personnel inspect the meter before and after each measurement to see that the meter is in good condition, that the cups spin freely, and that the cups do not come to an abrupt stop. Descriptive notations made at the appropriate location on the field-note sheet concerning the meter condition, such as “OK” or “free” or other such comments, denote that an inspection has been completed. To ensure that field personnel carry out their responsibilities in maintaining the equipment they use, Field Office Chief or Project Chief inspects equipment semiannually. They communicate noted deficiencies directly to the hydrographer responsible for the meter, and the hydrographer takes immediate corrective actions.

Regular repairs involve replacing a variety of parts that make up the current meter. Each Field Office keeps an inventory of spare parts for use in maintaining current meters. The combined responsibility of all hydrographers is to maintain this inventory and apprise the Field Office Chief or Project Chief when supplies of various parts are low so that they may be ordered immediately. Hydrographers replace damaged cups with new ones as soon as they become bent—bent cups can change the standard meter calibration. For meters that fail spin tests, hydrographers should change the pivot, pivot bearing, head assembly, or yoke until they obtain an acceptable spin test. Field Offices dispose of broken parts, but retain worn or slightly damaged parts for reconditioning by the HIF. Periodically, the Field Office Chief or Project Chief will return the aggregated used parts to the HIF for refurbishment, replacement, or recalibration. Metal parts that cannot be refurbished are recycled.

Direct Measurement of Discharge Using Hydroacoustic Instrumentation

Acoustic Doppler Current Profiler

Acoustic Doppler current profilers are used by the WAWSC to make low- to high-water discharge measurements depending on need and site characteristics. The Center (as of January 2011) has several models of ADCPs from Teledyne RD Instruments, including the Rio Grande, StreamPro, and RiverRay. All personnel operating ADCPs need to attend OSW classes and become familiar with the information contained in the following policy memorandums and reports:

- OSW Technical memorandum 2010.07, Independent Water Temperature Measurement for Hydroacoustic Measurements.
- Techniques and Methods Report Book 3 – Section A22, Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat (Mueller and Wagner, 2009; important new policies are summarized in OSW Technical memorandum 2009.05).

- OSW Technical memorandum 2009.02, Release of WinRiverII Software (version 2.04) for Computing Streamflow from Acoustic Doppler Current Profiler Data.
- OSW Technical memorandum 2006.04, Availability of the report "Application of the Loop Method for Correcting Acoustic Doppler Current Profiler Discharge Measurements Biased by Sediment Transport" (Mueller and Wagner, 2009) and guidance on the application of the Loop Method.
- Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers, (Oberg and others, 2005).
- OSW Technical memorandum 2005.08, Policy and Guidance for Archiving Electronic Discharge Measurement Data.
- OSW Technical memorandum 2002.01, Configuration of Acoustic Profilers (RD Instruments) for Measurement of Streamflow; (lists user configuration commands).

ADCP Quality-Assurance Binder

An ADCP Quality-Assurance Binder, maintained in each Field Office, contains the following:

1. List of ADCPs and serial numbers
2. Instrument History Log for each ADCP which includes:
    - model and frequency
    - acquisition date
    - firmware/hardware upgrade descriptions and dates
    - factory repairs
    - current software
    - instrument calibration checks (annual instrument checks or checks after an instrument is first acquired, after factory repair, or after firmware or hardware upgrades)
3. Logs of electronic distance-measurement device calibration checks
4. List of trained operators in the WAWSC
5. Archival procedures and examples
6. Guide for processing and reviewing ADCP measurements

Field Procedures

1. Prior to going into the field, the operators ensure that: the ADCP is in working order with the latest approved firmware; their laptop contains the latest approved software; they have sufficient space on the CD-ROM, flash memory card or USB drive for temporary backups; and they have a method and tools (such as a laser range finder, tape measure, or level rod) for measuring edge distances.
2. Prior to every discharge measurement, diagnostic tests are performed and the results are stored on the field computer. Diagnostic tests should be documented on the ADCP discharge-measurement field form.
3. Calibration of the compass is encouraged prior to measurements, but calibration is mandatory when using GPS for navigation, using the loop method for moving bed corrections, or when velocity direction is important.
4. Prior to each measurement, the temperature measured by the ADCP must be compared with an independent water temperature measurement made adjacent to the ADCP and recorded on the field measurement form.
5. Prior to each measurement, a moving-bed test is performed using one of the following acceptable methods, in order of preference: (1) the loop method, (2) a stationary test with GPS, or (3) a stationary test with no GPS. Detailed descriptions of these methods are provided in appendix B of Mueller and Wagner (2009, p. 43–53). Stationary tests should be recorded for no less than 10 minutes. If the stationary position is maintained by a tether or anchor so that upstream or downstream movement of the ADCP is not possible, the moving-bed test may be recorded for no less than 5 minutes. If a site routinely has a moving bed and GPS is always used with the ADCP, a moving-bed test still is required, but need be only 5 minutes. If using the loop method, the duration of the loop should be 3 minutes or greater, boat speed to be consistent, and the boat speed should not exceed 1.5 times the mean downstream water velocity.
6. The estimates used for edge distances shall always be measured. Distance may be measured using a laser range finder, level rod, tag line, or rule.
7. When using an RD Instruments Rio Grande with WinRiverII software, operators use the Configuration Wizard to set up the measurement. If any settings other than the Configuration Wizard settings are used, the reasons for the user settings are explained on the measurement note sheet.
8. The depth to the transducer below water surface shall always be verified before each measurement.
9. In accordance with OSW requirements, a minimum of four (4) transects (2 in each direction) will be made under steady-flow conditions. The measured discharge will be the average of the discharges from the 4 transects. If the discharge for any of the 4 transects differs more than 5 percent from the mean measured discharge and no critical data-quality problem can be identified and documented, a minimum of 4 additional transects will be obtained and the average of all 8 transects will be the measured discharge. Reciprocal transects should always be made to

reduce potential directional biases. For policy detail, see Mueller and Wagner (2009, p. 21–22). Note: There are exceptions for unsteady flow.

10. Immediately after completion of a measurement, all measurement data and diagnostic tests should be backed up on removable media, such as CD-ROMs, flash-memory cards, or USB drives, and stored separately from the field computer.

Office Procedures

ADCP data are transferred to permanent storage on the WAWSC server within 2 work days of returning to the office, and processed, archived, and reviewed within 5 working days after returning from the field. After processing, print the “Q Measurement Summary” from WinRiverII, cut it no larger than 8” width by 10” length, and attach it to the field note sheet for review and storage. Electronic measurement files, including diagnostic files, are retained and archived in accordance with the current draft of the WAWSC Memo “Archiving Electronic Discharge Measurement Data” (Mark Mastin, U.S. Geological Survey, written commun., 2008). An example of data archival for ADCP measurements is available in the ADCP Quality-Assurance Binder.

The ADCP operator is responsible for archiving all ADCP measurement and diagnostic files, processing all measurements, entering the measurement data into the database, and finding a trained ADCP operator to review each measurement.

The reviewer of an ADCP measurement is responsible for ensuring that correct methods were used to collect and process the measurements, measurement notes are accurate, and electronic measurement data have been archived correctly. If any changes are made during the review process, the changes should be discussed with the original ADCP operator and the database should be updated.

Acoustic Doppler Velocimeter

Acoustic Doppler velocimeters (ADVs), designed for use with a standard USGS top-setting wading rod, are used by the WAWSC to make wading discharge measurements. All the field offices in the Center have SonTek/YSI FlowTrackers. All hydrographers using FlowTrackers to make wading mid-section discharge measurements should become familiar with the information contained in the following policy memorandums and reports:

- OSW Technical memorandum 2010.07, Independent Water Temperature Measurement for Hydroacoustic Measurements
- OSW Technical memorandum 2010.06, FlowTracker Diagnostic Test Policy
- OSW Technical memorandum 2010.02, Flow Meter Quality-Assurance Check – SonTek/YSI FlowTracker Acoustic Doppler Velocimeter
- OSW Technical memorandum 2009.04, Application of FlowTracker firmware and software mounting correction factor for potential bias
- OSW Technical memorandum 2007.01, SonTek/YSI FlowTracker firmware version 3.10 and software version 2.11 upgrades and additional policy on the use of FlowTrackers for discharge measurements
- OSW Technical memorandum 2005.08, Policy and Guidance for Archiving Electronic Discharge Measurement Data
- OSW Technical memorandum 2004.04, Policy on the use of the FlowTracker for discharge measurements

FlowTracker Quality-Assurance Binder

A FlowTracker Quality-Assurance Binder is maintained in each field office and contains the following:

1. A list of FlowTrackers and serial numbers.
2. Instrument History Log for each FlowTracker, which includes:
   - acquisition date
   - firmware/hardware upgrade descriptions and dates
   - current software
   - factory or HIF repairs
   - Quality-Assurance Checks (to be performed by the Hydrologic Instrumentation Facility’s Hydraulic Laboratory [HIF-HL] at least once every 3 years for existing FlowTrackers, prior to being placed into service for all new FlowTrackers, and prior to being placed back into service for repaired FlowTrackers).
3. BeamChecks.
4. Archival procedures and examples.

Field Procedures

1. Prior to using a FlowTracker, the users must become familiar with the instrument by reviewing the FlowTracker Handheld ADV Technical Documentation. Users should also become familiar with the FlowTracker handheld controller, including all keypad operations, prior to collecting field data.
2. A full diagnostic test (BeamCheck) is required only (1) when a new instrument is received, (2) if physical damage (for example, dropping) may have occurred, (3) if a firmware upgrade or repair was made, and (4) after any QCTest failures. The test procedures are described in the

FlowTracker Operations Manual. The software displays signal-strength plots for each ADV receiving transducer. The FlowTracker Operations Manual describes the BeamCheck and provides examples of various signal-strength plots. If the signal-strength plots indicate a possible malfunction, the FlowTracker is not used to collect field data. In all instances, every diagnostic test is logged to a file, archived electronically, and the graph is printed and filed in the FlowTracker Quality-Assurance Binder. In the event of an instrument malfunction, diagnostic files can be provided to the manufacturer for troubleshooting.

3. Prior to each field trip, the user checks the recorder status to ensure there is adequate data-storage capacity for their needs.
4. Prior to each discharge measurement, the user runs the Auto QC Test and checks the following items on the ADV using the handheld controller Systems Functions Menu:
   - System clock—the clock displays the correct date and time.
   - Recorder status—there is adequate data-storage capacity for the discharge measurement.
   - Temperature data—the ADV probe is immersed in the stream, given time to acclimate, and the temperature noted. Prior to each measurement, the temperature recorded by the FlowTracker is checked against a temperature reading from an independent source, such as a digital thermometer. The temperature is noted on the discharge-measurement note sheet. (If temperature units on the ADV are different than those of the independent source, the mean temperature should be converted and noted as such on the field sheet when in the office.)
   - Battery data—the battery voltage is checked to ensure adequate capacity for the discharge measurement.
5. If the FlowTracker is being used in other than fresh water, the salinity at the data-collection site is measured with an approved sensor. The measured salinity is then entered in the handheld controller Setup Parameters Menu. A 12 parts-per-thousand error in salinity can result in a 2-percent error in measured velocity and discharge.
6. The FlowTracker is designed to be mounted on a standard top-setting wading rod. An offset bracket available from the manufacturer should be used to mount the FlowTracker probe head to the wading rod. The WAWSC uses the offset bracket, which allows the sample volume to be located about 2 in. from the wading rod. The bracket was designed to move the sample volume as close to the wading rod as possible while remaining outside the flow disturbance caused by the wading rod. As per OSW Technical memorandum 2009.04, the “mounting correction” (available in firmware version 3.7 and software version 2.30) must NOT be applied.
7. The FlowTracker probe head should be oriented so that the longitudinal axis passing through the center transmitting transducer is parallel to the tagline, and the receiving arm with the red band should be downstream. The wading rod should be held plumb so that the sample volume does not strike a boundary such as the streambed.
8. Velocity should be sampled as follows: The six-tenths-depth (0.6) method should be used for depths 1.5 ft or less. The two-point (0.2/0.8) method should be used for depths greater than 1.5 ft. If the velocity measurement at the 0.8 depth could be corrupted by a sample volume located on or near a boundary, then, a six-tenths method should be used. If a non-standard velocity profile is found while making a two-point velocity measurement (for example, the 0.8 depth velocity is greater than the 0.2 depth velocity or the 0.8 depth velocity is less than half the 0.2 depth velocity), a three-point method (0.2, 0.6, and 0.8 depth) should be used.
9. If a malfunction is suspected or if there has been a shock to the probe (such as striking a hard object), the user should run the Auto QC Test prior to further collection of field data.
10. When practical, the measurement data from the FlowTracker controller are backed up at least daily on removable media such as a CD-ROM, flash-memory card, or USB drive, and stored separately from the field computer.
11. Standard USGS measurement notes may be used to document the discharge measurement, although when available the USGS ADV Discharge Measurement Notes sheets should be used (see appendix B6).

Office Procedures

For each discharge measurement, a file with a .WAD extension is generated and stored on the handheld controller. The .WAD file is downloaded from the controller, and then the FlowTracker software is used to extract four files from the .WAD file:

.DIS file—an ASCII file containing a discharge-measurement summary.

.CTL file—an ASCII file containing the FlowTracker configuration.

.SUM file—an ASCII file containing station information and summary statistics from each measurement.

.DAT file—an ASCII file containing 1-second velocity component and signal-to-noise ratios.

A paper copy of the .DIS file is printed out, cut to no larger than an 8” width by a 10” length, and attached to the measurement note sheet for filing. All four extracted electronic files plus the .WAD file are archived permanently in accordance with the current draft of the WAWSC Memo “Archiving Electronic Discharge Measurement Data” (Mark

Mastin, U.S. Geological Survey, written commun., 2008). The .WAD file contains important data that are not extracted with any of the four files and could be valuable for instrument diagnostics in the event of malfunctions. An example of data archival for FlowTracker measurements is available in the FlowTracker Quality-Assurance Binder.

The reviewer of a FlowTracker measurement may use the following list of recommendations for using FlowTracker parameters and view the measurement with the FlowTracker software, to help assess the quality of a discharge measurement. Guidelines for the parameters are:

- Velocity standard error—If the average standard error for the measurement exceeds 8 percent of the mean measurement velocity, the measurement should be rated no better than “fair.” If the standard error exceeds 10 percent of the mean measurement velocity, the measurement should be rated no better than “poor.”
- Boundary flag—Four possible boundary flags are assigned to each station: “best,” “good,” “fair,” and “poor.” A boundary flag of “best” does not guarantee a lack of boundary interference (see the FlowTracker Technical Documentation). If the ADV sample volume was striking a solid boundary, a “best” flag likely would be displayed, but the measured velocity could be biased toward zero.
- Velocity spikes—An excessive number of velocity spikes (more than 10 spikes per measurement) could be cause to downgrade the quality of the measurement.
- Flow angles—A good measurement section typically shows some flow-angle variations, but angles should be less than 20 degrees.

This section on hydroacoustics will be updated as the use of hydroacoustics increases and as new instruments, software, and firmware are introduced.

Other Direct Methods of Measuring Discharge

Other direct methods of measuring discharge include the tracer-dilution method, volumetric methods, and portable weirs and flumes (Rantz and others,1982; Buchanan and Somers,1969; and Kilpatrick and Schneider,1983). WAWSC procedure dictates that USGS and OSW techniques and guidelines are followed when discharge measurements are made with these or any other selected method of measurement.

Indirect Methods of Measuring Discharge

In many situations, especially during floods, it is impossible or impractical to measure peak discharges by means of a direct method. There may not be sufficient warning for personnel to reach the site to make a direct measurement, or physical access to the site during the event may not be feasible. A peak discharge determined by indirect methods becomes, in many situations, the best available means of defining the upper portions of the stage-discharge relation at a site (Rantz and others, 1982, p. 334). Because the results may be unreliable, USGS generally does not accept extrapolation of a stage-discharge relation, or rating, beyond twice the measured discharge at a gaging station.

The WAWSC follows data-collection and computation procedures presented in Benson and Dalrymple (1967). That report includes policies and procedures related to site selection, field survey, identification of high-water marks, the selection of roughness coefficients, computations, and the written summary. The WAWSC also follows procedures for measurement of peak discharge by indirect methods presented in Rantz and others (1982, p. 273).

In addition to the general procedures presented in Benson and Dalrymple (1967), the WAWSC follows guidelines presented in other reports that describe specific types of indirect measurements suited to specific types of flow conditions. Barnes (1967) and Dalrymple and Benson (1967) describe the slope-area method used by the USGS, which is based on the Manning equation. Arcement and Schneider (1989) describe procedures for selecting the roughness coefficient. Fulford (1994) discusses computer program SAC, used for computing peak discharge with the slope-area method, and computer program CAP (Fulford, 1995), used to compute peak discharge at culverts. Jarrett and Petsch (1985) discuss NCALC, used to compute Manning’s n value from a known discharge, water-surface profile, and cross-section properties. Bodhaine (1982) describes procedures for the determination of peak discharge through culverts, based on a classification system which delineates six types of flow. Models described by Matthai (1967), along with the Water-Surface Profile Computation model (WSPRO) described by Shearman (1990), show how peak discharge can be estimated at sites where open-channel width contractions occur, such as flow through a bridge structure. OSW memorandum 92.11 discusses debris-flow conditions, which are most common in small mountainous basins. The programs and models mentioned here, along with many others, which are stored in directory /usr/opt/wrdapp, can be accessed from any directory on the WAWSC Unix Platforms simply by entering the program name. The three computer programs mentioned above are accessed by entering sac, Cap, or ncalc, respectively.

Water-surface profile studies involve delineations of flood plains or extensions to stage-discharge relations at streamflow sites. In such efforts, WAWSC personnel follow the procedures associated with step-backwater methods described in Davidian (1984). OSW memorandum 87.05 describes how to use WSPRO to compute water-surface profiles with step-backwater methods.

General guidelines that are followed by the WAWSC when making indirect measurements include those discussed in OSW memorandum 92.10 and in Shearman (1990). Violation of any one of the general guidelines does not necessarily invalidate an indirect measurement (OSW memorandum 92.10), but should be cause for careful scrutiny and analysis. Criteria that might invalidate an indirect measurement include possible presence of a hydraulic jump, a discontinuous water-surface slope, inadequate fall between cross sections, or evidence of bed changes between the time of the flood and the indirect measurement.

The Surface-Water Specialist, Data Chief, and Field Office or Project Chief ensure that indirect measurements are performed correctly. These personnel should review proper procedures and documentation with the data-collection staff at the beginning of the flood season each year. The WAWSC Surface-Water Specialist reviews indirect measurements to ensure that they are, in fact, being performed properly. If deficiencies are found during the review, actions taken to remedy the situations include discussing the deficiencies with the person or persons completing the indirect measurement or providing proper training. The Surface-Water Specialist refers questionable and difficult indirect measurements to Surface-Water Specialists in other WAWSCs, or to the Regional Surface-Water Specialist.

The Field Office Chief determines when and where indirect measurements are made, with guidance from the Surface-Water Specialist. Generally, an indirect measurement should be performed when the estimated discharge is more than twice the highest direct measurement made at the site. For quality assurance, validation, and training and skills maintenance purposes, a few indirect measurements should be made annually. Comparing a direct measurement and indirect measurement at similar stages is one of the best ways to verify or estimate the surface roughness coefficient (n value) for future indirect measurements.

The hydrographer should identify and flag high-water marks as soon as possible after the flood, and after obtaining permission from property owners. Because the quality and clarity of high-water marks are best just after a flood, personnel traveling in the field need flagging equipment such as nails and plastic markers, spray paint, paint sticks, and brightly-colored flagging tape in their field vehicles. Because selection of a suitable reach of channel is an extremely important element in making an indirect measurement, at some streamflow-gaging-station sites the stream reach for indirect measurements at specified ranges of stage has been preselected, and that information has been included in the station description.

After the computation of each indirect measurement, the Field Office or Project Chief, Data Chief, or Surface-Water Specialist checks graphs, field notes and data, plotted profiles, maps, calculations or computer output, and written analyses associated with the measurement. A single labeled folder organizes the information, which is then included with the primary folder for use in computing or reviewing the record. Historical indirect measurements become part of the archived indirect measurement files.

The WAWSC maintains and updates the peak-flow data files, including computer database files (OSW memorandum 92.10). The Field Office Chief or Project Chief ensures that appropriate indirect-measurement results are entered correctly into the peak-flow files.

Crest-Stage Gages

Crest-stage gages, or CSGs, are used as tools throughout the USGS for determining peak stages at otherwise ungaged sites, confirming peak stages at selected sites where recording gages are located, confirming peak stages where pressure transducers are used, and determining peak stages along selected stream reaches or other locations, such as upstream and downstream from bridges and culverts. When CSGs are used to confirm peak stages at recording gage sites, they need to be installed as close as possible to the transducer or orifice for the gage. CSG peak stages are invaluable for performing indirect measurements. At sites without CSGs, hydrographers must depend on obtaining a number of high-water marks to obtain flood profiles. The OSW requires quality-assurance procedures comparable to those used at continuous-record stations for the operation of CSGs and for the computation of annual peaks at CSGs (OSW memorandum 88.07).

Part of the WAWSC's surface-water program includes operation of CSGs. Generally, CSGs supplement other gage instruments and are used to confirm or determine peak stages. The procedures followed by the WAWSC in the operation of CSGs are presented in Rantz and others (1982, p. 9, 77, 78). One or more gages at each selected site mark peak water-surface elevations. Culvert stations, or other sites where water-surface elevations are required to compute the amount and type of flow through the structure, require upstream and downstream CSGs.

When CSG data are used to determine peak flows, field personnel develop stage-discharge relations from direct or indirect high-water measurements. Then, direct or indirect measurements obtained every year verify the rating or become the basis to adjust it. Hydrographers run levels to the gage every 3 years, or as soon as possible after significant changes in the gage because of damage to the gage, reconstruction, or other such situations. An outside high-water mark confirms recorded peak stages whenever possible. The hydrographer flags this mark as soon as possible after the event so that personnel can determine the elevation of the high-water mark the next time levels are run.

Field personnel write CSG observations on a CSG note sheet (appendix B8), measurement note sheet, or any other note sheet (appendix B), so long as they include all the necessary information. Properly completed CSG field notes contain, at a minimum, initials and last name of field personnel, date, time of observation, the reading above the base bolt, mathematics used to calculate elevation, and any pertinent notes regarding the conditions under which the data were collected. The CSG readings are entered into the electronic 9-207 form in ADAPS.

The Field Office Chief ensures that correct data-collection procedures are used by personnel in installing, maintaining, and reading CSGs. The Chief periodically reviews CSG note sheets and communicates any observed deficiencies to the appropriate hydrographer, along with recommendations to correct them. The Field Office Chief assures that hydrographers are properly trained in operating CSGs.

Artificial Controls

Artificial controls, including broad-crested weirs, thin-plate weirs, and flumes, are built in stream channels for the purpose of simplifying the procedure of obtaining accurate records of discharge (Rantz and others, 1982, p. 12). Such structures serve to stabilize and constrict the channel at a section, reducing the variability of the stage-discharge relation. In the WAWSC, these structures are most often used in low-flow projects rather than for long-term gaging stations.

In situations where artificial controls are installed as permanent structures, determination of stage-discharge relations depends on the design rating when direct measurements cannot be made. In most cases, however, hydrographers regularly make volumetric or current-meter measurements to validate the artificial control estimates. WAWSC personnel use portable weir plates and flumes in situations that include very low flow or unidentifiable controls. Buchanan and Somers (1969, p. 57) and Rantz and others (1982, p. 263) describe the methods used in applying these portable devices.

The Field Office Chief or Project Chief ensures that field personnel use artificial control designs appropriate for the gaging site and that they use correct methods to install and operate the control. When installing an artificial control, the WAWSC personnel take into account the criteria for selecting the various types of controls, principles governing their design, and the attributes considered to be desirable in such structures (Carter and Davidian, 1968, p. 3; Rantz and others, 1982, p. 15 and 348; and Kilpatrick and Schneider, 1983, p. 2 and 44).

During field inspections of artificial controls, hydrographers write specific information pertaining to control conditions on field note sheets for the purpose of assisting in analysis of the surface-water data. These notes include height of water above the control, the amount of free fall and submergence at weirs, time and date of observation, station number and name, name or initials of the field person, and comments on channel conditions upstream and downstream of the artificial control. Regular maintenance at artificial controls includes cleaning the control, cleaning the staff plate, and checking for and repairing any observed leaks. Field personnel should consult the Field Office Chief or Project Chief for help in solving issues associated with artificial controls.

Flood Conditions

Flood conditions present issues that otherwise do not occur on a regular basis. These issues can include difficulties in gaining access to a streamflow gage or measuring site because roads and bridges are flooded, closed, or destroyed. Debris in the streamflow can damage equipment and present dangers to personnel collecting the data. Rapidly changing stage or conditions requiring measurements to be made at locations some distance away from the gage can create difficulties in associating a gage height to a measured discharge. Because of the difficult and changing conditions, field personnel follow a series of specific guidelines during floods. These guidelines consist of a WAWSC Flood Plan and a Station and Flood Information Database.

The WAWSC flood plan provides WAWSC personnel with basic guidelines for collecting, analyzing, and reporting flood-related data, and is intended to ensure efficient and complete coverage of all floods. The flood plan describes responsibilities before, during, and after a flood, informational-reporting procedures, and field-activity priorities. The flood plan serves as a central reference for emergency communications, telephone numbers for key WAWSC personnel, Local Receiving Ground Station (LRGS) codes for accessing streamflow gages equipped with telemetry, and methods of obtaining the most current data.

The Data Chief ensures that the flood plan includes all appropriate information, reviews the flood plan annually, and makes updates to the plan as required. The Data Chief provides copies of the flood plan to all Field Office personnel and key project personnel who may assist in flood measurements and monitoring. Each individual that receives a copy of the plan keeps the document near their desk or with their field folders, and maintains copies of key information, such as telephone numbers, in their field vehicle. The Field Office Chief or Project Chief ensures that individuals who receive a copy of the plan are fully versed on the plan's contents.

The Station and Flood Information Database contains several different categories of flood-related information that enable the WAWSC flood coordinator to quickly formulate a plan for responding to a flood and aids each field person in rapidly making decisions about which stations and in what order they should collect flood data. This database contains station flood priorities, current flow and stage data and graphs, flood-frequency discharges, station flow and flood data, listings of which stations are maintained by which hydrographers, and much more.

During a flood, the Field Office Chief, in conjunction with the Data Chief, coordinates flood activities. Personnel who are not already in the field during flood conditions should first contact the Field Office Chief for their assignments. If the Field Office Chief is not available, field personnel should come directly to the office with an overnight bag in case of extended work hours. For personnel that are already in the field, their first responsibility during flood conditions is to contact the Field Office Chief for their assignment. If neither of these people can be reached, they should call and consult with other technical persons or co-workers in the office and, using the WAWSC Flood Plan and the WAWSC Station and Flood Information Database as guides, decide which stations they should proceed to first. Personnel who arrive at a gaging station to find that a flood has occurred should make a discharge measurement, note and flag HWMs as appropriate, and record any pertinent observations about the flood or weather conditions before proceeding to their next site.

WAWSC personnel apply methods such as observing high-water marks inside and outside wells, determining maximum clip readings, and taking CSG readings to determine peak stage at gaging stations (Rantz and others,1982, p. 60).

WAWSC personnel follow policies and procedures stated in a number of publications and memorandums when collecting surface-water data during floods. Rantz and others (1982, p. 159 to 170) present techniques for current-meter measurements of flood flow. Benson and Dalrymple (1967, p. 11) discuss procedures for identifying high-water marks for indirect discharge measurements. OSW memorandum 92.09 and Buchanan and Somers (1969, p. 54) present information on adjustments applied to make measured flow hydraulically comparable with recorded gage height when discharge measurements are made a distance from the gaging station. It is the responsibility of all personnel with questions about particular policies or procedures related to flood activities, or who recognize their need for further training in any aspect of flood-data collection, to address their questions to the Field Office Chief or Data Chief.

The Data Chief reviews all activities related to floods. This review includes seeing that guidelines and priorities spelled out in the flood plan are followed and that the guidelines appropriately address WAWSC requirements for obtaining flood data in a safe and thorough manner. The Data Chief communicates any deficiencies in following the flood plan orally or in writing to the Field Office Chiefs, who in turn provide corrective measures and(or) training for field personnel, as appropriate.

Low-Flow Conditions

Because of the typically sparse precipitation during summer in Washington, low flows occur at many streams in late summer and early fall. Low flows also may occur during periods of severe cold in winter when water will be frozen in the snowpack and glaciers, or water may be frozen in the stream itself. WAWSC procedure requires that field personnel make point-of-zero-flow determinations at least once annually during low flow at wadable stations and record the information on the Discharge Measurement Notes and in Measurement Database (ADAPS 9-207). These data help hydrographers extend rating curves down and determine the stage-discharge rating offset. WAWSC personnel use DCP data to decide when best to visit a site to obtain low-flow discharge measurements near the lowest flows of the year.

Low-flow conditions differ from those observed during periods of medium and high flow. Low-flow discharge measurements define or confirm the lower portions of stage-discharge relations for gaging stations, and as part of seepage runs, identify channel gains or losses. Gains and losses can result from either the hydraulic connection between the stream channel and adjacent aquifers or from underflow in gravel streambeds. Underflow is the portion of streamflow that flows through gravel streambeds. Streamflow during low-flow periods in late summer and early fall can change substantially within short distances as a result of variable amounts of underflow along a stream reach. Consequently, low-flow measurements made to define the low-flow portion of stage-discharge ratings for gages on streams with gravel streambeds should be made as close as possible to the low-flow controls for those gages. Additionally, low-flow data help in the interpretation of other associated data, such as well readings. Low-flow measurements also help define the relation between low-flow characteristics in one basin and those of a nearby basin for which more data are available (OSW memorandum 85.17). The designated wading-measurement location must be documented in the station description.

In many situations, factors during low flows reduce the accuracy of discharge measurements. These factors include algae growth that impedes the free movement of current-meter buckets and large percentages of the flow moving in the narrow spaces between cobbles. When measuring conditions are considered to be unsuitable, the hydrographer physically improves the cross section for measurement by removing debris or large cobbles, constructing dikes to reduce the amount of non-flowing water, or other measures (Buchanan and Somers, 1969, p. 39). In some cases, field personnel must clean the control, but only after reading and recording the gage height before cleaning. After modifying the cross section or control, personnel allow the flow to stabilize before initiating a discharge measurement. Because the modification will almost certainly affect the stage, personnel record gage-height readings on the field notes before and after they modify the channel so that appropriate adjustments to the gage-height record can be made. They should also note these readings on gage-shelter documents and on the recorder chart, if applicable.

The Field Office Chief or Project Chief ensures that WAWSC personnel use appropriate equipment and procedures during periods of low flow. Reviewing field measurement notes during the records review, or more often in the case of drought conditions, accomplishes this task. During periods of low flow, the Data Chief, Field Office Chief, or Project Chief provides answers to questions from WAWSC personnel pertaining to data collection during periods of low flow.

Cold-Weather Conditions

Surface-water activities in the WAWSC, particularly in the Spokane Field Office, include making streamflow-discharge measurements during freezing weather conditions. Sub-freezing air temperatures, near-freezing water temperatures, wind, snow, and ice can create difficulties in collecting data as well as dangers to field personnel. Employee safety remains the highest priority in collecting streamflow data during winter periods, or any other period for that matter.

Only in unusually severe cold snaps do streams in Washington completely freeze over, but when they do, WAWSC personnel follow procedures for discharge measurements under ice cover presented in Buchanan and Somers (1969, p. 42), Rantz and others (1982, p. 124-128), and OSW memorandum 84.05. These publications and guidelines deal with issues such as drilling holes in ice with drills, chisels, and augers, supporting reels and current meter assemblages on ice, information on computing depth of water under ice, and which types of equipment to use to measure flow under ice.

The OSW recommends the use of a type AA current meter built with a Water Survey of Canada (WSC) winter-style yoke with a conventional metal-cup rotor for discharge measurements under ice cover with slush-free conditions. For conditions where slush ice is present, the OSW recommends the use of the WSC winter-style yoke with a polymer rotor (OSW memorandum 88.18). Although polymer rotors are not allowed during all other conditions (OSW memorandum 90.01), the OSW considers the superior ability of the polymer rotor to shed slush ice and retard freezing in ice-covered streams to be more important than the turbulent-flow-related inaccuracies associated with the rotor (OSW memorandum 92.04). The OSW also regards the regular AA meters with conventional metal-bucket rotors to be acceptable for use in slush-free conditions if cutting the required larger holes through the ice is feasible (OSW memorandum 92.04)—this is what the Spokane Field Office generally does. The Field Office Chief or Project Chief ensures that personnel use the correct instruments for the conditions present and follow proper procedures for data-collection activities during freezing winter conditions. Annual reviews of the available instruments and their uses fulfills this responsibility.

Winter conditions demand that safety be of the utmost importance. Field personnel will contact the office, their spouse, or another designated person by an agreed-upon time each day to verify that they are all right and to provide updates on their plans and whereabouts for future data collection. Field personnel will maintain extra winter-type gear in their vehicle, such as insulated boots, down jackets, wool socks and caps, wool blankets, matches in a water-resistant case, and a pocketknife. Personnel should drive vehicles fully equipped for winter conditions. At a minimum, this would include chains, a shovel, a hatchet, a chain saw, a regular saw, and an emergency first aid-kit.

Processing and Analysis of Surface-Water Data

The computation of streamflow records involves the analysis of field observations and field measurements (including the stage record), the determination of stage-discharge relations, adjustment and application of those relations, and systematic documentation of the methods and decisions that were applied. The WAWSC computes streamflow records and publishes those data annually. The procedures followed by the WAWSC pertaining to the processing, analysis, and computation of streamflow records are based on those described in Rantz and others (1982) and in Kennedy (1983).

Measurements and Field Notes

The gage-height information, discharge information, control conditions, and other field observations written by personnel onto the measurement note sheets and other field note sheets form the basis for records computation for each gaging station. The USGS stores measurements and field notes that contain original data indefinitely (Hubbard, 1992). The WAWSC stores measurements and other field notes for the water year that is currently being computed in the primary station folder. The Field Offices store the previous water year’s measurements and notes for each station in a separate filing cabinet.

WAWSC procedure regarding checking discharge measurements varies depending on the measurement and experience of the hydrographer who made it. Generally, Field Office personnel check discharge measurements made by hydrographers with less than about 3 years of experience. Measurements made by experienced hydrographers that are within the check-measurement criteria for their station and are less than the highest measurement of the year, generally do not need to be checked. However, Field Offices should check measurements that define a substantial part of the rating or shift, or were made during significant floods or low flows. Measurements that reflect a change in the rating or shift should be checked. All measurements made at International Gaging Stations are checked. Procedures involved in checking a measurement include reviewing the mathematics, velocities, width calculations, gage heights and corrections; comparing the measurement gage heights with those from the recording instruments in the computer files; and other items (Kennedy, 1983, p. 7).

The hydrographer enters measurements into the computer files using the Automated Data Processing System (ADAPS 9-207) and keeps the original measurement notes made during the year in the primary station folder. The hydrographer enters the measurement into the computer files within 1 week of the field trip during which the measurement was made, unless there are extenuating circumstances or other arrangements have been made by the Field Office Chief.

Continuous Record

The WAWSC collects surface-water gage-height information as continuous-record data (hourly, 30-minute, 15-minute, or 5-minute values, for example) in the form of pen traces on graph paper, electronic readings in a data logger, telephone modem, and electronic transmissions by satellite.

Personnel apply stage-discharge ratings to convert gage-height record to discharge record. Therefore, the accuracy of gage-height record, in great part, reflects the accuracy of computed discharges.

Since October 1, 1999, WAWSC policy is to use real-time data as the primary record whenever possible. Exceptions are for stations with Synergetics DCPs, Bureau of Reclamation sites, sites with many regularly missing transmissions, and other extenuating circumstances. All real-time data ratings and shifts are updated every day at 5 a.m. ADAPS will automatically calculate a mean unless more than 480 minutes of data are missing from the DCP transmissions. Back-up record is inserted from data-logger data using ADAPS.

Hydrographers assemble the gage-height record for the period of analysis in as complete a manner as possible. They identify periods of inaccurate gage-height data, then correct those data using datum corrections, gage-height corrections, and shifts, or delete the data, as appropriate. WAWSC policy is to delete data that appear erroneous and cannot be verified. Authors discussing the assembly of gage-height record and procedures for processing those data include Kennedy (1983, p. 6) and Rantz and others (1982, p. 560 and p. 587).

The WAWSC utilizes a variety of methods for entering stage data into the computer files. For stations with DCPs, the computer uses specific software (ADAPS) to automatically store stage data transmitted from the satellite. In ADAPS, the primary instrument (data descriptor) for current records is denoted with an asterisk. Personnel transfer data from EDLs to portable laptop field computers, then transfer the data into the USGS computer files using appropriate software for that purpose.

Stage data from graphical recorders usually serve as backup data, and hydrographers hand-enter those data, as needed, into the computer data files. Gage-height record is never estimated. In the USGS computer files, flags after the original data denote the source: "e" from EDLs; "s" from DCPs; and "~" for ADAPS interpolated data (in edited unit values). These and other flags are defined in the ADAPS documentation, which can be accessed from ADAPS. Hydrographers flag estimated mean daily flow data in the computer with an "e" before the value. In all cases, the hydrographer checks the data for missing and erroneous values using computer software for that purpose.

Personnel may fill periods of bad or missing data with data from backup recorders. They enter these data into the computer files by computer software if possible, or by hand, and check for consistency in number and timing with other electronic data on either side of the bad or missing period. For DCP stations, data for missing transmissions will be entered from back-up sources only when the daily mean discharge would change by more than 10 percent. Exceptions are made for peak flow or minimum flow events in order to document instantaneous extremes. When personnel use data from backup recorders and enter those data in the computer, they document the periods and source of the data in the station analysis in the primary station folder. Likewise, hydrographers document periods and sources of estimated data in the station analysis in the primary folder. Typically, the hydrographer who operates and maintains the gage is the one who enters, maintains, and documents the stage data in the computer files.

Procedures for Computing, Reviewing, and Publishing Records

Hydrographers process the records for the stations to which they are assigned. The hydrographer assigned to the station usually works the first computation for the records associated with it. After the first computation, a different hydrographer reviews and checks the work of the first. Finally, a senior technical or review person reviews the record and makes any required changes. Records for one-third of the stations are earmarked for formal review by another Field Office within the WAWSC or outside the WAWSC. Thus, records for all stations should receive a review about once every 3 years. The goal of the review is to ensure that proper methods were applied throughout the process of obtaining the surface-water data and computing the record. After these steps are completed, the Field Offices send the reviewed station manuscripts and data tables to the Annual Data Report Coordinator. That person submits the documents in electronic format for publication in the USGS Annual Water Data Report.

A key element for a quality-assurance plan is ensuring the thoroughness, consistency, and accuracy of streamflow records. These records comprise a variety of data, which include the gage-height record including instantaneous extremes, levels, ratings, datum and gage-height corrections, shifts, hydrographs, station analyses, winter records, furnished records, and instantaneous and daily-mean values of discharge. The goals, procedures, and policies for each component differ.

Gage Height

The accuracy of surface-water discharge records depends on the accuracy of discharge measurements, the accuracy of rating definition, and the completeness and accuracy of the gage-height record (OSW memorandum 93.07). Computation of streamflow records includes ensuring the accuracy of gage-height record by comparisons of gage-height readings made from independent reference gages, comparison of inside and outside gages, examination of high-water marks, comparisons of the redundant recordings of peaks and troughs by use of maximum and minimum indicators, examination of data obtained at CSGs, and confirmation or updating of gage datums by levels.

Hydrographers examine the gage-height record to determine if the record accurately represents the water level of the body of water being monitored. As part of this examination, they identify periods of time during which inaccuracies have occurred and, whenever possible, determine the cause for those inaccuracies. When possible and appropriate, personnel correct inaccurate gage-height record and place notes to that effect in the primary station folder. When corrections are not possible, hydrographers should remove the erroneous gage-height data from the set of data used for streamflow records computation to avoid possible misunderstanding and misuse of the flawed data. When they delete erroneous data, the hydrographer documents this action, including their reasoning for deleting the data, on the station analysis included in the primary station folder.

Gage-height record documentation involves detailing observations in several parts of the record to clearly document stage changes at the station. Hydrographers must document all gage-height corrections by entering them in the computer and including a hardcopy of the file in the primary folder. They should note gage heights observed during field inspections or discharge measurements directly on the primary record on the day of observation to assure agreement between the observed and computed gage heights. Additionally, hydrographers note the source of gage-height data used to fill in periods of missing or erroneous gage-height data on the primary record sheet as well as on the station analysis within the primary station folder. Generally, the person assigned to the station will be the one who deletes or inserts backup data in the computer files. The hydrographer keeps hard copies or computer diskettes of the replacement data in the primary station folder.

Gage Datums and Levels

The running of levels can detect errors in gage-height data caused by vertical changes in the gage or gage-supporting structure. Hydrographers may reset gages or adjust gage readings by applying corrections based on levels (Kennedy, 1983, p. 6 and Kennedy, 1990). Procedures for computing level records for each station include ensuring that the front sheet has been completed for each set of levels, checking levels, ensuring that the level information was listed in the historical levels summary, and ensuring that information was applied appropriately as datum corrections. The individual computing the record checks field notes for indications that the gages were reset correctly by field personnel. If the gages were not reset to agree with the levels, then corrections must be applied to the record to make them do so, and the hydrographer responsible for the station will reset the gages on their next field trip to the site and document that action on a measurement note sheet. The individual computing the records makes appropriate adjustments to the gage-height record by applying datum corrections.

Discharge Ratings

One of the principal tasks in computing the discharge record is the development of the stage-discharge relation, also called the rating. The rating is usually the relation between gage height and discharge (simple rating). Ratings for some special sites involve additional factors such as rate of change in stage or fall in slope reach (complex ratings) (Kennedy, 1983, p. 14). WAWSC personnel follow procedures for the development, modification, and application of ratings that are described in Kennedy (1984). WAWSC personnel also follow guidelines pertaining to rating and records computation that are presented in Kennedy (1983, p. 14) and in Rantz and others (1982, Chap. 10-14 and p. 549).

For each gaging station, the most recent digital rating table can be obtained by accessing the rating table files in the computer using ADAPS. Additionally, the hydrographer maintains a paper copy of the rating table in the station primary folder and in the field folder. A graphical plot of the most recent rating can be obtained by using the computer to plot the rating, or accessing the original paper version or copy in the station primary folder or copies in the field folder.

Various WAWSC procedures apply to ratings. Typically, the hydrographer assigned to the station develops new ratings; however, sometimes a reviewer or checker of the first records computation develops the new rating. Hydrographers obtain in-house reviews of ratings and shifts before they are distributed outside the office. Final ratings are approved by the Field Office Chief. Hydrographers generally apply shifts to the rating when measurements indicate a change in the rating or previous shift of more than 5 percent. Shifts that extend over the entire range of the rating and(or) persist more than 1 year may reflect a fairly stable control change and should be analyzed and drawn up as new ratings. Ratings generally should be extended to no more than twice the discharge of the highest direct measurement. Hydrographers should include all measurements made to develop the new rating, along with the highest 10 measurements made at the site. The old rating should be outlined lightly on the same sheet as the new rating. Sheets showing the new and old rating should show the numbers of the ratings and the dates they were first applied and ended, station name and number, measurement numbers, the offset, and values for the x and y axis (discharge and stage). The Field Office Chief, Data Chief, or WAWSC Surface-Water Specialist provides the ultimate guidance to WAWSC personnel regarding ratings.

Datum Corrections, Gage-Height Corrections, and Shifts

Datum corrections, as measured by levels, represent a correction applied to gage-height readings to compensate for the effect of settlement or uplift of the gage (Kennedy, 1983, p. 9). Hydrographers apply datum corrections to gage-height record in terms of magnitude (in feet) and in terms of when the datum change occurred. In the absence of any evidence indicating exactly when the change occurred, hydrographers must assume that the change occurred gradually from the time the previous levels were run, and they prorate the correction with time (Rantz and others, 1982, p. 545). This may require records revision for previous years. Datum corrections apply when the magnitude of the vertical change becomes greater than 0.02 ft.

Gage-height corrections compensate for differences between the primary gage and the reference gage (Rantz and others, 1982, p. 563). These corrections apply in the same manner as datum corrections. Hydrographers apply gage-height corrections to make recorded data agree with reference-gage data. They apply these corrections when the difference between the primary (recording) gage and the reference gage is greater than 0.02 ft.

A shift represents a correction applied to the stage-discharge relation, or rating, to compensate for variations in the rating. Shifts reflect the fact that stage-discharge relations are not permanent but vary from time to time, either gradually or abruptly, because of changes in the physical features that form the control at the gaging station (Rantz and others, 1982, p. 344). Applied shifts vary in magnitude with time and with stage (Kennedy, 1983, p. 35). Generally, hydrographers do not apply shifts unless a measurement, or series of measurements, varies more than 5 percent from the rating. A stage-shift diagram documents shifts, plotting a measurement's shift from the rating against the measurement's gage height. The shift for the rating itself shows as zero. Using evidence from the hydrograph, rating, and plotted measurements determines how the shift diagram is drawn and applied. In the WAWSC, time shifts are normally used only when a stage shift cannot be justified by the available data. For some streams with very mobile bed material, time shifts may be more appropriate for working the record. Once shifts are applied, measurements should vary from the rating by less than 5-8 percent, unless the measurement was rated poor.

The hydrographer documents datum corrections, gage-height corrections, and shifts in the computer and station files. Datum and gage-height corrections and shift data in the computer are located in the ADAPS system files. Paper copies of these files are maintained in the primary station folder. After final review, copies of the gage-height corrections, datum corrections, and stage and time shifts are maintained with the station analysis as part of the historical record. Generally, transitions in gage-height corrections and shifts should be smooth between water years. However, as long as the computed discharge difference is less than 5 percent, no changes are made to the previous year's record.

Hydrographs

A discharge hydrograph is a plot of daily mean discharges versus time. The horizontal axis represents the date and the logarithmic vertical axis represents the discharge. In the process of computing station records, this hydrograph becomes a useful tool for identifying periods of erroneous information, such as incorrect shifts or datum corrections. Additionally, hydrographs help estimate discharges for periods of undefined stage-discharge relation, such as during backwater or ice conditions, and to estimate discharges for periods of missing record.

Information placed on the hydrograph for each station includes station name, station number, water year, date the hydrograph was plotted, drainage area, plot of daily mean discharge data, plots of measurements, and hydrograph(s) of the streamflow station(s) with which the hydrograph was compared. Climatological data, such as daily precipitation totals and maximum and minimum air temperatures, are sometimes included on a hydrograph to help evaluate the validity of the discharges. Personnel generally create the hydrograph in ADAPS and print it out on a plotter. Reviewers check and finalize hydrographs during the second computation or final review.

Hydrographic comparison helps verify the reasonableness of the computed discharge data. Station sites that are the most appropriate for hydrographic comparison are sites that are downstream or upstream of the station being analyzed, sites in adjacent watersheds, or sites with comparable drainage areas in the same general vicinity. Comparisons can also be made by adding or subtracting stations, which is useful for streams with diversions. Large differences noted by the hydrographic comparison can be an indication that the records for one or both stations have been misinterpreted. Regardless, large differences need to be explained and included with the hydrograph as part of the review package. Hydrographs generally are filed in a map drawer available to personnel in the Field Office. Final hydrographs should become part of the annual archived file.

Station Analysis

The station analysis documents the data collected, procedures used in processing the data, and the logic upon which the computations were based for each year of record for each station. The analysis serves as a basis for review and as a reference in case questions arise about the records at some future date (Rantz and others, 1982, p. 580). Topics discussed in detail in the station analysis include equipment, hydrologic conditions, gage-height record, datum corrections, rating, discharge, special computations, remarks, and recommendations. The section on gage-height record includes information on instrument issues and maximum and minimum recorded stages. The section on datum corrections provides information on levels and the zero of the gage. The rating section details the control conditions for the gage, type of bed material, rating and shifts used during the analysis, and maximum and minimum computed discharges. The discharge section provides information on the rating and hydrographic comparison used. Finally, the remarks section details record accuracy and miscellaneous information on the station record, such as rating irregularities, estimated record, assumptions and(or) reasoning needed to interpret the record or recommendations for station operation and maintenance. The hydrographer responsible for maintaining the station generally writes the station analysis. The Station Analysis Report function of the Miscellaneous Utility Functions (UT) sub-menu of ADAPS can be used to generate a listing of some of the information that goes into a station analysis—namely the corrections applied to the data, the ratings and shift curves used, and the periods of estimated daily discharges.

The WAWSC maintains electronic files for all station analyses. These files are stored in subfolders of the project directories for the Tacoma, Sedro Wooley, Spokane, and Kennewick Field Offices on a Sun Server running Solaris. Hydrographers create the files in the Record Management System (RMS) accessible through the WAWSC internal web page. Final station analyses become part of the final archived records.

Communication is a key element in records-working, processing, and review. The WAWSC encourages persons performing the second computation in the record check and review process to discuss all changes made to the record with the person performing the first computation. Such interaction not only allows education of the first computation person about errors they may have made in procedure or analysis, but will enable the first computation person to knowledgeably discuss any changes made to the record with future reviewers. The Field Office Chief or their designee decides differences that cannot be resolved by mutual discussion and agreement between the first and second computation persons. The final reviewer assures that the station analyses are properly completed and stored on the computer and in the final record. Station analyses are signed and dated by the persons who performed the first and second computations, and by the reviewer(s).

Winter Records

Computing records that represent winter periods for gaging stations sometimes involves procedures that are not applicable to records that represent other times of the year. The formation of ice in stream channels or on section controls affects the stage-discharge relation by causing backwater; the effect varies with the quantity and nature of the ice, as well as with the discharge (Rantz and others, 1982, p. 360). During some ice conditions the recorded gage-height data may be accurate, although the actual stage-discharge relation may be undeterminable and unstable. An example of this condition would be when surface ice forms on the stream but the stilling well remains unfrozen and the water level in the stilling well represents the backpressure caused by the ice in the channel. During other conditions the recorded gage-height data are inaccurate, resulting in periods of missing gage-height record. An example of the latter would be when a stilling well or the intakes to the stilling well freeze.

Ice-affected records usually are only an issue for the Spokane and Kennewick Field Offices. The individual computing the station record identifies ice-affected periods from weather records and hydrographic comparison and estimates discharge on the basis of measurements made at the site during ice conditions, or on hydrographic comparison with nearby stations unaffected by ice. Generally, ice-affected gage-height records are not considered erroneous, and the data are not removed from the computer files. Each field person processes their own data for ice-affected conditions.

Furnished Records

The WAWSC receives surface-water data collected under the supervision of other agencies, organizations, or institutions. The WAWSC performs quality assurance on these data, publishes the data in the USGS annual data report, and archives the data in NWIS. The quality-assurance program for data collection includes at least two annual check measurements and gage inspections. The assurance program for the furnished data, which includes mean daily discharge values and extreme stages and discharges, involves, at minimum, biannual records reviews. These reviews include checking the daily values summary, list of discharge measurements, copies of the front sheets for the discharge measurements, primary computation sheets showing gage-height and datum corrections and shifts, a hydrograph and hydrographic comparison with another station, rating tables and rating curves, shift diagrams, and the station analysis. If the USGS computer receives real-time data from the furnished-record station, then the real-time computations in ADAPS will also provide part of the quality-assurance check. In these cases, the WAWSC strives to minimize computed data differences by having the agency furnishing the record work from the same electronic data set received from the DCP in the USGS computer. In the case of errors in computation of the furnished record, or of questions regarding the standards under which the data were collected, the USGS will work with the furnishing agency to resolve these issues. In cases where the issues cannot be resolved, or the record is determined to be unreliable, the record should be published as “poor”; in extreme cases, the record should not be published or archived in NWIS. Documentation of the issues in these cases should be made part of the station record, and the USGS should work with the furnishing agency to remedy the situation.

Daily Values Table

With few exceptions, for each gaging station operated by the USGS, ADAPS computes and stores a mean discharge value for each day. The daily values table generated by ADAPS displays mean daily discharges stored for each day of the water year. Hydrographers compare the daily discharge values table with hydrographs to ensure reasonableness and accuracy of the tables. Paper copies of the daily values table kept in the primary station folder, which are periodically updated though the year, document the status of the record. The final manuscript is checked with these data.

Manuscript and Annual Report

When WAWSC personnel have computed, analyzed, checked, reviewed, and finalized records for the water year, the surface-water data for that water year are published, along with other data, in the USGS Annual Water Data Report. Information presented in the annual data report includes daily discharge values during the year, extremes for the year and period of record, and various statistics. Additionally, station-description information presented in the annual data report supplies important details such as physical descriptions of the gage and basin, history of the station and data, and statements of cooperation. In preparing data for publication the WAWSC follows the guidelines presented in the report, "WRD Data Reports Preparation Guide" (Novak, 1985). The WAWSC Data Chief maintains responsibility for producing the annual data report.

Crest-Stage Gages

In the WAWSC, CSGs frequently are installed near recording gages, especially those where pressure transducers are used, to document and(or) verify peak stages. Procedures for computing CSG records should be similar to those for other gaging stations. The field notes are examined for correctness and accuracy. Peak stages recorded by CSGs are cross referenced with other available information; the dates of the peaks are determined by analyzing available precipitation data and peak data from recording gages within the same basin or from nearby basins.

At sites where CSGs are used to compute peak discharges, an initial stage-discharge relation, or rating, is developed for the site by direct or indirect high-water measurements. The rating is verified or adjusted on the basis of subsequent direct or indirect high-water measurements.

For each station, a list of all measurements is maintained and each measurement is assigned a chronological number. For each station, a graphical plot of the current rating, along with each recent and each notably high stage-discharge measurement, is made readily available to those who check and review the station record. The original graphical rating plots are kept in the primary folder and copies are kept in the field folder. Current station descriptions and a summary of levels are maintained in the primary folder. A brief station analysis is written each year describing computation of the annual peak, identifying which rating was used and the type of flow condition, and describing how the dates of the peaks were determined.

The Data Section updates the Peak-Flow File promptly after peak data have been finalized. A current listing of annual peaks becomes part of the station folder for review purposes (OSW memorandum 88.07).

Real-Time Data

Processing of Real-Time Streamflow Data

A necessary and critical element in maintaining accurate streamflow records on a real-time basis is the need for rating analysis and shift application as soon as practicable after a discharge measurement has been made. The WAWSC's policy is that rating analyses and shift applications will be performed using the following procedures for data disseminated on the WAWSC's public Web page at the URL http://wa.water.usgs.gov/data/.

Generally, the hydrographer updates shifts or ratings within 1 week after the completion of a field trip. In certain situations, Field Office Chiefs may ask that information from discharge measurements be called in immediately from the field and input by office staff. This may be required during floods if shifts are likely to have a significant effect on peak flows and with special consideration given to sites co-located with National Weather Service (NWS) flood forecast points. Data from sites that are critical to water management agencies for their daily operational requirements also may require more stringent measurement review and shift-application procedures.

During floods, the Field Office Chief will make decisions about resource allocation for making discharge measurements or making field repairs to get telemetry functioning at a critical station.

Web Page Presentation Format

WAWSC real-time data are served from computers located in Tacoma and maintained by the WAWSC. The National Water Information System -Web (NWISWeb) software is used in order to conform to national USGS standards. The URL http://wa.water.usgs.gov/data/realtime/ provides access to real-time data on the Internet and other pertinent information, including Web page links. This site, which can also be accessed via links from the WAWSC's public Web page, contains links to pages that provide map locations of stations. The real-time data Web site is maintained by the surface-water database administrator. Review and approval of new design or content is by the WAWSC Web Advisory Committee and the Assistant Director for Hydrologic Data.

Review of Real-Time Streamflow Data

Real-time streamflow data that are disseminated on the public Web page must be reviewed frequently to ensure their quality and to prevent the distribution of erroneous information. The WAWSC utilizes both automated and manual review procedures to meet this objective.

To prevent erroneous spikes from appearing on NWISWeb, the hydrographer must enter thresholds in ADAPS (WRD Policy memorandum 99.34). At a minimum, the Very-high-value and Very-low-value must be set in ADAPS for every station for which NWISWeb displays real-time data. NWISWeb automatically checks all DCP stations for the occurrence of very high or very low stage or discharge values to detect probable erroneous data. The WAWSC is automatically notified by e-mail if a spike is detected (J. Michael Norris, U.S. Geological Survey, written commun., 2002). An automated system implemented by the WAWSC informs designated Field Office personnel if a DCP station has failed to transmit data after 8 hours. The WAWSC maintains a three-person Data Relay Team that has responsibility for 24-hour, 365-day monitoring of the overall real-time data and acquisition system. The team members are trained to address system problems, and are instructed to relay site-specific field questions to the appropriate Field Office.

In addition to the automated procedures, Water Resources Discipline memorandum 97.17 requires frequent and on-going screening and review of Web data, including at least the daily review of hydrographs during normal hours of operation. The WAWSC also requires that all Web pages containing real-time streamflow data are reviewed for accuracy and(or) missing data twice weekly.

Error Handling

There are two general types of errors associated with streamflow data that are delivered by the real-time system and disseminated on the Internet. The first are persistent-type problems usually associated with some type of equipment failure, whether in data collection or transmission, but could also be related to ice effects. Because of the nature of the problem, they generally occur on a continuing basis for more than a single recording interval. The second are the intermittent-type problems, which are frequently the result of a data transmission error. These often show up as either a zero or an unreasonably large value. Hydrographers use the Internet hydrographs of the data to determine if the gage's instruments are working correctly. Field Office personnel are responsible for reporting situations that cause either type of error to the Hydrologic Analysis and Data Management (HA) Unit. The determination of the course of action that needs to be taken and the identification of the individual that will undertake the action is decided by consultation and discussion between the Field Office and HA Unit personnel.

Data Qualification Statements

Water Resources Discipline memorandum 95.19 requires that streamflow data made available on the Web should be considered provisional until the formal review process has been completed. To ensure that everyone who accesses data from the Web is aware of this, data-qualification statements must be included at key locations with a clickable disclaimer on all real-time data pages. The disclaimer is located at the URL http://wa.water.usgs.gov/realtime/disclaimer.html.

Office Setting

Maintaining surface-water data and related information in a systematic and organized manner increases the efficiency and effectiveness of data-analysis and data-dissemination efforts. Good organization of files reduces the likelihood of misplaced information; misplaced data and field notes can lead to analyses based on inadequate information, with a possible decrease in the quality of analytical results. There are four Field Offices in the WAWSC. Procedures in each are nearly the same, although some differences exist.

Work Plan

Field Office Chiefs regularly communicate verbal work assignments to their staff. Each hydrographer is assigned a set of gaging stations that they are responsible for by the Field Office Chief. A list of gaging stations and records assignments is used to track the status of computations for those stations. The construction crew based in Tacoma performs most of the major gage-construction duties in the WAWSC. Occasionally, a contractor installs a cableway system at a new gage. Minor or routine gage maintenance and installation usually remain the responsibility of the hydrographer assigned to the gage.

File Folders for Surface-Water Stations

Files in each Field Office include a separate set of folders for each gaging station, organized by station number in downstream order. Separate folders for current-year data and previous-year data, as well as gaging-station history and special studies such as indirect measurements, are kept in one main station folder. Extraneous items are removed from the current files after records are finalized each year. Station review folders generally contain the final data for the most recent 3 years of record. The data for each year include mean daily and extreme discharge sheet, hydrograph, station analysis, station manuscript, measurements list, datum correction values, variable shift values, stage-discharge rating-shift analysis, summary of extreme events, shift diagrams, annual statistics, station description, surface-water review notes, and any other pertinent items.

The set of current files varies for each station. For all stations, a current-year folder holds all measurement notes, preliminary primary-records computations, shift diagrams, ratings, datum and gage-height correction notes, and other current-year information. The technical folder contains continuously updated information such as the station analysis, historical list of measurements, the station description, station statistics, and level notes, as well as items such as memorandums to the record, letters regarding the station, access information, old ratings, maps, photographs, and any historical data or information on the gage. Another folder contains any indirect measurements that had been made at the site.

Historical records are filed in a variety of ways. Past-year primary-record files are fastened together and stored by year in a designated area. Measurement notes, strip charts, ADR tapes, indirect-measurement analyses, and CSG records are kept in historical files for each type of data and are filed by station number. Records older than about 15 years should be archived appropriately and records of their archival and whereabouts maintained in the station folder. However, original discharge measurements should not be archived, but should be maintained in files on-site.

Field-Trip Folders

WAWSC hydrographers maintain a separate group of folders for each field trip area. The primary purpose of these folders is to compile driving logs, maps, station descriptions, station lists, traffic control plans, and other pertinent information, allowing field personnel to run the trips effectively at a moment's notice and with a minimum of time spent on last-minute preparations. The hydrographer responsible for maintaining the station updates the folder.

Levels

Each Field Office files level notes in a central file. These data are not archived, but are maintained in the files for the period of record of the station. All stations, current and discontinued, are included. Files are organized by station number in downstream order.

Station Analyses and Descriptions

The most recent station analysis and station description files exist in the Site Information Management System (SIMS) and RMS, available through the WAWSC internal web page. Hydrographers include paper copies of these documents in the station folder. Current water-year files contain copies of the previous year station analysis. Historical station analyses become part of the archived data.

Discontinued Stations

The WAWSC has no special treatment for files from discontinued stations. Annual data from these stations is filed with data from the same year from other stations. Measurements are filed by station number with other stations, current or otherwise, in the WAWSC's measurement files.

Map Files

The Administrative Services Section in Tacoma maintains files for USGS maps of Washington. Map scales include 1:100,000, 1:250,000, 1:24,000 (7.5 min. series), and 1:62,500 (15 min. series). The WAWSC files the 1:100,000 and 1:250,000 maps in separate drawers, and files the 1:24,000 and 1:62,500 maps in alphabetical order by map title in a series of drawers. Any of these maps can be marked on and used as work maps. When the user takes the next-to-the last map, they should request that the Administrative Services Section, who orders new maps, replace those used. The Spokane Field Office also maintains a set of Washington State topographic maps.

Archiving

The USGS has adopted policies for the management and retention of hydrologic data (WRD memorandum 92.59). Selected material not maintained in Field Offices is placed in archival storage. In the WAWSC, the WAWSC Administrative Services Section maintains detailed information on which records have been sent to archival centers. This information includes detailed letters of transmittal and accession numbers, so that the data can be retrieved when needed. Data targeted for archival include, but are not limited to, recorder charts and tapes, original data and edited data, observer's notes and readings, station descriptions, analyses, and other supporting information (Water Resources Discipline memorandum 92.59 and Hubbard, 1992, p. 12).

EDL data are archived on floppies, CD-ROMs, or Unix disks. All basic DCP data (gage height, discharge, and precipitation, for example) including back-up records are permanently stored in NWIS, whereas DCP performance data are kept only 180 days and then deleted.

The WAWSC sends surface-water information from the Field Offices to the Federal Records Center (FRC) every 7-10 years, on average. In the WAWSC, the Sand Point FRC in Seattle stores original surface-water data. The Field Office Chiefs decide which information is sent to the FRC and when that information is sent. The Administrative Services Section ensures that the information is properly packed and logged, and ascertains that the information is received by the FRC. In their office files, the Administrative Services Section maintains records of exactly what has been archived. For the Tacoma Field Office, these data include original discharge measurements for all stations prior to 1994, recorder charts, primary sheets, gage-height books, rating tables, and observer notebooks and cards. In Tacoma, measurements since 1994, all level notes, and snow-survey notes are maintained in files on-site. The Spokane and Kennewick Field Offices archive only recorder charts—all original measurement notes remain on site. Personnel who have questions concerning archiving procedures should address their questions to the Data Chief. Personnel who receive requests for information that require accessing archived records should contact the WAWSC Information Officer. The Information Officer can either provide the information directly, guide the requester through the steps needed to fulfill their needs, or ask the Administrative Services Section to make a special request to the FRC.

Project Chiefs ensure that surface-water data collected as part of their project are appropriately archived. WAWSC policy requires that surface-water data collected for investigative studies be archived within 2 years after completion of the studies. However, all time-series surface-water data should be included in the appropriate field-office files. Project-related streamflow data incorporated in ADAPS that are published in the annual data report are archived with other stations from the Washington Field Offices. However, it still remains the responsibility of the Project Chief to coordinate with the Field Offices for proper archival and storage of charts, streamflow measurements, indirect measurements, and other original data. Archiving procedures for specialized surface-water data, such as drainage-area delineations, rainfall-runoff models, and other hydrologic models, or related information such as evapotranspiration, depend on programs set up by the Project Chief and the WAWSC Computer Section. The Computer Section archives all electronic data provided them by Project Chiefs on magnetic tape, where it is stored and retrievable. In the future, these data will be transferred to permanent media, such as a CD-ROM. Project Chiefs are currently able to archive their own data on permanent media. The WAWSC Technical Communications Section files, then archives along with other pertinent project information and data, all original technical review comments, letters of approval, and other original information related to the processing, review, and publication of the report.

Publication and Review of Surface-Water Data Reports

The publication “Suggestions to Authors of the Reports of the United States Geological Survey” (Hansen, 1991, p. 36-41) summarizes procedures for publication and requirements for manuscript review by USGS. The WAWSC fulfills the requirements for review and approval of reports prior to printing and distribution through a special reports-review process (WAWSC Report-Review Process, Evaluation and Improvement Plan, 1995, internal publication). All reports written by USGS scientists in connection with their official duties must be approved by the originating Discipline and the Director, currently accomplished at the Regional level. USGS requires at least two technical reviews of each report (Hansen, 1991, p. 36). Competent and thorough editorial and technical review is the most certain way to improve and assure the high quality of the final report (Moore and others, 1990, p. 24). Moore and others (1990, p. 24-49) present principles of editorial review and responsibilities of reviewers and authors. USGS policy requires that Open-File Reports be reviewed only for policy and reproducibility (Hansen, 1991, p. 36), but they also receive editorial reviews in the WAWSC.

Types of Publications

Various types of book publications released by the USGS are available in which surface-water data and data analyses are presented. Publications of the formal series include the Professional Paper and the Circular. Publictions in the informal series include the Scientific Investigations Report, the Open-File Report, Techniques and Methods, Data Series, and Water Data Reports. Green (1991, p. 14) presents factors Science Centers should consider when deciding which form of publication to utilize in presenting various types of information.

Publication Policy

The USGS has created specific policies pertaining to publication of data and interpretation of those data. All USGS personnel, including those of the WAWSC, are required to abide by those policies. The WRD Publications Guide (Alt and Iseri, 1986, p. 4-37) summarizes publication goals, procedures, and policies.

All information obtained through investigations and observations by the staff of the USGS or by its contractors must be held confidential and must not be disclosed to others until the information is made available to all, impartially and simultaneously, through Director-approved formal publication or other means of public release, except to the extent that such release is mandated by law (Alt and Iseri, 1986, p. 14). With the approval of the Director, hydrologic measurements resulting from observations and laboratory analyses, after they have been reviewed for accuracy by designated USGS personnel, have been excluded from the requirements to hold unpublished information confidential (Alt and Iseri, 1986, p. 15).

All interpretive writings in which the USGS has a proprietary interest, including abstracts, letters to the editor, and all writings that show the author’s title and USGS affiliation, must be approved by the Director before release for publication. The objectives of the Director’s review are to final-check the technical quality of the writing and to make certain that it meets USGS publication standards and is consistent with policies of the USGS and Department of the Interior. Director’s approval ensures that each publication or writing (1) is impartial and objective, (2) has conclusions that do not compromise the USGS’s official position, (3) does not take an unwarranted advocacy position, and (4) does not criticize or compete with other governmental agencies or the private sector (Hansen, 1991, p. 10).

Safety

Performing work activities in a manner that ensures the safety of personnel and others remains the highest priority for the USGS and the WAWSC. Beyond the obvious negative impact unsafe conditions can have on personnel, such as accidents and personal injuries, they also can have a direct effect on the quality of surface-water data and data analysis. For example, errors may be made when an individual's attention to detail is compromised when dangerous conditions create distractions. So that personnel are aware of, and follow, established procedures and policies that promote all aspects of safety, the WAWSC communicates information and directives related to safety to all personnel through in-house and out-of-office training classes, memorandums, video tape sessions, and a Web page.

In the WAWSC, a designated Safety Officer heads the WAWSC Safety Committee, identifies and provides direction on safety issues, manages the safety budget, coordinates safety training, prepares safety reports for the Regional Office, and deals with new and ongoing safety issues. Currently, the USGS provides policy and guidelines for safety-related issues in the WAWSC. The WAWSC Safety Committee, which meets periodically, consists of 10 members: the WAWSC Safety Officer; the WAWSC Director; the Data Chief; one member from each of the 4 Field Offices; and 1 specialist each in aviation, hazardous waste, and boat safety. Personnel who have questions or concerns pertaining to safety, or who have suggestions for improving some aspects of safety, should direct those questions, concerns, and suggestions to their supervisor or the WAWSC Safety Officer.

Training

Ensuring that personnel obtain knowledge of correct methods and procedures is a vital aspect of maintaining the quality of surface-water data and data analysis. By providing appropriate training to personnel, the WAWSC increases the quality of work and eliminates the source of many potential errors.

In-house and out-of-town training sessions supplement the hydrographer's work experience and self-training. These sessions provide experience in areas the hydrographer is unfamiliar with, or needs more practice to become proficient in. The Field Office Chief or the designated supervisor arranges for the hydrographer's training. For most needs, however, on-the-job training is the most important aspect of the hydrographer's training experience in the WAWSC.

Summary

Information included in this WAWSC Surface-Water Quality-Assurance Plan documents the policies and procedures of the Washington Water Science Center that ensure high quality in the collection, processing, storage, analysis, and publication of surface-water data. Specific types of surface-water data discussed in this report include stage and streamflow data. The roles and responsibilities of Washington Water Science Center personnel for carrying out these policies and procedures are presented, as are issues related to management of the computer data base, including real-time data, and issues related to employee safety and training. In the Washington Water Science Center, the hydrographer responsible for operating and maintaining their assigned surface-water stations works with their fellow employees in a team effort to assure high-quality data, analyses, reviews, and reports for cooperating agencies and the general public.

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Appendix A. Office of Surface Water and Water Resources Discipline Memorandums Cited

The following memorandums were cited in the report:

Office of Surface Water Technical Memorandum 2010.07
Office of Surface Water Technical Memorandum 2010.06
Office of Surface Water Technical Memorandum 2010.02
Office of Surface Water Technical Memorandum 2009.05
Office of Surface Water Technical Memorandum 2009.04
Office of Surface Water Technical Memorandum 2009.02
Office of Surface Water Technical Memorandum 2007.01
Office of Surface Water Technical Memorandum 2006.04
Office of Surface Water Technical Memorandum 2006-01
Office of Surface Water Technical Memorandum 2005.08
Office of Surface Water Technical Memorandum 2004.04
Office of Surface Water Technical Memorandum 2002.01
Office of Surface Water Technical Memorandum 99.07
Office of Surface Water Technical Memorandum 97.02
Office of Surface Water Technical Memorandum 96.05
Office of Surface Water Technical Memorandum 96.02
Office of Surface Water Technical Memorandum 96.01
Office of Surface Water Technical Memorandum 95.03
Office of Surface Water Technical Memorandum 93.12
Office of Surface Water Technical Memorandum 93.07
Office of Surface Water Technical Memorandum 92.11
Office of Surface Water Technical Memorandum 92.10
Office of Surface Water Technical Memorandum 92.09
Office of Surface Water Technical Memorandum 92.04
Office of Surface Water Technical Memorandum 90.01
Office of Surface Water Technical Memorandum 89.08
Office of Surface Water Technical Memorandum 89.07
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Office of Surface Water Technical Memorandum 88.07
Office of Surface Water Technical Memorandum 87.05
Office of Surface Water Technical Memorandum 85.17
Surface Water Branch Technical Memorandum 85.07
Surface Water Branch Technical Memorandum 84.05
Water Resources Discipline Memorandum 99.34
Water Resources Discipline Memorandum 97.17
Water Resources Discipline Memorandum 95.19
Water Resources Discipline Memorandum 92.59

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Appendix B. Washington Water Science Center Note Sheets for Recording Surface-Water Data

1. Streamgaging cableways – Western Region Inspection Checklist
2. Form P-19, Gaging Station Service Notes
3. Summary and Adjustments of Gaging Station Levels
4. Form 9-276, Level Notes
5. Peg Test of Engineer's Level
6. Form 9-275F, Discharge Measurement Notes
7. Form 9-275D, Miscellaneous Field Notes
8. Form T-9335, Crest-Stage Gage Notes
9. Form T-9334, Snow Survey Notes
10. Form 9-275-I ADCP Discharge Measurement Notes available at http://hydroacoustics.usgs.gov/movingboat/forms/ADCPQmForm-20081024-2up.pdf.
11. Form 9-275-x ADV Discharge Measurement Notes available at http://hydroacoustics.usgs.gov/midsection/ADVQmForm-Shaded20070124.pdf.

STREAMGAGING CABLEWAYS
Western Region – Inspection Checklist

Station Name:________________________________ Number ____________;

Review previous inspection form. List any important notes:______________________;

Cable Type: EEIP EIP SS Other; Cable Diameter: ____in; Clear Span:____ft; Design Sag:____ft

Right Left Bank
(cable car side)

ANCHOR:
Anchor Type: Mass – Sidehill – Rock (Vertical or Horizontal / U-bar or Pin) – Tree – Other________;

Dimensions: H__W__D__; Height above ground:____; Tree species:______; Tree diameter:____;

Is U-bar installed in the vertical plane? Y N; at correct angle (in line with angle of main cable)? Y N

Anchors clean of debris: Y N ⟶ Soil – Weeds – Bushes – Trees – Other______________;

Signs of deterioration: Concrete Y N; Rock Y N; Tree Y N; Cable connections Y N

If YES, Explain:______________________________________;

Fractures: Y N; Movement: Y N; Rust-Corrosion on U-bar: Y N

If YES, Explain:______________________________________;

Notes:______________________________________;

FOOTERS:
Footing type: Pedestal – Pier – Slab – Other______________________;

Dimensions: H__W__D__; Height above ground level:____; Remarks:______________;

Support footers clean of debris: Y N ⟶ Soil – Weeds – Bushes – Trees Other:____________;

Signs of deterioration of concrete: Y N; Fractures Y N; Movement Y N

Attachments: Pins Bolts Other______; Rust/Corrosion/Missing Nuts ?: Y N; Explain:________;

Notes:______________________________________;

MAIN CABLE:
Unloaded Sag:_____; Angle to anchor:_____; Cable Length (A-frame to anchor):_____;

U-bar to cable: Socket – Turnbuckle – Clevis – Direct (must have thimble) – Other______________;

Thimbles where required?: Y N; Cable turnback length:______;

Cable clips: Y N; Type:______________; Installed properly?: Y N Explain____________;

Number:_____; Proper torque?: Y N; Proper spacing: Y N; Spacing:__________inches

Signs of deterioration to: Y N Cable – Socket – Turnbuckle – Clevis – Thimbles – Clips – Other

If yes, what?: Rust – Corrosion – Flaking – Broken/Kinked strands – Items missing – Cracks – Other

Explain______________________________________;

______________________________________;

Is main cable span free of debris, brush, and other obstructions: Y N

Are cable car routes from A-frames to banks free of trees, brush, and other obstructions: Y N

Other ______________________________________;

BACKSTAY/GUYLINES:
Cable use: Backstay – Guyline; Cable Type: EEIP EIP SS Other; Cable Diameter:_____in

Auxiliary U-bar(s)?: Y N; Connection at A-frame: Eyebolt – Welded steel loop – Other________;

Eyebolt/Loop diameter____; Forged?: Y N; Shouldered?: Y N; Remarks:______________;

U-bar to cable: Direct – Other____; Thimbles where required?: Y N; Cable turnback length:____;

Cable clips: Y N; Type:______________; Installed properly?: Y N Explain____________;

Number of clips:_____; Proper torque?: Y N; Proper spacing: Y N; Spacing:__________inches

Signs of deterioration: Y N Cable – Eyebolt – Thimbles – Clips – Other

If yes, what?: Rust – Corrosion – Flaking – Broken/Kinked strands – Items missing – Cracks – Other

Explain______________________________________;

AIRCRAFT WARNING MARKER:
Is warning device required? (see WRD policy memo 2000.13): Y N

Is warning device in place ? Y N

CABLE SUPPORTS :
Support type: A-frame (steel – pipe – wood) – Tower – Vertical beam – Tree

Base width:____Height:____; Cross members?: Y N; Tree species:______; Tree diameter:____;

Signs of deterioration: Y N; If yes, what?: Fatigue – Rust – Corrosion – Wood decay

Explain______________________________________;

Configuration of base: Rigid – Hinge (pin); Are all components in place?: Y N Explain:________;

Platform: Y N; Material:__________; Bolts/welds: VG G P; Grated: Y N; Handrails: Y N

Height above ground:____; Climbing device: Ladder – Bolts – Steps – Other______

Is Fall Protection required: Y N

Main cable support: Saddleblock – Sheave – Other________; Diameter:_____; D/d ratio > 10: Y N

Does groove size match cable diameter?: Y N Explain______________________;

Signs of deterioration of saddle block: Y N; If yes, what?: Rust – Corrosion – Decay – Other______;

Notes:______________________________________;

CABLE CAR:
Type: HIF ⟶ Stand up – Sit down Has retrofit been installed? Y N

Other ⟶ Stand up – Sit down – Power; Material: Steel – Wood – Aluminum – Other____;

Tested per [illegible] Explain[illegible]

Signs of deterioration: Y N; If yes, where?: Hanger bars – Sheaves – Seats – Floor – Other_______;

What?: Bent – Twisted – Deformed – Cracked – Rotted – Other

Explain______________________________________;

Bolts/Nuts: Rusted – Loose – Missing – Other; Remarks:______________________;

Overall condition based on visual inspection: Good Fair Poor

Notes:______________________________________;

______________________________________;

______________________________________;

Front

Appendix B1. Streamgaging cableways – Western Region Inspection Checklist.

Right Left Bank
(non-cable car side)

ANCHOR
Anchor Type: Mass – Sidehill – Rock (Vertical or Horizontal / U-bar or Pin) – Tree – Other________;
Dimensions: H__W__D__; Height above ground:____; Tree species:______; Tree diameter:____;
Is U-bar installed in the vertical plane? Y N; at correct angle (in line with angle of main cable)? Y N
Anchors clean of debris: Y N ⟶ Soil – Weeds – Bushes – Trees – Other________________;
Signs of deterioration: Concrete Y N; Rock Y N; Tree Y N; Cable connections Y N
If YES, Explain:____;
Fractures: Y N; Movement: Y N; Rust/Corrosion on U-bar: Y N
If YES, Explain:____;
Notes:____;

FOOTERS:
Footing type: Pedestal – Pier – Slab – Other________________________________;
Dimensions: H__W__D__; Height above ground level:____; Remarks:________________;
Support footers clean of debris: Y N ⟶ Soil – Weeds – Bushes – Trees Other:____________;
Signs of deterioration of concrete: Y N; Fractures Y N; Movement Y N
Attachments: Pins Bolts Other_____; Rust/Corrosion/Missing Nuts ?: Y N; Explain :________;
Notes:____;

MAIN CABLE:
Unloaded Sag:_____; Angle to anchor:_____; Cable Length (A-frame to anchor):_____;
U-bar to cable: Socket – Turnbuckle – Clevis – Direct (must have thimble) – Other______________;
Thimbles where required?: Y N; Cable turnback length:______;
Cable clips: Y N; Type:______________; Installed properly?: Y N Explain____________;
Number:_____; Proper torque?: Y N; Proper spacing: Y N; Spacing:_________inches
Signs of deterioration to: Y N Cable – Socket – Turnbuckle – Clevis – Thimbles – Clips – Other
If yes, what?: Rust – Corrosion – Flaking – Broken/Kinked strands – Items missing – Cracks – Other
Explain____;

BACKSTAY/GUYLINES:
Cable use: Backstay – Guyline; Cable Type: EEIP EIP SS Other; Cable Diameter:______in
Auxiliary U-bar(s)?: Y N; Connection at A-frame: Eyebolt – Welded steel loop – Other_________;
Eyebolt/Loop diameter____; Forged?: Y N; Shouldered?: Y N; Remarks:________________;
U-bar to cable: Direct – Other____; Thimbles where required?: Y N; Cable turnback length:_____;
Cable clips: Y N; Type:______________; Installed properly?: Y N Explain____________;
Number of clips:_____; Proper torque?: Y N; Proper spacing: Y N; Spacing:_________inches
Signs of deterioration: Y N Cable – Eyebolt – Thimbles – Clips – Other
If yes, what?: Rust – Corrosion – Flaking – Broken/Kinked strands – Items missing – Cracks – Other
Explain____;

CABLE SUPPORTS:
Support type: A-frame (steel – pipe – wood) – Tower – Vertical beam – Tree
Base width:____Height:____; Cross members?: Y N; Tree species:______; Tree diameter:____;
Signs of deterioration: Y N: If yes, what?: Fatigue – Rust – Corrosion – Wood decay
Explain____;
Configuration of base: Rigid – Hinge (pin): Are all components in place?: Y N Explain:_________;
Platform: Y N; Material:_________; Bolts/welds: VG G P; Grated: Y N; Handrails: Y N
Height above ground:____; Climbing device: Ladder – Bolts – Steps – Other______
Is Fall Protection required: Y N
Main cable support: Saddle block – Sheave – Other________; Diameter:_____; D/d ratio > 10: Y N
Does groove size match cable diameter?: Y N Explain____________________;
Signs of deterioration of saddle block: Y N; If yes, what?: Rust – Corrosion – Decay – Other______;
Notes:____;

Are office records describing this cableway system complete and accurate: Y N (Update as required)

What is the maximum stage this cableway can be safely used:________;

Is this stage posted in the gage house: Y N; Is this stage posted on the cableway: Y N

INSPECTION RESULTS: THIS CABLEWAY IS SAFE TO USE: Y N

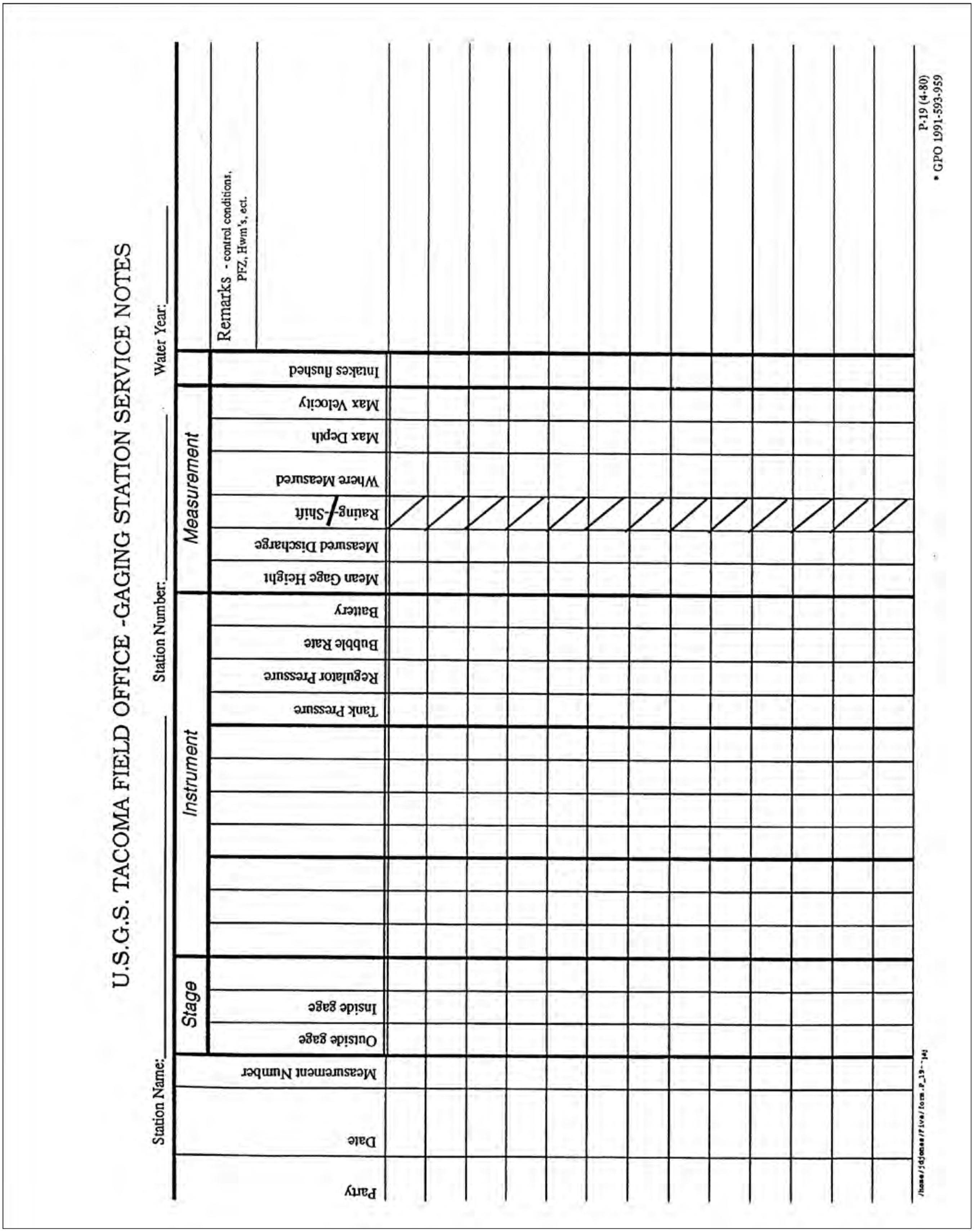
Explanation for any of the above items considered: "UNSAFE"
1.____
2.____
3.____
4.____
5.____
6.____
7.____

***** If cableway system is determined to be UNSAFE, it <u>must</u> be removed from service until repairs can be made. Lock the cablecar with a non-USGS lock or remove the cablecar completely at this time.**

I certify that the inspection was conducted on this date, all elements of the cableway were checked, deficiencies found were noted on the hazard elimination log, and <u>if necessary</u>, the cablecar was locked or removed until repairs can be made.
Inspected by______________________Title_______________Date___________
Reviewed by______________________Title_______________Date___________

Back

Appendix B1.—Continued



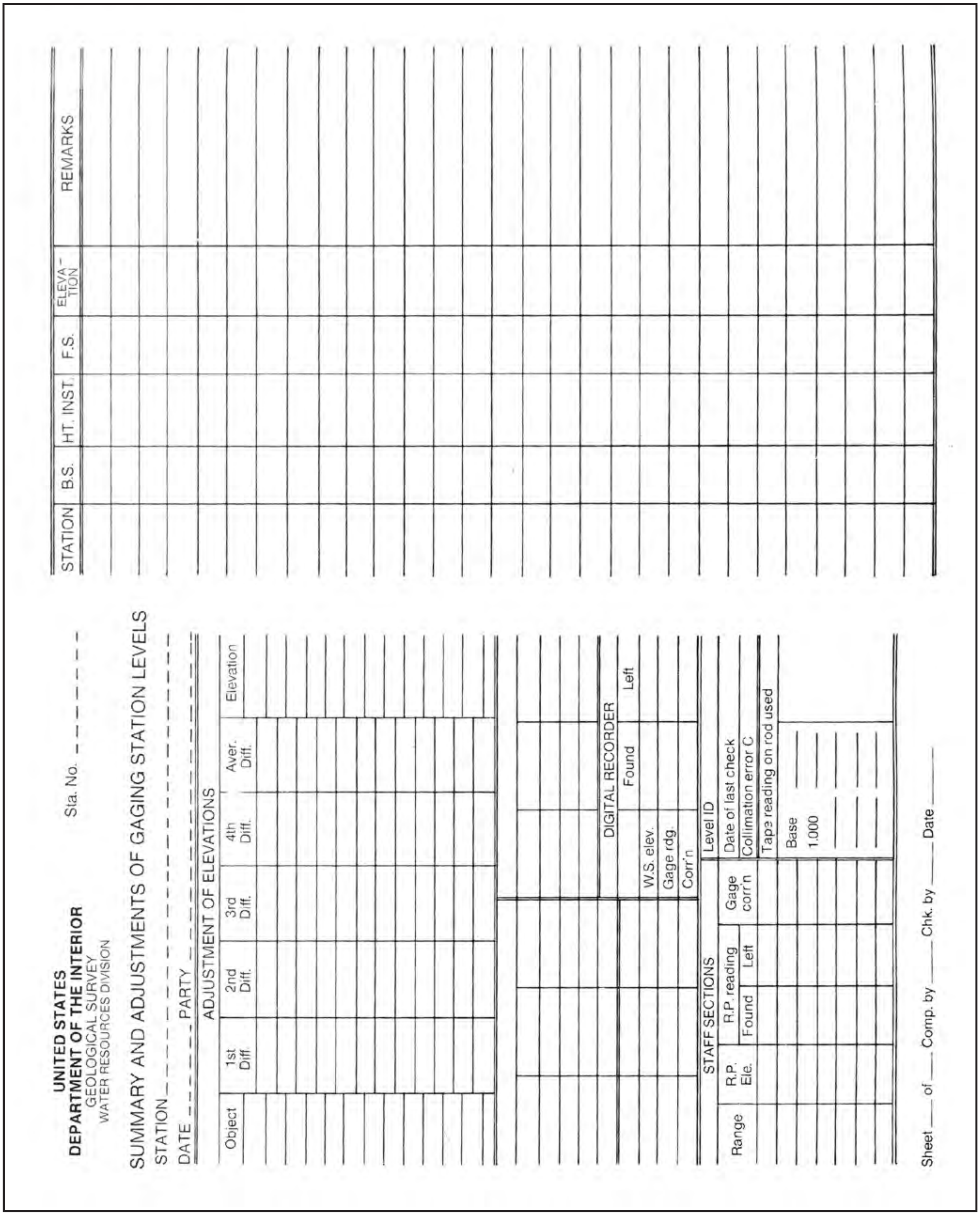
U.S.G.S. TACOMA FIELD OFFICE -GAGING STATION SERVICE NOTES

Station Name:________ Station Number:________ Water Year:________

Party	Date	Measurement Number	Stage				Instrument								Measurement						Intakes flushed	Remarks - control conditions, PFZ, Hwm's, ect.
			Outside gage	Inside gage							Tank Pressure	Regulator Pressure	Bubble Rate	Battery	Mean Gage Height	Measured Discharge	Rating-/-Shift	Where Measured	Max Depth	Max Velocity		

P-19 (4-80)
* GPO 1991-593-959

Appendix B2. Form P-19, Gaging Station Service Notes.


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Sta. No. ____________

SUMMARY AND ADJUSTMENTS OF GAGING STATION LEVELS

STATION ____________

DATE ________ PARTY ____________

STATION	B.S.	HT. INST.	F.S.	ELEVATION	REMARKS

ADJUSTMENT OF ELEVATIONS

Object	1st Diff.	2nd Diff.	3rd Diff.	4th Diff.	Aver. Diff.	Elevation

DIGITAL RECORDER

	Found	Left
W.S. elev.		
Gage rdg.		
Corr'n		

STAFF SECTIONS

Range	R.P. Ele.	R.P. reading Found	R.P. reading Left	Gage corr'n

Level ID

Date of last check

Collimation error C

Tape reading on rod used

Base	
1.000	

Sheet ____ of ____ Comp. by ______ Chk. by ______ Date ______

Appendix B3. Summary and Adjustments of Gaging Station Levels.

Form 9-276
(July 1967)

U. S. DEPARTMENT OF THE INTERIOR
Geological Survey
WATER RESOURCES DIVISION

STATION NUMBER

LEVEL NOTES

STREAM ________________________________

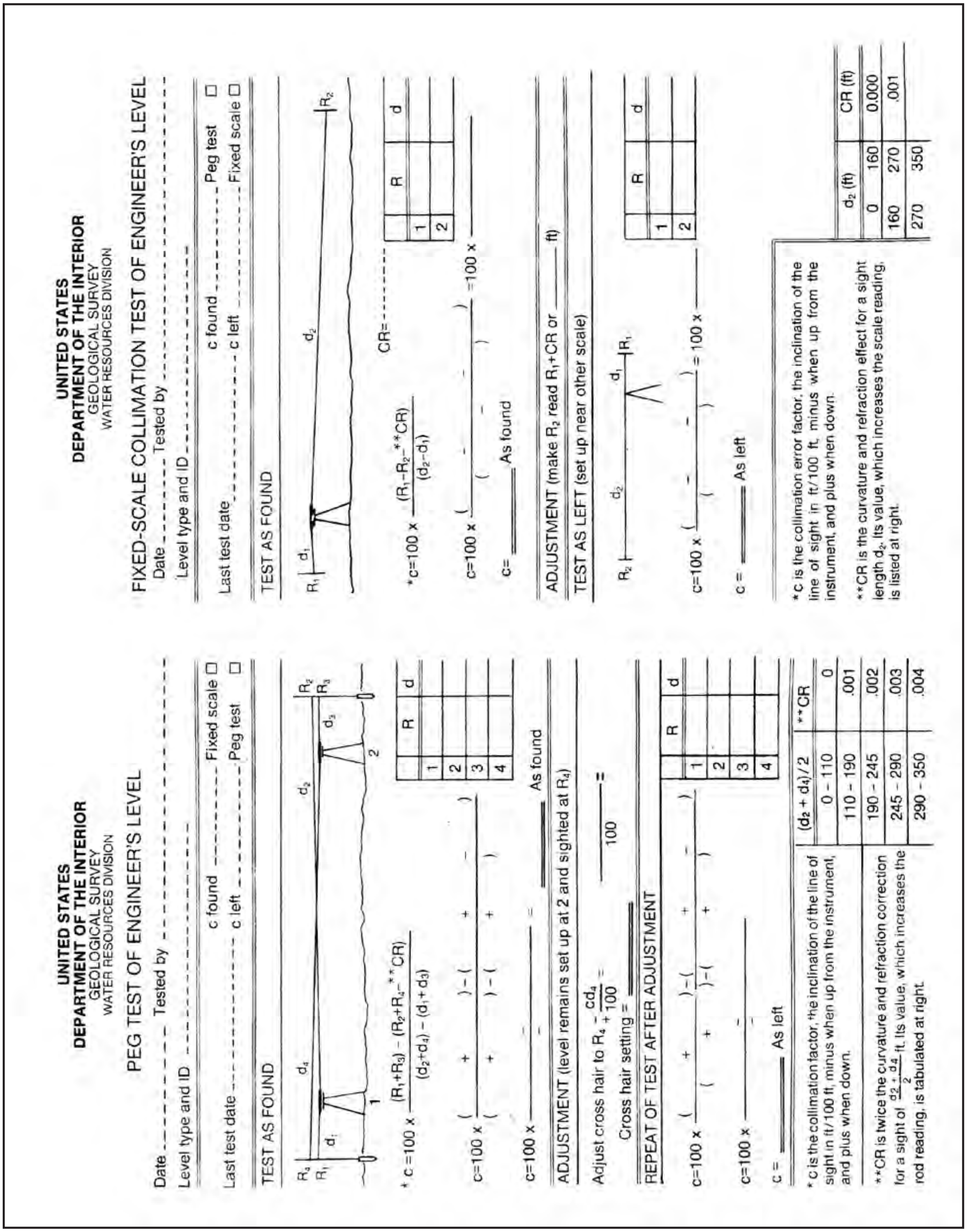
LOCALITY ________________________________

PARTY ____________________ DATE ______________, 19____

STATION	B. S.	HT. INST.	F. S.	ELEVA-TION	REMARKS

NO.______ OF____ SHEETS________ COMP. BY____________ CHK. BY______________

Appendix B4. Form 9-276, Level Notes.



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

PEG TEST OF ENGINEER'S LEVEL

Date ________ Tested by ____________________

Level type and ID ________________

Last test date ____________ c found ________ Fixed scale ☐ c left ________ Peg test ☐

TEST AS FOUND

$$* \; c = 100 \times \frac{(R_1+R_3) - (R_2+R_4-{**}CR)}{(d_2+d_4) - (d_1+d_3)}$$

$$c = 100 \times \frac{(\quad + \quad) - (\quad + \quad - \quad)}{(\quad + \quad) - (\quad + \quad)}$$

$$c = 100 \times \frac{\quad - \quad}{\quad - \quad} = \quad$$ As found

	R	d
1		
2		
3		
4		

ADJUSTMENT (level remains set up at 2 and sighted at R_4)

Adjust cross hair to $R_4 \mp \frac{cd_4}{100} = \quad \frac{\quad}{100} =$

Cross hair setting = ______

REPEAT OF TEST AFTER ADJUSTMENT

$$c = 100 \times \frac{(\quad + \quad) - (\quad + \quad - \quad)}{(\quad + \quad) - (\quad + \quad)}$$

$$c = 100 \times \frac{\quad - \quad}{\quad - \quad}$$

c = ______ As left

	R	d
1		
2		
3		
4		

* c is the collimation factor, the inclination of the line of sight in ft/100 ft, minus when up from the instrument, and plus when down.

**CR is twice the curvature and refraction correction for a sight of $\frac{d_2+d_4}{2}$ ft. Its value, which increases the rod reading, is tabulated at right.

$(d_2 + d_4)/2$	**CR
0 - 110	0
110 - 190	.001
190 - 245	.002
245 - 290	.003
290 - 350	.004

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

FIXED-SCALE COLLIMATION TEST OF ENGINEER'S LEVEL

Date ________ Tested by ____________________

Level type and ID ________________

Last test date ____________ c found ________ Peg test ☐ c left ________ Fixed scale ☐

TEST AS FOUND

CR= ________

$$* c = 100 \times \frac{(R_1-R_2-{**}CR)}{(d_2-d_1)}$$

$$c = 100 \times \frac{(\quad - \quad - \quad)}{(\quad - \quad)} = 100 \times \quad$$

c= ______ As found

	R	d
1		
2		

ADJUSTMENT (make R_2 read R_1+CR or ______ ft)

TEST AS LEFT (set up near other scale)

$$c = 100 \times \frac{(\quad - \quad - \quad)}{(\quad - \quad)} = 100 \times \quad$$

c = ______ As left

	R	d
1		
2		

*c is the collimation error factor, the inclination of the line of sight in ft/100 ft, minus when up from the instrument, and plus when down.

**CR is the curvature and refraction effect for a sight length d_2. Its value, which increases the scale reading, is listed at right.

d_2 (ft)		CR (ft)
0	160	0.000
160	270	.001
270	350	

Appendix B5. Peg Test of Engineer's Level.

Form 9-275F
(Apr. 2001)

U.S. DEPARTMENT OF THE INTERIOR
U.S. Geological Survey
WATER RESOURCES DIVISION

DISCHARGE MEASUREMENT AND GAGE INSPECTION NOTES

Meas. No. ________
Comp. by ________
Checked by ________

Sta. No. ________________

Sta. Name ________________________________

Date ________ , 20 ___ Party ________________

Width ________ Area ________ Vel. ________ G.H. ________ Disch. ________

Method ________________ No. secs. ______ G.H. change ________ in ________ hrs.

Method coef. ______ Horiz. angle coef. ______ Susp. ________ Tags checked ________

Meter Type ________ Meter No. ____________ Meter ______ ft. above bottom of wt.

Rating used ____________ Spin test before meas. __________ ; after ____________

Meas. plots ________ % diff. from rating no. ________ Indicated shift ____________

GAGE READINGS						
Time					Inside	Outside
	Start					
	Finish					
Weighted MGH						
GH correction						
Correct MGH						

Samples collected: water quality, sediment, biological, other ________

Measurements documented on separate sheets: water quality, aux./base gage, other ________

Rain gage serviced/calibrated ____

Weather: ____________

Air Temp. ______ °C at ______

Water Temp. ______ °C at ______

Check bar/chain found ________

Changed to ______ at ________

Correct ____________

Wading, cable, ice, boat, upstr., downstr., side bridge, __________ ft., mi. upstr., downstr. of gage.
Measurement rated excellent (2%), good (5%), fair (8%), poor (> 8%); based on following conditions: Flow: ________________

Cross section: ________________

Gage operating: ____________ Record Removed ____________

Battery voltage: __________ Intake/Orifice cleaned/purged: ____________

Bubble-gage pressure, psi: Tank ________ , Line ________ ; Bubble-rate ________ /min.

Extreme-GH indicators: max __________ , min __________ .

CSG checked: ______ HWM height on stick ______ Ref. elev. ______ HWM elev ______

HWM inside/outside: ________________

Control: ________________

Remarks: ________________

GH of zero flow = GH ______ - depth at control ______ = ______ ft., rated ______

Sheet No. ______ of ______ sheets

Front

ANGLE COEF-FICIENT	DIST. FROM INITIAL POINT	WIDTH	DEPTH	OBSERVA-TION DEPTH	REVO-LUTIONS	TIME IN SEC-ONDS	VELOCITY AT POINT	VELOCITY MEAN IN VER-TICAL	ADJUST-ED FOR HOR. ANGLE OR	AREA	DISCHARGE

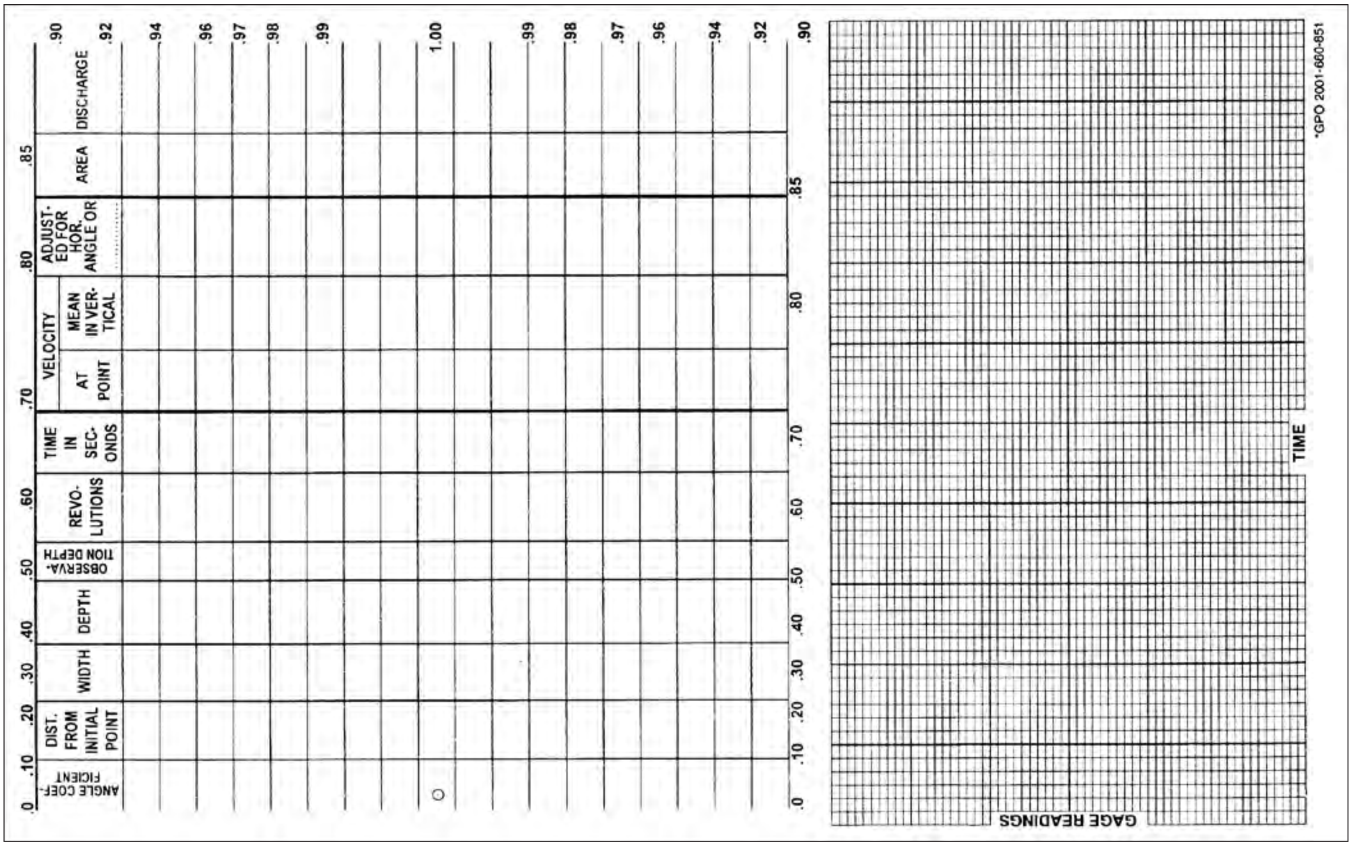
River at -

.0 .10 .20 .30 .40 .50 .60 .70 .75

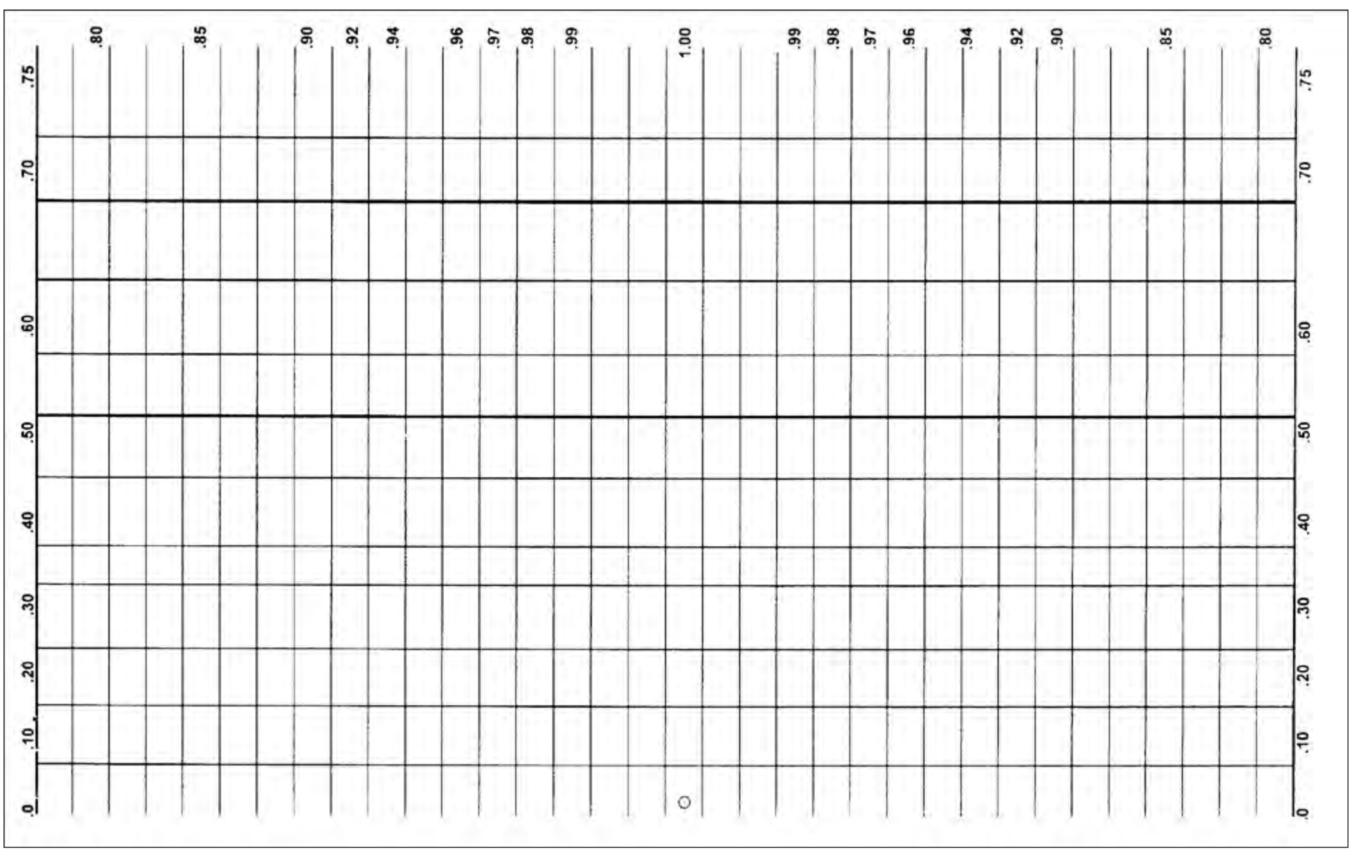
.80 .85 .90 .92 .94 .96 .97 .98 .99 1.00 .99 .98 .97 .96 .94 .92 .90 .85 .80

Inside Top

Appendix B6. Form 9-275-F, Discharge Measurement Notes.

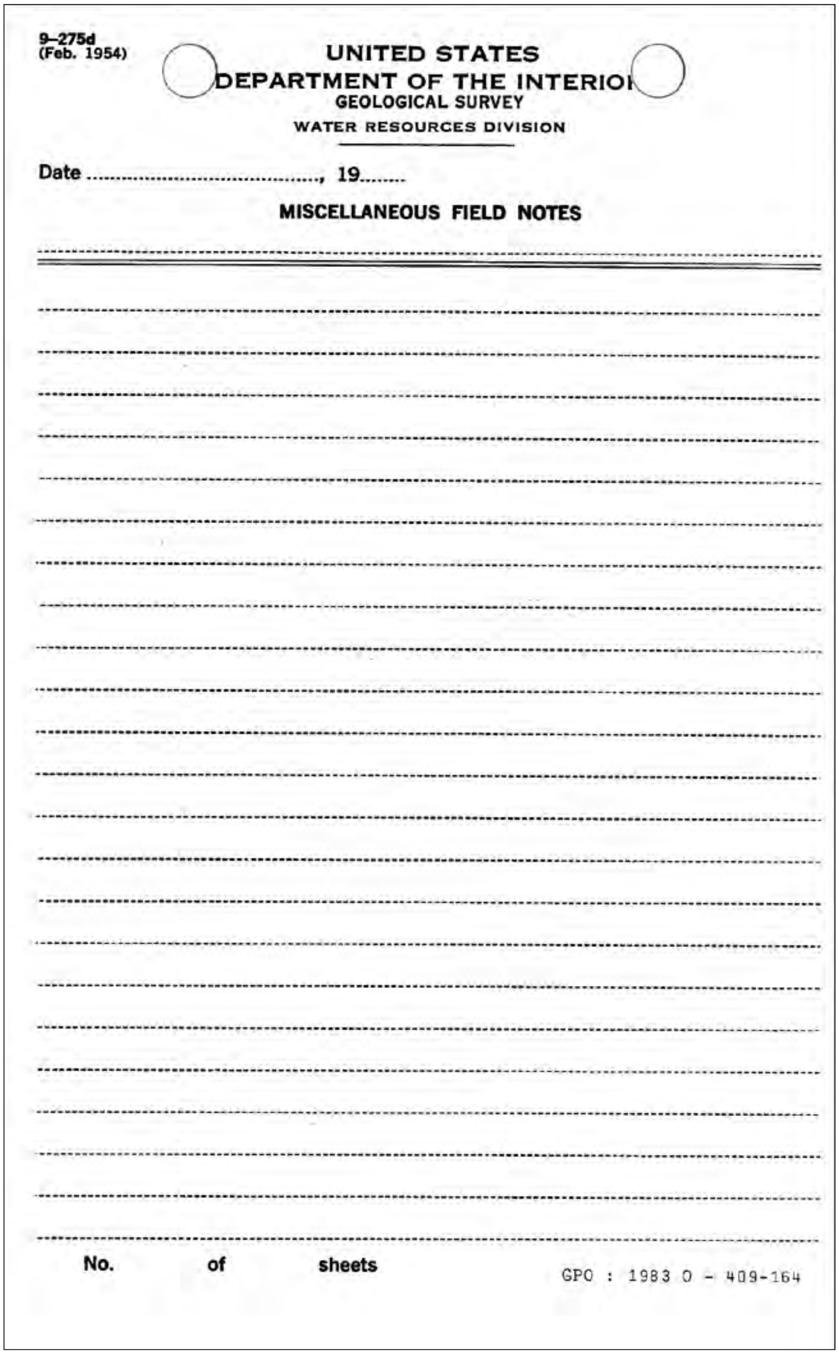


Back



Inside Bottom

Appendix B6.—Continued


9–275d
(Feb. 1954)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Date ...., 19........

MISCELLANEOUS FIELD NOTES

No. of sheets

GPO : 1983 O – 409-164

Appendix B7. Form 9-275D, Miscellaneous Field Notes.

T-9335 (Rev)
Sept. 1961

Crest-Stage Gage Notes

Party ______________________ Date ____________

Weather ____________________ Time ____________

Marks on gage sticks:

	Upstream		Downstream	
	Left bank	Right bank	Left bank	Right bank
Bolt elev.				
Highest stick reading				
Peak stage				
Quality of mark				
Additional gage readings				

Outside HWM's:

Quality, type of mark, and location	Distance from base bolt or top of stick

Date and time of peak ____________________

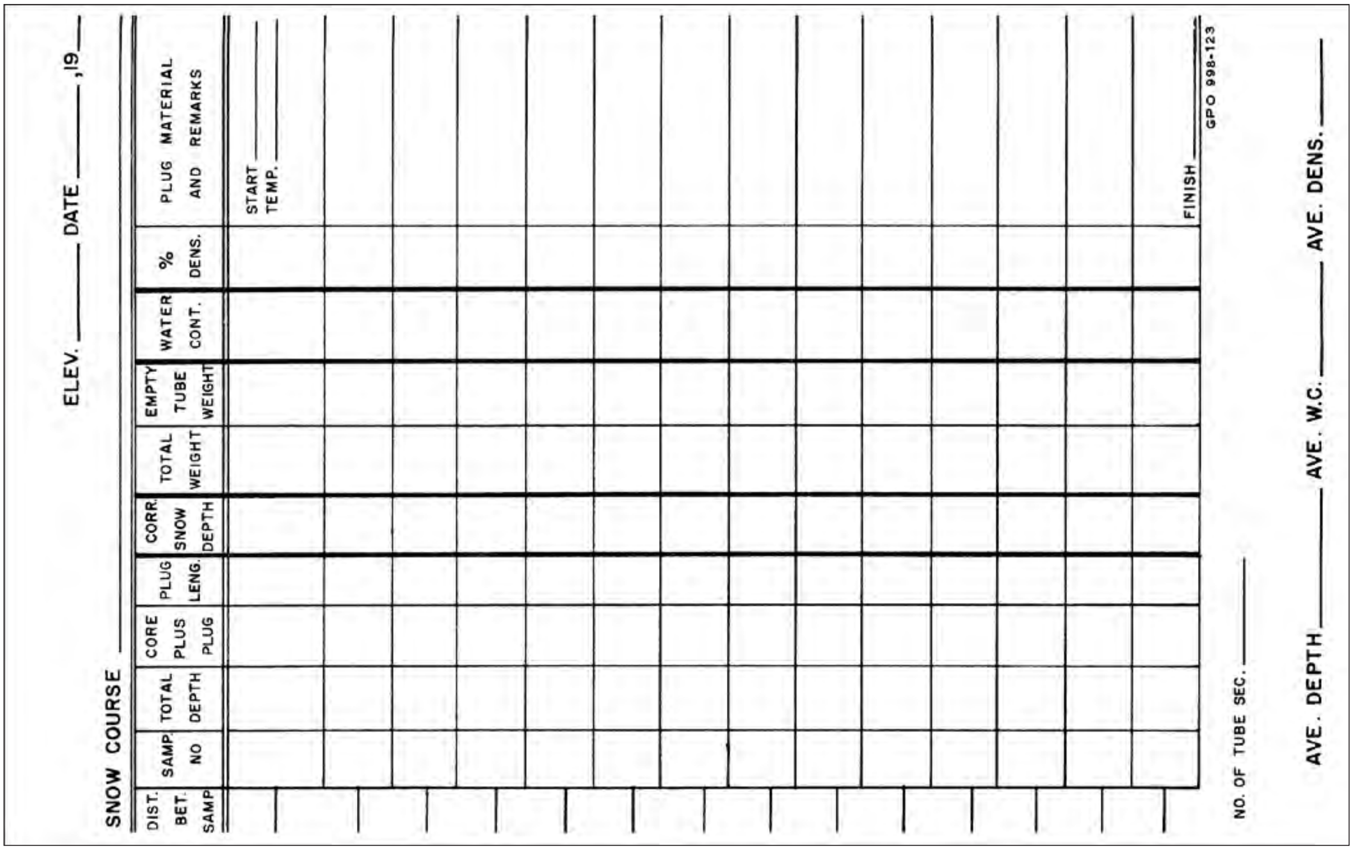
Condition of culvert ____________________

Condition of intakes ____________________

Do gages have cork? ____________________

Remarks ____________________

Appendix B8. Form T-9335, Crest-Stage Gage Notes.


SNOW COURSE ______ ELEV. ______ DATE ______, 19__

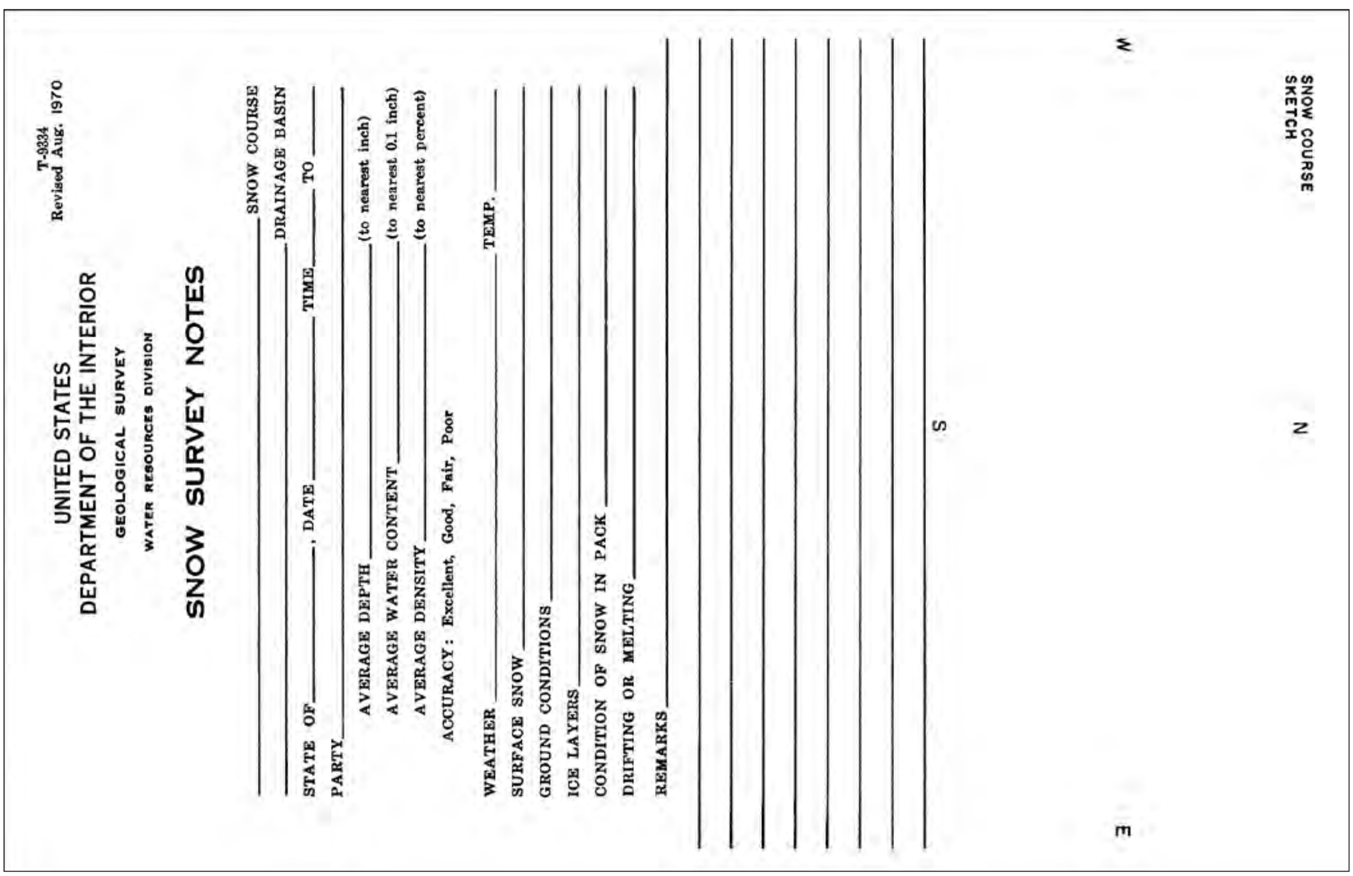
DIST. BET. SAMP	SAMP NO	TOTAL DEPTH	CORE PLUS PLUG	PLUG LENG.	CORR. SNOW DEPTH	TOTAL WEIGHT	EMPTY TUBE WEIGHT	WATER CONT.	% DENS.	PLUG MATERIAL AND REMARKS
										START ______ TEMP. ______
										FINISH ______

GPO 998-123

NO. OF TUBE SEC. ______

AVE. DEPTH ______ AVE. W.C. ______ AVE. DENS. ______

Back


T-9334
Revised Aug. 1970

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

SNOW SURVEY NOTES

______ SNOW COURSE
______ DRAINAGE BASIN
STATE OF ______, DATE ______ TIME ______ TO ______
PARTY ______
AVERAGE DEPTH ______ (to nearest inch)
AVERAGE WATER CONTENT ______ (to nearest 0.1 inch)
AVERAGE DENSITY ______ (to nearest percent)
ACCURACY: Excellent, Good, Fair, Poor

WEATHER ______ TEMP. ______
SURFACE SNOW ______
GROUND CONDITIONS ______
ICE LAYERS ______
CONDITION OF SNOW IN PACK ______
DRIFTING OR MELTING ______
REMARKS ______

Front

Appendix B9. Form T-9334, Snow Survey Notes.

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USGS

Kresch and Tomlinson

Surface–Water Quality–Assurance Plan for the U.S. Geological Survey Washington Water Science Center

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