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Surface-Water Data Manual for the Statewide Aquatic Resources Coordination Unit

by

Joe Klein

March 2013

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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SURFACE-WATER DATA MANUAL FOR THE STATEWIDE AQUATIC RESOURCES COORDINATION UNIT

By
Joe Klein
Alaska Department of Fish and Game, Division of Sport Fish, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

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Joe Klein,
Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, USA

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DEFINITION OF TERMS

Annual flood	The highest peak discharge in a water year.
Annual flood series	A list of annual floods.
Backwater	Water backed up or slowed down in its course as compared with its normal or natural condition of flow. In stream gaging, a rise in stage produced by a temporary obstruction such as ice or weeds, or by the flooding of the stream below. The difference between the observed stage and that indicated by the stage-discharge relation, is reported as backwater.
Bank	The margins of a channel. Banks are called right or left as viewed facing in the direction of the flow.
Bankfull stage	Stage at which a stream first overflows its natural banks.
Control	A natural constriction of the channel, a long reach of the channel, a stretch of rapids, or an artificial structure downstream from a gaging station that determines the stage-discharge relation at the gage. A control may be complete or partial. A complete control exists where the stage-discharge relation at a gaging station is entirely independent of fluctuations in stage downstream from the control. A partial control exists where downstream fluctuations have some effect upon the stage-discharge relation at a gaging station. A control, either partial or complete, may also be shifting. Most natural controls are shifting to a degree, but a shifting control exists where the stage discharge relation experiences frequent changes owing to impermanent bed or banks.
Correlation	The process of establishing a relation between a variable and one or more related variables. Correlation is simple if there is only one independent variable; multiple, if there is more than one independent variable. For gaging station records, the usual variables are the short-term gaging-station record and one or more long-term gaging-station records.
Cubic feet per second	A unit expressing rates of discharge. One cubic foot per second is equal to the discharge of a stream of rectangular cross section, 1 ft wide and 1 ft deep, flowing water an average velocity of 1 ft per second.
Current meter	An instrument for measuring the speed of flowing water. The United States Geological Survey (USGS) uses a rotating cup meter.
Discharge	The volume of fluid passing a point per unit of time, commonly expressed in cubic feet per second, million gallons per day, gallons per minute, or seconds per minute per day.
Drainage area	The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.
Flood	Any relatively high streamflow that overflows the natural or artificial banks of a stream.
Flood peak	The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.
Flow-duration curve	A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded.
Gage height	The water-surface elevation referred to some arbitrary gage datum. Gage height is often used interchangeably with the more general term stage although gage height is more appropriate when used with a reading on a gage.

DEFINITION OF TERMS (Continued)

Gaging station	A particular site on a stream or lake, where systematic observations of gage height or discharge are obtained.
Ground water	In the broadest sense, all subsurface water; more commonly that part of the subsurface water in the saturated zone.
Hydrograph	A graph showing stage, flow, velocity, or other property of water with respect to time.
Hydrology	The science that deals with water as it occurs in the atmosphere, on the surface of the ground, and underground.
Instantaneous discharge	The volume of water that passes a point at a particular instant of time.
Instream use	Any use of water that does not require diversion or withdrawal from the nature watercourse, including in-place uses such fish and wildlife habitat, recreation, navigation, and water quality purposes.
Mean discharge	The arithmetic mean of individual daily mean discharges of a stream during a specific period, usually daily, monthly, or annually.
Reach	The length of channel uniform with respect to discharge. The length of a channel for which a single gage affords a satisfactory measure of the stage and discharge.
Runoff	That part of the precipitation that appears in streams or surface-water bodies.
Sediment	Particles, derived from rocks or biological materials, that have been transported by a fluid or other natural process, suspended or settled in water.
Stage	The height of a water surface above an established datum plane; also gage height.
Stage-discharge curve (rating curve)	A graph showing the relation between the gage height, usually plotted as ordinate, and the amount of water flowing in a channel, expressed as volume per unit of time, plotted as abscissa.
Stream	A general term for a body of flowing water.
Streamflow	The discharge that occurs in a natural channel
Streamgaging	The process and art of measuring the depths, areas, velocities, and rates of flow in natural or artificial channels.
Streamgaging station	A gaging station where a record of discharge of a stream is obtained.
Surface water	An open body of water such as a lake, river, or stream.
Water year	A continuous 12-month period selected to present data relative to hydrologic or meteorological phenomena during which a complete annual hydrologic cycle normally occurs. The water year used by the U.S. Geological Survey runs from October 1 through September 30, and is designated by the year in which it ends. Thus, the year ended September 30, 2012, is called the “2012 water year.”

Note: Adapted from http://water.usgs.gov/wsc/glossary.html and http://water.usgs.gov/water-basics_glossary.html, accessed on March 5, 2013, and Annear et al. (2004).

ABSTRACT

This manual describes the standards, policies, and procedures used by the Statewide Aquatic Resources Coordination Unit (SARCU) for activities related to the collection, processing, storage, analysis, and publication of surface-water data. This manual serves as a guide to SARCU staff involved in surface-water data activities. Surface-water data are essential for SARCU to fulfill one of its core objectives to file reservations of water to protect fish and wildlife habitat, migration, and propagation. Key to providing scientifically sound and defensible instream flow recommendations is obtaining high quality surface-water data records.

Key words: surface-water data, streamgaging, rating curve, surface-water record computation, streamflow record extension

INTRODUCTION

The dearth of hydrologic data throughout most of Alaska has limited the ability to make scientifically sound water management decisions (Brabets 1996; Estes 1998; Klein 2012). Fish and other aquatic and wildlife species have adapted to natural streamflows that provide seasonal habitats. Seasonal quantities of flowing waters and water levels are needed by fish using freshwater and estuarine habitats for migration, spawning, incubation, and rearing (Hynes 1970; Estes 1984; Hill et al. 1991; Poff et al. 1997; Bovee et al. 1998; Annear et al. 2004; Mims and Olden 2012).

The Fish and Game Act requires the Alaska Department of Fish and Game (ADF&G) to "...manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the state in the interest of the economy and general well-being of the state" (AS 16.05.020). The act also enables ADF&G to use a variety of legal, regulatory, and administrative options to quantify and acquire water rights within lotic[1] and lentic[2] water bodies to sustain fish and wildlife resources (AS 16.05.050).

In 1980, Alaska passed an amendment to the Alaska's Water Act, commonly referred to as "Alaska's instream flow law." Alaska's water law treats the term *instream flow* more broadly than most states' jurisdictions because the term may be used to refer to the rate or volume of flow in a river, the volume of water in a lake, or a related physical attribute such as water depth for identified resources and values. Water rights to retain water in lentic and lotic habitats can be acquired from the Alaska Department of Natural Resources (DNR) by a private individual, group, or government agency for one or a combination of four purposes:

- protection of fish and wildlife habitat, migration, and propagation;
- recreation and park purposes;
- navigation and transportation purposes; and
- sanitary and water quality purposes.

Alaska's water law follows the prior appropriation doctrine which assigns seniority of water rights in the order they are filed (Alaska Constitution, Article VIII, Section 13). Under Alaska water law, an appropriation to retain water within a water body for any of these purposes may also be defined as a *reservation of water* (AS 46.15.145). The term *reservation of water* is often used to differentiate between retaining water within lotic or lentic water bodies versus out-of-stream withdrawals.[3] It is important to note that passage of the instream flow law expanded the

1 Lotic refers to flowing waters, such as rivers and streams.
2 Lentic refers to still waters, such as lakes and ponds.
3 Withdrawals can be from surface or subsurface water sources.

meaning of *appropriation* in Alaska to represent all water right uses, including retention of water in lotic and lentic water bodies. However, an *appropriation* is still more commonly associated with out-of-stream and diversionary uses/water rights, while the term *reservation* typically refers to retention of water within a lotic and lentic water body. Further information related to Alaska's instream flow law can be found in Curran and Dwight (1979), White (1982), Anderson (1991), Harle and Estes (1993), and Burkardt (2000).

In 1986, the Division of Sport Fish initiated a departmental instream flow program to focus on quantifying and protecting sufficient amounts of water in rivers and lakes for fish and wildlife. The program is now called the Statewide Aquatic Resources Coordination Unit (SARCU). When available, streamflow data are obtained from the U.S. Geological Survey (USGS), National Water Information System website. Prior to 2000, ADF&G primarily relied on existing USGS streamflow records for filing reservation of water applications[4]; however, as the program matured there was an increasing need to collect surface water records at priority sites with limited or no streamflow data. The purpose of this report is to document the standards, policies, and procedures to be followed by SARCU staff for activities related to the collection, processing, storage, analysis, and publication of surface-water data.

To address limited hydrologic information throughout the state, DNR consulted with the Interagency Hydrology Committee for Alaska to recommend a minimum of five years of streamflow or lake level data record to support all water management decisions. This five-year recommendation is intended to reduce potential bias that may be associated with intra- and inter-annual hydrologic variability. Although existing law and legal precedents have established "best available data" as the minimum requirement, ADF&G agrees it is in the best public interest to strive to meet this recommendation and that it should be uniformly applied to all classes of water right applications. However, in order to secure the department's interest and obtain a priority date before potential competing interests, the best available data may be utilized to quantify instream flow needs. Ultimately, the measure of success will be whether or not reservations of water applications are accepted by DNR, applications have sufficient hydrologic data for adjudication, and the quantity of water granted meets the purpose for the reservation.

METHODS

STREAMGAGING

Streamgaging is the process of measuring stage in a stream and developing a rating curve, which can be used to convert historic stage records to streamflow (Rantz and others 1982). For SARCU, the objective of operating a streamgage (or gaging station) is to obtain a continuous record of streamflow data at a site. A continuous record of stage is obtained by installing instruments that sense and record water-surface elevation every 15-minutes in the stream relative to an established datum. Discharge measurements are made at periodic intervals to define or verify the stage-discharge relation and to define the time and magnitude of variations in that relation (Stewart and Arvin 2003). The continuous stage record is converted to streamflow using rating curves then summarized and reported as a mean daily flow.

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[4] These reservations were made with various data record lengths in accordance with legal and regulatory requirements. At times, synthetic analyses were performed to extend limited hydrologic datasets or estimates derived using hydrologic models. Other state and federal agency hydrologists performed these analyses in cooperation with ADF&G when there was insufficient empirical data and it was a priority to file a reservation of water application.

Streamgage networks are commonly installed to provide information on seasonal and long-term streamflows over multiple drainage basins. A streamgaging network consists of an index gaging station that is operated over a long period of time (typically many years), and an associated network of semi-permanent streamgages, which are operated concurrently on nearby reaches, tributaries, and sometimes streams, if hydrologically similar. Ideally, the index streamgage is operated by USGS and the network of semi-permanent gages is operated by SARCU, with the records extended using the USGS index gage to obtain five years of records. The objective in establishing a streamgaging network is to correlate streamgages with those having longer periods of continuous record to increase the accuracy of seasonal and long-term hydrologic estimations and reduce uncertainty from limited or no data. For example, adding a semi-permanent gaging station provides site-specific data for a study reach thereby reducing bias from estimating hydrologic characteristics from a regional index gaging station and may provide an alternative point of reference if the original permanent station becomes inoperable.

For all SARCU gaging projects, the project leader is responsible for all aspects of the project including site selection, installation, maintenance, levels, data processing, database management, publication, and safety. The SARCU surface-water data coordinator will provide technical assistance and an annual record review.

Gage Installation and Maintenance

Proper installation and maintenance of streamgages are important activities for ensuring good quality streamflow records. Kresch and Tomlinson (2011; Appendix A1), provide a summary of USGS's recommendations for the proper installation and maintenance of gaging stations including factors important for selecting a good site. Additional information can be found in Rantz and others (1982) and Kennedy (1984).

It is the goal of SARCU to obtain a continuous and complete record of the stage at each streamgage and it is therefore essential that problems that result in loss of stage record be dealt with immediately. A checklist for gaging station maintenance is provided in Appendix B2.

Measurement of Stage

SARCU staff have historically used submersible pressure transducers to measure stage at streamgages. It is SARCU policy that surface-water-stage records at stream sites be collected with instruments and procedures that provide sufficient accuracy to support computation of discharge from a stage-discharge relation with the goal of collecting stage data at the accuracy of 0.01 ft or 0.2 % of the effective stage being measured, whichever is less restrictive (Kresch and Tomlinson 2011; USGS Office of Surface Water memorandums 89.08, 93.07, and 96.05). Information for USGS methods on the measurement of stage is provided in Appendix A2.

Accurate stage measurement requires not only accurate instrumentation but also proper installation and continual monitoring of all system components to ensure the accuracy does not deteriorate with time (USGS Office of Surface Water memorandum 93.07). Gages are set to register the height of a water surface above a selected level reference surface called the gage datum (Rantz and others 1982).

Levels

Establishing and monitoring a reference level is a crucial component for collecting quality streamflow records. The gage's supporting structures—rebar, pipe, brackets, stream-banks, and other structures—and staff gages tend to settle or rise as a result of earth movement, static or dynamic loads, vibration, or battering 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 bias in streamflow records (Stewart and Arvin 2003).

Leveling is a procedure by which surveying instruments are used to determine the differences in altitude between points and is used to establish datums and to check them from time to time for vertical movement (Kenney 2010). A minimum of three independent reference marks are needed at each gage (Kresch and Tomlinson 2011). It is SARCU policy that levels are run at all site visits unless a stable staff gage can be established. SARCU staff follow USGS leveling procedures and standards described in Kresch and Tomlinson (2011; Appendix A3).

Level instruments need to be kept in proper adjustment through the use of peg tests as described in Kenney (2010). Peg tests are done periodically on each instrument, typically once each year. If the accuracy of an individual instrument becomes suspect for any reason, however, a peg test should be performed immediately. Results of the tests are documented in a logbook. Ensuring that levels are run correctly at the appropriate frequency and level notes are completed correctly is the responsibility of the project leader.

Site Documentation

Providing accurate and thorough documentation is important to achieve quality streamflow records. Kresch and Tomlinson (2011; Appendix A4) provide information to meet this goal. The surface-water data coordinator is responsible for assigning station numbers for all ADF&G streamgage stations.[5] Each streamgage station will be assigned a unique five-digit number. The first three digits of the station number will be used to describe the particular watershed the station is located within. The last two digits of the station number will be used to describe each gage within the watershed. For example at Peterson Creek five streamgaging stations were installed: 10101, 10102, 10103, 10104, and 10105. The first three digits of the station numbers (101) were used to describe the Peterson Creek watershed and the last two digits of the station number (01, 02, 03, 04, and 05) were used to describe each of the five gages within the watershed.

Measurement of Discharge

A range of stream discharge measurements is needed to develop a relationship between stage and discharge (called a rating curve). Six to ten discharge measurements should be taken each year unless it has been demonstrated that the stage-discharge relation is unvarying with time. Measurements are needed at the highest and lowest streamflows that can practically be measured, with measurements replicated throughout the full range of streamflows for each year of record. This is necessary to ensure that the data are balanced throughout the range of seasonal hydrologic variability and that the rating curve is not overly influenced by streamflows in any particular range of the curve. The rating curve must be continually monitored and adjusted for shifts as needed following changes in the streambed from scour or deposition of sediments (Rantz and others 1982).

[5] Location of each streamgage should be recorded with respect to the North American Datum of 1927 (NAD27), which is the same coordinate system used by USGS.

Procedures used for measurement of discharge using a current-meter are described in Kresch and Tomlinson (2011; Appendix A5) and a checklist is provided in Appendix B3. SARCU staff select the type of current-meter to be used for each discharge measurement based on criteria provided by Kresch and Tomlinson (2011; Appendix A5). Any deviation from those criteria is noted, and the measurement accuracy is downgraded accordingly. Field notes should be well-documented (Appendix A6).

It is SARCU policy that timed spin tests are performed as described in Kresch and Tomlinson (2011; Appendix A7). The goal of the spin tests is to ensure that streamflow measurements are made with meters that are in good working order.

Kresch and Tomlinson (2011; Appendix A8 and A9) describe field and office procedures to follow when using an acoustic Doppler current profiler (ADCP) or acoustic Doppler velocimeter (ADV), respectively. SARCU staff performing activities in cold-weather should follow Kresch and Tomlinson (2011; Appendix A10). SARCU policy requires that point-of-zero-flow (PZF) measurements be made by field personnel during periods of low flow at all gages where the low-flow control is recognizable.

SARCU personnel who have questions concerning the appropriate procedures for making discharge measurements should address their questions to the surface-water data coordinator.

Alternatives to Streamgaging

A variety of other techniques are also available to quantify seasonal and long-term streamflow characteristics within watersheds with limited (less than five years) or no hydrologic data. Although they are mentioned here, use of techniques not based on site-specific information would typically only be used for planning purposes or to estimate streamflow characteristics in order to file a reservation to obtain a priority date, with the intent of collecting site-specific data in the near future. Investigators must also consider the bias and limitations when using these techniques.

It should be noted there are other methods available to quantify seasonal and long-term streamflow characteristics (e.g., watershed-runoff models, ARCGIS, etc.) but are not mentioned here since they typically depend on detailed analyses and site-specific information.

<u>Estimating the Magnitude and Frequency of Peak and Low Streamflows</u>. An approach to estimating the magnitude and frequency of peak and low streamflows in Alaska has been developed by USGS (Wiley and Curran 2003). This approach involved the development of equations for estimating peak and low streamflows at ungaged locations that were developed for Alaska and conterminous basins in Canada using a generalized least-squares regression model. Region-specific equations were developed that will allow prediction of the magnitude and frequency of peak streamflows in basins that are not gaged.

<u>Mass Balancing</u>. Mass balancing involves analysis of simultaneous upstream and downstream discharge measurements to calculate an unknown discharge. This method may be used at sites that have two or more gaging stations in the drainage basin in order to complete missing hydrologic records in the streamgaging network. For example, this would allow estimation of streamflow in a tributary between a relevant upstream and downstream gaging station.

<u>R10 STREAMFLOWMOD (1991)</u>. R10 STREAMFLOWMOD is a model developed from historic USGS streamflow records and basin characteristics to estimate regional streamflow

characteristics at ungaged sites in the Tongass and Chugach National Forests (Orsborn and Storm 1991). The model is applicable to other sites that are within the hydrologic regions and defined by the project and basin variables used to develop the model. A general assumption for using this model is that equations used to estimate hydrologic characteristics are representative for the selected ungaged basin.

USFS-Region 10 Water Resources Atlas (1979). Similar to R10 STREAMFLOWMOD, this model was developed from historic USGS streamflow records and basin characteristics to estimate regional streamflow characteristics at ungaged sites in the Tongass and Chugach National Forests (Ott Water Engineers Inc. 1979). The model is applicable to sites within the hydrologic regions defined by the project and basin variables used to develop the model. A general assumption is that the basins from which data used for model development were derived are representative for the selected ungaged basin.

Parks and Madison (1985). USGS derived a regional regression model using multiple linear-regressions to assess streamflow frequency characteristics for six hydrologic regions and the entire state. They found that the most reliable estimates of the mean annual streamflow were provided by regression equations using drainage area and mean annual precipitation as the independent variables. Results indicate that reliable estimates of streamflow frequencies can be made from the developed regional equations for ungaged sites in the southeast, south central, and Yukon regions of the state. For the northwest, Arctic Slope, and southwest regions, USGS concluded that the statewide equation offers the best alternative for estimating streamflow at ungaged sites. Likewise, a general assumption with using the model is that data used in model development are representative for selected ungaged basin.

Unit Runoff Approach. For ungaged basins with a streamgage nearby, a unit runoff analysis may be performed to determine streamflow characteristics at the ungaged site. Streamflow characteristics for ungaged sites are estimated using a unit runoff ratio calculated from the gaged basin characteristics. This method is based on the Unit Hydrograph theory which assumes rainfall and runoff processes are uniformly distributed over the drainage area (Chow et al. 1988).

Seasonal Streamflow Characteristics. Seasonal streamflow characteristics for a stream reach can be evaluated using one or both of the following techniques.

1. From a limited hydrologic database, it may be assumed that the available streamflow records provide a reasonable estimation of seasonal streamflow characteristics. Evaluation of this assumption should include localized precipitation analyses and comparison with long-term historic streamflow records from nearby gaging stations.

2. For ungaged basins, seasonal streamflow characteristics may be estimated by multiplying the calculated mean annual flow by the seasonal streamflow ratio from a representative nearby streamgage. Recommendations for appropriate streamgages to use should be sought from USGS and other hydrologist familiar with hydrologic and precipitation patterns in the region.

Water Quality and Environmental Data

Water quality data such as water temperature, pH, dissolved oxygen, and conductivity are often collected at ADF&G gaging stations. Typically, a water temperature sensor is contained within the depth sensor probe. Depending on site-specific installation procedures, the sensor may not provide an accurate representation of ambient water temperatures. For example, if the probe is located within a wellpoint, the slotted metal enclosure may affect cooling and heating rates of the water temperature probe that may differ from ambient conditions. Because site-specific conditions may vary, the scope of inference associated with water quality data should be carefully considered by the investigator.

SURFACE-WATER RECORD COMPUTATION

Ensuring the thoroughness, consistency, completion, and accuracy of streamflow records is important for obtaining quality surface-water records. Record computation is a process by which stage measured at the gage is converted to discharge using the stage discharge relationship. The accuracy of surface-water discharge records depends on the accuracy of discharge measurements, the accuracy of the rating definition, and the completeness and accuracy of the gage-height record (USGS Office of Surface-water memorandum 93.07).

Before being converted to discharge, the stage record may be corrected for movement of the staff gage, transducer movement and drift, or fill and scour of the hydraulic control. Computed discharge values are typically summarized as mean daily, mean monthly, and average annual flow values for the water year (October 1st–September 30th). Record computations by SARCU staff are to be completed by February 1 following the end of a water year. All data, computations, graphs, and analyses are checked by the Surface-water data coordinator by March 1.

Processing and Analysis of Streamflow Data

The WISKI© hydrologic data management software is used by SARCU to store transducer stage, water temperature, measured discharge values, and observed staff gage readings. It is also used to develop rating curves, make corrections to the stage record, apply rating curve to corrected stage values in order to calculate 15 minute discharges, and summarize these discharges to mean daily, mean monthly, and average annual flow values. WISKI© is used to store and reduce the data after they are proofed for nonsensical data and transformed into a WISKI© compliant format. A summary of the record computation process is presented in Appendix C and summarized below.

1. Create Station in WISKI©
2. Prepare/update Station Description Document
3. Station Analysis Document
4. Check and post levels
5. Compile and import stage record
6. Compile and import water temperature data
7. Determine gage height corrections and apply to stage record
8. Check discharge measurements and field notes
9. Develop Rating Curve
10. Apply shifts to stage record
11. Create Q.15 time series
12. Create Mean daily flow Time Series
13. Identify and estimate ice affected, missing, or bad discharge records
14. Summarize mean monthly flow and mean annual flow values for the water year
15. Update master file

Review of Records

After streamflow records for each station have been computed and checked, station records are reviewed by the surface-water data coordinator or other experienced individuals. 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. The findings of the review for each gaging station are provided in writing to the project leader, their supervisor, and the SARCU Supervisor. It is the responsibility of the project leader to ensure that any deficiencies identified in the review are corrected and that actions are taken to prevent the recurrence of those deficiencies. The written findings are maintained for future reference.

DATA ANALYSIS

Statistical analyses of the hydrologic data are conducted to estimate mean annual flow (QAA), mean monthly flow (QAM), and streamflow durations.

STATISTICAL ANALYSES

Equations 1-8b (below) apply to situations when mean daily flows may be taken as known values; that is, situations where five or more complete water years of mean daily flow values have been collected in the reach(es) of interest.

Calculation of QAA from historic mean daily flow records involves first obtaining the mean annual flow within each water year (1 October–30 September), given as:

$$qaa_h = \frac{\sum_{i=1}^{d_h} q_{hi}}{d_h}, \tag{1}$$

where qaa_h equals the mean annual flow for each year (h) of record, d_h equals the number of days in each year of record (note that only complete years of record are used in this analysis, as such d_h is the same for all years except leap years), and q_{hi} equals the mean daily flow in cubic feet per second for each day in the record.

Next, QAA is estimated as a mean of the mean annual flow values over all complete years of record:

$$\hat{QAA} = \frac{\sum_{h=1}^{n} qaa_h}{n}, \tag{2}$$

where n equals the years of record (with complete mean daily flow records for each water year).

As noted above, QAA is never calculated with data from water years with less than complete records (all days have streamflow estimates). No attempt to interpolate or impute missing data will be made so that the estimates of QAA obtained from Equations 1 and 2 will coincide with the "official" estimates from USGS. Note, however, that all "estimated" streamflows from USGS databases (i.e., those with the letter "e" preceding them) will be used in these calculations.

Although not specifically used in preparing reservation of water applications, dispersion around QAA is described by the variance, given as:

$$\hat{V}\left[\hat{QAA}\right] = \frac{\sum_{h=1}^{n}\left(qaa_h - \hat{QAA}\right)^2}{n(n-1)} \tag{3}$$

The standard error of the estimated QAA is given as the square root of the variance.

Both cumulative year (for the entire period of record) and individual year mean monthly flows (means of the monthly mean daily flows [QAM]) are estimated by first estimating the mean daily flow for each complete month in the record:

$$qam_{jh} = \frac{\sum_{k=1}^{d_{jh}} q_{jhk}}{d_{jh}} , \tag{4}$$

where qam_{jh} equals monthly mean daily flow for each month (j) for each year (h) of record, d_{jh} equals the number of days in each month of record (note that only complete months of record are used in this analysis), and q_{jhk} equals mean daily flow in cubic feet per second for each day in the record.

Next, QAM is estimated as the mean of monthly mean daily flows over all complete years of record:

$$\hat{QAM}_j = \frac{\sum_{h=1}^{n_j} qam_{jh}}{n_j} , \tag{5}$$

where n_j equals years of record (with complete daily flow records for each particular month).

Dispersion around QAM is described by the variance, given as:

$$\hat{V}\left[\hat{QAM}_j\right] = \frac{\sum_{h=1}^{n_j}\left(qam_{jh} - \hat{QAM}_j\right)^2}{n_j(n_j - 1)} \tag{6}$$

The standard error of the estimated QAM is the square root of the variance.

One of the requirements for reservation of water applications is to demonstrate that sufficient water is expected to be within the reach of a stream or water body during the various periods of the year in which the reservation is requested. Therefore, we also calculate monthly (and sometimes semi-monthly, weekly, and daily) flow duration estimates. Analysis of these estimates allows further refinement of reservation requests when these data are available. Duration estimates represent the expected frequency of occurrence of mean daily flows in each water body within a particular period, and are calculated as the percentiles of the empirical distribution of observed values within the time periods involved over the period of record. The result is an estimate of the percentage of time a given mean daily flow is equaled or exceeded within the distribution of mean daily flows for each period analyzed. In general, duration analyses are usually only performed on datasets with at least five years of record. For example, to obtain streamflow duration estimates in April, all mean daily flow values for April across all years of record (with complete streamflow records for the month of April) are combined. The frequency distribution is described by quantities calculated below. For each integer percentile (t), with $p = t / 100$, the quantities

$$np = j + g \tag{7}$$

are first set, where *n* is the number of observed mean daily flow values in the combined group (for example, 300 days for a 10-year record of complete months of April), *j* is the integer part of *n* times *p*, and *g* is the fractional part of *n* times *p*.

The t*th* percentile (y) is then defined as:

$$y = \left(x_j + x_{(j+1)}\right)/2 \;\; if\; g = 0, \tag{8a}$$

or

$$y = x_{(j+1)} \quad if\; g > 0, \tag{8b}$$

where x_j and $x_{(j+1)}$ are the ordered (from smallest to largest) values in the combined group of mean daily flow values.

Standard errors for streamflow quantities corresponding to the integer percentiles can be calculated using a bootstrap procedure, as outlined by Harrell and Davis (1982). Briefly, a “bootstrap sample” will be chosen, with replacement, at random from the set of observed values. The sample size of the bootstrap sample will be equivalent to the observed sample size (e.g., equal to 300 for a 10-year record of April streamflow values). Percentiles will then be estimated from this bootstrap sample. The bootstrap sampling and estimation procedure will be repeated a total of 1,000 times, resulting in 1,000 estimates of each percentile. The sample mean of the bootstrap estimates for each percentile will be used to estimate bias of the estimator defined above (see section 5.5 of Efron 1982). Additionally, the sample standard deviation calculated from the bootstrap estimates will be used as the estimated standard error of each percentile. Bootstrap statistics will not be included in the annual report or applications but will be retained on file by the Division of Sport Fish for future reference. SAS© programs developed by biometricians are used by SARCU staff to perform the above calculations.

EXTENDING STREAMFLOW RECORDS

When a sufficiently long and complete historic streamflow record is not available for the reach of interest, records may be extended by modeling the relationship between streamflows measured at semi-permanent (short-term) streamgage and streamflows measured concurrently at an index (long-term) streamgage.

Linear models will be used to quantify the relationship between semi-permanent and index gaging stations for subsequent calculation of streamflow statistics. The general approach involves developing a predictive model between the short-term site and a nearby, longer-term site with concurrent mean daily flow records (Nielsen 1999; USGS 1985; Stedinger and Thomas 1985; Hirsch 1982). Greater accuracy can be achieved if the watershed from which the data originated have similar characteristics of elevation, aspect and orientation, prevailing meteorology, and land use patterns (Bovee et al. 1998).

In general, the analytical approach taken will depend on the quantity and type of the data available. The analyses can be divided into two general categories: "data-rich" and "data-limited." "Data-rich" sites have extensive daily streamflow records (e.g., equal to or greater than the 10 years of concurrent mean daily flow records) in the reach(es) being evaluated. When in a "data-rich" situation, more sophisticated analytical methods may be justified because the potential for bias resulting from sampling only a relatively short time period is mitigated. The "data-limited" sites are those with less than ten years of concurrent mean daily flow records. In these situations, the relatively high potential for bias in the streamflow statistics due to the shortness of record makes it unproductive (and possibly misleading or confusing) to quantify sources of uncertainty that are likely to be of much lower magnitude than the bias. The goal will always be to limit the potential for bias but this goal needs to be balanced with the reality of resource limitations and the consideration of legal precedents to allow for acquisition of water for meeting departmental mandates and objectives.

Approach A – Data-Rich Sites

The analytical approach used by USGS (Nielsen 1999; USGS 1985; Stedinger and Thomas 1985; Hirsch 1982) will be employed when the streamflow record at the index gage contains at least 10 years of data concurrent with a mean daily flow record at a short term gage that comprises at least five years.

This technique is known by various names, such as the line of organic correlation (LOC; Kruskal 1953), geometric mean functional relationship or geometric mean regression (GMFR or GMR; Ricker 1973), and standardized major axis regression (SMA; Kermack and Haldane 1950). This technique is similar to simple linear regression, but rather than minimizing the sum of the squared deviations from the fitted line along the axis of the short term series, the sum of the triangular areas formed by connecting the measured data points to the estimated line with lines parallel to the coordinate axes are minimized (Barker et al. 1988). This linear model provides estimates of streamflow that maintain the variance (as well as the mean) of the short term series. Unlike simple linear regression, which generally yields predicted streamflows having less variability than the original observations, the extension equation (Equation 9) can be thought of as preserving the observed high and low streamflows of the short term series in the extended series, which may be important for developing reliable streamflow estimates and associated statistical summaries. The extension equation (Equation 9) was presented by Hirsch (1982) as MOVE.1 (Maintenance of Variance Extension, Type 1) and its theoretical basis has been described by Kruskal (1953), Barker et al. (1988), Warton et al. (2006), Leng et al. (2007).

$$\hat{y}(i) = \bar{y}_1 + \frac{S(y_1)}{S(x_1)}\left(x(i) - \bar{x}_1\right), \qquad (9)$$

where:

$\bar{y}_1$ is the mean of the portion of the short term record that overlaps with the long term record;

$\bar{x}_1$ is the mean of the portion of the long term record that overlaps with the short term record;

$S(y_1)$ is the standard deviation of the portion of the short term record that overlaps with the long term record;

$S(x_1)$ is the standard deviation of the portion of the long term record that overlaps with the short term record.

Equation 9 indicates that the slope of the fitted line is estimated as the ratio of standard deviations of the short and long term series whereas the slope, *m*, in simple linear regression is estimated by $\hat{m} = r\frac{S(y_1)}{S(x_1)}$ where *r* is the estimate of the true correlation coefficient, ρ.

The software R or other statistical packages may be used to estimate streamflows using Equation 9. USGS has made available an S-Plus (Insightful Corporation Seattle, WA) library which contains the functions move.1 and predict.move.1 (http://water.usge.gov/software/library.html). These functions can also be used to estimate mean daily flows at semi-permanent streamgages for the time period corresponding to the indexed gage. It should also be noted that MOVE.1 1og transforms the streamflow data, which should be performed when using other software packages. Bootstrap methods (Plotnick 1989) may be used if standard errors are desired for the predictions.

The estimates of mean daily flow will be substituted for q_{hi} and q_{jhk} in Equations 1 and 4 and QAA, QAM, and their variances will be estimated by Equations 2, 3, 5, and 6. Calculations have shown that the prediction errors associated with the estimates of mean daily flow, q_{hi} and q_{jhk}, are small relative to the variance components calculated in Equations 3 and 6. For this reason, the variance associated with predicting the mean daily flows will not be specified; however, this assumption should be checked routinely, particularly when inter-annual variability is relatively small. The predicted mean daily flows will also be used to estimate streamflow duration as described by Equations 7-8b.

Approach B – Data Limited Sites

When the overlap between the long term and short term mean daily flow records is short (e.g., two to three years) or when instantaneous discharge measurements are collected, the streamflow record will be extended to five years using simple linear regression to meet the DNR recommendation discussed in the introduction. Uncertainties in QAA, QAM, and flow duration estimates associated with the extension will not be quantified, however guidelines are provided below to reduce the potential for bias.

During the multi-year collection period, data will be analyzed annually to determine if the data collection protocols are sufficient for a reliable record extension. The goal will be to develop a simple linear regression model that has independent random errors and good fit to the data.

Diagnostics for linear models

During the multi-year collection period, data will be analyzed annually to determine if the data collection protocols established in the site-specific operational plan are sufficient for reliable record extensions. Considerations include the following:

1) The range of flows for the index gage, x, in the overlap with flows measured at the semi-permanent gage, y, (i.e., range of x in (x, y) pairs) must be compared with the range of x in the entire permanent record to be extended to the location of the temporary gage. The x range from (x, y) data pairs must cover a high percentage (e.g., 95%) of observed flows at the index gage.

2) Prefer (x, y) data pairs from multiple high and low flow events (i.e., near the extreme flows exhibited at the index gage) along with data from flows fairly evenly spread throughout the range of x.
3) High leverage values (i.e., those observations having disproportionately large influence on slope and intercept of the fitted line) are a source of bias that should be minimized through additional data collection.

In addition, use of standard diagnostics such as residuals plots and R^2, the coefficient of determination, will be used to assess model fit.

INFORMATION MANAGEMENT

For each gaging station, the project leader is responsible for maintaining project information in a systematic and organized manner. This includes ensuring that appropriate documentation is filed correctly and that unnecessary notes and work sheets are discarded. This information includes the information and forms discussed in this report and Appendix A and include:

- Station descriptions
- Level note sheets
- Station analyses
- Discharge summary sheet
- Photographs
- Level instrument log book

DATABASE MANAGEMENT

The overall process of storing surface-water data collected at continuous-record gaging stations includes entering the unit-value stage data into WISKI©, computing corresponding discharge values, computing daily mean discharges based on those unit discharges, and storing those daily means in WISKI©.

It is the responsibility of the project leader to ensure that surface-water data files are updated and that the data are correct. The project leader is responsible for all aspects of data collection, data entry, analysis, management, storage, and reporting.

OPERATIONAL PLANS

For SARCU projects that include the collection of surface-water data, project leaders need to complete an approved operational plan. Project leaders are responsible for ensuring that all aspects of the project associated with surface-water data collection, analysis, and storage meet the standards and guidelines presented in this report.

The following guidelines should be followed when developing data collection procedures:

1) A minimum of five complete water years of mean daily flow data (collected or synthesized) within the reach(es) to be reserved.
2) For streamgage record extensions:
    a. Continuous streamflow data from a gage installed at the site of interest (semi-permanent gage) is the preferred method to model the relationship.

b. Period of record overlap should be maximized with the goal of obtaining a minimum of two complete and concurrent years of record.

c. For instantaneous discharge measurements taken in lieu of continuous data, the following guidelines should be followed:

   i. A goal of ten measurements per year.

   ii. A goal of two years of measurements.

   iii. Discharge measurements should be fairly evenly spread throughout the range of streamflows during the data collection period.

   iv. Discharge measurements should be collected near the highest and lowest streamflows during the period of data collection.

   v. Efforts must be taken to ensure that the instantaneous discharge measurements are comparable to the mean daily flows at the index gage (e.g., discharge may vary by time of day).

PUBLICATION OF SURFACE-WATER DATA

It is the goal of SARCU that for all projects that require a significant investment of staff time, resources and/or funding, a divisional report be prepared and published. The latest version of *ADF&G Writer's Guide* and other applicable divisional policies and guidelines are to be followed.

SAFETY

Performing work activities in a manner that ensures the safety of personnel and others is of the highest priority. 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 (Kresch and Tomlinson 2011). It is the responsibility of all employees to comply with ADF&G standard operating procedures[6], laws, and good practices applicable to work related activities.

DATA ARCHIVING

It is SARCU policy that the WISKI© database should be the primary storage site for all pertinent records. Pertinent field and other hard copy documents should be scanned and an electronic copy stored in WISKI©. The Surface-water data coordinator will be responsible for setting the policy for all documents stored in WISKI©. It is the responsibility of the project leader to ensure records are complete and properly archived.

Surface-water data are stored in WISKI© within a root folder named by the station number. This folder will contain subfolders containing discharge measurement and level forms, streamgage and water temperature data, station descriptions, station analyses and legal descriptions. Other subfolders include electronic data files and summaries from discharge measurement equipment, such as AquaCalcs© and ADCP and ADV data. All other supporting data (e.g., photographs, field notes) should also be stored on the WISKI© server.

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[6] For a listing of ADF&G Standard Operating Procedures see http://intra.dfg.alaska.local/QRHome/Admin/QRAsops.html.

SUMMARY

Information presented in this report documents the policies and procedures for SARCU staff to ensure high quality in the collection, processing, storage, analysis, and publication of surface-water data.

Key to providing scientifically sound and defensible instream flow recommendations are obtaining high quality surface-water data records.

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APPENDIX A: EXCERPT FROM USGS WASHINGTON WATER SCIENCE CENTER SURFACE-WATER QAP

Appendix A1.–Gage Installation and Maintenance.

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).

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.

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.

Appendix A2.–Measurement of Stage.

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 or 0.2%, 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% of the flow. OSW memorandum 93.07 provides an explanation of USGS policy on stage-measurement accuracy as it relates to instrumentation.

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 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.

Appendix A3.–Levels.

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 three 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. For all levels at new stations, along with routine three-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 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 two 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.

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. The hydrographer reviews station descriptions every year and updates them if necessary.

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. 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.

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 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.

Appendix A5.–Measurement of Discharge.

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.

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 than 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.

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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% 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% of the total discharge and ideally not exceed more than 5% (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% 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% 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% should be used, and should document this in the Station Description and Station Analysis.

Excerpts from Kresch, D. L. and S. A. Tomlinson. 2011. *Surface-Water Quality-Assurance Plan* for the U.S. Geological Survey Washington Water Science Center, U.S. Geological Survey Open-File Report 03-490, Version 2.0, May 2011.

Appendix A6.–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). 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. 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.

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 electronic data logger (EDL) or data collection platform (DCP), condition of the battery and nitrogen tank (if applicable), type of instrument used for any discharge measurements, any observed high water marks (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) or any other sheet of paper, as long as the necessary information are included. 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.

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.

Appendix A7.–Spin Tests.

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.

Regular repairs involve replacing a variety of parts that make up the current meter. 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.

Appendix A8.–Acoustic Doppler Current Profiler 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 five 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 five minutes. If using the loop method, the duration of the loop should be three 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 transects (two in each direction) will be made under steady-flow conditions. The measured discharge will be the average of the discharges from the four transects. If the discharge for any of the four transects differs more than 5% from the mean measured discharge and no critical data-quality problem can be identified and documented, a minimum of four additional transects will be obtained and the average of all eight 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.

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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 two work days of returning to the office, and processed, archived, and reviewed within five 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, USGS, written communication, 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.

Appendix A9.–Acoustic Doppler Velocimeter 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% error in measured velocity and discharge.

    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

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mounting correction (available in firmware version 3.7 and software version 2.30) must NOT be applied.

6. 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.
7. 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.
8. 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.
9. 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.
10. 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.

ADV 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 one-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, USGS, written communication., 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.

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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% of the mean measurement velocity, the measurement should be rated no better than fair. If the standard error exceeds 10% 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.

Appendix A10.–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)

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.

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.

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 three 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. 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).

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 three 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

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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.

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; 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).

Various WAWSC procedures apply to ratings. Typically, the hydrographer assigned to the station develops new ratings. Hydrographers generally apply shifts to the rating when measurements indicate a change in the rating or previous shift of more than 5%. Shifts that extend over the entire range of the rating and (or) persist more than one 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 10 highest 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).

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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% 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%, unless the measurement was rated poor.

The hydrographer documents datum corrections, gage-height corrections, and shifts in the computer and station files. 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%, 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.

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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.

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.

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.

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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.

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 flows 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.

APPENDIX B: CHECKLISTS FOR SURFACE-WATER DATA COLLECTION

Appendix B1.–Example site visit checklist.

Pre-Site Visit

- ❑ Obtain approval to travel from supervisor via email
- ❑ Contact Watershed Councils or other partners
- ❑ Reserve cabin, air charter, ferry
- ❑ Charge Batteries: camera, Rugged Reader©, VHF, Aquacalc©
- ❑ Spin test velocity meters
- ❑ Check weather
- ❑ Read last Field Trip Report
- ❑ Review stage data, rating curves, rating table, discharge summary sheet
- ❑ Print rating table, rating curve, benchmark locations, survey notes

Equipment

- ❑ Velocity meters (Pryce and/or Pygmy)
- ❑ Wading rod
- ❑ Tape measure
- ❑ Aquacalc©
- ❑ Headphones
- ❑ Stopwatch
- ❑ Cables to connect Aquacalc© to velocity meters
- ❑ Pencils
- ❑ Notebook/Discharge Measurement Sheets
- ❑ Camera
- ❑ Rating Table
- ❑ Stadia Rod, Auto Level, Tripod, Survey Notes
- ❑ Rugged Reader© and cable to download data
- ❑ Dessicant
- ❑ Pipe wrenches, pipe goop, misc tools
- ❑ First Aid Kit
- ❑ Watch
- ❑ Extra 9V batteries for Aquacalc©
- ❑ 12 gage w/ slugs/bear spray (if needed)
- ❑ Spare parts and oil for velocity meters
- ❑ Calculator

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- ❑ Compact Flash Card
- ❑ Batteries for trail cam

Site Visit

- ❑ Take staff gage reading before and after discharge measurement along with photos
- ❑ Inspect site for changes to control, staff gage, channel, etc. Document changes.
- ❑ Take discharge measurement and record exact start/end time on discharge measurement notes sheet
- ❑ Take photos upstream/downstream, across discharge measurement
- ❑ Take picture of control
- ❑ Download datalogger data. Check battery level and memory. View data.
- ❑ Take instantaneous probe reading and compare to staff gage
- ❑ Make sure probe test is running (Running Man)
- ❑ Record all pertinent information on discharge measurement sheet i.e.; weather, site conditions, equipment problems, changes to channel, changes to control, differences between staff gage and probe, work that needs to be completed at next visit, wildlife seen (especially fish activity), etc.
- ❑ Survey benchmarks/staff gage/control/WSE at installation, yearly, at decommission, and if staff gage is suspected to have moved. Make sure to move level and survey all stations again. Check data in the field before leaving and compare with old survey data.

Post-Site Visit

1. Compare data entered into Aquacalc© to data entered on discharge measurement note sheet. aka pertinent changes to either Aquacalc file or note sheet.
   A. Download data file from Aquacalc© using Aquacalc© Data-link software.
   B. Import Aquacalc© file or create CSV for import into BIBER©.
   C. Post discharge measurement to Flow Summary and Shift Analysis Spreadsheets.
   D. Post all pertinent information to discharge measurements note sheet.
   E. Post discharge measurement to Shift Analysis Spreadsheet.

2. Download transducer data from Rugged Reader using Win-Situ 5 software.
   A. Create CSV files of corresponding transducer stage/water temperature and time readings.
   B. Import Stage CSV into S.1.O
   C. Import Water Temperature into Water Temperature.15
   D. Plot Stage and Water Temperature Data. Ensure that data looks reasonable and transducer is operating correctly.

3. Post staff gage and corresponding transducer stage readings to Gage Height Correction Spreadsheet.
   A. Create CSV file of staff gage readings and corresponding time.
   B. Import Staff Gage CSV into S.OBS.SG

4. Complete Field Trip Report.

5. Download pictures and label.

(Adapted from Kresch, D. L., and S. A. Tomlinson. 2011. Surface-Water Quality-Assurance Plan for the USGS Washington Water Science Center, USGS Open-File Report 03-490, Version 2.0, May 2011).

- Gage inspection information documented on USGS measurement form 9-275F and include:
  - Name of field person or observer
  - Date of visit and times of readings
  - Staff gage readings (if applicable)
  - Transducer reading
  - Station number and station name
- Remove debris and clean transducer well point
- Take corrective action if stages differ by more than 0.02 ft
  - Adjust and note data logger offsets
  - 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 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 hard copies of programming sheets in field folder or gage shelter
- Cut grass, brush, and tree limbs around gage and lines as needed
- 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

Appendix B3.–Checklist for direct measurement of discharge using a current meter.

(Adapted from Kresch, D. L., and S. A. Tomlinson. 2011. Surface-Water Quality-Assurance Plan for the USGS Washington Water Science Center, USGS Open-File Report 03-490, Version 2.0, May 2011).

- 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 conditions
  - Other pertinent information regarding conditions

- Number of measurement subsections
  - Ideally, about 25-30 stations
  - Target for no more than 5% 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% from current rating or shift
  - Change meter and stopwatch
  - Use different stationing, or change cross sections

- Work measurement in field whenever possible

Appendix B4.–Field Measurement Notes Checklist.

(Adapted from Kresch, D. L., and S. A. Tomlinson. 2011. Surface-Water Quality-Assurance Plan for the USGS Washington Water Science Center, USGS Open-File Report 03-490, Version 2.0, May 2011).

- 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
- 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

APPENDIX C: STEPS FOR WISKI© RECORD COMPUTATIONS

Appendix C1.–Checklist for WISKI© record computations.

1. Create Station in WISKI©

   In the WISKI© Station Explorer select an established station with the parameters you desire. Right click on the station and select COPY. Fill out the new Station Name, Station Number, and Station Short Name. Press F5 to update the database.

2. Prepare / update the Station Description Document:

   The station description document provides background information on the streamgage. Someone not familiar with the station after reading the document should be able to find the station and know what type of gage and site conditions to expect. The document should include; detailed directions to the gage, map, pictures, description of gage installation and equipment used, date of gage establishment and decommission, drainage area, reference marks locations, discharge measurements locations, descriptions of the channel and control, etc.

   - ❑ Print and place a copy of the Station Description in the master file.
   - ❑ Save a copy in the Streamflow Records folder as: StationName StationNumber Station Description.doc.

3. Station Analysis Document

   The station analysis document details a complete analysis of data collected, procedures used in processing the data, and the logic upon which the computations were based is documented for each year of record for each station to provide a basis for review and to serve 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, but are not limited to, equipment, hydrologic conditions, gage-height record (including when and why record is missing), datum corrections, rating, discharges used to develop the rating, special computations, hydrographic comparison, a listing of ice-affected periods, and remarks concerning the quality of the records. The station analysis is written by the hydrographer who works the records. If only parts of the year are worked, such as when records for a station are worked one month at a time for provisional purposes, the analysis is updated for that specific part by the hydrographer working the station records.

   It is the responsibility of the hydrographer who works the station record to ensure that the computation process is comprehensive and complete and that all aspects of the process are documented fully in the station analysis and associated material. Likewise, it is the responsibility of the checker to ensure that all aspects of the records-computation process for the station were carried out correctly and completely and that the documentation is clear, complete, and accurate.

4. Check and post levels.

   Errors in gage-height data caused by vertical changes in the gage or gage-supporting structure can be measured by running levels. Gages can be reset or gage readings can be adjusted by applying corrections based on levels (Kennedy 1983, p. 6).

   Each set of levels should be posted to the level summary spreadsheet and saved under the Streamflow Records Folder as: StationName StationNumber LevelSummary.xls. It is the responsibility of the hydrographer working the station records to ensure that level field notes have been checked, the front sheets of the field notes are complete and correct, and the information has been listed in the level-summary spreadsheet.

   The individual computing the record is required to check field notes for indications that the gages were reset correctly by field personnel. If gages have not been reset correctly to agree with the levels, the

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individual working the record informs the field personnel responsible for the upkeep of that specific station as to the need for correcting the gage setting. This information is communicated either orally or in writing. The individual computing the records makes appropriate adjustments to the gage-height record by applying datum corrections.

- ❑ Post survey measurements to Level Summary sheet.
- ❑ Print and place a copy of the Level Summary in the master file.
- ❑ Save the data from each survey as StationName StationNumber Survey.xls

5. Compile and import stage record.

Surface-water gage-height (stage) data are collected as continuous record typically every fifteen minutes in the form of electronic transmissions in electronic data recorders. Stage data should be imported into WISKI© after returning from a site visit. Before importing data into WISKI© save the data as a CSV file. After importing each parameter press F5 to update the database.

Ensuring the accuracy of gage-height record is a necessary component of ensuring the accuracy of computed discharges. Gage-height record is assembled for the period of analysis in as complete a manner as possible. Periods of inaccurate gage-height data are identified and then corrected by gage height corrections, shifts, or deleted as appropriate. Items included in the assembly of gage-height record and procedures for processing the data are discussed in Kennedy (1983, p. 6), and Rantz and others (1982, p. 560 and p. 587).

Computation of streamflow records includes ensuring the accuracy of gage-height record by comparisons of gage-height readings made by use of independent reference gages, comparison of inside and outside gages, examination of high-water marks, examination of data obtained at crest-stage gages, and confirmation or updating of gage datums by levels.

Records computation includes examination of gage-height record to determine if the record accurately represents the water level of the body of water being monitored. Additionally, it includes identifying periods of time during which inaccuracies have occurred and determining the cause for those inaccuracies. When possible and appropriate, inaccurate gage-height record is corrected. When corrections are not possible, the erroneous gage-height data are removed from the set of data used for streamflow-records computation. All missing gage-height records should be documented. Specifically, the period and the reason for the missing record should be listed in the station analysis.

- ❑ Import original stage data into StationName.S.1.O
- ❑ Import staff gage reading into StationName.S.Obs.SG

6. Compile and import water temperature data.

Water temperature data are collected as continuous record typically every fifteen minutes in the form of electronic transmissions in electronic data recorders. The pressure transducers that ADF&G typically use are capable of also measuring water temperature.

- ❑ Import water temperature data into StationName.WT.

7. Determine gage height corrections and apply to stage record.

The gage height corrections spreadsheet provides a summary of gage height corrections: 1) datum, 2) recorder, and 3) transducer drift applied to the stage record. A summary of each correction is detailed below.

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A) Datum Corrections – A correction applied to the stage record to compensate for the effect of settlement or uplift of the gage usually is measured by levels and is called a "datum correction" (Kennedy 1983, p. 9). Datum corrections are applied 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, the change is assumed to have occurred gradually from the time the previous levels were run, and the correction is prorated with time (Rantz and others 1982, p. 545). Datum corrections are applied when the magnitude of the vertical change is greater than 0.015 ft.

B) Recorder Corrections – In some cases, the recorder may not be set to the same datum as your primary reference gage. The gage height record should be corrected to agree with the reference gage.

C) Transducer Movement/Drift Corrections – At times, something may disturb the transducer and actually raise or lower it in the water column. This correction is likely evident as a rapid unexplained change in gage height level. Transducer drift is the unexplained variation in the difference between the recorder and the primary reference gage. Over time transducers typically will slowly record a higher or lower stage in relation to the reference gage. If a consistent difference greater than +- .03' is found a gage height correction should be applied to the stage record. Corrections also should be made at discrepancies of .01 ft if the effect of the change in stage creates a greater-than-5% change in discharge. These corrections are applied in the same manner as datum corrections.

- ❑ Import stage corrections into StationName.S.DC.E
- ❑ Apply S.DC.E to S.15.E to create S.15.R time series.
- ❑ Plot S.15.E, S.15.R, and S.DC.E. Check to make sure S.DC.E was applied to S.15.E correctly.
- ❑ Summarize the gage height corrections and how they were applied under the "Datum Corrections Paragraph" of the station analysis. A table of corrections may be included if it helps to clarify the corrections.
- ❑ Save a copy of the Gage Height Corrections spreadsheet in the Streamflow Records Folder as: Station Name Station Number Gage Height Corrections.xls
- ❑ Print and place a copy of the Gage Height Correction spreadsheet in the master file.

8. Check discharge 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. Measurements and field notes that contain original data are required to be stored indefinitely (Hubbard 1992). Measurements and other field notes for the water year that is currently being computed are filed in the current year primary folder. Measurements and notes for previous water years are filed in the station-records archive drawer.

It is SARCU policy that, at minimum, all high-water measurements and all measurements that vary from the current rating by 5% or more are checked. For conventional measurements, that check includes a check of computations and the procedure, such as stationing, number of sections, use of proper meter, correct gage height, and proper transcription of numbers. For measurements computed using an automated discharge-measurement calculator, only the procedural check will be made. The procedural check may be done by any hydrographer other than the hydrographer who made the measurement.

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It is the responsibility of the hydrographer who works the records for each station to ensure that the measurement note sheets are correct, that the information stored in the computer files agrees with the measurement note sheets, and that an updated printout of the measurement list is contained in the technical folder.

- ❑ Check that discharge measurement note sheets have been completely filled out. Make sure all pertinent information; station number, date, gage height, discharge, control condition, meter used, discharge measurement number, etc. are included.
- ❑ Check to make sure each discharge measurement was computed correctly. Check to make sure the discharge measurement note sheets, flow summary spreadsheet, and discharge measurement data values imported into BIBER© are all the same (especially staff gage reading, discharge, and date).
- ❑ Import discharge measurement data into BIBER©.
- ❑ Place a copy of each discharge measurement in the master file.

9. Develop Rating Curve

The development of the stage-discharge relation (rating) is one of the principal tasks in computing discharge record. The rating is usually the relation between gage height and discharge (simple rating). SARCU personnel follow procedures for the development, modification, and application of ratings that are described in Kennedy (1984). SARCU 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).

In general, changes in the stage-discharge relation that tend to be temporary are addressed through the use of variable-stage shifts. It is, however, left to the discretion of the hydrographer working the station records to determine if changes in the relation are addressed with shifts or if conditions warrant the introduction of a new rating. It is acceptable to introduce new ratings particularly if a new curve facilitates the quality and speed of record computation.

In general, changes in the stage-discharge relation that are deemed to be relatively stable warrant the introduction of new ratings, and well-defined trends also warrant new ratings. It is the responsibility of the hydrographer working the records to fully develop the new rating; enter all input values and offsets into the computer, and plot the new rating along with the measurement data.

Rating numbering:

- ❑ Plot discharge measurements and observed staff gage values in SKED©.
- ❑ Plot regression line through discharge values.
- ❑ Make rating curve by opening rating curve manager and clicking new rating curve version. Set up rating curve upper/lower limits, rating curve validities, etc.
- ❑ Update station analysis rating paragraph with number of discharge measurements taken during the year. Include the range in stage and discharges used to develop the rating. Note any measurements not used for the rating analysis and why they were not used. Note any ice affected measurements.

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10. Apply shifts to stage record.

A correction applied to the stage-discharge relation, or rating, to compensate for variations in the rating is called a shift. 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). Shifts can be applied to vary in magnitude with time and with stage (Kennedy 1983, p. 35). It is SARCU policy that shifts are applied in the form of variable-stage shifts.

Shifts are applied when field measurements rated "GOOD" indicate a temporary deviation of 5% or greater in discharge from the current rating. Shifting allowances change to 8% for measurements rated "FAIR." For those measurements rated "POOR," it is on a case-by-case basis as to how much weight the measurement is given or if it is used at all.

The hydrographer who works the station records documents the shifts by describing the shift magnitude and time of application in the station analysis and by including the shift-analysis printout and the shift-bar-diagram plot with the station analysis. The shift-diagram points should be plotted on a copy of the work rating so that the hydraulic logic of the shift curve can be seen. It is the responsibility of the checker to ensure that the logic and procedures used in developing and applying the shifts are correct and that the shifts are documented fully.

- ❑ If necessary develop stage shift diagrams to assure discharge measurements used in the rating analysis are all within the rated discharge measurement accuracy.
- ❑ Apply stage related shifts to gage record. Import stage related shifts into StationName.SRS.I and apply to S.15.R to create S.Adj.15 time series.
- ❑ Plot S.15.R and S.Adj.15. Check to make sure shifts were applied correctly to S.15.R.
- ❑ Update the shift analysis with the correct shifts and make sure all discharge measurements used in the rating analysis plot within the rated measurement accuracy.
- ❑ Update rating analysis paragraph to include a description of each stage shift diagram used. Include periods each were applied and rationale for starting and ending each. Note periods that rating was applied direct (no shifts). Also note the maximum percent measurements are off from rating after shifting.

11. Create Q.15 time series.

The 15 minute stage record time series has been corrected for gage height corrections and shifts and is now ready to be converted to fifteen minute discharge using the appropriate rating curve.

- ❑ Apply rating curve to S.Adj.15 to create Q.15 time series.

- ❑ Check to make sure the rating curve and shifts have been applied correctly by plotting (Q.Obs) and Q.15 values. The Q.Obs should plot close to the Q.15 concurrent value (i.e., within the measurement rated accuracy).

-continued-

12. Create Mean daily flow Time Series.

    With few exceptions, for each gaging station operated by ADF&G, a discharge value is determined and stored for each day. Daily mean discharges are one of the major products of the records-computation process. It is the responsibility of the hydrographer who works the records to determine that the calculated daily mean discharges accurately represent the actual streamflow conditions.

    - ❑ In WISKI© create Q.MeanDaily. O and Q.MeanDaily.E time series.

13. Identify and estimate ice affected, missing, or bad discharge records.

    The individual computing the station record is responsible for identifying ice-affected periods, missing gage-height record, and bad data. These identified periods need to be estimated in the daily mean discharge (Q.MeanDaily.E) time series and documented in the station analysis.

    Computing records that represent winter periods for gaging stations 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). Some of the record may be missing due to transducer malfunction, battery issues, data storage limits, etc and will need to be estimated. Discharge values from gage sites at tidally influenced locations may be affected by backwater from the tides and may need to be estimated.

    Streamflow patterns associated with the occurrence of ice can be identified and estimated by plotting the original mean daily flow (Q.MeanDaily.O), editable mean daily flow (Q.MeanDaily.E), 15-minute discharge (Q.15), discharge measurements (Q.Obs), and transducer water temperature (WaterTemp.15). A time series that can be plotted in WISKI© or a spreadsheet can also be created that details daily max/min air temperature, precipitation, and snow on the ground data from a nearby weather station. Hydrographic comparisons with nearby gaging stations are useful to estimate daily mean discharges. Generally, records are considered poor for days that discharges are determined by estimation.

    - ❑ Estimate mean daily flow (Q.MeanDaily.E) for identified ice affected, missing, and bad record time periods using hydrologic comparisons of nearby stations, weather records, trends of the hydrograph, and instantaneous discharges to. DO NOT estimate 15-minute discharge values.
    - ❑ Update the gage paragraph of the station analysis with the periods of ice affected days and other periods of missing or estimated days, reason if known, and how missing or ice affected records were determined.
    - ❑ A mean daily flow value (Q.MeanDaily.E) for each day within the water year should now be available.

14. Within WISKI© summarize mean monthly flow (Q.MeanMonthly) and average annual flow (Q.QAA) values for the water year.

    - ❑ Save a copy under the Streamflow Records Folder as: StationName StationNumber StationAnalysis.doc.

15. After completion of the streamflow records for the water year hard copies of the following station records should be placed in the master file.

    - ❑ Station Description
    - ❑ Level Summary

-continued-

- ❑ Discharge Measurements
- ❑ Discharge Measurements Summary
- ❑ Rating table/s and curves
- ❑ Shift Analysis
- ❑ Gage Height Correction Summary
- ❑ Station Analysis

APPENDIX D: SURFACE-WATER DATA FORMS

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

River at -

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

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

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

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: ________

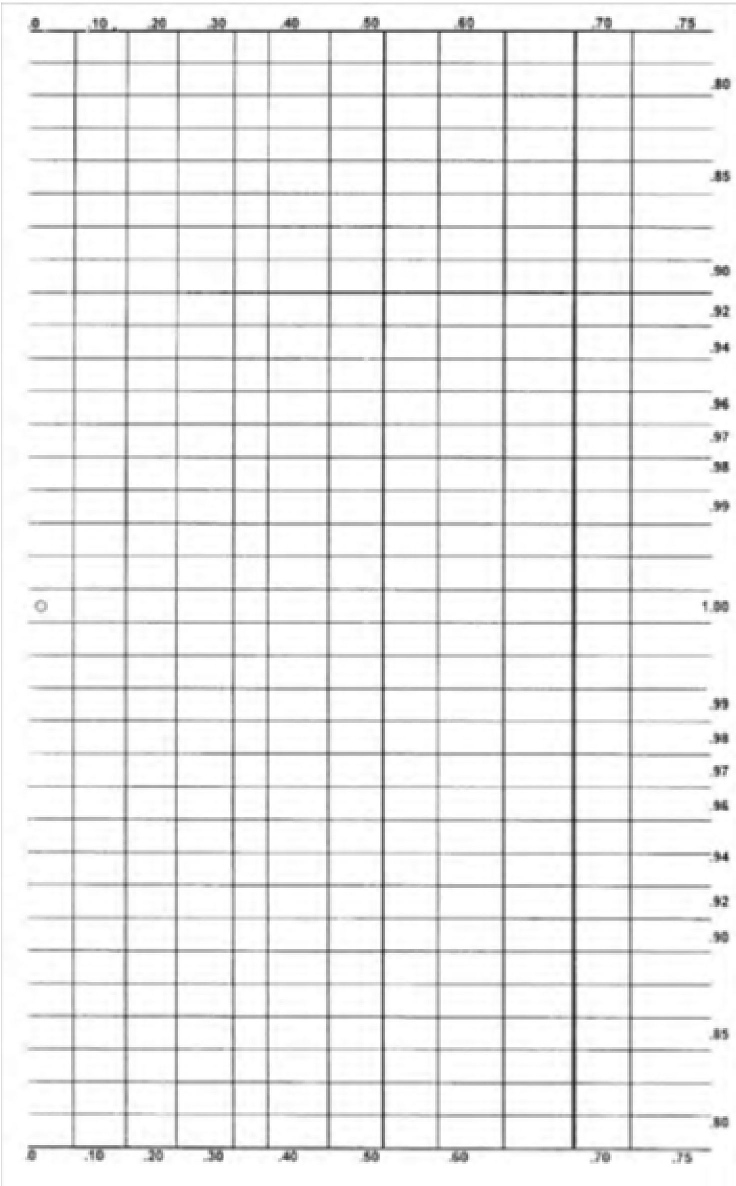
Gage operating: ________ Record Removed ________
Battery voltage: ________ Intake/Orifice cleaned/purged: ________
Bubble-gage pressure, psi: Tank ________, Line ________; Bubble-rate ________ /min.
Extreme-GH indicators: max ________, min ________.
CSG checked: ________ HWM height on stick ________ Ref. elev. ________ HWM elev ________
HWM inside/outside: ________
Control: ________

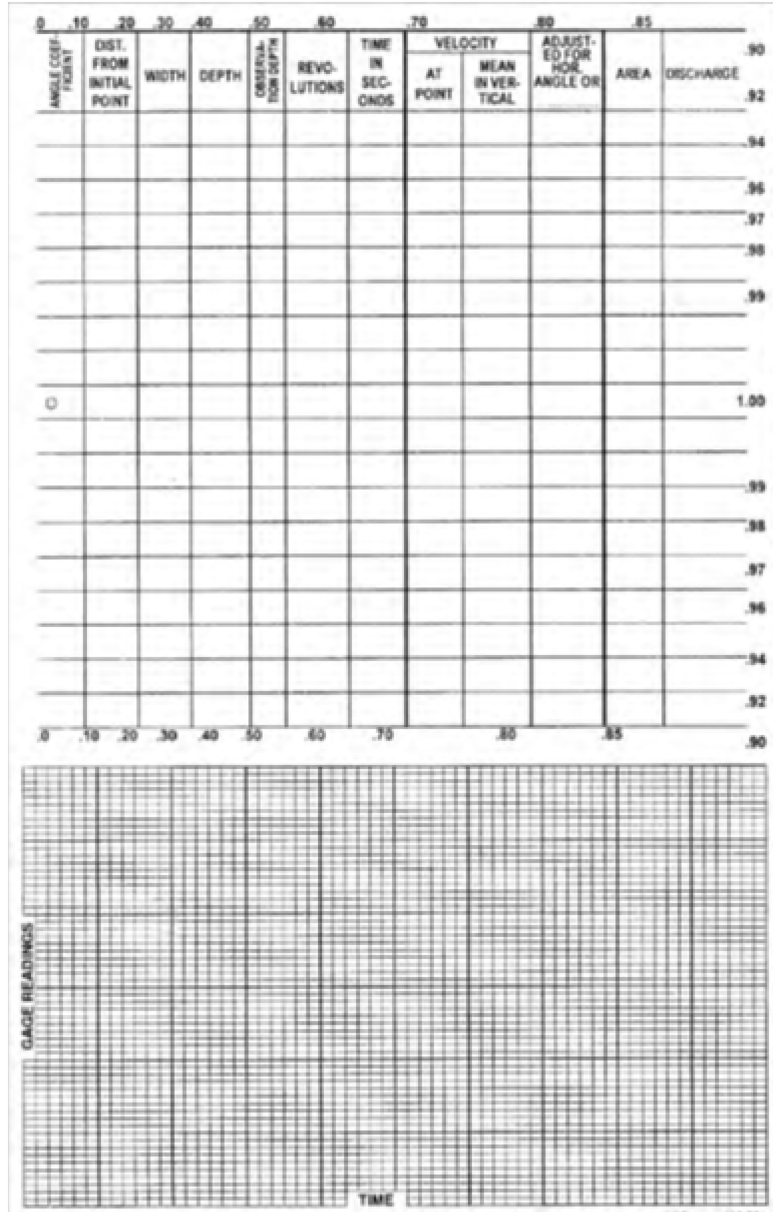
Remarks: ________

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

Sheet No. ________ of ________ sheets

-continued-





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

WATER RESOURCES DIVISION

SUMMARY AND ADJUSTMENTS OF GAGING STATION LEVELS

STATION ______________________

DATE ______ PARTY ______________________

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 D3.–Example ADCP Discharge Measurement Form.

9-275-I	10/24/08	U.S. DEPARTMENT OF THE INTERIOR ***U.S. Geological Survey***	*Meas. No.*	
Station Number			*Processed by*	
		ADCP Discharge Measurement Notes	*Checked by*	

Station Name			
Date	*, 20_____*	*Party*	

Width	*Area / Rated Area*	*Velocity*	*Index Vel.*	*Gage Height*	*Discharge*

Gage Height Change	*Meas. plots*	*From rating*	*Shift*	*ADCP Sync'd to WT*
in hrs.	*% diff*	*No.:*		*Y at ______ or N*

ADCP Mfr / Model / Frequency	*Serial No.*	*Firmware*	*Software*

Boat/Motors Used	*GPS Used*	*ADCP Depth*	*Diag. Test / Errors?*
			☐ *Y or N*

Compass Calib. & Total Error		*Mag. Var*	*MagVar Method*	*Moving Bed?*
Y or N			*On-site Model Previous*	*Y or N*

Meas. Water Temp	*ADCP Water Temp*	*Weather / Air Temp*	*Wind Speed / Dir.*
°F / C at	*°F / C at*	*°F / C*	

Gage Readings							***Site Conditions***	
Time					*Inside*	*Outside*	*Max Water Depth*	
							Max Water Speed	
							Max Boat Speed	
							Water Mode	
							Bottom Mode	
							Streambed material	
							Salinity	
							ppt at	
Weighted MGH							*Checkbar found*	
GH corrections							*Checkbar changed to:*	
Correct MGH							*at*	

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:		
Control:		

Gage operating:	*Y or N*	*Record removed:*	*Y or N*	*Filename:*	
Battery voltage	*V*	*Intakes/Orifice cleaned/purged:*			
Bubble-gage psi:	*Tank*		*Line*	*Bubble rate*	*/ min*
Extreme-GH indicators:	*Max*		*Min*	*CSG Checked*	*Y or N*
HWM on stick		*Ref elev.*		*HWM elevation*	
GH of zero flow = GH		*- depth at control*	*=*	*ft,*	*Rated=*
		Sheet No.	*of*	*sheets*	

-continued-

Acoustic Profiler Discharge Measurement Notes							**Filename Prefix:**
Left Bank:	Sloping Vertical Other:______________					Right Bank:	Sloping Vertical Other:______________
Transect No.	**Starting**			**Ending**		Total Discharge	Notes
	Bank	Time	Distance	Distance	Time		
	L R						
	L R						
	L R						
	L R						
	L R						
	L R						
	L R						
	L R						
	L R						
	L R						
	L R						
	L R						
	L R						
Notes							

Appendix D4.–Example ADV Discharge Measurement Form.

9-275-x	01/24/2007	U.S. DEPARTMENT OF THE INTERIOR	Meas. No.	
Station Number		*U.S. Geological Survey*	Comp. by	
		ADV Discharge Measurement Notes	Checked by	

Station Name			
Date	, 20_____	Party	

Width	Area	Velocity	SNR	Gage Height	Discharge

Method	# Sections	Gage Height Change	
		in hrs.	

Diagnostic Test File	Std Velocity Profile	Measured Water Temp	Weather
	Y or N or Uncertain	°F / C at	
Raw Data File	**ADV Sync'd to WT**	**ADV Water Temp**	**Wind Speed / Dir.**
	Y at ______ or N	°F / C at	

Manufacturer	Model	Serial No.	Firmware	Software

Gage Readings									
Time					Inside	Outside			
							Rating number	
							Percent from rating	
							Indicated shift	
							Rain gage serviced/calibrated	
							Salinity	
							ppt at	
Weighted MGH							Checkbar found	
GH corrections							Checkbar Changed to	
Correct MGH							at	

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	
Control	

Gage operating	Y or N	Record removed	Y or N	Filename			
Battery voltage	V	Intakes/Orifice cleaned/purged					
Bubble-gage psi	Tank		Line		Bubble rate	/ min	
Extreme-GH indicators:	Max		Min		CSG Checked	Y or N	
HWM on stick		Ref elev.		HWM elevation			
GH of zero flow = GH		- depth at control		=	ft,	Rated	
Remarks							

	Sheet No.		of		sheets