TECHNICAL APPENDIX

TO

METHOW BASIN STREAMFLOW MONITORING PLAN

TECHNICAL PROCEDURES AND SPECIFICATIONS

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1. INTRODUCTION

This technical appendix provided detailed technical procedures, equipment specifications, and forms for implementing the Methow Basin stream gage plan. This appendix is directed at the proposed county/Planning Unit stream gaging, not the proposed USGS gaging.

1.1 Recommended Equipment and Specifications

The equipment necessary to implement the stream gage plan is outlined on Tables 1 and 2. Table 1 shows the equipment necessary for measuring stream discharge with a current meter. Table 2 shows the equipment necessary for measuring and continuously recording river stage.

A current meter is necessary to measure the stream velocities. There are two basic types of meters available: a vertical axis type meter and an optical meter. Price AA and pygmy meters are common vertical axis meters, and Swoffer meters are common optical meters. Optical meters are a newer and more versatile technology, while vertical axis is a long-used standard method. We recommend using a Swoffer 3000 optical meter. Optical meters require less maintenance and are more accurate at measuring velocities in shallow streams at low flow. The Swoffer meter has a number of features that are also desirable, including a variety of wands, and a digital read-out with data recording capability. Technical specifications for the Swoffer 300 are provided in Attachment A. Other equipment necessary for streamflow measurements are readily obtained at a hardware store or field equipment supplier such as Forest Supply Inc..

A pressure transducer with a data recording device is necessary for continuously measuring stream stage. There are a number of transducer/datalogger systems available on the marketplace. We recommend using Instrumentation Northwest's Aquistar System. There are a number of reasons for this recommendation. Our 15 years of experience with these systems has been favorable and the technical support is both responsive and local (Redmond, Washington). The systems are dependable and versatile, with a number of hardware configurations and enclosure options. Different types of sensors are available to measure pressure, temperature, and water quality, while using the same data logger. It is desirable to establish a single monitoring "platform" for both surface water and groundwater so that interfaces and processing procedures can be standardized to the equipment, and there are not multiple instrument types at various locations. We recommend using the Aquistar XL-5 4-channel datalogger with a NEMA-4 lockable, weatherproof enclosure. This data logger can record up to 4 parameters and has the capability to interface with a modem or cellular phone if, at some time in the future, remote monitoring is desired. The PS9800 sensor is a two-channel sensor that measured pressure and temperature, and connects directly to the XL-5 datalogger. Technical specifications for the XL-5 datalogger and transducer are provided in Attachment A. Other equipment necessary for installing and monitoring dataloggers are available at a hardware store or field equipment supplier such as Forest Supply Inc.

Collection and management of streamflow data will require a computer and software. Portable computers are necessary to download data from the dataloggers. The Aquistar systems are supplied with software for downloading and displaying data. We recommend that two portable computers be purchased for the streamflow program. One computer would have minimal processing requirements, and would be used primarily as a field computer for downloading data. The second computer should have somewhat higher processing capabilities in order to process the data using a database or spreadsheet program. Licenses for a PC spreadsheet and/or database program, such as Microsoft EXCEL or ACCESS will also need to be purchased.

2. TECHNICAL SPECIFICATIONS AND PROCEDURES

2.1 Gage Installation

Criteria for establishing and operating gaging stations and streamflow measurement are available from the USGS and a good electronic link to this information can be found at www.recamn/.wr.usgs.gov/sws/fieldmethods/. The discussion below is a synopsis of the standards, but is not a substitute for becoming familiar with these documents.

2.1.1 Site Selection

After the general location of a gaging site has been determined, the precise location is chosen to take advantage of the best locally available conditions for stage and discharge measurements. Figure 1 shows a typical stream gage site layout. The most important location criteria is for the stream gages to be installed upstream of stable hydraulic controls that are sensitive to discharge changes. Hydraulic controls govern the water level at the station and determine the stage-discharge relation. The stability of the control is important because it maintains the consistency and stability of the stage-discharge relation. If the hydraulic control is not stable than the stage-discharge relation needs to be determined every time the control changes. The hydraulic control should be sensitive to discharge so that whenever there is a change in discharge there is a concurrent change in water level.

Hydraulic controls can include section controls and channel controls. A section control occurs where the channel width is reduced, including natural constrictions caused by bedrock or artificial constrictions, such as a bridge or box culvert, that make the channel narrower. An increase in downstream slope also produces a section control. Examples of these are heads or riffles, cascades, waterfalls or weirs. Channel control occurs when the natural roughness of the channel perimeter (bed and banks) controls the velocity, which, in turn, controls the depth of water. A long, straight stream reach with a uniform cross-section is an example of channel control. The ideal conditions for a gaging site are:

1. The streambed and banks are stable and banks are high enough to contain floods.
2. Total flow is contained to one channel at all flows and has little to no subsurface flow.
3. Unchanging reach controls are present downstream and a pool is present upstream from the control so that water stage can be read at extremely low flows and flood velocities are moderated. The flow should be perpendicular to the control.
4. The gage is far enough upstream from a confluence to insure no backwater effect.
5. The stream is relatively straight for about 300 feet upstream and downstream of the gage.

6. A satisfactory discharge measurement cross-section is close to the gage. It is not necessary to have the same discharge cross-section for high and low flows.
7. The site is accessible for measurement and maintenance.

2.1.2 Installing a Gage

The elevation datum for the stream gages should be set to two or three permanent benchmarks (reference marks). The benchmarks must be located on stable ground or structures and be separate from the recorder. The gage datum is usually set at an elevation of zero flow. The gage datum should be maintained as a permanent datum. The NAVD datum for the gage is recommended for reference benchmarks. The datum can be surveyed in through differential leveling, laser-level survey, or by survey grade GPS (± 1 cm accuracy). The location and elevation of the pressure transducer needs to be determined so that if it is disturbed it can be reset. Painted gradations or a tape with gradations to 0.01 feet attached to the pressure transducer housing can be referenced to the staff gage.

Non-recording staff gages are established near the pressure transducers and are used as the reference gages. The pressure transducer or other recording instrument is set to the staff gage. In some cases, more than one staff gage will be necessary, for instance, a low-flow gage, and a high-flow gage. The second staff gage is auxiliary and is set to the reference staff gage. The preferred staff gage is the standard vertical gage consisting of porcelain-enameled iron sections, each 4 inches wide by 3.33 feet long. The gages are graduated every 0.01 feet. The staff gage should be mounted on a 2-by-4 wood post (Figure 2). These can then be installed on permanent rocks or other structural features near the gage, preferably in a pool that will have water during low flow and be protected from flood velocities, floating debris, or moving rocks.

The staff gage is read by an observer, at first on a daily basis, then on a weekly basis using Form 1 in Section 4. These forms can be copied on Rite-in-the-Rain paper or similar waterproof material. Observers can be volunteers who live near the gage. The purpose of this is to develop the relationship between the water level read on the staff gage and water level measured by the pressure transducer. It also provides an indication of when the pressure transducer needs re-calibration because of drift in electrical signals.

If a self-logging pressure transducer is used, it can be installed in 2 inch I.D. PVC pipe, schedule 40 or ABS sewer drain pipe. The PVC schedule-40 electrical conduit (light gray with UV protectors) provides the greatest protection for the sensor and datalogger. Its can be bought with pre-formed bends that conform to stream banks. The pipe may be buried in the river bank, secured with rocks, or fastened to the bank with large staples made by bending pieces of concrete reinforcing steel in half and driving them into the bank. Drill several large (1/2" diameter) holes in the PVC near the sensor location in order to eliminate velocity effects on the sensor. Also, a smaller 1/4" hole should be drilled near the top of the pipe to allow air movement when the water goes up and down

(Figure 3). A standard slip cap or a locking well cap can be used to protect the top of the datalogger. You can also adapt the pipe for a screw-on cap.

In areas where there is a problem with vandalism, a 2" galvanized pipe may be used for the entire stilling pipe. Plastic pipe, adapted to this steel pipe above water, may be used for the underwater section since you don't want to add zinc to potential fish incubation sites. The proposed dataloggers include a locking NEMA 4x enclosure. Two small pipe wrenches are required to access the datalogger, but this installation makes it more bullet and vandal-proof.

Pressure transducers generally require calibration before they are used. Calibration provides the equation used to convert the electrical signal into head pressure or water depth. Most commercial pressure transducers come with instructions and software to calibrate the sensors.

2.1.3 Reading the Staff Gage

Read the gage to the nearest 0.01-foot. Sometimes it is difficult to see the water line when making observations under the conditions of poor light or clear water. Floating a small piece of wood, such as a Popsicle stick or matchstick, against the gage helps to define the water line. When the water level is surging, the stage is the mean of the elevations of the peak and trough of the waves. The date, time, and weather are recorded with the staff gage level (Form 1, Section 5).

Directions on reading and downloading pressure transducer data depend on the manufacturer. The recommended Aquistar datalogger includes software for downloading.

2.1.4 Maintenance of Gages

Gages should be maintained to an accuracy of ±0.02 feet. This requires that the datum be maintained at an accuracy criterion of ±0.02 feet. This is ensured by standard surveying techniques and running a level from reference benchmarks to gage datum every 2-3 years, and adjusting the gage, if necessary, to restore original datum. Flow events, human intervention, or animals (livestock or wildlife) may disturb non-recording staff gages and recording gages. Settlement or uplift of the structure supporting the staff gage may disturb the gage datum. Where levels from a reference mark show disturbance of the datum of a vertical staff gage or the housing of the pressure transducer, it will be necessary to reset the individual gage sections and pressure transducer.

Dataloggers run on batteries. The life of the battery depends on the sampling interval and manufactured unit. This information is generally contained in the manufacturer's user manual. The electrical signals generated by the pressure transducers may "drift" or show a changing trend in the lineal relationship between pressure exerted by water and the depth of water. Pressure transducers must be periodically checked for changes in their relation between pressure and water level. If there are changes than the pressure transducer will need to be re-calibrated. Most can be recalibrated in the field as per manufacturer's specifications. The equipment needed generally includes a computer (laptop or palm) that includes the calibration software, a calibration tube (e.g., 4-inch ID PVC pipe sealed at one end, and a tape, or yardstick graduated in 0.01-feet intervals. The length of the pipe should be 3 feet.

2.1.5 Missing or Inconsistent Records

The datalogger records should be examined routinely for abnormalities. This will help eliminate missing and inconsistent records where equipment are to blame. When the data are downloaded, they should be checked on-site for inconsistencies. For example, sudden decreases or increases in water level unless caused by precipitation or changes in diversions should not occur. If there are inconsistencies and no record of precipitation, such as during August or September, then the diversion gages should be checked. If there are no modifications to the diversion record, then the pressure transducers at the stream gage may not be working properly or the batteries need replacing. Other potential causes could be interference by humans, plugging of the intake holes, or the effects of ice or backwater during the winter and high flow periods.

The use of weather records, hydrographic comparison of records of flow upstream or downstream or on similar drainages in area, or calculation of ground water effluent to the stream are reliable and consistent methods for estimating flow during periods of missing record. They can be used to determine if the effect is due to backwater from ice or floods. The observers should note conditions of ice or backwater when collecting the field data.

2.2 Measuring Discharge

Discharge, expressed as volume per unit time (e.g., cubic feet per second, cubic meters per second), is the rate that water flows through a cross-section. The relationship between discharge (Q) and water depth (d), velocity (v), and width (w) is

$$Q=d*v*w$$

The traditional current meter method of discharge measurement requires of width, depth, and velocity to be measured at intervals in a cross section of a stream. The current meter is used to measure velocity. Discharge cross-sections are chosen based on standard criteria:

- The water velocities at all points are parallel to one another and at right angles to the cross-section of the stream.
- The curves of velocity distribution in the section are regular in the vertical and horizontal planes. The flow is relatively uniform and free of eddies, slack water or excessive turbulence.
- The bed of the channel is regular and stable.

- Minimum water depth is 0.5 ft (0.15 m) when using Price AA meter and 0.3 ft (0.09 m) when using a Pygmy meter or optical-type meter (e.g., Swoffer meters).
- Streambed is relatively uniform and free of numerous boulders or heavy aquatic growth.
- There is minimal formation of slush or frazil ice.
- The discharge cross-section is relatively close to the gaging station control with no tributaries or groundwater seepage between these two points.

Usually, all these criteria cannot be met, especially in mountainous areas. Low flow discharge cross-sections and high-flow discharge cross-sections may not be the same for a given gage. Figure 4 shows an example cross-sectional stream profile showing measurement locations and widths.

During lower flows, discharge for most of the stations can be measured with a wading rod and current meter.

Procedure:

Equipment: Current meter, timing mechanism, wading rod, tape, taping pins, rebar for marking cross-section, carabineers, pony clips, hand level, angle of coefficient chart, Form 2, and waders. In winter, warm clothing and a thermos of hot water to thaw the meter if necessary. Survey equipment will be needed if this is the first time out to the site. Refer to end of Section 4 for additional equipment lists.
Steps:

1. Establish location of discharge cross-sections and mark for future use if appropriate. If this is the first time using this discharge section, we recommend that the cross-section profile and channel slope be surveyed. The stage of zero flow is usually the lowest point on the downstream hydraulic control. Thus the control should be surveyed and the distance thalweg (deepest part of the flowing channel) between the discharge cross-section and the control be measured. This information can also be used for extrapolating rating curves. Reference the stage of zero flow to the staff gage.
2. Using taping pins and pony clips to fasten zero end of tape on right bank (looking downstream). Stretch tape across to left bank. Make sure that the tape is at right angles to the flow. Use the hand level to level tape and then secure to left bank.
3. Note the right and left edge of water on discharge measurement form (Form 2).
4. Calculate the width of water and use to establish the measurement intervals for the cross-section. The widths should not be evenly spaced unless both the cross-section and velocity distribution seem uniform. The following criteria are used to determine the width of the intervals.

The accuracy of a discharge measurement depends on the number of verticals at which depth and velocity are measured. Generally 25-30 verticals should be measured. The interval between any two verticals should not be greater than 1/20th of the total width. Observation verticals should be located to best define the variation in elevation of the streambed and the horizontal variation in velocity. Discharge between any two verticals should not exceed 5% of the total discharge. If previous discharge measurements show that the velocity distribution is relatively uniform than less than 25 verticals can be used.

5. Write down stream name, location of cross-section in relation to control and gage, staff gage level, time, date, type of meter, weather, water temperature, and control conditions before beginning measurement (Form 2).
6. Start measuring from right edge of water. Note the tape distance at the point of measurement. Use the wading rod to measure depth. If the water depth is less than 2.5 ft for a Price AA meter or 1.5 ft for a Pygmy or optical meter then measure velocity at 0.6 depth below the water surface. If water depths are greater than the criteria stated above, then the two-point method should be used. This requires measuring velocity at 0.2 and 0.8 depths of water. The average of the two velocities are taken as the mean velocity for the vertical.
7. Velocity is measured by counting the revolutions of a current meter rotor during a time period not less than 40 seconds. Do not stand where it would disrupt the current the meter is measuring. It is preferable to stand to the side and behind the meter. The wading rod must be held perpendicular to the water surface and the current meter parallel to the flow. After the meter is placed at the proper depth and pointed into the current, allow the rotation of the rotor to become adjusted to the speed of the current before beginning timing. If flow is pulsating than velocity should be measured for a longer period (not to exceed 3 minutes). Digital meter readouts have simplified this task somewhat. Write the velocity on the form.
8. If flow in any vertical measurement section is not at right angles to the tape, then a correction has to be made to the velocity reading. The correction is made using an angle of coefficient card (Form 3). The angle of coefficient for flow at right angles is 1.0. The method of using the angle of coefficient is on the card.
9. Write staff gages reading and time at end of measurement on Form 2.
10. Calculate discharge before leaving site. The measured widths, depths, and velocities permit computation of discharge for each segment of the cross-section. The sum of these segment discharges is the total cross-section discharge. Discharge is calculated using the mid-point method:

$$q_x=v_x*d_x*[(b_{(x+1)}-b_{(x-1)})/2],$$

where q_x is the segment discharge, v_x is the segment velocity, d_x is segment depth. The segment width is calculated by subtracting the tape measurement at the previous segment ($b_{(x-1)}$) from the tape measure at the next segment ($b_{(x+1)}$) and dividing the difference by 2. For example, segment x is located at 30 feet on the tape. The previous segment is located at 28 feet and the next segment is located at tape measure 32 feet. Then the width of segment x is (32-28)/2 or 2 feet. The sum of the q_xs is the total discharge.

11. If there is a rating curve, compare the observed water stage and discharge with the values on the curve.
12. Download the data from the sensors. Compare the water level reading with the reading on the gage.

Some of the gages may not have good discharge cross-sections where the predominant bed material consists of boulders or the channel slope is steep. These conditions create turbulent flow that can produce ±20% error in discharge measurements made with current meters. Under turbulent flow or non-wadable flow conditions, dilution methods can be used to calculate discharge. This method is described in Appendix B.

2.2.1 Angle of Coefficient Measurement

Currents that approach the measurement section at an oblique angle, that is not at a 90 degree angle to the measurement tape, must be corrected to find the true velocity. The velocity meter must be kept parallel to the flow. When the meter is not held 90 degrees to the tape (Figure 5) then the velocity measured is higher than the true velocity. The angle of coefficient is used to correct these velocities. The angle of coefficient is equal to the cosine of the angle α in Figure 5. The angle of coefficient can be determined by using a protractor. When the current meter is at 90 degrees to the tape measure than the angle of coefficient is equal to 1.0.

2.2.2 Operation, Maintenance, and Calibration of Current Meters

All current meters need to be maintained to ensure accurate velocity readings. Before using the meter, it should be inspected for wear or damage to the rotor and shaft alignment, bucket wheel and cups, pivot and bearings, contact chamber and tailpiece. The procedures are outlined in the USGS report "Calibration and Maintenance of Vertical-axis Type Current Meters;" a copy is provided in Attachment B. *A spin test is used to determine the condition of the bearings. Place the meter so that the shaft is in a vertical position and the bucket wheel is protected from wind. Give the bucket wheel a quick turn by hand to start it spinning and timed till it stops spinning. It should not stop abruptly and should spin freely for at least 1.5 minutes, preferably 4 minutes.*

At the end of each day's use, more often in turbid water conditions, Price AA and pygmy meters need to be thoroughly cleaned and oiled. Special attention should be made to the pivot and pivot bearing. The procedure is outlined on pp. 11 of the USGS report "Calibration and Maintenance of Vertical-axis Type Current Meters"; a copy is provided in Attachment B.

Meters should be recalibrated after 300 hours of use or every 2 years, whichever comes first. Procedures for recalibration are in the USGS report in Attachment B.

Optical meters need less maintenance than the conventional Price meters. The spin test described above still applies. Optical meters also should be recalibrated after 300 hours of use.

Important: Optical meters should not be oiled. Do not touch the optical reader with any oily substance including fingers. Instructions for maintaining cleaning and calibrating optical meters are included in the manufacturer's user's manual.

2.3 Streamflow Computations

2.3.1 Establishing a Stage-Discharge Rating Curve

Water levels recorded by the pressure transducers need to be converted to discharge using the stage-discharge rating equation for the gage. Figure 6 shows an example rating curve. The quality of the relation determines the quality of computed streamflow data. The points for the curve are determined by measuring discharge and reading on the staff gage concurrently for at least 5 points in each range of flow (e.g., low flow range, mean flow range, high flow range).

In a long, straight channel where channel control governs the stage-discharge relation, the rating curve has the form

$$Q=C(h+a)^N$$

Where Q=discharge
C and N=constants
h=stage
a=stage at which discharge is zero.

The stage of zero flow generally occurs when water level becomes less than the lowest point on the hydraulic control. Where there are a series of reach controls different values of C, N, and *a* may apply for each range of flow. The shape of the rating curve is determined by plotting stage on the y-axis versus discharge on the x-axis (Figure 6). Although stage is plotted on the y-axis, it is the independent variable in the equation. This must be remembered when developing the regression equation. The USGS uses logarithmic plotting paper for high flows and normal (arithmetic) plotting paper for low flows to determine the general shape of the rating curve. The curve maybe fitted by eye or analytically. The analytical form of the equation above is:

$$\text{Log } Q=\log C+N*\log (h+a)$$

When a is known, then C and N can be determined through least-squares regression. Where a is not known or cannot be measured, it has to be determined through numerical methods. After a is determined, least-squares regression is used to estimate C and N. Then a is varied and the regression is refitted until the regression error is minimized. In reaches with more than one control, equations must be fitted for each control and a transition point between them determined. The USGS has programs for calculating the stage-discharge rating curves.

2.3.2 Stage Velocity Curve

Plotting mean velocity and cross-section areas on the x-axis versus stage on the y-axis is useful for:

- Extrapolation of ratings.
- Checking for mistakes. For example a deviation in the plotted mean velocity without a concurrent deviation in cross-section area may indicate that the current meter was not working properly creating a deviation between stage and discharge.
- Identifying when scour or aggradation has occurred. In either case, the measured cross-section area departs from other measured cross-section areas for the same stage.

2.3.3 Hydrographs

Daily mean discharge is the average of the measured values for the day, divided by the total number of values used. Thus the 15-minute intervals measured by the pressure transducer would first be converted to discharge using the rating curve. Then these discharge values for each day would be summed and divided by 96 (the total number of 15 values in 24 hours). Daily mean discharge should be computed to the nearest 0.01 cfs (cubic feet per second) for discharges less than 1 cfs; to 0.1 for discharges between 1-10 cfs; and to whole numbers between 10-1000 cfs. The result would be the mean daily discharge. This data will provide the basis for future hydrologic analyses and water balance applications.

The daily mean streamflow and temperature data are visually displayed as time-series graphs. The time-series graph for streamflow is a hydrograph with discharge on the y-axis and time on the x-axis. The thermograph is for temperature. Daily precipitation is graphed on a hyetograph. Both Mazama and Winthrop daily precipitation should be graphed. Discharge and temperature are normally displayed as line graphs while precipitation is shown as a bar graph. Figure 7 shows an example daily hydrograph. Hydrographs of mean monthly flows will also be desirable as more data become available.

2.3.4 Standardized discharge

Discharge should be converted to inches of runoff in order to compare with precipitation and discharge from different sized watersheds. This computation is normally applied to mean monthly or mean annual flows. Discharge is converted to runoff by dividing mean discharge drainage area. Consistency in units must be maintained.

Example: The October mean discharge for the Methow River near Twisp is 425 cfs. The drainage area above the gage is 1,301 square miles. The October mean runoff in inches is calculated as

$$\frac{425 \text{ cfs}*3600 \text{ sec/hr}*24 \text{ hrs/day}*30 \text{ days}*12 \text{ inches}}{(1301 \text{ sq miles}*(5280 \text{ ft})^{\wedge}2)}$$

2.4 Extrapolation of Ratings

Ratings may need to be extrapolated for water levels that are lower or higher than the stage-discharge pairs measured. Where the cross-section is stable (not changing), the simplest method is to extend the stage-area and stage-velocity curves and for desired stage values, take the product of the velocity and cross-section area to discharge values for those stages. However, this will only be useful for conditions where roughness elements do not significantly control the stage-velocity relation. In lower flow conditions, channel bed roughness significantly controls velocity and thus discharge.

2.4.1 Low-Flow Extensions

Low-flow extensions are best done on rectangular-coordinate paper (arithmetic paper) so the coordinates of zero-flow can be plotted (there is no logarithm for zero). In order to do this, the stage of zero flow must be known. Basically a curve is drawn between the measured points and the stage of zero flow. Stage-discharge pairs can then be estimated from that curve.

The Manning's equation can be used to assist in the extrapolation

$$Q=(1.49/n)*d^{0.67}*S^{0.5}*A$$

where Q=discharge in cubic feet per second
n=Manning's coefficient for roughness
d=average depth of water in feet
S=water surface slope or channel slope
A=cross-section area in feet squared

Hydraulic models that are based on Manning's equation or the Chezy equation are relatively simple to use to develop the stage discharge relation beyond that measured. However, an understanding about open channel flow dynamics and the influence of channel and hydraulic characteristics on the stage-discharge relationship is essential for getting valid results.

The information that is needed to use these models are channel slope, cross-section profile for the discharge measurement section, and 3 water surface elevation and discharge measurements at the section that are referenced to the staff gage for calibrating the model. Both can be obtained through standard survey techniques.

2.4.2 Shifts in Rating Curves

The stage-discharge relationship is not permanent and may “shift” or vary over time in response to channel changes, aquatic vegetation, or ice accumulation. Shifting sand channels will not be an issue for gages in the Methow. However, the gages located on alluvial fans and other alluvial surfaces, for instance Early Winters Creek, will change over time. These shifts become evident when several stage-discharge readings deviate from the curve. If the change in rating lasts only a month or two, a new rating curve is prepared for that period. For changes of shorter duration, for instance shifts caused by aquatic vegetation, the old rating curve remains in effect but during the changed period, shifts or adjustments are applied to the ratings to determine the correct discharge. To define the stage-discharge relation during shifting periods, frequent discharge measurements must be made. Shifting controls should not be a problem for gages in irrigation ditches.

Shifts can be caused by changing water slope between rising and falling limb of a hydrograph or by channel storage. For example, the same discharge measured on the rising limb of a high flow peak may have a different stage than the same discharge measured on the falling limb of a peak. This is most likely to occur where the channel slope is low or the gage is affected by backwater. Sufficient measurements of stage and discharge on the rising and falling limb allow the formation of separate rating curves for each condition.

Changing storage can occur when the water stage is changing during the discharge measurement. A correction for channel storage can be may be applied to the measured discharge by adding to or subtracting from the measured discharge a quantity equal to the product obtained by multiplying the area of the water surface between the measuring section and the gage by the rate of change in stage at the gage. The mean stage at the gage at the time of measurement is the gage height to be used with the adjusted discharge obtained by this method. Each discharge measurement should be adjusted to the equivalent discharge at the gage or a section control by

$$Q_g=Q_m \pm W*L*C*dh/dt$$

Where Q_g=discharge at the gage or section control

Q_m=measured discharge

W=average width of the stream

L=length of stream between section where Q_g and Q_m are determined

C=a constant relating the rate of change of stage (dh/dt) to its equivalent effect in reach. This constant is close to 1.0.
dh/dt is the rate of change of stage with respect to time

If the discharge measurement is made below the gage, the correction will be positive for rising stages and negative for falling stages. This correction is just the opposite if the discharge measurement is made above the gage. If sufficient discharge measurements are available to describe a curve of relation between stage and discharge for constant-discharge conditions, Q_g may be obtained from this curve and the channel parameter W*L*C computed for each measurement under conditions of changing discharge.

Note: For rating curves that are not simply defined or are influenced by aquatic vegetation, ice accumulation, variable backwater or changing channel storage conditions, the USGS should develop these curves or provide training on the fine points of developing curves for shifting conditions.

2.5 Frequency of Sampling

Variable	Sampling Interval
Water level, staff gage	Daily the first low-flow season, then weekly. If flow is near critical low flow level then read twice daily.
Water level, pressure transducer	Set to measure every 15 minutes, download at every discharge-stage measurement or once a month.
Temperature	Set to measure every 1-hour, download at every discharge-stage measurement and once a week during August-September.
Discharge-stage	3-5 flows for each range of flow or a minimum of 10 observations to develop rating curve. Then once a month to check for changes in the rating curve and pressure transducer readings.

Frequency of discharge-stage measurements for any site depend on:

1. The stability of the stage-discharge relation;
2. Seasonal discharge characteristics and variability; and
3. Accessibility of the gage in various seasons.

Many measurements are necessary at new gages to define the relationship throughout the range of flows to be measured. For seasonal gages, this may only require that measurements be taken during low flow periods. A minimum of ten discharge measurements per year is recommended. Periodic measurements are then necessary to evaluate the rating curve over time and make changes.

3. DISCHARGE MEASUREMENT BY DILUTION METHOD

The tracer-dilution method is more difficult than current-meter method and under most conditions, is not as accurate. The method is recommended for rough, turbulent and shallow reaches where current meters cannot be used to accurately measure discharge.

The basic principle of the method is the addition of a known concentration of a suitable tracer to the flow. The tracer disperses throughout the cross-section through mixing. The tracer is measured at a distance downstream that insures that mixing is complete. The measured tracer concentration at this downstream point is used to determine discharge. There are two methods used in dilution gaging:

1. The *constant-rate injection method* requires the tracer solution be injected into the stream at a constant flow rate for a period sufficiently long to achieves a constant concentration of the racer in the streamflow at the downstream measurement cross-section.
2. The *sudden injection method* requires the instantaneous injection of a slug of tracer solution.

The constant-rate injection method is more accurate but needs more tracer solution and complicated injection apparatus than the second method. Since the dilution method should be rarely used, the sudden injection method is recommended. This method is described in the following section.

3.1 Sudden Injection Method

The least expensive tracer is NaCl or table salt. Since the conductivity of salt is linearly proportional to the salt concentration, conductivity measurement of the salt tracer and the river are indicators of concentration. The equipment needed for this tracer is relatively inexpensive and portable. Equipment is:

- Digital, battery-operated conductivity/temperature meter with probe ($450.00)
- Stop watch, measuring tape, calculator
- Dosing solution tank, 20-50 liter volume and salt
- 1-liter container and 1-liter graduated measuring cylinder

Note: dilution gaging is done in metric because this is the more easily converted format.
Steps:

1. Select reach based on criteria:
   a. No loss or gain of water within the reach,
   b. Mixing must be complete at the sampling station,
   c. Wide channels and reaches with splits should be avoided, and

   d. Pools and dead water zones should be avoided.

2. Measure the natural or background conductivity (m1) and water temperature (To°C) for the injection site and sampling stations.

3. Determine the mixing length (Lm in meters) using an estimate of discharge (Qe in cubic meters per second) and background conductivity.

   a. Estimate the average water width (meters) and depth (meters the injection point and the potential sampling points.

   b. Estimate mixing length: Lm=125*(Width*depth)

   c. Measure the distance Lm between injection point and downstream sampling point. The sampling point distance must be greater than Lm.

   d. Estimate velocity (meters per second) between the injection point and the sampling point. Velocity can be estimated using the floating object method. A floating object (e.g. cork, orange) is dropped in the stream at the injection point. Using the stopwatch measure the time it takes to travel (travel time Tt) from that point to the downstream point. Do three times to determine an average velocity.

   e. The estimated discharge, in cubic meters per second (cms) is then:

$$Q_e = width*depth*velocity$$

4. Calculate the volume of injection solution required from the estimated discharge and background conductivity.

   a. Find the constant injection rate (I), in liters per second, from estimated discharge:

$$I = Q_e*0.04$$

   b. Multiply the injection rate by the travel time Tt , from the injection point to the sampling station. This gives the volume of injection solution (Vi) in liters, needed at ¾ saturation for common salt;

$$V_i = I*T_t$$

   c. Determine volume of injection solution, in cubic meters, for later calculations,

$$V = V_i/1000$$

   d. Determine weight of salt needed for injection solutions, in kilograms,

$$W = V_i*0.20$$

5. Prepare the injection solution away from the stream, mix thoroughly, and measure the conductivity:

   a. Put 990 ml of river water in a clean container and measure the conductivity, m1.

   b. Add 10 ml of injection solution (salt).

   c. Mix thoroughly and measure the conductivity of this secondary solution, m3.

d. Calculate: $m_o=N(m_3-m_1)$

m_o is the conductivity of the dosing solution
m_1 is the background conductivity of the river water
m_3 is the conductivity of the secondary solution and
N is the dilution ratio (in this case 100, (10ml of injection solution/(10 ml injection solution+990 ml river water)).

6. Position observers for sampling:
   a. 1 person holding the tank of injection solution in midstream at the injection station.
   b. At the sampling station, persons to read the stopwatch, read the conductivity meter and to write down the measurements.
7. Take conductivity measurements:
   a. The lead observer gives the order, the injection solution is dumped quickly into the center of the stream, and the stopwatch is started.
   b. At the sampling station, the stopwatch reader states the time, the meter reader states the reading and the recorder writes both down on Form 3. A time interval of 5 0r 10 second should be used.

3.1.1 Discharge Computation

Discharge (Q in cubic meters per second, cms) is computed as by the volume of injection solution, in m_3, times the conductivity of the injection solution (m_o) divided by the area (A) under the conductivity-time graph,

$$Q=V*m_o/A= (V*N*(m_3-m_1))/A$$

The volume is calculated in Step 4d and conductivity of the injection solution m_o is calculated in Step 5d in the previous section. The area under the concentration curve can be approximated as:

$$A=T*(\Sigma m_k-n*m_1)$$

Where, T is the constant time interval between measurements (e.g., 5 seconds or 10 seconds)

m_k is measured conductivity for each time interval;
m_1 is the background stream conductivity
n is the total number of conductivity readings taken at the downstream sampling

point. So that the discharge for the stream is

$$Q=(VN(m_3-m_1))/(T*(\Sigma m_k-n*m_1)).$$

Conversion of discharge in cubic meters per second (cms) to cubic feet per second (cfs): Multiply Q in cms by 35.32 to get cfs

4. DATA MANAGEMENT AND QUALITY CONTROL

Data processing and management is essential for evaluation, storage and retrieval of the hydrologic information.

4.1 Station Identification

Every permanent site should be given a unique identifier that will be used to organize all data and other information pertinent to the site. In the USGS system, the identifiers are numeric. The County and Planning Unit may want to use identifiers that are both numeric and descriptive for their gages. A portion of the site's identification should reflect the location of gage within the basin. However, the acceptance of all parties of a single, unique system will facilitate data interchange and the multi-party coordination of data collection activities.

4.2 Station description

A complete description and documentation of each station is required, including:

- Distances to specific reference points. The reference points should be permanent and clearly identified.
- The date the station was first established.
- Description of water body upstream and downstream of the gage, including water depth, bank descriptions, bank and bed material, structures, and any irregularities that may affect flow. For example, river bends, large woody debris, a widening or narrowing of the channel, islands, rapids or cascades, tributaries, ditches. Bank description should include slope, bank material, and extent of vegetation. Bed material may be described as boulders, cobble, gravel, sand, etc.
- A narrative description of the location of the site and distance from the nearest town, important bridges, or other fixed landmarks. The narrative should be updated when changes are made to the gage.
- Photographs of the site and gages.

An investigator traveling to the site for the first time should have enough information to locate the station accurately. Maps include:

- A sketch of the location and layout of the station, including distances, with respect to local landmarks and permanent reference points should be drawn. Discharge cross-sections and equipment locations should be shown.
- A topographic map showing the site in respect to roads, highways or towns and the latitude and longitudinal coordinates of the site.

4.3 File Management

A typical stream gaging program will generate multiple types of data files, including raw field data, calculated flows, rating curves, datalogger databases, and hydrographs for each year. Because large volumes of data will accumulate, data must be carefully organized and maintained. Initially, an electronic file structure must be adopted to keep the data for each year easily accessible. Shown below is an outlined example of how the electronic files should be organized (files are shown in italics and directories are in bold).

- **RIVER FILES**
  - **EAGLE RIVER**
    - **...**
    - **1997**
    - **1998**
    - **1999**
      - **MEASURED_FLOWS_1999**
        - *STATION_1.XLS*
        - *STATION_2.XLS*
      - **RATING_CURVES_1999**
        - *RATING_1.XLS*
        - *RATING_2.XLS*
      - **STAGE_RECORDERS_1999**
        - *STAGE_1.XLS*
        - *STAGE_2.XLS*
      - **RAW_FLOW_DATA_1999**
        - **FLOW-STATION_1_RAW**
          - *STA10128.RAW*
          - *STA10325.RAW*
          - *STA10515.RAW*
        - **FLOW_STATION_2_RAW**
      - **RAW_STAGE_DATA_1999**
        - **STAGE_STATION_1_RAW**
          - *STA10128.RAW*
          - *STA10325.RAW*
          - *STA10515.RAW*
        - **STAGE_STATION_2_RAW**
      - **SUMMARY_1999**
        - *STATIONS_HYDGRPHS.XLS*

The files should be organized by River, Year, and data type. This will insure that the files will be easily found and updated. The data should be organized into sub-directories of similar data. Beneath these directories, data for each station for the selected year will be collected and maintained. It is highly recommended that a numeric system is adopted for naming the stations. Local names can often be ambiguous and mis-interpreted or changed. Kilometers or miles upstream from a confluence with a major reach is often a convenient and scalable method of nomenclature, e.g., STATION_3 is 3 miles from the confluence with the Columbia River and STATION_2 is 2 miles from the confluence with the Columbia River.

Once the nomenclature have been determined and the file structure has been set the field data may be entered for analysis and presentation. The initial data that will be collected should be flow measurements. The flow measurements that are taken by field personnel are the fundamental data for the stream gaging program. The data that are collected should therefore be reviewed for validity and accuracy by an experienced Hydrologist and should not be used until they have been reviewed.

Flow measurements, gage readings, and comments that have been collected in the field using notebooks should be copied and archived after each measurement session. To insure that no written data are lost, the original copy should be put in the archives and should not return to the field. The data collected from the field notebooks should be entered into the appropriate spreadsheet workbook each time new data are collected. It is imperative to include the date and time of the measurements, as well as any comments the field personnel included in their notes.

Once several rounds of measured data have been validated and entered into the appropriate spreadsheets, ratings curves may be developed to associate the relationship of stream stage and discharge. This process is described in Section 2. Rating curve data should be maintained separately and each time a new field measurement is taken, the curves should be updated.

After the stage versus discharge relationship has been established on a rating curve, data collected from dataloggers are be used to create a hydrograph for the reach. The data are downloaded from the dataloggers to a field computer, and should be given a file name that includes the station and date followed by a “RAW” file extension to indicate that the data have not been validated (e.g., STA30327.raw would include data collected from station 3 on March 27). The transducer data should be examined for large jumps in measurements or possible slippage or silting of the transducers that may have affected recorded measurements. Once the data are validated, they should be put into a database that is designed to calculate the daily discharge, instantaneous discharge, and weekly average discharge, and mean monthly discharge, consistent with the guidelines described in Section 2. The data should be easily accessible and capable of producing hydrographs of flow, stage, velocity, temperature and channel width.

4.4 Quality Control – Gaging Equipment

The basic elements of site inspection and maintenance include:

1) Routine inspection and maintenance on every visit.
   a) Note and record any change in the observation site.
   b) Arrange to fix any damage caused by flooding, vandalism or other actions.
   c) Check the instruments and make any necessary field repairs or adjustments.
      i) datalogger batteries
      ii) gage condition
      iii) check wires for connections and conditions
2) Check the calibration relation between the pressure transducer and non-recording staff gage, recalibrate if necessary.
3) Gage datum should be re-surveyed at least every other year.

Routine inspection and maintenance of the gaging site should be done on every visit. Gages should be maintained to an accuracy of ±0.02 feet. This requires that the datum be maintained at an accuracy criterion of ±0.02 feet. This is ensured by standard surveying techniques and running a level from reference benchmarks to gage datum every 1-2 years and adjusting the gage if necessary to restore original datum. Flow events, human intervention, or animals (livestock or wildlife) may disturb non-recording staff gages and recording gages. Settlement or uplift of the structure supporting the staff gage may disturb the gage datum. Where levels from a reference mark show disturbance of the datum of a vertical staff gage or the housing of the pressure transducer, it will be necessary to reset the individual gage sections and pressure transducer.

Dataloggers run on batteries. The life of the battery depends on the sampling interval and manufactured unit. This information is generally contained in the manufacturer's user manual.

The electrical signals generated by the pressure transducers may "drift" or show a changing trend in the lineal relationship between pressure exerted by water and the depth of water. Pressure transducers must be periodically checked for changes in their relation between pressure and water level. If there are changes than the pressure transducer will need to be re-calibrated. This can be done by a visual examination of sequential readings in terms of expected patterns or the simultaneous behavior of related variables or nearby gages. Most can be recalibrated in the field as per manufacturers specifications. The equipment needed generally includes a computer (laptop or palm) that includes the calibration software, a calibration tube (e.g., 4 inch ID PVC pipe sealed at one end, and a tape or yard stick graduated in 0.01 feet intervals. The length of the pipe should be 3 feet.

4.5 Quality Control - Data

The datalogger records should be examined routinely for abnormalities. This will help eliminate missing and inconsistent records where equipment is to blame. When the data are downloaded, they should be checked on-site for inconsistencies.
Visual checking of plotted daily time-series data (the hydrograph) is a rapid and effective technique for detecting data anomalies. Comparison of hydrographs between stations provides a technique for spatial variation and errors. The gages with historical data, e.g., the USGS gages, provide better checks to new data because the range of variability can be developed. Relative checks include:

1) Expected range of variables.
    a) The variation over time in discharge is used to describe the expected range of variables. Since the County maintained gages do not have historical records yet, only the daily data will provide the only relevant check to the historical daily discharge data for older gages.
2) Maximum expected change in a variable between successive observations.
    a) The method of comparing each data value with the immediately preceding value is a particular relevance to daily streamflow and temperature variables because they are serially correlated.
3) Maximum expected difference in variables between adjacent stations.

These relative checks are determined from the historical streamflow records. The expected ranges for discharge are prepared for each existing USGS station and the values are given in the annual streamflow report.

For example, sudden decreases or increases in water level unless caused by precipitation or changes in diversions should not occur. If there are inconsistencies and no record of precipitation, such as during August or September, then the diversion gages should be checked. If there are no modifications to the diversion record, then the pressure transducers at the stream gage may not be working properly or the batteries need replacing. Other potential causes could be interference by humans, plugging of the intake holes, or the effects of ice or backwater during the winter and high flow periods.

The use of weather records, hydrographic comparison of records of flow upstream or downstream or on similar drainages in area, or calculation of ground water effluent to the stream are reliable and consistent methods for estimating flow during periods of missing record. They can be used to determine if the effect is due to backwater from ice or floods. The observers should note conditions of ice or backwater when collecting the field data.

4.6 Data Archival

The raw data, field forms, maps and photographs should be archived after processing. Records from a particular site might be re-sampled to check on the stage-discharge relation. Raw data should be readily available to any user. Storage should minimize the potential for destruction by flooding, fire, insects, or other disturbances.
Store processed data on disk (CD-ROM, 3 ¼ inch, or zipdisks) for permanent storage. Storage conditions for any of these media should minimize destruction of stored records by excessive heat, temperature fluctuations, high humidity, dust, etc.. Periodically check the stored data to ensure that it has not become corrupted.

4.7 Data flow

The management and control of incoming data sets is important to maintaining an effective and efficient hydrologic information system. The data-control personnel responsibilities should include:

- Log incoming data batches.
- Monitor and log data-entry status and subsequent submission of data for initial processing, quality control, and validation.
- Route reports to appropriate hydrologic personnel and log edited data.
- Forward monthly and annual summary statistics to appropriate agencies and personnel.

4.8 Annual Streamflow Report

A summary report should be prepared for each gage site that includes:

- A narrative of operational conditions at the site.
- A narrative of flow and channel conditions.
- A description of maintenance/calibration performed.
- Stage/discharge curve.
- Daily flow hydrograph.
- Monthly flow hydrograph.
- Summary table of measured streamflow data.

5. MEASUREMENT FORMS AND EQUIPMENT LISTS

5.1 Form 1: Staff Gage Reader Form

This form will fit in a 5 ½ by 7 ¾ inch spiral notebook such as made by Rite-in-the-Rain. The forms are double sided and should be copied onto Rite-in-the-Rain paper or other waterproof writing paper as the example shows.

At sites that are only non-recording gages, readings should be taken twice daily during from June 1-October 31. The gages should be read weekly during the remaining year. The observers can be volunteers who are trained in the methods. Stage-discharge rating curves still need to be developed for these gages.

5.2 Form 2: Discharge Measurement Form

This form will fit in a 5 ½ by 7 ¾ inch spiral notebook such as made by Rite-in-the-Rain. The forms are double sided and should be copied onto Rite-in-the-Rain paper or other waterproof writing paper.

5.3 Form 3: Dilution Measurement Form

This form will fit in a 5 ½ by 7 ¾ inch spiral notebook such as made by Rite-in-the-Rain. The forms are double sided and should be copied onto Rite-in-the-Rain paper or other waterproof writing paper.

5.4 Form 4: Station Summary Table Template

This table layout is recommended for summarizing flow data at a station.

5.5 Form 5: Rating Curve Calculation Template

This spreadsheet layout is useful for calculating rating curves.

5.6 Form 6: Station Hydrograph Template

This file layout is recommended for developing station hydrographs.

FORM 1

Gage Height Observation Form

Station Name______________________________At or near______________________________
From: ______________________________,2000 To:______________________________,
2000
Station control conditions______________________________
Observers:______________________________
Comments:______________________________

Date	**Time**	**Gage Height**	**Remarks**
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		
	a.m.		
	p.m.		

Datalogger Download Notes:

FORM 2

Discharge Measurement Form

Station Name____________________ Cross Section ID:____________________

Date________________Weather____________________

Water temperature________________Air temperature________________

Time at beginning:________________Gage Height:________________

Time at end________________Gage Height:________________

Method: wading____________bridge____________ice____________

Meter used:________________________________

Spin test before:________________Spin test after:________________

Measurement units: Feet______Metric______REW station______LEW station______

Discharge cross-section information in relation to control:________________

Station control conditions________________________________

Observers:________________________________

Comments:________________________________

Station	**Width**	**Depth**	**Observa depth**	**Revolu-tions**	**Time in Sec**	**Velocity**		**Angle of Coeffic**	**Discharge**
						At pt	**Mean**		

Station	Width	Depth	Observa depth	Revolu-tions	Time in Sec	Velocity		Angle of Coeffic	Discharge
						At pt	Mean		

Additional Comments:

FORM 3

Dilution Discharge Measurement Form

Station Name____________________
Date______________Weather______________
Water temperature__________Air temperature__________
Time at beginning:__________Gage Height:__________
Time at end__________Gage Height:__________
River conductivity, m1 in mS/cm:__________
Average width of section, in meters__Average depth of section in meters__________
Mixing length, Lm=250*square root of (width*depth):__________
Distance from injection site to sampling site, L, in meters:__________
Time of travel, Tt, in seconds:__________
Estimated Discharge in m3/s, Qe=(L/Tt)*Width*Depth:__________
Constant Injection rate, I (liters/sec)__________Q_e*0.04__________
Volume of injection solution (liters)__________V_i=I*Tt__________
Volume of injection solution for later (cubic meters)__________V=V_i/1000__________
Weight of salt needed for injection solution (kilograms)____W=V_i*0.20__________
Dilution ration, N (normally 100),N:__________
Bucket conductivity, m_1 in mS/cm:__________
Conductivity of secondary solution, m_3 mS/cm:__________

Sample no	Conductivity mk	Sample no	Conductivity mk	Sample no	Conductivity mk
1		20		39	
2		21		40	
3		22		41	
4		23		42	
5		24		43	
6		25		44	
7		26		45	
8		27		46	
9		28		47	
10		29		48	
11		30		49	
12		31		50	
13		32		51	
14		33		52	
15		34		53	
16		35		54	
17		36		55	
18		37		56	
19		38		57	

Time interval between sample measurements, T seconds:__________
Number of sample measurements, n:__________Sum of mk for k=1 to n:__________

Discharge Q, in cms, Q=(V*N*(m_3-m_1))/(T*(Σm_k-n*m_1)):__________
Conversion, Q in cms to Q in cfs, Q*35.32:__________

FORM 4

Streamflow Summary Table

Station Name:____

Period of Record:___________________________________

Meter Type:______________________________________

Station Notes:____

Date	Time	Gage Height (ft)	Streamflow (cfs)	Precip (inches)	Comments

FORM 5

Rating Curve Template

Station Name:____

Period of Record:______________________________________

Meter Type:____

Notes:____

Date	Time	Gage Height (ft)	Measured Flow (cfs)	Fitted Flow[1] (cfs)	Comments

[1] USGS Equation q = c (g-a)

c = 0.03
a = -1.89
r = 6.54

Statistical Tests

F Test = 0.003
R = 0.96
Chi Test = 1.00

TABLES

TABLE 1

Equipment List for Measuring Discharge With a Current Meter

Discharge Measurement Equipment	**Specifications**
Current Meter	Swoffer Model 3000-15114 with expandable wading rod with 4-3 ft sections & digital reader; meter can be used from bridges Additional 3' extension for Swoffer
Tape Measure	Nylon coated steel tape graduated in feet, tenths and hundredths: 200'
Stop Watch	To 0.01 seconds, water resistant
Hand Level	No magnification
Chaining Pins	
Pony Clips	Found in most Hardware stores, 4/tape
Clip Board	Interior sheet-holder type
Rite-in-the-Rain Ring Binders	½-inch capacity, to hold gage and discharge forms
Neoprene Chest Waders/ Wading Boots	
Neoprene Gloves	
Dry Suit	1-piece for deeper water
Field Vest	
Camera	
Safety Ropes	
First-aid Kit	

TABLE 2

Equipment List for Continuous Stage Recorders

Pressure Transducer	Aquistar PS900 With/Temperature Sensor
Datalogger	Aquistar XL-5 4-Channel Datalogger With NEMA 4 Enclosure and Pad Lock
Software	
Portable Computer	486 or better with 8MB RAM
Staff Gage	
Site Hardware Mounting Strips (rebar) PVC Pipe for Transducers Stakes or Angle Iron UV Protected Electrical Conduit Hammer	
Camera	
Field Notebook/Clipboard	

TABLE 3

Components of Data Processing and Management

Data Preparation	Data Entry	Primary Processing	Quality Control/ Error Detection	Database Updating	Secondary Processing	Retrieval
1. Transcription of field notebook entries	1. Manually enter field notes into computer	1. Mean daily calculation	1. Range checks	1. Add new data to existing database	1. Programs for routine reports	1. Select data by: a. Parameter b. Parameter value c. Location d. Time interval e. Period of record
2. Coding of data	2. Download data from dataloggers	2. Standardize data	2. Stage discharge checks	2. Report any errors	2. Statistical summaries	2. Output formats/ GIS linkage
		3. Calculate derived variables	3. Sum checks		3. Infilling missing data values	3. Presentation of tables, graphs
		4. Arrange data in database format	4. Interstation consistency checks		4. Interpolation or aggregation of data	

FIGURES

ATTACHMENT A

MANUFACTURER EQUIPMENT SPECIFICATIONS

ATTACHMENT B

CALIBRATION AND MAINTENANCE OF VERTICAL AXIS TYPE CURRENT METERS