WATER QUALITY PROGRAMS DIVISION

Standard Operating Procedure for the Installation of
Nonrecording Gages and Measurement of Stage in Streams

Revised and Adopted October 2004

Draft Copy

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STANDARD OPERATING PROCEDURE FOR THE INSTALLATION OF NONRECORDING GAGES AND MEASUREMENT OF STAGE IN STREAMS REVISED AND ADOPTED OCTOBER 2004

1.0 Introduction

Continuous measurements of stream stage are used in determining records of stream discharge. In stream gaging, gage heights are used as the independent variable in a stage discharge relation to derive discharges. The stage of a stream is the height of the water surface above an established datum plane while the gage height is a water-surface elevation referenced from an arbitrary point to the gage datum. Reliability of the discharge record is therefore dependent on the reliability of the gage height record as well as the stage-discharge relation. Gage height records may be obtained through various means. They may include a water-stage recorder, by systematic observation of a non-recording gage, or by noting only peak stages with a crest-stage gage. This SOP describes the installation and operation of Nonrecording gages commonly used in obtaining a record of stream stage.

2.0 Definitions/ Terms (UNDER CONSTRUCTION)

Datum plane
Stage height
Reference Mark
Reference point

3.0 Safety

Upon reaching the sampling location, site safety determinations should be made before proceeding. These will be different for wadeable and bridge sites. Please refer to the OWRB safety manual for instructions on how to sample both kinds of sites. When regulating the flow of traffic is necessary, please refer to the portion of the safety manual outlining “Traffic Safety Protocols”.

4.0 Quality of the Measurement

When sampling for all programs, Quality Assurance/Quality Control (QA/QC) samples will be routinely collected to assure that environmental samples meet the Data Quality Objectives (DQO’s) that are outlined in the controlling Quality Assurance Project Plan (QAPP). QA/QC sampling is designed to control each step of the sampling process. Blanks are collected to ensure that field personnel are properly cleaning the plastics and glassware used in field sampling. Duplicate samples are collected to ensure that composite samples are properly processed. Replicate samples may be collected to ensure that the sampling methodology employed is collecting a representative sample. Spike or known samples may be submitted to test the efficacy of the analytical laboratory.

For all measurements of stage, quality assurance is measured through several means. First of all, all surveys to set datums should be periodically checked. Secondly, replicate measurements should be taken from outside reference gages when available. Lastly, duplicate stage measurements should be made under extreme hydrological or meteorological conditions and periodically (1 in 10) for each measurement taken.

5.0 Personnel and Equipment

Principle investigators for the OWRB are required to have degrees and/or experience with biological or other applicable sciences. Principle investigators are defined as crew leaders, and this designation may be made upon the leader of a multi- or a one-person crew. Training is required for all SOPs dealing with water quality and quantity collections and measurements as well as habitat assessments and biological collections. In-house training will be conducted for the use of all meters and digital titrators used for water quality or quantity measurements. Investigators must be familiar with OWRB SOP document and all training will follow the methods outlined in that document. Extra training will be provided when new SOPs are developed. Training of field crews will be done through dry run exercises in the laboratory to familiarize field crews with sample collection, sample preservation, instrument operation, calibration, and maintenance. In addition, when new personnel are hired or new methods developed, qualified staff will train on sample collection, measurement, and field analysis methods through side-by-side field trips. These trips will familiarize staff with SOP requirements. When training is considered adequate, a qualified staff member will check field staff for adherence to SOPs.

In most instances, the collection of water quality samples requires only one field person. However, depending on the safety requirements of a particular station, additional crewmembers may be necessary to ensure a safe work zone. Equipment used to collect the chlorophyll-a sample are described in the document “Standard Operating Procedure for the Collection of Water Quality Samples”.

6.0 Installation of Gages and Collection of Stage Data
6.1 Gage Datum

The gage datum is the level surface that is at the zero elevation of all the gages at a gaging station. This point can be tied to mean sea level or can be an arbitrary datum plane. Arbitrary datums are often established so that numbers are more manageable. A permanent datum must be maintained so that only one datum for the gage-height record is used for the life of the station. Though a benchmark is preferable, each gaging station requires at least two to four reference marks that are independent of the gage structure in order to maintain a permanent datum. The gage height is then established from the change in elevation between the gage datum and the gage. All gages are periodically checked under the procedures required and outlined by the Surveying Gaging Stations SOP. An individual Station Plan will outline in detail the frequency of surveys, the survey circuit, and the maintenance required to protect the gage datum.

6.2 Non Recording Gages

The types of non-recording gages generally used are staff, wire-weight, and manual tapedown. Staff gages are read directly whereas the other two types are read by measurement to the water surface from a fixed point. For the OWRB, nonrecording gages serve several purposes including:

1. A reference gage at nonrecording water quality stations
2. Useful when a recording gage is not practical or feasible
3. Outside reference gage at recording water quality stations
4. Inexpensive screening tool to determine best location for recording gages in watershed or aquifer specific studies.

6.2.1 Accuracy of Measurements at Nonrecording Gages

The level of measurement accuracy needed depends on the use of the data. In general, gages maintained to 0.01-0.05 foot have a high level of accuracy, and the stage-discharge rating that is developed may be used for all purposes. Accuracies maintained in a range of 0.05-0.20 foot may have limited utility but are still appropriate for certain purposes. Except in rare cases when data is used only as a screening tool, accuracy should never exceed 0.20 foot.

The most important parts of maintaining accuracy are attention to detail and consistency of effort. A long-term schedule for surveying should be made when the station is installed and adhered to over the period of record. Station characteristics should be noted when making discharge measurements. For example, comparison of inside and outside gage readings or comparison of flood marks with recorded peak gage heights should be made at every opportunity.

The management decisions outlined in workplans and individual Station Plans are the final guide on accuracy to be maintained. In addition, the OWRB's "Levels and Gaging Stations SOP" Section 6.3 makes general suggestions for the frequency of levels. However, rules of thumb concerning management decisions may be followed to assist in the determination of what level of accuracy is needed.

1. When minimal shifts in stage can dramatically influence management decisions, high levels of measurement accuracy are required. Examples include decisions made at the lower end of the rating curve (e.g., characterizing surface-ground water interactions), a small stream with relatively small medium to peak discharges, or a rating maintained to determine surface water yield.
2. When minimal shifts in stage will not dramatically influence management decisions, moderate levels of measurement accuracy are acceptable. For example, ratings used to assist in the calculation of surface water loadings because the great majority of constituent loading occurs during medium to peak discharges. Another example is when data are used to assist in trend analysis or comparison of a standard to a concentration.
3. If relative stage height is the only data need, a low level of accuracy may be sufficient. This is usually the case when using stage as a screening. However, it

should be kept in mind that the data gathered during the screen might be of limited utility once a station is put in place.

6.3 Manual Tapedown Gages

6.3.1 Accuracy and Use of Manual Tapedown Gages

Manual tapedown gages are the easiest and least expensive gages to install, measure, and maintain. The gage is placed directly in wing wall or a pier and usually consists of a chiseled mark or a pin. Accuracy and precision are normally low and are adversely effected by several things including: 1) difficult to accurately read and repeat reading of steel tape to a hundredth because of placement, 2) tape often not vertical due to winds and/or the lip of the bridge deck, and 3) susceptibility of marks and pins to movement and vandalism. By using a graduated engineer's tape, tapedowns can be accurate to 0.005 foot under perfect conditions. However, perfect conditions do not exist, and actual accuracy may be 0.01-0.10 foot. Therefore, they have limited utility. In certain instances (e.g., screening or starting a gage when limited funds are available), they can be used as the sole reference gage at a non-recording station. Tapedown stations are normally used in conjunction with another nonrecording gage as an index reference point. They should not be used as the outside reference gage for a recording station.

6.3.2 Installation and Maintenance of Manual Tapedown Gages

The chiseled arrow is simply a reference point that has been etched into the bridge wingwall or deck on the downstream side over the main channel. It is the most cost effective but least accurate method of stage measurement. The marks should be elevated if possible as well as labeled and painted. Tapedown should be free of any obstructions below the mark and in an area readily accessible by personnel. When placing marks in concrete, avoid scaling concrete. Because of the solid surface of angle or tubular iron, these often work best in steel bridges

Steel pins can also be installed as a reference point for tapedown gages. These are the more advanced cousin of the chiseled arrow because they have a more defined surface from which to measure and allow for a vertical measurement. However, they still yield low accuracy. Pins are installed by placing an anchor, bolt or nail into the bridge wingwall or pier on the downstream side over the main channel. They should be of sufficient length and set deeply enough to remain firmly fixed in place. Tapedown should be free of any obstructions below the pin and in an area readily accessible by personnel.

The marks should be consistently inspected for damage and, at a minimum, be surveyed annually to account for movement and loss of accuracy. If the gage is serving as a reference point for another type of nonrecording gage, it may be surveyed on the same schedule. Because they are inexpensive and easy to install, several should be installed at each station above all possible channels and labeled as primary (RP-1), secondary (RP-2), etc.

6.3.3 Measurement of Stage at Tapedown Gages

Stage is measured by taping down from the gage to surface of the water using a weighted, calibrated steel tape graduated in tenths and hundredths. The weight, known as a Louisiana ding-wop, is made of 2 inch tubular brass with a turned I-bolt sunk in the top and secured to the tape with plastic zip ties. The length of the dingwop can be changed by tightening the I-bolt and should be measured to one foot, or another known length. This length should be checked periodically using the steel tape. With the dingwop barely touching the surface of the water (look for slight ripples immediately around the weight or have a spotter), the steel tap is read at the pointed end of the chiseled arrow or the top of steel pin. After adding in the length of the ding-wop, stage is recorded to the nearest thousandth. If wind is affecting the measurement, attempt to measure stage between gusts, but if wind is constant, note the affect of wind in the discharge notes. Steel tapes are easily deformed and should be straightened before measurement.

6.4 Staff Gages

6.4.1 Accuracy and Use of Staff Gages

Vertical staff gages (Figure 1) are used as a stand-alone outside gage, an outside gage at a recording station, or a reference gage to another nonrecording device. Vertical gages are available in a variety of lengths, widths, and increments in both U.S. and metric scales. However, because of the necessary accuracy, comparability, and ruggedness, gages should be a Style A gage, which is made of porcelain enameled iron sections measuring 3 1/3’ by 4” and graduated at every foot, tenth, and 0.02 foot. They are accurate only to 0.02 foot and can be damaged or lost due to high flows or ice. They have a tendency to drift if not consistently kept free of debris. Accuracies to 0.01 foot may be obtained if needed by reading the gage with a point gage.

Because of their uniqueness to each station, inclined gages are normally not available commercially for stream gaging. They are used in situations where placement of another type of outside gage is not possible. They can be used as stand-alone outside gages or as an outside gage at a recording station. Inclined gages have a low level of accuracy of up to 0.10 foot. Because of issues with installation, maintenance, and accuracy, inclined staff gages should be used only when other options are not feasible.

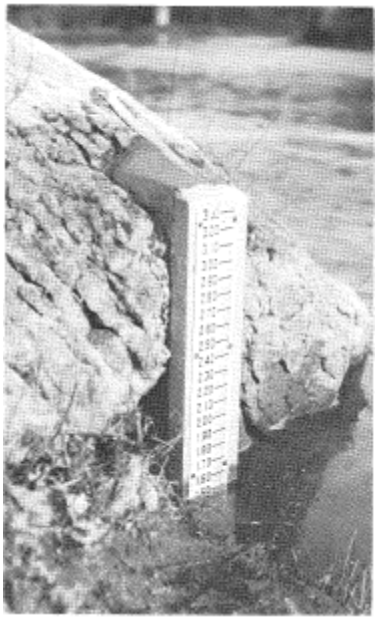
Figure 1. Vertical staff gage

6.4.2 Installation and Maintenance of Staff Gages

A vertical gage is mounted to permanently placed structure such as a piers or beam sunk to bedrock. If mounted in a stable location, a number of plates may be mounted one on top of the other. When mounting, find the high water bench and attempt to place the top of gage above that mark. Vertical height of gages should be kept to one plate and may require the installation of two or more to account for the vertical height of banks and potential high water level. When mounting to a pier, special equipment may be needed. The gage should be kept free of obstructions and be in an area readily accessible by personnel. A reference point should be placed on the backing of the gage plates and tied into the level circuit, and an RP reading should be noted by measuring against the steel plate using a steel tape. During subsequent surveys, new RP readings should be made and compared to the elevation for that RP. If these are different, a correction should be made to the gage datum. If a series of gages are used, each should be tied to the level circuit with a separate RP.

Inclined staff gages are usually made of a graduated heavy timber securely attached to a permanent foundation and are built flush with the stream bank The position of installation should be that the gage might be observed from a safe place during floods and high water conditions. To tie the gage into the level circuit, place an RP near the gage, and from the RP, make several side shots to footmarks throughout the range of the gage. Corrections should be made only if errors exceed 0.10 foot.

6.4.3 Measurement of Stage at Staff Gages

The measure is rather straightforward. The water level is read by a three-step method. As an example, 20.64 is used as a measurement. The footmark, 20.0, is noted. The next mark (6) is the inch mark. The next step is to locate the hundredth mark and count

the marks backward from the next highest inch mark. Using the example, the water level is at 0.64, and to determine the hundredth mark (0.04), the technician would count back from 0.7 to the water level. In this instance, the count was 0.06. By subtracting 0.06 from the inch mark, the hundredth mark (0.04) is obtained.

6.5 Wire Weight Gages

6.5.1 Accuracy and Use of Wire Weight Gages

The type A wire weight gage (Figure 2) consists of a drum wound with a single layer of cable, a bronze weight attached to the end of the cable, a graduated disc, and a Veeder counter, all within a cast-aluminum box. It is used as a stand-alone outside gage or an outside gage at a recording station. A full description of the gage is made in Section 4.4.3 of this document. The gage has a high level of accuracy ranging from 0.005 to 0.01 foot depending upon use. Several sources of error are associated with the use of the gage. The elevation of the gage may vary considerably due to placement along a bridge span. As top surface temperatures rise above bottom surface temperatures (hotter months), the bridge will arch upward and vice-versa when bottom surface temperatures are higher (cooler months). To avoid this potential source of error, every attempt should be made to place the gage near the end of a long span. Also, variations in the drum or cable diameter may lead to errors of up to 0.10 foot over 60 feet of spooled out cable.

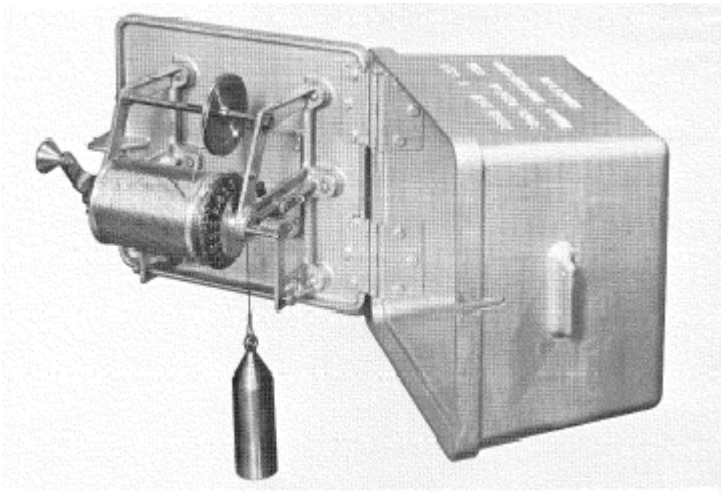

Figure 2. Type A wire weigh gage

6.5.2 Installation and Maintenance of Wire Weight Gages

A wire weight gage should be placed on the bridge wing wall directly above the deepest portion of the main channel. However, the area should be free of disturbance from piers, obstructions, and bridge supports so that the wire weight may be lowered freely without interference from the bridge and associated objects. Debris piles around piers can drastically reduce the accuracy of the measurement. Therefore, moving the weight away from the immediate vicinity of a pier is preferable. To ensure the gage can rotate freely to the water's surface, tapedown with a steel tape at an appropriate horizontal distance from the wing wall. The gage can be affixed to the wing wall through a variety

of means. However, the horizontal check bar must be parallel to the water surface and level, and metal shims, brackets, and/or washers may be required.

Levels should be run at several points when installing a wire weight gage. At a minimum, the wire weight should be leveled at the check bar in its outer position, and the gage datum should be leveled to the stream bottom. This requires two level circuits, but both begin at the same starting point allowing the wire weight to be tied to the gage datum. When possible, a reference gage (see tapedown measurements) should be established beside the wire weight. By tying the two marks together, changes in gage height may be more easily detected during normal measurements. An electric tape gage can also be mounted as the reference gage. Furthermore, if a gage is mounted near the center of long bridge span, placing reference points on both ends of the span may assist in determining the change of the gage datum that can be attributed to arching and sagging of the bridge. When possible, a reference point should also be established near the gage datum in a bridge pier or other permanent structure.

So that the gage height may be read, the dial is set to zero at the gage datum, and as the reel is brought back to the bridge, the gage height will gradually increase until it reaches the check bar reading. For streams with unstable substrates, the gage datum is often set above zero to allow for scour. When surveying, the gage height is calibrated and adjusted if needed. Follow these steps (an example in Table 1):

1. Survey the elevation of the check bar and the reference gage.
2. Tapedown to the water surface from the reference gage and correct gage height if necessary. A spotter should always be used and should not be done during windy conditions.
3. Read the check bar to the nearest thousandth.
4. Using a steel tape, tape to the water's surface from the check bar.
5. Using a steel tape, tape to the water's surface from the reference point.
6. Survey the elevation of the water surface.
7. Take a gage reading.
8. Adjust the check bar reading up or down so that the gage reading and the water surface elevation are equivalent to at least the hundredths.

The wire weight gauge should kept closed from the elements. The cable assembly should be periodically checked for kinks, twists and fraying. The drum assembly should be periodically lubricated to ensure smooth operation.

6.5.3 Measurement of Stage at Wire Weight Gages

A wire weight gage is simply a cabled drum attached to a counter. The diameter of the drum of the reel is such that each complete turn represents a 1-foot movement of the weight. The disc attached to the drum is graduated in tenths and hundredths of a foot and is permanently connected to the counter and to the shaft of the drum. The reel is equipped with a pawl and ratchet for holding the weight at any desired elevation. A horizontal checking bar is mounted at the lower edge of the instrument so that when it is moved to the forward position the bottom of the weight will rest on it.

A wire weight gage is rather simple to use. Before lowering the weight, ensure that the cable is fed through the wheel guide above the drum. The check bar located beneath the weight should be moved to the rear of the bracket. On the side of the drum, there is pawl with toothed gear. Holding the drum handle, ease the pawl away from the gear. The weight is now free to be lowered slowly to the water's surface. **DO NOT FREEWHEEL THE DRUM**. Upon contact with the water, the measurement can be made by looking at two counters. The Veeder counter, located on top of the instrument, represents the footmark. The tenths and hundredths footmarks are located on the disc attached to the drum. The arrow or pointer going from the drum to the disc represents the tenth mark. The hundredth mark is read going down from the tenth mark. Rewind the drum to the top and place the weight on the forward placed check bar. Lock the weight in place by locking the pawl. **LOCK THE COVER WHEN MEASUREMENT IS COMPLETED**.

6.6 Crest Gages

The crest-stage gage is a device for obtaining the elevation of the flood crest of streams. The gage is receiving widespread use because it is simple, economical, reliable, and easily installed. The one found most satisfactory is a vertical piece of " 2-inch galvanized pipe containing a wood or aluminum staff held in a fixed position with relation to a datum reference. Crest gages should be cleaned and reset after periodic floods. The crest gage should also be inspected for damage and level errors.

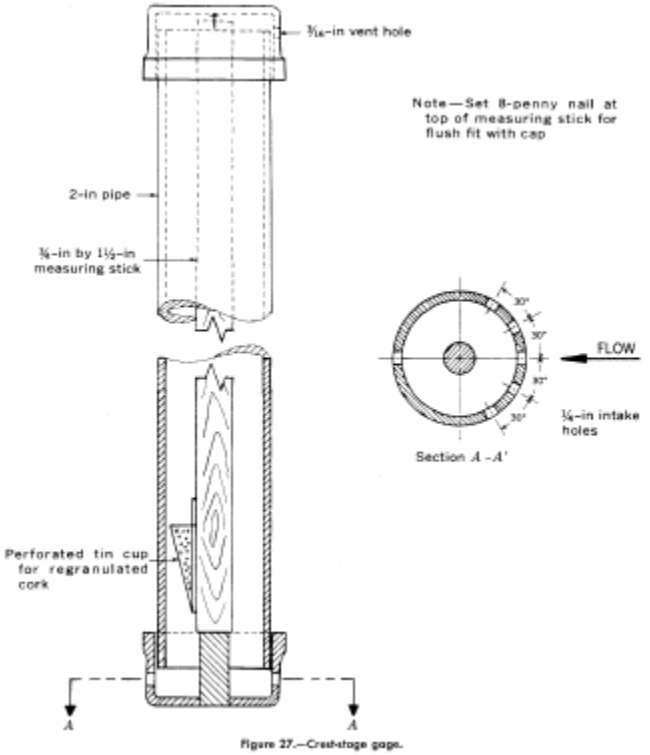

Figure 27.—Crest-stage gage.

Figure 3. Crest gage

The bottom cap has six intake holes located so as to keep the non-hydrostatic draw down or super elevation inside the pipe to a minimum. Tests have shown this arrangement of intake holes to be effective with velocities up to 10 feet per second, and at angles up to 30 degrees with the direction of flow. The top cap contains - one small vent hole. The bottom cap or a perforated tin cup or copper screening in cup shape attached to the lower end of the staff contains regranulated cork. As the water rises inside the pipe the cork floats on its surface. When the water reaches its peak and starts to recede the cork adheres to the staff inside the pipe, thereby retaining the crest stage of the flood. The gage height of a peak is obtained by measuring the interval on the staff between the reference point and the flood mark. Scaling can be simplified by graduating the staff.

A Crest gage should placed in location that allows personnel to readily access the gage and reset the cork. Locations usually are along the bridge abutments, downstream in a protected location, or suspended from the bridge. If suspending from a bridge, the scale inside should be built to allow the scale to be removed and reset

7.0 Forms

7.1 Field Notes

Field notes are documents used to annotate and record information that is gathered at the project site. They are a data sheet and should be treated as such. Therefore, they should be written, legible, and complete. To avoid confusion and loss of data, a new sheet should be used at each new project site. Field notes should be initialed and dated by the collecting personnel and data entry personnel. For guidance on proper procedure to complete the field notes, refer to your supervisor and or FTE. Field notes can be found at S:\Monitoring\STREAMS\forms\Field Notes.doc.

8.0 Data Storage

All completed paper copies of forms and data sheets should be maintained with the appropriate station notebook. The data from the field notes and laboratory data sheets should be either entered into or uploaded to the Water Quality Database or other approved electronic format. Each sample should be maintained electronically in the database under a unique sample number.

9.0 References

Stage measurement at gaging stations, by T.J. Buchanan and W.P. Somers: USGS–TWRI Book 3, Chapter A7. 1968.

Measurement and computation of streamflow Volume 1. Measurement of stage and discharge Volume 2. Computation of discharge, By S. E. Rantz, et al.: USGS—Water Supply Paper 2175.