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PROJECT SPOTLIGHT

Surface Water Flow Measurement for Water Quality Monitoring Projects

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Introduction

Measurement of surface water flow is an important component of most water quality monitoring projects. Flooding, stream geomorphology, and aquatic life support are all directly influenced by streamflow, and runoff and streamflow drive the generation, transport, and delivery of many nonpoint source (NPS) pollutants. Calculation of pollutant loads requires knowledge of water flow.

The purpose of this article is to provide some basic guidance on appropriate ways to estimate or measure surface water flow for purposes associated with NPS watershed projects. The discussion will focus on flow measurement in open channels (natural streams and ditches) or field runoff, but will not address flow in pipes or other structures. The article will provide a brief overview of surface flow fundamentals and discuss common purposes for flow measurement, fundamental measurements that go into determining flow, some practical methods for making these measurements, and some common applications of flow data in watershed projects. Those who are unfamiliar with flow measurement should seek help from local, state, or federal agencies that routinely measure surface water flows. The U.S. Geological Survey (USGS), for example, is widely recognized as an authority on the science and technology of flow measurement.

Purposes of flow measurement

Flow data can be used for a variety of purposes, including problem assessment, watershed project planning, assessment of treatment needs, targeting source areas, design of management measures, and project evaluation. Nonpoint source management

IN THIS ISSUE

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projects generally focus on reducing either flow, availability of pollutants, or both. It is often easier and less expensive to document changes in flow than in pollutant levels as a measure of project effectiveness. The selection of appropriate flow variables depends on the specific purpose and situation.

Discharge is the most critical flow-related variable when assessing habitat conditions for fish and benthic organisms in streams with flows of up to 5 cfs, while velocity is more important in streams and rivers with greater flows (Plafkin et al., 1989). Peak flows are important to the stability of the stream channel, the size and quantity of bed material, and sediment transport rates, while low flows are a concern with regard to stream water temperature and fish habitat.

Measurement of discharge and stage is important in situations where requirements for maintaining minimum flows or water levels exist. Water yield is important in western states dependent upon hydropower and irrigation. Development of effective urban runoff quantity control depends on good estimates of peak runoff flow rates (Horner, et al., 1994).

The relationship between discharge and pollutant concentrations is often used in both the planning and assessment phases of watershed projects. It may be possible to develop a preliminary understanding of the relative importance of various point and nonpoint sources by observing the relationship between water quality variables and discharge. Discharge and peak flow were used successfully as covariates in evaluating trends in total suspended sediment and total phosphorus data in the Sycamore Creek, Michigan, watershed (Suppnick, 1999).

The most common use of flow data by watershed projects is pollutant load calculation. Pollutant loads are critical elements of TMDL development and implementation, and reduction in pollutant load is often an important measure of success in nonpoint source watershed projects. For example, a central objective of the Otter Creek (WI) section 319 National Nonpoint Source Monitoring Program project was to reduce the loading of sediment and nutrients to the Sheboygan River and Lake Michigan through the installation of Best Management Practices (BMPs) in the Otter Creek watershed. The project documented success by showing significant decreases in suspended sediment, phosphorus, and nitrogen loads following implementation of BMPs (Corsi et al., 2005). Discharge data are essential for the estimation of loads of sediment or chemical pollutants exported from a river or stream.

A broad range of accuracy is possible in measurement of flow, from general estimates for planning purposes, to simple measurements that can be done by citizen groups, to detailed scientific measurements conducted by the USGS or other specialists. Numerous examples along this range will be discussed in this article; first, it is useful to present some fundamental technical information about measuring water flow.

EDITOR'S NOTE

Measuring surface water flow is often a crucial component of water quality monitoring for many nonpoint source (NPS) watershed projects. A number of methods exist, with method selection depending on factors such as project goals, size of stream, proximity to a USGS stream gage, and expertise available. The success of documenting a change in water quality resulting from best management practice implementation relies heavily on accurately obtained flow data. Less rigorous methods may apply, however, for different purposes such as project planning or volunteer monitoring.

In this issue of *NWQEP NOTES*, our feature article presents basic guidelines for the various ways to estimate or measure surface water flow for NPS watershed projects. Included is an overview of surface flow fundamentals, common purposes for flow measurement, basic measurements that go into determining flow, and practical methods for obtaining these measurements. Also included is a presentation of a range of applications of flow data in NPS watershed projects along with discussion of appropriate methods and considerations for measurement.

As always, please feel free to contact me regarding your ideas, suggestions, and possible contributions to this newsletter.

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Fundamental measurements

Surface water *flow* is simply the continuous movement of water in runoff or an open channel. This flow is often quantified as *discharge*, defined as the rate of flow or the volume of water that passes through a channel cross section in a specific period of time. Discharge can be reported as total volume (e.g., acre-ft or millions of gallons) or as a rate such as cubic feet per second (ft^3/s or cfs) or cubic meters per second (m^3/s) (USGS, 2007).

The depth of flow (m or ft) is most commonly measured as *stage*, the elevation of the water surface relative to an arbitrary fixed point. Stage is important because peak stage may exceed the capacity of stream channels, culverts, or other structures, while both very low and very high stage may stress aquatic life.

Basic principles of discharge measurement

Discharge is typically calculated as the product of *velocity* and *cross-sectional area*. Surface water velocity is the direction and speed with which the water is moving, measured in feet per second (ft/s) or meters per second (m/s). The cross-sectional area of an open channel is the area (ft^2 or m^2) of a slice in the water column made perpendicular to the flow direction.

Determination of discharge (usually symbolized as Q) thus requires two measurements: the velocity of moving water (V, e.g., in m/s) and the cross-sectional area of the water in the channel (A, e.g, in m^2). The product of these two measurements gives discharge in volume per unit time. The equation and an example calculation are shown below:

$Q = V*A$ $\quad\quad$ $1.25\ m/s \times 36\ m^2 = 45\ m^3/s$

The velocity of moving water varies both across a stream channel and from the surface to the bottom of the stream because of friction and irregularities in cross-section and alignment. Friction caused by the rough channel surfaces slows the water near the bottom and sides of a channel so that the fastest water is usually near the center of the channel and near the water surface. On a river bend, the water on the outside of the bend moves faster than the water on the inside of the bend, as it has to cover more distance in the same time. Figure 1 shows a generalized schematic of the pattern of water velocity in a cross-section of a stream.

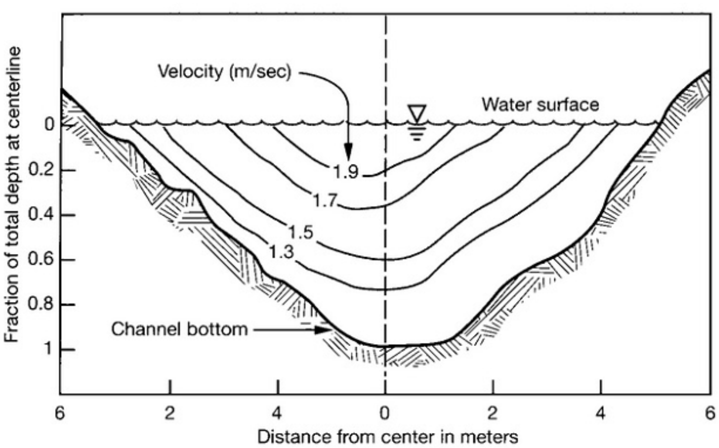


Figure 1. Water velocities in a typical stream cross-section. Source: L. L. Sanders. A Manual of Field Hydrogeology. Prentice Hall, Upper Saddle River, NJ, 1998. ISBN 0-13-227927-4.

Studies by USGS support several general rules of thumb to deal with this variability:

1. Maximum velocity occurs at 5 – 25% of the depth, this percentage increases with increasing stream depth.
2. Mean velocity in a vertical profile is approximated by the velocity at 0.6 depth.
3. Mean velocity in a vertical profile is more accurately represented by the mean of the velocities at 0.2 and 0.8 depth.
4. The mean velocity in a vertical profile is 80 – 95% of the surface velocity, the average of several hundred observations being 85%.

Clearly, more than a single measurement is needed to accurately characterize the velocity of water moving down the stream, particularly when the stream channel is irregular.

Determining the *cross-sectional area* of a flowing stream usually involves measuring water depths at a series of points across the stream and multiplying by the width of the stream within each segment represented by the depth measurement. The areas are summed to determine the entire cross-sectional area, as shown in Figure 2.

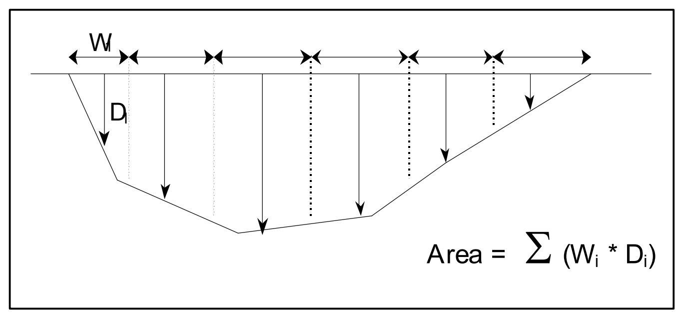


Figure 2. Dividing a stream cross-section into segments to compute cross-sectional area.

Specific approaches to measuring velocity and cross-section area are discussed later in "Flow Measurement Methods."

Stage measurement

Stream stage is an important parameter of streamflow measurement. Stage itself may be of direct interest in some cases, such as flood management or the design of structures. Stage can also be a surrogate for stream cross-sectional area if the stream channel has been surveyed, and is a key component of a stage-discharge relationship used to calculate flow.

In a particular location, stage is often measured relative to a fixed point using a staff gage, a rigid metal plate graduated in meters or feet attached to a secure backing and located in a part of the stream where water is present even at low flows (Figure 3). During installation, staff gages are usually related

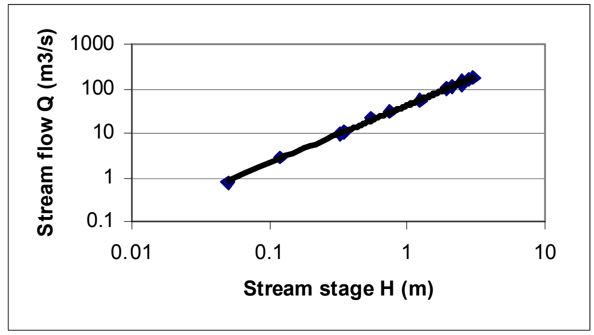
Figure 3. Staff gage.

by survey to a fixed reference (e.g., a bridge deck) so that the elevation of the gage can be checked periodically and re-established if it has been disturbed. Stage measurements are taken by simply noting the elevation of the water surface on the graduations of the staff gage; such instantaneous stage data are easily collected by volunteers. Volunteers can, for example, record stage observations each time they collect a sample or make a field measurement in order to place results in context of general flow conditions. In the case of very large rivers, stage can also be read by measurement of the distance from a fixed overhead point to the water surface, e.g., using a weighted wire or tape lowered from a bridge beam.

Stage-discharge curves

Simple manual stage measurements can give a rough qualitative indication of the magnitude of discharge although the relationship between stage and discharge is not linear. The greatest utility of stage measurements, however, is in the construction of a stage-discharge relationship, also known as a stream rating. A stage-discharge relationship is an equation determined for a specific site that relates discharge to stage, based on a linear regression of a series of concurrent measurements of stage and discharge. This equation should be based on measurements taken over a full range of streamflow conditions; it is not acceptable to extrapolate the rating equation beyond the range of observations that it is based on, unless measurements are being done in a precisely constructed channel of regular geometry. As shown in Figure 4, stage-discharge relationships usually take on a log-log form. With a valid stream rating, discharge can be determined simply from a stage observation plugged into the equation or read from a table. Additional information on stage-discharge ratings is available from USDA (http://www.info.usda.gov/CED/ftp/CED/neh630-ch14.pdf) and from USGS (http://wwwrcamnl.wr.usgs.gov/sws/SWTraining/RatingsWeb/Index.html).

Stream rating curves should be checked periodically, especially after major high-flow events because of possible changes in the stream channel. Rating curves sometimes shift due to changes in streambed slope, channel roughness, and due to filling, scouring, or reshaping of streambanks.



$$Q = 42.17(H)^{1.302}$$

Figure 4: Example of a stream stage-discharge rating.

Flow measurement methods

Depending on what kind of flow data are needed and the purpose(s) the data will serve, there are several options for obtaining flow data ranging from observation of peak stage during an event, estimation of average annual stream discharge, instantaneous flow measurement, and continuous flow measurement using automated equipment. Regardless of the particular method used, it is always essential to document the source and basis of flow measurements to assure acceptable data quality.

Peak stage measurement

Knowledge of peak stage – how high the water reached – during a storm event or flood is often crucial information. In urban watershed projects where reduction of peak stormwater flows is a major goal, tracking peak stream stage (and precipitation) during storm events before and after watershed treatment can be a simple and inexpensive surrogate for monitoring actual streamflow. Peak stage may be important to know for stream restoration projects where high flows shape the physical habitat of the stream. Of course, peak stage is essential to know in flood planning, especially for flood frequency statistics, floodplain management, and design/protection of structures.

Peak stage can be observed by several informal means. Direct observations made during high flow events can record the maximum height of water on buildings or other structures. After flood waters recede, debris lines left on buildings or riparian vegetation can suggest the general height of peak stage. More precise records of peak stage can be obtained using specialized crest gages (http://pubs.usgs.gov/fs/2005/3136/fs2005-3136-text.htm).

Estimation of annual discharge

Planning for a watershed project may require an estimate of total annual discharge from an ungaged watershed. Such an estimate can be made simply using data from a nearby stream gage with a good historical record, such as one operated by the USGS. Data summaries published by USGS (http://waterdata.usgs.gov/nwis/rt) typically contain statistics on annual total discharge, long-term mean discharge, and a statistic on average annual discharge per unit area of watershed, usually expressed as ft^3/mi^2, or cfsm. One very simple estimation technique is to multiply the cfsm for an appropriate nearby USGS station by the area of the study watershed to come up with an estimated annual discharge. Alternatively, the distribution of annual discharge from a nearby USGS station can be evaluated to predict the mean, median, and range of annual discharge to be expected from the study watershed. Thirdly, if precipitation data are available, the correlation between annual precipitation and annual discharge in a nearby monitored watershed can be used to predict annual discharge from the study watershed.

Selecting a nearby USGS gaging station as a basis for any of these estimation approaches requires careful consideration. It is best if the data come from a site very near the study watershed and that the monitored watershed has similar topography and land cover. This is especially true if direct comparisons of annual discharge values are to be made; be sure that land use and land cover – particularly urbanized areas with much impervious cover – in the gaged watershed are comparable with the study watershed.

Instantaneous flow measurement

It is often necessary to estimate or measure discharge at a particular site at a particular time, either to document flow under certain conditions or to develop a data base for a stage-discharge rating. There are numerous ways to come up with an instantaneous discharge number, varying in accuracy and in applicability by the size of the stream.

Manning's Equation. Discharge may be computed based on a slope-area method using the Manning equation:

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

Where:

Q = discharge in ft^3/s
A = mean area of the channel cross section in ft^2
R = mean hydraulic radius of the channel in ft
S = slope of the water surface
n = roughness factor depending on the character of the channel lining

Hydraulic radius is defined as the cross-sectional area divided by the wetted perimeter (the distance around the stream bed cross section that is under water).

Application of the Manning equation requires a straight stream reach between 200 and 1000 ft (61 – 305 m) in length. Slope of the water surface is determined from accurate measurements of stage at the upstream and downstream ends of the reach referenced to a common fixed point. The n factor depends on the character of the channel, varying between 0.01 for smooth concrete to 0.10 for weedy streams with deep pools. Note that the proper selection of a roughness factor is difficult in many cases and discharge determined by this method is only approximate.

Direct measurement. There are several approaches to direct measurement of discharge; the specific choice depends largely on the size of the stream and the resources or expertise available. In general, for any of these methods, it is important to select a straight stream reach, free of large obstructions and pools, with as regular a cross-section as possible. It is also advisable to avoid areas within or immediately downstream of bridges or culverts because of the changes in hydraulic conditions around these obstructions to flow.

Volumetric measurement. For very small flows, e.g., low-flows in ditches or small streams or discharge from drain outlets, the most accurate method of discharge measurement is to simply measure the time required to fill a container of known volume. Volumetric measurements should be repeated several times and an average computed.

Dilution methods. Dilution methods of discharge measurement consist of adding a concentrated tracer solution (salt or dye) of known strength to the stream and by chemical analysis determining its dilution after it has flowed far enough to mix completely with the stream and produce a uniform final concentration in the stream. Discharge is calculated as:

$$Q = q * (C_1 - C_2)/(C_2 - C_o)$$

Where:

Q = stream discharge
q = tracer injection rate
C_1 = tracer concentration in injection
C_2 = final concentration of tracer in the stream
C_o = background tracer concentration in the stream

Description	Normal value of n
Natural stream, clean, straight, full stage, no rifts or deep pools	0.030
Mountain stream, gravels, cobbles, and few boulders	0.040
Floodplain, light brush and trees	0.060
Excavated earthen channel	0.018
Corrugated metal culvert, 36 in.	0.019

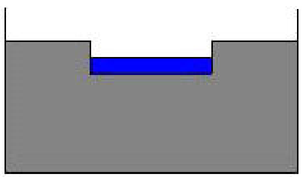
Some typical values for Manning's n

The particular tracer selected should be conservative, i.e. not taken up by sediments or living organisms in the stream and should be easily measured in the laboratory or in the field. Salt (NaCl) and Rhodamine dye are commonly used tracers; Rhodamine dye can be analyzed in the field by fluorescence. Regardless of the tracer selected, note that a permit or at least notification of the state environmental agency may be required before adding such materials to public waters.

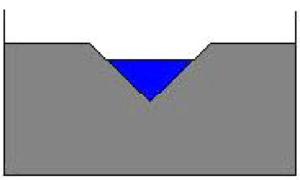
Weirs and flumes. For long-term projects, discharge can be measured using a weir or flume, structures that water flows through or over that has a known relationship between stage and flow. When a device can be used, discharge measurement can be as simple as observing the stage of water just upstream of the device and consulting a table or using a simple equation to calculate discharge.

There are numerous devices for this purpose, with different applicability. Weirs are essentially dams built across an open channel over which water flows through a specially shaped opening or edge. Weirs are classified according to the shape of their opening – e.g., a 90° V-notch weir has a notch shaped like an inverted right triangle, whereas a rectangular weir has a rectangular notch. Each type of weir has an associated equation for determining the discharge rate, based on the depth (stage) of water in the pool formed upstream of the weir. In practice, weirs can range from small wood or metal plates temporarily mounted across small ditches or streams to more permanent installations involving concrete walls and other structures (Figure 5). Note that erecting any obstruction in a stream will create a pool upstream and care must be taken to avoid creating the potential for flooding during high flows. In some cases a permit may be required.

Flumes are specially shaped open channel flow sections that restrict the channel area, resulting in increased velocity and a change in level of the flowing water. The discharge through a flume is determined by measuring the stage in the flume at a specific point, depending on the type of flume. In general, flumes are used to measure discharge where weirs are not feasible because flumes do not cause extensive ponding upstream; flumes are often used to measure field runoff where flows during storm events can be collected and channeled through the device. Commonly used flumes include the Parshall and the H-flume (Figure 6), a special flume developed for agricultural field research that can measure discharge over a wide range with good accuracy. Flumes come in a wide range of sizes denoting the maximum depth of flow they can accommodate and can be purchased as prefabricated units or built on-site. Most devices have exacting specifications for installation that may present construction challenges. More information on weirs and flumes is available from the U.S. Bureau of Reclamation (http://www.usbr.gov/pmts/hydraulics_lab/winflume/).



Rectangular weir



90° V-notch weir

120° V-notch weir

Figure 5. Examples of weirs for open channel flow measurement.

Parshall Flume

H Flume

Figure 6. Examples of flumes used to measure runoff flow.

Instantaneous discharge measurement. The most common method of measuring discharge in open channels is by measuring the cross-sectional area and the mean water velocity, as generally described earlier and further described in this section. This is known as the area-velocity technique.

Discharge in a small, wadable stream can be measured by the following process:

- **Select location** – Choose a straight reach, reasonably free of large rocks or obstructions, with a relatively flat streambed, away from the influence of abrupt changes in channel width.
- **Establish cross-section** – Determine the width of the stream and string a cable or measuring tape across the stream at a right-angle to the flow. Divide the width into 20 to 25 segments (streams less than 10 ft (3 m) wide may not allow as many segments) using tape or string to mark the center of each segment on the cable; typically, the stream is divided into enough segments so that each one has no more than 10 percent of the total streamflow.
- **Measure depth of each segment** – At each mark across the stream, measure the depth from the water surface to the bottom with a graduated rod or stick.
- **Measure water velocity** – At each mark, measure the velocity of the water (see below). Where depth is less than 2.5 ft (0.8 m), a single velocity measurement at 0.6 of the total depth below the water surface gives a reasonable estimate of the average velocity with respect to depth. For depths of 2.5 ft or more, the average of velocity measurements taken at 0.2 and 0.8 of depth is preferred.
- **Calculate discharge for each segment** – For each segment, stream discharge is the product of width of the segment and the measured depth (giving area) multiplied by the velocity measured in that segment.
- **Sum discharges –** Total stream discharge is the sum of all segment discharges.

While wading is the preferred method for accurate discharge measurement (Figure 7), there are obvious safety considerations that limit the flows at which wading can be accomplished. The USGS has a rule of thumb that prohibits wading if the product of depth (in ft) and velocity (in ft/s) exceeds 8 anywhere in the cross-section. Discharge measurement in larger rivers or at high flows follows the same principles of area and velocity, but requires specialized techniques. These include suspension of equipment from bridges, cranes, or cableways, use of weighted sounding lines, and the use of heavy equipment for velocity measurement.

Accurate velocity measurement is a critical component of the area-velocity technique. Several simple methods have been used to obtain rough estimates of velocity. Measuring the time required for a floating object (usually an orange or a tennis ball) to travel a length of stream is a common technique. This approach has the obvious limitation of measuring only velocity at or near the water surface (see discussion of velocity above). Velocity estimates of this type can be improved by averaging several measurements across the width of a stream, but such estimates still ignore vertical variations. In very small streams, vertical variations in velocity can be accounted for by releasing a floating object (such as a ping-pong ball) from the streambed and measuring the time and distance required for it to pop to the surface. In concept, this technique integrates the vertical velocity profile; in practice it is very difficult to measure both time and horizontal distance with acceptable accuracy.

Figure 7. Discharge measurement by wading.

In most cases, velocity is best measured using some sort of current meter. [Current meters (http://www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/chap10_07.html)](http://www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/chap10_07.html) of several different types exist, including rotating cup types like the Price AA or pygmy models, propeller types such as the Ott meter, and electromagnetic sensors (Figure 8.). Any of these can be attached to a wading rod that can simultaneously measure depth; larger models can be attached to weighted cables for suspension from bridges or cableways.

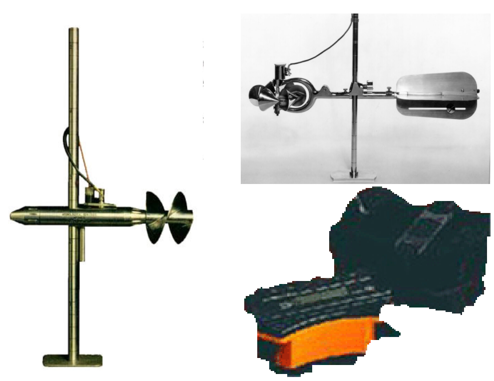


Figure 8. Examples of current meters

Technology for velocity measurement is evolving. For example, acoustic Doppler technology can measure velocity distributions within the flow, eliminating the need for wading or introducing instruments into the water. In tidal areas it may be necessary to use advanced technology to account for backflow.

Accurate measurement of stream discharge is an exacting task and there are many technical details that are beyond the scope of this article. The USGS offers standard technical guidance for stream gaging (http://pubs.usgs.gov/twri/twri3-A6/pdf/twri_3-A6_a.pdf) and for discharge measurement at gaging stations (http://pubs.usgs.gov/twri/twri3a8/pdf/TWRI_3-A8.pdf).

Continuous discharge measurement

A single instantaneous measurement of stream discharge is of limited utility because it provides information about only a single point in time. Where a project seeks to measure pollutant load over time or to assess relationships between stream discharge and pollutant concentrations or aquatic life, it usually becomes necessary to measure discharge continuously.

Continuous discharge measurement in open channels usually requires that the stage-discharge relationship is known, either through development of a stream rating as described earlier or by the installation of a weir or flume. In either case, continuous discharge measurement then becomes an exercise in continuously measuring stream stage. Depending on the installation, this can be accomplished in a number of ways.

A stilling well is a vertical tube or pipe that is hydraulically connected to the channel such that the level of water in the stilling well matches that in the channel, but the transient variations due to waves or turbulence are damped out. Stilling wells can range from an 8 in. (20 cm) diameter pipe connected to the side of a flume to a 3 ft (0.9 m) diameter pipe placed in the ground and connected by pipes to a stream. Several devices exist to measure and record stage in a stilling well. Traditionally, this was done using a float attached to a pulley that rose and fell with the water level in the well and moved a pen on a clock-drive chart recorder (e.g., Stevens Type A). There are modern versions that use electric chart drives or digital recording systems.

Other approaches to measuring and recording level, either in stilling wells or directly in the channel include:

- **Bubblers**, where air or an inert gas is forced through a small diameter bubble line submerged in the flow channel; the water level is measured by determining the pressure needed to force air bubbles out of the line;
- **Pressure transducers,** where a probe fixed to the bottom of the channel senses the pressure of the overlying water; and
- **Ultrasonic sensors,** where the sensor is mounted above the flow stream, and transmits a sound pulse that is reflected by the surface of the flow. The elapsed time between sending a pulse and receiving an echo determines the level in the channel.

Output from level recording sensors can either be recorded directly into a data logger for later processing or into a specialized flow meter. There are several manufacturers of such meters; the meters often include the facility to calculate and record discharge and summary statistics, record other data such as precipitation, and interact with other devices such as automated water samplers.

Applications of flow data

As for all monitoring, the collection of flow data should be designed to provide datasets suitable for data analysis procedures that will allow the project to meet specified objectives. A wide range of objectives are possible, including:

1. Determine basic hydrology of a watershed (e.g., water budget).
2. Characterize water quantity problems in a watershed and evaluate efforts to restore natural flow regimes.
3. Identify major sources of pollutant loads in a watershed.
4. Characterize habitat problems in stream channels.
5. Collect habitat data in support of benthic or fish monitoring.
6. Quantify discharges from tributaries or major sources.
7. Calibrate watershed models.
8. Collect design information for water quantity, water quality, or stream restoration practices.
9. Quantify pollutant loads in support of TMDL development or other watershed project planning efforts.
10. Quantify pollutant loads before and after implementation of practices to determine project effectiveness.

The flow variables and the frequency with which they are measured depend on the project objectives and data analysis plans. For example, single measures of instantaneous stream discharge are highly unlikely to satisfy any of the above objectives because they represent only a snapshot in time. If conducted as part of a synoptic survey within a study watershed, however, such data might be useful in comparing the hydrologic behavior of subwatersheds, characterizing the relative magnitudes of loads or flows from subwatersheds, or calibrating a hydrologic model for the study watershed.

Systematic collection of peak stream stage data has wide application for flood management, stormwater projects, nonpoint source projects, and habitat restoration efforts. In urban watersheds where streams are shaped by peak discharges, management of water quantity is often the first objective of watershed projects, for both stream morphology and biological concerns. Peak stage is relatively easy and inexpensive to monitor and a comparison of peak stage before and after a program of stormwater best management practices (BMPs) could be quite useful. Knowledge of changes in peak water levels can also be critical in stream restoration projects for both physical channel work and restoration of biotic communities. It will be necessary in these cases to monitor precipitation and other important explanatory variables to interpret changes in peak stage values.

Continuous stream discharge data are essential to any watershed project that focuses on pollutant loads. Discharge data play an important role in the design of sampling programs for many objectives. Because concentrations of many NPS pollutants are strongly associated with discharge, many sampling programs are stratified by flow conditions – more samples are taken at higher discharges, for example. Flow proportional sampling – a powerful and efficient sampling design for NPS load monitoring – requires good discharge data to drive sampling for water chemistry.

Discharge can be used to diagnose water quantity problems in watersheds and may itself be a variable expected to respond to implementation of BMPs. For example, Baker and Richards (2004) proposed a *Flashiness Index* – a measure of the frequency and rapidity of short-term changes in streamflow, calculated from mean daily stream discharge data. Flashiness is an important component of a stream's hydrologic regime; land use and land management changes may lead to increased or decreased flashiness, often impairing aquatic life. The Index can be used to quantify the hydrologic impacts of watershed change and to evaluate programs aimed at restoration of natural streamflow regimes. Flow data may also be useful in evaluating agricultural programs where BMPs may promote infiltration over runoff or where drainage practices influence surface water flows. The relationship between discharge and pollutant concentration may also change in response to BMP implementation. Suspended sediment concentrations might be lower after implementation of conservation tillage, for example, at comparable flows; good discharge data would be important to document this change.

Even simple calculation of loads based on multiplying a concentration by the total discharge over the period represented by the concentration observation (numeric integration) requires good discharge data. More sophisticated (and accurate) load estimation procedures such as regression of discharge and concentration or ratio estimators require accurate discharge data. Note that when chemical constituents are measured very precisely (e.g., to mg/L), accuracy of discharge measurements becomes the most critical component of load calculations and the largest source of error. In addition to the accuracy of flow measurement, there are numerous considerations for accurate estimation of pollutant load that are beyond the scope of this article. Consult other sources of information for guidance on proper load estimation techniques (e.g., USDA, 1996; Richards, 1997).

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INFORMATION

Action Plan to Reduce Nutrients to Mississippi River from 31 States Released

The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force recently released an Action Plan that involves state and federal partners in reducing hypoxia in the Northern Gulf of Mexico. The *2008 Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin* builds upon the 2001 plan by incorporating emerging issues, innovative approaches, and the latest science, including findings from EPA's Science Advisory Board.

The Task Force, made up of state and federal officials, leads efforts to promote and support nutrient management in the Mississippi/Atchafalaya River Basin and works to accelerate efforts to reduce the size of the hypoxic zone through building strong partnerships, developing voluntary and regulatory approaches, and increasing national awareness.

For more information on the 2008 Action Plan, visit: http://www.epa.gov/msbasin/

New EPA Water Quality Web Site - "ATTAINS" - Released

EPA released a new database/Web site for water quality assessment and total maximum daily loads information. The site, known as ATTAINS, combines two formerly separate databases: the National Assessment Database (for water quality assessment information reported by the states under Section 305(b)), and the National Total Maximum Daily Loads (TMDLs) Tracking System (for impaired waters information reported by the states under Section 303(d)). The site includes state-reported information on support of designated uses; identified causes and sources of impairment; identified impaired waters; and status of actions (TMDLs) to restore impaired waters. The Web site allows users to view dynamic, continuously-updated tables and charts that summarize state-reported information for the nation as a whole, for individual states and waters, and for the 10 EPA regions. The new Web site is online at http://www.epa.gov/waters/ir.

New WEF Website on Sustainable Stormwater Best Management Practices

The Water Environment Research Foundation recently released a new website that is designed to encourage and facilitate the integration of stormwater BMPs into development projects. The website provides tools and resources for effective communication and implementation, as well as in-depth case studies that examine BMP integration in several cities across the United States. See http://www.werf.org/livablecommunities/.

University of New Hampshire Stormwater Center 2007 Annual Report

The University of New Hampshire Stormwater Center 2007 Annual Report is available online at: http://ciceet.unh.edu/unh_stormwater_report_2007/index.php

Produced in partnership with the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), this publication contains performance data on the ability of stormwater treatment systems to treat water quality and manage water quantity.

To manage stormwater in a way that prevents flooding, protects infrastructure, and safeguards human and environmental health, coastal communities require science-based, independent information on the performance of stormwater treatment systems. The CICEET-sponsored UNH Stormwater Center is unique in its ability to conduct such evaluations in a side-by-side setting. Its field site is designed to test a range of stormwater treatment systems, from low impact development approaches to manufactured devices.

This report is one of several tools the Center uses to communicate the results of its research to coastal communities interested in designing stormwater projects that protect water resources and improve resilience in a time of rapid development and more frequent and intense storms.

In response to stakeholder feedback, the 2007 report includes information on the land use settings in which the evaluated systems are typically deployed, the type of application to which they are best suited, installation costs, and maintenance.

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MEETINGS

Call for Abstracts

2008 Florida Bay and Adjacent Marine Systems Science Conference: Dec. 8-11, 2008, Naples, FL. Visit website: http://www.conference.ifas.ufl.edu/FloridaBay2008. Abstracts due September 1, 2008.

Meeting Announcements — 2008

July

2008 UCOWR/NIWR Annual Conference – International Water Resources: Challenges for the 21st Century & Water Resources Education: July 22-24, 2008, Durham, NC. Website: http://www.ucowr.siu.edu

August

7th annual StormCon – the North American Surface Water Quality Conf & Expo: Aug. 3-7, 2008, Orlando, FL. Website: http://www.StormCon.com

Building Sustainable Communities for the 21st Century: Aug. 12-14, 2008, Charleston, SC. The first Southeast Region Quality Growth Conference, sponsored by Southeast Watershed Forum, NOAA's Coastal Services Center, U.S. Fish and Wildlife Service, the Gulf of Mexico Program, TVA and other agencies and organizations. Website: http://www.southeastwaterforum.org/roundtables/default.asp

September

16th National Nonpoint Source Monitoring Workshop – Getting the Point About Nonpoint: Sept. 14-18, 2008, Columbus, OH. See full announcement in the right-hand column.

November

2008 Southeast Regional Stream Restoration Conference, November 3-6, 2008, Asheville, NC. Website: http://www.ncsu.edu/sri

AWRA 2008 Annual Water Resources Conference: November 17-20, 2008, New Orleans, LA. See website: http://www.awra.org/meetings/NewOrleans2008/index.html ■

The NCSU Water Quality Group publications list and order form can be downloaded at http://www.ncsu.edu/waterquality/issues/pub_order.html

16th National Nonpoint Source Monitoring Workshop

Getting the Point about Nonpoint
September 14-18, 2008
Marriott Renaissance Hotel
Columbus, Ohio
http://streams.osu.edu/conf.php

About the Conference: The National Nonpoint Source (NPS) Monitoring Workshop is an important forum for sharing successes and improving communication regarding management and monitoring of NPS pollution control projects. By bringing together NPS personnel from state, federal, Tribal and municipal governments, private sector, academia, environmental groups and local watershed organizations, the workshop will focus on innovative solutions to NPS issues, effective monitoring techniques, demonstrations of new technologies, application of Best Management Practices (BMPs), and lessons learned from Section 319 National Monitoring Program projects and other watershed projects from throughout the United States. The workshop also will provide a number of technical workshops and tours. Technical workshops will include topics such as monitoring Low Impact Development (LID) projects, stream morphology analysis tools, and bio-assessment tools. Tours will include Conservation Effects Assessment Project (CEAP) monitoring sites, stream restoration sites, alternative urban and agricultural BMPs, and much more.

Specific topics of interest to be highlighted at the 16th annual workshop will include: Stream Restoration & Renaturalization Project Monitoring; Alternative Agricultural Best Management Practices; Urban NPS & Stormwater Management Practices; TMDL & Watershed Action Plan Implementation; Bio-Assessment & Water Quality Monitoring Tools & Methodology; Lake and Coastal NPS Issues; Linking Water Quality Changes to Best Management Practices; Social Indicators Associating with Monitoring Behavioral Changes.

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Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA). Project Officer: Tom Davenport, Office of Wetlands, Oceans, and Watersheds, EPA. 77 W. Jackson St., Chicago, IL 60604. Website: http://www.epa.gov/OWOW/NPS

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