STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

To Aid in Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station **April 2000**

How to Build a Bank-Operated Cableway to Measure Stream Discharge and Sediment

by James J. Paradiso

A hand-operated cableway with a traveling block system has been used on the Nez Perce National Forest in Idaho since 1977. The installation allows hydrographers to safely collect streamflow and sediment data during high flow conditions when wading measurements are impractical or extremely dangerous. Because it is operated from the bank, the cableway system provides a safe, low-cost, and effective method to acquire streamflow and sediment data year-round. The hand-operated cableway is a safe alternative to manned cable cars at sites not easily gaged by boat or bridges during high flows.

Cable measurements are performed whenever the stream or river to be gaged has flows that make gaging via the wading method impossible, impractical, or unsafe. The general rule is to avoid wading in the water any time the product of velocity (feet per second) and the depth of the water (in feet) exceeds 10. Temporary bridges and platforms are one alternative for reducing the risk of accidents and to avoid endangering hydrographers during high flow conditions. Platforms, however, are generally limited to relatively small streams. This cableway system offers distinct advantages over the use of temporary bridges because it can span medium-sized streams up to 100 feet wide.

This cableway system is generally limited to streams less than 100 feet wide. The sounding reel cable length limits the operating width. Present installations on the Nez Perce Forest are typically on 50-60 feet wide streams. Peak flow measurements have been made of discharges approaching 1,000 cfs and velocities as high as 9.2 feet per second.

Rocky Mountain Research Station General Technical Report RMRS-GTR-44, ***A Bank-Operated Traveling-Block Cableway for Stream Discharge and Sediment Measurements***, describes the system. The Stream Systems Technology Center supported the development of this 36-page publication. It describes the construction and use of the cableway system including figures describing parts and dimensions, installation methods, site selection, calibration, and field operation. The publication includes complete plans for building the device. Plans may also be downloaded in Auto-CAD format from the STREAM Web site (www.stream.fs.fed.us).

The system consists of six main parts (Figure 1). An upright steel post is installed on each bank. On the shore with easy access, a pulley-driven housing is mounted atop the post. On the far shore the post supports a pulley, the tailhold. Operated with a hand crank, the

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CONTRIBUTIONS *are voluntary and will be accepted at any time. They should be typewritten, single-spaced, and limited to two pages. Graphics and tables are encouraged.*

Phone: (970) 295-5983
FAX: (970) 295-5959
E-Mail:jpotyondy@ fs.fed.us
Web Site: www.stream.fs.fed.us

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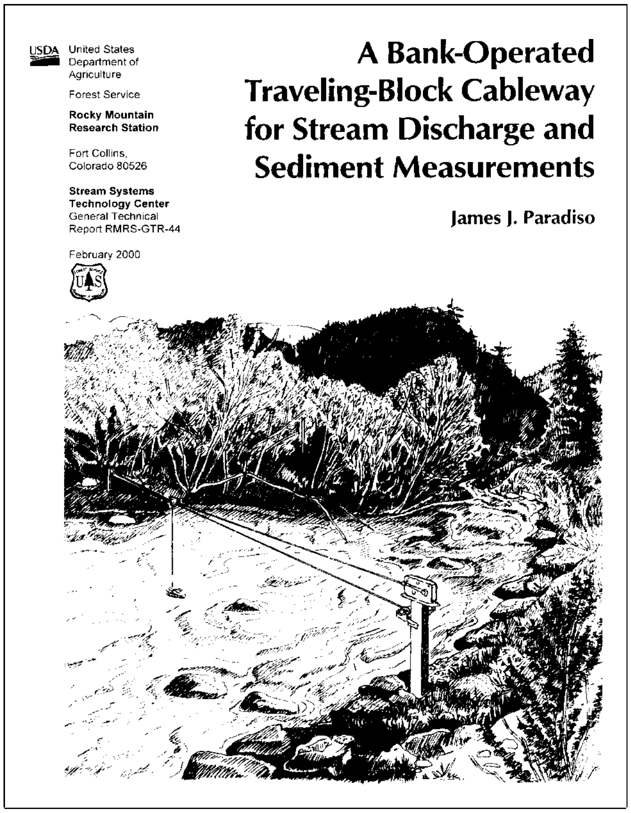
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A Bank-Operated Traveling-Block Cableway for Stream Discharge and Sediment Measurements

James J. Paradiso

pulley-drive controls the movement of a looped cable that is stretched between the posts. A traveling block rides on the upper cable loop and is attached to the lower cable loop. Suspended from this traveling block, the hydrographer's equipment (current meter, suspended sediment or bedload sampler) may be positioned and lowered anywhere in the cross-section.

A standard sounding reel, such as an A-55 or B-56, is attached to fittings on the near post (Figure 2). The cable from the sounding reel is used to suspend the measuring equipment, such as a current meter. The cable is supported by the lower pulley of the traveling block. Using the sounding reel, the equipment may be raised and lowered as needed for data collection. Thus, the horizontal position of the current meter is controlled by the cable crank, while the vertical movement is controlled by the sounding reel.

The cableway can be constructed from parts manufactured at a machine shop, with additional parts from a hardware store. Installation also requires readily available construction supplies including concrete, cable, cable clamps, and turnbuckles.

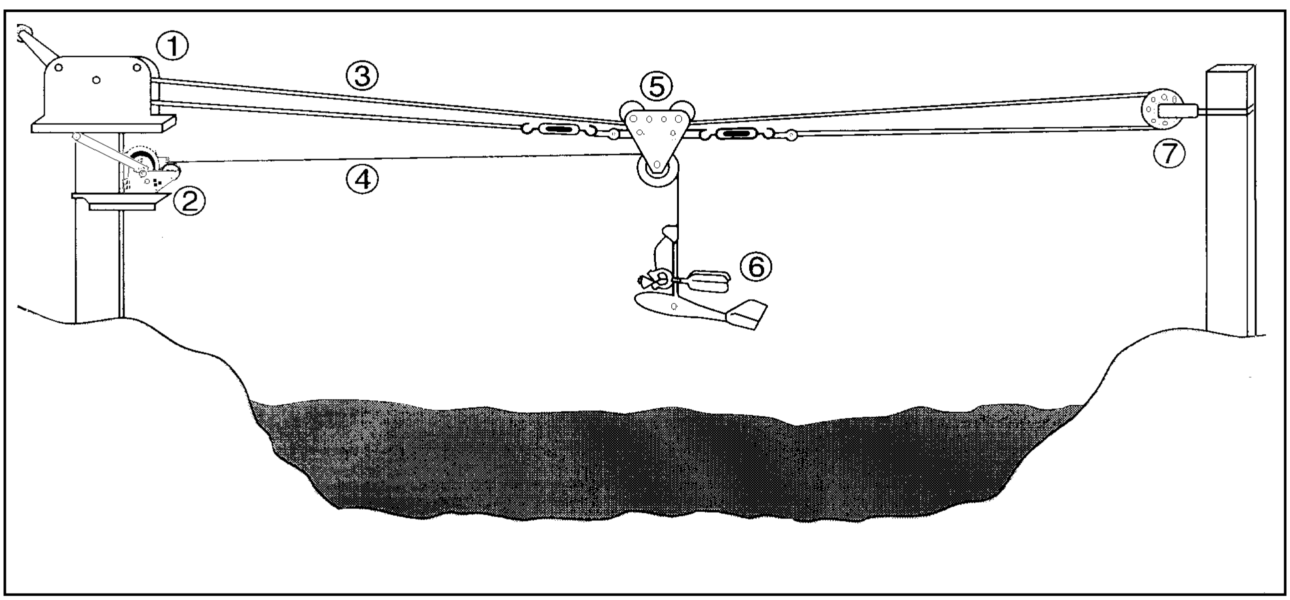

Figure 1. Schematic of the cableway system with sounding reel and current meter in use. (1) near post with pulley housing, (2) sounding reel, (3) cableway cable, (4) sounding reel cable, (5) traveling block, (6) current meter, and (7) tailhold on far post. The traveling block rides on the upper span of the main cable. The ends of the main cable are attached to the traveling block, controlling its movement. Measuring equipment is suspended from the traveling block with the sounding reel cable.

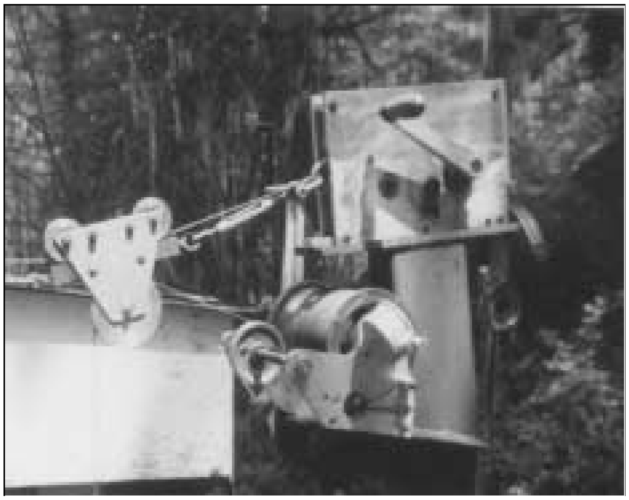

Figure 2. Key components of the cableway. Traveling block, sounding reel, and crank-pulley mechanism. The pulley housing remains on site between measurements, but the sounding reel is removed to deter vandalism.

The origin of the hand-operated cableway equipment described in this publication is obscure. It was not developed by the Nez Perce National Forest. A description and a photograph of a similar cableway appears in the U.S. Bureau of Reclamation's 1967 ***Water Measurements Manual***. Mechanical drawings of the cableway system dated to the 1970s were obtained from the Lolo National Forest and the Montana Department of Natural Resources and modified slightly.

Similar bank-operated cableway systems are in use across the country. Each has advantages and disadvantages with respect to ease of installation, use, portability, and cost. Several types are mentioned to provide a sense of what is available.

A simple, inexpensive cableway is used on the Clearwater National Forest. It uses a boat winch to replace the crank-pulley drive housing and attaches the cable to trees, rocks, or other available structures. A portable system has also been used by the Pacific Southwest Experiment Station. Instead of permanent posts, tripods with guylines support the equipment making it ideal for remote locations.

A variation of the cableway discussed here has been designed by the U.S. Geological Survey. It uses a static line to suspend the equipment from the traveling block, a hand-operated tow cable and pulleys to position it across the river, and a sounding reel to control vertical motion similar to our design. A 100-foot span version (excluding the sounding reel) is commercially available. Another USGS-based design uses the B-56 sounding reel modified so that vertical and horizontal control is achieved using one reel handle.

For larger installations, double drum winches may be purchased. Heavy-duty versions of this type can be used to span larger rivers. Commercially available systems range in cost from $2,500 to $10,000 depending on features.

Installation of the cableway is easiest when the stream can be waded. On-site installation time for one person is approximately four hours to set the posts and two hours to install the pulley mechanisms, cable, and carriage. The use of concrete will require a drying period between each of these steps.

The entire installation, excluding the cost of the sounding reel, is less than $2,500. For this relatively small investment, it is possible to construct a cableway that will allow safe and efficient data collection for medium-sized streams during dangerous high flow conditions.

James Paradiso is a hydrologist on the Nez Perce National Forest, Salmon River Ranger District; (208) 839-2211;jparadiso@fs.fed.us.

Readers can download copies of General Technical Report RMRS-GTR-44, ***A Bank-Operated Traveling-Block Cableway for Stream Discharge and Sediment Measurements***, from the STREAM Web site (www.stream.fs.fed.us) FTP download area.

You may also order copies by sending your mailing information in label form along with the publication title and number through one of the following media:
Telephone: (970) 498-1392; (970) 498-1396 (FAX)
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Mail: Publications Distribution, Rocky Mountain Research Station, 240 West Prospect Road, Fort Collins, CO 80526-2098.

Manning's Equation and the Internal Combustion Engine

Douglas J. Trieste

The internal combustion engine was invented in 1859. It consists of an engine block, pistons, intake and exhaust values, carburetor, crank shaft, flywheel, etc. It was based on the combustion of a mixture of fuel and air expanding in a cylinder, moving a piston, and turning a crankshaft. It's main nemesis were friction and heat loss. Since that time, there have been many refinements and improvements, but the basic design remains the same. Most improvements have come about by variation on a theme. There has been honing and refining, but it is still the same basic design. Is there no other way to make an internal combustion engine, or are the concepts and principles used in 1859 still the best that we can do in today's world?

In a like fashion, Manning's equation for open channel flow was developed in 1889 and remains in use today. The general Manning equation is:

$$Q = \frac{1.49 A R^{2/3} S^{1/2}}{n}$$

in which Q = the discharge (ft^3/s); A = cross-sectional area (ft^2); R = the hydraulic radius (ft); S = the energy gradient, and *n* = Manning's roughness coefficient.

Manning's equation was based on data from flume studies and developed for uniform flow conditions in which the water-surface slope, friction slope, and energy gradient are parallel to the streambed, and the cross-sectional area, hydraulic radius, and depth remain constant throughout the reach. Today, the Manning equation is probably the most popular for practical open-channel flow computations, including hydraulic computer models. It is easy to use, gives results that range from reasonable to accurate in many situations, and is accepted by the industry. It has served us well for many years and is to be commended.

However, the results from the Manning equation are essentially at the mercy of *n*-values. And the selection of appropriate n values is as much an art as a science. Many sources offering guidance are available on n selection. Some of these include Barnes (1967), Benson and Dalrymple (1967), Chow (1959), Limerinos (1970), and, Jarrett (1985). But, due to the variability found in nature, it is difficult, if not impossible, to accurately estimate *n* in complex hydraulic situations.

Manning's equation is commonly used in natural channels for conditions that are not consistent with that from which it was developed. These conditions include non-uniform reaches, unsteady flow, irregular shaped channels, turbulence, steep channels, sediment and debris transport, moveable beds, etc. It is assumed that the equation is valid in these conditions, and the energy gradient adjusted via roughness coefficients (n-values) to make the equation as accurate as possible. As a result, much research as been performed on *n*-values.

Most improvements pertaining to the Manning equation have come about by variation on a theme – the original design of the Manning equation remains an industry standard. Only the "theme" (*n*-values) is changed to improve its performance. We work on making "Volkswagon improvements" on *n*-values – honing, shaping, defining, etc. But, even the famous and ever popular Volkswagon Bug was eventually discontinued for new and different models that combine and integrate all that has been learned and developed. Is it best to keep refining what we have? Or, would we be ahead to develop new equations that would eventually give better results?

Can no better equation than the Manning equation be developed, or are the concepts and principles used in 1889 still the best today?

It is interesting to wonder that if the Manning equation, or, piston-based internal combustion engine as we know it were never developed, then what would we use today?

Is it possible to replace the Manning equation with something new and different that draws upon all the knowledge that we learned since its development? The Manning equation is at the mercy of *n*-values which are a black box (Trieste and Jarrett, 1987) in many situations. The equation itself is rarely challenged, but *n*-values are continually debated. Could there be a better approach?

Is it time to develop new concepts in engines to better meet future needs such as mechanical efficiency, simplicity, fuel type and consumption, pollution, and costs? And, is it time to develop new open-channel flow equation to better solve continual nemesis in computation such as non-uniform channels, unsteady flow, large floods, high-gradient channels, unstable beds, sediment and debris transport, supercritical/ subcritical flow regimes, etc.?

This paper in no way intends to discount the Manning equation or internal combustion engine, but to provide food for thought on improvement of old designs, versus development of new designs.

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Douglas J. Trieste was a Hydraulic Engineer, Bureau of Reclamation, Denver, CO when he wrote this article. Presently he is the owner of Flow Technologies, Lakewood, CO; (303) 989-1427; dtrieste@msn.com. The original article was published in W.H. Espey, Jr, and P.G. Combs (editors), Proc. of 1st International Conf., Water Res. Engineering, Amer. Soc. of Civil Engineers, San Antonio, TX, Aug. 14-18, 1995, Vol. 1, pp. 76-78. Copyright (c) 1995 ASCE; Reproduced by permission of the publisher (ASCE). (www.pubs.asce.org)

Verifiying Roughness Coefficients for Stream Channels in Arizona

USGS Professional Paper 1584, ***Verification of roughness coefficients for selected natural and constructed stream channels in Arizona,*** by Jeff Phillips and Todd Ingersoll, is just one of a series of publications written over the years to help designers and engineers select roughness coefficients for stream channels. The best known publication of this genre, long considered the standard reference for estimating roughness coefficients by the "visual comparison" approach, is ***Roughness Characteristics of Natural Channels*** by Harry H. Barnes, Jr. (USGS Water Supply Paper 1849). The 1967 publication contains color photographs and descriptive data for over 50 stream channels in the United States. Other similar investigations include *n*-values determined for 21 high-gradient streams in Colorado (Jarrett, 1985), 15 floodplains in the southeastern United States (Acement and Schneider, 1989), 78 rivers and canals in New Zealand (Hicks and Mason, 1991) 67 gravel-bed streams in Canada (Bray, 1979) and 21 perennial

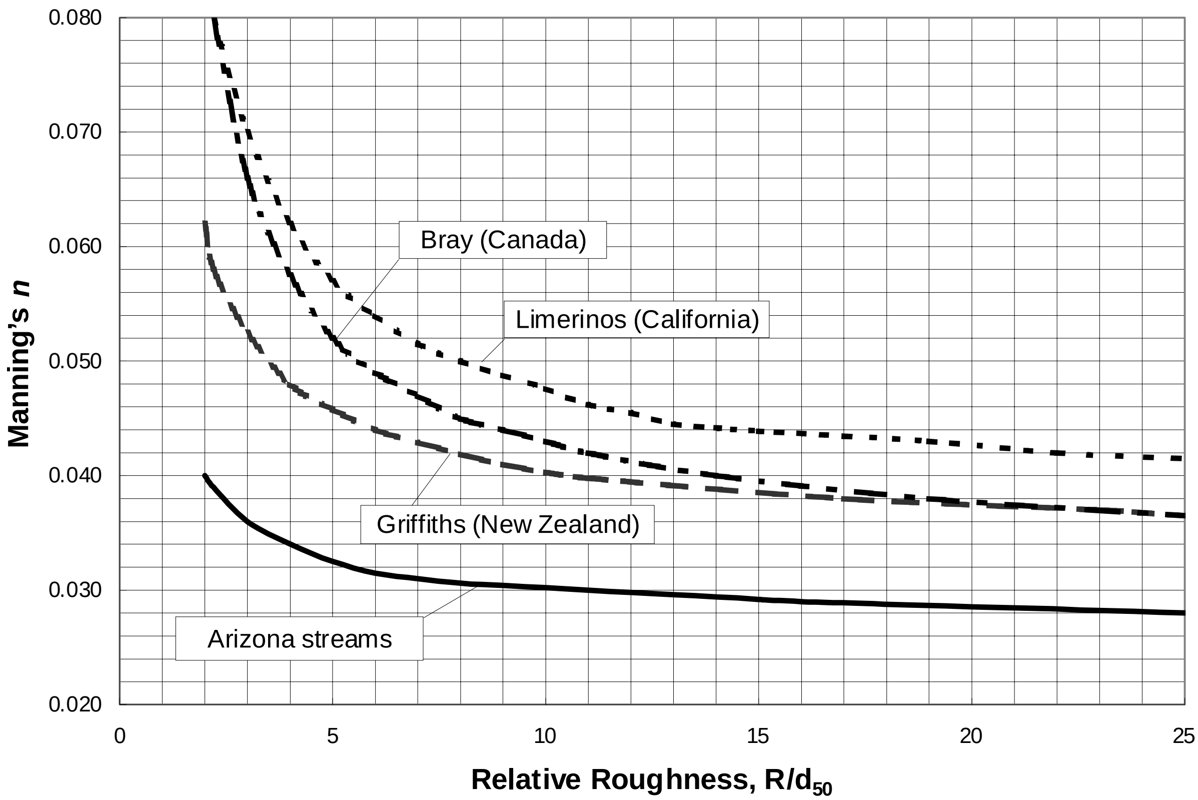

Figure 1. Relation of Manning's *n* and relative roughness for gravel-bed stream channels in Arizona and throughout the world. All trend lines are plotted for values of d_{50} equal to 0.30 foot, and values of R (hydraulic radius) range from 0.6 to about 8 feet.

channels in New York State (Coon, 1995). Few *n*-verification measurements have however been made in drylands such as the arid and semiarid regions of the southwestern United States.

USGS Professional Paper 1584 presents verified Manning's roughness coefficient values for 37 discharge measurements at 14 selected streams in Arizona. Selected sites include unstable alluvial sites, high-gradient boulder-strewn channels, and manmade flood control channels.

The verification-measurement data are used to develop empirical relations between channel and hydraulic components and Manning's *n*. The relations include an equation for gravel-bed streams that relates Manning's *n* to relative roughness and an equation to determine the effects of vegetation on total roughness.

The equation developed for base values of n for gravel-bed channels in Arizona have substantially lower n values for a given R and d_{50} compared to similar equation from other parts (Figure 1). The larger values for other channels may have resulted from the flow-retarding effects associated with channel irregularities, poorly sorted coarser bed material, or more bank vegetation compared to Arizona streams.

Phillips, Jeff V., and Todd L. Ingersoll, 1998. Verification of roughness coefficients for selected natural and constructed stream channels in Arizona. U.S. Geological Survey Prof. Paper 1584, 77 pages.
Copies are available from libraries or they may be purchased from the USGS Information Services, Denver, CO (303) 202-4700 for $14.

Ask DOCTOR Hydro

Dear Doc Hydro: Particle sizes are often classified into phi (Ø) size classes. What's the basis for phi size classes and how do I convert mm into phi units and phi units into mm?

The phi scale (Krumbein, 1934) is a logarithmic transformation of the Wentworth (1922) grade scale based on the negative logarithm to the base 2 of the particle size. Wentworth suggested the starting point of size grades as 1 mm and a constant geometric ratio of 2 between grades (with further subdivisions of the ratio as the square root of 2). The following table shows parts of the normal progression of sizes in mm and phi units from the Wentworth scale.

mm	phi	Size Class Description
0.5	1.0	Course sand
1	0.0	Very course sand
2	-1.0	Very fine gravel
4	-2.0	Fine gravel
8	-3.0	Medium gravel

The logarithmic transformation also normalizes the distribution for easier description, plotting, and analysis. Base 2 logs are converted to base 10 logs because of customary usage.

To covert mm into Ø-units ,use the formula:

$$\mathbf{Ø = -\log_2 D(mm) = -3.3219 \log_{10} D(mm)}$$

For example, to compute Ø for a 6 mm particle:

$$Ø = -3.3219 \log_{10}(6) = (-3.3219)(0.7782) = -2.6.$$

To covert Ø-units into mm, use the formula:

$$\mathbf{D(mm) = 2^{-phi}}$$

For example, to compute mm for Ø = -2.5:

$$D(mm) = 2^{-(-2.5)} = 2^{2.5} = 5.66 \text{ mm.}$$

Krumbein, W.C., 1934. Size frequency distributions of sediments, J. Sed. Petrology, **4**, 65-77.
Wentworth, C.K., 1922. A scale of grade and class terms for clastic sediments, J. Geol., **30**, 377-392.

FROM OUR READERS

Comments on Exaggerated Channel Cross-sections

I teach three levels of intensity of stream geomorphology to students in local, state, and federal agencies, and like proud pups they come up with exaggerated cross-sections and longitudinal profiles to present to me. True to these individual's skills, their engineering and surveying notes are excellent; yet, they miss the intimate form and process of bankfull channel dimensions and their width to depth/ entrenchment ratio characteristics which are pivotal in planning.

Although most profiles of reasonable distances may need some exaggeration, cross-sections rarely do. I personally, could not have better-stressed the point you made about understanding the true fluvial form of the bankfull discharge and its relative connection to the floodplain. It's a shame to go to the work of profiles and particularly cross-sections and then lose the visual effect of a land form on paper.

I too have found the 1:1 scale superior for most planning and eventually design reasons. I also find that trackhoe operators relate better to non-exaggerated scales of cross-sections and slightly exaggerated profiles. Yes, we use up more paper and wind up folding them to fit in design and planning reports, but it is a more honest representation of form.

The one use I have found legitimate for exaggerated ordinate axis on cross-section has been in the comparisons of permanent monitoring and assessment plots on streams of interest, over shorter periods of time. One can see more subtle changes, particularly on larger rivers regarding depth changes. However, I always like to include a 1:1 just above or to the side of the exaggerated plot to keep the dimensions well defined.

W. Barry Southerland
Stream Geomorphologist, USDA-Natural Resources Conservation Service, Washington State Office, Spokane (barry.southerland@wa.usda.gov).

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USDA Forest Service
Rocky Mountain Research Station
2150 Centre Ave., Bldg A, Suite 368
Fort Collins, CO 80526-1891

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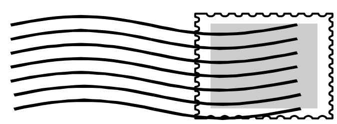

Mailing List Update

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To make this newsletter a success, we need ***voluntary contributions*** of relevant articles or items of general interest. You can help by taking the time to share innovative approaches to problem solving that you may have developed. We prefer short articles (2 to 3 pages in length) with graphics and photographs that help explain ideas.