Article 20

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Stream Channel Geometry Used to Assess Land Use Impacts in the Pacific Northwest

Many urban watershed programs fail to fully consider the implications of past, present, or future geometry of the stream system. In many instances, historical data can be used to correlate stream geometry with land use changes and watershed protection efforts. Results from efforts in other watersheds can be extrapolated to predict changes in similar stream systems. As discovered in the Pacific Northwest, the effectiveness of earlier stormwater treatment practices can be assessed by examining current stream channel stability. The observed alterations to stream channel geometry can be linked to changes in land use patterns and, therefore, can provide practical guidelines for predicting and preventing degradation in similar stream systems.

Once a minimum level of watershed imperviousness is exceeded, stream systems begin to exhibit quantifiable impacts to water quality, biological, and physical condition (Schueler, 1994). Booth and Reinelt (1993) found that 10 to 15% effective impervious cover can lead to noticeable changes in channel morphology, biological populations, vegetative succession, and water chemistry in streams and wetlands in western Washington state. Generally, an increase in impervious cover increases the volume of runoff associated with precipitation events of all magnitudes (Hollis, 1975). Consequently, the frequency of occurrence of mid-bankfull flow events also increases with increasing imperviousness. Mid-bankfull flow events have been found to be geomorphically significant in terms of their capacity to transport sediment and form the stream channel (Harvey *et al*., 1979; MacRae and Rowney, 1992). Ultimately, stream geometry, and hence stability, are adversely affected by these events.

The hydrological impacts associated with increased watershed imperviousness may lead to catastrophic channel expansion or channel incision as the stream channel attempts to reestablish equilibrium. The impacts of stream geometry changes can be severe and occur over long periods of time. Eventually, eroding channels destroy habitat diversity and clog downstream systems. Table 1 summarizes the physical characteristics that make stream reaches susceptible to destabilizing erosion, in the Pacific Northwest. One early indicator of a destabilizing channel is when sediment transport changes within the channel itself. Sediment transport is a function of shear stress and the resistance of bottom sediments to movement (Booth, 1990). Sediment transport is directly proportional to slope and inversely proportional to grain size, respectively.

A second indicator of stream erosion susceptibility is the presence of large woody debris (LWD) in the channel, such as trees limbs. LWD adds an external and transitory component of roughness to the stream channel. The increased roughness allows a stable channel to evolve, albeit at a gradient significantly steeper than resistance to sediment transport alone would support (Keller and Swanson, 1979). The channel rapidly incises, lowering the stream bed as the stream attempts to reach equilibrium by reducing the overall channel gradient. The LWD is then stranded above the low flow path. If the bed lowering significantly reduces the overall gradient, the stream incision may potentially be alleviated or halted because much of the total shear stress is dissipated on non-erodible material (i.e., the LWD). However, if the overall gradient is not significantly reduced, incision will be much more difficult to halt (Booth, 1990).

Unfortunately, these generalizations do not specifically reveal how any single stream would respond to land use changes and the timetable over which those responses would occur. This is due to specific physical conditions that differ from stream to stream. Booth (1994) established a protocol for evaluating physical stream channel condition impacts that have resulted from development. The protocol is relatively simple, requires little equipment, and can be implemented using a two-member team. An overview of the protocol is presented Table 2. Specifically designed for regions with steeper slopes, some adaptation is needed to make Booth's protocol applicable to other areas, such as humid coastal zones and the arid Southwest. In addition, all steps may not apply to certain water bodies; for example, bankfull width and depth measurements are not always practical for large rivers.

Table 1: Characteristics of Erosion-Susceptible Stream Reaches

1. Low-order, high gradient streams
2. Fine-grained, noncohesive geologic deposits
3. Low infiltration capacities of upland soils
4. Channel form and gradient controlled by large organic debris

Table 2: Overview of Rapid Channel Assessment Protocol

The protocol is intended to evaluate current stream channel conditions and not susceptibility to future disturbance.

Personnel/Equipment: two people; hip chain, 50' tape, wading rod, notebooks, clinometer

Procedure: Define a channel reach of approximately 2000'. Use a hip chain to measure out channel segments of equal length of about 10-20 channel widths each (typically 100'-200'). Within each segment:

- Determine single representative values for bankfull width and depth (with or without a measured and monumented cross section), percent of channel-bank scour (and/or artificial armoring), and sediment-size distribution.
- Keep a running total of the number of large woody debris pieces within the bankfull channel.
- Generate a thalweg profile in the vicinity of all large pools.

Rapid Channel Assessment Protocol

The protocol is applied to representative channel reaches approximately 2,000 feet in length. The reach is subdivided into segments of equal length of about 10 to 20 channel widths. The protocol is applied to each segment, focusing on representative physical measurements, large woody debris, and thalweg profiles.

Representative Measurements

Bankfull width and depth

Representative dimensions of the active channel are measured first. Bankfull width and depth are indicated by change in slope at top of bank, lower limits of perennial vegetation, and/or height of active scour (Williams, 1978). In any channel segment where the reach is incised or this measurement is otherwise not possible, it should be omitted.

Channel cross-section

The representative measurements may not always yield sufficient data for tracking channel changes. When additional detail is required, several channel cross-sections should be measured. The cross-sections should be taken at representative channel location(s), normally in straight reaches without prominent pools and with alluvial (i.e. loose water-transported) sediment on the bed and banks. The cross-section locations should be permanently marked (monumented). Rebar can be driven into the floodplain at a location several feet back from both channel edges and the top of rebar and nearby trees should be flagged to make stations easier to find.

The two-member team measures the cross-section, stretching a 50 foot tape level across the channel from the left-bank rebar (looking downstream) to the right. One person moves along the tape at one-foot intervals, reading off horizontal distance and depth from tape to channel bed. The second person maintains tape tension and records data. The bankfull depth and width are also estimated and the hip-chain distance of the cross section is noted.

Percent channel-bank scour

In each 100 to 200-foot channel segment, both stream banks are scored using the following categories:

Score	Category	Description
1.0	Stable	Vegetated or low bars to level of low flow
2.0	Low scour	Steep, raw banks only below bankfull level
3.0	Full scour	Steep, raw banks above bankfull level
4.0	Armored	Artificial bank protection of any kind

Each person tracks the scour of one bank, noting the hip-chain distance at each change of category; category changes less than 10 feet are usually ignored. Each segment is given a single length-weighted score (e.g. one bank fully “Stable” and one bank fully at “Low Scour” yields an aggregate score of 1.5).

Sediment size distribution and embeddedness

At one or more sites in each segment, 100 substrate samples known as *clasts* are counted in the streambed using the “first-touch” technique of Wolman (1954), paying particular attention to sediments in the “less than 4 mm” category (matrix sediment). Sampling is conducted at consistent morphologic locations in the stream, ideally in channel-spanning riffles midway between alternate meanders (small streams) or midway between the apex and upstream end of point bars (large rivers). Channel cross-sections should coincide with the site of pebble counts.

Large Organic Debris

The second set of measurements focus on organic debris, specifically on large woody debris (LWD) pieces. In each channel segment, running LWD totals are tallied. To qualify for data collection, LWD must (1) be a minimum of four inches in diameter and three feet long, (2) be in contact with the flow at the bankfull discharge,

(3) be not easily dislodged from position, and (4) show some influence on channel-bed topography or sediment sorting. Where a debris jam is present, the minimum number of pieces necessary to maintain the jam (the "framework" pieces) should be estimated.

Thalweg Profiles

The final protocol step focuses on large pools. Within each channel segment, pools with a downstream length at least as great as the average bankfull channel width (w_{bf}) of the entire channel reach are counted. Water depths within these pools are measured with a wading rod at maximum spacing of 0.25 w_{bf} for subsequent plotting and volume estimation using the "Rapid Streambed Profile" of Stack and Beschta (1989) and Robinson and Kaufman (1994).

Flow control in urbanizing basins, especially in areas with steeper slopes and fine-grained substrates, is a critical factor in protecting stream channels. To be fully effective, detention volumes should be sufficient to match both peaks and durations for pre- and post-development conditions typical of at least the two-year event, and possible even lower discharges (MacRae 1993). These detention volumes often exceed typical municipal requirements by an order of magnitude. Given the high additional cost and space requirements for these larger facilities, underscores the importance of recognizing erosion-susceptible terrain (Table 1). Where development impacts are anticipated, adequate detention, extensive upland buffers, and perhaps flow diversion may be used to reduce channel impacts.

Although it is a descriptive rather than predictive approach, Booth's methodology can potentially be used to correlate impacts to physical stream conditions with upstream development or land use changes. To effectively do so, however, subwatershed land use conditions and impervious cover must be recorded over time. It is not always possible to directly correlate physical stream conditions to various levels of imperviousness. The type of noticeable, large-scale stream stability changes considered in Booth's protocol may lag development by several decades or more, and may not be immediately evident during the early stages of urbanization.

These considerations do not diminish the particular usefulness of Booth's protocol. This protocol provides a simple, repeatable method to monitor the effectiveness of stormwater quantity controls with respect to hydrology and channel stability. This information can provide insight into a watershed's development capacity, the types of stormwater treatment practices needed, and where practices are most useful for protecting stream stability. When used in conjunction with other stream assessment techniques such as EPA's Rapid Bioassessment Protocol (Plafkin *et al.*, 1989) and Galli's Rapid Stream Assessment Technique (unpubl.), Booth's protocol can provide insight to how currently unimpacted streams of similar size and morphology might respond to different development intensities. An understanding of morphological responses, then, can be used to design protection strategies for these relatively untouched streams. Early modeling and field research has shown that Booth's method is a robust predictor of stream erosion potential in the Pacific Northwest.

-RLO

References

Booth, D. 1994. A Protocol for Rapid Channel Assessment. unpubl. paper.

Booth, D.B. 1990. "Stream-Channel Incision Following Drainage-Basin Urbanization." *Water Resources Bulletin* 26(3): 407-417. American Water Res. Assoc.

Booth, D.B. and L.E. Reinelt. 1993. "Consequences of Urbanization on Aquatic Systems—Measured Effects, Degradation Thresholds, and Corrective Strategies." In conf. proc.: *Watershed '93 A Nat. Conference on Watershed Mgt.* Mar. 21-24, 1993. Alexandria, VA.

Galli, J. undated. Rapid Stream Assessment Technique (RSAT). unpubl. paper. Available through the Metropolitan Washington COGs: 777 North Capitol Street, NE, Washington, DC 20002.

Harvey, A. M. *et al.* 1979. "Event Frequency and Morphological Adjustment of Fluvial Systems in Upland Britain." In conf. proc. *10th Annual Geomorphology Symposia Series*. September 21 - 22, 1979. Binghampton, NY.

Keller, E.A. and F.J. Swanson. 1979. "Effects of Large Organic Material on Channel Form and Alluvial Process." *Earth Surface Processes.* 4:361-380.

MacRae, C. R. 1993. "An Alternative Design Approach for the Control of Instream Erosion Potential in Urbanizing Watersheds." In conf. proc. *Sixth International Conference on Urban Storm Drainage.* September 12-17, 1993. Niagra Falls, Ontario.

Plafkin et al. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish.* U.S. EPA, Office of Water, Washington, DC. EPA/330/4-39-001.

Robinson, E.G. and P.R. Kaufman. 1994. "Evaluating Two Objective Techniques to Define Pools in Small Streams." In: *Effects of Human-Induced Changes in Hydrologic Systems.* Summer Symposium. American Water Resources Association. Jackson Hole, WY. pp. 659-668.

Schueler, T.R. 1994. "The Importance of Imperviousness." *Watershed Protection Techniques.* 1(3): 100-111.

Stack, W.R. and R.L. Beschta. 1989. "Factors Influencing Pool Morphology in Oregon Coastal Streams." In: Woesner, W.W. and D.F. Potts (eds), *Symposium on Headwater Hydrology.* American Water Resources Association. pp. 401-411.

Williams, G.P. 1978. "Bank-full Discharge of Rivers." *Water Resources Research* 14: 1141-1154.

Wolman, M.G. 1954. "A Method of Sampling Coarse Bed Material." *Transactions of the American Geophysical Union* 35: 951-956.