



STREAM NOTES

To Aid in Securing Favorable Conditions of Water Flows

April 1997

Approaches for Evaluating Stream Channel Cross-Section Data

Permanent channel cross-sections have long been used to assess the effects of management activities on stream channel morphology and fish habitat. Objective, quantitative, and repeatable procedures are highly desirable to evaluate channel change over time and to support resource management decisions.

A paper appearing in the *North American Journal of Fisheries Management* by Olson-Rutz and Marlow describes four indices useful for quantifying change in channel form over time using cross-section data from permanent transects. Properly applied to multiple transects, the indices provide statistically testable means and standard errors useful for comparing pre- and post-treatment channel morphology changes. The indices can be used individually or in combinations to address specific information needs.

The indices are:

1. Net percent change in area ($\Delta A\%$),
2. Absolute percent change in area ($|\Delta A\%|$),
3. Width/depth ratio (w/d), and
4. Gini coefficient (G).

The approach requires permanent transects that are measured before and

after a proposed treatment. The distance from the horizontal transect tape to the bottom of the channel (Y_i) is measured at fixed intervals (e.g., every 10 cm) along the tape. Pre- and post-project measurements must be taken at identical distance points along the tape and standardized to a common horizontal datum for valid before-and-after comparisons.

1. Net percent change in area ($\Delta A\%$) quantifies the net change in cross-sectional area of a transect computed as:

$$\Delta A\% = \frac{\sum_{i=1}^n (Y_{before} - Y_{after})}{\sum_{i=1}^n Y_{before}} \times 100$$

Changes in area are important because they influence flow and water temperature. However, a channel can experience aggradation and degradation without a net change in area since erosion in one part of the channel may balance an equal amount of deposition in another. Consequently, in certain

STREAM NOTES is produced quarterly by the Stream Systems Technology Center, Fort Collins, Colorado.

The PRIMARY AIM is to exchange technical ideas and transfer technology among scientists working with wildland stream systems.

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

Ideas and opinions expressed are not necessarily Forest Service Policy. Trade names do not constitute endorsement by the USDA Forest Service.

Phone: (303) 498-1731

FAX: (303) 498-2306

DG: STREAM:S28A

e-mail: /s=stream/oul=s28a

@mhs-wa.attmail.com

IN THIS ISSUE

- **Evaluating Cross-Sections**
- **Temporal Variation of Bedload**
- **Hierarchical Framework of Aquatic Ecological Units**
- **Ask Doctor Hydro: Albert Shields**

situations, a computed net change in area of zero may incorrectly characterize the channel as stable (see Figure 1 for an illustration of how this may happen). To avoid this potential bias, absolute percent change is often more useful.

2. Absolute percent change in area ($|\Delta A\%|$) quantifies cumulative channel change ($(|\Delta A\%|) = \text{erosion} + \text{deposition}$). It is computed as:

$$|\Delta A\%| = \frac{\sum_{i=1}^n |(Y_{before} - Y_{after})|}{\sum_{i=1}^n Y_{before}} \times 100$$

Absolute changes in area are important because they represent the total amount of streambed material movement during the monitoring period; frequent changes in channel shape may be detrimental to fish habitat and populations.

3. The width/depth ratio (w/d) is a relative index of channel shape. Width is the total distance across the channel and depth is the mean depth of the channel. Mean depth is best calculated as total cross-sectional area divided by width. Channels with high w/d ratios tend to be shallow and wide. Channels with low w/d ratios tend to be narrow and deep.

Applied to permanent cross-sections, w/d ratios are independent of water level. For some applications, it may be desirable to calculate separate water level-related w/d ratios to evaluate underwater channel shape or usable fish habitat. When permanent transects are used the width is fixed, and therefore the w/d index may be misleading. For example, as shown in Figure 1, channels may have identical w/d ratios (w/d_{pre}) yet have remarkably different shapes. To avoid this potential bias, the Gini coefficient better describes changes to channel cross-sectional shape.

4. The Gini coefficient (G) quantifies channel form independent of stage height and cross-sectional area. It is the arithmetic average of the differences between all pairs of depths ($Y_i - Y_k$) and is computed as:

$$G = \frac{\sum_{i=1}^n \sum_{k=1}^n |Y_i - Y_k|}{2n^2 \bar{Y}}$$

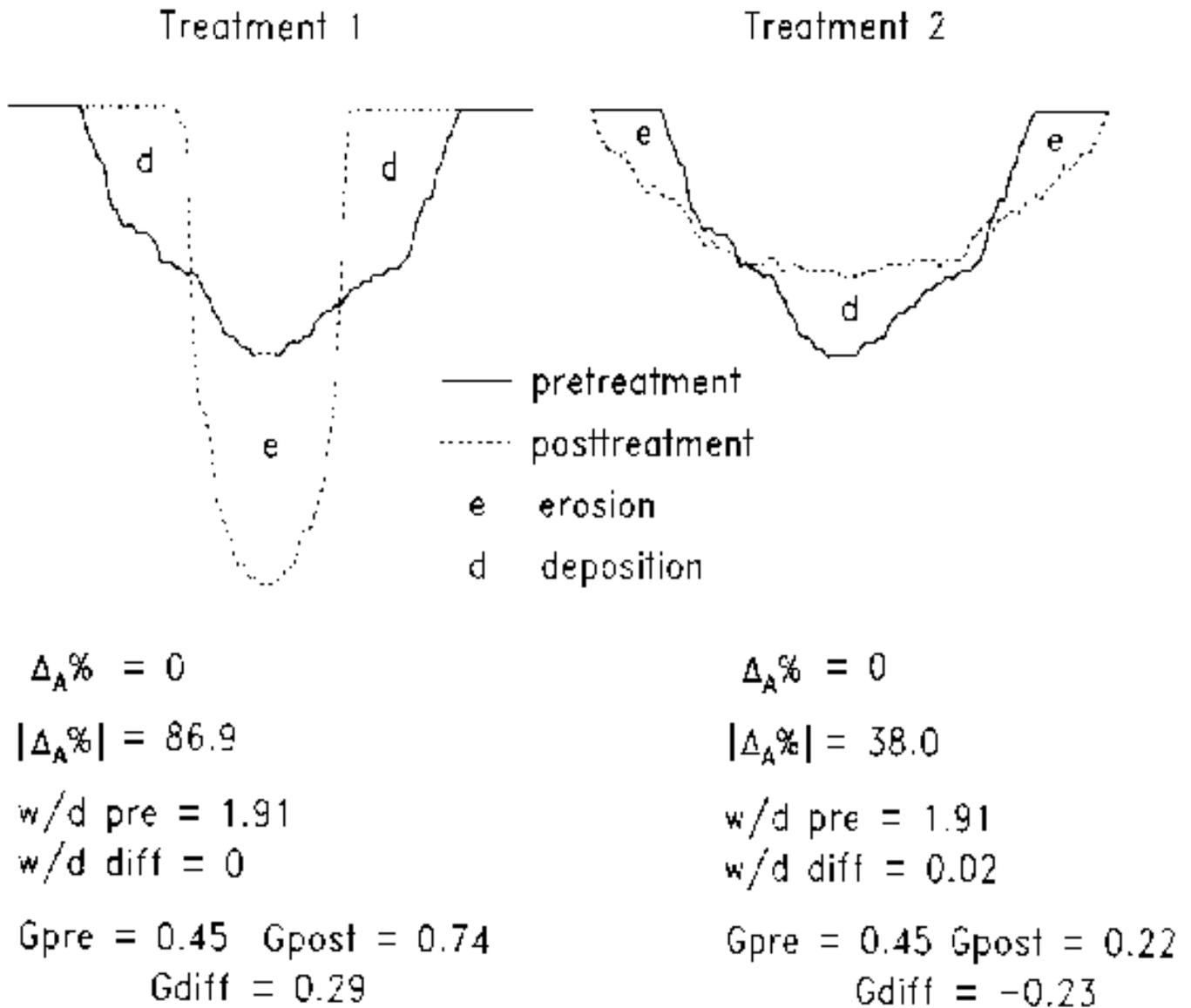
The direction and magnitude of change in the Gini coefficient over time describes whether a channel is becoming wider and shallower or narrower and deeper in response to management or natural events. When all depths are equal, G approaches a minimum value of zero. Wide flat channels have low G values (Figure 1, Treatment 2, G_{post}). When depths vary a large amount across a transect, G approaches a maximum value of 1. Deep and narrow channels have G values near 1 (Figure 1, Treatment 1, G_{post}).

When the Gini coefficient is calculated from pre- and post-treatment scenarios, the difference (diff) in G ($G_{diff} = G_{post} - G_{pre}$) describes the direction of channel change. Positive differences indicate the channel is becoming deeper and narrower. Negative differences indicate the channel is becoming shallower and wider.

The magnitude of change that can be detected using these indices is a function of the number of permanent transects monitored and the variability among transects and stream reaches. The indices can detect small changes in channel area and form, along with the movement of streambed and streambank materials, provided a sufficient number of transects are measured. These changes may be short-term, representing normal dynamic stream channel processes, or they may be substantial long-term changes induced by management or natural events.



ANALYSIS OF STREAM CROSS SECTIONS

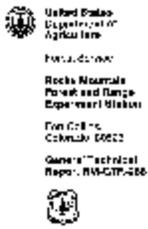


For more information see the complete article:

Olson-Rutz, K.M., and C.B. Marlow. 1992. Analysis and interpretation of stream channel cross-sectional data. *North Amer. Journal of Fisheries Management* 12:55-61.

The authors are range scientists affiliated with the Department of Animal and Range Sciences, Montana State University, Bozeman, Montana. Use of the Gini coefficient to describe channel cross-sectional shape was adapted from economics and plant population biology literature.

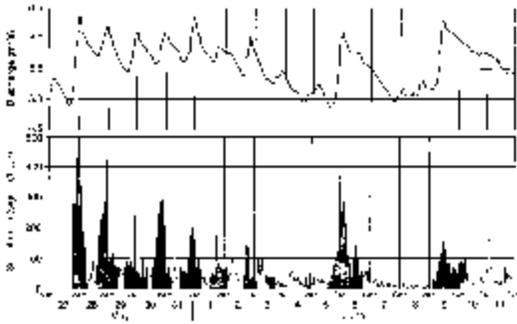




Analyses of the Temporal Variation of Coarse Bedload Transport and Its Grain Size Distribution

Squaw Creek, Montana, USA

Kristin Bunte



A recent book published by the Rocky Mountain Station, *Analyses of the Temporal Variation of Coarse Bedload Transport and Its Grain Size Distribution, Squaw Creek, Montana, USA*, General Technical Report RM-GTR-288), by Kristin Bunte reports on a short continuous record of coarse material bedload measurements obtained for an entire snowmelt period at Squaw Creek, a tributary of the Gallatin River in southwest Montana. A magnetic tracer technique, which makes use of naturally magnetic rocks, was imported from Germany and used to measure the bedload of the gravel-bed mountain stream which drains a watershed of 41 square miles. The stream channel is mostly cobbles and the gravel bars are mostly coarse gravels. Since 76% of the rocks in the watershed are magnetic, the site is ideal for using the magnetic detector.

The magnetic detection device was installed across the channel bottom and whenever a magnetic particle larger than 32 mm in size passed over the device, it induced a voltage peak that was recorded. This allows for continuous recording of bedload movement. The detector simply registers whether a particle has passed the measurement site but is not able to measure particle size. Nevertheless, the technique is ideal for investigating the temporal variation of bedload movement.

In addition to the magnetic detector, a series of bedload measurements were collected using standard Helley-Smith bedload samplers and a large net sample. The net sampler (1.55 meters wide and 0.3 meters high) was designed to be capable of sampling all coarse particles, but its 1 cm mesh size, let all smaller particles pass.

From the strip chart record, bedload signal rates were determined at a 1-hour resolution for 17 days (Figure 1) and at a 5-minute resolution over a 3-day period. (Figure 2). The temporal record of bedload transport shows fluctuating signal rates, and the relation between discharge and bedload transport shows the typical one order of magnitude variability of bedload data.

Daily bedload waves show a pattern of three consecutive waves: The primary bedload wave corresponds to rising and peak flows while secondary and tertiary bedload waves pass on the falling limbs of the hydrograph. The size of the three bedload wave varies over the course of the hydrograph and is attributable to the preceding flow history and the condition of the river bed (degree of consolidation). A more detailed analysis looking at shorter 5-minute time scales (Figure 2) showed that major bedload waves occur daily in association with daily peak flows. Minor bedload waves (not illustrated) occur about every five hours and smaller bedload waves were observed to occur with hourly frequencies.

These observations were combined with temporal records of transport rates and bedload particle sizes, water surface slope, and channel bottom change, to yield a conceptual model useful for describing bedload transport in coarse gravel-bed rivers. The model includes both systematic particle exchange and adjustment processes that occur during the rising limbs of the daily hydrograph and discontinuous adjustment processes, which result from spatially and temporally variable conditions of flow, roughness, and channel geometry.

Kristin Bunte is a research associate and fluvial geomorphologist presently at Colorado State University, Department of Civil Engineering, Engineering Research Center, Fort Collins, CO. The work reported here was done when she was a graduate student at the Freie Universität Berlin, Germany.



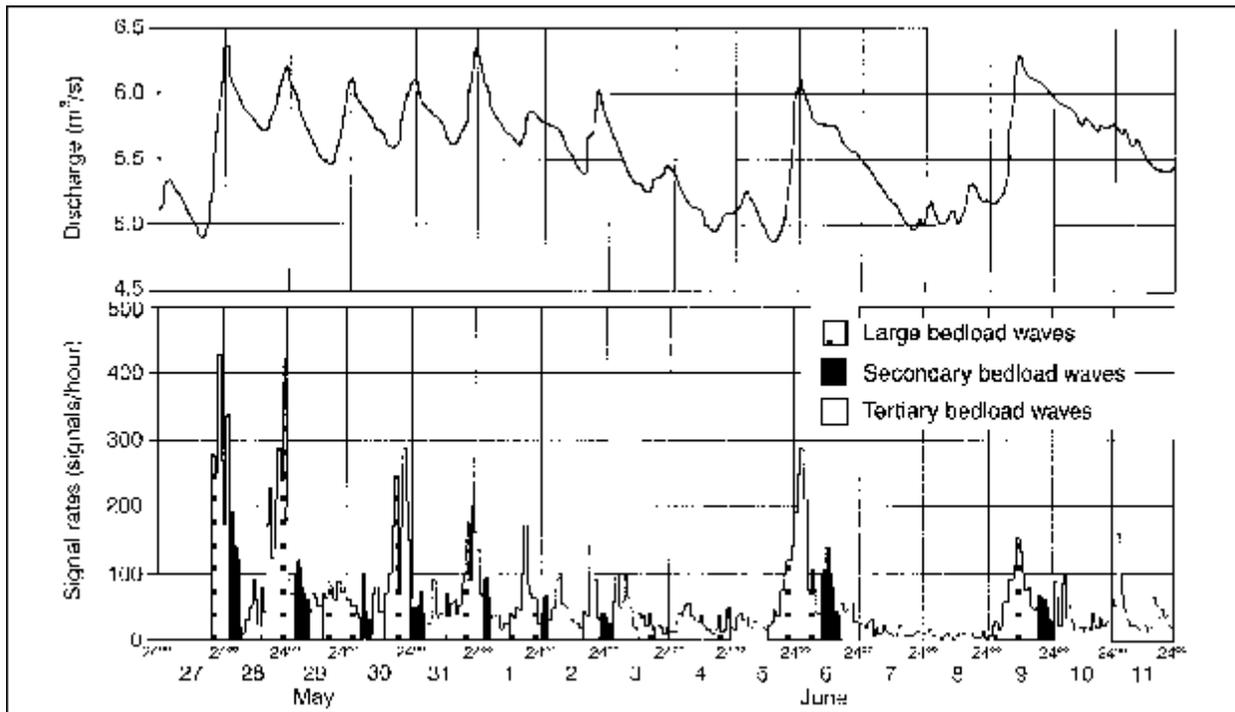


Figure 1. Temporal variation of bedload signal rates in 1-hour resolution over a 17-day period during a typical snow melt high flow in 1986.

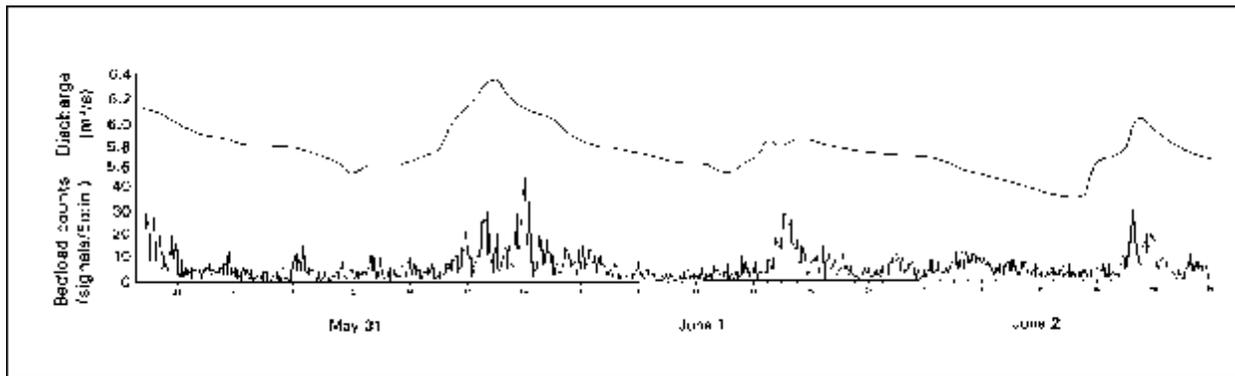
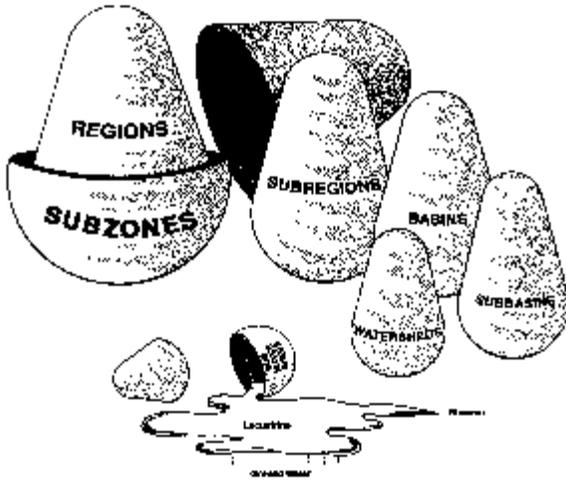


Figure 2. Temporal variation of bedload signal rates in 5-minute resolution over a 3-day period from May 31 to June 2, 1986.



A Hierarchical Framework of Aquatic Ecological Units in North America (Nearctic Zone)

James Maxwell, Clay Edwards, Mark Jensen, Steve Paustian,
Harry Parrott, and Donley Hill



A recent book published by the North Central Forest Experiment Station, *A hierarchical framework of aquatic ecological units in North America (Nearctic Zone)* (General Technical Report NC-176), by James Maxwell, Clay Edwards, Mark Jensen, Steve Paustian, Harry Parrott, and Donley Hill, proposes a framework for classifying and mapping aquatic systems at various scales using ecologically significant physical and biological criteria (Figure 1). Classification and mapping concepts follow tenets of hierarchical theory, pattern recognition, and driving variables.

The objectives of the publication are to provide:

1. A generic hierarchical framework for characterizing aquatic ecosystems.
2. A description of linkages between terrestrial and aquatic biophysical environment maps.
3. Primary map unit criteria for hierarchical mapping of aquatic systems.
4. Classification criteria to be considered in describing the form, function, and the evolution of aquatic systems at various spatial scales.
5. Standardized terminology to be used in the classification, mapping, and inventory of aquatic systems.

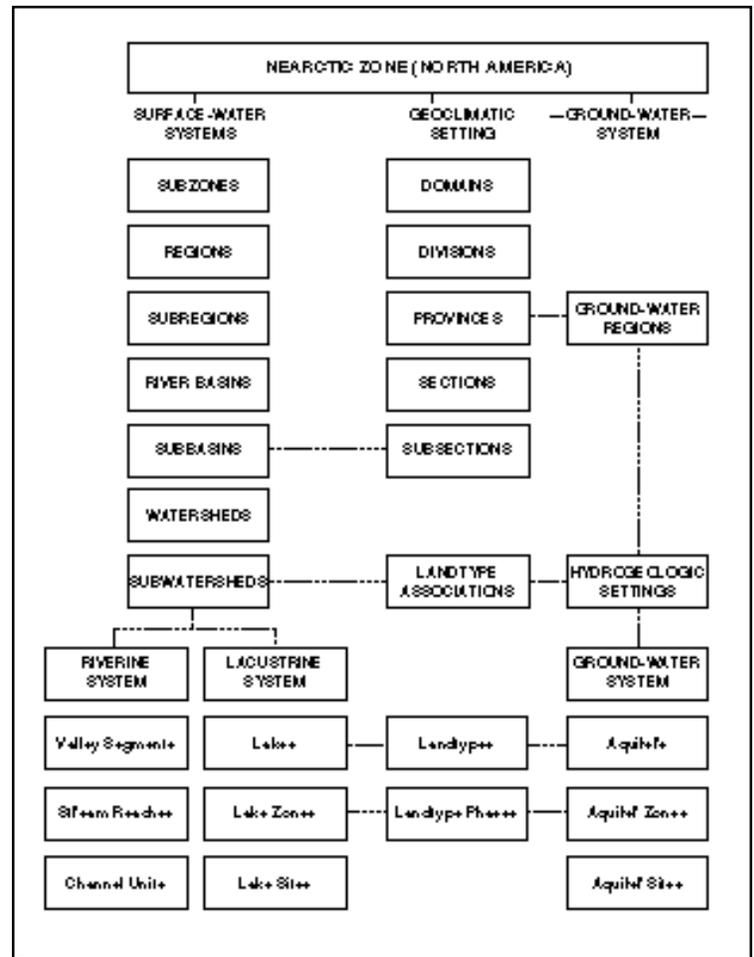


Figure 1. General framework of aquatic ecological unit hierarchy. Sizes of units decrease from top to bottom. Larger hydrologic units and ground-water regions are regionalized based on zoogeography and physiography. Smaller aquatic systems are classified based on biophysical criteria and are nested within these overlying settings. Primary functional linkages between aquatic systems and terrestrial (geoclimatic) systems are shown as dashed lines.

Copies of General Technical Reports NC-176d and RM-GTR-288 discussed in this issue of STREAM NOTES are available from the Stream Systems Technology Center, or the respective Research Stations. To obtain a copy from STREAM: Send a DG message to STREAM:S28A, FAX (970) 498-1660, or E-mail: /s=stream/ou1=s28a@mhs-fswa.attmail.com



Ask DOCTOR Hydro

Dear Doc Hydro: Everyone is familiar with the Shields diagram for critical tractive force (initiation of motion), but I haven't seen other publications written by Shields. Who was Shields and whatever happened to him?

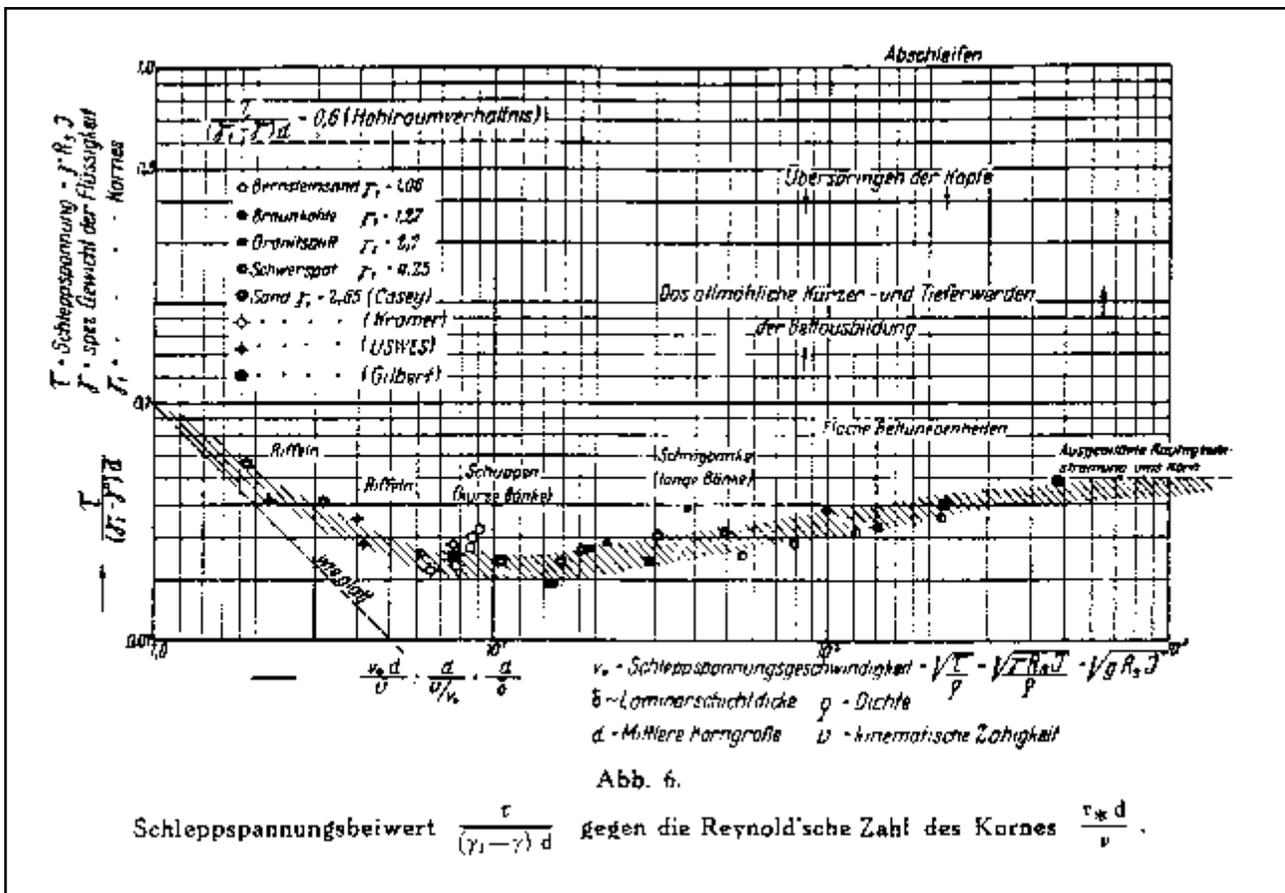
Albert F. Shields (1908-1974) was an American who obtained his doctoral degree in Nazi Germany from the

Technischen Hochschule Berlin in 1936. Going to Germany on a scholarship, his original intent was to do a thesis on ship design, but the only available research assignment was in the field of bedload sediment transport. The now famous Shields Diagram (see below) appeared in his doctoral thesis and was later translated into English.

Shields was unable to find full-time employment in his newly chosen field upon returning to the United States and had a successful career as a machine designer and inventor. At the time of his retirement, he held more than 200 patents in the corrugated-box machinery design field.

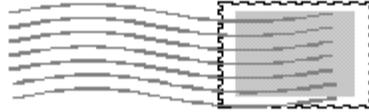
For more information on the fascinating chain of events surrounding Shields and the eventual discovery of his work in America see:

Kennedy, J.F., 1995. The Albert Shields Story. ASCE Journal of Hydraulic Engineering, p. 766-772.



The original diagram by Shields: Shields, A. 1936. "Anwendung der Aehnlichkeitsmechanik und der Turbulenzforschung auf die Geschiebepbewegung." Mitteilungen der Preussischen Versuchsanstalt für Wasserbau und Schiffbau, Heft 26, Berlin, Germany (in German), English translation by W.P. Ott and J.C. van Uchelen available as Hydrodynamics Laboratory Publication No. 167, Hydrodynamics Lab., California Institute of Technology, Pasadena.





Mailing List Update

We hope that you value receiving and reading STREAM NOTES. If you wish to receive future issues, no action is required. If you would like to be removed from the mailing list for STREAM NOTES or if the information on your mailing label needs to be updated, please contact us via mail at:

Rocky Mountain Station, Stream Systems Technology Center,
240 West Prospect Road, Fort Collins, CO 80526-2098,
DG (Stream:S28a), FAX (970-498-1660), or sends us an E-mail
message (/s=stream/ou1=s28a@mhs-fswa.attmail.com).

USDA policy prohibits discrimination because of race, color, national origin, sex, age, religion, or handicapping condition. Any person who believes he or she has been discriminated against in any USDA-related activity should immediately contact the Secretary of Agriculture, Washington, DC 20250.

STREAM NOTES

STREAM SYSTEMS TECHNOLOGY CENTER
USDA Forest Service
Rocky Mountain Station
240 West Prospect
Fort Collins, CO 80525

APRIL 1997

IN THIS ISSUE

- **Evaluating Cross-Sections**
- **Temporal Variation of Bedload**
- **Hierarchical Framework of Aquatic Ecological Units**
- **Ask Doctor Hydro: Albert Shields**

**BULK RATE
POSTAGE & FEES PAID
USDA-FS
Permit No. G-40**

OFFICIAL BUSINESS
Penalty for Private Use \$300