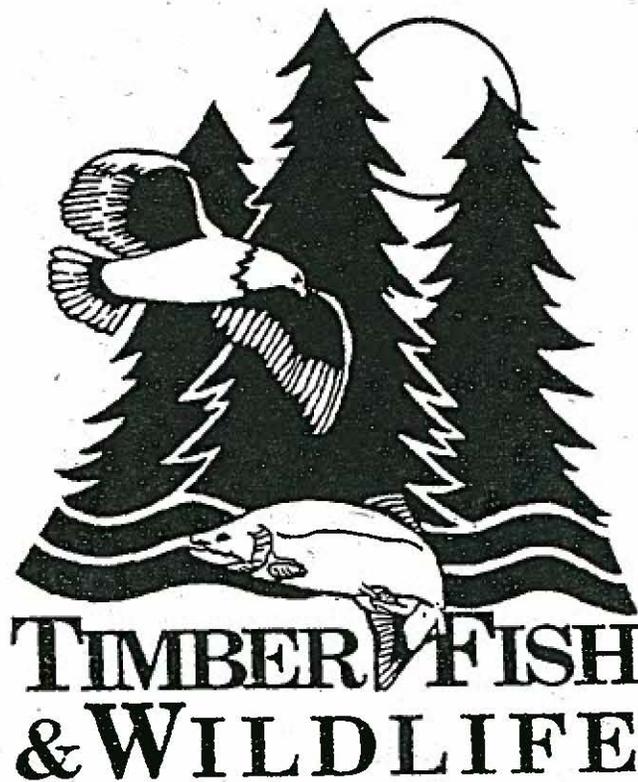


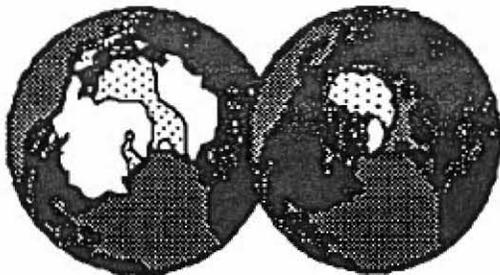
**GEOMORPHOLOGICAL WATERSHED ANALYSIS PROJECT**  
**ANNUAL REPORT FOR THE PERIOD FROM 10/91 TO 5/92**

By

David Montgomery



May 18, 1992



QUATERNARY RESEARCH CENTER

University of Washington, Seattle, Washington 98195  
(206) 543-1166 FAX 543-3836

Geomorphological Watershed Analysis Project

Annual Report for the period from 10/91 to 5/92

Submitted to the Sediment, Hydrology and Mass Wasting Committee  
of the Timber/Fish/Wildlife Agreement

compiled by

David R. Montgomery  
Quaternary Research Center and Department of Geological Sciences  
University of Washington  
Seattle, WA 98195

5/18/92

Nancy Sturhan  
DNR Forest Practice Division  
P.O. Box 47012  
Olympia, WA 98504-7012

Dear Ms. Sturhan,

This document constitutes the first annual report for the Geomorphological Watershed Analysis project funded by the SHAMW committee under the Timber/Fish/Wildlife agreement. The report covers the seven month period from October 1, 1991, to May 1, 1992. The format of this report may differ from the standard TFW report format, but it is intended to communicate our progress in research on the geomorphology of mountain watersheds. We present a brief overview of our project, review the objectives defined in our proposal, compare progress to date with the projected targets, and briefly discuss some objectives for research in the upcoming year. Finally, in an appendix format we present a series of draft research papers and preliminary results produced by the project to date. One of these papers has been accepted for publication by a scientific journal. Two others are draft manuscripts. The abstract of a third draft manuscript that is almost completed is also included. The draft manuscripts are presented in this report with the understanding that they are not for distribution outside of the SHAMW committee at this time. We include them to allow assessment of project progress. In the immediate future we will be soliciting preliminary reviews from experts both within and external to the TFW process. Reviewers comments and revisions based on our upcoming field work will be incorporated at a later date when these draft manuscripts are presented in a formal report. It is our intention to publish our results in the scientific literature, as well as in TFW reports, and we have chosen this presentation format for our annual report to facilitate ongoing dialog with the SHAMW committee while maintaining progress toward our research objectives. Our final biennial report will be more formal.

#### Geomorphological Watershed Analysis

The overall goal of the Geomorphological Watershed Analysis project is to provide the scientific basis for predicting the response of hillslopes and channel systems in forested mountains to both long-term average conditions [climate, geology, topography, vegetation] and short-term perturbations [fire, extreme storm events, and timber harvest]. Our approach is oriented toward developing objective, physically-based procedures for assessing and interpreting the current condition of channels and hillslopes, and for predicting response to watershed perturbations such as accompany timber harvesting. Conceptually, we view

potential hillslope and channel responses as linked through the processes controlling sediment mobilization, routing, and storage within a watershed. While maintaining this watershed context, we have divided our study into three distinct components: shallow sediment sources, deep-seated landslides, and channel condition and response. Study plans and schedules for each of these components are presented in our original proposal. A brief review of progress toward our objectives follows.

#### Interactive Team of Researchers

A major goal of our project is the development of an interactive team of faculty and graduate student researchers studying the geomorphology of mountain drainage basins. Personnel directly funded by the project include one of the PI's [Montgomery] and three graduate students [Bauer, Buffington, and Schmidt], one working on each aspect of our project. Two computer programmers [Greenberg and Reiss] are partially supported by TFW funding. A fourth student has been admitted to UW to work on the channel assessment component starting in Fall, 1992. A post-doctoral fellow [Miller] will be funded in academic year 92-93 to work on the deep-seated mass wasting component of the project. The timing of recent budget uncertainties relative to our admission process and the subsequent elimination of \$28k from our project precluded further expansion of the program.

Communication between the PI's [Dunne, Montgomery, and Dietrich] occurs frequently and the entire project met at UW on April 5th to discuss progress and research directions. The TFW salaried personnel and the other PI's [Dunne and Dietrich] also have brought several collaborators to work on projects directly relating to project goals. Dr. Weihua Zhang (Univ. of Washington postdoctoral researcher funded from federal sources) has been working with Dr. Montgomery on examining the effects of digital elevation model (DEM) resolution on simulations of surface and hydrologic processes. Dr. Efi Foufoula (Univ. of Minnesota) has begun a collaborative effort with Dr. Montgomery focused on investigating methods to delineate the hillslope/channel network transition from DEM's. Dr. Montgomery also has been coordinating research efforts on channel assessment and response with Dr.'s Lee MacDonald and Ellen Wohl at Colorado State University with the goal of standardizing data collection procedures so as to maximize the usefulness of data collected by both groups. Communication is continuing with Dr. Cathy Wilson of CSIRO (Australia). She is working with the research group that developed the digital terrain model TOPOG, which we are using as the basis for our shallow debris flow prediction model. Their group is trying to develop a dynamic version of TOPOG. Dr. Wilson will be visiting UW at the expense of the Australian government during mid-June to discuss our research.

We also have provided input to other TFW funded, or related, projects through consultations, collaboration, and loans of equipment. The Ambient Monitoring Project approached us for advice on data collection methodologies and analysis in October and November, 1991. Prior to the program's termination, we suggested revisions to their field methods that would have increased the utility of their data for use in our analyses and those of other resource management professionals. We also suggested revisions in their analysis procedures that they have incorporated with productive results. A desired set of data for collection in any future efforts was transmitted to the Ambient Monitoring Committee through Jeff Light and Kate Sullivan. We also provided input for Ed Rashin's project on BMP evaluation at Washington State Department of Ecology, JoAnne Metzler's peak discharge channel damage assessment methodology, and Phil Peterson's response thresholds review. Additionally, we are pursuing plans for collaborative research on the history of landsliding in the Hoh River basin with Susan Calder, the DNR geologist located in Forks. In an effort to stimulate collaboration between fisheries biologists and geomorphologists we have been working on field measurements with, and loaning equipment to, Phil Peterson of the TFW "Big Fish" project for his study on channel scour and bed modifications at Kennedy Creek. Also, at the request of the SHAMW committee we have been developing a process-based channel classification that we hope will encourage further interdisciplinary research and provide insight into watershed analysis. In summary, we have established an interactive research group that extends well beyond the size of our TFW-funded personnel and we are involved in projects that extend beyond the scope of our original proposal.

### Shallow Sediment Sources

Progress toward the objectives outlined in our proposal is summarized below.

- 1) Develop a method for determining how well digital elevation data represent actual watershed topography to the degree necessary for locating sediment sources.

We have developed two methods for examining the quality of landscape representation in digital elevation models. These methods are outlined in two of the draft manuscripts included in this report as appendices 1 and 2 [Bauer, in prep., Zhang and Montgomery, in prep.]. The method developed by Bauer is based on calculating the signal to noise ratio of a digital elevation surface. This approach provides a method for determining the quality with which an object of a given size (a hillslope or a debris flow source area, for

example) is represented in a DEM. The approach developed by Zhang and Montgomery examines the effect of DEM grid size on the distribution of the topographic parameters that influence both runoff generation and surface process models and on hydrologic simulations based on these models. Both of these studies have fundamental implications for the use of DEM's in surface process models and point to the need to use a DEM scale that is appropriate for resolving landscape features and processes of interest.

2) Test the use of a steady state shallow subsurface runoff model to predict spatial distribution of ground saturation in steep, realistically complex terrain.

We recently had a paper accepted in the journal "Geology" based on TFW-supported work on predicting the spatial pattern of runoff production and erosion mechanisms using the steady state shallow subsurface runoff model TOPOG. This paper discusses the partitioning of landscapes into different process regimes on the basis of slope, contributing drainage area, and threshold process theories. These thresholds provide the theoretical underpinnings of the DEM-based watershed modelling approach that we are developing. The paper is included in this report as Appendix 3. Also we are conducting steady state sprinkler experiments on a small catchment in Coos Bay, Oregon, from May 26 to June 14, 1992, in part to provide a data set against which to test the predictions of steady state shallow subsurface runoff models. Together with an earlier set of sprinkler experiments this data set will allow examination of the utility of the hydrologic model for use in steep terrain.

3) Develop a method for predicting areas prone to shallow landsliding in a watershed through the use of topographic analysis software.

We have developed a DEM-based method for predicting relative debris flow hazard in a catchment. A draft manuscript describing the model and documenting model predictions [Montgomery and Dietrich, in prep.] is included in this report as Appendix 4. To date, this model has been tested in two catchments: one in Marin County, California, and one in the Oregon Coast Range near Coos Bay. Model results are quite encouraging and are detailed in the draft manuscript. We have acquired high-resolution DEM data for another catchment in the Hoh River basin on the Olympic Peninsula and are commencing analysis of this data set. We also intend to test the method at an as yet undetermined catchment in the Cascades.

4) Develop and test DEM-based predictions of channels most likely to be affected by debris flows.

In the debris flow model manuscript we outline a method for identifying channels subject to potential debris flow scour [Montgomery and Dietrich, in prep.]. The method has been used for two catchments and we anticipate expanding this aspect of our study in conjunction with further predictions of relative debris flow initiation hazard in other catchments.

In summary, we have made significant progress toward the objectives of the shallow sediment source component of our project. Further development, testing, and refinement of model predictions and investigations of the effect of DEM scale on process models are anticipated to proceed according to our originally proposed schedule.

#### Deep-Seated Mass Failures

Our research in deep-seated mass failures is oriented toward three objectives:

- 1) Developing a method for systematic prediction of potential sites of deep-seated mass failures in a watershed.

Kevin Schmidt, a TFW-supported graduate student in Geological Sciences at UW, is examining controls on large-scale mass wasting in the Cascades. He is working in the Chuckanut formation in the Nooksak River basin and is currently analyzing initial data derived from air photographs and topographic maps. Comparing empirical observations with predictions of a two-dimensional slope stability model he has found evidence for both topographic and local structural/hydrologic controls on the size of stable hillslopes. A summary of his research to date is presented in Appendix 5. Dan Miller, currently a Ph.D. candidate in Geological Sciences at UW, will begin a TFW-supported post-doctoral fellowship in Fall 1992 to work on further developing models for the controls on deep-seated mass failures.

- 2) Developing a method for predicting the alteration of stability as a result of changes in hydrology due to natural weather fluctuations or to management.

Progress toward this objective is predicated upon satisfactorily testing a model for controls on deep-seated mass wasting and will be pursued later in the project.

- 3) Development of guidelines for field studies to refine predictions in areas that have been flagged as potentially unstable.

Progress toward this objective is predicated upon the previous two objectives and will be pursued later in the project.

#### Assessment of Channel Condition and Response

In addition to the objectives listed below, we have been working on developing a process-based channel classification. The abstract of the manuscript is included as Appendix 6 [Montgomery and Buffington, in prep.]. The proposed classification was developed in response to enthusiasm from the SHAMW committee when presented with our initial ideas on the subject. We have pursued further development of the scheme in addition to our other projects. Although the manuscript is quite long, it is essentially 80% completed. We estimate that it will take at least 3 to 4 more weeks to generate a rough draft. We hope to solicit TFW review of a draft in late June or early July, 1992. We anticipate completion of the paper [incorporation of reviewers comments, experience gained through field application, etc...] by late summer or early fall, 1992, and will be using the system to guide data collection this upcoming summer. Research groups at Colorado State University and the University of Montana have expressed interest in the system and will also be testing it's utility independent of our effort. Thus we hope to have a field-tested version available within the next six months. We plan on publishing the manuscript as a TFW report upon incorporation of reviewers comments and after testing its utility in the field.

Progress toward our other objectives in the channel assessment project is outlined below.

- 1) Test the ability of digital elevation data to resolve local channel slope with sufficient accuracy to be useful for geomorphic modelling and habitat classification.

Field data necessary to conduct this comparison will be collected this upcoming summer. U.S.G.S. 7.5' DEM's (30 m resolution) have been obtained for the Hoh River, Tennessee Valley, and Coos Bay study sites. Appropriate DEM's will be obtained for other study areas after completion of summer field work.

- 2) Produce a summary of existing data on channel properties from forested mountainous watersheds that can be used to test our threshold and transport controlled characterization of channels.

John Buffington, a TFW-supported graduate student in Geological Sciences at UW, has collected and analyzed much of the available data pertinent to assessing our threshold channel model for predicting sediment size from channel slope and bankfull depth. A summary of his research is included as Appendix 7. Results to date are encouraging and illustrate the probable effects of bedform roughness, bed armoring, and large woody debris. Much of the available data from previous studies, however, is unsatisfactory because we either do not know exactly how it was collected, or do not approve of the methods used during data collection. John will be collecting and analyzing a field data set to address these effects this summer.

- 3) Develop a method for prediction of channel attributes from a digital elevation model (DEM) and field observations that test the predictions.

We outline a hypothesis for predicting channel type from digital elevation models in our draft manuscript on channel classification (Appendix 6) [Montgomery and Buffington, in prep.]. Data necessary to test this hypothesis will be collected this upcoming summer.

- 4) Develop methods for predicting sediment flux through a channel network.

One of the dominant effects on sediment routing and storage in low-order channels is the interaction between large woody debris and sediment. This interaction, however, has not been studied systematically and there exists no coherent theoretical context within which to view this interaction. Tim Abbe, currently a consulting hydrologist in San Francisco, California, has been admitted to the Department of Geological Sciences at UW with RA support to study this interaction. He will begin graduate studies in the fall of 1992.

Another control on sediment routing through channel networks is the spatial distribution of sediment contributed across channel banks. Bill Dietrich is developing methods for predicting the flux of sediment into channels from across channel banks. This is a crucial component of any spatially distributed sediment budget and progress to date is summarized in Appendix 8.

#### Goals for FY 1992-1993

In fiscal year 1992-1993 we plan on continuing the studies outlined above and on achieving the objectives of our proposed work. We anticipate that some components will be effectively completed by the end of the biennium (June, 1993). For example, we anticipate that the debris flow prediction and runout model will be essentially tested by then. Other components of this study lend themselves to further development. For example, we see great value in continuing to develop methods for predicting and modelling sediment flux through channel networks. Field work on sediment storage and transport processes in steep low-order channels is especially needed and provides an avenue for future research. We can continue to build on existing models and new findings to refine our capabilities. Similarly, the coupling of large woody debris and sediment transport will likely require significant effort to document and model. Further studies of the influence of bedform roughness and woody debris on sediment transport mechanics and channel morphology are likely to be productive. Consequently, we anticipate continuing our efforts in each of our project subcomponents.

We value the input and involvement of the SHAMW committee and look forward to our scheduled briefing in the fall, at which time we hope to discuss preliminary interpretations of our summer field work. Additional copies of the appended manuscripts will be available upon their completion. Copies for review purposes are available on request. We look forward to continued progress toward our project goals.