FE 537: Hillslope and Watershed Hydrology

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This lecture

◆ What are the main questions that this course will address?
◆ Introductions
◆ Grading, readings, project and other class business
◆ This course in the context of water resource issues locally, nationally and internationally
This course addresses 3 basic questions:

- **Where does water go when it rains?**
- **How long does it reside in the catchment?**
- **What flowpath does the water take to the stream?**

*Kevin McGuire*
“It may seem as though a great deal is known about how, and from where, water gets from rainfall through hillslopes into streams, at least for some areas. There are, however, still major difficulties when we try either to particularize or generalize from our present knowledge”

Andy Pearce, 1990

*(Water Resources Research, p. 3046)*
Why such a class?

Figure 1. Model representation of a watershed.

http://hydrology.pnl.gov/forest.asp
Why the need for this process understanding?
Traditional watershed hydrology
New problems that watershed hydrologists are tackling

We will open the black box of hillslope and catchment processes...

Unsolved problems:

- Spatial and temporal distribution of processes?
- Runoff generation processes:
  - Horton overland flow
  - Saturation overland flow
  - Subsurface storm flow
- Interaction between macropores and matrix?

...we’ll search for macroscale laws....

Uhlenbrook, McDonnell and Leibundgut, 2001
Hillslopes are a fundamental landscape unit.

Photo by Jim Kirchner, UC Berkeley
We'll explore how hillslopes filter rainfall inputs to watersheds.
We’ll counter this idea
...and we’ll find a multi-scale, complex system with non-linear network behavior at all scales.
The hillslope hydrology grand challenge

New Hydrologic Theory: Laws governing process, pattern and function

What we need to know (but do not with today's process understanding)

Temporal hydrograph separation

Spatial hydrograph separation

Takahiro Sayama, used with permission
Course details
Introductions

- Me (see web page)
  - http://www.cof.orst.edu/cof/fe/watershd

- You (self introductions)
  - Who you are
  - Your background
  - What you are now studying
Acknowledgements

some of the recent OSU PhDs and Post Docs whose ideas have contributed to this course

◆ Fabrizio Fenecia, TU Delft
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◆ Markus Weiler, now University of British Columbia
Labs this term

◆ Chris Graham, PhD Student
  ■ Plot Scale (Oct 11)

◆ Luisa Hopp, Post Doc
  ■ Hillslope Scale (Nov 1)

◆ Takahiro Sayama, Post Doc
  ■ Catchment Scale (Nov 15)
Fall 2003: The Department of Forest Engineering

FE 537 Hillslope Hydrology

A course for specialists and non-specialist alike - the only prerequisite is an undergraduate hydrology class or its equivalent.

Hillslope hydrology will address basic questions of how watersheds function at the plot-hillslope-catchment scale:

1. Where does water go when it rains?

2. How long does it reside in the watershed?

3. What pathway does it take to the stream channel?
Virtual lectures....if you ever suffer from insomnia

Table of contents

- Physical properties, \textit{vertical} water flow and solute transport
  - Soil structure and properties
  - Water content and water potential
  - Unsaturated and saturated water flow and solute transport
  - Preferential flow
- Experiments and case studies
- Conceptual models and runoff generation processes
  - Overland Flow (Horton, Saturation) and Percolation
  - Infiltration (Green-Ampt, preferential flow)
  - Reservoir model

Lecture 2 Oct 3 Plot Scale - Basics_Slide 1
What this section will address

Table of contents

- Soil Physics Context
- Typical soils in Oregon: Interceptisols
- Typical soils in Oregon: Andisols
- Typical soils in Oregon: Spodosols
- Typical soils in Oregon: Mollisols
- Soil Structure
- Complexity of soil - I
Course Structure

- Powerpoint lectures
- Interactive question and answer as much as possible
- Please interrupt and ask questions whenever something is unclear or you would like to add a comment—this will add greatly to the learning experience for everyone!
Good basic material
Advanced material

Hillslope Hydrology

Edited by
M. J. Kirkby
School of Geography
University of Leeds

Spatial Patterns in Catchment Hydrology

Observations and Modelling

Rainfall-Runoff Modelling
The Primer

Keith J. Beven

Isotope Tracers in Catchment Hydrology

Edited by
Carol Kendall
Jeffrey J. McDonnell

Elsevier
Journals you should consult
A good book to consult if you are new to the area
The Tarboton web module
for those without a hydro background
Rainfall Runoff Processes

Workbook

How to use this module

This online Rainfall-Runoff Processes Web module is designed to provide a comprehensive and quantitative understanding of infiltration and runoff generation processes. The module includes:

- A complete workbook on Rainfall Runoff Processes serving as the textbook for this module.
- Streaming video and slide presentations.
- Visualizations and computer animations to convey key concepts.
- Powerpoint presentations.
- Online quizzes serving as exercises where the user needs to respond to multiple choice questions or enter numeric answers to problems.
- An online final test.

The module should take about 6-15 hours to complete depending on your quantitative background and a priori knowledge in this area.

Target audience:

- Professionals with a scientific or engineering background with a college degree in science or engineering
- Students (senior and graduate level) in a hydrologic science or engineering program.

No prior knowledge on Rainfall Runoff Processes is required.
The new Encyclopedia of Hydrological Sciences
Benchmark Papers in Hydrology

STREAMFLOW
GENERATION PROCESSES

Selection, Introduction and Commentary by
Keith J. Beven

Series Editor: Jeffrey J. McDonnell
International Association of Hydrological Sciences / Association Internationale des Sciences Hydrologique
Benchmark Papers


Hewlett, JD and Hibbert, AR, 1963, Moisture and energy conditions within a sloping soil mass during drainage, **J. Geophys. Res.**, 68, 1081-1087.


Benchmark Papers


Sklash, MG and Farvolden, RN, 1979, The role of groundwater in storm runoff, J. Hydrol., 43, 45-65. **


Read 15 Benchmark papers and...
What do I expect?

◆ **Read general introduction** this week
◆ **Read the light colored references** (make sure you read ** plus Beven and Kirkby by mid-term exam)
◆ **Know the authors, the titles and the main contributions**
◆ **Know why these are benchmark papers**
◆ **Remember the key points, key figures and key concepts.**
◆ **Know how they build upon and relate to each other**
Schedule

- Sept 27 (next class): Field trip!
- Oct 11: Lab 1
- Oct 16: Virtual lecture: Keith Beven (author of your text)
- Oct 18: Quiz (lecture material and Benchmark Papers)
  - take virtual field trip beforehand
- Nov 1: Lab 2
- Nov 15: Lab 3
- Dec 3: Project reports due
- Final Exam

Grading: 1/3 grade Quiz/Exam; 1/3 grade Project; 1/3 Grade Labs

(adjustments up based on participation in class)
Lecture Schedule

Introduction, field trip, Runoff overview 2 weeks

Wrap-up, Lab/project discussion, mid-term 2 weeks

Scale

catchment scale

hillslope scale

plot scale
Example locations used in the class
½ from sites where my group has worked

- Maybeso, AK
- Hj Andrews, OR
- CSSL, CA
- Maimai, New Zealand
- Svartberget, Sweden
- Fudoji, Japan
- Reynolds Creek, ID
- Sleepers River, VT
- Huntington, NY
- Panola, GA
- Dry Cr, NY

(Kendall and Coplen, 2001)
Questions you’ll be able to answer after taking the class
How does water infiltrate to depth in the soil profile?

Photo: Markus Weiler UBC
How does water move laterally?
How do near-stream zones control streamflow response?
How do different parts of the watershed contribute to flow in the stream (during and between events?)

Photo: Ross Woods, NIWA
How can we map runoff hotspots?

Petra Fackle, ETH Zurich
How to break up the watershed into its component parts?
How do processes scale?
This course in the context of water resource issues locally, nationally and internationally
How does forest harvesting and road construction affect flow in the stream?
How do water flow pathways flush nutrients to the stream?

Charlie Driscoll, SU
Does land use change in the headwaters cause flooding in the lowlands?
How will climate change and variability affect the flow regime?

Virtually gone. Computer models suggest that even moderate warming will drastically reduce the spring (peak) snowpack in the Oregon and Washington Cascades.
Summary
"...accurate prediction of the headwater hydrograph implies adequate modeling of sources, flowpaths and residence times of water and solutes." Hewlett and Troendle, 1975
Why headwater watersheds?

Percentage of Headwater Stream Length by Watershed

Legend: This map shows the percentage of headwater streams greater than one mile long, relative to total stream length, within each watershed. This analysis highlights the regional pattern of headwater stream occurrences in the United States, excluding Alaska, where NHD data are not available. In the 49 states there are 5,484,159 total kilometers of linear streams, of which 53% (2,915,824 km) are headwaters. Based on data from the National Hydrography Dataset at medium resolution. The value ranges in the key were devised to reveal underlying groupings and patterns in the data displayed on the map. One mile is equal to 1.61 kilometers.

From Tracy Nadeau, EPA
What we *will* and *will not* cover

Sivapalan et al. 1995
We’ll consider the “control volume” of the watershed.
We will explore how the experimentalist and the modeler view hillslopes and catchments.
What are the main questions that this course will address?

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