ESM 235: Watershed Analysis

Winter 2008

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ESM 235: Watershed Analysis 2004

Lectures: Mondays and Wednesdays, 2:00 – 3:15 pm; **Location**: BH 1424

Lab: Thursdays 5:00 – 7:50 pm [TA: Nina Kilham]

Readings:

A reader will be available at *Grafikart*, Isla Vista
Other readings will be made available as pdf files from time to time

If you intend to pursue this topic professionally, you may want to pick up a copy of one or more of the following texts:

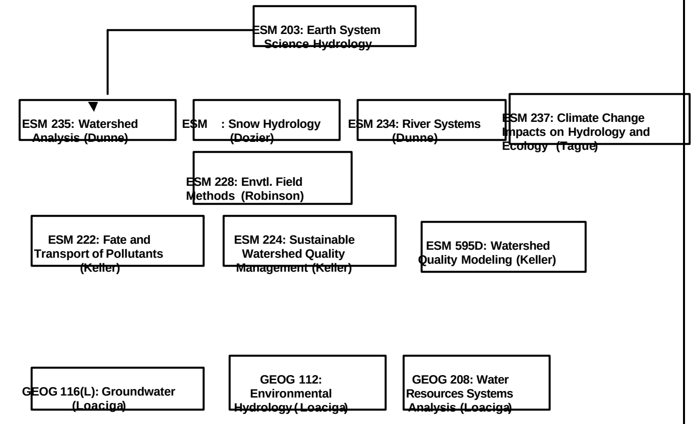
Dingman, L. (2003) *Physical Hydrology*
Ward, A. D. & Trimble, S. W. (2004) *Environmental Hydrology.*
Dunne, T. and Leopold, L.B.(1978) *Water in Environmental Planning*
Branson F. et al. (1981) *Rangeland Hydrology* . (out of print)
Reid, L. M. and Dunne, T. (1995) *Rapid evaluation of sediment budgets*. Catena Verlag (only available source in US is the University Bookstore at Humboldt State University, Arcata CA)

Grading:

Preparation of four project reports (three computational projects and one field project) that will be returned fully edited.

The intention is that over the course of ESM 235 you will practice writing insightful and clear accounts of your analyses.

Curriculum Context



What is Watershed Analysis needed for?
Recent Involvement (with others) in Watershed Analysis

- Analyze the potential for timber harvest in the Freshwater Creek basin of northern California to cause downstream flooding. For California Department of Forestry and Fire Protection.
- Advise on prediction of potential impacts of 2000 Cerro Grande fire on runoff/ sedimentation at Los Alamos Nuclear Reservation, NM.
- Advise on monitoring of a TMDL plan for mercury control in Santa Clara River, central California
- Advise on a methodology for modeling the effects of urban runoff on channel dimensions in rapidly urbanizing suburbs of San Jose, CA .
- Landcare New Zealand Limited: methodology for Integrated Catchment Management (with Gene Likens, ecologist).
- Develop a "Scientific basis for the analysis and prediction of cumulative watershed effects" for State of California Department of Forestry and Fire Protection

Other examples of friends' involvement concerned with water availability and quality

- Increased use often > recharge rates
- Resource often over-allocated – conflict about whether/how to operate water supply system differently and the consequences of that
- Because WR spatially variable – often in 'wrong' place, so can they be transferred, and what are the costs and consequences?
- WR temporally variable – seasonal, stochastic, persistent, subject to climate change
- WRs vulnerable to landscape change: limits of predictability?
- WRs as parts of connected systems with downstream effects
- Water availability is considered a 'human right' because it is required for life and health. But how much is required and who is responsible for supplying for it?

Differences from other activities

- Montgomery et al., 1995 Water Resour Bull, 31:369-386, Watershed Analysis as a framework for implementing ecosystem management
- Heathcoate, 1998, Integrated Watershed Management: Principles and practice, Wiley, Chap on The Watershed Inventory.

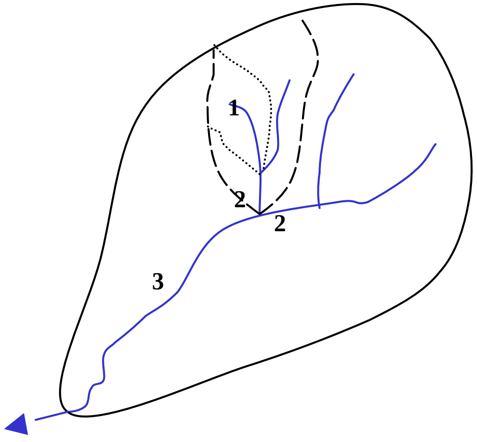
Watershed Analysis is a Social Process

- Watersheds
- Watershed Analysis
- Origin of the need for Watershed Analysis
- Cumulative Effects
- Cumulative Watershed Effects
- Watershed Analysis as a Social Process
- Ideological Context
- ***Value*** of Social Processes in Watershed Analysis

Watershed definition

- Synonyms: drainage basin, catchment, or (if large) river basin.
- The area that drains water, sediment, and chemicals to any point on a stream.
- There is an infinite number of watersheds.
- Usually refers to the drainage area above some particular, distinctive point on a stream (such as above a reservoir, a city water intake, or some distinctive geographical feature such as the exit from a mountain range).
- Since channel networks are dendritic (tree-like), there are watersheds nested within larger watersheds.

Nested Watersheds of Differing 'Order'



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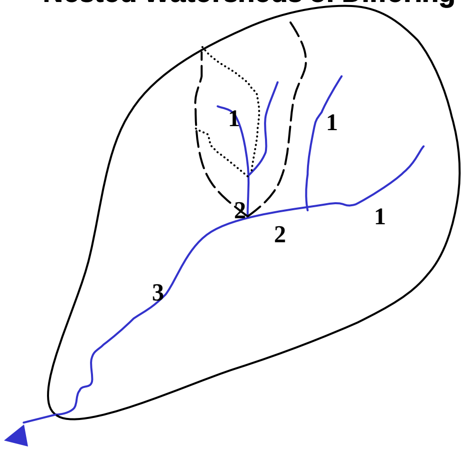

Watershed Analysis:
General scientific meaning

- Analysis of processes and relationships in a watershed for scientific purposes:
  - How does Earth's surface become organized into hierarchical sets of nested drainage channels and their contributing areas?
  - What is the influence of this organization on magnitude and timing of river flows, forms of stream channels, patterns of soil and vegetation, etc.?

A watershed perspective is also useful for analyzing effects of resource development

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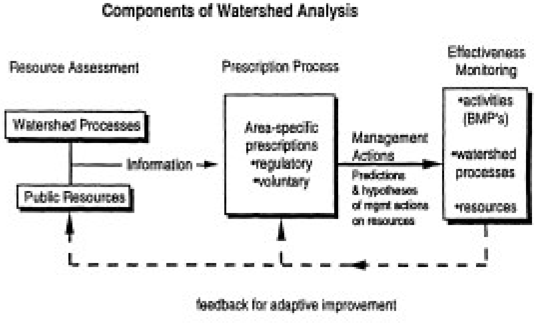
- Many other biological processes (such as the creation of some animal habitats), some forms of agricultural and industrial land use, and most socio-political units ***not*** topographically controlled.
- However, even for many of these situations watersheds are convenient accounting and administrative units (though rarely in the US, where administrative units are generally not associated with watersheds).

Watershed Analysis:
Planning and regulatory meaning (1)

- E.g. Washington State Dept. of Natural Resources defines:
  - "W/A is a structured approach to developing a land-use plan … based on (1) a physical, chemical, and biological *inventory* of land surface characteristics and processes, and (2) an *analysis of the functioning* of those processes."
  - "In W/A, scientists(?) first develop information and interpretations of resource conditions and sensitivities at a watershed scale, *guided by a series of key questions*." Whose questions? --- scientists, or stakeholders? Difference between Washington State, Oregon, and New Zealand approaches
  - Defined by the *need for regulation* of resource use
  - Thus increasingly defined in legal and social terms



Washington Dept of Natural Resources Nov. 1995

Watershed Analysis:
Planning and regulatory meaning (2)

- Defined as a collaborative process, involving resource managers. Resource scientists, representing land owners, agencies, and other interested parties.
- Usually conducted in a short and legally specified time interval [Washington State 2 -5 months; EPA-required TMDLs, which have less economic urgency, ~ 1 year?]
- W/A is increasingly defined in legal and social terms because it has the capacity to affect wealth creation, individual property rights, and the continued existence and public access to natural resources

Origin of the need for Watershed Analysis

- After Earth Day (1970), increase in environmental regulation
- Aimed at preventing or minimizing damage such as soil erosion, pollution, affecting some public resource (water quality, fish, wildlife). Most effective for point sources or those amenable to local treatments called “Best Management Practices”, designed to lower the impact below some local nuisance level.
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- Involved one activity at a time and site-by-site
- Increasingly recognized that organization of landscape into watersheds focuses transport of waterborne materials downstream and mixes them with products from other parts of landscape. Led to concept of Cumulative Watershed Effects.
- Extensive effects, insignificant on site, may produce significant effects downstream.
  - E.g Lake Tahoe watershed protection lawsuit (1989)
  - E.g. PNW fine sediments in stream gravels

Cumulative Effects

- “The changes to an environment caused by the interaction of natural landscape processes with the effects of two or more land-use practices. They may result from the accumulation of small effects of many practices that are insignificant at any one site, including practices that are separated in time or space.”

Cumulative Effects: California Forest Practices Regulations

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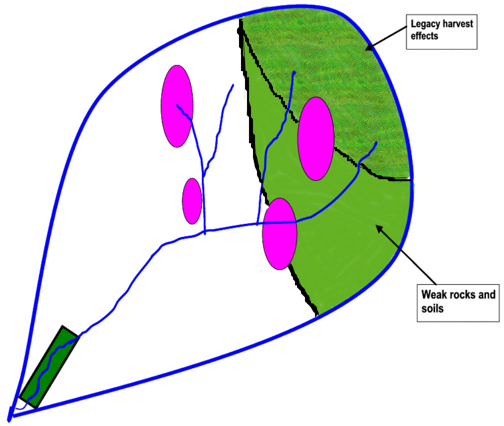
- [*Note the critical term "significant". No one has ever been able to define to the satisfaction of the timber industry what effect is "significant."]

Cumulative Watershed Effects [CWEs]

- Special kinds of cumulative effects resulting from the hydrologic functioning of watersheds.
- Watersheds are ensembles of hillslopes that interact with the stream channels at their bases and transmit the material fluxes (water, sediment, chemicals) resulting from those interactions downstream along hierarchical networks of channels with relatively numerous small channels draining into a few larger channels.
- Transmission generally involves an increase in the absolute size of the flux with increasing distance down the network (i.e. with increasing drainage area), but the storage processes accompanying the flux usually result in some reduction in the flux per unit area of watershed (i.e. the flux increases at a rate lower than that of the accumulation of drainage area.

Cumulative Watershed Effects



Cumulative Watershed Effects

- Although written into law, this idea is contentious, poorly demonstrated, and is supported by little or no agreed-upon methodology for prediction.
- Thus, it is usually paid only lip service, and is widely avoided, leading to weak application of the concept in low-visibility cases and train wrecks in high-visibility cases.
- Opponents argue that there are no cumulative effects beyond the addition of site-scale effects, which are thus better dealt with on a site-by-site strategy of utilizing "Best Management Practices". The BMPs are then *defined to* preclude any CWE under the design conditions of the BMP.

Watershed Analysis: Planning and regulatory meaning (2)

- Defined as a collaborative process, involving resource owners/managers (public or private), resource scientists representing resource owners, regulatory agencies, and other interested parties.
- Usually conducted in a short and legally specified time interval [Washington State 2-5 months; although hydro power re-licensing c. 15 years]
- Thus, increasingly defined in legal and social terms because it has the capacity to affect wealth creation, individual property rights, and the continued existence and public access to natural resources

W/A is a social process as well as an exercise in analyzing the physical and biological functioning of watersheds

- Need to keep all stakeholders involved, either by simply informing them of the process of study, or entraining them in problem definition and analytical procedures [SW Washington gravel study]
- Also useful for developing historical understanding [Tanzania soil erosion]

W/A is also conducted in an ideological context

- By conducting a W/A, one is often facilitating the manipulation of natural resources (timber harvest, agricultural settlement, expanding urbanization, flow regulation).
- Questions asked are limited by the ideological context that favors such developments.
  - **"How can this watershed be logged in a fairly benign fashion?"**
  - ***Not* "Have we logged enough or too much of the regional old-growth forest already?"**
- Leads to conflict, confusion, defeat, and burnout, if you don't resolve whether or *how to use* W/A.

Ideological context example (1)

•One of the first institutions to develop a methodology for watershed analysis was the Washington State Department of Natural Resources in the early 1990s.
•Methodology put together by committees of specialists on hydrology, geomorphology, and aquatic habitat.
•Impetus - devise a means of rebuilding salmon habitat, which had been significantly damaged by extensive timber harvest, dam construction, river flow diversion, urbanization, and drainage of valley-floor wetlands.
•An attempt to keep the various stakeholders (timber companies, power companies, fishers, environmental groups) out of court.
•Led by the timber companies (and, therefore the State!) and applied only to timber harvest lands.
•Gave companies significant freedom, based on a form of technological optimism, to continue to harvest timber while promising to utilize "Best Management Practices" to minimize damage, restore watershed functions, and to partially restore salmon habitat into a form that would restore populations.

Ideological context (2)

- Note the *conceptual model* behind this process:
  - Timber harvest may be limiting salmon production by degrading habitat
  - Specification of controls on the distribution and conduct of timber harvest will improve salmon habitat
  - When the habitat is improved, the salmon will return in larger numbers.

Ideological context (3)

- There are some untested, and some probably incorrect aspects to this belief, but we can discuss them elsewhere.
- But that is the context for the watershed analysis, and it is useful to continue critiquing these contexts.
- But for most of the course, we will focus on the technical aspects of the analysis.
- I will repeatedly remind you of the belief structures behind (and influencing the effectiveness of) watershed analysis.

Even the natural science part of the problem is hard to do well

- A number of interacting phys/chem/biol processes
- Great spatial variability of land surfaces
- Duration of responses to land-use change can be up to 10s - 100s of years
  - removal of LWD from PNW rivers by sluicing, channel simplification, cedar mining occurred over decades and effects recognizable in stream habitat morphology 100yr later. "Legacy effects" of earlier logging cycles.
  - gullying in N. Tanzania still expanding unchecked after triggering by bush clearing by colonial authorities to control tsetse fly in 1950s
  - soil conservation effects in Upper Midwest.and East Coast have altered streams and valley floor floodplains for 150 years

Therefore, disputes about environmental management are usually fueled by at least three factors

- lack of knowledge about the environmental consequences of human actions
- the extremely large uncertainties about the outcomes even when scientifically we understand the underlying driving mechanisms
- the lack of institutions or individuals that can act as mediators among the various stakeholders.

Value of understanding the social aspects of Watershed Analysis (1)

- 1. The need for W/A is driven by social, political, developments, economic conflict, regulation, and legal proceedings.
- 2. The issues of concern arise through social interactions, including conflicts, and are best defined through consultation with all stakeholders.

Value of the social aspects of Watershed Analysis (2)

3. Analyses are likely to be more effective, to miss fewer important issues, and to encounter less resistance if there is organized attempt at community development of conceptual models of system behavior. Conflicting models can be treated as hypotheses to be tested during watershed studies.

Value of the social aspects of Watershed Analysis (3)

- 4. Construction of consistent and interactive data bases requires, or at least can be facilitated by, collaboration with the community (through sharing of information or assistance with data collection, or simply assuring access to land.)
- 5. Traditional knowledge. Historical archives, oral histories of observations, and photographic and other records that can define the history of the landscape and its ecosystems are most easily obtained through community participation.

Value of the social aspects of Watershed Analysis (4)

- 6. Buy-in by the community, or at least its leaders, to the analytical process (what data should be collected, and how should it be analyzed to test or elaborate the original conceptual models) may enhance ultimate acceptability of results. Clear articulation of the analytical plan and its results at all stages of the W/A is a necessary social process in a successful W/A.

- 7. Clear articulation of the relevance, choice, and use of simulation models to predict change and to explore various management scenarios also increases the probability of acceptance.

Value of the social aspects of Watershed Analysis (5)

- 8. The process of choosing conceptual and analytical models of watershed functions is a process influenced by the history of analytical training and it varies between various disciplines involved in W/A. Understanding the background of a method, its underlying conceptual foundations, and the limitations of data supporting (parameterizing) it are important for effective utilization and articulation to a community.

Value of the social aspects of Watershed Analysis (6)

- 9. Since predictions made by environmental models are imprecise, the utility and acceptability of computational results to other professionals (acting in a review capacity), to managers, regulators, and the public are socially modulated aspects of W/A. Thus, it is important that these aspects of W/A be carefully, skillfully, thoroughly, and ethically presented to these groups.

Read: "*Prediction and the Future of Nature*" by D. Sarewitz et al. to appreciate the mutual lack of understanding among specialists responsible for environmental predictions