The Secret Life of Watersheds

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“to understand any part of the fluvial system, something must be know about the quantity and type of sediment, the manner in which water is supplied from the source area, and the climatic and geologic controls on that sediment and water supply.”
(Stanley Schumm, The Fluvial System)

Watersheds and their streams are dynamic systems
Outline

• How geophysical characteristics influence watershed and stream processes
• The flow regime and factors that affect it
• The effects of forest harvesting on stream channels
To understand the stream you must first understand the watershed

- What are the physical characteristics of the watershed?
  - Size of watershed
  - Slope aspects and elevations, gradients
  - Geology/glacial history
  - Vegetation
- What meteorologic process(es) is controlling flood flows?
- What hydrogeomorphic processes are controlling sediment delivery?
- How is sediment moving through the stream network?
- How is the riparian vegetation functioning with respect to sediment mobility and channel processes?
- How has all of the above changed over the past millennia
Influence of physiography on watershed processes
Physiography influences volume and rate of water and sediment delivery

Mather Creek – RMT (fluvial dominated)

Bull River trib. Main Ranges RM (Alpine dominated)
Influence of geology on watershed processes
Different geology results in different characteristics and volume of sediment load

Duhamel Cr – Nelson Batholith
Granodiorite

Schroeder Creek – Lardeau Gp
Meta-sediments
Influence of hydroclimate region on watershed processes
Hydroclimate region determines annual hydrograph and flood regime characteristics

Maritime – rain (ROS)

Interior snowmelt
Hydrological differences due to hydroclimate variability are substantial even within single region – e.g. Columbia Mountains

Rover Creek – Southern Selkirks—more runoff higher unit discharge also rain-on-snow peaks

Teepee Creek – Southern Purcells – drier climate, lower unit discharge, fewer rain on snow events
Influence of vegetation on watershed processes
Spruce, lodgepole pine, balsam fir less resilient during flood flows than cedar-hemlock

Spruce – Balsam fir

Cedar - Hemlock
Influence of riparian vegetation on channel processes

Shrubs and trees produce root networks that provide increased cohesion to gravel soils and reduce the velocity of flowing water by increasing flow resistance/roughness of stream banks and adjacent valley flat or floodplain.

\[ V = \left( \frac{R^{2/3}S^{1/2}}{n} \right) \]

- Reducing the erosion of channel banks and adjacent valley flat during bankfull and overbank floods
- Reducing the rate of lateral migration of stream channel
The flow regime

- 5 key components of the flow regime regulate geomorphic and ecological processes in river ecosystems:
  - magnitude and
  - frequency of floods,
  - duration,
  - timing, and
  - rate of change of peak flows
Annual maximum flood series

- Multiple years of annual maximum flood peak values constitutes the time series of peak flows over the period of record (AMS)
- From year to year the peak flow value is independent and continuously variable.
- Because of the stochastic nature of the annual maximum flood series it must be described in terms of a frequency (probability) distribution
- Data from Env. Canada archived hydrometric data website

Because they are independent it doesn’t matter what order the floods occur so we describe the series by looking at it using a frequency distribution
Estimating historical flood frequency

- Step 1 - Rank floods from largest to smallest so 1 = largest
- Step 2 – calculate exceedance probability using plotting position formula
  - Cunnane unbiased: \( \frac{m-0.4}{n+0.2} \)
- Step 3 calculate return period from plotting position: \( RP = \frac{1}{\text{exceed}} \).
- What does a 100 year flood event mean?
  - It means that there is 1% chance of seeing that discharge in a given year.
  - Avg. flood at 2 years has a 50% chance of occurring each year or 100/2.
CDFs, FFCs and PDFs

- We describe the frequency distribution using statistics including the mean, variance and skew of the distribution.
- The average annual flood or bankfull flood (Q1.5 to Q2) is referred to as the channel maintaining flood. Moves the most sediment over the long term.
- Larger magnitude floods (Q10 to Q100 depending on stream) are channel forming floods. These are the damaging floods when people and infrastructure are involved.
How does the flow regime change over space and time?

- **Factors that influence F(Q)**
  - **Hydroclimate region**
    - Rainfall regions display ffc’s that are much steeper than snowmelt ffc
  - **Scale**
    - Decreasing scale within similar hydroclimate region results in increasing flow variability – steeper ffc
  - **Climate change**
    - These are long-term changes longer than decadal fluctuations
  - **Landcover change**
    - Urbanization can result in very ‘flashy’ watershed where flow variability is increased dramatically
    - Forest harvesting can also change runoff processes. This is especially obvious in snowmelt regions
Influence of forest harvesting on the snowmelt flood regime
Green and Alila, 2012 (WRR)
Alila et al., 2009 and Green and Alila 2012 are the first studies in 100 years to consider how forest harvesting affects flood frequency.

- Previous studies attempted to understand the effect of forest harvesting by looking at only the change in flood magnitude ...
- This lead to a century of confusion and mis-information.
Municipal infrastructure is often not properly sized to deal with higher magnitude lower frequency floods. Add to this increased frequency of larger floods due to upstream harvesting and things get interesting (and costly)…
In addition, stream channel morphology and processes of sediment transfer are closely linked to the flow regime.

Bedload yield and discharge for Elk and Cotton Creeks (Moyie):

Bankfull flood is referred to as the effective flood because it moves the most bedload over the long term.

*From Wolman and Miller, 1960*
What happens to channels once the flood regime changes due to too much logging?

- They start to look like a channel that experiences the 10 yr flood every year...
“Learn to read the land (river), and when you do I have no fear of what you will do with it; indeed, I am excited about what you will do for it.”

Aldo Leopold, 1966  A Sand County Almanac
Further reading

- www.apexgeoconsultants.com
- Schumm, The fluvial system
- Wohl, Mountain streams
Google earth is a fabulous tool in the study of watersheds