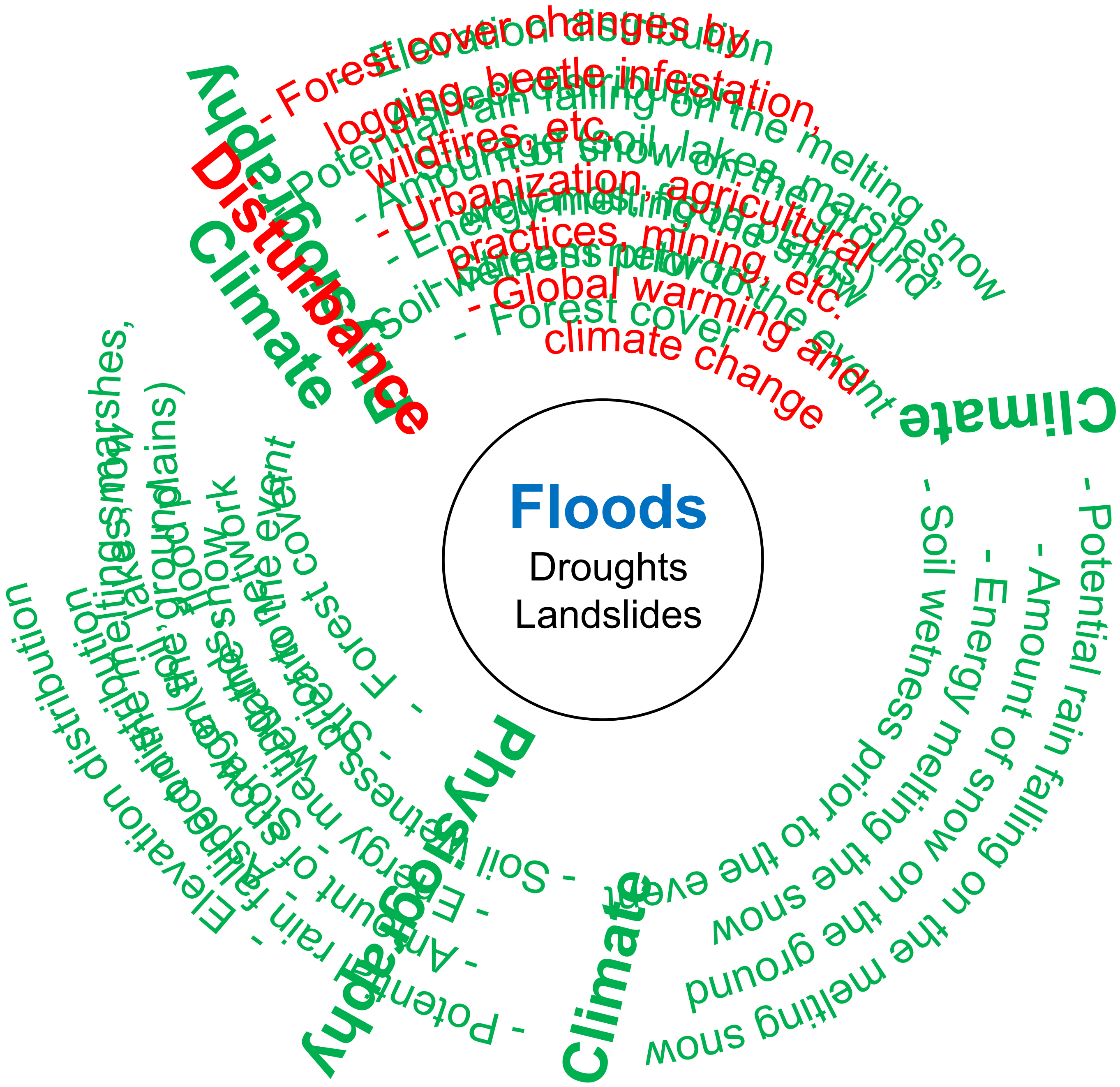
Forest Harvesting Effects on Floods

Dr. Younes Alila, P.Eng.
Faculty of Forestry
UBC-Vancouver

Environmental Drivers of Floods in Interior BC



WATER RESOURCES RESEARCH, VOL. 45, W08416, doi:10.1029/2008WR007207, 2009

Forests and floods: A new paradigm sheds light on age-old controversies

Younes Alila,[1] Piotr K. Kuraś,[1,2] Markus Schnorbus,[3] and Robert Hudson[1]

Received 9 June 2008; revised 15 April 2009; accepted 30 April 2009; published 13 August 2009.

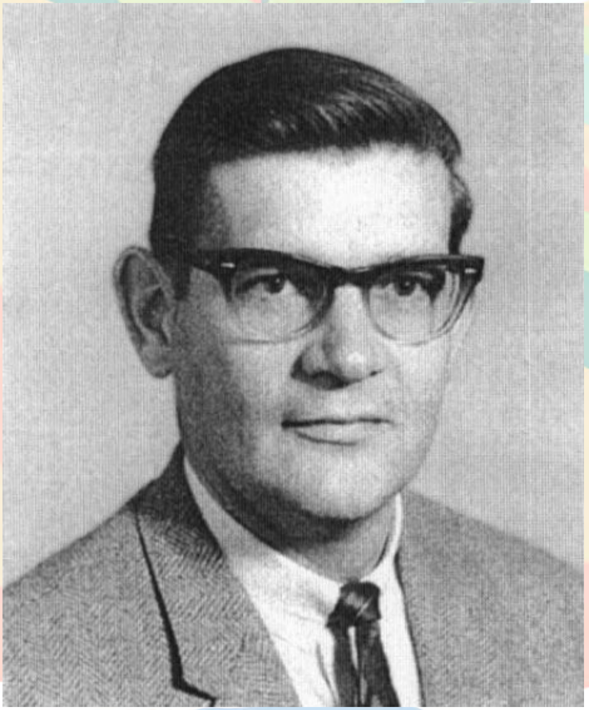
- In 2009, we called upon the Forest Hydrology community to abandon an old non-causal framework and adopt instead the only causal framework:

Floods like all other extremes must be investigated using the magnitude-frequency relation often referred to by hydrologists as the flood frequency distribution.

UBC Forestry

A ‘New’ Way of Thinking in Forest Hydrology

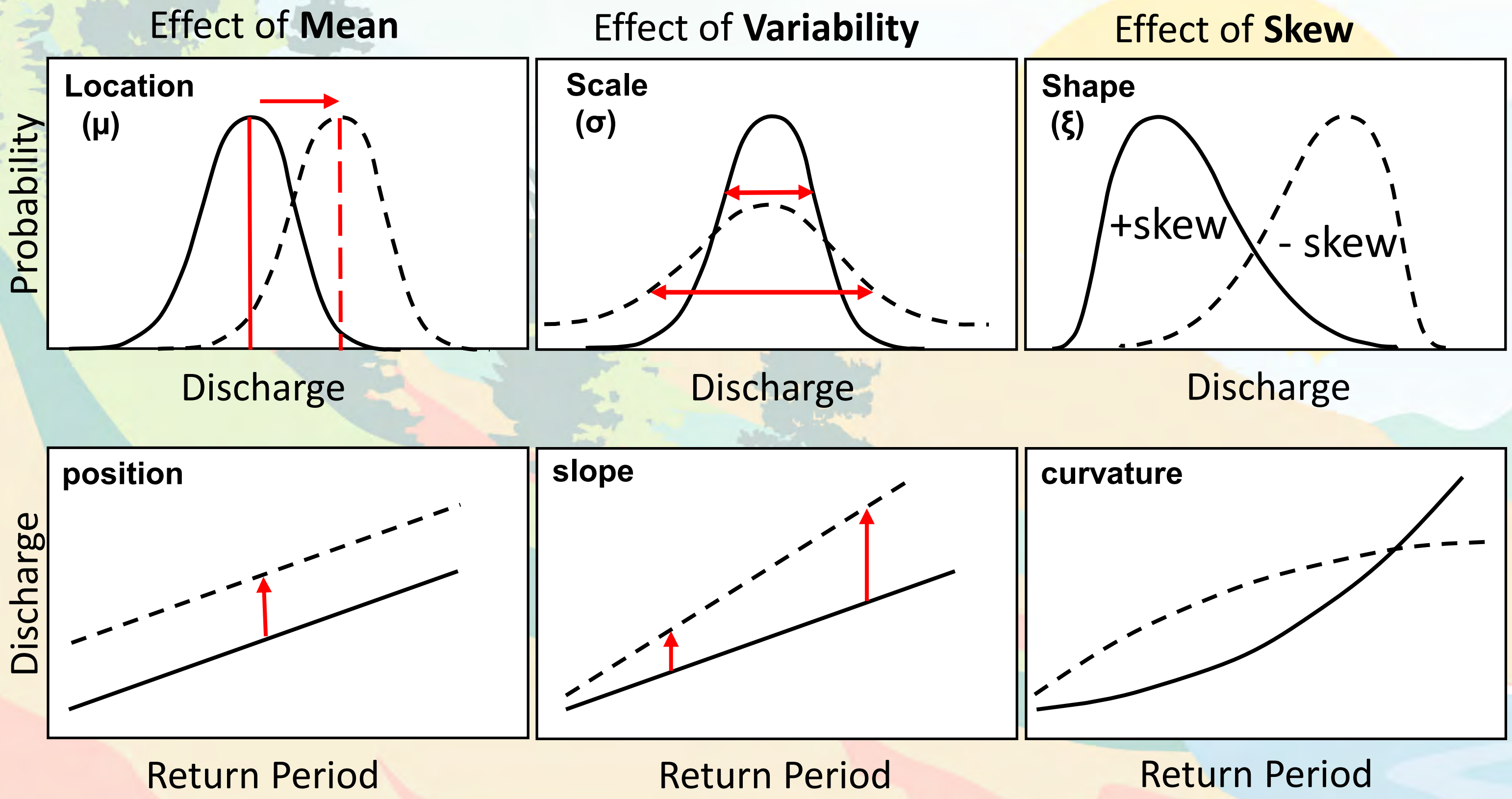
John D. Hewlett
(1922-2004)



“[H]ydrologists have understandably been confused by the difficulties inherent in describing the nature and frequency of floods to laymen, who are apt to have little patience with probability statements. . ..But among ourselves we must drop back to rigorous language in order to discuss and trade information about land-use causes and flood effects.”

Hydrology 101: Understanding the Flood Frequency Curve

Environmental Controls on Flood Frequency Distributions
Pre-Disturbance Conditions



Two equivalent graphical displays of FFC

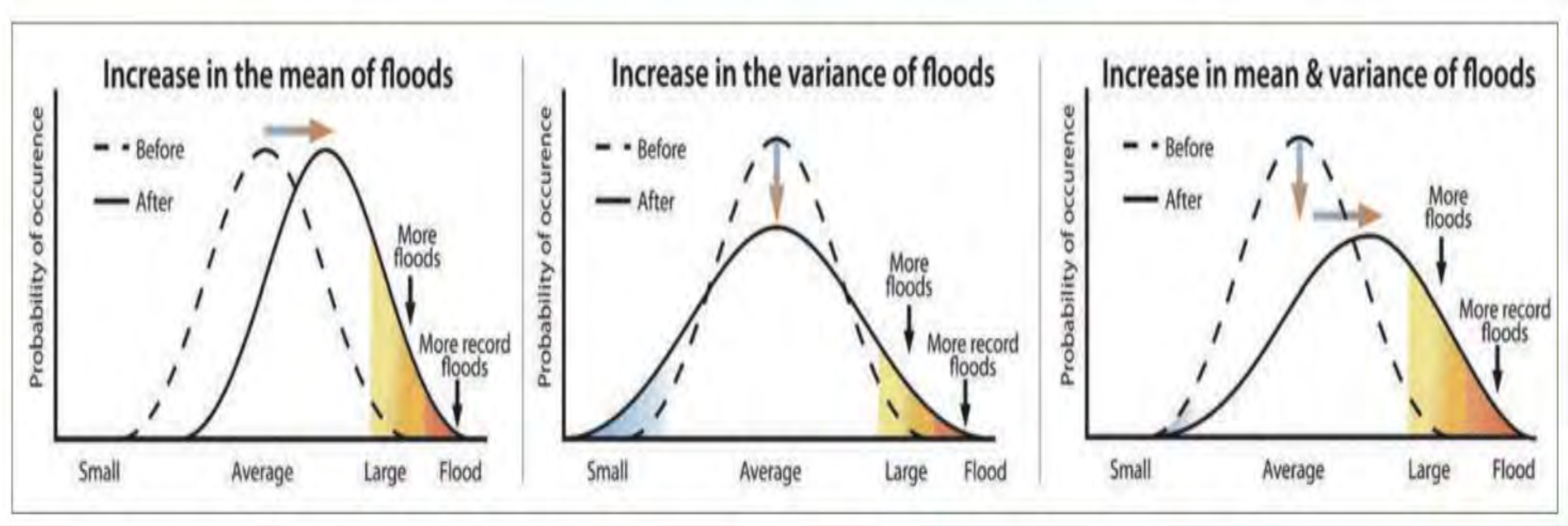
For Lay Person

For Professionals

Take home message: Changes to the mean, variability, and skew of the flood frequency curve affects floods in different ways

Idiosyncrasies of the Science of Extremes

I. Extremes can be highly sensitive to even small changes in mean, variability, and skew of the frequency distribution

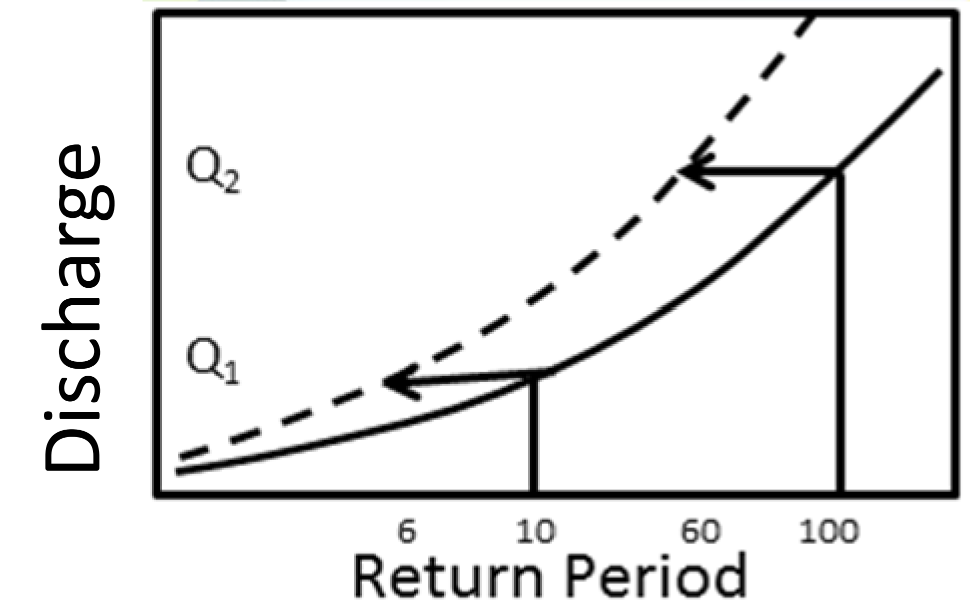


Disturbances can increase the mean, variability, and skew of the FFC, hence increasing the likelihood of extremes (shaded area under the upper tails)

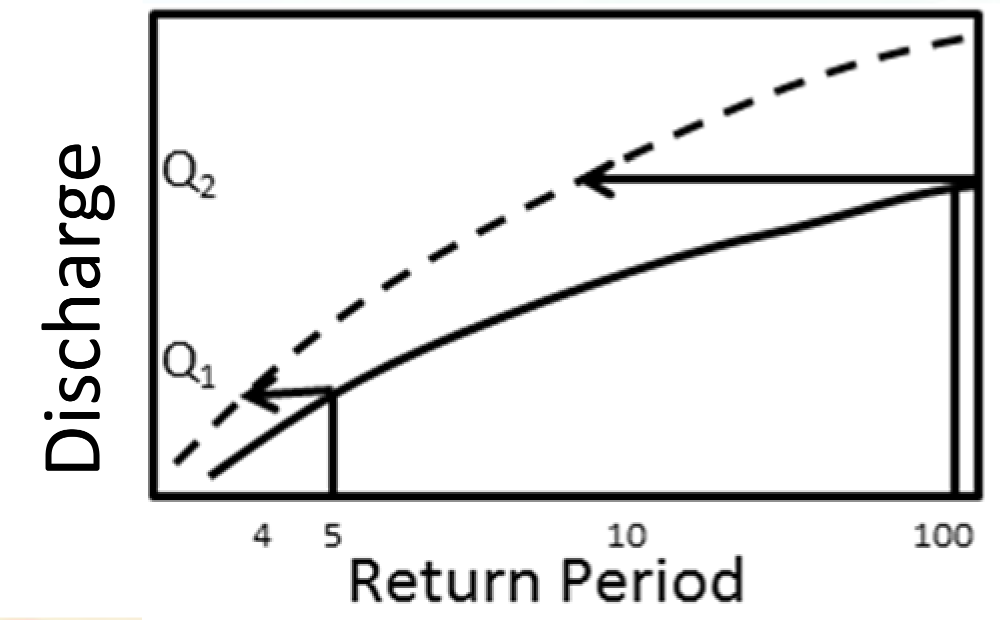
Idiosyncrasies of the Science of Extremes

II. Floods in BC are Hyper Sensitive to Disturbances

Legend: continuous line: Pre-disturbance
Dashed line: Post-disturbance



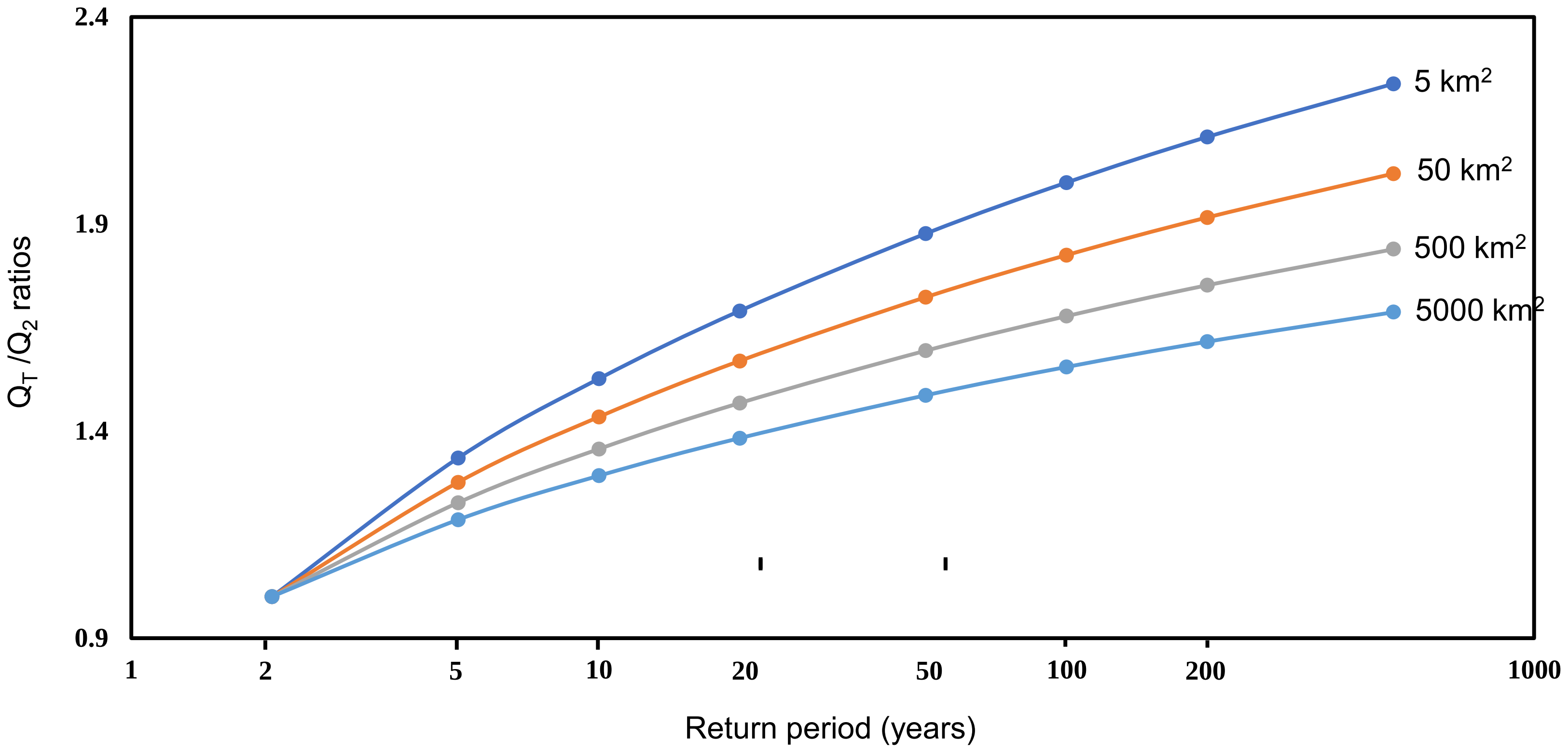
Typical FFC in BC Under Undisturbed Conditions



The curvature of the flood frequency curve can affect the change in return period with a greater effect for larger return periods

Idiosyncrasies of the Science of Extremes

III. Larger watersheds can be more sensitive to disturbances than their smaller, upstream headwater tributaries



Why larger watersheds have a milder slope flood frequency distributions?

Runoff is delivered to the outlet more efficiently in smaller watersheds – this is why typically unit discharges decrease with an increase in the size of watersheds.

- **Larger elevation ranges**
- **Wider range of aspects**
- **More opportunity for below and above surface storages**
- **Desynchronization of flows from various tributaries**

Case Study 1: Clearcut Logging in Mountainous Terrains Redfish Creek (Columbia Mountains Southeastern BC

- **Size of Watershed :** 26 km^2
- **Elevation Range:** 1.6 Km
- **Basin median slope:** 50%
- **Upper 40%:** Subalpine Parkland
- **Lower 60%:** BEC: ICH & ESSF

Schnorbus, M., and Y. Alila (2004), Forest harvesting impacts on the peak flow regime in the Columbia Mountains of southeastern British Columbia: An investigation using long-term numerical modeling, Water Resour. Res., 40,W05205, doi:10.1029/2003WR002918.

Power of physiography in mitigating the effect of clearcut logging on floods

Physiography Renders the Forests Causally Inert

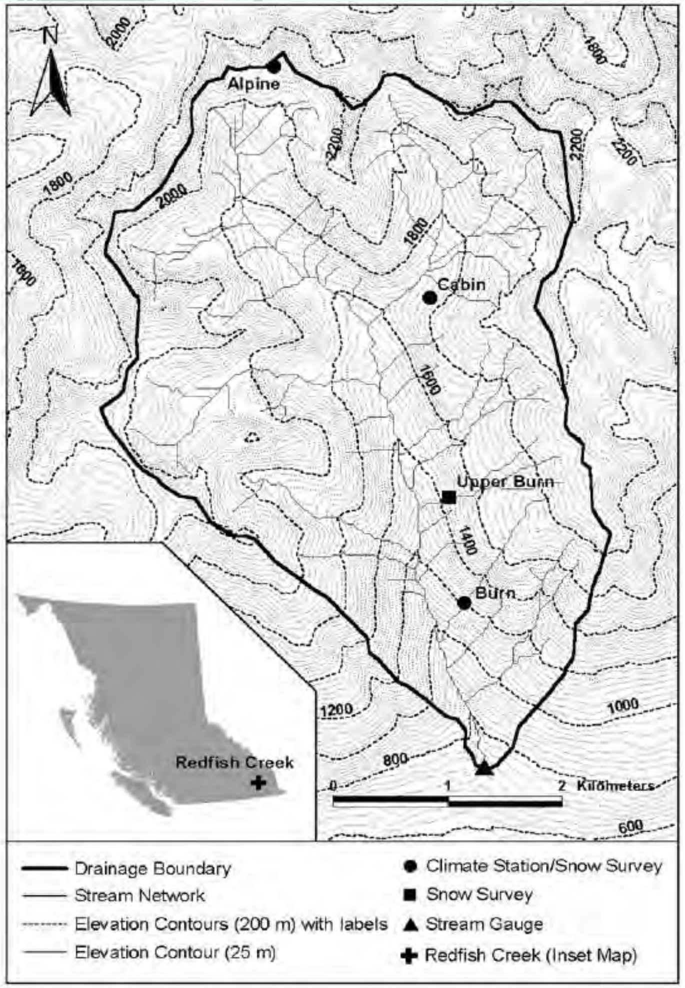


Figure 1. Redfish Creek study area.

- Even before logging melt is desynchronized because of the large elevation range of 1600 m
- Clearcut logging the lower 60% furthered such desynchronization of melt
- Upper 40% of subalpine parkland receive highest amount of precipitation.

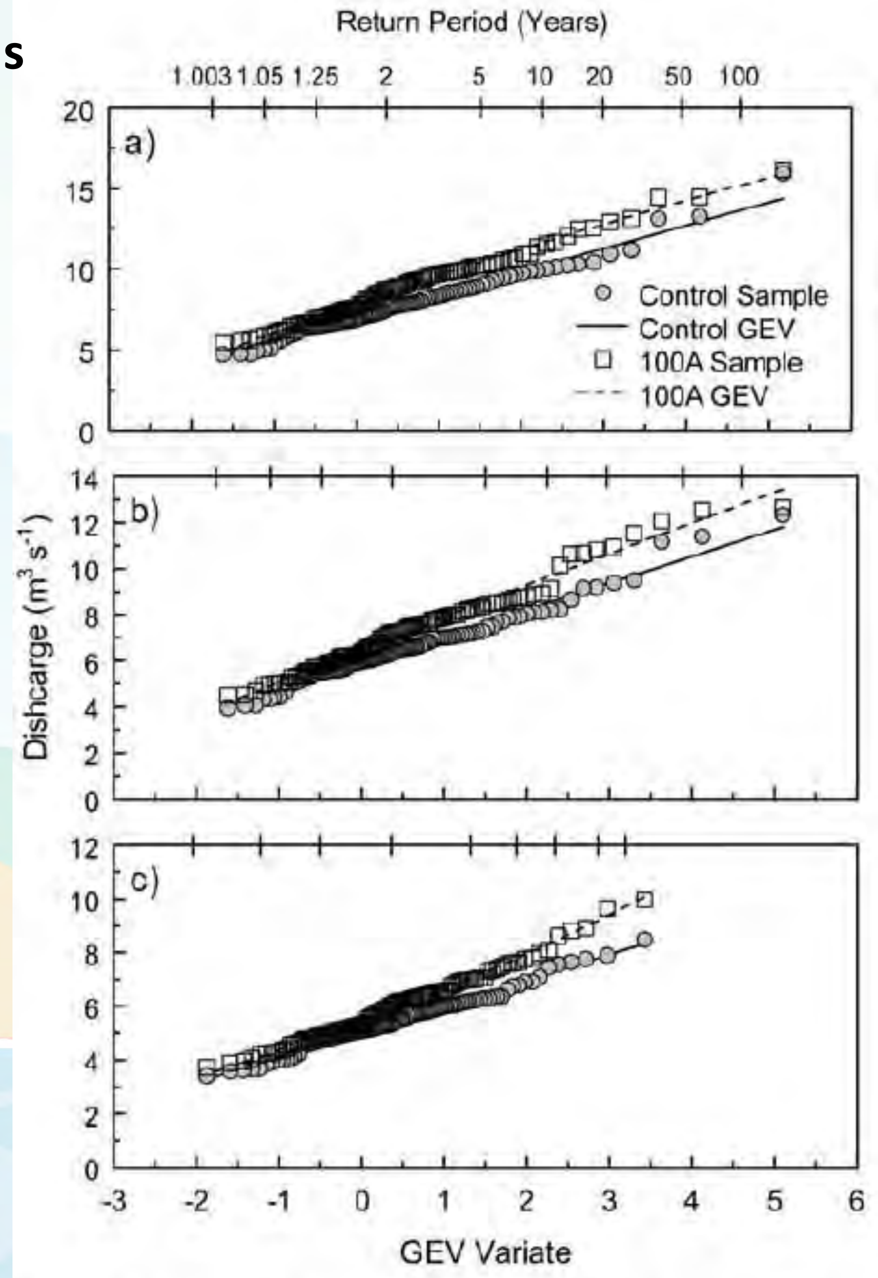


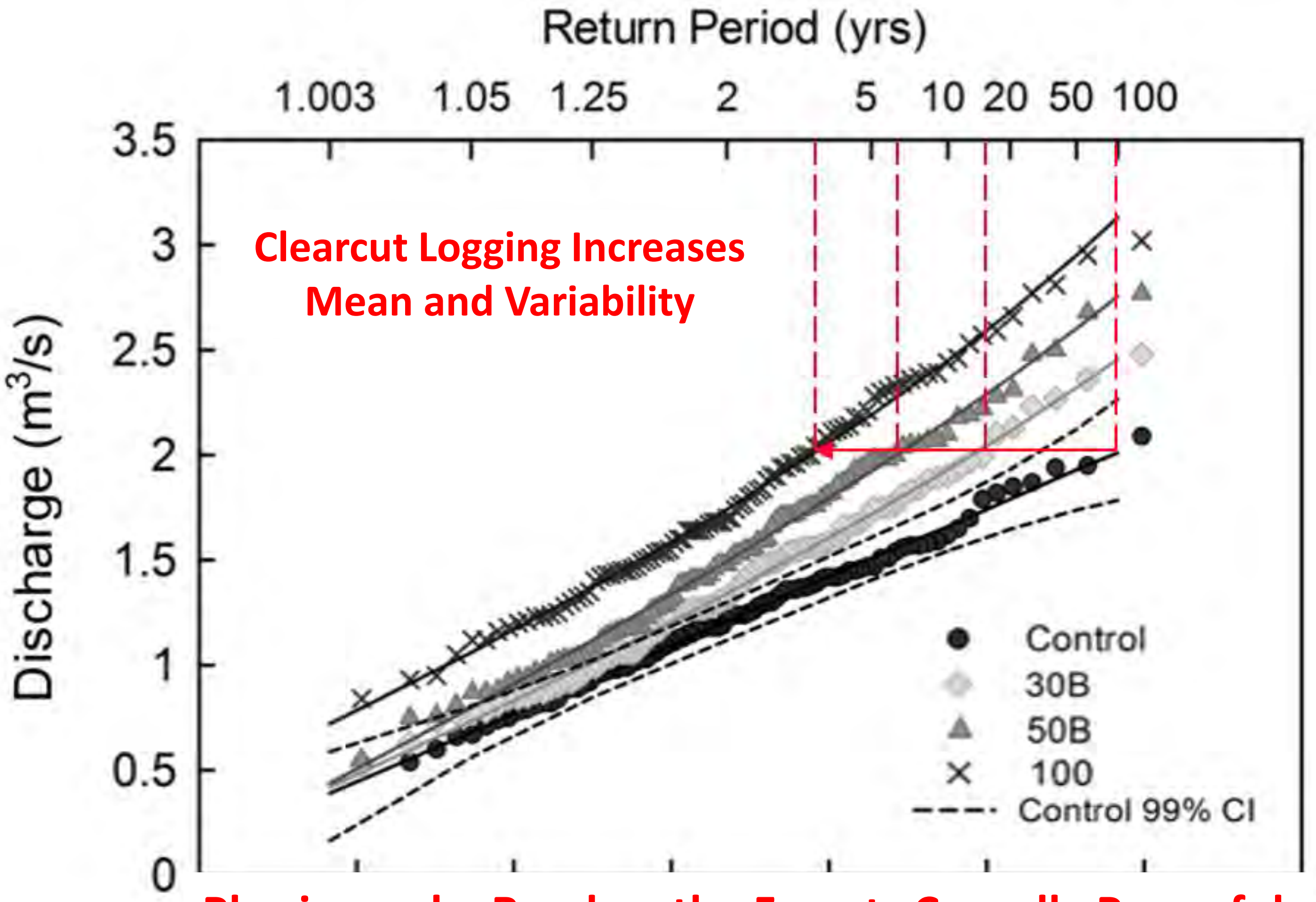
Figure 9. Plotting positions for control and scenario 100A for (a) hourly, (b) daily, and (c) 7-day discharge.

Schnorbus, M., and Y. Alila (2004), Forest harvesting impacts on the peak flow regime in the Columbia Mountains of southeastern British Columbia: An investigation using long-term numerical modeling, Water Resour. Res., 40,W05205, doi:10.1029/2003WR002918.

Case Study 2: Clearcut Logging in Subdued Terrains 240 Creek (Okanagan Highland)

Size : 4.7 km^2; Elevation Range: 427 m; Slope: 24%; Aspect: Eastwest; BEC Zone: ESSF

- With 30% cut rate 100-yr event becomes 15-yr
- With 100% cut rate 100-yr event becomes 3-yr event
- Higher cut rates have larger effects on flood risk



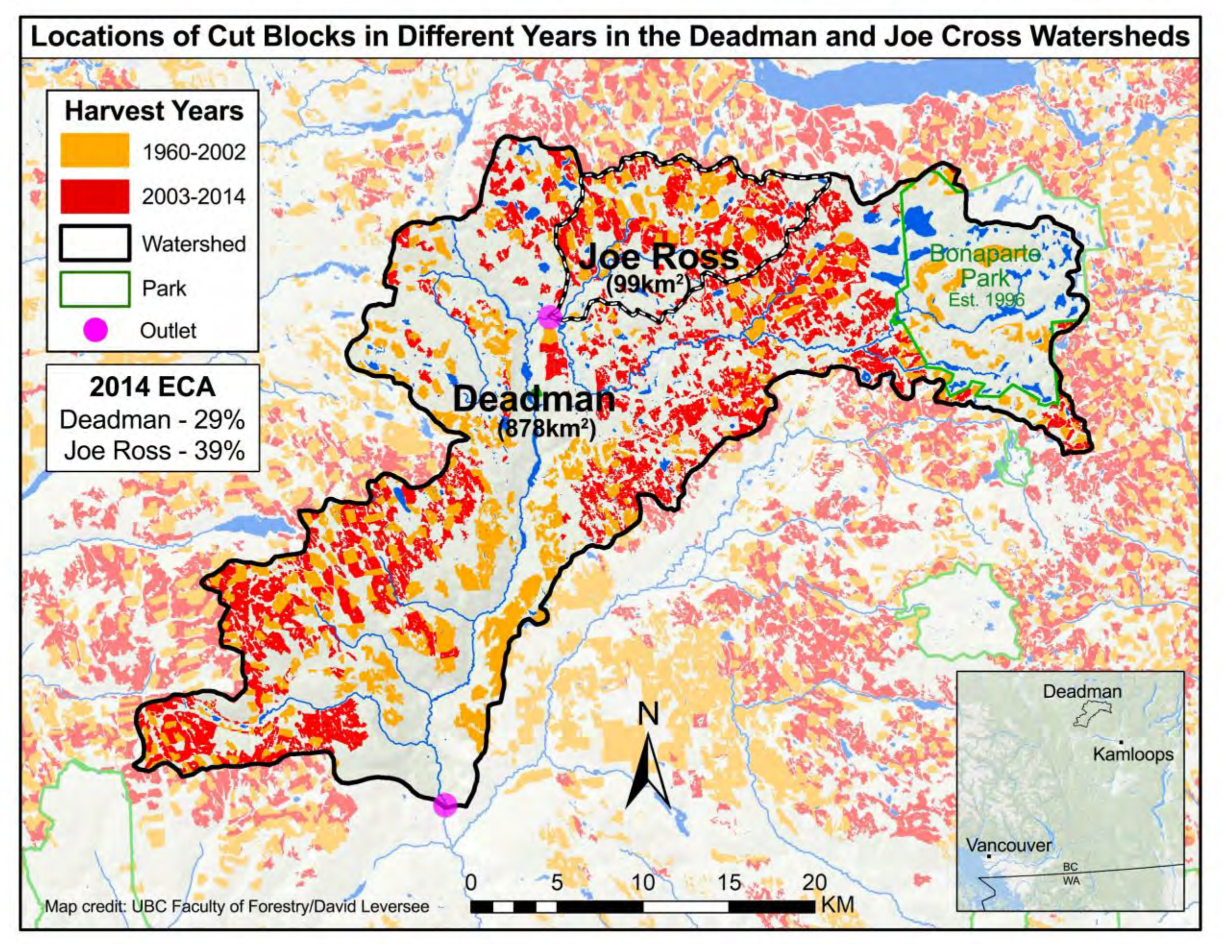
Physiography Renders the Forests Causally Powerful

figure 6 in Schnorbus & Alila (2013)

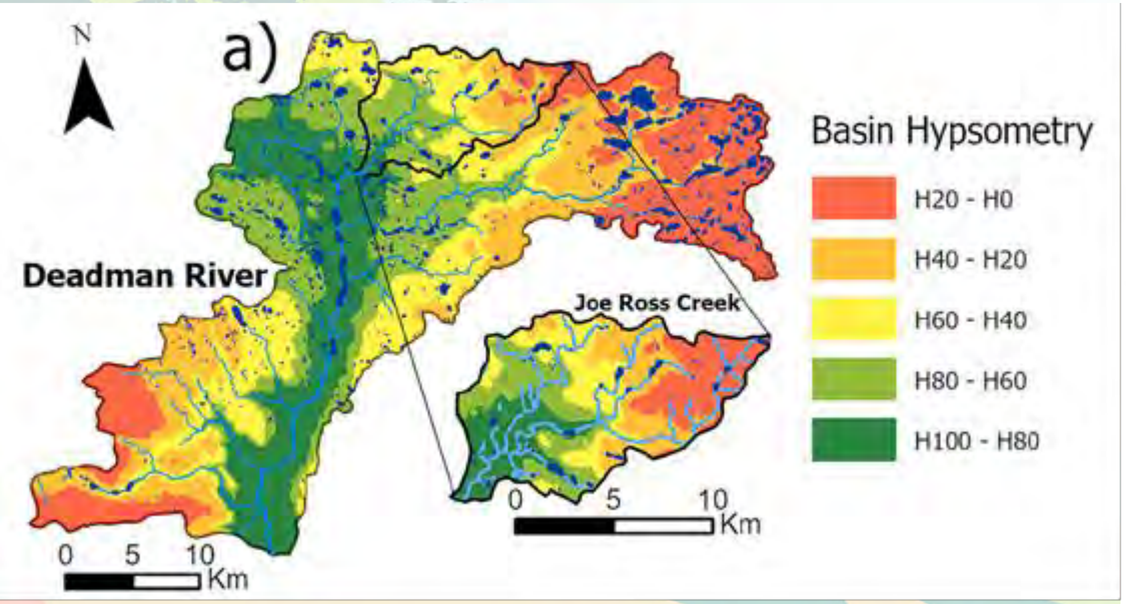
Schnorbus, M., & Alila, Y. (2013). Peak flow regime changes following forest harvesting in a snow-dominated basin : Effects of harvest area, elevation, and channel connectivity. Water Resources Research, 49(1), 517–535.

Case Study 3: Clearcut Logging in Larger Watersheds
Deadman River (Thompson Plateau)

- Deadman Watershed: 878 km^2
- Subdued, 90% of watershed within 750 m
- Slope and aspects evenly distributed
- BEC: IDF, SBPS, MS



Case Study 3: Clearcut Logging in Larger Watersheds
Deadman River (Thompson Plateau)



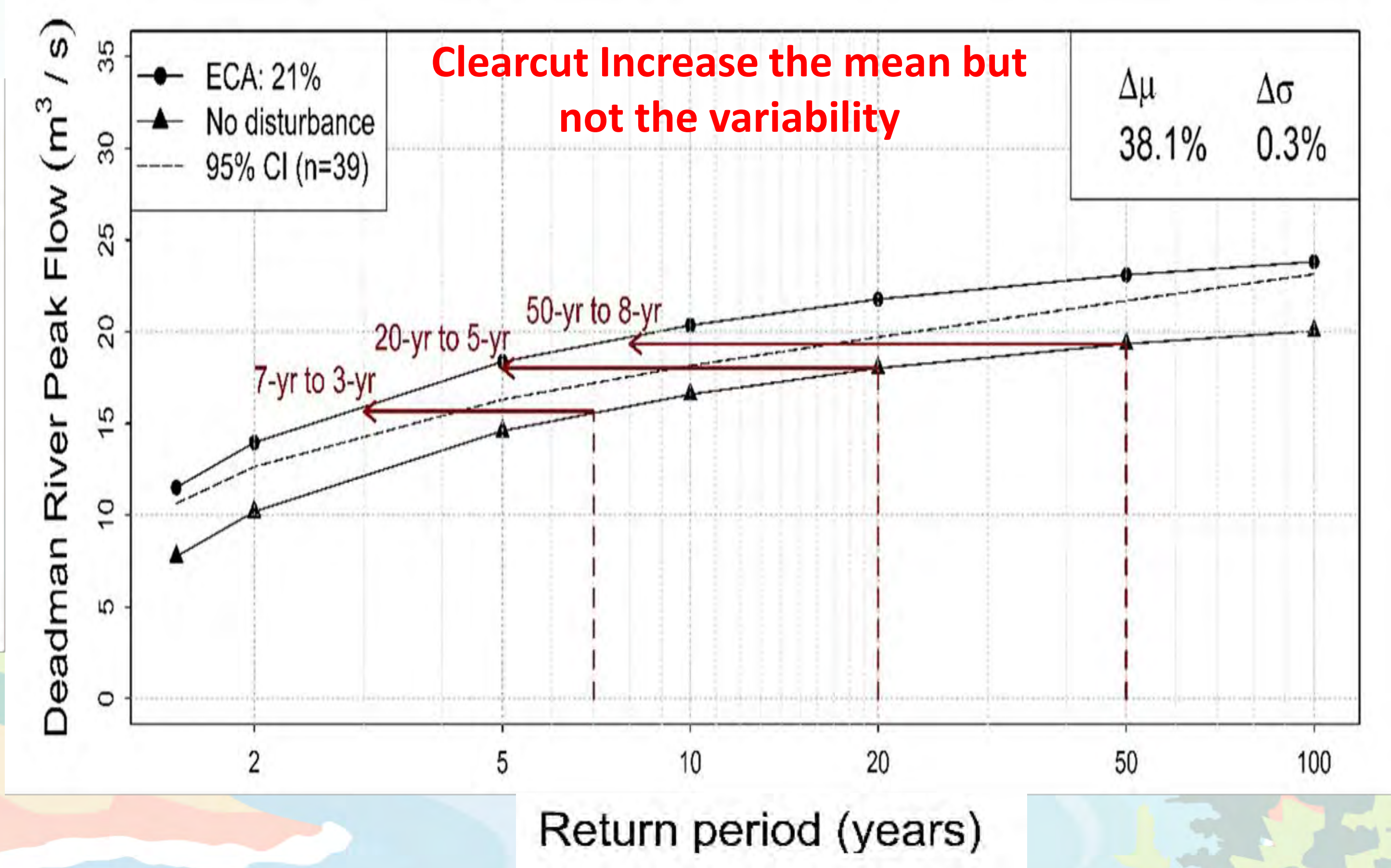
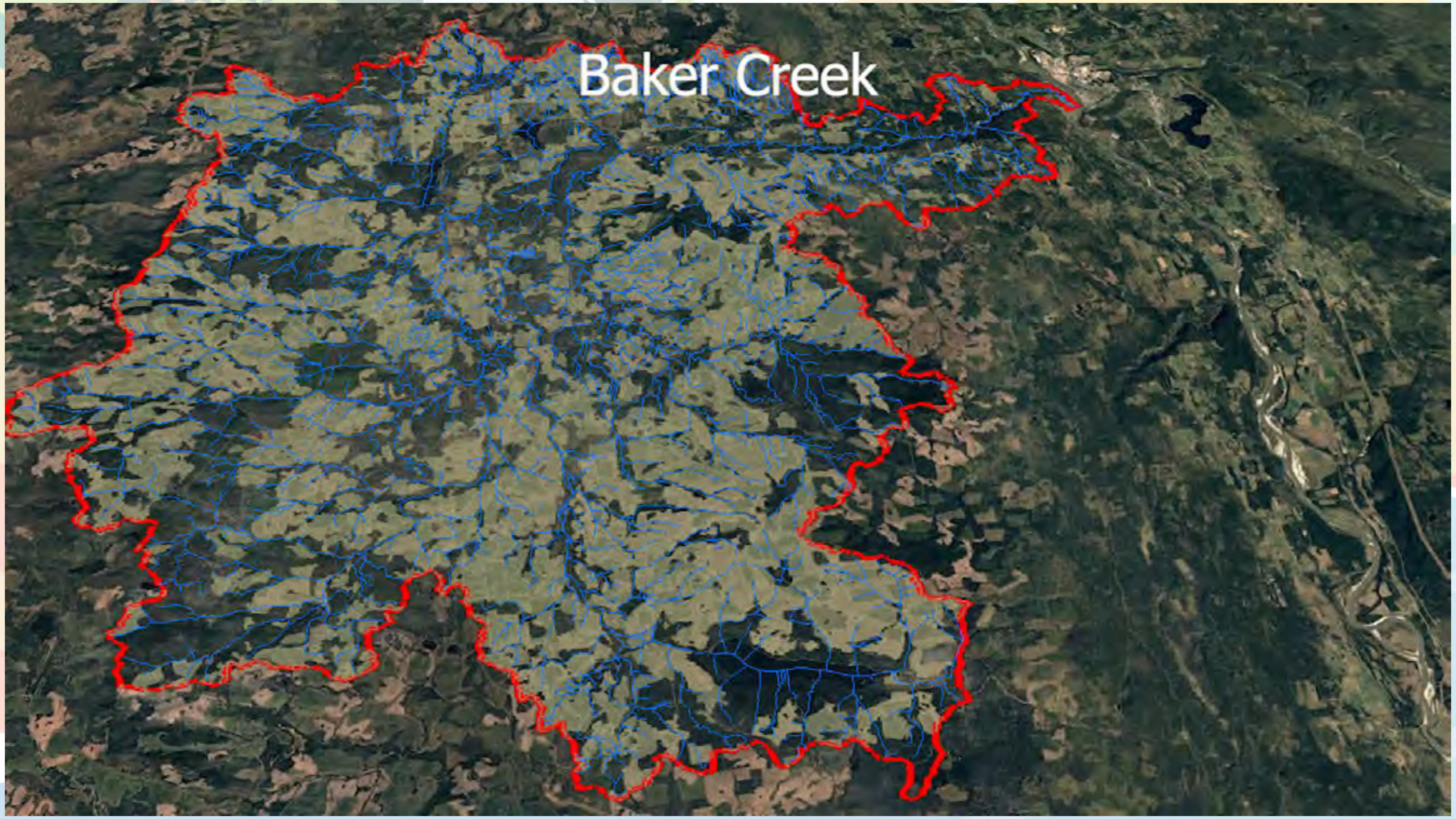


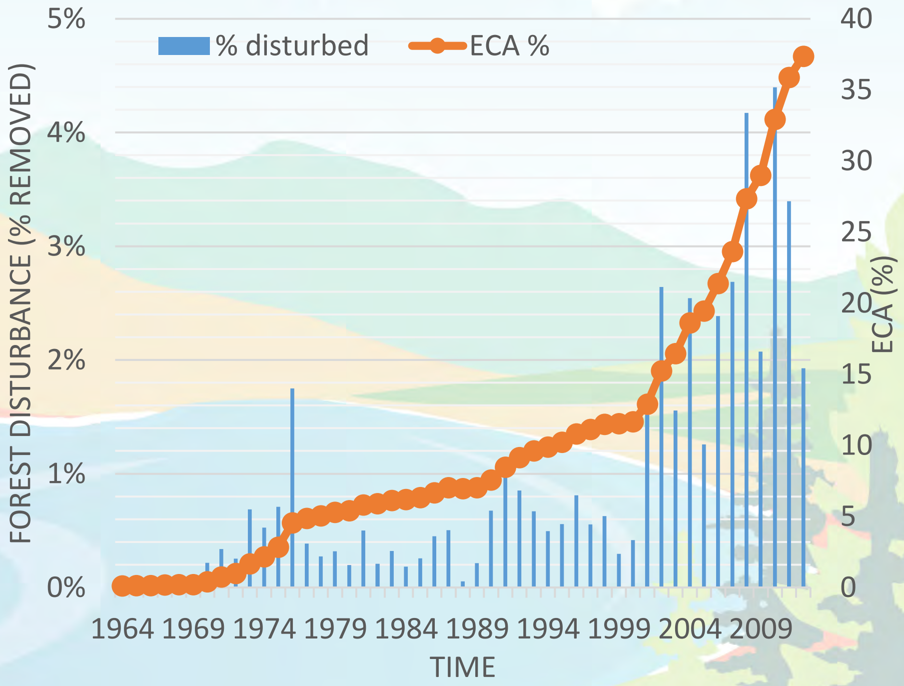
Figure 6 in Johnson & Alila (2023)

Johnson, R., Alila, Y., (2023). Nonstationary Stochastic Paired Watershed Approach: Investigating Forest Harvesting Effects on Floods in Two Large, Nested, and Snow-dominated Watersheds in British Columbia, Canada *Journal of Hydrology*, *625*, 129970.

Case Study 4: Clearcut Logging in Large Watersheds Baker Creek (West Quesnel)

- Watershed Size: 1564 km2
- Ranges in elevation between 469 to 1524 m (Plateau-like).
- 48% was harvested by 2012, mostly as a response to a widespread MPB outbreak.
- Logging is fairly comparable among elevation bands.





Can the outcomes of the non-stationary frequency pairing be validated?

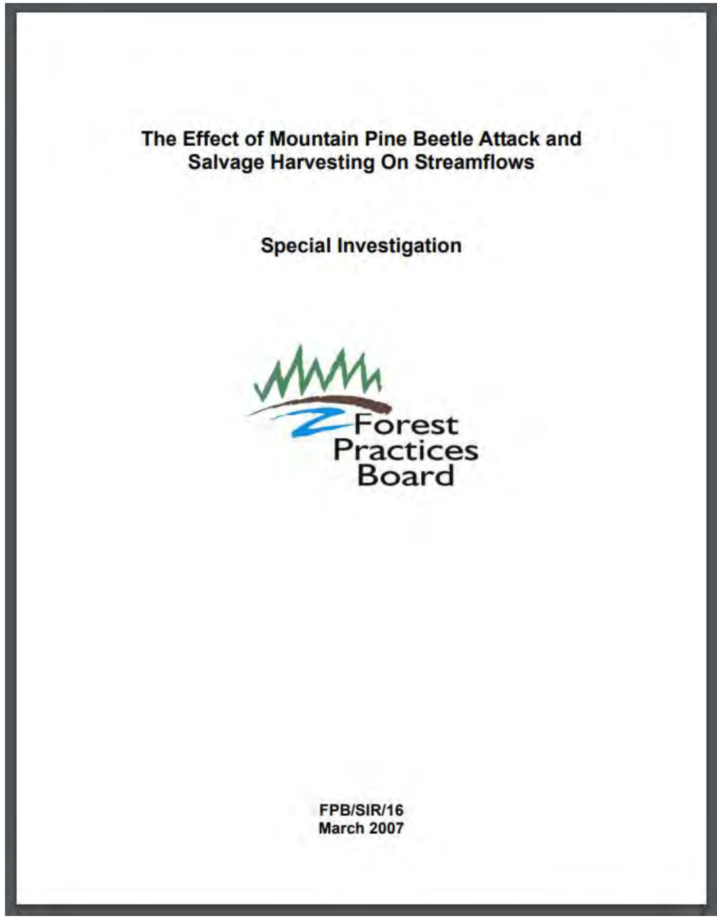
- https://www.mycariboonow.com/31218/should-quesnel-residents-be-worried-about-flooding/
- https://www.quesnelobserver.com/news/city-monitoring-baker-creek-and-rivers-closely/
- https://thenarwhal.ca/sprawling-clearcuts-among-reasons-for-b-c-s-monster-spring-floods/
- https://www.quesnelobserver.com/news/baker-creek-waters-rising/

Baker Creek

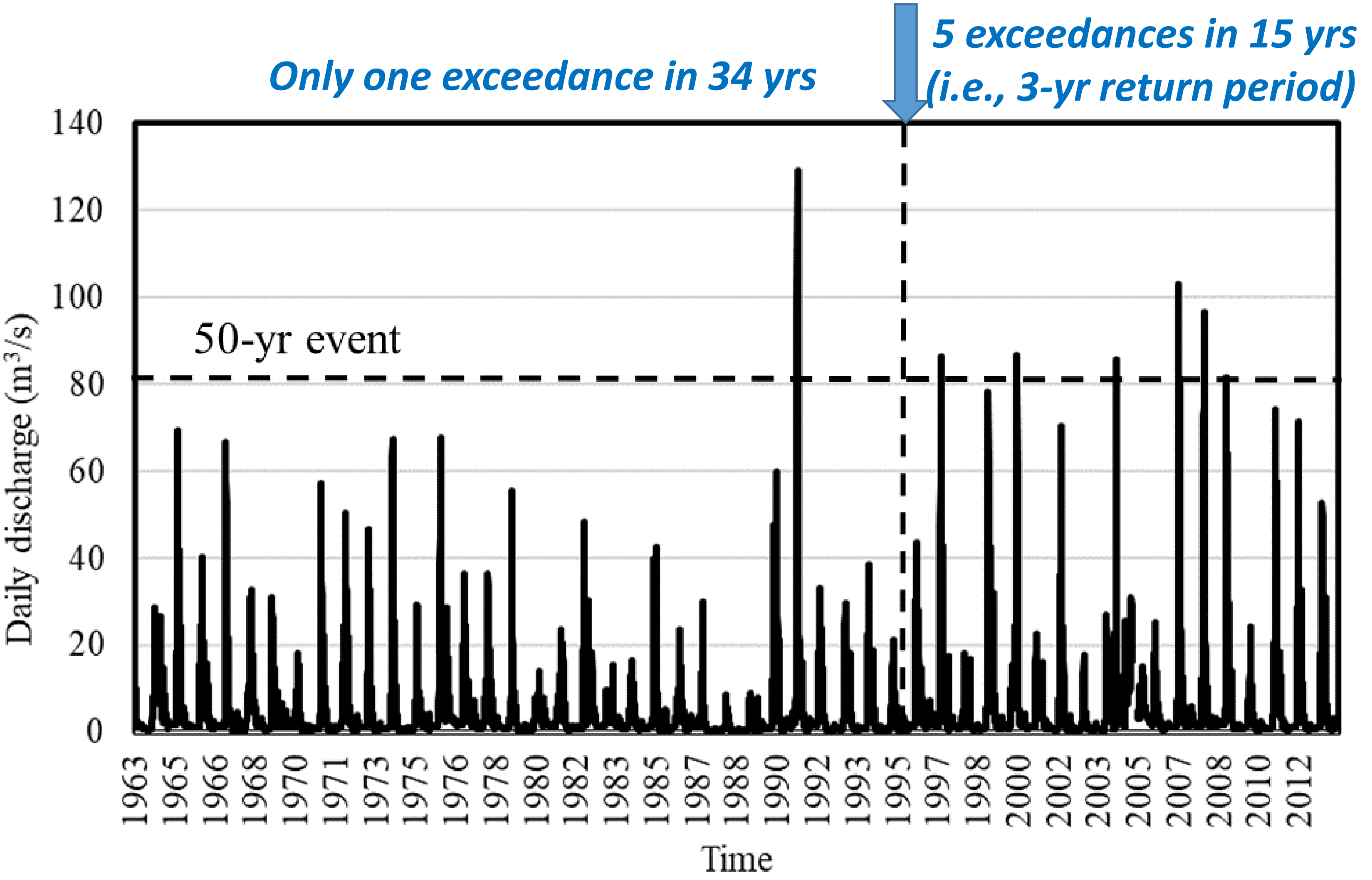
Flood watch, advisory, and warnings at Baker Creek becoming the norm over the past two decade

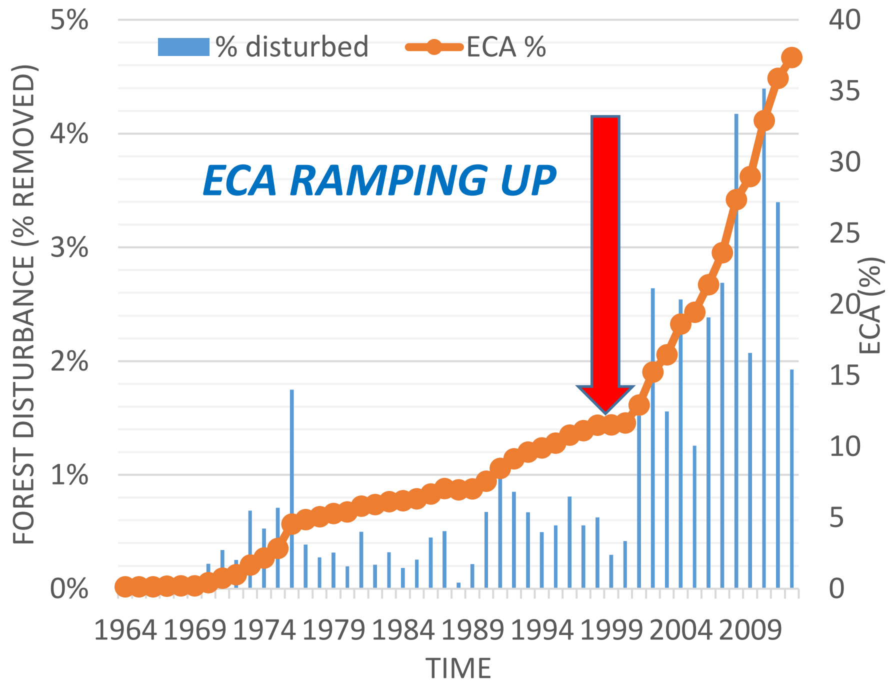
Can the outcomes of the non-stationary frequency pairing be validated?

Two independent studies by FPB (2007) and PCIC (2010) at Baker using two different hydrologic models (DHSVM and VIC) to simulate the long-term floods with and without forest disturbance. Their use of the FP framework revealed ***a similar highly sensitive flood regime*** to forest disturbances.



May the data speak for themselves?





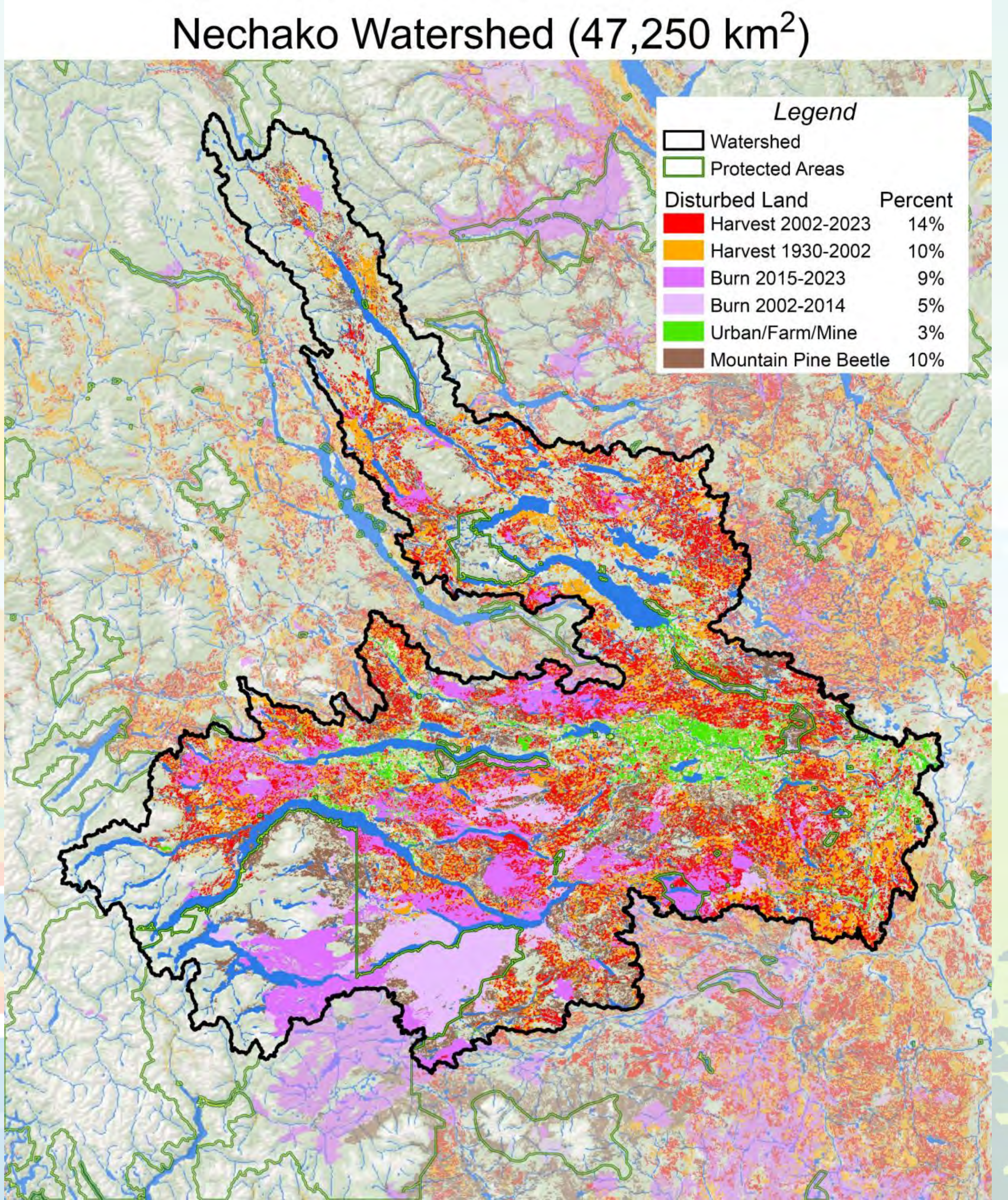
Conclusions

1. Use science of extremes for designing policy and guiding professional practice in the management of forests and water.
2. Abandon stand level in favor of landscape management in the practice of forestry because the power of the forests in mitigating the risk to hydrology and geomorphology lies not at the tree or stand but on the watershed scales.
3. Future downstream flood management strategies must be in sync with our land use and forest cover related policies.
4. Relying solely on an increase in size of downstream infrastructures such culverts, bridges, and dikes will not meet the objectives of a flood management strategy.
5. Abandon clearcut logging in favor of alternative eco-system friendly logging practices such as selective tree logging, small patch logging, etc.

Thank You

Acknowledgments:

Current and previous members of my graduate research lab who contributed substantially to our research on the topic of forests and floods over the last 30 years.



*"We are controlled by nature, but by discovering **causes** we can recover some of the **control**."* I.J. Good

OLD CP

Non-Causal

What is the difference in magnitude between control and treatment peak flows, when paired by the **same storm**?

Uncontrolled experiment

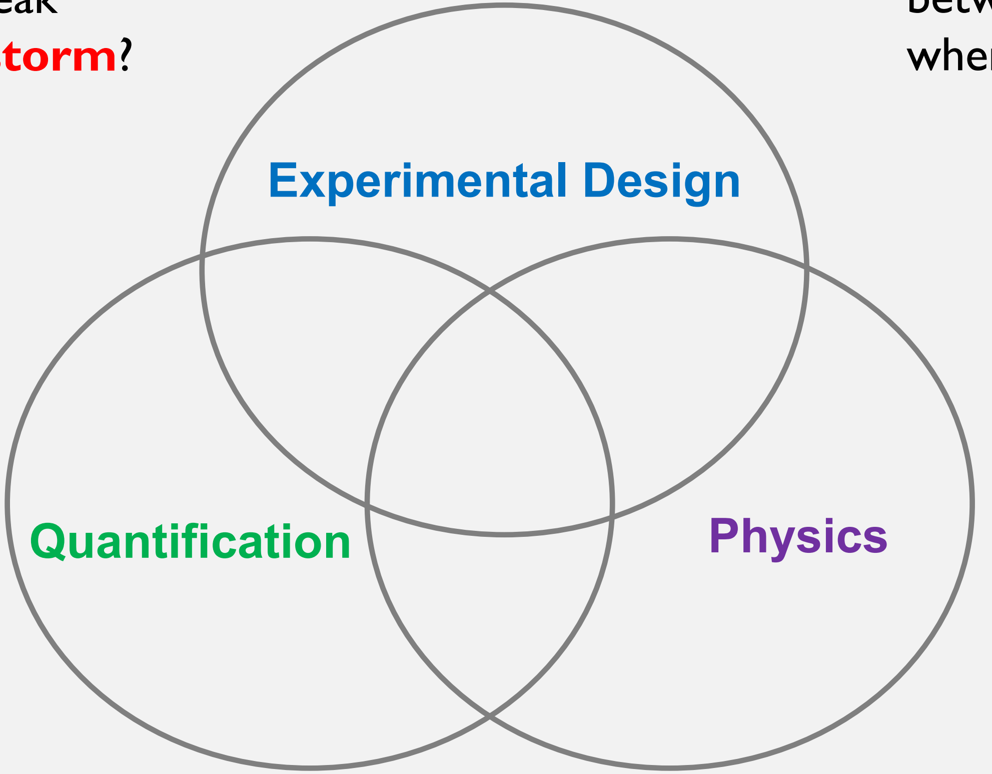
Pre and Post Regression (Conventional Statistics)

Deterministic physics

FRAMEWORK

Investigation

Research Question



NEW FP

Causal

What is the difference in magnitude between control and treatment peakflows, when paired by the **same frequency**?

Controlled Experiment

Pre and Post Frequency Distributions (Statistics of Extremes)

Probabilistic physics