

Glacial Outburst Floods



Outline

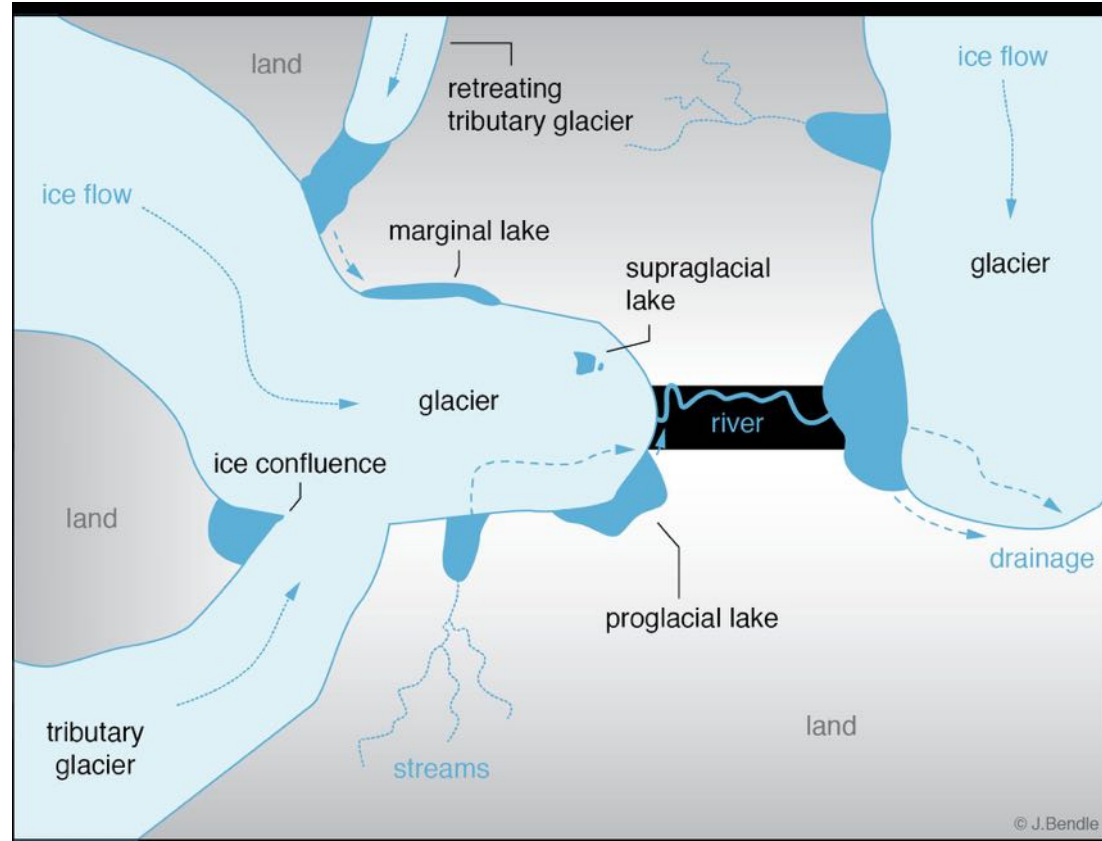
- Types of Glacial Lake Outburst Floods
 - Subglacial
 - Moraine Dammed
 - Ice Dammed
- Chamoli Landslide
- Downstream Impacts
- Megafloods

Types of Glacial Outburst Floods (GLOFs)

Subglacial Outburst Floods

Moraine Dammed Lakes

Ice Dammed Lakes (Marginal)



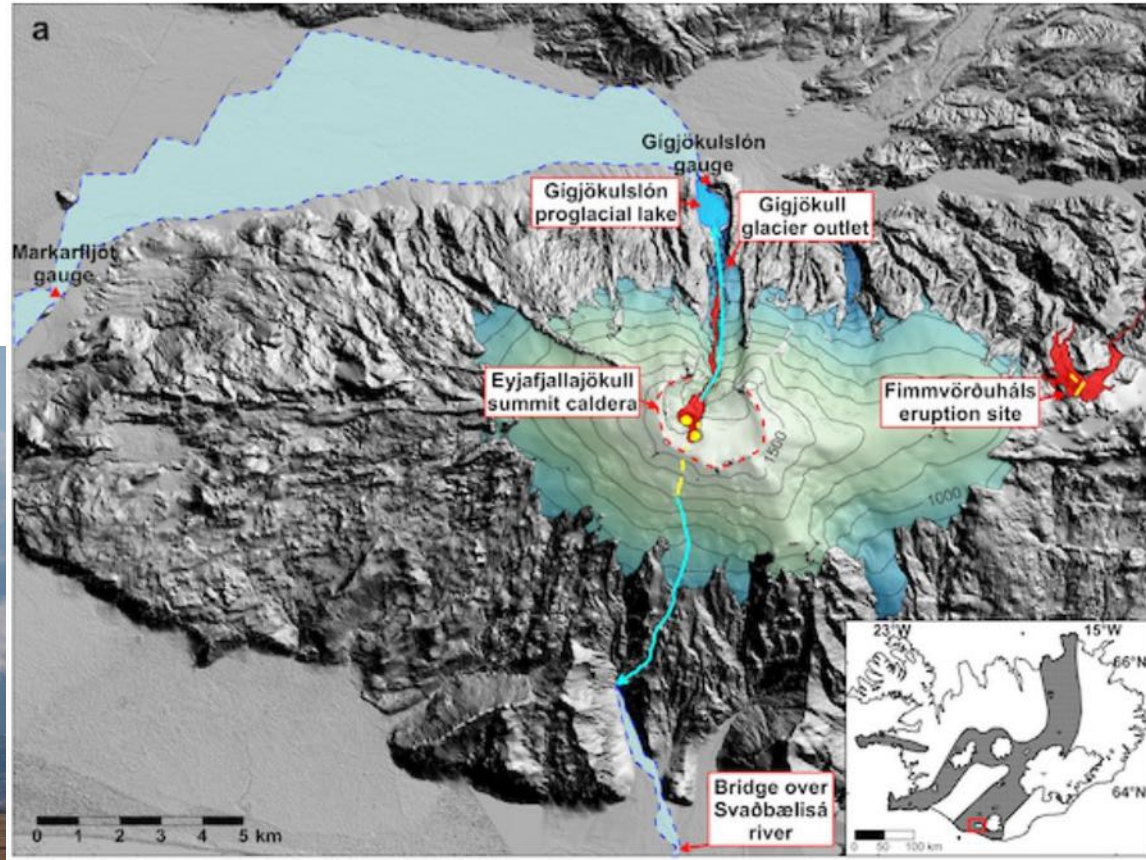
Subglacial Outburst Floods

Heating from volcanic eruption underneath glacier



Subglacial Outburst Floods

2010 Eyjafjallajökull Eruption



Subglacial Outburst Floods

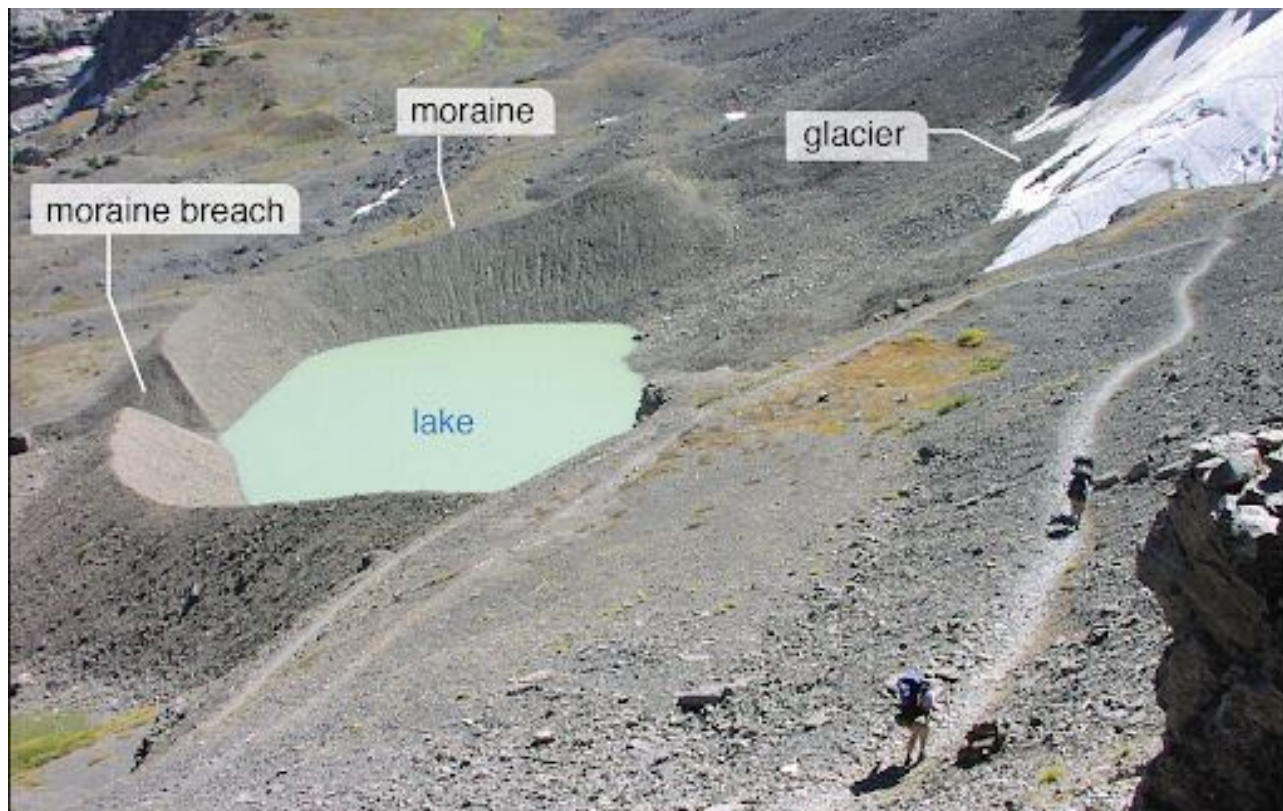
- Peak discharge of 2640 $\text{m}^3 \text{s}^{-1}$
- Sediment and ash laden water
- Extensive flood area



Moraine Dammed Lakes



Moraine Dammed Lakes



Moraine Dammed Lakes

- Physical experiment with packed sand dam
- Analogous to moraine, landslide, or human manufactured sediment dam failure



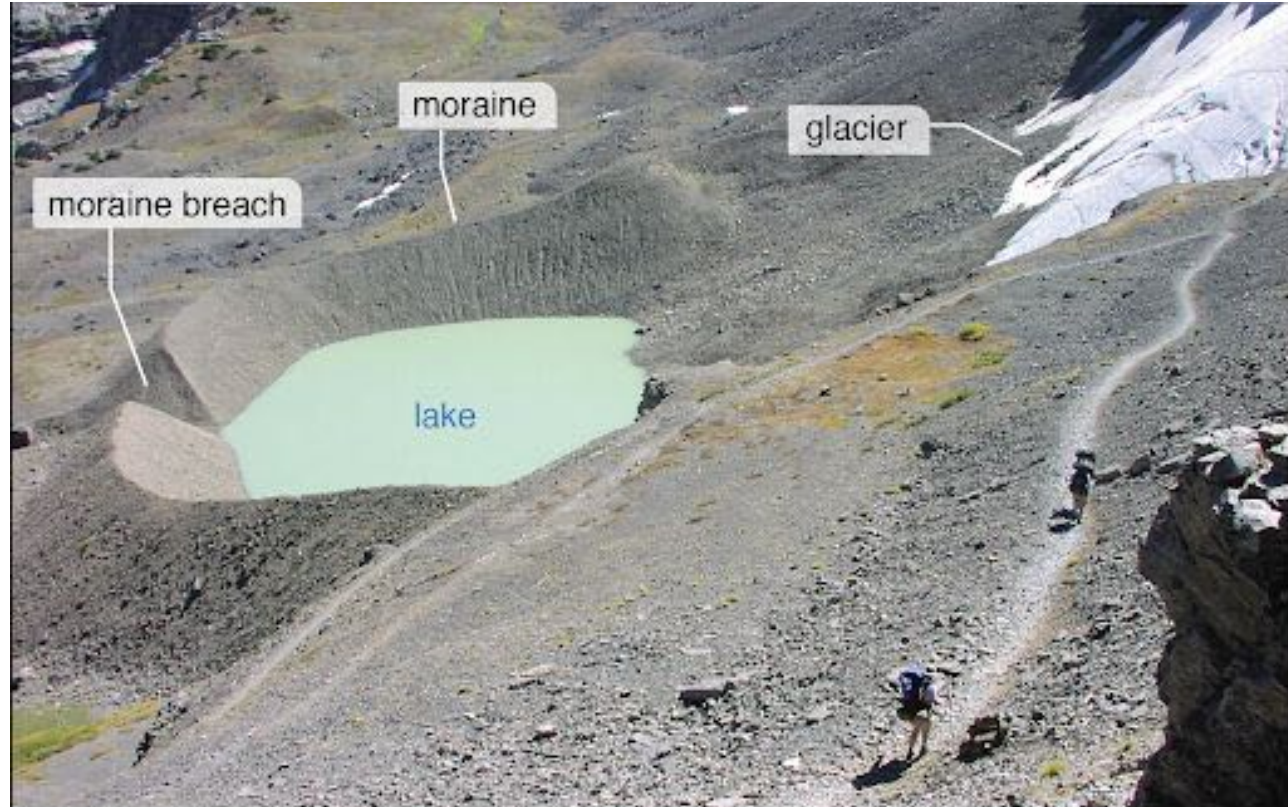
Moraine Dammed Lakes

Key Observations:

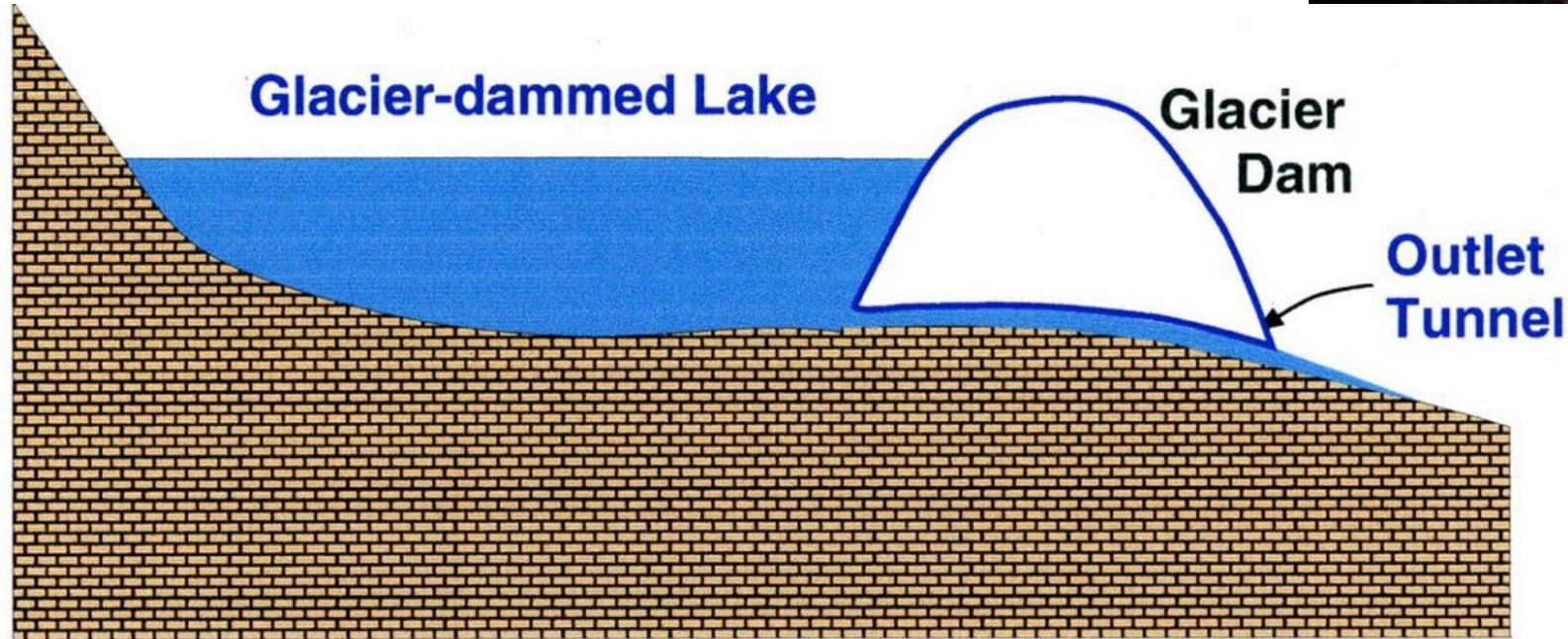
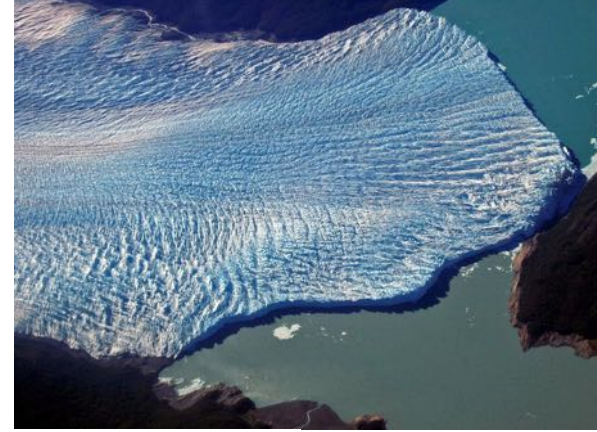
- Only small event needed to initiate breach
- Discharge first occurs slowly, then more quickly as a larger channel is incised
- Discharge is limited when
 - Lake level drops so that hydrostatic pressure is insufficient to erode a larger channel
 - Lake level drops to the new outlet height

Moraine Dam Mitigation

- Drain lake in a controlled manner
- Pre-cut channel to initiate earlier and smaller outburst flood
- Reinforce moraine with engineered materials

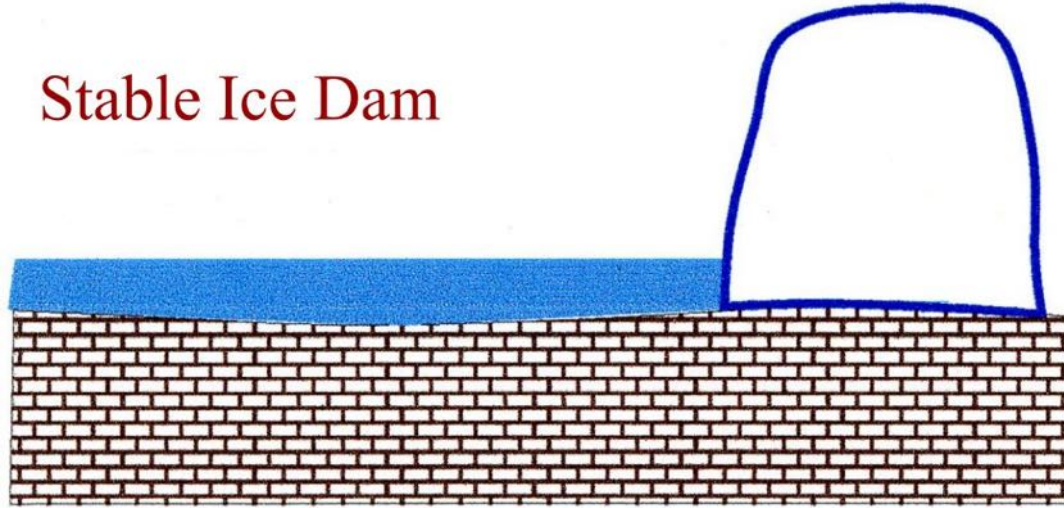


Ice Dammed Lakes



Ice Dammed Lakes

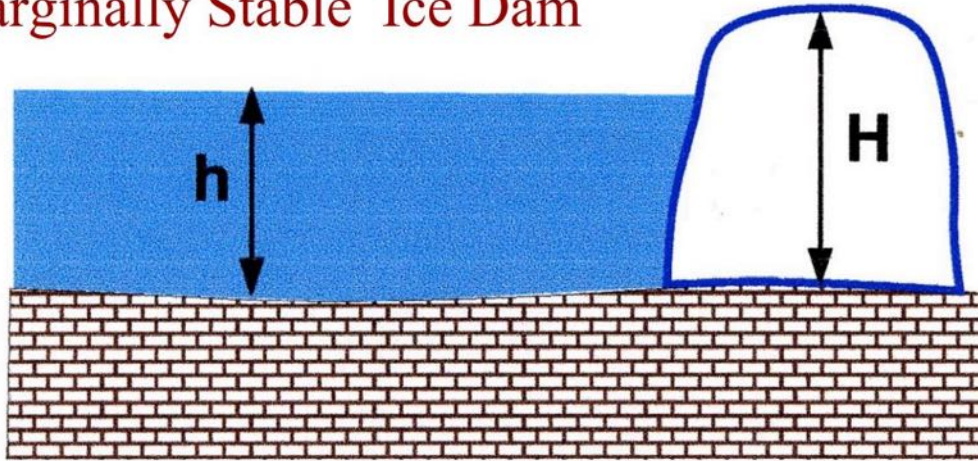
Stable Ice Dam



- Water pressure is low compared to ice pressure (weight of overlying ice).
- Ice pressure closes tunnels and cracks.
- System is self-sealing.

Ice Dammed Lakes

Marginally Stable Ice Dam



Ice density is $\frac{9}{10}$ of water density.

- Ice can float when water depth h reaches 90% of ice depth H
- Water pressure = ice pressure at bedrock.
- Water pressure still cannot force open tunnels.
- But, if a tunnel exists, ice pressure cannot close it.

Ice Dammed Lakes

Oops ... Unstable Dam



$h > 0.9 H$ - dam can float!

- Water pressure exceeds ice pressure.
- Tunnels forced open by water pressure (like inflating balloons), and ...
- Tunnels melted open by turbulent energy from water. Look out downstream!

2018 Bear Glacier GLOF

- Lake fills in late summer
- Remains steady through winter
- Dam breaches after snowmelt

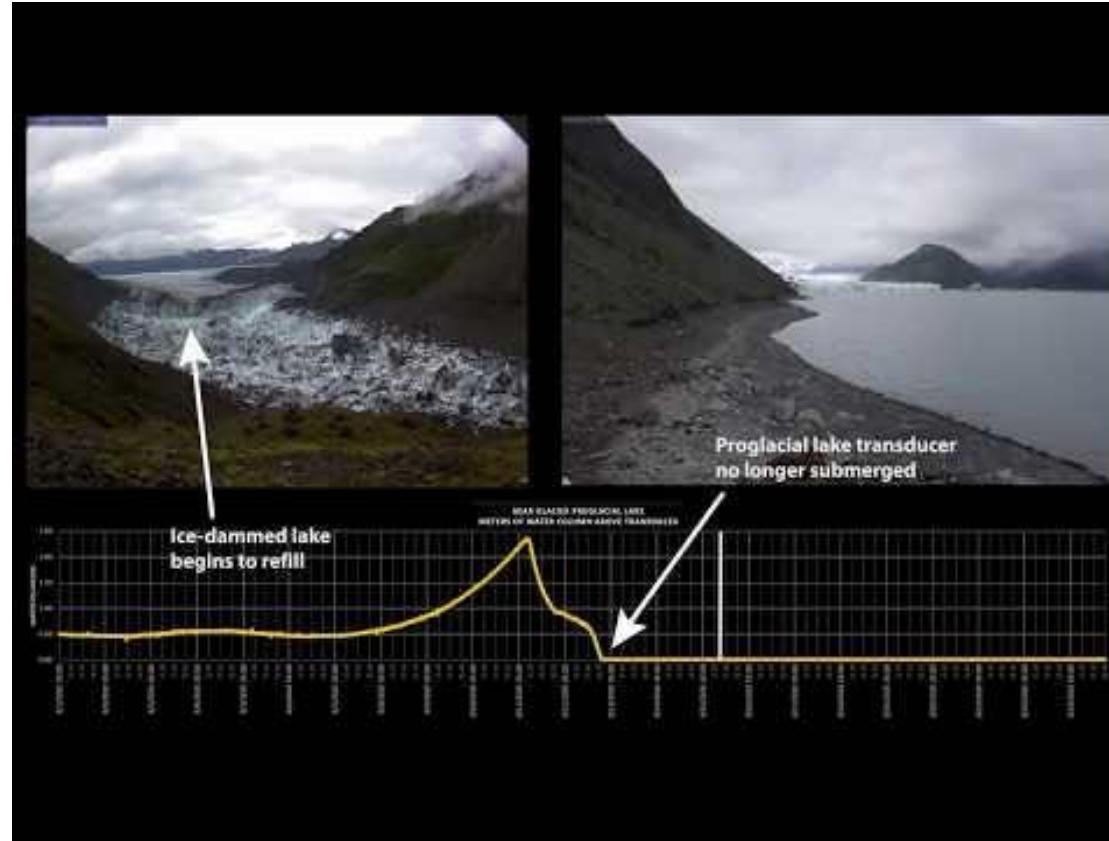
NOTE:

- Glacier collapses with draining lake
- Lake immediately begins to refill



2018 Bear Glacier GLOF

Let's watch the same event in more detail

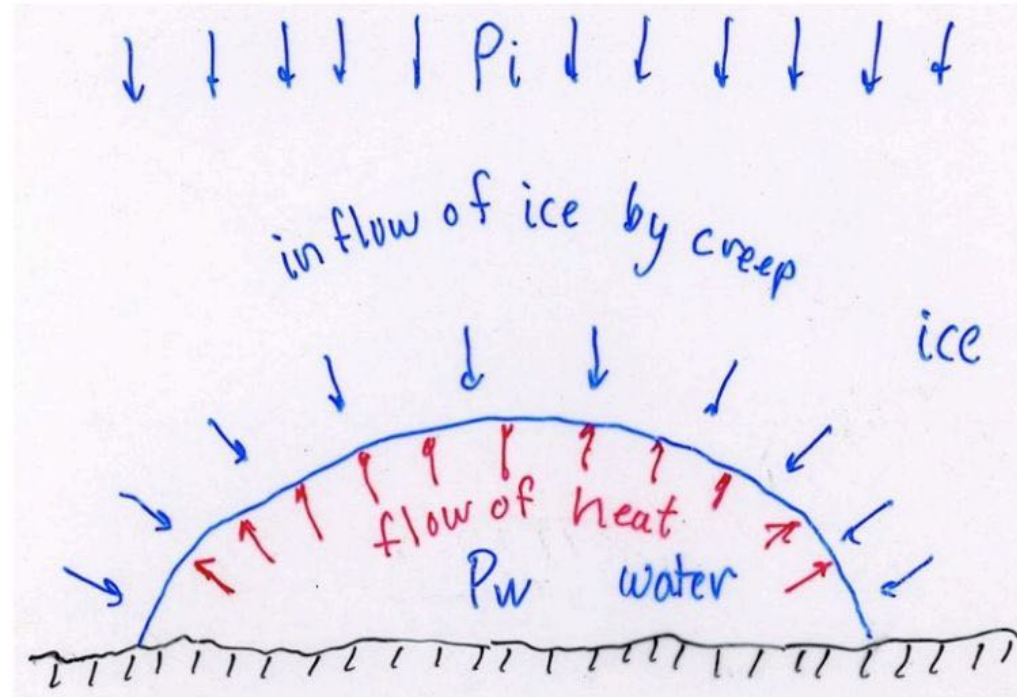


Subglacial Tunnels

A leak starts through a small tunnel...

- Energy from falling water is converted to turbulent energy.
- Turbulence heats water in tunnel.
- Warmed water melts and enlarges tunnel.
- More flow, more turbulence, more heating, more melting...

(Positive feedback loop!)



Subglacial Tunnels

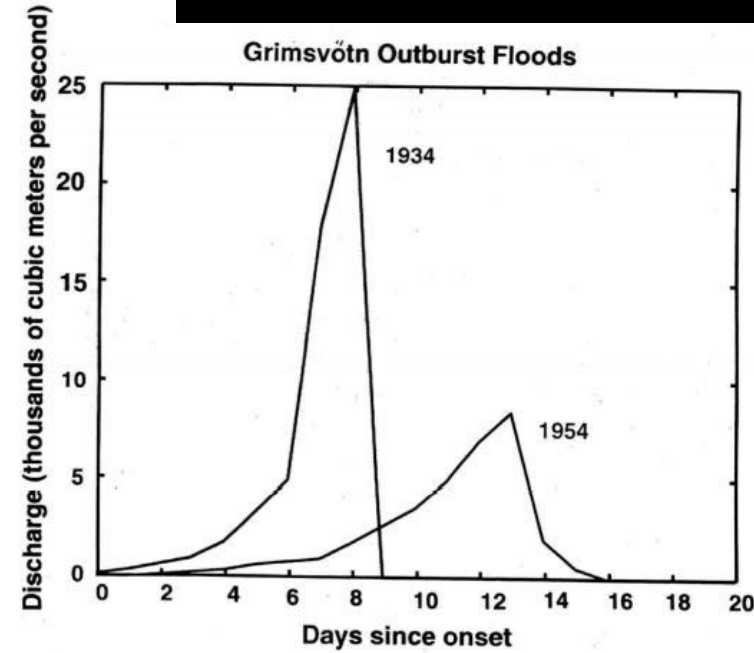
Perito Moreno



Discharge Patterns

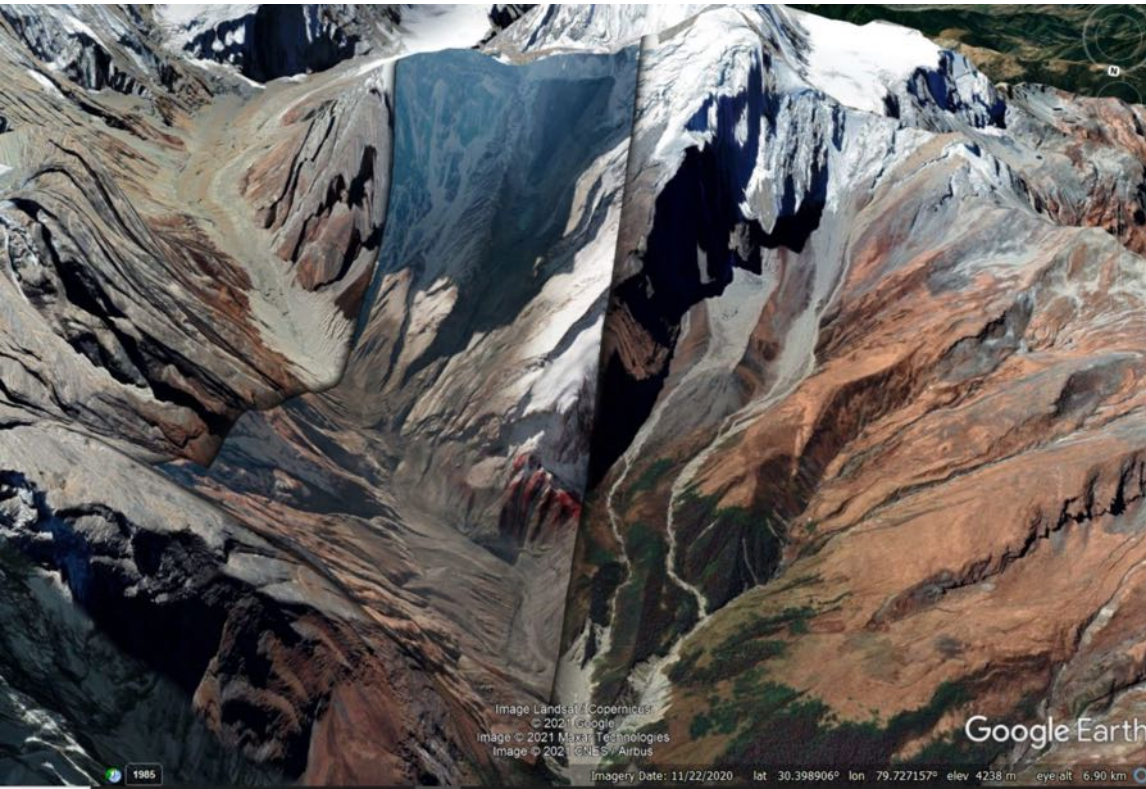
Recall that both moraine dam and ice dam outburst floods have mechanisms with positive feedback loop behavior.

What does this mean for discharge?



Chamoli Landslide

Feb 7, 2021



Chamoli Landslide



Chamoli Landslide

As of Feb 15th, 54 people are known to have lost their lives and 179 people are reported to be missing.

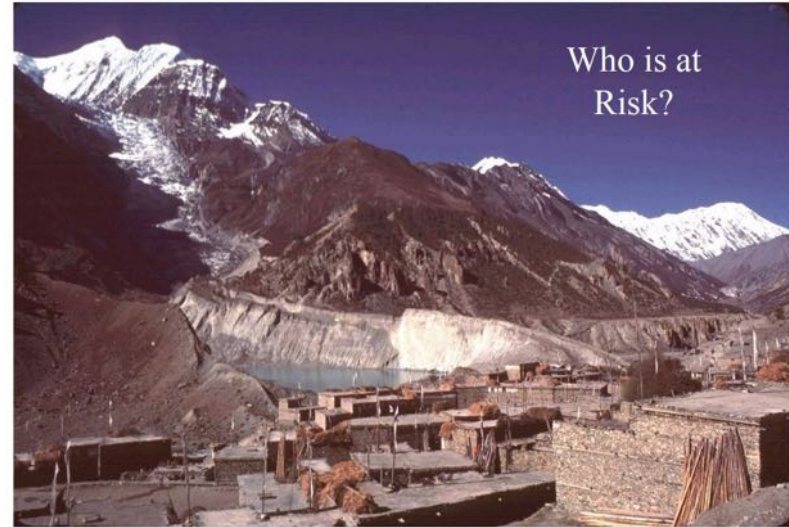
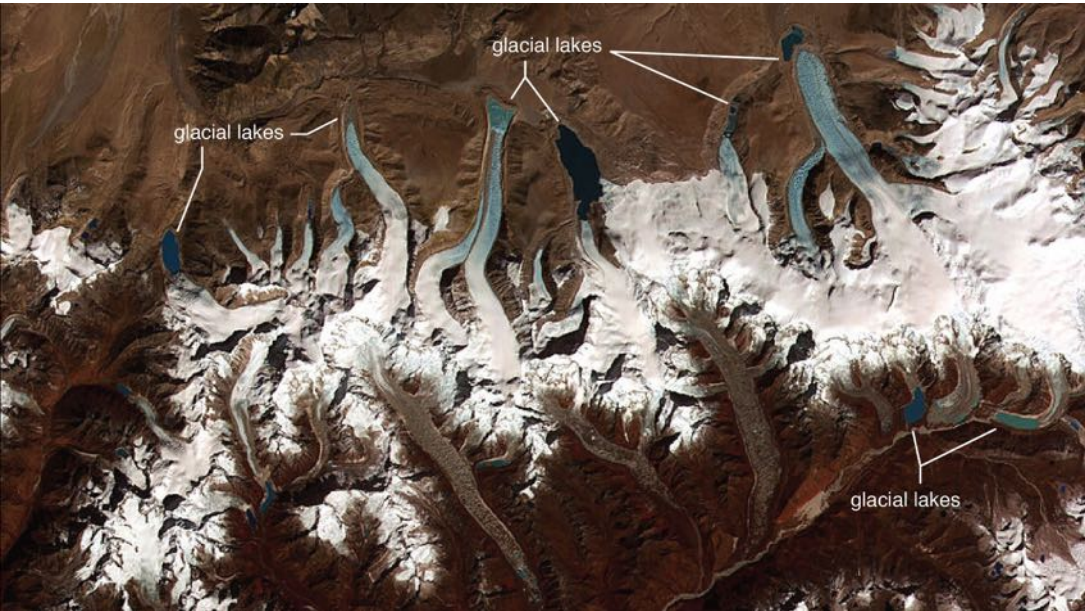




Downstream Impacts

Himalayas particularly prone. Why?

Are GLOFs an increasing hazard?



Downstream Impacts

Himalayas particularly prone. Why?

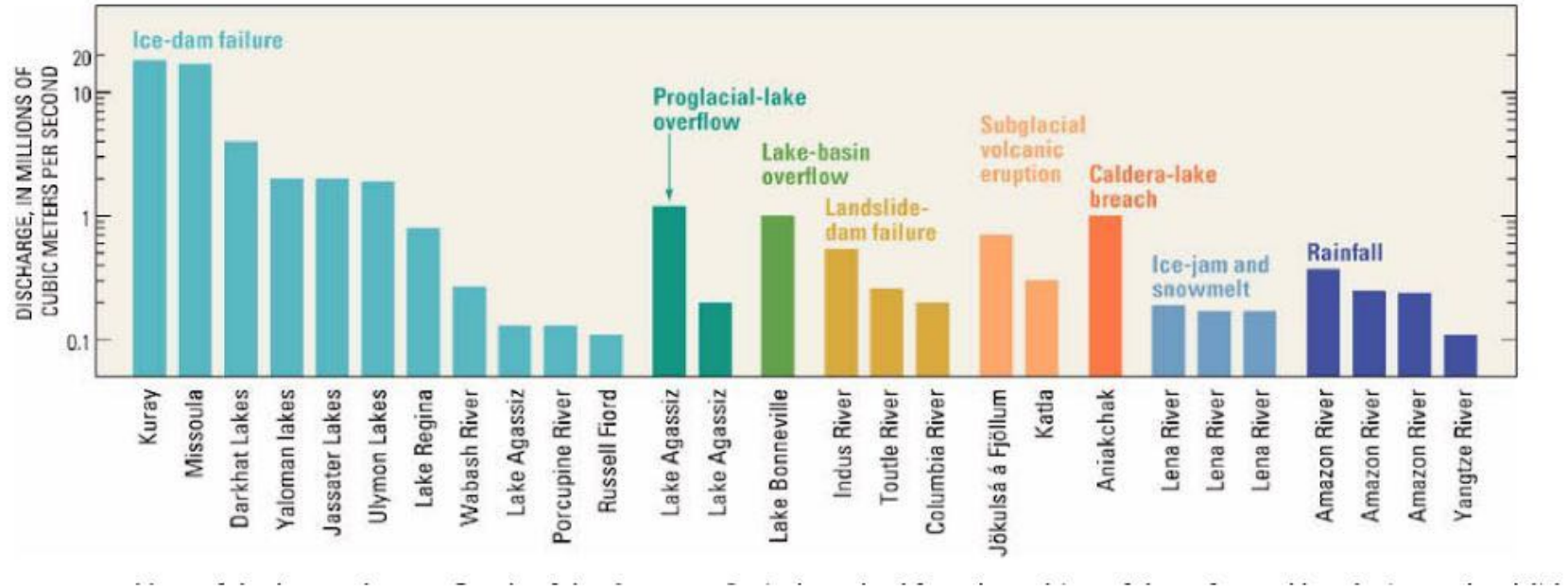
- Reliance on glacial lakes for water
- Tendency to build near rivers or near glacial lakes
- Steep terrain -> available land in flood zone

Are GLOFs an increasing hazard?

Yes!

- Global warming
 - Creation of new glacial lakes during recession
 - More water
- Increasing population in mountainous regions

What if we had even bigger floods?

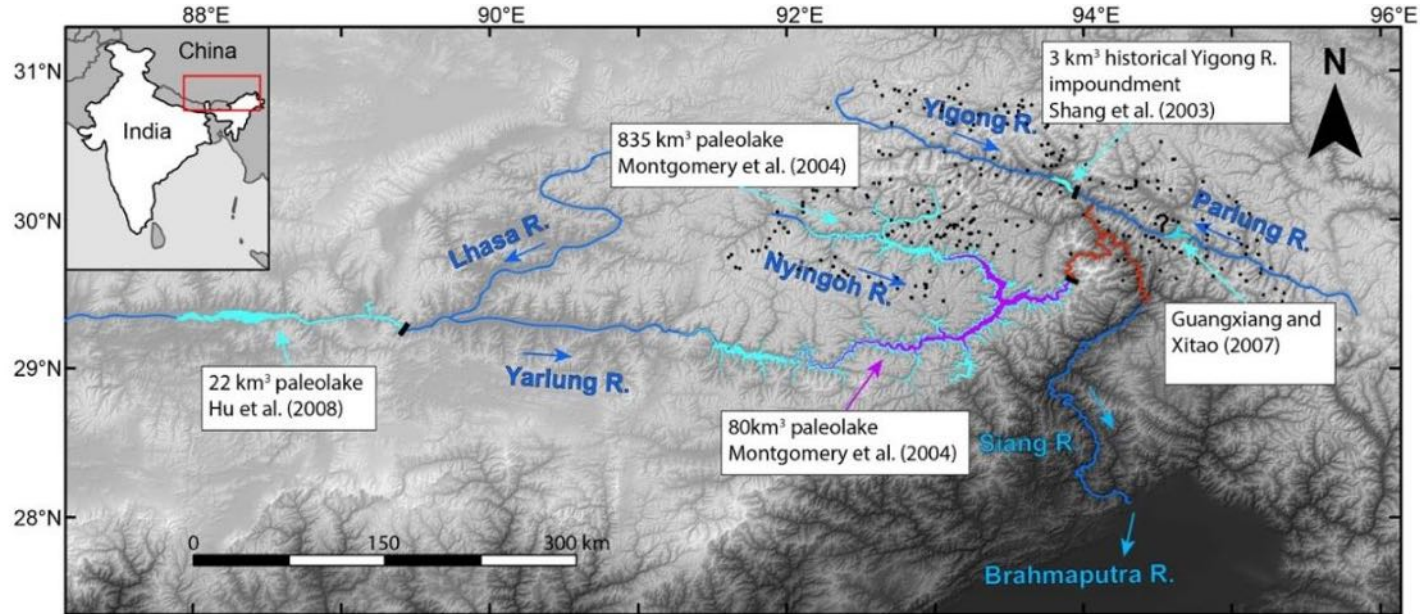


The world's largest floods from: [O'Connor, Jim E., and John E. Costa. *The world's largest floods, past and present: their causes and magnitudes*. No. 1254. Geological Survey \(USGS\). 2004.](#)

MEGAFLOODS



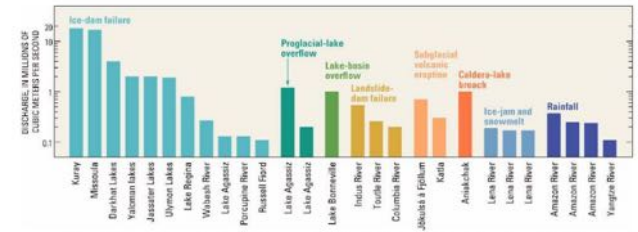
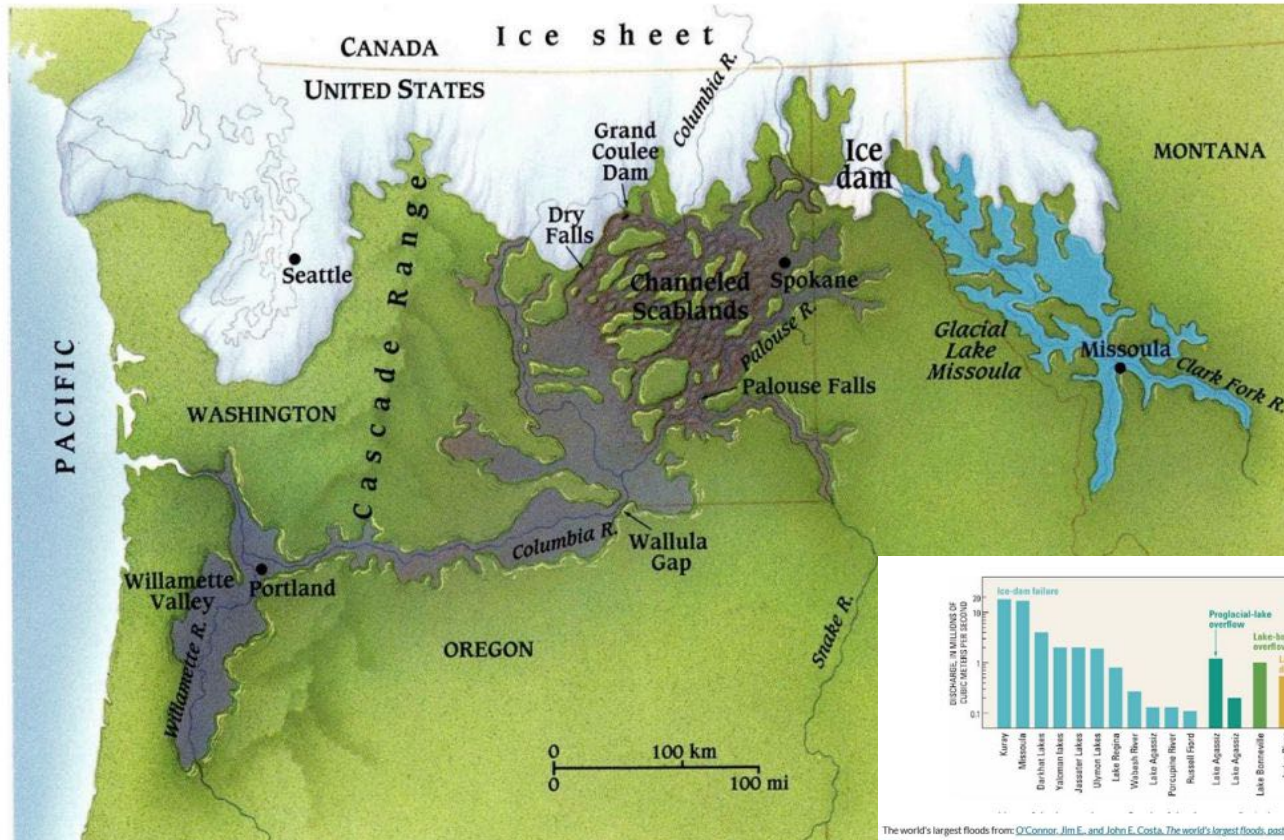
Himalayan Megafloods- Susannah Morey



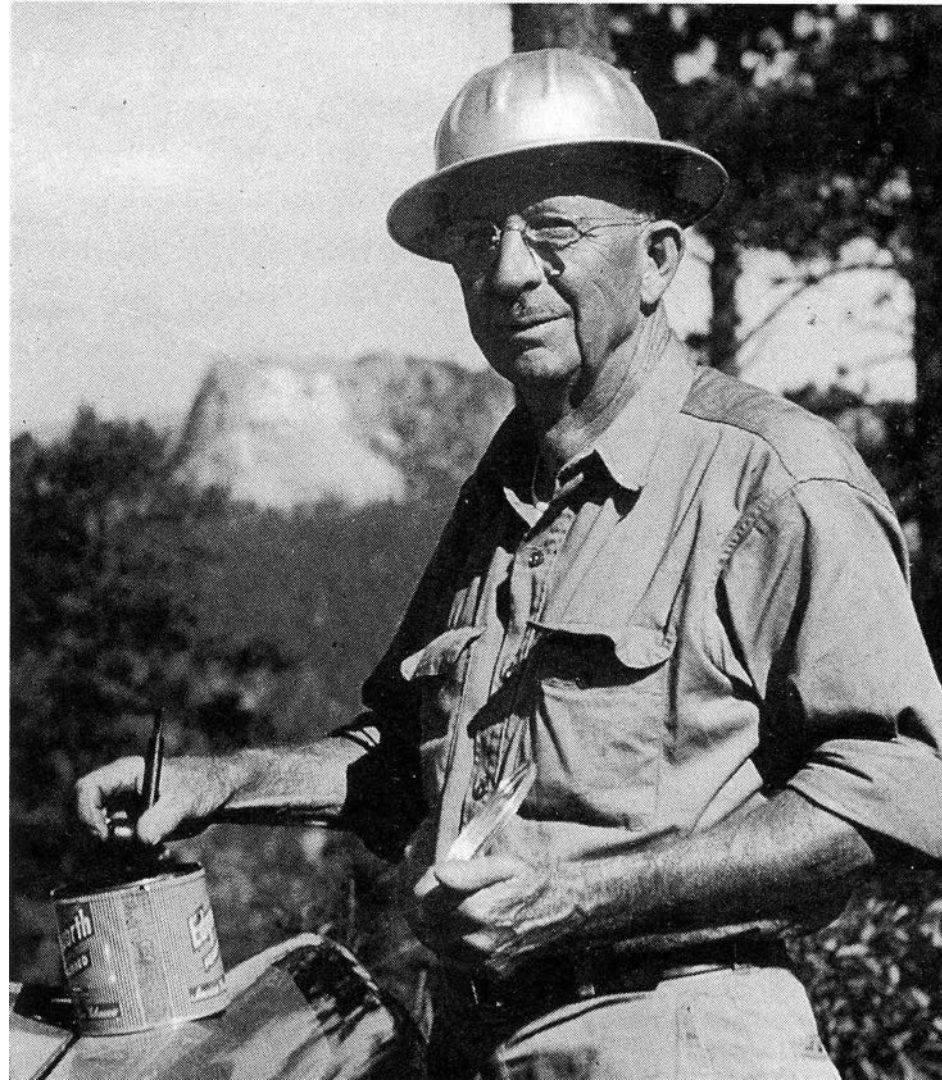
<https://sites.google.com/uw.edu/susannah-does-science/agu-2020>



Glacial Lake Missoula- Channeled Scablands



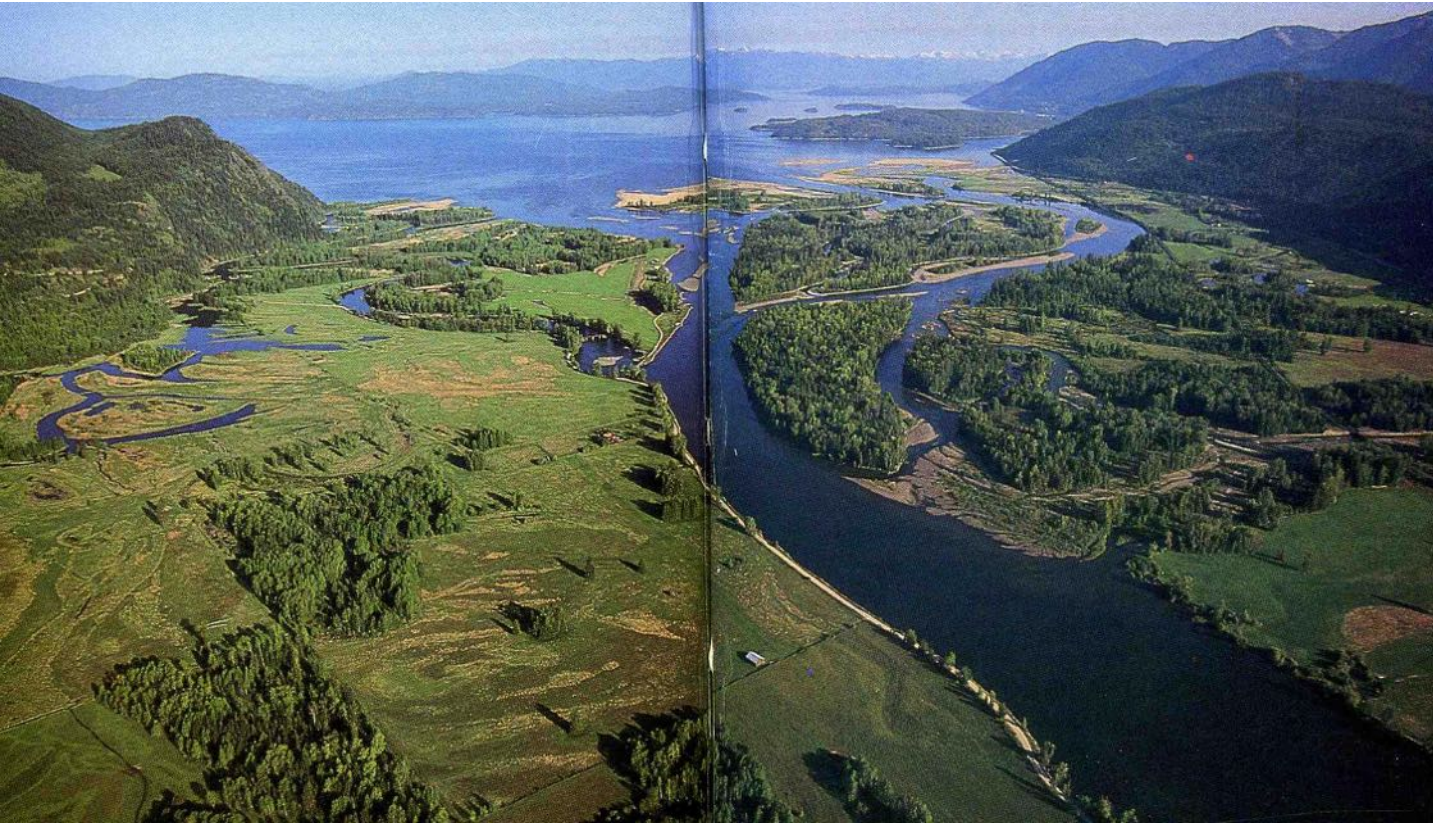
J. Harlen Bretz



M. Parfit 1995

Smithsonian 26(1) 48-59

Dam Location – Lake Pend Oreille



M. Parfit 1995 *Smithsonian* 26(1) 48-59

Missoula Bathtub Ring



M. Parfit 1995 *Smithsonian* 26(1) 48-59



Quincy Basin Potholes



M. Parfit 1995 *Smithsonian* 26(1) 48-59

THE CHENEY-PALOUSE TRACT OF WASHINGTON'S CHANNELED SCABLANDS



During the last ice age, a lake of the Cordilleran Ice Sheet formed an ice dam that blocked a major valley in what is now western Montana, creating Glacial Lake Missoula. Between 15,000 and 13,000 years ago the ice began to recede and the lake periodically breached the ice dam. These breaches created an estimated 40 catastrophic floods that flowed westward during this time period. These ice-age floods, also known as the Missoula Floods, swept across what is now eastern Washington and onward to the Pacific Ocean along the Columbia River corridor. The floods scoured the landscape on a massive scale, leaving behind scoured terrain known as the Channeled Scablands. Flood features are so large, they can be seen from space.

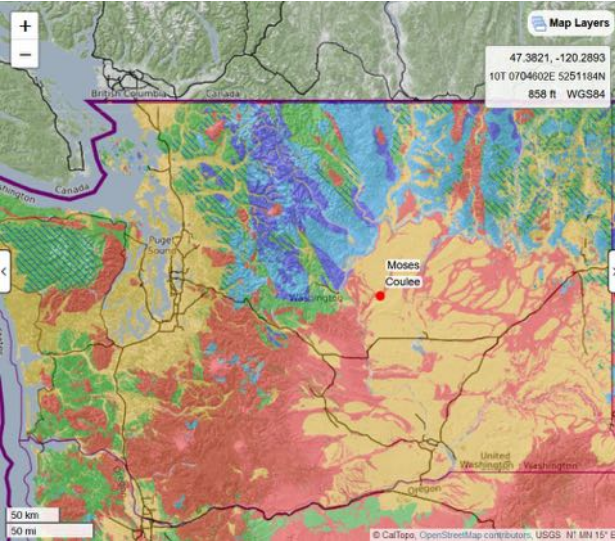
This map shows the topographic evidence of the Missoula Floods on a portion of the Channeled Scablands in eastern Washington known as the Cheney-Palouse scabland tract. Smooth, linear features are former channels of the floods, which the more textured land adjacent to the pathways was higher in elevation, and was thus unaffected by the flooding.

Flooded areas were often scoured down to bedrock, as can be seen east of Sprague Lake and the Karakul Hills. In the Cheney-Palouse scablands region, the former channels are also composed of layers of silt. The largest and deepest scoured lake is 2.4th Lake in the northwest portion of this map.

In the area adjacent to the flooded channels, much of the landscape is covered in loess (windblown glacial silt). Loess covers the agriculturally productive Palouse region, the area of rolling hills in the southeastern corner of this map.



Erratics! - Joel Gombiner



Nearest upstream granite is 50mi away

Small, seasonal stream. Incapable of transporting boulders of this size.



