

Step 1: Recognize the Problem

Explaining Riverbank Instability



River Behaviour and Response

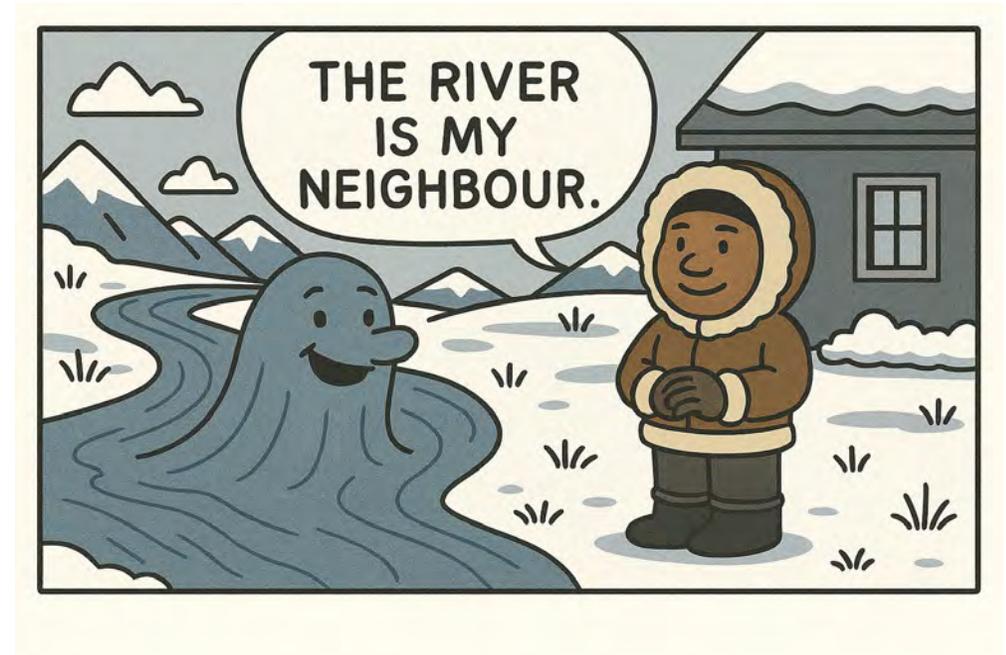
Part 1: Understanding Rivers and Forces Affecting Riverbank Instability



Can we address riverbank instability once and for all?



- Well, it depends...
 - What is causing the instability?
 - How much money do you have?
 - What kind of impact to the local environment are you willing to accept?
 - Who is going to maintain any protection measures in the future?
 - How do you expect the river to respond to your solution?



What controls how rivers behave?



1. Water ← including ice!
 2. Channel steepness
 3. Bed and bank materials ← including permafrost!
 4. Confinement
 5. Riparian vegetation
- “Worst-case” erosion scenario?
 - Lots of water flowing down a steep channel with sandy banks, no riparian vegetation, and no accessible floodplain

Don't forget about human activities and climate change!...they can affect all these controls

1. Water



- What do you think of when you think of water in rivers?...
 - **Low** or **high** – how much water is there, and when will it rise?
 - **Fast** or **slow** – how quickly is the water flowing?
 - **Warm** or **cold** – how close is the water to freezing?
 - **Surface water** or **groundwater** – what's the source of the water?



1. Water



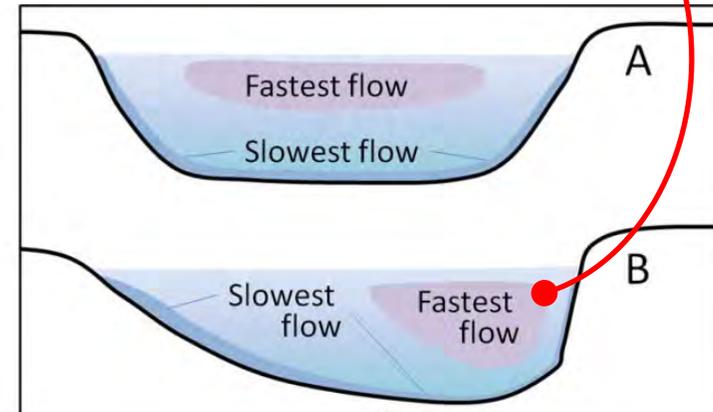
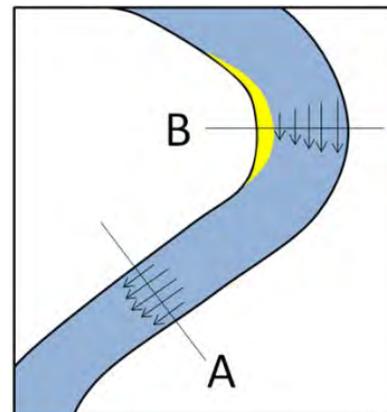
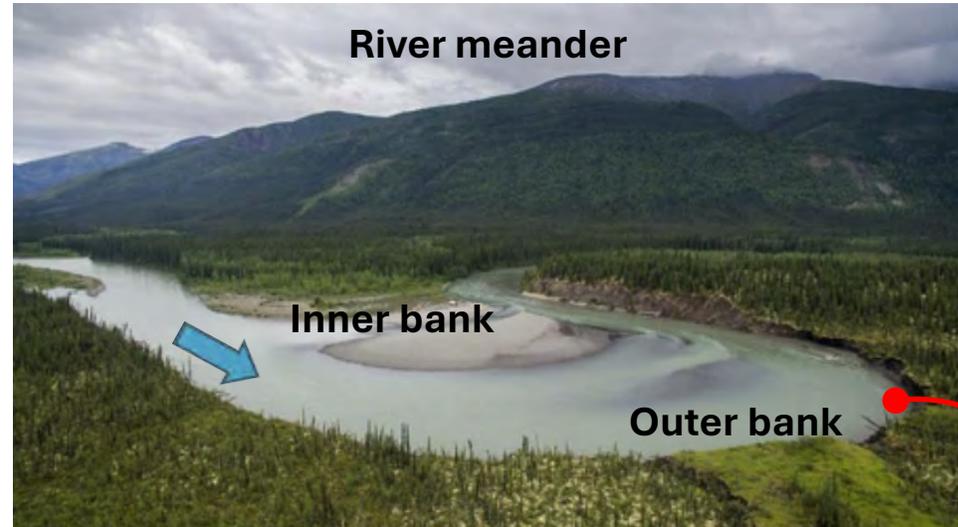
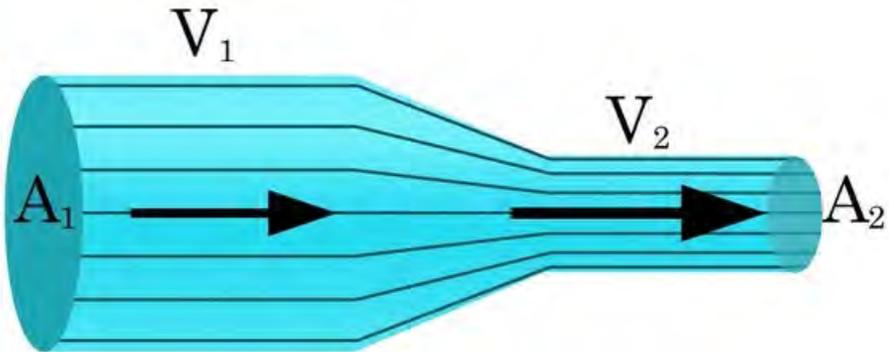
- How can water make riverbanks unstable?
 - **Surface runoff** (overland flow) – sheet erosion and gullyng
 - **Groundwater seepage** – pore water pressure and piping/sapping
 - **Rapid drawdown** – rapid drop in water level weakens soils in banks
 - **Scour (toe erosion)** – carrying soil grains away



1. Water



Continuity equation
 $A_1V_1 = A_2V_2$



A = Area (space river flows through)
V = Velocity (speed of water flow)

Ice

1. Water



Shore ice

Credit: Zhiming Yuan & Ran Chen



Ice 1. Water



- Effects of river ice

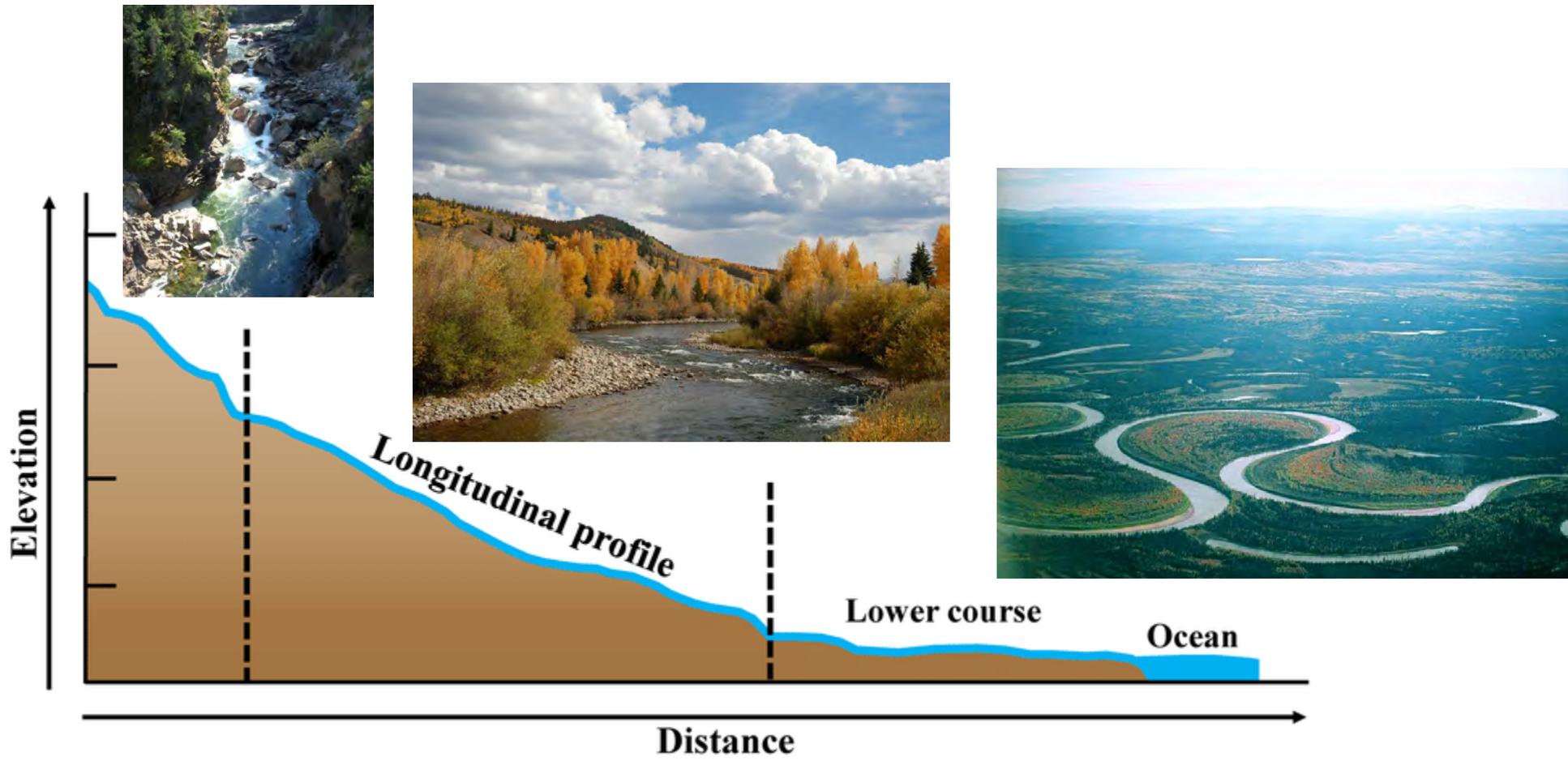
- Scour and plucking of soil from bank (rafted downstream)
- Flooding – slows flow (frazil ice!)
- Ice jams
 - **Thermal break-up** – gradual warming and melt; few to no jams
 - **Mechanical break-up** – rapid increase in flow (snowmelt/rainfall); jams and flooding common (upstream? downstream?)



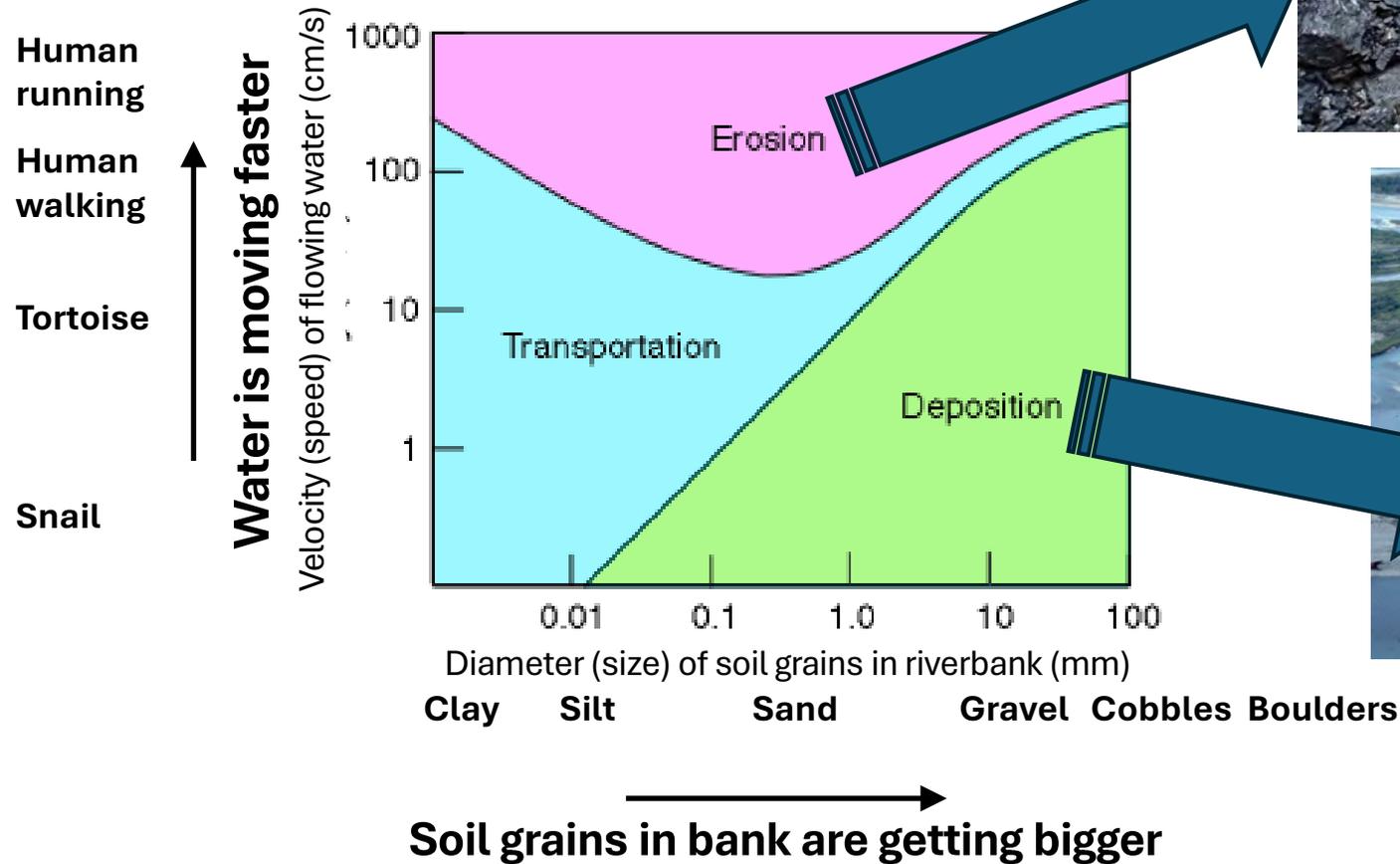
2. Channel steepness



- Steeper channel → faster flow



3. Bed and bank materials

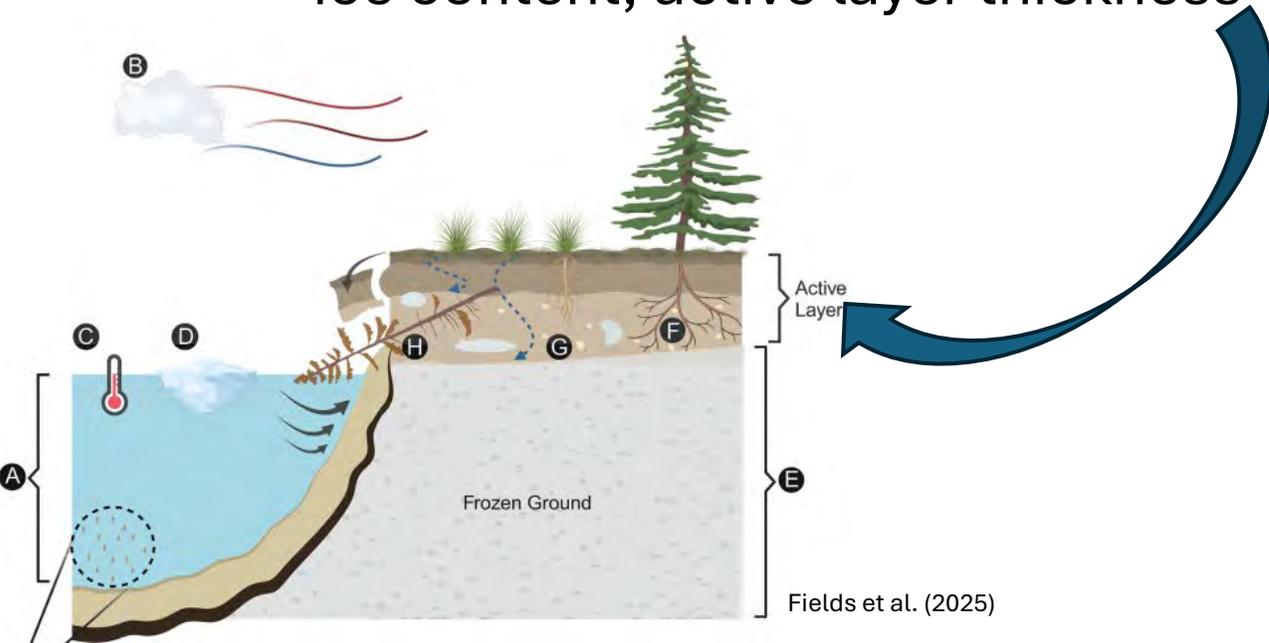
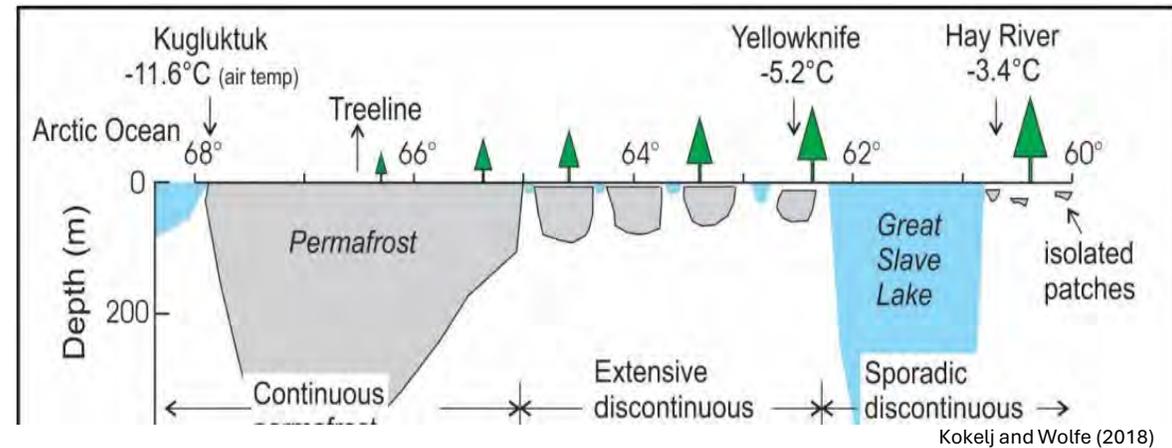


Credit: Geological Digressions

Effects of permafrost

3. ~~Bed and bank materials~~

- Permafrost – Peat, soil or rock that remains frozen (at or below 0°C) for more than 2 years
- Key characteristics
 - Distribution, depth, temperature, ice content, active layer thickness



Effects of permafrost

3. Bed and bank materials



- **Degradation** (thaw) vs. **aggradation** (growth)
 - Amount of frozen ground in riverbank changes over time
- **Warmer** permafrost ($> -2^{\circ}\text{C}$) = weaker;
colder permafrost = stronger
 - Permafrost makes riverbanks stronger...until it warms and thaws!
- **Ice-rich** permafrost is “**thaw-sensitive**”
 - Stability of frozen riverbank changes over time
 - Thermokarst
 - Thermal niching
 - Retrogressive thaw slumps (thaw-flow slides)
 - <https://www.nwtgeoscience.ca/services/permafrost-thaw-slumps/video-permafrost-thaw-causes-lake-drainage-peel-plateau-nwt>



Effects of permafrost

3. Bed and bank materials



**Retrogressive thaw slump entering the
Takhini River, near Whitehorse, YT**



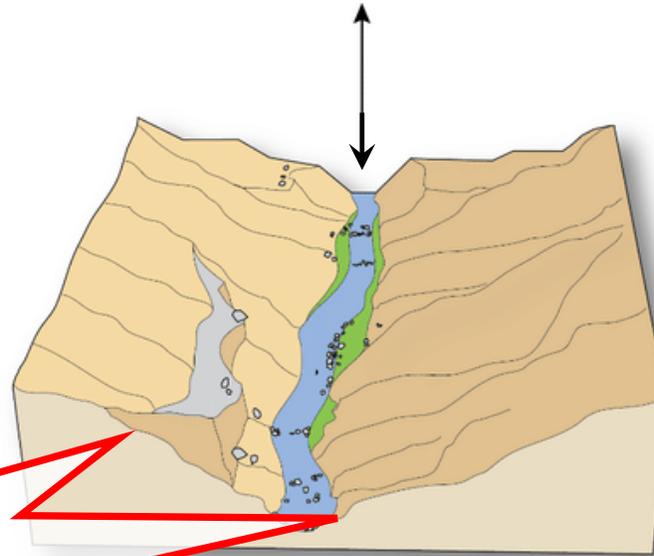
Credit: Yukon University

4. Confinement

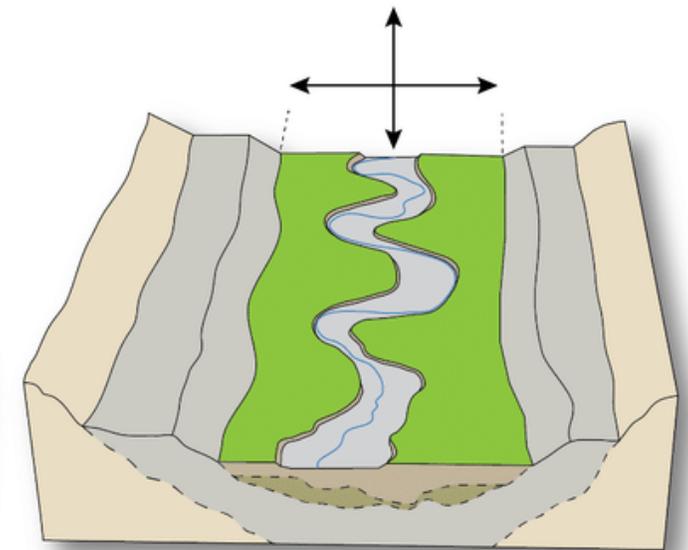


• **Confinement** – How much a river’s ability to move back-and-forth is restricted by surrounding slopes

- Valley walls
- Terraces
- Unnatural features
 - Road embankments
 - Erosion control measures



Confined valley setting



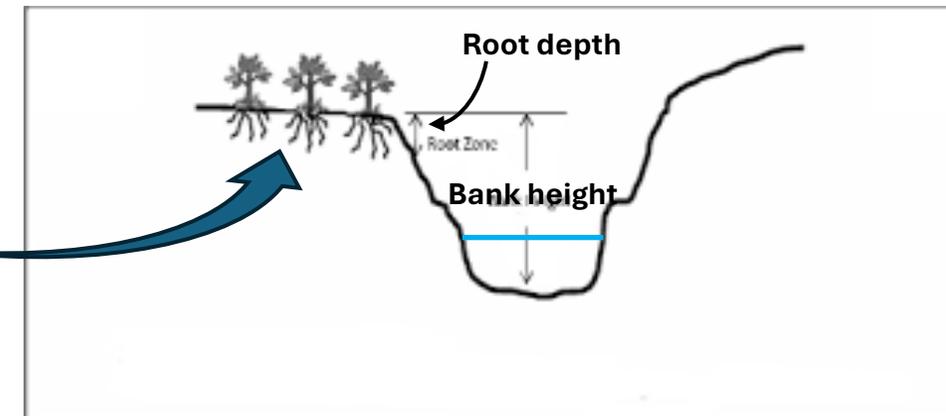
Laterally unconfined valley setting

Take note! We will return to these terms when discussing “taking action.”

5. Riparian vegetation



- Riparian (river-edge) vegetation helps maintain riverbank stability
 - Roots of grasses, shrubs and trees help **hold soil together** and resist erosion
 - Plants **suck up water** so bank soils are drier and stronger
 - Bank vegetation **flexes and slows flow** during floods
- Beware!...How much vegetation helps depends on the type, density and depth of **roots**



Climate change

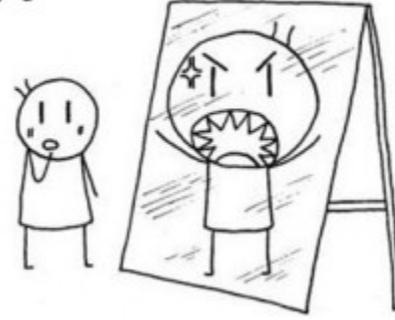


- Human activities (mostly in the South) have begun to accelerate climate change beyond natural trends
- In NWT, climate is changing nearly 4 times more quickly than the global rate!
 - Warmer
 - Wetter
 - More extreme climate events
- Main effects
 - **Permafrost thaw** → uneven ground settlement + more/larger landslides
 - **Increased lightning strikes and wildfires** → accelerated permafrost thaw
 - **Longer ice-free periods** → more erosion by waves and currents
 - **Higher runoff and river flows** → more erosion



Human activities!

We are our own worst enemy



- **Snow piles**

- Saturate soils with meltwater
- Thicken active layer

- **Stormwater mismanagement**

- Ditching over ice-rich permafrost
- Unnatural concentration toward riverbank

- **Land clearing**

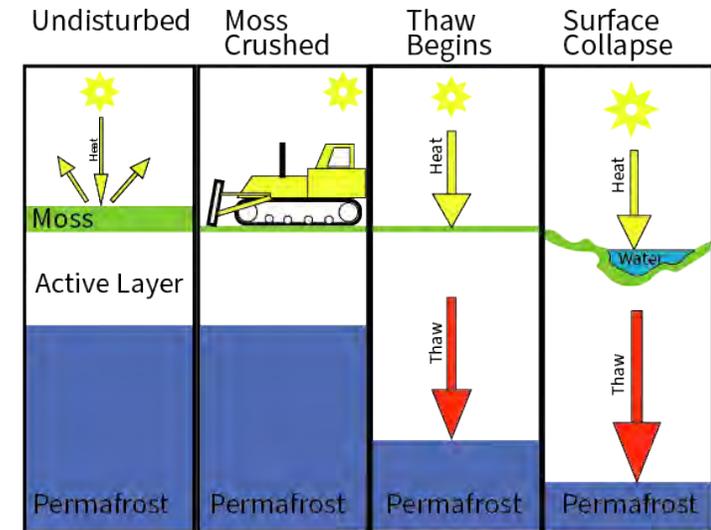
- Stripping/compaction of organics

- **Loading slopes**

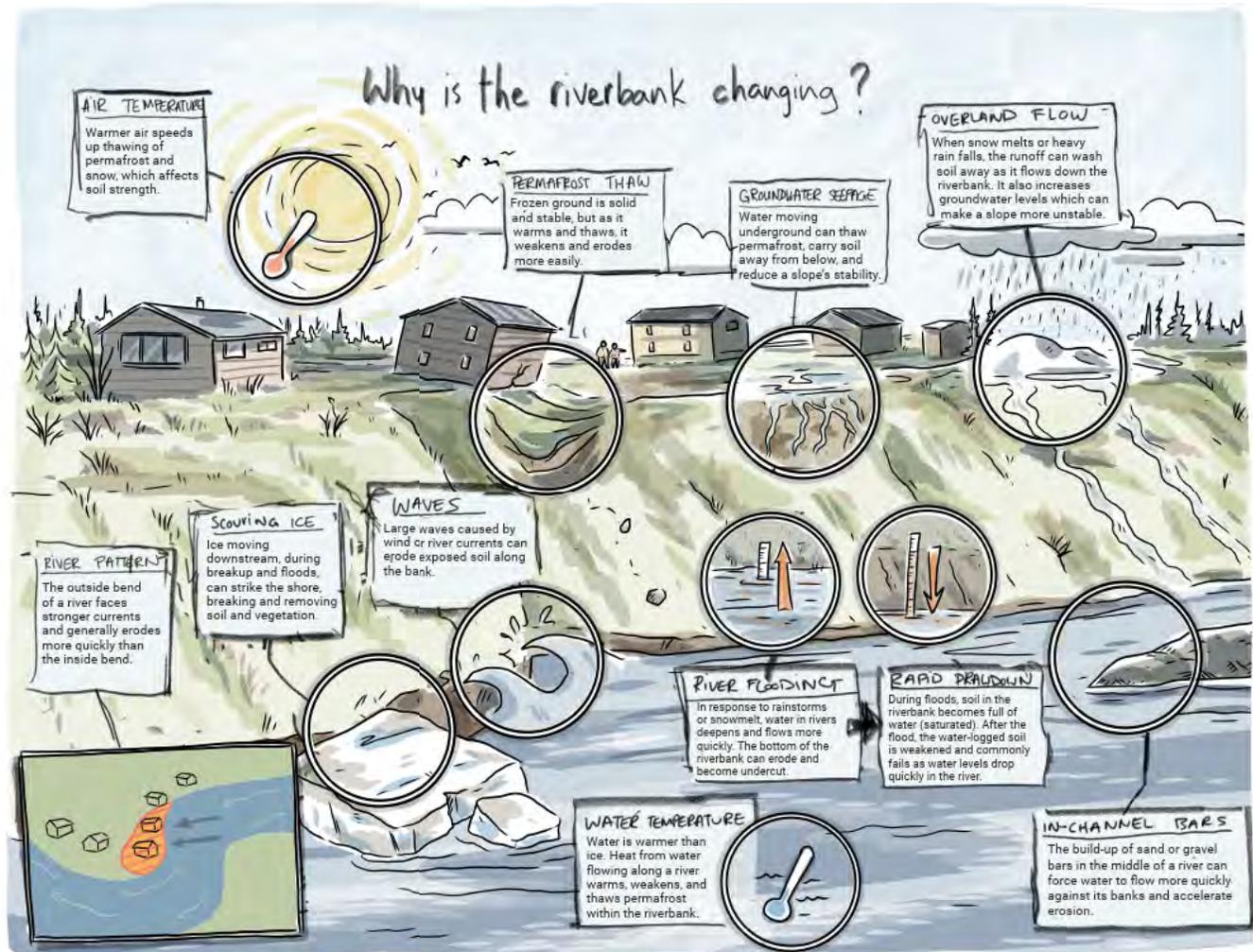
- Fill placement or other heavy structures near slope crest

- **Erosion control measures with inadequate length**

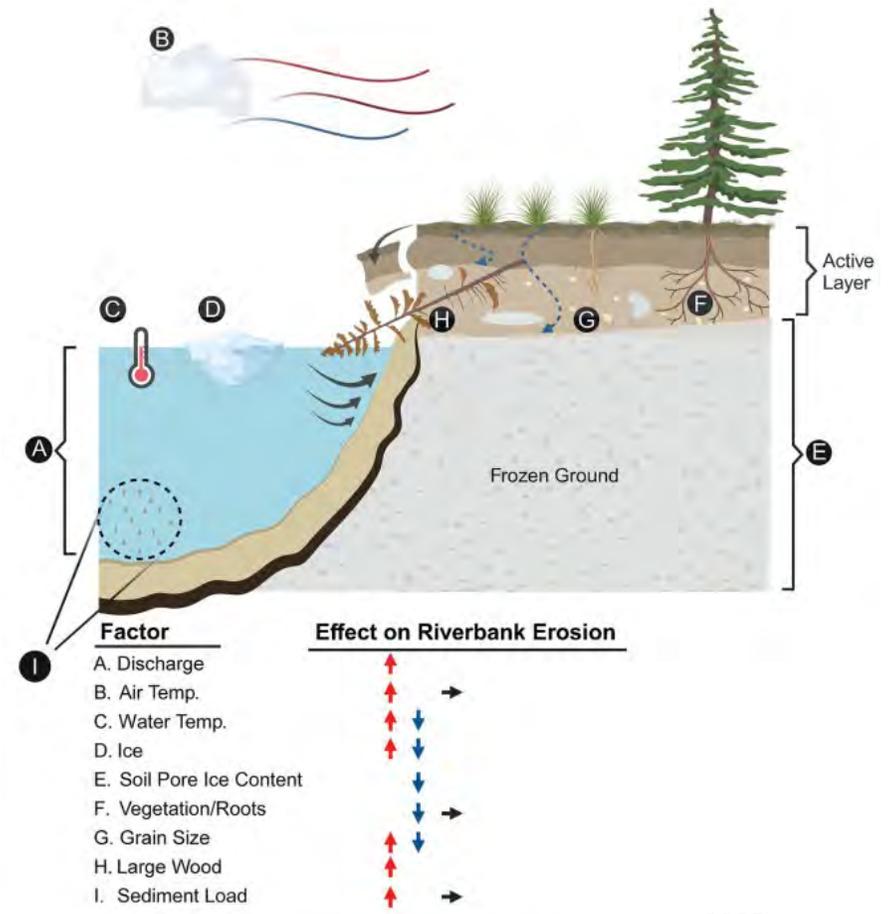
- Don't forget about your downstream neighbour!



Summary of causes of riverbank instability



Alison McCreesh (2025)



Fields et al. (2025)

Common community settings: What must we consider?



*Which setting is your
community in?*

- **Deltas**
 - Competing processes!
- **Outer banks of meanders**
 - Natural location for erosion – it's how rivers migrate!
- **Confluences**
 - Prone to ice jams, and erosion may attack from both sides!
- **High slopes**
 - More potential for gulying and large slope failures, so keep a safe distance!
- **Ponded water**
 - Heat from water warms surrounding permafrost, so avoid waterfront property!
- **Downstream end of river confinement**
 - Bedrock canyons, confined valleys and erosion control commonly transfer energy downstream!

Reading the River

Part 2: Identifying Signs and Symptoms of Instability



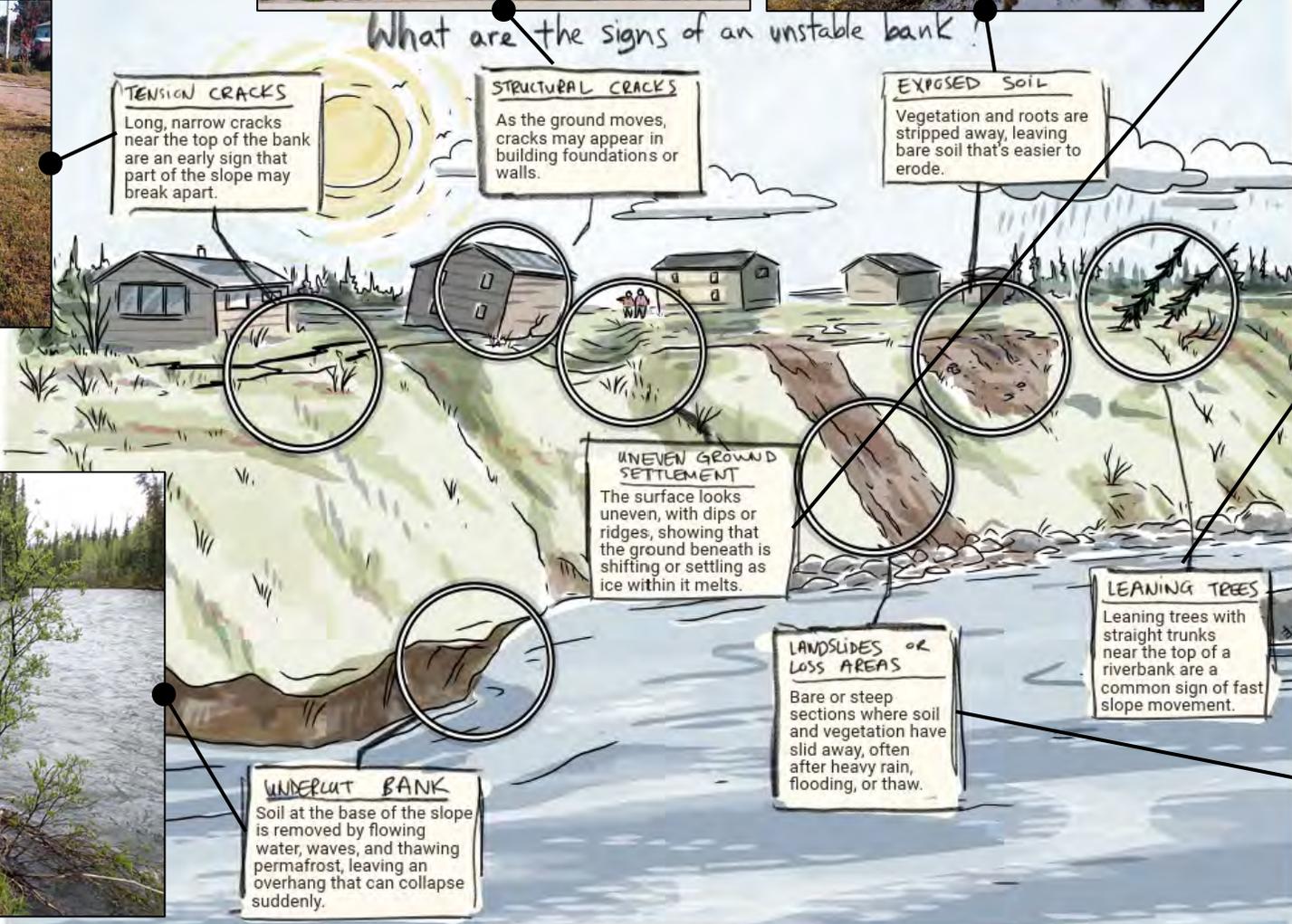
You are the detective!



- Searching for clues about riverbank instability...



Signs of Riverbank Instability



Other things to look for

- Gullies
- Irregularities in bank steepness
 - Hollows and bulges
- Exposed tree roots
- Undermined/collapsing structures

