Ques 1 "The crossing of geomorphic thresholds due to anthropogenic forcing has altered the equilibrium profile of the Himalayan river basins, compounding slope vulnerabilities." Critically analyze.

This quote captures the core of contemporary Himalayan geomorphology. It posits that human interventions have pushed the fragile Himalayan fluvial systems past their tipping points (geomorphic thresholds), disrupting their balanced state (equilibrium profile), which in turn has triggered severe hillslope instability.

To critically analyze this, we must evaluate how anthropogenic actions alter river dynamics, how this translates into slope failures, and whether humans are the primary culprit or merely accelerating an inherently volatile natural system.

Deconstructing the Core Concepts

Geomorphic Thresholds

Formulated by the renowned geomorphologist **Stanley Schumm** in 1973, the **Geomorphic Threshold Model** revolutionized how we understand landform evolution.

Before Schumm, classical geomorphology (like William Morris Davis's theories) viewed landscape change as a slow, continuous, and linear process. Schumm argued instead that landforms change **abruptly and non-linearly** when they hit a tipping point—a **geomorphic threshold**.

A geomorphic threshold is a **capacity level within a geomorphic system past which significant change or equilibrium upheaval occurs**, even without any change in external driving forces (like climate or tectonics). When this threshold is crossed, the landform abruptly transitions from a state of stability to instability.

The Two Types of Thresholds

Schumm divided these tipping points into two distinct categories based on what triggers the change:

Extrinsic Thresholds

These are crossed due to an **external push or shock** to the system. The landform itself is stable until an external variable changes drastically.

Example: A sudden, catastrophic cloudburst delivers intense rainfall, dramatically increasing river discharge and causing immediate, widespread channel erosion.

Intrinsic Thresholds

This is Schumm's most groundbreaking concept. Here, the threshold is crossed due to **internal, progressive changes within the system itself**, under completely constant and normal external conditions. The landform essentially "prepares its own failure" over time.

Example: A river gradually deposits sediment in its channel over decades. The slope of the riverbed steepens bit by bit. Eventually, the slope reaches a critical angle where the next ordinary, routine rain shower triggers a massive, sudden shift in the river's course (**avulsion**). The trigger wasn't an extraordinary storm; the system was simply intrinsically ready to fail.

Key Concepts Associated with the Model

Complex Response: When a threshold is crossed in one part of a river basin (e.g., sudden incision), it triggers a chain reaction of adjustments (aggradation, degradation, headward erosion) throughout the entire basin. One single cause leads to multiple, complex effects.

Episodic Erosion: Landforms do not erode at a steady pace. They experience long periods of relative stability (storing energy/sediment) punctuated by short, violent episodes of landform modification when thresholds are breached.

In the Himalayas, these thresholds are incredibly delicate due to high relief, weak lithology, and intense seasonal precipitation.

The Equilibrium (Graded) Profile

A river basin achieves an equilibrium profile when its slope, volume, and velocity are perfectly balanced to transport the sediment load supplied to it without net aggradation (deposition) or degradation (erosion).

Anthropogenic Forcing and the Alteration of River Profiles

Human activities act as "extrinsic thresholds" that abruptly alter the variables governing the graded profile.

Fluvial Fragmentation via Hydropower Projects

The Himalayas host hundreds of run-of-the-river and reservoir projects (e.g., Tehri on Bhagirathi, projects on the Alaknanda and Teesta).

- **Upstream Aggradation:** Reservoirs trap sediment, causing the river to deposit its load upstream, raising the local base level.
- **Downstream Degradation:** "Hungry water" (sediment-starved water) released from dams has high kinetic energy. It aggressively erodes the riverbed downstream, lowering the base level and steepening the channel gradient.

Unregulated Sand and Gravel Mining

Extensive riverbed mining in the foothills and lesser Himalayas (e.g., Gaula river in Uttarakhand) directly removes bed material. This causes **channel incision** (deepening), disrupting the longitudinal profile and creating local knickpoints (abrupt drops in the river profile).

Encroachment and Channelization

Urbanization and tourism infrastructure built on active floodplains (as seen during the 2013 Kedarnath and 2023 Himachal floods) constrict the river channel. This increases hydraulic radius and velocity, forcing the river to adjust its profile through vertical incision rather than lateral migration.

The Cascade Effect: Compounding Slope Vulnerabilities

The alteration of the river's equilibrium profile does not happen in a vacuum; it is coupled dynamically with the surrounding hillslopes through **fluvial-slope coupling**.

Channel Incision & Base-Level Lowering
↓
Toe Erosion / Undercutting of Slopes
↓
Loss of Lateral Support
↓
Slope Failure / Massive Landslides

- **Toe Undercutting:** As rivers incise deeply to adjust to new base levels, they aggressively erode the base ("toe") of adjacent valley slopes. When the toe of a debris-covered slope is removed, the safety factor drops below 1, triggering catastrophic mass wasting.

- **Aggressive Road Engineering (e.g., Char Dham Highway):** Vertical slope cutting for highways, combined with the removal of excavated debris into river channels, creates a dual crisis. It steepens the hillslope past its shear strength threshold while simultaneously choking the river profile with sudden sediment pulses.

- **Saturated Slope Dynamics:** Reservoir fluctuation raises the local water table in surrounding slopes. The sudden drawdown of water leaves hillslopes saturated, increasing pore-water pressure and inducing slope failures (e.g., the land subsidence challenges observed in Joshimath).

Critical Evaluation: Anthropogenic vs. Endogenic Forcing

While anthropogenic forcing is undeniably a catalyst, a balanced geomorphic analysis requires acknowledging that the Himalayas are inherently prone to crossing thresholds due to natural, endogenic (internal) factors.

Dimension	Anthropogenic Forcing (The Accelerator)	Natural/Endogenic Forcing (The Foundation)
Tectonics	Road cutting and blasting destabilize the surficial rock mass.	Active convergence of Indian and Eurasian plates creates high seismicity, active faults (MCT, MBT), and highly fractured lithology.
Climate	Localized microclimate changes due to deforestation and concrete heat islands.	Extreme South Asian Monsoon pulses and Cloudburst events deliver high discharge over short windows, naturally exceeding thresholds.
Glacial Dynamics	Anthropogenic warming accelerates glacial melt, increasing the volume of proglacial lakes.	Natural **GLOFs** (Glacial Lake Outburst Floods) carry immense paraglacial sediment loads that instantly alter downstream profiles regardless of human presence.

Therefore, human activities do not create these vulnerabilities out of thin air; rather, they **superimpose highly dynamic stress onto an already metastable environment.** The anthropogenic alteration of the equilibrium profile reduces the "buffer capacity" of the river basins, making them hyper-sensitive to even minor triggers.

Conclusion

The crossing of geomorphic thresholds in the Himalayas is a stark manifestation of the **Anthropocene** running parallel with active mountain building. By mechanically altering the longitudinal profiles of Himalayan rivers, human engineering has decoupled the natural sediment-water balance. The resulting toe erosion, channel incision, and slope destabilization have converted manageable geomorphic adjustments into acute natural disasters.

Geomorphic-guided Engineering- Infrastructure development in the Himalayas must shift from hard structural interventions to a basin-wide, ecosystem-based approach that respects the *graded profile* of these young rivers, incorporating strict Environmental Impact Assessments (EIAs) and slope-stability zoning before thresholds are permanently crossed.