Presentation 6: RoR HEP basics (II)

Dr Yasir Abbas
Mr Umar Farooq

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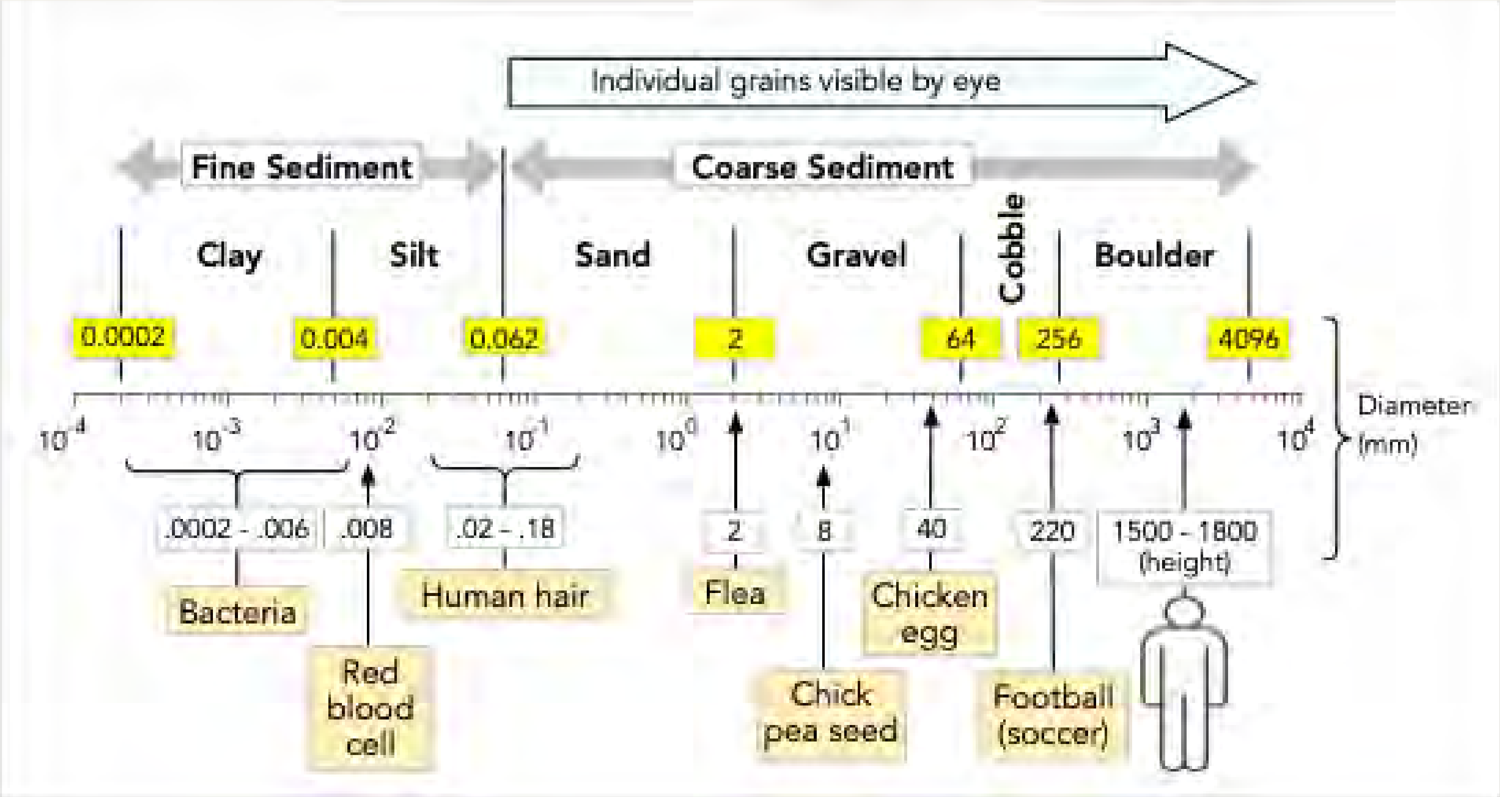
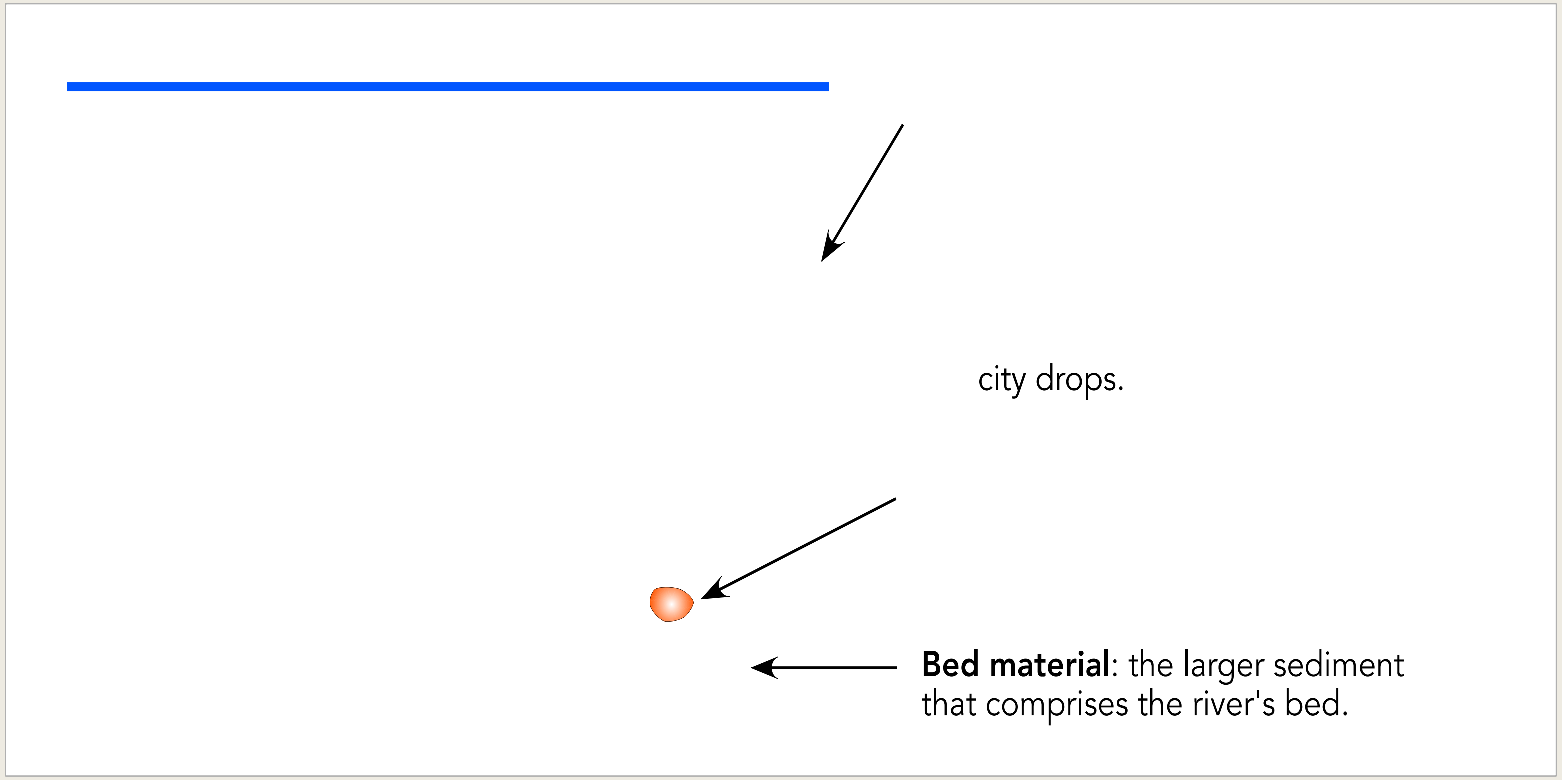
Overview of sediment issues



Sediment size

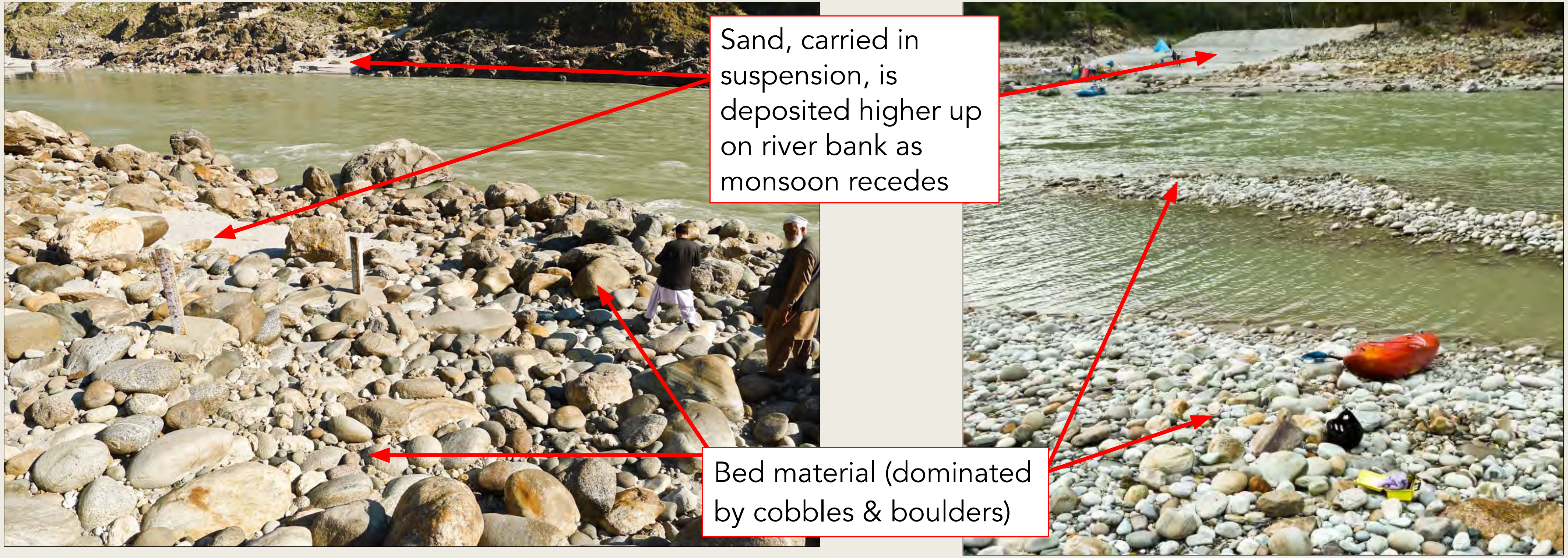
- Sediment size is measured in accordance with the **Wentworth scale**.
- The largest sediments in the Himalaya (boulders) are 10 million times larger than the smallest sediments (clays).



Sediment transport

- Two basic modes of sediment transport in rivers: **suspended load** and **bed load**.
- The great majority of fluvial sediment is sand or finer material transported in **suspension** (suspended load).

Himalayan riverbeds



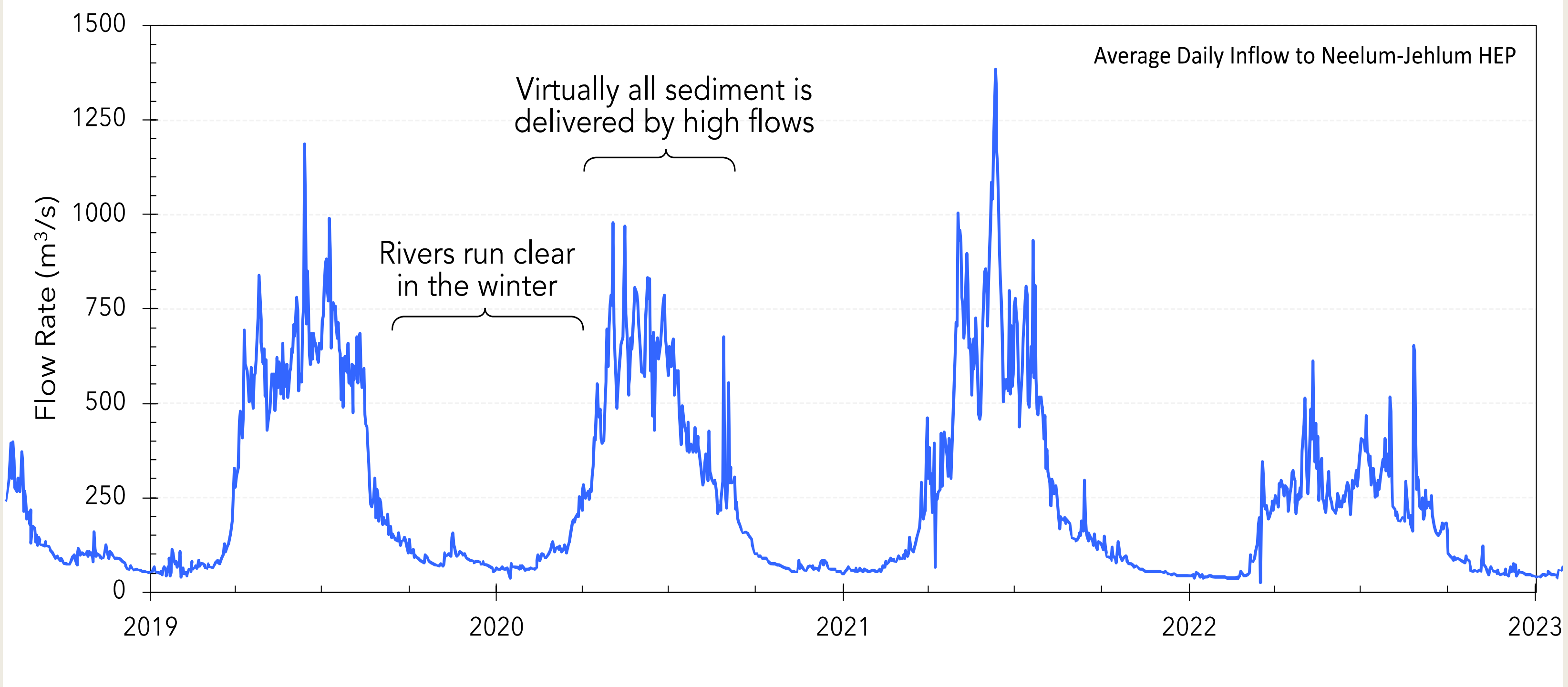
Indus River above Tarbela reservoir at low flow (November)

Kali Gandaki River, Nepal, at low flow (January)

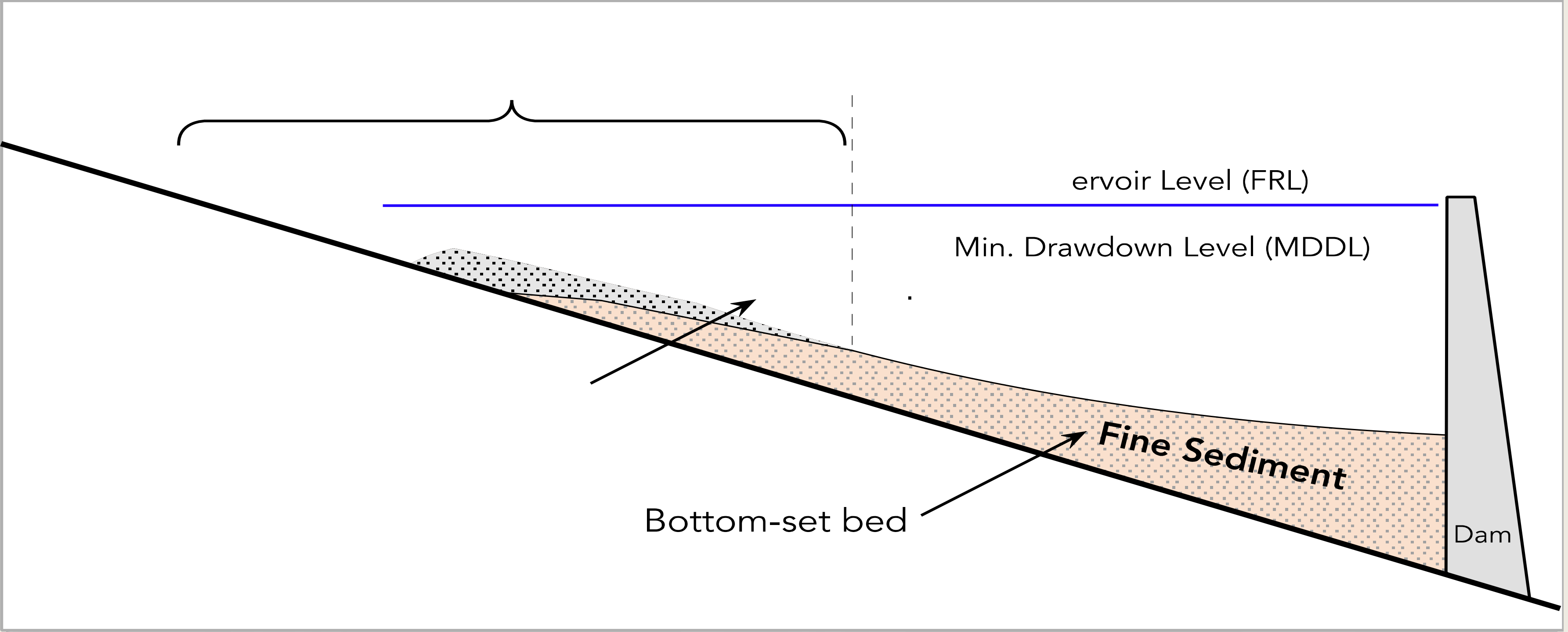
Himalayan sand

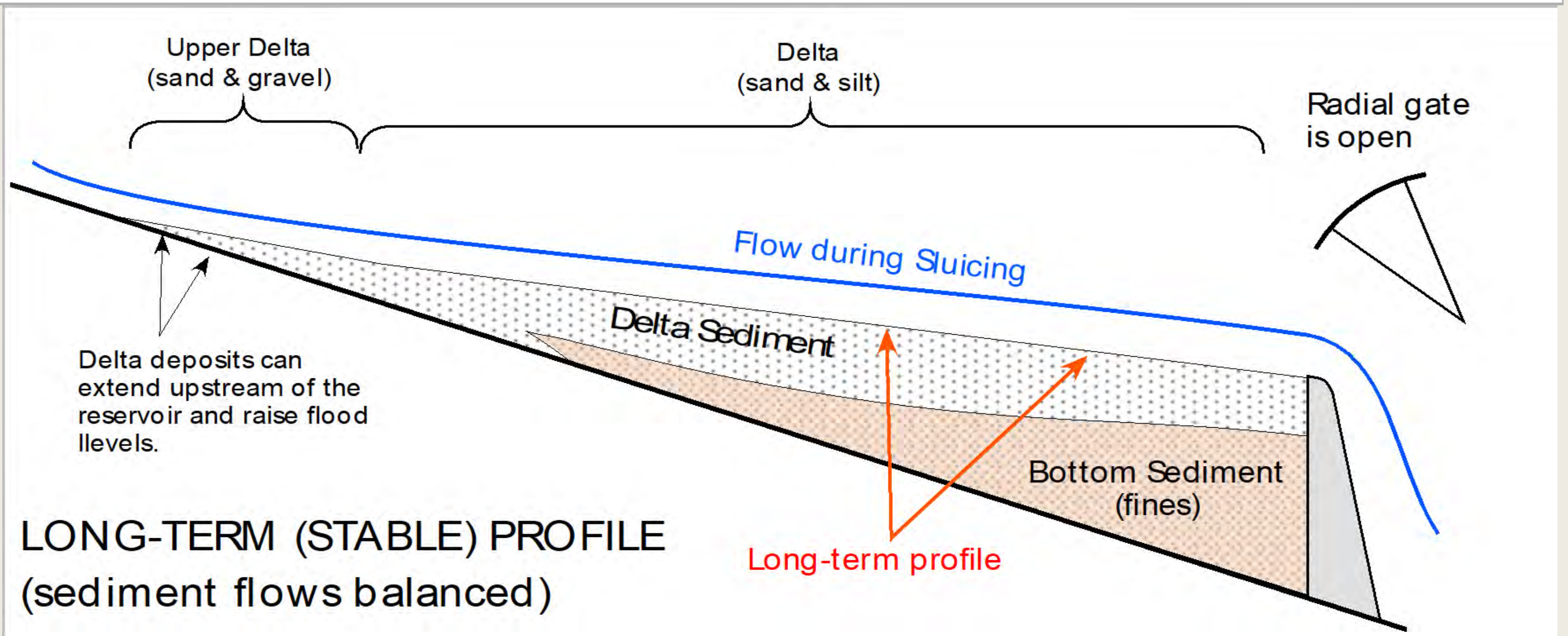
- Predominately **quartz**, which is harder than steel. Typically transported as **suspended load**.
- Freshly eroded from parent rock, making it angular and **highly abrasive** to HEP turbines.

Seasonal variability



- Himalayan flows are highly seasonal.
- Nearly all sediment is eroded and transported downstream during the summer wet season.





Reservoir sedimentation

- **Sediments** deposit in different zones according to grain size.
- **Delta deposits**: coarser sediments settle rapidly to form a delta that advances downstream.
- **Bottom-set deposits:** fine sediments settle more slowly and are primarily deposited downstream of the delta.
- **Long-term sediment balance** is achieved when multi-year sediment inflow and outflow are matched.

Reservoir deltas

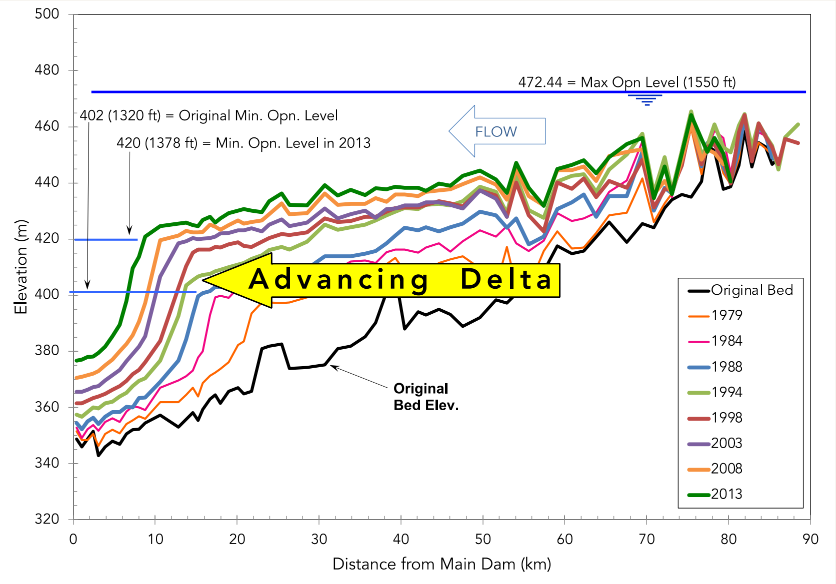
Sandy delta deposits advancing downstream in Porce II HEP reservoir, Colombia.

Top of the sand-silt delta advancing toward Tarbela HEP dam, Pakistan.

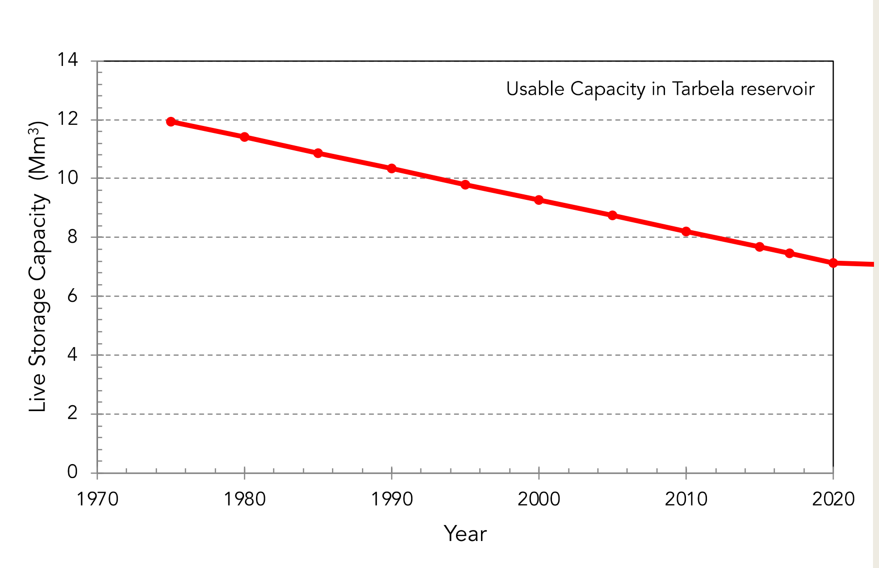
Sediment management: live storage

Capacity loss from sedimentation

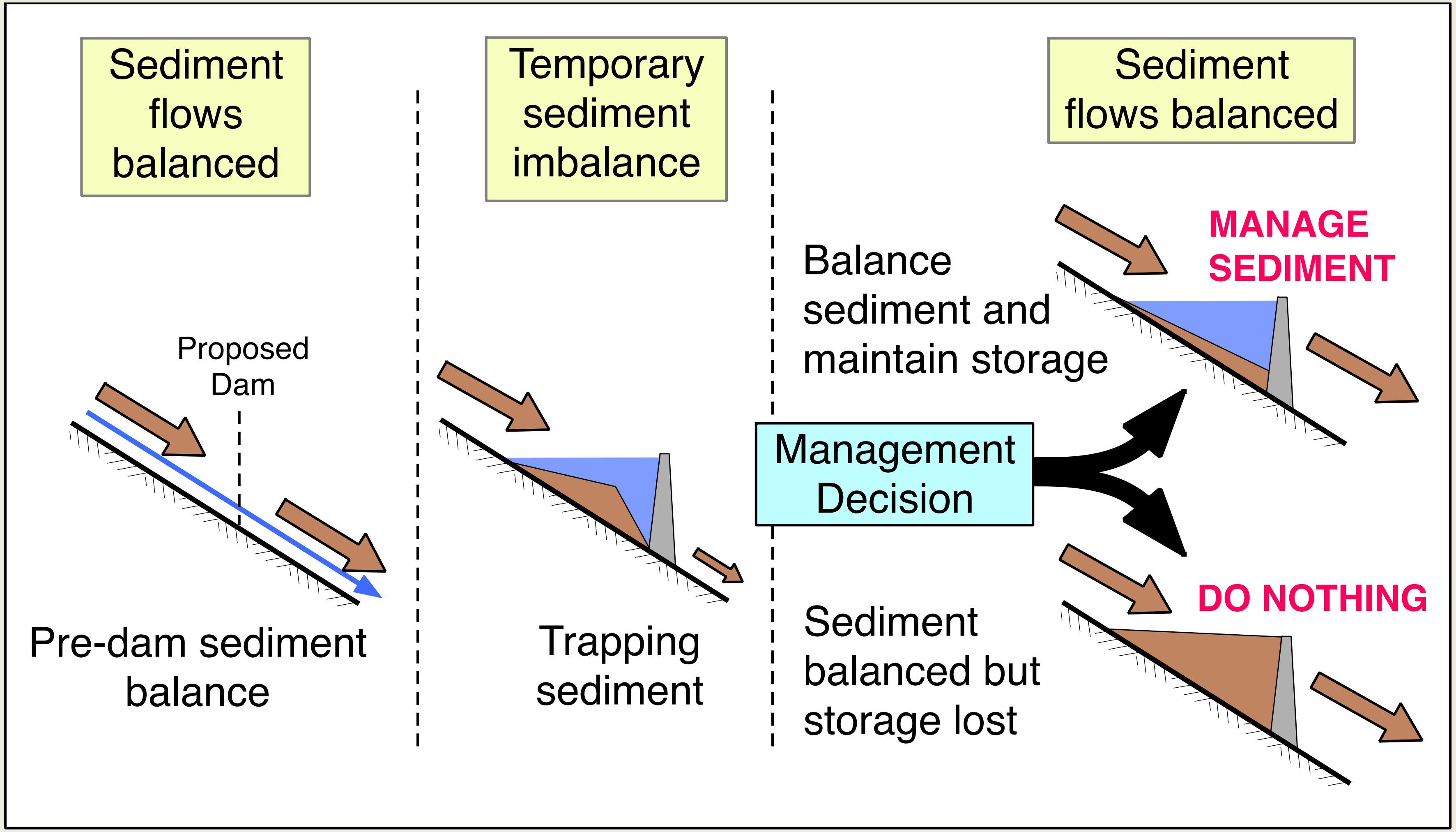
DELTA PROGRESSION

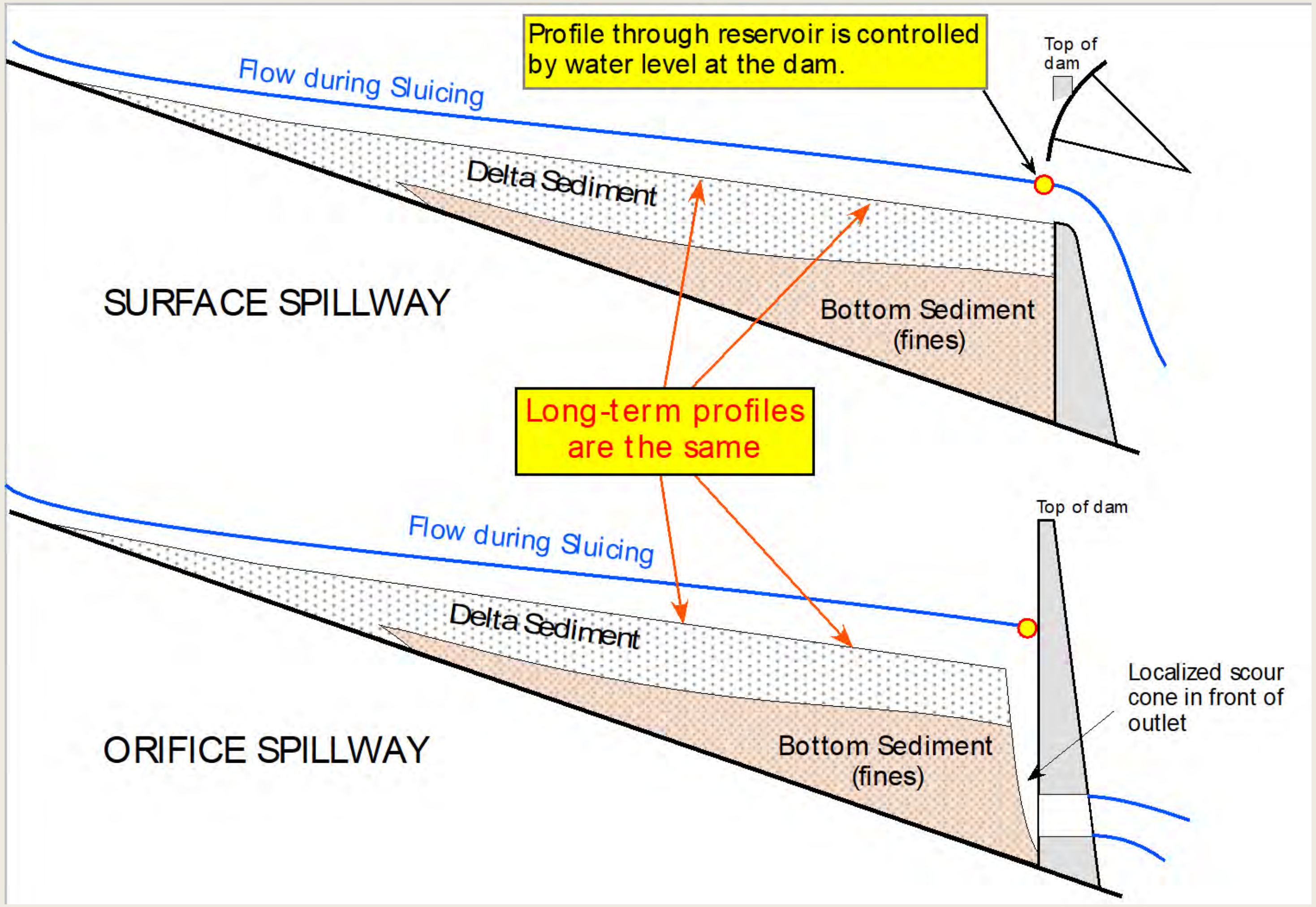


LOSS OF USEABLE STORAGE



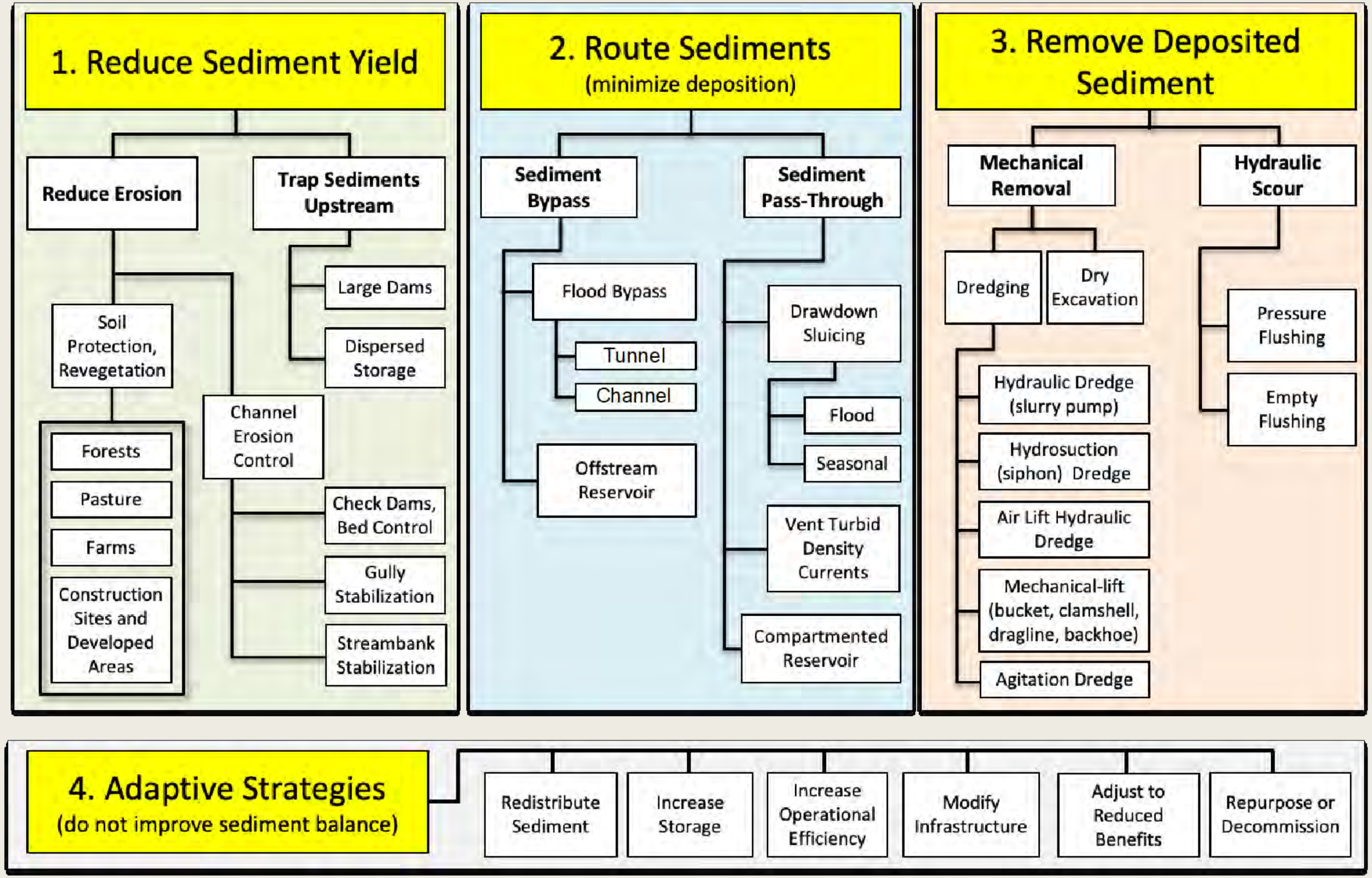
Sediment management objectives





Outlet placement

- Water level at the dam is a key factor controlling the sediment profile along the length of a reservoir.
- Changing outlet depth will not change the profile if the water level at the dam remains constant.
- A low level outlet will create a localized scour cone at the upstream side of the outlet.



Sediment management strategies

Selection of sediment management strategy

- Multiple factors are involved in the selection of the combination of sediment management strategies appropriate for a given site.
- There is no ‘one size fits all’ solution – everything is case-by-case.

Economic

- Value of storage
- Short term vs. long term
- Management cost vs. financial capacity
- No action vs. alternatives
- Downstream damage
- Mitigation measures

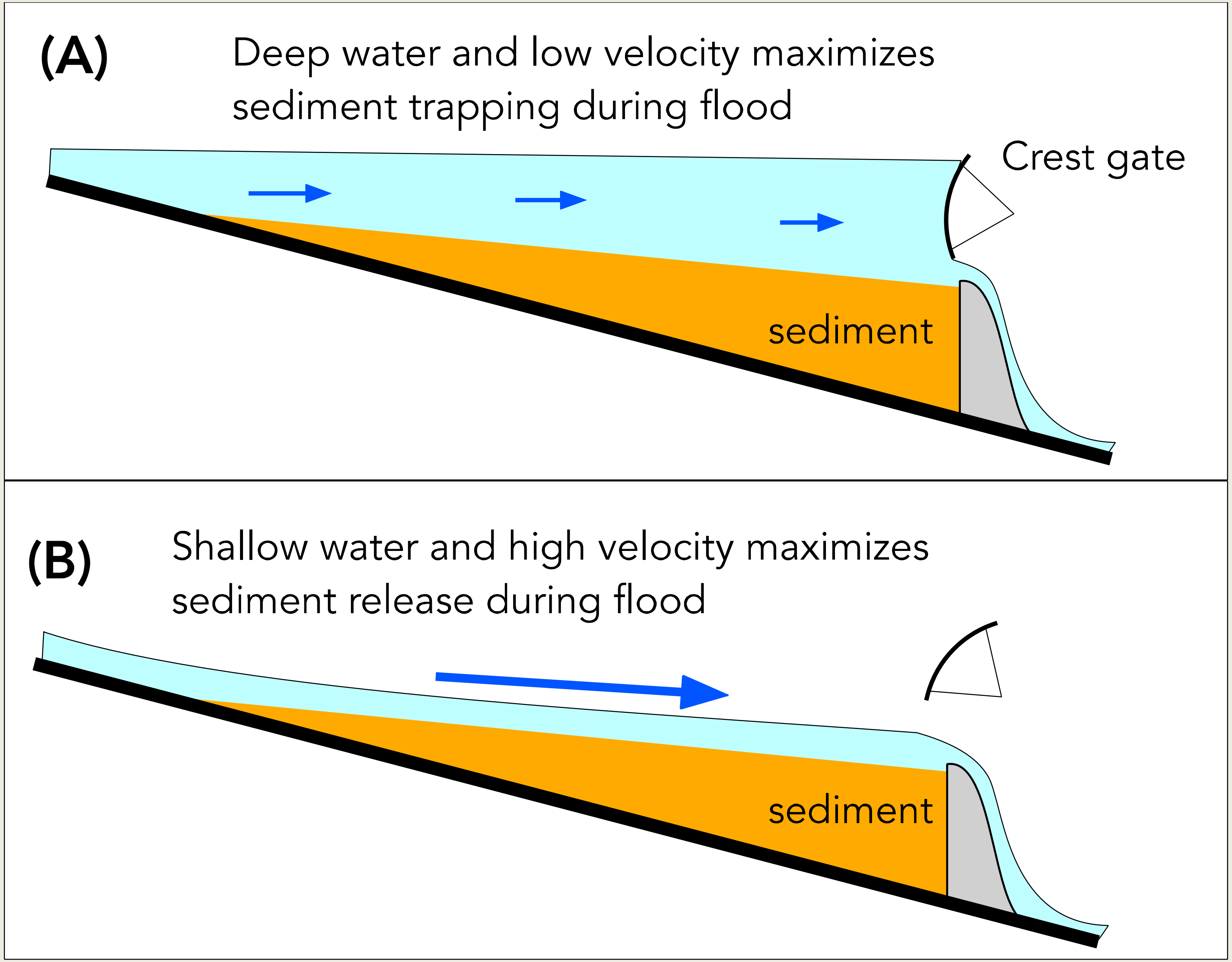
Physical

- Reservoir geometry
- Outlet configuration
- Hydrology
- Size of sediment in reservoir

Social & legal

- Environmental impact
- Regulations
- Sensitive downstream users
- Potential liabilities
- Inter-state agreements

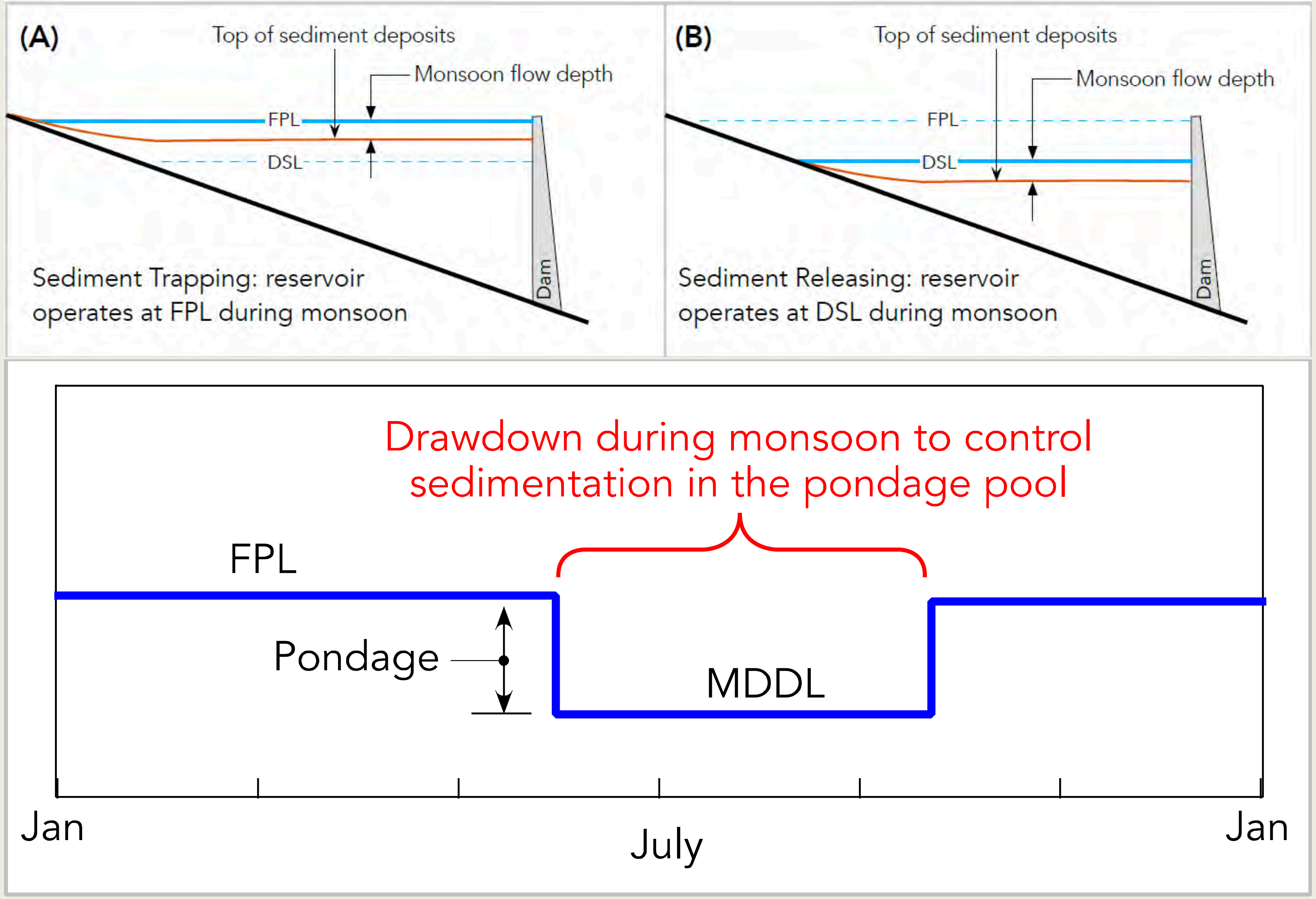
Erosion control: reduce sediment input



Flood sluicing

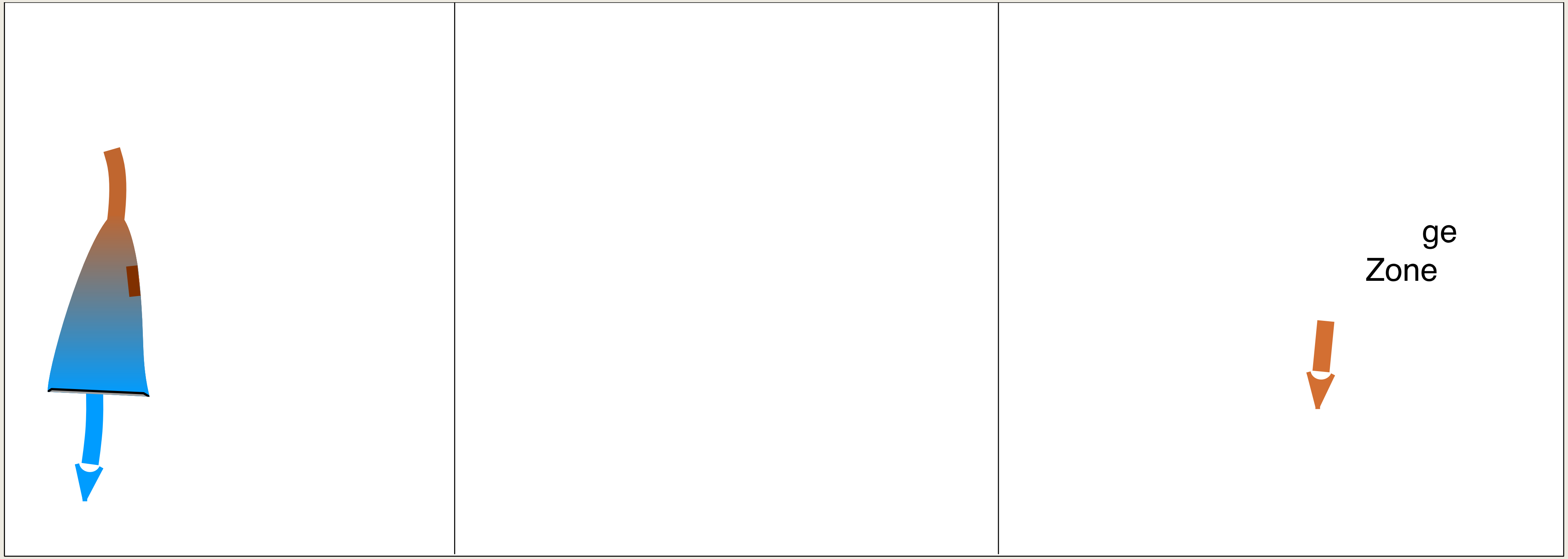
- Pass sediment-laden floods through the reservoir at the highest possible velocity to minimize sediment trapping.
- Sediments are routed through the reservoir and exit downstream through the high-capacity gates that are opened to pass the flood.

Seasonal sluicing

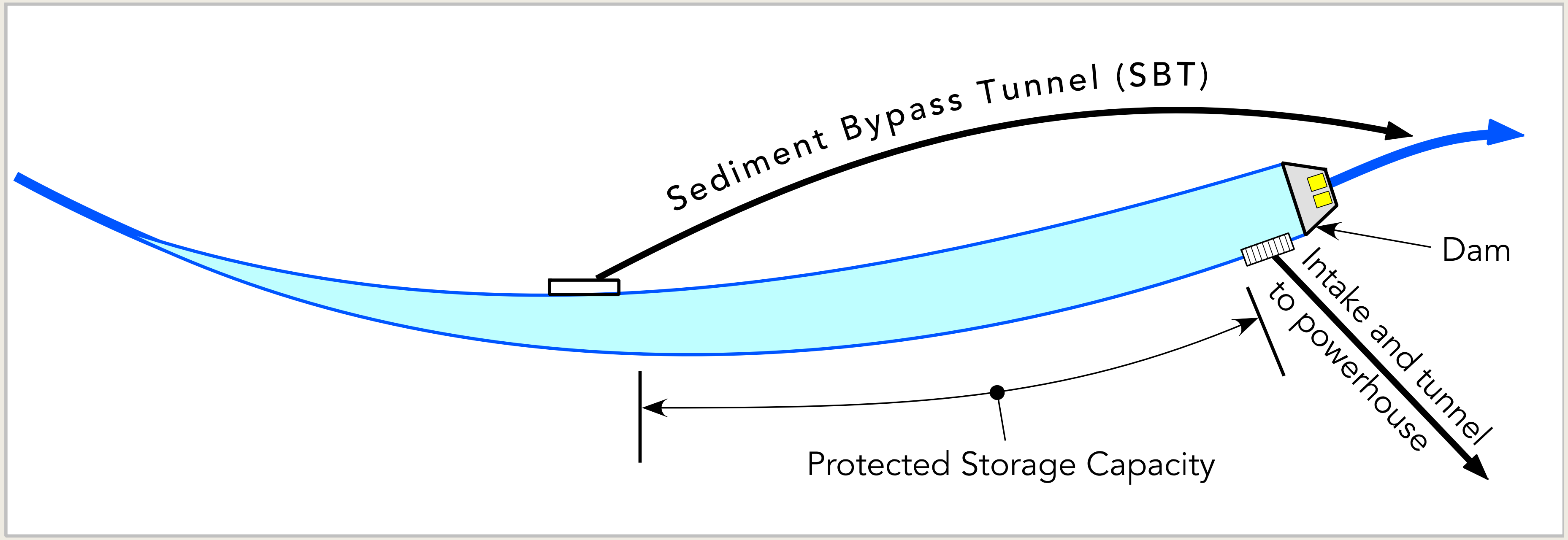


- Reservoir level is lowered to the **minimum drawdown level** (MDDL) during monsoon, keeping the pondage pool empty to avoid sedimentation.
- Absence of water in the operating pool prevents **sediment accumulation**.

Sediment bypass strategies

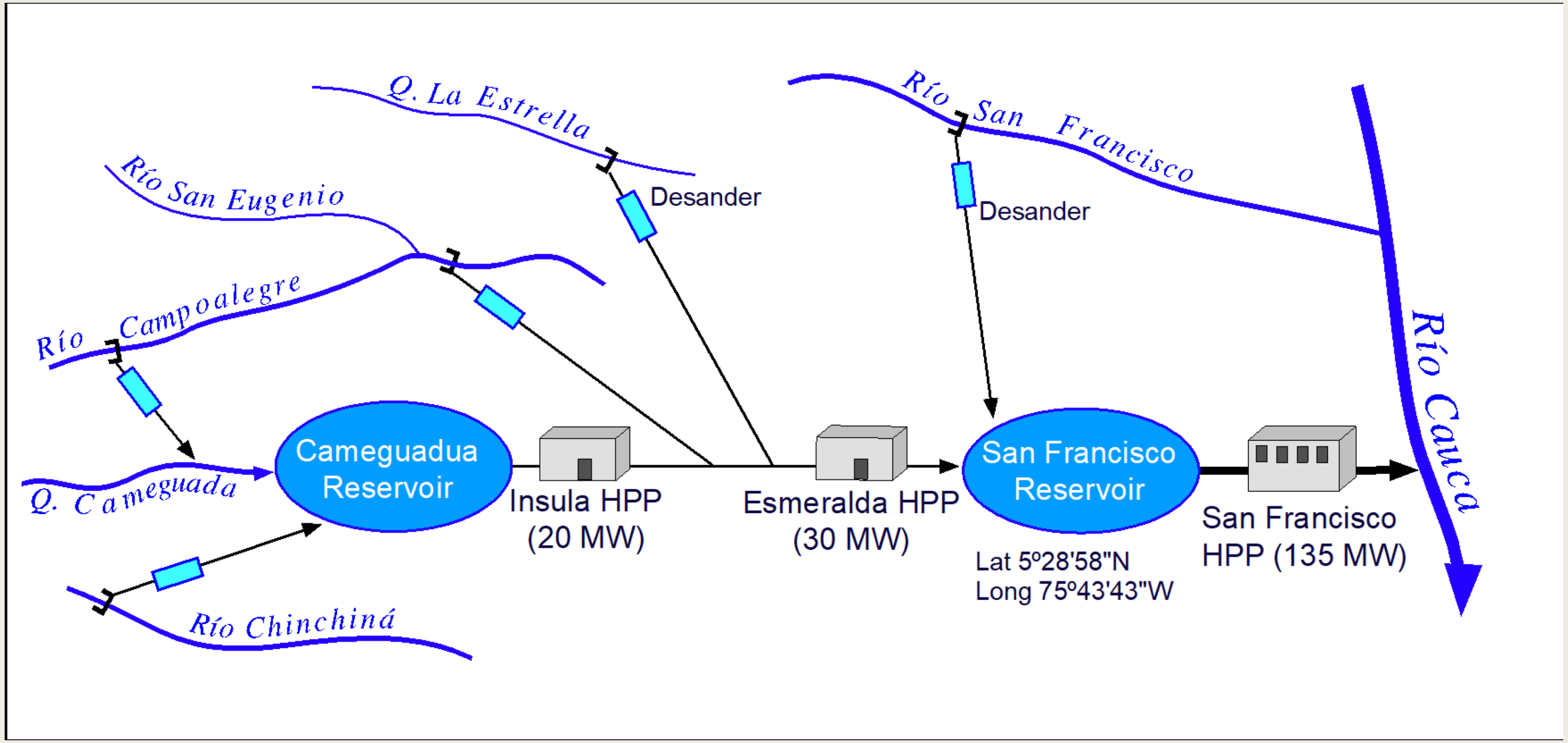


Bypass tunnel for sediment routing



Bypass tunnel configuration

Off-stream reservoir for sediment routing



- Reservoir is placed outside the main river and is fed by an intake.
- Water with low sediment concentration is passed into the reservoir.
- Sediment-laden floods run downstream along the river channel.

Off-stream reservoir configuration

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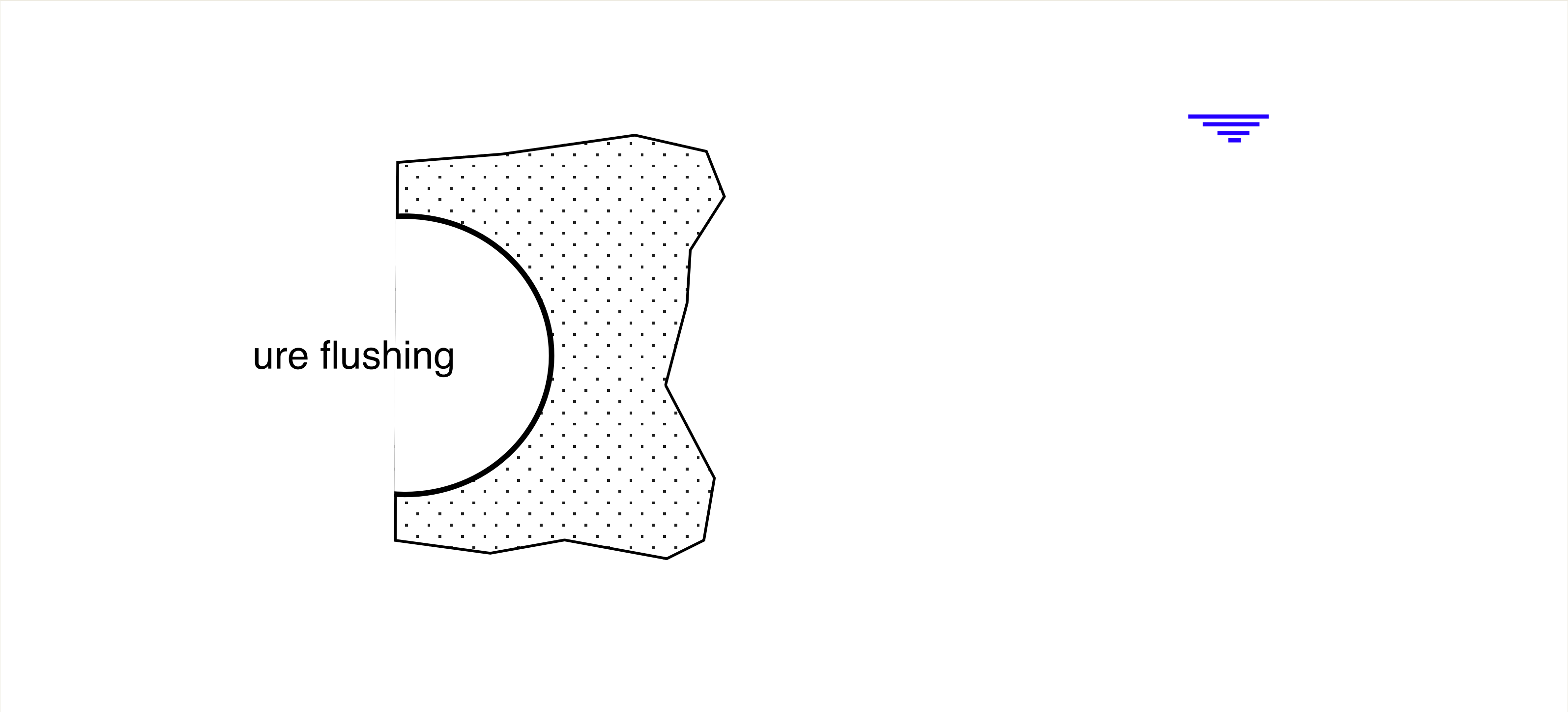
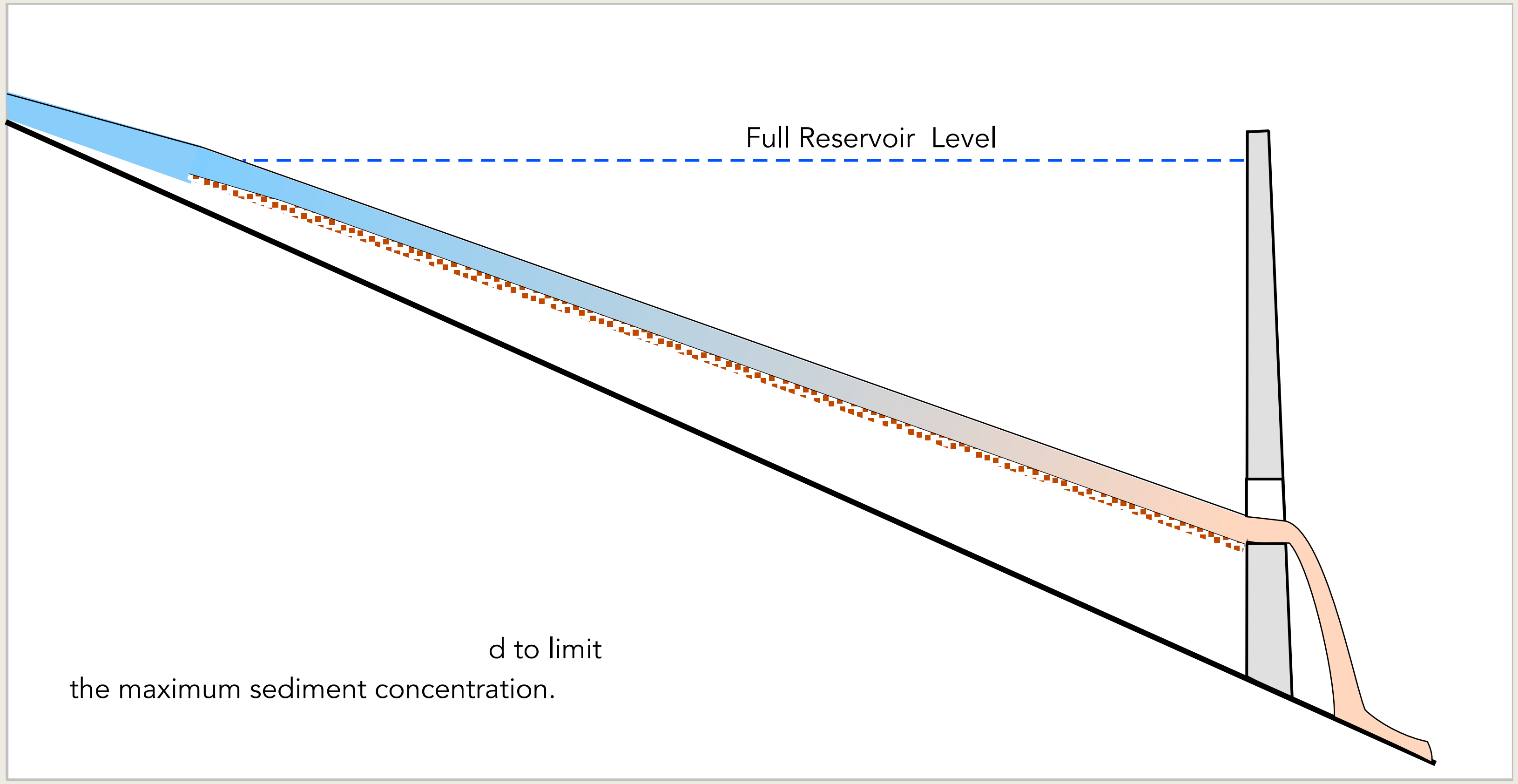


Pressure Flushing

- When a low-level outlet is opened, but the reservoir remains at a high level, a **scour cone** will develop in the immediate vicinity of the outlet.
- The process is termed **pressure flushing** because it does not involve reservoir drawdown.

Pressure flushing in progress

Empty flushing



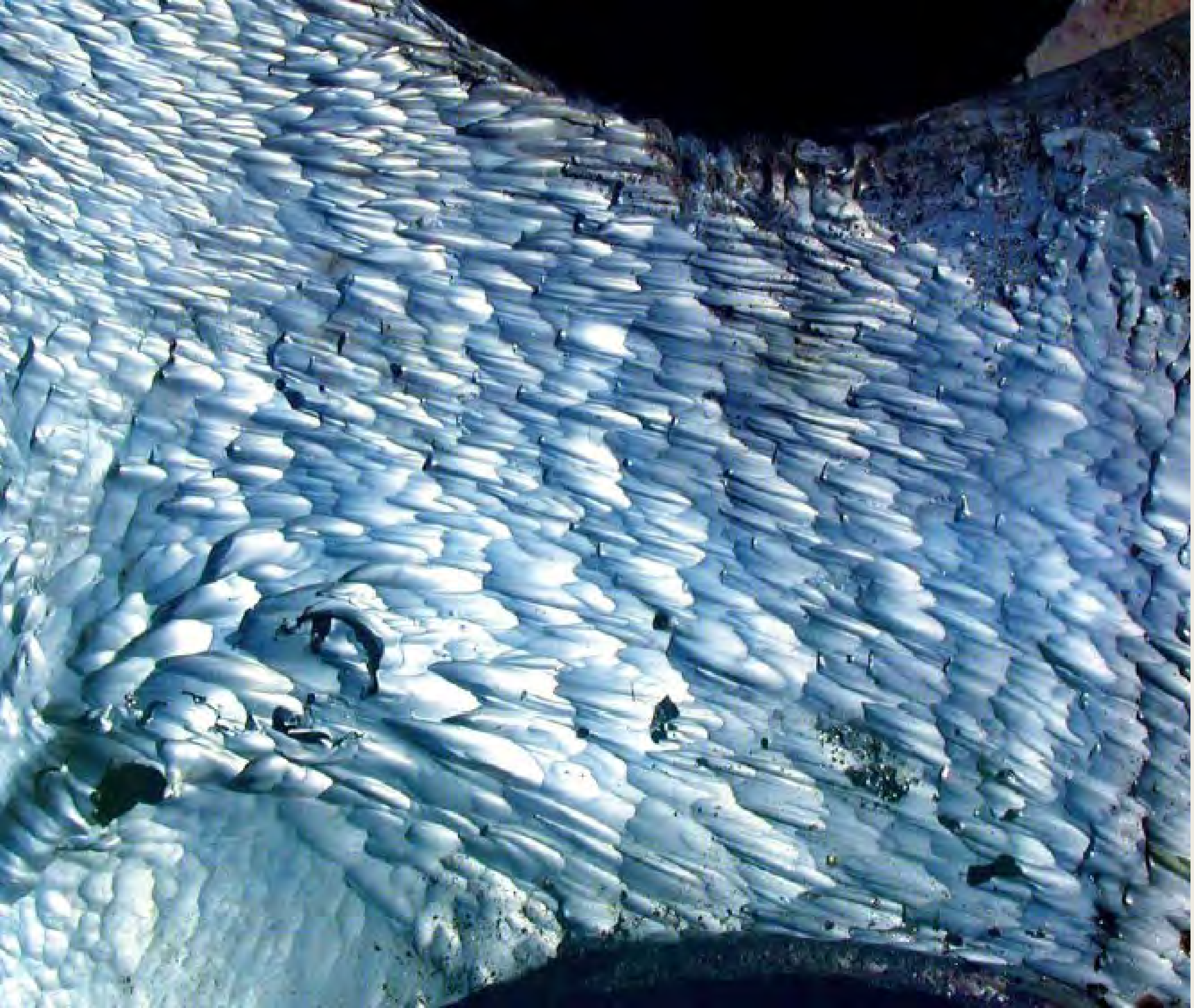
- Empty flushing involves **emptying the reservoir** and allowing the river to scour the sediment deposits through low-level outlets in the dam.
- Flushing often has **significant downstream environmental impact** due to extremely high sediment concentrations.
- Flushing is rarely the only available form of sediment management (cf. sluicing). Downstream impacts can be minimized through **mindful design and operation of the HEP**.

Empty flushing in progress

Mechanical removal

- Actual physical removal of accumulated sediment in reservoir.
- Can be achieved through **dredging**, in which the sediment is removed from underwater and the HEP remains active, or by **dry excavation**, in which the HEP does not continue generating.
- If done diligently, can be very effective (e.g. Bajo Anchicayâ, Colombia).

Sediment management: intakes and turbines

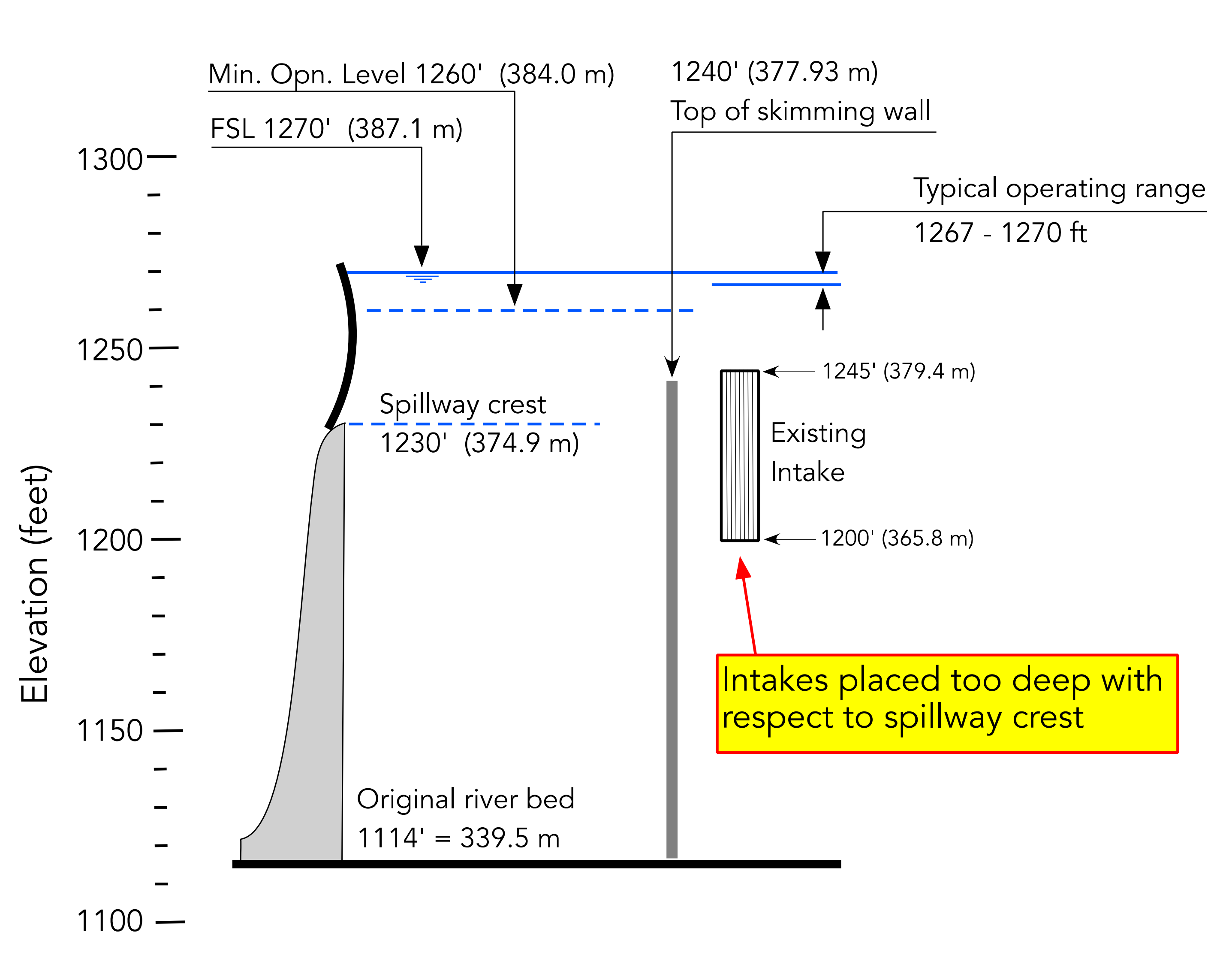


Turbine abrasion

- Coarse sediment, if allowed into the headrace, may erode the turbines, diminishing power generation efficiency.
- Each Francis turbine runner costs around USD 3.5 million and can take several weeks to replace.

Intake design

- Poor intake design is a significant factor influencing sediment ingress into the turbines.
- Sediment management begins at the design stage.



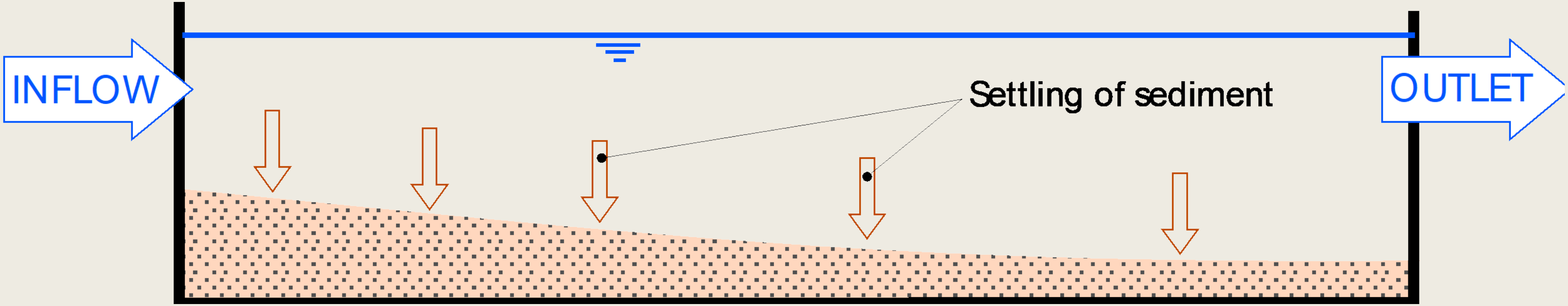
Intake placement

- Sedimentation issues can be minimized by optimizing intake geometry.
- A higher intake will have fewer sediment problems as gravity causes coarser (more abrasive) sediments to sink to deeper depths.

Turbine coating

- One sediment management strategy is applying a Tungsten carbide coating to the turbine runner.
- Sacrificial coatings can protect the softer underlying stainless metals of the runners and wicket gates from abrasive erosion by small particles for about 4 years.
- Runner can be sent back to the factory for re-coating at a cost of around USD 0.5 million.

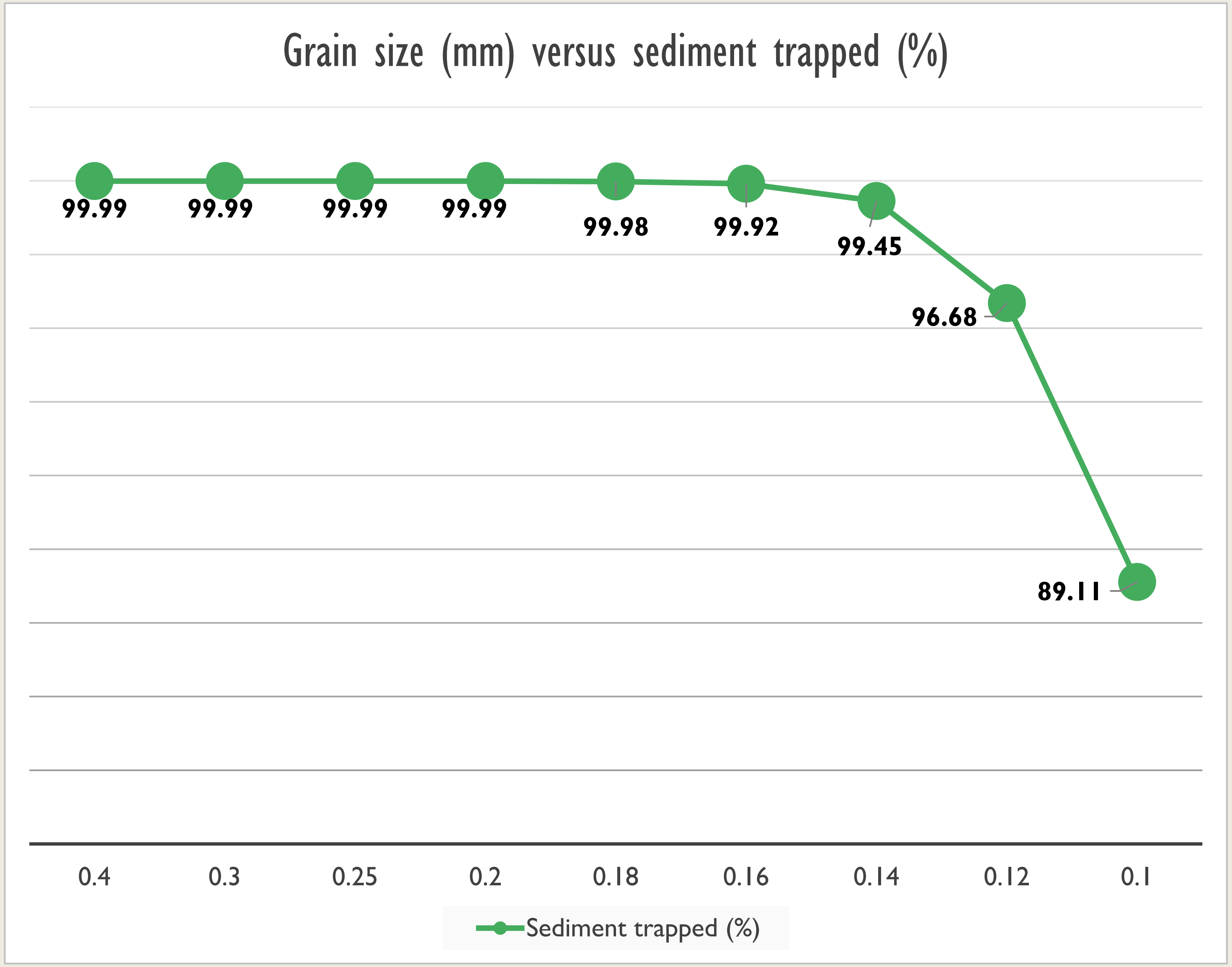
Desander



- A **desander is** a sedimentation basin downstream of the intake which traps larger and rapidly-settling sediment particles, which are highly abrasive, before they reach the turbines.

- Desanders can be constructed on the surface (as at NJHEP) or as large underground tanks.

NJHEP desander



Desander efficiency

- Based on SSIM model study results.
- Traps 89.1% of sand up to 0.1mm (width of human hair) in diameter and between 99.9 and 96.7% of all coarser grains.