HYPERCONCENTRATED FLOW CLASSIFICATION, RHEOLOGY AND STRUCTURAL DESIGN

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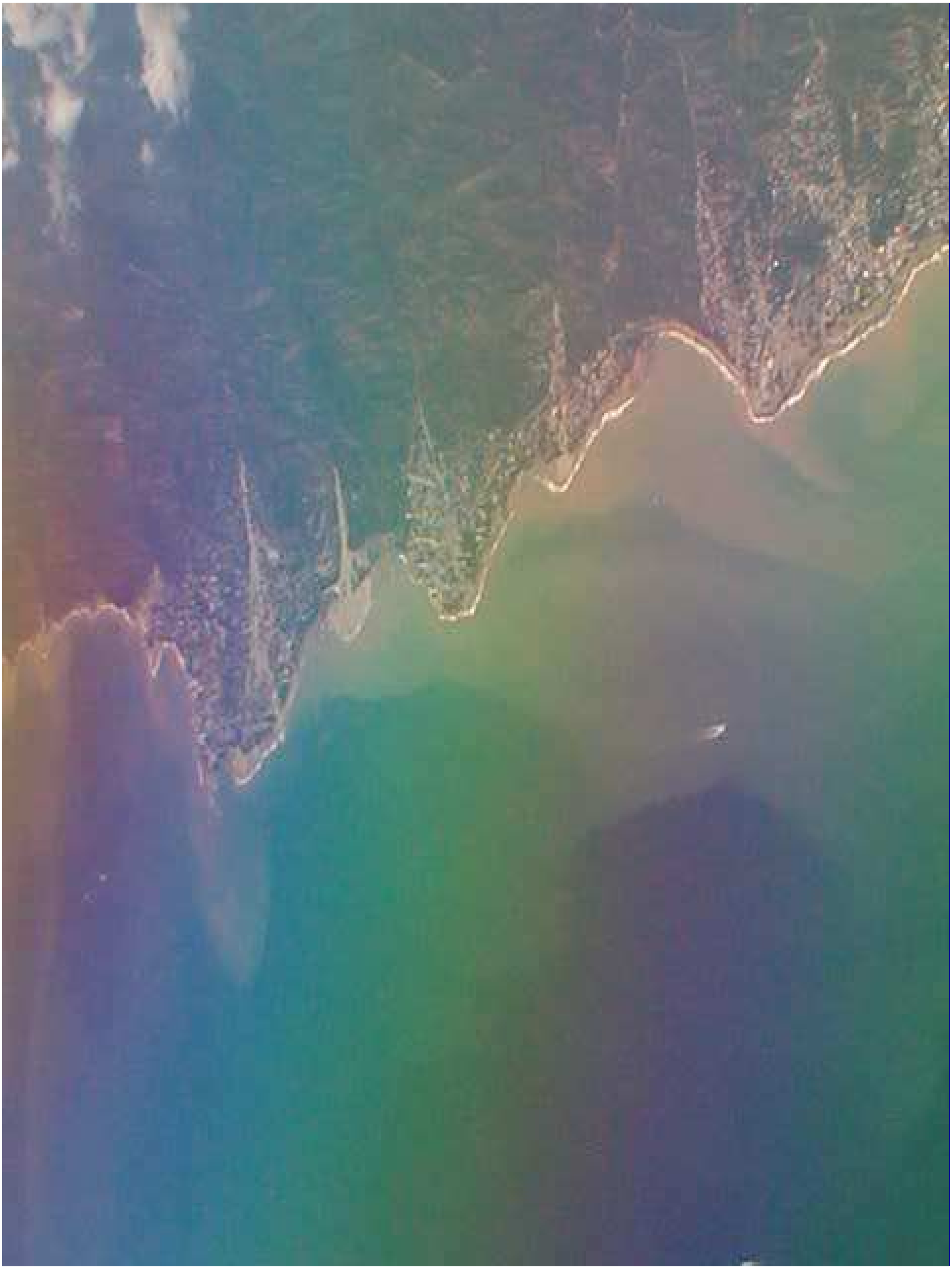


Objective

Provide guidelines for designing mitigation countermeasures based on the type of hyperconcentrated flow

Rheology of Hyperconcentrated Sediment Flows

Total shear stress :

$$\tau = \tau_y + \tau_v + \tau_t + \tau_d$$

Yield stress

Viscous stress

Turbulent stress

Dispersive stress

Quadratic rheological equation

(O'Brien and Julien, 1985)

$$\tau = \tau_y + \eta \frac{du}{dy} + \zeta \left(\frac{du}{dy} \right)^2$$

- τ_y: Yield stress, where $\tau_y = \tau_c + \tau_{mc}$
- $\eta \frac{du}{dy}$: Viscous stress
- $\zeta \left(\frac{du}{dy} \right)^2$: Turbulent stress and Dispersive stress, where $\zeta = \rho_m l_m^2 + a_i \rho_s \lambda^2 d_s^2$

Dimensionless quadratic rheological model

(Julien and Lan, 1991)

$$\tau^* = 1 + (1 + T_d^*) a_i D_v^*$$

$$\tau^* = \frac{\tau - \tau_y}{\eta \frac{du}{dy}}$$

$$T_d^* = \frac{\rho_m l_m^2}{a_i \rho_s \lambda^2 d_s^2}$$

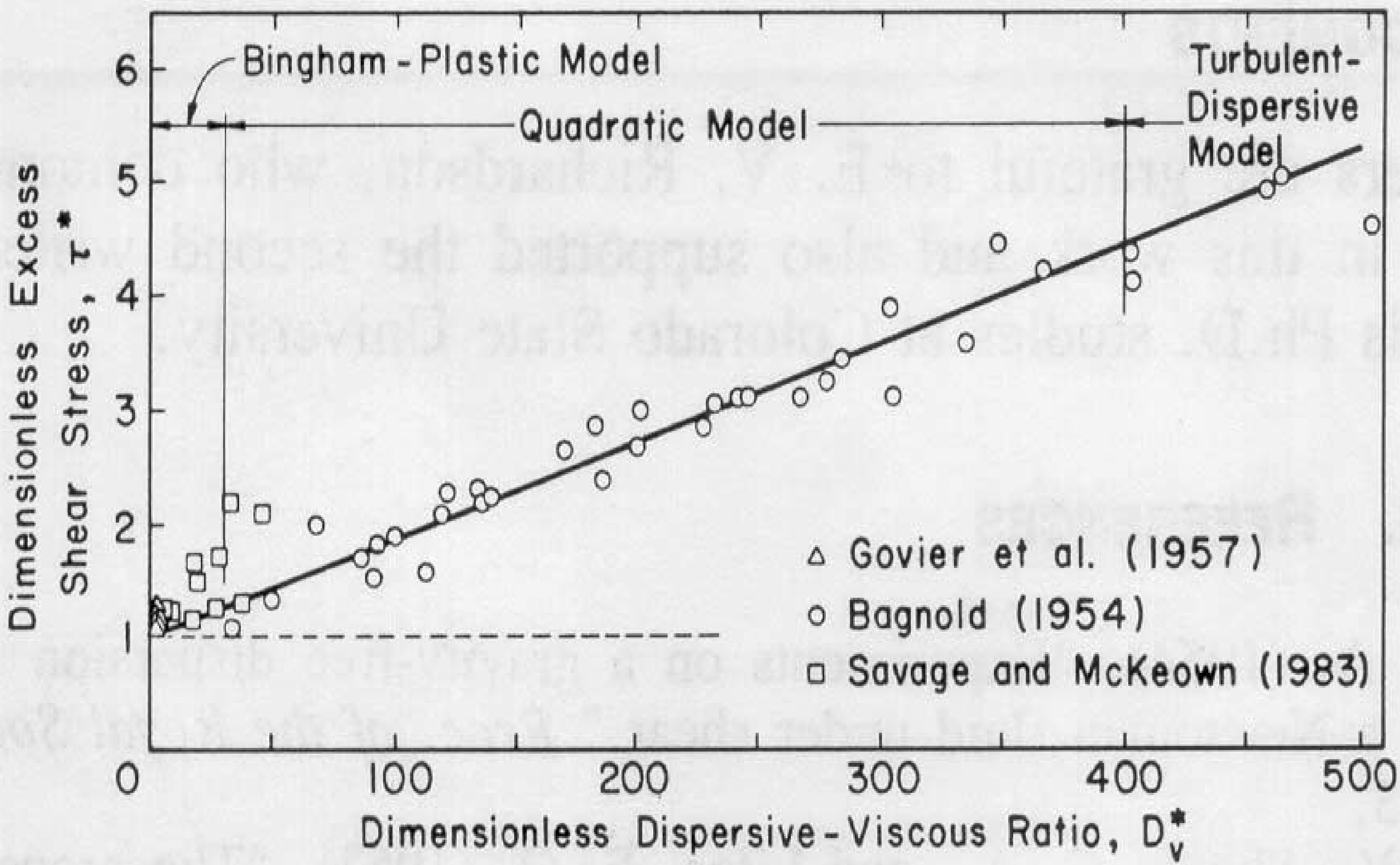
$$D_v^* = \frac{\rho_s \lambda^2 d_s^2}{\eta} \left(\frac{du}{dy} \right)$$

Low τ^* → Viscous Flow

High T_d^* → Turbulent Flow

High D_v^* → Dispersive Flow

Dimensionless quadratic rheological model



Flow Classification

Viscous → Mudflow

$D_v^* < 30$

Turbulent → Mud Flood

$D_v^* > 400$ and $T_d^* > 1$

Dispersive → Debris Flow

$D_v^* > 400$ and $T_d^* < 1$

Mudflow

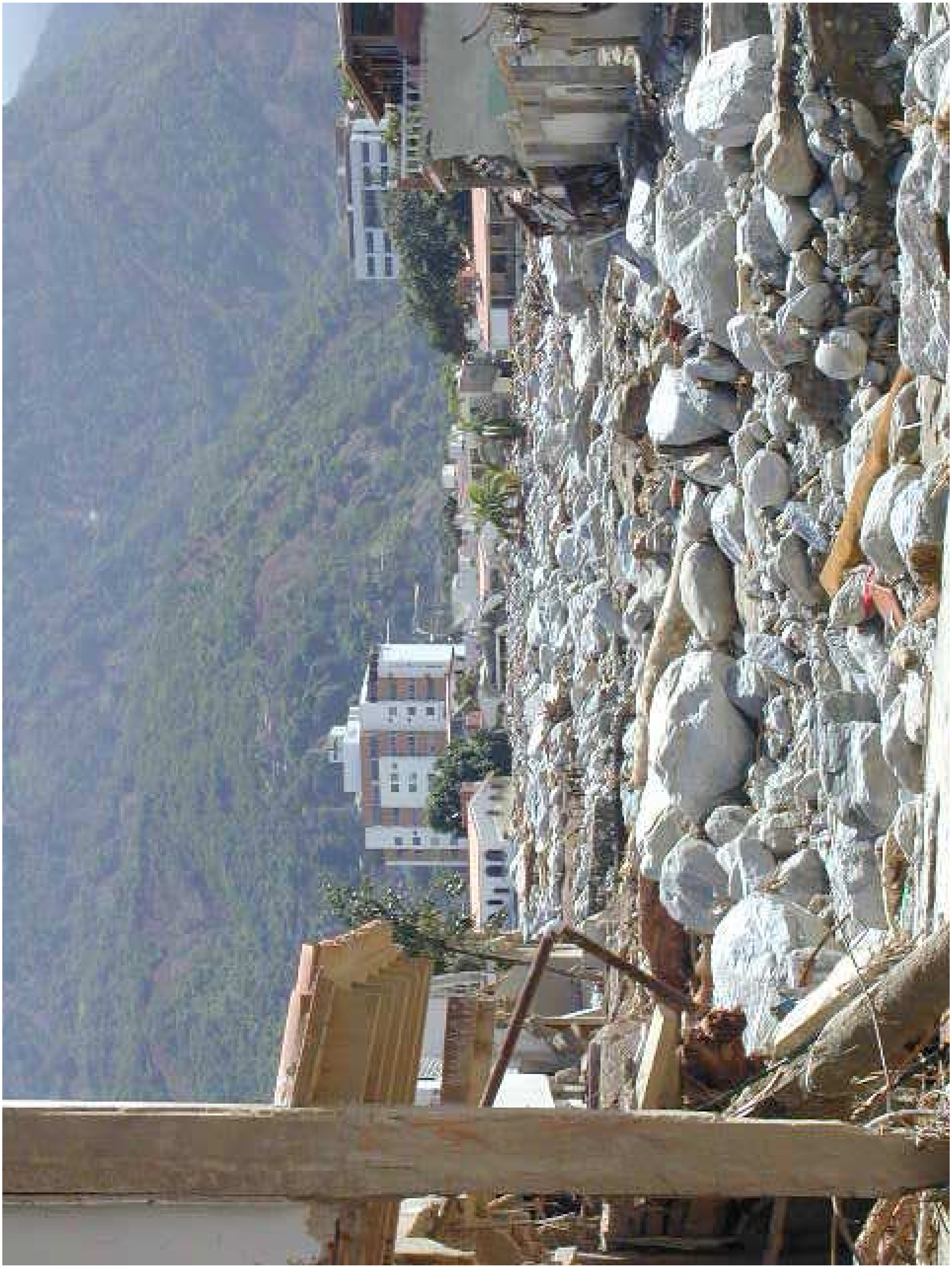
- High viscosity and yield stress
- High concentration of silts and clays
- 45% < Cv < 55%
- Low velocity
- Low Froude Number
- No abrasion
- Large flow depths
- High pressure

Mud Flood

- Turbulent
- Non-cohesive particles
- Cv as high as 40%
- High velocity
- High Froude Number
- Abrasive

Debris Flow

- Dispersive
- Large clastic particles
- Non cohesive
- Low viscosity
- High velocity
- Destructive impact force



Countermeasures

Mudflow Features:

- High viscosity and yield stress
- High concentration of silt and clay
- 45% < Cv < 55%
- Low Froude Number
- No abrasion

Effective Solution ➡ Store, Deflect, Spread

- Storage basins
- Deflection walls

Storage Basin

Deflection Wall

Countermeasures

Mud Flood Features:

- Turbulent
- Non cohesive particles
- Cv as high as 40%
- High Froude Number
- Abrasive

Effective Solution ➡ Convey

- Straight channels
- Lined canals, berm and levee channels
- Drop structures, energy dissipators

Straight Channel

Lined canal with drop structures

Countermeasures

Debris Flow Features:

- Dispersive
- Large clastic particles
- Low viscosity
- Large velocity
- High impact

Effective Solution ➡ Retain large clasts
Drain fluid matrix

- Concrete Sabo dams
- Steel frames and debris rakes

Sabo Dam Construction

Sabo Dam and Steel Frames

Debris Rakes

Conclusions

- Quadratic rheological model describes continuum of hyperconcentrated flow behavior
- Mudflows exhibit high yield and viscous stresses
- Mud floods have dominant turbulent stress
- Debris flows have dominant dispersive stress

Conclusions

- Mitigation structures for mudflows
  - » Detention basins
  - » Deflection walls
- Mitigation structures for mud floods
  - » Straight channels
  - » Lined canals, berm and levee channels
  - » Drop structures, energy dissipators
- Mitigation structures for debris flows
  - » Concrete Sabo dams
  - » Steel frames and debris rakes