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Modelling bank erosion on the Mekong river

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Context

- Flood damage throughout Cambodian Mekong and the Vietnam Mekong Delta is currently being influenced by rapid population growth, the expansion of farmland and infrastructure
- Bank erosion phenomena causes
  - Loss of agricultural land
  - Damage of structures which are located next to the river channel
  - Accumulation of sediments in downstream reaches, which can promote flooding there
  - Channel instability

Ang Nyay (Pamong)

Friendship Bridge

Pakse

Ban Don Sang Khi

Purpose

River bank erosion model development and simulation.

Development and application of coupled bank erosion modelling: Integrating channel and bank hydrology, flow hydraulics, hydraulic erosion and mass-wasting of river banks

What **processes** do we need to model?

- Bank retreat involves a combination of interacting processes
  - Mass-wasting
  - Fluvial (hydraulic) erosion
- Fluvial erosion and mass-wasting both require modelling the in-channel and in-bank flow hydraulics

River Mekong near Pakse, Laos; October 2006

Study sites

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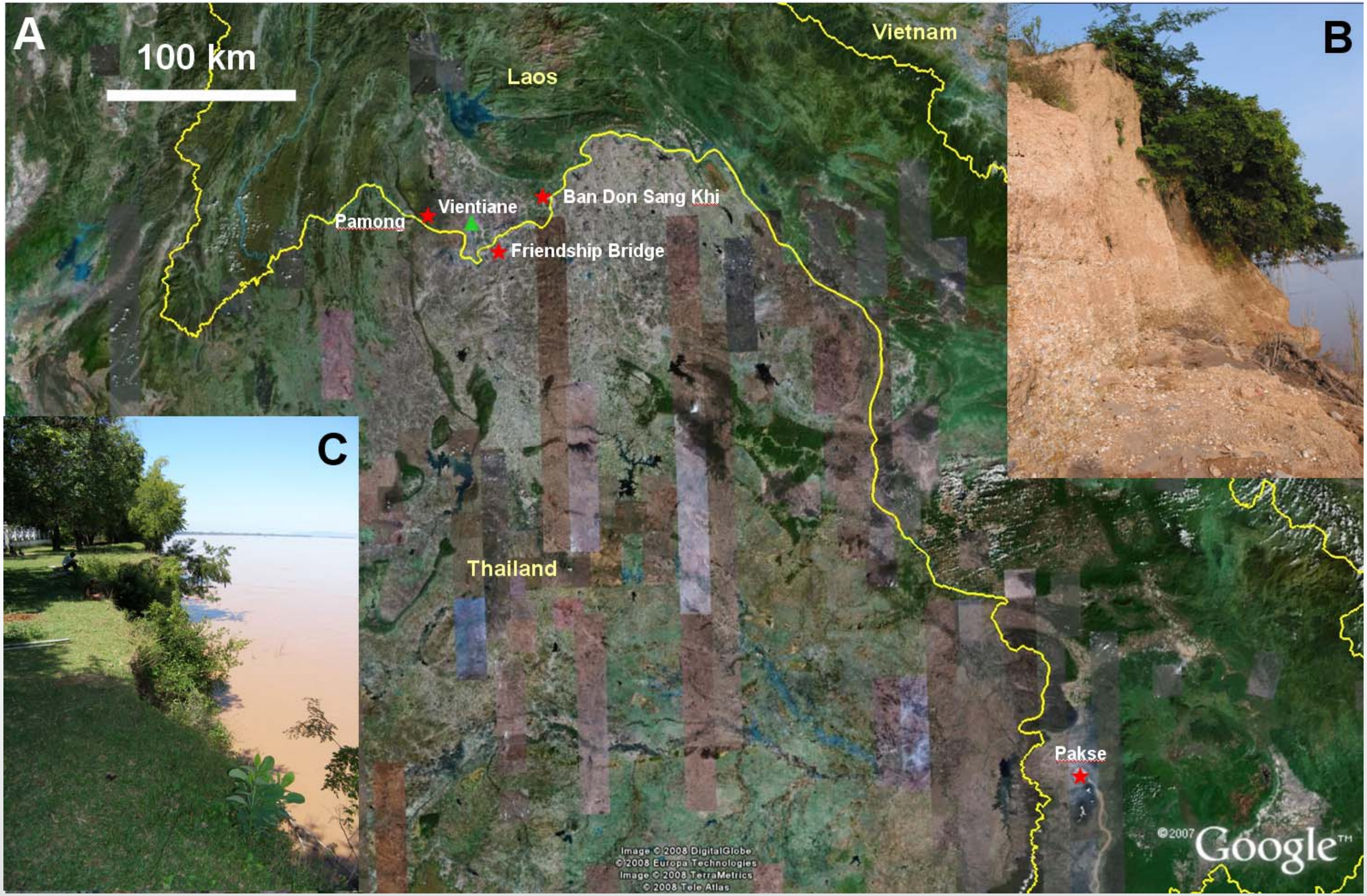

(A) Study reach of the Mekong River in Laos (B) Friendship Bridge and (C) Pakse. Photographs taken in October 2006 at Q ≈ 8900 m3/s.

Modelling mass-wasting

- It is necessary to account for
  - Bank material strength
  - Bank profile morphology
  - Hydrological effects – seepage flows and changing pore water pressure due to (i) rainfall and (ii) variations in the level of the river

Logic diagram

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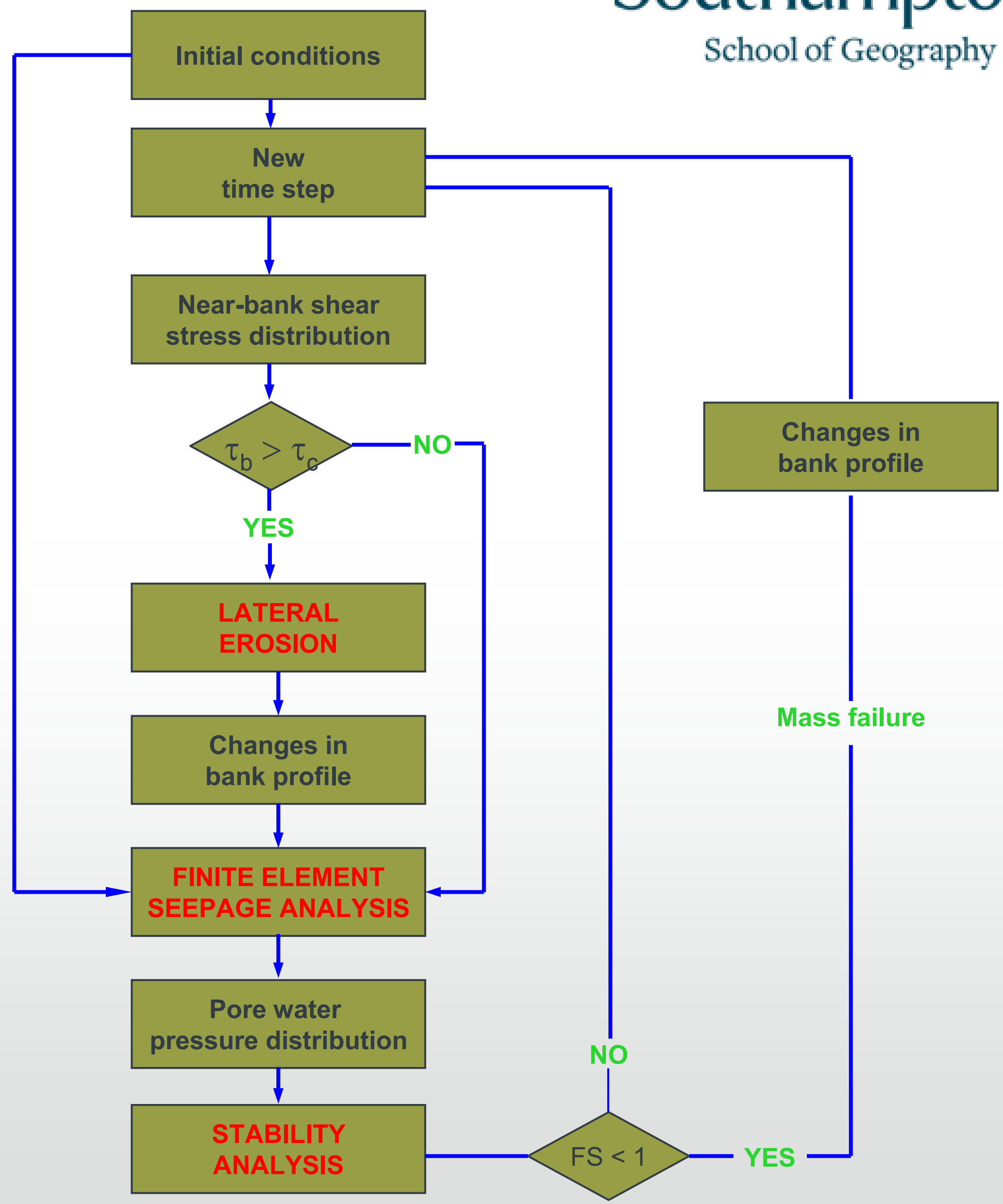
Computational logic for coupling mass-wasting and fluvial erosion simulations



Geotechnical and Hydrology data

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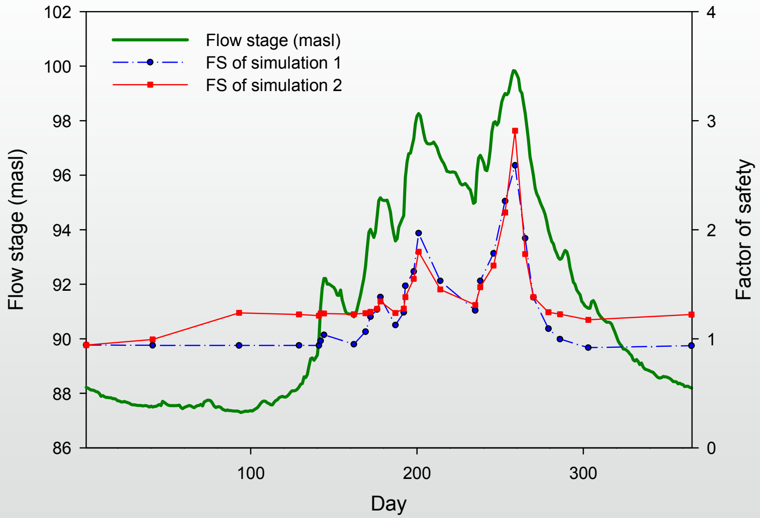
- Simulations are based on measured geotechnical parameters
  - Cohesion, friction angle
  - Bank material density & porosity
  - Hydraulic conductivity
  - Grain size distribution
- Simulating a range of annual flow regimes to evaluate the effects of flood hydrology on bank stability



Simulated stability results of simulation 1 and 2 for flow year 2000 at Pakse

Seepage model SEEP/W

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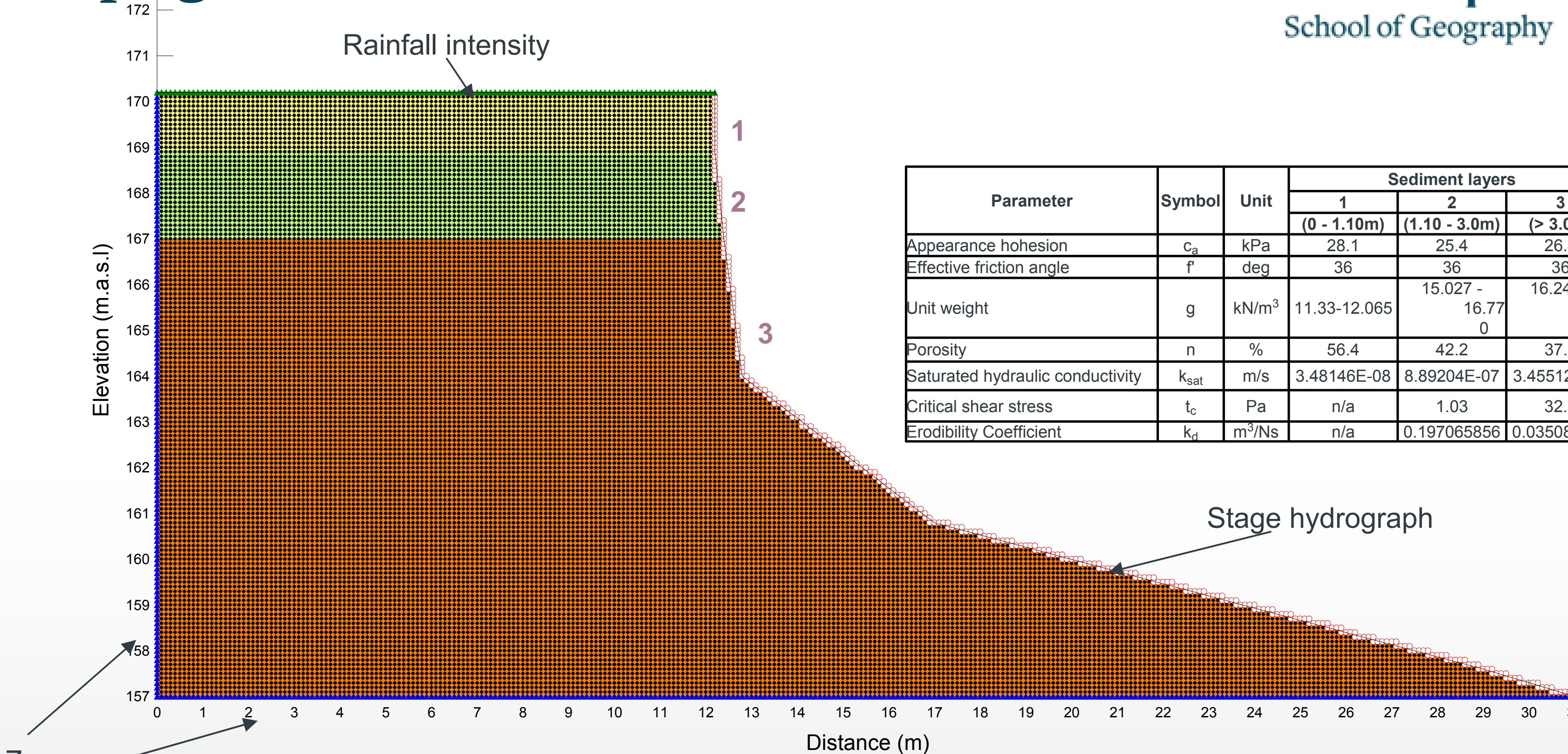
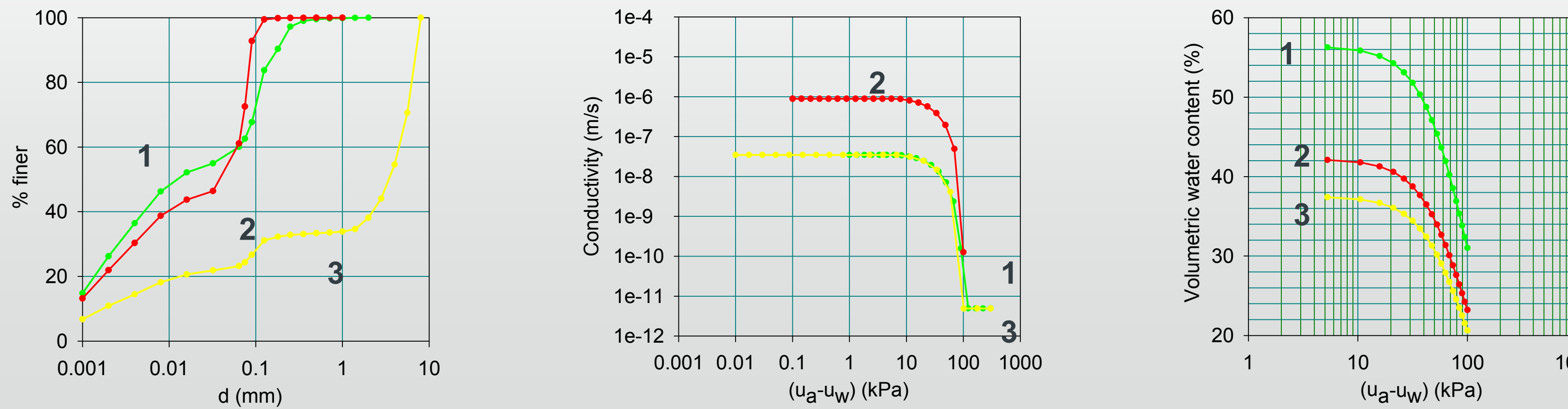


Parameter	Symbol	Unit	Sediment layers		
			1	2	3
			(0 - 1.10m)	(1.10 - 3.0m)	(> 3.0m)
Appearance hohesion	c_a	kPa	28.1	25.4	26.4
Effective friction angle	f'	deg	36	36	36
Unit weight	g	kN/m^3	11.33-12.065	15.027 - 16.770	16.249 - 17.594
Porosity	n	%	56.4	42.2	37.5
Saturated hydraulic conductivity	k_{sat}	m/s	3.48146E-08	8.89204E-07	3.45512E-08
Critical shear stress	t_c	Pa	n/a	1.03	32.5
Erodibility Coefficient	k_d	m^3/Ns	n/a	0.197065856	0.035082321



SEEP/W and SLOPE/W integration

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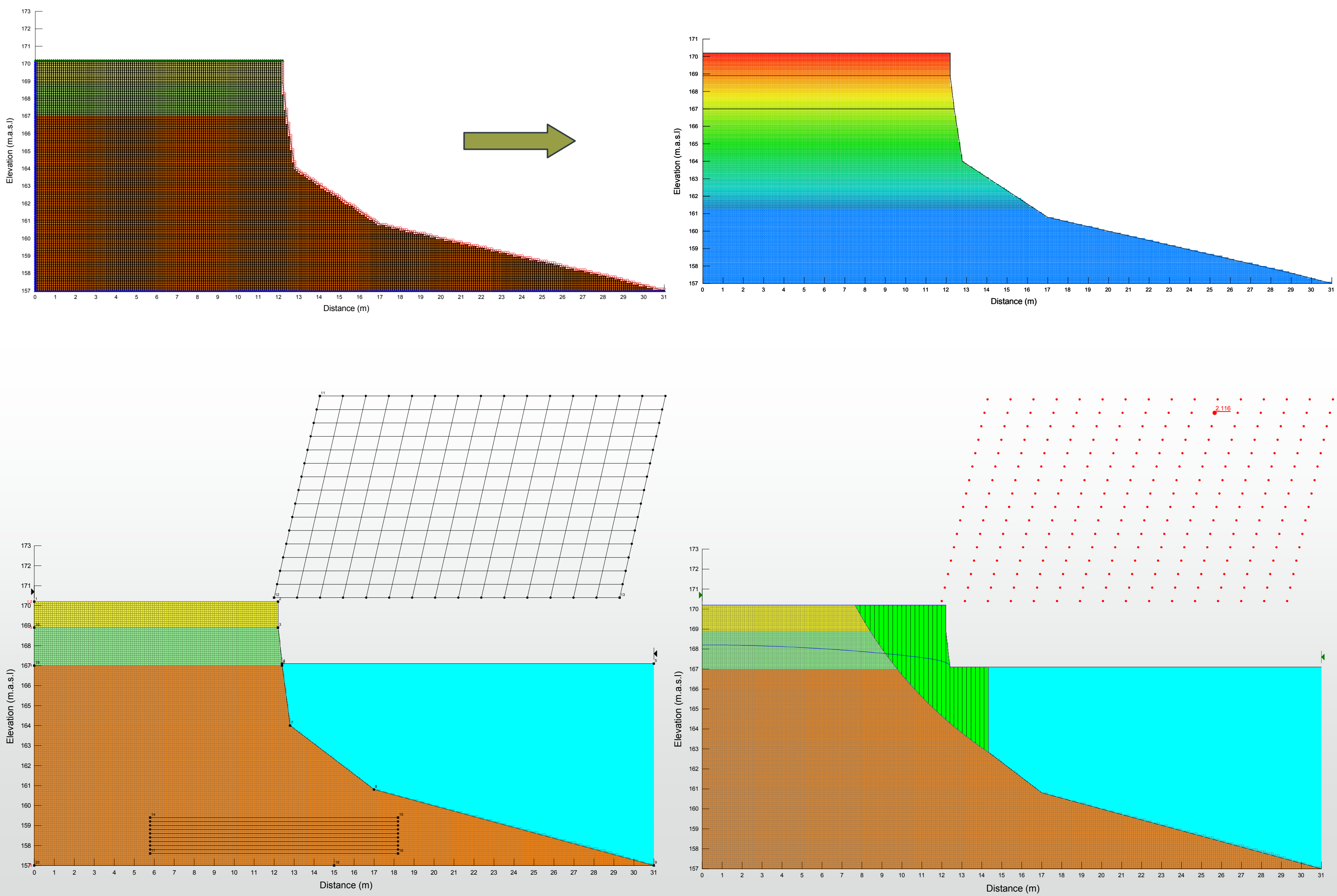

Modelling Fluvial Erosion

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- A widely accepted model of fluvial bank erosion already exists:

$$\boldsymbol{\varepsilon = k\,(\tau - \tau_c)}$$

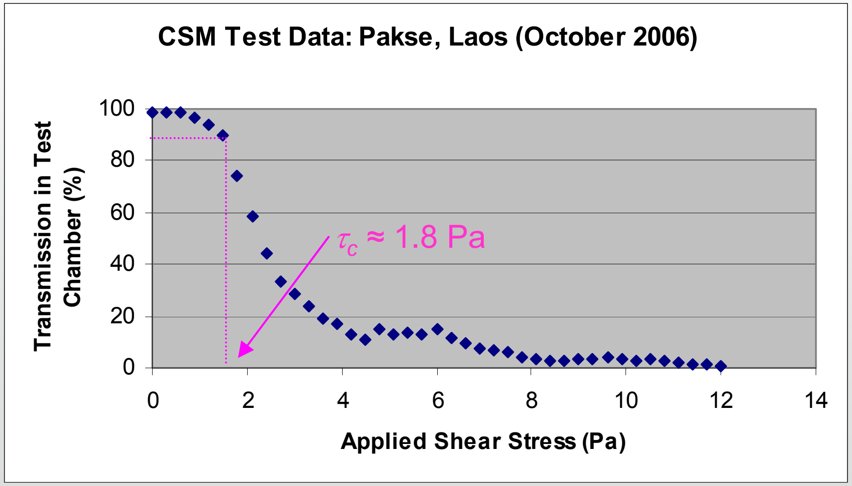
- However, it has poor predictive ability
- This is because it is difficult to parameterise the model accurately
- We have been focusing on the methods used to estimate τ, τ_c and k

Parameterising bank erodibility

- CSM was being used at various study sites in Vientiane and Pakse
- Sampling is undertaken by extracting cores of bank material (drilling)
- Subsequent testing is rapid, providing robust estimates of τ_c

- $k = 0.2\tau_c^{-0.5}$

[*Hanson & Simon*, 2001]

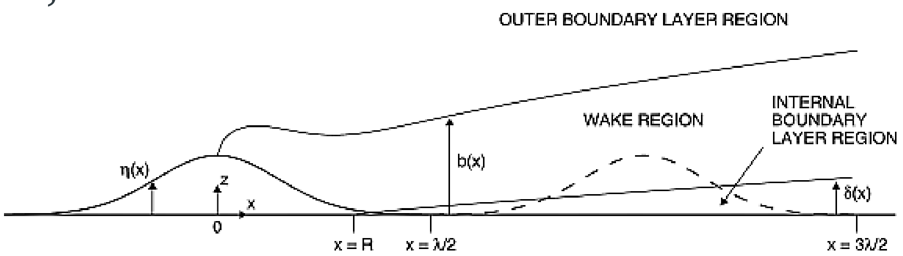


Shear Stress Partitioning

- Shear stress partitioning [Kean and Smith, 2006 a,b]:

$$\tau = \rho \left\langle u_{*IBL} \right\rangle^2 + \frac{1}{2} \rho C_D \frac{H}{\lambda} u_{ref}^2$$

Skin drag Form drag



Source: Fig. 2 of Kean and Smith [2006a]

- U_{ref} is controlled primarily by wakes generated by roughness elements upstream
- H, λ and C_d are functions of the geometry of the bank topography

  H = protrusion height of roughness element

  λ = spacing of roughness elements

  C_d = drag coefficient
- The roughness elements are modelled as Gaussian shapes

River Mekong at Ban Hom (near Vientiane), Laos; May 2007

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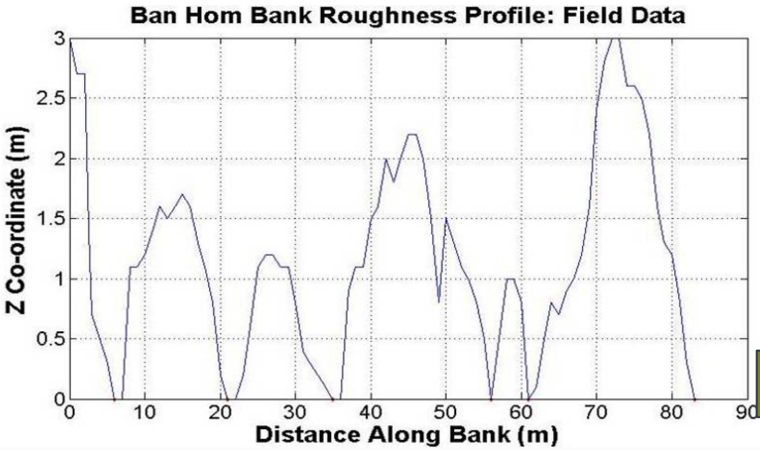
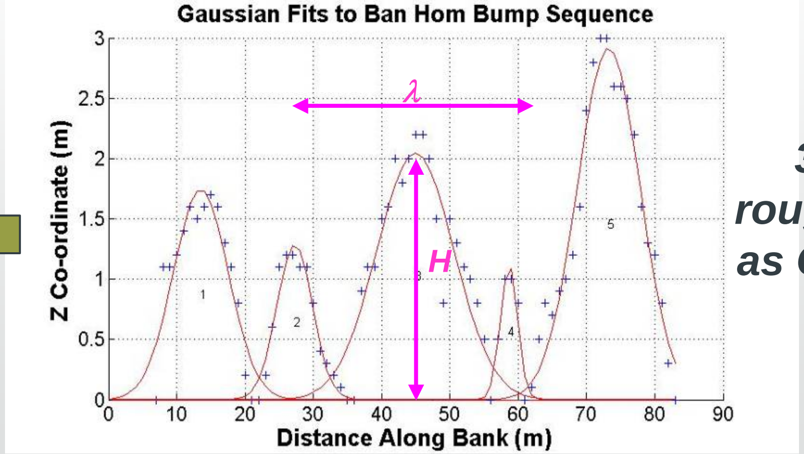
Bank Roughness Estimation

1. Field survey

2. Transect

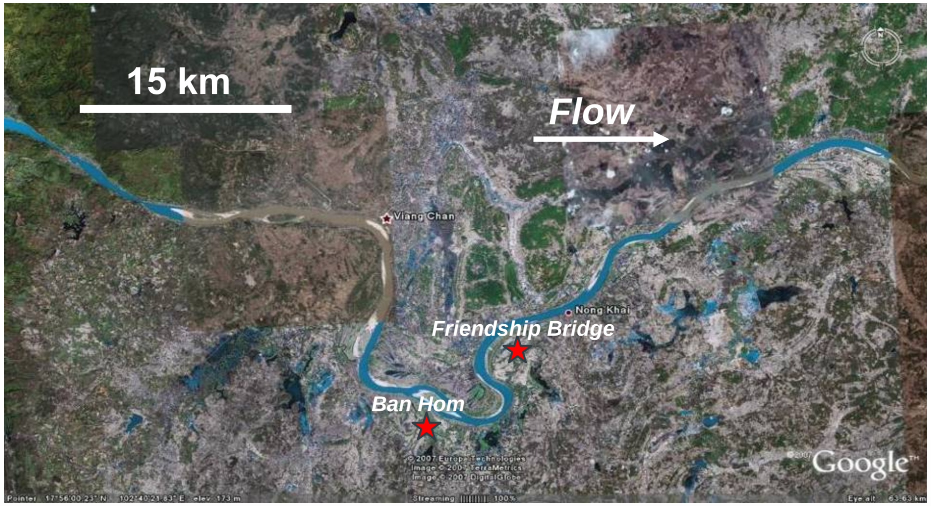


3. Model bank roughness elements as Gaussian shapes



4. Provides a statistical model of bank roughness in terms of H, λ, C_d

- Two sites near Vientiane, Laos
  - Ban Hom
  - Friendship Bridge
- Bank roughness and CSM survey define H, λ, C_d, τ_c, k directly
- Secondary data was used to estimate the reference flow velocity (u_{ref})
  - CFD simulations of the Vientiane reach
  - aDcp data
  - Note: any simple flow measurements are OK



Ban Hom

Friendship Bridge

Overview and Further study

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- Applications of model
  - Across a range of Mekong study sites, and for multiple flow hydrographs: Statistical emulator for application across the Mekong
  - Identifies key controlling factors and driving processes (e.g. hydrograph shape and timing) and critical erosion zones for management planning
- Future work
  - Expand study sites to Cambodia and Vietnam
  - Linking with other MRC's projects

SIMULATION

1966 FLOW YEAR

AT FRIENDSHIP BRIDGE

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Thank you!