Fluvial-geomorphic dynamics of a Subarctic catchment under changing climatic conditions

TULeVAT project (2007–2010)
a collaborator in the
IPY initiative ID 104 "Arctic-Hydra"

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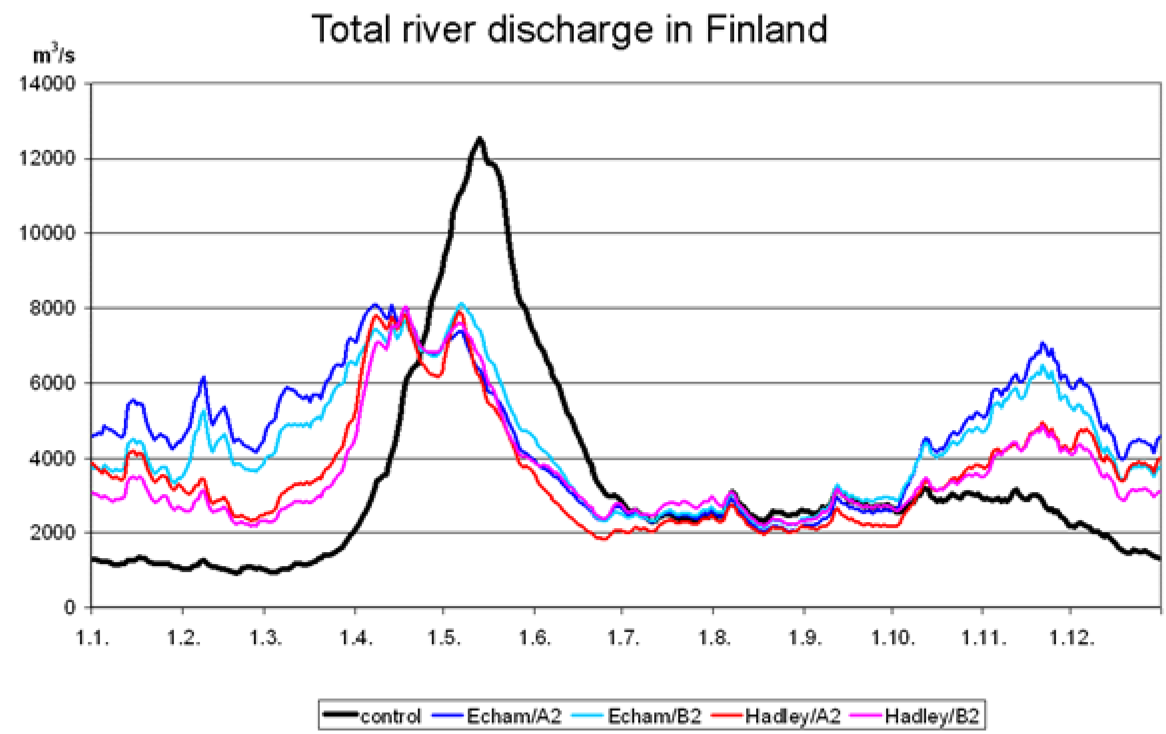
Background

- Flooding and flood-related damages have increased lately
- River discharges will increase due to climate change, but seasonal variations may be subdued
- Finnish Flood Report issued in 2004 listed suggestions of action
  - all flood-prone areas to be identified and mapped
- EU flood directive issued in 2007
- Finnish national research programme ”ISTO” on adaptation to climate change



Control = total river discharge in Finland.
Estimated total river discharges by different climate change scenarios (A1, B1) and climate change models (Echam,Hadley).

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FLOOD HAZARD MAPS

EU flood directive, Chapter III, Article 6, Paragraphs 3 & 4:

”…3. Flood hazard maps shall cover the geographical areas which could be flooded according to the following scenarios:

(a) floods with a low probability, or extreme events scenarios;

(b) floods with a medium probability (likely return period ≥ 100 years);

(c) floods with a high probability, where appropriate.

4. For each scenario referred to in paragraph 3 the following elements shall be shown:

(a) the flood extent;

(b) water depths or water level, as appropriate;

(c) where appropriate, the flow velocity or the relevant water flow.”

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FLOOD RISK MAPS

EU flood directive, Chapter III, Article 6, Paragraph 5:

”…Flood risk maps shall show the potential adverse consequences associated with flood scenarios referred to in paragraph 3 and expressed in terms of the following:

(a) the indicative number of inhabitants potentially affected;

(b) type of economic activity of the area potentially affected;

(c) installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control which might cause accidental pollution in case of flooding and potentially affected protected areas identified in Annex IV(1)(i), (iii) and (v) to Directive 2000/60/EC;

(d) other information which the Member State considers useful such as the indication of areas where floods with a high content of transported sediments and debris floods can occur.”

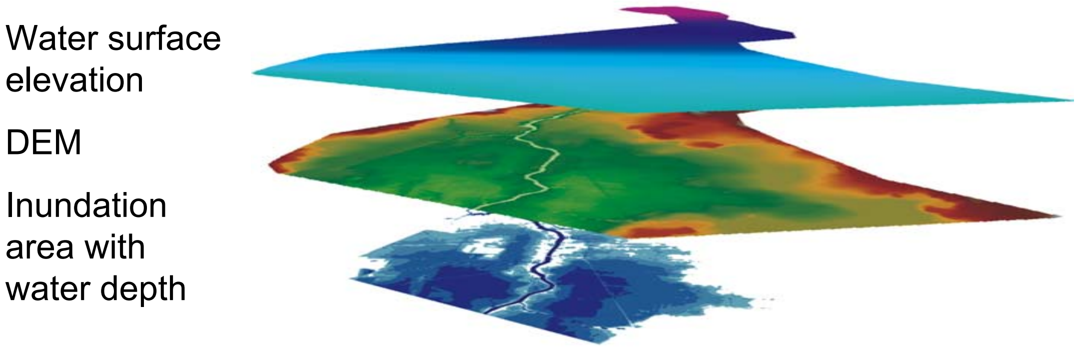
Delineating inundation areas

Land surface elevation

- 25 metre national raster DEM
- where applicable and available, further local datasets (municipal DEMs)
- additional field work with RTK-GPS where necessary
- TIN extraction
- accuracy assessment

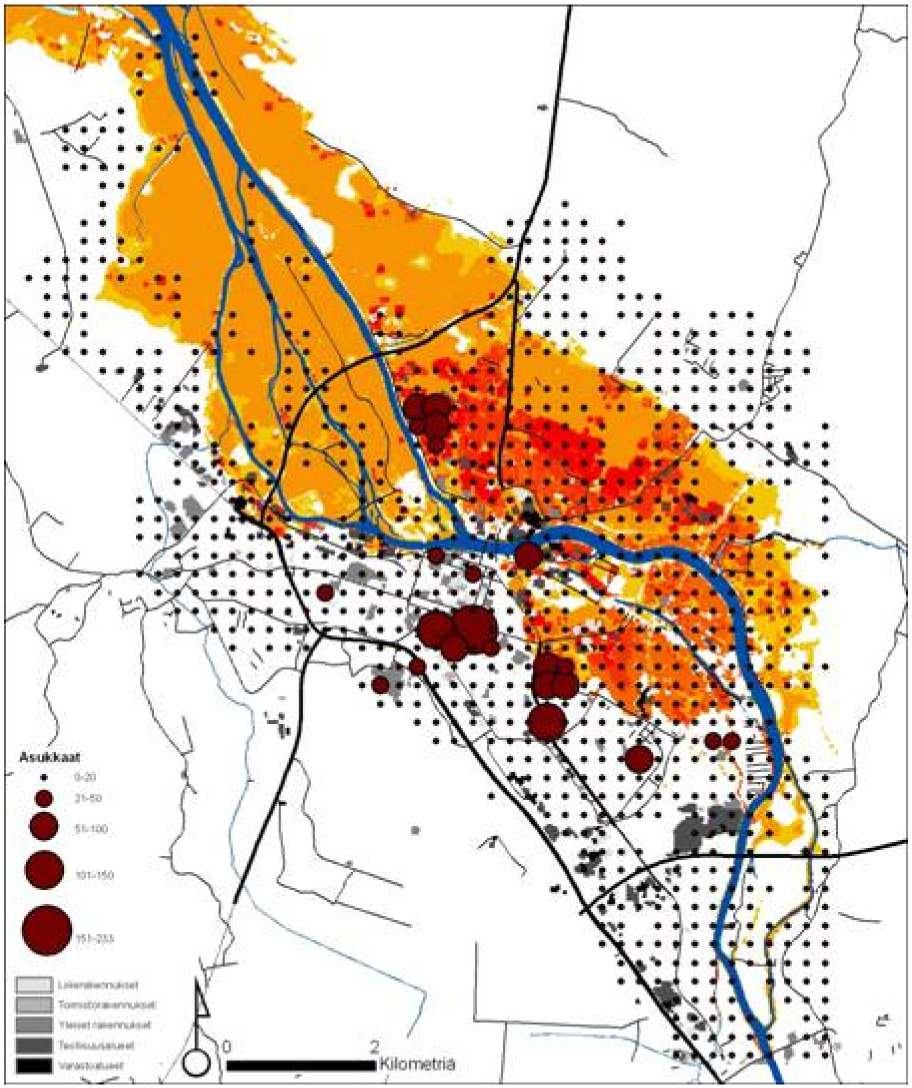
Water surface elevation

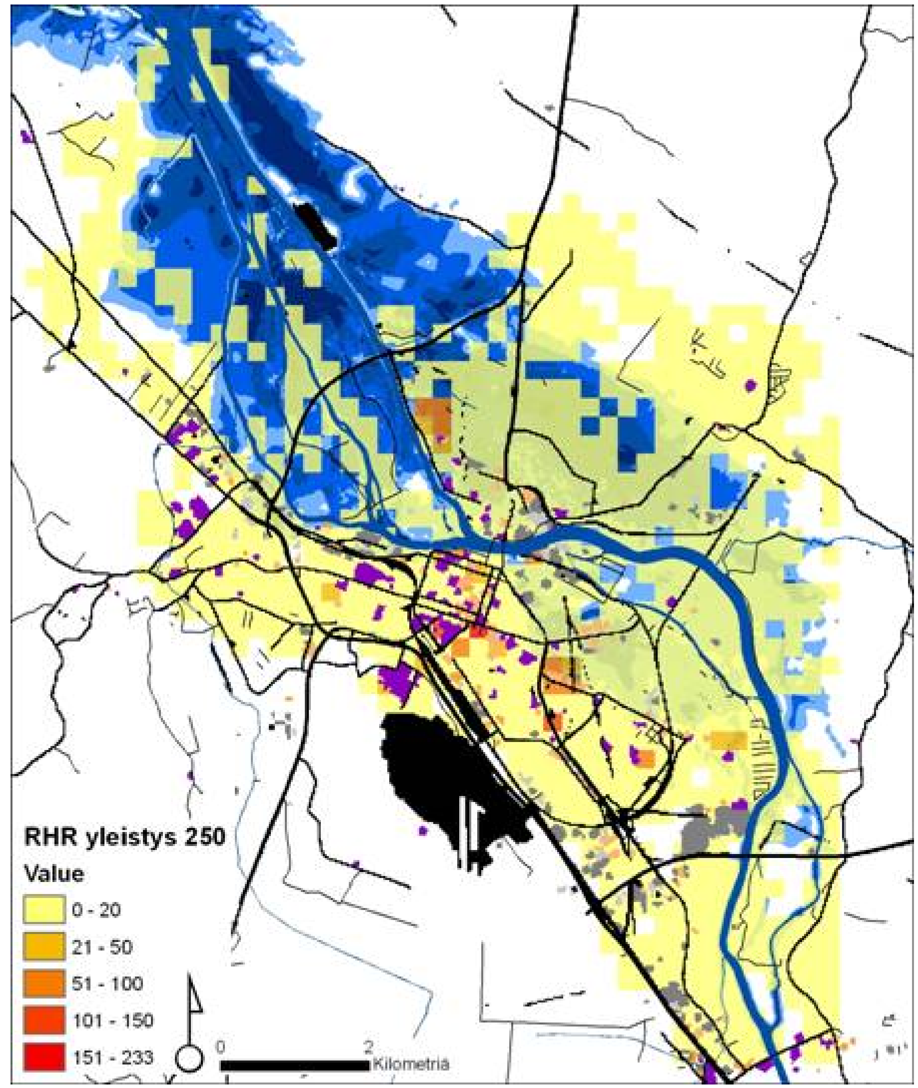
- return periods 20, 50, **100**, **250** and 1000 years
- Statistical model (Gumbel mixed model etc.)
- Watershed models by SYKE
- Linear interpolation, or
- Hydraulic model (HEC-RAS 1D, TELEMAC 2D)
- Merging with TIN



Various prototype designs of flood risk maps

(City of Pori on the SW coast of Finland)





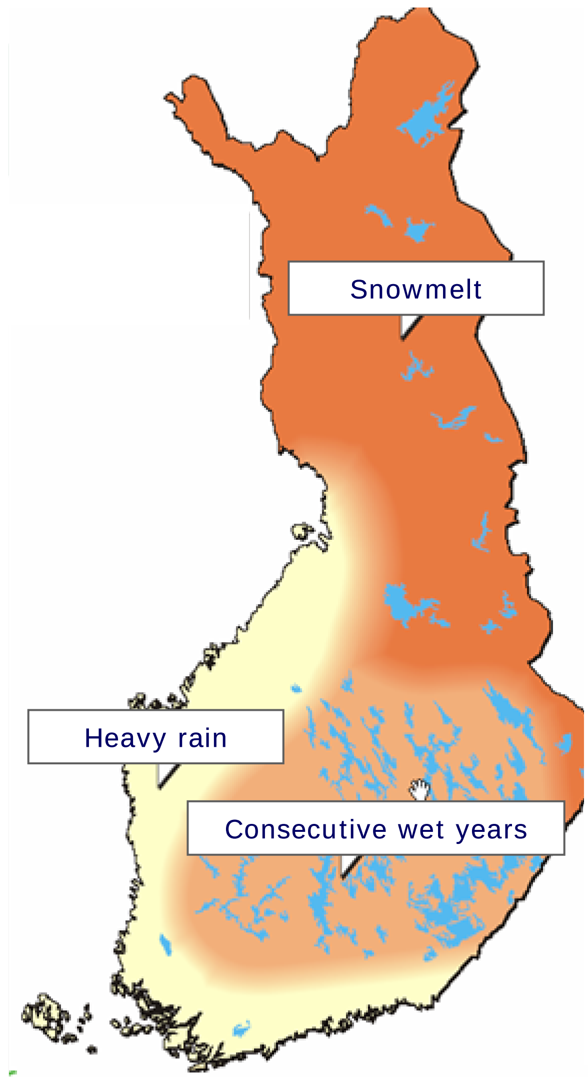
How about future discharges?

Grounded ice jam at Teno River, 19 May 2008

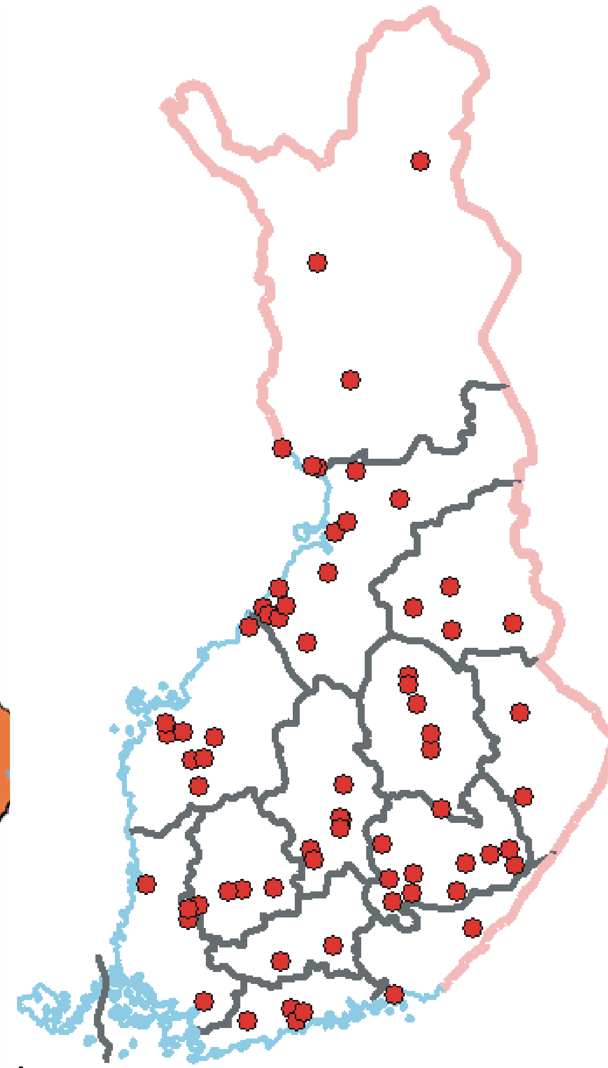
Finland, land of lakes
– and some rivers

Four study areas

Typical causes for flooding

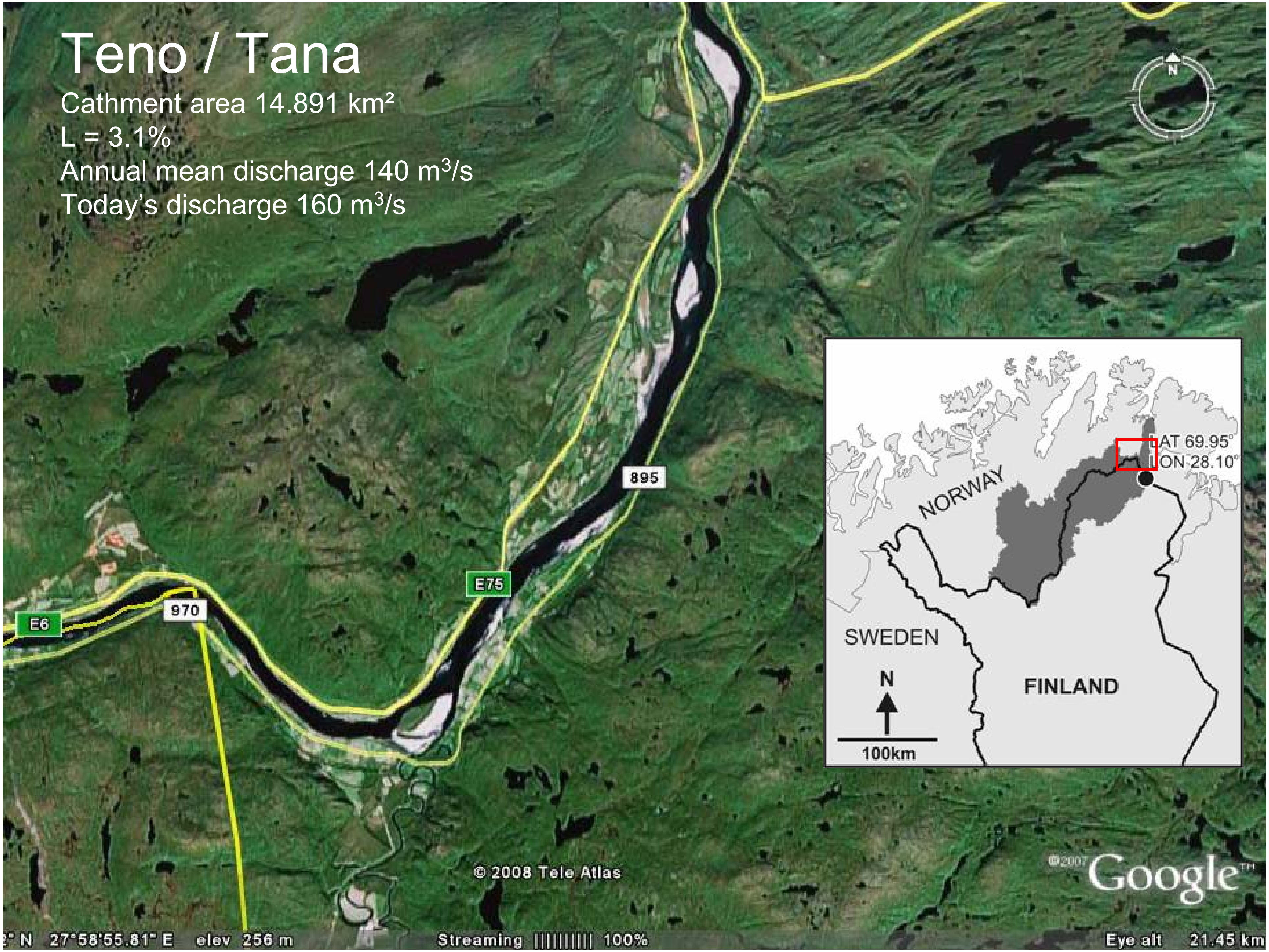


Over 60 flood-prone localities



Teno / Tana

Cathment area 14.891 km²
L = 3.1%
Annual mean discharge 140 m^3/s
Today's discharge 160 m^3/s



TULeVAT research approach

CHANGING HYDROLOGY:

- Discharge scenarios in a century time frame based on ***Hadley and Echam GCMs*** and ***A2 & B2 SRES emission scenarios***

CHANGING GRADIENT

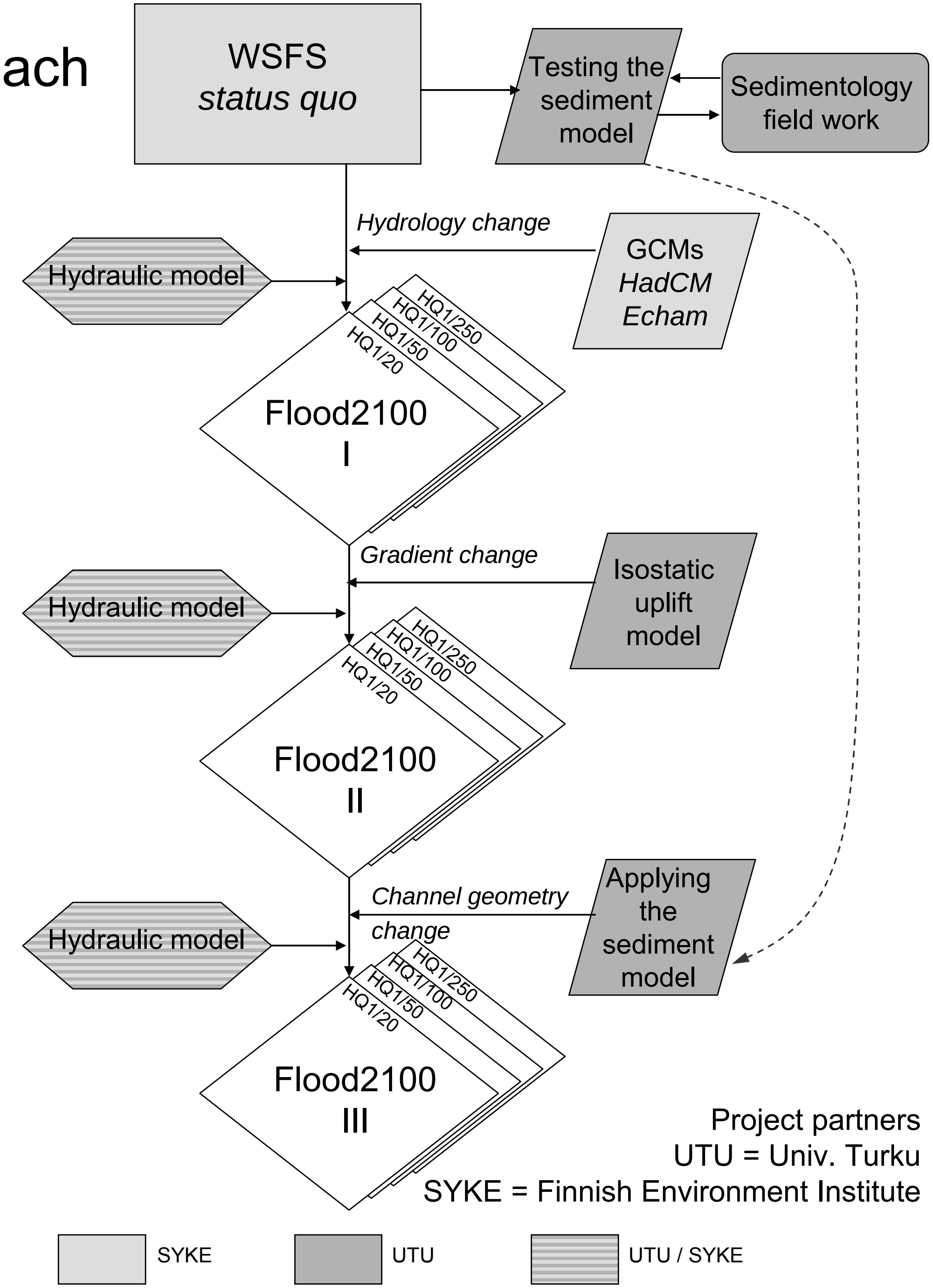
- Impact of ***isostatic land uplift*** on delta formation and dynamics, plus the overall gradient

CHANGING GEOMETRY

- Impact of changing channel geometry due to ***sediment entrainment, transport and deposition*** processes within the channel and on the delta

SYNTHESIS:

- ***Detailed flood maps*** for various flood magnitudes with recurrency periods HQ1/20, HQ1/50, HQ1/100, and HQ 1/250.



Project partners
UTU = Univ. Turku
SYKE = Finnish Environment Institute

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Modelling future discharges
(hydrological modelling)

- Hadley and Echam GCMs, different emission scenarios
- Daily future discharges modelled with “Watershed simulation and forecasting system WSFS” by Finnish Environment Institute
  - Control data: measured hydrological data from 1971-2000
- Flood frequencies: Gumbel's distribution
  - Control period 1971-2000 and years 2070-2099

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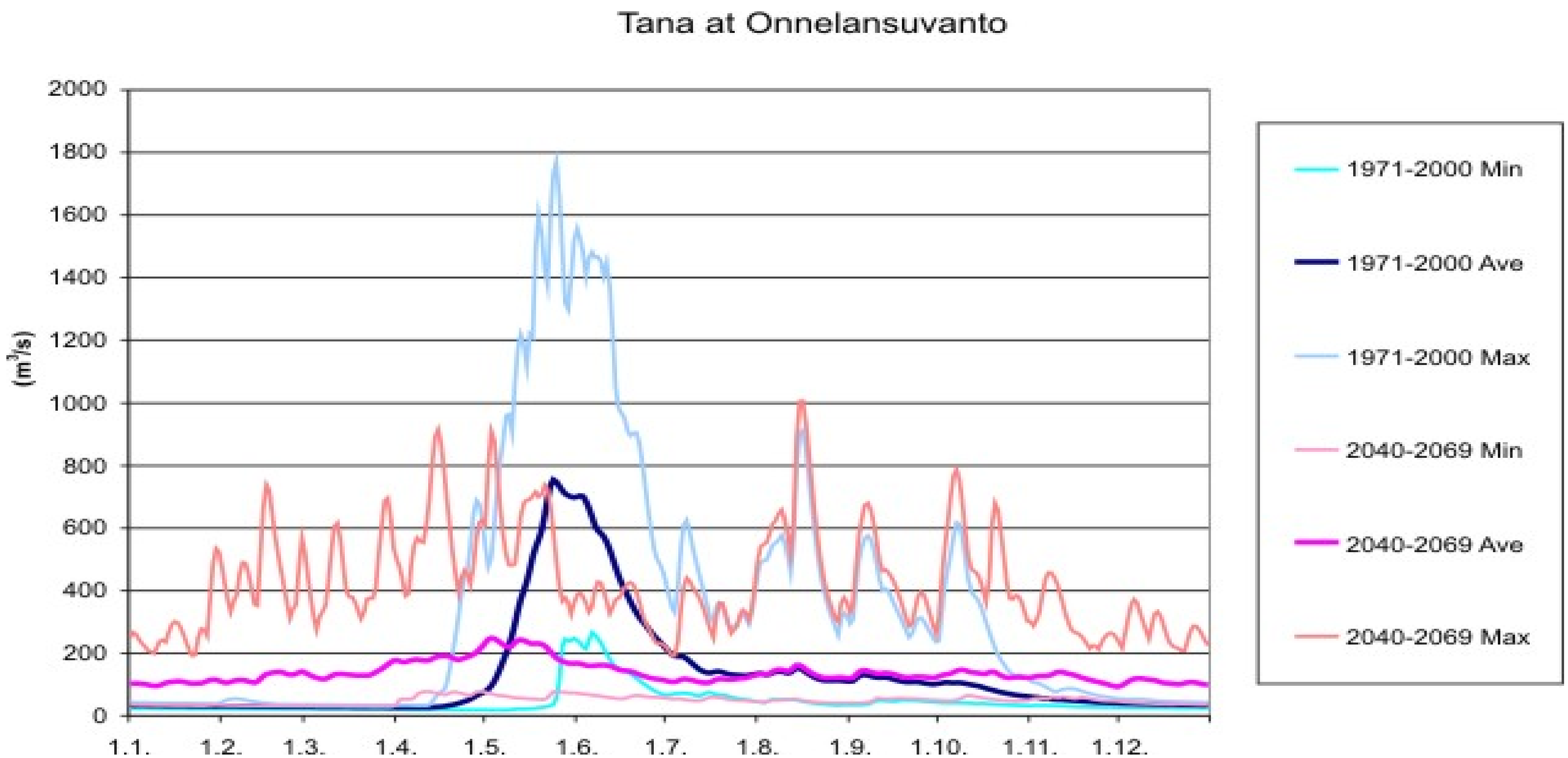
Future hydrological conditions

- Maximum spring flood will diminish and occur earlier in the spring
- In most discharge scenarios, the future 1/250a flood decreases to the level of 1/20a discharge in the control period



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Mapping future floods
(hydraulic modelling)

- For discharge, we use a doppler device (Sontek River Surveyor)
- For channel bathymetry, we employ echo sounding with RTK-GPS, plus
- Ongoing tests with bathymetry modelling based on aerial photographs
- Subaerial part of the channel (= river banks, flood plains) mapped with laser scanning; ground-based and from a vessel
- When repeated, scanning can be used for monitoring changes in geometry
- Discharge information employed in 1D (and in the future, 2D) hydraulic modelling
- Future discharges modelled with 1D hydraulic modelling
    - Standard step method, HEC-RAS
    - Steady flow analysis (subcritical) performed based on selected 1/250a flood discharges for years 2070-99.
- Results of the modelling exported into GIS for flow distribution and stream power calculations

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Doppler discharge measurement device (SonTek) at Pulmanki tributary, May 2007

Remotely sensed bathymetry

- True colour aerial photography, 0.5 m resolution
- Clear water is imperative
- *Lyzenga algorithm* is employed to isolate depth signal in reflectance values for each band
- Multiple regression:

  echo-sounded depths ~ Lyzenga adjusted reflectance
- model can also be used for removing depth signal to map bottom characteristics instead

method based on: Winterbottom, S. J. & Gilvear, D. J. (1997), 'Quantification of channel bed morphology in gravel-bed rivers using airborne multispectral imagery and aerial photography', Regulated Rivers-Research & Management 13, 489–499.

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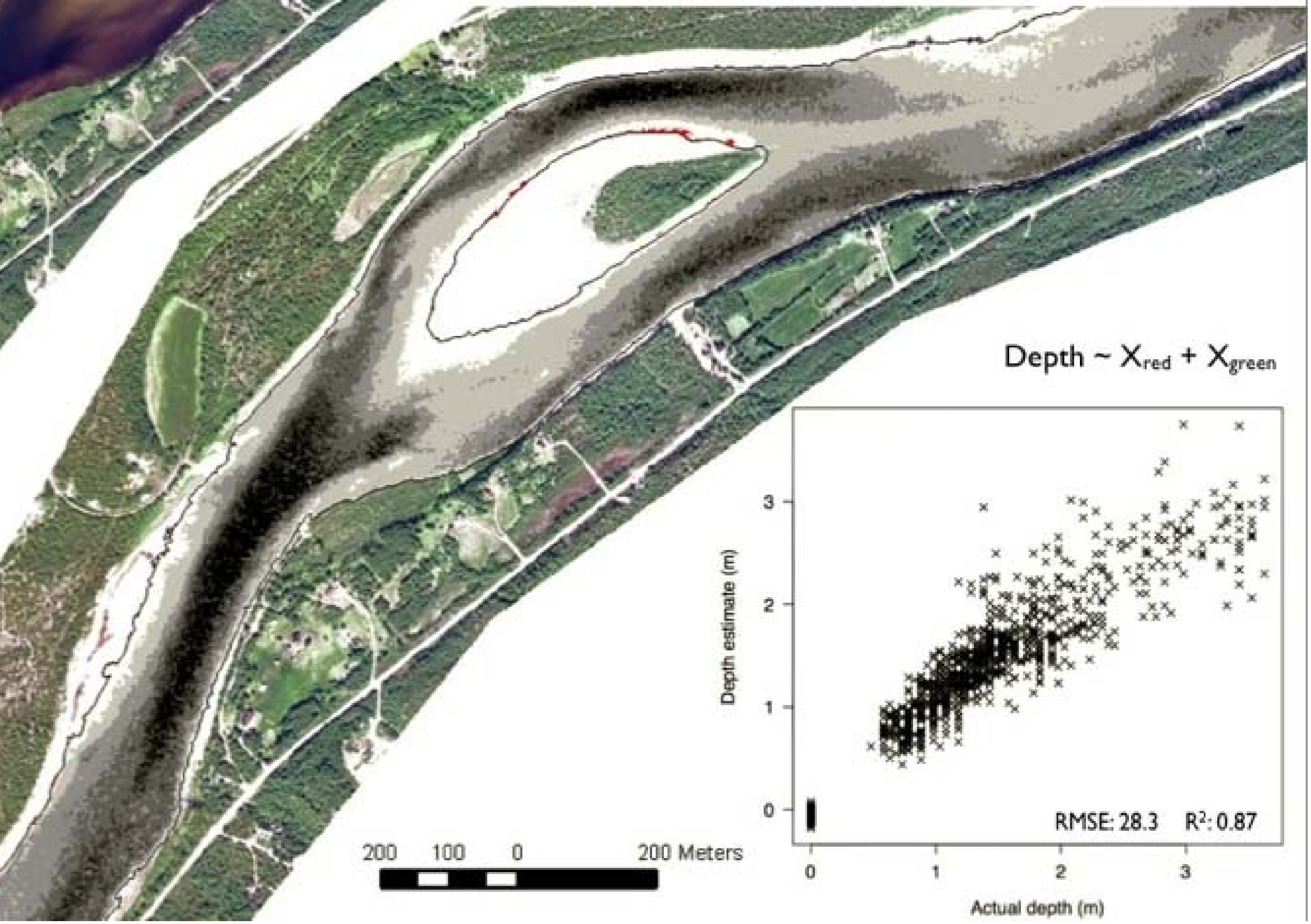
Empirical bathymetry model

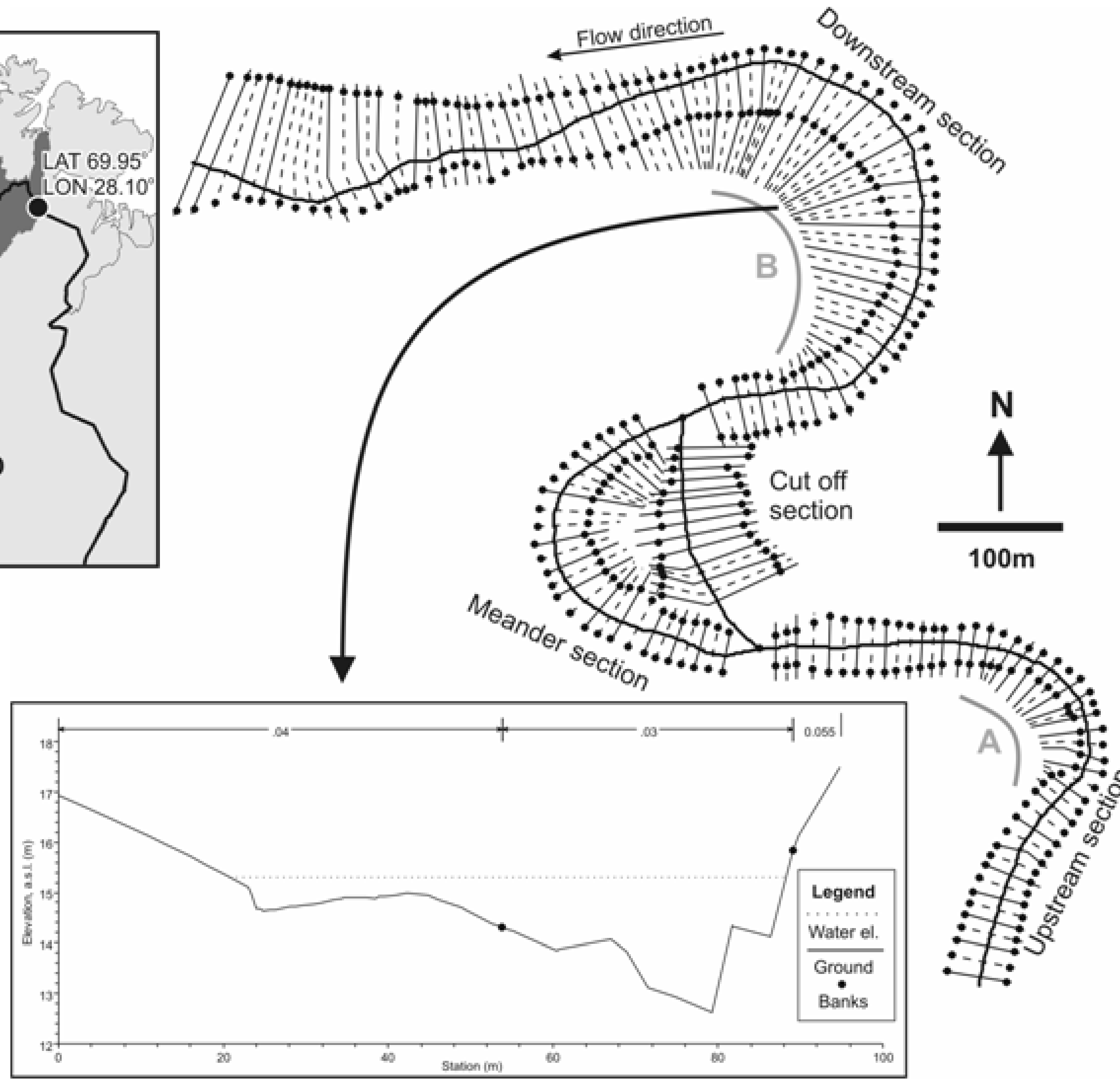


Terrestrial laser scanning equipment attached to a dinghy at Pulmanki tributary, 27 Aug 2008

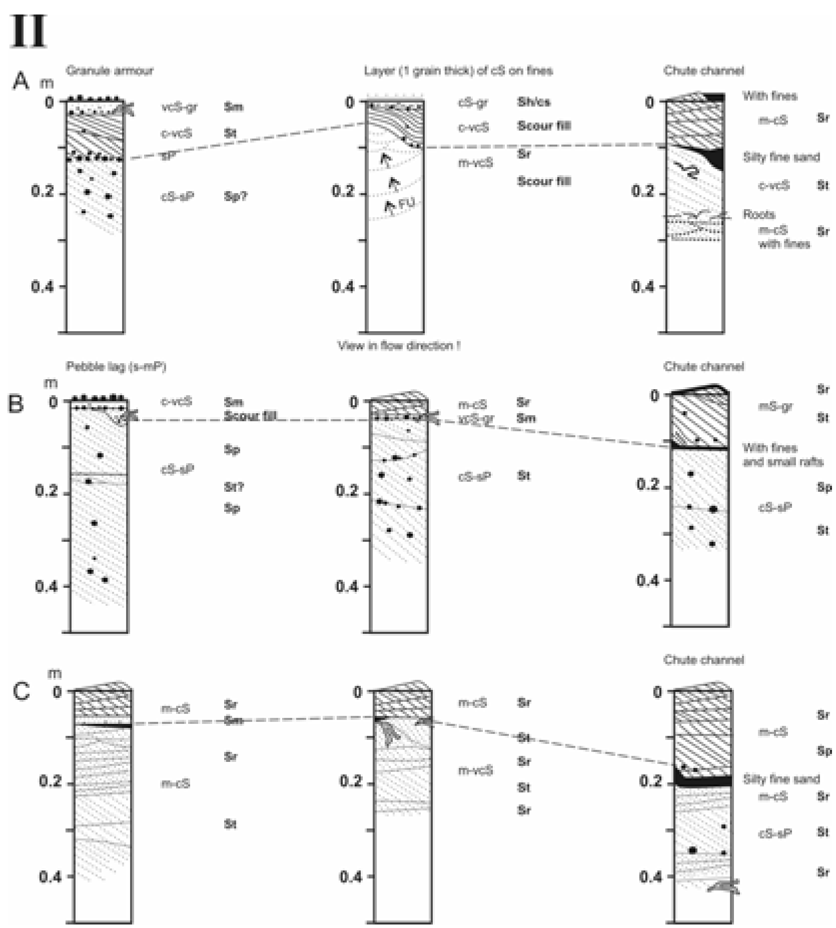
An example visualisation of terrestrial laser scanning campaign, 30 Aug 2008

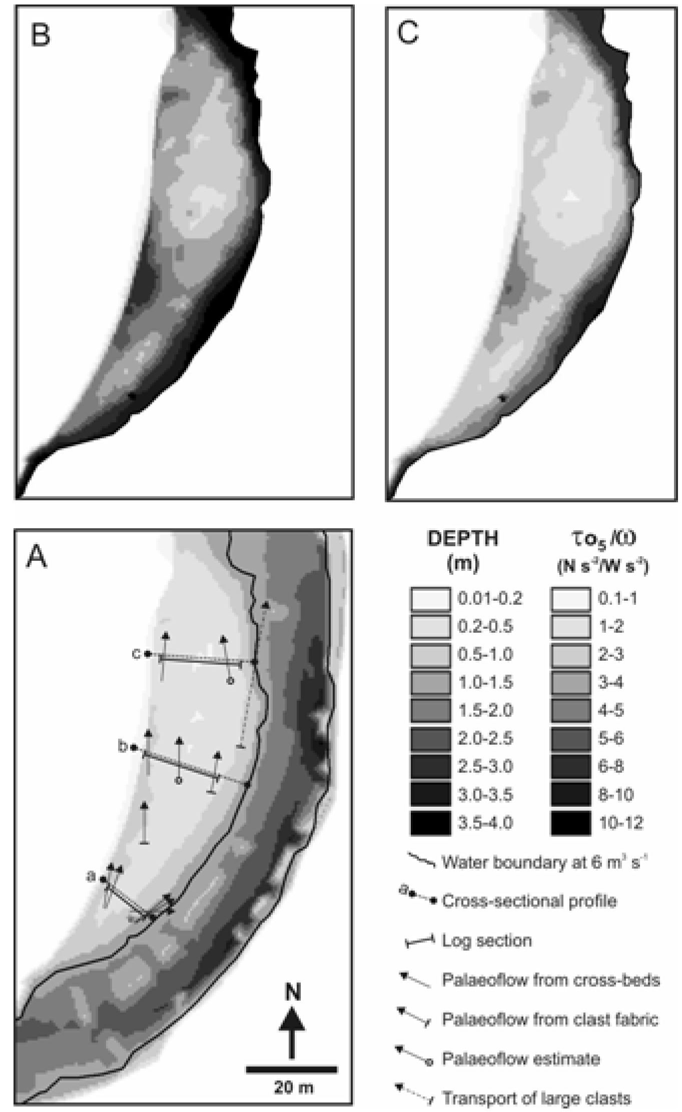
Combining 1D hydraulic modelling (HEC-RAS) with actual sedimentary structures:

a pilot study at highly meandering Pulmanki tributary of Tana



Sediment structures vs. model results of shear stress and stream power





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Some concluding remarks

- Hydrological scenarios
  - Peak spring floods will be subdued “dramatically” also in Lapland
  - Instead, relatively high discharge during winter and autumn, and somewhat higher annual averages
  - Large uncertainties are related to e.g. ice jams and frazil ice formation
- Hydraulic modelling & sediment dynamics
  - The hydraulic+GIS modelling method may prove applicable in sediment dynamics work aiding in understanding the channel evolution
  - This approach is, however, computing intensive: 2D modelling required, applicable only for limited stretches

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Kiitos mielenkiinnosta!

Further information on our website:

www.extreflood.fi

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