

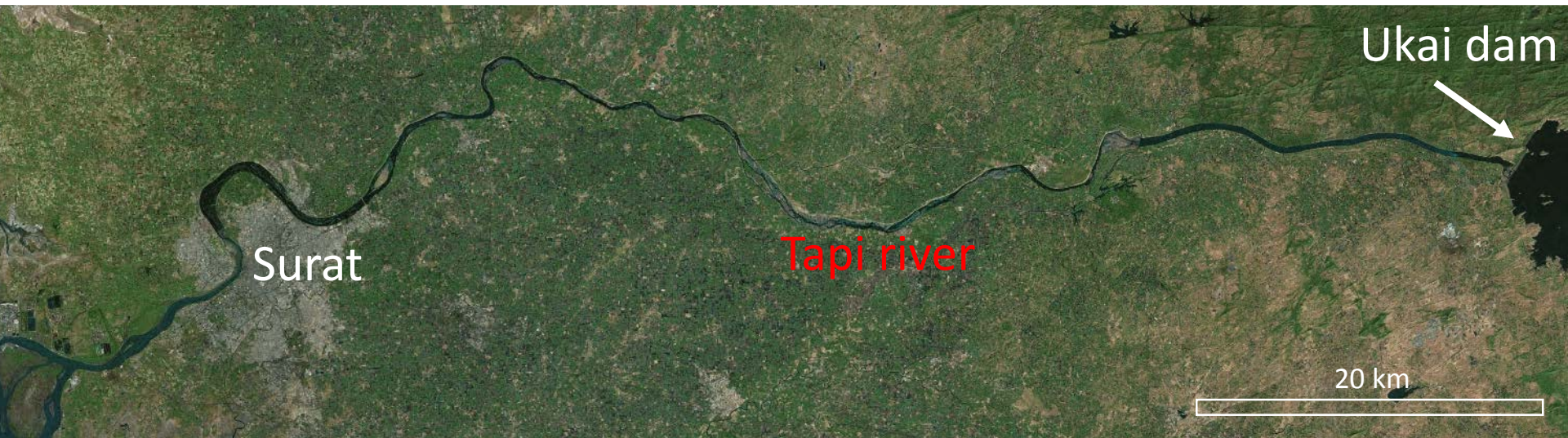
Estimating urban flood exposure: Application to extreme events in Surat, India



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Tom J. Coulthard, Margreth Keiler

u^b

Study site



Tapi river reach

- Northwest India
- From the Ukai dam to the Arabian Sea
- 120 km of the Tapi river

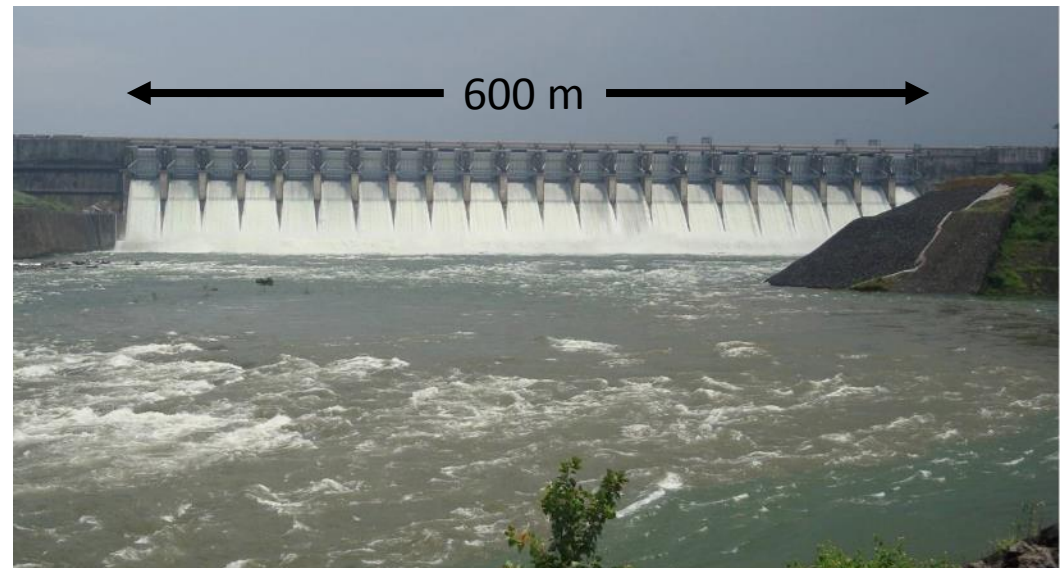


Study site



Ukai dam

- Irrigation
- Power generation
- Flood control
- Year completion: 1972
- Max discharge: $46,000 \text{ m}^3 \text{ s}^{-1}$



Study site



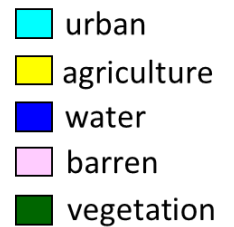
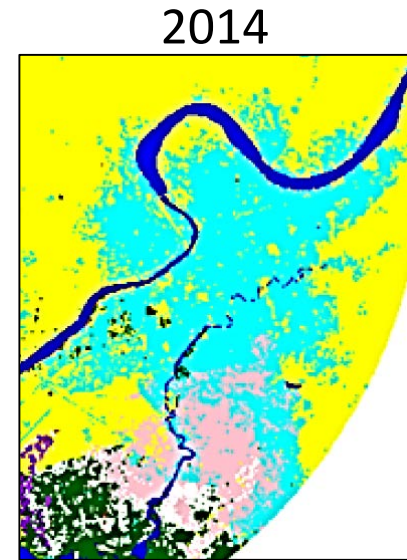
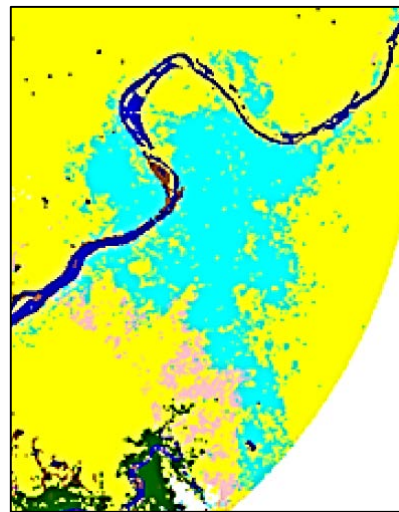
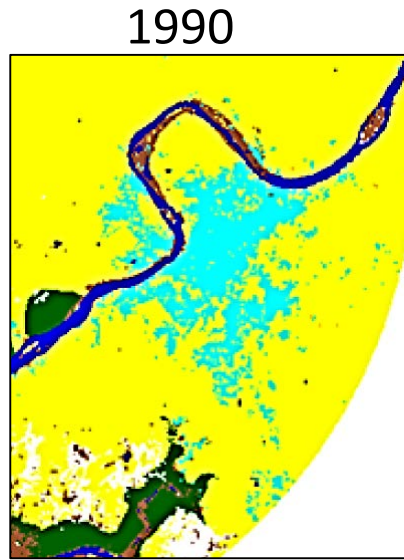
Surat

- 7th largest city in India
- Major industrial and commercial center and port
- Area: 325,000 km²
- Population: 3 million
- Bisected by Tapi river

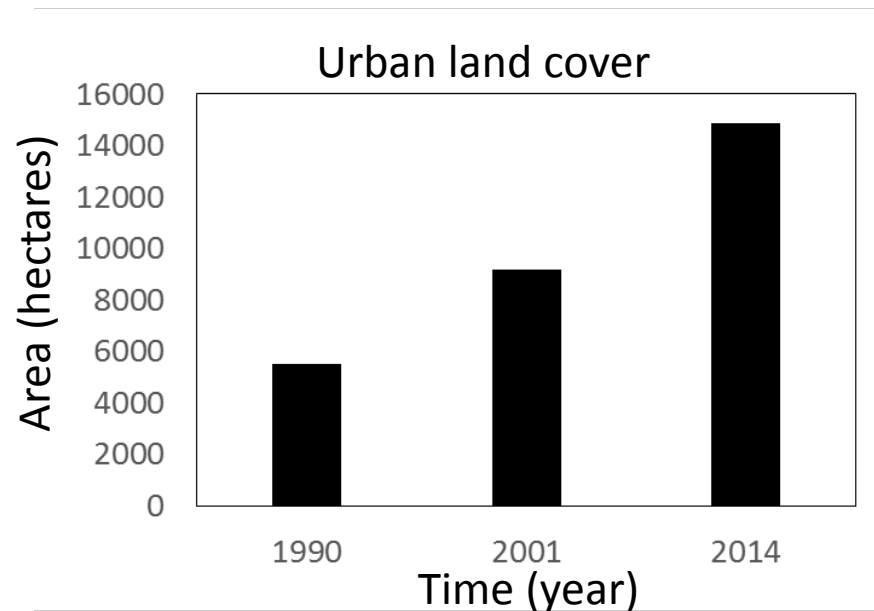


Study site: Surat

Surat land cover

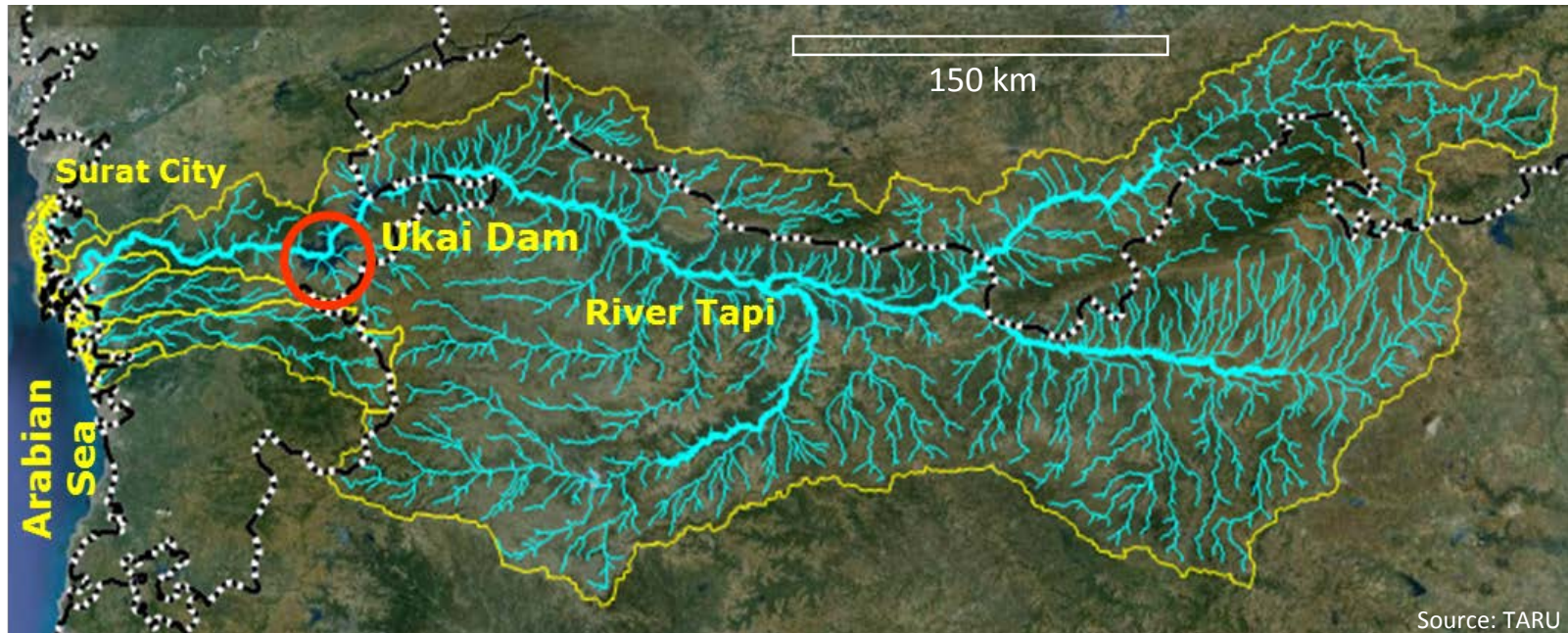


- Increase in urban area, construction in the floodplains, construction of embankments
- 170% increase in urban land cover in 25 yrs



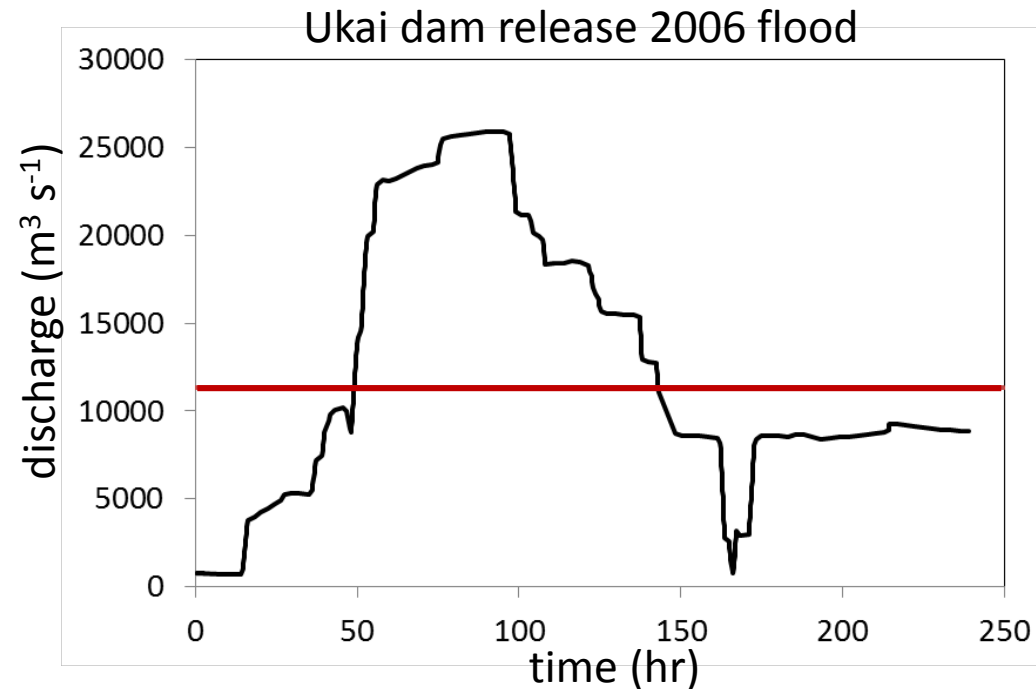
Upstream from Ukai dam

- Catchment area: 62,000 km²
- Tapi river is fed by monsoonal rains
- 90% of the annual rainfall is received during the monsoon months (June to October)
- Average annual rainfall: 830 mm



- Difficult to prevent flooding in Surat and also manage dam for irrigation and hydropower
- **5 major floods since the construction of the dam (1972)**

Surat flood 2006

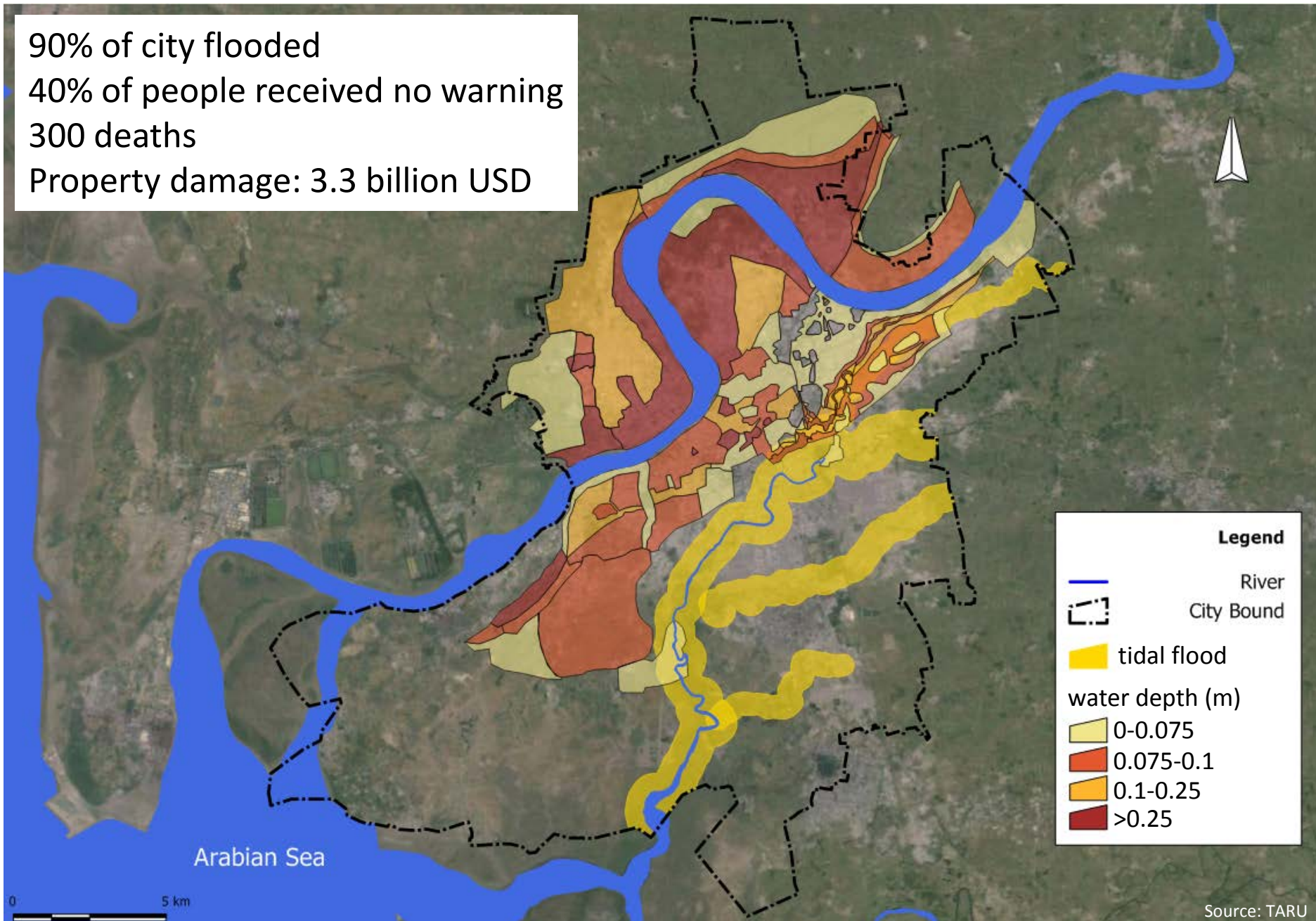


- Intense rainfall in the Tapi catchment
- Max. reservoir capacity during monsoon
- Dam release near $25,000 \text{ m}^3 \text{ s}^{-1}$
- Release lasted 15 days
- Release exceeded flood warning discharge for Surat ($11,000 \text{ m}^3 \text{ s}^{-1}$)

— Flood warning discharge

Surat flood 2006

90% of city flooded
40% of people received no warning
300 deaths
Property damage: 3.3 billion USD



Surat flood 2006



Objectives

A first step towards strengthening resilience in Surat requires:

- Mapping critical infrastructure exposed to flooding
- Raising awareness of flood exposure to the public

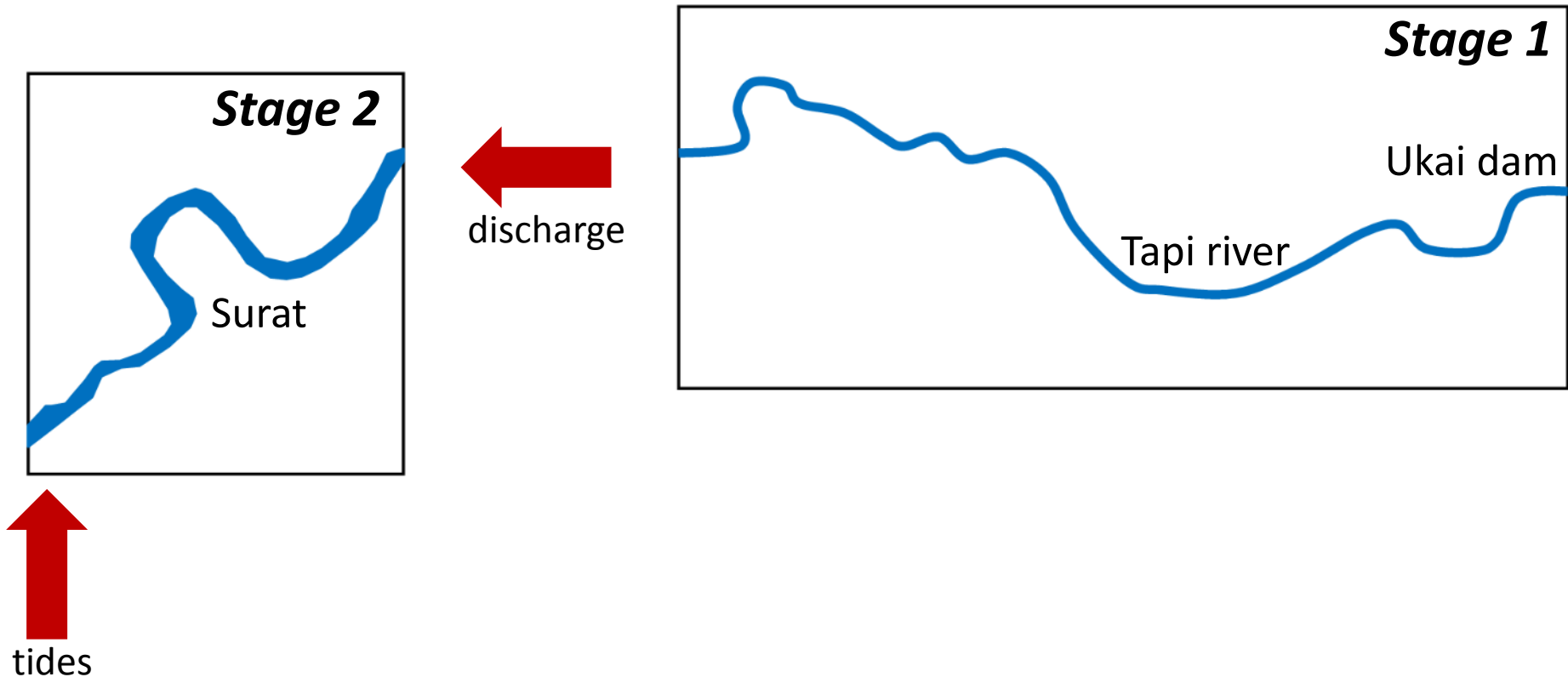


Method

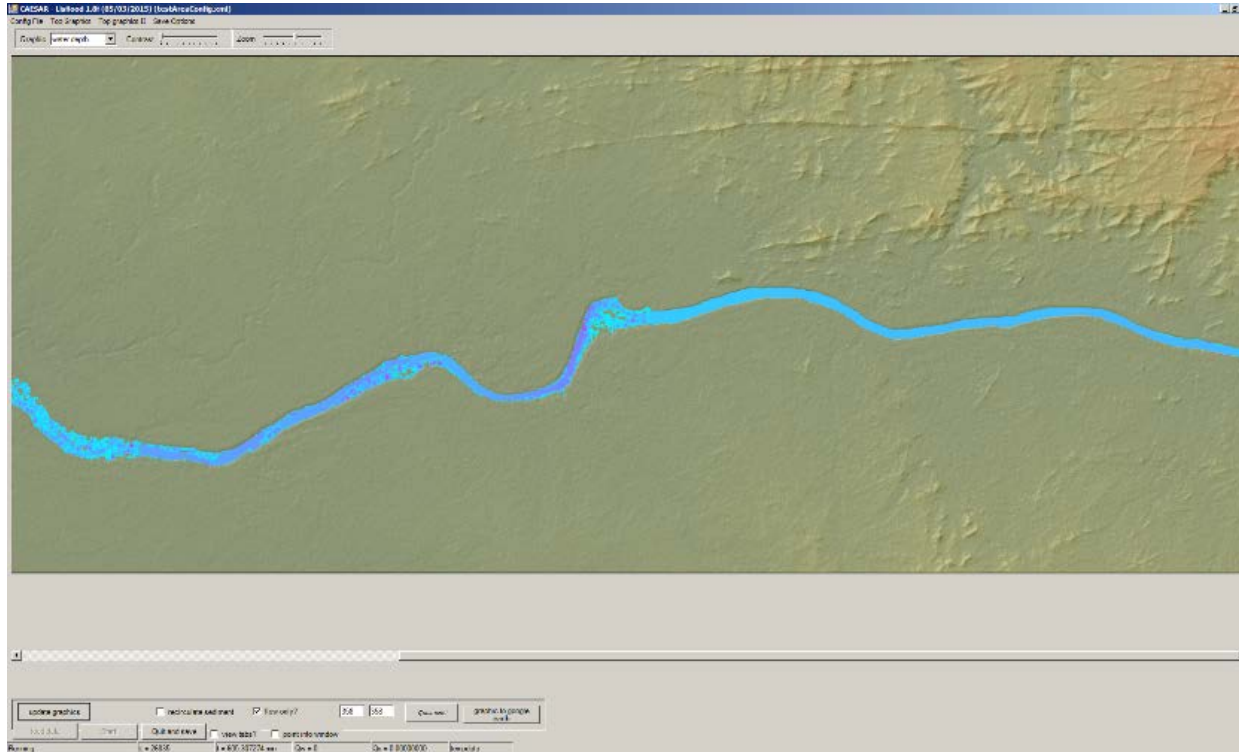
Use CAESAR-Lisflood two dimensional flow model to simulate flooding in Surat

Two distinct stages:

- **Stage 1:** Model the flow of water from the Ukai dam to the city of Surat
- **Stage 2:** Model flood inundation in Surat



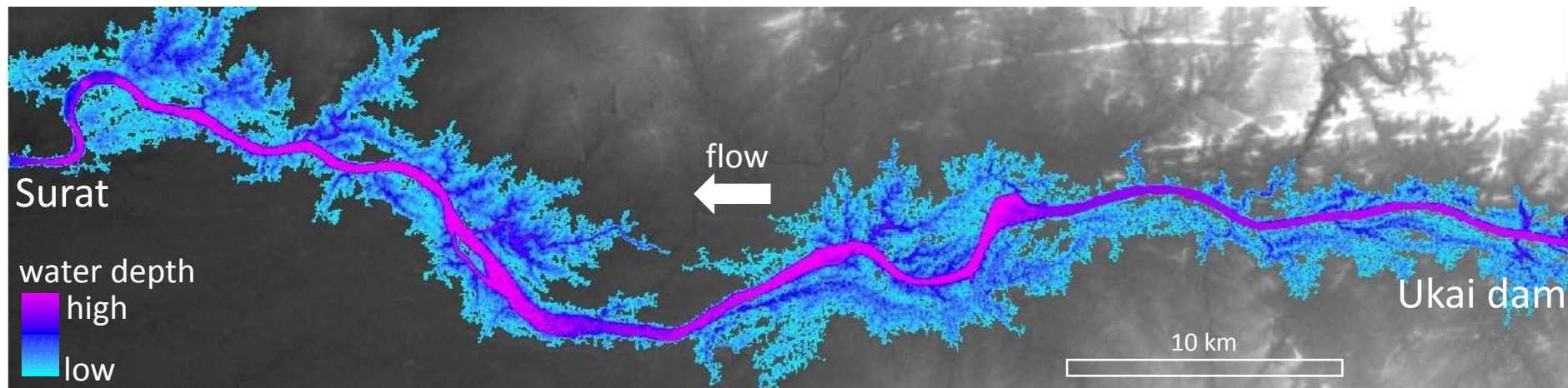
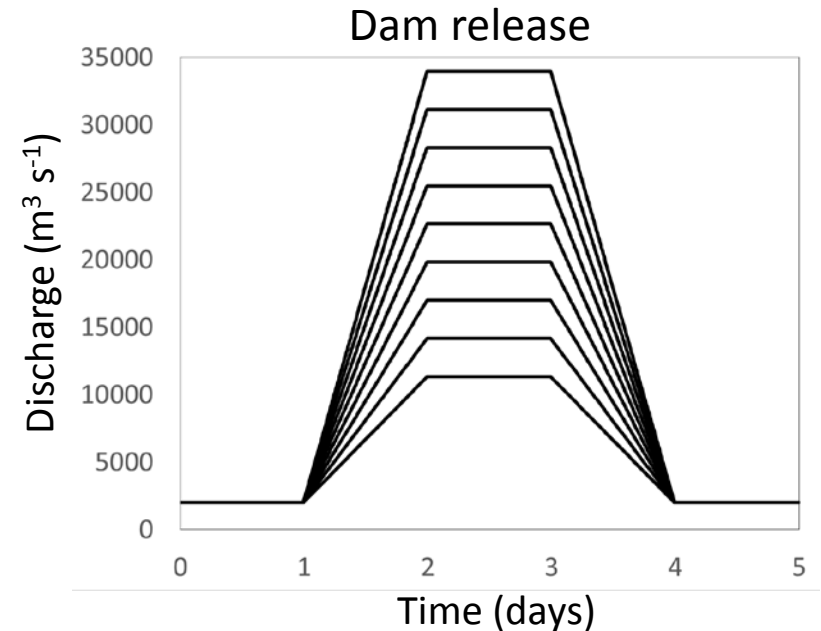
CAESAR-Lisflood



- CAESAR-Lisflood is a storage cell model, where a Digital Elevation Model (DEM) represents the landscape and water is stored at the raster cell locations
- Water is routed over the landscape in the X and Y directions (2D) from raster cell to cell using a simplification of the shallow water equations
- Open source
- Low computational demands
- Low data requirements

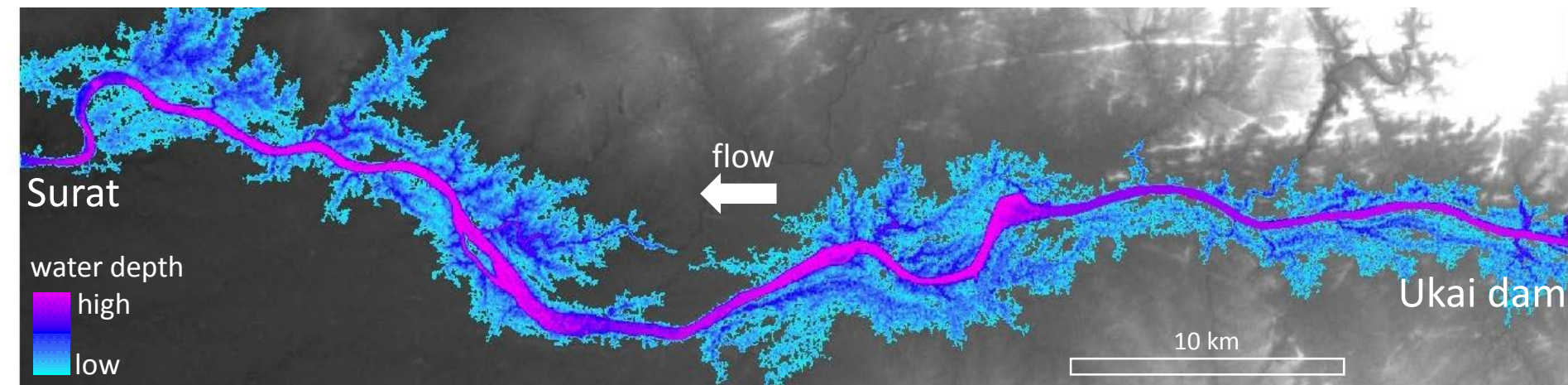
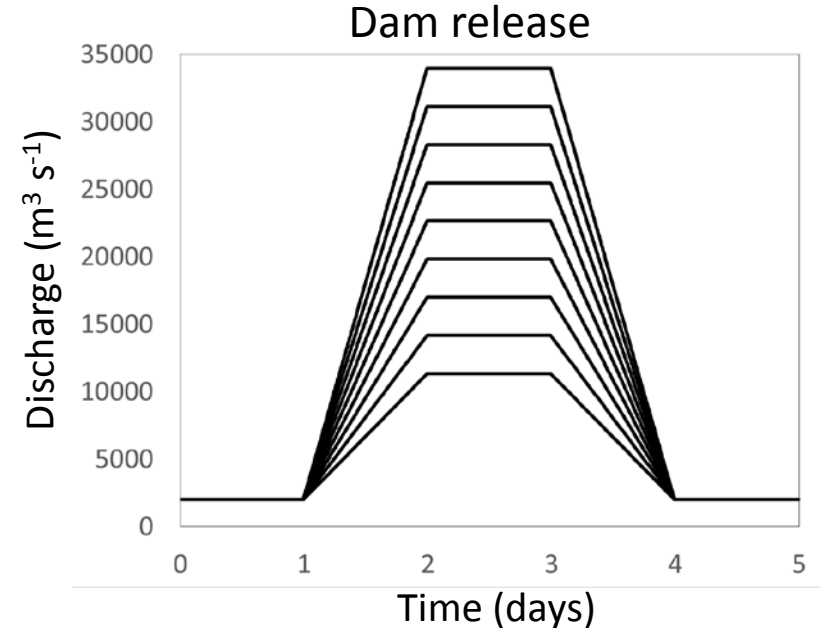
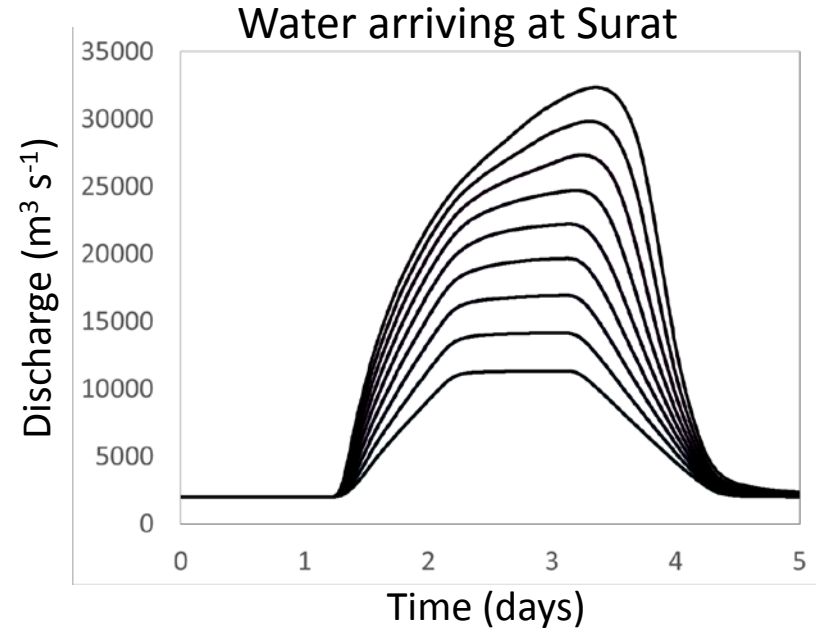
Stage 1: Modelling Ukai dam to Surat

- Digital elevation model (DEM): SRTM 30 m
- 9 synthetic dam releases, with different peak discharge
- Flooding reduces amount of water arriving at Surat



Stage 1: Modelling Ukai dam to Surat

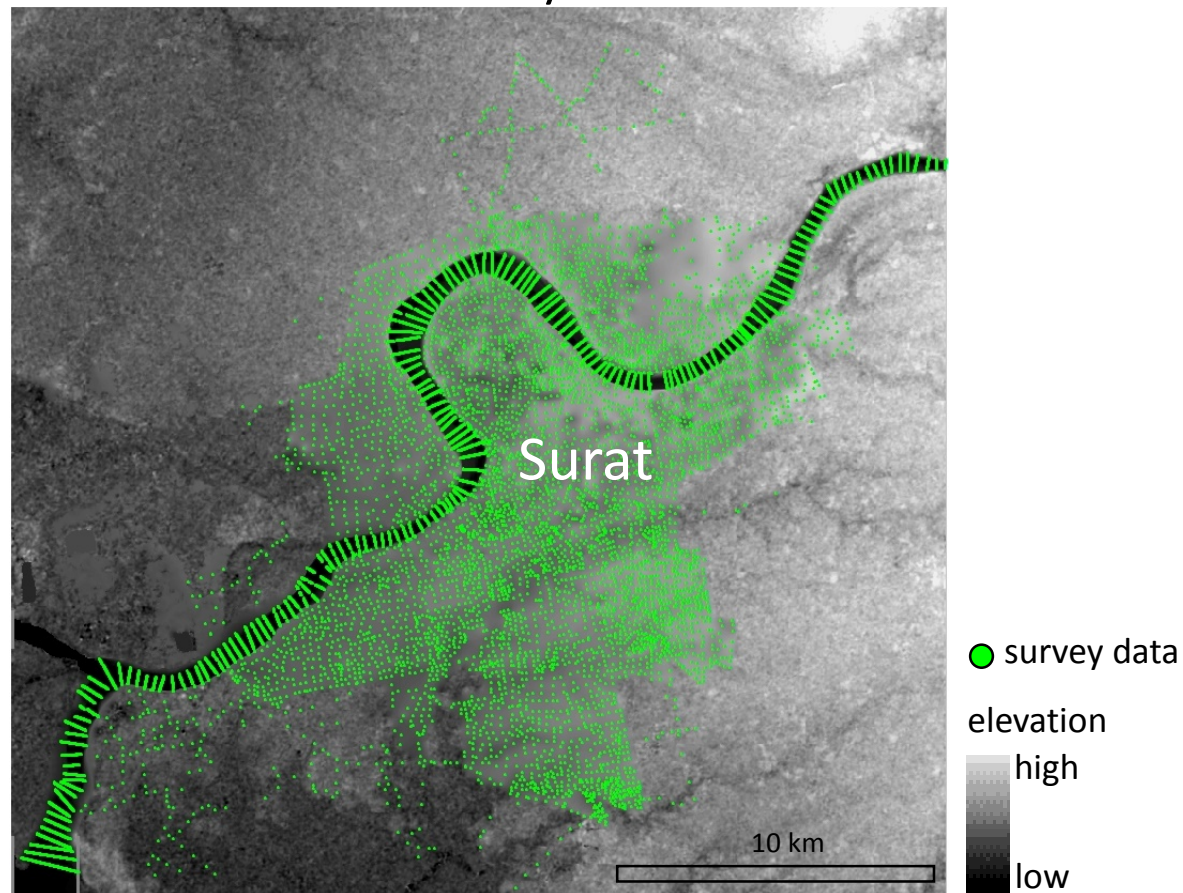
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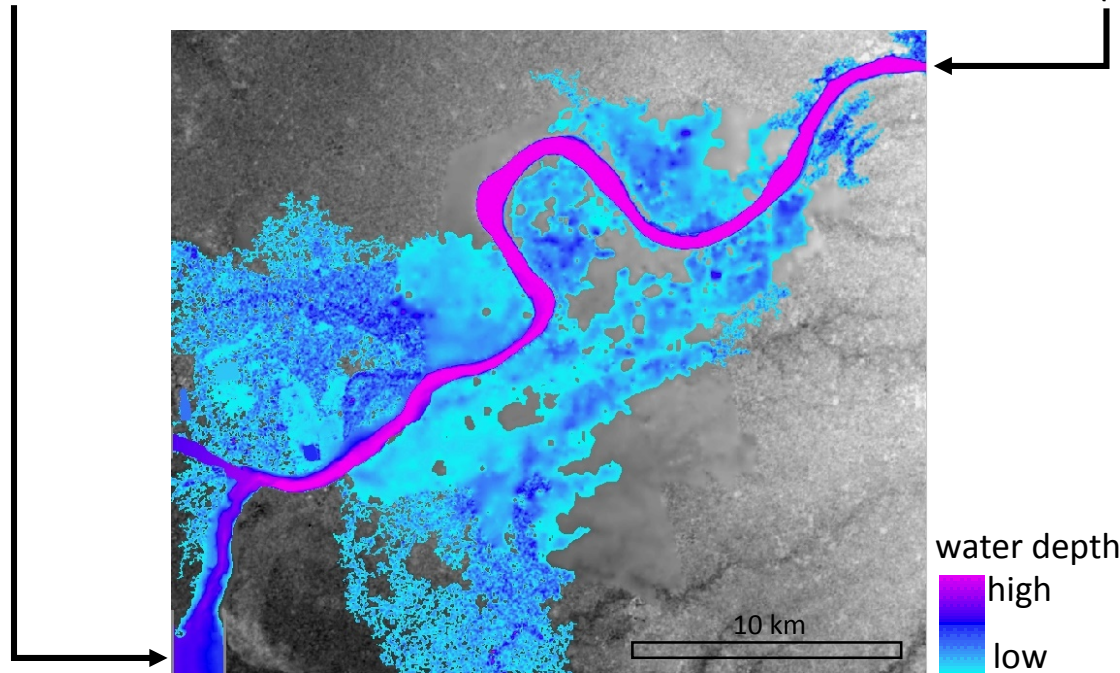
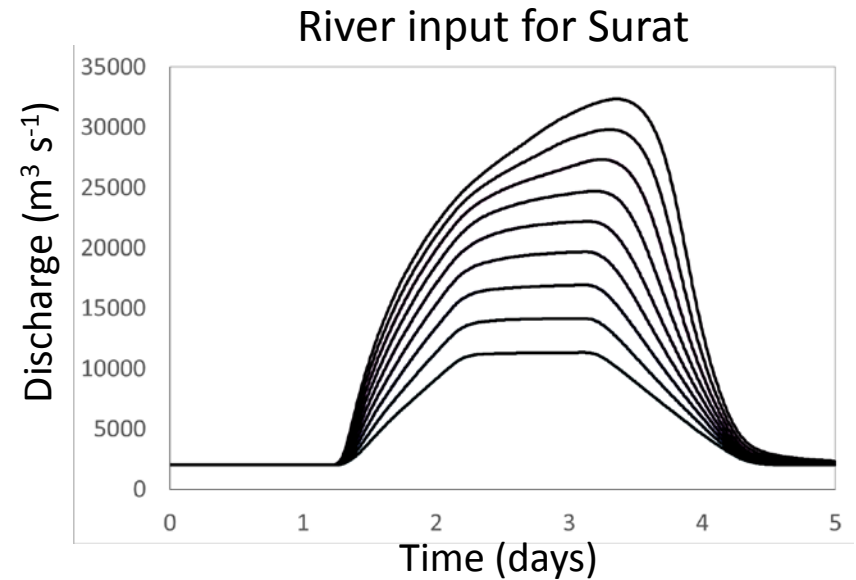
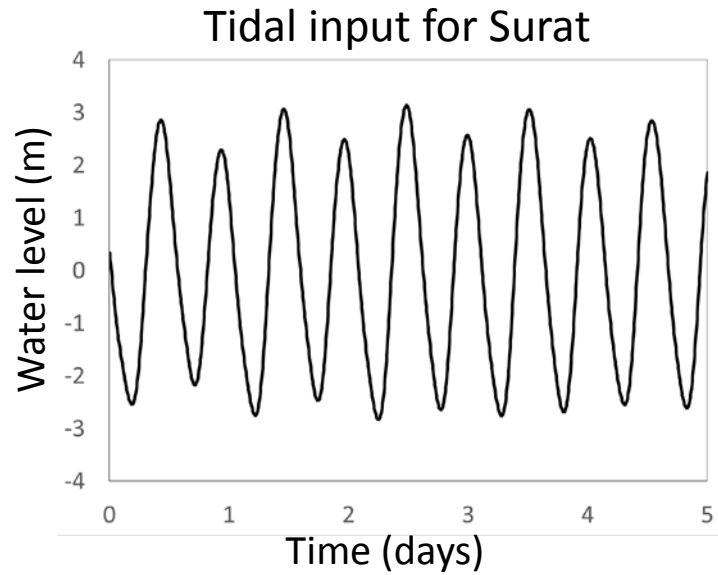
Stage 2: Modelling flooding in Surat

- Ground survey to acquire 6,200 point elevations
- 172 river bed cross-sections collected to represent the river bed elevations
- Ground survey interpolated to represent bare Earth at 30 m spatial resolution
- Outside of the city limits elevation information was obtained from a 30 m SRTM DEM

Bare earth city DEM



Stage 2: Modelling flooding in Surat

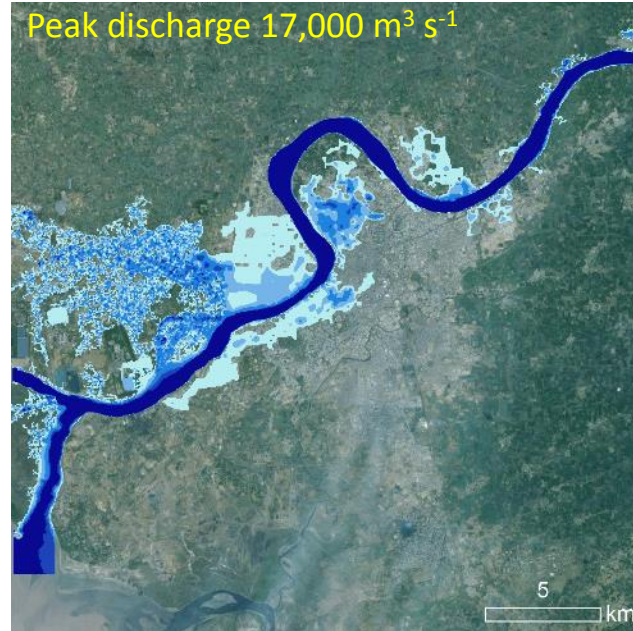
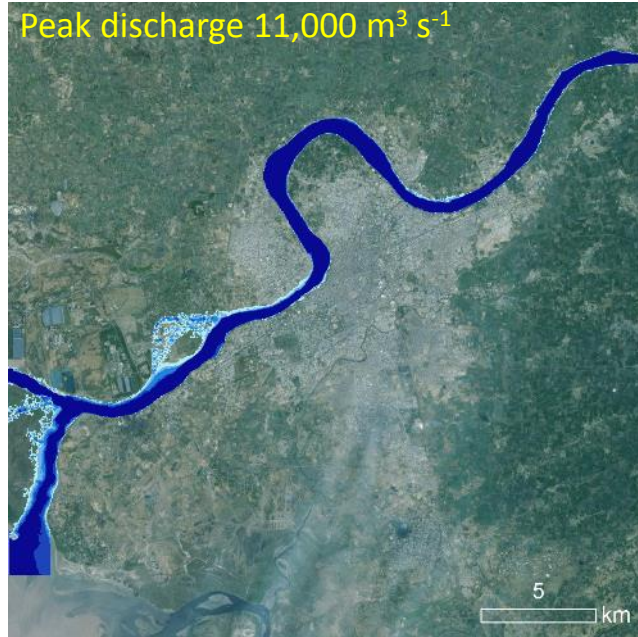


Stage 2: Modelling flooding in Surat

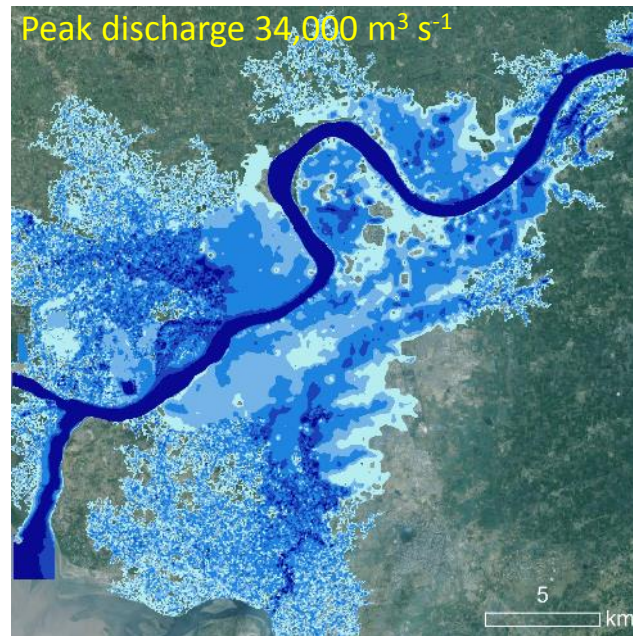
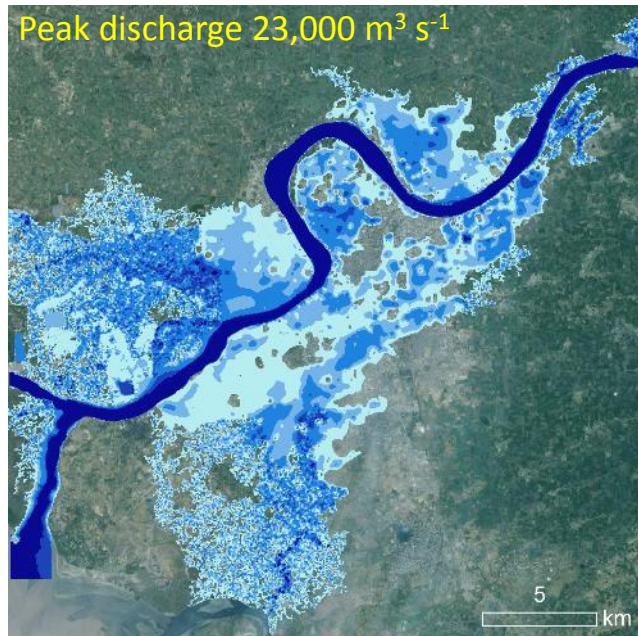


Flood scenario with peak dam release of $23,000 \text{ m}^3 \text{ s}^{-1}$

City flooding



- Flood maps represent maximum water depth at each DEM location
- Simulated flood map quality verified by Surat city engineers



Water depths (m)

0-1

1-2

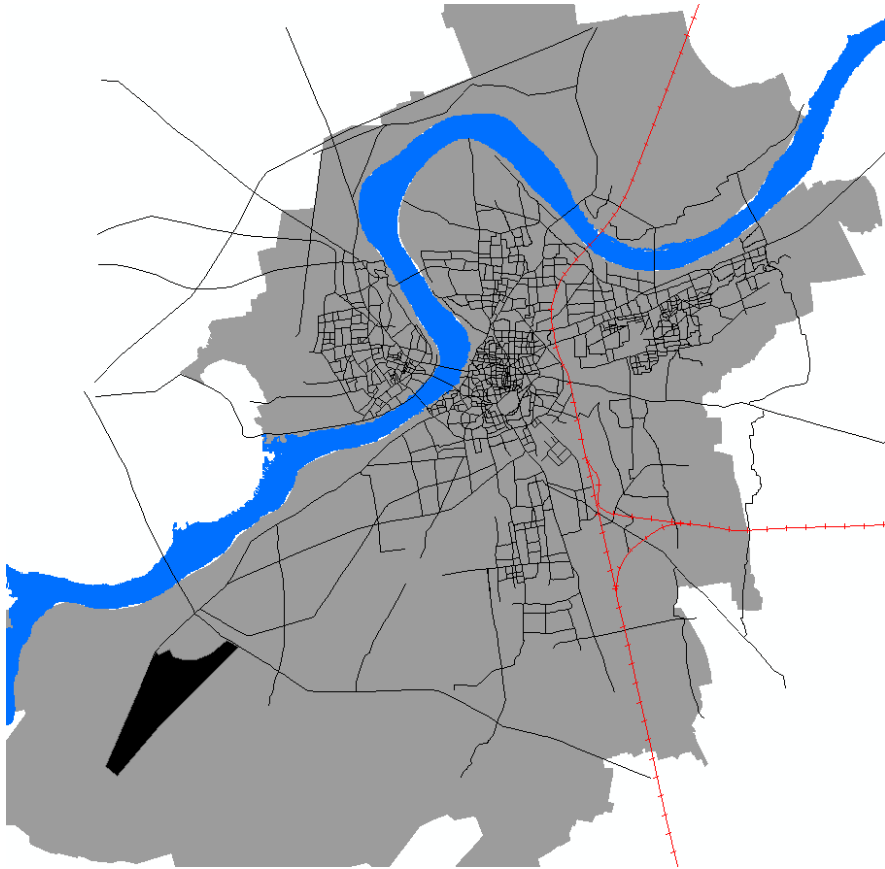
2-4

4-6

>6

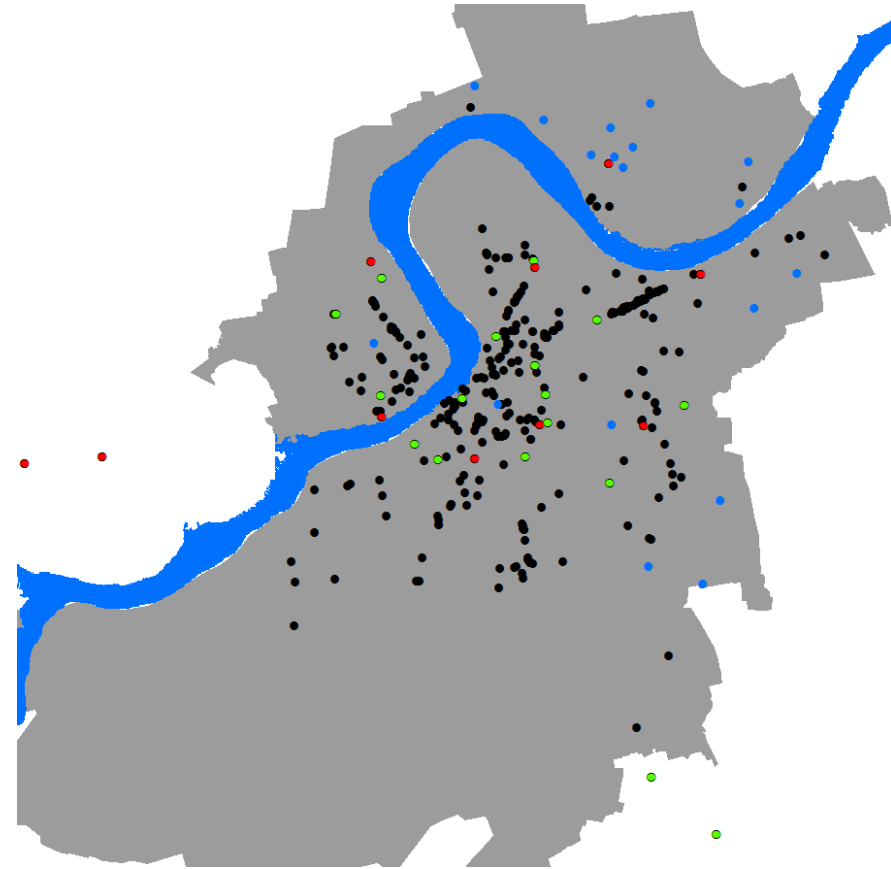
Critical infrastructure

Transport



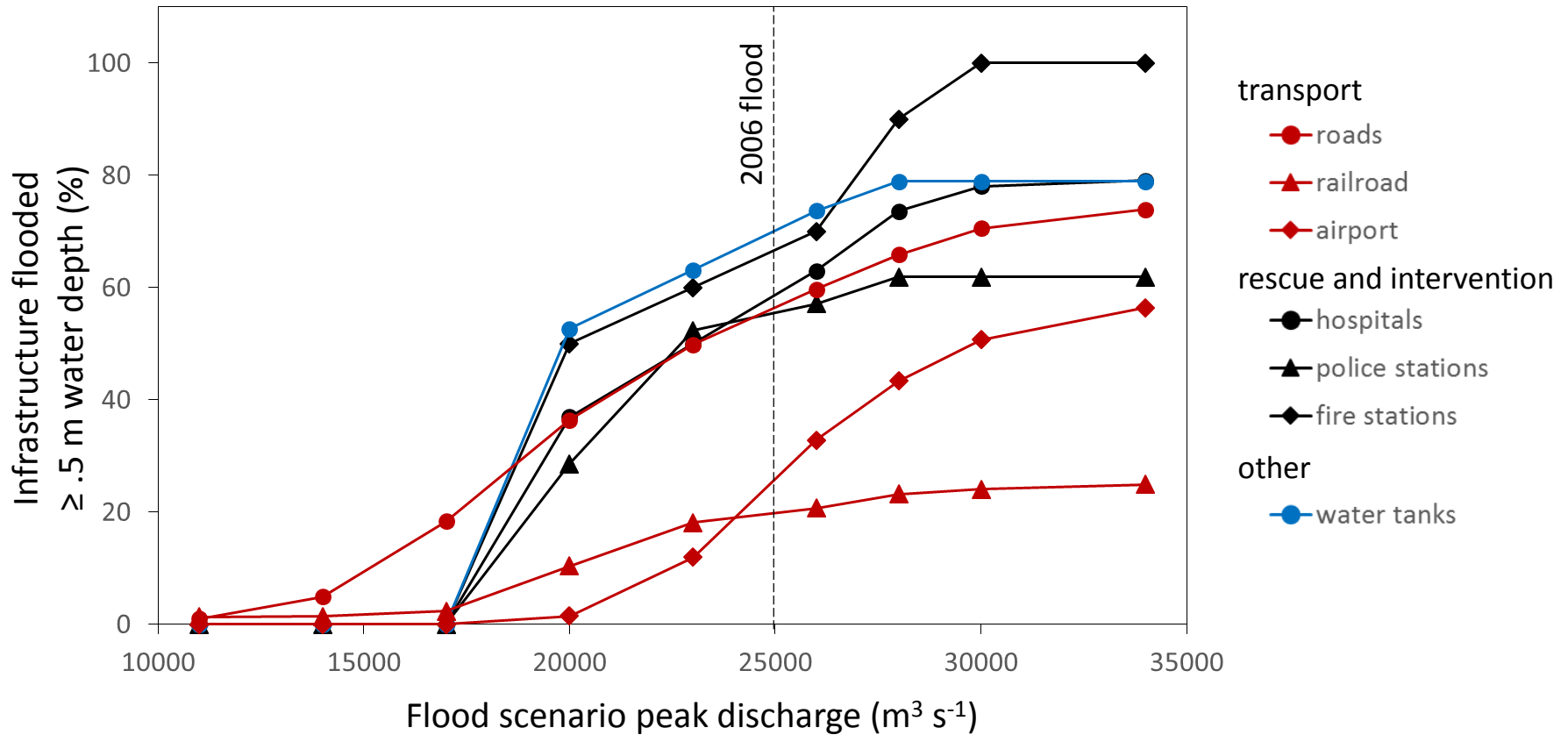
- roads
- + railroad
- airport

Rescue, intervention, and other



- hospitals (n=292)
- police station (n=21)
- fire station (n=10)
- water tanks (n=19)

Critical infrastructure exposure

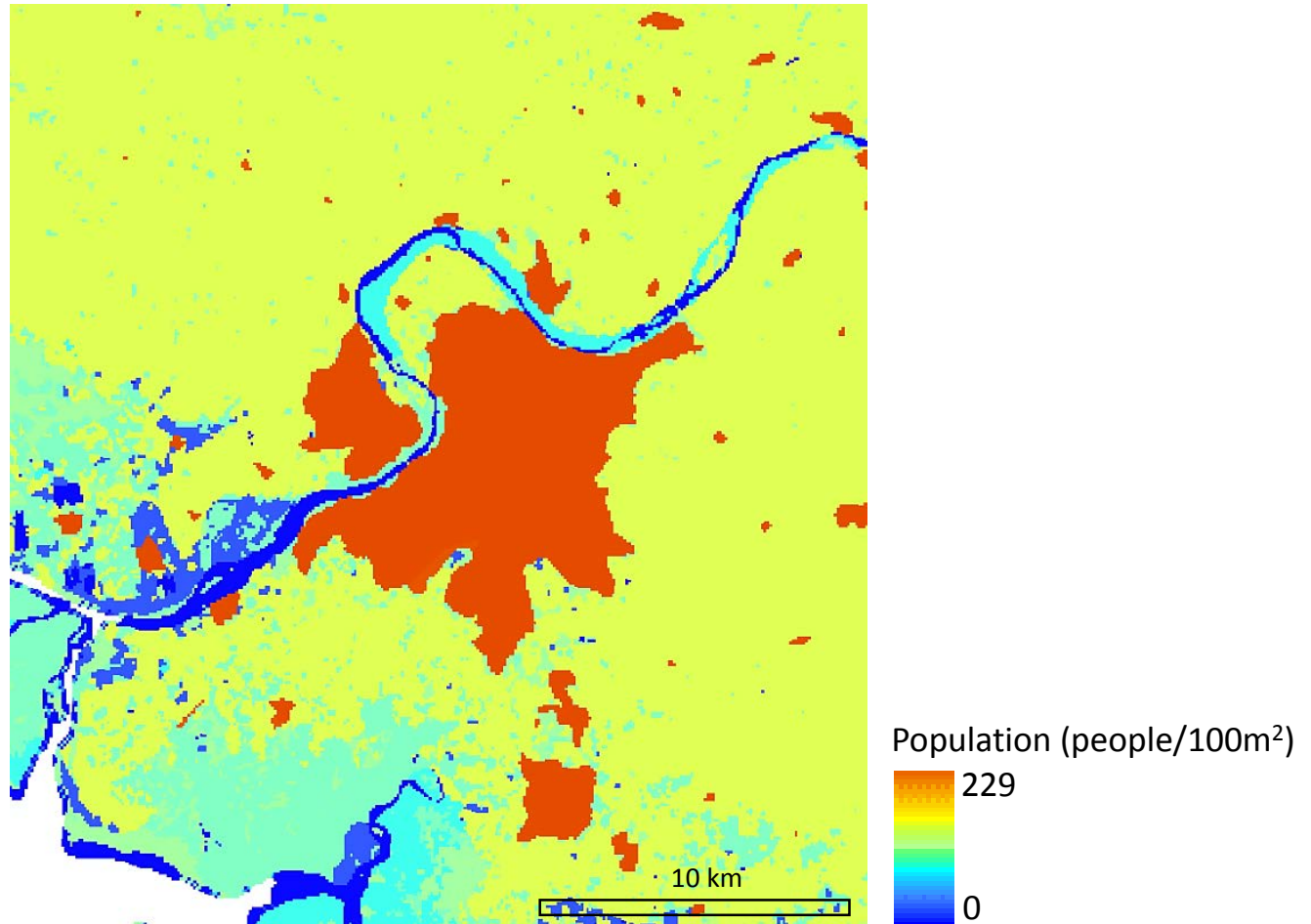


Dam releases 17,000 – 20,000 $\text{m}^3 \text{s}^{-1}$ exposure begins

Dam release of 25,000 $\text{m}^3 \text{s}^{-1}$ (2006 flood), majority critical infrastructure exposure is > 50 %

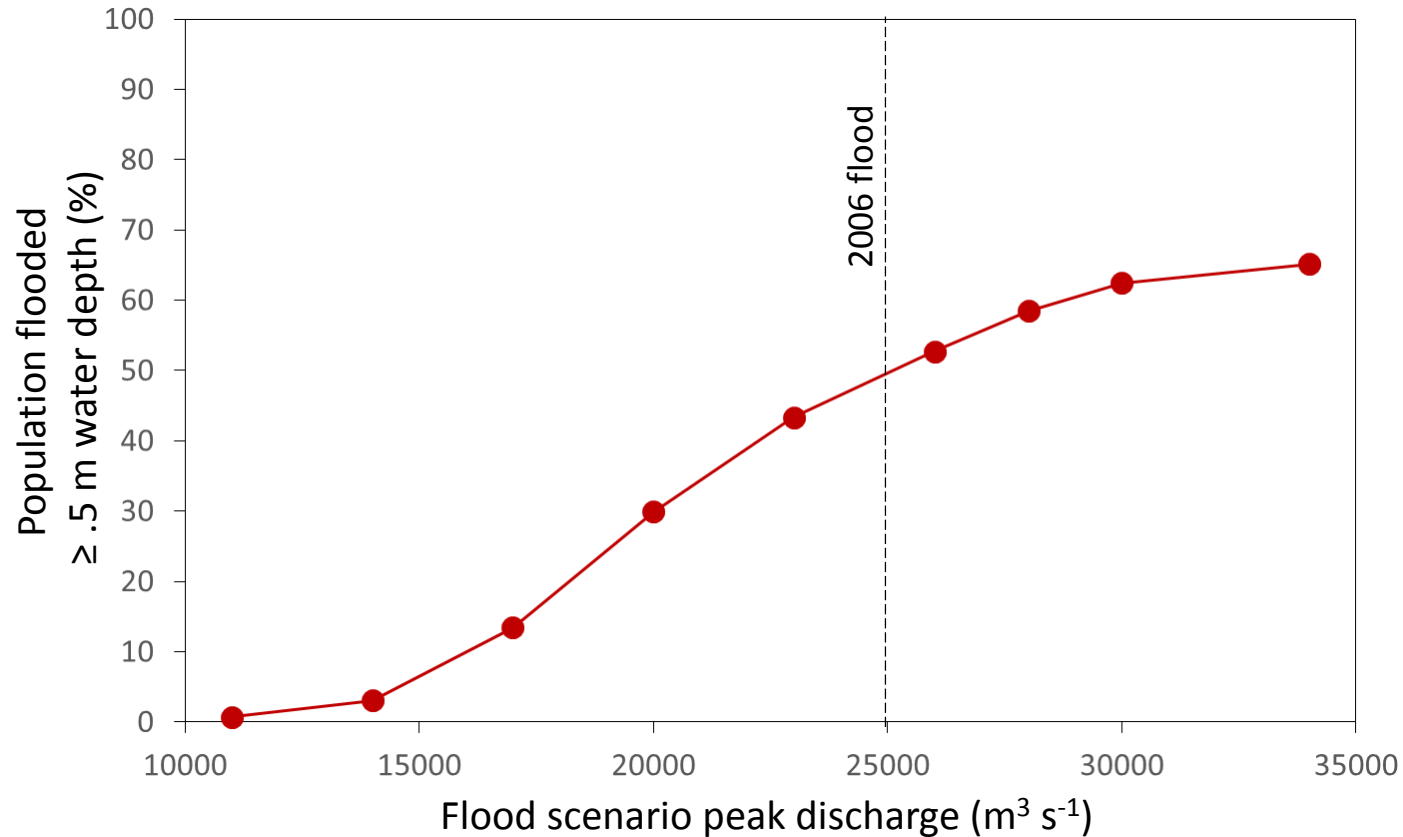
Population

2015 population estimates



Total population: 3 million

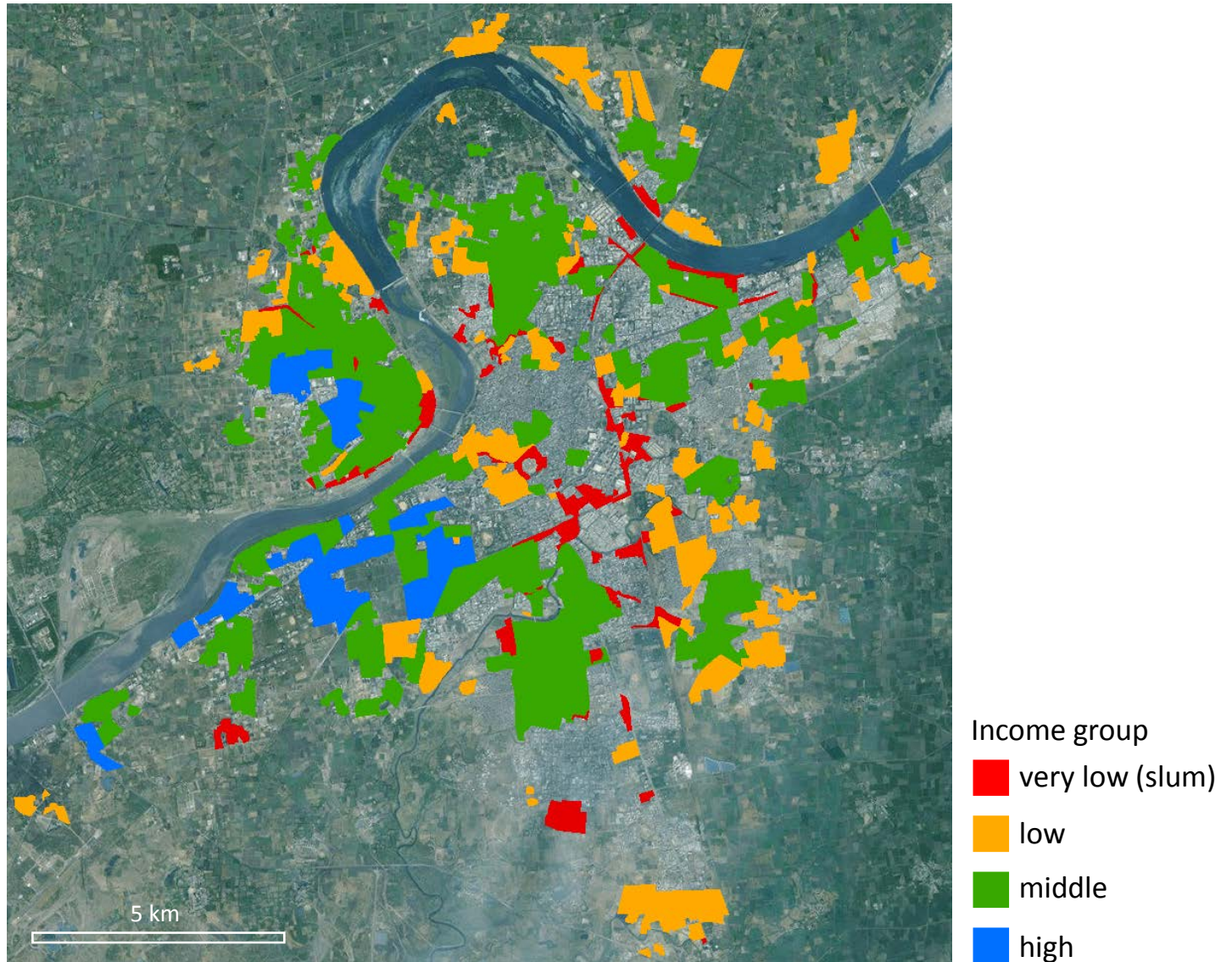
Population exposure



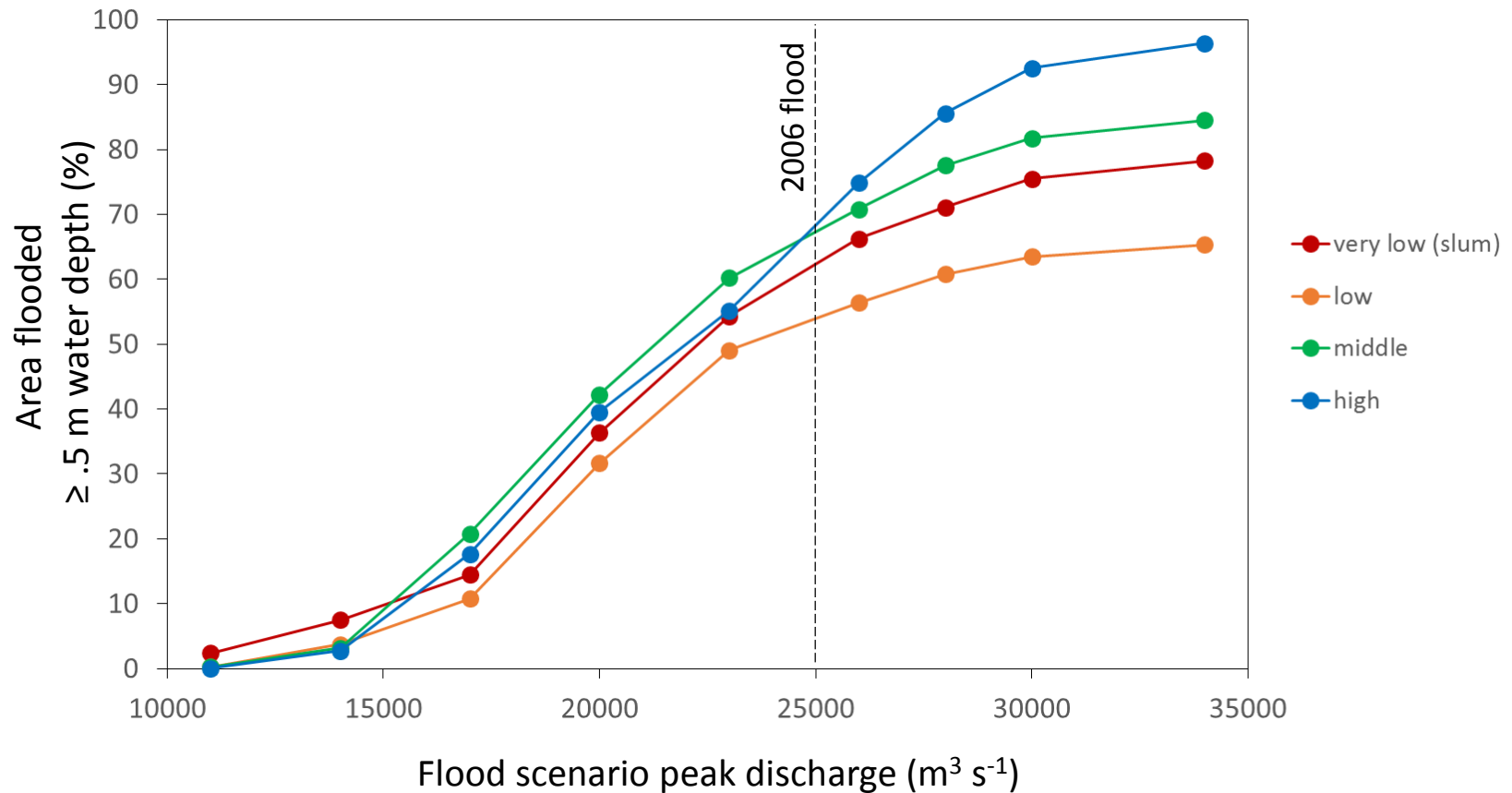
Total population: 3 million

Flood of 25,000 $\text{m}^3 \text{s}^{-1}$ (2006 flood), exposure is near 50 % (1.5 million)

Income group



Income group exposure



More exposure: High to middle income groups live proximate to the river

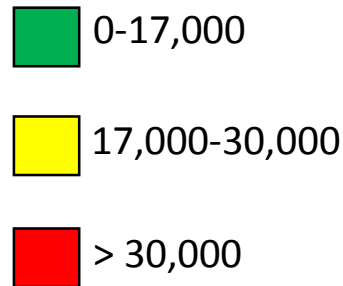
Less exposure: Low to very low income groups live in the periphery of the city, further from the river

Communicating flood exposure



- Modelled flood maps have been used to demarcate possible flood heights within the city
- City is developing a smartphone app that displays flood animations derived from modelled floods

Modelled flood scenarios ($\text{m}^3 \text{s}^{-1}$)



Lamp Post Number: GDR55
(Kala Mandir Ghdo Road)

Conclusions

- Large, but possible floods in Surat will expose:
 - more than 50% of the critical infrastructure to deep water
 - 1.5 million people to deep water
 - more middle to high income groups to deep water

