Geospatial Technologies for Flood Hazard Assessment in Pakistan

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SUPARCO

Ref: UNESCO Project Phase-I

Space Application Centre for Response in Emergency and Disasters (SACRED)

- The centre provides **space based information** to national / provincial disaster management agencies
- Rapid assessment of the **extent of natural disasters** and damages to human lives, property and infrastructure.
- The centre also provides assistance to regional countries in case of natural disasters.

Web: disasterwatch.sgs-suparco.gov.pk

Sequence of presentation

- Background
- Hydrological cycle overview
- Hydrological model classification
- Rainfall-runoff-inundation (RRI) model
  - Model overview
  - Input data requirements
- RRI model for indus river basin
- Flood Hazard Maps
- Conclusion

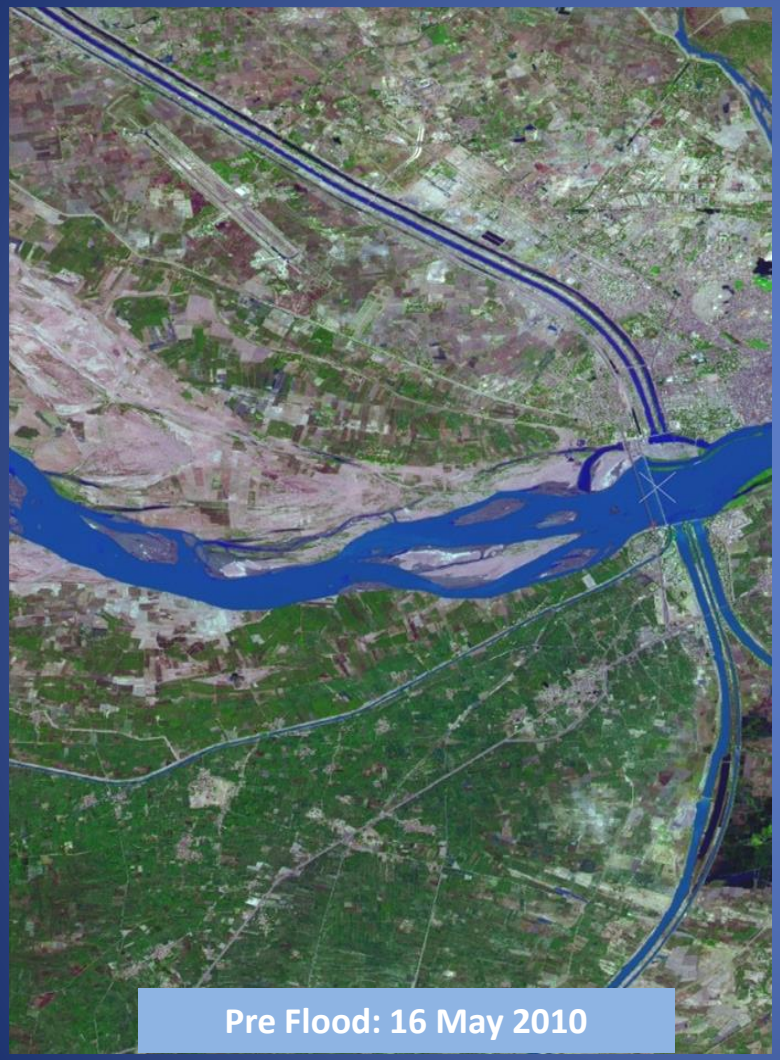
Background

Flood 2010 at Guddu Barrage

Pre Flood: 02 June 2010

Post Flood: 12 Aug 2010

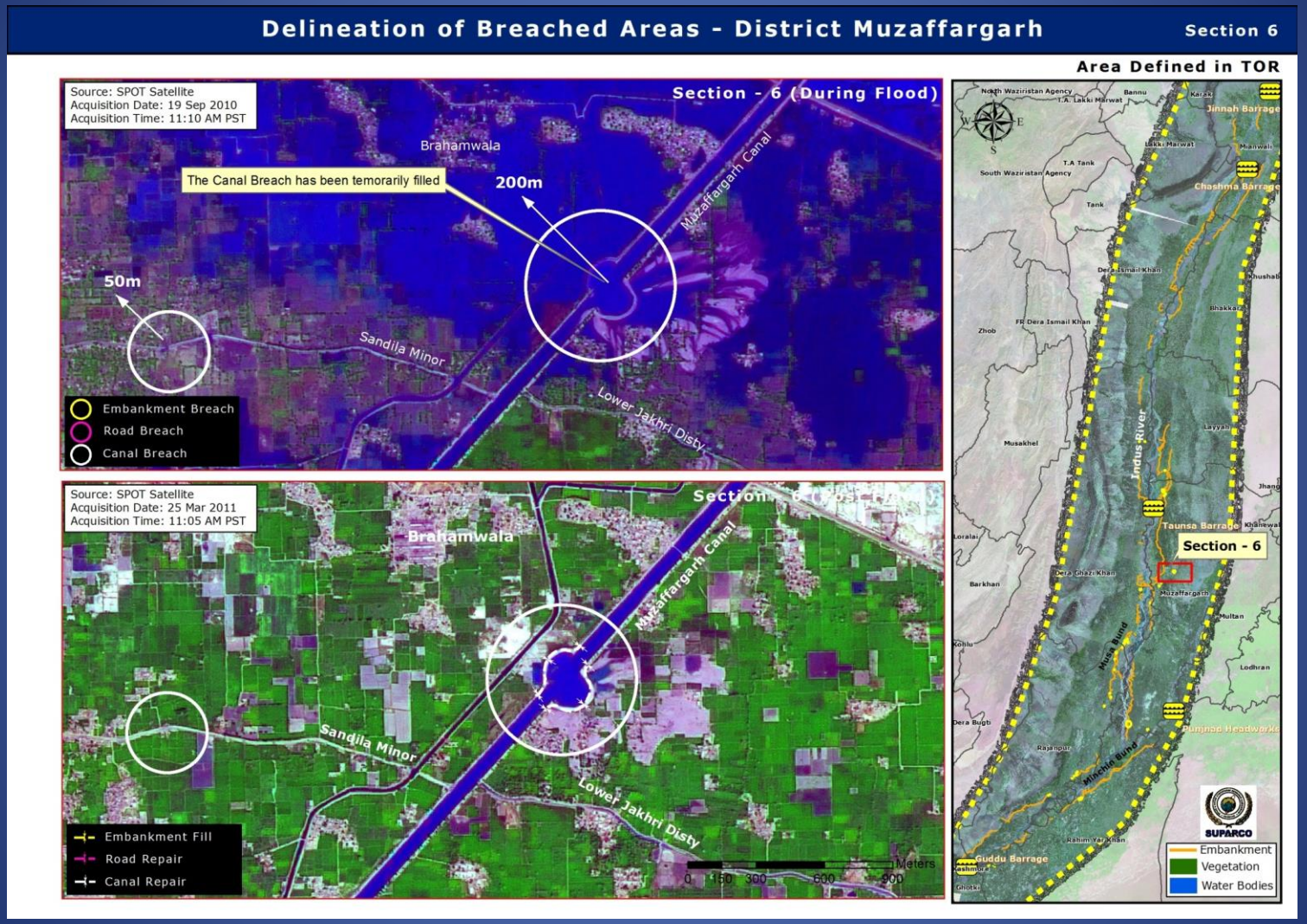
Flood 2010 at Sukkur Barrage



Pre Flood: 16 May 2010

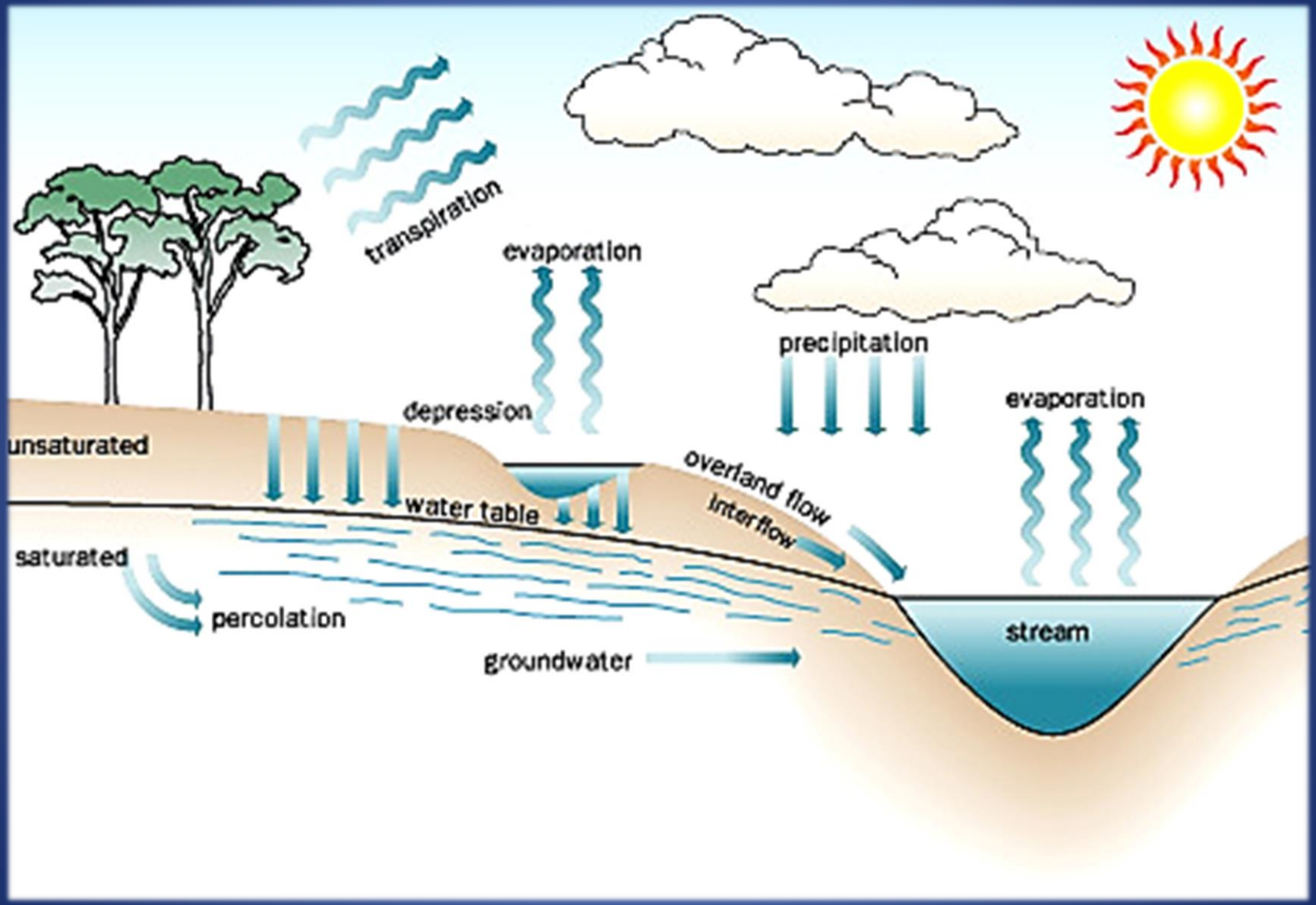
Post Flood: 13 Aug 2010

Flood 2010 – Breaches in District Muzaffargarh



Basic Concepts

The Water Cycle



Source: http://soer.justice.tas.gov.au/2003/image/267/index.php

Hydrological Modeling Classifications

1D Model

Can model flow as far as it remains within channel or flows parallel to the channel

Ex. HEC-RAS 1D, MIKE11, SOBEK 1D etc

2D Model

Can model overland flow

Ex. HEC-RAS 2D, MIKE21, SOBEK 2D, RRI etc

1D/2D Couple Model

Can model flow within channel with 1D approach while overland flows with 2D

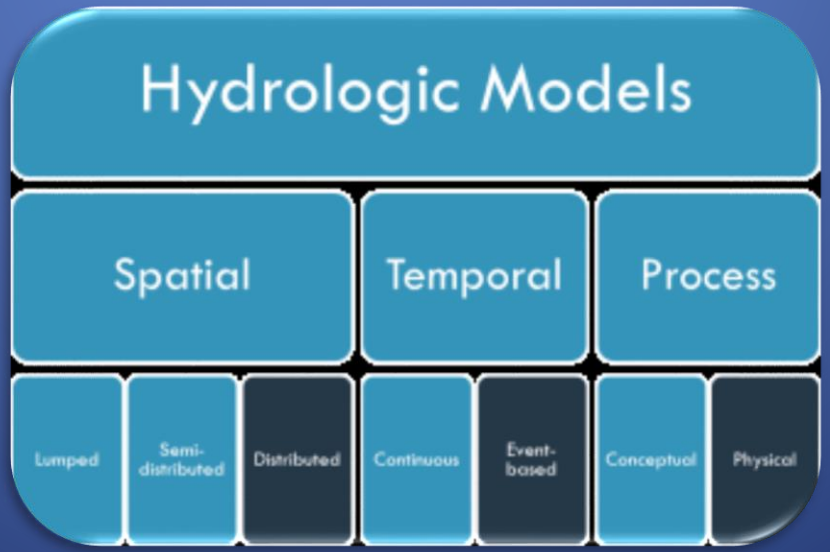
Ex. RRI, HEC-RAS 1D/2D, MIKE Flood etc

Rainfall-runoff-inundation (RRI) Model

RRI model is a 2-Dimensional Inundation Model based on diffusion wave approximations – can simulate rainfall-runoff and flood inundation simultaneously.

- ✓ Rainfall-Runoff
- ✓ Flood Routing
- ✓ Inundation

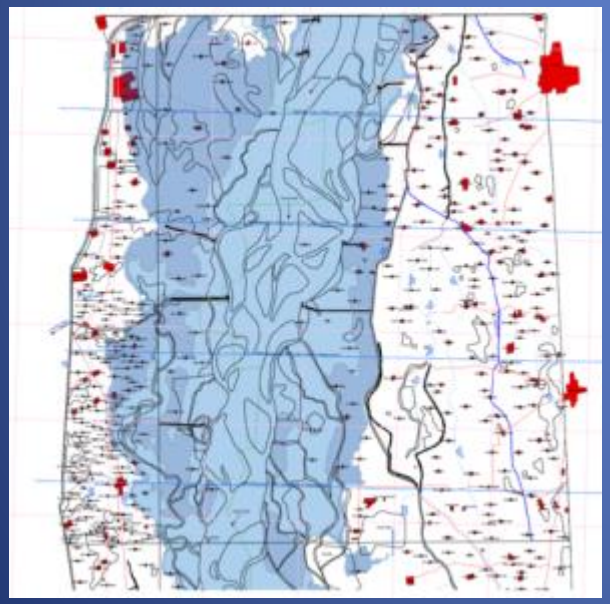
Integrated
Simple
Physically Sound



How to Make Flood Hazard Maps?

- Community based
- Past Event : display past flood event (e.g. remote sensing)
- Simulation model based

1D hydraulic model (e.g. HEC-RAS)



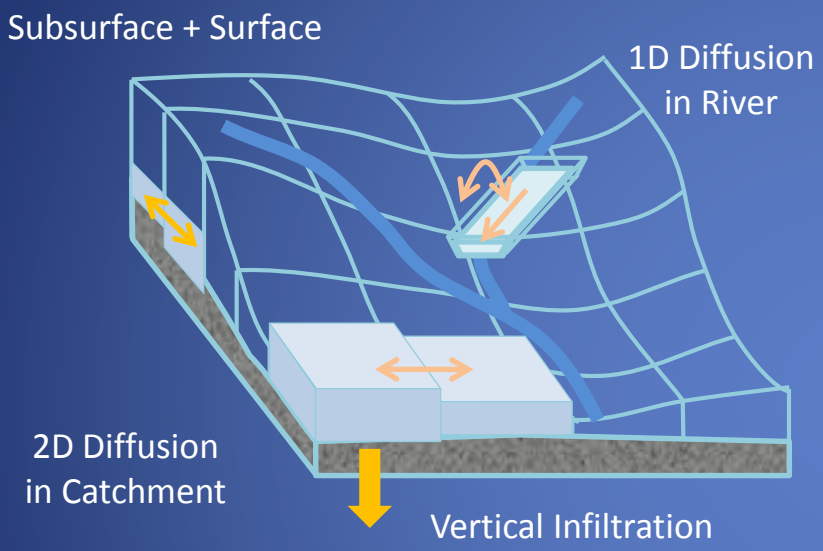
Indus River

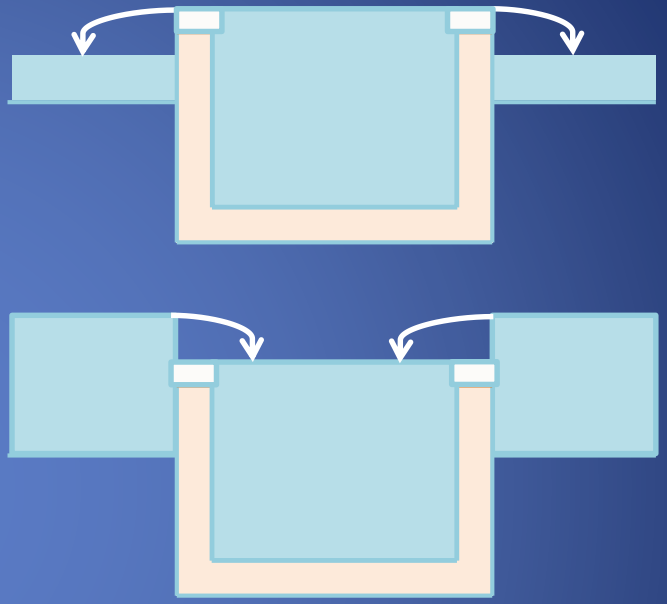
for diffusive-type inundation
2D hydraulic model

1D river routing + 2D inundation interaction model

e.g. Rainfall-Runoff-Inundation Model

Rainfall-Runoff-Inundation (RRI) Model





- Diffusion Wave Approximations
  - 1D in River
  - 2D in floodplain
- Subsurface flow
  - Vertical Infiltration with Green-Ampt
  - Saturated Subsurface + Surface Flow
- Rectangular river cross sections
  - Width, Depths, Levee heights can be assigned for each river grid-cells
- Over-topping and step-down formulae are used to compute the interactions between water in river and on slope
- Water depth and discharge boundary conditions can be wet at any grid-cell

Sayama, T. et al.: Rainfall-Runoff-Inundation Analysis of Pakistan Flood 2010 at the Kabul River Basin, *Hydrological Sciences Journal*, 57(2), pp. 298-312, 2012.

Case Study

River Indus Flood Modeling

UNESCO Phase-I

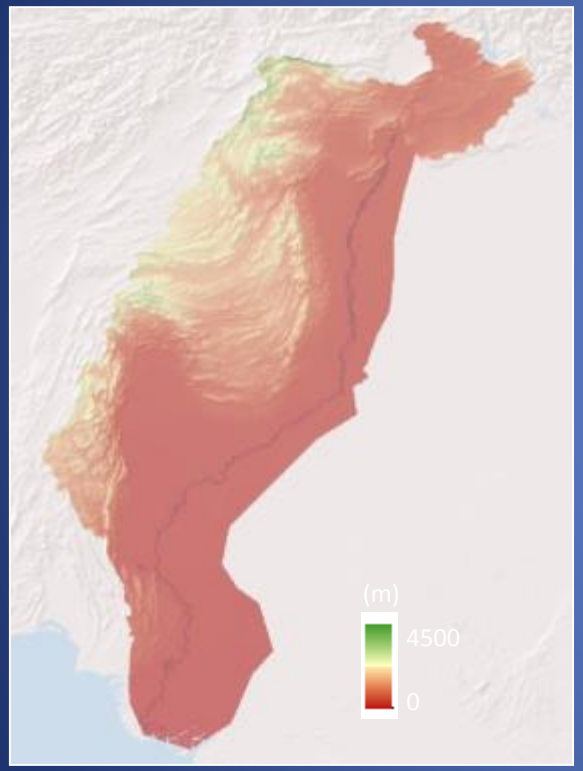
Study Area

Indus is categorized as a 'Poorly-gauged' basin.

- ✓ Poor rain gauge density, coarse temporal resolution
- ✓ Few discharge gauge stations on tributaries
  - Large number of sub-catchments have no discharge gauge stations
- ✓ Highly heterogeneous topography and soil characteristics
- ✓ Area = ~340,000 km^2

Geographic Datasets for RRI

Elevation

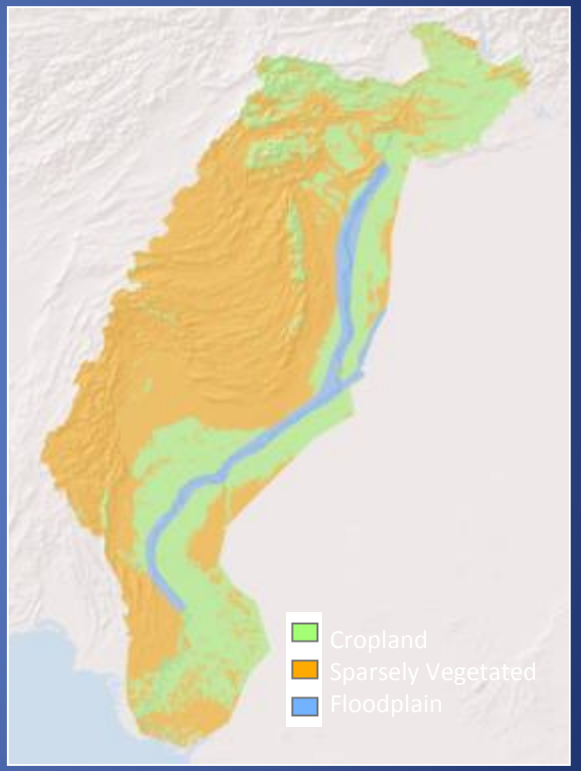


SRTM DEM

River and levee locations

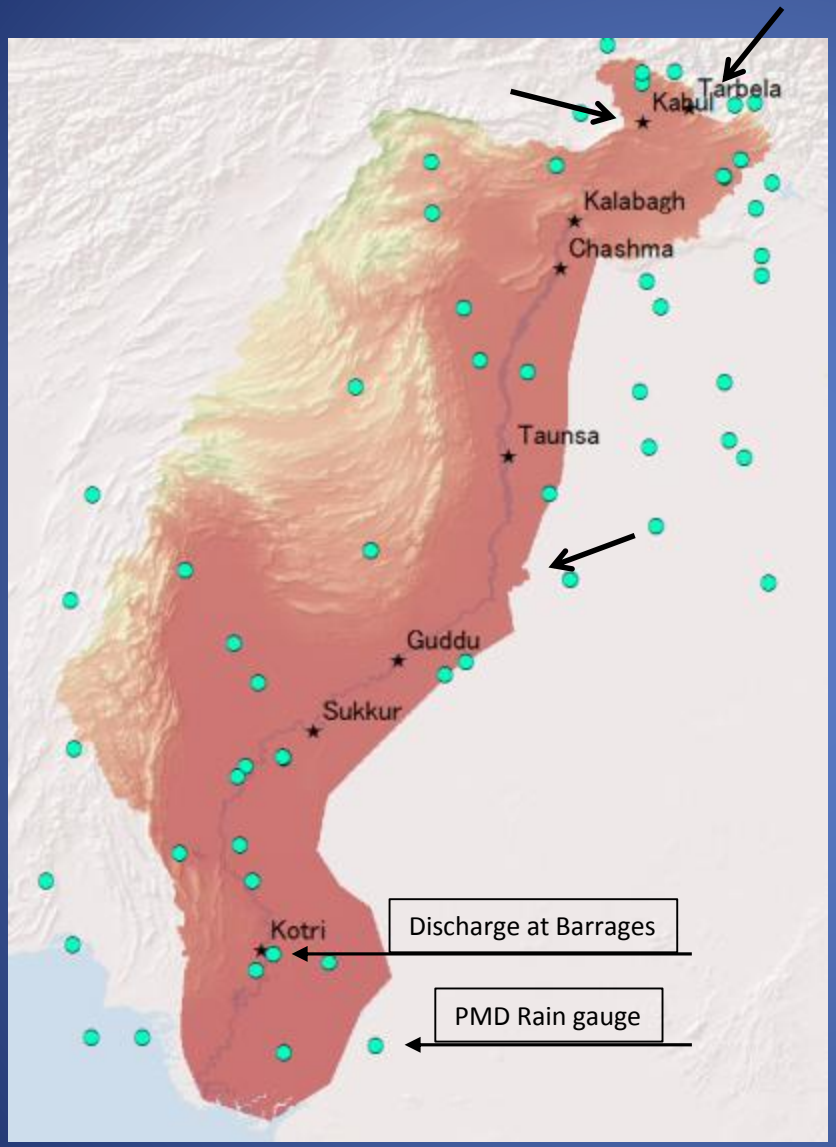
HydroSHEDS / SUPARCO

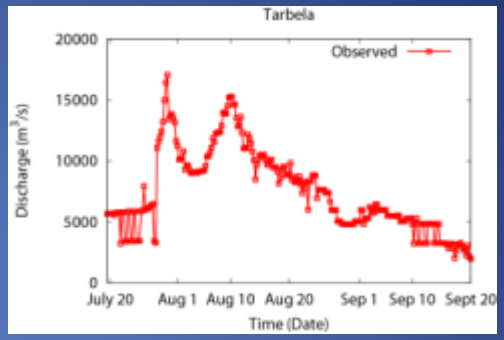
Land cover

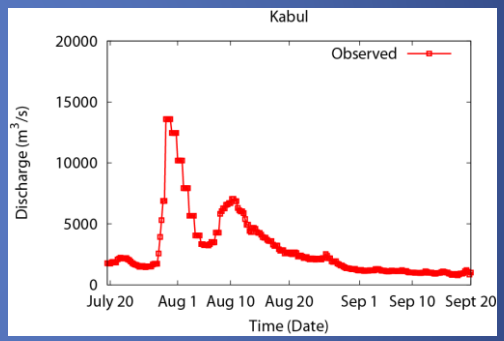


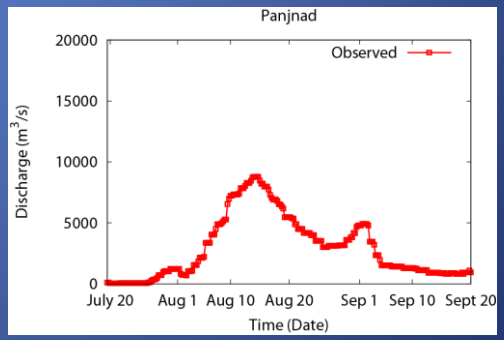
GLCC v2

Rainfall and Discharge Data Locations



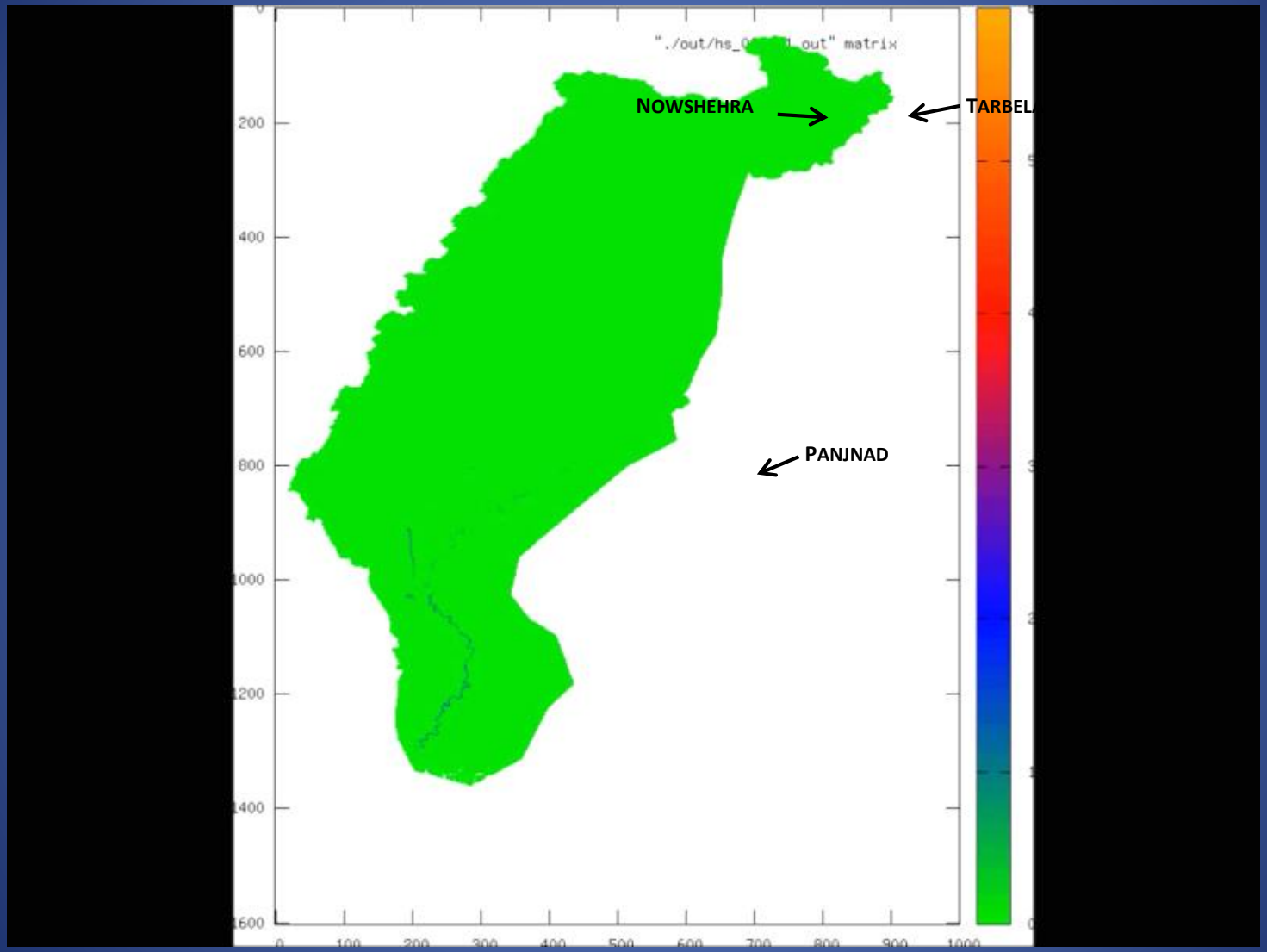






Discharge Boundary Conditions from 2010

RRI simulation of 2010 floods



Hazard Mapping at the lower IRB

- Use Kalabagh and Guddu as the discharge reference points
- Use 2010 as the shape of synthetic hydrographs

Kalabagh Peak Discharge [x10^3 cusec]

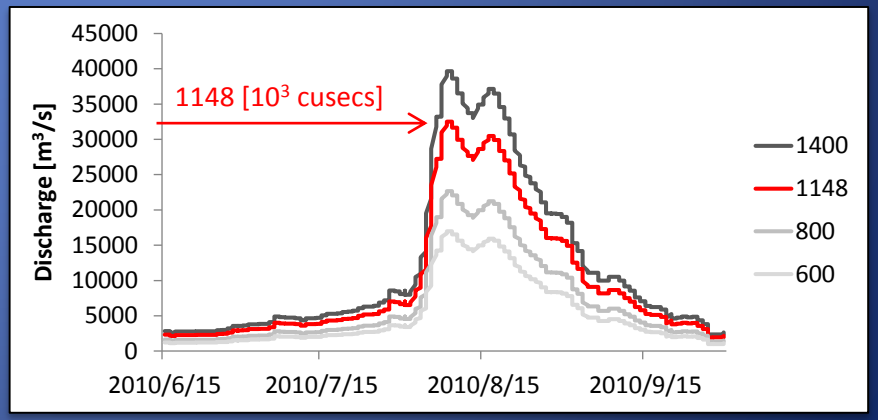
	500	700	897	1100
No Break	○	○	○	○

Guddu Peak Discharge [x10^3 cusec]

	600	800	1148	1400
No Break	○	○	○	○
Br 1			○	
Br 2			○	
Br 3			○	

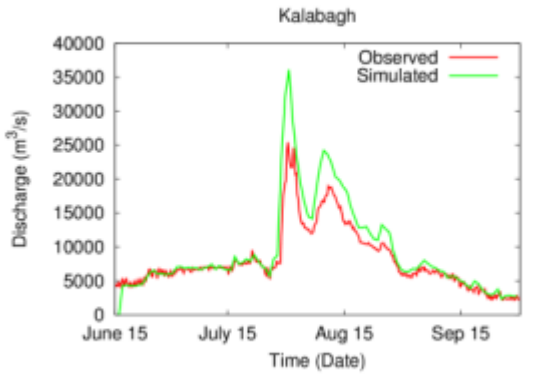
2010 Flood

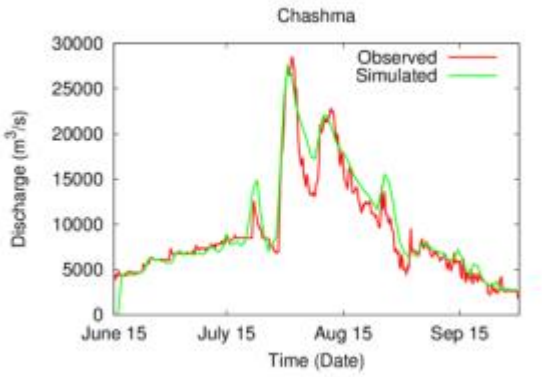
E.g. Synthetic Hydrographs at Guddu

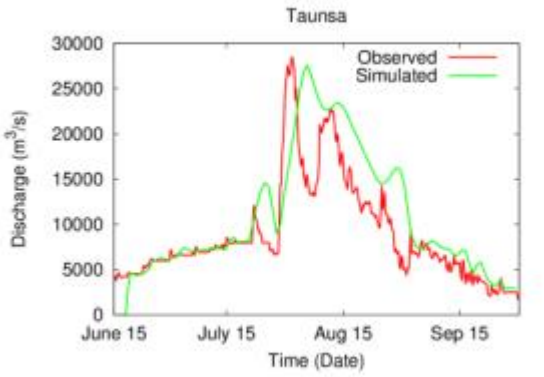


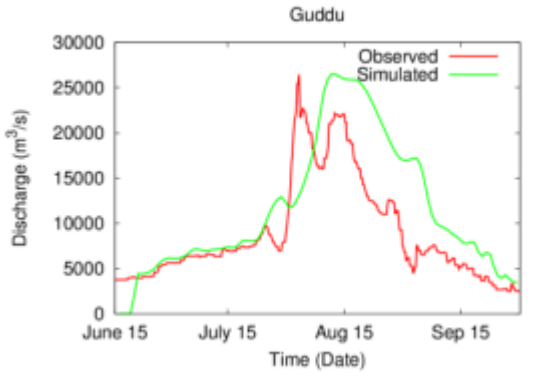
(Rainfall record in 2010 is used for all the scenarios)

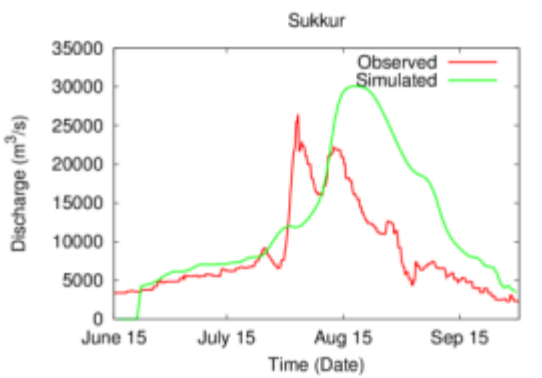
Discharge Hydrographs of 2010 Flood Event

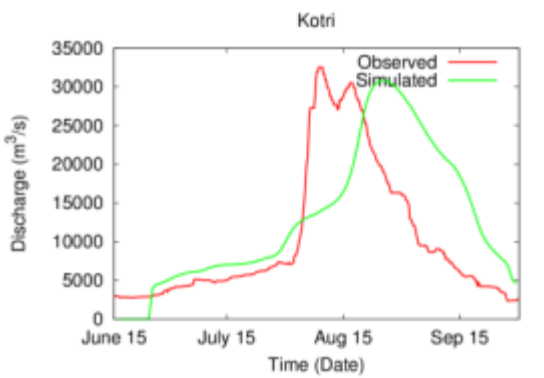






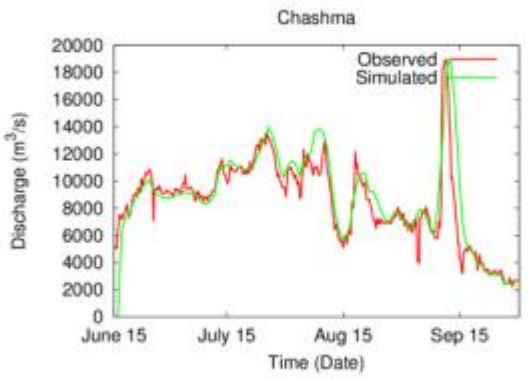


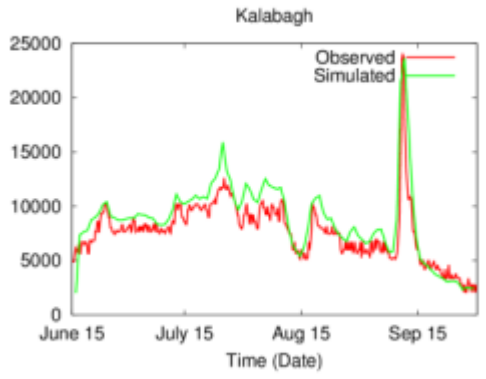


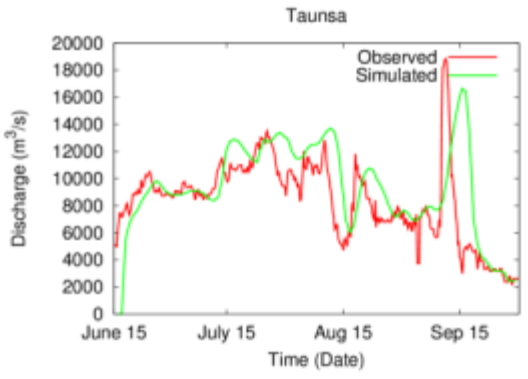


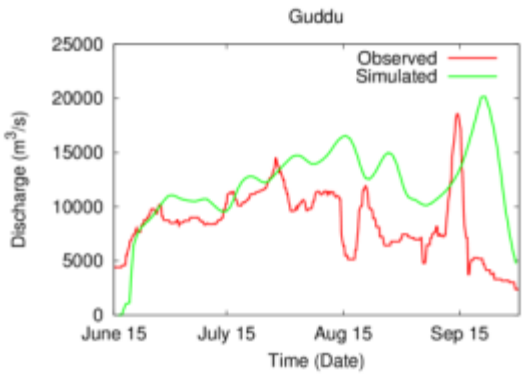
Peak Discharges : OK Arrival Time : Late

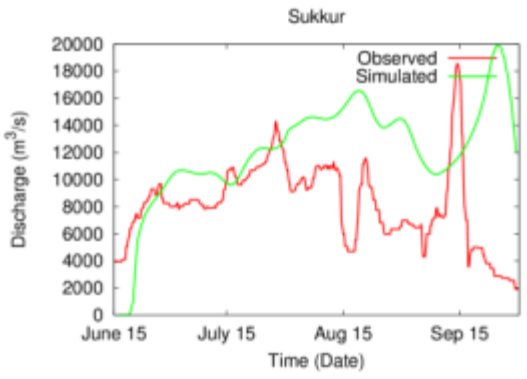
Discharge Hydrographs of 1992 Flood Event

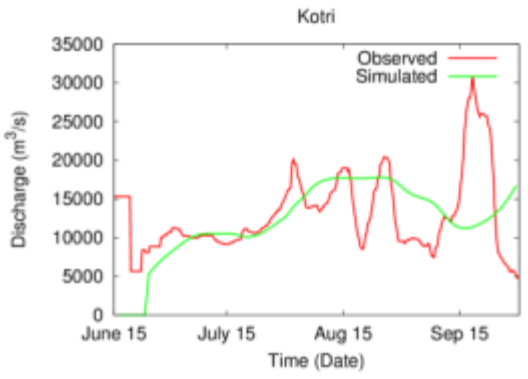










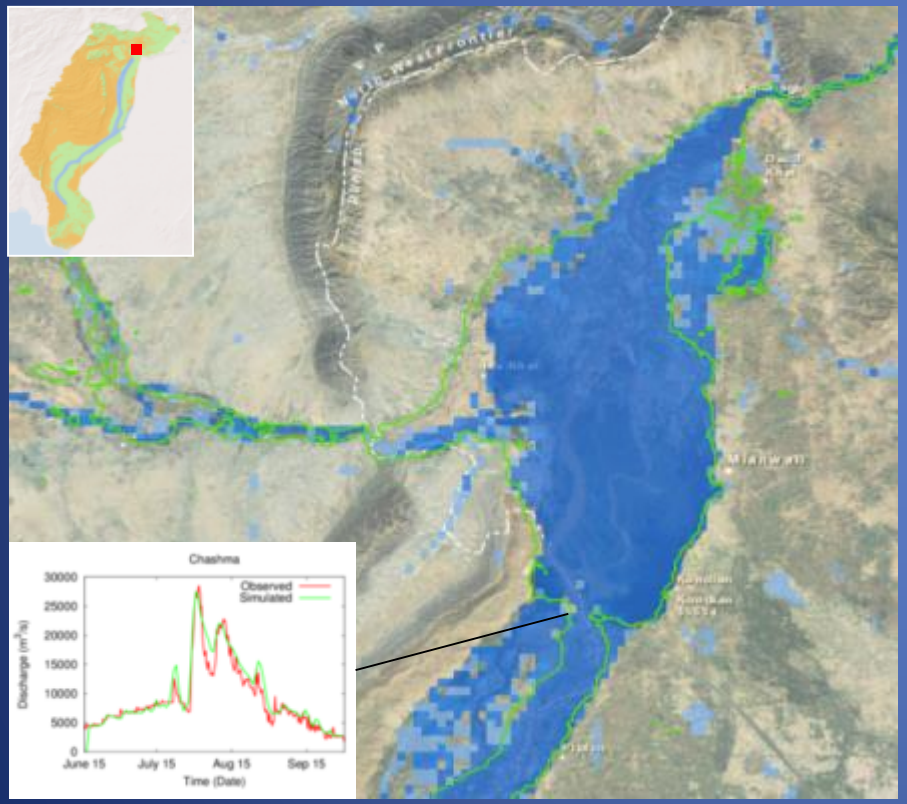


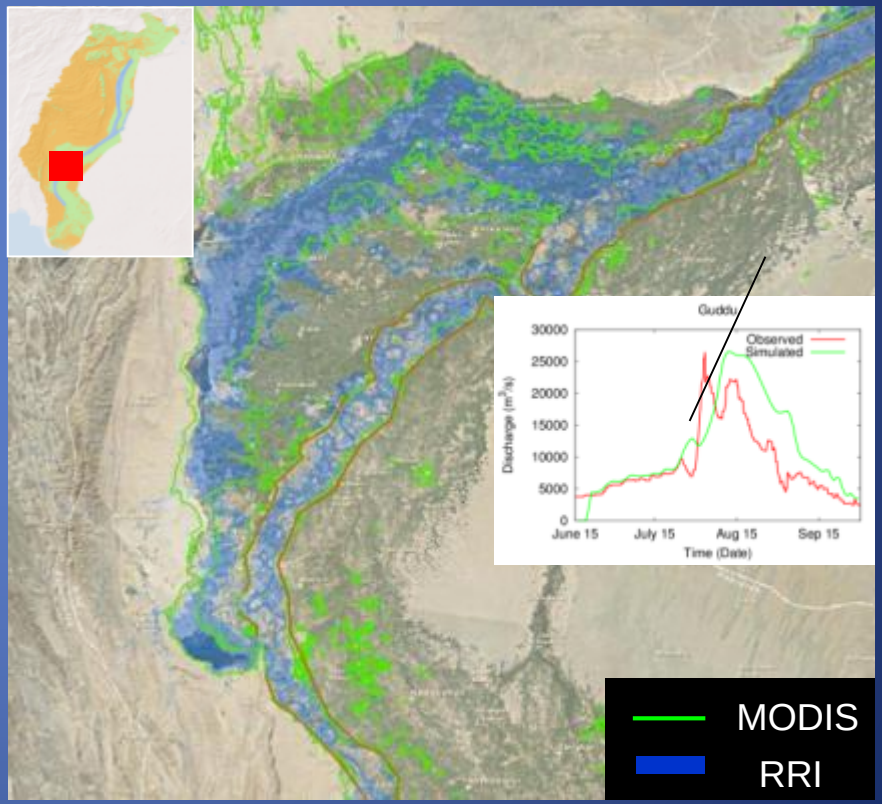
Peak Discharges : OK

Arrival Time : Late

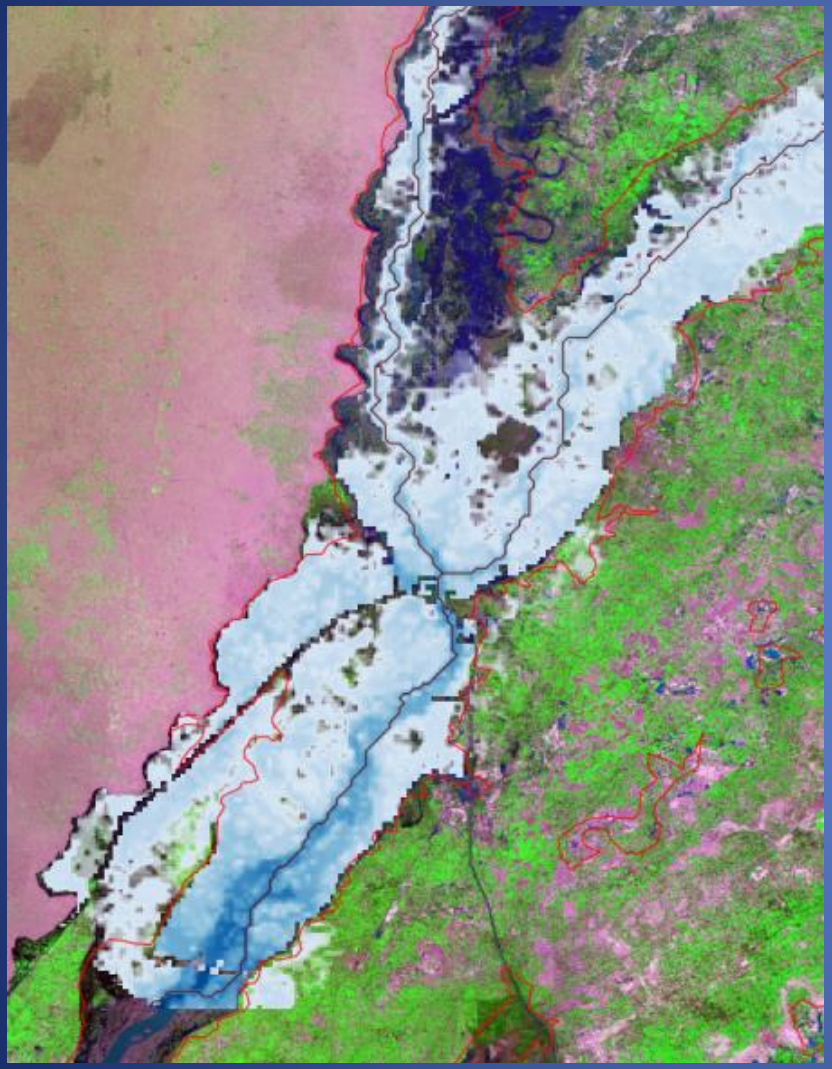
Model calibration and validation

- Calibrate with 2010 Flood
- Validate with 1988, 1992, 1994, 1997





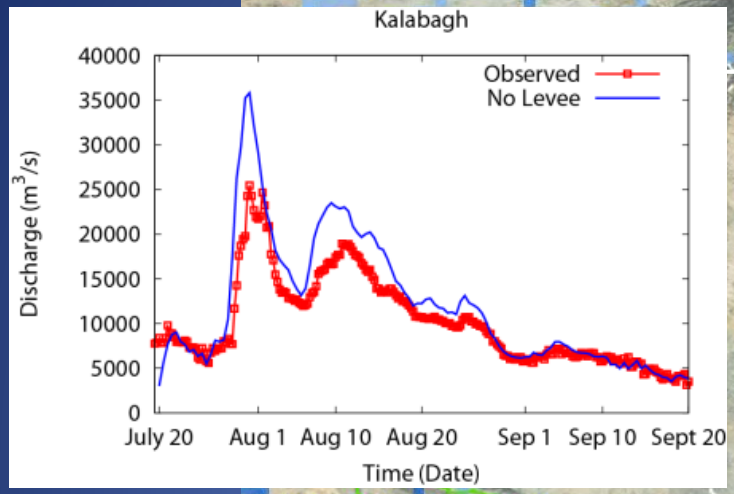
Model calibration and validation

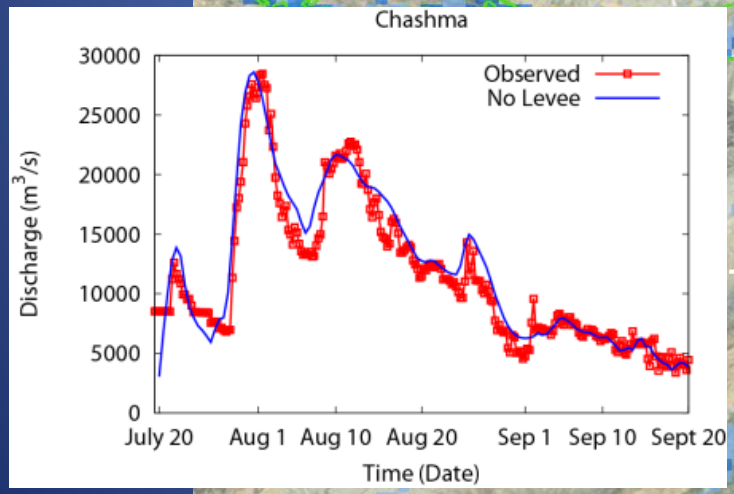


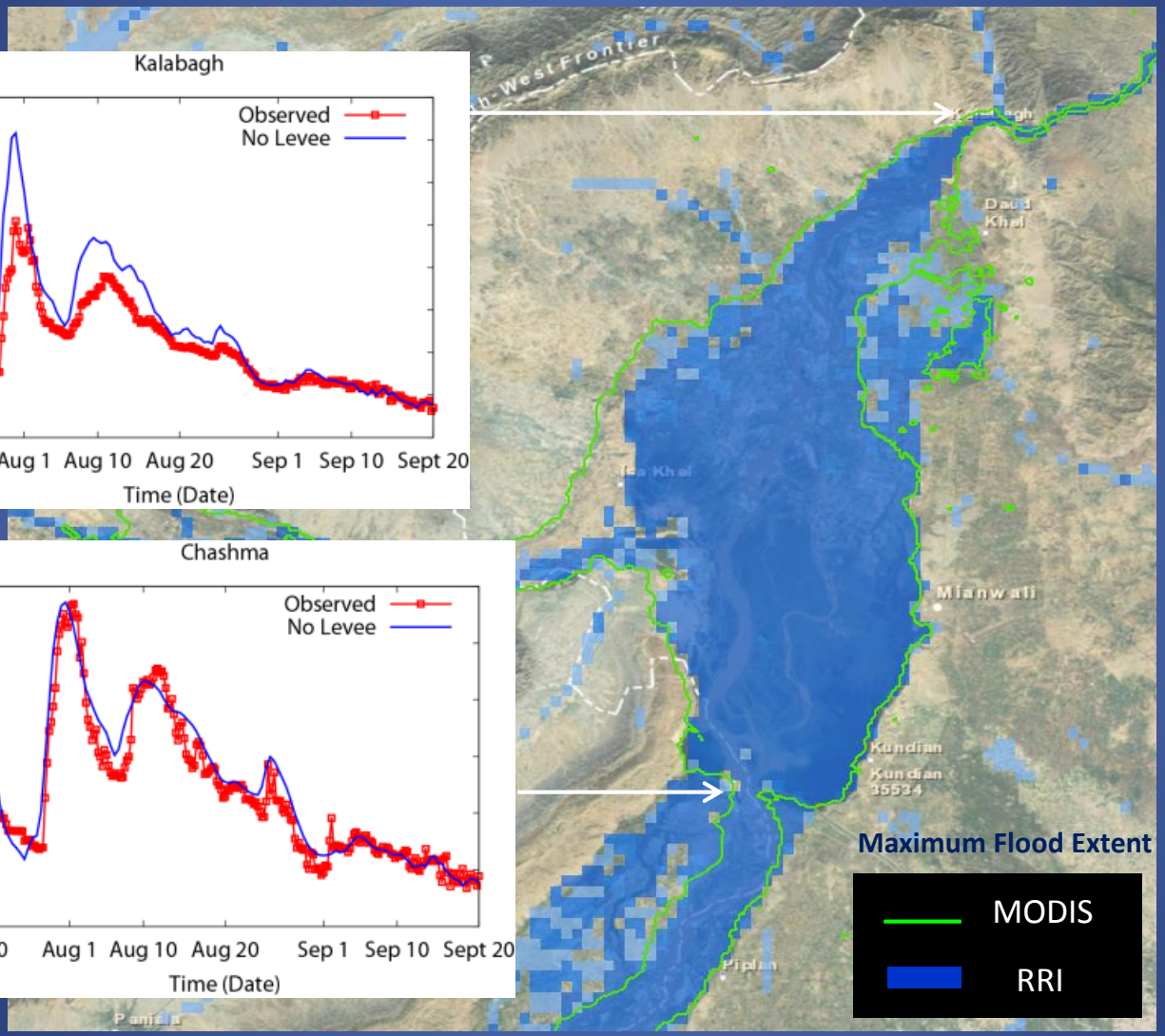
Maximum simulated inundation extent for 2014 around Trimmu and Athara Hazari.

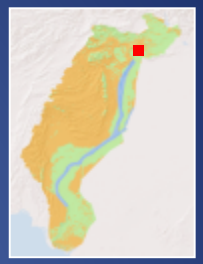
Devastation caused by 1992 floods around Trimmu and Athara Hazari.

Model calibration and validation





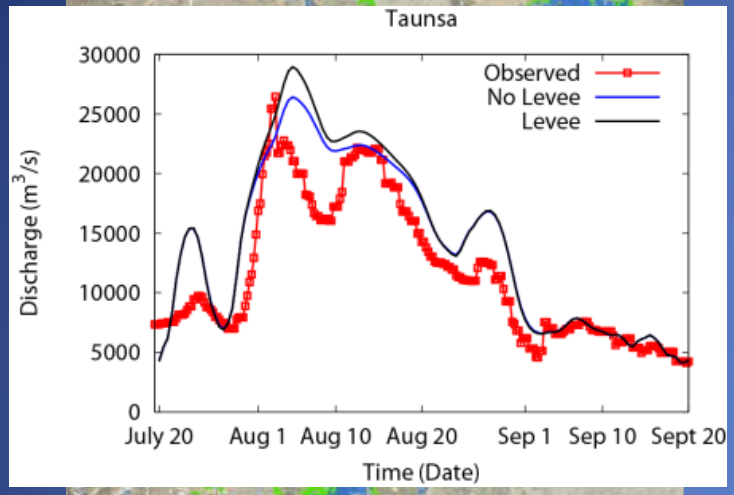


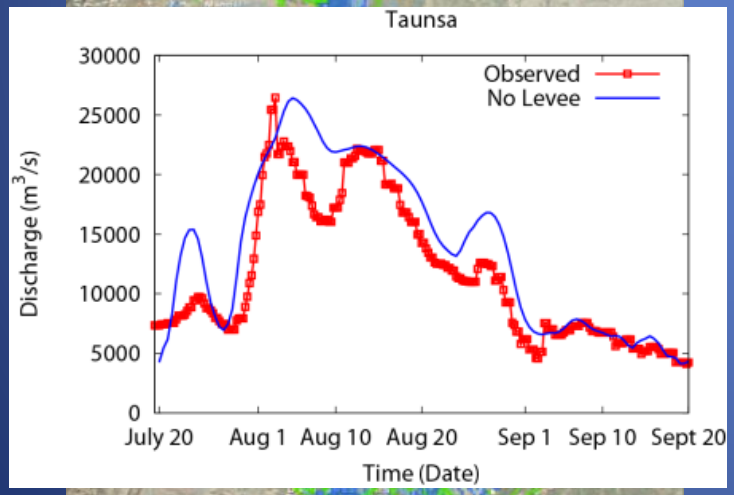


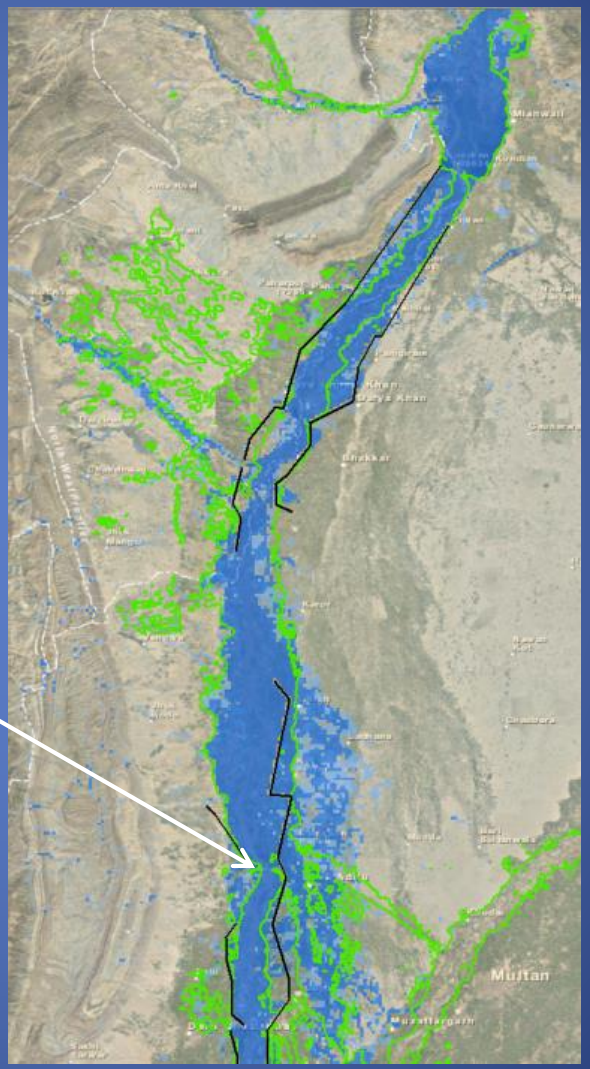
Tarbela - Kalabagh
200 km, 1/1400

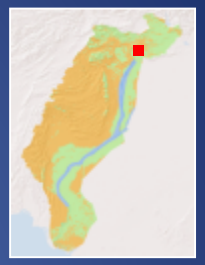
Kalabagh - Chashma
60 km, 1/3100

Model calibration and validation









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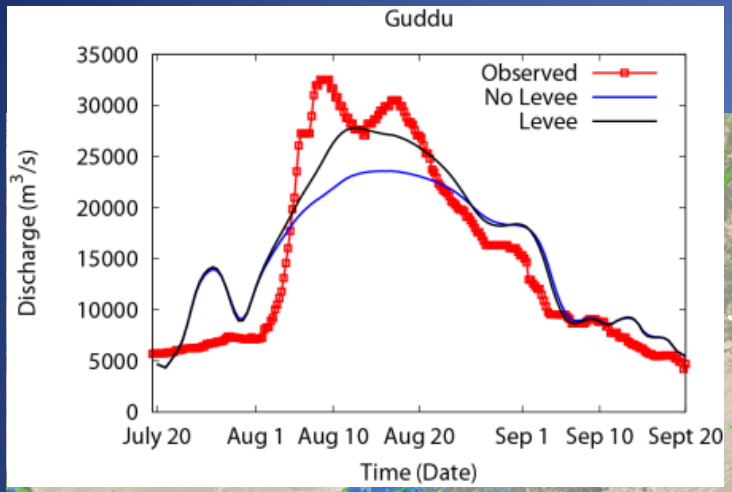
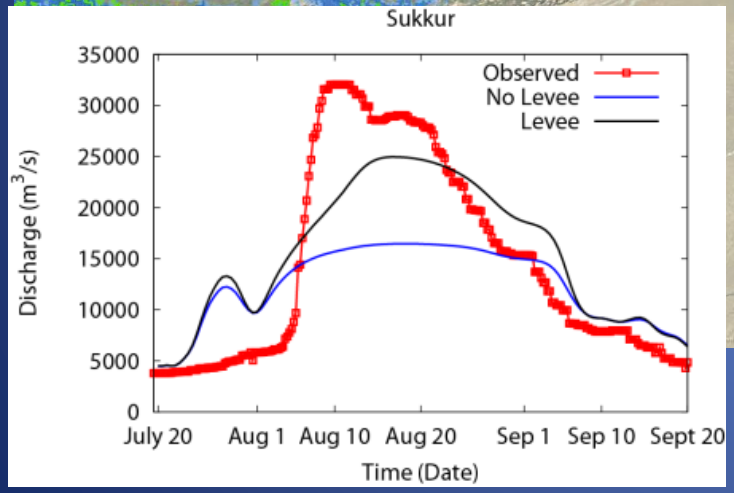
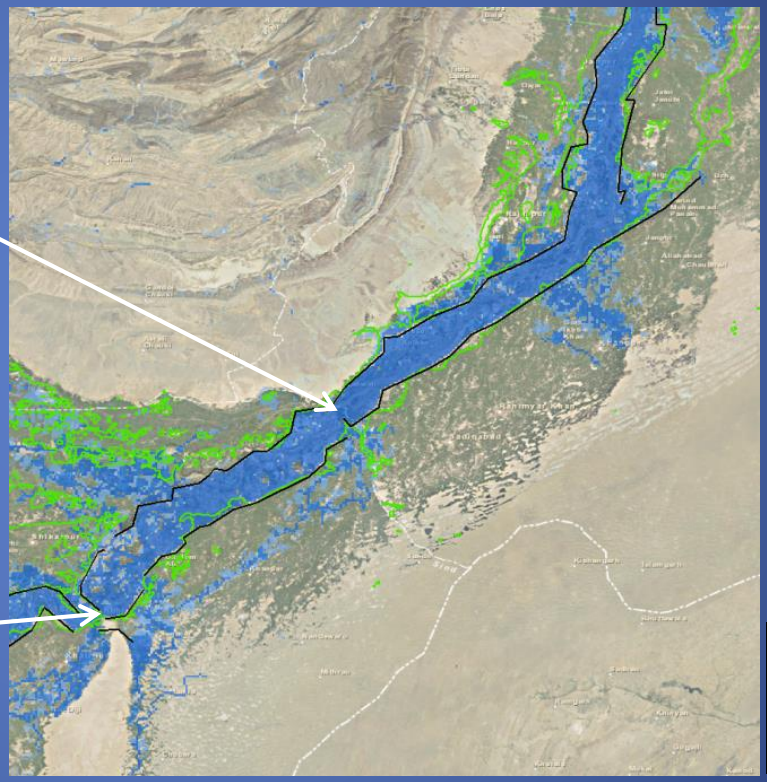
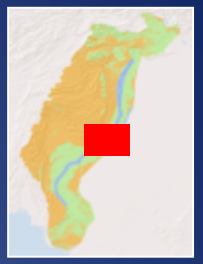








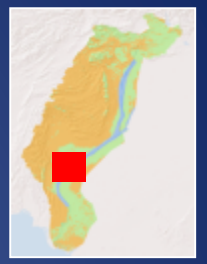
Taunsa - Guddu
290 km, 1/4900

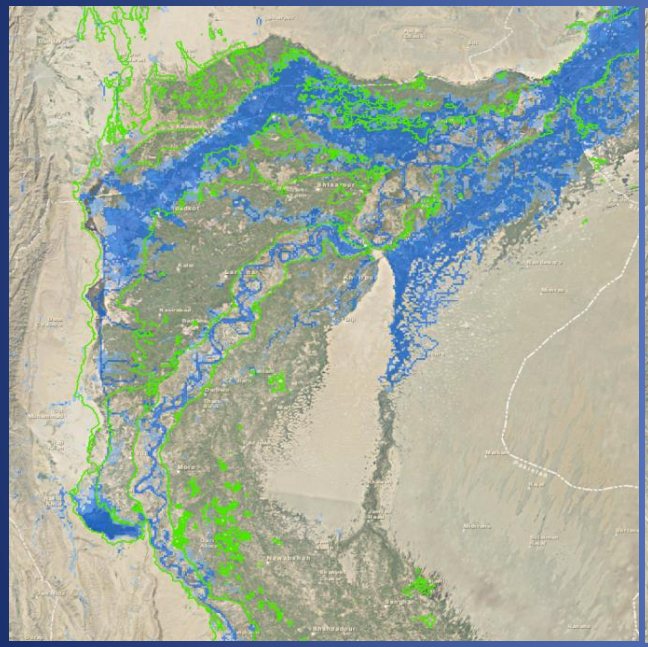
Guddu - Sukkur
130 km, 1/11800

MODIS

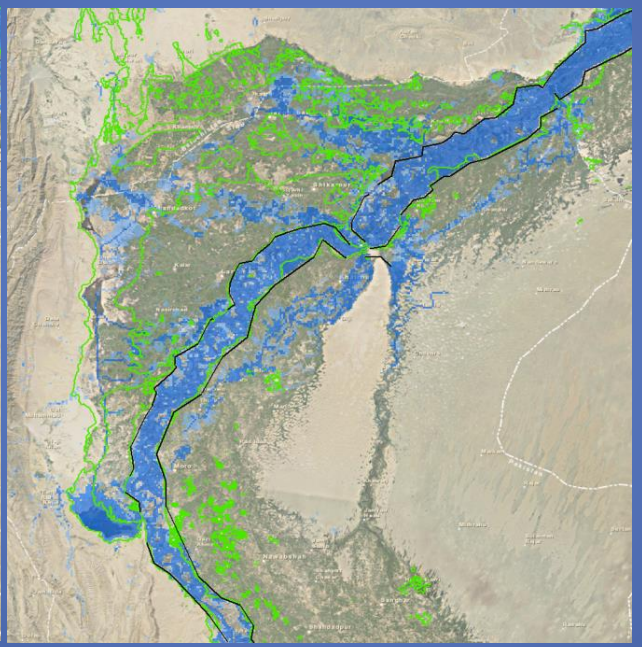
RRI

Model calibration and validation

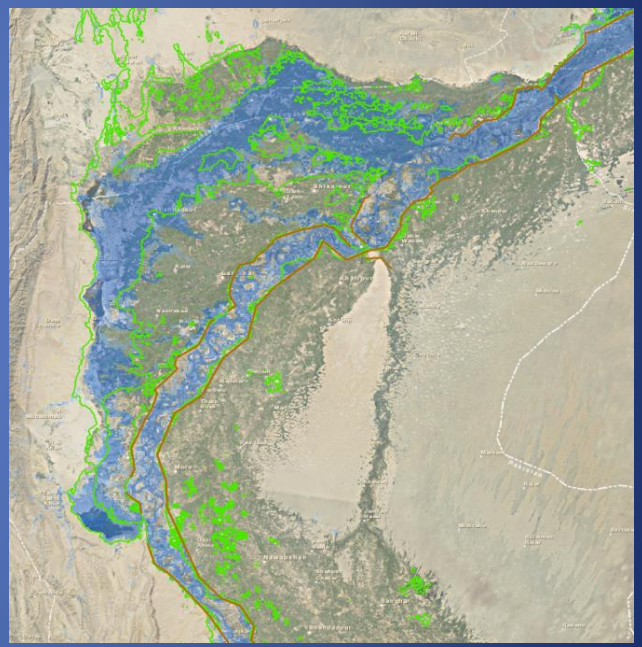




No Levee



Levee

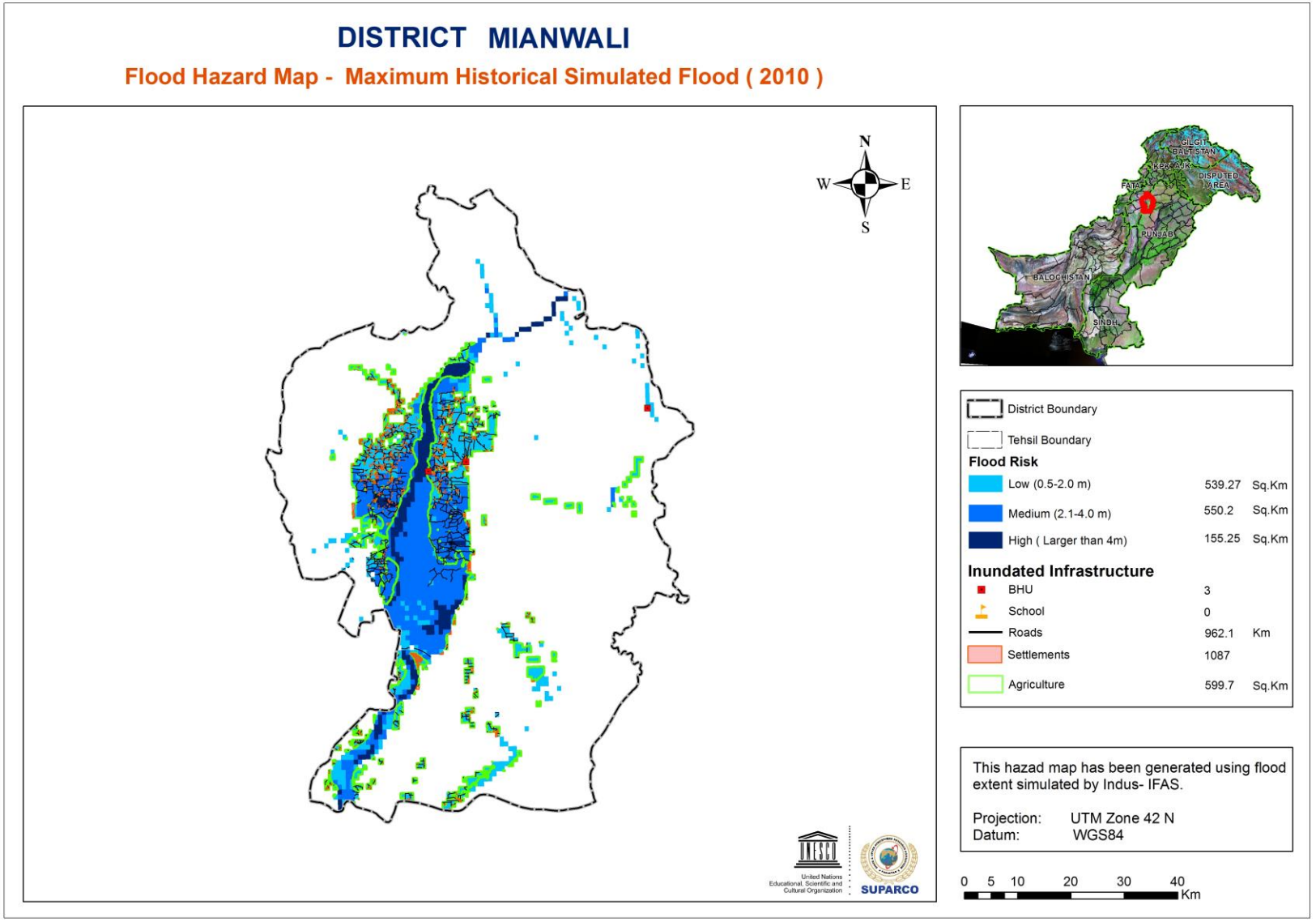


Levee + Open

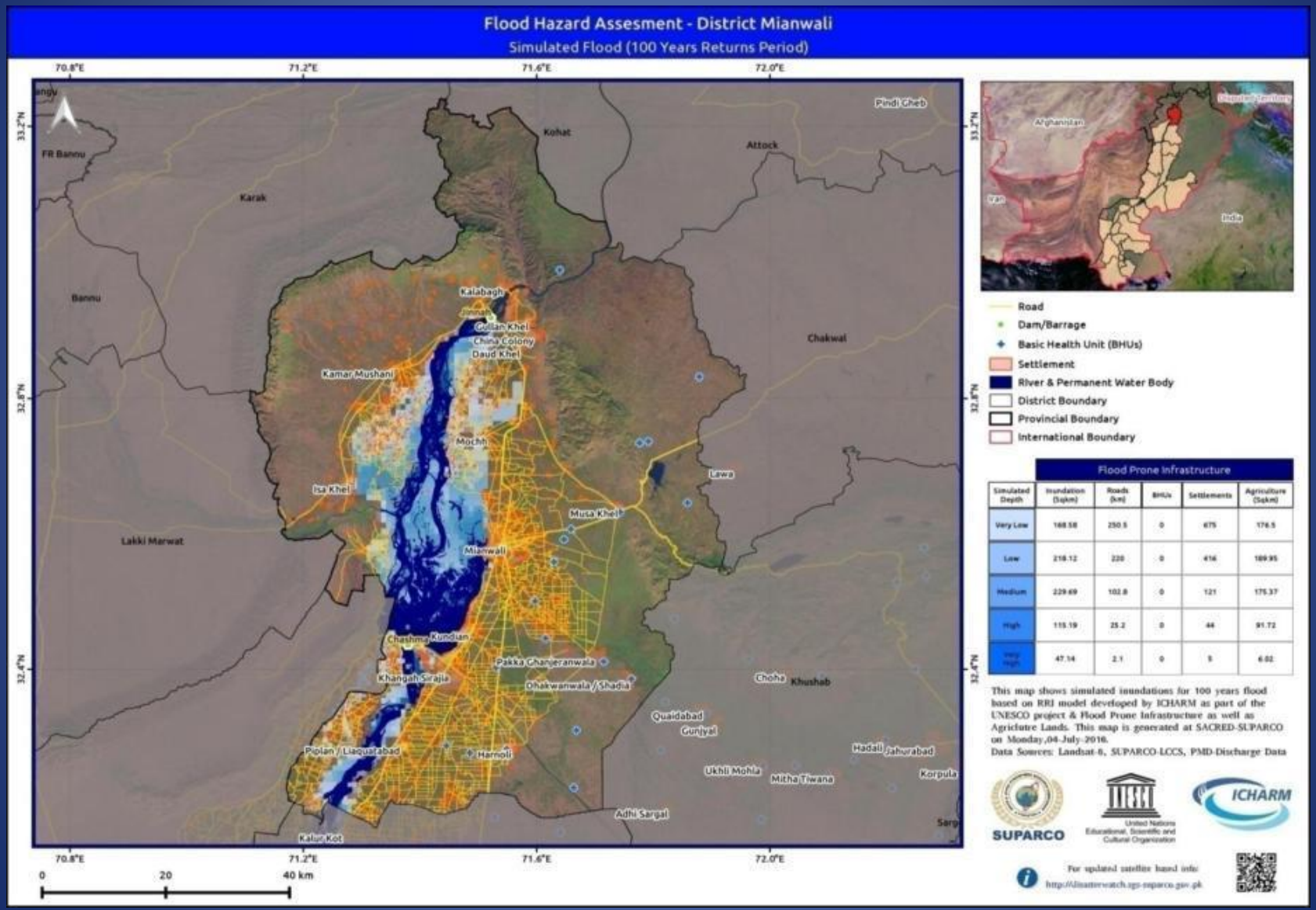
MODIS

RRI

Flood hazard mapping Ver 1.0

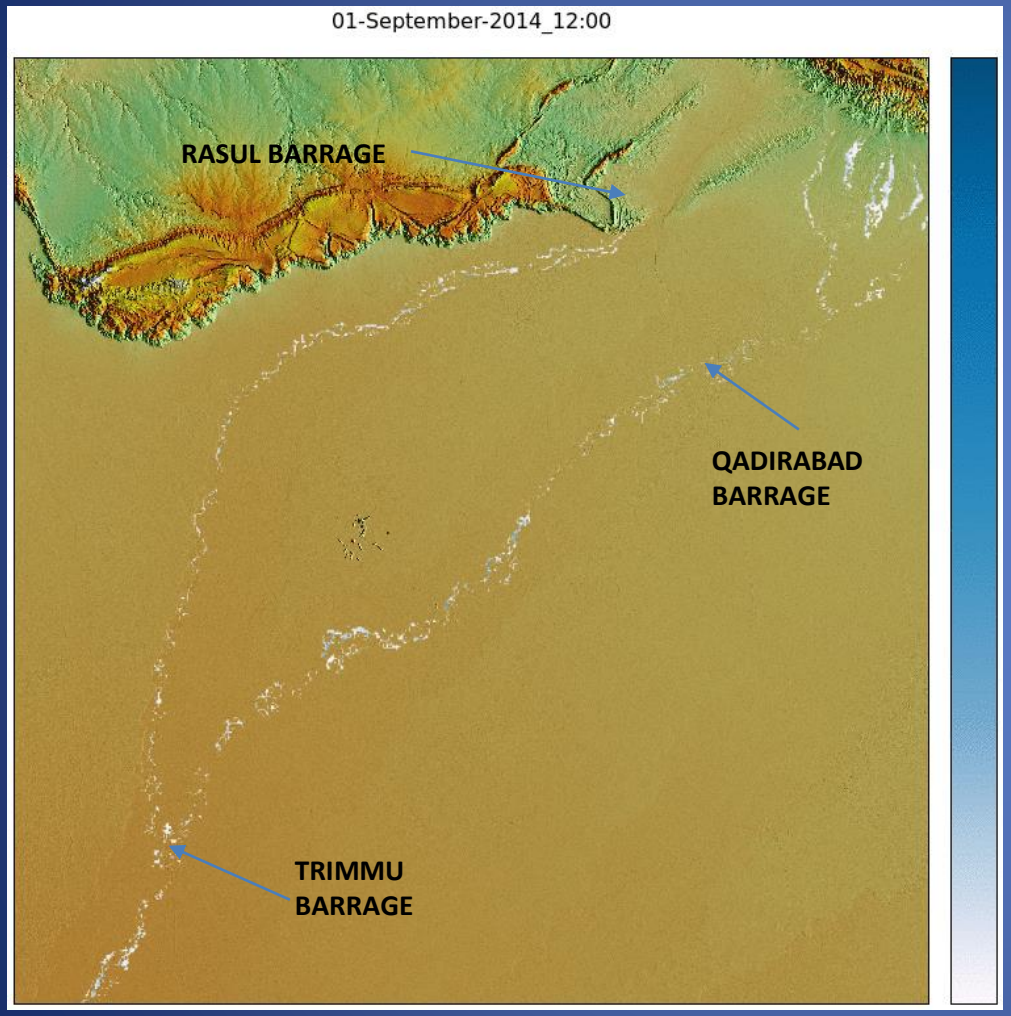


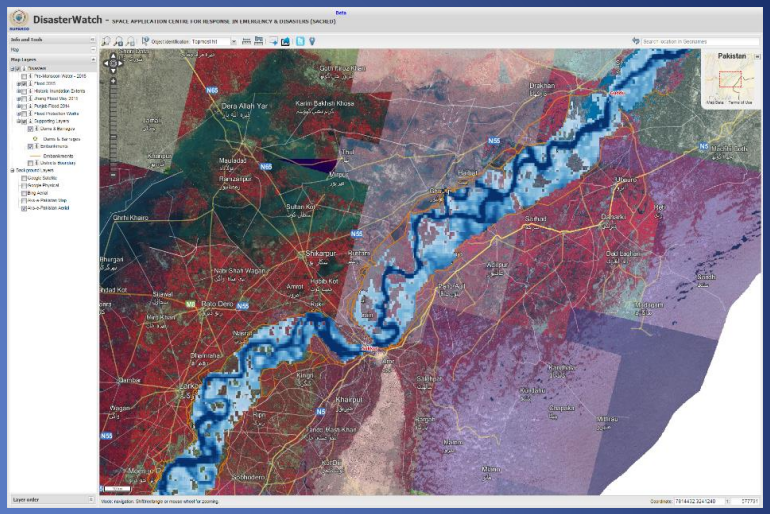
Flood hazard mapping Ver 2.0



Hydrological modeling applications

Beyond the UNESCO Project Ph-1





SUPARCO HAS THE CAPACITY TO CARRY OUT FLOOD MODELLING AND PROVIDE INUNDATION FORECASTING BASED ON HYDROLOGICAL MODELLING FRAMEWORK (INDUSIFAS) AND REAL-TIME DISCHARGE INFORMATION.

Simulation results show how flood waters progress along Jhelum and Chenab rivers causing heavy inundations. Darker blue represents deeper inundations

Conclusion

- RRI model was applied to the lower IRB
- Large-scale flood inundation was well represented
- River discharge simulation was also reasonable (up to Guddu)
- RRI was used for Flood Simulation of 2015 and 2014 floods
- RRI model will be extended to River Jhelum, Chenab and Kabul Rivers in near future

- Two issues in the river flow simulations
  - Over estimates in the end of July 2010
  - Discharge at Sukkur and Kotri

Way Forward

- RRI model simulation with improved geometric data (30m DEM, Landcover, Embankment)

- Flood Hazard Maps for Chenab, Jhelum, Ravi, Sutlej and Kabul Rivers