Integrated Flood Management in Bagmati river basin of Bihar, India Using Modern Technology

Presented by
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STUDY AREA – BAGMATI RIVER, BIHAR, INDIA
Floods are most recurring natural disasters.

More than 520 million people are affected by flood per year in the world. It gives result in estimates up to annual deaths of 25,000.

In India average annual deaths due to flood about 1800 and total losses about 2700 crores (ref. CWC report).

Main causes of damage are:

1) Unpreparedness
2) Failure to give warnings
3) Lack of accurate information about expected flood inundation areas and
4) Time lag in mobilization of resources

### Average annual loss due to Floods in India

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Items</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Area affected</td>
<td>7.35 million hectare</td>
</tr>
<tr>
<td>2.</td>
<td>Population affected</td>
<td>40.967 million</td>
</tr>
<tr>
<td>3.</td>
<td>Human lives lost</td>
<td>1793 number</td>
</tr>
<tr>
<td>4.</td>
<td>Cattle lost</td>
<td>85599 number</td>
</tr>
<tr>
<td>5.</td>
<td>Houses damaged</td>
<td>1452904 number</td>
</tr>
<tr>
<td>6.</td>
<td>Houses damaged</td>
<td>370.607 crore</td>
</tr>
<tr>
<td>7.</td>
<td>Crop area damaged</td>
<td>3.72 million hectare</td>
</tr>
<tr>
<td>8.</td>
<td>Crop damaged</td>
<td>1095.132 crore</td>
</tr>
<tr>
<td>9.</td>
<td>Public Utilities damaged</td>
<td>1186.456 crore</td>
</tr>
<tr>
<td>10.</td>
<td>Total losses</td>
<td>2706.243 crore</td>
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</tbody>
</table>
Bihar is India's most flood-prone state.

From 1999 to 2005 the flood damages reached US$531 millions in North Bihar only.

2007 floods will be remembered for high degree of rainfall which was even more than year 2004 flood. About 700 persons died. Public property damage was worth 1700 crores.

Present practice of Flood Management by WRD GoB – Anti-erosion works (recommended by TAC and SAC) after flood. Real time flood forecasting and expected inundation mapping can provide cost-effective mitigation to water managers.
THE GROUND REALITY
SAFETY ON THE EMBANKMENTS
ROAD CUM EMBANKMENT BREACH
STRANDED
EMERGENCY RELIEF - AIRDROPPING
DISRUPTED COMMUNICATION
OVERTOPPED ROAD
FLOOD HAZARD TYPOLOGY

- **TYPOLOGY I**: FLASH FLOODS – FLOODS FROM NEPAL RAINFALL, LEAD TIME IS SHORT 8 HOURS, RECESSION IS FAST, NO IMPACT ON AGRICULTURE

- **TYPOLOGY II**: RIVER FLOODS – LEAD TIME 24 HOURS, RECESSION IS 1 WEEK OR MORE,

- **TYPOLOGY III**: DRAINAGE CONGESTION IN RIVER CONFLUENCE- LEAD TIME > 24 HOURS, LASTING INUNDATION, NO KHARIF SEASON AGRICULTURE

- **TYPOLOGY IV**: PERMANENT WATER LOGGING - SHRINKAGE IN AREA ONLY IN FEB, LOCAL RAINFALL, MICRO-RELIEF ASPECTS

- **TYPOLOGY V**: FLOOD MANAGEMENT IN URBAN AREAS

- **TYPOLOGY VI**: FLOOD MANAGEMENT IN IRRIGATION COMMANDS
FLOOD HAZARD TYPOLOGY IN STUDY AREA

TYPOLOGY VII: FLOOD MANAGEMENT IN HIGHLY VULNERABLE REACHES OF RIVER EMBANKMENTS

TYPOLOGY VIII: FLOOD MANAGEMENT IN AREAS WHERE THERE IS HIGH POPULATION LOCATED VERY NEAR TO RIVER

TYPOLOGY IX: FLOOD PRONE AREAS HAVING WATER LOGGING WITH HIGH DEPTH FOR LONG PERIOD OF TIME

TYPOLOGY X: FLOOD PRONE AREAS HAVING DRAINAGE CONGESTION FOR SMALL PERIOD OF TIME

TYPOLOGY XI: HAZARD CAUSED BY HIGH PEAK AND LOW VOLUME

TYPOLOGY XI: HAZARD CAUSED BY HIGH VOLUME AND LOW PEAK

TYPOLOGY X: HAZARD CAUSED BY HIGH PEAK AND HIGH VOLUME
Addresses only negative aspects of flooding

Focuses on reducing flooding and reducing the susceptibility to flood damage

Provides adhoc reactions and are carried out in isolation

Expresses the risk of flooding simply as the exceedence probability of a flood of a given magnitude on a particular stretch of river

In limited studies flood inundation modeling for various return periods has been attempted.
present practice of flood management

- Before monsoon period anti-erosion works and during the monsoon flood fighting works are done at vulnerable sites. A joint committee, after seeing the river regime after the flood, and erosion, suggests vulnerable sites and propose for anti-erosion schemes.

- On the basis of the committee’s report, field Executive Engineers measure the damages and frame schemes as per relevant design and prepare estimate. They put it before Technical Advisory committee (TAC). After recommendation by TAC the schemes are sent to Scheme Review Committee (SRC) and with concurrence of Principal Secretary, the agenda are sent to State Flood Control Board.

- The State Flood Control Board is headed by State Chief Minister. Agenda gets approved and fund is made available.
Absolute protection from floods is a myth.

We should aim at maximizing net benefits from the use of flood plains, rather than trying to fully control floods.
Integrated Flood Management

- Improves functioning of the river basin as a whole
  - Recognizing that floods have beneficial impacts and can never be fully controlled.

- Integrates land and water resources development in a river basin.

- Maximizes the efficient use of floodplains and minimizes loss of life.

(WMO No. 1047, 2009)
Integrated Flood Management

Elements of IFM

- Manage the Water Cycle as a Whole
- Integrate Land and Water Management
- Manage Risk and Uncertainty
- Adopt a Best-Mix of Strategies- Structural and non-structural
- Ensure a Participatory Approach
- Adopt Integrated Hazard Management Approaches
Integrated Flood Management

Flood Hazard Mapping

Basin Planning

Flood Proofing and Building Codes
Use of New Technologies & Softwares in Flood sector
FROM IMAGES TO INFORMATION...

 IMAGES

 GIS

 ~ 1:12500 THEMATIC

 ANALYSIS

 MAPS

 DISASTER MANAGEMENT APPLICATIONS:

 MULTI-LAYER

 TABLES/ REPORTS

 TO DECISION AND ACTION

 HAZARD ZONES

 RISK MAP

 FLOOD MAP

 DROUGHT MAP

 TANK

 PADD

 DAMAGE MAP

 DROUGHT MAP

 FLOOD MAP

 HAZARD ZONES

 RISK MAP

 MAPS

 ~ 1:12500 THEMATIC
FLOOD MANAGEMENT INFORMATION SYSTEM

DATABASE DESIGN
- Database
- Attribute
- Information
- Historical
- Database

MONITORING/MAPPING
- Ground-based/Satellite based

MODELING

NETWORKING
- Statistical/physical
- Multi-Point

INTERFACES
- Agency-Agency

PREPAREDNESS
- Mitigation
- Reconstruction
- Rehabilitation
- Relief
- Disaster Event
CHALLENGING TASKS

- Modifying SWAT model for real time flood forecasting of river basins using web based data,

- Mapping expected inundation, and flood zonation by integrating SWAT outputs into HEC GeoRAS and HEC-RAS models
1. Rainfall Runoff Model

2. Runoff Routing Model.

3. Error Analysis and Updating Technique

4. Hydrodynamic model for channel routing (HEC-RAS)

5. Generating TIN and delineating flood plain
SWAT Model – A Physically Based Model

To use the equations of mass, energy and momentum to describe the movement of water over the land surface and through the unsaturated and saturated zones.
Model Set up for study area

Data sets used

- (1) DEM – SRTM (90 m resolution)
- (2) Landuse – Global USGS (2 M)
- (3) Soil – FAO Global soil (5 M)
- (4) Rain gauges /Temperature gauges – IMD
- (5) Stream Gauges – CWC
Summary (m)
Min. Elevation: 10
Max. Elevation: 2913
Mean. Elevation: 103
Std. Deviation: 318
Automatically Delineated Sub-basins

Summary
Threshold: 25000 ha
No of Sub basins: 37
Area: 1532353 ha
India: 6500 sq km
Nepal: 7884 sq km

Summary
Threshold: 10000 ha
No of Sub basins: 77
Land use - Global

Summary
Agriculture: 73%
Forest: 7%
Grassland: 18%

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<tr>
<th>Land Use</th>
<th>% Watershed Area</th>
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<tr>
<td>Agricultural Land-Row Crop</td>
<td>60.24</td>
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<tr>
<td>Pasture</td>
<td>17.79</td>
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<tr>
<td>Agricultural Land-Close-gr</td>
<td>11.45</td>
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<tr>
<td>Forest-Mixed</td>
<td>3.9</td>
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<tr>
<td>Forest-Deciduous</td>
<td>2.3</td>
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<tr>
<td>Agricultural Land-Generic</td>
<td>1.54</td>
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<tr>
<td>Summer Pasture</td>
<td>1.21</td>
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<tr>
<td>Forest-Evergreen</td>
<td>1.06</td>
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<tr>
<td>Urban</td>
<td>0.3</td>
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<tr>
<td>Water</td>
<td>0.2</td>
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Weather Stations

Summary

Rain Gauges: 7
Period of data – Daily: 2000-2005

Stream Gauges: 10
Period of data – Daily: 1996-2005

Gauges
- Khatmandu
- Nagarkot
- Jankpur
- Sonbarasa
- Saulighat
- Kamtaul
- Benibad
- Hayaghat
- Khagaria
- Runi Saidpur
### Soil Properties

<table>
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<tr>
<th>SEQN</th>
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<td>0.137</td>
<td>7.17</td>
<td>27</td>
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Calibration - Output

FLOW_OUT_18

Calibration Chart for Hayaghat

Discharge m$^3$/s

Time in months of years 95-99
Calibration Results

- Seventeen parameters were selected for sensitivity analysis, calibration, validation and uncertainty analysis to be carried out by SWAT-CUP4 using SUFI algorithm. On the basis of global sensitivity analysis it can be concluded that most sensitive parameter is CN2.mgt followed by GW_DELAY, CH_N2.rte, ESCO.hru, HRU_SLP.hru, GWQMN.gw, GW_REVAP.gw and SURLAG.bsn.

- P-factor and r-factor for calibration were found to be 0.74 and is 0.44 respectively, which are very much within the range recommended for a perfect model. Seventy four percent observed and simulated values lie in 95PPU.

- P-factor and r-factor for validation period are 0.63 and 0.36 respectively which are satisfactory. Nash-Sutcliffe coefficient for calibration period for Hayaghat gauge station was found to be 0.95 which indicates best performance of the model. Nash-Sutcliffe coefficients for validation of the model for daily simulation for years 2004 and 2010 were found to be 0.93 and 0.91 respectively.

- \( R^2 = 0.96 \)
Validation for monthly flow

Validation Chart for monthly simulation for Hayaghat

Time in months for years 2000-2001
Daily Flow Validation

FLOW_OUT_18

Flow at Hayaghat

Discharge in cumecs

1-4-2004  Time in days  31-12-2004
Flow Hydrograph of Hayaghat of July-04

Discharge in cumecs

1-July - 31-July

RF at Simra
RF at Kathmandu
RF at Nagarkot
RF at Benibad
RF at Hayaghat

HayaOBS
HayaSim

15-10-2018
Validation for daily flow 2010

Validation Chart for daily simulation for year 2010 at Hayaghat

Discharge in cumecs

Time in months for years 2010
Validation for hourly flow
NE = 0.72
Real time forecasts issued on 20th July and 23rd July'04

Real time forecasting graphs for 2004 Flood Event
Real time forecast for 2010 Flood event
Inundation mapping using HEC-RAS and SWAT Model

Reach lengths, bank lengths in between cross-sections, cross sections etc. are derived from SRTM DEM
Figure 7.1 Cross section positions of Bagmati Reach between Dheng Bridge and Hayaghan Without bank lines
Figure 7.7 Typical cross sections of Bagmati river at 20km downstream of Dheng bridge
FLOOD INUNDATION MAPPING
Non-structural aspects combined with structural measures will give a better flood management policy for integrated flood management planning.

Modified SWAT model combined with HEC-RAS hydraulic model can be used as an efficient tool for real-time flood forecasting, inundation mapping and flood hazard zoning.
Suggested Components of Integrated Flood Management for future

- Natural resources management (including water resources for domestic, agriculture, fishery, and industry)
- Land use management (agriculture, industry, dwelling, urban development, etc)
- Environmental management (conservation and modification)
- Risk management policies, and
- Social development issues (living conditions, level of poverty, equity and fairness principles)
Questions to be answered for framing Flood Management Policy

What role do the flood plains play in the economy of the country/region?

What issues in National development vision/policy have relevance to the condition of floods or flooding and its management?

How flood management can contribute to the national development?
Questions to be answered for framing Flood Management Policy

- How flood risks can be appropriately factored in national development planning?
- How national development vision/policy should be aligned to the existing and future flood risks?
- How flood risks are shared between federal, state, and local governments on one hand and the individual on the other?
- What role do the different institutions play in flood management?
Thank You