RECENT TECHNOLOGICAL ADVANCEMENT

AND SUSTAINABLE SOLUTIONS FOR FLOOD

ISSUES IN NORTH BIHAR

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INDIA

My Journey as a CIVIL ENGINEER

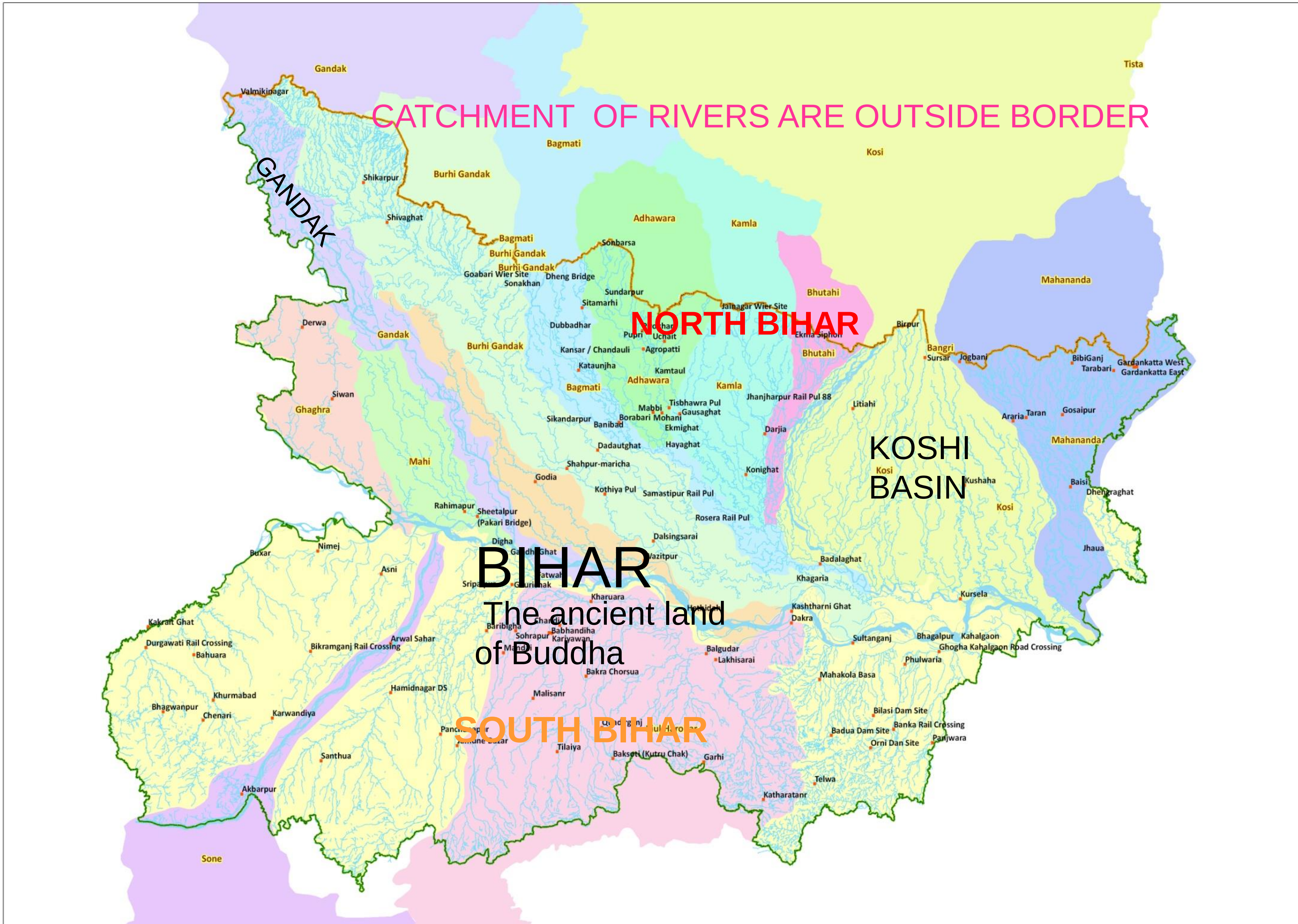
- Graduated from VNIT NAGPUR in 1981
- Railway Bridge----AFCONS—1981
- Tower Foundation in River- 1982
- Gopalpur Port Project—Orissa-1983-85
- Jawahar Lal Nehru Port Trust-1985-87 July
- WRD govt Bihar—1987-----2015(Subernrekha project,Kitanala Dam,canal system ,etc)
- WALMI- Training and Research on flood management, River Engineering,Water Management

Bihar flood Issues

- Perennial Rivers
- Catchment is trans boundary.
- Alluvial and unstable.
- Meandering features.
- Carries a lot of sediment.
- Discharge -Minimum and Maximum has got a big gap.
- Storage Reservoirs – Not possible

- Flood embankments 3430 km.on Gandak, Burhi Gandak, Bagmati, Kamla, Kosi & Mahananda etc. to protect an area of 2.916 Million Ha. only out of total flood affected area of 6.88 Million Ha. Bihar is a major flood affected area in India
- Bihar's total flood affected area is 68.80 Lac Ha
- It is 73% of its total geographical area.
- It is 17.20% of countries total flood affected area which is 400 Lac Ha

Landslides occur in the catchment area


CATCHMENT OF RIVERS ARE OUTSIDE BORDER
GANDAK
NORTH BIHAR
KOSHI BASIN
BIHAR
The ancient land of Buddha
SOUTH BIHAR
Gandak
Valmikinagar
Tista
Bagmati
Kosi
Burhi Gandak
Shikarpur
Shivaghat
Adhawara
Kamla
Sonbarsa
Mahananda
Bhutahi
Derwa
Siwan
Ghaghra
Mahi
Sone
Buxar
Nimej
Asni
Digha
Kharuara
Sultanganj
Kursela
Khagaria
Badalaghat
Jhaua
Gosaipur
Araria
Birpur
Darjia
Hayaghat
Ekmighat
Dalsingsarai
Rosera Rail Pul
Samastipur Rail Pul
Kothiya Pul
Godia
Rahimapur
Durgawati Rail Crossing
Bahuara
Khurmabad
Chenari
Bhagwanpur
Karwandiya
Santhua
Akbarpur
Hamidnagar DS
Malisanr
Tilaiya
Garhi
Telwa
Katharatanr
Lakhisarai
Balgudar
Bakra Chorsua
Bikramganj Rail Crossing
Arwal Sahar
Phulwaria
Mahakola Basa
Bilasi Dam Site
Badua Dam Site
Orni Dan Site
Panjwara
Kushaha
Baisi
Dhengraghat

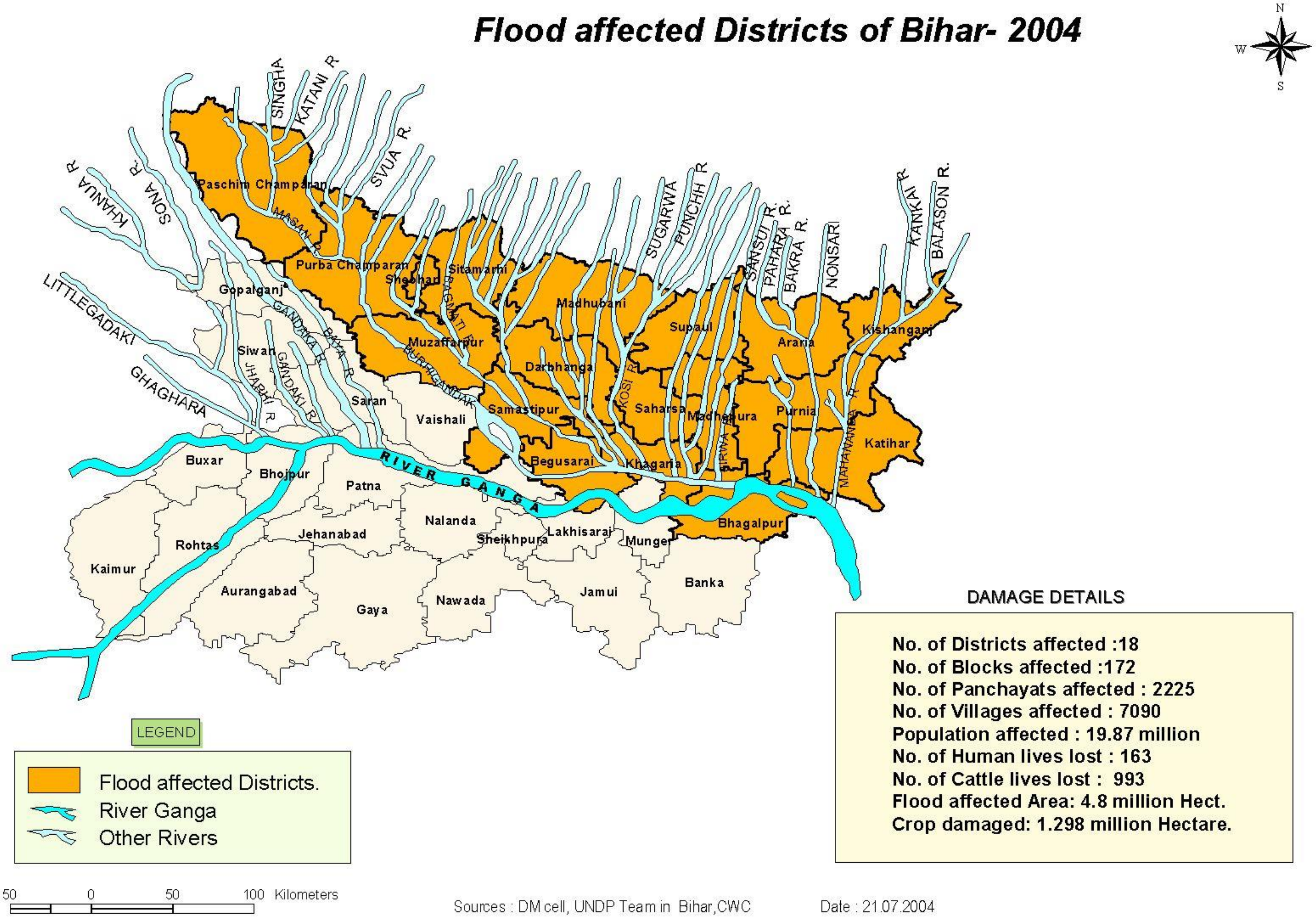
AN IDEA ABOUT NORTH BIHAR

- PEAKS

FMIS BIHAR

GANDAK
UTTAR PRADESH
BURHI GANDAK
NEPAL
BAGMATI
ADHWARA
GANDAK
BHUTAHI
KAMLA
MAHANANDA
KOSI
GHAGHRA
MAHI
BAYA
BAGMATI
WEST BENGAL
SON
GANGA
Buxar
Bhojpur
Patna
Bhagalpur
Munger
Lakhisarai
Nalanda
Sheikhpura
Jehanabad
Bhabhua
Rohtas
South Bihar
Aurangabad
Gaya
Nawada
Jamui
Banka

Flood affected Districts of Bihar- 2004



LEGEND

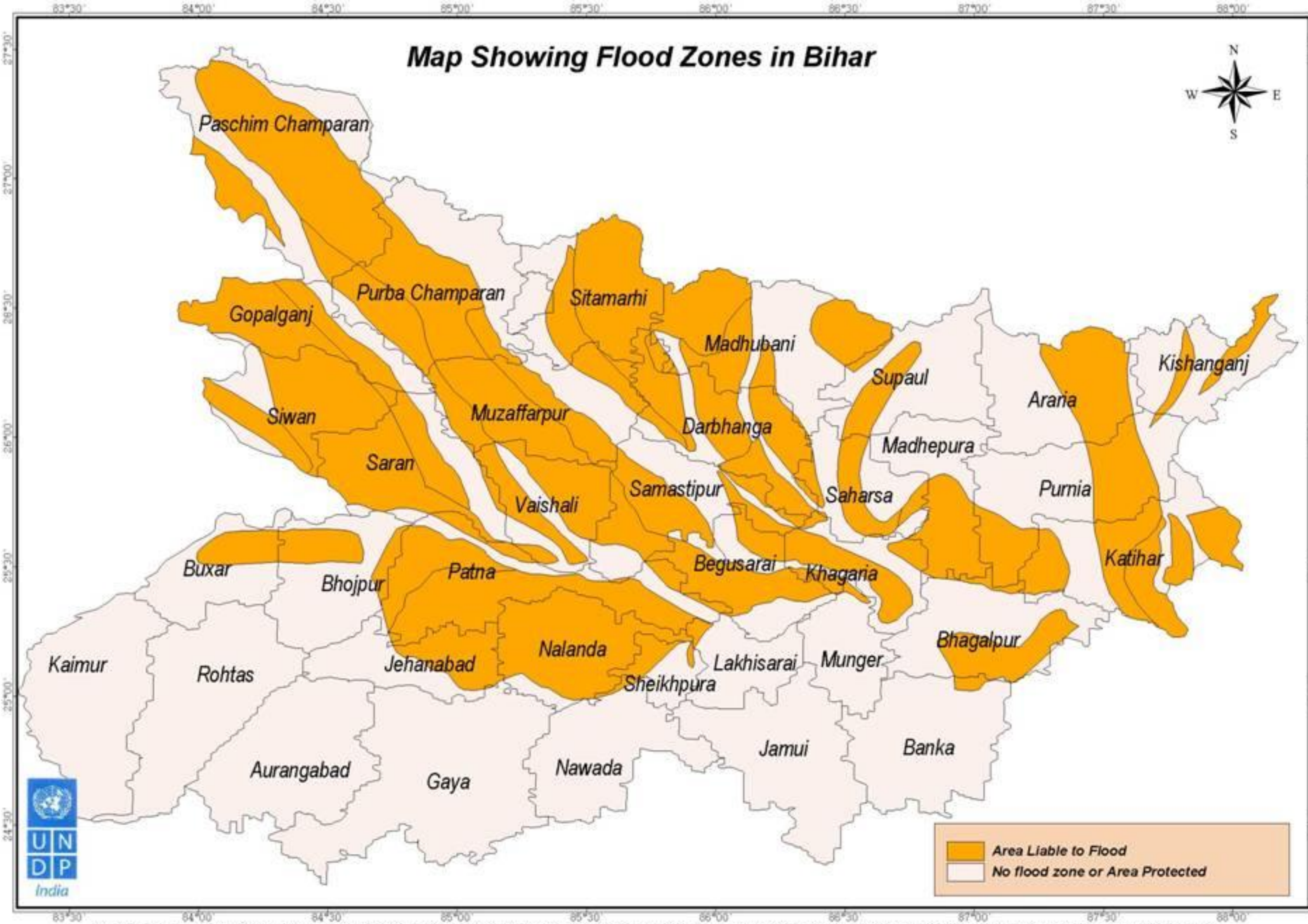
- Flood affected Districts.
- River Ganga
- Other Rivers

DAMAGE DETAILS

No. of Districts affected :18
No. of Blocks affected :172
No. of Panchayats affected : 2225
No. of Villages affected : 7090
Population affected : 19.87 million
No. of Human lives lost : 163
No. of Cattle lives lost : 993
Flood affected Area: 4.8 million Hect.
Crop damaged: 1.298 million Hectare.

Sources : DM cell, UNDP Team in Bihar,CWC

Date : 21.07.2004



Disclaimer: This map was collated based on the data/information compiled by the Ministry of Urban Development and Poverty Alleviation; UNDP has not verified the accuracy of information of the Map. Source: BMTPC, India

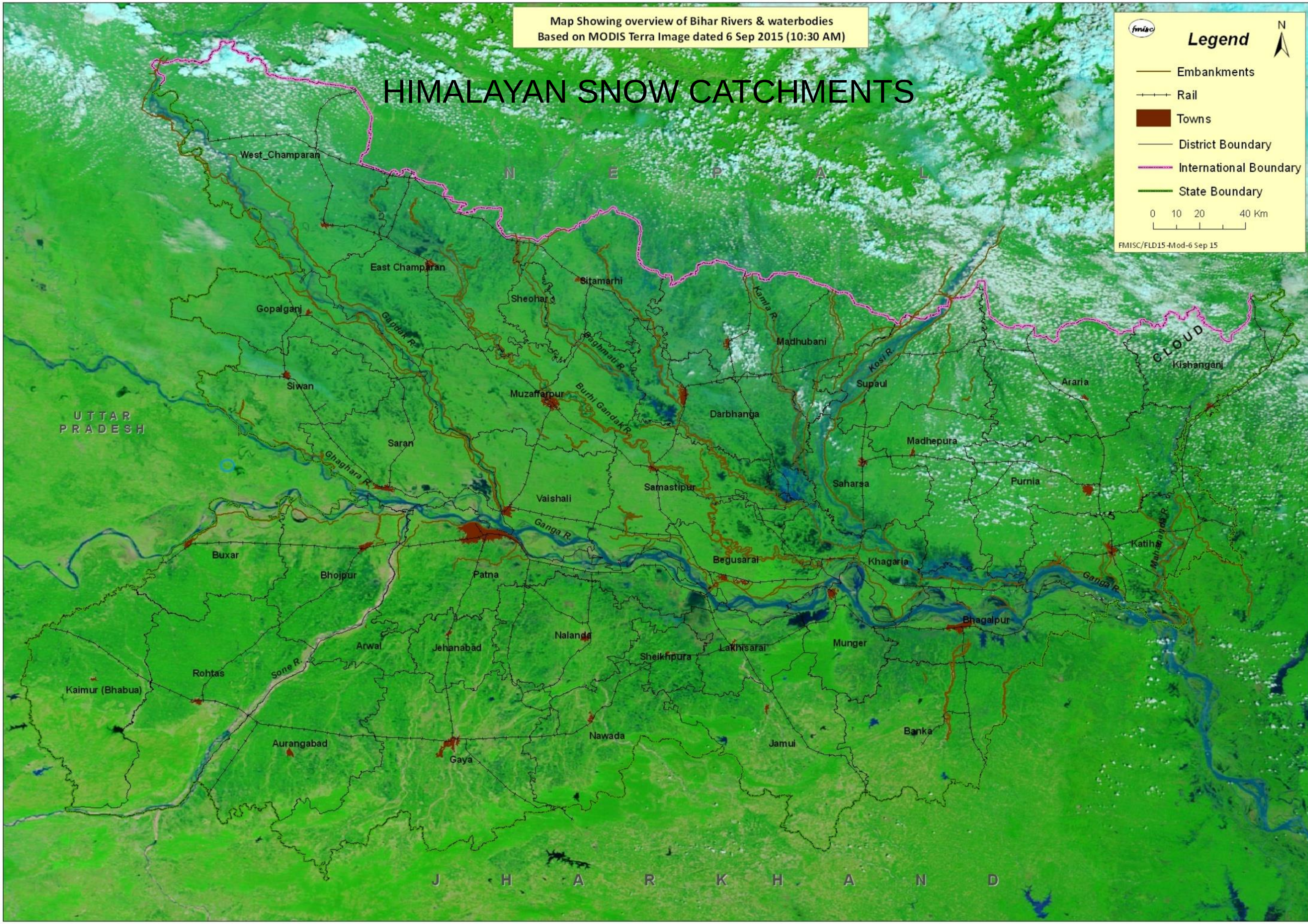
Bihar is a state in East India. It is the 13th largest state, with an area of 94,163 km² and the 3rd largest by population; its population is the fastest-growing of any state.

Population:
99.02 million (2012)

Capital:
Patna

Area:
36,357 mi²


C H I N A
N e p a l
Gandak
Kosi
Bagmati
Burhi Gandak
Adhwara
Kamla
West Champaran
Gandak
Burhi Gandak
Mahananda
Bhutahi
Uttar Pradesh
East Champaran
Sitamarhi
Gopalganj
Sheohar
Adhwara
Madhubani
Bagmati
Kamla
Bhutahi
Supaul
Kishanganj
Araria
Mahananda
Ghaghra
Muzaffarpur
Siwan
Darbhanga
Mahi
Madhepura
Saran
Baya
Samastipur
Saharsa
Kosi
Purnia
Kosi
Vaishali
Ganga
Bhojpur
Katihar
Buxar
Patna
Begusarai
Ganga
Bhagalpur
Kaimur
(Bhabua)
Nalanda
Arwal
Jehanabad
Sheikhpura
Lakhisarai
Munger
Rohtas
Karmnasa
Kiul Harohar
Nawada
Banka
Aurangabad
Jamui
Gaya
Punpun
West
Bengal
Sone
J h a r k h a n d
N
fmisc
CWC-proposal-Revised.jpg


Map Showing overview of Bihar Rivers & waterbodies
Based on MODIS Terra Image dated 6 Sep 2015 (10:30 AM)
HIMALAYAN SNOW CATCHMENTS
Legend
N
Embankments
Rail
Towns
District Boundary
International Boundary
State Boundary
0 10 20 40 Km
FMISC/FLD15-Mod-6 Sep 15
N E P A L
UTTAR PRADESH
J H A R K H A N D
CLOUD
West_Champaran
East Champaran
Gopalganj
Siwan
Saran
Sheohar
Sitamarhi
Madhubani
Muzaffarpur
Darbhanga
Supaul
Araria
Kishanganj
Madhepura
Saharsa
Purnia
Vaishali
Samastipur
Begusarai
Khagaria
Katihar
Bhagalpur
Buxar
Bhojpur
Patna
Nalanda
Arwal
Jehanabad
Sheikhpura
Lakhisarai
Munger
Rohtas
Kaimur (Bhabua)
Aurangabad
Gaya
Nawada
Jamui
Banka
Gandak R.
Baghmati R.
Burhi Gandak R.
Kamla R.
Kosi R.
Ghaghara R.
Ganga R.
Sone R.
Mahananda R.

FLOOD HISTORY

- Bihar is India’s most flood-prone State, with 76 percent of the population, in the North Bihar living under the recurring threat of flood devastation. About 68800 sq Km out of total geographical area of 94160 sq Km comprising 73.06 percent is flood affected.

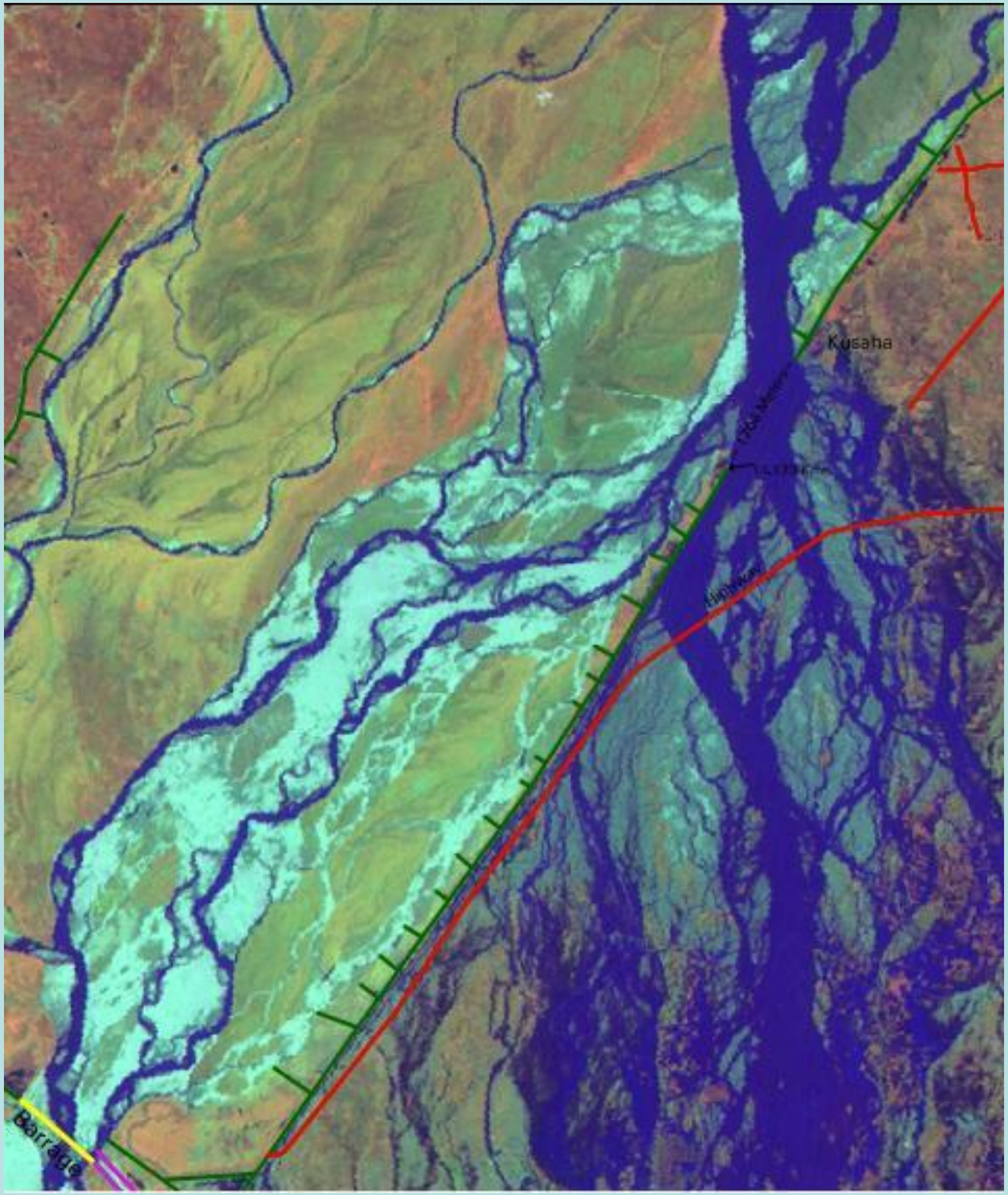
Drainage System of Bihar

- The plains of Bihar, adjoining Nepal, are drained by a number of rivers that have their catchments in the steep and geologically nascent Himalayas. Kosi, Gandak,Burhi Gandak, Bagmati, Kamla Balan, Mahananda and Adhwara Group of rivers originates in Nepal, carry high discharge and very high sediment load and drops it down in the plains of Bihar. About 65% of catchments area of these rivers falls in Nepal/Tibet and only 35% of catchments area lies in Bihar. A review by Kale (1997) indicated that the plains of north Bihar have recorded the highest number of floods during the last 30years. In the years 1978, 1987, 1998, 2004 and 2007 Bihar witnessed high magnitudes of flood.

2008 Koshi breach

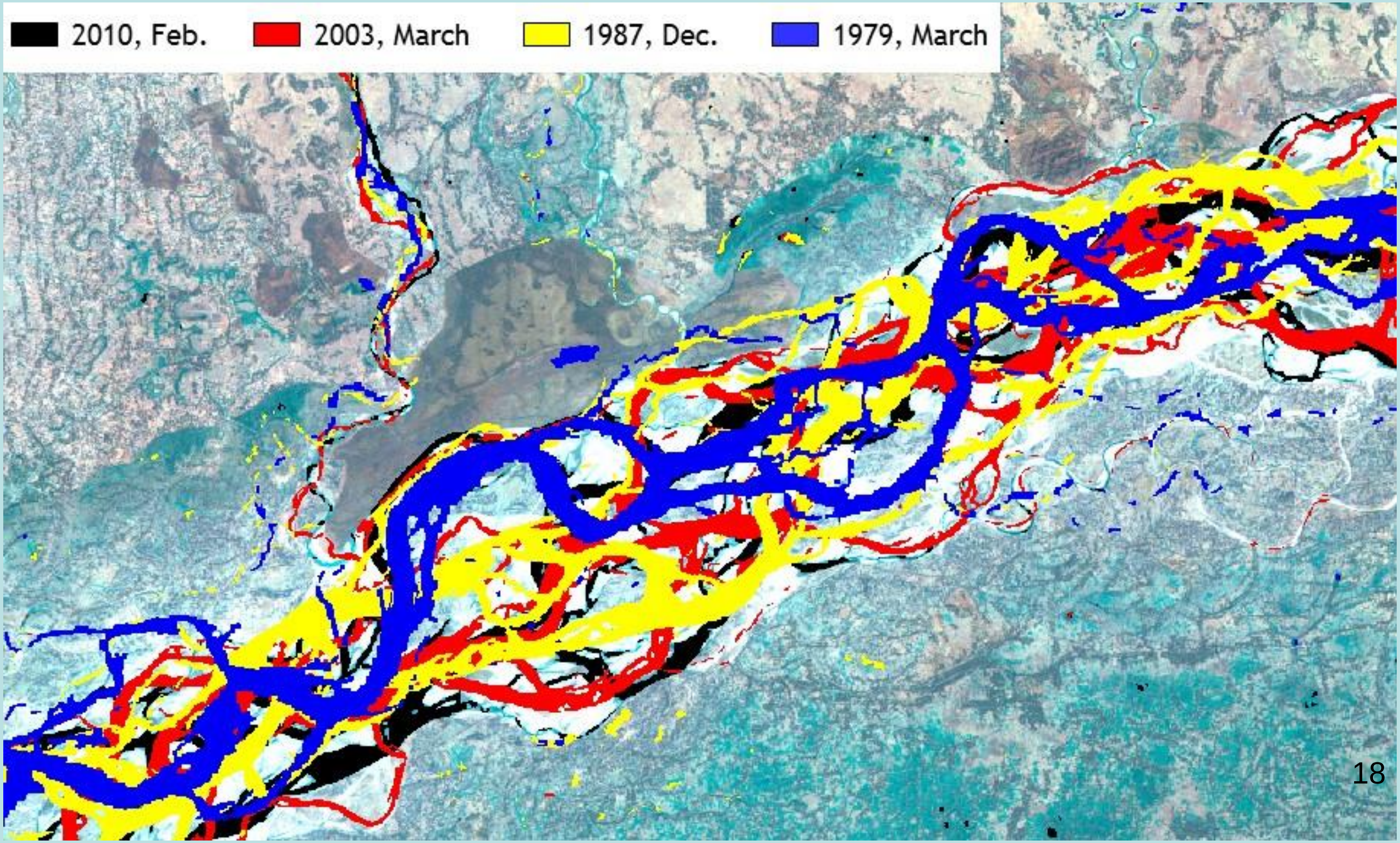
- **2008 :-** an appreciable amount of rainfall was received on very first day of monsoon season i.e. 15th June (160mm at Chanpatia, 141 mm at Sikanderpur and 92.2 mm at Khagaria). July was the wettest month having maximum rainy days followed by August-08.
  There was an unprecedented flood due to breach near 12.9km of Eastern Kosi Afflux Embankment near Kussha village in Nepal on 18th August 2008 that took a shape of a catastrophe leading to miseries to lakhs of people in Sunsari and Saptari districts of Nepal and Supaul, Madhepura, Araria, Saharsa, Katihar and purnea districts of Bihar. River Kosi entirely changed its course from earlier one which was again tamed to its original course by Water Resources Department after a tremendous effort keeping in line with the advice of Kosi Breach Closure Advisory Committee (KBCAT).

Koshi Breach
18th Aug 2008



BRB : Braiding river classified by ILMSimage

As a result of uncontrolled management and geotectonic activity the channel system is continuously braiding.



A FLOOD SCENE AFTER KOSHI BREACH IN D/S AREA

RECENT TECHNOLOGICAL ADVANCEMENT IN RIVER TRAINING

USE OF RIVER TRAINING TECHNIQUES

Management of stream bank erosion,

Flood control,

Fairway development for Inland navigation

RIVER TRAINING STRUCTURES

Cost effective river training techniques

- **Bandalling**
- **Porcupine**
- **Steel Jack Jetty system (Presently used with trial and error approach with element of conjecture in USA)**

RIVER TRAINING STRUCTURES

Conventional river training techniques

- Spurs
- Groynes
- Bank revetments

PROBLEM OF CONVENTIONAL RIVER TRAINING STRUCTURES

Expensive and less cost effective Due to

- **Rising costs of labour**
- **Rising costs of the construction material such as boulders, wire nets etc.**
- **Costly both in terms of capital cost as well as with regard to high yearly maintenance cost**
- **Practically unaffordable for large river network**

PRESENT PRACTICE OF FLOOD MANAGEMENT IN BIHAR by State WRD

- Before monsoon period anti-erosion works and during the monsoon, flood fighting works are done at vulnerable sites by State Water Resources Department
- The joint committee seeing the river regime after the flood, erosion, vulnerable sites are suggested and proposed for anti-erosion schemes.
- On the basis of the committee's report, field Executive Engineers measure the damages, frame scheme as per relevant design and prepare estimate. They put it before Technical Advisory committee(TAC).

PRESENT PRACTICE OF FLOOD MANAGEMENT IN BIHAR by state WRD

- After recommendation by TAC, the scheme are sent to Scheme Review Committee(SRC)
- 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.
- In the board other members are Minister Water Resources Department, Principal Secretary W.R.D, Principal Secretary Finance & Engineer in Chief (North)

- AGENDA GETS APPROVED AND FUND MADE AVAILABLE.

Bank Protection With Boulder

Channelization of river

Channelization of a stream may be undertaken for several reasons.

To make a stream more suitable for navigation or for navigation by larger vessels with deep draughts.

To restrict water to a certain area of a stream's natural bottom lands so that the bulk of such lands can be made available for agriculture.

For flood control, with the idea of giving a stream a sufficiently large and deep channel so that flooding beyond those limits will be minimal or nonexistent.

To reduce natural erosion; as a natural waterway curves back and forth, it usually deposits sand and gravel on the inside of the corners where the water flows slowly, and cuts sand, gravel, subsoil, and precious topsoil from the outside corners where it flows rapidly due to a change in direction.

It simply washes away. Channelization of a waterway by straightening it prevents the water from changing directions randomly, and net erosion is greatly reduced.
(Gray D. Harding, Schumm. S & Kahn H)

Types of Channelisation

1. Resectioning by Widening and Deepening: - Widening and deepening increase the channel cross section; therefore, channel capacity to contain flows is increased and floodplain is inundated less frequently (flood control and agricultural purposes).

2. Straightening:- Straightening implies the cut of river bends (meander cutoff in the case of a meandering river); it produces shortening of the river channel, increasing of the gradient, and increasing of the flow velocity. The purpose is to reduce flood heights.

3. Levees (or Embankments):- The aim of levees is to increase channel capacity so that flood flows are confined and do not inundate the areas adjacent to the channels (floodplains), which would be inundated under normal conditions.

4. Flood Walls and Lined Channels: - This type of method is commonly used in urban areas where other kinds of channelization are limited or where access for maintenance is restricted.

5. Bank Protection Structures: - Groynes are structures built transverse to the river flow and extending from the banks into the channel. The aim of these structures, which deflect the direction of the flow, is to protect the banks from erosion processes .

6. Diversion Channels: - New channels can be constructed to divert flows out of the existing channel.

7. Culverts: - This type of channelization has often been used for urban streams, but also for small rural/mountain streams.

Some River Channelised

No	Name of River	Country	Type of River	River Training work	Remark	Year
1	Los Angeles River	United State	Alluvial	Concrete embankment, Earthen embankment slope lined	City area balance	
2	Danube river	Austria	Alluvial	Embankment slope Lined Earthen embankment	City area balance	
3	Rhone river	France	Alluvial	Embankment slope Lined Earthen embankment	City area balance	
4	Wolf river, Tennessee	United State	Alluvial	Earthen embankment	complete	
5	Kissimmee river, Florida	United State	Alluvial	Earthen embankment	complete	
6	Salt river, Arizona	United State	Alluvial	Earthen embankment		
7	Garonne river	France	Alluvial	Embankment slope Lined Earthen embankment	City area balance	
8	The Lower Mississippi River basin	United State	Alluvial	Earthen embankment	complete	
9	Odra river,	Poland	Alluvial	Embankment slope Lined Earthen embankment	City area balance	

Note:- In India channelisation of SWAN RIVER and BATA RIVER is in progress

Navigation route of Rhone river, France

Channelisation of Rhone river, France

Rhone river, France

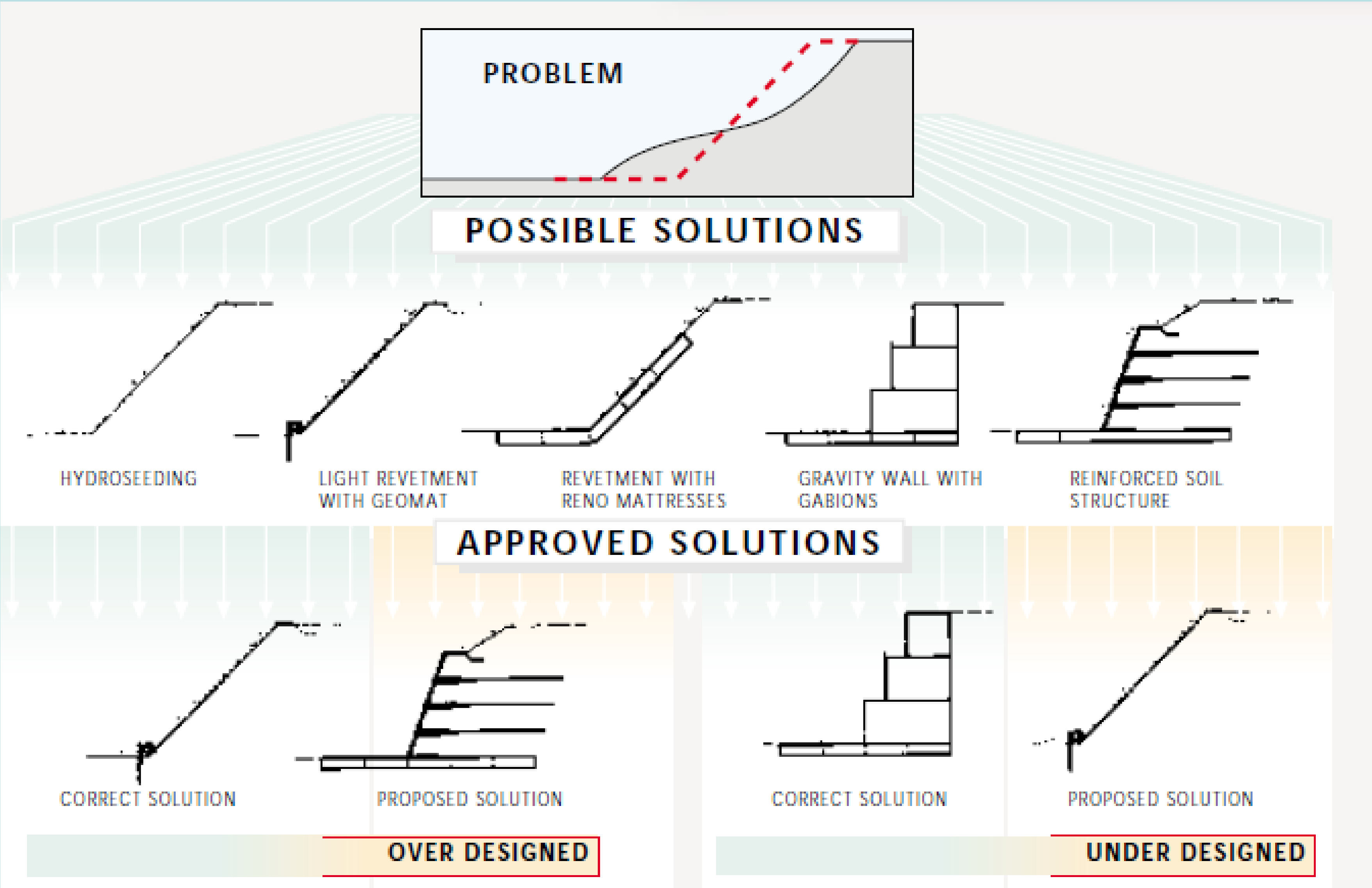
Channelisation of Rhone river, France

The Lower Mississippi River basin

Note:- The river is constrained by levees and dikes for flood control and to maintain a safe navigation channel for the towing industry.

The Lower Mississippi River Towboats, barges and ships near New Orleans

For a well-balanced Design of River works



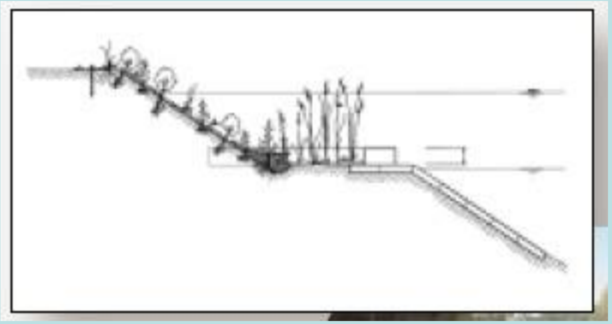
Channelisation Methods

channelized with earthen embankments

channelized with riprap

channelized with concrete embankments

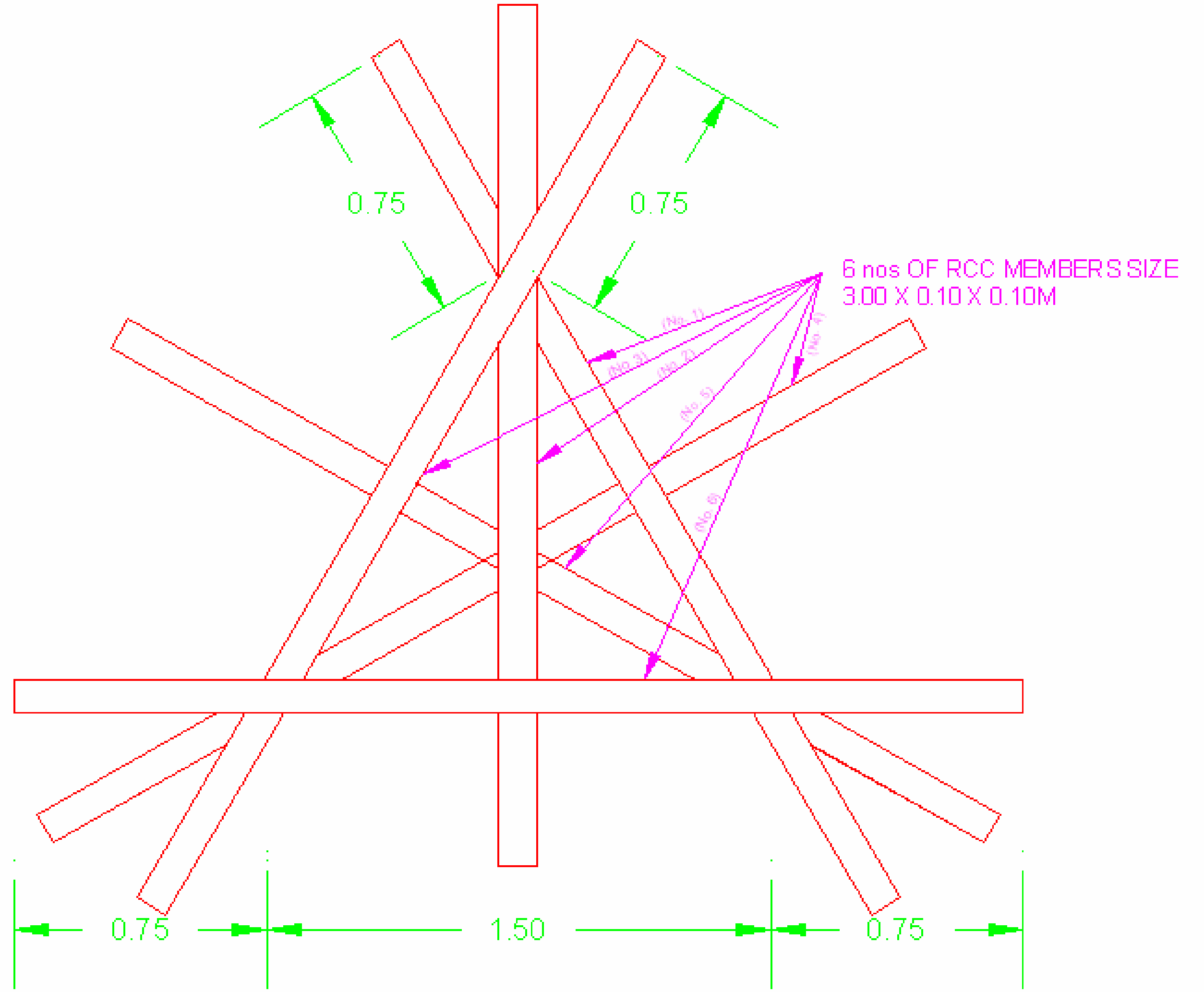
channelized with earthen embankments



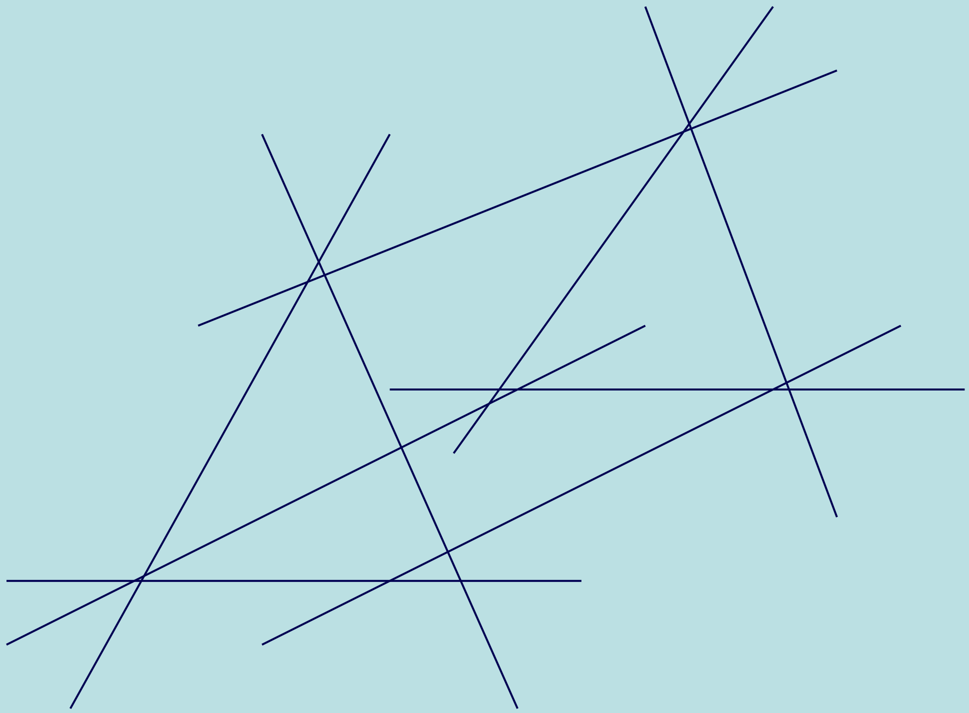
Effect of Channelisation

Table 1 Examples of studies documenting the effects of channelization

Location	Effects (channel morphology, ecology, structures, etc.)
Danube River, Austria	Ecology
Rhone River, France	Incision; destabilization of infrastructures; lowering of water table
Garonne River, France	Ecology
England and Wales	Channel adjustments
Main River, Ireland	Flows
Skawa and Wisloka Rivers, Poland	Incision; decrease of overbank flow and deposition
Raba River, Poland	Increased flood magnitude
Denmark	Channel adjustments
Italy	Channel adjustments
Spoon River, Illinois	Channel aggradation; good ecological effects
Wolf River, Tennesse	Incision; habitat destruction; increase earthquake risk
Iowa	Degradation; loss of land; damage to infrastructures
Several Rivers in Tennessee	Incision; aggradation; riparian vegetation
Kissimmee River, Florida	Ecology
Salt River, Arizona	Channel changes
Rio Puerto Nueva, Puerto Rico	Groundwater changes
Kuchoro River, Japan	Aggradation; vegetation change in wetlands
New Zealand	Riparian ecology; channel morphology
Australia	Aquatic habitat



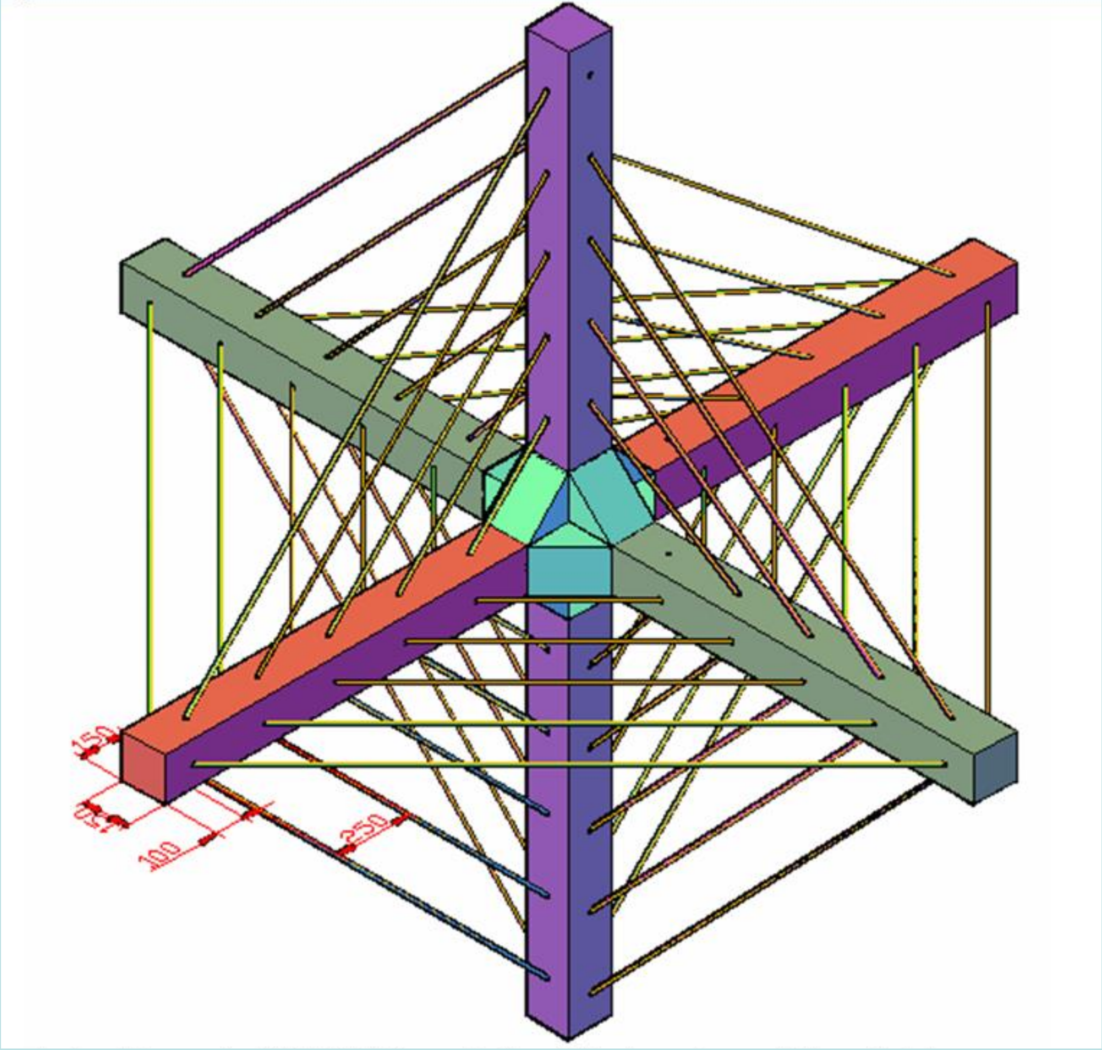
Six Member Porcupine Front elevation of typical 3m size



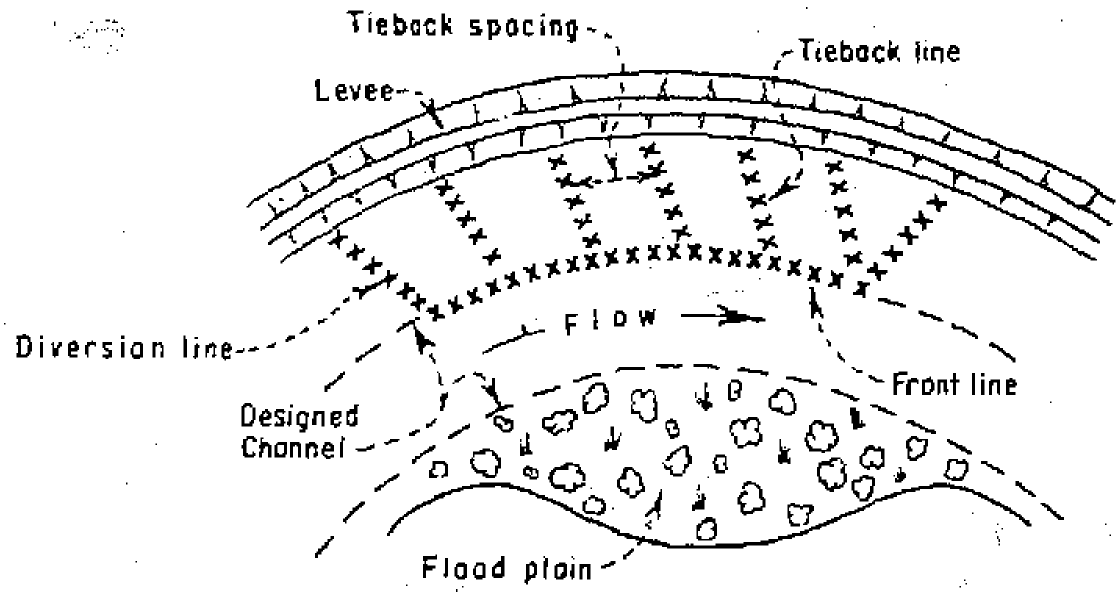
New Nine Member Porcupine

Trapezoidal vanes with and without collar installed in Solani river

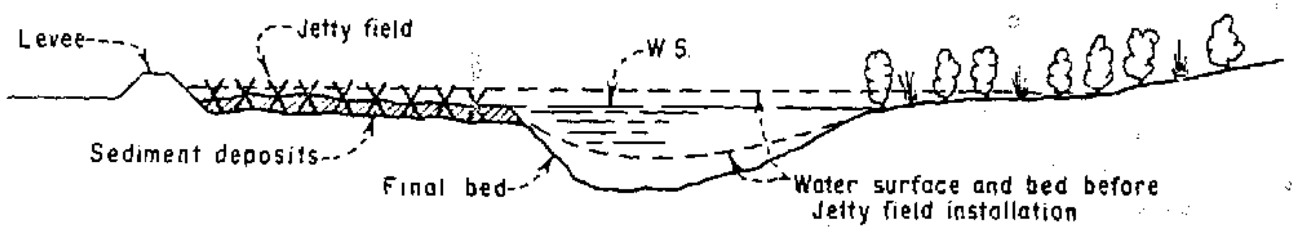
Sediment deposited on vanes after flood in Solani river



RCC Jack Jetty of 3m length and 15cm thickness with 15cmx15cm haunch at junction mesh with 4mm GI wire



PLAN AT JETTY FIELD

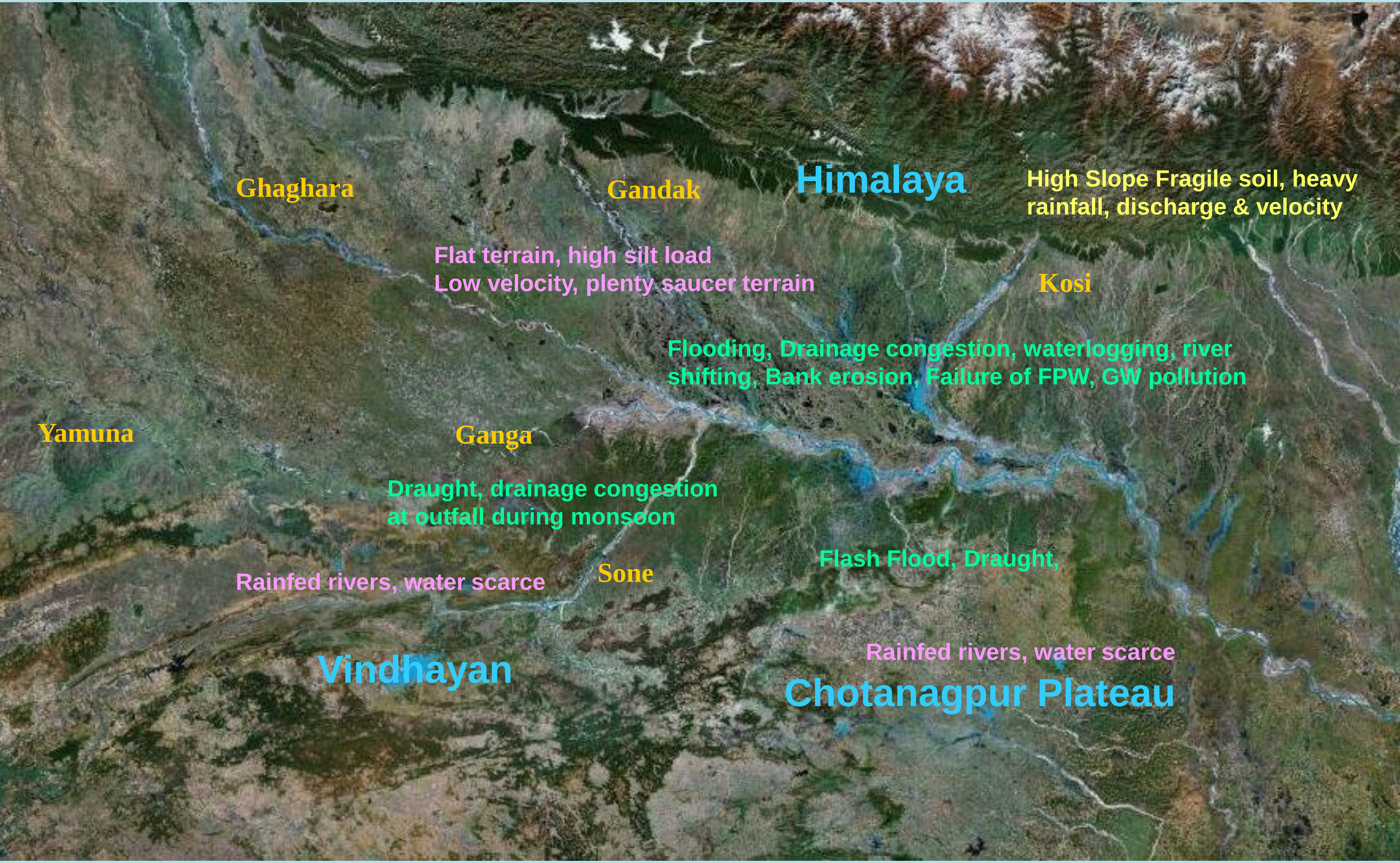


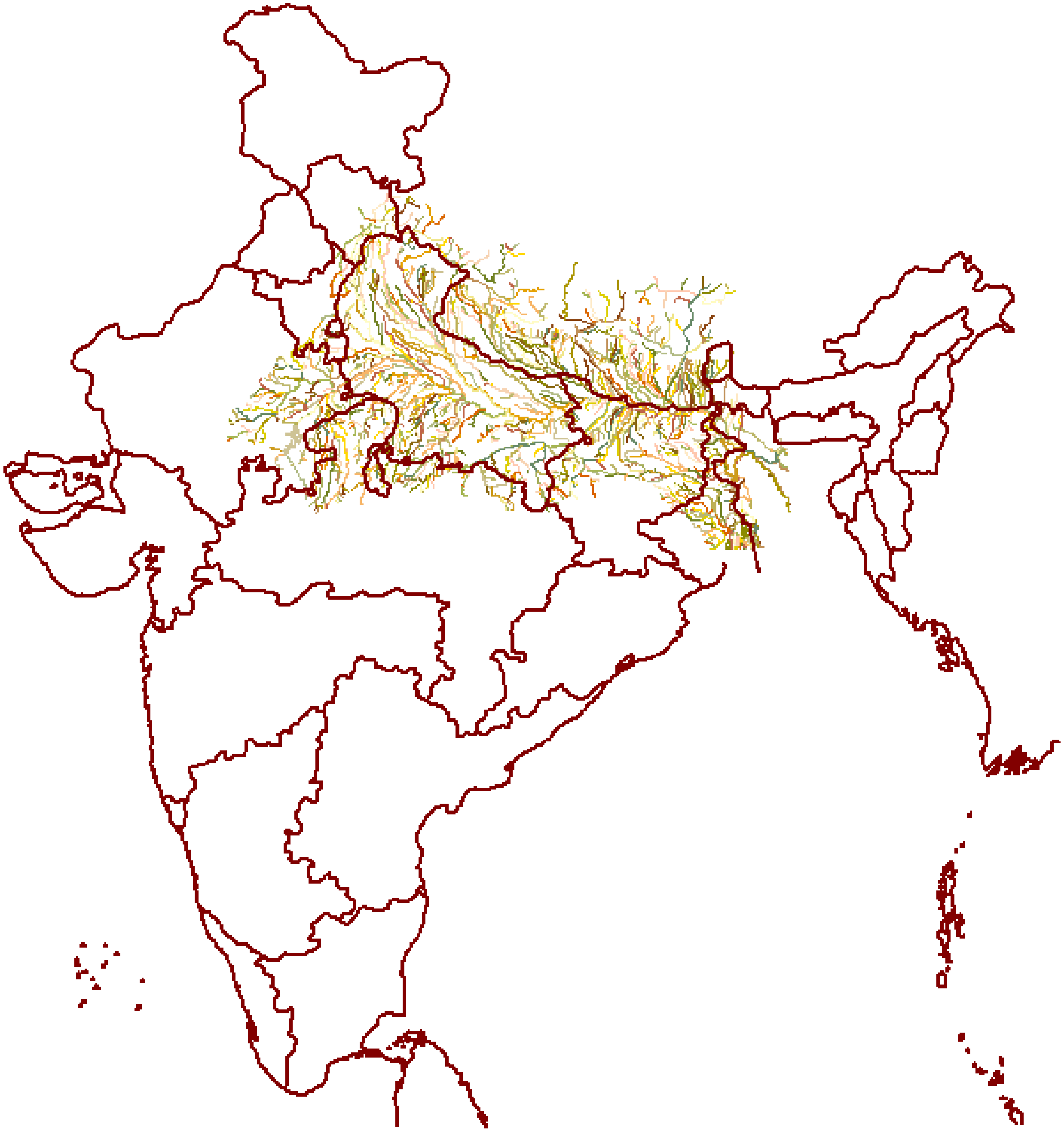
CROSS SECTION THROUGH JETTY FIELD

United States Department of the International Bureau of Reclamation.
Control of Alluvial Rivers by Steel Jetties


4/10/2

SUSTAINABLE SOLUTIONS OF NORTH BIHAR FLOODS


Ghaghara
Gandak
Himalaya
High Slope Fragile soil, heavy rainfall, discharge & velocity
Flat terrain, high silt load
Low velocity, plenty saucer terrain
Kosi
Flooding, Drainage congestion, waterlogging, river shifting, Bank erosion, Failure of FPW, GW pollution
Yamuna
Ganga
Draught, drainage congestion at outfall during monsoon
Flash Flood, Draught,
Rainfed rivers, water scarce
Sone
Vindhayan
Rainfed rivers, water scarce
Chotanagpur Plateau



IN INDIA

The river Ganga travels through the State of

Himachal,
Uttranchal,
Uttar Pradesh,
Bihar,
West Bengal.

The tributaries of river Ganga have coverage of

Haryana,
Rajasthan,
Madhya Pradesh,
Jharkhand,
Chattisgarh

Hydrological Problems

- **Basins of Himalayan Origin**
  - Drainage area in Nepal and Tibet.
  - Gradient 10-5m/km in upper catchment.
  - Rainfall in hilly terrain is about 1.75 times more than the plains.
  - In downstream, flatter topography results in blockage of water due to substantial loss of velocity causing flood and deposition of silt.
  - River shifting and Chaur formation. Kosi shift 113km in last 200 years. Silt deposition 0.23 billion tonne per year.
  - Blockage of water due to network of Road, Rail system, inadequate opening of bridges and culverts further causes flood hazards.
  - Walerlogging and drainage congestion are of grave concern.
  - Water pollution in the river system endangering the ecological front.

Hydrological Problems of the Region (Contd…)

- **Basins of Vindhayan Origin**
  - Rivers are rainfed, therefore seasonal in nature and mostly go dry during rainless months.
  - Hilly terrain receives about 1.25 times more rain than the plain areas during monsoon months.
  - About 80% rainfall rainfall during monsoon months.
  - Problem of erosion in the upper terrain and siltation in the constructed structures are common as Himalayan basin.
  - Problem of scarcity of water.

Hydrological Problems of the Region (Contd…)

- **Basins of Chotanagpur Plateau origin**
  - Similar problem as Vindhayan origin.
  - Flash flood usual phenomena.
  - Secondary porosity more pronounced.
  - Groundwater mostly in confined condition.

Name of the basin	Catchment area (km^2)	Annual rainfall (mm)	Hydrological Problems
Ghaghra	1,27,950(total) 57,647(in India) 54,417(U.P), 3,230 (Bihar)	970-1560 1127 (north Bihar)	1. flood, 2. erosion, 3. water logging & drainage,
Sone	47,656(In M.P) 5,952(in U.P) 17,651(Bihar)	990-1620	1. flood in lower stretches, 2. drainage,

Name of the basin	Catchment area (km^2)	Annual rainfall (mm)	Hydrological Problems
Sone (South Bihar) (Kanhar & N. Koel are tributaries)	10,57.44 (N.Koel)	990	1. bank spilling, 2. drainage congestions, 3. drought in North Koel basin.
Gandak (North Bihar)	46,300 (total) 7,620 (Bihar)	1120	1. river course shifting & erosion, 2. flood, 3. water logging & drainage,
Buri Gandak (North Bihar)	12,500(total) 10,150 (Bihar)	1180-1390	1. flood, 2. erosion, 3. drainage congestion,
Bagmati & Adhwara (North Bihar) (Tributaries of the Kosi)	13,400(total) 6320 (Bihar) 3720(Bagmati) 2600(Adhwara)	1180	i) severe flood, ii) Drainage congestion

Name of the basin	Catchment area (km^2)	A/rainfall (mm)	Hydrological Problems
Kamala-Balan (N/Bihar tributary of Kosi)	5445(total) 2980(Bihar)	1210-1380	1. flood, 2. river course shifting, 3. drainage congestion,
Kosi (North Bihar)	70,409(total) 11,070(Bihar)	1590-1380 3500 (in hilly area, mm)	1. enormous siltation, 2. river shifting 3. drainage congestion, 4. flood, 5. waterlogging due to rise of ground water table,
Mahananda	25,043(total) 17,440(India) 6,340(Bihar)	6000 in u/ catchment and 1000 in plains	1. flood due to spilling of banks,
	11,100 (West Bangal)	6000 in u/catchment and 1000 in plains	1. landslides during monsoon in upper stretches, 2. drainage congestion,

Name of the basin	Catchment area (km^2)	A/rainfall (mm)	Hydrological Problems
Karamnasa (South Bihar)	5,127 (Bihar)		1. drought
Punpun (South Bihar)	8,530	990-1340	1. flood de to bank spilling,
Kiul-Harohar (South Bihar) (Harohar is a tributary of Kiul)	16,580	990-1260	1. water logging & drainage (Tal), 2. Flood due to backwater from Ganga,
Belharna (South Bihar)	2,215	1040-1370.	1. drainage congestion,
Badua-Bilasi-Chandan (South Bihar) (Bilasi & Chandan are tributaries of Badua)	4,093	1040-1370	1. flash floods in plains of Badua system in Bhagalpur & Mongher district and also the drought problems, 2. Flood in Chandan river system.

Name of the basin	Catchment area (km^2)	A/rainfall (mm)	Hydrological Problems
Gumani (South Bihar)	4,286	1470	1. drought
Mayurakshi (South Bihar)	8,530 (total) 2,070 (Bihar) 6,460(Bengal)	1280-1380	1. sedimentation, 2. drought,
Ajay	6,050 (total) 2,798(Bihar)	1280-1380 mm.	1. drought in Deoghar area,
	3,252(Bengal)	1380 mm.	1. flash floods in some pockets, 2. drought,
Sankh (South Bihar)	4,027.43	1430	1. drought,
South Koel (South Bihar)	10,588.56	1280	1. drought,
Barakar (S.Bihar tributary of Damodar)	7,026	1300	1. soil erosion & sedimentation. 2. drought,

Name of the basin	Catchment area (km^2)	A/rainfall (mm)	Hydrological Problems
Damodar	31,228(total i/c Barakar) 20,570(Bihar)	1250-1480	1. soil erosion in u/catchment, and ii) sedimentation in the reservoirs site. 2. WQ due to coal mines and industrial pollution, 3. drought in some areas,
	10,650(Bengal)	1300 -1520 mm.	1. erosion & sedimentation, 2. flood in the right bank of the river,
Subarnarekha (S. Bihar)	8591.46	1338 -1372 mm.	1. drought,
Jalangi	5,640	1280-1340	1. drainage congestion, 2. siltation,
Rupnarayan	10,930	1320	1. drainage due to the tide, 2. siltation,
Haldi	10,210(total) 2,070(Bihar) 8,138(Bengal)	1270-1470	1. deterioration of river stretches due to the siltation,

Flood Mitigation/Control Measures

Aims at

- ✓ Modifying the flood
- ✓ Modifying the susceptibility to flood damage
- ✓ Living with flood

Flood Control Measures aim at avoiding damages from floods by

- ✓ Structural Measures
- ✓ Non-Structural Measures

Structural Mitigation Measures

- ✓ **Storage reservoirs – Multipurpose**
- ✓ **Confining river flow by embankments**
  - – **Surrounding area is protected from flooding**
- ✓ **Channel improvement works**
  - – **Includes increase in size of X-section and excavation of stream bed - to increase discharge or velocity**
- ✓ **Diversion Works**
  - - **Form the u/s side of the flood affected area a diversion channel is excavated to connect the river at the d/s area**
- ✓ **Flood Wall**
  - – **when no space is available or site condition is not suitable**

Structural Measures…….

- ✓ **Flood Ways**
  - A portion of the flood water is diverted in the low lying areas along the course of the river through a natural or artificial channel
- ✓ **Runoff reduction by watershed management – an indirect method applied to the watershed which has long term effect on flood disaster mitigation**
  - Includes Afforestation, Contour farming, Contour bunds, Check bunds, Gully plugging, Bank protection, Diversion drains, Strip cropping

Non-Structural Mitigation Measures

Include modifying the susceptibility to flood damage by

- ✓ **Flood plain management**
- ✓ **Flood proofing including disaster preparedness**
- ✓ **Response planning**
- ✓ **Flood forecasting and warning**

Include modifying the loss burden by

- ✓ **Disaster relief**
- ✓ **Flood fighting including public awareness**
- ✓ **Flood insurance**

Non-Structural Mitigation Measures……

Flood Plain Zoning

- ✓ **Area near the river are the most vulnerable to flood hazards if not upland**
- ✓ **Therefore, no dwelling in these flood prone areas**
- ✓ **Places below HFL should not be recommended for inhabitation**
- ✓ **These areas may be used as parks, recreation ground etc.**

Thrust Areas of Research

Based on the hydrological problems of the region the thrust areas of research can be categorised as follows

1. Flood estimation
2. Flood forecasting.
3. Mathematical modelling of river flows
4. Water logging and drainage congestion
5. Failures analysis of dams/ embankments
6. Watershed management for flood control
7. Flood plain zoning
8. Erosion and Sedimentation,
9. Water assessment and availability,
10. Hydrological Network design and data management

Non-Structural Mitigation Measures……

Flood Forecasting

- ✓ Data observation, quick transmission, analysis and dissemination
- ✓ Temporary evacuation of persons and properties to safer places before flood arrives

Flood Proofing

Mathematical Modelling

- ✓ Can predict flood intensity in d/s , area of inundation and depth of flooding

SWAT MODEL USE FOR FINDING SUSTAINABLE SOLUTIONS FOR NORTH BIHAR RIVER FLOODS

1. Development of hydrologic response modelling for the trans-boundary watershed for simulation of discharge dynamics driven by season monsoon rains complemented by snow and glacier melt water runoff along with sediment yield.

   The above will provide the required hydrological information on runoff generation from the watershed pertaining to water and sediment on spatial and temporal basis, which are responsible for shaping the river behaviour.

   Latest modelling software will be used supplemented with high resolution multispectral satellite data for assessment of Land Use Land Cover (LULC) characteristics, and identify zones for required implementation of watershed management measures.
2. Assessment of river plan form changes using multi-spectral multi-date satellite imageries to identify & prioritize the vulnerable locations, as well as monitor the behaviour / hazard of spur protected bank-line.
3. Development of flow simulation computerized river model of

3. the Koshi,Gandak ,Bagmati, Kamala and all other rivers which should be calibratedwith surveyed river cross-sections & other hydrological data.

The above model will be helpful for flood forecasting, planning for channel improvement programme etc. of North bihar Rivers

4. Development of robust, sustainable and cost effective river training system for Kosh all the rivers for channelization & imparting hydraulically efficient sediment transport capacity, desired flow conveyance .
5. Assessment of confluence zone of all north Bihar rivers with the Ganga near their meeting points with Ganga from the standpoint of fluvial behaviour and evolve suitable measures.

4. Assessment of human dimension of flood and erosion vulnerability for evolving appropriate disaster mitigation & rehabilitation plan duly incorporating socio-economic factors.

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Thank You