Cumulative environmental impact assessment of hydropower projects in Alaknanda and Bhagirathi basins

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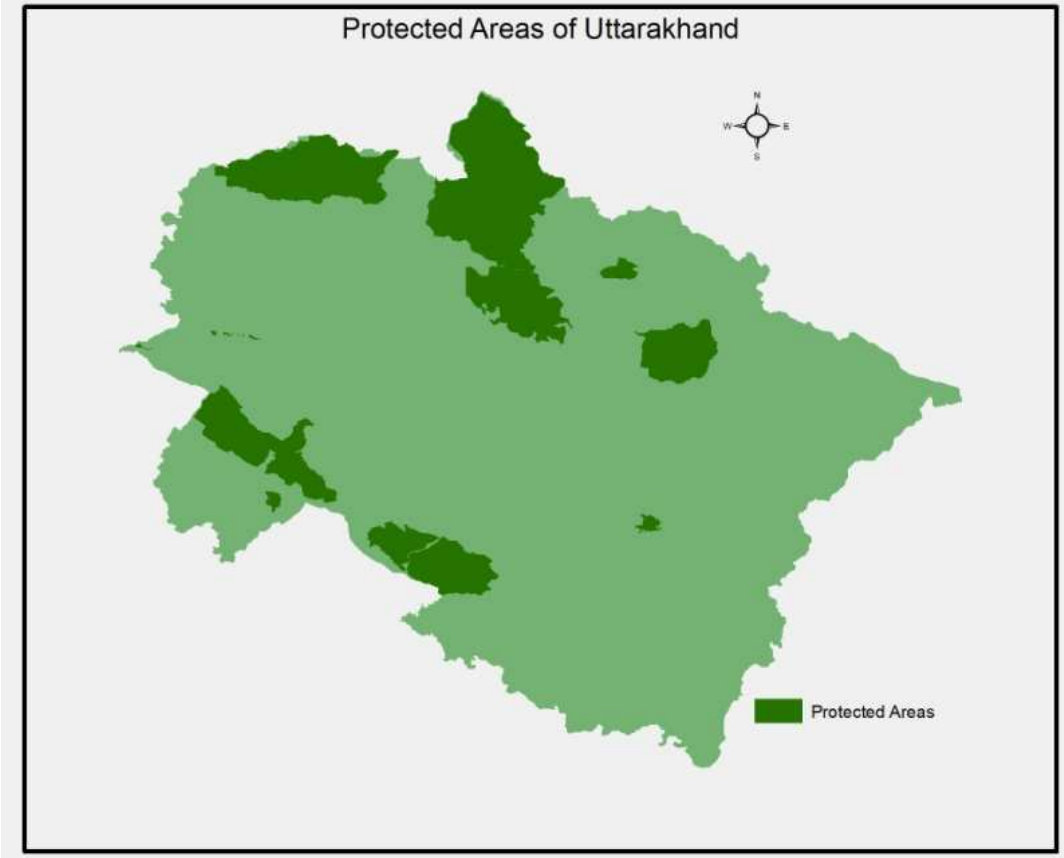
Uttarakhand's Hydropower Potential

- **Uniquely endowed with glaciers and rain fed monsoonal rivers, the natural incline/gradient**
- **Hydropower potential of the order of 20,000 MW ; 3,164 MW (16% approx.) harnessed so far**
- **12,235 MW under-development (in various stages) in State, Central and Private sector.**
- **Major hydropower development in Alaknanda and Bhagirathi river basins.**
- **70 projects planned**
- ✓ **17 commissioned**
- ✓ **14 under-construction**
- ✓ **39 proposed**

Biodiversity of Uttarakhand



65% of the State's geographic area is under forest (3.47 m ha)

13.68% of its geographic area under Protected Area network

6 National Parks

6 Wildlife Sanctuaries

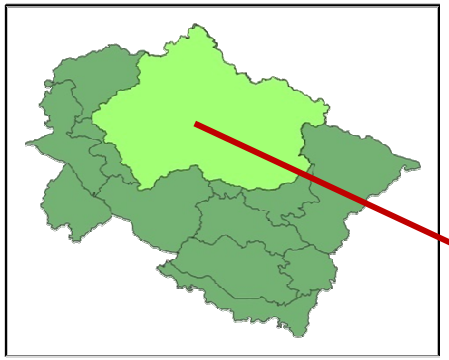
1 World Heritage Site

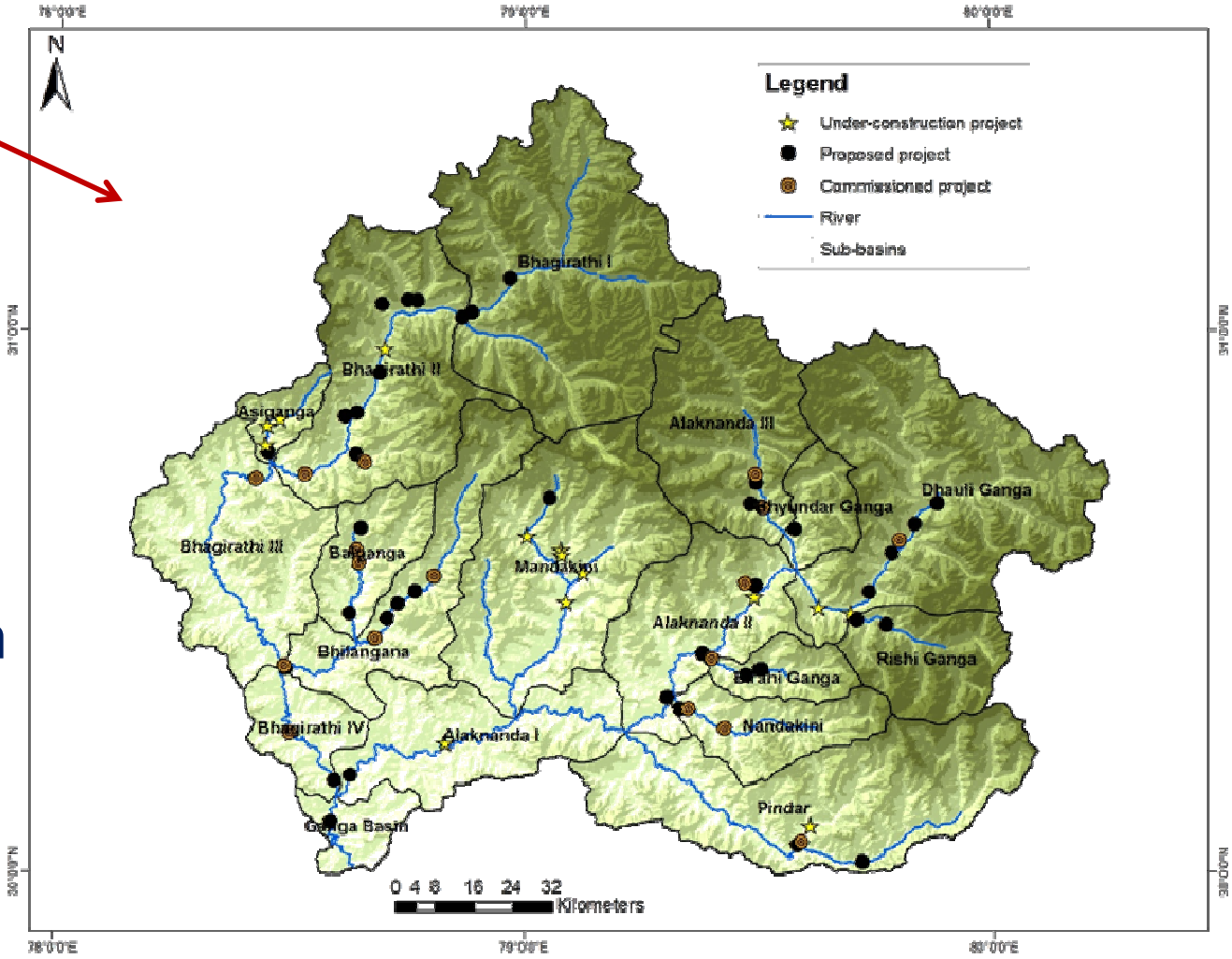
1 Biosphere Reserve

2 Conservation Reserves

Home to several Rare, Endangered and Threatened (RET) and endemic floral and faunal species eg. Snow leopard, Golden mahseer, Cheer pheasant.

Study Area





17 Commissioned

14 Under-construction

39 Proposed

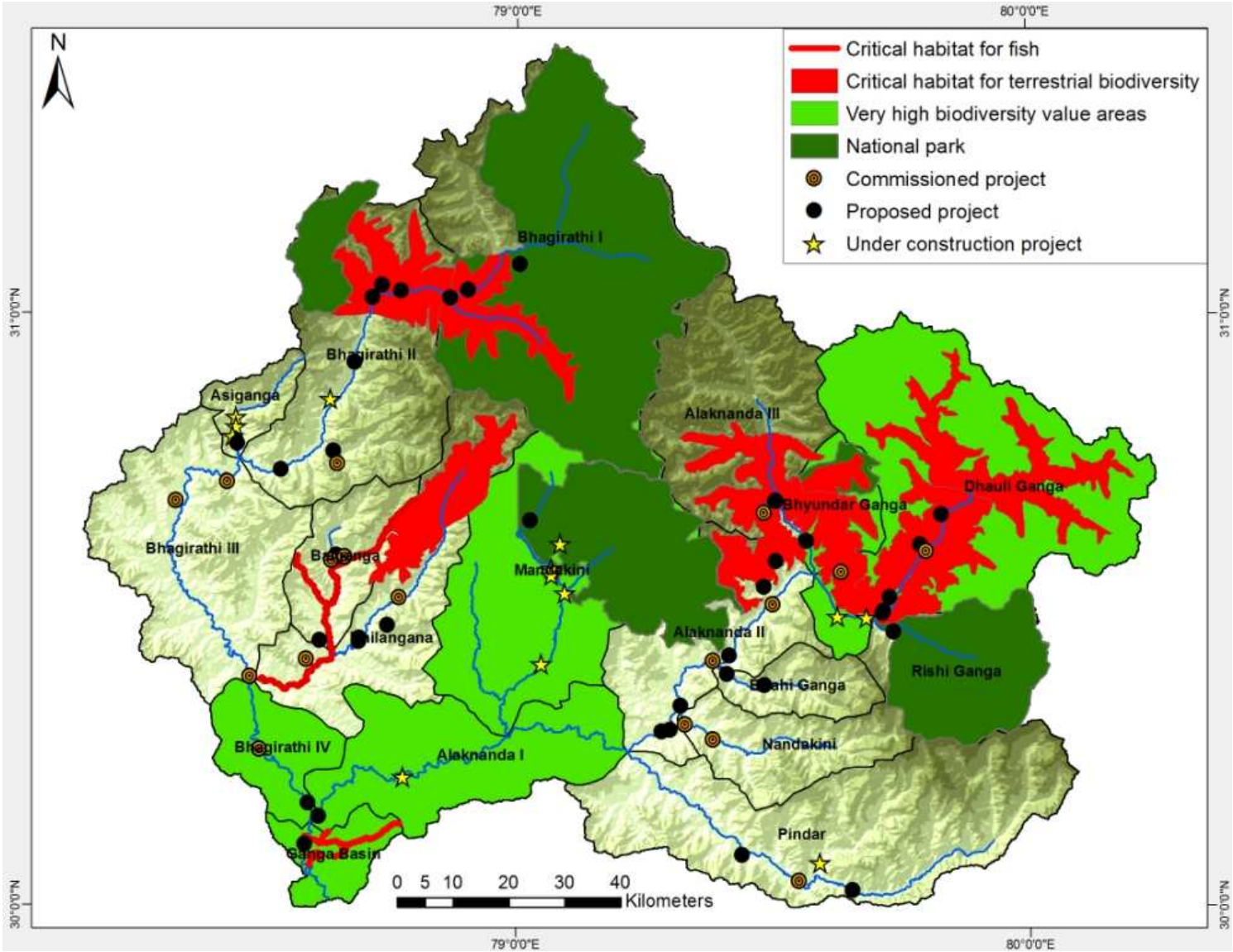
Biodiversity: Alaknanda & Bhagirathi basins

These basins encompass diverse forest and riverine ecosystems, represented by sub-tropical, mixed temperate and alpine elements.

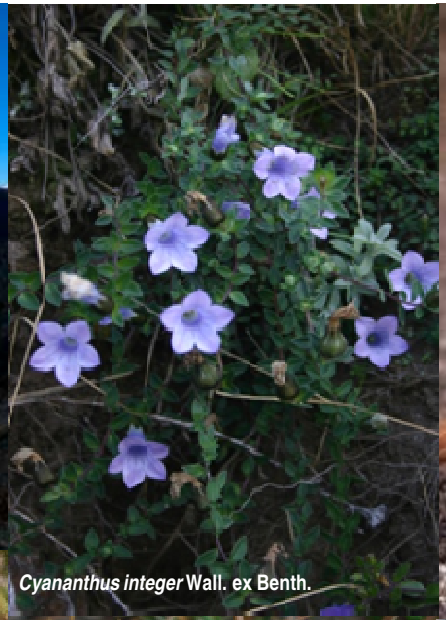
Key Taxa	Total Species	RET Species
Plants	1000	55
Mammals	85	06
Birds	530	06
Fishes	76	16

Presence of long-distance migrants (e.g. Golden Mahseer, high altitude birds) that use the river/riverine vegetation as corridor.

Critical Habitats



Snow leopard



Cyananthus integer Wall. ex Benth.

Himalayan monal

Musk deer

Berberis osmastonii Dunn.

Snow trout.

Cheer pheasant

Golden mahseer

Silver mahseer

Cumulative Environmental Impact Assessment (CEIA) Process

Scoping

- Defining the boundary of the study area and Zone of Influence of projects; Development of evaluation criteria and knowledge base

Baseline Generation

- Development of baseline of terrestrial and aquatic biodiversity, including RET species and medicinal plants

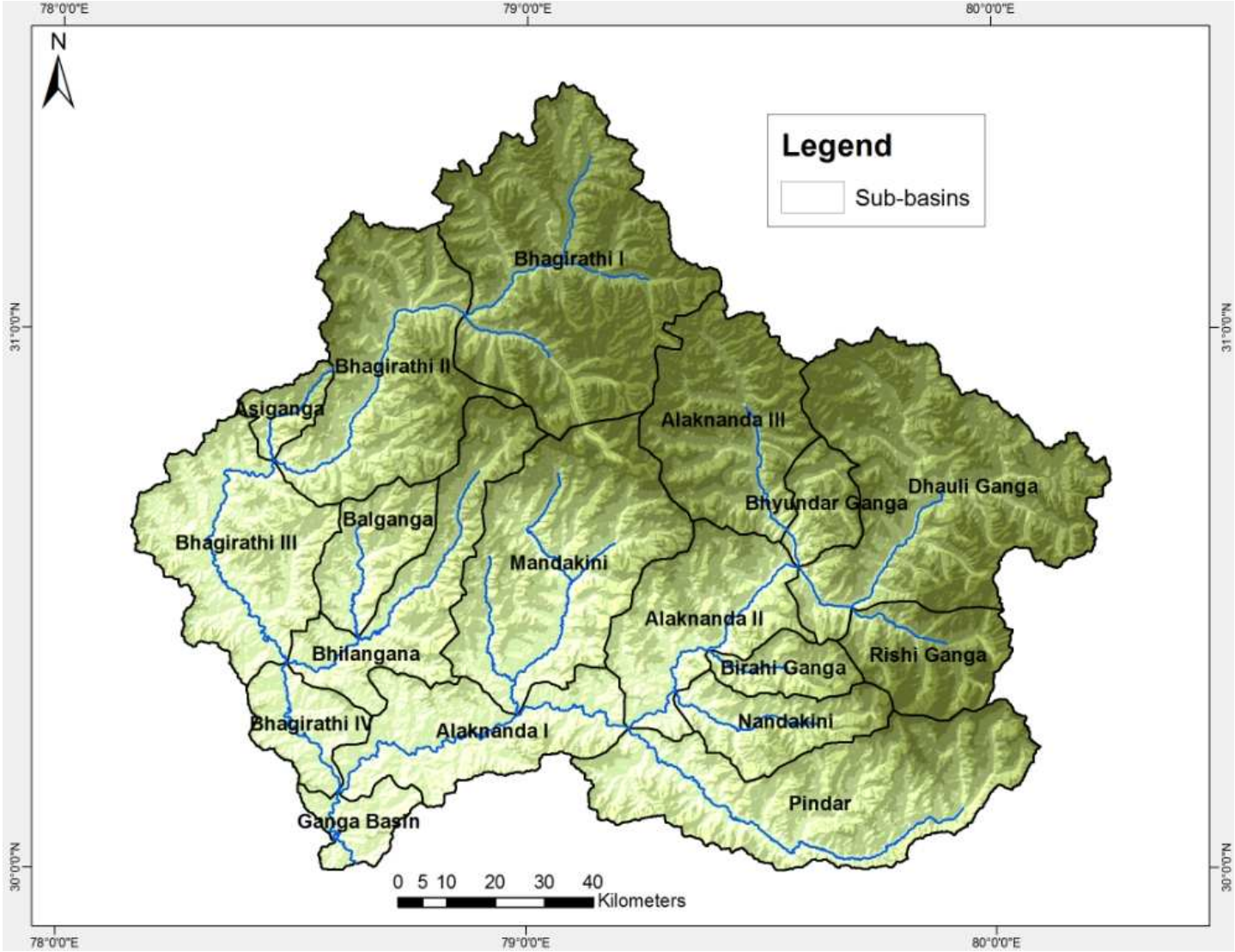
Impact Evaluation

- Assessment of cumulative impacts based on weight scoring of biodiversity values and impact potential of the projects

Mitigation

- Review of alternatives via scenario modeling for projecting present and futuristic trends of impact significance on biodiversity values and mitigation options

Study Area: Defining Sub-basins



Criteria for Impact Sources

Criteria	Description
River Length Affected (River dryness and submergence	The length of river which would be deprived of water by water diversion through head/tailrace tunnel, and the area lost to submergence.
Forest Area Loss	The location, extent and nature of forest area cleared and submerged due to Hydro Electric Projects construction and operation.

Criteria for Impact Receptors

(Aquatic)

Criteria	Description
RET (Rare, Endangered and Threatened) Species, as per IUCN and other Global Criteria	Number of RET species present in the sub-basin.
Endemic Species	Number of endemic species present in the sub-basin, reflecting the irreplaceability, and national importance that the species command
Habitat Diversity	Number of habitat types available. This is a surrogate for habitat heterogeneity and biodiversity richness
Species Richness	Number of different species present in a given land units
Breeding/Congregation	Presence/ absence of breeding sites and congregation opportunities for the target taxonomic group in a sub-basin.
Migratory Pathways/Corridor	Presence/ absence of migratory pathways/corridor for aquatic biodiversity in the sub-basins

Criteria for Impact Receptors

(Terrestrial)

Criteria	Description
RET (Rare, Endangered and Threatened) Species, as per IUCN and other Global Criteria	Number of RET species present in the sub-basin.
Schedule Species	Number of species that are listed in the Schedule-I of Indian Wildlife Protection Act (IWPA), 1972, reflecting legal provisions.
Species Richness	Number of different species present in a given land units
Medicinal Species	Number of species having medicinal properties hence valuable ecologically and economically.

Assigning Biodiversity Value

Data pooled for sub-basins

Calculated the % of that value.

Scores assigned from 1 to 5 according to 5 classes

Scores for each sub-basin added and converted into %

Scores classified as low (L), medium (M), high (H) & very high (VH)

$$\text{\% RET species in the sub-basin} = \frac{\text{No. of RET species in the sub-basin}}{\text{Total RET species in the study area}} \times 100$$

0-20 (%)	1
21-40	2
41-60	3
61-80	4
81-100	5

Maximum score for a sub-basin is 30 (6 criteria) for aquatic biodiversity and 15 (3 criteria) for terrestrial biodiversity

0-25 (%)	L
26-50	M
51-75	H
76-100	VH

Determining Impact Values

Values for each criteria for each sub-basin added

Calculated the % of that value.

Scores assigned from 1 to 5 according to 5 classes

Scores for each sub-basin added

Scores classified as low (L), medium (M), high (H) and very high (VH

$$\%\ \text{River Affected in the sub-basin} = \frac{\text{Y (km) affected in the sub-basin}}{\text{Total river length in the sub-basin}} \times 100$$

0-20 (%)	1
21-40	2
41-60	3
61-80	4
81-100	5

Maximum impact score for a sub-basin is 10

0-25 (%)	L
26-50	M
51-75	H
76-100	VH

Impact Significance

Significance of an impact = Magnitude of the impact X Sensitivity of the receptor
(given by biodiversity value here)

Matrix showing impact significance based on interaction between biodiversity values and impact potential (ICEM, 2007).

Biodiversity values	Impact Potential			
	Very high	High	Moderate	Low
Very high	Very high	Very high	High	Low
High	Very high	High	Moderate	Low
Moderate	High	Moderate	Moderate	Low
Low	Low	Low	Low	Low

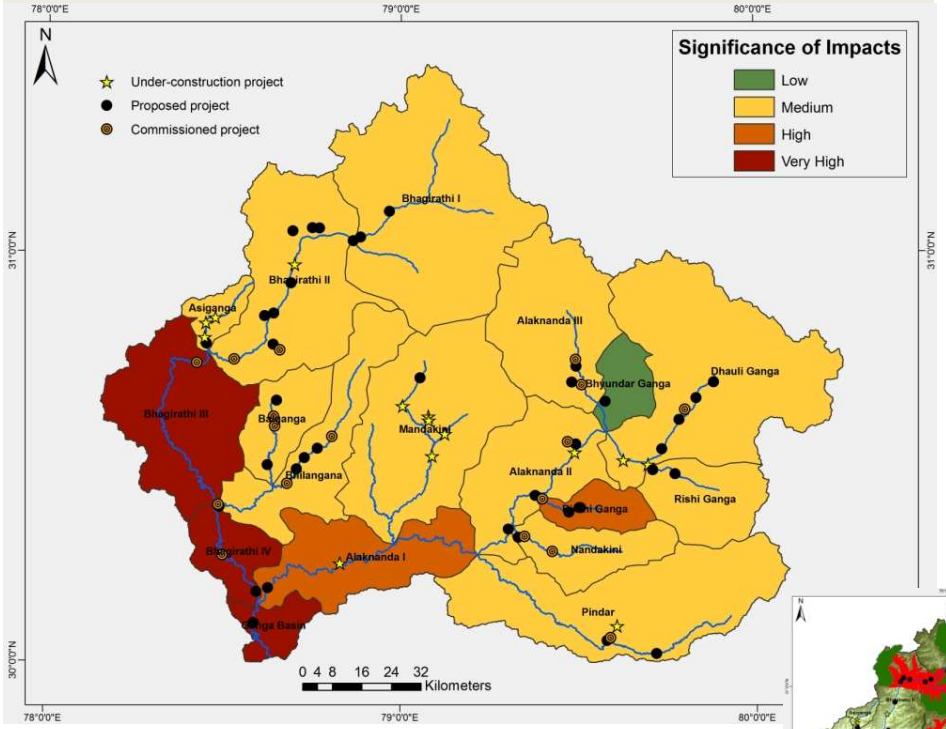
Scenario Analysis

- **Scenario-based approaches most appropriate in CEIAs**
- **'Futuring' approaches :**
  - ✓ ***improve information and provide a variety of approaches***
  - ✓ ***advice for decision-makers by reviewing alternative possibilities ; important tool for planning and policy***
- **In the present context, four scenarios developed each for aquatic and terrestrial biodiversity**

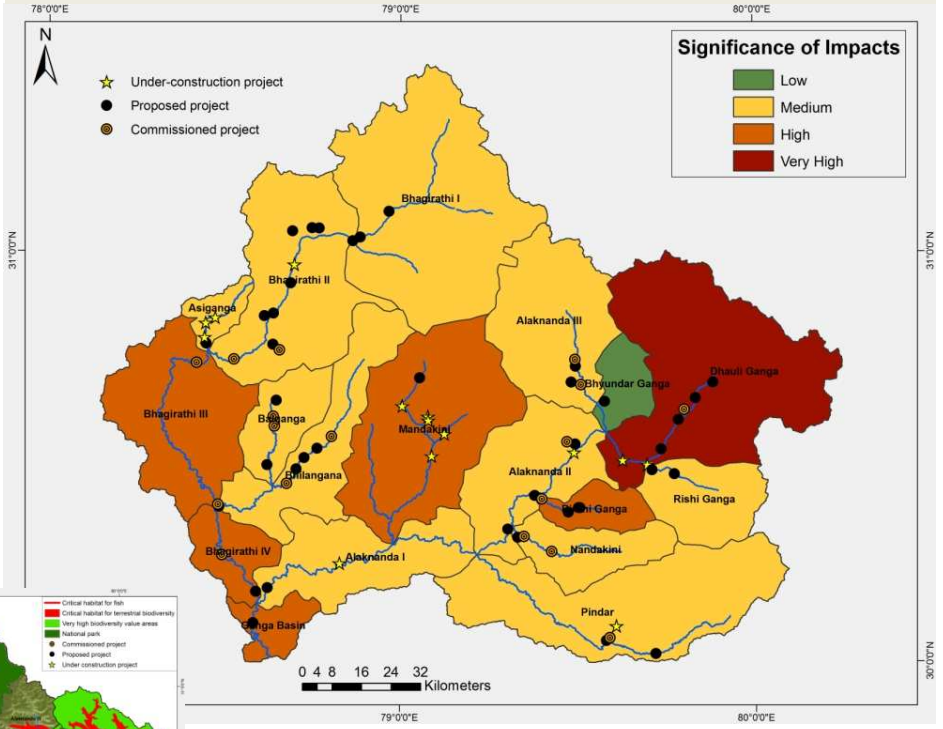
Scenario 1

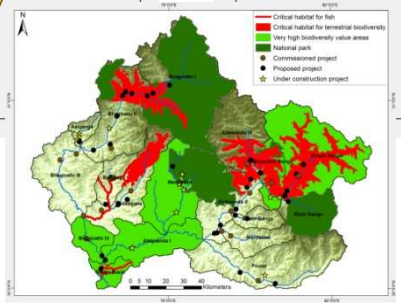
Cumulative impact significance of all projects (existing, under-way and proposed)

Aquatic Biodiversity



Terrestrial Biodiversity

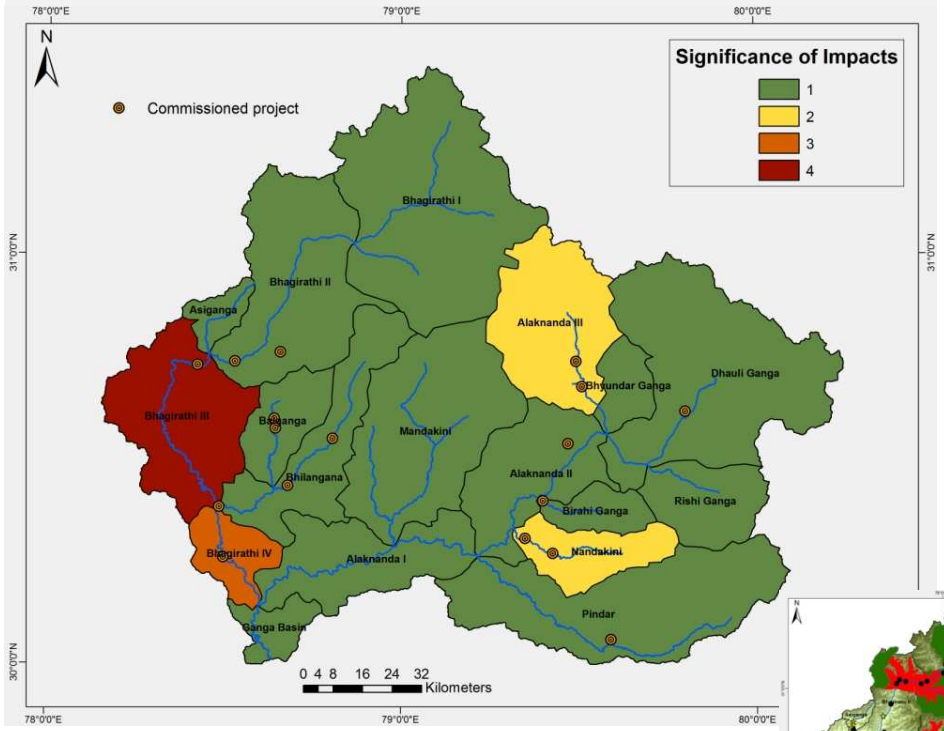




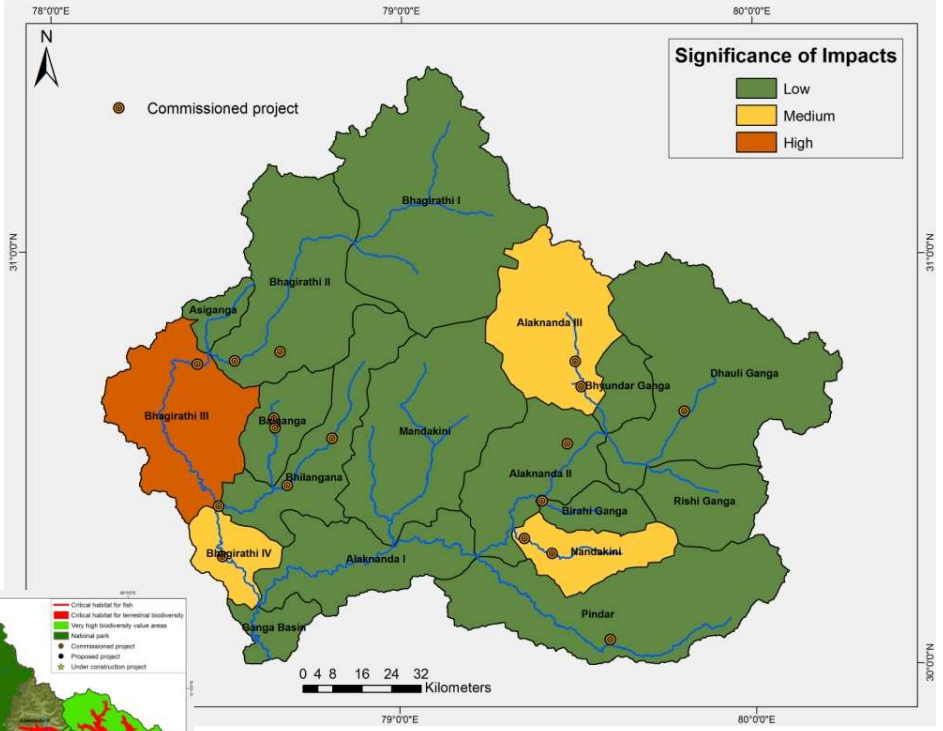
Scenario 2

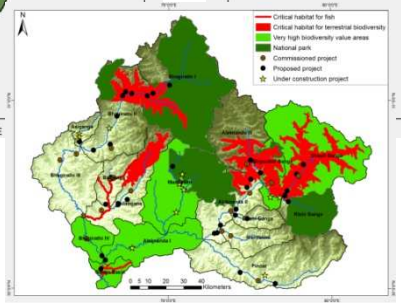
Exclusive impacts of existing projects (*Provides a starting point for reviewing impacts of projects under different stages)*

Aquatic Biodiversity



Terrestrial Biodiversity

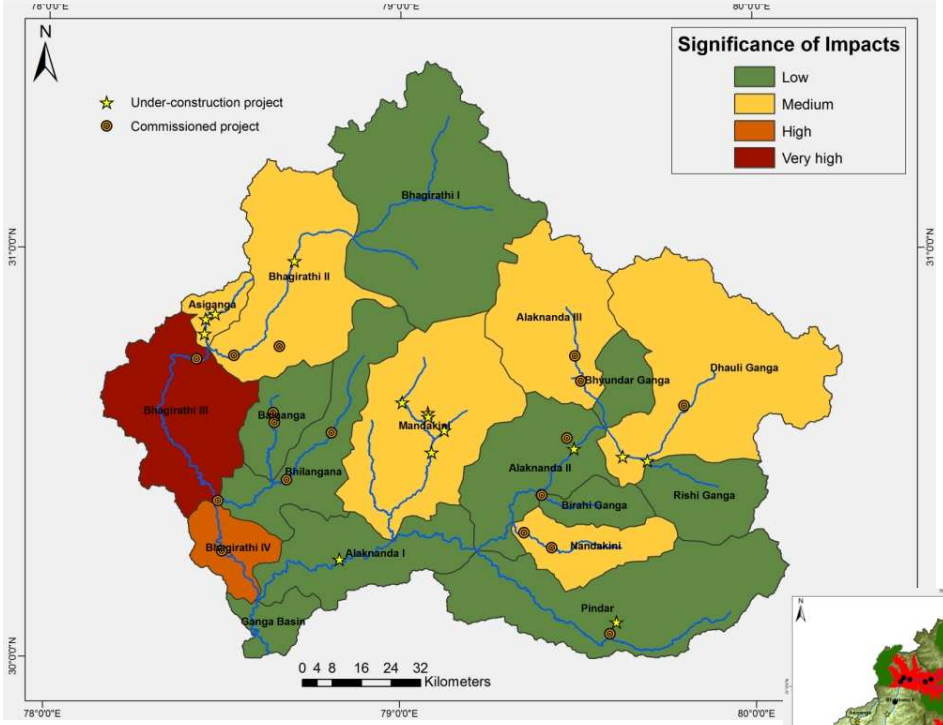




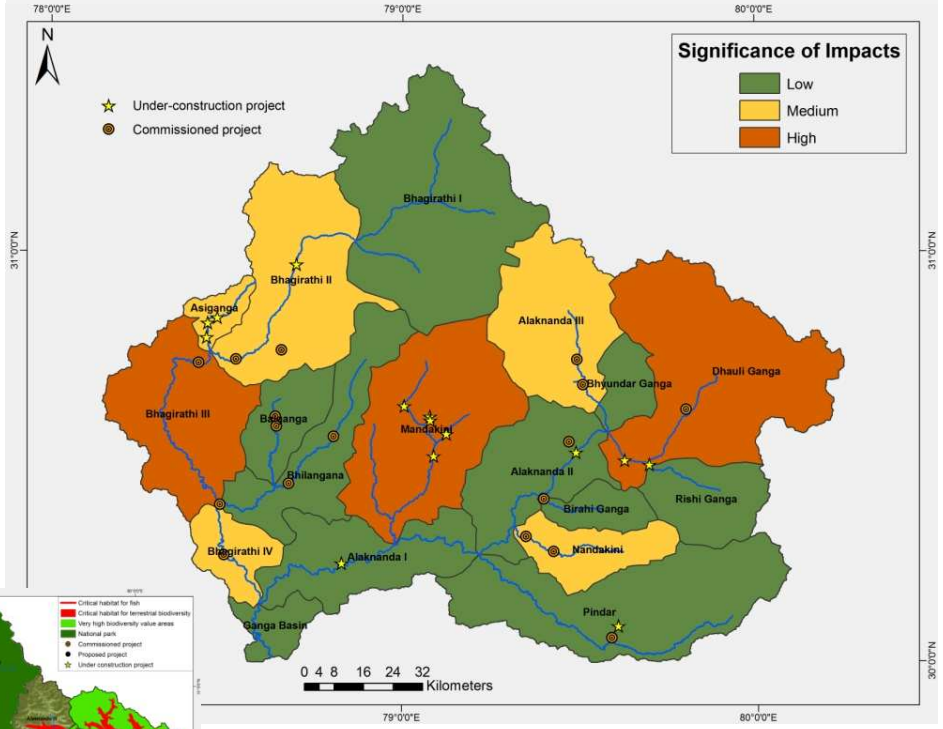
Scenario 3

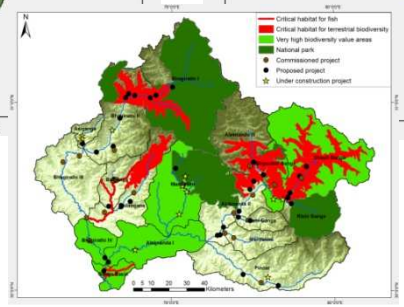
Impact significance: combined impacts of commissioned projects and those under construction

Aquatic Biodiversity



Terrestrial Biodiversity

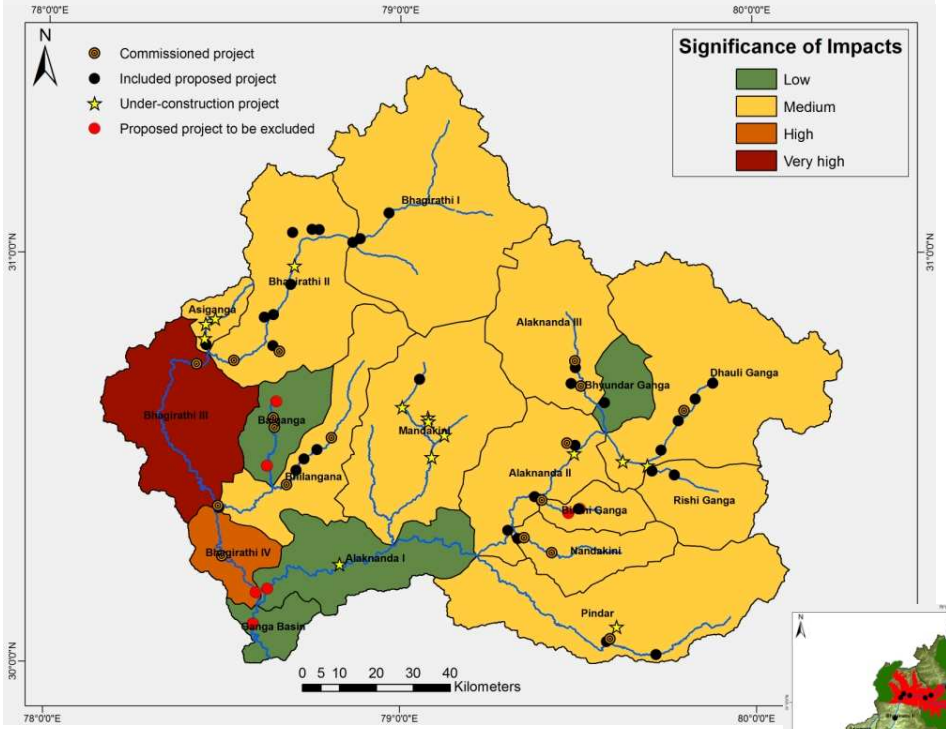




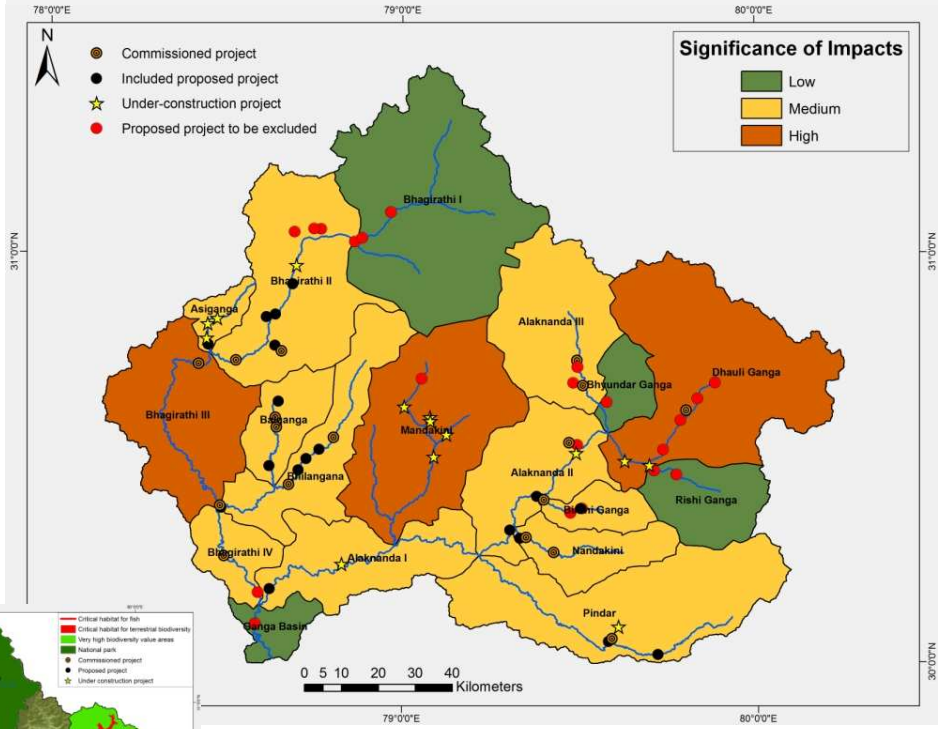
Scenario 4

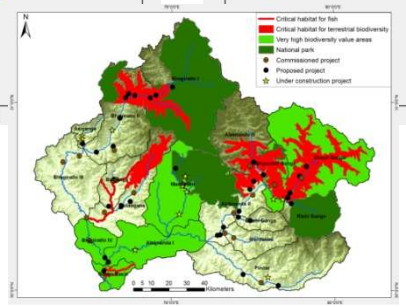
Addressing significant impacts on aquatic/terrestrial biodiversity and their critically important habitats by exclusion approach targeting only the proposed projects.

Aquatic Biodiversity



Terrestrial Biodiversity





Comparing the Scenarios

NOT ACCEPTABLE	ACCEPTABLE	ACCEPTABLE with CONDITIONS
Scenario 1	Scenario 2 Scenario 3	Scenario 4
Only development	**Only conservation**	**Conservation & development**

List of 24 Projects that need to be reviewed

Sub-basin	Name of the project	River	River length Affected (m)	Forest Area Loss (ha)	Power generation Capacity (MW)	Aquatic Biodiversity Values	Terrestrial Biodiversity Values
Bal ganga	Bal ganga II	Bal ganga	3250	NA	7.00	VH	-
	Jhala koti	Bal ganga	4750	NA	12.50		-
Bhagirathi II	Bharon ghati	Bhagirathi	18500		381.00	-	H
	Jalandrigad	Jalandharigad	3500	12.11	24.00	-	
	Siyangad	Siyangad	4500	4.96	11.50	-	
	Kakoragad	Kakoragad	3500	4.98	12.50	-	
Bhagirathi IV	Kotlibhel IA	Bhagirathi	18400	258.04	195.00	VH	H
Bhagirathi I	Karmoli	Jadhganga	11300	9.94	140.00	-	H
	Jadhganga	Jadhganga	2900	8.35	50.00	-	
Mandakini	Rambara	Mandakini	8000	NA	24.00	-	VH
Alaknanda I	Kotlibhel IB	Alaknanda	27500	599.75	320.00	VH	-
Alaknanda III	Alaknanda	Alaknanda	7000	49.648	30.00	-	H
	Khirao ganga	Khirao ganga	2750	NA	4.00	-	
Alaknanda II	Urgam II	Kalpganga	1750	NA	3.80	-	H
Dhauliganga	Lata tapovan	Dhauli ganga	8500	NA	170.00	-	VH
	Malari jhelam	Dhauli ganga	6500	NA	114.00	-	
	Jelam tamak	Dhauli ganga	8500	70	126.00	-	
	Tamak lata	Dhauli ganga	10500	24	250.00	-	
Bhyundar ganga	Bhyundar ganga	Bhyundar ganga	3250	NA	24.30	-	VH
Rishi ganga	Rishi ganga I	Rishi ganga	6525	8.06	70.00	-	H
	Rishi ganga II	Rishi ganga	5497	2.48	35.00	-	
Birahi ganga	Birahi ganga I	Birahi ganga	6500	NA	24.00	H	H
	Gohana Tal	Birahi ganga	12000	NA	50.00		
Ganga	Kotlibhel II	Ganga	59200	647.45	530.00	VH	H
TOTAL	24		244572	1699.77	2608.6	-	-

Implications for excluding 24 projects

As a result of exclusion:

- ✓ **37.31% reduction in the total river length that would be affected (244572 m); significant value for conservation of aquatic biodiversity;**
- ✓ **21.71% decrease in the total forest land required (9494.68 ha); +ve gain for terrestrial biodiversity conservation;**
- ✓ **Conservation of critical habitats for fishes and terrestrial biodiversity to a certain extent;**
- ✓ **Reduction in power generation capacity of 27% (of the total of 9563 MW from 70 projects).***

**In this context it is stated that India has one of the world's highest power transmission losses of about 30-40% against global average of 15% . Better and effective power transmission management system can to a large extent offset this loss in power generation*

Aquatic Biodiversity Values

- **Of the 76 fish species found in the Alaknanda-Bhagirathi basins, a total of 66 species of fishes have been reported from the study area based on the data collected from the zones of influence of 70 Hydro Electric Projects.**
- **16 species are globally threatened and 17 species are either long distance or local migrants.**
- **At least 4 exotic fish species have been found in the two basins. There is no record of fish presence above 2400 masl elevation.**

Aquatic Biodiversity Values

- **Diverse habitats conducive for breeding and nursery grounds of mahseer, snow trouts etc were observed within the Balganga and the Ganga (Nayar) sub-basins and Nayar – Ganges complex.**
- **There was no observation on the presence of Otters in the Alaknanda and Bhagirathi basins during this study. However, potential otter habitats occur in sub-basin Alaknanda I and Ganges.**

Minimum Environmental Flow

The Concept…

- **Flow to provide required various ecological cues to perform natural life cycle of aquatic organisms during different seasons**
- **Flow to support normal ecological functioning of river at least in minimum level even in the dry zones of hydro-electric projects**
- **Flow to make sure that cultural and heritage values of river not affected significantly**

Minimum Environmental Flow: Environment Management Category (EMC)

- **The habitats and dynamics of the biota of Alaknanda and Bhagirathi Rivers have been observed to be disturbed, but basic ecosystem functions are still intact.**
- **Some sensitive species are lost and/or reduced in extent. Alien species were present.**
- **Therefore, Environmental Management Category (EMC) of the Alaknanda and Bhagirathi Basins has been assessed as 'C' Class (as per Smakhtin et al., 2007).**

Minimum Environmental Flow: Environment Management Category (EMC)

- **Based on above observation, it has been calculated that Minimum Environment Flow required for a river stretch that falls in the Mahseer zone and Snow-trout zone should be 21.8% of Mean Seasonal Runoff (as per Smakhtin et al., 2007).**
- **The stretch that falls in the 'No fish zone' may be equal to 14.5 % of MSR as this stretch is devoid of fishes but has other aquatic biota**

Minimum Environmental Flow: Environment Management Category (EMC)

- **The suggested E-Flows have been reduced from 28.9% MAR (as suggested by Smakhtin et al., 2007) to 21.8% on basis of lesser biodiversity in Bhagirathi-Alaknanda Basin than in Rishikesh-Farakka. About 75% of MSR has been recommended in the fish zone of Bhagirathi-Alaknanda basin, although, the presence of biodiversity is lesser than 50% when compare to downstream of Ganges.**

- **We have suggested 25% more MSR as conservative estimate due to unique composition of cold water fish community and local environmental settings, which include river length. Further, we have suggested 50% MSR in the 'no-fish zone' area because of importance of other lesser known fauna and flora might be found in this region.**

Minimum Environmental Flow

- **Minimum Environmental Flow Required at the dry zones of HEPs were calculated wherever flow data were made available. Other stretches of rivers may be recommended with 21.5% of Mean Seasonal Flow of river if it falls in the mahseer or trout zones and 14.5% of Mean Seasonal Flow if the river stretch falls in the 'no fish zone'. This calculation is based on Environment Management Class.**
- **In the last five years, maximum number of species of fish were found in the mahseer zone where the average flow recorded was 8.1± SD 6.2 cumec/day (during the lean season) that was approximately 20% of average flow of lean seasonal flow.**

Minimum Environmental Flow

- **Similarly, maximum number of species were found in trout zone when the average flow was 0.05 cumec/day was approximately 20% of average flow of lean seasonal flow. Therefore, baseline for minimum required flow of 20% was set during the lean season while applying 'Modified Building Block Method'.**
- **The social aspects were not included, while fixing the Minimum Environmental Flow.**
- **The estimated 20% flow of lean season is also expected to fulfil the habitat requirements of 16 threatened fish species. This calculation based on Ecological Requirement of Fishes.**

Minimum flow required to sustain riverine ecology with special reference to fishes in the dry zones of HEPs in the Alaknanda and Bhagirathi basins for providing the required ecological cues in different seasons

Month	Percentage of Mean Seasonal Flow suggested (%) (Cumec/day)
June	30
July	30
August	30
September	30
October	25
November	20
December	20
January	20
February	20
March	20
April	25
May	30

Suggested Minimum Environmental Flows based on Environmental Management Class of Alaknanda and Bhagirathi Rivers

		Season I (High Flow)	Season II (Average Flow)	Season III (Low Flow)	Season IV (Average Flow)
A	Bhagirathi River				
1	Asiganga-III	2.53	0.41	0.08	0.15
2	Agunda thati	1.59	1.11	0.91	0.81
3	Bhilangana-III	5.28	1.92	1.24	1.20
4	Bhilangana	15.04	10.46	8.63	7.63
5	Lohari Nagpala	44.14	7.30	1.46	2.66
6	Maneri bhali I	54.64	9.05	1.81	3.29
7	Maneri bhali II	58.78	9.72	1.95	3.55
8	Tehri stage-I	93.57	34.01	21.92	21.28
9	Koteshwar	99.83	36.28	23.38	22.72
10	Kotlibhel I A	102.38	37.21	23.98	23.28
B	Alaknanda River				
2	Birahi ganga II	3.08	1.94	0.67	0.65
3	Bhyunder ganga	3.85	1.79	0.61	0.74
4	Phata Byung	6.51	2.79	1.47	1.48
5	Rajwakti	7.46	4.69	1.61	1.57
7	Singoli Bhatwari	21.30	9.09	3.76	4.82
8	Alaknanda	16.90	7.89	2.67	3.23
9	Devsari	7.53	4.29	1.55	1.57
10	Vishnuprayag	28.08	13.10	4.43	5.36
12	Vishnugad Pipalkoti	78.19	36.47	12.35	14.91
13	Nandaprayag Langrasu	104.32	48.68	16.48	19.90

Suggested Minimum Environmental Flows to fulfill ecological requirements of aquatic biodiversity of Alaknanda and Bhagirathi Rivers

		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
A	Bhagirathi River												
1	Asiganga-III	0.06	0.06	0.06	0.18	0.99	2.55	5.13	5.73	3.00	0.48	0.12	0.08
2	Agunda thati	0.84	0.86	0.84	0.93	1.26	1.62	2.43	3.18	2.43	1.28	0.76	0.86
3	Bhilangana-III	1.12	1.14	1.14	1.38	2.79	5.34	9.81	11.52	6.90	2.20	1.10	1.18
4	Bhilangana	7.92	8.12	8.04	8.75	11.82	15.39	23.10	30.24	22.95	12.00	7.30	8.22
5	Lohari Nagpala	1.18	0.98	1.18	3.05	17.25	44.55	89.70	99.87	52.35	8.38	1.96	1.40
6	Maneri bhali I	1.46	1.22	1.46	3.78	21.36	55.14	111.03	123.63	64.80	10.38	2.44	1.74
7	Maneri bhali II	1.58	1.32	1.58	4.08	22.95	59.31	119.46	132.99	69.72	11.15	2.62	1.86
8	Tehri stage-I	19.94	20.12	20.20	24.40	49.14	94.65	173.76	203.79	122.46	39.00	19.46	20.82
9	Koteshwar	21.26	21.48	21.54	26.05	52.44	100.98	185.40	217.44	130.65	41.60	20.76	22.22
10	Kotlibhel I A	21.80	22.02	22.10	26.70	53.79	103.56	190.14	222.99	133.98	42.68	21.28	22.78
B	Alaknanda River												
2	Birahi ganga II	0.48	0.44	0.50	0.75	1.23	2.04	5.04	7.08	5.79	2.23	0.94	0.70
3	Bhyunder ganga	0.36	0.32	0.38	0.85	2.49	5.01	7.53	6.81	4.62	2.05	1.02	0.70
4	Phata Byung	1.10	1.22	1.32	1.70	2.70	4.74	11.91	15.90	9.54	3.20	1.50	1.60
5	Rajwakti	1.16	1.08	1.20	1.80	3.00	4.92	12.18	17.16	14.04	5.38	2.26	1.70
7	Singoli Bhatwari	2.62	2.78	3.42	5.53	8.97	14.40	37.56	53.01	32.64	10.43	4.60	3.84
8	Alaknanda	1.60	1.38	1.68	3.70	11.01	22.02	33.12	29.91	20.25	9.05	4.52	3.08
9	Devsari	1.16	1.10	1.20	1.80	2.97	5.25	12.66	17.31	13.65	4.93	2.14	1.50
10	Vishnuprayag	2.64	2.28	2.80	6.15	18.27	36.60	55.02	49.71	33.63	15.03	7.50	5.12
12	Vishnugad Pipalkoti	7.36	6.36	7.78	17.10	50.85	101.91	153.21	138.36	93.66	41.83	20.88	14.26
13	Nandaprayag Langrasu	9.82	8.48	10.40	22.83	67.86	135.96	204.39	184.62	124.98	55.83	27.86	19.02

Minimum Environmental Flow

- **The suggested minimum environmental flows would provide the necessary environmental cues to trigger the breeding and migration behaviour of Himalayan fishes. Most importantly, the suggested Minimum Environmental Flows are only for the dry zones of the HEPs and not for the entire stretch of the rivers.**

- **Minimum environmental flows suggested need to be reviewed periodically in relation to changes in the population status of fishes that occur in the stretch.**

- **Flow suggested by WII to provide different ecological cues to facilitate normal lifecycle of aquatic organisms has been harmonized with flows suggested by IIT-Roorkee.**

Minimum Environmental Flows suggested by other Institutions/Experts

- **Ganga River Basin Environment Management Plan – Consortium of IITs:**
  - **E-flows assessment is both a social and a scientific process. There is no one correct Environmental Flow regime for rivers – the answer will depend on what people want from river**
  - **For Ganga, holistic E-flow assessment method such as Building Block Method is found to be most robust with high confidence level although it has its own limitations as it require intensive resources. (WII used this method but without including social aspects).**
  - **Recommended that the long term Ecological Management Class (EMC) for Ganga as 'A' . However, EMC of 'B' was recommended as an acceptable goal in the short term. (WII assessed the present EMC of Upper Ganges as 'C')**
  - **No specific flow recommendations by the Consortium of IITs.**

Environment Management Classification of Upper Ganga by various Institutions/Experts

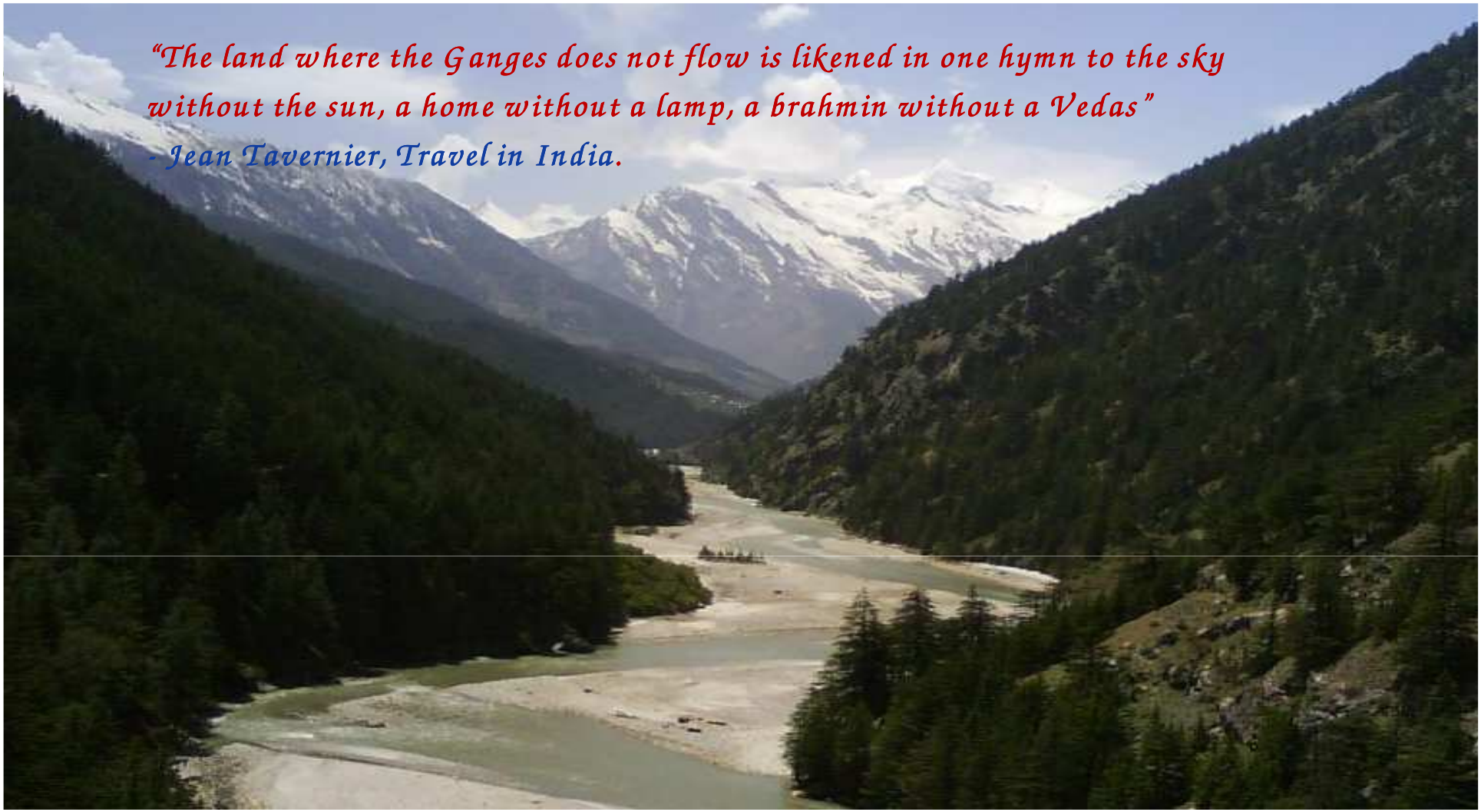
EMC Status	Ecological description	Recommended Flow (% of Mean Annual Flow)	Institutions/Experts
A: Natural	Pristine condition or minor modification of in-stream and riparian habitat	67.6	Consortia of IITs & Dr. Bharat Jhunjhunwala
B: Slightly modified	Largely intact biodiversity and habitats despite water resources development and/or basin modifications	44.2	Consortia of IITs
C: Moderately modified	The habitat and dynamics of the biota have been disturbed, but basic ecosystem functions are still intact. Some sensitive species are lost and/or reduced in extent. Alien species present.	28.9	WII / IIT-Roorkee (WII assessed EMC at basin level as EMC require larger landscape level approach, however, IIT-R assessed EMC at sub-basin level)
D: Largely modified	Large changes in natural habitat, biota and basic ecosystem functions have occurred.	20.0	IIT-Roorkee
E: Seriously modified	Habitat diversity and availability have declined.	14.9	
F: Critically modified	Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota.	12.1	

Minimum Environmental Flows suggested by other Institutions/Experts

- **IIT-Roorkee:**
  - **E-flows have been assessed using various methods such as Hydrological Index Method, Desktop Approach, EMC, Habitat stimulation methodology, etc. but not tried with Building Block Method as suggested by Consortia of IITs**
  - **Finally supported Hydraulic Habitat analysis and EMC-HMD as these methods takes care of requirement of biodiversity**
  - **In conclusion, the IIT-R report has suggested site specific studies for final e-flow estimation although it has recommended e-flows which are more or less similar to WII recommendations.**
  - **Some places, minimum flows assessed by WII during lean months are similar or lesser than ITT-R e-flows. But ,minimum flows assessed by WII during monsoon months are higher than ITT-R . This is largely to provide required environmental cue to various aquatic biodiversity in the river to perform their routine life-cycle.**

Comments on WII's suggested Minimum Environmental Flows by South Asia Network on Dams, Rivers and People

- **Environmental flows describes the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems. But social aspects completely brushed away in WII report.**
- **Thus, the e-flows recommendations need to be reworked with a much more holistic perspective including social aspects.**
- **However, the releases mentioned in the report should be considered as the minimum threshold values**
- ***WII Remarks: E-flows have been estimated based on biological requirement and social aspects were not included. Moreover, WII has suggested that minimum environmental flows needs to be reviewed periodically in relation to changes in the population status of fishes that occur in the stretch.***



"Nothing alters a river as totally as a dam. A reservoir is the antithesis of a river – the essence of a river is that it flows, the essence of a reservoir is that it is still."
– Patrick McCully, Silenced Rivers

THANK YOU !!