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CUMULATIVE IMPACT STUDY OF HYDRO POWER PROJECTS ON RIVER YAMUNA AND TONS & ITS TRIBUTARIES, UTTARAKHAND

For

Uttarakhand Jal Vidyut Nigam Limited
(A Government of Uttarakhand Enterprise)
Dehradun, Uttarakhand

By

Indian Council of Forestry Research & Education
Dehradun, Uttarakhand

In association with

Alternate Hydro Energy Centre,
Indian Institute of Technology, Roorkee, Uttarakhand

Directorate of Coldwater Fisheries Research
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EXECUTIVE SUMMARY

1 PREAMBLE

Uttarakhand Jal Vidyut Nigam Limited (UJVNL), Government of Uttarakhand has assigned the task of Cumulative Environment Impact Assessment Study (CEIAS) of Hydro electric power projects along Yamuna, Tons and its tributaries in Uttarakhand to Indian Council of Forestry Research and Education (ICFRE), Dehradun with the defined Terms of Reference (ToR). ICFRE took up the study in association with three national subject expert institutions Alternate Hydro Energy Center, Indian Institute of Technology, Roorkee, Directorate of Coldwater Fisheries Research, Bhimtal, Uttarakhand and Salim Ali Centre for Ornithology and Natural History, Coimbatore. The report was compiled scientifically by the ICFRE, as the lead institution. The report consists of two volumes. Volume I contains this executive summary, an introduction, a brief review of the study area, baseline data on the environmental components (physical, biological and socio-economic), a cumulative environmental impact assessment, an environmental action plan and recommendations. Volume II contains all the annexure cited in Volume I. CEIA study of Yamuna and Tons basin has been prepared with a view to provide optimum support for various national processes and allowing sustainable activities. The study covers the following broad frame work:

- To provide optimum support for various natural processes and allowing sustainable development undertaken by its inhabitants.
- Assess the stress /load due to varied hydro projects activities covering, but not limited to exploitation of natural resources, population growth which lead to varying degree of impacts on various facets of environment and also to envisage a broad framework of environment action plan to mitigate the adverse impact on environment.

The study was initiated during December, 2012 and field survey was completed in September 2014 due to the blockage of road during the disaster that occurred in Uttarakhand on 16 June 2013 and inaccessibility in the hills during harsh conditions. The survey involved extensive field data collection in different seasons to establish baseline status, data analysis and cumulative impact assessment followed by recommendation and action plan for long term sustainable hydropower development in the basin. The basin study is a step beyond the EIA, as it incorporates an integrated approach to assess the impacts due to 46 hydroelectric projects to:

- Provide environmentally and ecologically sustainable and optimal ways of hydropower development of river Yamuna, Tons and its tributaries, keeping in view the environmental settings of the basin and development imperative.
- Suggestion regarding the environmental flow during lean season.

- Suggestion of length of free flowing riparian distance to be maintained between two successive hydropower projects in the cascading series.
- A practical environmental action plan to mitigate the adverse impact on environment as listed in the scope of the study including ecological restoration.
- Suggestion of institutional mechanism for implementing and monitoring the same at the river basin level.

2 BASIN CHARACTERISTICS

The Yamuna River originates from the Yamnotri Glacier, near Bhandar Punch, the peak in the Mussoorie Range of the Lesser Himalaya in Uttarkashi district of Uttarakhand. The upper catchment area of Yamuna is mountainous with deep and narrow valleys. The river Tons in the largest tributary of River Yamuna, originates from Jamdar Bamak Glacier that joins at Har ki Dun in Uttarakhand. The River Yamuna from its origin to Kulhal in Uttarakhand has ten tributaries and Tons has two streams the Rupin and Supin from Uttarakhand and one Pabber river joining Tons from Himachal Pradesh. The total length of the river in Uttarakhand up to the Kulhal is 844 km that comprises the main stream of the Yamuna (183 Km.), the tons (209km.) and tributaries varying in length from 8km to 104 km. The total catchment area of Yamuna up to Kulhal is 10769 Km^2 and Tons is 5140 Km^2 up to the Hasipur Vyas confluence. The catchment area of the tributaries up to the confluence in the main river ranged from 33 km^2 to 1437 Km^2.

3 HYDROPOWER PROJECTS IN THE BASIN

The present estimated hydroelectric potential of the 46 hydropower projects (HEPs) undertaken for the study in the basin is 2251.8 MW, that includes nine commissioned HEP (483.1 MW), six under construction (438.9 MW) projects that are on the advanced stage and 31 HEP (1329.80 MW) identified for future development. The HEPs considered for the study include 17 large HEPs of having capacity of more than 25MW and 29 small HEP (less than 25MW). The projects taken up prior to 1994 there were no Environmental Impact Assessment (EIA) and for the projects taken up after 2002/2006 no EIA reports were required for installed capacity of 25MW and below. The salient features and details of the hydropower interventions were generated from Detailed Project Reports (DPR), Environmental Impact Assessment (EIA), Environmental Management Plans (EMP) and Pre feasibility Reports (PFR) which were made available. In terms of project intervention details, the HEPs under operations were commissioned during 1907,1965,1975 and 1985 had only salient features for 7 HEPs and DPR; four under construction HEPs had EIA -EMP /DPR and Deep Roots of Geothermal Systems (DRGS); six each of under development projects had only salient features and DPR/DRGS. For the rest considering the capacity and type of the HEP assumptions were made by IIT as directed by the UJVNL. A comprehensive list of all the HEP that are under various stages of development is given in Table 1

Table 1: Comprehensive list of all the HEP that are under various stages of development in river Yamuna, Tons and Its tributaries in Uttarakhand

S. No.	Name of HEP	District	River and Tributary	River/ Gad Name	Name of Company
Commissioned					
1	Chibro (240MW)	Dehradun	Tons		UJVNL
2	Khodri (120MW)	Dehradun	Tons		UJVNL
3	Ister gad (0.20MW)	Uttarkashi	Tons	Istar Ganga	UREDA
4	Janki-Chatti (0.20MW)	Uttarkashi	Yamuna		UREDA
5	Dhakrani (33.75MW)	Dehradun	Yamuna		UJVNL
6	Dhalipur (51MW)	Dehradun	Yamuna		UJVNL
7	Kulhal (30MW)	Dehradun	Yamuna		UJVNL
8	Galogi (3MW)	Dehradun	Yamuna	Asan/Kiyarkuli	UJVNL
9	Hanuman Ganga (4.95MW)	Uttarkashi	Yamuna	Hanuman Ganga	Regency Yamuna Energy
Under construction					
10	Gangnani (8 MW)	Uttarkashi	Yamuna		Regency Yamuna Energy
11	Badiyar (4.9MW)	Uttarkashi	Yamuna	Vadya Gad/Badiyar gad	Regency Yamuna Energy
12	Rayat (3MW)	Tehri	Yamuna	Aglar	Aglar Power
13	Langrasu (3MW)	Tehri	Yamuna	Aglar	Aglar Power
14	Lakhwar (300MW)	Dehradun	Yamuna		UJVNL
15	Vyasi (120MW)	Dehradun	Yamuna		UJVNL
Under Development					
16	Taluka Sankri (140MW)	Uttarkashi	Tons		UJVNL
17	Sidri Deori (60MW)	Uttarkashi	Tons		
18	Naitwar Mori (33MW)	Uttarkashi	Tons		SJVNL
19	Mori Hanol (63MW)	Uttarkashi	Tons		Krishna Knitwear
20	Hanol Tiuni (60MW)	Dehradun	Tons		Sunflag
21	Tuini Plasu (66MW)	Dehradun	Tons		Irrigation Deptt.
22	Kishau Dam (600MW)	Dehradun	Tons		UJVNL
23	Jakhol Sankri (35MW)	Uttarkashi	Tons	Supin	SJVNL
24	Arakot Tuini (70MW)	Uttarkashi	Tons	Pabar	Irrigation Deptt.
25	Rupin II (10MW)	Uttarkash	Tons	Rupin Nalla	Identified
26	Rupin –III (3MW)	Uttarkashi	Tons	Rupin	Tons Hydro
27	Rupin –IV (10MW)	Uttarkashi	Tons	Rupin	Tons Hydro
28	Rupin –V (24MW)	Uttarkashi	Tons	Rupin	Himalaya
29	Hanuman Chatti-Saina Chatti (40MW)	Uttarkashi	Yamuna		UIPC
30	Saina-Chatti -Kuthnaur (12MW)	Uttarkashi	Yamuna		UIPC
31	Sauli – Barnigad (10MW)	Uttarkashi	Yamuna		UIPC
32	Barnigad (6.50MW)	Uttarkashi	Yamuna		UJVNL
33	Barnigad- Naingaon (10MW)	Uttarkashi	Yamuna		UIPC
34	Pali gad (0.30MW)	Uttarkashi	Yamuna	Pali gad	UREDA
35	Riknal Khad (4MW)	Dehradun	Yamuna	Garsad gad	Identified
36	Garsad Khad (4.50MW)	Dehradun	Yamuna	Garsad gad	Identified
37	Thatyur (4MW)	Tehri	Yamuna	Aglar	Identified
38	Ringali (1MW)	Tehri	Yamuna	Aglar	UREDA
39	Purkul (1MW)	Dehradun	Yamuna	Asan	UIPC
40	Tewa (3.50MW)	Tehri	Yamuna	Aglar	Identified
41	Bangseel (3.50MW)	Tehri	Yamuna	Aglar	Identified
42	Asnor gad (0.50MW)	Uttarkashi	Yamuna	Asnor gad	Identified
43	Bhadri gad (24MW)	Tehri	Yamuna	Bhadri gad	Identified
44	Obra (12MW)	Uttarkashi	Tons	Supin	
45	Kashla (14MW)	Uttarkashi	Tons	Supin	
46	Amlawa (5MW)	Dehradun	Yamuna	Amlawa	

4 PHYSICAL ENVIRONMENT

Geologically the study area is delineated by Main Boundary Thrust (MBT) in the lower region of the basin in the Lesser Himalaya, with Siwalik and main Central Thrust (MCT) in the upper region with Greater Himalayas. Seismically, the entire study area falls under Earth quake zone IV as per earthquake zone map of India. On the basis of geology and climate the study area shall be grouped under two environmental units i.e., the upper and middle (Aglar catchment of Janupur) catchment of Yamuna basin under Lesser Himalaya having warm sub humid eco region (to Humid with inclusion of Perhumid-14.4 and warm Sub humid Eco-Region to Humid with inclusion of Perhumid-14.2 respectively); and the Upper Tons catchment falling under Greater Himalayas of the Western Himalayan region.

Alternate Hydro Energy Centre, an academic centre of Indian Institute of Technology, Roorkee conducted the comprehensive baseline study for the following components based on the ToR:

4.1 Land Use/Land Cover Change

Land use/land cover change detection were assessed from the images (IRS-LISS-III of NRSC, Hyderabad) during March and October in 2001 and 2012 for pre and post monsoon seasons that showed a mixed trend. The commissioned hydropower projects such as Chibro and Kulhal during 1975, recorded an increase in the dense forest and agriculture land. The under construction Vyasi HEP recorded a decrease in dense forest may be due to diversion of forest land for development of hydropower projects. The proposed HEP such as Gangnani small HEP and Kishau dam showed increased agriculture and dense forest area. The overall changes observed in the commissioned project may be attributed to the afforestation and reforestation management of forest and the irrigation facility created due to the project have contributed to increase in agriculture land and reduced fallow land. The land use changes in case of under construction and proposed projects can be attributed to population growth, demand for various land categories for allied developments. Thus it is evident that the hydro project related changes are of temporary nature and shall be restored as observed in Chibro and Kulhal HEP.

4.2 Meteorology

Reliable estimates due to the absence of meteorological stations, lack of scientific data and collaborative studies are the major constrains for the study area. There are only two Indian Meteorological Department Observatories, namely, Dehradun (located in the compound of the Survey of India Office, Dehradun) the location of this station falls outside the boundaries of the study area, and Mussoorie (located at the compound of the Water Works Engineer's Office, City Board, Mussoorie) lies in the basin of the Yamuna and the Tons in Uttarakhand that partially covers the study area. Thus meteorology part presented in the report heavily depends on secondary sources of information that include published journals, Detailed Project Reports etc. In addition Meteorological Department data from Dehradun, New Tehri and Uttarkashi districts were also incorporated to provide the relative trends for the meteorological parameters.

4.3 Water Allocation

There are two water sharing agreements on Yamuna waters. Based on the Union Minister of Water Resources D.O. letter no. 10/66174-WD/IT-I035 dated 29.10.1991 the drinking water requirement for Uttar Pradesh is indicated as 0.44 BCM (0.357 MAF). Later during the inter-state meeting held on 10.1.1992 keeping in view the fact that Lakhwar-Vyasi project approved by the Planning Commission, the drinking water to Uttar Pradesh was reassessed and indicated as 3.412BCM (2.767 MAF). A series of meetings were held after formation of new State Uttarakhand with Uttar Pradesh and neighboring states. The Upper Yamuna Board New Delhi has initiated the process of revising the MoU in January, 2013. The agreement is in process between the states. Reliable estimates due to the absence of adequate hydrological gauge station, scientific data and collaborative studies are the major constrains for the study area to assess the water resources availability except for the one broad study by Rai *et al*., (2010 and 2012) to the best of our knowledge.

4.4 Hydrology

Hydropower development is the most important intervention that impacts the flow regimes of the rivers. The available data from river gauging sites and meteorological data from Detailed Project Reports (DPRs) were used to estimate the mean monthly hydrological flows at different project sites and the flow duration curves indicate variability in the flow due to seasonality. Melting snow and ice provides water supply to much of the rivers during the dry months before the summer monsoon especially in the Western Himalayas. The river having high seasonal variation in their flow will have high order and magnitude of changes in the hydrological regime with seasonal variation.

4.5 Sediment Load

Sediment transport data for monsoon period for the commissioned HEPs such as Ichhari dam, on the Tons River and Dakpathar barrage, on the Yamuna River were obtained from UJVNL. Data gaps and consistency in the data were observed, however the average four year data recorded silt content of 714.8ppm or 714 mg/lit for Ichhari dam and 1138 ppm or 1136.7 mg/lit for Dakpathar barrage. In terms of sediment transport per unit area Ichhari dam recorded 0.146ppm/ km^2; Dakpathar barrage 0.155 ppm/km^2. The data recorded is well below the reported value of 3204 mg/lit for Bhagirathi River.

4.6 Water Quality

The water quality was monitored during the lean, pre-monsoon and post- monsoon seasons between February 2013 and May 2014 through 27 parameters using standard methods. The results were compared with secondary data with the Central Pollution Control Board. There is no information on the generation, mode of collection, conveyance, treatment and disposal of sewage in the study area. Yamunotri is a religious place; however, there is no proper sanitation facility in the hill villages. Open defecation near water sources is the normal practice. Also, the waste water from bathrooms/kitchens finds its way to the streets, rivers/tributaries, *nallas* or springs. The water quality parameters studied were observed well within the prescribed limits of Central Pollution Control Board Guidelines.

5 BIOLOGICAL ENVIRONMENTS

Terrestrial floral diversity baseline assessment was carried out by the ICFRE.

5.1 Forest Types

The altitudinal stratification in the catchment supports 21 forest types in seven forest groups (Champion and Seth, 1968) with a total forest cover area of 2748.98 km^2.

Distinct pattern of the forest types with the extent of area was recorded, where H*ippophae/Myricaria* Scrub (13/1S1) with only 0.04 km^2, Alder Forest (12/1S2) 0.1 km^2 and that of Birch/Rhododendron Scrub Forest (15/C1) 0.61 km^2. The maximum area is that of Upper or Himalayan Chir-Pine Forest (9/C1b), followed by Ban Oak (*Quercus incana*) Forest (12/C1a) and Western Himalayan Upper Oak/Fir forest (12/C2b).

5.2 Biodiversity Information Systems (BIS)

The disturbance index, fragmentation index and biological richness index of the generated by the Indian Institute of Remote Sensing (IIRS) were used to characterize the landscape-level biodiversity:

(a) Disturbance index: The upper zones of the study area were found to fall in the low-disturbance class, especially Govind Pashu Vihar Wildlife Sanctuary and Govind Pashu Vihar National Park, while the disturbance level was high around drainages due to anthropogenic factors. Most of the area in the middle and lower zones of the study area fell in the moderate- and high-disturbance classes of BIS.

(b) Fragmentation index: The upper hills of the study area, *i.e.*, Govind Pashu Vihar Wildlife Sanctuary and Govind Pashu Vihar National Park, were mostly vegetated, and the fragmentation level was low. There was moderate fragmentation in the river valleys and high fragmentation in the upper reaches, mainly due to topographic and climatic factors such as landslides, cloud bursts and flash floods. Most of the areas in the lower and middle zones are under agriculture. The forests around settlements and agricultural areas were found to have moderate to low levels of fragmentation as per BIS.

(c) Biological richness index: Overall a gradient from moderate to high and very high biological richness values with increasing altitude was found. Very high biological richness was observed in the upper hills, especially in and around Govind Pashu Vihar Wildlife Sanctuary and Govind Pashu Vihar National Park. Patches with low and moderate levels of biological richness were observed in the lower and middle zones as per BIS.

5.3 Composition of Vegetation

5.3.1 Secondary sources

Based on the secondary sources of information, a total of 961 species of angiosperm (245 tree, 197 shrub, 329 herb, 85 grass, 92 climber and 13 bamboo species) belonging to 542 genera and 133 families have been reported from the basin of the Yamuna, the Tons and their tributaries in Uttarakhand. The dicotyledons are represented by 825 species belonging to 470 genera and 124 families and the monocotyledons by 123 species belonging to 72 genera and

nine families. The eight dominant families of phanerogam constitute about 35.96% all the angiosperm species. The family Poaceae as a whole constituted 9.77% of the angiosperms and 76.42% of the monocotyledons. The family Fabaceae makes up 5.92% the total angiosperms and 6.90% of the dicotyledons. A total of 14 gymnosperm species belonging to nine genera and four families have been reported from the study area.

Out of 961 angiosperm species, 32 species in 29 genera and 14 families known to be invasive alien species have been reported from the study area in the past. Most of them are of tropical American origins. Seven endemic species in six genera and four families have been reported from the study area. A total of 41 plant species assigned to different threat categories of the IUCN, the Red Data Book of the Botanical Survey of India, CITES and working plans of state forest departments. Among these are *Abies spectabilis*, *Cryptomeria japonica* and *Juglans regia* (categorized as Near Threatened by the IUCN); *Abies pindrow*, *Acorus calamus*, *Cupressus torulosa*, *Juniperus indica*, *Picea smithiana* and *Pinus wallichiana* (Least Concern) and *Taxus wallichiana* (Endangered) (Ver. 3.1). Seven species has been categorized as Endangered or Vulnerable in the Red Data Book of the Botanical Survey of India. Twenty-six species have been listed in Appendix-II of CITES. The bryophyte species *Aitchinsoniella himalayensis* Kash (Categorized by the IUCN as Endangered) and *Sewardiella tuberifera* Kash. (Vulnerable) have been reported from the area in the past. A total of 692 cryptogram species (214 lichens, 223 algae, 40 fungi, 80 bryophytes and 135 pteridophytes) in 258 genera and 131 families have been reported from here in the past.

5.3.2 Primary baseline survey

The altitude and climate both contribute to the vegetation pattern, considering that the study area was divided into the upper, middle and lower zones of the Yamuna and of the Tons. The trees, shrubs and herbs in the 46 HEP sites were sampled at 80 locations during the period from May, 2013 to September, 2014 covering three seasons using standard methodologies. Secondary information from various sources was also used to substantiate the findings.

5.3.2.1 Upper zone of River Yamuna

A total of 317 species consisting of 314 angiosperms and 3 gymnosperms were recorded. Out of these, 269 were dicots and 45 monocots. The angiosperms comprised 158 herbs, 54 shrubs, 47 trees, 33 grasses and 22 climbers. There were 11 invasive species among these, and 13 species belonged were classified in threat categories of the IUCN, the Red Data Book of Botanical Survey of India and CITES.

5.3.2.2 Middle zone of River Yamuna

A total of 358 species (consisting of one gymnosperm) were recorded from different sampling sites. Of the angiosperms, 303 were dicots and 54 were monocots. These included 159 herbs, 61 shrubs, 61 trees, 46 grasses and 30 climbers. There were 20 invasive species and 11 species that fell in the different threat categories of the IUCN, the Red Data Book and CITES.

5.3.2.3 Lower zone of River Yamuna

A total of 501 species (500 angiosperms and one gymnosperm) were recorded. There were 429 dicots and 71 monocots among the angiosperms. These included 217 herbs, 79 shrubs, 101 trees, 53 grasses and 50 climbers. Among these, there were 28 invasive species and 15 species that fell in the different threat categories of the IUCN, the Red Data Book and CITES.

5.3.2.4 Upper zone of River Tons

A total of 312 species (307 angiosperms and five gymnosperms) were recorded from this zone. There were 264 dicots and 43 monocots among the angiosperms, including 150 herbs, 56 shrubs, 49 trees, 33 grasses and 19 climbers. These included 14 invasive species and 12 species falling in the different threat categories of the IUCN, the Red Data Book and CITES.

5.3.2.5 Middle zone of River Tons

A total of 329 species were recorded in this zone, including 327 angiosperms two gymnosperms. The angiosperms included 275 dicots and 52 monocots. Among the angiosperms were 149 herbs, 55 shrubs, 53 trees, 43 grasses and 27 climbers. These included 20 invasive species and 12 species that fell in different threat categories of the IUCN, the Red Data Book and CITES.

5.3.2.6 Lower zone of River Tons

A total of 326 species (325 angiosperms and one gymnosperm) were recorded. The angiosperms included 268 dicots and 57 monocots. These comprised 141 herbs, 45 shrubs, 68 trees, 48 grasses and 23 climbers. Among these were 24 invasive species and 11 species that fell under different threat categories of the IUCN, the Red Data Book and CITES.

5.4 Terrestrial and Avian Faunal Biodiversity

A terrestrial and avifaunal baseline assessment study was conducted by Sálim Ali Centre for Ornithology and Natural History (SACON), Coimbatore. The study focused on five major faunal groups: (1) insects (particularly butterflies), (2) amphibians, (3) reptiles, (4) birds and (5) mammals. The data were collected between May 2013 and June 2014, in all the three seasons, using standard methods. The status of fauna present below include both primary and secondary source of information of the study area.

A total of 535 species were recorded. These included 125 butterfly, three amphibian, 16 reptile, 359 bird and 32 mammal species.

- Seventy-five butterfly species in 53 genera and five families were recorded. In addition, a complete list of the butterflies was drawn up, which included 50 species from secondary information.
- Only three species of amphibian belonging to two families were recorded. No secondary information specific to the study area is available.
- A total of 16 reptile species in 14 genera and nine families were recorded. Nine of these species were included on the basis of direct sightings and seven species on the basis of secondary sources.

- A total of 359 bird species belonging to 198 genera, 63 families and 17 orders were documented from primary and secondary sources. The bird list includes 173 species recorded during the present survey and 186 species listed in various secondary sources. Eighty-eight species were recorded in both the primary and secondary sources. A total of 238 species (66.30%) were resident, 78 species (21.73%) were winter visitors, 25 species (6.96%) were summer visitors, and the rest of the species were passage visitors/individual records. There were 115 bird species that are associated with wetlands, including 86 water birds (highly dependent on water for their survival) and 29 wetland-dependent bird species.
- A total of 32 species of mammal belong to 17 families and six orders were documented from the study area. Fifteen species were sighted during the present survey, and 17 species have been recorded in various secondary sources. The family Felidae was dominant, with six species, followed by the family Bovidae, with four species, and the family Cervidae, with three species. The families Canidae, Cercopithecidae, Sciuridae, Ursidae and Viverridae were represented by two species each. The families with the least number of representatives were the families Herpestidae, Hystricidae, Leporidae, Moschidae, Muridae, Mustelidae, Pteropodidae, Rhinolophidae and Suidae, having a single species each.

5.4.1 Critical Fauna

5.4.1.1 IUCN Red List Fauna

Forty of the 535 species (28 birds, 11 mammals and one amphibian) fall under the four major categories of the IUCN Red List (Critically Endangered, Endangered, Vulnerable and Near Threatened). Of the three amphibian species recorded, one is classified as Vulnerable. Out of the 359 species of bird, 28 fall in threatened categories of the IUCN Red List: five are Critically Endangered, two are Endangered, seven are Vulnerable, and 14 are Near Threatened. Out of the 32 species of mammal, 11 species falls under threatened categories: three species are Endangered, three species are Vulnerable, and five species are Near Threatened.

5.4.1.2 Indian Wildlife (Protection) Act, 1972

Among the 125 butterfly species recorded, seven species are protected under different schedules of the Indian Wildlife (Protection) Act, 1972 (IWPA). Three species are listed in Schedule-I, two in Schedule-II and two in Schedule-IV of the IWPA.

Among the reptiles, 10 species are listed in various schedules of the IWPA. One species is listed in Schedule-I, five species are listed in Schedule-II, and the remaining four species are listed in Schedule-IV.

Twenty of the 359 bird species are listed in Schedule-I of the IWPA, and the rest (338 species) are listed in Schedule-IV. Only one species, the House Crow, is listed in Schedule-V.

Among the 32 species of mammals recorded, 26 are listed in various schedules of the IWPA. Ten species are listed in Schedule-I; eight species are listed in Schedule-II; five species are

listed in Schedule-III; two species are listed in Schedule-IV; and one species is listed in Schedule-V.

5.4.1.3 CITES –fauna

Among the 16 species of reptile recorded, six are listed in various appendices of CITES. Of these six species, one is listed in Appendix-I, three in Appendix-II and two in Appendix-III. Forty-two of the 359 species of bird are in various appendices of CITES. Three of these species are listed in Appendix-I, 38 species are listed in Appendix-II, and one species is listed in Appendix-III.

Twenty of the 32 mammal species that were recorded are listed in CITES appendices. Of these 20 species, 10 are listed in Appendix-I, four are listed in Appendix-II, and six are listed in Appendix-III.

5.4.1.4 Threatened fauna

Threatened species were recorded in most of the project sites (19 out of 46). A total of 21 threatened species were recorded, including five Critically Endangered species (all birds), five Endangered species (two bird species and three mammals) and 11 Vulnerable species (seven bird species, three mammals and one amphibian).

5.4.1.5 Endemic fauna

Approximately 35 species of bird endemic to the Himalayan area (11 in the Western Himalaya, three in the Central Himalaya and 21 in the Eastern Himalaya) were documented. Out of the 359 bird species recorded, three are endemic to the Western Himalaya (Birdlife International, undated).

5.4.2 Existence of corridors and barriers for wildlife

There were no significant wildlife corridors observed during the survey and also reported by WII (2011) that the Asan Conservation Reserve and the Tons river basin that falls in Kalsi Forest Block in the north western part is lesser known for any spectacular mammal.The probability study conducted by Jhala *et al*., (2010) have reported low occurrence of Tigers in most of the areas in and around the HEPs of Uttarakhand (2010). Govind Pashu Vihar Wildlife Sanctuary and Govind Pashu Vihar National Park are reported to provide habitats for the Snow Leopard and corridors for large mammals within Uttarakhand and to and from neighboring states (MoEF, 2008).

5.4.3 Presence of protected areas (PAs)

Five PAs fall within the study area: one National Park (Govind Pashu Vihar National Park), three wildlife sanctuaries (Govind Pashu Vihar Wildlife Sanctuary, Mussoorie or Bino WLS, Talra WLS) and one conservation reserve (Asan Barrage Wetland Conservation Reserve).

5.4.3.1 Ecological sensitive areas

Ecologically Sensitive Areas (ESAs) have been identified and notified by the Indian Ministry of Environment & Forests (MoEF) since 1989 under the Environment (Protection) Act 1986. The clauses of the EPA which allow for the notification of ESAs to assess the possibility of realizing landscape-level conservation. To assess the eco-sensitive areas close /falls within

areas a ~10 km radial aerial distance from the project barrage sites were assessed. Of the 46 HEPs, 24 are located within 10 km of a PA (16 are within 5 km, eight within 5–10 km). A total of 12 HEPs are located within Govind Pashu Vihar WLS, eight HEPs are in Govind Pashu Vihar NP, six HEPs are in Mussoorie WLS, three HEPs are in the Asan Barrage Conservation Reserve, and one HEP is close to Talra WLS.

5.5 Aquatic Faunal Diversity

An aquatic faunal diversity baseline assessment study was conducted by the Directorate of Coldwater Fisheries Research (DCFR), Bhimtal. Data on the aquatic flora and fauna were collected from a total of 28 locations during March 2013 to April 2014. All the HEP sites were covered. Salient points are as under:

- Productivity increases with decreasing altitude, and it also increases with increasing temperature during the pre-monsoon period. In general, the productivity was observed to be higher in the lower zone than in the middle and upper zone. The overall primary productivity in the upper zones of the Yamuna and Tons was poor compared to the middle and lower zones of the rivers. In the River Yamuna, Tons and its tributaries, the net primary productivity (NPP) in the upper zone was estimated to be very low as compared to the middle and lower zones. The productivity was higher at existing barrage sites (*e.g.*, Chibro/Icchadi, Kulhal) due to the lacustrine environment. The productivity was also relatively higher in the middle zones of the tributaries of the Yamuna and Tons, compared to the main streams.
- The phytoplankton of the Yamuna and Tons and their tributaries comprised members of the Bacillariophyceae (20 genera), Chlorophyceae (17 genera), Mixophyceae (Cynophyceae, seven genera) and Euglenophyceae (two genera). The Bacillariophyceae dominated the phytoplankton fauna, followed by the Chlorophyceae, which accounted for 73% and 21% of the total biomass, respectively. Quantitative analysis of phytoplankton density recorded comparatively high during the pre-monsoon season and lowest in the post-monsoon season.
- The zooplankton of the area sampled in the Yamuna basin comprised 32 taxa, including protozoans (nine genera), rotifers (nine genera), copepods (six genera) and the Ostracoda (2 genera). The zooplankton was dominated by rotifers followed by protozoans and copepods.
- The value of the Simpson index and Shannon index indicate that the diversity of planktons was poor to medium.
- The benthic macrobiota (benthos) consists of 21 taxa belonging to six orders, namely, the Ephemeroptera (42%), Trichoptera (22%), Coleoptera (16%), Plecoptera (12%), Diptera (6%) and Odonata (2%). The macroinvertebrate communities varied significantly from location to location.
- The benthic macrophytes were sparsely distributed and were mostly observed in the lower reaches of the river basin. The important species include *Marchantia polymorpha, Madotheca* spp., *Riccia* spp., *Chara* spp., *Potomogeton* spp. and *Ceratophyllum* spp.

- The periphyton consisted mostly of the Bacillariophyceae and Chlorophycea. The important species include *Tabellaria fenestris, Fragellaria inflata, Meridion* spp., *Nitzschia* spp., *Navicula* spp., *Cymbella* spp., *Synedra* spp., *Gomphonema* spp., *Ulothix* spp. and *Zygnema* spp. There were variations in the flora of the periphyton in different zones, and generally there was poor diversity in the study area.
- A total of 35 fish species belonging to six orders, namely, Cypriniformes, Perciformes, Beloniformes, Mastacembeliformes, Siluriformes and Salmoniformes, were recorded during the survey. The species were recorded in different three seasons, *viz*, the pre-monsoon season, the monsoon and the post-monsoon season, from Janki Chatti to Kulhal in the Yamuna River and from Liwadi to the confluence of the Yamuna and Tons.
- The order Cypriniformes was the dominant group, represented by 19 species and nine genera. *Schizothorax* spp., *Barilius* spp. and *Tor* spp. were the common species. No fishes were recorded or observed at the higher altitudes in the Yamuna or Tons (Janaki Chatti to Saina Chatti and from Liwadi to Jakhol).
- In the middle zone of the River Yamuna as well as the River Tons populations of fish were recorded frequently, with Snow Trout, barils and loaches dominating. The adjoining habitats within the tributaries (*e.g.*, Kamla Gad, Sari Gad, Bhadri Gad, Barni Gad and Pali Gad) are the breeding and larval rearing places of these species. However, the populations of these species are fragmented.
- The occurrence of fish was rare downstream of Ichhari dam; however, significant populations of fish were observed where sufficient water was available due to the joining of small tributaries.
- The presence of Mahseer near Barkot and Bhadri Gad indicates that it migrates from the lower zone and that there is breeding activity in the side streams, mainly near the confluences of different tributaries. Mahseer in different life stages were observed at Kamla Gad, Barni Gad, Bhadri Gad and Aglar Gad.
- A sizable population of the exotic Brown Trout (*Salmo trutta fario*) was observed in the River Rupin. It migrates into the side streams for breeding. This species plays an important role in the aqua-tourism and sports fisheries that have developed in the study area which also support the livelihoods of the local people.
- The lower reaches (below the confluence of the Yamuna and Tons, up to Kulhal), with their gentle slopes, increasing depth, comparatively high temperatures and high productivity, with rich plankton biota, permits a diverse fish fauna, including garrids, barils, Mahseer, minor carps, major carps, catfishes and Snow Trout, to survive.
- The river Yamuna above Dakpathar largely supports Snow Trout followed by Mahseer, *Garra* & *Glyptothorax* and other species. However, Snow Trout is the major fishery resource during winter and the pre-monsoon season, while Mahseer is mostly found during the post-monsoon season.
- Between Dakpathar barrage and Kulhal, the Yamuna drains the main fish species largely consists of Mahseer followed by minor carps, major carps, catfishes. There is occurrence

other fish species that are seasonal such as minor cold water species such as *Garra*, *Glyptothorax* and *Neomacheilus* mostly during the pre-monsoon and catfishes in the shallow, muddy areas of the lower Yamuna.

- The fishery resources of the mountainous section of the River Tons were mostly dominated by Snow Trout (80%) of the total catch. Other species include barils and grids were observed from occasional to frequent.
- The Catch Per Unit Effort (CPUE) fish data indicated a decreasing trend with increasing altitude in the basin, indicative of low fish densities in the middle and higher sections of the river basin. The CPUE data also indicates that the fish catch is higher from the post-monsoon season to the pre-monsoon in both river Yamuna and Tons. However the catch is greatest during the monsoon.

5.5.1 Threatened fish based on IUCN criteria

Snow trout (*Schizothorax* spp.) and Mahseer (*Tor putitora* and *Tor tor*) are categorized as vulnerable and endangered according to the IUCN Red List criteria mainly because the populations of these species are declining in Himalayan rivers.

5.6 THE FLOW CHARACTERISTICS

AHEC-IIT assessed the diurnal variation of flow characteristics for the Khodri HEP with the power generation data which showed pronounced hourly variations during the non-monsoon period compared with the monsoon period. The variations in the discharge were the same on weekdays as in the weekends. Based on the power market and the availability of diurnal or seasonal storage the flashiness index may vary proportionally with the height of the diversion structure. Thus, the higher the diversion structure, the greater is the flashiness index.

5.6.1 The Environmental Flow

The environmental flow assessment was prepared by Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee in association with Directorate of Coldwater Fisheries Research, Bhimtal. Water requirements of aquatic species in terms of depth and velocity and flow were assumed as they have a linear relationship with the flow rate, state of stream health and that there is a cut off level or minimum flow below which the aquatic life will not sustain. These guidelines were employed to determine EFR for each HEP considering the 10-day flow and design of the HEPs. For any 10-days period, if the difference between 10-daily flow and design discharge exceeds the needs of the aquatic life than EFR is equal to this difference else it is the same requirement for the aquatic fauna. Month wise EFR requirements of the HEPs (Fish Zone and No Fish Zone) were estimated and area presented below:

Fish Zone EFR—I. The discharge required to maintain a hydraulic depth of 15 cm and velocity for fish during the lean months (December–Feb), 30% of the cumulative discharge during the monsoon months (June–September), the higher of 20% of the inflow and the discharge required during the non-monsoon and non-lean months (March–May and October–November).

Fish Zone EFR—II. The discharge required to maintain a hydraulic depth of 20 cm and velocity for fish during the lean months (December–February), 30% of the cumulative discharge during the monsoon months (June–September), the higher of 20% of the inflow and the discharge required during the non-monsoon and non-lean months (March–May and October–November).

No Fish Zone EFR—I. 20% of the average inflow during the lean months (December–February), 30% of the cumulative discharge during the monsoon months (June–September), 20% of the inflow for the non-monsoon and non-lean months (March–May and October–November).

No Fish Zone EFR—II. 30% of the average inflow during the lean months (December–February), 30% of the cumulative discharge during the monsoon months (June–September), 20% of the inflow for the non-monsoon and non-lean months (March–May and October–November).

No Fish Zone EFR—III. 10% of the mean annual flow during the lean months (December–February), 30% of the cumulative discharge during the monsoon months (June–September), 10% of the mean annual flow for the non-monsoon and non-lean months (March–May and October–November).

6 SOCIO-ECONOMIC ENVIRONMENT‘

A socio-economic survey was conducted in the three districts of the study area by the ICFRE: (1) Dehra Dun, *i.e.,* the upper Dehra Dun, (2) Uttarkashi and (3) Tehri Garhwal (Jaunpur Block). Various secondary sources of information were used to generate the district- and block-level population and economy data. Information on the project-affected villages (PAVs) and households (HH) was gathered from primary and secondary sources using appropriate tools and data collection techniques.

- The population distribution is varied within the study area: the population of Dehra Dun was 16.8% of the population of the state; in Tehri Garhwal the corresponding figure was 6.13%; and in Uttarkashi it was 3.27%. The average literacy rate was significantly higher in Dehra Dun compared with the upper and middle valley.
- Within the district, there were variations in GDPP mainly due to the different locations, terrain and climatic regions. In Dehradun District, Kalsi and Vikash Nagar are agriculturally developed due to better connectivity and access to marketing facilities compared with Chakrata and Tiuni and with Mori, in Uttarkashi. Due to limited opportunities for employment and a harsh geography and climate, there is no skill-based workforce in the study area. Men aged between 20 and 50 years migrate in search of employment, and the women look after the family and farming.
- With small and marginal land holdings, a high input cost per unit and a lack of irrigation, the people depend critically on community forests for their subsistence.
- Rice, wheat, *mandwa* and *jhangora* are the major crops. Apple is the major fruit, and potato, onion, beans, ginger, cucumber, pumpkin, turmeric and chili are the major vegetables grown. Immediate monetary benefits are being realized due to diversification

to off-season vegetables, which are being grown in the middle and high elevations. There is also an increase in the demand for fodder for livestock. The area under agriculture/horticulture in Dehra Dun District increased from 2887 ha during 2002–2003 to 9104 ha in 2010–2011.

- The trade in medicinal aromatic plants is an important and integral part of the socio-economy of the region. It has been reported that the traders earn the maximum percentage of the profits. However, because the profits are good, they get into illegal collection. The Char-Dham Yatra also supports the local people substantially. The state government promotes aquaculture through various schemes in the lower floodplain to enhance the livelihood options scheduled castes and tribal communities. The aqua-tourism in the River Rupin support local livelihoods in the valley.
- Infrastructure related to the supply of water and waste water disposal are yet to be developed, and waste water is released into streams and thence into the natural water course or water bodies.
- In the PAVs that were surveyed, the populations of scheduled castes and tribes constitute 19.18% and 12.57% of the total population, respectively. The majority of the agricultural land holdings are marginal. There are 85 educational institutions and 10 hospitals. Natural springs and tap water are the sources of drinking water.
- The household survey indicates that there are 5.69 members per family on average in the Yamuna River Basin and 5.83 members per family in the Tons River Basin. Scheduled castes make up 18.52% of the population, scheduled tribes 14.02% and the other communities represent the largest group, 67.46%. The majority of the households are Hindu, followed by Muslim households (3.65%).
- The majority of the farmers had small land holdings (74.41%), followed by medium land holders (21.91%). Large land holders represented only 3.68%. The monthly income was Rs.6891.18 in the Yamuna River zone and Rs.8301.50 in the Tons River zone. The monthly expenditure was Rs.5420.44 in the Yamuna zone and Rs.6484.68 in the Tons zone.
- The benefit of Resettlement and Rehabilitation (R&R) could not be assessed as majority of the commissioned projects are before 1985 when the state was with Uttar Pradesh and no documentations are available. The Government of Uttarakhand has proposed R&R policy in line with Government of Himachal Pradesh. However the new Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 and the draft Local Area Development Assistance proposed by Government of Uttarakhand for the projects proposed to be implemented will contribute to enhance the infrastructure and local economy in the study area.
- Consultation meetings were conducted with panchayat members, individuals, household members, women and youths of the PAVs within a 5 km radius to assess the people's perceptions of hydropower development vis-à-vis social welfare. The people's perceptions were grouped according to the stage of completion: commissioned, under construction and under development. Overall, the people of the basin were concerned

about reduced fodder availability (68%); loss of cultivable land (48%); loss of livelihood (42%); floods and landslides (58%); and loss of culture (36%). There were demands for development of infrastructure (roads, bridges, schools, colleges, hospitals, *etc*.) (65%); fair compensation and R&R schemes (75%); free electricity (81%, including the Upper Tons area, where there is no electricity yet); employment for the local (73%) and landless PAFs; agricultural/horticultural marketing facilities and value addition (64%); and entrepreneurship activity and community development (62%).

7 POTENTAIL IMPACT ASSESSMENTS

The potential impact assessed as outlined in the ToR is as below:

7.1 Impact due to modification in Hydrologic Regime due to Diversion of water

In the present study the HEP schemes undertaken for assessment include two reservoirs and 44 RoR. Of the total RoR schemes, 9 have diurnal reservoirs, 14 have barrages and remaining 21 have trench weirs. Two out of 46 HEPs have the tunnel length more than 10km; 35 out of 46 HEPs have less than 5km length of tunnel and penstock. The diverted lengths as well as the submergence were worked out to assess the affected length of the river and presented in table 2. Considering the number of project and the diversion proposed in river Rupin, Supin; in river Tons due to Naitwar-Mori, Mori-Hanol, Hanol-Tiuni Tuni-Plasu and a reservoir; some starches in Yamuna such as Sauli-Barnigad, Rinknal Khad, Barnigad, Barigad and Barnigad, Nainagaon due to diurnal reservoir and barrage there will be significant changes in the hydrological flow which will have negative impact on river ecology, aquatic and riparian ecosystem.

Table 2: Affected length of the river Yamuna, Tons and its tributaries in Uttarakhand

S. No.	Name of River/ Tributary	Number of HEPs	Total River stretch (m)	River Stretch Diverted (m)	River stretch Submerged (m)	Affected Length (m)	% of river length		
							Diverted	Submerged	Total
Major River									
1	Yamuna	6C+6UC+16UD	183000	63000	41000	63000	34%	22%	57%
2	Tons	3C+15UD	209000	68400	44500	68400	33%	21%	54%
Tributaries									
3	Pabber	1UD	104000	11000	-	11000	11%	0%	11%
4	Rupin	4UD	58000	5100	-	5100	9%	0%	9%
5	Supin	3UD	46000	10600	-	10600	23%	0%	23%
6	Istar gad	1C	9000	1600	-	1600	18%	0%	18%
7	Hanuman Ganga	1C	22000	500	-	500	2%	0%	2%
8	Pali gad	1UD	16000	3000	-	3000	19%	0%	19%
9	Garsad gad (Rinknal & Garsad)	2UD	20000	1900					
11	Badiyar gad		32000	3900	-	3900	12%	0%	12%
12	Rikhnal gad		20000	1900	-	1900	10%	0%	10%
13	Badrigad		23000	6900	-	6900	30%	0%	30%
14	Aglar Nadi		40000	9900	-	9900	25%	0%	25%
15	Asan river	1C+1UD	74000	(1000C +900UD) 1900	-	1900	3%	0%	3%
16	Ringali		8000	2900	-	2900	36%	0%	36%
17	Asnor gad		4800	1000	-	1650			
18	Amlawa		30000	2000	-	2328			

7.2 Impact due to flashiness

The storage of water is utilized for peaking power plants. The storage to meet peaking power in the upstream will experience a diurnal cycle of deep flooding and exposure (draw down) instead of the normal flow that occurred in the river channel in normal course before diversion due to HEP. In addition the abstraction determines the amplitude and frequency of fluctuation which result in exposure of the littoral and tail reach areas of the reservoir. Such changes in the hydrological regimes will often be high in order and magnitude for the rivers having seasonal variations in flow. Below downstream the power house where the diverted water joins the river, the diurnal change in production of power will result in fluctuation of discharge resulting in Flashiness (diurnal fluctuations). The fluctuations of water-level and velocities will vary with the power demand as the peak demand of electricity may vary with time within a day from few hours to several hours. During such period a flash is generated in the stream flow in the downstream stretch due to sudden release of water. Such frequent water level fluctuations on a daily basis will affect all kinds of organisms as well as physico-chemical environment of the river stretch.

In the study area the proposed HEPs such as Mori-Hanol has the maximum length of closed water conductor system in the form of tunnel and penstock for 11.4km. Two out of 46 HEPs have the tunnel length more than 10km; 35 out of 46 HEPs have less than 5km length of tunnel and penstock. Considering the number of project and its diversion the river Rupin, Supin; Tons due to Naitwar-Mori, Mori-Hanol, Hanol-Tiuni Tiuni-Plasu and a reservoir; some starches in Yamuna such as Sauli-Barnigad, Rinknal Khad, Barnigad, Badrigad and Barnigad-Naingaon in Yamuna. The hydrological flow changes to meet the peak demand will have negative impact on river ecology, aquatic and riparian ecosystems.

7.3 Impact on Agriculture

In the Yamuna basin, there is significant agricultural activity along the sides of the river because of the availability of water. No systematic report on the crop productivity with reference changes in soil moisture due to hydropower development is available to assess impact due to water stress. However, there will be negative impacts due to loss of agricultural land and stress due to diversion and varied hydrological flows with the development of hydroelectric project development in the basin.

7.4 Impact on Fisheries

The Brown Trout (*Salmo trutta fario*) is found in the River Rupin in limited numbers. The proposed projects (Rupin II, III, IV and V) and allied activities will have negative impacts on the Brown Trout population during the construction stage. During operation, there will be habitat loss and local migration due to diversions.

The proposed projects such as Naitwar-Mori, Mori-Hanol, Hanol-Tiuni, Tiuni-Plasu and Arakot-Tiuni, all put together will affect a 50 km river stretch due to the diversion and regulated downstream flow. The projects will also result in the loss of migratory routes, in addition to loss of biodiversity due to fragmentation, and the population will be confined to side streams. In the long term, there may be a loss of genetic diversity. The presence of the Mahseer, an important migratory fish species near Barkot indicates it migration from lower

region of Yamuna up to this area to breed in the side streams, mainly near the confluences of different tributaries. The proposed projects of various stage one after the other from Pali Gad to Vyasi, on the main river, as well as on the tributaries, will have a negative impact on the migration of the Mahseer and other indigenous species such as the Snow Trout. The regulation of the flow will alter the nutrient status in the streams below and consequently may lead to loss of aquatic biota.

The Vyasi and Lakhwar are under construction projects on the main Yamuna where the indigenous Mahseer (*Tor* spp.) and Snow Trout (*Schizothorax* spp.) are found regularly. The creation of reservoirs will result in changes from lotic to lentic systems and further restrict the upward migration of migratory species due to the creation of barriers. However, the lentic environment also provides opportunities for development of fisheries by establishing suitable fish species in the reservoirs.

7.5 Impact on Forest

Information on total land to be acquired (such as revenue, agriculture, private and forest) is not available for commissioned and proposed HEPs. However, assuming that the land required for developing a kilometer of road of width 7.5 m is about one hectare, if about 5 km of total road length is developed for each proposed scheme for access roads to connect the different project sites and facilities, a significant extent of land will be converted for road development alone, resulting in fragmentation of the forest. The development of hydropower also includes transmission lines. Based on the extent of proposed HEPs the forest land diverted would be high may result in loss of few forest types that are in less extent and are specific to few catchments or result in fragmentation due to spatial and temporal crowding which will reduce the availability of habitats for the wild animals, especially in the upper hills.

7.6 Identification of Threats to Wildlife

The GPW sanctuary area is fragmented by 42 villages located in three valleys along the Supin, Tons and Rupin Rivers (WII, 2009). At the moment the impact of tourism is limited due to lack of a motorable road but can dramatically increase if roads are constructed. In addition the villagers of Dooni, Masri, Liwari, Phithari, Osla, Poani and Gangahar were reported to be involved in organized poaching of musk deer. The proposed development of hydropower, road and transmission line in the higher elevation especially in the river Rupin and supin may further open the inaccessible areas to people and many times result in increased illegal activities. Inadequate understanding of ecological and social issues especially wildlife and human conflicts will make the resolution of conflicts more critical during construction time with labours.

8 CUMULATIVE ENVIRONMENT IMPACT ASSESSMENTS THROUGH QUALITATIVE PROCESS

The number of proposed run of river (R-o-R) schemes in each tributary and river varies is one or two, except for the Aglar (six), Rupin (four) and Supin (three).The key valued ecosystem components (VECs) specific to the study area were identified with the input from local stakeholders and experts include water resources (quantity, quality and availability),

sediment, terrestrial ecosystems, and fish, natural resource and local people social economic indicators.

To assess the cumulative impacts on each VEC, potential impacts were first identified using an impact hypothesis approach by which cause –effect chains leading from project action and stressor towards the VECs are conceptualized to identify the impact indicators for each VEC and potential impacts. Given the lack of information on some of the VECs, the indicators used for the assessment are spatial indicators of pressures and risk affecting the VECs rather than on the evaluation of specific impacts (*i.e.,* the ecological process underlying the cumulative impacts). As simple surrogates for complete ecological processes watershed habitat indicators are unlikely to accurately represent direct cause- and effect relationships but act as estimates for the pressures or risk acting on the VEC.

Thus the identified cumulative impacts have been assessed in terms of its significance taking into consideration that the projects contribution to such impacts under two scenarios i.e. ., the current state and the expected evolution of the VECs status based on the available baseline information. The most significant cumulative impacts negative includes fragmentation of forest due to land use changes, floral diversity and indigenous fish species such as the Snow Trout, Mahseer and the exotic Brown Trout. In terms of positive impact on the social environment such as infrastructure, skills, per-capita income, energy consumption and benefit sharing due to commissioned projects is assessed to be low. The irrigation facilities though have contributed to increased land under agriculture in the lower region of the Yamuna basin the impact due to hydropower is yet to scientifically establish. In addition the strategic location of state capital have contributed to road networks, infrastructure and market facility.

Although, hydropower development is fast growing sector in Himalayan region, there is a certain degree of uncertainty as to the number of hydropower projects that will be finally implemented in the basin. For, this reason a scenario based on option assessment such as economics of hydropower development and eco-sensitive areas has been made for the study area for undertaking strategic planning process to identifying and prioritizes the developmental issues. To meet the sustainable hydropower development in the basin following are the options recommended such as single large or cascade on the main river for considerable and continuous supply of electricity and connect rural communities with a significant grid extension programme and upgrading the existing HEPs for generating additional power; several small HEPs on the tributaries which will require significant new distribution network and micro HEPs on the fast-flowing streams that are close to target communities to supply electricity to the local communities with their involvement which will village distribution networks or short transmission.

9 RECOMMENDATIONS

The study makes specific and general recommendations for sustainable development of hydropower. A few are highlighted here:

- The creation of a Basin Management Unit (BMU), with adequate infrastructure and human resources, to coordinate and guide the hydropower developers' forum for

hydropower development in the basin is recommended. The creation of a scientific technical facilitation unit (STFU), consisting of various subject specialists, to facilitate the decision making process is also recommended.

- Basin-wise standards and guidelines will be required to focus on the safety systems of the dams, and a co-ordination mechanism will be needed to integrate and manage the basin-wide safety/risks/emergency response planning to protect the community during the operation of an HEP, the development of the infrastructure and flood control.
- Various monitoring mechanisms *i.e.*, regional and national-level monitoring committees, should be established that involve experts from outside the state.
- Implementation of the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 with adequate monitoring mechanism as outlined in the Act and Local Area Development Assistance for long term sustainability.
- There should be a depository where all the data generated, *viz*, data on hydrology, discharge, water quality, hydro-meteorology, land use, land diverted, snow/glaciers, biotic life and sediment flushing in relation to the project, should be deposited and made available to any interested person. It should preferably be on the Internet.
- A small set of pilot projects to demonstrate the methodology and efficacy of the indicative plans should be undertaken. Further, a detailed plan for the HEP construction sequence should be formulated (starting the construction from a major tributary or from the river, starting the process at the lower region or upper region to avoid stress on various VECs during the construction.
- Scientific studies must be initiated to understand the sediment sources, their characteristics and the processes that control erosion, sediment transport and sediment deposition with and without the HEPs at the basin level for generating baseline data to assess the impacts due to the different types of HEPs.

In addition, general recommendations have been made for environmental components such as the geology, land use changes, meteorology, hydrology, water resources, water quality/water use, soil erosion, sedimentation, muck disposal, terrestrial flora/fauna, aquatic ecosystems, environmental flow requirements, flashiness, diverted and submerged lengths, socio-economic environment and benefit sharing.

9.1 No go areas or critical biological conservation

Where hydropower plants emerge as the best solution, mitigation measures need to be designed carefully, and compensatory measures such as the designation of critical or conservation area need to be considered. Accordingly, the following recommendations have been made:

- *The entire landscape of [the] protected area of GPNP and GPVWLS drained by the Rupin and Supin rivers is an important wildlife habitat of conservational importance for diverse flora (species specific to 14/C1 a West Himalayan Sub-alpine Birch/Fir*

Forest cover with an area of 3.11 km^2; *13/1S1* Hippophae/Myricaria *Scrub Forest type with an area of 0.04 km^2; and 15/C1 Birch/Rhododendron Scrub Forest with an area of 0.61 km^2) and fauna including endemics and the endangered species such as [the] Snow Leopard. Restricted occurrence of Brown Trout (Salmo trutta fario) species that prefer cool, clean and well oxygenated water in [the] River Rupin contributes to eco-tourism potential and local livelihood. Keeping in view the strategic location of the protected the hydropower development in the entire river stretch and catchments of the rivers Rupin and Supin shall be made after due consideration and in consultation with the relevant State Forest Department and the National authorities.*

- *However, part of [the] PA along [the] River Supin has been excluded from [the] PA, i.e. Jakhol to Liwari, for developing [a] link road under the Pradhan Mantri Gram Sadak Yojana (PMGSY).*

10 ACTION PLAN

Based on the results of the cumulative impact analysis, a number of mitigation and monitoring measures are proposed to help minimize potential cumulative impacts on the selected VECs. Such measures should be developed and implemented within a framework of a cumulative impact management through integrated approach for shared responsibility of the project proponents. For which an institutional framework involving various stakeholders such as state departments, expert institutions and local people has been proposed under the basin management for the parameters outlined for implementation.