River Basin Plans, Hydropower Development Master Plan and Strategic Environmental and Social Assessment

Final Main Report

Government of Nepal

Water and Energy Commission Secretariat

Singhadurbar, Kathmandu

2024

Final Main Report

Project	**Preparation of River Basin Plans, Hydropower Development Master Plan and Strategic Environmental and Social Assessment**
Prepared for	Government of Nepal Water and Energy Commission Secretariat
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Abbreviations and Acronyms

AEPC	Alternative Energy Promotion Centre
BCR	Benefit Cost Ratio
BDV	Baseline Development
BZ	Buffer Zone
CA	Conservation Area
CBA	Cost Benefit Analysis
CBS	Central Bureau of Statistics
CDO	Chief District Officer
CFC	Compensation Fixation Committee
CI	Cropping Intensity
CITIES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
COD	Chemical Oxygen Demand
CSI	Connectivity Status Index
DDC	District Development Committee
DFS0	DHI time series file format
DHM	Department of Hydrology and Meteorology
DMU	Decision Making Under Uncertainty
DoED	Department of Electricity Development
DoWRI	Department of Water Resources and Irrigation
DNPWC	Department of National Parks and Wildlife Conservation
DSS	Decision Support System
DWS	Drinking Water Supply
DWSS	Department of Water Supply and Sanitation
EES	Efficiency, Equity and Sustainability
EIRR	Economic Internal Rate of Return
EMP	Environment Management Plan
ENPV	Economic Net Present Value
ESIA	Environmental and Social Impact Assessment
ESMP	Environment and Social Management Plan
ESMS	Environmental and Social Management System
FFR	Free-flowing Rivers
FIRR	Financial Internal Rate of Return
FNPV	Financial Net Present Value
FUGs	Forest User Groups
GCM	Global Climate Model
GIS	Geographic Information System
GLOF	Glacier Lake Outburst Flood
GoN	Government of Nepal
GWRDB	Groundwater Resources Development Board
ha	Hectare
HCV	High Conservation Value
HCVR	High Conservation Value River
HDMP	Hydropower Development Master Plan
HEP	Hydroelectric project
HP	Hydropower
IBA	Important Bird Area

IBT	Inter-Basin Transfer
ICL	Issued Construction License
IDML	Industrial District Management Limited
IEE/EIA	Initial Environmental Examination/ Environmental Impact Assessment
IMP	Irrigation Master Plan 2019 (updated 2024)
IRR	Internal Rate of Return
IRRG	Irrigation Sector
IWRM	Integrated Water Resources Management
KcDV	Karnali Chisapani Development Scenario
km	Kilometre
KPI	Key Performance Indicators
KV	Kilovolt
KWH	Kilowatt hour
lpcd	Litres per capita per day
LPG	Liquified Petroleum Gas
LRO	Land Revenue Office
MALD	Ministry of Agriculture and Livestock Development
MCA	Multi-Criteria Analysis
MCE	Maximum Credible Earthquake
MHB	MIKE HYDRO Basin
MICS	Multiple Index Cluster Survey
MLD	Million Liter per Day
mm	Millimetre
MoALD	Ministry of Agriculture and Livestock Development
MoEST	Ministry of Environment, Science and Technology
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MoFE	Ministry of Forest and Environment
MoHP	Ministry of Health and Population
MOM	Management Operation and Maintenance
MoWS	Ministry of Water Supply
MPP	Multi-purpose Project
MW	Megawatt
MxDV	Maximum Hydropower Development Scenario
NBSAP	National Biodiversity Strategy and Action Plan (2014 -2020)
NEA	Nepal Electricity Authority
NP	National Park
NPC	National Planning Commission
NPR	Nepalese Rupees
O&M	Operation and Management
OCC	Opportunity Cost of Capital
OFWM	On-farm Water Management
PA	Protected Areas
PAANI	USAID Panni Program
PCTMCDC	President Chure Terai Madhesh Conservation and Development Committee
PDA	Project Development Agreement
PPE	Personal Protective Equipment
RAP	Resettlement Action Plan
RBM	River Basin Model

RBO	River Basin Organization
RBP	River Basin Plan
RCOD	Required Commercial Operation Date
RCP	Representative Carbon Pathway
ROR, PROR	Run of River, Peaking Run of River HP plant
RPF	Resettlement Policy Framework
S1-4	Irrigation Suitability Land Classes, 1-4
SC1	Development Scenario 1
SC2	Development Scenario 2
SDG	Sustainable Development Goals
SEE	Safety Evaluation Earthquake
SERF	Shadow Exchange Rate Factor
SESA	Strategic Environmental and Social Assessment
TN#xx	Project technical note #xx. E.g., TN#10 is Technical Note #10
TOR	Terms of Reference
TS	Time Series
USAID	United States Agency for International Development
USD	United States Dollar
VDC	Village Development Committee
VECs	Valued Environmental and Social Components
WASH	Water, Sanitation and Hygiene
WCO	Watershed Conservation Officers
WECS	Water and Energy Commission Secretariat
WRDP	Water Resource Development Plan
WRRDC	Water Resources Research and Development Centre
WSSA	Water Supply and Sanitation Act
WWF	World Wildlife Foundation

Executive Summary

Background

The Government of Nepal (GoN) has issued the National Water Plan 2005 and the National Water Resources Policy 2020 for the implementation of the Water Resources Strategy formulated in 2002. As guided by the National Water Plan and Water Resources Strategy, water resources development and management are to be undertaken in accordance with the principles of Integrated Water Resources Management (IWRM). The impacts of climate change on water resources have adversely affected the reliability and safety of the drinking water supply, irrigation, hydropower production and other uses of water. In the recent years, increased geohazards such as landslides in the fragile mountains, floods and inundation in the Terai and the plains due to extremely high precipitation in short duration, and more frequent and longer duration droughts during the dry seasons are additional challenges of water resources management.

The Water and Energy Commission Secretariat (WECS) is envisaged as the apex body for the development, management and regulation of water resources in coordination with relevant agencies and stakeholders at all levels to achieve optimal water resources development. In this context, WECS has prepared River Basin Plans and Hydropower Development Master Plan (HDMP), along with Strategic Environmental and Social Assessment (SESA).

River Basin Plans

The key objective of the River Basin Plans is the utilization and management of the available water and land resources in the basin to meet the water supply and sanitation needs of the growing population, urbanizations, increased development activities and changing lifestyle, expand year-round irrigation to increase food production, develop the hydropower potential, mitigate and manage the risks due to water-induced disasters, maintain the ecosystem services of the rivers and protect the national parks and cultural sites of importance in the river basins.

The River Basin Plans have been prepared with an implementation plan up to 2050. Separate River Basin Plans of four major basins (Mahakali, Karnali, Gandaki, Koshi Basins), six medium basins (West Rapti, Babai, Bagmati, Kamala, Kankai and Mechi)[1] and Southern River Blocks have been prepared. Water Resources development and management will be based on the river basin plans being developed. The River Basin Plans are prepared based on the principles of IWRM and prioritization of multiple purpose projects. Water resources development and management will be undertaken by coordinating and defining roles and responsibilities of the local, provincial and federal governments.

The water resources development and water allocation in the river basins are based on optimal development of different uses of water resources such as the drinking water supply, irrigation, hydropower, environmental services and other uses. The water resources development scenarios were formulated and evaluated considering the recommendations and findings of the Irrigation Master Plan (IMP) 2019 (updated 2024), HDMP and SESA.

The River Basin Plan of each basin is structured as follows:

Volume 1	**Basin status**	• Physical characteristics • Socio-economic characteristics • National legislation, policies and plans
Volume 2	**Water Resources Development Plan (WRDP)**	• Basin context and planning objectives • Proposals for water resources development by sector • Development of recommended integrated development scenarios • Financial and economic analysis of scenarios • Investment plan up to 2050
Volume 3	**Strategic Environmental and Social Assessment (SESA)**	• Environmental impacts of recommended development scenarios • Social impacts of recommended development scenarios • Proposed environmental and social safeguards
Volume 4	**Atlas**	• Maps of key spatial features

[1] Summary findings of the River Basin Plan of Bagmati Basin prepared under a separate project by WECS are also included.

The Hydropower Development Master Plan is prepared separately, while considering it as an important component of the water resources development and forms an integral part of the river basin plans.

Drinking Water Supply (DWS): GoN has made good progress in providing “basic” water supply and sanitation for both rural and urban citizens. The proportion without such facilities is below 10% in the country and the goal, although difficult and expensive, is to improve on this. Nevertheless, there is no cause for concern about the adequacy of supply. The current water use for drinking water and industry in the basin is relatively small and the projected demand to 2050, considering population growth and urbanization, is expected to be met reliably from available water sources.

Goal: Accounting for the increased water demand and potential increased variability associated with climate change, providing reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.

The projected drinking water supply demand up to 2050 is given in Table 0-1 and Figure 0-1. The River Basin Plans aims to meet the water supply demand as the priority allocation of the available water.

Table 0-1: Projected Water Supply Demand (MLD)

Basin	2025	2030	2035	2040	2045	2050
Mahakali	38.3	43.2	47.9	52.4	56.7	57.4
Karnali	230.2	263.7	296.5	328.3	359.0	365.5
Babai	76.6	93.3	109.1	127.5	146.6	158.5
West Rapti	55.4	61.9	69.0	76.0	82.8	83.8
Gandaki	312.1	363.0	413.1	469.1	525.1	551.8
Kamala	43.4	50.6	57.6	63.5	69.4	70.7
Koshi	175.3	196.3	217.8	239.2	259.2	262.0
Kankai	20.5	23.8	26.8	29.3	31.9	32.4
Mechi	24.3	27.6	30.7	33.6	36.4	36.8
Bagmati	359.7	437.4	509.2	591.5	675.9	727.3
Southern Blocks	794.9	921.8	1,040.7	1,159.6	1,282.4	1,318.6
Total (MLD)	2,130.8	2,482.5	2,818.4	3,169.9	3,525.2	3,664.9
Total (m^3/s)	**24.66**	**28.73**	**32.62**	**36.69**	**40.80**	**42.42**

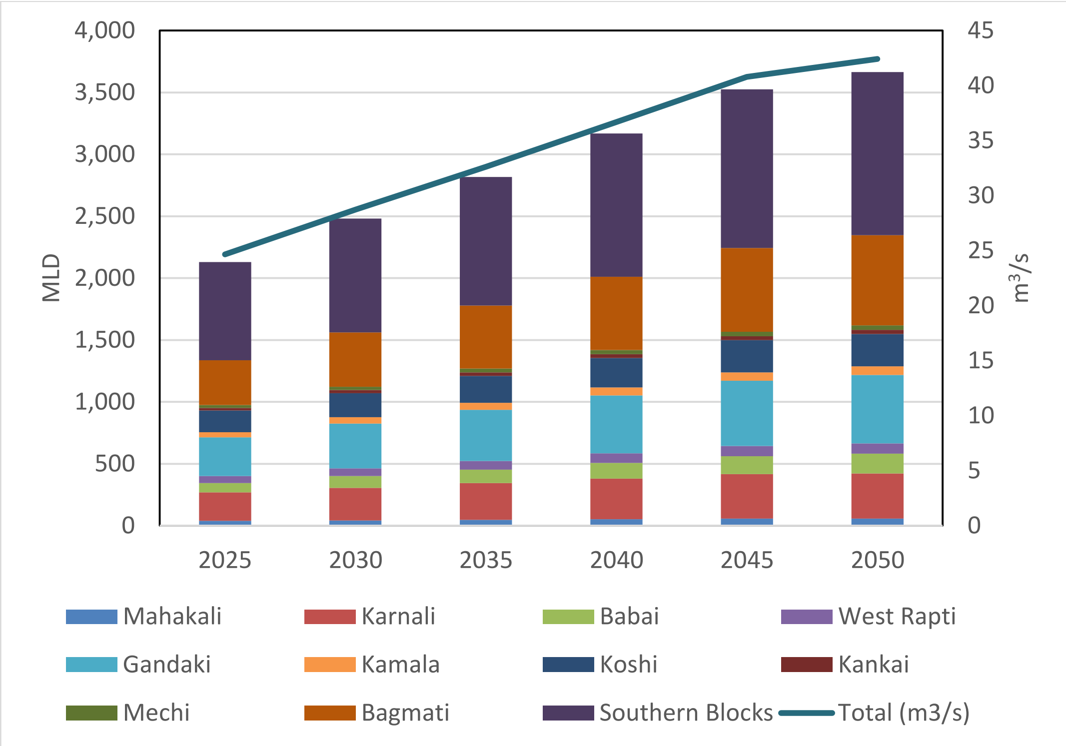


Figure 0-1: Projected Water Supply Demand

Irrigation (IRRG): The agricultural demand in all basins will increase over the planning horizon as population growth, urbanization and changing lifestyles increases food demand. Based on IMP's approach to quantifying food demand in terms of production and value and, under stated assumptions, the incremental increase in crop production required by 2043 (the most extended projection available in the IMP) is estimated. The approach for irrigation development has followed the four systems:

- Increase year-round irrigation through two means:
  (i) Inter-basin transfer
  (ii) Groundwater development, either independent or conjunctive use
- Develop new gravity systems in the hills and mountains
- Develop new non-conventional irrigation, through electrical pumping or solar pumping
- Rehabilitation, modernisation, irrigation management transfer and on-farm water management (OFWM)

Irrigation Master Plan 2019 (updated 2024) has identified agricultural land covering 3.558 million ha, of which 1.593 million ha are in the Terai, and 1.564 million ha and 0.401 million ha in the Hill and Mountain agro-ecological zones[2], and suitable irrigable land of 2.536 million ha of which 1.499 (59%), 0.837 (33%) and 0.201 (8%) million ha are in the Terai, Hill and Mountain zones, respectively. The suitable irrigable land is classified into four classes (S1 to S4) by IMP. The IMP irrigation system inventory lists the current gross irrigated area is about 1.435 million ha of which about 0.941 million ha (66%) are irrigated from surface water and 0.494 million ha (34%) from groundwater sources, principally on the Terai. The gross irrigated area on the Terai is about 1.171 million ha, of which about 0.686 million ha is from surface water and 0.486 million ha from groundwater. In the Hill zone, the total gross irrigated area is about 0.213 million ha largely supplied from surface water (about 96%) and, in the Mountain zone, irrigated area is about 50,779 ha. There is an estimated area of 1.275 million ha of new lands which are suitable, based on slope and soils, for development for irrigated agriculture, of which approximately 0.709 million ha are in the Terai, 0.421 million ha in the Hills and 0.144 million ha in the Mountains.

[2] For the purposes of classification and planning Nepal is divided into three agro-ecological zones; Terai; lowlands to the south, Hill; hills up to 3,000 meters through the center of the country west to east, and Mountain; hills to the north.

A planning priority is (i) improvement of existing irrigated area (systems) in the existing 1.435 million ha (gross) by increasing cropping intensities, conveyance efficiency, distribution equity and productivity, (ii) development of new irrigated lands in about 1.275 million ha. The priorities are to identify storage and inter-basin diversion opportunities to improve water supply in the dry season and water deficit basins, including the Southern Blocks. To minimize cost, it is preferable to focus on dam sites and water transfer opportunities within the basin. To maximize economic benefit, water from the reservoir projects and inter-basin water diversions needs to be supplied to the Terai in the dry season, where the quantity and quality of land suitability for irrigation is relatively greater than in the Hills.

Table 0-2 and Figure 0-2 present the total agricultural land, irrigable land and irrigated areas in 2025 and 2050 considered in the river basin modelling.

Table 0-2: Total Agricultural Land, Irrigation Suitability and Irrigated Area in 2025 and 2050 considered in the River Basin Modelling

Basin	Agricultural Land[1] (ha)	Irrigation Suitable[1] (ha)	Irrigation Area 2025[2] (ha)	Irrigation Area 2050[2] (ha)	IBT 2050[3] (ha)
Mahakali	81,986	55,268	3,178	22,391	31,486
Karnali	466,369	227,877	69,341	94,642	91,628
Gandaki	668,857	467,596	64,838	96,933	42,000
Koshi	624,516	316,826	81,813	106,399	431,000
Babai	123,945	96,836	64,638	70,663	
West Rapti	144,528	63,579	61,490	63,829	68,000
Kamala	80,917	65,834	48,662	57,016	
Kankai[4]	43,089	19,556	21,814	67,680	
Mechi	41,152	34,325	6,271	28,041	
Bagmati	124,600	93,695	50,000	74,956	
Southern Blocks[5]	1,158,006	1,089,423	497,522	1,089,423	
Groundwater[6]			493,830	811,830	
Total[6]	**3,557,963**	**2,530,815**	**1,457,286**	**2,544,703**	**664,114**

Note:

[1] The agricultural land and irrigation suitable land are based on the land resources maps prepared by IMP (2019, updated 2024). These are delineated strictly following the individual basin boundary up to the Nepal-India border.

[2] The basin-wide irrigation areas in 2025 and in 2050 are within the basin and are mainly irrigated by surface water sources.

[3] The area under this column covers the diversion of water for irrigation in the adjacent Southern Blocks or inter-basin water transfer (IBT) from the respective basins to another basin. For example, the IBT area for Mahakali Basin covers the irrigation areas of Mahakali 1, 2 and 3 irrigation projects in Southern Block 1.

[4] The irrigation areas of Kankai Basin are greater than the irrigation suitable area, which is because some parts of the Southern Blocks irrigated from the Kankai River are also included.

[5] Most of the irrigation command areas of the Southern Blocks will be irrigated by either inter-basin transfer from major river basins, ground water sources and conjunctive use of both.

[6] The command areas under groundwater are based on IMP, 2019 (updated 2024). For planning purpose, this area is assumed to be the same for 2025.

[7] The total irrigation areas of the Southern Blocks and groundwater irrigation areas presented includes some double counting and hence are larger than the actual. For example, the total irrigation area in 2050 is slightly larger than the total irrigation suitable area. The figures are used for basin level planning.

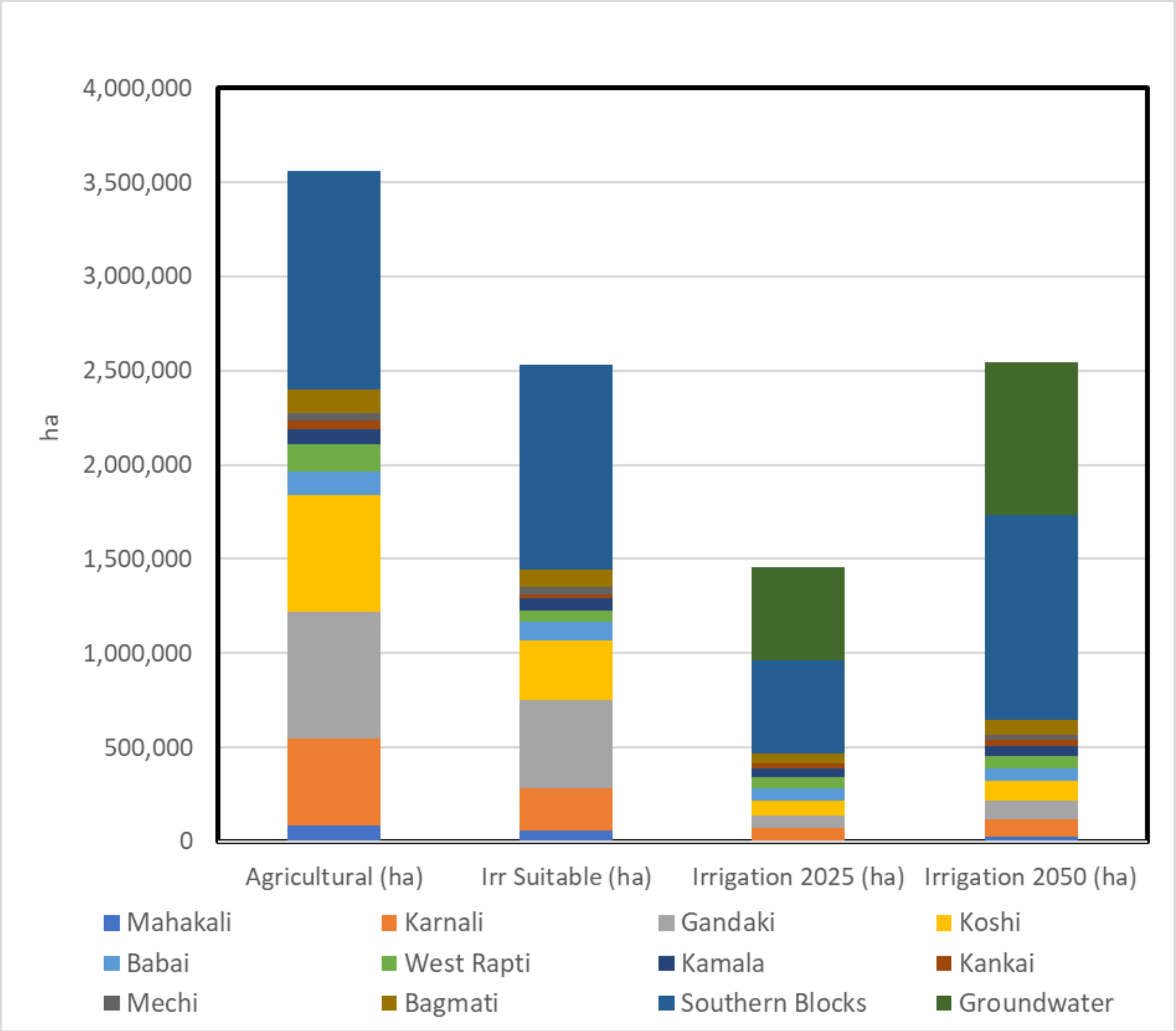


Figure 0-2: Agricultural Land, Irrigable and Irrigation in 2025 and in 2050 considered in the River Basin Modelling

The River Basin modelling used the IMP proposed cropping patterns and crop water requirements to estimate the irrigation water requirements across the basins. Individual cropping patterns were proposed for each of the three major basins (Mahakali/Karnali, Gandaki and Koshi) and each ecological zone (Terai, Hills and Mountains). Cropping intensities will rise to 213% in the Terai, 180 to 198% in the hills, and to 128% in the mountains. The River Basin modelling used the irrigation water requirements and the irrigation areas given in Table 0-2 to allocate the available water across the river basins (temporally and spatially). The annual water available and the projected irrigation demand in 2025 and 2050 are given in Table 0-3.

Table 0-3: Annual Surface Water Availability and irrigation Demand in 2025 and 2050 considered in river basin modelling

	Catchment Area[1] (km^2)	Annual Average Precipitation[2] (mm)	Water Available[3] (m^3/s)	Water Available[3] (mcm)	Irrigation Demand 2025[4] (mcm)	Irrigation Demand 2050[4] (mcm)
Mahakali	15,769	1,867	720	22,700	762	1,104
Karnali	46,193	1,280	1256	39,606	1,424	3,920
Gandaki	36,497	1,680	1952	61,568	1,155	2,701

	Catchment Area[1] (km^2)	Annual Average Precipitation[2] (mm)	Water Available[3] (m^3/s)	Water Available[3] (mcm)	Irrigation Demand 2025[4] (mcm)	Irrigation Demand 2050[4] (mcm)
Koshi	56,145	1,032	1827	57,601	1,254	9,070
Babai	3,579	1,514	80	2,520	1,616	1,767
West Rapti	6,971	1,587	176	5,550	1,494	2,601
Kamala	2,219	1,629	112	3,523	1,030	1,153
Kankai	1,332	1,999	56	1,760	466	599
Mechi	806	2,764	41	1,286	67	372
Bagmati	3,844	1,795	128	4,027	1,068	1,601
Southern Blocks	21,016	1,817	963	27,868	11,837	28,291
Total	**194,371**	**-**	**-**	**226,495**	**22,174**	**53,188**

Note:
[1] The area covers the entire catchment area up to Nepal-India border delineated using the combination of SRTM 30 m DEM and topographical data of the Department of Survey developed in the study.
[2] The long-term annual precipitation (using data from 1986 to 2015) estimated presented here are for the full catchments of the river basins of Nepal. The long-term average precipitation of catchments (areas) within Nepal only is 1,609 mm compared to the full catchment average of 1,444 mm presented here.
[3] The water availability is estimated using the Mike SHE hydrological modelling. The estimate is based on the hydrological model results and is subject to some uncertainty due to data and model uncertainty. For planning purpose, the estimate is reliable.
[4] Irrigation demand is estimated using the IMP (2019, updated 2024) future cropping patterns and irrigation water requirements for the irrigation area estimates given in Table 0.2.

Goal: Supply surface water to existing schemes for rehabilitation within the basins to minimize irrigation shortages especially in the dry season and to improve food security as well as to establish new irrigation schemes. Additionally, develop inter-basin transfers (IBTs) to take advantage of water-surplus rivers (major river basins) to improve supply to water deficit regions (medium river basins and the Southern Blocks).

Water Availability and Balance: The assessment of water resources was carried out by hydrological and water balance modelling. This assessment considered the available land use resources, the topography, soils, existing water supply and irrigation projects, future domestic water demand based on population projections, hydropower projects, potential hydropower storage dams, and climate change to determine available water availabilities. Table 0-3 and Figure 0-3 show that the total annual irrigation demand of about 22.2 billion m^3 and 53.2 billion m^3 in 2025 and 2050, respectively. The total annual surface water available has been estimated at about 226.5 billion m^3. It should be noted that about 8 to 12 billion m^3 of renewable groundwater is available in the study region (WRS, 2002).

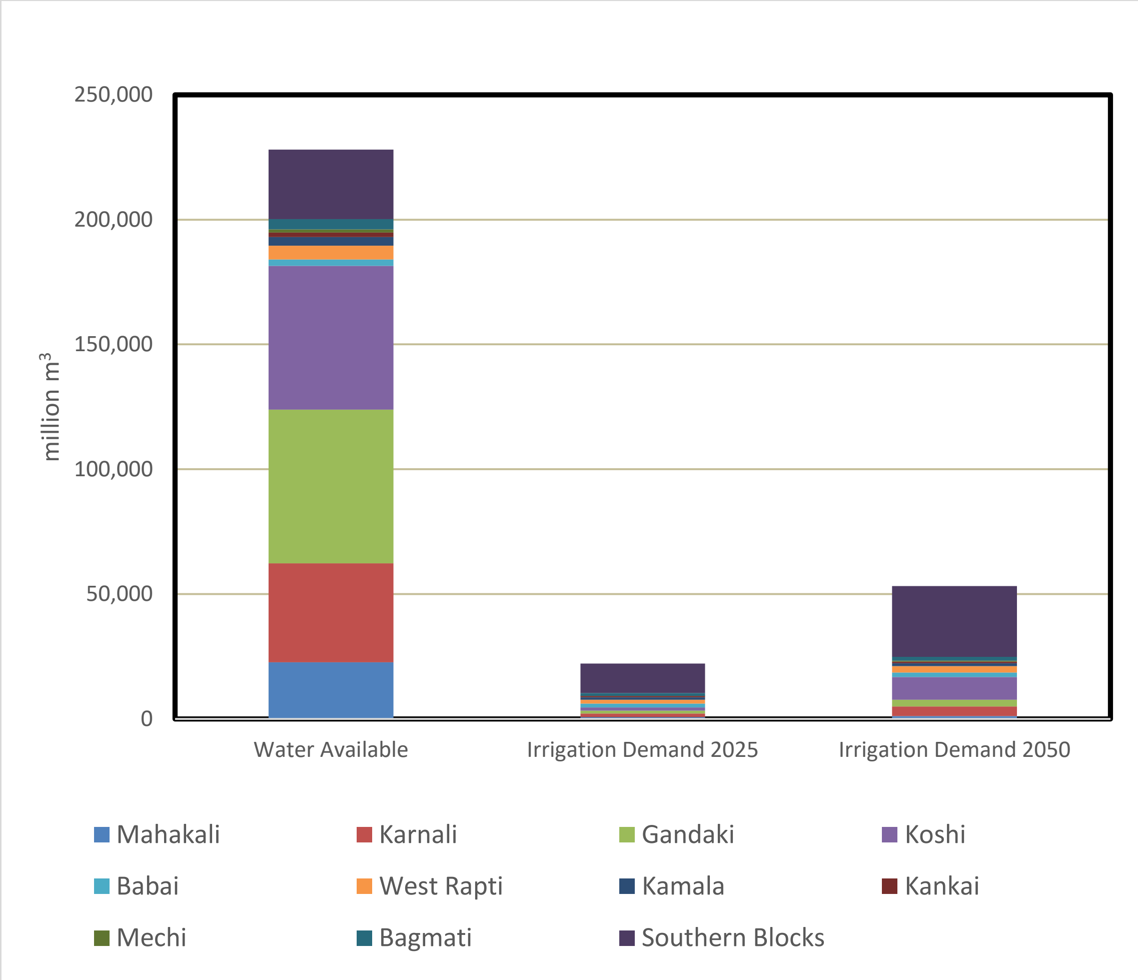


Figure 0-3: Annual Surface Water Available and Irrigation Demand

Although on an annual basis the total available water can meet the irrigation water requirement (Figure 0-3) there will be deficits in the dry months in the case of medium basins and the Southern Blocks (Figure 0-4). The major basins however have sufficient water available even in the dry months (see Figure 0-5). The water balance presented here do not consider water supply demand and other consumptive uses as they are a small fraction of the irrigation water requirements. No development intervention such as storage projects or inter-basin diversions are considered in computing the water balance.

The water balance assessment therefore shows that the major basins are what can be called “surplus basins” while the medium basins and the Southern Blocks can be called “deficit basins”. The rationale of implementing storage type projects and inter-basin diversions is to meet the demand and of the medium basins and the Southern Blocks. Multi-purpose projects (MPP) that generate hydroelectricity, supply water for irrigation and water supply, and even augment low flows therefore form an important components of water resources development in the river basins of Nepal.

Figure 0-4: Water Balance without Development Interventions in Medium Basins and Southern Blocks

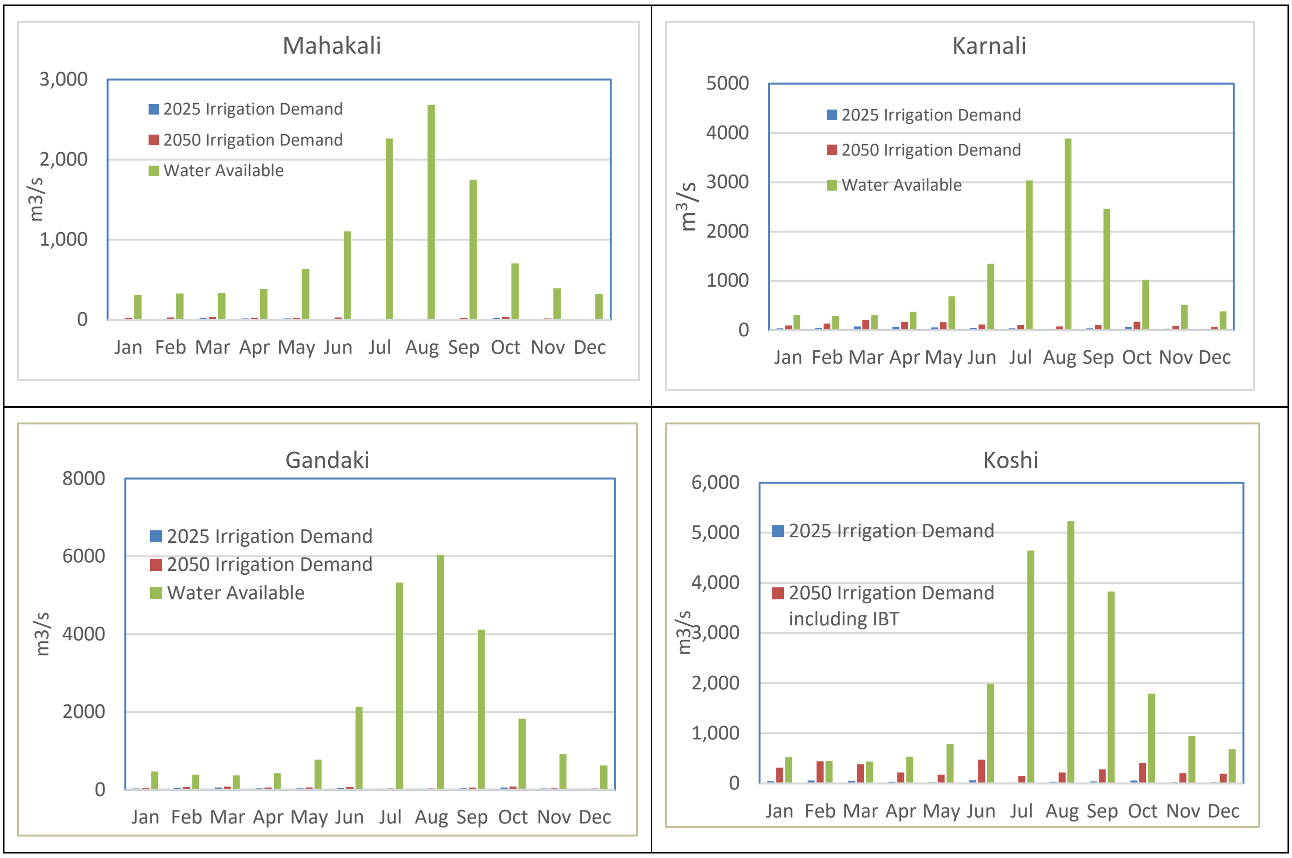


Figure 0-5: Water Balance without Development Interventions in Major Basin

Climate change impacts: Eight future climate change scenarios for the period of 2021 to 2050 were selected to assess the impacts of climate change on hydrology and water availability. These scenarios include four conditions, labelled as cold-dry (cd), cold-wet (cw), warm-wet (ww) and warm-dry (wd), each for the Representative Concentration Pathway (RCP) 4.5 (stabilization scenario) and RCP 8.5 (high emission scenario). These future climate scenarios represent wettest, driest, warmest and coldest projections from the total ensemble of climate models (Table 0-4). The selected Global Climate Models (GCMs) were bias corrected and statistically downscaled using the quantile mapping approach with observed climate (precipitation and temperature) data for the analysis of future changes in climate. The bias corrected and downscaled climate data were then used as input in the hydrological models to analyse the impacts of climate change on the hydrology of the river basins.

Table 0-4: Selected Climate Models

Scenarios \ conditions	RCP 4.5	RCP 8.5
Cold-dry (cd)	HadGEM2-CC_rcp45_r1i1p1	HadGEM2-CC_rcp85_r1i1p1
Cold-wet (cw)	CCSM4_rcp45_r2i1p1	CSIRO-Mk3-6-0_rcp85_r3i1p1
Warm-wet (ww)	CanESM2_rcp45_r2i1p1	CanESM2_rcp85_r3i1p1
Warm-dry (wd)	MPI-ESM-LR_rcp45_r3i1p1	MIROC-ESM-CHEM_rcp85_r1i1p1

The selection of the GCMs across the spectrum of their inter-model variation (warm-cold and wet-dry conditions) of the projections is done to capture the uncertainty of future climate. The increase in the future (2021 – 2050) projected temperature compared to the historical period (1981-2005) is likely to be higher in winter compared to the other seasons. The increase is also projected to be elevation dependent, where the increase will be higher in the mountains compared to the plains (Terai). The change in future projected annual average temperature is likely to vary by an increase of about 0.5ºC up to 1.7ºC in the RCP 4.5 scenario, and by an increase of about 0.7ºC up to 2.2ºC in the RCP 8.5 scenario. Similarly, the changes in future projected winter average temperature is likely to vary by an increase of about 0.6ºC up to 2.2ºC in the RCP 4.5 scenario, and by an increase of about 0.9ºC up to 3.3ºC in the RCP 8.5 scenario. The changes in future (2021 – 2050) projected annual precipitation is likely to vary from a decrease of about 7% to an increase of up to 27% in the RCP4.5 scenario, and from a decrease of 11% to an increase of up to 91% in the RCP8.5 scenario. The change (increase) in precipitation is likely to be more in the monsoon than in the winter season.

Climate change impacts on runoff

The hydrological response to any changes in climate, particularly precipitation and temperature, depends on the catchment characteristics, including size, shape, drainage density, land use and land cover, elevation and topography, geology etc. Catchments in Nepal can be broadly categorized as glacier, snow and rain-fed catchments. Catchment areas above approximately 5,000 m have year-round snow, areas above approximately 3,000 m have seasonal (winter) snow and areas below are rain-fed. The hydrological regimes of the catchments therefore vary according to the catchment areas with snow- and rain-fed runoff generation. Smaller catchments are also more sensitive to climate change than larger catchments. The impacts of climate change on hydrology therefore vary according to the areas under snow and rain, and according to the size of the catchments.

In general, the total annual and monsoon runoffs are projected to increase in the future (2021 – 2050) compared to the historical period (1986 – 2015) for most climate scenarios (RCP 4.5 and RCP 8.5). There are, however, high uncertainty (both increase and decrease) in the other seasons especially the pre-monsoon season (Figure 0-6). Overall, the conclusion to be reached is that future climate change under most scenarios will result in an *increase* in annual and monsoon streamflows across the basin. However, the changes in other seasons are uncertain. This means that water resources planning need to be robust to the future uncertainties.

The high variability and extreme events of the current climate are projected to be further exacerbated by future climate change. Hence, water resources planning, and development will thus need to be resilient to more frequent and intense extreme events such as droughts, floods and other geo-hazards like landslides and increased sediment load.

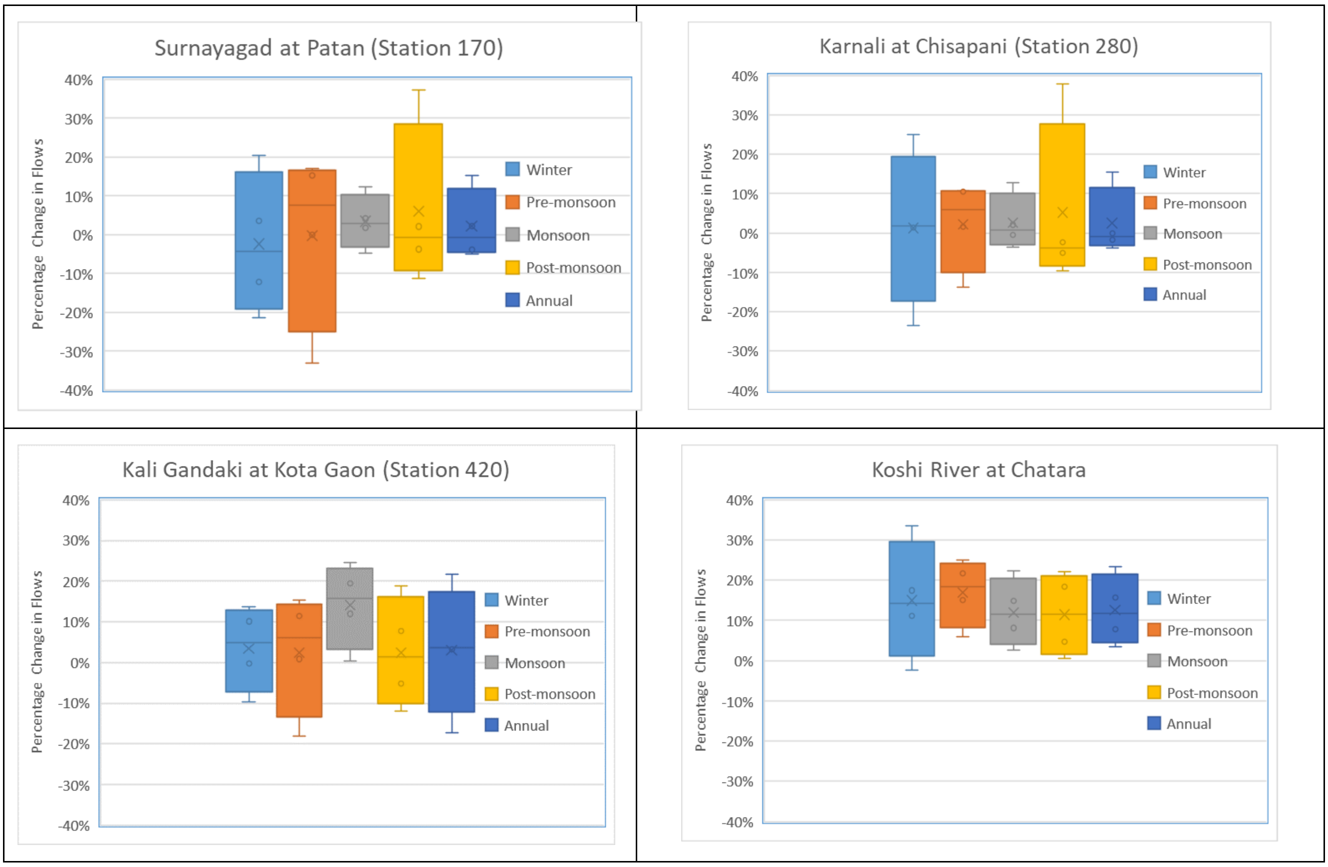


Figure 0-6: Projected changes (RCP 4.5) in annual and seasonal runoff in selected stations

Development Scenarios: Given the water resources issues in the respective river basins and the objectives outlined in the Water Resources Strategy (WRS), development scenarios were established and evaluated to examine the government policies and strategies, four development scenarios have been simulated/evaluated to illustrate the trade-offs and possible futures. These scenarios include:

1. **Baseline Development (BDV)**: simulates population increases (DWS), small and medium irrigation scheme expansion (IRR) according to IMP, and operating HPPs,
2. **Development Scenario 1 (SC1)**: BDV, construction license and greenfield HPPs, selected inter-basin projects and multi-purpose projects according to HDMP[3] Scenario 2 and IMP
3. **Development Scenario 2 (SC2)**: BDV, construction license HPP and favorable greenfield HPP and selected inter-basin projects and multi-purpose projects according to HDMP Scenario 1 and IMP.
4. **Maximum HP Development (MxDV)**: BDV plus construction license HPPs, favorable greenfield HPPs and selected inter-basin projects and multi-purpose projects according to HDMP Maximum Development Scenario. This is the maximum proposed IRR and HPP development.[4]

The current monthly water balance show that the major river basins (Mahakali, Karnali, Gandaki and Koshi) are water “surplus” basins and the other medium and smaller basins are water “deficit” basins where demand is more than available supply particularly in the dry months. Southern blocks (Terai) are considered the major command areas of irrigation development of the river basins. Hence, the river development plans include the following major interventions (recommended by the IMP). The projects (from west to east) in summary are:

- **Bheri-Babai Diversion Multipurpose**; for diversion of water from the Bheri to Babai river, it will supply water for year round irrigation to total area of 51,000 ha, including 36,000 ha of the Babai IP and an additional area of 15,000 ha. It will also generate hydropower of a capacity of 46.8 MW.
- **Karnali Diversion**; for diversion of water from the Karnali river for irrigation of 46,000 ha, mostly new lands, and hydropower generation (about 80 MW).
- **Madi Dang Diversion**; for diversion of water from the Madi river to the Dang valley, for irrigation of about 17,000 ha, mostly to existing systems, and hydropower generation (about 61 MW). The economic feasibility of the scheme should be further verified through a feasibility study.
- **Rapti Kapilbastu Diversion**; for diversion of water from the West Rapti river to Kapilvastu for irrigation of about 51,000 ha, of which 15,000 ha are under existing systems and hydropower generation (with inclusion of Naumure dam and Kapilvastu diversion, about 330 MW).
- **Kaligandaki Tinau Diversion**; for transfer of water from the Kaligandaki river to the Tinau, for which there are two options: (i) tunnel only for irrigation of about 31,000 ha and hydropower generation (244 MW), and (ii) addition of dam (Andhi khola) to increase irrigated area to about 42,000 ha and installed capacity to 424 MW.
- **Kaligandaki Nawalparasi (East) Diversion**; for diversion from the Kaligandaki river for the irrigation of about 11,500 ha and hydropower generation (4 MW).
- **Trishuli Shaktikhor (Chitwan) Diversion**; for diversion of water from the Trishuli river with two options: (i) tunnel only with an irrigated area of about 21,000 ha, and (ii) addition of storage dam (Budhi Gandaki) and increase in irrigated area to 35,000 ha and hydropower generation (1,200 MW).
- **Sunkoshi Diversion**; the project concept is for transfer of water from the Sun Koshi River to Marin and/or Kamala rivers, for irrigation up to 352,264 ha and hydropower generation, for which there are four options: (i) diversion to the Marin river for irrigation of 122,000 ha and power generation (31 MW), (ii) diversion to the Kamala river for irrigation of 129,000 ha and power generation (44 MW), (iii) diversions to both the Marin and Kamala rivers and construction of a storage dam (Dudhkoshi), for irrigation of 236,000 ha and power generation (2,830 MW), and (iv) diversion to both the Marin and Kamala rivers and construction of storage dam (Sunkoshi 3) for irrigation of 352,000 ha and power generation (701 MW).

[3] The HDMP scenarios are described in the HDMP section in the following sections.
[4] In the case of Karnali River Basin, an additional scenario with the proposed mega Karnali Chisapani MPP on top of the MxDV is considered.

- **Tamor Morang Diversion**; for transfer of water from the Tamor Nadi river, for which there are two options: (i) tunnel only for irrigation of about 45,000 ha, and (ii) addition of storage dam Tamor 3 for irrigation of about 114,000 ha and power generation (117 MW).
- **Kankai Multipurpose**; with the construction of a storage dam for the irrigation of about 40,000 ha (including the Kankai and Jhapa systems) and power generation (90 MW).
- **Saptakoshi Barrage**; with the construction of a barrage on the Saptakoshi river for improved water supply to the Sunsari-Morang irrigation system plus an additional irrigated area of about 66,000 ha.

The development plans also include the following major storage (reservoir) projects:

- Pancheshwar MPP Dam in Mahakali Basin
- West Seti, Nalgad and Karnali Chisapani MPP Dams in Karnali Basin
- Madi Dang MPP and Naumure MPP Dams in West Rapti
- Budhi Gandaki Dam in Gandaki Basin
- Dudh Koshi, Sun Koshi 1 – 3, and Tamor MPP in Koshi Basin
- Kankai MPP Dam in Kankai Basin

Evaluation of Development Scenarios: To evaluate the hydrological implications of development scenarios, DHI's MIKE HYDRO Basin (MHB) was used. MHB is a water allocation model consisting of a network of catchment inflows, branches representing rivers, and nodes representing confluences, diversions, and locations where certain water activities may occur along the stream network. Water user nodes represent DWS and irrigation diversions while reservoir and hydropower nodes represent storage reservoirs and attached hydropower plants. Once the catchment inflows reach gains, water usage, storage reservoirs, hydropower plants, and operational rules have been defined, the model simulates the performance of the overall system by applying a water mass balance method at every node. Results from the model are monthly time series of water flow, allocation, and use, and specified reservoir operations throughout the model domain. For this study, model results were extracted, processed, aggregated, and compared per sector against performance and outcome indicators that characterize the production, reliability, and vulnerability of each sector.

The water management alternatives are evaluated based on changes in the hydrologic system provides water and impacts economic, social, and ecological systems. Evaluation of complex systems is typically achieved through indicators that are compared to metrics and/or against other simulations. Appropriate indicators, often referred to as key performance indicators (KPIs), can be further subdivided into outcome indicators that measure the benefit from the quantum of water delivered, and performance indicators that evaluate how well the system performed at achieving the outcome indicator. Per sector, model results were extracted, processed, aggregated, and compared against performance and outcome indicators that characterize the production, reliability, and vulnerability of each sector.

For the evaluation of the WRDP scenarios, outcome and performance indicators have been selected for drinking water supply (DWS), agriculture (IRRG), hydropower (HP), and environmental and social (ENV-SOC). Data used to compute indicators includes both MHB time series output and parameter data. Beyond outcome and performance indicators, cost estimates were calculated for DWS, IRRG, HP, and ENV-SOC mitigations.

Hydropower Development Master Plan (HDMP)

As Nepal has a national power market, and an interconnected grid, in line with the requirements of the national economy and its increasing power demand, hydropower development needs to be analysed and planned from the national perspective and not for individual river basins. As of 1 April 2023, the installed capacity of the operating HPPs in Nepal is 2,188 MW. Based on the scenarios assessed in the HDMP, the 2050 HP installed capacity requirement ranges from 18,591 MW to 44,812 MW. Hydropower development scenarios for a single river basin should, therefore, indicate which projects are recommended for development with priority according to their economic merit order, with acceptable socio-economic and environmental impacts, and considering the requirements and the existing infrastructure. National "balance" of infrastructure development should also be considered.

Goals: Increase HP projects to service the increasing demand from growing populations, agricultural pumping, and industrial use to meet national and regional energy needs. HP Development Plans were developed for five-year increments starting at the year 2022 and then from 2025 each five years up to the year 2050 for a Base Case and two alternative scenarios (Scenarios 1 and 2) versus the predicted development of the required installed capacity of the Integrated Nepal Power System (Table 0-5).

Table 0-5: Scenarios for the Development of the Hydropower Development Plan

Scenario	System Power Demand
Base Case	Optimistic (High) - adapted from 15th Plan of Planning Commission (NPC, 2020b)
Scenario - 1	Medium - adapted from Zhou et al. (2020)
Scenario - 2	Low - extrapolation of actual peak power demand (NEA)

Hydropower Development Master Plan – Base Case: For the Base Case of the present nationwide Hydropower Development Masterplan, the available official information on the following were considered:

- the power system demand or required power system capacity as per "15th National Plan" and
- the Recommended Commercial Operation Date - RCOD of the hydropower or multipurpose projects (provided by WECS, NEA, Ministry of Energy, Water Resources & Irrigation, DoED, IBN)

<u>Assumption for the Base Case</u>

a)	Available Power Generation Facilities (1 April 2023)		**2,188 MW**
b)	HPP with Issued CL, PPA and RCOD before 12/2025		3,198 MW
c)	HPP with Issued CL and RCOD before 12/2030		1,820 MW
d)	HPP with Issued CL, without RCOD, in 2026-2030		3,649 MW
	Subtotal b) + c) + d)		**8,667 MW**
e)	GON Hydropower projects with RCOD		**11,327 MW**[5]
	Including Arun 3 HEPP (21.9% as per PDA)	by 2023	197 MW
		By 2048	900 MW
	Upper Karnali HPP	by 2030	108 MW
	Tamor Storage	by 2030	369 MW
	Lower Arun HPP	by 2030	366 MW
	Upper Arun	by 2035	1,060 MW
	Budhi Gandaki Storage	by 2035	1,200 MW
	West Seti HPP	by 2035	750 MW
	Dudhkoshi Storage	by 2035	640 MW
	Sunkoshi 3 HPP	by 2035	542 MW
	Upper Marsyangdi 2 HEPP	by 2035	327 MW
	Nalgad	by 2035	417 MW
	Pancheswar HPP (50% bi-national project)	by 2050	2,520 MW
	Sunkoshi 1	by 2045	2,128 MW
f)	Multipurpose Projects with HP component as per IMP	as per Section 3.2.3	**768 MW**
	Including Bheri-Babai	by 2023	47 MW
	Sunkoshi Marin diversion	by 2030	31 MW
	Sunkoshi Kamala diversion	by 2030	62 MW

[5] The total assumes the full capacity of Arun 3 (900 MW) will be fully transferred after the concession period. During the concession period, 21.9% of total capacity (197 MW), as per PDA, will be available.

Naumure Dam & Rapti diversion	by 2035	330 MW
Karnali diversion	by 2035	80 MW
Tamor – Morang diversion	by 2040	117 MW
Kaligandaki – Tinau diversion	by 2045	101 MW

g) Greenfield HPP **25000 MW**

Table 0-6: Nationwide Hydropower Development Masterplan – Base Case

Year	Required Capacity (MW)	Capacity + Reserve (MW)	HPP Operation (MW)	HPP ICL (MW)	IMP Projects (MW)	GoN-HPP Projects (MW)	HPP Greenfield (MW)	Total HPP (MW)
2022	4,717	4,717	2,188	0	0	0	0	2,188
2025	6,697	7,367	2,188	3,198	47	197	0	5,630
2030	11,041	12,145	2,188	8,667	140	1,040	550	12,585
2035	16,850	18,535	2,188	8,667	550	5,976	1,600	18,981
2040	24,302	26,003	2,188	8,667	550	5,976	9,100	26,481
2045	33,567	35,245	2,188	8,667	768	8,104	15,500	35,277
2050	44,812	47,053	2,188	8,667	768	11,327	25,000	47,950

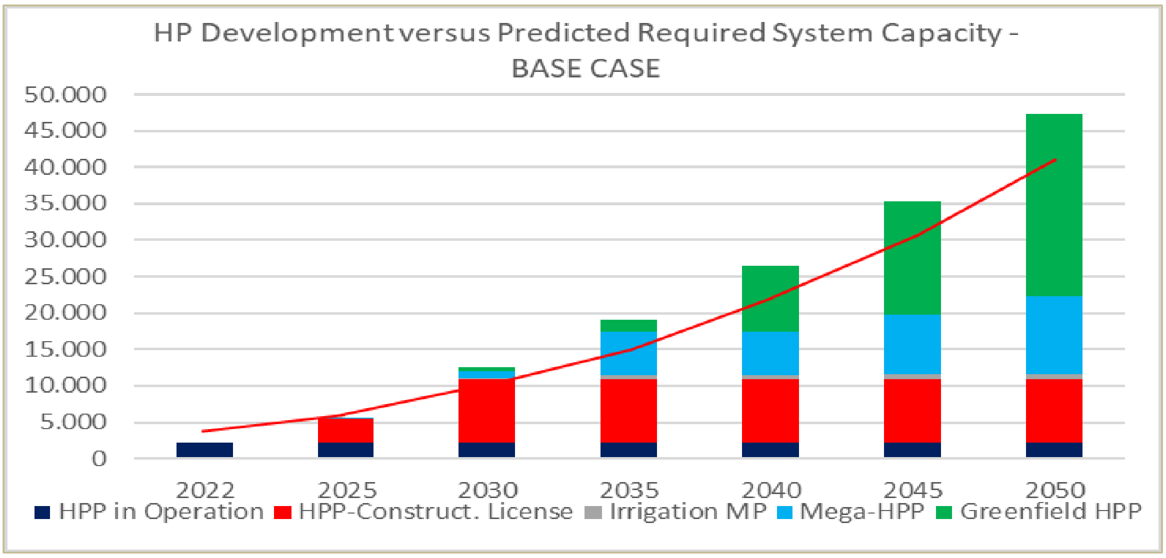


Figure 0-7: Hydropower Development versus Power demand for the period till 2050- Base Case

Hydropower Development Masterplan – Scenario 1: A lower growing national power demand is considered under Scenario 1. The total installed capacity of all HPPs with issued construction licenses exceeds 7000 MW and is larger than the assumed peak power demand in Nepal by the year 2035. Such situation may affect the project developers and the possible repayment of loans. Accordingly, construction and commissioning of several HPPs is expected to be delayed or some even disregarded.

Assumption for the Scenario 1

a)	Available Power Generation Facilities (1 April 2023)	**2,188 MW**
b)	HPP with Issued CL, PPA and RCOD before 12/2025	
	HPPs with 70 % of capacity commissioned by 12/2025	2,239 MW
	HPPs with 20 % of capacity commissioned by 12/2030	640 MW
	HPPS with 10 % capacity not commissioned	0 MW
c)	HPP with Issued CL and RCOD before 12/2030	
	HPPs with 67% of capacity commissioned by 12/2030	1,219 MW
	HPPs with 23 % of capacity commissioned by 12/2035	419 MW
	HPPS with 10 % capacity not commissioned	0 MW
d)	HPP with Issued CL and RCOD before 12/2030	
	HPPs with 40 % of capacity commissioned by 12/2030	1,460 MW
	HPPs with 30 % of capacity commissioned by 12/2035	1,095 MW
	HPPS with 30 % capacity not commissioned	0 MW
	Subtotal b) + c) + d)	**7,072 MW**

e)	GoN Hydropower Projects with RCOD			**8,355 MW**[5]
	Including	Arun 3 HEPP (21.9% as per PDA)	by 2023	197 MW
			By 2048	900 MW
		Upper Karnali HPP (12% as per agreement)	by 2030	108 MW
		Sunkoshi 3 HPP	by 2032	542 MW
		Lower Arun	by 2035	366 MW
		Upper Arun	by 2035	1,060 MW
		Tamor Storage	by 2040	369 MW
		Dudhkoshi Storage	by 2040	640 MW
		Budhi Gandaki Storage	by 2045	1,200 MW
		Tamakoshi 3 HPP	by 2045	650 MW
		Pancheswar HPP (50% bi-national project)	by 2050	2,520 MW
f)	Multipurpose Projects with HP component as per IMP			**768 MW**
	Including	Bheri-Babai	by 2023	47 MW
		Sunkoshi Marin diversion	by 2029	31 MW
		Sunkoshi Kamala diversion	by 2029	62 MW
		Naumure Dam & Rapti diversion	by 2033	330 MW
		Karnali diversion	by 2035	80 MW
		Tamor – Morang diversion	by 2040	117 MW
		Kaligandaki – Tinau diversion	by 2042	101 MW
g)	Greenfield HPP		by 2030	900 MW
			by 2035	2,100 MW
			by 2040	7,450 MW
			by 2045	12,000 MW
			by 2050	18,500 MW

Table 0-7: Nationwide Hydropower Development Masterplan – Scenario 1

Year	Required Capacity (MW)	Capacity + Reserve (MW)	HPP Operation (MW)	HPP ICL (MW)	IMP Projects (MW)	GoN-HPP Projects (MW)	HPP Greenfield (MW)	Total HPP (MW)
2022	2,882	2,882	2,188	0	0	0	0	2,188
2025	4,234	4,658	2,188	2,239	47	197	0	4,671
2030	7,331	8,064	2,188	5,558	140	197	900	8,983
2035	11,660	12,826	2,188	7,072	550	1,105	2,100	13,015
2040	17,428	18,823	2,188	7,072	550	2,114	7,450	19,374
2045	24,845	26,585	2,188	7,072	768	5,132	12,000	27,160
2050	34,119	36,166	2,188	7,072	768	8,355	18,500	36,883

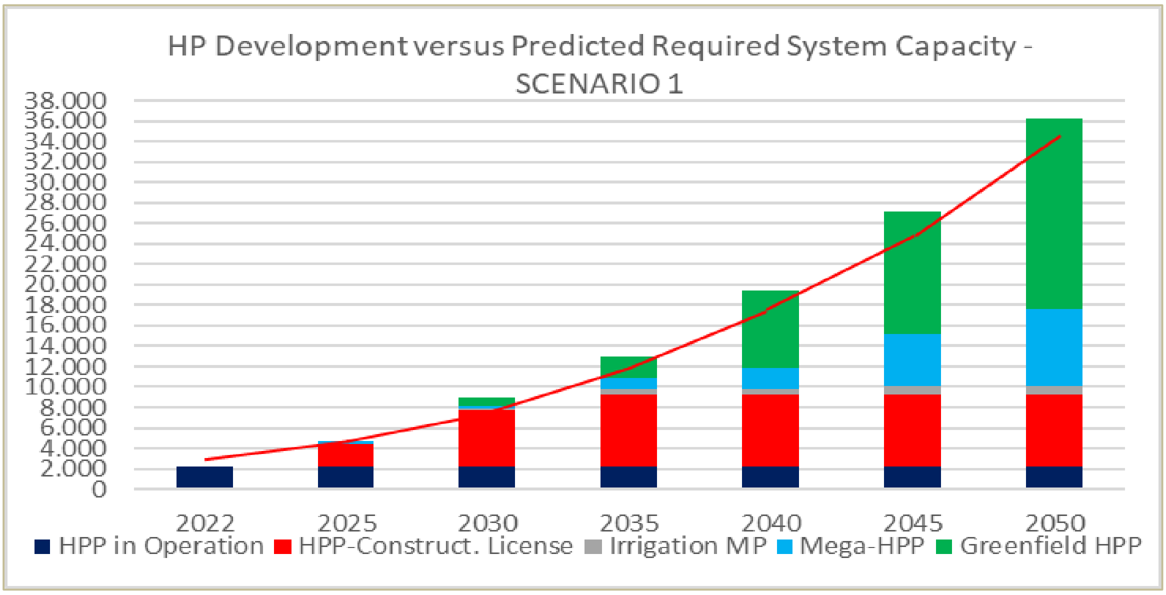


Figure 0-8: Hydropower Development versus Power demand for the period till 2050 – Scenario 1

Hydropower Development Masterplan – Scenario 2: Under Scenario 2, an even lower growing national power demand is considered as compared to Scenario 1 applying a linear extrapolating of the historic grow of the peak power system demand. A substantial number of project developers in possession of a construction license is assumed to reconsider the implementation of the licensed hydropower projects due to reasons as outlined above. Such trend can be observed at present as despite of issued licenses the implementation of a substantial number of hydropower projects has been delayed for several years. The system demand of Scenario 2 and the corresponding required system capacity is substantially lower as to Base Case (41.5 %) and Scenario 1 (54.5 %), such lower demand may create a less attractive environment for private developers. A substantial number of the identified Greenfield HPPs may turn out economically more attractive and could replace some of the already licensed projects. Accordingly, it can be assumed that construction and commissioning of a considerable number of licensed HPPs will be delayed or even disregarded.

Accordingly, the Scenario 2 is based on the following assumptions:

Assumption for the Scenario 2

a)	Available Power Generation Facilities (1 April 2023)			**2,188 MW**
b)	HPP with Issued CL, PPA and RCOD before 12/2025			
	HPPs with 40 % of capacity commissioned by 12/2025			1,279 MW
	HPPs with 25 % of capacity commissioned by 12/2030			800 MW
	HPPS with 35 % capacity not commissioned			0 MW
c)	HPP with Issued CL and RCOD before 12/2030			
	HPPs with 40 % of capacity commissioned by 12/2030			728 MW
	HPPs with 25 % of capacity commissioned by 12/2035			455 MW
	HPPS with 35 % capacity not commissioned			0 MW
d)	HPP with Issued CL and RCOD before 12/2030			
	HPPs with 20 % of capacity commissioned by 12/2030			730 MW
	HPPs with 20 % of capacity commissioned by 12/2035			730 MW
	HPPS with 60 % capacity not commissioned			0 MW
	Subtotal b) + c) + d)			**4,722 MW**
e)	GON Hydropower Projects with RCOD			**5,835 MW**[5]
	Including	Arun 3 HEPP (21.9% as per PDA)	by 2023	197 MW
			By 2048	900 MW
		Upper Arun	by 2035	1,060 MW
		Sunkoshi 3 HPP	by 2035	542 MW
		Dudhkoshi Storage	by 2040	640 MW
		Tamor Storage	by 2040	369 MW
		Budhi Gandaki Storage	by 2045	1,200 MW
		Tamakoshi 3	by 2045	650 MW
		Lower Arun	by 2050	366 MW
		Upper Karnali HPP (12% as per agreement)	by 2050	108 MW
f)	Multipurpose Projects with HP component as per IMP			**768 MW**
	Including	Bheri-Babai	by 2023	47 MW
		Sunkoshi Marin diversion	by 2029	31 MW
		Sunkoshi Kamala diversion	by 2029	62 MW
		Naumure Dam & Rapti diversion	by 2033	330 MW
		Karnali diversion	by 2035	80 MW
		Tamor – Morang diversion	by 2040	117 MW
		Kaligandaki – Tinau diversion	by 2042	101 MW
g)	Greenfield HPP		by 2035	0 MW
			by 2040	1,400 MW
			by 2045	4,000 MW
			by 2050	7,500 MW

Table 0-8: Nationwide Hydropower Development Masterplan – Scenario 2

Year	Required Capacity (MW)	Capacity + Reserve (MW)	HPP Operation (MW)	HPP ICL (MW)	IMP Projects (MW)	GoN-HPP Projects (MW)	HPP Greenfield (MW)	Total HPP (MW)
2022		2,093	2,188	0	0	0	0	2,188
2025	2,930	3,223	2,188	1,279	47	197	0	3,711
2030	4,249	4,674	2,188	3,537	140	197	0	6,062
2035	6,161	6,777	2,188	4,722	550	1,799	0	9,259
2040	9,241	10,165	2,188	4,722	550	2,808	1,400	11,668
2045	13,862	15,248	2,188	4,722	768	4,658	4,000	16,336
2050	18,591	20,078	2,188	4,722	768	5,835	7,500	21,013

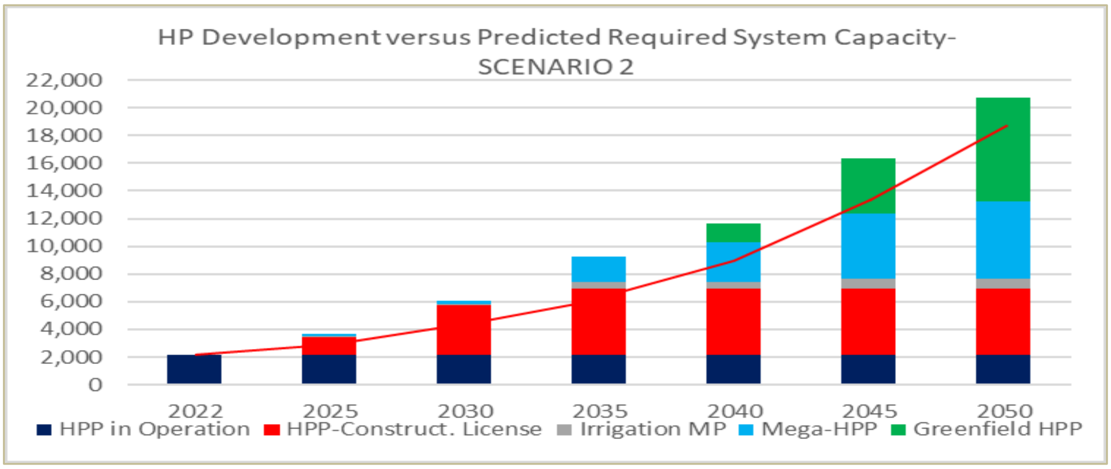


Figure 0-9: Hydropower Development versus Power demand for the period till 2050 – Scenario 2

For the successful implementation of the HDMP, the following recommendations are made to setup a corresponding institutional and administrative environment that supports the implementation of the proposed hydropower projects and development of the power market and system in Nepal.

- Government needs to proactively establish an environment that attracts private developers to implement hydropower projects as required.
- Governmental institutions need to ensure adequate conditions, policy and guidelines for development and operation of hydropower cascade projects (River Basin Organizations).
- Present licensing practice may be partly substituted by competitive bidding procedures for the preferred (most attractive) project development.
- Program for development of GoN (Mega) projects ("White Paper-2075") appear rather ambitious and may need adjustment, as financial and administrational resources are limited, and it is advisable to develop at most 2-3 large projects in parallel.
- Government of Nepal is recommended to establish or assign an existing organization to

a) Carry out future least cost system expansion planning

b) Ensure, manage and negotiate with potential international partners (India, Bangladesh, China) the export of surplus (wet season) energy

- Promote the (economically reasonable) development of renewable energy options (solar, wind, geothermal, hybrid-systems).
- Promote studies and the development of energy storage options (pumped storage, hydrogen, battery).
- Promote continuous implementation of Demand Side Management measures (Improved energy efficiency, time-variant consumer tariffs etc.).
- Efforts are to be made to maintain and improve current system of discharge and sediment measurement/sampling,

Strategic Environmental and Social Assessment (SESA)

Environment (ENV): In Nepal, national parks, buffer zones, and conservation areas support biodiversity and provide valuable habitat for endangered species of fish, birds, and mammals. Many fish species migrate in response to stream temperatures and turbidity associated with snow melt. Satisfying e-flow requirements is important for maintaining the biodiversity of these protected areas.

The environmental safeguard objective is to maintain healthy stocks of migratory and non-migratory fish and the dolphin population, where appropriate, and preserve e-flows, especially in the protected areas.

Social (SOC): The major livelihood in the basins of Nepal is agriculture with local communities using river water for irrigation. Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages are common. Many rituals and festivals require the use of holy river water with significant flow.

The social safeguard objective is to preserve cultural sites and mitigate impacts to communities that use freshwater ecosystems for sustenance or making a livelihood.

The Water Resources Development Plans (WRDP) of the ten river basins (Volume 2 of the River Basin Plans) aims to identify a set of water-related interventions that will benefit the people of the basins and of Nepal as a whole, in line with Nepal's Water Resources Policy of 2020. For this purpose, the WRDP presents and analyses a range of development scenarios. Each scenario is understood as a combination of projects, including projects for drinking water supply, irrigation and hydropower generation. The irrigation projects are identified from the IMP, 2019 (updated 2024) while the hydropower projects are as per the National Hydropower Development Master Plan (HDMP).

Identification of Valued Environmental and Social Components (VECs): SESA assessed the impact indicators focusing on selected criteria, both for the properties of the proposed projects and for the affected local environment. The baseline information is reviewed to identify so-called Valued Environmental and Social Components (VECs). These are selected sensitive or valued receptors of impacts which tend to be at the ends of ecological pathways and on which the SESA's impact assessment is focused.

For the SESA of River Basin Plans, the types of cumulative impacts that were systematically assessed are:

- Destruction or transformation of existing land uses and habitats by the footprints of new projects (HPPs' dams, reservoirs, dewatered river stretches; access road and transmission line connections; and new irrigation areas).
- Barrier effect of weirs and dams and the resulting fragmentation of rivers / river systems.
- Changes to river flow volumes due to water abstraction for domestic water supply and irrigation and due to hydropower operation.
- Adverse impacts on population, cultural and religious sites.

Based on the baseline information review and stakeholder consultations, the VECs of interest in the different basins are of the following types:

i. Fish populations that depend on migrating between breeding and feeding habitats

ii. The river and wetland habitats and species that depend on the current flow regime

iii. Important terrestrial habitats which are functionally connected with the river and wetland habitats

iv. Cultural and religious sites near rivers and streams

v. Population in settlements near rivers and streams

vi. River dependant sociocultural and spiritual values

vii. Population practising irrigated agriculture for their livelihoods

viii. Wider rural and urban population, who will get socio-economic benefits in various ways

ix. Land use and land cover change by project components

Environmental and Social Impacts: The environmental and social impacts that typically occur for the types of projects which are included in the River Basin Plans are reviewed, and the most relevant issues due to their significance are identified. A screening methodology is used, i.e. the criteria that are systematically applied, and the impact indicators that are either qualitatively considered or quantitatively measured and rated for their significance. As a basis for the impact assessment, GIS mapping of the new projects was carried out, identifying the location and extent of their impacting features, including:

- Spatial "footprint" of dams, reservoirs, access roads, transmission lines;
- Diversion reaches of HPPs (dewatered river reach between dam and powerhouse tailrace);
- New proposed irrigation scheme areas.

Criteria for which the impacts of the development scenarios were systematically evaluated include:

- HPP/IBTs' footprints and/or new irrigation scheme areas overlapping with the following categories of areas:
    - Nepal's legally Protected Areas
    - Internationally recognised area (Ramsar, IBA)
    - Other ecologically significant areas (ecological corridors, geographic range of fauna species, conservation landscapes)
    - Land uses (agriculture, forest, total affected area)
- River section affected by habitat conversion (dam& reservoir footprints, dewatered reaches):
    - Length of affected river sections
    - HCV value of affected river sections
    - Affected fish species (total number, threatened, migratory);
    - Other important species: dolphin, gharial
- Barrier effect of new dams
    - Record of existing dams and current connectivity status of the affected rivers
    - Mapping and count of proposed new dams/weirs for each scenario
    - Determining of severity of fragmentation impact, by considering:
    - Current free-flow river status (river connectivity and length)
    - Presence of migratory fish

- Instream flow changes
    - Magnitude of hydrology changes due to re-regulation of flows by the reservoir operation, and due to water abstractions for irrigation
    - Ecological performance indicators: Applying four different e-flow calculation methods, determining for each:
        - The minimum flows required to meet each e-flow target;
        - The frequency by which these minimum flows are not reached (e-flow violations)
    - Use of hydropeaking

- Impact on population / social aspects
    - Agricultural land affected by projects' footprints
    - Physical resettlement, indicated by count of residential houses inside reservoirs
    - Likely impact on river-dependent ethnic groups

- Impact on cultural and religious sites
    - Religious value of affected river reaches
    - Additional information on importance of affected sites, where available.

Impact findings for the above-described criteria are reported for each basin and scenario, on different levels of aggregation, including on the level of projects, rivers, subbasins and finally on the level of the river basin. The rating presents a classification on a qualitative scale, using five categories

- No impact
- Minor adverse impact
- Moderate adverse impact
- Substantial adverse impact
- Major adverse impact

Evaluation of the Development Scenarios: The evaluation of the development scenarios, which are generally labeled as Baseline Development (BDV), Scenario 1 (SC1), Scenario 2 (SC2) and Maximum Development Scenario (MxDV). The impact findings were compared between the future scenarios. The project portfolio (based on HDMP and IMP) and the composition of the scenarios are considered in the evaluation. The results from the impact screening for the environmental and social topics, and the findings for main impact indicators are summarised on the level of sub basins and are rated for their impact significance.

The key environmental and social impacts arise from the existing and new dams proposed in the River Basin Plans and the HDMPs in the river basins. The topics for which significant impacts were most often found:

- Resettlement
- Legally protected areas
- Aquatic habitat conversion
- Barrier effect of new dams (disrupting biological connectivity of the rivers)
- Instream flow changes

The following recommendations are made for further planning of the projects and scenarios of the River Basin Plans:

- The ecological value of a river should be considered when selecting rivers for development.

- As far as possible, planning should aim to preserve the connectivity of long and medium long free-flowing rivers. Priority for development should be given to:
  - rivers with already impacted connectivity,
  - shorter tributaries (instead of mainstream rivers)
  - locations in the upper parts of the catchments (instead of lower parts of mainstreams and larger tributaries)
- Planning should aim to minimize the adverse impacts on National Parks and Ramsar sites.
- Planning should aim to avoid and, if avoidance is not possible, minimise resettlement as far as possible. Studies of design alternatives and optimisation for the various components (e.g. the location of access roads, transmission lines, quarry and borrow areas etc.) should be undertaken, considering the minimising of environmental and social impacts.
- To mitigate the adverse social impacts of land acquisition and resettlement, in-kind compensation of losses should be offered wherever feasible. Livelihood restoration support should be provided.
- Appropriate fish passes should be provided, and their functioning should be monitored.
- Environmental flow requirements should be further studied, including setting of appropriate e-flow targets for the dewatered reaches of the Run-of River (ROR and peaking ROR (PROR).
- Impacts of peaking operations should be further studied and appropriate mitigation should be applied (e.g. reducing the ramping rates).
- Best practice standards for environmental and social planning and management of implementation should be applied.
- Establish and implement long-term monitoring programmes for water quality and fish biodiversity
- For the irrigation schemes, both new areas and existing schemes where production will be intensified, agricultural extension services should be provided that include capacity building on how farming operations can be optimised to protect the environment, especially wetlands, from pollution, to avoid health risks due to misuse of pesticides and fertilisers, and to prevent degradation of soils. This could include, but need not be limited to,
  - develop best management practices to establish and retain soil fertility and avoid land degradation
  - modern irrigation design and good water management practices to avoid overirrigation
  - implementation and regular maintenance of drainage infrastructure
  - avoid over-application of fertilisers and pesticides

Basin Level SESA Recommendations:

- **Regular stakeholder engagement:** Implementation of river basin management will not be an activity that WECS will carry out in isolation, but it will require the participation of a wide range of stakeholders. It is thus recommended that activities are undertaken by WECS for regular stakeholder engagement. Details of the stakeholder groups to be engaged and the types and frequencies of engagement meetings to be envisaged should be determined once WECS and the RBOs move towards implementation of the river basin plans.
- **Need for basin-wide spatial planning for the effective conservation of aquatic habitats and biodiversity:** The analyses of the baseline situation and impacts of development scenarios undertaken for the SESA have shown that significant adverse impacts are expected on aquatic habitats, mainly caused by the hydropower and irrigation transfer projects.
- **Long-term conservation plan**: It is recommended that WECS develops, for each river basin, a plan for the long-term conservation of aquatic habitats and biodiversity. The plan should identify and delineate areas where damming of rivers is completely prohibited and areas where it can be conditionally allowed. In developing this plan, WECS can coordinate with the MOFE and Department of National Parks and

Wildlife Conservation (DNPWC) and support the implementation of the National Biodiversity Strategy and Action Plan (NBSAP) and other strategies through identifying major rivers that would be most suitable for maintaining unhindered north-south biological connectivity, suitable wetlands to be declared as fish sanctuaries, and river corridors that would be suitable to connect Protected Areas and other important biodiversity areas.

Consolidated Costs and Benefits for All Basins Investment

Economic Analysis: Economic analysis at basin level gives an opportunity to measure the impact of Multi-purpose projects (MPP) at national level. MPPs are selected for their strategic importance to transfer water to areas suitable for irrigation but without adequate water resources to improve agricultural productivity. Table 0-9 and Table 0-10 compare the costs and benefits for HDMP Scenario 1, the former including MPP, the latter excluding them. Table 0-11 and Table 0-12 show the same analysis for HDMP Scenario 2 (lower electricity demand).

Investment and operational costs of MPP (hydropower and irrigation) are estimated to be NPR 1,143 billion (USD 8.8 billion) between 2021 and 2050 (the costs of Bheri-Babai, Madi Dang and Kankai MPPs are included). That is about 15% of the total economic cost of the water infrastructure investment presented. In the same period, they are expected to generate NPR 2,042 billion (USD 15.7 billion) in benefits, or about 16% of the total benefits expected.

The economic indicators show that Economic Net Present Value (ENPV) is increased from NPR 1,151 billion to NPR 1,221 billion during the discounting period, but Economic Internal Rate of Return (EIRR) falls from 18.9% to 16.0%. It follows that MPP have a lower rate of return compared with the other elements of the investment (in total) but the rate of return is well above the discount rate of 9% used.

Switching values show that the sensitivity of the investment to cost increases and benefit decreases is heightened with the inclusion of MPP in the investment programme. Without MPP, costs would have to increase by 77% to bring EIRR to zero at 9% discount rate. With MPP, costs would have to increase by only 66% to have the same impact. Sensitivity to changes in benefits is less marked.

It should be noted that the impact of depreciation on the investment (depreciation is not included in cost benefit analysis unless a salvage value and/or replacement costs are budgeted in current prices). For groundwater irrigation, costs are estimated including replacement, so the rate of depreciation of the investment is much lower. Replacement, and management, operation and maintenance (MOM) of the surface irrigation systems that MPP will supply is assumed to be only 5% of investment cost per annum. If this amount were collected and spent then the condition of the irrigation systems may be maintained, but there is no mechanism to ensure payment of water charges by farmers, or that routine maintenance is carried out.

Table 0-9: All River Basins: Consolidated Costs and Benefits: HDMP Scenario 1 Hydropower, MPP, Groundwater and Gravity-pump Schemes, Economic NPR million Including Costs and Benefits of MPP

	Cost stream, NPR million						Benefit stream, NPR million								Net benefit stream	Economic Indicators	
	Irrigation Costs			Development & Operation Cost of HP Scenario	Drinking water	Total	Irrigation Benefits			Hydropower Generation Benefits			Drinking water	Total			
	MPP	Groundwater	Gravity/Pump Hill schemes				MPP	Groundwater	Gravity/Pump Hill schemes	Domestic resource cost saving, NPR million	Domestic incremental benefits, NPR million	Export sales, NPR million					
	All MPP						All MPP										
2021-2025	41,035	33,485	686	23,959	119,517	218,682	-	2,866	-	-	-	-	119,517	122,383	(96,298)	ENPV	1,221,200
2026-2030	87,314	40,225	6,314	413,183	156,211	703,247	16,958	40,818	1,052	5,408	16,537	1,928	156,211	238,911	(464,336)	EIRR	16.0%
2031-2035	46,195	52,856	8,314	594,136	73,815	775,316	65,555	86,808	12,184	119,818	366,405	42,003	73,815	766,588	(8,728)	NPV benefit	3,078,585
2036-2040	49,786	70,311	12,065	1,646,169	76,061	1,854,393	158,297	135,356	23,473	252,769	772,974	88,611	76,061	1,507,540	(346,853)	NPV costs	1,857,385
2041-2045	19,952	51,156	5,489	1,708,423	78,307	1,863,327	215,214	187,475	29,025	794,838	2,430,635	278,638	78,307	4,014,131	2,150,803	BCR	1.66
2046-2050	19,634	52,156	2,168	1,938,261	80,553	2,092,773	244,125	205,915	36,161	1,218,199	3,725,283	427,051	80,553	5,937,287	3,844,514	Switching value costs	66%
Total	**263,916**	**300,190**	**35,035**	**6,324,133**	**584,464**	**7,507,737**	**700,148**	**659,237**	**101,895**	**2,391,031**	**7,311,834**	**838,230**	**584,464**	**12,586,840**	**5,079,103**	Switching value benefits	-40%

Table 0-10: All River Basin: Consolidated Costs and Benefits: HDMP Scenario 1, Groundwater and Gravity-Pump Schemes, Economic NPR million Excluding Costs and Benefits of MPP

	Cost stream, NPR million						Benefit stream, NPR million								Net benefit stream	Economic Indicators	
	Irrigation Costs			Development & Operation Costs of HP Scenario	Drinking water	Total	Irrigation Benefits			Hydropower Generation Benefits			Drinking water	Total			
	MPP	Groundwater	Gravity/Pump Hill schemes				MPP	Groundwater	Gravity/Pump Hill schemes	Domestic resource cost saving, NPR million	Domestic incremental benefits, NPR million	Export sales, NPR million					
	All MPP						All MPP										
2021-2025	-	33,485	368	-	119,517	153,370	-	2,866	-	-	-	-	119,517	122,383	(30,987)	ENPV	1,150,962
2026-2030	-	40,225	7,683	244,644	156,211	448,764	-	40,818	1,052	-	-	-	156,211	198,081	(250,683)	EIRR	18.9%
2031-2035	-	52,856	9,569	411,538	73,815	547,778	-	86,808	12,184	91,840	280,848	32,195	73,815	577,690	29,912	NPV benefit	2,637,690
2036-2040	-	70,311	8,501	1,377,840	76,061	1,532,714	-	135,356	23,473	193,403	591,433	67,799	76,061	1,087,526	(445,188)	NPV costs	1,486,728
2041-2045	-	51,156	6,841	1,590,498	78,307	1,726,803	-	187,475	29,025	689,016	2,107,029	241,541	78,307	3,332,393	1,605,590	BCR	1.77
2046-2050	-	52,156	2,168	1,820,336	80,553	1,955,214	-	205,915	36,161	1,112,377	3,401,678	389,954	80,553	5,226,639	3,271,426	Switching value costs	77%
Total		**300,190**	**35,131**	**5,444,856**	**584,464**	**6,364,641**	**-**	**659,237**	**101,895**	**2,086,637**	**6,380,989**	**731,490**	**584,464**	**10,544,711**	**4,180,070**	Switching value benefits	-44%

Table 0-11: All River Basins: Consolidated Costs and Benefits: HDMP Scenario 2 Hydropower, MPP, Groundwater and Gravity-pump Schemes, Economic NPR million Including Costs and Benefits of MPP

	Cost stream, NPR million						Benefit stream NPR million								Net benefit stream	Economic Indicators	
	Irrigation Costs			Development & Operation Costs of HP Scenario	Drinking water	Total	Irrigation Benefits			Hydropower Generation Benefits			Drinking water	Total			
	MPP	Groundwater	Gravity/Pump Hill schemes				MPP	Groundwater	Gravity/Pump Hill schemes	Domestic resource cost saving, NPR million	Domestic incremental benefits, NPR million	Export sales, NPR million					
	All MPP						All MPP										
2021-2025	41,035	33,485	1,910	23,959	119,517	219,906	-	2,866	-	-	-	-	119,517	122,383	(97,523)	ENPV	506,534
2026-2030	87,314	40,225	13,325	150,951	156,211	448,026	16,958	40,818	1,052	5,408	16,537	1,928	156,211	238,911	(209,115)	EIRR	13.8%
2031-2035	46,195	52,856	5,592	340,650	73,815	519,108	65,555	86,808	12,184	23,629	72,257	8,283	73,815	342,531	(176,577)	NPV benefit	1,639,929
2036-2040	49,786	70,311	6,133	642,574	76,061	844,865	158,297	135,356	23,473	97,883	299,328	34,314	76,061	824,711	(20,154)	NPV costs	1,133,394
2041-2045	19,952	51,156	6,884	909,862	78,307	1,066,161	215,214	187,475	29,025	279,307	854,128	97,914	78,307	1,741,369	675,208	BCR	1.45
2046-2050	19,634	52,156	2,168	1,042,111	80,553	1,196,622	244,125	205,915	36,161	509,661	1,558,557	178,666	80,553	2,813,638	1,617,016	Switching value costs	45%
Total	**263,916**	**300,190**	**36,012**	**3,110,107**	**584,464**	**4,294,688**	**700,148**	**659,237**	**101,895**	**915,887**	**2,800,807**	**321,105**	**584,464**	**6,083,543**	**1,788,855**	Switching value benefits	-31%

Table 0-12: All River Basin: Consolidated Costs and Benefits: HDMP Scenario 2, Groundwater and Gravity-Pump Schemes, Economic NPR million Excluding Costs and Benefits of MPP

	Cost stream, NPR million						Benefit stream, NPR million								Net benefit stream	Economic Indicators	
	Irrigation Costs			Development & Operation Costs of HP Scenario	Drinking water	Total	Irrigation Benefits			Hydropower Generation Benefits			Drinking water	Total			
	MPP	Groundwater	Gravity/Pump Hill schemes				MPP	Groundwater	Gravity/Pump Hill schemes	Domestic resource cost saving, NPR million	Domestic incremental benefits, NPR million	Export sales, NPR million					
	All MPP						All MPP										
2021-2025		33,485	863	-	119,517	153,865		2,866	-	-	-	-	119,517	122,383	(31,482)	ENPV	441,268
2026-2030		40,225	6,151	5,190	156,211	207,777		40,818	1,052	-	-	-	156,211	198,081	(9,696)	EIRR	17.5%
2031-2035		52,856	6,074	141,090	73,815	273,835		86,808	12,184	1,208	3,695	424	73,815	178,133	(95,702)	NPV benefit	1,210,377
2036-2040		70,311	12,977	419,420	76,061	578,769		135,356	23,473	38,517	117,787	13,503	76,061	404,696	(174,073)	NPV costs	769,109
2041-2045		51,156	4,311	754,925	78,307	888,699		187,475	29,025	180,012	550,483	63,105	78,307	1,088,406	199,707	BCR	1.57
2046-2050		52,156	2,002	924,186	80,553	1,058,897		205,915	36,161	403,839	1,234,951	141,570	80,553	2,102,990	1,044,092	Switching value costs	57%
Total		**300,190**	**32,376**	**2,244,811**	**584,464**	**3,161,842**		**659,237**	**101,895**	**623,577**	**1,906,915**	**218,601**	**584,464**	**4,094,690**	**932,848**	Switching value benefits	-36%

Consolidated Financial Plan: The Consolidated Financial Plan for all basins was prepared to show that investment in water infrastructure in Nepal's river basins need not be a permanent burden on Government finance if consumers of water services pay for a reasonable proportion of the costs of management, operation, maintenance and replacement.

- **Drinking water services:** The National Water Supply and Sanitation Sector Policy 2017-30[6] acknowledges that coverage and quality of service in existing schemes is poor, tariffs do not cover basic operational costs and consumer participation in management is low. To address these issues, the policy includes the objectives of increasing provincial and private sector involvement, including concessional financing, service regulation and tariff setting and benchmarking. The objective is to not only to improve cover and service quality but also to relieve Government and financing agencies of at least some of the responsibility of financing new schemes and subsidizing existing ones.

  Tariffing aims to give access to essential potable water to the poorest, while extracting the consumer surplus (what they would pay over and above the cost of supplying potable water) of the more affluent. If water utilities are to survive and expand without government subsidy, the aggregate income from consumers' tariff must cover MOM and allow the utility manager to accumulate capital to expand and improve the service offered. The financial plan for all basins shown in Table 0-13 to Table 0-16 assumes that investment costs are paid by government, possibly through concessionary finance, while MOM is charged at 7% of accumulated investment costs per annum. Over the life of the incremental investment in water supply, 2023-2050 GoN pays NPR 24.5 billion in investment costs, while consumers' payments allow the accumulation of NPR 36.8 billion to cover annual MOM and capital accumulation to expand and improve utility services. Calculations to show that this payment is likely to be both sufficient for utility operators and affordable to customers. It also conforms to the aspirations of The National Water Supply and Sanitation Sector Policy.

- **Groundwater Irrigation:** Pumping groundwater for irrigation is an important part of the recommendations of the IMP, to increase productivity in those parts of the (lower) Terai which will benefit only partly or not all from water transfer MPP. Groundwater irrigation provides an opportunity to achieve the recovery of MOM and replacement costs in full by adjusting the water charge, which is levied volumetrically (or by time) to cover these costs. Of course, the charge must be affordable to irrigators and provide a better standard of service than alternative sources of supply (shallow tube wells, canal irrigation etc.). The costs can be transparently calculated though the operational accounts of individual tube wells.

  The consolidated Financial Plan for all basins shows that of the total costs of groundwater irrigation, only 31% is for investment. The balance is for replacement and MOM. The cost relationship is similar for potable water: in the long term, MOM and replacement are more expensive than the original investment. The government, perhaps with concessionary financing, will pay for the initial investment costs but subsequent costs, including replacement, will be paid for by irrigators.

- **Surface Water Irrigation:** Surface water irrigation presents problems for recharging farmers for investment and operational costs because service varies through the system (head, middle and tail effects) and the reliability of water deliveries (sufficient, timely and controllable) is inferior to that provided by a groundwater scheme. The older surface irrigation systems on the Terai were designed for supplementary irrigation for the paddy crop during the monsoon. Given these constraints, it has proved very difficult to manage surface water irrigation centrally. Farmer organizations (water user groups) are favored, but such groups seldom manage to accumulate funds to pay for replacement.

[6] https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/ eng_wss_policy_2014_draft-1.pdf

The Financial Plan in Table 0-13 to Table 0-16 below therefore assumes that irrigators pay no more than the O&M costs of surface irrigation. That implies that the schemes will deteriorate over time and eventually must be replaced. The Financial Plan focusses on investment and does not calculate surface water scheme depreciation, because there is no reliable way of making it good.

Hydropower Investment and Operation: The government has developed a system for financing hydropower development by granting concessions to private operators. The Financial Plan assumes that this system is followed and as a result Government contributions to financing are avoided. About 95% of funds flow through the Plan are accounted by HP concessionaires.

Table 0-13: Consolidated Financial Plan: All Basins, 2023-2050, HDMP Scenario 1, Current NPR million

	Financial Flow, NPR million																		
	Irrigation Costs										Operator' s Expenditure & Revenue, NPR million						Drinking water		Total
	MPP Irrigation Costs		Tubewell investment and Operation			Tubewell Support and Supervision													
	All MPP Investment	All MPP O&M	Investment costs	Replacement costs, tubewells	MOM costs at site	Investment costs	Replacement costs, tubewell support	MOM costs	Gravity/Pump Hill schemes investment costs	Gravity/Pump Hill schemes O&M	Equity	Loan Repayment	Taxes	O&M	Royalty payment	Sales Revenue	Investment cost	O&M	
2021-2025	49,978	135	31,150	-	2,656	1,315	-	823	1,423	-	-	-	-	-	-	-	104,840	14,678	206,998
2026-2030	117,154	1,535	34,066	2,633	13,282	929	781	3,093	7,625	209	147,669	-	-	-	-	-	104,840	51,371	485,188
2031-2035	38,330	11,309	20,546	6,548	19,541	829	1,038	3,697	9,212	722	227,804	77,220	15,545	20,237	4,545	231,786	6,418	67,397	762,723
2036-2040	37,333	19,071	18,416	7,983	25,931	184	1,800	4,742	6,992	1,485	868,137	251,140	44,546	40,133	12,077	615,942	6,418	69,643	2,031,972
2041-2045	872	19,521	-	10,984	26,353	-	3,090	4,249	932	1,933	753,325	641,720	145,802	141,950	40,035	2,041,805	6,418	71,889	3,910,879
2046-2050	-	19,521	-	11,933	26,353	-	4,226	4,249	-	1,964	-	1,238,370	256,260	220,774	70,305	3,585,533	6,418	74,136	5,520,041
Total	**243,668**	**71,091**	**104,178**	**40,081**	**114,116**	**3,257**	**10,936**	**20,852**	**26,184**	**6,313**	**1,996,935**	**2,208,450**	**462,154**	**423,094**	**126,962**	**6,475,066**	**235,351**	**349,113**	**12,917,802**

Table 0-14: Consolidated Financing: All Basins, 2023-2050, HDMP Scenario 1, Current NPR million

	Irrigation		Hydropower Generation			Drinking Water		
	GoN/Concessional Finance	Irrigators	Conncessionaire	GoN	Electricity Consumers	GoN	Water Consumers	Total
2021-2025	83,867	3,614	-	-	-	104,840	14,678	206,998
2026-2030	159,775	21,533	147,669	-	-	104,840	51,371	485,188
2031-2035	68,917	42,854	345,352	-	231,786	6,418	67,397	762,723
2036-2040	62,924	61,011	1,216,033	-	615,942	6,418	69,643	2,031,972
2041-2045	1,805	66,130	1,722,832	-	2,041,805	6,418	71,889	3,910,879
2046-2050	-	68,247	1,785,708	-	3,585,533	6,418	74,136	5,520,041
Total	**377,287**	**263,389**	**5,217,595**	**-**	**6,475,066**	**235,351**	**349,113**	**12,917,802**

Table 0-15: Consolidated Financial Plan: All Basins, 2023-2050, HDMP Scenario 2, Current NPR million

	Financial Flow, NPR million																		
	Irrigation Costs										Operator' s Expenditure & Revenue, NPR million						Drinking water		Total
	MPP Irrigation Costs		Tubewell investment and Operation			Tubewell Support and Supervision													
	All MPP Investment	All MPP O&M	Investment costs	Replacement costs, tubewells	MOM costs at site	Investment costs	Replacement costs, tubewell support	MOM costs	Gravity/Pump Hill schemes investment costs	Gravity/Pump Hill schemes O&M	Equity	Loan Repayment	Taxes	O&M	Royalty payment	Sales Revenue	Investment cost	O&M	
2021-2025	49,978	135	31,150	-	2,656	1,315	-	823	3,198	0	11,820	-	-	-	-	-	104,840	14,678	220,593
2026-2030	117,154	1,535	34,066	2,633	13,282	929	781	3,093	7,691	342	87,904	3,490	977	2,154	196	9,985	104,840	51,371	442,424
2031-2035	38,330	11,309	20,546	6,548	19,541	829	1,038	3,697	5,585	906	230,773	47,290	5,425	12,357	1,104	56,313	6,418	67,397	535,404
2036-2040	37,333	19,071	18,416	7,983	25,931	184	1,800	4,742	5,907	1,314	403,351	210,990	31,164	36,306	6,904	352,113	6,418	69,643	1,239,569
2041-2045	872	19,521	-	10,984	26,353	-	3,090	4,249	3,803	1,745	454,180	408,910	77,882	82,652	17,767	906,112	6,418	71,889	2,096,428
2046-2050	-	19,521	-	11,933	26,353	-	4,226	4,249	-	1,964	-	632,480	136,886	132,371	32,967	1,681,327	6,418	74,136	2,764,831
Total	**243,668**	**71,091**	**104,178**	**40,081**	**114,116**	**3,257**	**10,936**	**20,852**	**26,184**	**6,270**	**1,188,027**	**1,303,160**	**252,334**	**265,840**	**58,938**	**3,005,850**	**235,351**	**349,113**	**7,299,248**

Table 0-16: Consolidated Financing: All Basins, 2023-2050, HDMP Scenario 2, Current NPR million

	Irrigation		Hydropower generation			Drinking water		Total
	GoN/Concessional Finance	Irrigators	Conncessionaire	GoN	Electricity consumers	GoN	Water consumers	
2021-2025	85,641	3,614	11,820	-	-	104,840	14,678	220,593
2026-2030	159,841	21,666	94,720	-	9,985	104,840	51,371	442,424
2031-2035	65,290	43,037	296,949	-	56,313	6,418	67,397	535,404
2036-2040	61,840	60,840	688,715	-	352,113	6,418	69,643	1,239,569
2041-2045	4,675	65,942	1,041,391	-	906,112	6,418	71,889	2,096,428
2046-2050	-	68,247	934,704	-	1,681,327	6,418	74,136	2,764,831
Total	**377,287**	**263,347**	**3,068,300**	**-**	**3,005,850**	**235,351**	**349,113**	**7,299,248**

Financing Plan for Preferred Scenario: Table 0-9 and Table 0-10 show the economic valuation of a consolidated economic analysis of water infrastructure assuming HDMP Scenario 1 (medium demand for electricity) and Scenario 2 (lower demand) respectively. Converting costs to financial prices and disaggregating into fund flows for both scenarios, an indicative financial plan was prepared. This is shown in Table 0-11 and Table 0-12 for HDMP Scenario 1 and 2, respectively. The plan assumes:

- GoN will arrange for concessional financing of surface irrigation works associated with all MPP
- Irrigators will pay all O&M costs associated with surface water irrigation
- Irrigators will pay all MOM and replacement costs associated with groundwater irrigation
- GoN will either fund or arrange for concessionary financing for capital cost of pump and gravity schemes in the Hills and Mountains
- Irrigators will pay for O&M for pump and gravity schemes
- A concessionaire will be responsible for the construction and MOM of all infrastructure pertaining to hydropower development (not irrigation: any costs below the tunnel outlet of MPP schemes is assigned to irrigation); this will include raising equity, financing loans and paying taxes
- Government will receive from the concessionaire generation royalties based on installation capacity and distribute them to Provincial accounts
- Electricity consumers (including, for simplicity foreign consumers of exported power) will pay the concessionaire for power consumed through the appropriate tariffs (via NEA).

The overall flow of funds is substantially greater than the economic value of the programme, mainly because it includes financing charges on the construction of major infrastructure. For this reason, the financing plan is extended to 2064, to show the completion of the financing cycle for construction of hydropower plants.

Some funding flows are slightly less than when expressed in economic values. This difference is a result of the adjustments made to calculate financial from economic values, such as the addition of taxes and other transfer costs, adjusting for the premium placed on foreign exchange and applying the full cost of unskilled labour (or the converse when adjusting financial to economic).

If the programme is financed according to these guidelines, GoN would be responsible for a very small proportion of programme financial costs. The major investment in the basin is intended to be financed through hydropower site concessionaires who will be reimbursed by sales of electricity to consumers (via NEA). Consumers of water services are expected to be pay at least for O&M. Groundwater irrigators and consumers of potable water are expected to pay for MOM and replacement in full, because consumption can be metered.

GoN may seek concessionary financing for some investment. New irrigation systems are amenable to external financing. Larger gravity-pump irrigation schemes and drinking water supply projects may also attract donor interest. But Government may have to pay replacement and management costs on smaller schemes, and if water charging is not secure, some or all of O&M. But a higher contribution by Government is a necessary condition of investment and operation in more remote river basins.

Comparing this with investment in major hydropower infrastructure, constructed under the assumption that cost recovery of MOM and replacement is met by consumers of services, construction costs are increased by the need of concessionaires to borrow at commercial rates and these costs are passed on to electricity consumers,

The consumers of program services are expected to pay about 66% of programme costs through water charges and electricity tariffs. The concessionaires will pay 32% of costs but be reimbursed by generators' tariffs. Even at commercial rates of interest on construction, the greenfield sites identified under HDMP Scenario 1 are overall attractive to investors. A 16% return on the development of all 92 sites identified under HPMP Scenario 1 is expected which would be a return greater than the opportunity cost of concessionaires' capital. However, there will be good and less good sites. The MPP are estimated to return only 9% on investors' capital, which is lower than their opportunity cost of capital. For that reason, the investment costs of some or all MPP may have to be funded through government finance and concessionary loans.

Policy Interventions and Institutional Requirements

The development and effective management of water resources are governed by sound and pragmatic policy combined with an enforceable regulatory framework with support from appropriate institutional mechanisms. These three components combined play a crucial role in Nepal's sustainable development and overall welfare through the water resources sector. Legal frameworks serve as the cornerstone for governing water access, distribution, and use while guaranteeing fair distribution among various sectors and stakeholders. To maintain Nepal's water security and stop overuse, pollution, and disputes over water resources, clear and enforced regulations are necessary. Policies implemented by the GoN provide sustainable water management with the strategic direction it needs. Policies in Nepal handle important concerns such as the development of hydropower projects, irrigation systems, and environmental protection measures. They also take climate change's effects on water supply and quality into account. Lastly, robust institutions are indispensable for translating legal and policy frameworks into actionable initiatives. They play a pivotal role in coordinating and implementing water management strategies, ensuring accountability, and fostering collaboration among various governmental and non-governmental entities. Moreover, institutions facilitate engagement with international organizations and neighbouring countries, enabling Nepal to navigate transboundary water management challenges and foster regional cooperation. Thus, the effective integration of these elements is crucial to ensure the responsible and equitable management of Nepal's precious water resources, thereby benefiting both the nation and its people.

In developing the river basin plans, the legal, policy, and institutions influencing water resources have been reviewed, and recommendations provided on how to strengthen these frameworks and institutions.

Policy Context and Requirements: Whilst the "development plans" provide guidance on how to fulfil the responsibilities of the State and achieve a balance between sectoral uses of water, the plans have to be in the hands of a governmental organization that has clear and explicit responsibilities and powers to ensure that coordination and any such regulation is undertaken. In other words, without a suitably empowered lead agency (or "Champion") to guide the country in the overall development and implementation of its water resources master plans the State will fail to fulfil its responsibilities, the master plans will become redundant and water resource development is likely to be ad hoc and piecemeal – project by project-based - and fail to secure the optimal benefits for the country and the people and fail to prevent the broader and deeper environmental impacts which can arise in large rivers.

Having such a lead agency or champion, with a clearly defined role and the relevant power needed, is of such critical importance in ensuring that the State can safeguard the nation's water resources that **the paramount recommendation is that the Role of WECS must be fully and explicitly defined and establish and as necessary supported by law**.

This recommendation is essentially a "gatekeeper" recommendation, a key to the door giving access to implementing the other recommendations. Thus, for example, WECS would be responsible for leading the effort across agencies, ministries, and local administrations to come up with a properly practical way forward regarding River Basin planning and the three tiers of government. It is worth pointing out here that the existing river basins of Nepal will not change their boundaries even in the distant future – administrative boundaries may well change numerous times. The State therefore will continue to undertake national-level planning based on river basins and their boundaries.

Legal Landscape and Requirements: The *Water Resources Act* (1992) is to be revised to incorporate provisions for ensuring dam safety, managing groundwater, and promoting multipurpose water use. These provisions are to be implemented when granting licenses and constructing projects.

To establish a comprehensive framework, the River Basin Plan, Hydropower Master Plan, and SESA are to be interconnected under the Act. This can be achieved by introducing specific provisions that make these plans enforceable and mandatory, while also implementing a basin-level licensing regime. The implementation of federalism and the fair distribution of water resources pose challenges. Ownership issues and the distribution of water resources between or among tiers of government are to be addressed.

Furthermore, water quality and pollution concerns to be considered to achieve optimal efficiency. It may be necessary to establish a clear regulatory regime for restricted lands or buffer zones and define the right of way for rivers or water resources.

Institutional Landscape and Recommendations: Major institutional hurdles facing Nepal's water resources sector as underlined by various past and present policy documents are summarized below:

- Lack of an Effective Central Institution that can meaningfully oversee the planning, implementation, and regulation of projects and programs related to the water resources sector. This has resulted in a piecemeal approach to development rather than taking an integrated approach overlooking long accepted principle of IWRM. This is further reinforced during the conduction of Province level workshops where participants also vocally pointed it out.
- Blurred Responsibilities in terms of policy formulation, planning, implementation, operation, and regulation among various organizations and various levels.
- Lack of clarity in jurisdiction results in problems of coordination.

Major recommendation in terms of institutional back up for effective planning and management of water resources sector are:

- A clear institutional mechanism for taking custodian role in terms of all river basin planning which will be performed by WECS as has been underlined by past and present policy documents.
- Preparation of policy regarding jurisdiction among 3 tiers of governments and appropriate mechanism therein to ensure coordination for the optimal benefits from the development of water resources and enhanced management with due consideration of lesser environmental impact.
- Reinforcement of WECS to effectively address above mentioned recommendations.
- Refinement of Policy, Act, and Regulations to instil dynamism in the development of the sector.
- Promotion of International Water Law to prepare Nepal for undertaking mutual understanding with neighbouring countries as per international law and practices.

The entry points to effectively implement RBP and the above-mentioned institutional recommendations are:

- **Reinforcing WECS** through its institutional strengthening that to consolidate present tasks of a) Prepare Policies, Strategies and Legislation; b) Recommending Mega/Medium Projects; and c) Advice on International Issues; to be enlarged and encompass a) Electrical Studies-forecast, transmission, efficiency; b) Hydro-data Centre task; c) River Basin Plans-preparation, implementation and audit; d) Projects related task-national standards and codes; pre-license consent for central level projects; monitor safety of basins, infrastructures and SESA issues.
- **Setting up the River Basin Offices (RBOs)** to implement the mandate of WECS at provincial and local levels and will have a role a) to act as a local data center; b) support regulation through issuance of pre-license consent at provincial and local levels, regulating sand and gravel extraction from rivers; c) audit of RBPs including quality assurance and RBP update; d) communicative role on sharing and explaining RBPs, good practice, guidelines; e) supportive role in terms of sharing information, support investment development and training as required.

Moving Forward: a) Water Energy Commission (WEC) as Steering body for inter-ministry coordination in policy and planning; b) WECS as planning and regulating agency, providing pre-license consent to federal level projects and programs; c) RBO as implementing arms for WECS mandate at basin level; d) RBOs provide pre-license consent on projects and programs at basin level.

The RBPs, HDMP and the SESA for each basin provide a multi-sectoral analysis of potential water resources development in the river basins. The analysis reviewed several development scenarios, with the SC1 and SC2 Scenarios, illustrating development pathways that balance social and economic benefit with lesser environmental impact. Ultimately, the water resource development in the river basins will be decided by water managers and key stakeholders. The RBP Development Scenarios provide insight into how water management decisions might impact future development. The RBP and accompanying Decision Support System (DSS) support multi-stakeholder engagement helping WECS inform government, river basin organizations, key stakeholders, and financial institutions make informed and collaborative decision about the water resources in Nepal.

1 Introduction

1.1 Background

The Government of Nepal (GON) approved the Water Resources Strategy (WRS) in 2002, the National Water Plan (NWP) in 2005, and the Water Resources Policy in 2020. The NWP focuses on implementation of activities in the water resources sector according to the principles of Integrated Water Resources Management (IWRM) as described in WRS. The Water and Energy Commission Secretariat (WECS) is envisaged as a central planning and coordinating agency with a mandate to promote and advance river basin planning to optimize the benefits of water resources development while minimizing conflicts by coordinating with relevant agencies at all levels.

A need was felt by the government to prepare detailed plans for water resources development with updated data and information for all the river basins. Development of an updated hydropower master plan was also needed for all the basins. These river basin plans as well as the hydropower master plans were to be prepared incorporating the findings of the strategic environmental and social assessments (SESA). Therefore, SESA related activities are integrated into the process of project planning.

WECS has therefore, undertaken the ***Preparation of River Basin Plans and Hydropower Development Master Plans and Strategic Environmental and Social Assessment*** (this “Project”) to have an up-to-date master plan to support relevant government agencies in implementing multi-sectoral water resources development projects in the country. The Project comprises four major components: (A) preparation of river basin plans, (B) preparation of hydropower master plans, (C) strategic environmental and social assessment, and (D) support for capacity development of WECS and related agencies.

1.2 Objectives

The objectives of the study (Project) are:

(i) To prepare river basin plans through IWRM principles for all rivers of Nepal (except Bagmati River Basin)

(ii) To prepare hydropower development master plan for all the major rivers of Nepal

(iii) To concurrently undertake SESA of the river basin and hydropower development master plans

(iv) To strengthen capacity within WECS and of other relevant agencies representatives to carry out integrated water resources development and management planning at basin level to meet local, provincial and national level needs utilizing appropriate knowledge and information management system, analytical and modelling tools, and planning methodologies

1.3 Content of the Report

This summary report covers the summary of the four components of the Project. The River Basin Plans of the ten basins of Nepal (excluding Bagmati) is summarised in Chapter 2. The basin context, objectives and guiding principles, methodology, development scenarios considered and their evaluation, and finally an all-basin summary of water availability and use, and water resources development plans of all basins.

The Hydropower Development Master Pan (HDMP), an integral part of the river basin plans, is presented in Chapter 3. The summary includes the overall approach, basin wide optimization of the hydropower projects and description of the three development scenarios of the HDMP considered.

The Strategic Environmental and Social Assessment (SESA) is summarised in Chapter 4, where the scope, approach and methodology, main findings of the SESA impacts assessment of the development scenarios of the River Basin Plans, and the mitigation strategies are covered.

The overall investment and financial planning is covered in Chapter 5, where the sectoral as well as the consolidated costs and benefits of all basins, and consolidated financial plans are summarized.

The policy interventions and institutional requirements to implement the river basin plans and the HDMP are summarised in Chapter 6. A short summary of the capacity building training undertaken are summarised in Chapter 7. List of key references in provided in Chapter 8. The development scenarios and the simulation runs with the list of key interventions and their milestones for all the basins are presented in Annex A. The list of supporting key technical notes and reports is presented in Annex B. The technical notes and reports provide the detailed description of all relevant subject matters and sectors that cover the River Basin Plans, HDMP and SESA.

2 River Basin Plans

The River Basin Plans has a time horizon of 2050. Separate River Basin Plans of four major basins (Mahakali, Karnali, Gandaki, Koshi), six medium basins (West Rapti, Babai, Bagmati, Kamala, Kankai and Mechi)[7] and Southern River Blocks have been prepared (Figure 2-1. The river systems directly originating from the Siwalik (Chure) range are categorized as Southern River Blocks.

Figure 2-1: River Basins of Nepal

2.1 Basin Context

2.1.1 Mahakali Basin

Mahakali River is a mixed rain- and snow-fed river on the western border between Nepal and India (**Figure 2-2**). The catchment area of the Mahakali Basin is 15,769 km^2 at the Nepal-India border, with 67% of the catchment lying in India and 33% in Nepal. About 25% of the basin areas lie above 3,000 m, and 5% lie above 5,000 m.

[7] River Basin of Bagmati Basin is not included as it is prepared under a separate project by WECS.

Figure 2-2: Mahakali Basin

The annual rainfall within the catchment in Nepal is 1925 mm, and the total basin annual average rainfall is about 1867 mm, 79% of which is in the monsoon season from June to September. There is a high variability of surface water availability within the year, with about 73% of the surface runoff flowing in the four monsoon months. The surface and groundwater are the major water resources in the basin to meet the water demand and the irrigation water in the agricultural area.

There is a treaty between Nepal and India concerning the Integrated Development of the Mahakali Barrage including Sarada Barrage, Tanakpur Barrage, and Pancheshwar Project (Mahakali Treaty) signed in 1996, which ensures equal partnership regarding waters of the Mahakali River and its utilization. The treaty envisages the development of a Multi-purpose Pancheshwar Project that will generate 5,040 MW of hydropower, irrigate land in Nepal and India, and provide flood control benefits to downstream regions, particularly in India.

Table 2-1: Drivers and pressures acting on the hydrological system in the Mahakali Basin

Water Resources Development Issues	
DWS	• The basin's population is anticipated to grow from 0.6M in 2025 to 0.7M people by 2050: a 14% increase. Drinking water use rate, per capita, will rise by 2050. Population growth and drinking water use rate will be disproportionally increased in urban areas. • To accommodate the growth, water delivery will increase from 38.3 MLD to 57.4 MLD • Accounting for the increased water demand, reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.
IRRG	• Within the basin, surface water irrigation in the basin is projected to increase from 3178 ha to 22391 ha by 2050. The extension of irrigated land is primarily along the Mahakali River (6775 ha), Rangun Khola (8344 ha), and Surnay Gad (3933 ha) • In addition, surface water diversion from the lower Mahakali River is used to irrigate 11600 ha of the Mahakali I and II areas in Southern Block 1. Additional, implementation of Mahakali III with 19886 ha is ongoing.
HP	• Currently, 2 ROR and 1 PROR HPPs in the Chameliya-Mahakali Subbasin have an Installed Capacity of 47MW. Two of the projects have been constructed in the Api Nampa Conservation Area. • One ROR and one PROR HPP with construction licenses have a combined Installed Capacity of 50 MW. These are likely to be built in 2025 and 2030. Both will be developed in the Api Nampa Conservation Area. • The proposed Pancheshwar MPP has an Installed Capacity of 5040 MW. As this is a joint project with India, Nepal will receive 50% of the energy produced. • A proposed greenfield ROR project (CHEM056) in Chameliya River with 77 MW Installed Capacity lies within the Api Nampa Conservation Area. • The full increase in Installed Capacity in the basin is 2112 MW with the full capacity of 2158.5 MW. This is 4%, 6%, and 10% of the target Installed Capacity in the HDMP scenarios.
ENV-SOC	• In the Mahakali, the Shuklaphanta NP and its buffer zone, Api Namapa Conservation Area support biodiversity and provide valuable aquatic and terrestrial habitat for endangered species of fish, birds, and mammals. The Api Nampa Conservation Area forms the upper catchment for the Chameliya River, and the Mahakali River flows through Shuklaphanta National Park on the Terai. • With construction of hydropower plants, most of the Mahakali River and Chameliya River have been classified as High Conservation Value River (HCVR) 2, low connectivity but high water quality. Tributaries of the Chameliya Khola and the Surnaya and Rangun Rivers are classified as HCVR 1, the most ecologically desirable classification. • The Chameliya Khola and Mahakali are home to up to 66 species, 9 of which are threatened or near-threatened. The rivers are inhabited by mahseer and snow trout, the later of which uses the Chameliya River as spawning habitat. • The major livelihood in the basin is agriculture with local communities using river water for irrigation. • Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages. Many Hindu rituals and festivals require the use of holy river water with significant flow. The Parasuram Dham temple and at the Brahmadev temple are located on riverbanks. • Regional benefits of development can lead to lower food prices, increased labour opportunities, and increased and more reliable secure drinking water and electrical supply.

The surface and groundwater are the major water resources in the basin to meet the water supply demand and the irrigation water in the agricultural area. The current water use for domestic water and industry

(38.3 MLD) and the projected demand based (57.4 MLD by 2050) on projected population growth are expected to be met by the available water sources.

The current irrigated command area within the basin is 3,178 ha, and it will increase to about 22,391 ha by 2050. In addition, the agricultural area in the adjacent Terai districts of Kanchanpur and Kailali (Southern Block 1) is dependent on the water of the Mahakali and Karnali Rivers. Currently, irrigation water is diverted from the Sharada Barrage in the Mahakali River to Kanchanpur and Kailali districts through the Mahakali Irrigation Project. The first and second phases of the Mahakali Irrigation Project, have a command area of 4,800 ha and 6,800 ha, respectively. The third phase of the Mahakali Irrigation is currently under implementation to irrigate a command area of 19,886 ha. The third stage comprises a 151 km long canal on the Nepal side, of which a 28.5 km section has been completed as of 2023.

There are three existing ROR hydropower projects in the Mahakali Basin in Nepal, Chameliya (30 MW), Nau Gad Khola (8.5 MW), and Upper Nau Gad (8.0 MW). As of 1 April 2023, the Upper Chameliya HPP (40 MW) and Makari Gad HPP (10 MW) have been issued construction licenses by DoED. The HDMP considers the proposed Pancheshwar Dam of an installed capacity of 4,800 MW with reregulating dam of an installed capacity of 240 MW at Rupaligad. Nine greenfield hydroelectric projects were identified in the main and 2nd order tributaries of the Mahakali River. Based on the detailed technical and economic assessment, one identified greenfield PROR project, Chameliya_05 in Chameliya River (CHEM056) with an installed capacity of 77 MW (417.4 GWh pa) is recommended.

2.1.2 Karnali Basin

Karnali River is one of the three major rivers of Nepal, which originates from the south of Mansorovar and Rokas lakes in China (Tibet) and enters Nepal as Humla Karnali near Khojarnath. From its source, it flows 507 km within Nepal, until it meets the Ghaghara River in India. The Karnali River is the longest river flowing through Nepal and along with other snow-fed rivers constitute the Karnali Basin. The catchment area of the Karnali Basin is 46,193 km^2 at the Nepal-India border. About 53.1% of the basin areas lies above 3,000 m, and 14.4% lies above 5,000 m. An overview of the sub-basins and tributaries is given in Figure 2-3.

Figure 2-3: Karnali Basin

The annual rainfall within the catchment in Nepal is 1225 mm, about 24% lower than the national average of 1,609 mm, and the total basin annual average rainfall is about 1,280 mm. There is a high seasonal rainfall variation, with 12% of rainfall occurring in pre-monsoon (March - May), 76% of rainfall in monsoon (June - September), 4% of rainfall in post monsoon (October - November) and 8 % in winter (December - February).

The average annual discharge of the Karnali river at its downstream section at Nepal-India border is 1256 m^3/s equivalent to 39,606 million cubic meters, the seasonal pattern being influenced by the Monsoon, the period with the highest discharge (about 72% of the average annual runoff) followed by the post monsoon period (about 12%), while during winter and pre-monsoon periods the river discharge is even lower (about 7% and 9% respectively).

The surface water and groundwater are the major water resources in the basin to meet the water supply demand and the irrigation water in the agricultural area. The current water use for drinking water and industry in the basin is small and the projected demand based on projected population growth is expected to be met by the available water sources. The provision of safe water supply to 90% by 2030 of the population is an important policy objective for the GoN. The basin's population is anticipated to grow from 3.80M to 4.52M people by 2050, an increase of 18%, and drinking water use rate, per capita, will rise by 2050. Population growth and drinking water use rate will be disproportionally increased in urban areas. Accounting for the increased water demand, reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.

Table 2-2: Drivers and pressures acting on the hydrological system in the Karnali Basin

Sector	Water Resources Issues
DWS	• The basin's population is anticipated to grow from 3.80M to 4.52M people by 2050, an increase of 18%. Drinking water use rate, per capita, will rise by 2050. Population growth and drinking water use rate will be disproportionally increased in urban areas. • To accommodate the growth, water delivery is projected to increase from 230.2 MLD to 365.5 MLD by 2050. • Accounting for the increased water demand, reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.
IRRG	• Only about 5% of Karnali Basin is suitable for irrigation and the quality of land suitability is very low compared with other basins (even Gandaki and Koshi). However, by 2050 the surface water irrigation in the basin is projected to increase from 69,341 ha to 94,642 ha: a 36.5% increase in command area. • The extension of irrigated land is primarily in the Bheri Subbasin (58362 ha to 71077 ha), Karnali Mainstream (47597 ha to 92327 ha), and West Seti Subbasin (4309 ha to 10609 ha). Within the basin, expansion is areas are primarily in the Hill agro-ecological zone. • Upon completion in 2025, the Bheri-Babai Diversion IBT will supply water for year round irrigation to total area of 51,000 ha, including 36,000 ha of the Babai IP and an additional area of 15,000 ha. It will also generate hydropower of a capacity of 46.8 MW. • The Karnali Diversion IBT diverts the Karnali River to rehabilitate 7,632 ha and expand 32,996 ha in the Kailali District in Southern Block 1. • Only about 5% of the basin is located on the Terai, so no groundwater investment is envisaged for the basin and the opportunity for surface irrigation from MPP is very limited. Most new irrigation must be gravity/pump in the Hills and Mountains • Urbanization is expected to occur at the same rate as the Gandaki and Koshi Basins, but in contrast to these basins the rural population is expected to increase, thus increases in agricultural productivity must be planned to reduce food imports from other basins and create employment opportunities.
HP	• Currently, 4 operating ROR in the Karnali basin have an Installed Capacity of 22.9 MW. 3 PROR and 10 ROR HPP with constructions licenses have an Installed Capacity of 980 MW. The largest, Tila-1 and Tila-2 have Installed Capacity of 440 MW and 420 MW, respectively.

Sector	Water Resources Issues
	• 4 Mega HPP, under study by DoED, could potentially increase Installed Capacity by 6,084 MW. • The Karnali Diversion IBT will have 80 MW as a side benefit to surface irrigation water delivery. Bheri-Babai Diversion IBT, currently under construction, has an Installed Capacity of 46.8 MW. • 48 favourable greenfield HPP have been identified in the HDMP with a combined Installed Capacity of 11,918 MW. • In total, the potential increase in Installed Capacity from HP is 19,075 MW.
ENV-SOC	• Four national parks and buffer zones (Bardia, Khaptad, Rara, and Shey-Phoksundo), and the Dhorpatan Hunting Reserve lie within the basin. The location of several construction license, mega, and greenfield HPP are within these areas. • Mahseer and snow trout use rivers in the West Seti Subbasin, Karnali Sub basin, and Bheri Sub basin for breeding and nursing and migration for rearing juveniles and adult habitat. Furthermore, the fish migrate in response to stream temperatures and turbidity associated with snow melt. • Fourteen endangered or threatened fish, mammal, and reptile species rely on river system in the Karnali Basin. This includes the iconic Gangetic dolphin. • Given its pristine conditions, 99% of all rivers are classified as HCVR 1 with high connectivity and high water quality. • The major livelihood in the basin is agriculture with local communities using river water for irrigation. • Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages. Dolpo is the home to Bon culture and the Musto culture originated in Jumla district. The sacred Mt. Kailash and the holy Lake Manasarovar are the most attractive spots for pilgrims of Tibetan Buddhism, Hinduism, Bon and Jainism. • Regional benefits of development can lead to lower food prices, increased labour opportunities, and increased and more reliable secure drinking water and electrical supply.

By 2050, the surface water irrigation in the basin is projected to increase from 69,341 ha to 94,641 ha: a 36% increase in command area. The surface water available in the basin has the potential to meet the irrigation requirements for adjacent water deficit basins. IMP has considered two inter-basin diversions from Karnali Basin: the Bheri-Babai Diversion IBT and the Karnali Diversion IBT.

The Karnali Chisapani Project, if implemented, would irrigate a command area of 83,320 ha in the east bank (Bardiya and Banke Districts) and 90,630 ha in the west bank (Kailali District). A further 13,000 ha of farmers schemes in the Geruwa Island of the Karnali River would also be covered, giving a command area of 188,950 ha in Nepal. The command area would incorporate existing projects in the districts, including the right bank areas of Sikta Project and the entire Bheri-Babai Project area. The irrigation benefits in India would include a command area of about 2 million ha. Other multi-purpose benefits include flood control, navigation and recreation benefits. The social-environmental costs of the project of this magnitude would be also very high, which would need to be considered while make further decision about the project.

Currently, three ROR hydropower plants are operational in the Karnali Basin, which have an installed capacity (IC) of 12 MW. Three PROR and 10 ROR HPP with constructions licenses have an Installed Capacity of 980 MW. Tila-1 and Tila-2 have Installed Capacity of 440 MW and 420 MW, respectively. Four mega HPP (Upper Karnali, 900 MW; West Seti, 750 MW; Nalgad, 417 MW; Karnali Chisapani, reduced capacity of 4,024 MW) could potentially increase Installed Capacity by 6084 MW. The Bheri-Babai Diversion IBT and Karnali Diversion IBT will have 46.8 MW and 80 MW, respectively, as side benefits of surface irrigation water delivery. Forty-eight favourable greenfield HPP have been identified in the HDMP with a combined Installed Capacity of 11,918 MW. In total, the potential increase in Installed Capacity from HP is 19,083 MW.

The Karnali River bifurcates its river course at Chisapani, the Kuleriya River in the west and the Geruwa River in the east, forming an island of an alluvial fan of about 15,000 ha of agricultural land. The main stem of the Karnali River has shifted westward from the Geruwa River to the Kuleriya River due to the sediment deposition in the river course. The riverbanks of the Kauriyala and Geruwa Rivers are prone to erosion and inundation of the adjacent land every year (JICA, 1993).

The scenarios and development paths assessed in the Basin Plan includes the above interventions to meet the projected water demand for various uses, including water supply, irrigation, hydropower requirement, and other environmental and ecological requirements of the river. Four national parks and buffer zones (Bardia, Khaptad, Rara, and Shey-phoksundo), the Krishnasaar Conservation Area, and the Dhorpatan Hunting Reserve lies within the basin. The location of several construction license, mega, and greenfield HPP are within these areas. The environmental sensitivities of development activities on the national parks and conservation zones, flow requirements of the downstream water uses, river connectivity are important parameters for any basin development interventions in the Karnali Basin.

2.1.3 Babai Basin

The Babai Basin is located in the mid-western part of Nepal draining parts of Rolpa, Salyan, Dang and Bardiya districts totaling a catchment area of 3,579 km^2 at Nepal-India border. The Babai River originates and flows westwards in the inner Terai Valley of Dang formed between the Mahabharat Range and the Siwaliks, at an altitude of about 2816 m asl, then flows southwards after it enters the Terai through Bardiya and further downstream crosses the Nepal-India border, at an altitude of about 132 m asl, to merge into Ghagra River (Karnali in Nepal) in Uttar Pradesh, India, ending its 240 km path in Nepal. An overview of the Babai Basin, including Block 1 is shown in Figure 2-4.

The major tributaries of Babai are Katuwa Khola, Jangawa Khola, Guhar Khola, Hapur Khola, Patu Khola, Sharada Khola in the hill region and Bhada Khola in the Terai. Babai is a typical river originating from the Siwalik/Mahabharat range, being rain-fed and with no snow melt. The dry flow is low sustained by local groundwater discharges.

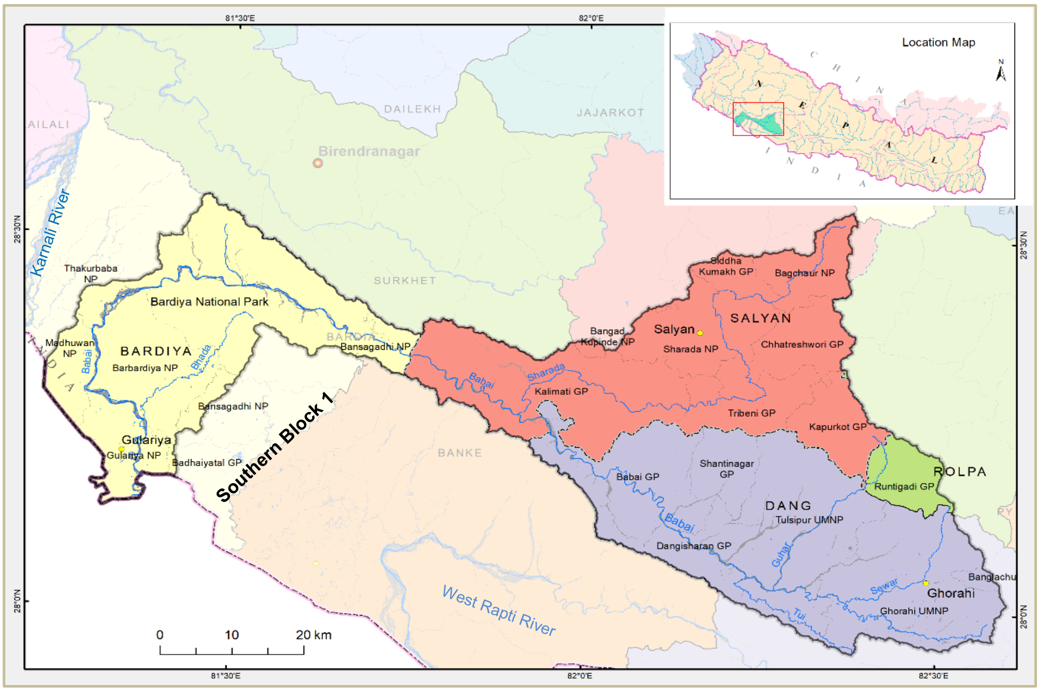


Figure 2-4: Babai Basin

The basin receives an average annual rainfall of about 1514 mm, 83% of which is in the monsoon season from June to September. The average annual discharge of the Babai river at the Nepal-India border is

79.9 m³/s equivalent to 2,520 million cubic meters, the seasonal pattern being influenced by the monsoon, the period with the highest discharge (about 76% of the average annual runoff) followed by the post monsoon period (about 13%), while during winter and pre-monsoon periods the river discharge is even lower (about 6% and 4% respectively). The current water use for drinking water and industry in the basin is small and the projected demand based on projected population growth is expected to be met by the available water sources.

The current command area irrigated by surface water within the basin is 61,662 ha. Upon completion in 2025, the Bheri-Babai Diversion IBT will supply water for year round irrigation to total area of 51,000 ha, including 36,000 ha of the Babai IP and an additional area of 15,000 ha. It will also generate hydropower of a capacity of 46.8 MW. Potential waters transferred from the West Rapti Basin by the Madi Dang Dam can rehabilitate 28,200 ha in the Dang Valley. The current irrigation requirements are barely met and are not provided with year-round irrigation by the existing water infrastructure in the basin. There is a potential of further year-round irrigation within the basin as well as in the water-deficit regions of the adjacent districts of the Bardiya District, but the dry season water available within the basin is not sufficient to meet the demand. The existing Babai Irrigation Project (IP) and the Dhodhari Taratal IP in Bardiya District have water deficit. Hence, either seasonal storage reservoir or inter-basin diversion from water-surplus Karnali Basin will be required.

Table 2-3: Drivers and pressures acting on the hydrological system in the Babai Basin

Sector	Water Resources Development Issues
DWS	• The basin's population is anticipated to grow by 11%, from 0.93M to 1.03M people by 2050. Drinking water use rate, per capita, will rise by 2050. Population growth and drinking water use rate will be disproportionally increased in urban areas. • To accommodate the growth, water delivery will increase from 76.6 MLD to 158.5 MLD in the basin. • Accounting for the increased water demand, reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.
IRR	• Estimates of future demand for food show that because Babai Basin has a small area of relatively low-quality land suitable for agriculture, the basin will need to expand the area of irrigation, increase the volume and reliability of delivery, and improve management to raise the cropping intensity and value of the cropping pattern. • The irrigation area within the basin is expected to increase from 61662 ha to 67686 ha in 2025. • Waters transferred from the West Rapti Basin can rehabilitate 17100 ha in the Dang Valley. Surface water irrigation will increase Irrigation by surface water in the Dang Valley is frequently limited in December and January. • Upon completion in 2025, the Bheri-Babai Diversion IBT will supply water for year round irrigation to total area of 51,000 ha, including 36,000 ha of the Babai IP and an additional area of 15,000 ha. It will also generate hydropower of a capacity of 46.8 MW.
HP	• There is no existing HPP in operation in the Babai Basin. • 46.8 MW ROR in the tunnel of the Bheri-Babai MPP/IBT. This project is under construction. • Madi Dang Dam (61 MW) is a multi-purpose storage reservoir that was deemed economically unfeasible in the HDMP and IMP. Primary purpose is irrigation with secondary HP benefit.
ENV-SOC	• The Babai River flows through the Banke National Park and its buffer zone to the north. Further downstream, the river flows through the Bardiya National Park as it heads towards the Terai region. • Most of the Babai River has been classified as HCVR code 3,4, indicating poor water quality, lack of connectivity, and not free-flowing. The Sharada River and its tributaries have HCVR 1, the most ecologically desirable classification.

Sector	Water Resources Development Issues
	• Mahseer and snow trout use the upper Babai and Sharada Rivers for breeding and nursing and migrate to the Babai River for rearing juveniles and adult habitat. • The major livelihood in the basin is agriculture with local communities using river water for irrigation. • Regional benefits of development can lead to lower food prices, increased labour opportunities, and increased and more reliable secure drinking water and electrical supply.

There is no existing hydropower project in the Babai Basin. The Bheri-Babai Diversion MPP under construction will generate up to 46.8 MW power, while diverting water for irrigation purpose from Karnali basin. Seven greenfield hydropower projects were identified, but none of them meet the minimum economic criteria in the basin plan.

The scenarios and development paths assessed in the Basin Plan includes the above interventions to meet the projected water demand for various uses, including water supply, irrigation, hydropower requirement, and other environmental and ecological requirements of the river. The Babai River traverses through the buffer zone of the Banke National Park, Bardiya National Park and he Krisnasar Conservation Area in the downstream area of the basin. The environmental flow requirements of the downstream water users including the National Parks and Conservation Areas are important parameters for any basin development interventions in the Babai Basin.

2.1.4 West Rapti Basin

The West Rapti Basin is a rain-fed, medium-sized river basin with a catchment area of 6,971 km² at the Nepal-India border. West Rapti Basin with its neighbouring basins (Karnali, Babai, Gandaki and Southern Block 2A) as well as its sub-basins are presented in Figure 2-5.

The basin receives an average annual rainfall of about 1587 mm, 80% of which is in the monsoon season from June to September. There is a high variability of surface water availability within the year, with about 73.5% of the surface runoff flowing in the four monsoon months. The hydrologic model estimates the annual catchment runoff averages 5,550 Mm³, which exceeds the overall current demand of 1.494 Mm³, but the monthly timing and annual volumetric variation (±11% for the 20% and 80% exceedance percentile) create shortages to surface water diverters (Figure 2-6). The West Rapti Basin is considered a "water deficit" basin as the dry season water availability is currently not sufficient to meet the year-round irrigation demand of the potential agricultural areas within the basin and the adjacent Terai region, which has the potential to be irrigated by diversions from the West Rapti River.

Figure 2-5: West Rapti Basin

The current water use for drinking water and industry in the basin is small and the projected demand based on projected population growth is expected to be met by the available water sources. The current irrigated command area within the basin is 61,490 ha, including the Praganna Irrigation Project (IP) (6,090 ha), Badkapath IP (453), and Sikta Irrigation Project (42,700 ha). The current irrigation requirements are barely met and are not provided with year-round irrigation by the existing water infrastructure in the basin. There is a potential for further year-round irrigation within the basin as well as in the water-deficit regions of the adjacent Kapilbastu Districts (51,000 ha) and Dang Districts (17,100 ha). There is one existing hydropower project of 12 MW capacity in the Jhimruk River, a tributary of the mainstream West Rapti River.

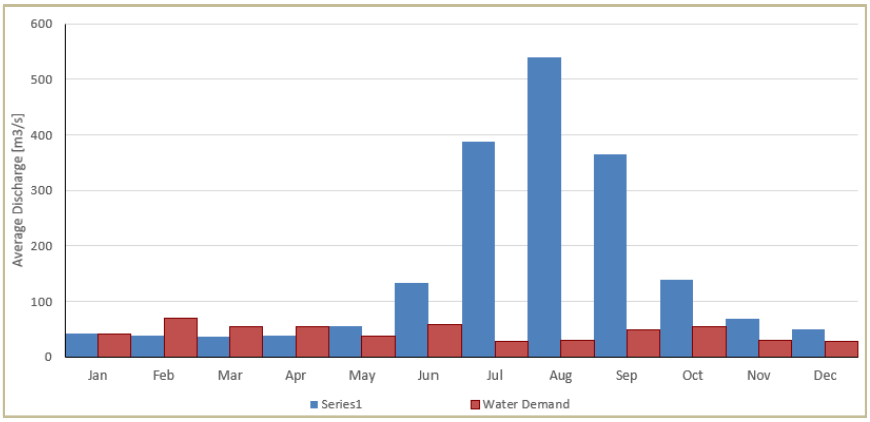


Figure 2-6: Simulated monthly catchment runoff and demand in the West Rapti Basin

Table 2-4: Drivers and pressures acting on the hydrological system in the West Rapti Basin

Water Resources Development Issues	
DWS	• The basin's population is anticipated to grow from 1.01M in 2025 to 1.13M people by 2050: a 12% increase. • Drinking water use rate, per capita, will rise by 2050. • Population growth and drinking water use rate will be disproportionally increased in urban areas. • To accommodate the growth, water delivery will increase from 55.4 MLD to 83.8 MLD • Accounting for the increased water demand, reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.
IRR	• The Basin irrigation is anticipated to grow from 61,490 ha to 63,829 ha by 2050, a 3.8% growth in irrigated land. • Some surface water irrigation schemes not connected to major rivers only supply water during high river discharge periods during the monsoon (August through October). • Two inter-basin transfer (IBTs) including the proposed reservoir projects, Naumure and Madi-Dang, can supply 51,000 ha in the Kapilvastu District (Terai) and 17100 ha in the Dang Valley (Babai Basin). These IBTs will benefit regional agricultural production, but may affect water security for downstream drinking water and irrigation uses • Irrigation by surface water in the Deukhuri Valley is frequently limited in December and January. The Naumure Dam may provide relief for water users diverting from the lower West Rapti River. • Climate change will increase extreme precipitation events and duration of drought.
HP	• Currently, the Jhimruk ROR (12 MW) is in operation. • Naumure Dam (230.0 MW) is a multi-purpose storage reservoir proposed by the IMP, HDMP. Primary purpose is irrigation with secondary HP benefits. • A HPP at the end of the Kapilbastu Diversion IBT tunnel could provide 100 MW of energy as a secondary benefit to the delivery of irrigation water. This is proposed in the IMP, HDMP • Madi Dang Dam (61 MW) is a multi-purpose storage reservoir that was deemed economically unfeasible in the HDMP and IMP. Primary purpose is irrigation with secondary HP benefit.

Water Resources Development Issues	
	• The full Installed Capacity potential in the basin is 407.2 MW. This is 1% of the target Installed Capacity in the HDMP scenarios.
ENV-SOC	• In the West Rapti Basin, the southern border of Banke National Park and its buffer zone follow the north bank of the West Rapti River through the Deukhuri Valley. Satisfying e-flows is important for maintaining biodiversity of these conservation areas. • The West Rapti, Madi, and Jhimruk Rivers are home to up to 66 species, 9 of which are threatened or near-threatened. The rivers are inhabited by mahseer and snow trout, the latter of which uses the Jhimruk River as spawning habitat. • Jhimruk Khola breeding and nursing and migrate to the West Rapti River for rearing juveniles and adult habitat. Furthermore, these species migrate in response to stream temperatures and turbidity associated with snow melt. • The major livelihood in the basin is agriculture with local communities using river water for irrigation. • Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages. Many Hindu rituals and festivals require the use of holy river water with significant flow. The Swargadwari Temple and Airawati Temple are located on riverbanks and influenced by flows. • Regional benefits of development can lead to lower food prices, increased labour opportunities, and increased and more reliable secure drinking water and electrical supply.

The current River Basin Plan has considered Naumure Dam as an option for basin development, which will also supply irrigation water to about 51,000 ha in Kapilvastu. In addition, the IMP has proposed a Storage Reservoir Dam (Mad-Dang Diversion) further upstream in the Madi River, with a hydropower capacity of 61 MW to divert water irrigation a command area of 17,000 ha in the Dang District, outside the basin. These two interventions are the key infrastructure assessed in the river basin plan for West Rapti Basin. It should be noted that the Madi Dang Dam multi-purpose storage reservoir was deemed economically unfeasible in the HDMP and IMP.

2.1.5 Gandaki Basin

The Gandaki River is a transboundary river flowing through China, Nepal and India, meeting the Ganges River on the left bank at Konhara Ghat, Hajipur, India. The total catchment area of Gandaki Basin at Nepal at Nepal-India border is 36,497 km^2, of which about 11.9% is in China (Figure 2-7).

Figure 2-7: Gandaki Basin

The Gandaki Basin is formed by eight major tributaries: Budhi Gandaki, Daurandi, Marsyangdi, Seti, Kaligandaki, East Rapti, Madi, and Trishuli. The Kaligandaki forms the major and larger sub-basin at around 11,900 km² (about a third of the overall river basin area), followed by the Trishuli and Budhi Gandaki at around 7,100 and 5,000 km², respectively and considering the catchment areas in China. The river is also called “Sapta Gandaki” (Seven Gandakis) or Narayani south of Devghat where Kaligandaki and Trishuli converge.

The annual rainfall within the catchment in Nepal is 1823 mm, about 13% higher than the national average of 1,609 mm, and the total basin annual average rainfall is about 1,680 mm. The precipitation over the river basin exhibits considerably spatial variability. While in Lumle Area the average rainfall is 4,000 mm, in Upper Mustang it reduces to 200 mm. The rainfall pattern in the basin in southern side of the Himalayas has almost 80% rainfall in four months (July-October) of wet season and rest over the remaining eight months. March and April are the driest months in the basin. The basin’s river system is fed by snow melt, springs, and direct runoff originating from rainfall. In the wet season (monsoon), heavy rainfall can lead to water-induced disasters such as floods, inundations, and landslides. During winter, the basins’ rivers have relatively low discharge and are calm.

The average annual discharge at the Nepal-India border 1,952 m³/s equivalent to 61,568 million cubic meters, the seasonal pattern being influenced by the Monsoon, the period with the highest discharge (about 74% of the average annual runoff) followed by the post monsoon period (about 12%), while during winter and pre-monsoon periods the river discharge is even lower (about 6% and 8% respectively).

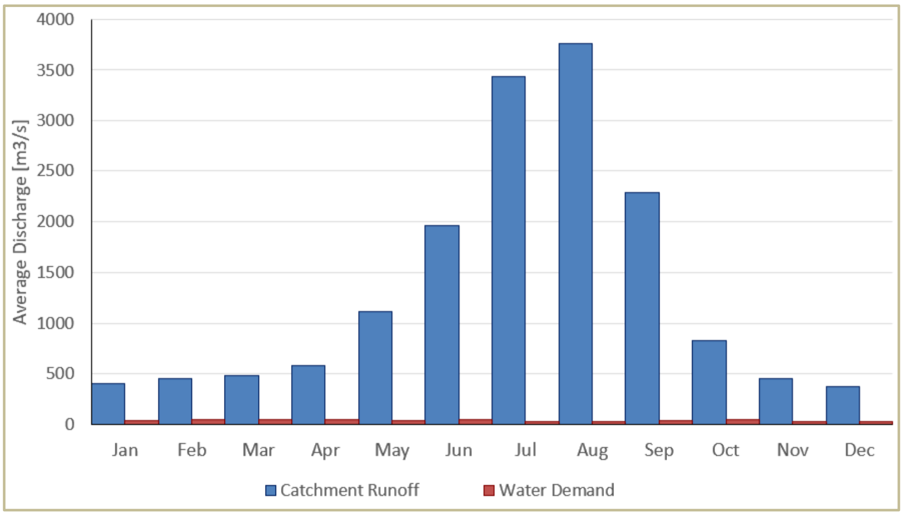


Figure 2-8: Estimated catchment runoff and water demand for the Gandaki Basin

The current water use for drinking water and industry in the basin is small and the projected demand based on projected population growth is expected to be met by the available water sources. The provision of safe water supply to 90% by 2030 of the population is an important policy objective for the GoN.

The basin’s population is anticipated to grow from 4.65 million (2025) to 5.48 million in 2050, an increase of 18%, and drinking water use rate, per capita, will rise by 2050. Population growth and drinking water use rate will be disproportionally increased in urban areas. To accommodate the growth, water demand is projected to increase 77% by 2050: from 312 MLD to 552 MLD. Accounting for the increased water demand, reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.

Table 2-5: Drivers and pressures acting on the hydrological system in the Gandaki Basin

Sector	Water Resources Development Issues
DWS	• The basin’s population is anticipated to grow from 4.65M in 2025 to 5.48M people by 2050, an increase of 18%. Drinking water use rate, per capita, will rise by 2050. • Population growth and drinking water use rate will be disproportionally increased in urban areas.

Sector	Water Resources Development Issues
	• To accommodate the growth, water demand is projected to increase 77% by 2050: from 312 MLD to 551.8 MLD. • Accounting for the increased water demand, reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.
IRR	• By 2050, the surface water irrigation in the basin is projected to increase from 64838 ha to 96933 ha: a 50% increase in command area within the basin • The extension of irrigated land is primarily 61% in the hills (19553 ha) with the Terai expanding by 26% (8461 ha), and the mountains by13 % (4083 ha). • Climate change is projected to increase extreme precipitation and flood events, and duration of drought.
HP	• Currently, 49 operating ROR and PROR HPP have an Installed Capacity of 808.7 MW in the Gandaki Basin • 105 HPPs with constructions licenses have an Installed Capacity of 3470.5 MW. • 2 Mega HPP, under study by DoED, could potentially increase Installed Capacity by 1527 MW. These include Budhi Gandaki Mega HPP (STOR Installed Capacity 1200 MW) and Upper Marsyadi-2 (PROR Installed Capacity 327 MW). • The Kaligandaki – Tinau Diversion MPP will have 101 MW that is a side benefit of surface irrigation water delivery. • 37 favourable greenfield HPP have been identified in the HDMP with a combined Installed Capacity of 6304 MW. • In total, the potential increase in Installed Capacity from HP is 12123 MW.
ENV-SOC	• Four national parks, 2 conservation areas and one hunting reserve (Chitwan, Langtang, Parse, and Shivapuri), the Annapurna and Manaslu Conservation Areas, and the Dhorpatan Hunting Reserve lie in the basin. The location of several construction license, mega, and greenfield HPPs are within these areas. • Ramsar has identified three significant wetlands in the basin: Beeshazar and Associated Lakes (3,200 ha) lie in the buffer zone of Chitwan National Park, Gosaikundais an alpine freshwater oligotrophic lake in Nepal's Langtang National Park (1,030 ha), and the lake cluster of Pokhara Valley (17,900 ha) • Approximately 2,800 ha of proposed irrigation schemes affects the Chitwan National Park. 19 proposed new schemes lie on the left bank of East Rapti river inside the park. Further upstream, another proposed scheme of 143 ha lies inside the Parsa National Park. Most of the HPPs in the basin identified are hydropeaking. The frequently and rapidly changing discharges and water levels may be dangerous for people bathing in the river downstream of the dam. • Mahseer and snow trout use the Budhi Gandaki, Kali Gandaki, Trishuli, Marsyandi, Seti, and Narayani Rivers are the habitats for the mahseer and snow trout. In general, reaches in higher elevation are used for spawning and rearing with adults migrating to lower reaches of the Gandaki River for adult habitat. • Dolphin and gharial, major species depending on the flow regime, are found in lower reaches of the Gandaki Basin. • The major livelihood in the basin is agriculture with local communities using river water for irrigation. Communities living near national parks and conservations area rely on nature-based tourism. • River dependent vulnerable groups in the basin are Bote, Mushahar, Kumal and Darai who depend on fishing in the river system. The population of Bote is mainly concentrated on the Rapti and Narayani Rivers' (Chitwan and Nawalparasi Districts) and in Tanahu District near the Seti River.

Sector	Water Resources Development Issues
	• Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages. Many rituals and festivals require the use of holy river water with significant flow. The basin has two religiously important sites at the flood plain of rivers: Triveni Dham and Devghat Dham.

The surface and ground water are the major water resources in the basin to meet the water supply demand and the irrigation water in the agricultural area. About 668,857 ha of the land is currently under cultivation (based on land use/landcover map prepared under IMP), out of which, 467,596 ha of land is suitable for irrigation (Suitability classes S1 to S4, IMP) within the basin. The irrigation inventory prepared under the IMP included gross command area of only 64,838 ha. The adjacent Terai districts in Southern Block 2A which has considerable land suitable for irrigation (223,953), but lacks the water resources within the Terai districts, that can be irrigated from diversions from the Gandaki and West Rapti River Basins. It is estimated that the current water use within the basin is 1,155 Mm^3. The potential water use in the basin and IBT (2,701 Mm^3) is much less than the available water resources (61,568 Mm^3 at Gandaki River at Nepal-India border). The Gandaki Basin is thus considered a “water surplus” basin as the water available is sufficient to meet the year-round water supply and the irrigation demand of the potential agricultural areas within the basin and the adjacent Terai region which has the potential to be irrigated by diversions from the Gandaki River. However, some deficits may occur during the dry season of dry years,

The surface water available in the basin has the potential to meet the irrigation requirements for adjacent water deficit districts in the Southern Block 2A. The IMP has considered 3 inter-basin diversion projects from the Gandaki Basin, namely: Kaligandaki – Tinau, Kaligandaki – Nawalparasi, and Trishuli Shaktikhor. Of the 3, only Kaligandaki-Tinau IBT was considered favourable in the IMP and assessed in this river basin plan.

There are currently 46 hydropower projects with a total capacity of 777 MW in operation, and construction licenses has been issued to 99 number of projects with 3131 MW capacity in the basin. There are 2 mega projects under study: Budhi Gandaki Mega HPP (STOR Installed Capacity 1200 MW), Upper Marsyadi-2 (PROR Installed Capacity 600 MW). The IMP identified the Kaligandaki-Tinau Diversion IBT as a multipurpose project with 244 MW capacity. Hydropower Development Master Plan has identified 107 greenfield projects of which 47 are recommended providing an additional 6304 MW of IC. With 12123 MW of IC, the Gandaki Basin provides a good potential for hydropower development to meet national and export energy demands.

The scenarios and development paths assessed in the Basin Plan includes the above interventions to meet the projected water demand for various uses, including water supply, irrigation, hydropower requirement, and other environmental and ecological requirements of the river. The Gandaki Basin hosts some of Nepal's most famous national parks and conservation areas such as the Chitwan National Park and the Annapurna and Manaslu conservation areas, and a diverse floral habitat and numerous wildlife species.

The location of several construction licenses, mega, and greenfield HPP are within these areas. The environmental sensitivities of development activities on the national parks and conservation zones, flow requirements of the downstream water use, river connectivity are important parameters for any basin development interventions in the Gandaki Basin.

2.1.6 Kamala Basin

Kamala Basin is a rain-fed, medium sized river basin with a catchment area of about 2,219 km^2 at the Nepal-India border (Figure 2-9). The Basin the southern part of the Eastern Region of Nepal draining parts of the Sindhuli, Udaypur, Siraha and Dhanusha districts in Koshi, Madhesh and Bagmati Provinces. The Kamala River originates from Mahabharat range and drains south to the Gangetic plain after crossing the Nepal-India border.

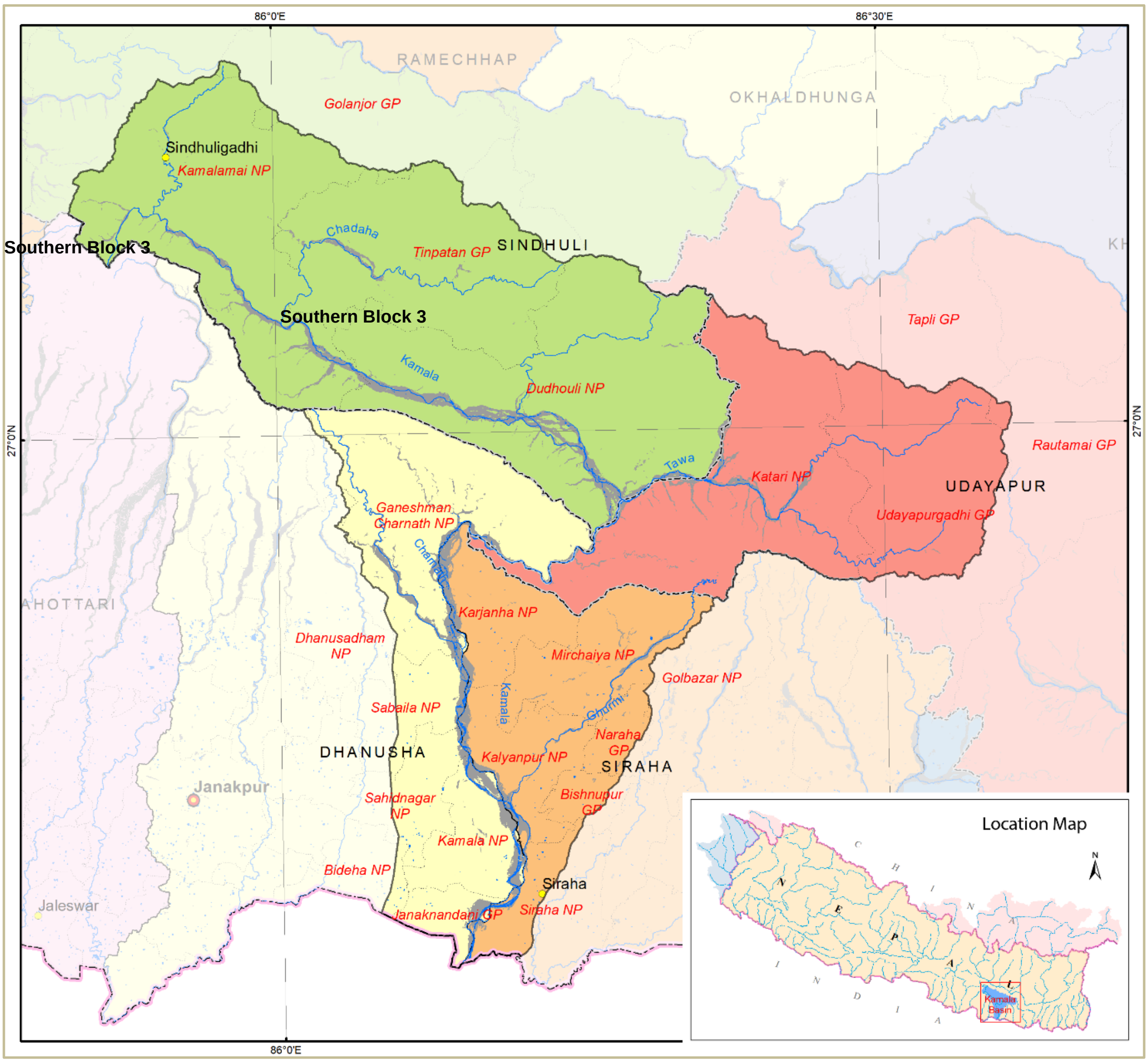


Figure 2-9: Kamala Basin

The basin receives an average annual rainfall of about 1,629 mm, 80% of which is in the monsoon season from June to September. The spatial variability is high, with the northwest of the basins averaging above 2,200 mm while in some northeastern areas the averages are below 1000 mm. The intra-annual rainfall pattern is dominated by the summer monsoon (June to September), time during which the basin receives about 80% of its annual rainfall, while winter (November to January) accounts for only about 2% of the rainfall. November and December are the driest months in the basin.

The surface and ground water are the major water resources in the basin to meet the water supply demand and the irrigation water in the agricultural area. The Kamala Basin is considered a “water deficit” basin as the dry season water availability is not currently sufficient to meet the year-round irrigation demand of the potential agricultural areas within the basin and the adjacent Terai region which has the potential to be irrigated by the Kamala River.

The current water use for drinking water and industry in the basin is small and the projected demand based on projected population growth is expected to be met by the available water sources. The current command area irrigated by surface water within the basin is 48,663 ha, and the projected irrigated command area within the basin in 2050 is 57,016 ha, out of the total agricultural land equal to 80,917 ha. However, there is a potential of irrigating about 65,834 ha of agricultural land within the basin. The current water availability, especially in the dry season, is insufficient to meet the irrigation requirement in the Basin (Figure 2-10).

The adjacent Terai districts east of Bagmati River and west of Koshi River, have vast agricultural areas that are rain-fed. A Sunkoshi-Kamala Interbasin diversion project is considered to bring water from the Sunkoshi River, Koshi Basin through 17 km tunnel diverting 72 m³/s to irrigate an area of 129,00 ha of land in the adjacent districts of the Terai and generate 44 MW power. There are no operational or planned hydropower projects in the basin, except the one with the Sunkoshi-Kamala interbasin transfer.

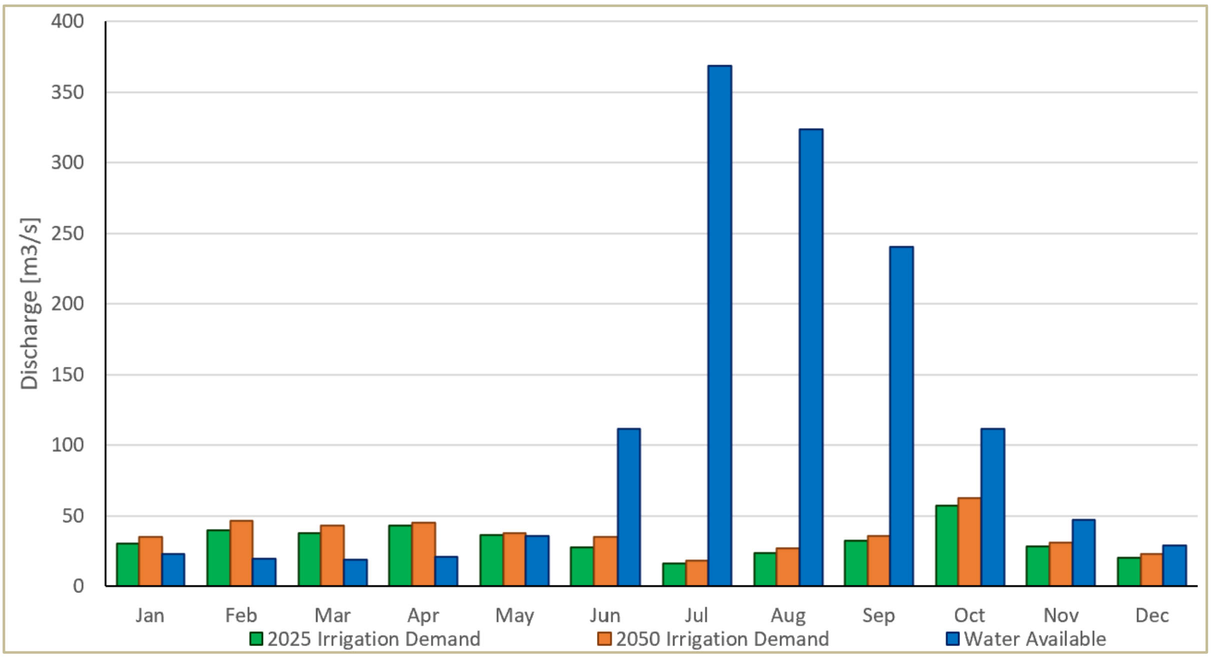


Figure 2-10: Monthly catchment runoff and irrigation water demand in 2025 and 2050

Table 2-6: Drivers and pressures acting on the hydrological system in the Kamala Basin

Sector	Water Resources Issues
DWS	• Kamala Basin's population is anticipated to grow from 0.69 M to 0.82 M people by 2050, so growth is 18.6%. A strong growth of the urban population is expected (from 10% of the basin population to 30%) as municipal populations become urbanized and rural population moves to urban. Drinking water use rate, per capita, will increase over the planning period. • The growth will be disproportionally increased in urban areas 18% in comparison to 5% in rural areas. • To accommodate the growth, water demand within the basin is projected to increase 63% by 2050: from 43.4 MLD to 70.7 MLD. • Reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.
IRRG	• Kamala Basin is 1.5% of the area of Nepal and has 3% of all land suitable for irrigation; the availability and quality of land suitable for irrigation is high. • The population density is 3 persons/ha, which is moderate. Urbanization is expected to occur rapidly, from about 10% of the population now to 30% by 2043, but the rural population will increase much more slowly. • About one third of the basin is located on the Terai where irrigation from groundwater and surface irrigation by water transfer is feasible, therefore the opportunities for improvements in agricultural production are good, additional opportunities to increase the area of gravity/pump schemes in the Hills exist. • The demand for food is not expected to grow significantly but there may be increased demand for higher value crops. • The IMP has identified 38 small- to large-scale pump lift and gravity irrigation schemes in the hills and inner Terai to expand irrigation. Approximately 8,353 ha are recommended for expansion in the IMP.

Sector	Water Resources Issues
	• The Kamala Dhanusha and Kamala Siraha IPs irrigate 47,209 ha of the Kamala Basin and Southern Block 3. Current river flow in the Kamala River during February through May is insufficient to meet the irrigation demands. A portion of the water divert by Sunkoshi-Kamala Diversion IBT will provide surface water irrigation during the deficit periods. • A Sunkoshi-Kamala Interbasin diversion project is considered to bring water from the Sunkoshi River, Koshi Basin through 17 km tunnel diverting 72 m³/s to irrigate an area of 129,00 ha of land in the adjacent districts of the Terai and generate 44 MW power.
HP	• The Kamala Basin has no hydropower economically favourable HP. The ROR HPP in the Sunkoshi-Kamala Diversion IBT will have an installed capacity of 44 MW.
ENV-SOC	• Fish species richness is high in the Kamala River and its tributaries with 81 species. Four of these are listed as “threatened” by the IUCN. • Within the Kamala River system, there is one long distance, 7 medium distance and 5 short distance migratory fish species. The upstream section including Chanda and Tawa Khola are still free flowing while the downstream section of the main river is impacted with reducing the river connectivity. • There are no legally protected areas, IBAs, or Ramsar Sites in the basin, but the Kamala River flows through the Chure Hills Conservation zone. • Most of the cultural and pilgrimage sites are located either on the bank of the river or at the temple sites. The confluence of Tawa Khola and Kamala River is called Tribeni and is considered a holy site.

The scenarios and development paths assessed in the Basin Plan include the above interventions to meet the projected water demand for various uses, including water supply, irrigation, hydropower requirement, and other environmental and ecological requirements of the river. No protected areas lie within the Kamala Basin, but the Kamala River flows through the Chure Hills Conservation zone.

2.1.7 Koshi Basin

The Koshi Basin is a transboundary river basin – stretching over the territories of Nepal and China – located in eastern Nepal. The Kalinchowk Mountain ridge divides the Koshi Basin from the other western basins of Nepal. The catchment area of the Koshi Basin is 56,145 km² at the Nepal-India border, of which about almost half (27,818 km²) lies within Nepal. The basin contains the high Himalayas rising to above 8,000 m in the north, including Sagarmatha (Mt Everest, 8,848.86 m), the highest mountain in the world. The southern area, called Terai in Nepal, is a part of the flat lands of the Gangetic Plains with elevation as low as 65 m. In Nepal, the basin areas cover parts of the Koshi, Madhesh, and Bagmati Provinces (Pradesh) of Nepal (Figure 2-11).

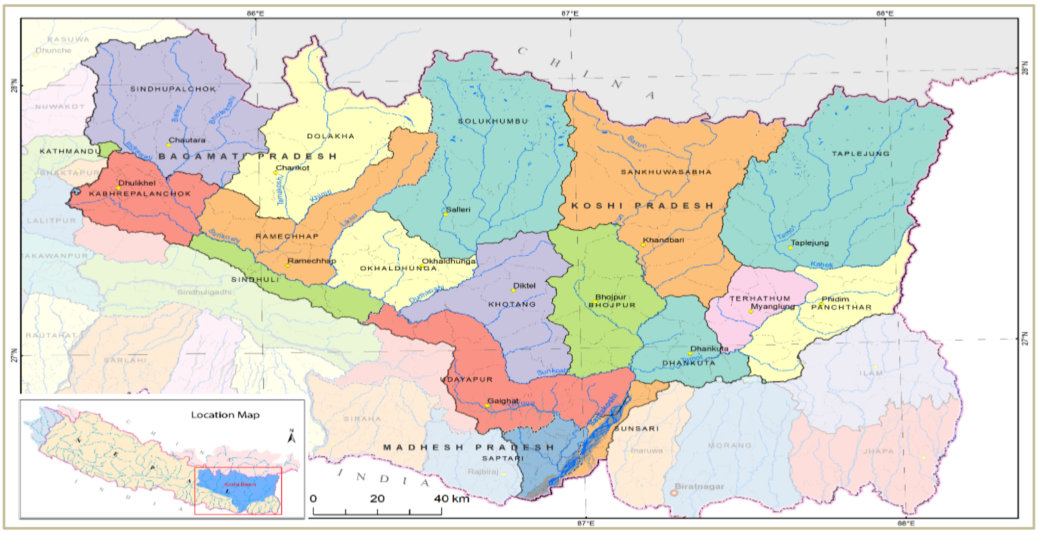


Figure 2-11: Koshi Basin

The annual rainfall within the catchment in Nepal is 1,667 mm, about 4% higher than the national average of 1,609 mm, and the total basin annual average rainfall is about 1,032 mm. The river system of the Koshi Basin is fed by snow and glacial melt, groundwater springs, and direct runoff originating from rainfall. The seasonal rainfall distribution pattern is 16% of rainfall in pre-monsoon (March, April, May), 77% of rainfall in monsoon (June, July, August, September), 5% of rainfall in post-monsoon (October, November), and 3% in the winter season. In the wet season (monsoon), the heavy rainfall can lead to water-induced disasters such as floods, inundations, and landslides, while during the dry season, especially from January to March, the river flows can reduce up to about 10 times their peaking, generally in August (Figure 2-12).

The average annual discharge of the Koshi Basin at Nepal-India border is estimated as 1,827 m³/s equivalent to 57,601 million cubic meters. The intra-annual runoff pattern is heavily influenced by the monsoon, the period with the highest discharge (ranging between 67 and 78% of the average annual runoff) followed by the post-monsoon period (between 11 and 14%), while during winter and pre-monsoon periods the river discharge is even lower (between 5 and 11%).

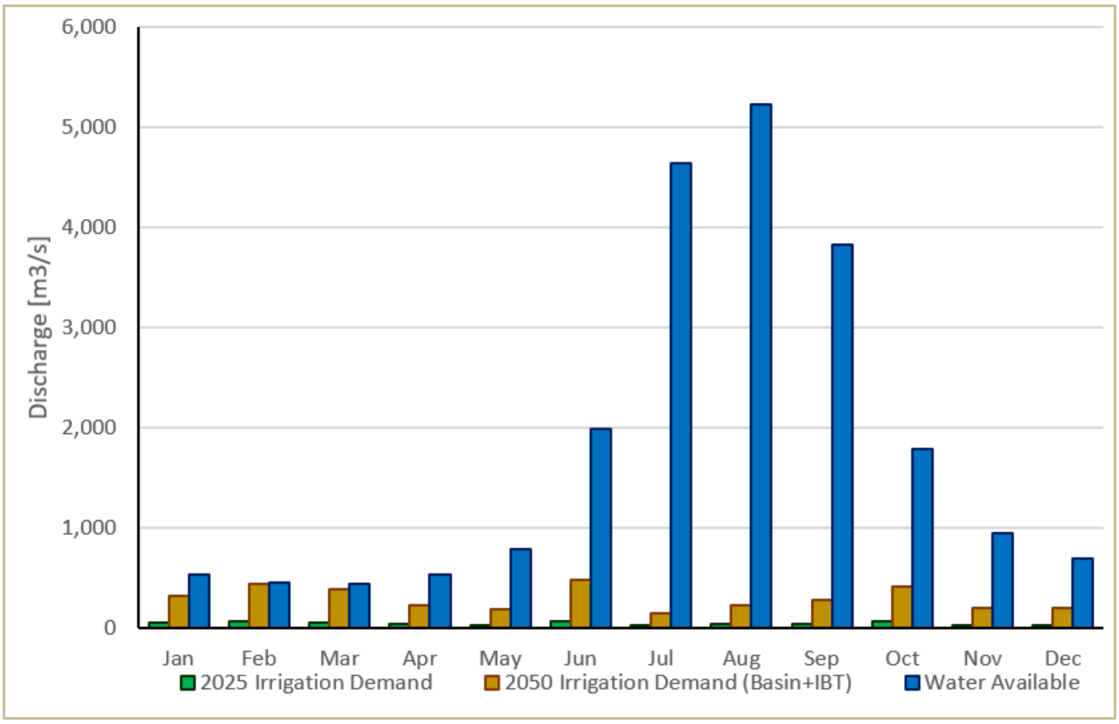


Figure 2-12: Catchment runoff and irrigation demand for 2025 and 2050.

The surface and ground water are the major water resources in the basin to meet the water supply demand and the irrigation water in the agricultural area. About 624,516 ha of land currently under cultivation (based on landuse/land cover map prepared under IMP), out of which, 316,826 ha of land is suitable for irrigation (Suitability classes S1 to S4, IMP) within the basin. The irrigation inventory prepared under the IMP included a gross command area of only 81,813 ha, which shows that information on many projects is not yet available. The adjacent Terai districts in Southern Blocks 3 and 4, having considerable land suitable for irrigation, lack the water resources within the Terai districts that can be irrigated from diversions from the Koshi Basin. It is estimated that the current water use for irrigation within the basin is 1,254 Mm³. The potential water use in the basin (9,070 Mm³) is much less than the available water resources (5,760 Mm³). The Koshi Basin is thus considered a “water surplus” basin as the water available is sufficient to meet the year-round water supply and the irrigation demand of the potential agricultural areas within the basin and the adjacent Terai region which has the potential to be irrigated by diversions from the Koshi River.

The surface water available in the basin has the potential to meet the irrigation requirements for adjacent water deficit districts in the Southern Blocks 3 and 4. The IMP has considered 3 inter-basin diversion projects from the Koshi Basin, namely: Sunkoshi- Marin, Sunkoshi – Kamala and Tamor- Morang.

Table 2-7: Drivers and pressures acting on the hydrological system in the Koshi Basin

Sector	Water Resources Development Issues
DWS	• The basin's population is anticipated to grow from about 2.99 M in 2025 to about 3.3 M people by 2050. Drinking water use rate, per capita, will rise by 2050. • Population growth and drinking water use rate will be disproportionally increased in urban areas. • To accommodate the growth, water demand within the basin is projected to increase 49% by 2050: from 175.3 MLD to 262.0 MLD. • Through the Melamchi, Yangre and Larke IBT, 570 MLD will be available to the 4.43 M people in the Kathmandu Valley in 2050. • Accounting for the increased water demand, reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.
IRRG	• Koshi Basin is 19% of the area of Nepal and has 12% of land suitable for irrigation; this is below average but the availability and quality of land suitable for irrigation is higher than the comparable basins Gandaki and Karnali. About 13% of the basin is located on the Terai where irrigation from groundwater and surface irrigation by water transfer is feasible, therefore the opportunities for improvements in agricultural production are good, additional opportunities to increase the area of gravity/pump schemes in the Hills exist. • By 2050, the surface water irrigation in the basin is projected to increase from 81,813 ha to 106,399 ha: a 30% increase in command area within the basin. • The extension of irrigated land is primarily 70.1% in the hills (17,225 ha) with the Terai expanding by 20.1% (4,953 ha), and 9.8% in the mountains (2,409 ha). • Sunkoshi-Marin and Sunkoshi-Kamala Diversion IBTs have the potential to rehabilitate and expand irrigated lands in Southern Block 3 by up to 351,000 ha. The lands include districts in the Southern Block 3. • Tamor-Morang Diversion IBT diverts 123 m³/s of water from the Tamor River to the Morang District in Southern Block 4. With the Tamor Dam, the project will irrigate 114,000 ha in the Kamala D and Kamala S irrigation systems. • Chatara Barrage diverts 72 m³/s to the Saptari Morang District in Southern Block 4. The diverted water allows 66,000 ha of year-round irrigation in the Sunsari-Morang system. • Combined, the potential regional rehabilitation and expansion of irrigable lands from IBTs is 431,000 ha. • Climate change is projected to increase precipitation events and the duration of drought.
HP	• Currently, 35 operating ROR and PROR HPP have an Installed Capacity of 863 MW in the Koshi Sub basin • 32 PROR and 65 ROR HPP with construction licenses have an Installed Capacity of 2,783 MW. • 10 Mega HPP, under study by DoED, could potentially increase Installed Capacity by 12,448 MW. Storage projects include Sunkoshi-1, Sunkoshi-2, Sunkosi-3, Dudhkoshi, Tamor, and Saptakoshi. • As identified in the IMP, in addition to delivering irrigation water, ROR HPP within the Sunkoshi-Marin, Sunkoshi-Kamala, and Tamor-Morang Diversion IBTs will have a combined Installed Capacity of 208 MW. • 69 favourable greenfield HPPs have been identified in the HDMP with a combined Installed Capacity of 7,263 MW. • In total, the potential Installed Capacity from HP in the Koshi Basin has a potential 23,565 MW.

Sector	Water Resources Development Issues
ENV-SOC	• The designated protected areas in the Koshi Basin are Langtang, Sagarmatha, Makalu Barun, Shivapuri National Parks, Gaurishankar and Kanchenjunga Conservation Area, and Koshi Tappu Wildlife Reserve as well as the Koshi Tappu and Gokyo and associated lakes Ramsar Sites. • Satisfying e-flow requirements is important for maintaining the biodiversity of these protected areas. Proposed interventions such as dams and diversions may be detrimentally impacting the habitat of these fish species as well as the dolphin population in the Koshi Basin. • Agricultural and urban runoff contributes to nutrient loading with negative impacts on water quality. • Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages. Many rituals and festivals require the use of holy river water with significant flow.

As of 1 April 2023, 34 HPPs with a total installed capacity of 1,005 MW are in operation, and construction licenses have been issued for 87 HPPs with 2,783 MW capacity. Under study by the GoN are 10 number of mega projects (installed capacity of 12,448 MW) and 3 multipurpose projects with 208 MW capacity have been proposed in the IMP. HDMP identified 121 new greenfield projects of which 69 are recommended for an installed capacity of 7,263 MW. With 214 HPPs at an installed capacity of 23,565 MW, the Koshi Basin provides significant potential for hydropower development to help reach the national energy demand.

The scenarios and development paths assessed in the Basin Plan include the above interventions to meet the projected water demand for various uses, including water supply, irrigation, hydropower requirement, and other environmental and ecological requirements of the river. The Koshi Basin is home to four national parks, two conservation areas and one wildlife reserve, which including the parks' buffer zones account for a total area of 1,556 km^2 equivalent to about 28% of the basin's surface. The location of several construction licenses, mega, and greenfield HPPs are within these areas. The environmental sensitivities of development activities on the national parks and conservation zones, flow requirements of the downstream water use, and river connectivity are important parameters for any basin development interventions in the Koshi Basin.

2.1.8 Kankai Basin

The basin stretches over three districts draining a total area up to the Nepal-India Border of about 1,332 km^2. Adjacent basins are Mechi, Koshi, and Southern Block 4 (Figure 2-13). The basin receives an average annual rainfall of about 1,999 mm, about 24% higher than the national average of 1,609 mm, approximately 80% of which falls during the monsoon season from June to September. The spatial variability is high, with the areas west and northwest of Ilam averaging between 1,200 to 1,800 mm while the eastern and southern basin areas have averages above 2,200 mm. There is a high variability of surface water availability within the year, with about 77% of the surface flowing in the four monsoon months.

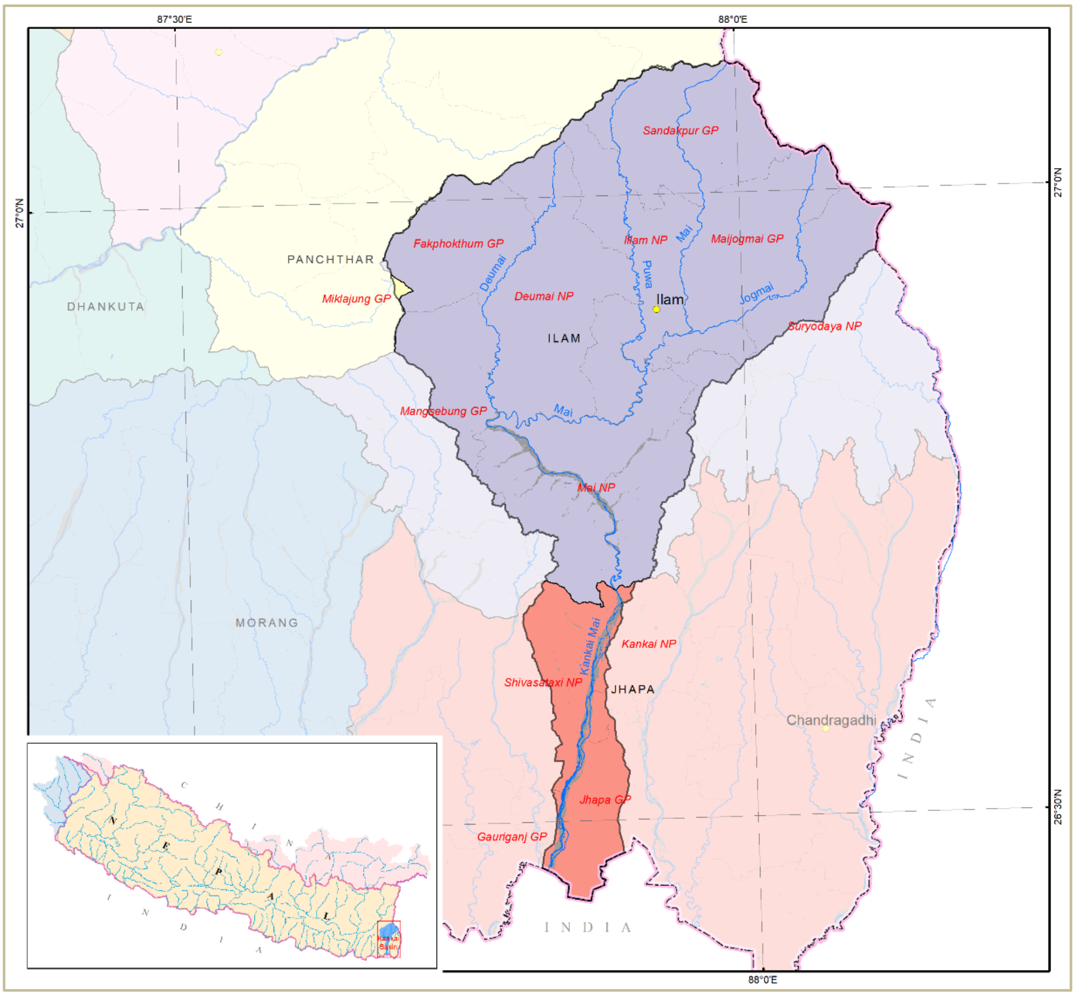


Figure 2-13: Kankai Basin

The surface and groundwater are the major water resources in the basin to meet the drinking water demand and the irrigation water in the agricultural area. The Kankai Basin is considered a “water deficit” basin as the dry season water availability is not currently sufficient to meet the year-round irrigation demand of the potential agricultural areas within the basin and the adjacent Terai region which has the potential to be irrigated by the Kankai River (Figure 2-14).

The current drinking water and industry water use in the basin is small and the projected demand based on forecasted population growth is expected to be met by the available water sources. The current command area irrigated by surface water within the basin is 21,814 ha, and the projected irrigated command area in 2050 is 28,041 ha, out of the total agricultural land equal to 43,089 ha. The future irrigated area is a slightly higher than the irrigation suitable area, which is because part of the Southern Block is also considered through the Kankai MPP. However, there is a potential to irrigate about 40,000 ha of agricultural land in the adjacent Jhapa District in the Terai. The current water availability, especially in the dry season, is insufficient to meet the irrigation requirements in the Kankai and Terai command areas. A Kankai Multi-Purpose Project (MPP) has been proposed in the IMP to provide year-round irrigation to 40,000 ha within the basin and the adjacent agricultural area of SB4, with an HPP having an installed capacity of 90 MW.

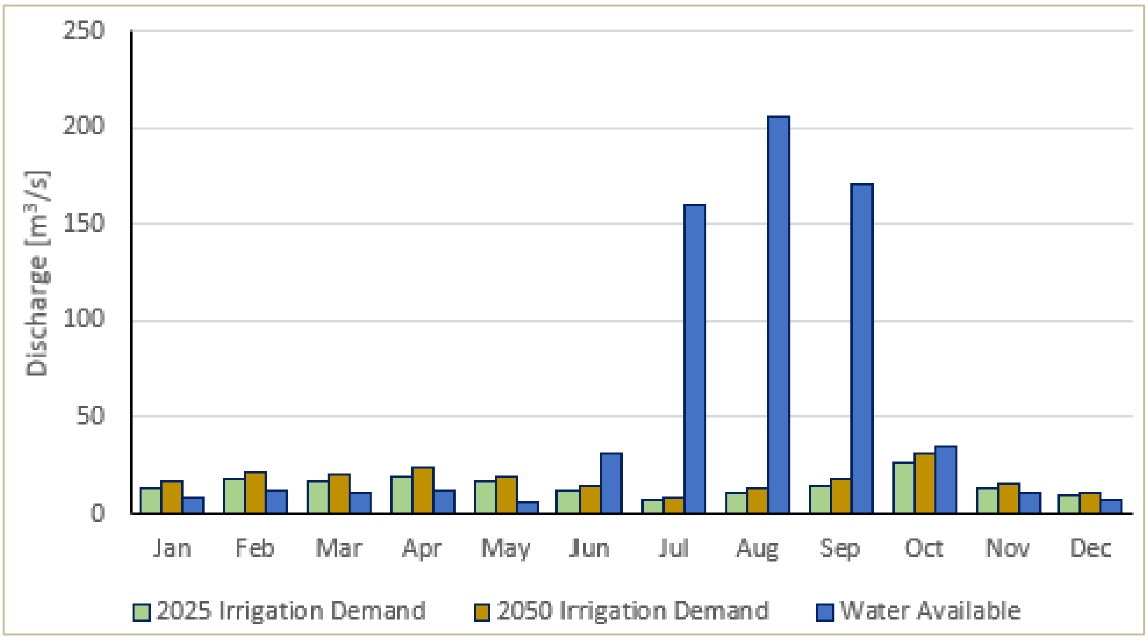


Figure 2-14: Monthly catchment runoff and irrigation water demand in 2025 and 2050

Within the Kankai Basin, there are 15 HPPs currently operating with an installed capacity of 116.5 MW. Construction licenses have been issued to 3 projects with a total installed capacity of 17.0 MW. The HDMP identified four potential greenfield HPPs, but only Kankai071, with an installed capacity of 48 MW, is recommended as an attractive project.

Table 2-8: Drivers and pressures acting on the hydrological system in the Kankai Basin

Sector	Water Resources Development Issues
DWS	• The basin's population is anticipated to grow from 0.29 M to 0.36 M people by 2050, an increase of 23%. Drinking water use rate, per capita, will rise by 2050. • Population growth and drinking water use rate will be disproportionally increased in urban areas. • To accommodate the growth, water demand within the basin is projected to increase 58% by 2050: from 20.5 MLD to 32.4 MLD. • Accounting for the increased water demand, reliable sources of clean, fresh water will be required for drinking, sanitation, and hygiene. • Climate change is projected to increase precipitation events and the duration of drought, potentially affecting the reliable delivery of drinking water supply.
IRRG	• Kankai Basin is only 0.9% of the area of Nepal and has 1% of the total land suitable for irrigation in Nepal, but at the basin level, the availability and quality of land suitable for irrigation is high. • The population density is moderately high (2.4 persons/ha) because nearly one-third of the basin is on the more densely populated Terai. Urbanization is expected to be rapid, but the rural population will increase more slowly; there may be decrease in districts in the Hill physiographic zone. • The demand for food is not expected to grow significantly, but there may be an increased demand for higher-value crops due to urbanization. • About 28% of the basin is located on the Terai where irrigation from groundwater and surface irrigation by water transfer is feasible, therefore the opportunities for improvements in agricultural production are good. • The IMP identified opportunities to expand the irrigated area (approximately 1,210 ha) of gravity/pump schemes in the Hills exist.

Sector	Water Resources Development Issues
	• The irrigation area will increase from 21,814 ha (2025) to 28,041 ha in 2050, • Kankai Basin has good water resources but good quality land to use it is limited, hence the Kankai MPP is being reconsidered to export water to adjacent basins, Kankai MPP has been re-designed to improve economic indicators. • To accommodate the projected irrigation expansion within the basin, water delivery will increase from 16.0 to 25.6 m³/s. • Current climate variability and future climate change impact operation.
HP	• Currently, 15 ROR HPPs with an Installed Capacity of 116.5 MW are operating in the Kankai Basin • 5 HPPs with construction licenses have an Installed Capacity of 30.3 MW. • The Kankai Multi-Purpose Project (MPP) is a storage project with 90 MW installed capacity. • Of the 4 greenfield HPPs identified, 1 favourable PROR was selected with an Installed Capacity of 48 MW. • In total, the potential Installed Capacity from HP in the Kankai Basin has a potential of 264.7 MW. • The potential Installed Capacity represents the national installed capacity targets, the installed capacity contributes to 0.6%, 0.8%, and 1.4% for the Baseline, Scenario 1, and Scenario 2 as outlined in the HDMP.
ENV SOC	• Fish species richness is high in the Kankai River and its tributaries. Two IUCN red-listed species under the category of endangered and Near Threatened are present in the basin. Similarly, one endemic species is found in the basin. • The Kankai River consists of 4 medium and 3 short migratory fish. The connectivity of the mainstem of the Kankai Mai River and the tributaries Puwa Khola, Jogmai Khola, and Mai Khola is not free-flowing and obstructed upstream-downstream interaction. However, the Beumai Khola and other small tertiary rivers have good connectivity. The proposed hydropower and inter-basin transfer projects will further impact the river connectivity in the basin. • Most of the cultural and pilgrimage sites are located either on the bank of the river or at the temple sites. Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages. Many rituals and festivals require the use of holy river water with significant flow. The Kankai Mai Dham is located on the bank of the Kankai River in the Jhapa District.

The scenarios and development paths assessed in the Basin Plan include the above interventions to meet the projected water demand for various uses, including water supply, irrigation, hydropower requirement, and other environmental and ecological requirements of the river. Though no protected areas lie within the Kankai Basin, the Puwa, Mai, and Jo are important habitats for endangered species. The location of several construction licenses, mega, and greenfield HPPs are within these areas. The environmental sensitivities of development activities in the national parks and conservation zones, flow requirements of the downstream water use, and river connectivity are important parameters for any basin development interventions in the Kankai Basin.

2.1.9 Mechi Basin

The Mechi River Basin is a transboundary river basin located in the eastern-southern tip of Nepal in Mechi Zone, Koshi Province. The total area of the basin up to the Nepal-India border is about 806 km², of which about 88 % of the land (about 708 km²) lies in Nepal and the rest is in India. In Nepal, the basin covers about 0.5 % of the country's land area. Adjacent to the Mechi Basin are Southern Block 4 and Kankai Basin (Figure 2-15).

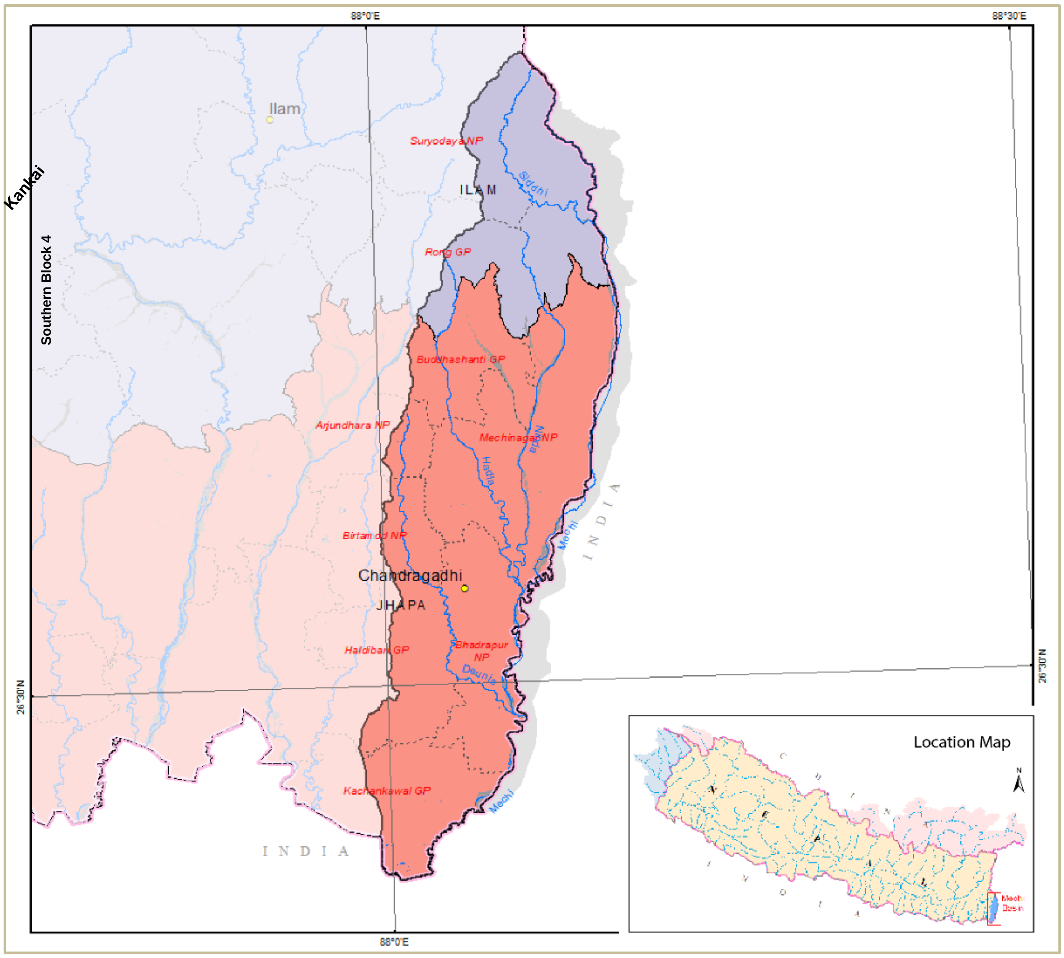


Figure 2-15: Mechi Basin

The annual rainfall within the catchment in Nepal is 2,735 mm, about 70% higher than the national average of 1,609 mm, and the total basin annual average rainfall is about 2,764 mm. The spatial variability is high, with the northeast of the basin averaging above 3,200 mm while the southern basin areas around Chandragadhi have averages below 2,400 mm. The intra-annual rainfall pattern is dominated by the summer monsoon (June-September), a time during which the basin receives about 80% of its annual rainfall. The pre-monsoon – March to May – counts with about 12% of the average annual rainfall, followed by the post-Monsoon with about 5%. Winter – December to January – is the driest period in the basin, averaging about 1.2% in which the driest month December contributes to only 0.2% of the yearly average rainfall.

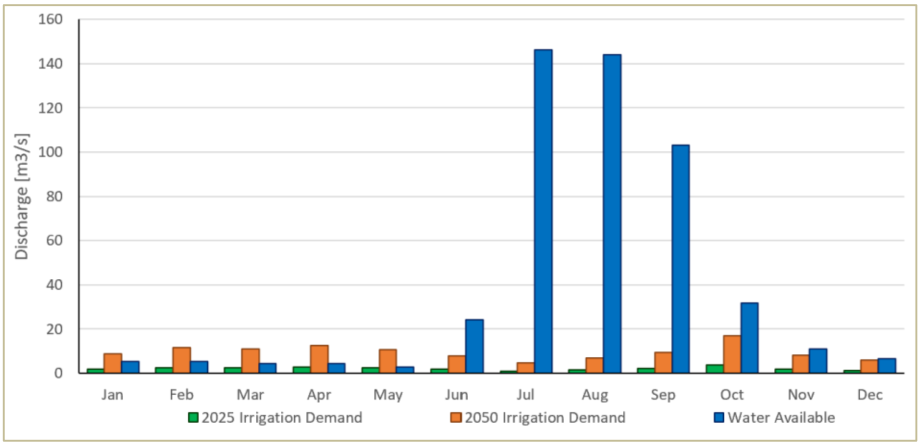


Figure 2-16: Monthly catchment runoff and irrigation water demand in 2025 and 2050

The surface and groundwater are the major water resources in the basin to meet the drinking water demand and the irrigation water in the agricultural area. The Mechi Basin does receive higher rainfall than the national average, but the water availability in the dry season is not adequate to meet the year-round irrigation demand of the potential agricultural areas within the basin and the adjacent Terai region.

The current water use for drinking water and industry in the basin is small and the projected demand based on projected population growth is expected to be met by the available water sources. The current command area irrigated by surface water within the basin is 3,136 ha, and the projected irrigated command area in 2050 is 31,559 ha. The total agricultural land is 41,152 ha, out of which 34,325 ha is considered suitable (S1 – S4) for irrigation by the IMP.

As of 1 April 2023, no hydropower projects are in operation in the Mechi Basin. The Siddhi Khola HPP, with an installed capacity of 10 MW, has a construction license. No mega, IMP or greenfield projects have been identified as economic feasible in the basin.

Table 2-9: Drivers and pressures acting on the hydrological system in the Mechi Basin

Sector	Water Resources Issues
DWS	• The basin's population is anticipated to grow from 0.38 M to 0.44 M people by 2050, an increase of 15.8%. The population density is high (5 persons/ha). Drink water use rate, per capita, will rise by 2050. • Population growth and drinking water use rate will be disproportionally increased in urban areas. It is assumed that 75.8% of the total population lives in urban municipalities, whereas 24.2 % live in rural municipalities. • Urbanization is expected to occur rapidly, from 14% in 2021 to over 40% in 2043. • To accommodate the growth, water demand within the basin is projected to increase 62% by 2050: from 27,6 MLD to 36.8 MLD. • Accounting for the increased water demand, reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.
IRRG	• Mechi Basin is only 0.5% of the area of Nepal but has 2% of all land suitable for irrigation and about 53% of the basin total area is suitable for irrigation; the availability and quality of land suitable for irrigation is high. • About 75% of the basin is located on the Terai where irrigation from groundwater and surface irrigation by water transfer is feasible • Within the basin, irrigation area s projected to expand from 3,136 ha to 31,559 ha by 2050. • There is very little suitable land available in Mechi's Hills region for additional gravity pump irrigation
HP	• Currently, there are no operating HPP in the Mechi Basin • One ROR HPP with a construction license has an installed capacity of 10.0 MW. • There are no mega projects under study by the GoN. • There are no multi-purpose projects with HP listed in the IMP. • No greenfield projects were identified by the HDMP.
ENV-SOC	• The Kanchenjunga Landscape support biodiversity and provide valuable habitat for endangered species of fish, birds, and mammals. • Maintain healthy stocks of migratory and none-migratory fish species. Preserve environmental flow requirements to sustain biodiversity. • Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages. Many Hindu rituals and festivals require the use of holy river water with significant flow. No significant religious sites are within the Mechi Basin. • The major livelihood in the basin is agriculture with local communities using river water for irrigation. • River and wetland ecosystem services that contribute to local livelihoods include subsistence fisheries and livestock grazing on floodplain grassland. Especially the

Sector	Water Resources Issues
	livelihood of riparian communities who depend on the river livelihood such as Bote, Majhi, Tharu, Mallah and Mushahar can be affected with reduced water flow regime. These communities depend on river fishing and reduced water level will drastically reduce the fishing opportunities.

The scenarios and development paths assessed in the Basin Plan includes the above interventions to meet the projected water demand for various uses, including water supply, irrigation, hydropower requirement, and other environmental and ecological requirements of the river. Though no protected areas lie within the Mechi Basin, the location of several construction licenses HPP and irrigation diversion threaten to disrupt freshwater ecosystems of the Siddhi River. The environmental sensitivities of development activities on the national parks and conservation zones, flow requirements of the downstream water use, river connectivity are important parameters for any basin development interventions in the Mechi Basin.

2.1.10 Southern Blocks

The river systems directly originating from the Siwalik (Chure) range are categorized as Southern Blocks. Four Southern Blocks are identified starting from west to east (Figure 2-17).

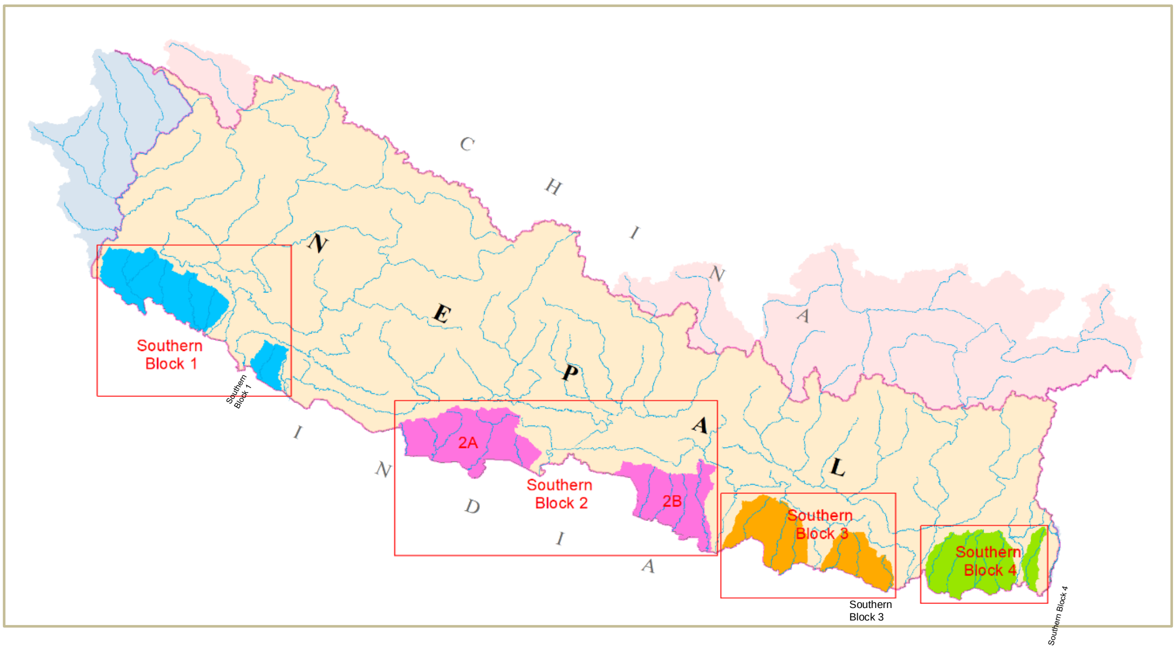


Figure 2-17: Southern Blocks 1 to 4

The catchment area between Mahakali Basin and West Rapti Basin is defined as Southern Block 1, which is located in the far western part of Nepal. The Karnali Basin and Babai Basin separate this block into two parts. The total catchment area of Block 1 up to the Nepal- India Border is 4,821 km². The altitude of the Block 1 area in Nepal ranges from 125 m to 1,959 m. About 78.5 % of the area of Southern Block 1 lies in the Terai region whereas the Siwalik region covers about 21.5 % land. The main rivers in Southern Block 1 are Mohana and Khutiya in Kailali and Dodha in Kanchanpur districts. Other rivers are Chaudhara, Shyali, Banhara, Surmi, Godavari, and Manohara (tributaries of Mohana), Shivaganga (Tributary of Khutia), and Godkhola-Karha nadi. There are two small river systems namely, Kiran and Jethan Nala in the eastern sub-block of Banke District.

The catchment area originating from Mahabharat and Siwalik (Chure) range between West Rapti Basin and Gandaki Basin in Lumbini Province is defined as Southern Block 2A. The total catchment area of the block up to the Nepal-India Border is about 4,395 km². The altitude of the area in Nepal ranges from 79 m to 2,268 m. About 69.4 % of the area of Southern Block 2A lies in the Terai region whereas the Middle Mountain and Siwalik regions cover about 9.9% and 20.7% land, respectively. The main rivers in Southern

Block 2A, Banganga, Tinau, Dano, Rohini Mahao, and Jharahi. Tinau and Banganga originate from the Mahabharat range and other smaller rivers originate from the Chure hills.

The catchment area originating from Mahabharat and Siwalik (Chure) range between Gandaki Basin and Bagmati Basin in Madhesh and Bagmati Provinces is defined as Southern Block 2B. Districts in the block are Bara, Parsa, Makwanpur, and Rautahat. The total catchment area of the block up to the Nepal-India Border is about 3,397 km². The altitude of the area in Nepal ranges from 70 m to 2,135 m. The main rivers in Southern Block 2B are Lal Bakeya, Pasaha, Tilabe, and Sirsiya. Except for the Lal Bakeya, which originates from the Mahabharat range, all other smaller rivers originate from the Chure hills.

The catchment area originating from Siwalik (Chure) range in between Bagmati Basin and Koshi Basin is defined as Southern Block 3. It is located in the central part of Nepal in Sarlahi, Mahottari, Dhanusa, Siraha, and Saptari in Madhesh Pradesh. The Kamala Basin separates the block into two parts. The total catchment area of the block up to the Nepal-India Border is about 4,425 km². The altitude of the area in Nepal ranges from 60 m to 964 m. About 81 % of the area of Southern Block 3 lies in the Terai region whereas the Siwalik region covers only 19 % land.

Southern Block 4 lies in Koshi Province. The catchment area originating from Mahabharat and Siwalik (Chure) range between Koshi Basin and Mechi Basin is defined as Southern Block 4 which is located in the eastern part of Nepal. Districts in the basin are Sunsari, Morang, Ilam, Jhapa, Panchthar, and Dhankuta in Koshi Province. The Kankai Basin separates the block into two parts. The total catchment area of the block up to the Nepal-India Border is about 3,978 km². The altitude of the area in Nepal ranges from 60 m to 2,410 m. About 81.4 % of the area of Southern Block 4 lies in the Terai region whereas the Middle Mountain and Siwalik regions cover about 7.5% and 11.1% of land respectively. The main rivers in Southern Block 4 are Budhi, Lohandra, Chisang, Bakraha, Ratuwa, Kamal, and Biring. These rivers originate from the Chure hills and drain to India.

The Southern Blocks are crossed by many small rivers that flow into India. These rivers are mostly ephemeral rivers that have water only in the wet months during the monsoon season. They are notorious for bringing large flood water and transporting high sediments load during the rainy season. The flood hazards, inundation of adjacent land, and bank erosions create great loss to this region.

The current water use for drinking water and industry in the basin is the Southern Blocks are mostly met by groundwater. The plain areas of the Southern Blocks in the Terai have large agricultural land and are the bread-basket of the country. The total agricultural land in the Southern Blocks is equivalent to about 1.2 Mill. ha, and almost all is suitable for irrigation (IMP). However, most of these lands now depend on rain, as adequate irrigation facilities are not yet developed. Even in case of the areas irrigated, only about one-third receives year-round irrigation. Hence, the agricultural areas of the Southern Blocks are proposed to be irrigated by water diversions schemes bringing in water from the larger river basins or by groundwater. The important multi-purpose projects and interbasin diversions transfer projects planned to provide year-round irrigation to the agricultural land in the Southern Blocks are the following (IMP):

- Southern Block 1 – to be irrigated by the Mahakali Irrigation Projects, and the Karnali Diversion (40,628), and partly by the Bheri-Babai Diversion IBT project
- Southern Block 2A – to be irrigated by the West Rapti-Kapilvastu diversion project (51,000 ha) and the Kali Gandaki-Tinau Diversion project (31,000 ha)
- Southern Block 2B – to be irrigated by the Sunkoshi-Marin Diversion IBT project (western canal)
- Southern Block 3 - to be irrigated by the Sunkoshi-Kamala Diversion IBT project (129,000 ha)
- Southern Block 4 - to be irrigated by the Tamor-Morang diversion project (114,000 ha), and Kankai MPP (41,000 ha)
- Some of the districts in the Southern Blocks also have a good groundwater irrigation potential, and the IMP has proposed groundwater irrigation to 688,275 ha of land in 20 districts of the Southern Blocks.

The scenarios and development paths assessed in the Basin Plan include the above interventions to meet the projected water demand for various uses, including water supply, irrigation, hydropower requirement, and other environmental and ecological requirements of the river.

Table 2-10: Drivers and pressures acting on the hydrological system in the Southern Blocks

Sector	Water Resources Issues
DWS	• The Southern Blocks population is anticipated to grow from 12.2 M in 2025 to 14.8 M people by 2050 so growth is very high (due to rural-urban migration and a lingeringly high birth rate) • A strong growth of the urban population is expected as municipal populations become urbanized and rural population moves to urban • Drinking water use rate, per capita, will increase over the planning period • The growth will be disproportionally increased in urban areas • To accommodate the growth, water demand within the basin is projected to increase 66% by 2050, from 794.9 MLD to 1318.6 MLD. • Reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene
IRR	• The Southern Blocks is 14.4% of the area of Nepal and about 64% of the Terai region. It has 44% of the total land suitable for irrigation in Nepal • The total land suitable for irrigation in the Southern Basin is 1.1 Mha, out of the total cultivated area of 1.2 Mha. The water requirement for year-round irrigation is much higher than the available surface and groundwater in the Southern Blocks, especially in the dry season. • Diversions from the larger river basins with surplus water are proposed to irrigate the lands in the Southern Blocks. These include diversions from Mahakali River, Karnali River, West Rapti River, Kali Gandaki River and Koshi River. Key diversion schemes are as follows: • Rapti Kapilvastu Diversion; for diversion of water from the West Rapti river to Kapilvastu for irrigation of about 51,000 ha, of which 15,000 ha are under existing systems and hydropower generation (with inclusion of Naumure dam and Kapilvastu diversion, about 330 MW). • Kaligandaki Tinau Diversion; for transfer of water from the Kaligandaki river to the terai, for which there are two options: (i) tunnel only for irrigation of about 31,000 ha and hydropower generation (244 MW), and (ii) addition of dam (Andikhola) to increase irrigated area to 42,000 ha and installed capacity to 424 MW. • Kaligandaki Nawalparasi (East) Diversion; for diversion from the Kaligandaki river for the irrigation of about 11,500 ha and hydropower generation (4 MW). • Trishuli Shaktikhor (Chitwan) Diversion; for diversion of water from the Trishuli river with two options: (i) tunnel only with an irrigated area of about 21,000 ha, and (ii) addition of storage dam (Budhi Gandaki) and increase in irrigated area to 35,000 ha and hydropower generation (1,200 MW). • Sunkoshi Diversion; the project concept is for transfer of water from Sun Koshi River to the Marin and/or Kamala rivers, for irrigation up to 351,264 ha and hydropower generation, for which there are four options: (i) diversion to the Marin river for irrigation of 55,000 ha and power generation (31 MW), (ii) diversion to the Kamala river for irrigation of 122,000 ha and power generation (44 MW), (iii) diversions to both the Marin and Kamala rivers and construction of a storage dam (Dudhkoshi), for irrigation of 236,000 ha and power generation (2,830 MW), and (iv) diversion to both the Marin and Kamala rivers and construction of storage dam (Sunkoshi 3) for irrigation of 352,000 ha and power generation (701 MW). • Tamor Morang Diversion; for transfer of water from the Tamor Nadi river, for which there are two options: (i) tunnel only for irrigation of about 45,000 ha, and (ii)

Sector	Water Resources Issues
	addition of storage dam Tamor 3 for irrigation of about 114,000 ha and power generation (117 MW). • Climate change is projected to increase precipitation events and duration of drought.
HP	• As of 1 April 2023, the Tinau HPP, with an installed capacity of 1 MW, is in operation in Southern Block 2A • The Tinau Khola HPP (IC 3.4 MW) and the Chisang Khola HEP (IC 1.8 MW) are ROR HPPs with construction licenses in Southern Blocks 2A and 4, respectively. • Of the 7 priority projects identified by the IMP that divert irrigation waters to the Southern Blocks, 6 include HP. The cumulative installed capacity, including the Kankai MPP (not a priority project), is 635 MW. • No favourable greenfield HPP were identified in the HDMP in any Southern Block
ENV SOC	• In Nepal, national parks, buffer zones, and conservation areas support biodiversity and provide valuable habitat for endangered species of fish, birds, and mammals. • Increased water diversions create migration barriers. • Agricultural and urban runoff contributes to nutrient loading with negative impacts on water quality. • Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages

2.2 Objectives and Guiding Principles of the River Basin Plans

The key objective of the river basin planning study is the utilization and management of the available water and land resources in the basin to meet the water supply and sanitation needs of the growing population and urban centers, expand year-round irrigation to increase food production, develop the hydropower potential, mitigate and manage the risks due to water-induced disasters such as floods and droughts, maintain the ecosystem services of the rivers and protect the national parks and cultural sites of importance in the river basin. Water Resources development and management will be based on the river basin plans being developed. The River Basin Plans are prepared based on the principles of IWRM and prioritization of multiple purpose projects. Water resources development and management will be undertaken by coordinating and defining roles and responsibilities of the local, provincial and federal governments. The River Basin Plan of each basin is structured as follows:

Volume 1	**Basin status**	• Physical characteristics • Socio-economic characteristics • National legislation, policies and plans
Volume 2	**Water Resources Development Plan**	• Basin context and planning objectives • Proposals for water resources development by sector • Development of recommended integrated development scenarios • Financial and economic analysis of scenarios • Investment plan to 2050
Volume 3	**SESA**	• Environmental impacts of recommended development scenarios • Social impacts of recommended development scenarios • Proposed environmental and social safeguards
Volume 4	**Atlas**	• Maps of key spatial features

The Hydropower Development Master Plan is prepared separately, while considering it as an important component of the water resources development, and forms an integral part of the river basin plans.

The guiding principles that underpin the development of river basin plans (RBP) follows the national polices and strategies such as the National Water Resources Strategy (2002), the National Water Plan (2005) and the Water Resources Policy (2020), and principles of Integrated Water Resources Management (IWRM). These include:

- *Evaluate water use holistically (Efficiency, Equity and Sustainability (EES) systems)*: RBPs simulate/evaluate availability, delivery, and use by different water sectors and ideally link the impacts to the EES.
- *Sustainable development, sound socio-economic development that safeguards the resource base for future generations*: RBPs evaluate conditions and alternatives over a long planning horizon and reveal trade-offs between sectors and potential conflicts.
- *Inclusive, multi-stakeholder participation*: RBPs narratives allows for a shared understanding of water allocation.
- *Decision-making at the lowest possible level (subsidiarity)*: Allows River Basin Offices (RBO) to test scenarios and communicate results with key stakeholders, agencies, and organizations.
- *Adaptive learning and management:* the need for continuous cycles of planning, implementation, and adjustment due to the inherent complexity of development including climate uncertainty.

The overarching planning objectives adopted in the river basin plans are:

- To help reduce the incidence of poverty, unemployment, and under-employment;
- To provide people with access to safe and adequate drinking water and sanitation for ensuring health security;
- To increase agricultural production and productivity, ensuring the food security of the nation;
- To generate hydropower to satisfy national energy requirements and to allow the export of surplus energy;
- To supply the needs of the industrial and other sectors of the economy;
- To protect the environment and conserve the biodiversity of natural habitat; and
- To prevent and mitigate water-induced disasters

2.3 River Basin Planning Methodology

Each river basin plan includes the following methodology:

i.) Describes the basin context and the planning objectives of the basin for water management in the basin.

ii.) Presents the water available and demand of water for:

- *Water Supply and Sanitation.* Describes the population and settlement, water demand per capita, and input data analysed in the development scenarios.
- *Agriculture and Irrigation.* Provides context for agricultural production, lays out irrigation demands, and *describes* major water projects (e.g., reservoirs, inter-basin transfer) that support future agricultural development. The information is largely derived from the IMP including agricultural development goals.
- *Hydropower.* Based on the Hydropower Development Master Plan (HDMP), presents the current production and future demand of hydropower (HP) in the basin. Lists the projects that are current satisfying the demand and future opportunities, including multi-*purpose* reservoirs in the basin.
- *Other water uses. Industrial purposes, water transport, religious, cultural, or environmental protection, and tourism.*

- *Social and Environmental.* Outlines the freshwater ecosystems and the ecological goods and services they provide. Describes the potential opportunities and impacts of water management alternatives on social and environmental systems in the basin.

iii.) *Development Scenarios.* Evaluates current and future water resources development scenarios.

iv.) Financial and Economic Analysis, Investment Program. Outlines the financial and economic impacts of water distribution and cost and benefits of investment water management alternatives. Provides an investment program based on the water resources development scenarios.

v.) *Institutional Requirements.* Provides insights into the institutional, policy, and programs necessary to implement the water resources development scenarios.

The overall modelling and analytical framework used in the preparation of the river basin plans for each river basin consisted of the following steps:

i.) Undertake basin level situational analysis.

ii.) Determine basin goals and objectives.

iii.) Formulate strategies to achieve the objectives.

iv.) Select optimal set of actions to achieve the goals.

v.) Undertake economic and financial analyses.

vi.) Finalize investment program.

vii.) Prepare Strategic Environmental and Social Assessment (SESA).

viii.) Prepare river basin plans.

The water availability and demand for various uses, including drinking water supply and irrigation, hydropower and other multipurpose projects, environmental and other uses were analysed and identified to define the development options. A suite of analytical methods including the use of climate change projections, hydrological modelling (Mike SHE), and river basin modelling (Mike Hydro Basin) were used. A Decision Support System (DSS) was developed to support the evaluation of the development options and scenarios considered in the river basin plans. The modelling and analytical framework and steps used for the development of the river basin plans is presented in Figure 2-18.

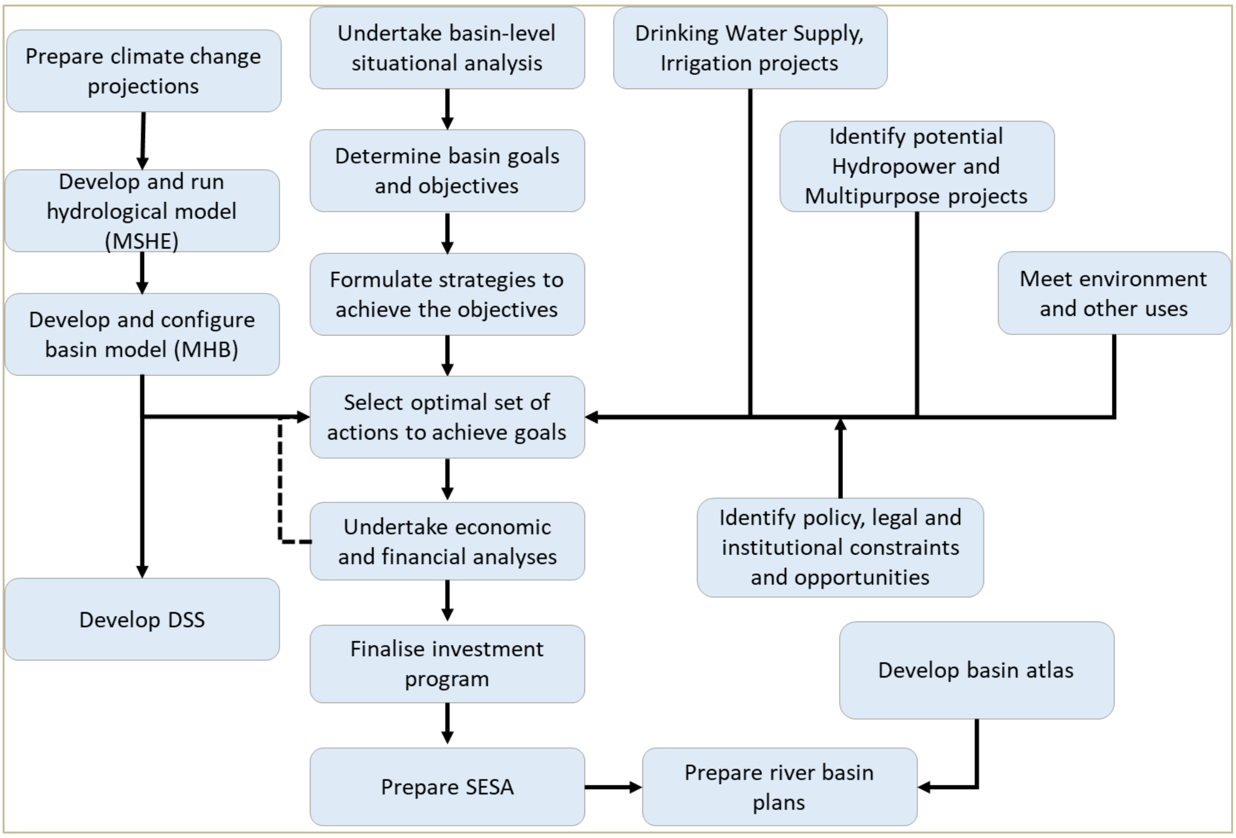


Figure 2-18: Modeling and Analytic Framework of the preparation of the River Basin Plans

2.4 Evaluation Method

Development scenarios provide water management agencies, funding agencies, and stakeholders insight into the trade-offs of water management policy, program, and infrastructure options. For each river basin required is development of a plan. For this document, a "plan" is water resources development from 2025-2050 that is evaluated in five-year development horizons (i.e., years 2025, 2030, 2035, 2040, 2045, 2050). "Scenarios" examine conditions at a time point within the plan timeline (e.g., 2025, 2030, etc.)

2.4.1 Scenario Development

Selection of projects to evaluate in a scenario follows the National Water Resources Act (NWRA) (1992), priority list: to ensure access to water resources in all sectors and levels by giving the first priority to drinking-water and domestic use, followed by irrigation, livestock and fisheries, hydropower, industrial purposes, water transport, religious, cultural, or environmental protection, and tourism. For scenarios modeled in the river basin modelling (RBM)[8], the input time series and parameters are changed to reflect projected changes in each sector including:

i.) Supply drinking water for humans and livestock according to the population estimates.

ii.) Irrigation use will follow the schedule outlined in the IMP 2019 (Updated 2024).

iii.) Inter-basin transfers according to IMP.

iv.) Hydropower Project (HPP) implementation following the construction licenses issued by the Department of Electricity Development (HDMP 2024)[9] and IMP.

[8] DHI's Mike Hydro Basin was used as the river basin model.
[9] The Hydropower Development Master Plan (HDMP) prepared under this study considered three development scenarios, namely Scenario 1, Scenario 2 and Baseline (Maximum Development Scenario), which varies from a low to maximum power demand by 2050.

v.) Implement prioritized greenfield HP, mega HP and additional infrastructures such as inter-basin transfers.

In the list above, the first four have fixed development schedules, thus, the implementation of storage HPPs, inter-basin transfers and the attractive greenfield HPs are the only variable project changes directly modelled in RBM altered in scenarios. Other water uses such as flood protection, tourism, religious, environmental, are non-consumptive and are treated as in-stream water requirements. The industrial water uses in Nepal is small, and hence is estimated as a fixed percentage of the domestic water supply. For generating input data to model scenarios and developing potential river basin plans, a portfolio of water supply, irrigation, HPP, and inter-basin transfer projects was identified for each basin.

2.4.2 Evaluation Criteria

Water management alternatives are evaluated based on changes the hydrologic system as they impact economic, social, and ecological systems. Appropriate indicators, often referred to as key performance indicators (KPIs), can be further subdivided into:

- Outcome indicators measure the benefit from the quantum of water delivered, e.g., the number of people being serviced by water supply, the quantum of water delivered.
- Performance indicators evaluate how well the system performed at achieving the outcome indicator, e.g., reliability of water supply delivery.

For evaluation of RBP simulations, outcome and performance indicators have been selected for drinking water supply (DWS), agriculture (IRRG), hydropower (HP), and environmental and social (ENV-SOC). Data used to compute indicators includes both MHB time series output and parameter data. Beyond outcome and performance indicators, cost estimates were calculated for DWS, IRRG, HP, and ENV-SOC mitigations.

Table 2-11: Indicators used to evaluate water management simulations and scenarios

Sector	Outcome Indicator	Performance Indicator	Notes
DWS	Population supplied by DWS Water delivered for DWS	Reliability of DWS delivery	By Nepal's NWP, reliable delivery of DWS is top priority
IRRG	Hectares irrigated Water delivered for irrigation	Reliability of irrigation delivery	IBTs diverted to other basins are included
HP	Annual Energy Produced	Change is water availability	Power generated from the IBTs is included.
ENV-SOC	Change in environmental and social conditions	e.g. Maintaining environmental flows	Overall, 10% minimum mean monthly discharge. 50% mean monthly discharge for projects/structures in conservation areas[10]

2.5 Water use and Balance

2.5.1 Water Supply and Sanitation

GON has made good progress in providing "basic" water supply and sanitation for both rural and urban citizens. The proportion without such facilities is below 10% in the country and it will be difficult and expensive to improve on this. Nevertheless, there is no cause for concern about the adequacy of supply. The current water use for drinking water and industry in the basin is relatively small and the projected

[10] These flow requirements are minimum requirements for hydropower and irrigation project but may be increased for site-specific target species.

demand to 2050, considering population growth and urbanization, is expected to be met reliably from available water sources.

Management Goal: Accounting for the increased water demand and potential increased variability associated with climate change, providing reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene.

Nepal's Multiple Indicator Cluster (MIC) Survey (CBS, 2020) provides up-to-date statistics designed to measure Nepal's progress towards the achievement of Sustainable Development Goals (SDG), including progress on Drinking Water, Sanitation, and Hygiene (WASH). The survey presents indicator data by province, distinguishing between urban and rural populations. Additional data is presented by the educational status of respondents and the wealth quintile that they represent. The data is consistently presented for a very wide range of human development indicators. CBS makes available key statistical data in the form of "ladders' to show progress towards achieving SDG, including WASH. For water supply, the key indicators are "safely managed supply" and "basic supply". "Safely managed" water supply is defined by a connection within the dwelling area together with sufficient supply as and when needed which is free of contamination by E. coli bacteria.

NPC (2020a) has stated the target is to provide "safe drinking water" to 90% of the population by 2030. While recognizing that targets are not being met (only 25% of the population with pipe connection in 2019 compared with a 35% target) the recommendation in the report is that progress "needs to be accelerated". The National Water Supply and Sanitation Sector Policy 2017 to 2030 acknowledges that coverage and quality of service in existing schemes is poor, tariffs do not cover basic operational costs and consumer participation in management is low. To address these issues the policy includes the objectives of increasing provincial and private sector involvement, including concessional financing, service regulation tariff setting, and benchmarking. The objective is not only to improve coverage and service quality but also to relieve Government and financing agencies of at least some of the responsibility of financing new schemes and subsidizing existing ones. Nepal's target is for 90% of the population to have "Water accessible on the premises" by 2030.

Overall, only 14% of Nepal's 2020 population had a safely managed supply in 2018. The proportion now seems to be about 21%. Of this, about 38% of the urban population had a safe supply, but only about 17% of the rural population. The situation in the Terai region (with 50% of the population on about 23% of the area of the country) is better, with 49% of the urban population with a safe supply, but also only 17% of the rural population.

The SDG defines basic water supply as the use of an improved water supply (pipe, spring, protected well, tubewell, or transported source (tanker, bottles)) within 30 minutes of the point of use. The Nepal Government has provided basic water supply to a large proportion of the population. Overall, 95% of Nepal's 2020 population had a basic supply. In the Mountain region, 94% of the population had a basic supply, in the Hill also 94%, and in the Terai 97%. The basins with the highest populations have the highest numbers who still do not have a basic service. The reason for this is most likely a problem of targeting limited funds and implementation capacity.

The main issues for consideration in planning water supply and sanitation are shown below.

	Drinking Water Supply Overview
Water Resources Issues	The provision of safe water supply to 90% by 2030 of the population is an important policy objective of the National Water Supply and Sanitation Sector Policy 2017-30 The policy also emphasises the importance of planning for financial sustainability of water utilities Nepal's population is anticipated to grow from 32.0 M in 2025 to 38.6 M people by 2050 The rural population will hardly grow due to rural-urban migration and falling birth rate (which is anticipated to fall below replacement rate in about 2053)

	Drinking Water Supply Overview
	Drinking water use rate, per capita, will increase over the planning period The growth will be disproportionally increased in urban areas Reliable sources of clean, freshwater will be required for drinking, sanitation, and hygiene
Demand Pressure	To accommodate the growth, water delivery will increase from 2,131 MLD to 3,666 MLD Climate change will increase precipitation events and duration of drought
Scenario Evaluation	Assess the reliability, resilience, and vulnerability of water delivery to rural and urban settings given demand from other water sectors
Management Alternatives	Identify reliable sources of freshwater to meet demand Build infrastructure for water distribution, waste removal, and storm drainage given the increased demand and risk to flooding and drought

2.5.1.1 Sanitation

Nepal's progress towards meeting SDG in respect of sanitation has been successful. According to the Multiple Indicator Cluster (MIC) Survey (CBS, 2020), the proportion of households using improved and unshared sanitation facilities was nearly 80% in 2018, compared to the Government's target of 70% . The target for 2030 is 95% coverage.

For river basin planning, people's sanitary practices are less interesting than the eventual disposal of excrement and its effect on water quality. Unsafe disposal of waste is only attributable to about 9% of the 2020 population, and highest in the Mountain and Terai regions. A slighter higher proportion of the rural population have unsafe waste disposal (10%) than urban (6%).

The Government has made substantial progress in the provision of basic water supply and sanitation, to the point where planning for these facilities as part of a river basin master plans is not required. However, to meet the policy goal for the provision of safe water supply considerable investment will be required. The remainder of this section estimates the volume of potable water required to ensure adequate allowance is made in water resource modelling.

2.5.1.2 Projected Drinking Water Demand

In 2025, the daily per capita use rates for Nepal, as set by the DWSS, are 45- 65 lpcd for rural municipalities (gaunpalika), 66 – 90 lpcd for urban municipalities (nagarpalika, upamahanagarpalika), and 91-160 lpcd for metropolitan cities (mahanagarpalika). In 2050, water use, per capita, is projected to rise by 44%, 38%, and 78% for rural, urban, and metropolitan communities, respectively (Table 2-12). The key factors that impact the future domestic water use are:

1. *Economic development: As economies grow, citizens will have more money to spend on water and water-related infrastructure, which will lead to an increase in per capita water use.*
2. *Changing lifestyle:* With the change in lifestyle, citizens are becoming more conscious about the importance of clean drinking water which may lead to an increase in demand.
3. *Rising awareness of health and sanitation*: Increased awareness about the importance of good health and sanitation may lead to an increase in demand for clean drinking water.
4. *Improved access to clean water*: Efforts to improve access to clean drinking water through infrastructure development and water treatment facilities may also lead to an increase in per capita water use.
5. *Urbanization:* As city population increases, the demand for drinking water will increase in urban areas.
6. *Climate change:* Climate change may lead to changes in precipitation patterns and water availability, which could lead to an increase in the use of drinking water as citizens try to compensate for water shortages.

Table 2-12: Current and projected domestic water demand per capita use rate per day (LPCD) in Nepal

Year	Metropolitan	Urban	Rural
2020	90	65	45
2025	100	70	47
2030	110	75	50
2035	120	80	55
2040	135	85	60
2045	150	90	65
2050	160	90	65

Considering the urbanization pattern of local units of Nepal, it is assumed that 19.4% of the total population lives in metropolitan and sub-metropolitan cities, whereas 22.6 % live in municipalities and 58% in rural municipalities. The projected water supply demand up to 2050 is given in Table 2-13 and Figure 2-19.

Table 2-13: Projected Water Supply Demand

	2025	2030	2035	2040	2045	2050
Mahakali	38.3	43.2	47.9	52.4	56.7	57.4
Karnali	230.2	263.7	296.5	328.3	359.0	365.5
Babai	76.6	93.3	109.1	127.5	146.6	158.5
West Rapti	55.4	61.9	69.0	76.0	82.8	83.8
Gandaki	312.1	363.0	413.1	469.1	525.1	551.8
Kamala	43.4	50.6	57.6	63.5	69.4	70.7
Koshi	175.3	196.3	217.8	239.2	259.2	262.0
Kankai	20.5	23.8	26.8	29.3	31.9	32.4
Mechi	24.3	27.6	30.7	33.6	36.4	36.8
Bagmati	359.7	437.4	509.2	591.5	675.9	727.3
Southern Blocks	794.9	921.8	1,040.7	1,159.6	1,282.4	1,318.6
Total (MLD)	**2,130.8**	**2,482.5**	**2,818.4**	**3,169.9**	**3,525.2**	**3,664.9**
Total (m^3/s)	**24.66**	**28.73**	**32.62**	**36.69**	**40.80**	**42.42**

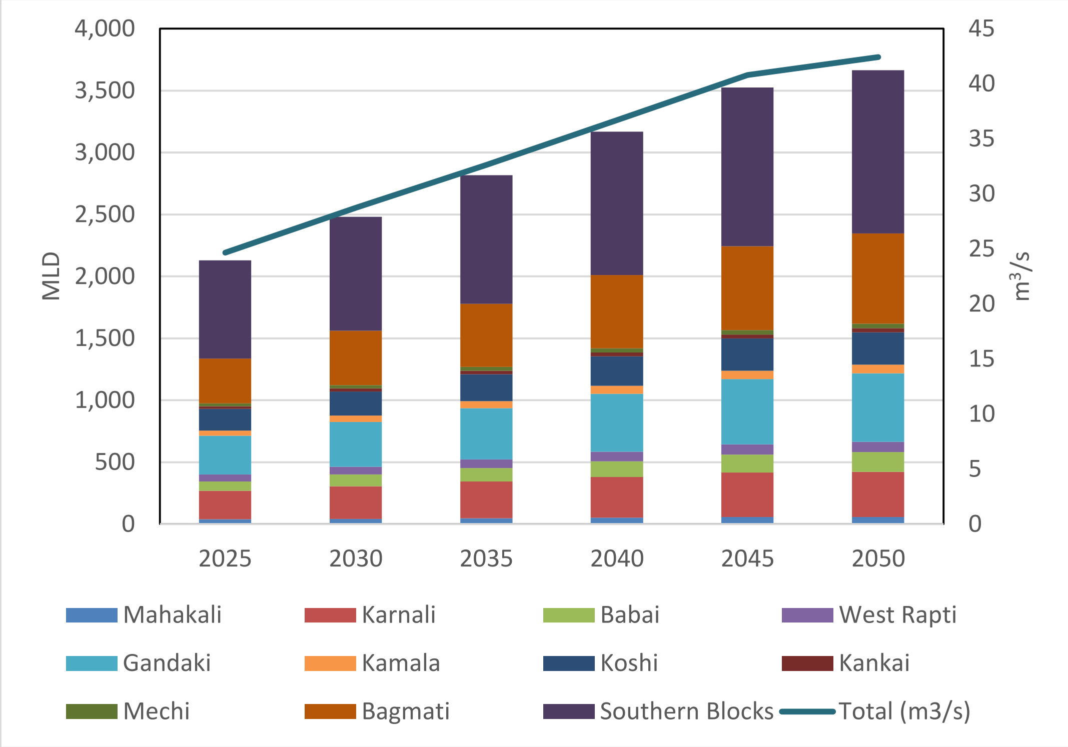


Figure 2-19: Projected Water Supply Demand

2.5.2 Irrigated Agriculture

The agricultural baseline in all basins will increase over the planning horizon as population growth increases food demand, urbanization, and changing lifestyles require higher value production and timeliness of food supply. IMP's approach to quantifying food demand in terms of production and value is explained and, under stated assumptions, the incremental increase in crop production required by 2043 (the most extended projection available in the IMP) is estimated. The approach for irrigation development has followed the four systems:

- Increase year-round irrigation through two means:
  - (i) Inter-basin transfer
  - (ii) Groundwater development, either independent or conjunctive use
- Develop new gravity systems in the hills and mountains
- Develop new non-conventional irrigation, through electrical pumping or solar pumping
- Rehabilitation, modernisation, irrigation management transfer and on-farm water management (OFWM)

IMP (2019, updated 2024) has identified agricultural land covering 3.558 Mill. ha, of which 1.593 million ha are in the Terai, and 1.564 million ha and 0.401 million ha in the Hill and Mountain agro-ecological zones[11] , and suitable irrigable land of 2.537 Mill. ha of which 1.499 (59%), 0.837 (33%) and 0.201 (8%) million ha are in the Terai, Hill and Mountain zones, respectively (Table 2-14). The suitable irrigable land is classified into four classes (S1 to S4) by IMP . The IMP irrigation system inventory lists the current gross irrigated area about 1.435 million ha of which about 0.941 million ha (66%) are irrigated from surface water and 0.494 million ha (34%) from groundwater sources, principally on the Terai. The gross irrigated area on the Terai is about 1.171 million ha, of which about 0.685 million ha is from surface water and 0.485 million ha from groundwater. In the Hill zone the total irrigated area is about 0.213 million ha, and in the Mountain zone irrigated area is about 51,000 ha. There is an estimated area of 1.275 million ha of new lands which are suitable, based on slope and soils, for development for irrigated agriculture, of which

[11] For the purposes of classification and planning Nepal is divided into three agro-ecological zones; Terai; lowlands to the south, Hill; hills up to 3,000 metres through the centre of the country west to east, and Mountain; hills to the north.

approximately 0.709 million ha are in the Terai, 0.421 million ha in the Hill and 0.144 million ha in the Mountains. The details are given in Table 2-14.

Table 2-14: Land Resources

SN	Category (ha)	Terai	Hill	Mountain	Total
1	Agricultural Land (ha)	1,592,504	1,564,133	401,127	3,557,764
	Percentage of total	45%	44%	11%	
2	Total Irrigable Lands (ha)	1,499,176	836,617	200,526	2,536,319
	Percentage of total	59%	33%	8%	
	Existing Irrigated Land (Net area ha)				
3	Surface water	511,688	148,490	36,317	696,495
4	Conjunctive use	2,435	5,407	1,769	9,611
5	Groundwater	364,408	5,965		370,373
6	**Net Existing Irrigated Land Total**	**878,531**	**159,862**	**38,086**	**1,076,479**
	Existing Irrigated Land (Gross area ha)				
7	Surface water	685,497	205,195	50,779	941,471
8	Groundwater	485,877	7,953		493,830
9	**Total (Gross area ha)**	**1,171,374**	**213,148**	**50,779**	**1,435,301**
	Percentage of total	82%	15%	4%	
10	New Irrigated Land (ha)	**709,000**	**421,600**	**144,400**	**1,275,000**
	Percentage of total	56%	33%	11%	

Source: IMP 2019 (Updated 2024)

A planning priority is (i) improvement of existing irrigated area (systems) in the existing 1.435 Mill. Ha (gross), to increase cropping intensities, conveyance efficiency, distribution equity and productivity, (ii) development of new irrigated lands in about 1.275 Mill. Ha (net). The priorities are to identify storage and inter-basin diversion opportunities to improve water supply in the dry season and water deficit basins, including the Southern Blocks. To minimize cost, it is preferable to focus on dam sites and water transfer opportunities within the basin. To maximize economic benefit, storage needs to be released to the Terai in the dry season, where the quantity and quality of land suitability for irrigation is relatively greater than in the Hills.

Goal: Supply surface water to existing schemes for rehabilitation within the basins to minimize irrigation shortages especially in the dry season and to improve food security as well as to establish new irrigation schemes. Additionally, develop IBTs to take advantage of water-rich rivers (major river basins) to improve water deficit regions (medium river basins and the Southern Blocks).

	Irrigated Agricultural Overview
Water Resources Issues	• Land suitable for irrigation comprises 15% of Nepal, 7% is in the Mountains with 35% of the land area, 28% is in the Hills with 42% of the land area and 65% is on the Terai with 23% of the land area • The Terai (Southern Blocks) is the major land resource to increase national agricultural productivity but lacks large scale water storage (apart from groundwater) and therefore reliable distribution systems for irrigation • The total demand for food will ease over the next forty years as birth rate declines, particularly in rural areas, but the urban population will increase by nearly 5 million people; this will lead to increases in the quality and diversity of food demanded • Farmers (those who remain on the land as the rural population declines) need the resources to respond to this demand, to reduce the ballooning food import

	Irrigated Agricultural Overview
	bill; the fundamental strategy is to maximize the area of land suitable for irrigation with sufficient, timely and reliable water supply • Climate change will increase precipitation events and duration of drought.
Demand Pressure	• To accommodate the projected irrigation expansion, water delivery from storage projects and inter-basin diversions will be required. • Current climate variability and future climate change impact operation.
Scenario Evaluation	• Assess the reliability, resilience, and vulnerability of water delivery to small and medium irrigation schemes, IBTs. • Evaluate environmental flows downstream of major projects.
Management Alternatives	• Identify reliable sources of freshwater to meet demand. • Build infrastructure for water distribution, water storage, and IBT given the increased demand and risk of flooding and drought.

2.5.2.1 Irrigation Development Scenarios and Water Requirements

Based on the agricultural land and irrigation suitable areas identified, and the existing and projected irrigated area in IMP, the river irrigation development scenarios at each 5 year interval up to 2050 was formulated for the river basin modelling. The irrigation suitability classification by IMP used the following criteria.

- **S1:** Highly suitable for surface irrigation, deep soil > 90 cm, flat land <3% slope, medium textured soils
- **S2:** moderately suitable for surface irrigation, medium depth, 60-90 cm, lighter soils, on slopes 3-10%
- **S3:** marginally suitable for surface irrigation, shallow depth, but greater than 30 cm, light soils on radical terrace, slopes 10-25%
- **S4:** this is a new category not used in the IMP-1990, to include those steep level terraces that are irrigated for paddy. This was not identified as irrigable area in IMP 1990. Slopes up to 60% are acceptable provided the land is identified as level terrace.
- **NS:** all sloping terraces we deemed unsuitable for surface irrigation but was included in a new suitability class for pumping (non-Conventional) irrigation. This is because mechanized irrigation can be used to irrigate sloping terrace, and all classifications S1 to S3 are available to be classified as pumping suitable provided it meets the requirements of less than 140 m above the river source, and within the 3.0 km. Table 2-15 presents the total agricultural land, irrigable land and irrigated are in 2025 and 2050 considered in the river basin modelling. It is currently used for the base line case in the river basin modelling. The current irrigation area presented is mainly surface irrigation area and an additional command area of about 370,373 ha is irrigated by ground water sources (IMP, 2019. Updated 2024).

Table 2-15: Total agricultural land, irrigation suitability and irrigated area in 2025 and 2050 in the River Basin Modelling

Basin	Agricultural Land[1] (ha)	Irrigation Suitable[1] (ha)	Irrigation Area 2025[2] (ha)	Irrigation Area 2050[2] (ha)	IBT 2050[3] (Ha)
Mahakali	81,986	55,268	3,178	22,391	31,486
Karnali	466,369	227,877	69,341	94,642	91,628
Gandaki	668,857	467,596	64,838	96,933	42,000
Koshi	624,516	316,826	81,813	106,399	431,000
Babai	123,945	96,836	64,638	70,663	
West Rapti	144,528	63,579	61,490	63,829	68,000
Kamala	80,917	65,834	48,662	57,016	
Kankai[4]	43,089	19,556	21,814	28,041	
Mechi	41,152	34,325	6,271	31,559	
Bagmati	124,600	93,695	50,000	74,956	
Southern Blocks[5]	1,158,006	1,089,423	497,522	1,089,423	
Groundwater[6]			493,830	811,830	
Total[7]	**3,557,963**	**2,530,815**	**1,457,286**	**2,544,703**	**664,114**

Note:
[1] The agricultural land and irrigation suitable land are based on the land resources maps prepared by IMP (2019, updated 2024). These are delineated strictly following the individual basin boundary up to the Nepal-India border.
[2] The basin-wide irrigation areas in 2025 and in 2050 are within the basin and are mainly irrigated by surface water sources.
[3] The area under this column covers the diversion of water for irrigation in the adjacent Southern Blocks or inter-basin water transfer (IBT) from the respective basins to another basin. For example, the IBT area for Mahakali Basin covers the irrigation areas of Mahakali 1, 2 and 3 irrigation projects in Southern Block 1.
[4] The irrigation areas of Kankai Basin are greater than the irrigation suitable area, which is because some parts of the Southern Blocks irrigated from the Kankai River are also included.
[5] Most of the irrigation command areas of the Southern Blocks will be irrigated by either inter-basin transfer from major river basins, ground water sources and conjunctive use of both.
[6] The command areas under groundwater are based on IMP, 2019 (updated 2024). For planning purpose, this area is assumed to be the same for 2025.
[7] The total irrigation areas of the Southern Blocks and groundwater irrigation areas presented includes some double counting and hence are larger than the actual. For example, the total irrigation area in 2050 is slightly larger than the total irrigation suitable area. The figures are used for basin level planning.

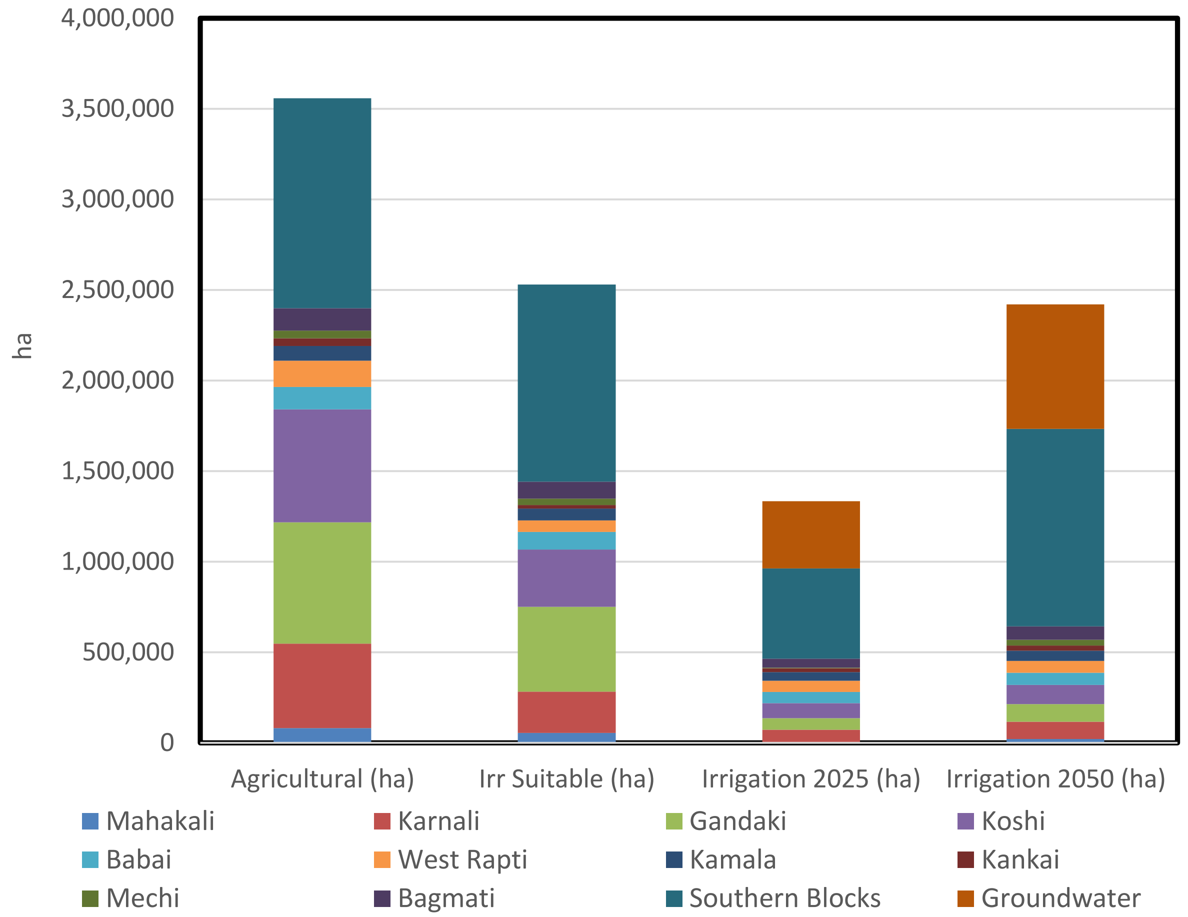


Figure 2-20: Agricultural Land, Irrigable and Irrigation in 2025 and in 2050 considered in the River Basin Modelling

The River Basin modelling used the IMP proposed cropping patterns and crop water requirements to estimate the irrigation water requirements across the basins. Individual cropping patterns were proposed for each of the three major basins (Mahakali/Karnali, Gandaki and Koshi) and each ecological zone (Terai, Hills and Mountains). This means 9 cropping patterns. The crop water requirements were calculated using CropWat and both FAO climate data, and adjusted with more recent local meteorological station data. Planting dates have been adjusted to obtain a reduced peak water requirement in the monsoon. Cropping intensities will rise to 213% in the Terai, 180 to 198% in the hills, and to 128% in the mountains. Annex G of the IMP provides the details of the estimates. The River Basin Modeling used the irrigation water requirements and the irrigation areas given in Table 2-15 to allocate the available water across the river basins (temporally and spatially).

Table 2-16: Annual Surface Water Availability and Irrigation Demand in 2025 and 2050 considered in River Basin Modelling

	Catchment Area[1] (km^2)	Annual Average Precipitation[2] (mm)	Water Available[3] (m^3/s)	Water Available[3] (mcm)	Irrigation Demand 2025[4] (mcm)	Irrigation Demand 2050[4] (mcm)
Mahakali	15,769	1,867	720	22,700	762	1,104
Karnali	46,193	1,280	1256	39,606	1,424	3,920
Gandaki	36,497	1,680	1952	61,568	1,155	2,701
Koshi	56,145	1,032	1827	57,601	1,254	9,070
Babai	3,579	1,514	80	2,520	1,616	1,767
West Rapti	6,971	1,587	176	5,550	1,494	2,601
Kamala	2,219	1,629	112	3,523	1,030	1,153
Kankai	1,332	1,999	56	1,760	466	599
Mechi	806	2,764	41	1,286	67	372
Bagmati	3,844	1,795	65	4,027	1,068	1,601
Southern Blocks	21,016	1,817	963	27,868	11,837	28,291
Total	**194,371**	**-**	**-**	**226,495**	**22,174**	**53,180**

Note:
[1] The area covers the entire catchment area up to Nepal-India border delineated using the combination of SRTM 30 m DEM and topographical data of the Department of Survey developed in the study.
[2] The long-term annual precipitation (using data from 1986 to 2015) estimates presented here are for the full catchments of the river basins of Nepal. The long-term average precipitation of catchments (areas) within Nepal only is 1,609 mm compared to the full catchment average of 1,444 mm.
[3] The water availability is estimated using the Mike SHE hydrological modelling. The estimate is based on the hydrological model results and is subject to some uncertainty due to data and model uncertainty. For planning purpose, the estimate is reliable.
[4] Irrigation demand is estimated using the IMP future cropping patterns and irrigation water requirements for the irrigation area estimates in Table 2-15
.

2.5.2.2 Summary of IMP Investment Proposals

The recommendations of IMP for irrigation expansion in all basins from water diversions by multi-purpose projects MPP (10 in number) are shown by basin in Figure 2-21. The total benefit area is 815,600 ha in the Terai region (out of a total area suitable for irrigation of 1.1 Mill. ha on the Terai). This comprises areas of new irrigation (327,500 ha) and rehabilitated areas (488,100 ha).

The benefit area of one MPP is not shown, that is Sunkoshi-Kamala MPP with Dudhkoshi Dam storage, which is mutually exclusive from the Sunkoshi-Marin-Kamala MPP with storage from Sunkoshi-3. Overall, the latter was found to have the highest cost: benefit ratio (see Koshi River Basin Plan). The benefit areas of "small" versions of some MPP (i.e. not supported by upstream storage) is also not shown. In nearly all cases these smaller MPPs are only marginally economic both for irrigation supply and hydropower production. Benefit areas of two MPP not recommended by IMP, Madi-Dang and Kankai MPP, are included.

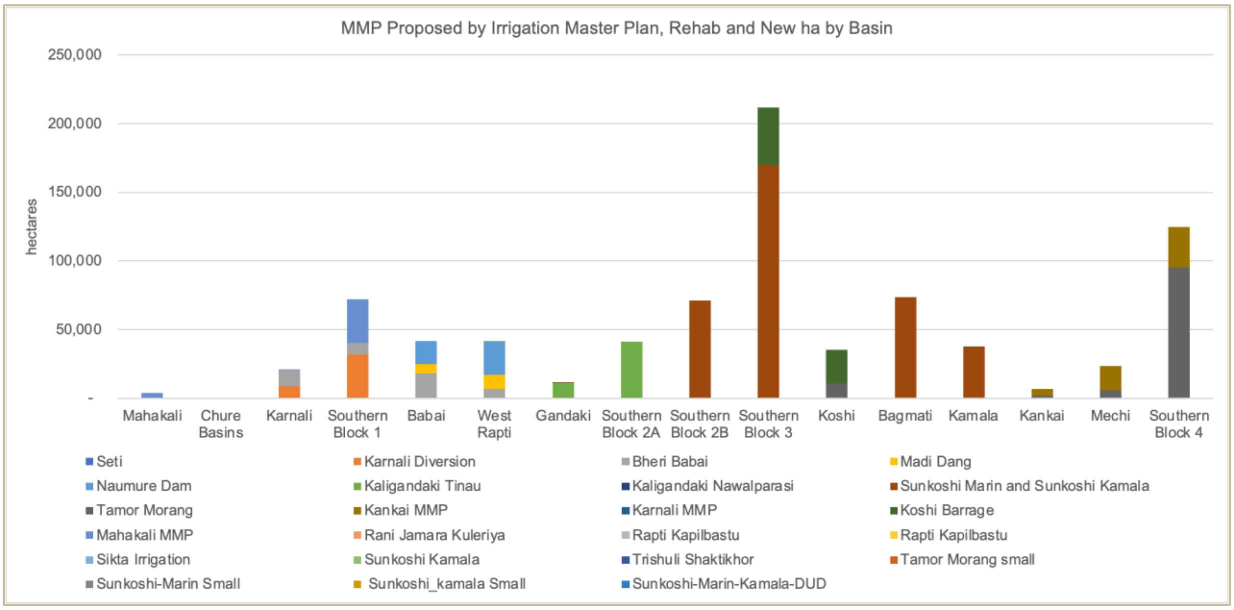


Figure 2-21: Multi-Purpose Projects Recommended by IMP: Irrigation Benefit Areas, ha

IMP also recommended 12 groundwater development projects on the Terai which were located and sized to support MPP benefit areas, being either (i) on the lower Terai where water transfer from MPP is not feasible, or (ii) where supply from water transfer may also require conjunctive irrigation from groundwater or (iii) when the associated MPP was not scheduled for implementation until later in the 2030s.. The benefit areas are shown by project name and basin in Figure 2-22. These are approximations. IMP did not prepare maps of these proposed projects because groundwater resources are not sufficiently well known. The total area recommended by IMP is 358,000 ha.

Together, water transfers from MPP and Groundwater Irrigation projects would provide water to irrigate nearly 80% of land suitable for irrigation on the Terai.

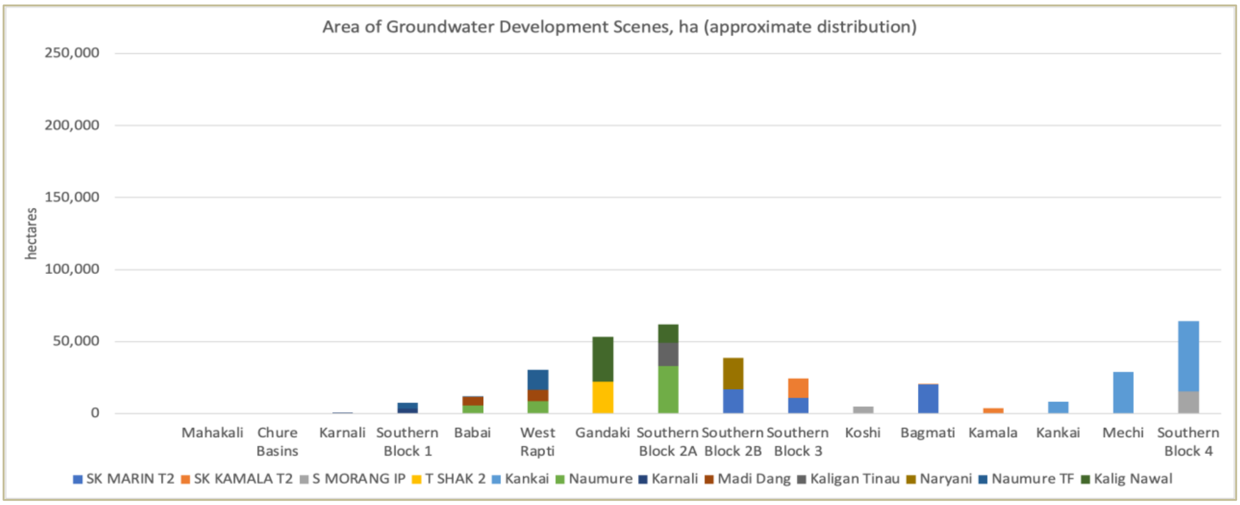


Figure 2-22: Irrigation Benefit Areas from Pumped Groundwater Schemes, ha

IMP also recommend the expansion of gravity-pump irrigation in the Hill and Mountain regions of all basins, where about 50% of Nepal's population live. However, these regions hold only about 35% of land suitable for irrigation and it is much lower quality – 80% is S4 and most of the relatively higher quality land has already been developed.

A screening procedure for Category #1 schemes (schemes located and costed by DoWRI) is described in the IMP Main Report (section 10.3). However, this screening was only applied to Category #1 (8,700 ha) schemes because no costs of development were available for Category #2 and #3. Nevertheless, the procedure could also be applied to Category #2 and #3 schemes by using the estimates of maximum economic development costs per ha derived for different classes of irrigation suitability for Category #1.

About 786,000 ha of suitable land is in the Mountains and Hills was considered for gravity-pump irrigation. Of this, 239,300 ha is already irrigated. From the balance, 546,600 ha, the method described above selected 289,000 ha that could be developed economically. The distribution of this area by basin and land suitability class for Irrigation is shown in Figure 2-23. Most of this investment would be through provincial budgets, so a stochastic approach to scheduling investment was used. See Figure 2-24.

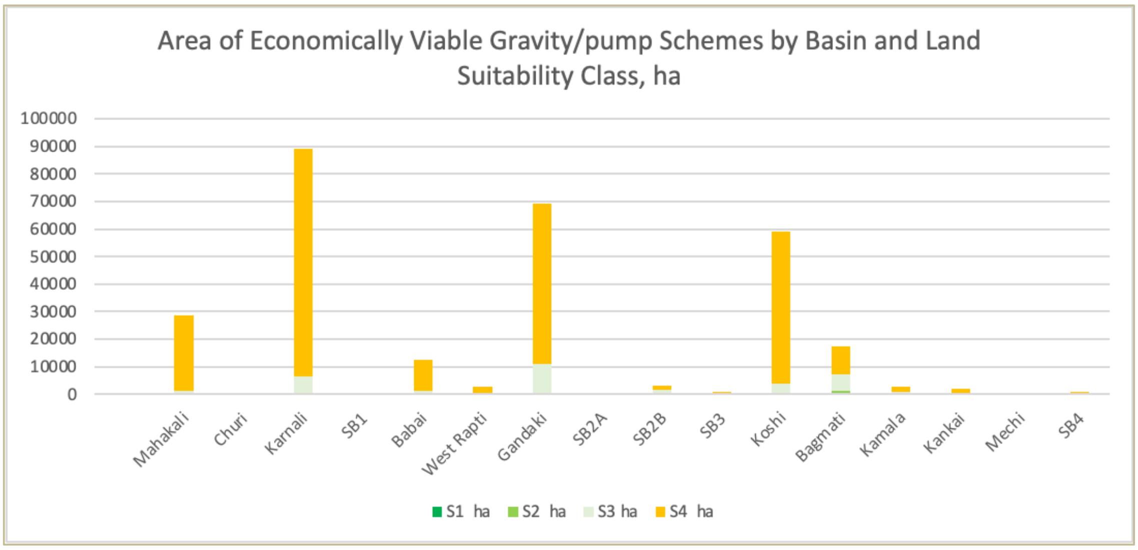


Figure 2-23: Gravity-Pump Irrigation Areas, by Basin and Suitability class, ha

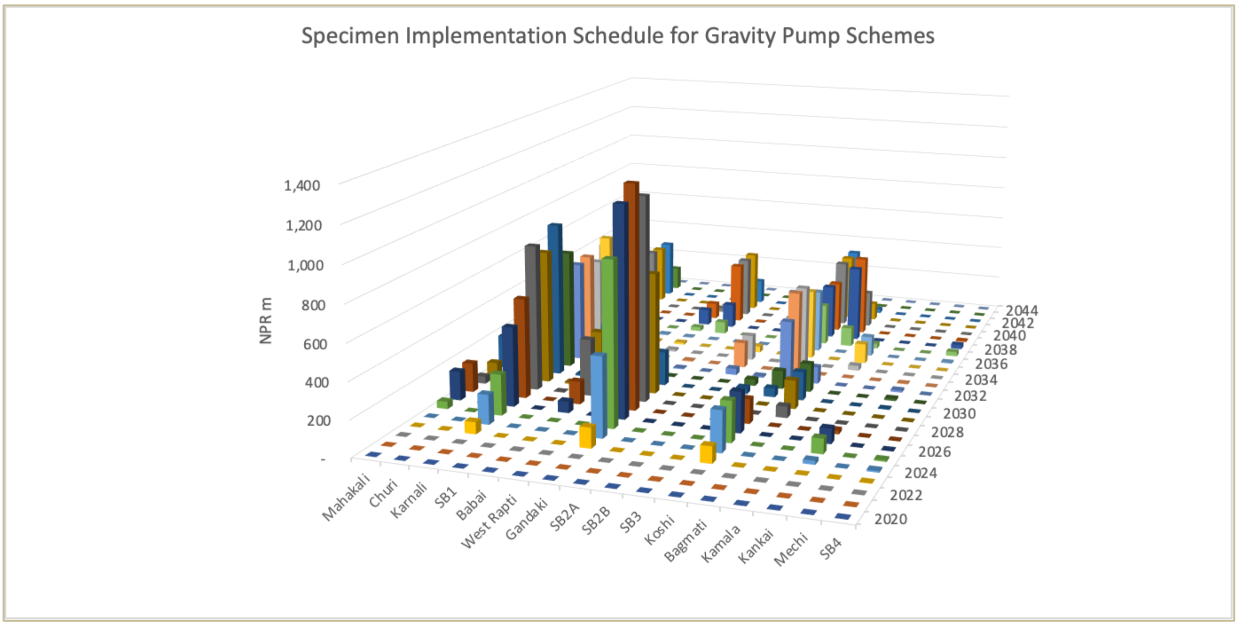


Figure 2-24: Schedule of Investment, Gravity-Pump Irrigation, NPR million

The areas of planned irrigation by basin and type of irrigation system are shown in Figure 2-25. The addition of Kankai MPP in Kankai basin (total benefit area 51,750 ha) has led to benefit areas in Mechi and Kankai basins exceeding the area of land suitable for irrigation available. The reduction of the size of the very large Kankai Groundwater Project (86,000 ha) would compensate for the increase in surface irrigation from Kankai MPP.

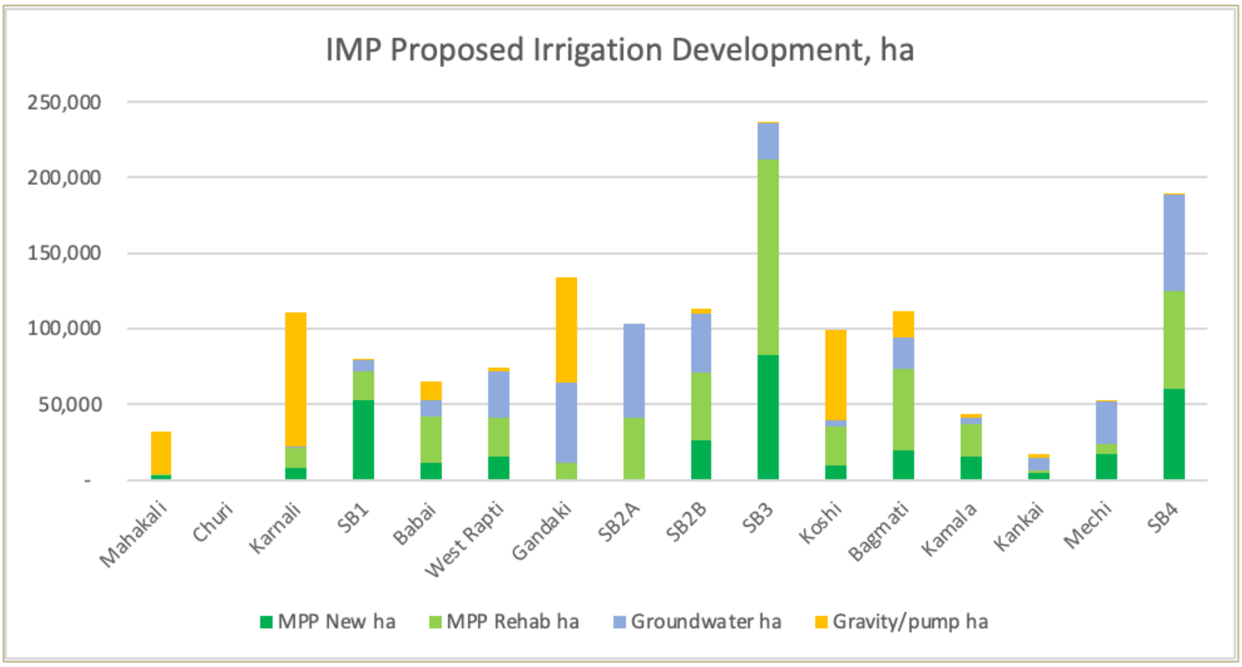


Figure 2-25: IMP Recommended Irrigation Development by Basin and Technology, ha

2.5.3 Water Availability Assessment and Water Balance

2.5.3.1 Hydrological and Water Balance Modeling

The assessment of water resources was carried out by hydrological and water balance modelling. This assessment considered the available land use resources, the topography, soils, existing water supply and irrigation projects, future domestic water demand based on population projections, potential hydropower storage dams, and climate change to determine available water availabilities.

For this, the approach was done in two stages: (i) Generating discharge time series data based on a hydrological model, and (ii) assessment of the results and water balancing accounting for basin priorities, hydropower, transboundary interactions, population increases, and subsequent drinking water needs, plus the environmental needs. For stage 1, MIKE SHE models were used for all country-wide basins. Stage 2 was done using the river basin model MIKE HYDRO Basin, which incorporates reservoirs and their hydropower generation, drinking water, irrigation schemes, and environmental flow requirements in the water allocation modelling.

The domains for the model set-up were fixed in such a way so that the outputs of the MIKE SHE models can be used effectively in river basin planning, inter-basin diversion projects across the basins, and in the plan of the establishment of River Basin Organization (RBO) in three regions of Nepal; because of these, the basins into three domains were grouped together for MIKE SHE modeling as presented in Figure 2-26. 1km x 1km grid size is selected to set up MIKE SHE.

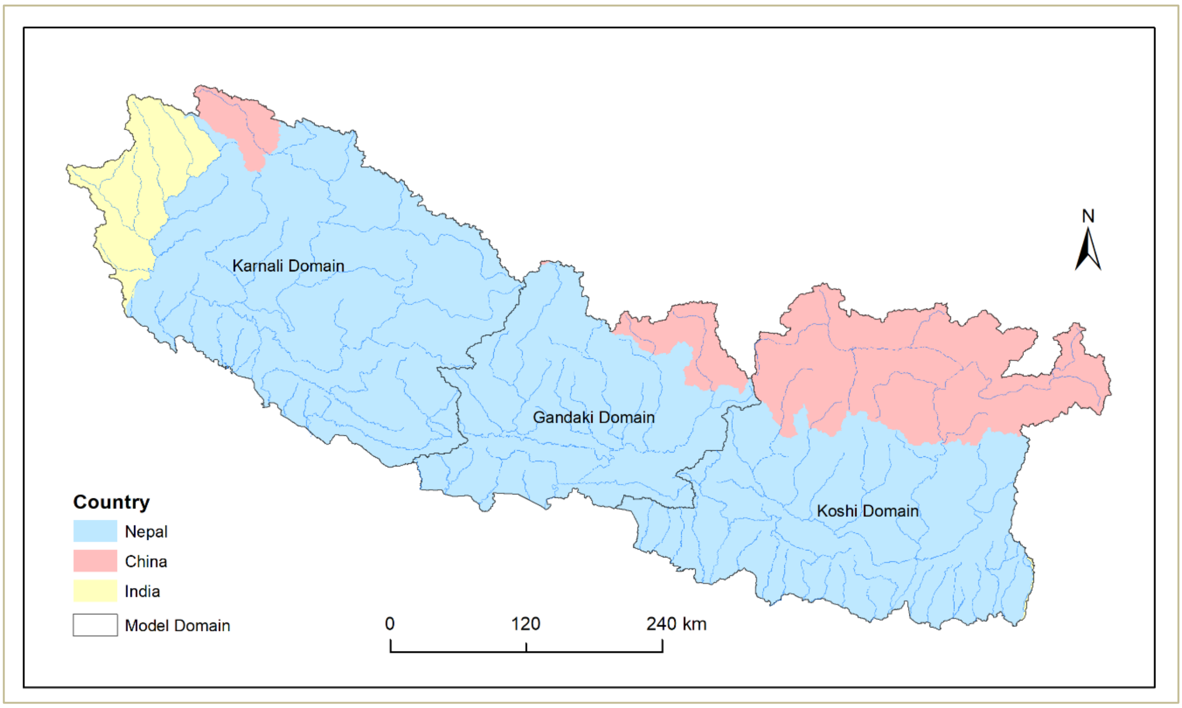


Figure 2-26: MIKE SHE model domains covering Nepal

Domain 1-East region: Koshi, Kamala, and Southern Block 3, Kankai/Mechi and Southern Block 4 and Bagmati and upstream transboundary catchment

Domain 2-Middle region: Gandaki (Narayani) and Southern Block 2 and upstream transboundary Catchment

Domain 3-West region: Karnali, Babai, Mahakali, and Southern Block 1 and upstream transboundary catchment.

The water balance within each domain has been processed in the MIKE HYDRO Basin (MHB). MHB is a versatile and highly flexible model framework for a large variety of applications concerning the management and planning aspects of water resources within a river basin. MHB models utilize a river network and catchments within the specific river basin as the basic model data. Three types of water users were applied at MHB, namely, irrigation, domestic water supply, and hydropower.

- Irrigation water users have been represented by regular water user components in MHB. Demands of the different irrigation users have been processed outside of the model, which is then entered as irrigation demand time series.

- Domestic water supply has been simulated in the MHB model as regular water users. The water uses demand timeseries for each domestic water supply scheme is calculated outside MHB and entered the model as a water use demand.

- Storage hydropower plant projects have been considered in the MHB model setup as they have a considerable impact on the water balance due to seasonal alterations of the hydrograph. ROR HPPs neither alter the hydrological regime nor the water balance. The run-of-river hydropower project was assessed in detail outside MHB.

- Other instream water use including minimum environmental flows are used as constraints to be met before diversions to other uses are made.

2.5.3.2 Climate Change

Eight future climate change scenarios for the period of 2021 to 2050 were selected to assess the impacts of climate change on hydrology and water availability. These scenarios include four conditions, labelled as cold-dry (cd), cold-wet (cw), warm-wet (ww) and warm-dry (wd), each for the Representative Concentration Pathway (RCP) 4.5 (stabilization scenario) and RCP 8.5 (high emission scenario). These future climate scenarios represent wettest, driest, warmest and coldest projections from the total ensemble of climate models. These scenarios cover the full range of projected future climate and are represented by the selected General Circulation Models (GCMs) (Table 2-17). The models were selected using the envelop method (Lutz et al., 2016; MoFE, 2019). The selected GCMs were bias corrected and statistically downscaled using the quantile mapping approach with observed climate (precipitation and temperature) data for the analysis of future changes in climate. The bias corrected and downscaled climate data were then used as input in the hydrological models to analyse the impacts of climate change on the hydrology of the river basins.

Table 2-17: Selected Climate Models

Scenarios \ conditions	RCP 4.5	RCP 8.5
Cold-dry (cd)	HadGEM2-CC_rcp45_r1i1p1	HadGEM2-CC_rcp85_r1i1p1
Cold-wet (cw)	CCSM4_rcp45_r2i1p1	CSIRO-Mk3-6-0_rcp85_r3i1p1
Warm-wet (ww)	CanESM2_rcp45_r2i1p1	CanESM2_rcp85_r3i1p1
Warm-dry (wd)	MPI-ESM-LR_rcp45_r3i1p1	MIROC-ESM-CHEM_rcp85_r1i1p1

The analyses of the future climate change conditions include the projected changes in annual, monsoon and winter precipitation, and temperature; and projected changes in the precipitation extreme indices for the period of 2021 to 2050 from the baseline period of 1981-2005. The increase in the future (2021 – 2050) projected temperature compared to the historical period (1981-2005) is likely to be higher in winter compared to the other seasons. The increase is also projected to be elevation dependent, where the increase will be higher in the mountains compared to the plains (Terai). The change in future projected annual average temperature is likely to vary by an increase of about 0.5°C up to 1.7°C in the RCP 4.5 scenario, and by an increase of about 0.7°C up to 2.2°C in the RCP 8.5 scenario. Similarly, the changes in future projected winter average temperature is likely to vary by an increase of about 0.6°C up to 2.2°C in the RCP 4.5 scenario, and by an increase of about 0.9°C up to 3.3°C in the RCP 8.5 scenario (Table 2-18 and Table 2-19). The changes in future (2021 – 2050) projected annual precipitation is likely to vary from a decrease of about 7% to an increase of up to 27% in the RCP4.5 scenario (Table 2-20), and from a decrease of 11% to an increase of up to 91% in the RCP8.5 scenario (Table 2-21). The change (increase) in precipitation is likely to be more in the monsoon than in the winter season.

Table 2-18: Projected Changes in Temperature (RCP4.5)

Basin	Historical precipitation (mm) (1981-2005)			Changes in RCP4.5 - 2021-2050 (°C)											
				cold, dry			cold, wet			warm, wet			warm, dry		
	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win
Mahakali - India	8	14	2	1.0	0.8	1.3	0.7	0.5	0.9	1.0	0.8	1.3	1.0	0.6	1.1
Mahakali	12	17	6	1.0	0.7	1.2	0.7	0.5	0.9	1.0	0.7	1.2	1.0	0.5	1.1
Karnali - China	-6	3	-13	1.7	1.2	2.2	0.9	0.6	1.0	1.7	1.2	2.2	1.6	1.0	1.7
Karnali	8	14	2	1.0	0.8	1.2	0.6	0.5	0.8	1.0	0.8	1.2	1.1	0.6	1.3
Gandaki - China	-2	5	-9	1.4	1.1	1.7	0.8	0.6	0.8	1.4	1.1	1.7	1.5	1.0	1.9
Gandaki	13	19	8	1.0	0.8	1.1	0.7	0.5	0.7	1.0	0.8	1.1	1.0	0.6	1.3
Koshi - China	-2	5	-9	1.3	1.0	1.4	0.9	0.7	0.9	1.3	1.0	1.4	1.4	1.0	1.5
Koshi	15	20	9	0.9	0.8	1.0	0.6	0.5	0.6	0.9	0.8	1.0	1.0	0.7	1.0
Babai	21	26	16	0.8	0.6	0.9	0.6	0.4	0.8	0.8	0.6	0.9	0.8	0.4	1.0
West Rapti	21	25	15	0.8	0.6	0.9	0.6	0.4	0.8	0.8	0.6	0.9	0.8	0.4	0.9
Bagmati	22	27	17	0.9	0.8	0.9	0.6	0.4	0.6	0.9	0.8	0.9	0.9	0.6	1.0
Kamala	24	28	18	0.9	0.9	0.9	0.7	0.6	0.8	0.9	0.9	0.9	0.9	0.7	1.0
Kankai	22	26	16	0.8	0.7	1.0	0.6	0.5	0.7	0.8	0.7	1.0	0.8	0.7	0.9
Mechi - India	24	29	18	1.0	0.9	1.0	0.9	0.8	0.9	1.0	0.9	1.0	1.0	0.9	1.0
Mechi	25	29	19	1.0	0.9	1.0	0.8	0.7	0.8	1.0	0.9	1.0	0.9	0.9	1.0
Southern Block 1	23	28	17	0.9	0.6	0.9	0.7	0.4	0.8	0.9	0.6	0.9	0.9	0.4	0.9
Southern Block 2A	24	29	18	0.9	0.6	1.0	0.7	0.5	0.8	0.9	0.6	1.0	0.8	0.4	1.0
Southern Block 2B	25	29	19	1.0	0.9	0.9	0.5	0.5	0.6	1.0	0.9	0.9	0.9	0.6	1.1
Southern Block 3	26	30	19	1.0	1.0	1.0	0.7	0.7	0.8	1.0	1.0	1.0	1.0	0.9	1.0
Southern Block 4	25	30	19	1.1	1.0	1.0	0.8	0.7	0.8	1.1	1.0	1.0	1.1	1.0	1.0

Table 2-19: Projected Changes in Temperature (RCP8.5)

Basin	Historical precipitation (mm) (1981-2005)			Changes in RCP8.5 - 2021-2050 (°C)											
				cold, dry			cold, wet			warm, wet			warm, dry		
	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win
Mahakali - India	8	14	2	1.2	0.9	1.5	0.9	0.8	0.9	1.2	0.8	1.5	1.4	0.6	2
Mahakali	12	17	6	1.2	0.9	1.3	0.9	0.8	1	1.2	0.8	1.5	1.3	0.7	1.8
Karnali - China	-6	3	-13	2	1.4	2.4	1.3	1.3	1.2	1.9	1.3	2.6	2.2	1.1	3.3
Karnali	8	14	2	1.2	1	1.3	0.9	0.8	1.1	1.3	0.9	1.6	1.4	0.8	2
Gandaki - China	-2	5	-9	1.6	1.4	1.8	1.1	0.8	1.2	1.5	1.1	1.9	1.8	1.1	2.4
Gandaki	13	19	8	1.2	0.9	1.2	0.8	0.5	0.9	1.1	0.7	1.2	1.3	0.7	1.6
Koshi - China	-2	5	-9	1.5	1.3	1.5	1.2	1.1	1.3	1.4	1.1	1.4	1.7	0.9	2.2
Koshi	15	20	9	1.1	1	1.2	0.9	0.6	1	1.1	0.8	1.1	1.2	0.6	1.5
Babai	21	26	16	1	0.7	1.1	0.8	0.6	0.9	1	0.7	1.2	1.1	0.6	1.5
West Rapti	21	25	15	0.9	0.6	1	0.7	0.5	0.9	0.9	0.6	1.1	1	0.5	1.4
Bagmati	22	27	17	1.1	1	1.1	0.9	0.6	1	0.9	0.6	0.9	1.1	0.5	1.4
Kamala	24	28	18	1.1	1.1	1.2	0.9	0.6	1	1	0.9	1.1	1.1	0.6	1.4
Kankai	22	26	16	1	0.9	1.1	0.8	0.6	1	1	0.7	1.1	1	0.5	1.4
Mechi - India	24	29	18	1.2	1.1	1.1	1	0.8	1	1.1	0.9	1.1	1.2	0.7	1.5
Mechi	25	29	19	1.1	1.2	1.2	1	0.8	1	1.1	1	1.1	1.1	0.7	1.5
Southern Block 1	23	28	17	1	0.7	1	1	0.9	1	1.1	0.8	1.2	1.2	0.6	1.5
Southern Block 2A	24	29	18	1	0.7	1.1	0.9	0.6	1	0.8	0.6	0.9	1.1	0.5	1.5
Southern Block 2B	25	29	19	1.2	1.1	1.1	0.9	0.7	1	0.9	0.7	0.9	1.2	0.6	1.5
Southern Block 3	26	30	19	1.2	1.3	1.2	0.9	0.8	1	1.1	1	1	1.2	0.7	1.5
Southern Block 4	25	30	19	1.3	1.2	1.2	1.1	0.9	1	1.2	1	1.1	1.3	0.7	1.5

Table 2-20: Projected Changes in Precipitation (RCP4.5)

Basin	Historical (1981-2005) mm			Future Changes RCP 4.5 - 2021-2050 (%)											
				cold, dry			cold, wet			warm, wet			warm, dry		
	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win
Karnali	1311	987	151	-5%	-3%	-11%	9%	3%	10%	14%	22%	-8%	6%	9%	-20%
Mahakali	1930	1514	197	-7%	-5%	-8%	8%	3%	-1%	13%	17%	2%	7%	12%	-13%
Gandaki	1741	1347	125	-3%	-1%	-7%	5%	2%	10%	15%	19%	-7%	6%	6%	-16%
Koshi	1058	809	66	0%	5%	-11%	12%	15%	3%	15%	19%	12%	2%	-3%	-21%
Babai	1595	1315	101	2%	6%	-18%	11%	6%	11%	24%	31%	-12%	10%	11%	-27%
West Rapti	1654	1355	105	9%	13%	-18%	9%	5%	7%	16%	21%	-8%	7%	10%	-25%
Bagmati	1896	1540	74	5%	11%	-16%	14%	15%	4%	17%	21%	3%	2%	-2%	-34%
Kamala	1718	1360	58	7%	13%	-13%	21%	25%	13%	24%	31%	10%	2%	-4%	-32%
Kankai	2146	1708	79	4%	7%	-12%	24%	28%	7%	22%	28%	12%	1%	-9%	-23%
Mechi	2853	2319	75	7%	8%	-10%	23%	28%	8%	20%	25%	16%	1%	-8%	-23%
Southern Block 1	3060	2467	81	6%	7%	-10%	23%	29%	9%	18%	23%	16%	1%	-8%	-23%
Southern Block 2A	1832	1579	108	4%	7%	-21%	12%	7%	12%	27%	34%	-11%	6%	8%	-33%
Southern Block 2B	1891	1604	81	16%	19%	-20%	9%	7%	7%	17%	20%	4%	4%	6%	-32%
Southern Block 3	1893	1560	66	5%	7%	-17%	18%	18%	4%	18%	23%	4%	6%	3%	-35%
Southern Block 4	1577	1271	50	14%	17%	-16%	24%	28%	16%	26%	34%	11%	2%	-4%	-30%

Table 2-21: Projected Changes in Precipitation (RCP8.5)

Basin	Historical (1981-2005) mm			Future Changes RCP 4.5 - 2021-2050 (%)											
				cold, dry			cold, wet			warm, wet			warm, dry		
	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win	Ann	Mon	Win
Karnali	1311	987	151	-6%	-4%	2%	58%	60%	27%	10%	6%	36%	2%	6%	-10%
Mahakali	1930	1514	197	-11%	-10%	0%	80%	87%	30%	10%	3%	47%	0%	4%	-13%
Gandaki	1741	1347	125	-2%	-1%	11%	37%	31%	11%	12%	12%	35%	2%	4%	-1%
Koshi	1058	809	66	-4%	0%	0%	24%	0%	24%	23%	26%	41%	-3%	-2%	1%
Babai	1595	1315	101	5%	7%	0%	48%	47%	12%	11%	7%	44%	6%	9%	-13%
West Rapti	1654	1355	105	11%	12%	8%	48%	42%	19%	12%	9%	49%	3%	6%	-10%
Bagmati	1896	1540	74	3%	8%	-1%	31%	23%	-2%	19%	20%	65%	-2%	-1%	-3%
Kamala	1718	1360	58	3%	9%	-1%	28%	20%	-6%	37%	44%	48%	-8%	-8%	10%
Kankai	2146	1708	79	-5%	-1%	-20%	9%	4%	20%	32%	38%	36%	-8%	-9%	4%
Mechi	2853	2319	75	1%	3%	-29%	9%	5%	18%	28%	33%	31%	-9%	-9%	0%
Southern Block 1	3060	2467	81	0%	2%	-27%	11%	6%	21%	26%	30%	30%	-8%	-8%	-2%
Southern Block 2A	1832	1579	108	13%	15%	-11%	91%	96%	33%	11%	6%	45%	8%	10%	-7%
Southern Block 2B	1891	1604	81	19%	20%	9%	64%	54%	19%	20%	19%	73%	-1%	0%	-6%
Southern Block 3	1893	1560	66	5%	7%	-3%	52%	43%	-2%	20%	20%	68%	-1%	0%	-2%
Southern Block 4	1577	1271	50	8%	11%	-9%	24%	18%	-10%	35%	41%	57%	-7%	-6%	11%

Climate Change impacts on Runoff

The hydrological response to any changes in climate, particularly precipitation and temperature, depends on the catchment characteristics, including size, shape, drainage density, land use and landcover, elevation and topography, geology etc. Catchments in Nepal can be broadly categorized as glacier, snow and rain-fed catchments. Catchment areas above approximately 5,000 m have year-round snow, areas above approximately 3,000 m have seasonal (winter) snow and areas below are rain-fed. The hydrological regimes of the catchments therefore vary according to the catchment areas with snow- and rain-fed runoff generation. Smaller catchments are also more sensitive to climate change than larger catchments. The impacts of climate change on hydrology therefore vary according to the areas under snow and rain, and according to the size of the catchments.

In general, the total annual and monsoon runoffs are projected to increase in the future (2021 – 2050) compared to the historical period (1986 – 2015) for most climate scenarios (RCP 4.5 and RCP 8.5). There are, however, high uncertainty (both increase and decrease) in the other seasons especially the pre-monsoon season (Figure 2-27).

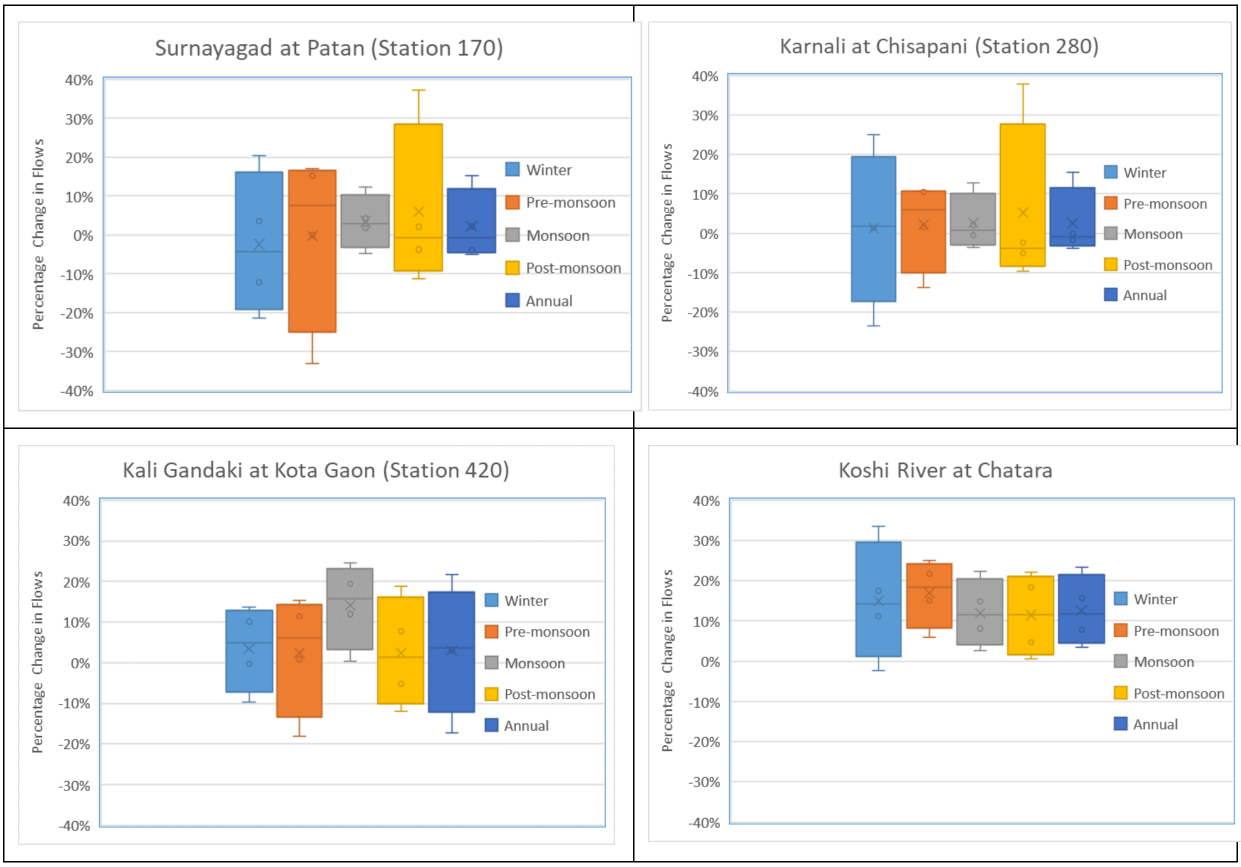


Figure 2-27: Projected changes (RCP 4.5) in annual and seasonal runoff in selected stations

Overall, the conclusion to be reached is that future climate change under most scenarios will result in an *increase* in annual and monsoon streamflows across the basin. However, the changes in other seasons are uncertain. This means that water resources planning need to be robust to the future uncertainties.

The high variability and extreme events of the current climate are projected to be further exacerbated by future climate change. Hence, water resources planning, and development will thus need to be resilient to more frequent and intense extreme events such as droughts, floods and other geo-hazards like landslides and increased sediment load.

2.5.3.3 Water Balance without Development Interventions

Based on estimated irrigation requirements and the water availability estimated in the hydrological modelling, a water balance scenario without any development interventions can be assessed. Figure 2-28 shows that the total annual irrigation demand of about 22.4 billion m^3 and 53.2 billion m^3 in 2025 and 2050, respectively. The total annual surface water available has been estimates at about 226.5 billion m^3. It should be noted that about 8 to 12 billion m^3 of renewable groundwater is available in the study region (WRS, 2002).

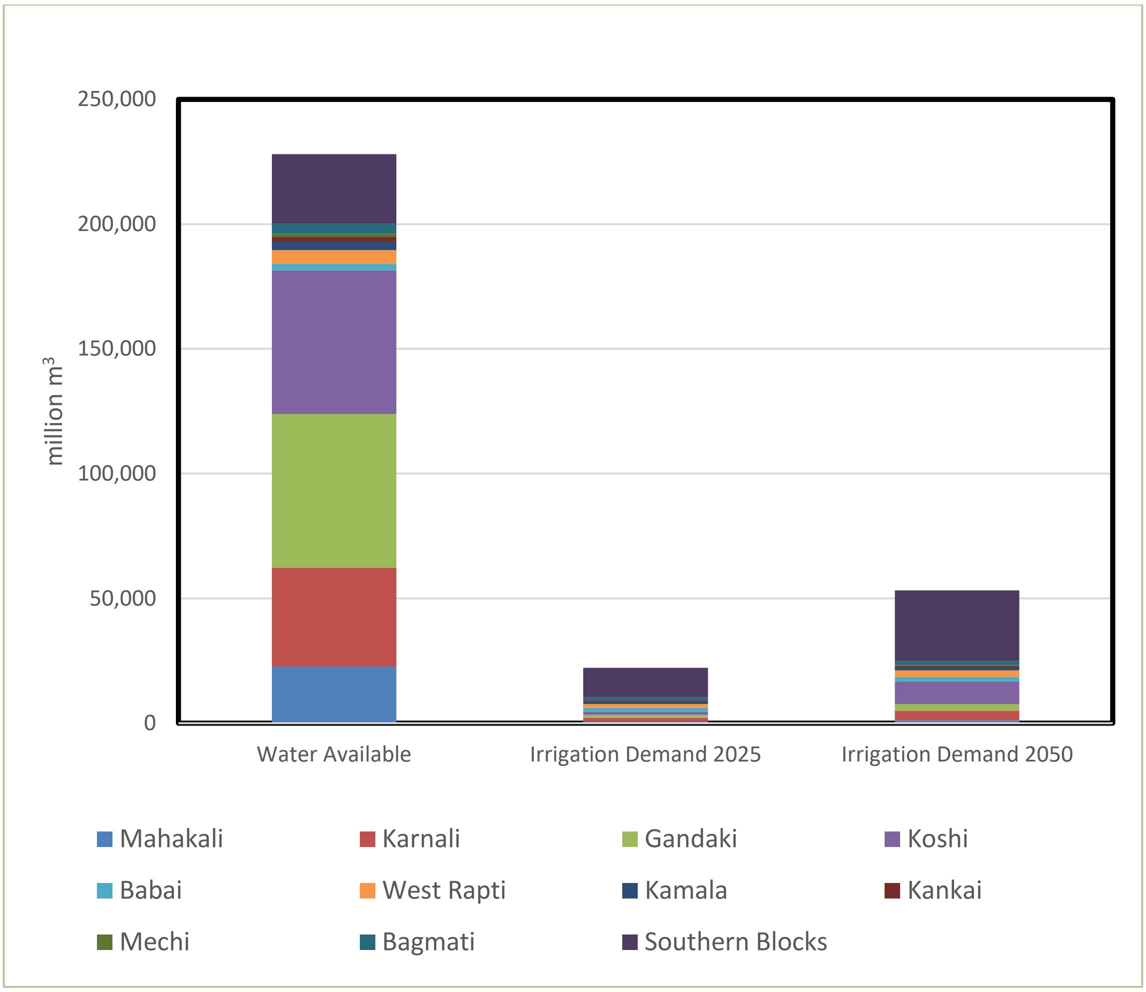
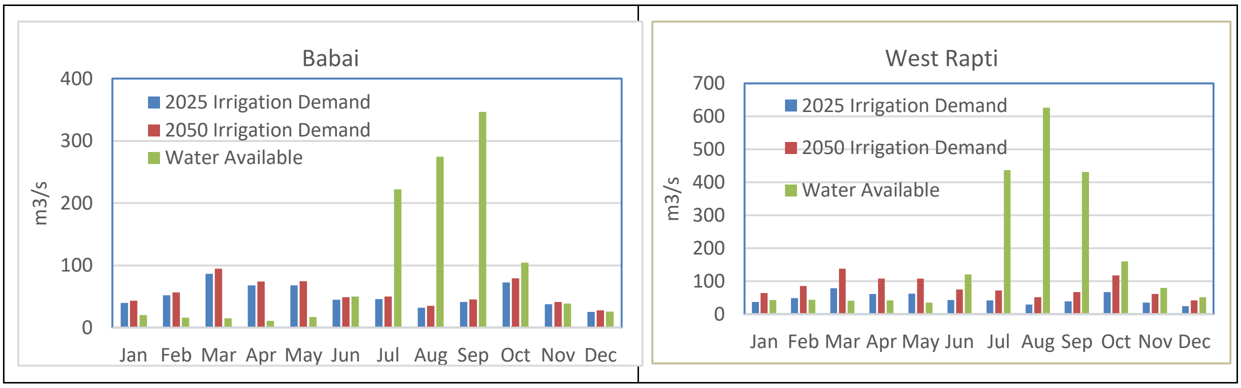


Figure 2-28: Annual Surface Water Available and Irrigation Demand

Although on an annual basis the total available water can meet the irrigation water requirement (Figure 2-28), there will be deficits in the dry months in the case of medium basins and the Southern Blocks (see Figure 2-29). The major basins however have sufficient water available even in the dry months (see Figure 2-30). The water balance presented here do not consider water supply demand and other consumptive uses as there are a small fraction of the irrigation water requirements. No development intervention such as storage projects or inter-basin diversions are considered in computing the water balance.



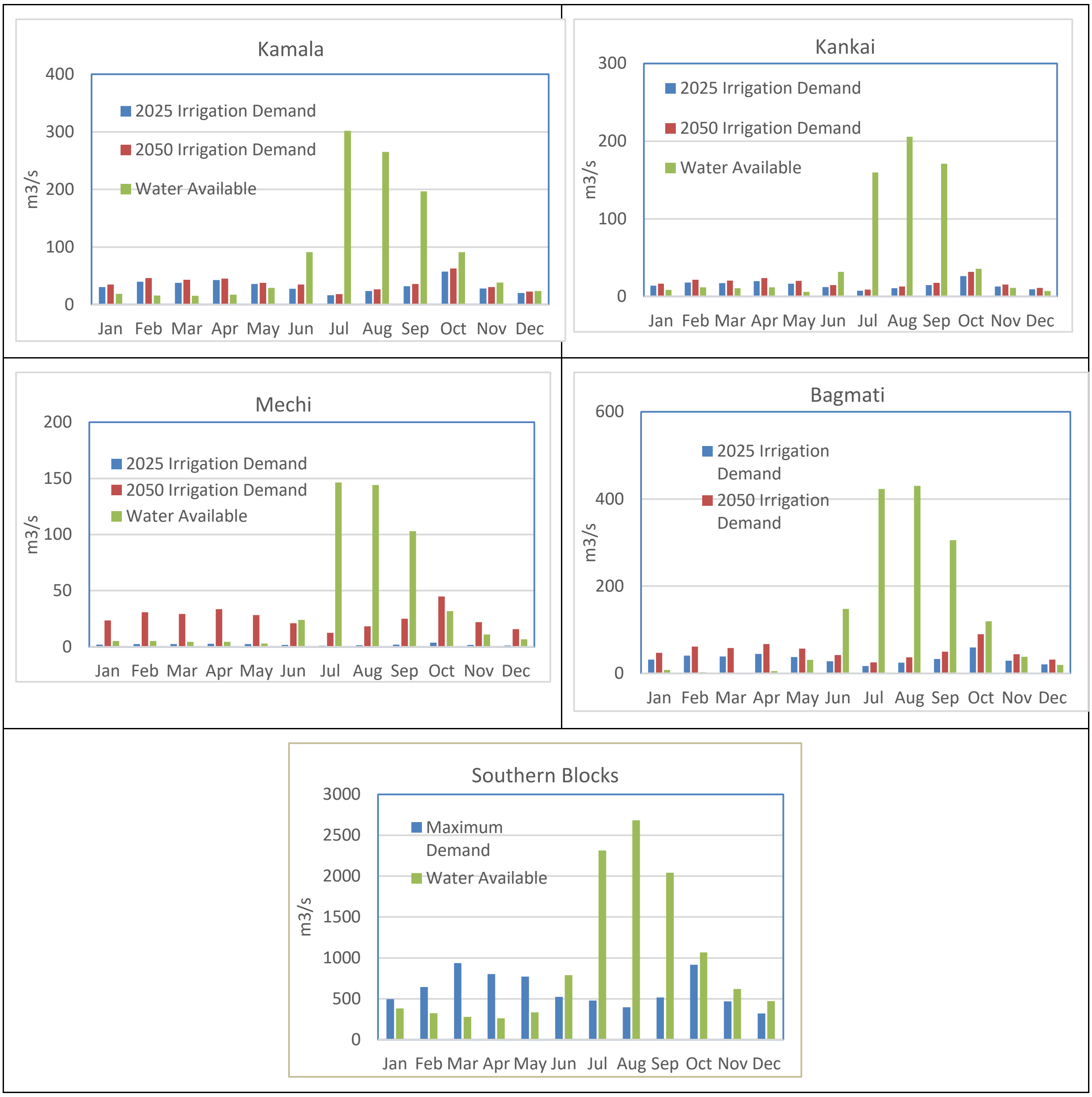
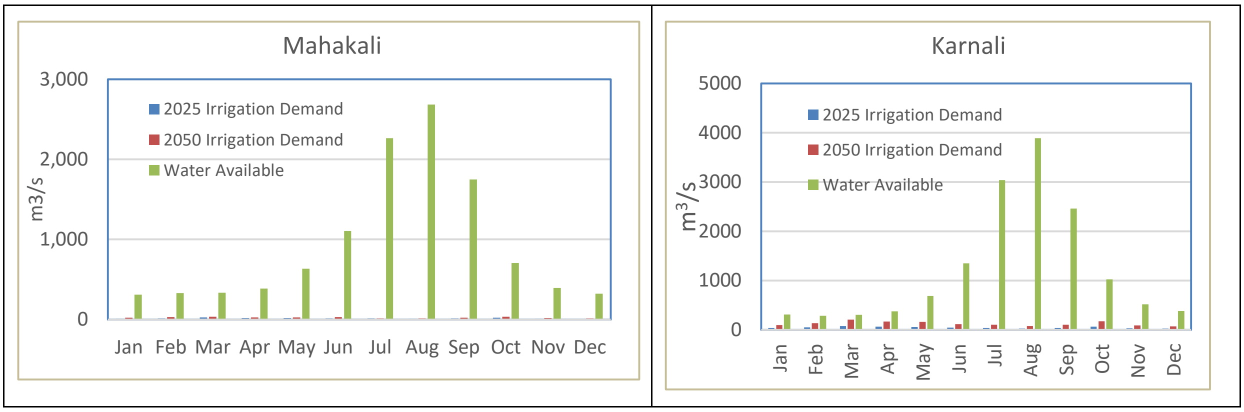


Figure 2-29: Water Balance without Development Interventions in Medium Basins and Southern Blocks



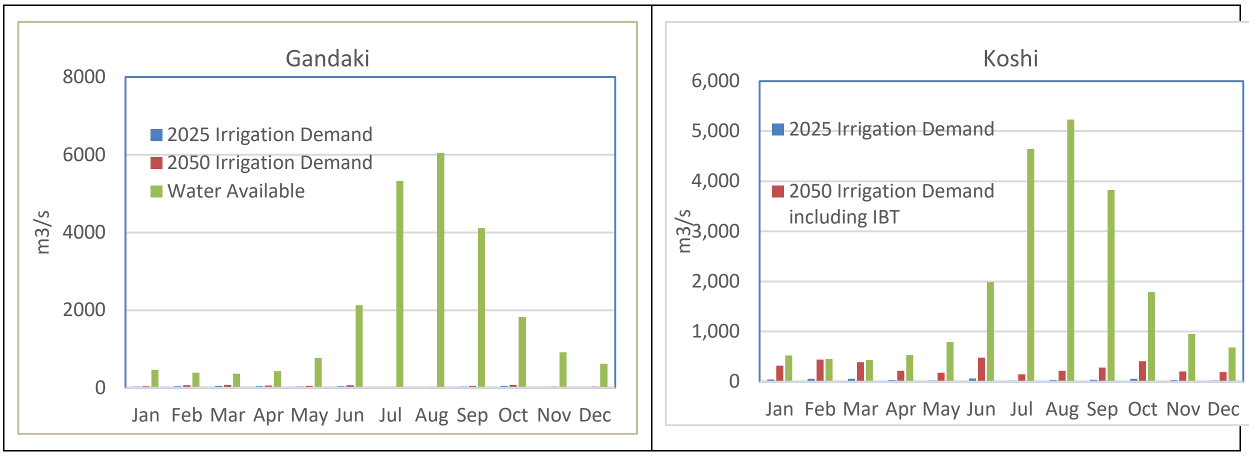


Figure 2-30: Water Balance without Development Interventions in Major Basin

2.6 Development Scenarios

Water resources development plans present portfolios of water management projects and policy alternatives that guide water managers and key stakeholders. These alternatives are developed and analyzed to illustrate the multi-sectoral trade-offs from possible future development paths. The following four development scenarios with a development pathway defined at each five year interval from 2025 up 2050 were generally considered in each river basin plans:

1. **Baseline Development (BDV)**: simulates population increases (DWS), small and medium irrigation scheme expansion (IRR) according to IMP, and operating HPPs,
2. **Development Scenario 1 (SC1)**: BDV, construction license and greenfield HPPs, selected inter-basin projects and multi-purpose projects according to HDMP Scenario 2 and IMP.
3. **Development Scenario 2 (SC2)**: BDV, construction license HPP and favorable greenfield HPP and selected inter-basin projects and multi-purpose projects according to HDMP Scenario 1 and IMP (2019).
4. **Maximum HP Development (MxDV)**: BDV plus construction license HPPs, favorable greenfield HPPs and selected inter-basin projects and multi-purpose projects according to HDMP Maximum Development Scenario. This is the maximum proposed IRR and HPP development.[12]

The current monthly water balance show that the major river basins (Mahakali, Karnali, Gandaki and Koshi) are water “surplus” basins and the other medium and smaller basins are water “deficit” basins where demand is more than available supply particularly in the dry months. Southern blocks (Terai) region are considered the major command areas of irrigation development of the river basins. Hence, the river development plans include the following major interventions (recommended by the IMP). The projects (from west to east) in summary are:

- **Bheri-Babai Diversion Multipurpose**; for diversion of water from the Bheri to Babai river, it will supply water for year round irrigation to total area of 51,000 ha, including 36,000 ha of the Babai IP and an additional area of 15,000 ha. It will also generate hydropower of a capacity of 46.8 MW.
- **Karnali Diversion**; for diversion of water from the Karnali river for irrigation of 46,000 ha, most new lands, and hydropower generation (about 80 MW).
- **Madi Dang Diversion**; for diversion of water from the Madi river to the Dang valley, for irrigation of about 28,200 ha, mostly to existing systems, and hydropower generation (about 61 MW). The economic feasibility of the diversion scheme should be verified through a feasibility study.

[12] For the Karnali Basin, an additional basin development scenario (**Karnali Chisapani Development (KCDV)):** combines MxDV Scenario with construction of the Karnali High Dam (2050 only). This is the maximum proposed IRRG and HP development with Karnali Chisapani MPP and MxDV was evaluated.

- **Rapti Kapilbastu Diversion**; for diversion of water from the West Rapti river to Kapilvastu for irrigation of about 51,000 ha, of which 15,000 ha are under existing systems and hydropower generation (with inclusion of Naumure dam and Kapilvastu diversion, about 330).
- **Kaligandaki Tinau Diversion**; for transfer of water from the Kaligandaki river to the terai, for which there are two options: (i) tunnel only for irrigation of about 31,000 ha and hydropower generation (244 MW), and (ii) addition of dam (Andikhola) to increase irrigated area to 42,000 ha and installed capacity to 424 MW.
- **Kaligandaki Nawalparasi (East) Diversion**; for diversion from the Kaligandaki river for the irrigation of about 11,500 ha and hydropower generation (4 MW).
- **Trishuli Shaktikhor (Chitwan) Diversion**; for diversion of water from the Trishuli river with two options: (i) tunnel only with an irrigated area of about 21,000 ha, and (ii) addition of storage dam (Budhi Gandaki) and increase in irrigated area to 35,000 ha and hydropower generation (1,200 MW).
- **Sunkoshi Diversion**; the project concept is for transfer of water from Sun Koshi River to the Marin and/or Kamala rivers, for irrigation up to 351,264 ha and hydropower generation, for which there are four options: (i) diversion to the Marin river for irrigation of 55,000 ha and power generation (31 MW), (ii) diversion to the Kamala river for irrigation of 122,000 ha and power generation (44 MW), (iii) diversions to both the Marin and Kamala rivers and construction of a storage dam (Dudhkoshi), for irrigation of 236,000 ha and power generation (2,830 MW), and (iv) diversion to both the Marin and Kamala rivers and construction of storage dam (Sunkoshi 3) for irrigation of 352,000 ha and power generation (701 MW).
- **Tamor Morang Diversion**; for transfer of water from the Tamor Nadi river, for which there are two options: (i) tunnel only for irrigation of about 45,000 ha, and (ii) addition of storage dam Tamor 3 for irrigation of about 114,000 ha and power generation (117 MW).
- **Kankai Multipurpose**; with the construction of a storage dam for the irrigation of about 40,000 ha (including the Kankai and Jhapa systems) and power generation (90 MW).
- **Saptakoshi Barrage**; with the construction of a barrage on the saptakoshi river for improved water supply to the Sunsari-Morang irrigation system plus an additional irrigated area of about 66,000 ha.

The development plans also include the following major storage (reservoir) projects:

- Pancheshwar MPP Dam in Mahakali Basin
- West Seti, Nalgad and Karnali Chisapani MPP Dams in Karnali Basin
- Madi Dang MPP and Naumure MPP Dams in West Rapti
- Budhi Gandaki Dam in Gandaki Basin
- Dudh Koshi, Sun Koshi 1 – 3, and Tamor MPP in Koshi Basin
- Kankai MPP Dam in Kankai Basin

The details of the simulation runs for the Development Scenarios considered in each river basin are given in **Annex A**.

Evaluation Metrics

Overall, the development plans are trying to increase power production and expand increasing irrigation without sacrificing DWS delivery for a growing population and minimizing environmental and social impacts.

Table 2-22 includes the outcome and performance indicators used to evaluate scenarios. Note, the methodology used to compute the environmental and social indices herein have been simplified from the detailed methodology used in Volume *3: Strategic Environmental and Social Assessment* (SESA). This methodology illustrates the relative change in conditions between alternatives given the factors acting on the system. A more comprehensive, basin-wide analysis can be found in Water Resources Development Plan (Volume 2) for each basin.

Table 2-22: Indicators used to evaluate water management simulations and scenarios

Sector	Outcome Indicators	Performance Indicators
DWS	Population supplied by DWS: ○ Target: Potential population served ○ Metric: Σ population for all Water user nodes Water delivered to Water user nodes: ○ Target: Total demand discharge required ○ Metric: Σ water delivered to Water user nodes	Reliability of DWS delivery: ○ Target (violation): >10% monthly delivery deficit ○ Metrics: – Σ violations per WU node – Σ Water user nodes with violations
IRRG	Hectares irrigated: ○ Target: Potential hectares irrigated ○ Metric: Σ hectares for all Water user nodes Water delivered to Water user nodes: ○ Target: Total demand discharge required ○ Metric: Σ water delivered to Water user nodes	Reliability of IRRG delivery: ○ Target: violation >20% monthly delivery deficit ○ Metrics: – Σ violations per WU node – Σ Water user nodes with violations
HP	Annual energy produced: ○ Target: Potential energy from all HPP ○ Metric: Σ energy produced.	Reliability of Storage HP: ○ Energy Targets: – % energy production during dry season ○ Metrics: – Σ violations per storage reservoir
ENV	Environmental conditions. ○ River conditions targets (basin-wide): ○ Legal Protected and International Areas ○ Other Ecologically Significant Areas ○ Affected Rivers (Σ HCVR[ƚ] *Length) ○ Key Species ○ Flow Regime Metrics: – Σ HCVR[ƚ] *Length – Σ Longitudinal connectivity/fragmentation - Env Index = Σ HCV * $Wt._{HCV}$ + Σ Connectivity * $Wt._{Connectivity}$ where $Wt._{HCV} + Wt._{connectivity} = 1$	Maintaining environmental flows: ○ E-Flow Target (site specific): monthly discharge < E-Flow target discharge/river reach ○ Metrics: – Σ months below E-Flow target (site specifics) – Σ sites with E-Flow target violations
SOC	Social Conditions ○ Resettlement of Households ○ Impacted Riverine Communities ○ Religious and Cultural Sites Metrics: – Soc Index = Σ $Indicator_i * Wt_i$ where Σ $Wt_i = 1$	None

[ƚ] HCV – typology combining freshwater status and values (Paani, 2020)

[#] Recreation: reaches identified for recreational based tourism (Paani, 2020)

3 Hydropower Development Master Plan

A Hydropower Development Master Plan (HDMP) was prepared under this study with the specific objectives of:

- Review existing hydropower development master plans, projects in operation and projects at different stages of development
- Carry out the identification and optimization of the hydropower projects considering the market conditions within and outside Nepal and the value of water for other uses
- Prepare updated and upgraded hydropower development master plans for the relevant river basins in Nepal

3.1 Overall Approach

The analysis and assessment of potential hydropower project (HPP) are based on a greenfield analysis of river basins. HPPs for which the Department of Electricity Development (DoED) issued Generation/Construction Licenses, HPPs in operation or projects of national interest under study are to be considered “locked project”, not subject of further studies.

3.1.1 Identification and Selection of Greenfield HPPs

For the identification and study of hydropower projects. a detailed GIS digital terrain model and data base of all river basins of Nepal and corresponding hydrological MIKE based models were setup. These models cover among others detailed topographic and hydrologic information, data on infrastructure such as roads and transmission lines as well as environmental and social aspects relevant for identification and assessment of hydropower projects including their cost and benefits.

For identification of greenfield hydropower projects, screening was conducted in all major river basins of Nepal. Screening of the river basins of Nepal for potential new hydropower projects was carried out to a level of catchment size of 100 km² and in selected cases even below based on the GIS Digital Terrain Model.

In this process efforts were made aiming on

- technically reasonable and economically attractive project options
- to the possible extent socio-economically acceptable projects
- achieving a possible full utilization of the hydropower potential of the river basin.

Project layouts were developed for

a) Run-off River HPPs (RoR HPP), discharging the river flow through the turbine
b) Peaking Run-off River HPPs (PRoR HPP), daily peaking operation of a 4 to 6 hours
c) Storage (STOR HPP) type Hydropower Projects, capable of storing > 60 days of mean annual reservoir inflow to make available a firm capacity of not less than 40 % of the installed capacity

The corresponding studies identified in total 443 additional Greenfield Hydropower Projects in 8 river basins, with an overall installed capacity of approx. 50 GW. The projects were subject to a technical and economic assessment and corresponding process of prioritization. Eventually, 156 additional economic attractive hydropower projects were identified, developed in this Masterplan having a total installed capacity of 25610 MW, which are recommended for implementation as and when required by the power system of Nepal.

3.1.2 Nepal’s Power System and Available Studies

From all relevant available sources of information including website of DoED, NEA Annual Report etc. the information were collected on the Nepali Power System and the Power Market. As per 01.04. 2023 the total installed capacity of the Nepali power System is in total 2241 MW.

1. Hydropower plant
   Hydropower (Capacity > 1 MW) : 2147.249 MW (123 projects)
   Hydropower (Capacity < 1 MW): 13.232 MW (17 projects)

Total from hydropower plant 2160.481 MW

2. Fossil fuel plant
   Hetauda diesel plant: 14.41 MW
   Duhabi multifuel power plant: 39.00 MW

   Total from thermal plant: 53.41 MW
3. Solar power plant: 24.18 MW (5 plants)
4. Co-generation (sugarcane bi-product) 3.00 MW (1 plant)

Subtotal 2241.071 MW

The National Power Market is largely under administration and management of the Nepal Electricity Authority (NEA). NEA negotiates power purchase agreements (PPA) with private power producers based on generation licenses issued by the DoED NEA dispatches the existing hydropower projects under state and under private ownership as well as import and export of electric energy according to the grid requirements and effectuates corresponding payments to the private power producers based on the terms of conditions agreed in the corresponding PPAs.

3.1.3 Listing Government of Nepal's (GON) Projects

Nepal has a huge hydropower potential that includes various large hydropower and multipurpose dam projects (Table 3-1). Such potential "Mega Projects" will have a high importance for the national power market and also for the export of electricity to Nepal's neighbouring countries. Some of these projects require bi-national development (with India). The large dam projects have the potential to contribute substantially to flood control and the stable provision of water for large irrigation projects in Nepal and India. The majority of these large multipurpose projects have been under study by the Government of Nepal or by bi-national study teams for substantial time. The required large investment and the associated substantial environmental and socio-economic impacts have resulted in delays in their implementation.

For example, the Arun 3 HEPP is an "Export Project" and 78.1% of the generated energy will be supplied directly to India as defined in the respective agreements. Similarly, present agreements foresee that only 12% of 900 MW installed capacity of the Upper Karnali HPP will be available for the Nepali power market during the 30 years lease period while the remaining major part will be evacuated to the Indian grid.

The tentative information communicated by governmental planning organization on the implementation of the above GON Projects with 6 projects commissioned by the year 2030 and another 6 projects by the year 2035 appears rather optimistic in view of the required financial and administrational efforts Available technical information were collected and corresponding project data sheets were prepared to conduct the technical assessment.

Table 3-1: GON HPP projects with estimated RCOD

SN	Project name	River	River basin	Installed capacity (MW)	Annual Energy generation (GWh)	RCOD (Year)	Assessment	Special remarks (protected area etc.)
1.	Arun 3	Arun	Koshi	900	3,924	2023	site visit	under construction, located in buffer zone
2.	Upper Karnali	Karnali	Karnali	900	4,405	2029	viability confirmed by study team	Free flowing river proposed by PAANI Program
3.	Budhi Gandaki storage	Budhi Gandaki	Gandaki	1200	4250	2031		
4.	West Seti	Seti	Karnali	750	2437	2031		
5.	Tamor storage (TAMO060)	Tamor	Koshi	369	2,022	2030	viability confirmed by Study team	IMP Project
6.	Dudhkoshi storage	Dudhkoshi	Koshi	640	2815	2031	viability confirmed by Study team	Alternative dam site and layout recommended

SN	Project name	River	River basin	Installed capacity (MW)	Annual Energy generation (GWh)	RCOD (Year)	Assessment	Special remarks (protected area etc.)
7.	Lower Arun (ARUN093)	Arun	Koshi	366	2189	2030	viability confirmed by Study team	Located in buffer Zone
8.	Tamakoshi -3	Tamakoshi	Koshi	650	2300	2030		
9.	Upper Marsyangdi -2	Marsyangdi	Gandaki	327	1806	2033		Located in conservation area
10.	Nalgad	Nalgad	Karnali	417	1232	2031		
11.	Upper Arun	Arun	Koshi	1060	4492	2030	viability confirmed by Study team	Located in buffer zone
12.	Sunkoshi -3 (SUNK220)	Sunkoshi	Koshi	542	2244	2031	viability confirmed by Study team	Alternative dam site and layout recommended
13.	Budhiganga HPP	Budhiganga	Karnali	20	109.61	2027		

SN	Project name	River	River basin	Installed capacity (MW)	Annual Energy generation (GWh)	RCOD (Year)	Assessment	Special remarks (protected area etc.)
14.	Saptakoshi High Dam MPP	Saptakoshi	Koshi	4975	21766	NA	viability confirmed by Study team	High resettlement impact
15.	Pancheshwar	Mahakali	Mahakali	5040	9116	NA		With regulating dam 5040 MW
16.	Karnali (Chisapani) KARN038	Karnali	Karnali	4024	18480	NA	viability confirmed by Study team	Located in National Park,
17.	Sunkoshi -2 (SUNK158)	Sunkoshi	Koshi	817	3576	NA	viability confirmed by Study team	High resettlement impact
18.	Sunkoshi -1 (SUNK116)	Sunkoshi	Koshi	2128	8839	NA	viability confirmed by Study team	High resettlement impact
			Total	25126				

3.1.4 Listing of Inter-basin Water Transfer Projects

Irrigation Masterplan of Nepal (IMP. 2019) has proposed 9 number of inter basin water transfer projects mainly to provide year-round irrigation under the potential command area lying in plain/Tarai area of Nepal in which hydropower is the bi-product. The list of such projects is given in Table 3-2.

Table 3-2: List of selected inter-basin water transfer projects with hydropower development

SN	Project name	River	River basin	Installed capacity (MW)	Annual Energy generation (GWh)	RCOD (Year)	Assessment	Special remarks (protected area etc.)
1.	Bheri - Babai Diversion	Bheri	Karnali	46.8	400	2023	Selected in IMP	
2.	Karnali Diversion	Karnali	Karnali	80.0		2035	Selected in IMP	Proposed free flow river
3.	Madi – Dang diversion (MADI266)	Madi	West Rapti	66.7	233	2037	Not confirmed by Study team	Not priority project
4.	Naumure dam & Rapti- Kapilvastu diversion (WRAP203)	West Rapti	West Rapti	330.4	1207	2033	Selected in IMP, viability confirmed by Study team	
5.	Kaligandaki -Tinau Diversion	Kaligandaki	Gandaki	101.0		2042	Selected in IMP	
6.	Kaligandaki - Nawalparasi	Kaligandaki	Gandaki	4.0		NA	Selected in IMP	
7.	Sunkoshi – Marin Diversion	Sunkoshi	Koshi	30.7		2029	Selected in IMP	
8.	Sunkoshi – Kamala Diversion	Sunkoshi	Koshi	62.0		2029	Selected in IMP	
9.	Tamor – Morang Diversion	Tamor	Koshi	117.0		2040	Selected in IMP	

3.1.5 Assessing the Transmission System

An essential requirement for the rapid development of the hydropower resources of Nepal is the development of robust and reliable national and cross boarder transmission network to properly transmit, distribute and export power generated from these hydroelectric plants. Considering operating projects, under construction projects and planned potential hydropower projects under development, NEA prepared a Transmission Line Master Plan in 2015. In 2018, a Transmission System Development Plan of Nepal was prepared by “Rastriya Prasaran Grid Company Nepal” that covers the planning of the country's grid network for the period from 2020 to 2040.

The Transmission Line Master Plan proposes the extension of the existing grid including cross-border transmission lines for increasing export of power to India. The Transmission Line Master Plan assumed an installed capacity of 25.6 GW and peak domestic load of 4.7 GW by the year 2035. The proposed transmission line network to be implemented by the year 2035 is indicated in Figure 3-1.

Existing Cross-Border Transmission Line

Presently Nepal imports power from Bihar and Utter Pradesh power grid from India and surplus power is exported to India (in the high flow season). In total, 14 cross-border Transmission Line links are under operation, most at 33 kV level, some on 132 kV level and Dhalkebar -Muzaffarpur on 400 kV level (see Figure 3-1).

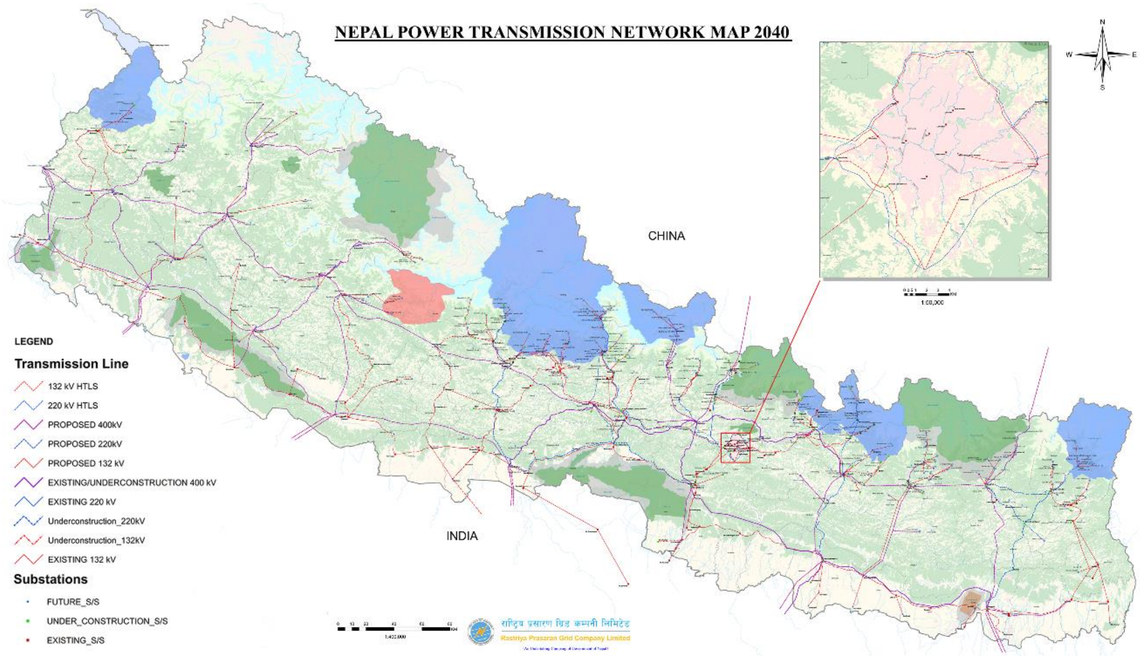


Figure 3-1: Proposed transmission line Network for 2040 - Rastriya Prasaran Grid Company

Planned and proposed cross border transmission line

“The Transmission System Master Plan and Nepal-India Joint Technical Team” has been identified and proposed 6 locations for new cross-border power transmission with India & 2 locations with China, as under have been defined in the Transmission Masterplan.

Considering the above implementation of the 400kV "East-West Power Highway", the Hydropower Development Masterplan is based on a nationwide planning prospective rather than referring to the power demand in the individual river basin. Potential feeder points (points of interconnection to the grid) and related cost of transmission lines were estimated based on the configuration of the national transmission line network indicated in the above Transmission Line Master Plan.

3.1.6 Assessing the National Power Demand Period 2022-2050

Forecasting of the future domestic demand for power, and the required installed hydropower capacity to supply that demand reliably, is essential if an effective hydropower plan is to be prepared beyond the provision of adequate power project options (in terms of number, economic attractiveness, and capacity). The forecast will determine what investment will be needed if the "primary goal" proposed above is to be achieved in steps of five years up to 2050.

Several demand forecasts had been developed previously elaborated by different sector entities.

- System peak demand projections according to NEA (Annual Report)
- The National Strategy of Nepal of 2013 forecasting the required installed capacity until 2030
- Estimated demand for the year 2040 according to the "Integrated Master Plan for Evacuation of Power from Hydro Projects in Nepal" - Joint Technical Team (JTT) of Nepal and India
- WECS published forecast until 2040
- The projection of demand according to the 15th National Plan of the National Planning Commission

The above forecasts of power demand or required installed capacity were analysed and a critical analysis was carried out. Based thereon, the Base Case and alternative demand scenarios were elaborated to realistically reflect the current status as well as the potential power sector development.

3.1.6.1 Present System Demand of Nepali Power Market

The NEA Annual Report (2021-2022) provides information on the historic increase of the system peak demand of the period from 2012 to 2022.

Table 3-3: Historic Development of system peak demand (NEA, 2022)

Source	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Peak Demand (MW)	1027	1095	1201	1291	1385	1444	1508	1320	1408	1482	1748

It indicates a system peak demand of 1482 MW for the year 2021 and 1748 for 2022. The system peak demand of the years 2019 to 2021 was affected by the Covid pandemic. When extrapolating the historic development of the peak demand from 2012 to 2017 a peak system demand in the magnitude of 4,500 MW is projected in the year 2050. The power deficit in the dry season has been balanced by power import from India. The load growth from the NEA annual report indicates a rate of approximately 8% annually.

3.1.6.2 Prediction of the System Demand of Nepali Power Market

One of the most recent available predictions of the demand growth of the Nepali power system (required installed capacity) is presented in the Fifteenth National Plan (Fiscal Year 2019/20 – 2023/24) of the National Planning Commission, GoN. It states the following vision, goal and objectives for hydropower:

Vision: Contribution to prosperity of the nation through sustainable & reliable development of hydropower.

Goal: To ensure energy security through intensifying hydropower generation

The Fifteenth National Plan presents the assumed development goals of the available installed hydropower capacity in the Nepali power system indicating a nearly linear growth.

Table 3-4: Required Installed capacity in the Nepali power system as per 15th Plan (NPC, 2020b)

Year	2018	2023	2029	2043	2050
Installed Capacity MW	1250	5820	15000	35000	45000 1)

1) extrapolated value

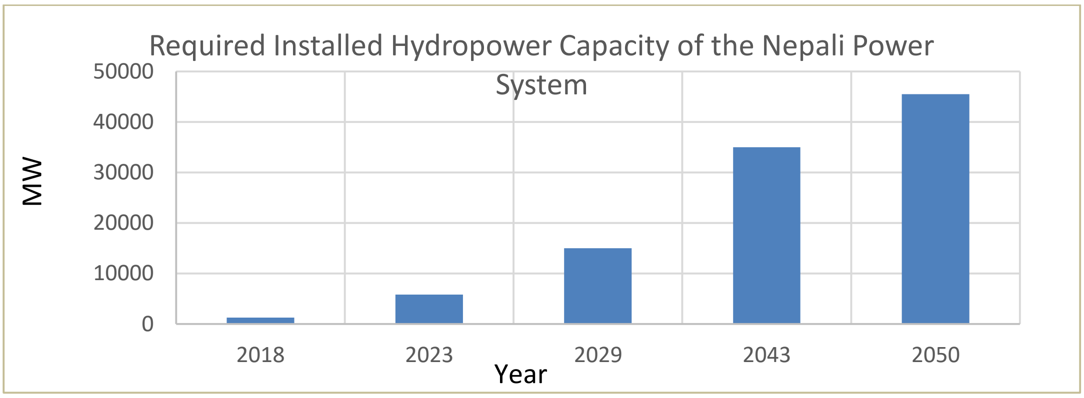


Figure 3-2: Required installed capacity of Nepal Power System as per NPC (NPC, 2020b)

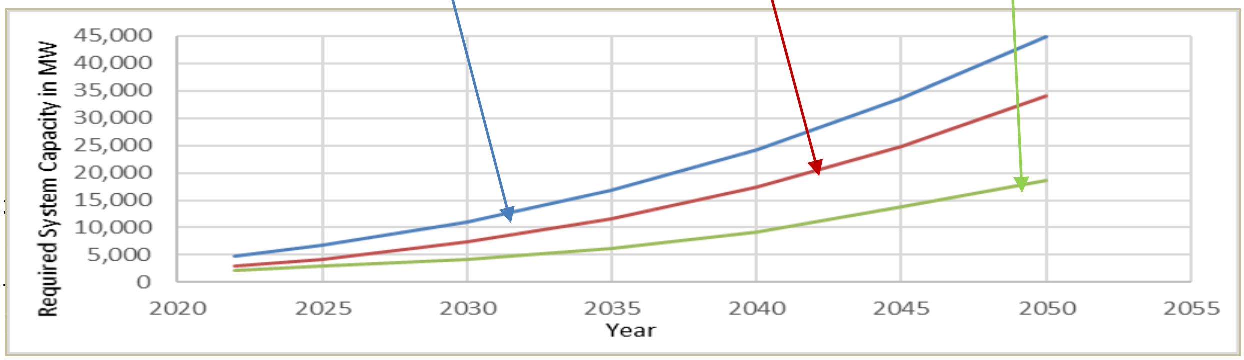
The above forecast of the required installed hydropower till the year 2043 (extrapolated to the year 2050) as derived from the Fifteenth National Plan will be considered as **Base Case** in the nationwide Hydropower Development Masterplan.

ADB South Asia presented in a Working Paper Series "A Study on the Prospect of Hydropower to Hydrogen in Nepal" (Zhou et al., 2020) an alternative approach in August 2020 and concluded. "*This presents critical challenges to the target of meeting peak demand over the short- to medium-term, forecasted to increase from 2,225 MW in 2020, to 6,848 MW in 2030, and further to 18,137 MW in 2040.*" When extrapolated to the year 2050 it results in a required installed capacity of 34,119 MW. The above prediction of the required installed hydropower capacity is considered as **Scenario 1** in the nationwide Hydropower Development Masterplan.

Considering various impacts such as "…underinvestment, external shocks, trade blockade, and weak implementation capacity" including recent the worldwide pandemic situations and military conflicts, one could recommend applying a less optimistic outlook for the power demand of the Nepal power market. For such scenario the extrapolation of the historic peak demand growth reported by NEA was considered resulting in a predicted peak system demand of approx. 5,000 MW in the year 2050. Such a less optimistic **Scenario 2** results in a required installed hydropower capacity of approx. 19,000 MW in the year 2050. The demand forecast for the Base Case and Scenario 1 and 2 are summarized below.

Table 3-5: Required installed Hydropower Capacity in the Nepali Power System

Year	Installed HP Capacity Base Case MW	Installed HP Capacity Scenario 1 MW	Installed HP Capacity Scenario 2 MW
2022	4,717	2,882	2,093
2025	6,697	4,234	2,930
2030	11,041	7,331	4,249
2035	16,850	11,660	6,161
2040	24,302	17,428	9,241
2045	33,567	24,845	13,862
2050	44,812	34,119	18,591



a) Most HPPs in Nepal are of the run-of-river type and not able to regulate river flow.

b) Major part (75% or more) of river flow occurs in the so-called wet season from June to September, With the increasing implementation of hydropower projects Nepal will become a net exporter of energy in the near future, both in the dry and the wet season. At present the following two principal types of arrangements for export of energy from Nepal to India exist.

1.) **"Export Projects" by foreign (Indian) developers / IPP**
Hydropower Projects implemented and operated to export the major amount of energy generation to India and providing in compensation a fixed share to the Nepali market. During the agreed lease period (30 years), the export projects provide only a certain (royalty) share of energy generation to Nepal at no cost. After lapse of the lease period the project will be handed over to the Government of Nepal free of cost and in operational condition to be operated further.

2. **"NEA Export" – Export of surplus energy by NEA**
Surplus energy is available in the Nepal power system (in the wet season) from HPPs operated by NEA or by Private Power Producers which entered into Power Purchase Agreements (PPA) with NEA. The Government of Nepal has been in negotiations with the Indian government and/or Indian utilities for sale of such surplus energy at prices acceptable to both parties.

3.1.7.1 Energy Exports to India – "Export Projects"

The following "Export Projects" have been agreed between Government of Nepal and Indian investors.

SN	Project Name	Installed Capacity (MW)	Share to Nepal at Free of Cost (MW)	IPP	Remarks
1.	Arun-3	900	197.1	Satluj Jal Vidyut Nigam	21.9% energy to Nepal at free of cost, under advance stage of construction
2.	Upper Karnali	900	108	GMR	Under Feasibility study (west Seti: 750 MW & SR6: 450 MW
3.	West Seti+SR6	1100	unknown	NHPC Limited	12% energy to Nepal, under construction license
4.	Lower Arun	679	unknown	Satluj Jal Vidyut Nigam	PDA signed between IBN Nepal and Satluj Jal Vidyut Nigam, India
5.	Fukot Karnali	480	unknown	NHPC Limited	MOU signed between VLCI, Nepal & NHPC Limited, India

3.1.7.2 Energy Exports of Surplus Energy

Recently, a series of discussions between Nepal and Indian Government on power projects development and power import from and export to India have been conducted. Based on the available information, it is understood that such negotiations will be a continuous process as the power markets in Nepal and India are rather dynamic and are also affected by international energy and fuel price developments etc. Central Electricity Authority of India initially approved the import of up to 39 MW of power from two generating stations namely Trishuli and Devighat Hydropower Projects in Nepal. In the beginning of 2022, the approved quantum was increased to 364 MW. In total, Central Electricity Authority of India, Ministry of Energy agreed to purchase the power from the following six Nepalese power plants.

As envisaged by India-Nepal Joint Vision Statement on Power Sector Cooperation issued in April 2022, NEA is committed to prepare itself for the adequate market access of neighbouring countries by developing more high voltage transmission interconnections with India and using the existing transmission network in India for power trade with Bangladesh.

Bangladesh demonstrated their interest to purchase 500 MW of power from the 900 MW Upper Karnali HPP. The necessary infrastructure in terms of transmission facilities still needs to be established. In March 2021, India government announced its Interstate Energy Trade Procedure endorsing a working guideline for cross-border power trade which opened the gateway for the trilateral power trade. The procedure will allow Nepal to export its excess electricity to Bangladesh.

India and Bangladesh intend to phase out coal fired power generation and offer large market opportunities for the energy generation sector in Nepal. Surplus electricity generated in Nepal is competitive on the Bangladesh power market. The Bangladeshi government manifested its interest in a long-term power purchase agreement between Bangladesh and Nepal's private sector. Nepal – Bangladesh Joint Steering Committee 5th meeting was held in Bangladesh dated 16th May 2023, in which understanding was maintained to sign a joint venture agreement between Nepal Electricity Authority and Bangladesh Power Development Board within six months for the development & construction of Sunkoshi-3 HPP in Nepal.

3.2 Hydropower Project Development and Assessment

For the identification of Greenfield Hydropower Projects, a GIS - database including a digital terrain model of all river basins combined with the Mike-Basin hydrological model were established. Information on the location of hydropower projects in operation, with issued construction licenses and hydropower projects of national importance, and as information on the road and transmission line grid were included to the database. The following categories of hydropower projects were considered as "locked" and their project area disregarded in the project identification:

- HPPs in operation
- HPPs in advanced level of development with issued construction licenses
- HPPs of particular national importance under study (large dam/multipurpose projects)

For each greenfield hydropower project, a seven-digit code was established to ensure a systematic and consistent management of project data. The first four letters of the project code are derived from the name of the river, which were combined with a three-digit code representing the distance of the dam/weir site from the end of the river (confluence with next higher order river) measured in km.

<u>Technical Assessment</u>

Considering the prevailing natural boundary conditions for hydropower development, adequate dam/weir and powerhouse sites were identified and a project layouts elaborated. The specific hydrological data in combination with topographic and geological information governed the arrangement of flood evacuation facilities and dam types. By application of the design software packages EVALS the required design, hydraulic, structural, and design calculations were carried out including the elaboration of a bill of quantities and economic optimization of the individual project components.

The identification and elaboration of the greenfield hydropower projects included the consideration of alternative project layouts to determine identify the technical and economical best suited concept for exploitation of the available hydropower resources.

<u>Hydrological Data base</u>

As part of the River Basin Masterplan. The available hydrological data were collected, analysed and processed to prepare hydrological models covering the river basins of Nepal. The hydrological models were used to generate the hydrological data required for the design of the greenfield hydropower projects and the simulation of their operation such as

- River flow time series (daily flow data of 30 years)
- Precipitation and Evaporation time series
- Design flood peaks and hydrographs
- Sediment yield

<u>Economic Parameters for Project Assessment</u>

For the estimation of cost and benefits, the economic analysis and optimization of the selected greenfield HPPs a set of principal economic parameters are used. The following key parameters were defined in coordination with WECS at project inception.

- Discount Rate 9 %
- Economic lifetime 50 years
- Optimization criteria Benefit Cost Ratio, Maximum net Benefit
- Currency(ies) USD

Approach to estimation of Power Generation Benefits and Cost Benefit analysis

The economic cost benefit analysis was applied, which is a method used to evaluate projects based on their value to the nation to ensure the most efficient use of a nation's resources. The analysis of a country's resources must be conducted from the viewpoint of the national economy. An economic cost-benefit analysis compares the value to the country “with the project” to the value “without the project”.

The hydropower plant will be able to guarantee a certain amount of annual energy production year-round, this is the Firm Energy. Due to this uncertainty and its effect on system stability and plannability, non-firm energy has a lower economic value to the country (and energy system) than firm energy.

- **Firm Energy** is the energy that the plant will generate year-round and is the guaranteed value generally used for system planning, PPAs and Export agreements. Firm power is the lower bound of energy generation, therefore *maximizing firm energy maximizes reliable power in the dry season*.
  - To determine the value of firm energy, the cost of the HPP is compared to the cost of the best (thermal) alternative comprising fixed & variable cost (capital expenses + operating expenses) equal in capacity to firm capacity of HPP.
- **Non-Firm (Secondary)** energy that may be generated above the guaranteed amount, particularly in the wet season, though some portion will also be produced in the dry season. Non-firm energy is procured on an “as needed” basis.
  - To establish the value of non-firm energy, the cost of the HPP is compared to the variable cost of thermal alternative, which is primarily the value of fuel saved.

3.3 Basin-wide Optimization of Hydropower Projects

Part of the basin-wide optimization of HPPs was the definition of their economic optimum project configuration including its optimum installed capacity. For the optimization of the hydropower projects. the market conditions used was as follow:

a) National Power Market
b) Market conditions for export of electricity to Nepal’s neighbouring countries, mainly India
c) A possible combination of both

Identified Hydropower Potential of Nepal

In total, 443 Greenfield HPPs were identified in the present Masterplan. The majority of projects is located in Koshi, Gandaki and Karnali river basin. For each HPP, the following set of data was prepared:

- a pre-feasibility level design,
- bill of quantities for civil works, electro-mechanical and electrical equipment
- results of simulation of plant operation (based on 30 years of daily flow data)

Project Prioritization

In the technical, economic and environmental assessment of the potential greenfield hydropower projects the following sequence of activities and project prioritization was followed:

1. Identification of potential Greenfield HPPs: Total number of projects → 443
2. First prioritization of HPPs (specific cost of installed capacity) < 4000 USD/kW → 301
3. Project optimization and second prioritization based on Benefit-Cost Ratio >1 → 156

MCA Analysis of Greenfield Hydropower Projects

Following the technical and economic assessment and optimization of their project configuration and installed capacity, the 156 attractive Greenfield HPPs with an overall installed capacity of 25610 MW were subject to a multicriteria assessment MCA.

1.) Technical and Economic aspects Overall weight 60 %
2.) Environmental and Social impacts Overall weight 40%

Table 3-6 indicates the technical and economic assessment criteria and corresponding valuation parameter and summarizes the environmental and social assessment. Projects with high MCA score are recommended to be developed with priority.

Table 3-6: Technical, Economic and ESIA Criteria for Assessment of Hydropower Projects

Assessment Category		Measurement/ Assessment	Valuation(high score = most favourable)	max value	min value	Weight	Max weighted value (=max value x by weight)
Technical/Economic	Criterion						
Hydrology	Risk related to GLOF	No. of glacier lakes	Low No. 0 < No. < 10	10	1	5.0%	0.50
Geology	Seismicity of project area	Ground acceleration low to high	low seismicity 100 <No.< 400	10	1	10%	1.00
	Risk of underground works	Tunnel Length	length in km 0>L<8	10	1	7.0%	0.70
Infrastructure	New Access Road	Length	low length 0<L< 100	10	1	3.0%	0.30
Power/ Energy	Installed Capacity	Optimum range	optimum implementation 50 to 200 MW	10	1	5.0%	0.50
	Plant Factor	Plant Factor	high ratio 1.0 > PF > 0.2	10	1	5.0%	0.50
Economics	Benefit Cost Ratio	B/C Ratio	high B/C 3 > B/C > 1	10	1	20.0%	2.00
	Construction Period / Stagin	Require construction period in years	short period 2<CP	10	1	5.0%	0.50
				Subtotal		60.0%	
		*1) Plant Factor = annual energy generation vs. Theoretical max annual generation					

3.4 Portfolio of Projects in the Hydropower Development Master Plan

The Hydropower Development Plan provides recommendations and portfolios of potential projects for consideration in the further development of Nepal's power sector up to the year 2050 to cover the national energy demand, to permit revenues from export of energy to neighbouring countries in an increasing extent and thus contribute to the economic growth and prosperity of the country.

At present, there is a large number of hydropower projects under development and under study in Nepal at different stages of design, with corresponding licenses issued or applied and with different financial and technical capacities of the potential project developers. In addition, there is a substantial additional potential for the economic development of hydropower projects in Nepal that was assessed as part of the present Masterplan as so called "Greenfield Hydropower Projects".

Goals and Objectives for elaboration of the HDMP are:

a. Primary Goal: Supply all domestic electricity demand incl. a reserve margin.
b. Economic objective: To minimize investment cost of Hydropower, **while** maximizing national economic benefit.
c. Environmental objective: To minimize adverse environmental impacts of HP development.
d. Social objective: To minimize adverse social impacts and maintain continuous improvement of the standard of living for all Nepalese people.

The present HDMP considers the relevant forecasts for the demand of the power market and starts at the present status of development and planning achieved by end of April 2023, it considers:

- Existing power generation facilities
- Hydropower Projects in advanced stage of Development (with issued Construction License)
- Hydropower Projects decided for Implementation by GoN (Mega Projects)
- Multipurpose Projects decided for Implementation by GoN.
- Potential additional attractive (Greenfield) Hydropower Projects

It is observed that a large number of Projects is in advanced stage of development by private developers or has been decided by the GoN for implementation during the forthcoming 15 years. Information was collected on the estimated commissioning dates of such "locked" projects from governmental authorities for consideration in the Hydropower Development Masterplan.

The HDMP was developed for five-year increments starting at the year 2022 and then from 2025 each five years up to the year 2050 for a Base Case and two alternative scenarios versus the forecasted development of the required installed capacity of the Integrated Nepal Power System

Table 3-7: Scenarios for the Development of the Hydropower Development Plan

Scenario	System Power Demand
Base Case	Optimistic (High)- adapted from 15th Plan of Planning Commission (NPC, 2020b)
Scenario - 1	Medium adapted from Zhou et al. (2020)
Scenario - 2	Low- Extrapolation of actual peak power demand (NEA)

As the experience has shown, not all licensed HPPs or HPPs presently under study will be implemented according to their original schedule or may even not be implemented for various reasons. Accordingly, and considering potential effects of recent international crises (COVID pandemic or recent military conflicts) and their impacts on international trade and the energy market, **Scenario 1 and 2** were introduced for the nationwide Hydropower Development Plan.

The ratio between required installed capacity of the Integrated Nepal Power System and system peak demand is presently approx. 5:1 and governed by the availability of firm power from the (RoR) HPPs in the low flow season. Implementation of storage dam projects will reduce the ratio substantially.

3.4.1 Hydropower Development Masterplan – Base Case

For the **Base Case** of the present nationwide Hydropower Development Masterplan, the available official information were considered on

- the power system demand or required power system capacity as per "15th National Plan" and
- the Recommended Commercial Operation Date - RCOD of the hydropower or multipurpose projects (provided by WECS, NEA, Ministry of Energy, Water Resources & Irrigation, DoED, IBN)

Assumption for the Base Case

h)	Available Power Generation Facilities (1 April 2023)		**2,188 MW**
i)	HPP with Issued CL, PPA and RCOD before 12/2025		3,198 MW
j)	HPP with Issued CL and RCOD before 12/2030		1,820 MW
k)	HPP with Issued CL, without RCOD, in 2026-2030		3,649 MW
	Subtotal b) + c) + d)		**8,667 MW**
l)	GON Hydropower projects with RCOD		**11327 MW**[13]
	Including Arun 3 HEPP (21.9% as per PDA)	by 2023	197 MW
		By 2048	900 MW
	Upper Karnali HPP	by 2030	108 MW
	Tamor Storage	by 2030	369 MW
	Lower Arun HPP	by 2030	366 MW
	Upper Arun	by 2035	1,060 MW
	Budhi Gandaki Storage	by 2035	1,200 MW
	West Seti HPP	by 2035	750 MW
	Dudhkoshi Storage	by 2035	640 MW
	Sunksohi 3 HPP	by 2035	542 MW
	Upper Marsyangdi 2 HEPP	by 2035	327 MW
	Nalgad	by 2035	417 MW
	Pancheswar HPP	by 2050	2,520 MW
	Sunkoshi 1	by 2045	2,128 MW
m)	Multipurpose Projects with HP component as per IMP		**768 MW**
	Including Bheri-Babai	by 2023	47 MW
	Sunkoshi Marin diversion	by 2030	31 MW
	Sunkoshi Kamala diversion	by 2030	62 MW
	Naumure Dam & Rapti diversion	by 2035	330 MW
	Karnali diversion	by 2035	80 MW
	Tamor – Morang diversion	by 2040	117 MW
	Kaligandaki – Tinau diversion	by 2045	101 MW
n)	Greenfield HPP		**25,000 MW**

[13] The total assumes the full capacity of Arun 3 (900 MW) will be fully transferred after the concession period. During the concession period, 21.9% of total capacity (197 MW), as per PDA, will be available.

Table 3-8: Nationwide Hydropower Development Masterplan – Base Case

Year	Required Capacity (MW)	Capacity + Reserve (MW)	HPP operation (MW)	HPP ICL (MW)	IMP Projects (MW)	GON – HPP Projects (MW)	HPP Grenfield (MW)	Total HPP (MW)
2022	4,717	4,717	2,188	0	0	0	0	2,188
2025	6,697	7,367	2,188	3,198	47	197	0	5,630
2030	11,041	12,145	2,188	8,667	140	1,040	550	12,585
2035	16,850	18,535	2,188	8,667	550	5,976	1,600	18,981
2040	24,302	26,003	2,188	8,667	550	5,976	9,100	26,481
2045	33,567	35,245	2,188	8,667	768	8,104	15,550	35,277
2050	44,812	47,053	2,188	8,667	768	11327	25,000	47,950

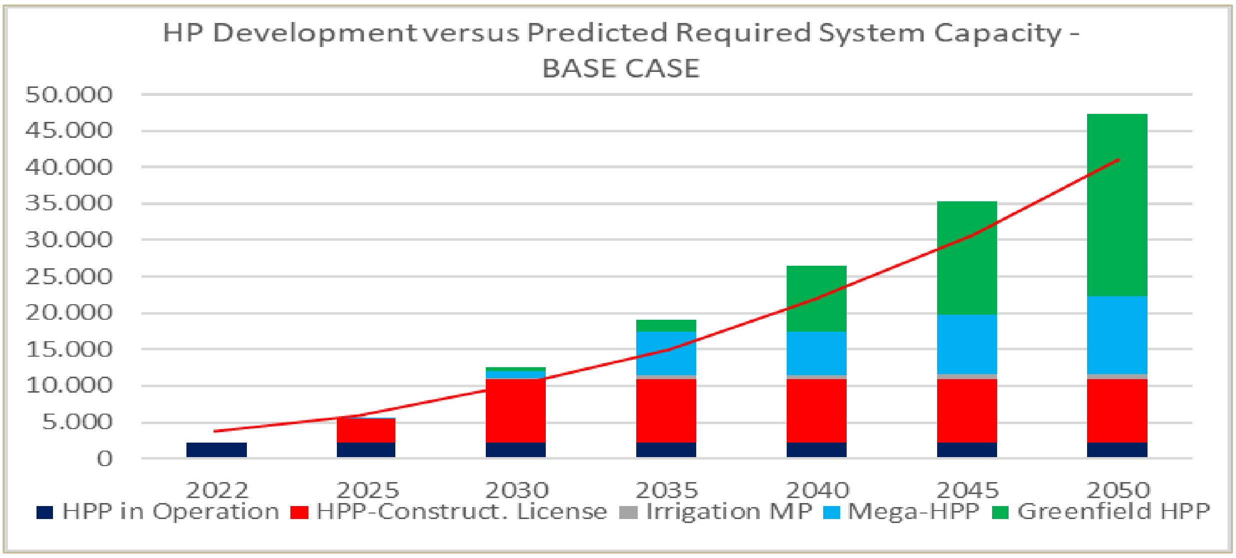


Figure 3-3: Hydropower Development versus Power demand for the period till 2050- Base Case

3.4.2 Nationwide Hydropower Development Masterplan – Scenario 1

The Hydropower Development Masterplan assumes a lower growing national power demand under Scenario 1. The total installed capacity of all HPPs with issued construction licenses exceeds 7000 MW and is larger than the assumed peak power demand in Nepal by the year 2035. Such situation may affect the project developers and the possible repayment of loans. Accordingly, construction and commissioning of several HPPs is expected to be delayed or some even disregarded.

Assumption for the Scenario 1

h) Available Power Generation Facilities (1 April 2023) **2,188 MW**

i) HPP with Issued CL, PPA and RCOD before 12/2025
   HPPs with 70 % of capacity commissioned by 12/2025 2,239 MW
   HPPs with 20 % of capacity commissioned by 12/2030 640 MW
   HPPS with 10 % capacity not commissioned 0 MW

j) HPP with Issued CL and RCOD before 12/2030
   HPPs with 67% of capacity commissioned by 12/2030 1,219 MW
   HPPs with 23 % of capacity commissioned by 12/2035 419 MW
   HPPS with 10 % capacity not commissioned 0 MW

k) HPP with Issued CL and RCOD before 12/2030
   HPPs with 40 % of capacity commissioned by 12/2030 1,460 MW
   HPPs with 30 % of capacity commissioned by 12/2035 1,095 MW

HPPS with 30 % capacity not commissioned		0 MW
Subtotal b) + c) + d)		**7,072 MW**

l) GoN Hydropower Projects with RCOD **8,355 MW**[13]

Including	Arun 3 HEPP (21.9% as per PDA)	by 2023	197 MW
		By 2048	900 MW
	Upper Karnali HPP (12% as per agreement)	by 2030	108 MW
	Sunkoshi 3 HPP	by 2032	542 MW
	Lower Arun	by 2035	366 MW
	Upper Arun	by 2035	1,060 MW
	Tamor Storage	by 2040	369 MW
	Dudhkoshi Storage	by 2040	640 MW
	Budhi Gandaki Storage	by 2045	1,200 MW
	Tamakoshi 3 HPP	by 2045	650 MW
	Pancheswar HPP (50% bi-national project)	by 2050	2,520 MW

m) Multipurpose Projects with HP component as per IMP **768 MW**

Including	Bheri-Babai	by 2023	47 MW
	Sunkoshi Marin diversion	by 2029	31 MW
	Sunkoshi Karnali diversion	by 2029	62 MW
	Naumure Dam & Rapti diversion	by 2033	330 MW
	Karnali diversion	by 2035	80 MW
	Tamor – Morang diversion	by 2040	117 MW
	Kaligandaki – Tinau diversion	by 2042	101 MW

n) Greenfield HPP

	by 2030	900 MW
	by 2035	2,100 MW
	by 2040	7,450 MW
	by 2045	12,000 MW
	by 2050	18,500 MW

Table 3-9: Nationwide Hydropower Development Masterplan – Scenario 1

Year	Required Capacity (MW)	Capacity + Reserve (MW)	HPP operation (MW)	HPP ICL (MW)	IMP Projects (MW)	GON – HPP Projects (MW)	HPP Grenfield (MW)	Total HPP (MW)
2022	2882	2882	2188	0	0	0	0	2188
2025	4234	4658	2188	2239	47	197	0	4671
2030	7331	8064	2188	5558	140	197	900	8983
2035	11660	12,826	2188	7072	550	1105	2100	13015
2040	17,428	18,823	2188	7072	550	2114	7450	19374
2045	24,845	26,585	2188	7072	768	5132	12000	27160
2050	34,119	36166	2188	7072	768	8355	18500	36883

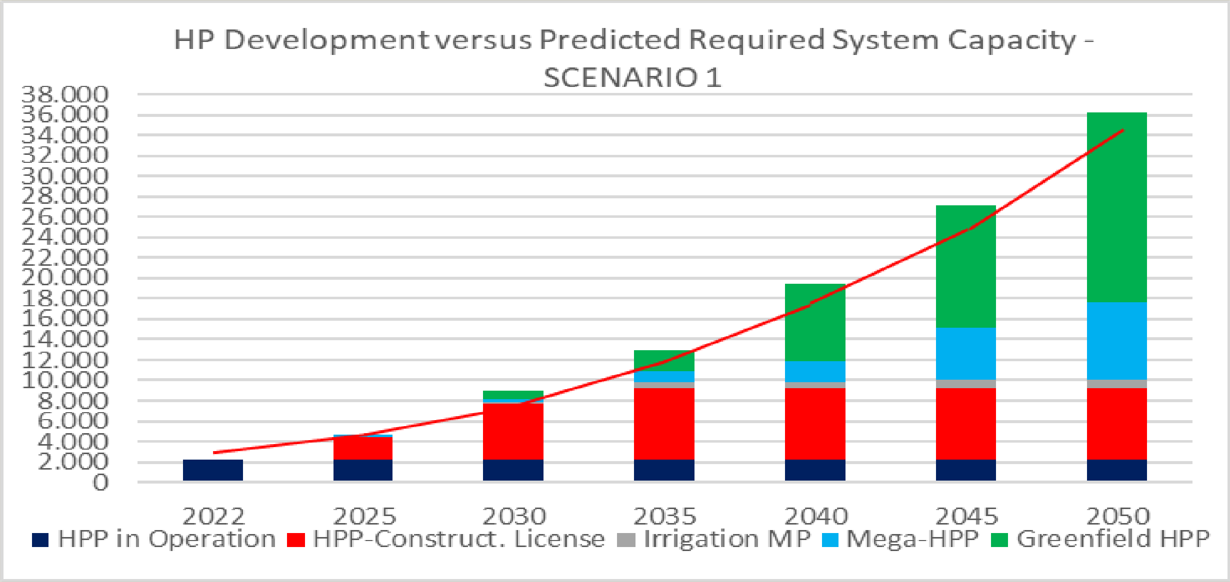


Figure 3-4: Hydropower Development versus Power demand for the period till 2050 – Scenario 1

3.4.3 Nationwide Hydropower Development Masterplan – Scenario 2

Scenario 2 assumes an even lower growing national power demand as compared to Scenario 1 applying a linear extrapolating of the historic grow of the peak power system demand. A substantial number of project developers in possession of a construction license is assumed to reconsider the implementation of the licensed hydropower projects due to reasons as outlined above. Such trend can be observed at present as despite of issued licenses the implementation of a substantial number of hydropower projects has been delayed for several years.

The system demand of Scenario 2 and the corresponding required system capacity is substantially lower as to Base Case (41.5 %) and Scenario 1 (54.5 %), such lower demand may create a less attractive environment for private developers. A substantial number of the identified greenfield HPPs may turn out economically more attractive and could replace some of the already licensed projects. Accordingly, it can be assumed that construction and commissioning of a considerable number of licensed HPPs will be delayed or even disregarded.

Accordingly, the Scenario 2 is based on the following assumptions:

<u>Assumption for the Scenario 2</u>

h)	Available Power Generation Facilities (1 April 2023)	**2,188 MW**
i)	HPP with Issued CL, PPA and RCOD before 12/2025	
	HPPs with 40 % of capacity commissioned by 12/2025	1,279 MW
	HPPs with 25 % of capacity commissioned by 12/2030	800 MW
	HPPS with 35 % capacity not commissioned	0 MW
j)	HPP with Issued CL and RCOD before 12/2030	
	HPPs with 40 % of capacity commissioned by 12/2030	728 MW
	HPPs with 25 % of capacity commissioned by 12/2035	455 MW
	HPPS with 35 % capacity not commissioned	0 MW
k)	HPP with Issued CL and RCOD before 12/2030	
	HPPs with 20 % of capacity commissioned by 12/2030	730 MW
	HPPs with 20 % of capacity commissioned by 12/2035	730 MW
	HPPS with 60 % capacity not commissioned	0 MW
	Subtotal b) + c) + d)	**4,722 MW**

l) GON Hydropower Projects with RCOD **5,835 MW**[13]

Including	Arun 3 HEPP (21.9% as per PDA)	by 2023	197 MW
		By 2048	900 MW
	Upper Arun	by 2035	1,060 MW
	Sunkoshi 3 HPP	by 2035	542 MW
	Dudhkoshi Storage	by 2040	640 MW
	Tamor Storage	by 2040	369 MW
	Budhi Gandaki Storage	by 2045	1,200 MW
	Tamakoshi 3	by 2045	650 MW
	Lower Arun	by 2050	366 MW
	Upper Karnali HPP (12% as per agreement)	by 2050	108 MW

m) Multipurpose Projects with HP component as per IMP **768 MW**

Including	Bheri-Babai	by 2023	47 MW
	Sunkoshi Marin diversion	by 2029	31 MW
	Sunkoshi Kamala diversion	by 2029	62 MW
	Naumure Dam & Rapti diversion	by 2033	330 MW
	Karnali diversion	by 2035	80 MW
	Tamor – Morang diversion	by 2040	117 MW
	Kaligandaki – Tinau diversion	by 2042	101 MW

n) Greenfield HPP

by 2035	0 MW
by 2040	1,400 MW
by 2045	4,000 MW
by 2050	7,500 MW

Table 3-10: Nationwide Hydropower Development Masterplan – Scenario 2

Year	Required Capacity (MW)	Capacity + Reserve (MW)	HPP operation (MW)	HPP ICL (MW)	IMP Projects (MW)	GON – HPP Projects (MW)	HPP Grenfield (MW)	Total HPP (MW)
2022	2,093	2,093	2,188	0	0	0	0	2,188
2025	2,930	3,223	2,188	1,279	47	197	0	3,711
2030	4,249	4,674	2,188	3,537	140	197	0	6,062
2035	6,161	6,777	2,188	4,722	550	1,799	0	9,259
2040	9,241	10,165	2,188	4,722	550	2,808	1,400	11,668
2045	13,862	15,248	2,188	4,722	768	4,658	4,000	16,336
2050	18,591	20,078	2,188	4,722	768	5,835	7,500	21,013

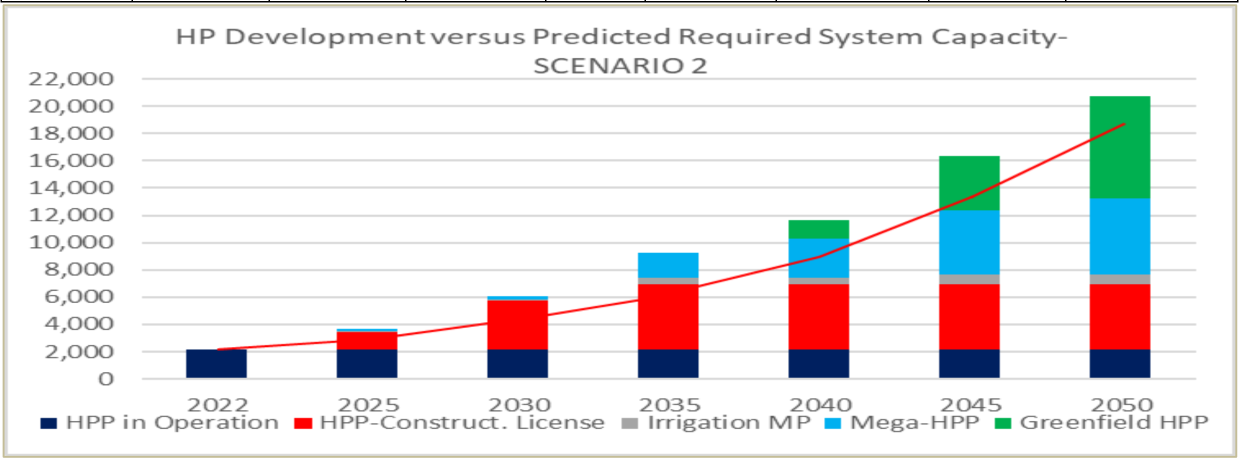


Figure 3-5: Hydropower Development versus Power demand for the period till 2050 – Scenario 2

3.5 Summary and Recommendations

The HDMP presents a portfolio of HPP and MPP projects and provides recommendations for their implementation. HDMP demonstrates that the identified hydropower resources are sufficient in capacity and economically attractive to provide sufficient energy for national market and for export to Nepal's neighbouring countries for the period up to the year 2050.

For the implementation of the identified and additional Greenfield HPPs, feasibility study and detailed design shall be carried out; including site specific ESIA and e-flow studies.

For the successful implementation of the HDMP, the following recommendations are given to setup a corresponding institutional and administrative environment that supports the implementation of the proposed hydropower projects and development of the power market and system in Nepal.

- Government needs to proactively establish an environment that attracts private developers to implement hydropower projects as required;
- Governmental institutions need to ensure adequate conditions, policy and guidelines for development and operation of hydropower cascade projects (River Basin Organizations);
- Present licensing practice may be partly substituted by competitive bidding procedures for the preferred (most attractive) project development;
- Program for development of GON (Mega) projects ("White Paper-2075") appear rather ambitious and may need adjustment, financial and administrational resources are limited make it advisable to develop at most 2-3 large projects in parallel;
- Government of Nepal is recommended to designate an organization to
  a) Carry out future least cost system expansion planning
  b) Ensure, manage and negotiate with potential international partners (India, Bangladesh, China) the export of surplus (wet season) energy
- Promote the (economic reasonable) development of renewable energy options (solar, wind, geothermal, hybrid-systems);
- Promote studies and the development of energy storage options (pumped storage, hydrogen, battery);
- Promote continuous implementation of Demand Management measures (Improved energy efficiency, time-variant consumer tariffs etc.)
- Efforts are to be made to maintain and improve current system of discharge and sediment measurement/sampling;

The investment plan indicates that

a) A large number of the identified Greenfield hydropower projects are economically and financially attractive

b) The tariff system needs to be adjusted on regular basis to maintain/establish an investor friendly environment for the development of RoR/PRoR projects as required

4 Strategic Environmental and Social Assessment

Increasing global pressure on freshwater resources has led to the rapid development of environmental sustainability as an underpinning principle for basin planning. The decisions made in the river basin can have environmental as well as social consequences. Development projects such as dams and hydropower plants, irrigation projects, water supply schemes, and other types of projects will create a range of direct and indirect impacts on the physical, biological, and human environment. These physical and environmental problems also have social ramifications, including involuntary resettlement due to land acquisition; conflict caused by changing access to water; and population changes that may alter the conditions for public health. On the other hand, there will be beneficial effects such as energy generation, flood protection, water supply for irrigation and improved agricultural production, employment opportunities during construction, and due to induced developments.

Table 4-1: Environmental and social water resources issues overview

	Environmental/Social Overview
Water Resources Issues	• Nepal boasts a diverse range of ecosystems, spanning from the towering peaks of the Himalayas to the lowland Terai region. These ecosystems provide valuable habitat for endangered species of fish, birds, and mammals. Furthermore, functional ecosystems provide valuable provisioning, regulating, and cultural services to local and regional communities. • In Nepal, national parks, buffer zones, and conservation areas support biodiversity and provide valuable habitat for endangered species of fish, birds, and mammals. • Increased water diversions and construction of storage schemes impact the timing and magnitude of seasonal flows as well as create migration barriers. • Agricultural and urban runoff contributes to nutrient loading with negative impacts on water quality. • Most of the cultural and pilgrimage sites are located either at the bank of the river or the temple sites. Uses of river water for sociocultural aspect consists of ritualistic bathing and ceremonial usages. Many Hindu rituals and festivals require the use of holy river water with significant flow.
Demand Pressure	• Increased water diversions and construction of storage schemes impact the timing and magnitude of seasonal flows as well as create migration barriers. • Agricultural and urban runoff contributes to nutrient loading with negative impacts on water quality.
Scenario Evaluation	• Assess the reliability, resilience, and vulnerability of water delivery to freshwater ecosystems. • Compare downstream flows of instream structures (dams, diversion weirs) and environmentally and culturally significant river reaches against e-flow targets. • Evaluate the impacts of structures on the "Free-Flowing River" (FFR) status and determine the impact on connectivity and aquatic habitat quality for endangered and iconic species
Management Alternatives	• Identify reliable sources of freshwater to meet demand. • Restrict instream structural development of selective river to provide long-term biodiversity and conservation of Nepal's natural resources. • Develop mitigation strategies to reduce degradation of aquatic ecosystems and minimize impact of migration barriers.

The Water Resources Development Plans (WRDP) of the ten river basins (Volume 3 of the River Basin Plans) aim to identify a set of water-related interventions that will benefit the people of the basins and of Nepal as a whole, in line with Nepal's Water Resources Policy of 2020. For this purpose, the WRDP presents and analyses a range of development scenarios. Each scenario is understood as a combination of projects, including projects for drinking water supply, irrigation and hydropower generation. The irrigation projects are identified from the Irrigation Master Plan (DoWRI, 2019), while the hydropower projects are as per the HDMP developed under the current Project.

The Strategic Environmental and Social Assessment (SESA) assesses the river basin development scenarios against the objective to minimise adverse environmental and social (E&S) outcomes. SESA of each basin (Volume 3) has been prepared with this objective.

4.1 Scope

The spatial scope of SESA is each river basin within Nepal, and the temporal scope of the impact assessment is the WRDP's final time horizon of year 2050, which reflects for each scenario its full development.

The water resource projects included in the development scenarios generally cause changes to rivers and land uses, which in turn lead to:

- Positive outcomes for the projects' beneficiaries;
- Adverse outcomes for some other groups of people;
- Adverse outcomes for natural habitats and biodiversity.

The beneficial outcomes of the scenarios are assessed and accounted for in the WRDPs and the HDMP. The SESA complements these findings by focusing on the potential adverse social and environmental outcomes.

4.2 Approach

To assess the river basin development scenarios, the SESA:

- Analyses the current environmental and social baseline information to inform decision makers and other stakeholders;
- Identifies impact indicators, which describe the E&S outcomes of a scenario in quantitative and qualitative terms and which can be systematically assessed for all projects and all basins;
- Rates the impact findings (factual information) for their significance. This rating is a valuation process, considering the factual information against objectives derived mainly from policies, laws and good practice standards;
- Compares the impact findings between the future scenarios; and
- Provides recommendations on mitigation measures to minimize or avoid the impacts for the establishment of sustainable development pathways that may be implemented and monitored by hydropower developers, local communities, and national stakeholders

4.3 Methodology

4.3.1 Baseline Data and Information

For its baseline descriptions, the SESA analysed existing data and information, collected by literature review and obtained from governmental and non-governmental institutions and organisations. Much of this information was obtained as GIS layers or developed into GIS layers from existing maps.

4.3.2 Identification of Valued Environmental and Social Components (VECs)

Given the wide spatial scope of the SESA and the large number of potential projects to be assessed, the SESA assessed the impact indicators focusing on selected criteria, both for the properties of the proposed projects and for the affected local environment. The baseline information is reviewed to identify so-called Valued Environmental and Social Components (VECs). These are selected sensitive or valued receptors of impacts which tend to be at the ends of ecological pathways and on which the SESA's impact assessment is focused.

For the SESA of River Basin Plans, the types of cumulative impacts that were systematically assessed are:

- Destruction or transformation of existing land uses and habitats by the footprints of new projects (HPPs' dams, reservoirs, dewatered river stretches; access road and transmission line connections; and new irrigation areas).
- Barrier effect of weirs and dams and the resulting fragmentation of rivers / river systems.
- Changes to river flow volumes due to water abstraction for domestic water supply and irrigation and due to hydropower operation.
- Adverse impacts on population, cultural and religious sites.

Based on the baseline information review and stakeholder consultations, the VECs are selected to assess the impacts in the basin. The selection takes into account the VECs' sensitivity to the expected types of impacts.

The VECs of interest in the different basins are of the following types:

i. Fish populations that depend on migrating between breeding and feeding habitats
ii. The river and wetland habitats and species that depend on the current flow regime
iii. Important terrestrial habitats which are functionally connected with the river and wetland habitats
iv. Cultural and religious sites near rivers and streams
v. Population in settlements near rivers and streams
vi. River dependant sociocultural and spiritual values
vii. Population practising irrigated agriculture for their livelihoods
viii. Wider rural and urban population, who will get socio-economic benefits in various ways
ix. Land use and land cover change by project components

4.3.3 Environmental and Social Impacts

The environmental and social impacts that typically occur for the types of projects which are included in the WRDP are reviewed, and the most relevant issues due to their significance are identified. A screening methodology is used, i.e. the criteria that are systematically applied, and the impact indicators that are either qualitatively considered or quantitatively measured and rated for their significance. As a basis for the impact assessment, GIS mapping of the new projects was carried out, identifying the location and extent of their impacting features, including:

- Spatial "footprint" of dams, reservoirs, access roads, transmission lines;
- Diversion reaches of HPPs (dewatered river reach between dam and powerhouse tailrace);
- New proposed irrigation scheme areas.

GIS intersecting of the projects' footprint layers with the GIS mapped baseline information resulted in quantitative impact information. Moreover, the results from the MHB models were used to quantitatively assess the instream flow changes. In addition to the quantitative impact indicators, other information on affected environment and some types of impacts was assessed in qualitative categories.

Criteria for which the impacts of the development scenarios were systematically evaluated include:

- HPP/IBTs' footprints and/or new irrigation scheme areas overlapping with the following categories of areas:
    - Nepal's legally Protected Areas

  - Internationally recognised area (Ramsar, IBA)
  - Other ecologically significant areas (ecological corridors, geographic range of fauna species, conservation landscapes)
  - Land uses (agriculture, forest, total affected area)

- River section affected by habitat conversion (dam& reservoir footprints, dewatered reaches):
  - Length of affected river sections
  - HCV value of affected river sections
  - Affected fish species (total number, threatened, migratory);
  - Other important species: dolphin, gharial

- Barrier effect of new dams
  - Record of existing dams and current connectivity status of the affected rivers
  - Mapping and count of proposed new dams/weirs for each scenario
  - Determining of severity of fragmentation impact, by considering:
  - Current free-flow river status (river connectivity and length)
  - Presence of migratory fish

- Instream flow changes
  - Magnitude of hydrology changes due to re-regulation of flows by the reservoir operation, and due to water abstractions for irrigation
  - Ecological performance indicators: Applying four different e-flow calculation methods, determining for each:
    - The minimum flows required to meet each e-flow target;
    - The frequency by which these minimum flows are not reached (e-flow violations)
  - Use of hydropeaking

- Impact on population / social aspects
  - Agricultural land affected by projects' footprints
  - Physical resettlement, indicated by count of residential houses inside reservoirs from Google Earth images
  - Likely impact on river-dependent ethnic groups (population data of ethnic groups as per population census 2011)

- Impact on cultural and religious sites
  - Religious value (as determined by PAANI's HCVR-assessment) of affected river reaches
  - Additional information on importance of affected sites, where available.

Impact findings for the above-described criteria are reported for each basin and scenario, on different levels of aggregation, including on the level of projects, rivers, subbasins and finally on the level of the river basin.

As a guidance for readers / stakeholders / decision makers, the impact are rated for their significance. The rating presents a classification on a qualitative scale, using five categories

- No impact
- Minor adverse impact
- Moderate adverse impact

- Substantial adverse impact
- Major adverse impact

To make value judgements that are inherent to the valuation process transparent and consistent, rating guidelines were developed and followed. The distinction between the categories thus follows a set of documented basic principles. However, there is no full set of rules predefining the rating of all potential impact findings. To some extent, the valuation process leaves room for expert judgement.

4.3.4 Evaluation of the Development Scenarios

The development scenarios evaluated are generally labeled as Baseline Development (BDV), Scenario 1 (SC1), Scenario 2 (SC2) and Maximum Development Scenario (MxDV). The impact findings were compared between the future scenarios. The project portfolio (based on HDMP and IMP) and the composition of the scenarios are considered in the evaluation. The results from the impact screening for the environmental and social topics, and the findings for main impact indicators are summarised on the level of sub basins and are rated for their impact significance.

4.3.5 Recommendations on Mitigation Measures

Finally, recommendations on mitigation measures to avoid or minimise the impacts for the establishment of sustainable development pathways are provided.

4.4 Main Findings from the SESA's Impact Assessment

The key E & S impacts arise from the existing and new dams proposed in the River Basin Plans and the HDMPs in the river basins (See Figure 4-1, Figure 4-2 and Figure 4-3).

The topics for which significant impacts were most often found are:

- Resettlement
- Legally protected areas
- Aquatic habitat conversion
- Barrier effect of new dams (disrupting biological connectivity of the rivers)
- Instream flow changes

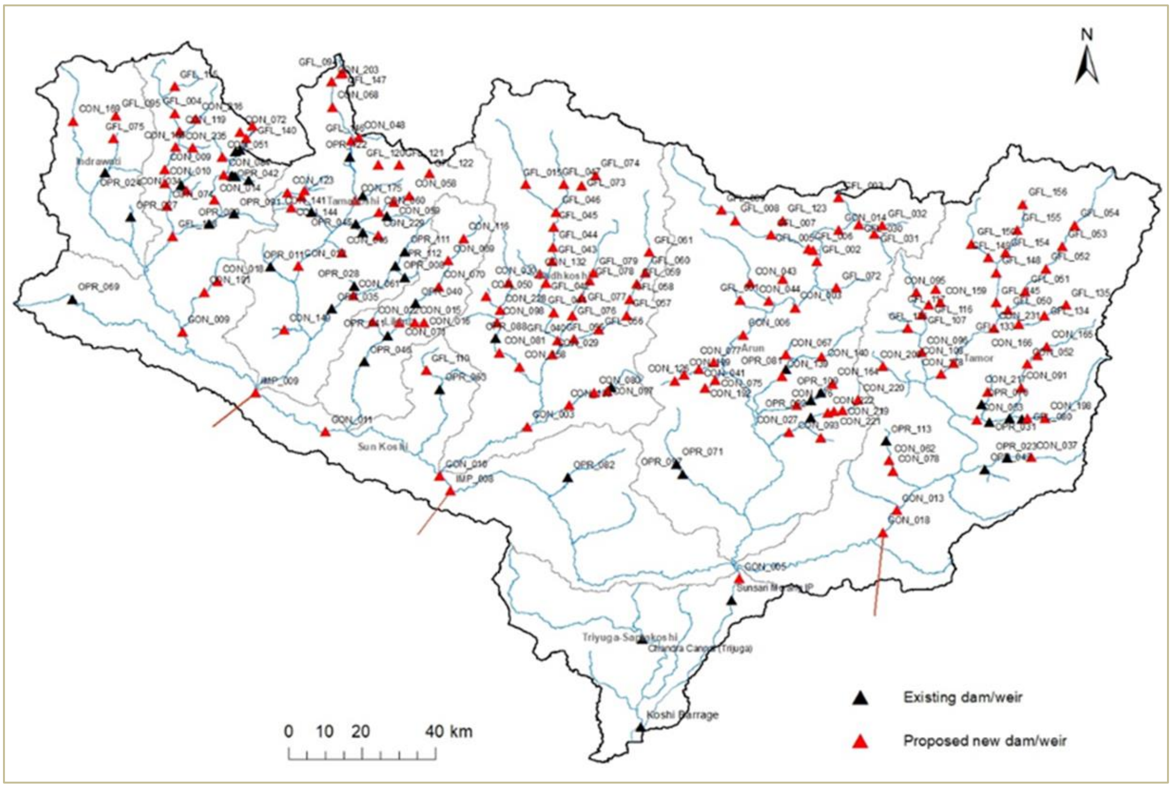


Figure 4-1: Existing and New Dams in MxDV Scenario (Koshi Basin)

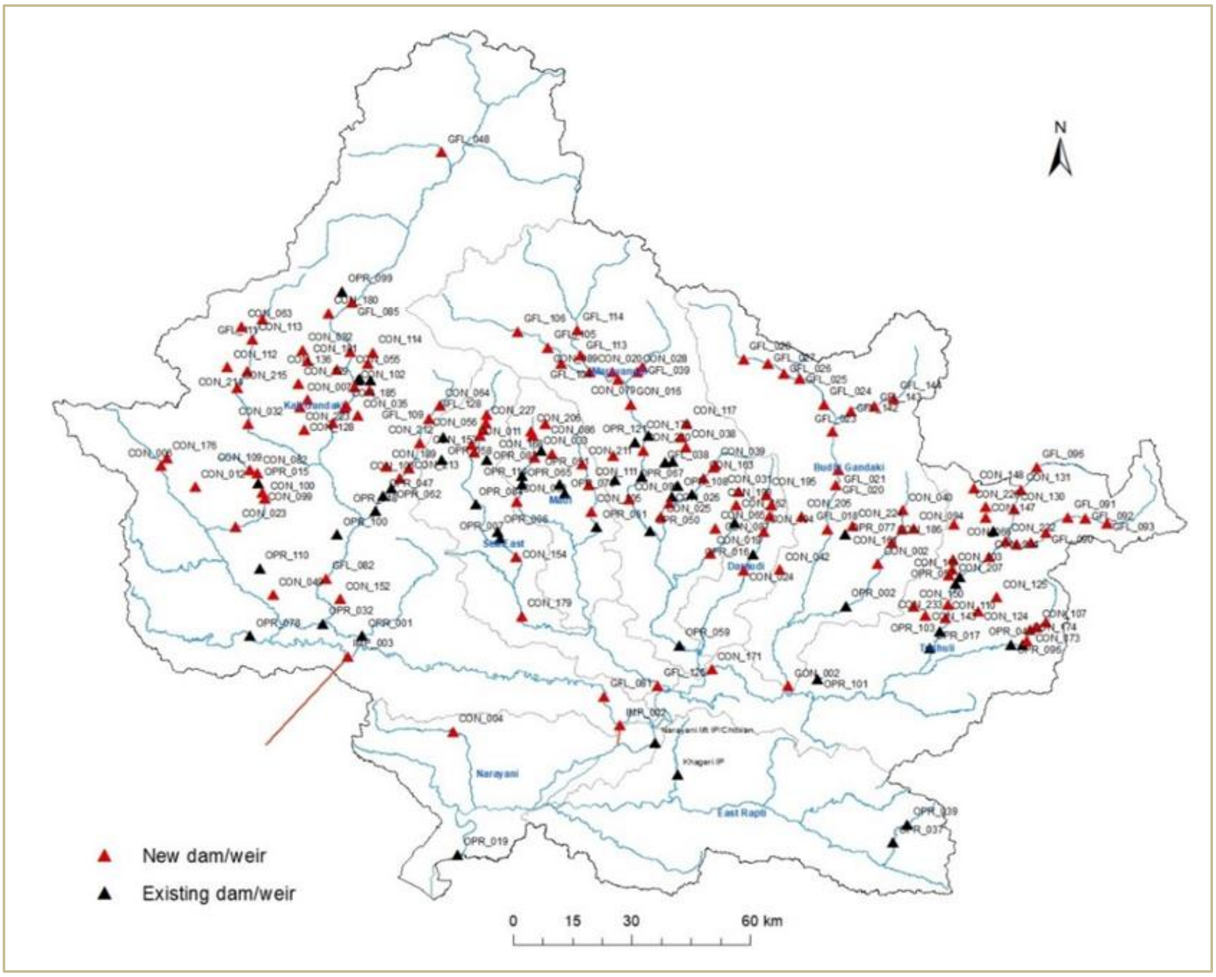


Figure 4-2: Existing and New Dams in MxDV Scenario (Gandaki Basin)

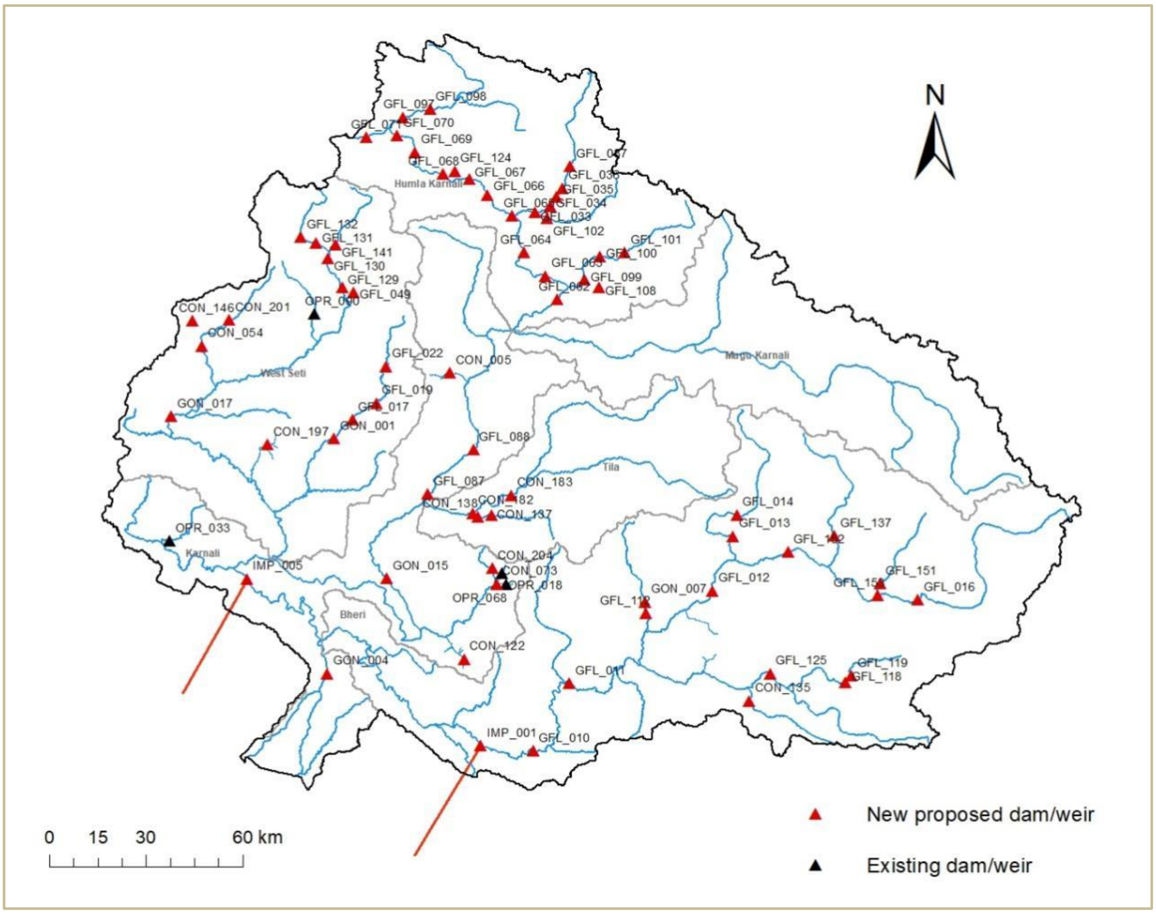


Figure 4-3: Existing and New Dams in MxDV Scenario (Karnali Basin)

The analyses of the baseline situation and impacts of development scenarios undertaken for the SESA have shown that significant adverse impacts must be expected on aquatic habitats, mainly caused by the hydropower and irrigation transfer projects. The envisaged scale of hydropower production for Nepal is large and combined with the dams proposed for irrigation priority projects results in a total of 386 new dam/weir projects[14].

4.4.1 Land Footprints of HPPs and IBTs

The land footprints of the HPPs and IBTs for the different development in all basins in terms of their impacts on agricultural land, forest and others are assessed in Figure 4-4. The Karnali Chisapani Development (KCDV) scenario is relevant to Karnali Basin only as it the development scenario with Karnali Chisapani MPP on top of the MxDv scenario.

[14] This is the number of projects combined for all basins, maximum development scenario, year 2050 (project portfolio as per HDMP, July 2022).

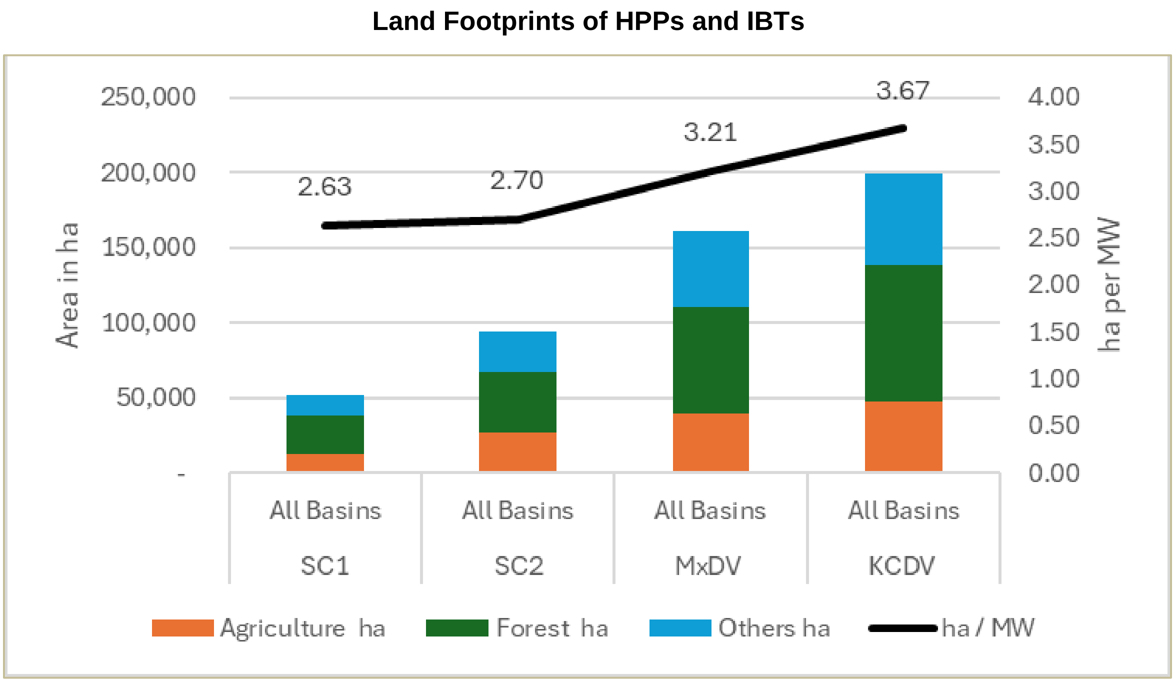


Figure 4-4: Land Footprints of HPPs and IBTs

4.4.2 Physical Resettlement

The residential houses that are affected by the large reservoirs for the different development scenarios are presented in Table 4-2.

Table 4-2: Physical Resettlement in All Basins

Scenario -2050	Installed Capacity (MW)	Residential Houses Counted In Large Reservoirs	
	MW	No. of houses	Houses / MW
SC1	19,488	9,423	0.48
SC2	34,620	26,155	0.76
MxDV	50,309	42,798	0.85
KCDV	54,332	53,097	0.98

4.4.3 Projects in Protected Areas and Ecologically Sensitive Areas

For the various categories of ecologically significant areas that are analysed in this SESA. Many new projects are located within key biodiversity areas such as Nepal's legally protected areas, Important Bird Areas (IBAs), or Ramsar sites. Table 4-3 and Figure 4-5 present the projects with footprints in Protected Areas (national parks, conservation areas, NP buffer zones). The footprints of some projects are even located within the most strictly protected area category of National Park. In total 74 projects are inside the national park with total installed capacity of 11147 MW.

Table 4-3: Projects with footprints in Protected Areas

Scenari0-2050	Projects inside National Parks		Projects inside CA		Projects inside NP-BZ		Projects inside HR	
	No.	MW	No.	MW	No.	MW	No.	MW
SC1	5	507	40	3,100	15	3,521	--	--
SC2	10	1,166	63	6,396	26	4,724	--	--
MxDV	29	2,725	97	8,411	35	5,816	2	57
KCDV	30	6,749	97	8,411	35	5,816	2	57

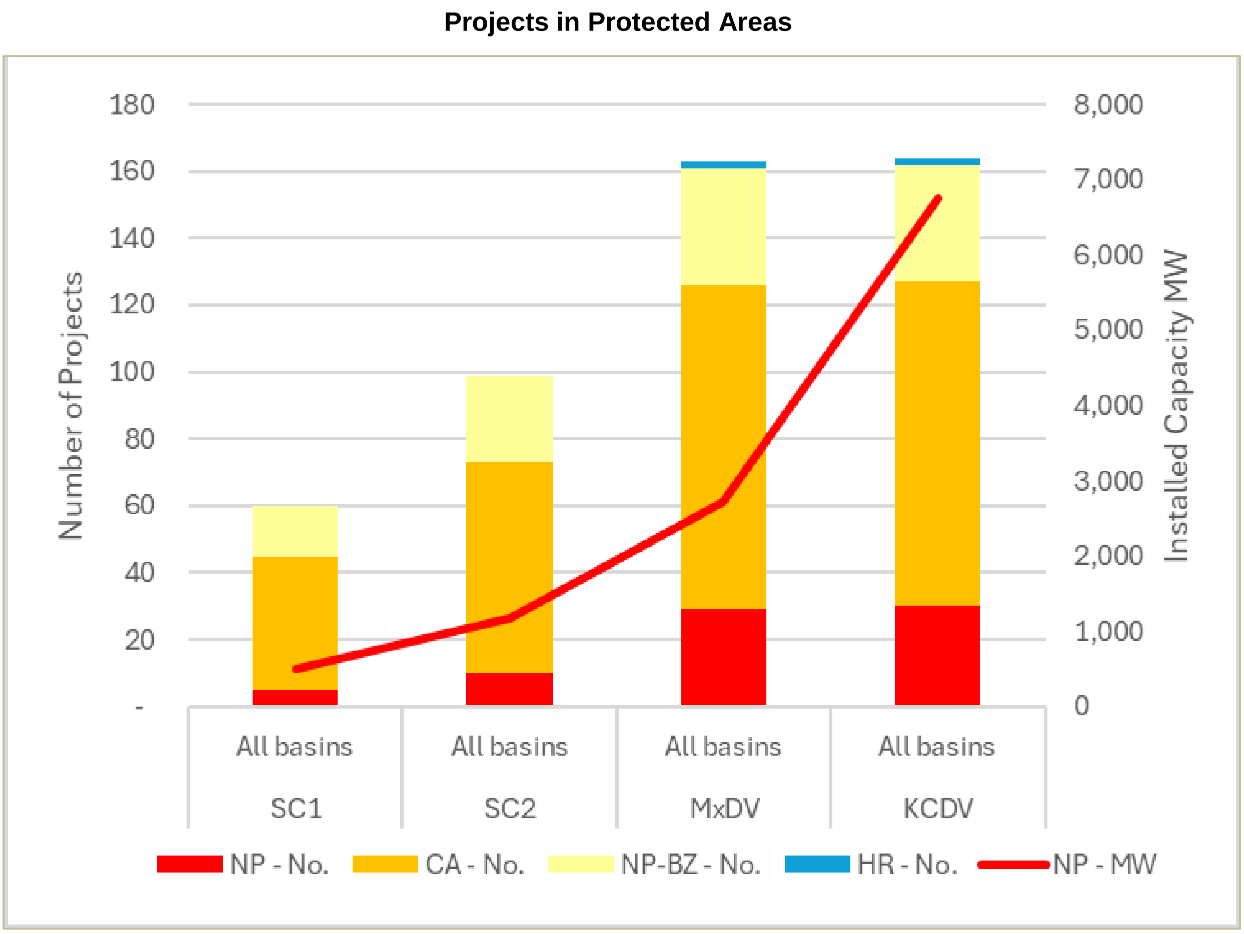


Figure 4-5: Projects in Protected Areas

The areas of proposed new irrigation projects are mapped in the project's GIS database at the basin level where some of the schemes lies in the protected areas (mostly buffer zones and conservation area) and other internationally recognized areas. Table 4-4 shows the number of schemes and area within the protected areas and internationally recognized areas IBA and Ramsar sites at the basin level. Total 258 irrigation schemes are within the ecologically sensitive areas from all basins which cover total area of 31,336 ha.

Table 4-4: New irrigation areas in the ecologically sensitive areas of the basin

Basin	Type of ecologically sensitive area	No. of schemes located within	Scheme area located within (ha)
Koshi	Ramsar (Koshi Tappu Wildlife Reserve)	1	108
	IBA	26	3,828
	PAs	15	1,542
Gandaki	Ramsar (Lake Cluster of Pokhara Valley)	8	1228
	IBA	73	6,750
	PAs	79	7167
Karnali	IBA	8	574
	PAs		
Mahakali	PA (Apinampa CA)	6	1,152
West Rapti	IBA	4	543.36
	PA (Banke NP-BZ)	4	301.26

Basin	Type of ecologically sensitive area	No. of schemes located within	Scheme area located within (ha)
Babai	IBA	2	97.60
	PA (Banke and Bardia NP-BZ)	8	486.22
Mechi	IBA	4	1,218
Kankai	IBA	1	9.00
Southern Block 2B	IBA	3	1,955.00
Southern Block 4		12	2,422.00
Southern Block 2B	PAs (Buffer zone of Chitwan Parsa National Park)	4	1,955.00
Total		**258**	**31,336.44**

4.4.4 River Length Affected by Habitat Conversion

Table 4-5 and Figure 4-6 show the length of the river sections affected by habitat conversion[15], summarised over all basins by scenarios.

Table 4-5: River Length affected by Habitat Conversion

Scenario (2050)	Inst. Cap. (MW)	Sum Of Baseline Length of The Rivers Affected In The Respective Scenario (KM)	Affected River Sections		Affected Sections Relative To Installed Capacity M / MW
			Length (km)	% of total	
SC1	19,488	6,232	1,413	23%	73
SC2	34,620	8,257	2,212	27%	64
MxDV	50,309	10,263	3,313	32%	66
KCDV	54,332	10,818	3,700	34%	68

River Length affected by Habitat Conversion

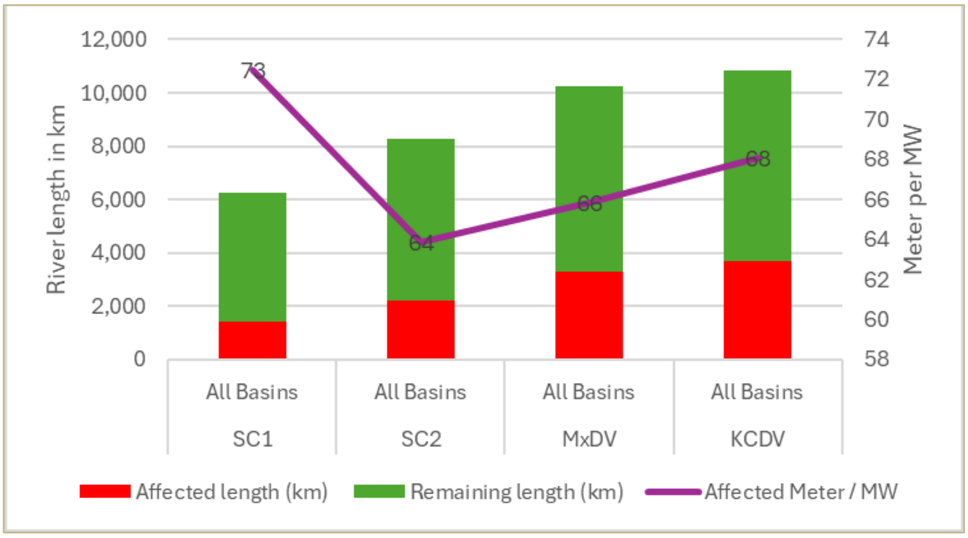


Figure 4-6: River Length affected by Habitat Conversion

[15] This includes river sections affected by dam and reservoir footprints and the dewatered reaches between dam and powerhouse.

The extent of river sections that will be affected is significant. Moreover, the new dams are wide-spread through all major river systems and the connectivity of all major mainstream rivers and many tributaries would be disrupted.

It will no longer be possible to implement the wetland-related priority action included in Nepal's National Biodiversity Strategy and Action Plan (NBSAP, 2014 – 2020) (DNPWC, 2022), which is:

- (WB-B2): Development and implementation of a plan for maintaining unhindered north-south biological connectivity in at least three major rivers (one each in the eastern, central and western parts of the country).

This and other biodiversity protection objectives[16] have not been considered when the hydropower projects and scenarios were developed. During the preparation of the WRDPs and HDMP, no spatial constraints were introduced for the siting of projects. Many new projects are located within key biodiversity areas such as Nepal’s legally protected areas, Important Bird Areas (IBAs), or Ramsar sites. As shown in Table 4-3, the footprints of some projects are even located within the most strictly protected area category of National Park.

4.4.5 River Connectivity and Barrier Effects

NBSAP (2014 – 2020) proposes to develop and implement a plan for maintaining unhindered north-south biological connectivity in at least three major rivers (eastern, central, western parts of country). The baseline status of river connectivity is presented in Table 4-6.

[16] E.g. NBSAP (2014 – 2020): WB-B10: Declaration and management of at least three suitable wetlands as fish sanctuaries (DNPWC, 2022)

Table 4-6: River Connectivity – Baseline Status

Basin	River	River in baseline			New barriers added to river in scenario (2050)			
		length (km)	Length category L 250 – 500 km M 100 – 250 km	Connectivity – status of river	SC1	SC2	MxDV	KCDV
Karnali	Karnali Nadi	356	Long	Free-flowing	--	4	4	5
	Humla Karnali Nadi	136	Medium	Free-flowing	7	7	10	10
	Bheri Nadi	299	Long	Free-flowing	1	4	6	6
	West Seti Nadi	203	Medium	Free-flowing	5	2	5	5
Gandaki	Budi Gandaki Nadi	119	Medium	Free Flowing	3	7	10	10
	Kali Gandaki Nadi	350	Long	Impacted	2	4	9	9
	Marsyangdi Nadi	149	Medium	Impacted	3	5	8	8
	Seti Nadi	126	Medium	Impacted	3	4	8	8
	Trishuli Nadi	150	Medium	Impacted	1	2	3	3
Koshi	Arun Nadi	149	medium	free-flowing	4	5	5	5
	Dudhkoshi Nadi	132	medium	free-flowing	5	6	10	10
	Saptakoshi Nadi	73	short	impacted	0	0	1	1
	Sunkoshi Nadi	254	long	impacted	3	3	6	6
	Tamur Nadi	167	medium	free-flowing	4	7	9	9
Mahakali	Mahakali Nadi	251	Long	impacted	2	2	2	2
West Rapti	West Rapti Nadi	177	Medium	impacted	2	2	2	2

Table 4-7 to Table 4-11 summarise information on the connectivity remaining in the longer mainstream rivers in case of implementing the development scenarios:

- Baseline length of the river, coverage of physiographic zones and current connectivity status
- Current importance of the river for fish species (as far as data availability allows, total no. of fish species, no. of migratory fish species, no. of fish species in threatened categories)
- Importance of the river for other aquatic mega fauna (dolphin, gharial)
- The number of new dams on a mainstream river and the notably long rivers / river system which would be kept free of barriers (dams, weirs that would block the entire river channel) in the development scenarios.

Koshi basin

Table 4-7 summarises the information for the Mainstream Rivers of Koshi basin. In the south, the connectivity of Saptakoshi is impacted in the baseline situation by the Koshi barrage. However, the river stretch upstream of the Koshi barrage has a high biodiversity and is partially protected in the Koshi Tappu wildlife reserve, which is also a Ramsar site.

In the upstream, the Saptakoshi is currently connected with the Sunkoshi / Dudhkoshi, Arun and Tamor Rivers, forming a wide-stretching well connected river system of many hundreds of km length which spans all physiographic zones.

In the MxDV development scenario, the Saptakoshi High Dam (GON_005) would disrupt this connectivity downstream of the confluences of Sunkoshi, Arun and Tamor with Saptakoshi.

In case of SC2 or SC1 scenarios, which exclude GON_005, the Saptakoshi (over a length of 55 km from upstream of the Koshi barrage) would remain connected to:

- 104 km of lower Sunkoshi up the diversion for IMP_008 (Sunkoshi-Kamala Transfer)
- 77 km of lower Arun up to GON_006 (Lower Arun HPP)
- 52 km of lower Tamor up to GON_018 / GON_013 (Tamor-Morang diversion / Tamor storage)

The physiographic zones covered by this remaining connected river system are the Terai, Siwalik and Middle Mountains. High mountains and High Himal would no longer be connected to it.

The Lower Sunkoshi stretch of 104 km from u/s of Saptakoshi confluence to IMP_008 is well connected and confined in the middle mountain range and represents mostly the cool to warm water zone, however small part of the river lies in the warm water zone. This stretch is important range for *Tor putitora, Schizothorax ricardsonii* and *Neolissocheilus hexagonolepsis*. Tor putitora (Golden mahseer), listed as endangered in IUCN Red List, uses this stretch during the summer season (monsoon). This river stretch is suitable for cold water species *Schizothorax ricardsonii* and *Neolissocheilus hexagonolepsis* that are categorized as near threatened in IUCN Red List, and these species migrate downstream to this zone during winter. So, this river section could be important habitat to sustain the globally threatened species.

The 77 km stretch of Arun from confluence to all the way up to GON_006 is confined in the middle mountain zone, and the stretch consists of cold to cool and cool to warm water zone. Beside the altitude, the water temperature in the river is governed by the slope. The upstream of the stretch is with steep slope and the water get less time to heat up before it flows down. The lowermost stretch near to the confluence is warm water zone. The stretch includes the cold-water fish like *Schizothorax ricardsonii*, *Glypothorax* species, *Neolissocheilus hexagonolepsis, Schizothoraichys* species and warm water fish like *Tor putitora, Tor tor, Ompok bimaculatus,* etc. The cold-water fish migrate to the stretch from High Mountain and High Himalaya during winter while the warm water fish migrate to the stretch during summer.

Further down, if GON_005 (Sapta Koshi high dam) is not considered (SC1 and SC2), will add a 55 km long stretch to each of above river section providing the fish habitat in Siwalik and Terai zone. This provides opportunity of up and downstream migration to the warm water fish like *Wallago attu* (vulnerable in IUCN Red List), *Ompok bimaculatus* (near threatened in IUCN Red List), *Tor putitora* (endangered in IUCN Red

List), etc. Besides rich in fish diversity (201 species), this stretch is important for aquatic megafauna like crocodiles (both gharial and mugger), dolphin and otter. The conservation of lower Sunkoshi, lower Arun and Koshi river sections altogether will significantly support the conservation of Nepal's threatened, long and medium migratory fish species.

Gandaki basin:

Table 4-8 summarises the information for the mainstream rivers of Gandaki basin. In the south, the connectivity of Narayani is impacted in the baseline situation by the Gandak Barrage at the India-Nepal border. However, together with the free-flowing East Rapti, the upstream parts of Narayani remain well connected. The Narayani and East Rapti are buffer zone rivers of the Chitwan National Park.

In the upstream, the Narayani is connected with the Kaligandaki and Trishuli, which however both have an already impacted connectivity due to existing barriers. Major tributaries of Trishuli, including the Seti / Madi and Marsyangdi, are also with already impacted connectivity. Only the Budhi Gandaki (Trishuli tributary) is currently still free-flowing. It extends in Middle Mountain and High Mountain region providing good migratory habitat for cold and cool water fish.

In the development scenarios, all mainstream rivers except the Narayani and East Rapti will receive additional barriers. In the SC1, the lower Kali Gandaki would remain connected with Narayani and lower Trishuli, including lower Seti / lower Madi rivers. However, the currently still free-flowing Budhi Gandaki is disrupted in all scenarios in its lowermost stretch by GON_002.

The remaining connectivity in Gandaki basin would span the Siwalik zone by the Narayani / East Rapti river system and reach into some lower stretches of Middle Mountain Rivers. No connectivity with the High Mountain and High Himal zones would be remaining.

In Gandaki basin, most of the rivers are already impacted with dams, but the Rapti-Narayani river system along the national park has good connectivity. Though the Gandak barrage at the Indo-Nepal boarder has cut the connectivity, the upstream Narayani along with East Rapti provides around 250 km long stretch that can be good habitat for fish and aquatic mega fauna. The Rapti-Narayani river system lies at the border of national park and there are no existing and planned projects in any of the scenarios. Moreover, the river system is rich in fish diversity harbouring around 188 species. The river system includes one of the world's six breeding population of gharial, dolphin, several species of turtles including endangered *Chitra indica* and vulnerable *Nilssonia gangetica*, and otter. Keeping this river system intact will provide the opportunity to conserve the wide variety of biodiversity. The Narayani-Rapti river system lies mostly in Siwalik range and small part in Terai at the downstream of Narayani.

Karnali basin:

Table 4-9 summarises the information for the mainstream rivers of Karnali basin. In this basin, all mainstream rivers are still free-flowing in the baseline situation, providing unhindered north-south biological connectivity through all physiographic zones. The mainstream Karnali has the highest aquatic biodiversity, followed by Bheri.

In the development scenarios, SC1 considers no new dams on the mainstream Karnali and only one new dam on Bheri (the IMP_001 – Bheri-Babai diversion, which is in an advanced stage construction). Choosing this scenario would thus enable implementing the NBSAP priority action of maintaining unhindered north-south biological connectivity in a major river in the western parts of the country. Mainstream Karnali would remain free-flowing over its entire length of 356 km, and this length would be extended by the Mugu Karnali and Namlang Khola rivers, for which no new barriers are foreseen in any of the scenarios. The mainstream of Karnali represents all the physiographic zones that will provide migration and spawning habitat to warm, cool and cold water fish. More than 15 migratory species reside in the river and major habitat for globally threatened golden mahseer. The downstream of the river in Siwalik and Terai is rich in other aquatic species such as otter, gharial and Nepal's largest population of dolphin.

In the scenarios SC2 and MxDV, the connectivity of the mainstream Karnali would get disrupted approx. 110 km upstream of the India-Nepal border by IMP_005 (Karnali diversion project). In the KCDV, the remaining connectivity is further reduced due to the GON_004 (Karnali Chisapani), which disrupts the Karnali approx. 38 km upstream of the India-Nepal border.

Mahakali basin:

Table 4-10 summarises the information for the mainstream rivers of Mahakali basin. The Mahakali river is not any more free-flowing over its entire length, its lower reaches (of approx. 56 km) are impacted by existing barrages, while the middle and upper reaches still have a good connectivity (over approx. 195 km).

In the development scenarios, SC1 does not consider any new dams on the mainstream Mahakali, which would preserve the current good connectivity status in the middle and upper reaches.

In SC2 and MxDV, 2 new barriers are added and these are the Pancheshwar dam (GON_008), and the Rupaligad re-regulation dam related to it. Only some 48 km would remain connected between the existing barrages and the re-regulation dam.

West Rapti basin

Table 4-11 summarises the information for the Mainstream Rivers of West Rapti basin. The connectivity of the West Rapti river is impacted over most of its length. Further upstream, the Jhimruk Khola is also impacted while Madi is still free-flowing.

In all development scenarios, the 2 additional dams will be implemented on the upper West Rapti sections, further disconnecting the West Rapti from the Madi and Jhimruk rivers. In MxDV a new dam would be implemented on Madi in addition.

The remaining connectivity would be limited to an approx. 100 km stretch of West Rapti in the Siwalik zone. No connectivity with the Middle Mountain zone would be remaining. But the Siwalik zone of the river is rich in fish diversity which consists of threatened and long migratory species like *Tor putitora, Anguilla bengalensis, Labeo pangusia* and *Begarius yarelii.* The zone is also important for the winter migration habitat for *Schizothorax richardsonii,* however, upstream connectivity will be cut off by IMP_007. This 100 km stretch also consists the IBA Dang Deukhuri foothill forests and West Rapti wetlands which further provides the opportunity to conserve biodiversity. Although, whole stretch of West Rapti could not be intact, this 100 km can be kept intact to conserve the aquatic as well as bird diversity since no projects along this stretch are foreseen. Further, the 45 km stretch in downstream lies in Terai zone facilitating the migration from warm water to cool water and vice versa.

Babai basin

The mainstream Babai is with 194 km a medium-long river. Its current connectivity status is impacted in the lower reach (Terai zone) due to an existing irrigation barrage. The remaining almost 150 km in the Siwalik zone still have a good connectivity. The Babai has a total of 56 fish species, 2 of which are threatened; 4 are long and 5 are medium to short distance migratory species. Part of the Babai flows through Bardiya National Park, where it also is current Gharial habitat. The river is important for the golden mahseer population and angling activity. Upstream of that it flows along the boundary of the buffer zone of Banke National Park and is met by the Sharada, a still free flowing 95 km long river coming from the Middle Mountain Zone.

No new dams are proposed in the Babai basin. The Babai river system's north-south span is limited, giving it no good potential for the NBAP's priority action of maintaining unhindered north-south biological connectivity in selected major rivers. However, the considerable biodiversity value of the aquatic ecosystem could get under increasing pressure due to intensified agriculture in the basin. It could thus be considered with priority for other wetland conservation actions.

Table 4-7: Remaining connectivity of mainstream rivers in scenarios – Koshi basin

River / River sections	Physiograph. zones	Length (km)	Baseline connectivity	Fish species richness	Migratory Fish		Fish species Threat-ened	Other species	No. of new dams[1] (2050)		
					L	M/S		D - Dolphin G - Gharial	SC1	SC2	Mx DV
Saptakoshi – from u/s of Koshi Barrage to confluence Sunkoshi / Arun/ Tamor	Terai, Siwalik	55	impacted	183	5	7	6	G (historic) D (current)	--	--	1
Sunkoshi	Middle Mountain, High Mountain, High Himal	254	impacted (upper parts)	201	5	8	7		3	3	6
Dudhkoshi	Middle Mountain, High Mountain, High Himal	132	Free-flowing	32	3	6	3		5	6	10
Lower Sunkoshi – from u/s of Saptakoshi confluence to IMP_008	Middle Mountain	104	good connectivity	201	5	8	7		--	--	--
Arun	Middle Mountain, High Mountain	149	free-flowing	76	3	7	4		4	5	5

River / River sections	Physiograph. zones	Length (km)	Baseline connectivity	Fish species richness	Migratory Fish		Fish species Threat-ened	Other species	No. of new dams[1] (2050)		
					L	M/S		D - Dolphin G - Gharial	SC1	SC2	Mx DV
Lower Arun – from u/s Sunkoshi confluence up to GON_006	Middle Mountain	77	free-flowing	76	3	7	3		--	--	--
Tamor	Middle Mountain, High Mountain, High Himal	167	free-flowing	69	5	7	3		4	7	9
Lower Tamor – from u/s Saptakoshi confluence up to GON_018	Middle Mountain	52	free-flowing	69	5	7	3		--	--	--

Note: [1] All weirs, barrages and dams with heights more than 15m are categorized as dams.

Table 4-8: Remaining connectivity of mainstream rivers in scenarios – Gandaki basin

River / River sections	Physiograph. zones	Length (km)	Baseline connectivity	Fish species richness	Migratory Fish		Fish species Threat-ened	Other species	No. of new dams (2050)		
					L	M/S		D - Dolphin G - Gharial	SC 1	SC2	Mx DV
Narayani – from u/s of Gandak barrage to confluence Kali Gandaki / Trishuli	Siwalik	110	impacted, with good connectivity stretch u/s of East Rapti confluence	188	5	7	4	G (current) D (historic)	--	--	--
East Rapti	Siwalik	138	free-flowing	111	5	7	3	G (current)	--	--	--
Kali Gandaki	Middle Mountain, High Mountain, High Himal	350	impacted, with good connectivity in upper parts	199	5	8	6		2	4	9
Lower Kali Gandaki – from u/s Trishuli confluence to IMP_003	Middle Mountain	128	impacted	199	5	8	5		--	1	2
Lower Kali Gandaki – from u/s Trishuli confluence to GFL_081	Middle Mountain	24	impacted	199	5	8	5		--	--	1
Lower Kali Gandaki – from u/s Trishuli confluence to IMP_002	Middle Mountain	14	impacted	199	5	8	5		--	--	--

River / River sections	Physiograph. zones	Length (km)	Baseline connectivity	Fish species richness	Migratory Fish		Fish species Threat-ened	Other species	No. of new dams (2050)		
					L	M/S		D - Dolphin G - Gharial	SC 1	SC2	Mx DV
Trishuli	Middle Mountain, High Mountain	150	impacted	110	3	7	4		1	2	3
Lower Trishuli up to OPR_017	Middle Mountain	117	impacted	110	3	7	4		--	--	--
Budhi Gandaki	Middle Mountain, High Mountain	119	Free-flowing	197	5	8	5		3	7	10
Seti	Middle Mountain, High Mountain, High Himal	126	impacted	49	3	7	5		3	4	8
Lower Seti – up to Madi confluence	Middle Mountain	32	impacted	49	3	7	5		--	--	1
Madi	Middle Mountain, High Mountain	71	impacted	77	3	7	5		1	2	3
Lower-middle Madi up to CON_008 / OPR_114)	Middle Mountain	51	impacted	77	3	7	5		--	--	--

Note: [1] All weirs, barrages and dams with heights more than 15m are categorized as dams.

Table 4-9: Remaining connectivity of mainstream rivers in scenarios – Karnali basin

River / River sections	Physiograph. zones	Length (km)	Baseline connectivity	Fish species richness	Migratory Fish		Fish species Threatened	Other species D - Dolphin G - Gharial	No. of new dams[1] (2050)			
					L	M/S			SC1	SC2	Mx DV	KC DV
Karnali	Terai, Siwalik, Middle Mountain, High Mountain	356	free-flowing	166	5	8	6	D (current)	--	4	4	5
Lower Karnali – up to IMP_005 only	Terai, Siwalik	110	free-flowing	166	5	8	5	D (current)	--	--	--	1
Bheri	Siwalik, Middle Mountain, High Mountain	299	free-flowing	14	2	4	2		1	4	6	6
West Seti	Middle Mountain, High Mountain	203	free-flowing	13	1	6	3		5	2	5	5
Tila	High Mountain, High Himal	64	free-flowing	23	1	3	3		2	2	2	2
Mugu Karnali	High Mountain	75	free-flowing	65	3	6	5		--	--	--	--
Namlang Khola	High Himal	42	free-flowing						--	--	--	--
Humla Karnali	High Mountain, High Himal	136	free-flowing	65	3	6	5		7	7	10	10

Table 4-10: Remaining connectivity of mainstream rivers in scenarios – Mahakali basin

River / River sections	Physiograph. zones	Length (km)	Baseline connectivity	Fish species richness	Migratory Fish		Fish species Threat-ened	Other species D - Dolphin G - Gharial	No. of new dams[1] (2050)			
					L	M/S			SC1	SC2	Mx DV	
Mahakali	Terai, Siwalik, Middle Mountain, High Mountain, High Himal	251	impacted in lower reaches; good connectivity in middle and up-per reaches	152	3	8	7	G (historic)	--	2	2	
Mahakali – between u/s of Tanakpur barrage and Rupaligad re-regulation dam	Terai, Siwalik, Middle Mountain	48	impacted	152	3	8	7		--	--	--	
Chameliya	Middle Mountain, High Mountain, High Himal	81	impacted	59	3	5	3		2	2	2	

Note: [1] All weirs, barrages and dams with heights more than 15m are categorized as dams.

Table 4-11: Remaining connectivity of mainstream rivers in scenarios – West Rapti basin

River / River sections	Physiograph. zones	Length (km)	Baseline connectivity	Fish species richness	Migratory Fish		Fish species Threatened	Other species	No. of new dams (2050)			
					L	M/S		D - Dolphin G - Gharial	SC1	SC2	Mx DV	
West Rapti	Terai, Siwalik	177	impacted	36	2	2	2	D (current)	2	2	2	
Madi	Middle Mountain	92	free-flowing	18	2	2	2		--	--	1	
Jhimruk	Middle Mountain	81	impacted	18	2	2	2		--	--	--	

4.4.6 Summary of Impacts and Rating Significance

The ratings from the impact evaluation are summarised by scenario in Table 4-12 to Table 4-21 with key aspects that influenced the rating. In all the basin, the main issue identified for the scenario **Baseline Development (BDV)**, which does not include any new HPPs, is the expansion of new irrigation schemes within ecologically sensitive areas and rest of other scenarios include the impacts from set pf projects.

Koshi Basin

Table 4-12: Summary of impact significance ratings by scenarios of Koshi Basin

Topic / issue	BDV - 2050	SC1 - 2050	SC2 - 2050	MxDV - 2050
Nepal's legally Protected Area	Moderate adverse (some new irrigation area within CA and BZ)	Major adverse (1 new HPP inside National Park)	Major adverse (3 new HPPs inside National Park)	Major adverse (17 new HPPs inside National Park)
Internationally recognised area	Major adverse (for one irrigation scheme inside Koshitappu Ramsar site);	Major adverse (for one irrigation scheme inside Koshitappu Ramsar site);	Major adverse (for one irrigation scheme inside Koshitappu Ramsar site);	Major adverse (for one irrigation scheme inside Koshitappu Ramsar site);
	Moderate adverse (for IPs inside IBAs)	Substantial adverse (for 29 HPPs inside IBAs)	Substantial adverse (for 53 HPPs inside IBAs)	Substantial adverse (for 80 HPPs inside IBAs)
Other ecologically significant areas	Moderate adverse (some new irrigation area in tiger habitat and conservation landscapes)	Moderate adverse (some new irrigation area and HPPs in tiger habitat and conservation landscapes)	Moderate adverse (some new irrigation area and HPPs in tiger habitat and conservation landscapes)	Moderate adverse (some new irrigation area and HPPs in tiger habitat and conservation landscapes)
Land uses	No impact	Minor adverse (2.3 ha land footprint per MW)	Minor adverse (2.3 ha land footprint per MW)	Minor adverse (3.1 ha land footprint per MW)
Mainstream rivers – aquatic habitat conversion	No impact	Rating for extent: Substantial adverse (mainstreams combined have 30% of their length affected and lose 30% of their HCV*km)	Rating for extent: Substantial adverse (mainstreams combined have 32% of their length affected and lose 32 % of their HCV*km)	Rating for extent: Major adverse (mainstreams combined have 71% of their length affected and lose 74 % of their HCV*km)

Topic / issue	BDV - 2050	SC1 - 2050	SC2 - 2050	MxDV - 2050
		Rating for affected species: Major adverse (max. number of fish species in an affected reach is 201, with one endangered-EN)	Rating for affected species: Major adverse (max. number of fish species in an affected reach is 201, with one endangered-EN)	Rating for affected species: Major adverse (max. number of fish species in an affected reach is 201, with one fish ssp. EN, and dolphin and gharial (CR) habitat affected)
Mainstem rivers – barrier effect of new dams	No impact	Substantial adverse (13 new barriers fragment three medium-long free-flowing rivers; 8 new barriers fragment 2 short and 1 long non-free-flowing rivers)	Substantial adverse (18 new barriers fragment three medium-long free-flowing rivers; 7 new barriers fragment 2 short and 1 long non-free-flowing rivers)	Substantial adverse (24 new barriers fragment three medium-long free-flowing rivers; 16 new barriers fragment 4 short and 1 long non-free-flowing rivers)
Instream flow changes	Rating for consumptive uses: Minor adverse (<1% of baseline MAF abstracted for irrigation & drinking water supply)	Rating for consumptive uses: Moderate adverse (approx. 17% of baseline MAF abstracted from Sunkoshi)	Rating for consumptive uses: Moderate adverse (approx. 17% of baseline MAF abstracted from Sunkoshi)	Rating for consumptive uses: Moderate adverse (approx. 17% of baseline MAF abstracted from Sunkoshi)
	Rating for re-regulation: No impact	Rating for re-regulation: Major adverse (59% of baseline MAF diverted from Dudhkoshi; 31 projects with hydropeaking)	Rating for re-regulation: Major adverse (59% of baseline MAF diverted from Dudhkoshi; 51 projects with hydropeaking)	Rating for re-regulation: Major adverse (59% of baseline MAF diverted from Dudhkoshi; 74 projects with hydropeaking)
Reservoir water quality	Not applicable	Substantial adverse (3 new reservoirs, one with storage capacity much larger than dry season inflow)	Substantial adverse (3 new reservoirs, one with storage capacity much larger than dry season inflow)	Substantial adverse (6 new reservoirs, one with storage capacity much larger than dry season inflow)
Social aspects – resettlement and river dependent groups	No impact	Major adverse (4 HPPs with a total of 3,991 houses affected)	Major adverse (4 HPPs with a total of 3,991 houses affected)	Major adverse (8 HPPs with a total of 16,721 houses affected)
Cultural and religious sites	No impact	Moderate adverse (affected length or religious value-river section is 803 km and 0.10 km per MW)	Moderate adverse (affected length or religious value-river section is 977 km and 0.08 km per MW)	Moderate adverse (affected length or religious value-river section is 1,862 km and 0.09 km per MW) Substantial adverse for impact on major religious site in Saptakoshi river

Gandaki Basin

Table 4-13: Summary of impact significance ratings by scenarios of Gandaki Basin

Topic / issue	BDV - 2050	SC1 - 2050	SC2 - 2050	MxDV - 2050
Nepal's legally Protected Area	Major adverse for some irrigation schemes (2,782 ha new irrigation area inside National Park and Wildlife Reserve)	Major adverse for some irrigation schemes (2,782 ha new irrigation area inside National Park and Wildlife Reserve); Major adverse for some HPPs (4 new HPPs inside National Park)	Major adverse for some irrigation schemes (2,782 ha new irrigation area inside National Park and Wildlife Reserve); Major adverse for some HPPs (7 new HPPs inside National Park)	Major adverse for some irrigation schemes (2,782 ha new irrigation area inside National Park and Wildlife Reserve); Major adverse for some HPPs (11 new HPPs inside National Park)
Internationally recognized area	Major adverse for some irrigation schemes (1,228 ha new irrigation area inside Ramsar)	Major adverse for some irrigation schemes (1,228 ha new irrigation area inside Ramsar) Substantial adverse (for 26 HPPs inside IBA)	Major adverse for some irrigation schemes (1,228 ha new irrigation area inside Ramsar) Major adverse (for 2 HPPs inside Ramsar)	Major adverse for some irrigation schemes (1,228 ha new irrigation area inside Ramsar) Major adverse (for 2 HPPs inside Ramsar)
Other ecologically significant areas	Moderate adverse (some new irrigation area in red panda and tiger habitat and conservation landscapes)	Moderate adverse (some new irrigation area and HPPs in red panda and tiger habitat and conservation landscapes)	Moderate adverse (some new irrigation area and HPPs in red panda and tiger habitat and conservation landscapes)	Moderate adverse (some new irrigation area and HPPs in red panda and tiger habitat and conservation landscapes)
Land uses	Moderate adverse (12% of new irrigation area lies within non- agricultural land use, mainly shrub land/ grassland/ degraded land)	Moderate adverse for new irrigation schemes (12% of new scheme area lies within non-agricultural land use) Minor adverse for new HPPs (3.27 ha land footprint per MW)	Moderate adverse for new irrigation schemes (12% of new scheme area lies within non-agricultural land use) Minor adverse for new HPPs (3.93 ha land footprint per MW)	Moderate adverse for new irrigation schemes (12% of new scheme area lies within non-agricultural land use) Minor adverse for new HPPs (3.60 ha land footprint per MW)
Mainstream rivers - aquatic habitat conversion	No impact	Rating for extent: Moderate adverse (mainstreams combined have 15% of their length affected and lose 15%	Rating for extent: Substantial adverse (mainstreams combined have 28% of their length	Rating for extent: Substantial adverse (mainstreams combined have 37% of their length affected and lose 39% of their HCV*km)

Topic / issue	BDV - 2050	SC1 - 2050	SC2 - 2050	MxDV - 2050
		of their HCV*km) Rating for affected species: Major adverse (max. number of fish species in an affected reach is 197, with one endangered-EN)	affected and lose 30% of their HCV*km) Rating for affected species: Major adverse (max. number of fish species in an affected reach is 199, with one endangered-EN)	Rating for affected species: Major adverse (max. number of fish species in an affected reach is 199, with one endangered-EN)
Mainstream rivers - barrier effect of new dams	No impact	Substantial adverse (3 new barriers fragmenting a medium long free flowing river, 1 new barrier on a short free-flowing river; 15 new barriers on one long, three medium and two short length mainstream rivers with already impacted connectivity)	Substantial adverse (7 new barriers fragmenting a medium long free flowing river, 1 new barrier on a short free-flowing river, 22 new barriers on one long, three medium and two short length mainstream rivers with already impacted connectivity)	Substantial adverse (10 new barriers fragmenting a medium long free flowing river, 1 new barrier on a short free-flowing river, 36 new barriers on one long, three medium and two short length mainstream rivers with already impacted connectivity)
Instream flow changes	Rating for consumptive uses: Minor adverse (<1.5% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: No impact	Rating for consumptive uses: Substantial adverse (approx. 22% of baseline MAF abstracted from Kali Gandaki) Rating for re-regulation: Substantial adverse (24 projects with hydropeaking)	Rating for consumptive uses: Substantial adverse (approx. 22% of baseline MAF abstracted from Kali Gandaki) Rating for re-regulation: Substantial adverse (39 projects with hydropeaking)	Rating for consumptive uses: Substantial adverse (approx. 22% of baseline MAF abstracted from Kali Gandaki) Rating for re-regulation: Substantial adverse (48 projects with hydropeaking)
Reservoir water quality	Not applicable	Substantial adverse (1 new reservoir with long average water retention time)	Substantial adverse (1 new reservoir with long average water retention time)	Substantial adverse (1 new reservoir with long average water retention time)
Social aspects - resettlement and river dependent groups	No impact	Major adverse (1 HPP with a total of 3,560 houses affected)	Major adverse (3 HPPs with a total of 11,076 houses affected)	Major adverse (3 HPPs with a total of 11,076 houses affected)

Topic / issue	BDV - 2050	SC1 - 2050	SC2 - 2050	MxDV - 2050
Cultural and religious sites	No impact	Moderate adverse (affected length or religious value-river section is 521 km and 0.11 km per MW)	Moderate adverse (affected length or religious value-river section is 847 km and 0.10 km per MW)	Moderate adverse (affected length or religious value-river section is 1,106 km and 0.10 km per MW)

Karnali Basin

Table 4-14: Summary of impact significance ratings by scenarios of Karnali Basin

Topic / issue	BDV - 2050	SC1 - 2050	SC2 - 2050	MxDV - 2050	KCDV - 2050
Nepal's legally Protected Area	Moderate adverse (some new irrigation area in NP-BZ)	Moderate adverse (some new irrigation area in NP-BZ)	Moderate adverse (some new irrigation area & 2 HPPs in NP-BZ)	Major adverse (1 HPP in NP, 4 in NP-BZ, 2 in HR)	Major adverse (2 HPP in NP, 4 in NP-BZ, 2 in HR)
Internationally recognised area	Moderate adverse (some new irrigation area in IBA)	No impact	Substantial adverse (2 HPPs in IBAs)	Substantial adverse (7 HPPs in IBAs)	Substantial adverse (8 HPPs in IBAs)
Other ecologically significant areas	Moderate adverse (some new irrigation area in red panda and tiger habitat, and in conservation landscapes)	Moderate adverse (affected fauna habitat: 4,960ha; affected conservation landscapes: 6,833ha)	Moderate adverse (affected fauna habitat: 7,261ha; affected conservation landscapes: 7,297ha)	Moderate adverse (affected fauna habitat:14,038ha; affected conservation landscapes: 16,239ha)	Moderate adverse (affected fauna habitat: 35,016ha; affected conservation landscapes: 50,441ha)
Land uses	No impact	Minor adverse (1.8 ha land footprint per MW)	Minor adverse (1.8 ha land footprint per MW)	Minor adverse (2.8 ha land footprint per MW)	Moderate adverse (4.2 ha land footprint per MW)
Mainstream rivers – aquatic habitat conversion	No impact	Rating for extent: Moderate adverse (most affected rivers combined have 15% of their length affected, and lose 12% of their HCV*km)	Rating for extent: Substantial adverse (most affected rivers combined have 27% of their length affected, and lose 27% of their HCV*km)	Rating for extent: Substantial adverse (most affected rivers combined have 39% of their length affected, and lose 36% of their HCV*km)	Rating for extent: Major adverse (most affected rivers combined have 51% of their length affected, and lose 52% of their HCV*km)
		Rating for affected species: Moderate adverse (max. number of fish species in an affected reach is 65, with one endangered-EN)	Rating for affected species: Major adverse (max. number of fish species in an affected reach is 154, with one endangered-EN)	Rating for affected species: Major adverse (max. number of fish species in an affected reach is 154, with one endangered-EN)	Rating for affected species: Major adverse (max. number of fish species in an affected reach is 166, with one endangered-EN)
Mainstream rivers – barrier effect of new dams	No impact	Substantial adverse (25 new barriers are fragmenting 2 medium long free-flowing rivers and 8 short free-flowing rivers)	Major adverse (35 new barriers are fragmenting 2 long free-flowing rivers, 2 medium long free-flowing rivers, and 15 short free-flowing rivers)	Major adverse (67 new barriers are fragmenting 2 long free-flowing rivers, 2 medium long free-flowing rivers, and 27 short free-flowing rivers)	Major adverse (71 new barriers are fragmenting 2 long free-flowing rivers, 2 medium long free-flowing rivers, and

Topic / issue	BDV - 2050	SC1 - 2050	SC2 - 2050	MxDV - 2050	KCDV - 2050
					27 short free-flowing rivers)
Instream flow changes	Minor adverse	Rating for consumptive uses: Minor adverse (approx. 8% of baseline MAF abstracted from Tila river, 2% from Karnali river)	Rating for consumptive uses: Minor adverse (approx. 8% of baseline MAF abstracted from Tila river, 6% from Karnali river)	Rating for consumptive uses: Minor adverse (approx. 8% of baseline MAF abstracted from Tila river, 6% from Karnali river)	Rating for consumptive uses: Minor adverse (approx. 8% of baseline MAF abstracted from Tila river, 6% from Karnali river)
		Rating for re-regulation: Major adverse (84% of baseline MAF diverted from West Seti; 16 projects with hydropeaking)	Rating for re-regulation: Substantial adverse (24 projects with hydropeaking)	Rating for re-regulation: Major adverse (84% of baseline MAF diverted from West Seti; 39 projects with hydropeaking)	Rating for re-regulation: Major adverse (84% of baseline MAF diverted from West Seti; 40 projects with hydropeaking; strong seasonal re-regulation of lower Karnali by KCP)
Reservoir water quality	Not applicable	Moderate adverse (1 new reservoir with storage capacity larger than dry season inflow)	Substantial adverse (3 new reservoirs, one with long water retention time)	Substantial adverse (4 new reservoirs, one with long water retention time)	Substantial adverse (5 new reservoirs, two with long water retention time)
Social aspects – resettlement and river dependent groups	No impact	Substantial adverse (1 storage HPP with 682 houses affected)	Major adverse (1 storage HPP with 1,310 houses affected, and 3 storage HPPs with 275 / 299 / 582 houses affected. Total 2,466 affected houses)	Major adverse (2 storage HPP with 3,224 / 1,310 houses affected, and 5 storage HPPs with each affecting several hundred houses. Total 6,632 affected houses)	Major adverse (3 storage HPP with 10,299 / 3,224 / 1,310 houses affected, and 5 storage HPPs with each affecting several hundred houses. Total 16,931 affected houses)
Cultural and religious sites	No impact	Moderate adverse (affected length of religious value-river sections is 349 km and 0.06 km per MW)	Moderate adverse (affected length of religious value-river sections is 573 km and 0.05 km per MW)	Moderate adverse (affected length of religious value-river sections is 968 km and 0.07 km per MW)	Moderate adverse (affected length of religious value-river sections is 1,184 km and 0.06 km per MW)

Mahakali Basin

Table 4-15: Summary of impact significance ratings by scenarios of Mahakali Basin

Topic / issue	BDV - 2050	SC2 - 2050	MxDV - 2050
Nepal's legally Protected Area	Moderate adverse (some new irrigation area in CA)	Moderate adverse (some new irrigation area and 2 HPPs in CA)	Moderate adverse (some new irrigation area and 2 HPPs in CA)
Internationally recognised area	No impact	No impact	No impact
Other ecologically significant areas	Moderate adverse (some new irrigation area in Tiger habitat and conservation landscape)	Moderate adverse (some new irrigation area in Tiger habitat and conservation landscape: 2 HPPS in conservation landscape)	Moderate adverse (some new irrigation area in Tiger habitat and conservation landscape; 3 HPPS in conservation landscape)
Land uses	No impact	Minor adverse (1.7 ha land footprint per MW)	Minor adverse (1.7 ha land footprint per MW)
Mainstream rivers - aquatic habitat conversion	No impact	Rating for extent: Minor adverse adverse (mainstreams combined have 5% of their length affected and lose 5% of their HCV'km) Rating for affected species: Moderate adverse (max. number of fish species in an affected reach is 48, with one endangered-EN)	Rating for extent: Substantial adverse adverse (mainstreams combined have 28% of their length affected and lose 35% of their HCV'km) Rating for affected species: Substantial adverse (max. number of fish species in an affected reach is 115, with one endangered-EN)
Mainstream rivers - barrier effect of new dams	No impact	Moderate adverse (2 new barriers fragment 1 short non-free-flowing river with long-migratory fish)	Substantial adverse (4 new barriers fragment 1 short non-free-flowing river and 1 medium-long stretch with good connectivity and long-migratory fish)
Instream flow changes	Rating for consumptive uses: Minor adverse (0.1% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: No impact	Rating for consumptive uses: Minor adverse (0.1% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: Substantial adverse due to hydropeaking	Rating for consumptive uses: Minor adverse (0.1% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: Substantial adverse due to hydropeaking
Reservoir water quality	Not applicable	No impact (only daily pondage)	Substantial adverse (Pancheshwar reservoir)

Topic / issue	BDV - 2050	SC2 - 2050	MxDV - 2050
Social aspects - resettlement and river dependant groups	No impact	Minor adverse (presence of river-dependent ethnic group in some of the affected river reaches)	Substantial adverse (1 storage HPP with 880 houses affected)
Cultural and religious sites	No impact	Moderate adverse (affected length of religious value-river sections is 5 km and 0.03 km per MW)	Moderate adverse (affected length of religious value-river sections is 288 km and 0.11 km per MW)

West Rapti Basin

Table 4-16: Summary of impact significance ratings by scenarios of West Rapti Basin

Topic / issue	BDV - 2050	SC2 - 2050	MxDV - 2050
Nepal's legally Protected Area	Moderate adverse (some new irrigation area in NP-BZ)	Moderate adverse (some new irrigation area in NP-BZ)	Moderate adverse (some new irrigation area in NP-BZ)
Internationally recognized area	Moderate adverse (some new irrigation area in IBA)	Moderate adverse (some new irrigation area in IBA)	Moderate adverse (some new irrigation area in IBA)
Other ecologically significant areas	Moderate adverse (some new irrigation area in Ecological Corridor, Tiger habitat and conservation landscape)	Moderate adverse (some new irrigation area and 1 IBT in Ecological Corridor, Tiger habitat and conservation landscape)	Moderate adverse (some new irrigation area and 1 IBT in Ecological Corridor, Tiger habitat and conservation landscape)
Land uses	No impact	Moderate adverse (7.3 ha land footprint per MW)	Moderate adverse (7.5 ha land footprint per MW)
Mainstream rivers – aquatic habitat conversion	No impact	Rating for extent: Minor adverse (mainstreams combined have 10% of their length affected and lose 8% of their HCV'km) Rating for affected species: Minor to substantial adverse (max. number of fish species in an affected reach is 36, with one endangered-EN)	Rating for extent: Minor adverse (mainstreams combined have 12% of their length affected and lose 9% of their HCV'km) Rating for affected species: Minor to substantial adverse (max. number of fish species in an affected reach is 36, with one endangered-EN)
Mainstream rivers – barrier effect of new dams	No impact	Moderate adverse (2 new barriers fragment 1 medium-long non-free-flowing river with long-migratory fish)	Substantial adverse (3 new barriers fragment 1 short free flowing river, and 1 medium-long non-free-flowing river with long-migratory fish)
Instream flow changes	Rating for consumptive uses: Minor adverse (3% to 6% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: No impact	Rating for consumptive uses: Substantial adverse (6% to 23% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: Substantial adverse due to hydropeaking	Rating for consumptive uses: Major adverse (37% to 64% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: Substantial adverse due to hydropeaking
Reservoir water quality	Not applicable	Substantial adverse (Naumure reservoir)	Substantial adverse (Naumure reservoir and Madi Dang reservoir)

Topic / issue	BDV - 2050	SC2 - 2050	MxDV - 2050
Social aspects – resettlement and river dependant groups	No impact	Substantial adverse (1 IBT storage reservoir with total 995 houses affected)	Substantial adverse (2 IBT storage reservoirs with total 1,190 houses affected)
Cultural and religious sites	No impact	Moderate adverse (affected length of religious value-river sections is 53 km and 0.16 km per MW)	Moderate adverse (affected length of religious value-river sections is 53 km and 0.13 km per MW)

Babai Basin

Table 4-17: Summary of impact significance ratings by scenarios of Babai Basin

Topic / issue	BDV2050	MXDV2050
Nepal's legally Protected Area	Moderate adverse (some irrigation area in NP-BZ)	Moderate adverse (three HPPs located in NP-BZ)
Internationally recognised area	Moderate adverse (some irrigation area in IBA)	Moderate adverse (some irrigation area in IBA)
Other ecologically significant areas	Moderate adverse (some irrigation area in tiger habitat, chure area and conservation landscapes)	Moderate adverse (some irrigation area in tiger habitat, chure area and conservation landscapes)
Land uses	No impact	No impact
Mainstream rivers – aquatic habitat conversion	No impact	No impact
Mainstream rivers – barrier effect of new dams	No impact	No impact
Instream flow changes	Sharada subbasin: Minor adverse Babai subbasin: Minor adverse	Sharada subbasin: Minor adverse Babai subbasin: Minor beneficial
Reservoir water quality	No impact	No impact
Social aspects – risk of increased flooding in lower Babai	No impact	Minor adverse
Cultural and religious sites	No impact	No impact

Mechi Basin

Table 4-18: Summary of impact significance ratings by scenarios of Mechi Basin

Topic / issue	BDV - 2050	MxDV - 2050
Nepal's legally Protected Area	No impact	No impact
Internationally recognised area	Moderate adverse for some irrigation schemes (1,218 ha new irrigation area inside IBA)	Moderate adverse for some irrigation schemes (1,218 ha new irrigation area inside IBA) Moderate adverse (for 1 HPPs inside IBA)
Other ecologically significant areas	Moderate adverse (most new irrigation area in conservation landscapes)	Moderate adverse (most new irrigation area and 1 HPP in conservation landscapes)
Land uses	No impact (99.7% of new irrigation area lies within land already used for agriculture)	No impact for new irrigation schemes (99.7% of new irrigation area lies within land already used for agriculture) Substantial adverse for new HPP (26 ha land footprint per MW)
Mainstream rivers – aquatic habitat conversion	No impact	Rating for extent: Moderate adverse (affected river has 20% of its length affected and loses 16% of its HCV*km) Rating for affected species: Minor adverse (max. number of fish species in an affected reach is 33; no endangered species affected)
Mainstem rivers – barrier effect of new dams	No impact	Moderate adverse (1 new barrier fragments a short river with already impacted connectivity but with presence of long and medium-distance migratory fish)

Topic / issue	BDV - 2050	MxDV - 2050
Instream flow changes	Rating for consumptive uses: Substantial adverse (25% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: No impact	Rating for consumptive uses: Substantial adverse (25% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: No impact
Reservoir water quality	Not applicable	Not applicable
Social aspects – resettlement and river dependent groups	No impact	Minor adverse (possible presence of river-dependent groups in HPP-dewatered reach)
Cultural and religious sites	No impact	No impact

Kankai Basin

Table 4-19: Summary of impact significance ratings by scenarios of Kankai Basin

Topic / issue	BDV - 2050	SC1 - 2050	MxDV - 2050
Nepal's legally Protected Area	No impact	No impact	No impact
Internationally recognised area	Moderate adverse for one small irrigation scheme (9 ha) inside IBA	Moderate adverse for one small irrigation scheme (9 ha) inside IBA Substantial adverse for 3 HPPs (187 ha) inside IBA	Moderate adverse for one small irrigation scheme (9 ha) inside IBA Substantial adverse for 3 HPPs (187 ha) inside IBA
Other ecologically significant areas	Moderate adverse (all new irrigation area in conservation landscapes)	Moderate adverse (all new irrigation area and 3 HPPs in conservation landscapes)	Moderate adverse (all new irrigation area, 3 HPP and Kankai multipurpose project in conservation landscapes)
Land uses	Minor adverse (98.6% of new irrigation area lies within land already used for agriculture)	Minor adverse for new irrigation schemes (98.6% of new irrigation area lies within land already used for agriculture) Moderate adverse for new HPPs (6.5 ha land footprint per MW)	Minor adverse for new irrigation schemes (98.6% of new irrigation area lies within land already used for agriculture) Major adverse for new HPPs and Kankai MPP (54 ha land footprint per MW)
Mainstream rivers – aquatic habitat conversion	No impact	Rating for extent: Moderate adverse (main affected rivers combined have 18% of their length affected and lose 12% of their HCV*km) Rating for affected species: Moderate adverse (max. number of fish species in an affected reach is 39; with one endangered species affected)	Rating for extent: Substantial adverse (affected river has 26% of its length affected and loses 17% of its HCV*km) Rating for affected species: Moderate adverse (max. number of fish species in an affected reach is 39; with one endangered species affected)

Topic / issue	BDV - 2050	SC1 - 2050	MxDV - 2050
Mainstem rivers – barrier effect of new dams	No impact	Moderate adverse (3 new barrier fragment 3 short rivers with already impacted connectivity but with presence of long and medium-distance migratory fish)	Moderate adverse (4 new barrier fragment 3 short rivers with already impacted connectivity but with presence of long and medium-distance migratory fish)
Instream flow changes	Rating for consumptive uses: No impact (0% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: No impact	Rating for consumptive uses: No impact (0% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: Substantial adverse (1 HPP with hydropeaking)	Rating for consumptive uses: Minor adverse (5% of baseline MAF abstracted for irrigation & drinking water supply) Rating for re-regulation: Substantial adverse (1 HPP and Kankai MPP with hydropeaking)
Reservoir water quality	Not applicable	Not applicable	Substantial adverse (1 new reservoir, with storage capacity much larger than dry season inflow)
Social aspects – resettlement and river dependent groups	No impact	Minor adverse (possible presence of river-dependent groups)	Major adverse (1 new reservoir project with a total of 2,896 houses affected)
Cultural and religious sites	No impact	Moderate adverse (affected length of religious value-river-section is 2 km and 0.03 km per MW)	Moderate adverse (affected length of religious value-river-section is 22 km and 0.19 km per MW)

Kamala Basin

Table 4-20: Summary of impact significance ratings by scenarios of Kamala Basin

Topic / issue	BDV - 2050	MxDV - 2050
Nepal's legally Protected Area	No impact	No impact
Internationally recognized area	No impact	No impact
Other ecologically significant areas	Moderate adverse (most new irrigation area in conservation landscapes and some in tiger habitat)	Moderate adverse (most new irrigation area in conservation landscapes and some in tiger habitat)
Land uses	Minor adverse (97.9% of new irrigation area lies within land already used for agriculture)	Minor adverse (97.9% of new irrigation area lies within land already used for agriculture)
Mainstream rivers – aquatic habitat conversion	No impact	No impact
Mainstream rivers – barrier effect of new dams	No impact	No impact
Instream flow changes	Rating for consumptive uses: no adverse impact Rating for re-regulation: No impact	Rating for consumptive uses: no adverse impact Rating for re-regulation: no adverse impact
Reservoir water quality	Not applicable	Not applicable
Social aspects – resettlement and river dependent groups	No impact	No impact

Topic / issue	BDV - 2050	MxDV - 2050
Cultural and religious sites	No impact	No impact

Southern Basin

Table 4-21: Summary of impact significance ratings by scenarios of Southern Block Basin

Topic / issue	BDV - 2050	MxDV - 2050
Nepal's legally Protected Area	Moderate adverse for some irrigation schemes (1,955 ha new irrigation area in buffer zones of National Park and Wildlife Reserve)	Moderate adverse for some irrigation schemes (1,955 ha new irrigation area in buffer zones of National Park and Wildlife Reserve)
Internationally recognized area	Moderate adverse for some irrigation schemes (4,377 ha new irrigation area inside IBA)	Moderate adverse for some irrigation schemes (4,377 ha new irrigation area inside IBA) Moderate adverse (for 1 new HPPs inside IBA)
Other ecologically significant areas	Moderate adverse (most new irrigation area in conservation landscapes, some area in tiger habitat and ecological corridor)	Moderate adverse (most new irrigation area and 2 new HPPs in conservation landscapes, some area in tiger habitat and ecological corridor)
Land uses	No impact (99.2% of new irrigation area lies within land already used for agriculture)	No impact for new irrigation schemes (99.2% of new irrigation area lies within land already used for agriculture) Major adverse for two new HPPs (61 ha land footprint per MW)
Mainstream rivers – aquatic habitat conversion	No impact	Rating for extent: Minor adverse (affected rivers have 5% of their length affected and lose 4% of their HCV*km) Rating for affected species: Moderate adverse (max. number of fish species in an affected reach is 22; two vulnerable species affected)
Mainstream rivers – barrier effect of new dams	No impact	Moderate adverse (2 new barriers, one on a short river with already impacted connectivity but presence of long and medium-distance migratory fish; the other on a short free-flowing river)

Topic / issue	BDV - 2050	MxDV - 2050
Instream flow changes	Rating for consumptive uses: No impact (abstractions for irrigation and drinking water supply cause no notable change of MAF compared to baseline) Rating for re-regulation: No impact	Rating for consumptive uses: No adverse impact (interbasin transfers and abstractions for irrigation and drinking water supply cause increase of MAF compared to baseline) Rating for re-regulation: No impact
Reservoir water quality	Not applicable	Not applicable
Social aspects – resettlement and river dependent groups	No impact	Minor adverse (possible presence of river-dependent groups in HPP-dewatered reach)
Cultural and religious sites	No impact	No impact

4.5 Proposed Mitigation Strategies

The term “mitigation” is used in a broad sense to include:

- Avoidance: measures to avoid an identified potential impact occurs, e.g. selecting an appropriate project alternative, site alternative, alternative construction or operation practices.
- Minimization: measures to reduce the levels of impacts
- Compensation/offset: where impacts cannot be avoided or reduced to acceptable levels, residual impacts will remain. Compensation / compensatory offsets can be provided that is meant to re-place / balance the losses

A mitigation hierarchy approach should be adopted, i.e., the mitigation principles should be applied in hierarchical order:

- As a matter of priority, developers should seek to **avoid** impacts.
- When avoidance of impacts is not possible, measures to **minimize** impacts should be taken.
- For remaining impacts, measures to **offset** the losses and restore the functions should be implemented.

These mitigation principles apply to all types of risks and impacts for the environment and human health and safety, including but not limited to resettlement and acquisition of productive land, the use of natural resources, pollution risks, biodiversity losses and impacts on cultural heritage.

If the decision is taken to continue with further planning of the above projects and scenarios, preliminary recommendations go for biodiversity losses and connectivity and environmental flows.

For the biodiversity loses, the major recommended strategies are:

- Avoid impacts by selecting alternative sites, modifying project design etc.
- Design and implement fish pass, and monitor its functioning
- Determine and implement downstream environmental flows
- Catchment afforestation (preferring tree species with high biodiversity value) to compensate for forest habitat losses. Where possible, this can take the form of increasing the protection and thereby enhancing the natural regeneration of existing but degraded woodland vegetation.
- Vegetated buffer zones along rivers and around the reservoir boundaries; preferring local species with high biodiversity value.
- Where there is existing (not project-related) overexploitation of natural resources, measures to control such unsustainable practices can be taken. Reduce existing pressure on species and habitats and thereby improving their ecological status can be chosen as a way to compensate/offset the project-related impacts.
- ESMPs for the construction phase to include provisions to minimise disturbance of habitats, prohibit hunting, fishing, collection of wood and non-wood forest products by the workforce, aware-ness raising for workforce on the need to protect flora and fauna species. Capturing and trans-locating individual animals and transplantation of individual plants from the impacted areas is also sometimes practiced (especially for threatened, endangered and legally protected species).
- Long-term monitoring to determine effectiveness of mitigation measures. Long-term monitoring is particularly important for biodiversity issues, because population changes as a reaction to impacts (such as habitat connectivity loss and others) usually come with a long delay time.

- As far as possible, planning should aim to preserve the connectivity of long and medium long free-flowing rivers. Priority for development should be given to:
  - rivers with already impacted connectivity,
  - shorter tributaries (instead of mainstream rivers)
  - locations in the upper parts of the catchments (instead of lower parts of mainstream and larger tributaries)
- Planning should aim to minimize the impacts on National Parks and Ramsar sites.
- Planning should aim to avoid and, if avoidance is not possible, minimise resettlement as far as possible. Studies of design alternatives and optimisation for the various components (e.g. the location of access roads, transmission lines, quarry and borrow areas etc.) should be undertaken, considering the minimising of environmental and social impacts.
- To mitigate the adverse social impacts of land acquisition and resettlement, in-kind compensation of losses should be offered wherever feasible. Livelihood restoration support should be provided.
- Environmental flow requirements should be further studied, including setting of appropriate e-flow targets for the dewatered reaches of the PROR and ROR projects.
- Impacts of peaking operations should be further studied and appropriate mitigation should be applied (e.g. reducing the ramping rates).
- Best practice standards for environmental and social planning and management of implementation should be applied.
- Establish and implement long-term monitoring programmes for water quality and fish biodiversity
- For the irrigation schemes, both new areas and existing schemes where production will be intensified, agricultural extension services should be provided that include capacity building on how farming operations can be optimised in order to protect the environment, especially wetlands, from pollution, to avoid health risks due to misuse of pesticides and fertilisers, and to prevent degradation of soils. This could include, but need not be limited to,
  - develop best management practices to establish and retain soil fertility and avoid land degradation
  - modern irrigation design and good water management practices to avoid over irrigation
  - implementation and regular maintenance of drainage infrastructure
  - avoid over-application of fertilisers and pesticides

4.6 Basin Level Recommendations

The following recommendations are made at the basin level.

4.6.1 Regular stakeholder engagement

Implementation of river basin management will not be an activity that WECS will carry out in isolation, but it will require the participation of a wide range of stakeholders. It is thus recommended that activities are undertaken by WECS for regular stakeholder engagement. Details of the stakeholder groups to be engaged and the types and frequencies of engagement meetings to be envisaged should be determined once WECS and the RBOs move towards implementation of the river basin plans.

The full list of potential stakeholders is very long and for practical reasons, it is necessary to prioritise the most relevant ones. One way of doing this is by categorising stakeholders according to their power over the river basin plan activities and their interest in it. An example of such a power/interest grid is shown in Figure 4-7.

DEGREE OF INFLUENCE

← **High influence** — **Low influence**

DEGREE OF INTEREST	**High influence**	**Low influence**
High Interest ↑	**Box A** **High power, highly interested people.** **Manage closely.** Full engagement of the stakeholders with the great effort required to satisfy them.	**Box B** **Low power, highly interested people.** **Keep informed** Inform these people to ensure that no major issues are arising. These stakeholders can be very helpful with the details of the projects
Low interest	**Box C** **High power, less interested people** **Keep satisfied** Keep them informed, but not so much that they become bored with your messages	**Box D** **Low power, less interested people.** **Monitor** Monitor these people with limited communication.

Figure 4-7: Sample matrix for categorizing stakeholders

The **Box A – quadrant** maps the stakeholders deemed to be the most influential, interested, or affected by the development in the river basins. Stakeholders falling into this quadrant should be kept in close contact during the planning processes due to their mandates and objectives. Some important stakeholders mapped are the Ministry of Finance (MOF); Ministry of Energy, Water Resource and irrigation (MOEWRI); Ministry of Forests and Environment (MOFE), Ministry of Agriculture and Livestock Development (MOALD); and Ministry of Home Affairs (MHA)); and Ministry of Women Children and Senior Citizens (MOWCSC); Ministry of Water Supply (MOWSS), and different departments under each Ministry. The stakeholders mapped here are deemed to be the most influential, interested, or affected by the development in the river basins because of their pertinent roles and functions in the development process.

The NPC is important as it is responsible for the overall planning of the country. It prepares a list of projects which need to be implemented by the GON in consultation with different Ministries and Departments. These are reflected in the annual plans and budget of the government. Among other important stakeholders, the Ministry of Finance (MoF) is perhaps the most important one. This ministry is the source of finance for every project's implementation. The sources can be either internal or external. All financial resources have to be channeled through the MOF. Even with the federal system now emphasizing decentralization, the MOF still continues to play a dominant role.

The MOEWRI is important for energy, water resources and irrigation sector. The MOFE has a challenging role. All big projects, especially hydropower projects, have to obtain an environmental clearance from MOFE. In the absence of the clearance no projects can be implemented. The MHA has the responsibility for determining compensation for the resettlement of households displaced by the proposed projects. MHA also plays an instrumental role during major floods during the monsoon periods. The MOWSS and MOALD are responsible for developing drinking water, agriculture and livestock sectors respectively within the country and hence are very crucial ministries. The MOWCSC monitors GESI activities which are vital especially if the projects are financed by Inter- national Donors. It is also responsible for registration and monitoring of I/NGOs through Social Welfare council. Different ministries are found to work through their respective departments.

Stakeholders positioned in the **Box B – quadrant** include those with significant interest in the planning and development process, but hold little influence with respect to projects. These organizations should be consulted and kept informed of the planning and developmental processes. Majority of such organizations fall under local level NGOs and CBOs. They come in the form of user groups who are important stakeholders at project level implementation except for mega hydropower projects. However, users group play prominent roles in drinking water schemes, forest management, small irrigation projects along with agriculture and livestock projects. The universal approach in Nepal has been to work with user group in many rural development projects. Another important stakeholder in this category is the Ministry of Culture, Tourism and Civil Aviation which directs its activities more towards providing basic services for the promotion of tourism. The Department of Mines and Geology regulates the exploration of mines. The Chamber of Industry works more on business interests.

Stakeholders positioned in the **Box C – quadrant** are those with more influence but little interest in – or with little impact on them – from river basin planning and hydro- power development. These entities only need to be consulted on an on-going basis. Some of the important stakeholders are: Ministry of Labor, Employment and Social Security (MOLESS), Department of Cottage and Small Industries (DCSI) and National Agricultural Research Council (NARC). Ministries and Departments are influential because they are found to be working for the welfare of the citizens of the country but have objectives different from basin planning. Other stakeholders such as NARC are research organizations and are responsible for agricultural development. National Trust for Nature Conservation (NTNC) works in National Park areas and hence its influence is limited, as long as there is no development of hydropower projects in National Parks. Stakeholders under this category influence hydropower development along with drinking water, irrigation, and agriculture in isolated way but these stakeholders have little interest in the river basin and hydropower development planning activities.

The **Box D – quadrant** includes all of the remaining stakeholders that were identified in the original stakeholder mapping exercise. These entities have almost no influence in affecting river basin or hydropower planning and development and no interest in it either. Some of the stakeholders are: District Lead Support Agencies listed as per District Administrative Office; Urban Planning Projects; National / Local Media and Federations of Nepali Journalists. These stakeholders are mostly stand-alone units engaged in pursuing their specific interests for local development and have no influence and interest on river basin development. These entities should be simply monitored for developing levels of interest and for collection of data.

4.6.2 Need for basin-wide spatial planning for the effective conservation of aquatic habitats and biodiversity

The analyses of the baseline situation and impacts of development scenarios undertaken for the SESA have shown that significant adverse impacts must be expected on aquatic habitats, mainly caused by the hydropower and irrigation transfer projects. The envisaged scale of hydropower production for Nepal is large and combined with the dams proposed for irrigation priority projects results in a total of 386 new dam projects[17].

Determining measures for mitigation and management of such impacts is generally only undertaken during the planning of individual projects. Legally, this is done through the EIA/ESIA procedures which are required to be followed for the licensing of each project. However, the scopes of project-specific ESIAs are often too limited to develop mitigation measures for potential cumulative impacts of various projects. Moreover, EIA studies tend to focus on pre-selected projects and sites and assess their compliance with legally binding requirements. And while there may be higher-level strategies that contain objectives for preserving certain areas and features, a project’s alignment with such higher-level strategies is usually only assessed if there is mapping of the areas and features that should be protected, and if there are clearly formulated restrictions on the location of projects in such areas.

Specifying the objectives of sectoral strategies in the form of spatial plans is often the most effective way of making them accessible for other planners. Spatial plans can be made on different administrative levels and

[17] This is the number of projects combined for all basins, maximum development scenario, year 2050 (project portfolio as per HDMP, July 2022).

scales, e.g. for a municipality or a particular urban area (town planning), or for a province or district (e.g. land use planning). Spatial plans are most useful when all sector planning is integrated into a single spatial master plan, because in the process of doing so, conflicting planning can be identified and harmonised or prioritised.

It is understood that Nepal does currently not have a standardised approach for such spatial planning. And while it is beyond the scope of this SESA to make recommendations for overall spatial planning in Nepal, it is recommended here that a river basin-wide spatial planning should be developed specifically for the purpose of conservation of aquatic habitats and biodiversity.

4.6.3 Long-term conservation plan

It is recommended that WECS develops, for each river basin, a **plan for the long-term conservation of aquatic habitats and biodiversity**. The plan should identify and delineate areas where damming of rivers is closely monitored and regulated. In developing this plan WECS can coordinate with the MOFE and DNPW and support the implementation of the NBSAP and other strategies.

As a basis for the conservation plan for aquatic habitats and species, **detailed biological and ecological specialist studies** should be undertaken in each river basin to identify:

- a set of rivers / river sections that would represent all major river habitat types and fish populations; and
- the spatial extent over which connectivity is required to enable the fish populations to sustain themselves.

Alongside with this, presence of existing threats to fish populations (such as overfishing, habitat destruction through sand and gravel mining, high levels of pollutions intakes, etc.) should be investigated in these target areas and the need for new protective legislation and/or enhanced enforcement of existing legislation should be identified.

To consider the lake or river as the fish sanctuary, detail information on following parameters should be analyzed:

- biophysical conditions: water quality parameters, temporal fluctuation of water depth and flow, availability of spawning and feeding sites,
- fish diversity and population status: fish population, species including migratory and threatened
- existing socio-economic condition: fishing communities, fish harvest rate, people's perception, social conflict

Such detailed recommendations cannot be drawn from the level of data that have been available for the preparation of the SESA. However, the SESA findings can be used as a starting point for such detailed specialist studies. Table 4-7 to Table 4-11 summarise information on the connectivity remaining in the longer mainstream rivers in case of implementing the development scenarios:

- Baseline length of the river, coverage of physiographic zones and current connectivity status
- Current importance of the river for fish species (as far as data availability allows, total no. of fish species, no. of migratory fish species, no. of fish species in threatened categories)
- Importance of the river for other aquatic mega fauna (dolphin, gharial)

5 Investment and Financial Planning

5.1 Cost and Benefits of Drinking Water Supply

The policies and goals of water supply and sanitation are given in section. The conclusion is that policy requires that “safely managed” water supply will be provided to 90% of the population by 2030. However, progress on the provision of sanitation facilities has been good and there is no need to make special provision for investment in wastewater disposal in the basin at this stage.

Overall, about 21% of the 2019 population had a safely managed supply. About 38% of the urban population had a safe supply, but only about 17% of the rural population (80% of the population live in rural and municipal areas and the latter is classified as rural for this analysis).

NPC has stated the target to provide "safe drinking water” to 90% of the population by 2030[18] but targets are difficult to meet (25% of the national population with pipe connection in 2019 compared with a 35% target). The National Water Supply and Sanitation Sector Policy 2017-30[19] acknowledges that coverage and quality of service in existing schemes is poor, tariffs do not cover basic operational costs and consumer participation in management is low. To address these issues the policy includes the objectives of increasing provincial and private sector involvement, including concessional financing, service regulation and tariff setting and benchmarking. The objective is to not only to improve cover and service quality but also to relieve Government and financing agencies of at least some of the responsibility of financing new schemes and subsidizing existing ones. Nepal’s target is 90% of the population having “Water accessible on the premises” by 2030. It is reasonable to assume this 90% target can be extended to the planning life of this study, 2050.

Planning investment in drinking water supply over time requires an estimate of the change in population. An extended population estimate is available only up to 2043 (see Technical Note: Socio Economic Review of River Basins, 2021 section 2). The projection shows the impact of a falling birth rate and migration to urban areas. The population is expected to increase by about 4.1 million people by 2043, leading to about 885,000 new connections[20]. The total population in 2045 (including Bagmati basin) is expected to be 35.02 million, which is close to internationally accepted demographic estimates[21]. The investment and O&M costs can be planned to take this into account.

The very high standards of a “safely managed” water connection under the SDG should be relaxed when estimating investment costs because some of those standards are directly concerned with management, in particular adequacy of supply and quality of water. Considering only the incremental investment necessary for “water accessible on the premises” to achieve 90% coverage by 2043, the magnitude of the task by basin is shown in Table 5-1.

The investment required can be costed very roughly by assuming average connections costs simplified from recent estimates[22]:

- Urban connection developed from groundwater: USD 250/connection
- Urban connection developed from surface water: USD 300/connection
- Rural connection developed from groundwater: USD 325/connection
- Rural connection developed from surface water: USD 350/connection

[18] https://sustainabledevelopment.un.org/content/documents/26541VNR_2020_Nepal_Report.pdf, Table 5.6
[19] https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/ eng_wss_policy_2014_draft-1.pdf
[20] Household size was assumed to be 4.8 in rural areas and 4.2 in urban areas. Note that the number of connections required is not equivalent to the net change in population over the planning period. Once connections have been provided they cannot be “un-made” for a declining population, though in practice a local water utility would plan more efficiently.
[21] https://population.un.org/wpp/Download/Standard/Population/: estimate of 35.22 million
[22] Life cycle costs approach for private piped water and service delivery (Grant et al 2020): https://iwaponline.com/washdev/article/10/4/659/77472/Life-cycle-costs-approach-for-private-piped-water

Table 5-1: New Drinking Water Connections Planned: 2023-2050 (in thousand

	Urban connections		Rural connections			Additional urban connections	Additional rural connections	Investment, NPR million	O&M, NPR million
	Hill	Terai	Mountain	Hill	Terai				
2021-2025	405	184	166	815	935	179	15	104,840	14,678
2026-2030	405	184	166	815	935	179	15	104,840	51,371
2031-2035	-	-		-	-	179	15	6,418	67,397
2036-2040				-	-	179	15	6,418	69,643
2041-2045				-	-	179	15	6,418	71,889
2046-2050				-	-	179	15	6,418	74,136
Total	**8130**	**368**	**332**	**1,630**	**1,870**	**1,074**	**90**	**235,351**	**349,113**
NPR/connection	39,000	32,500		45,500	42,250	32,500	39,000		7%

The budget in Table 5-1 assumes that a 90% connection rate of the present population is achieved by 2030. This will require substantial investment of about NPR 21 billion m (USD 161 m) per annum. Implementation difficulties may cause spillage into later planning periods. Investment for the incremental population also assumes 90% connection rate but can be planned to be equally distributed over the planning period.

Incremental O&M at 7% is assumed to be paid by consumers through tariffs. Note that O&M is cumulative and includes payment at 7% pa on all previous investment. No capital cost recovery is envisaged.

No financial or economic benefits have been calculated for the provision of drinking water. The supply is driven by the policy of 90% access by the population to good quality supply by 2030. The financial benefit (what is recovered through water tariffs) will inevitably be lower than the costs if cost recovery is not factored into tariffs. The economic value is likely to be greater than the costs; it should be the value of the tariff plus consumer surplus for incremental water consumption at existing connections. For new connections the economic value will be the resource saving (the value of reduced sickness from using inferior supply, time for water collection etc.). In this analysis the costs and benefits are treated as neutral by assuming that the costs and benefits are equal.

Over the life of the incremental investment in water supply, 2023-2050 GoN pays NPR 235.4 billion in investment costs, while consumers' payments allow the accumulation of NPR 349.1 billion to cover annual MOM and capital accumulation to expand and improve utility services. This is sufficient to re-build the system (in current prices) so is likely to be in the right order of magnitude to cover all MOM and replacement.

The charge to consumers is shown to be affordable by working out the unit price of the incremental water supplied. The daily consumption per urban and rural household is known as is the incremental number of urban and rural connections that will be supplied Table 5-1. The water supplied to households during the period will be cumulative, following the investment plan and will total 2,946 MCM. The charge to consumers assumed is also known from Table 5-1 i.e. NPR 349.1 billion. Consumers will have paid NPR 119/m3 in the period 2021-2050. The household water consumption (weighted between urban and rural users) is projected to be 32m3 per annum (88 liters per connection per day) in 2050, giving an annual water bill of NPR 3,809 pa in current prices. This is high, but in the right order of magnitude[23]. It is also possible to argue, that if the tariffs applied are capturing the full consumer surplus of the benefitting population (which if the tariffs are well designed, they should), then the economic benefit is equal to the cost of supply.

[23] Water charges in Kathmandu Valley in 2016 were in the order of NPR 267/month (https://www.researchgate.net/publication/312492422_Household_water_use_in_the_Kathmandu_Valley_A_dry_season_survey). Household Consumption in 2015 was estimated at NPR 30,500 pa Water services normally account for 5-7% of household consumption.

5.2 Costs and Benefits of Irrigated Agriculture

5.2.1 Present Value of Cropping

IMP prepared a set of District level recent-present gross margins using Ministry of Agriculture and Livestock Department (MALD) published statistics (yields, areas and production by crop) and information from special purpose agro-economic surveys carried out by Agri-business Promotion and Marketing Development Directorate. The crop groups identified were paddy, wheat, maize, other cereals, roots, sugar cane, oilseeds, tobacco, temperate fruit, tropical fruit, vegetables and spices. Within the roots, oilseeds, fruit, vegetables and spice crop groups there is considerable variation in crop type between Districts. This variation was captured with reference to MALD publications and various special surveys, as described in IMP Annex G-3. This information is mostly collected, compiled and reported by District, so it is straightforward to apply District area weights by basin to present cropped area by crop and Region, cropping intensity and the area of agriculturally suitable land.

Figure 5-1 shows the gross cropped area, the area of suitable land and the cropping intensity by river basin. As far as possible the basins are shown in geographical order from west to east. Regions are shown in altitudinal order.

Some general trends can be identified. Cropping intensity is highest in basins with greater proportions of the Terai region and cropping intensity generally declines from east to west. Land suitable for irrigation is also concentrated in basins with a high proportion of the Terai region.

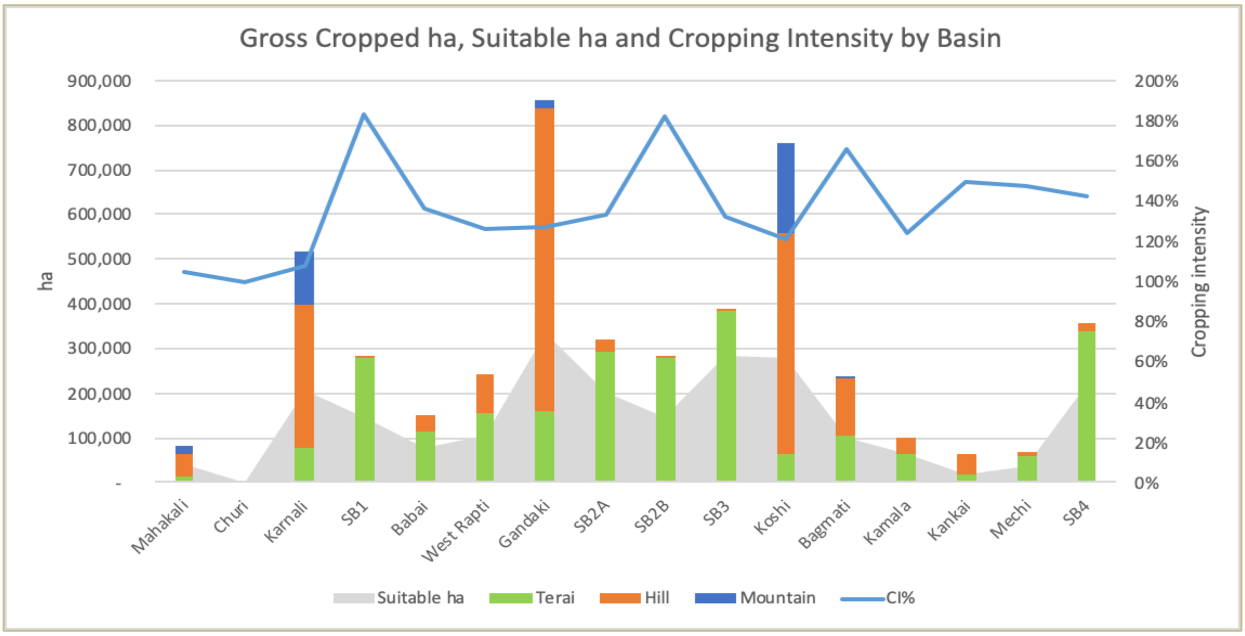


Figure 5-1: Gross Cropped ha, Suitable ha and Cropping Intensity by Basin

Figure 5-2 shows the distribution of crop group areas between basins. Cereals dominate the cropping pattern (74% of the gross cropped area) but the areas are variable between basins. Karnali, Gandaki and Koshi account for a large proportion of the maize and “other cereals” area, whilst the Southern Blocks account for most of the rice area. Wheat is grown widely but its cultivation increases to the west.

Other crops account for only 26% of the gross cropped area. Only the Southern Blocks can be considered having a “diversified” cropping pattern with other crops taking well over 30% of the cropping pattern. By far the most diversified basin cropping pattern is Bagmati (38%). Crop diversification is positively correlated with the proportion of the basin population that is urban. Regression analysis shows that a unit change in urbanization gives a 0.26 change crop diversity (t statistic=8.5, 13 degrees of freedom).

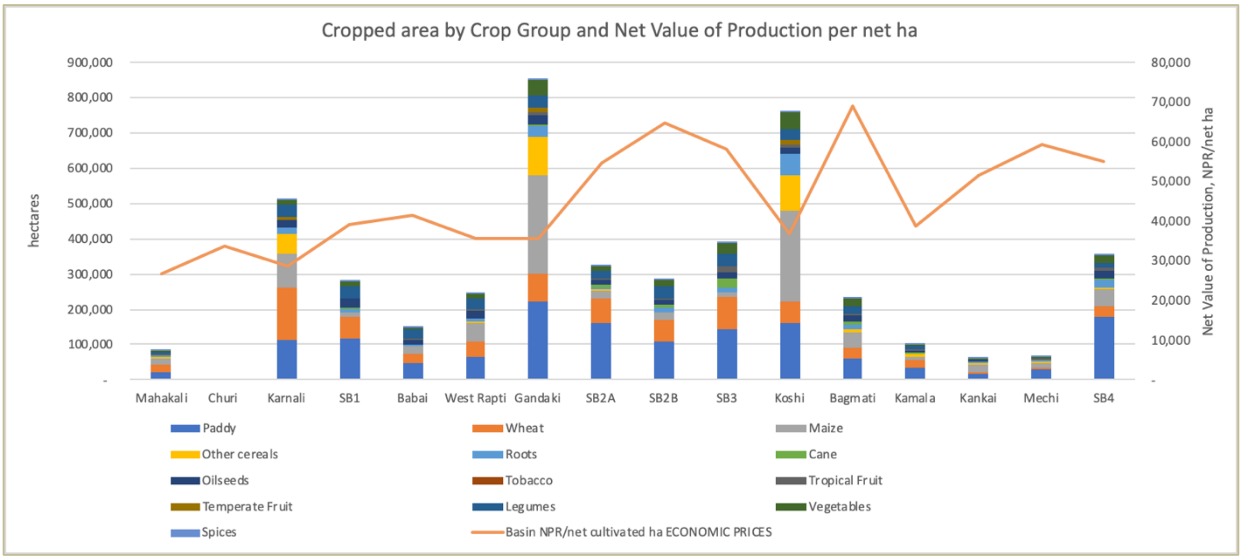


Figure 5-2: Cropped area by Crop, ha and Economic Net Value of Production, NPR/net cropped ha

Since MoALD crop area statistics are supported by production data and Agri-business Promotion and Marketing Development Directorate carries out periodic surveys to estimate crop gross margins by District, IMP prepared estimates of the net value of production per net cropped hectare by District. These estimates are weighted by the proportion of each District area in each basin to prepare an estimate of the value of crop production per net hectare (Figure 5-2).

The estimates by basin hide substantial differences between the value of production on cropped areas in the Mountain, Hill and Terai regions (Figure 5-3). Some high value cropping occurs in the Mountain region – this is explained by the presence of temperate fruit orchards.

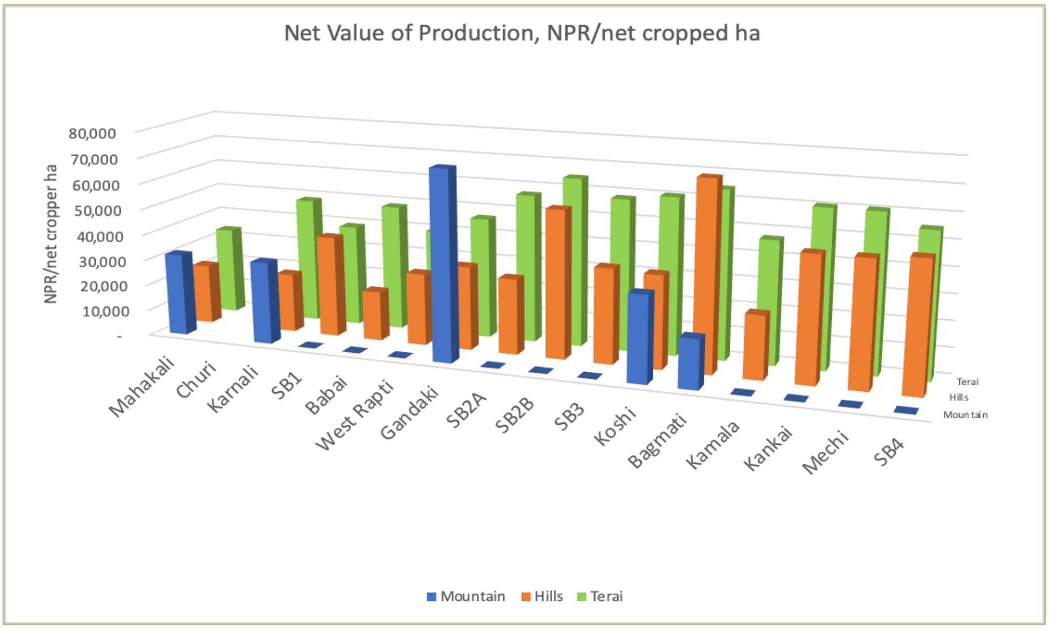


Figure 5-3: Net Value of Production, NPR/net cropped ha (Economic Prices)

5.2.2 Expected Changes in Cropping and Productivity

Figure 5-1, Figure 5-2 and Figure 5-3 broadly represent the present cropping pattern and value of crop production by basin. The planning for IMP investment carried this further to estimate the changes that might take place in the future (interpolating between the present and two future reference points of 2031 (the limit of reliable population projections by CBS) and 2043 (the end of the IMP planning period). This was done to estimate the magnitude of change in value of the cropping pattern at District level because of expected changes in demand for food and the type of food demanded which might, under certain assumptions, be expected from the relocation and growth of the population and increased urbanization over time. How this was done is described in detail in Annex G-2 of the IMP report. The results are summarized by basin

Figure 5-4 shows that the basins with the greatest change in value of the future cropping pattern and change in gross cropped area are those basins with the greatest proportion of the Terai region. Crop diversification is an important explanatory variable of the value of the cropping pattern. The three large basins Karnali, Gandaki and Koshi show progressively smaller changes in crop area due to the difference is growth of the population that are expected to be higher in the west than the east.

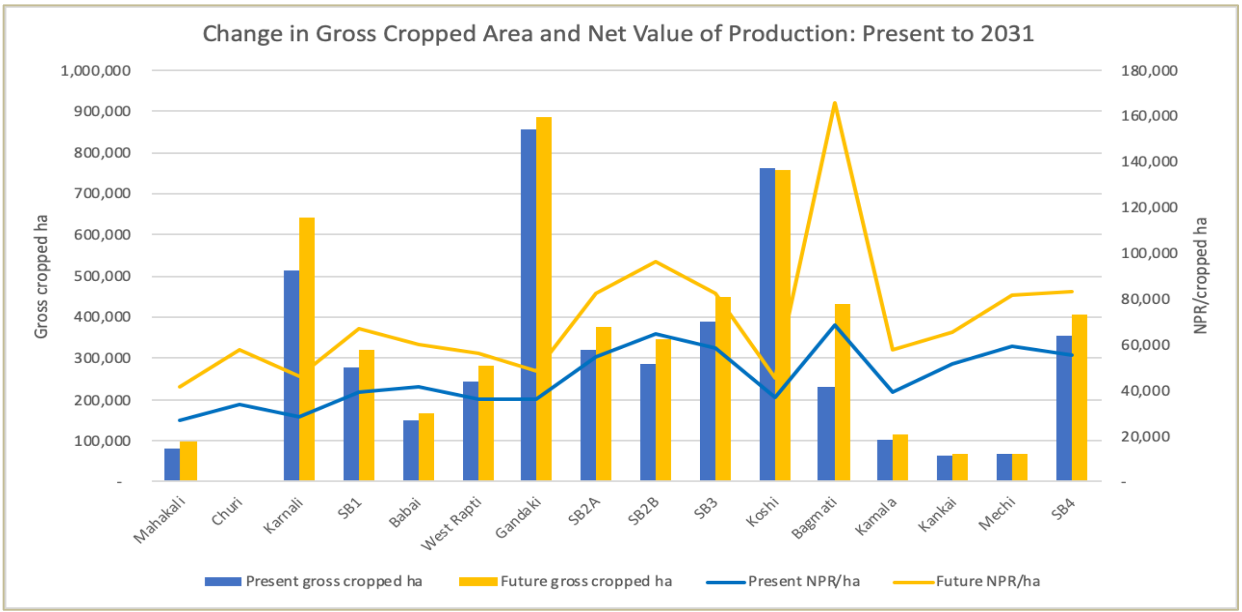


Figure 5-4: Change in Gross Cropped Area and Net Value of Production (Economic Prices): Present to 2031

5.2.3 Irrigation Development Cost-Benefit Analysis

If all the recommendations of IMP were implemented, then the country would benefit from an additional new and rehabilitated 1.5 Mill. ha of irrigation. 20% would be gravity-pump irrigation in the Hills and Mountains, and the balance would be on the Terai.

Table 5-2 and Table 5-3 show the expected economic and financial indicators respectively. A summary of the costs and benefit streams is given in Table 5-5.

The results in economic prices are satisfactory – but this is not surprising as the proposed interventions have already been screened for viability by IMP. It is also unsurprising that in financial prices the results are weaker – taxes are included in costs, as well the full price of labour. Transfer costs (including the cost of re-settlement, the budget for which is considerable) are deducted from economic value.

Table 5-2: Economic Indicators for Proposed IMP Interventions: All Basins, NPR million

	Irrigation Project Indicators For All Basins In Economic Prices, NPR million			
	All Proposed Investment	MPP	Groundwater	Gravity/pump
ENPV at 9%	112,705	43,231	59,159	10,315
EIRR	13.4%	11.7%	16.5%	15.6%

	Irrigation Project Indicators For All Basins In Economic Prices, NPR million			
	All Proposed Investment	MPP	Groundwater	Gravity/pump
NPV benefit	326,404	150,532	153,896	21,976
NPV costs	213,699	107,301	94,736	10,169
BCR	1.53	1.40	1.62	2.16
Switching value costs	53%	40%	62%	116%
Switching value benefits	-35%	-29%	-38%	-54%

Table 5-3: Financial Indicators for Proposed IMP Interventions: All Basins, NPR million

	Irrigation Project Indicators For All Basins In Financial Prices, NPR million			
	All Proposed Investment	MPP	Groundwater	Gravity/pump
FNPV at 9%	(46,420)	(68,005)	20,095	1,490
FIRR	7.3%	5.2%	11.5%	10.0%
NPV benefit	189,038	63,948	112,316	12,774
NPV costs	235,458	131,953	92,221	9,851
BCR	0.80	0.48	1.22	1.30
Switching value costs	-20%	-52%	22%	30%
Switching value benefits	25%	106%	-18%	-23%

The basins can be ranked according to estimated future economic performance, best to worst, see Table 5-4. All the poorly performing basins are in the west. The basins with the largest proportion of their area on the Terai generally perform the best. An exception is Southern Block 1. Neither Mahakali Water Transfer nor Bheri Babai MPP perform well in economic terms. Only 7,500 ha of groundwater irrigation (which usually has good economic indicators) has been allocated to Southern Block 1. Of the large basins dominated by the Hills and Mountain regions, Gandaki basin performs the best because it has 12% of its area on the Terai (376,500 ha). Karnali and Koshi basins have only 3% of their area on the Terai; only 212,650 ha between them. The ranking may assist in prioritising investment, though the interventions have already been scheduled in the IMP.

Table 5-4: Basins Ranked by Irrigation Economic Indicators

	ENPV at 9%, NPR million	EIRR	NPV benefit, NPR million	NPV costs, NPR million	BCR	Switching value costs	Switching value benefits
SB3	24,570	15%	57,909	33,339	1.74	74%	-42%
SB4	21,225	16%	53,939	32,714	1.65	65%	-39%
Bagmati	18,484	16%	37,239	18,755	1.99	99%	-50%
SB2B	15,450	16%	33,670	18,221	1.85	85%	-46%
Mechi	9,247	16%	23,942	14,695	1.63	63%	-39%
Gandaki	8,007	15%	20,446	12,439	1.64	64%	-39%
SB2A	6,560	16%	17,547	10,987	1.60	60%	-37%

	ENPV at 9%, NPR million	EIRR	NPV benefit, NPR million	NPV costs, NPR million	BCR	Switching value costs	Switching value benefits
Koshi	5,613	16%	13,852	8,239	1.68	68%	-41%
Kamala	3,896	14%	9,019	5,123	1.76	76%	-43%
Kankai	2,666	15%	6,972	4,306	1.62	62%	-38%
Karnali	3,017	12%	10,704	7,687	1.39	39%	-28%
West Rapti	728	10%	13,381	12,653	1.06	6%	-5%
Churi	-	0%	0	-	-	0%	0%
Babai	(395)	9%	9,611	10,006	0.96	-4%	4%
Mahakali	(645)	7%	1,597	2,242	0.71	-29%	40%
SB1	(5,685)	7%	15,771	21,455	0.74	-26%	36%

Table 5-5 summarizes the cost and benefit steams in financial prices. It shows that the MPP investment and O&M costs – for irrigation only – totals about NPR 400.6 billion (USD 3.1 billion), implying an annual expenditure over 50 years (2021-2070) of USD 61.2 million in current prices. The cost of groundwater investment is expected to be even more (for only 44% of the area) and demands an annual expenditure of USD 69.8 million per annum. Gravity-pump scheme investment and O&M would demand only USD 6.3 million per annum. Bearing in mind these costs are expressed in current prices the demands on the national budget would be considerable.

Table 5-5: Summary of Cost and Benefit Streams for Irrigation Development NPR million, Financial Values

	Financial Prices Undiscounted, current prices, NPR million					
	MPP Investment & O&M, NPR million	Groundwater Investment & O&M, NPR million	Pump & gravity schemes, Investment & O&M, NPR million	MPP Benefit Stream, NPR million	Groundwater Benefit Stream, NPR million	Pump & gravity schemes, Benefit Stream, NPR million
2021-2025	70,812	49,373	1,298	177	4,940	-
2026-2030	117,000	32,542	5,516	6,626	36,143	982
2031-2035	36,423	67,969	10,835	21,382	66,951	7,306
2036-2040	55,338	52,574	7,516	36,428	108,898	15,390
2041-2045	19,521	45,312	4,940	92,512	144,363	18,899
2046-2050	19,521	43,145	1,964	151,849	153,538	22,397
2051-2055	19,521	43,189	1,964	166,884	153,837	22,397
2055-2060	19,521	41,160	1,964	177,683	153,837	22,397
2061-2065	23,425	42,711	2,357	214,193	153,837	22,397
2066-2070	19,521	35,592	1,964	178,494	184,604	26,876

Table 5-6 shows the cumulative area by irrigation technology to be developed. It shows not only the rate of implementation expected, but also enables a check on the unit cost of each irrigation technology. These are as expected, USD 3,200/ha for surface irrigation, USD 7,200/ha for groundwater development and USD 1,200/ha for gravity-pump irrigation.

Table 5-6: Cumulative Irrigation Area Developed, ha

	Cumulative Area Developed, ha				
	MPP new irrigation	MPP rehabilitation irrigation	Groundwater irrigation	Gravity/pump irrigation	Total irrigation development
2021-2025	634	10,190	19,424	2,150	32,398
2026-2030	123,925	180,938	123,207	43,717	471,787
2031-2035	181,148	274,476	207,513	118,414	781,551
2036-2040	291,205	399,920	292,524	187,194	1,170,843
2041-2045	319,468	464,101	354,742	222,038	1,360,349
2046-2050	325,180	478,191	358,000	222,038	1,383,409
2051-2055	327,585	487,022	358,000	222,038	1,394,645
USD/ha	3,193		7,179	1,192	3,898

5.3 Costs and Benefits of Greenfield Hydropower and MPP Projects

5.3.1 Investment Planning Model

The Economic/Financial Analysis are required to “Assess and develop financial projections to each river basin plan, (to) each project for hydropower plan including SESA” This requires the valuation of hydropower sites, as distinct from screening hydropower sites as done in the HDMP. Therefore, an investment planning model has been prepared to value using financial and economic indicators the sites for hydropower development identified by the Hydropower Development Master Plan. The model calculates the economic and financial analysis of the development of one, some or all proposed sites in any basin; so avoiding the difficulty of a one-by-one comparison of the economic and financial viability of site options.

However, the analysis criteria differ from those used in the screening process. The economic benefit of incremental generation is assumed to accrue to the energy consumer, either through incremental use by existing users (valued at consumer surplus) or non-incremental use (valued at domestic resource savings of diesel, kerosene, LPG etc.). The screening valuation carried out by the hydropower economists calculates the opportunity cost of developing an equivalent capacity using thermal generation.

5.3.2 Results of the Model

HDMP considered three development scenarios, baseline (maximum hydropower development), Scenario 1 (high future demand for electricity) and Scenario 2 (low to moderate future demand for electricity, conforming to the historical trend). Different scenarios may be adopted for different basins when testing economic viability of different hydropower development options, but all basins will face the same demand curve at national level. However, to meet total demand, some basins may be prioritized for development above others. For example, HEP sites in Gandaki and Koshi basins may be prioritized for development over sites in Karnali basin to maintain free-flowing rivers in the latter.

The costs and benefits for Scenarios 1 and 2 were compiled by basin as shown in Table 5-7 and Table 5-8. The schedule of development of HEP sites recommended by HDMP under each scenario was maintained.

In both scenarios the importance of Karnali, Gandaki and Koshi basins for economic efficiency and scale of production of HEP is obvious. The highest EIRR comes from investment in Gandaki basin where sites are cheaper to develop, but the greatest ENPV comes from Karnali basin where the installed capacity per site is much greater.

Investment in Babai, West Rapti and Kankai all relate to the development of MPPs and return low EIRRS for hydropower production. They would not be selected but for their strategic importance of providing water transfer.

Table 5-7: HDMP Electricity Demand Scenario 1: Sites by Basin

	Economic Cost, Current NPR million	No of sites	EIRR	ENPV	FIRR	FNPV	Levelized cost, NPR/kWh	Levelized cost, USDc/kWh	MW generation capacity
Mahakali	56,592	1	16.5%	6,339	11%	(819)	9.1	7	77
Babai	73,310	1	12.0%	6,993	5%	(8,115)	11.5	9	47
West Rapti	434,566	2	7.9%	(10,615)	5%	(27,261)	16.2	12	384
Karnali	4,077,665	27	18.8%	378,968	16%	6,362	8.1	6	9,562
Gandaki	2,346,691	22	20.0%	239,973	15%	1,685	7.7	6	4,790
Koshi	3,627,090	46	17.3%	334,655	14%	(11,776)	8.5	7	6,869
Kankai	91,879	2	9.2%	429	4%	(7,357)	14.4	11	115
Total	**10,707,793**	**101**							**21,844**

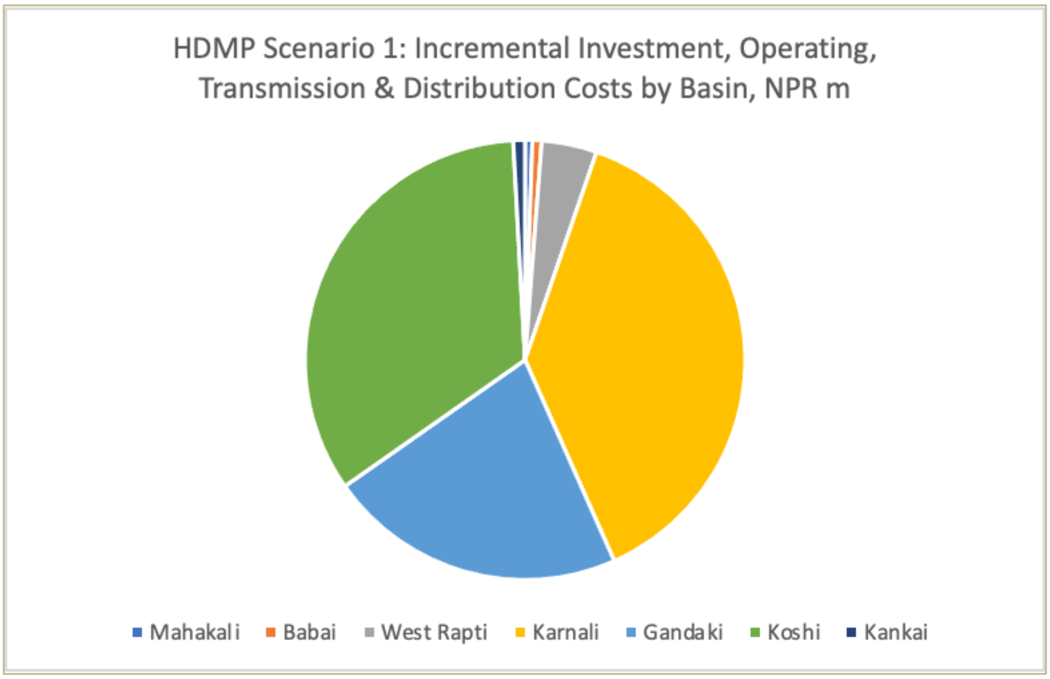


Figure 5-5: Scenario 1: Incremental Cost by Basin, Economic NPR million

Table 5-8: HDMP Electricity Demand Scenario 2: Sites by Basin

	Economic Cost, Current NPR million	No of sites	EIRR	ENPV	FIRR	FNPV	Levelized cost, NPR/kWh	Levelized cost, USDc/kWh	MW generation capacity
Mahakali	56,592	1	16.5%	6,339	11%	(819)	9.1	7	77
Babai	73,310	1	12.0%	6,993	5%	(8,115)	11.5	9	47
West Rapti	434,566	2	7.9%	(10,615)	5%	(27,261)	16.2	12	384
Karnali	1,830,679	14	19.1%	192,212	16%	4,245	7.9	6	4,028

	Economic Cost, Current NPR million	No of sites	EIRR	ENPV	FIRR	FNPV	Levelized cost, NPR/kWh	Levelized cost, USDc/kWh	MW generation capacity
Gandaki	1,233,076	9	19.2%	143,304	13%	(4,411)	7.9	6	2,053
Koshi	2,257,777	21	15.8%	195,550	12%	(18,446)	9.2	7	3,804
Kankai	91,879	2	9.2%	429	4%	(7,357)	14.4	11	115
Total	**5,977,879**	**50**							**10,508**

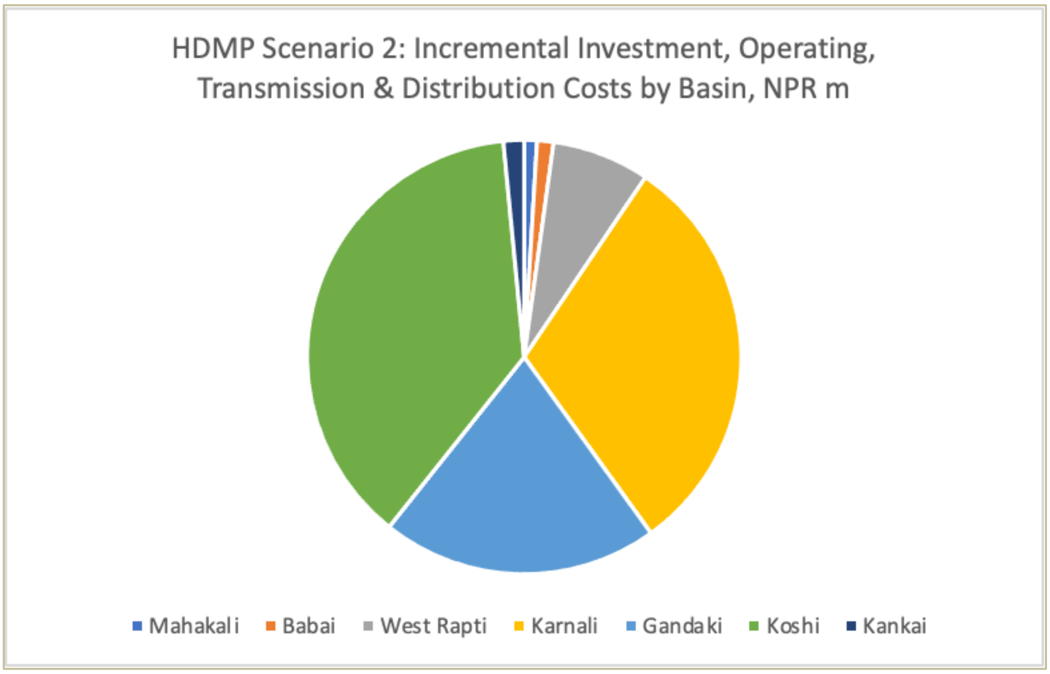


Figure 5-6: Scenario 2: Incremental Cost by Basin, Economic NPR million

5.4 Consolidated Costs and Benefits for All Basin Investment

5.4.1 Overview

The analysis below compiles costs and benefits for all basins as recommended in the IMP and HDMP. The economic analysis is of less importance because it has been shown in sections 5.3above that the constituent projects are economically viable. The decision-making process between projects takes place at basin level. The financial analysis is of more importance because it shows the liability incurred by water utilities and water users to pay for water services, as well as the potential impact on the GoN budget.

5.4.2 Economic Analysis

Economic analysis at basin level gives an opportunity to measure the impact of MPP at national level. None are particularly good sites for hydropower generation. MPP are selected for their strategic importance to transfer water to areas suitable for irrigation but without adequate water resources to improve agricultural productivity. Table 5-9 and Table 5-10 compare the costs and benefits for HDMP Scenario 1, the former including MPP, the latter excluding them. Table 5-11 and Table 5-12 show the same analysis for HDMP Scenario 2 (lower electricity demand).

Investment and operational costs of MPP (hydropower and irrigation) are estimated to be NPR 1,143 billion (USD 8.8 billion) between 2021 and 2050 (the costs of Bheri-Babai, Madi Dang and Kankai MPPs are included). That is about 15% of the total economic cost of the water infrastructure investment presented. In the same period, they are expected to generate NPR 2,042 billion (USD 15.7 billion) in benefits, or about 16% of the total benefits expected.

The economic indicators show that ENPV is increased from NPR 1,151 billion to NPR 1,221 billion during the discounting period, but EIRR falls from 18.9% to 16.0%. It follows that MPP have a lower rate of return compared with the other elements of the investment (in total) but the rate of return is well above the discount rate of 9% used.

Switching values show that the sensitivity of the investment to cost increases and benefit decreases is heightened with the inclusion of MPP in the investment programme. Without MPP, costs would have to increase by 77% to bring EIRR to zero at 9% discount rate. With MPP, costs would have to increase by only 66% to have the same impact. Sensitivity to changes in benefits is less marked.

It should be noted that the impact of depreciation on the investment (depreciation is not included in cost benefit analysis unless a salvage value and/or replacement costs are budgeted in current prices). For groundwater irrigation, costs are estimated including replacement, so the rate of depreciation of the investment is much lower. Replacement and MOM of the surface irrigation systems that MPP will supply is assumed to be only 5% of investment cost per annum. If this amount were collected and spent then the condition of the irrigation systems may be maintained, but there is no mechanism to ensure payment of water charges by farmers, or that routine maintenance is actually carried out.

Table 5-9: All River Basins: Consolidated Costs and Benefits: HDMP Scenario 1 Hydropower, MPP, Groundwater and Gravity-pump Schemes, Economic NPR million Including Costs and Benefits of MPP

	Cost stream, NPR million						Benefit stream, NPR million										
	Irrigation Costs						Irrigation Benefits			Hydropower Generation Benefits							
	All MPP	Groundwater	Gravity/Pump Hill schemes	Development & Operation Costs of HP Scenario	Drinking water	Total	All MPP	Ground water	Gravity/Pump Hill schemes	Domestic resource cost saving, NPR million	Domestic incremental benefits, NPR million	Export sale	Drinking water	Total	Net benefit stream	Economic Indicators	
2021-2025	41,035	33,485	686	23,959	119,517	218,682	-	2,866	-	-	-	-	119,517	122,383	(96,298)	ENPV	1,221,200
2026-2030	87,314	40,225	6,314	413,183	156,211	703,247	16,958	40,818	1,052	5,408	16,537	1,928	156,211	238,911	(464,336)	EIRR	16.0%
2031-2035	46,195	52,856	8,314	594,136	73,815	775,316	65,555	86,808	12,184	119,818	366,405	42,003	73,815	766,588	(8,728)	NPV benefit	3,078,585
2036-2040	49,786	70,311	12,065	1,646,169	76,061	1,854,393	158,297	135,356	23,473	252,769	772,974	88,611	76,061	1,507,540	(346,853)	NPV costs	1,857,385
2041-2045	19,952	51,156	5,489	1,708,423	78,307	1,863,327	215,214	187,475	29,025	794,838	2,430,635	278,638	78,307	4,014,131	2,150,803	BCR	1.66
2046-2050	19,634	52,156	2,168	1,938,261	80,553	2,092,773	244,125	205,915	36,161	1,218,199	3,725,283	427,051	80,553	5,937,287	3,844,514	Switching value costs	66%
Total	**263,916**	**300,190**	**35,035**	**6,324,133**	**584,464**	**7,507,737**	**700,148**	**659,237**	**101,895**	**2,391,031**	**7,311,834**	**838,230**	**584,464**	**12,586,840**	**5,079,103**	Switching value benefits	-40%

Table 5-10: All River Basin: Consolidated Costs and Benefits: HDMP Scenario 1, Groundwater and Gravity-Pump Schemes, Economic NPR million Excluding Costs and Benefits of MPP

	Cost stream, NPR million						Benefit stream, NPR million										
	Irrigation Costs						Irrigation Benefits			Hydropower Generation Benefits							
	All MPP	Groundwater	Gravity/Pump Hill schemes	Development & Operation Costs of HP Scenario	Drinking water	Total	All MPP	Groundwater	Gravity/Pump Hill schemes	Domestic resource cost saving, NPR million	Domestic incremental benefits, NPR million	Export sales, NPR million	Drinking water	Total	Net benefit stream	Economic Indicators	
2021-2025	-	33,485	368	-	119,517	153,370	-	2,866	-	-	-	-	119,517	122,383	(30,987)	ENPV	1,150,962
2026-2030	-	40,225	7,683	244,644	156,211	448,764	-	40,818	1,052	-	-	-	156,211	198,081	(250,683)	EIRR	18.9%
2031-2035	-	52,856	9,569	411,538	73,815	547,778	-	86,808	12,184	91,840	280,848	32,195	73,815	577,690	29,912	NPV benefit	2,637,690
2036-2040	-	70,311	8,501	1,377,84 0	76,061	1,532,714	-	135,356	23,473	193,403	591,433	67,799	76,061	1,087,526	(445,188)	NPV costs	1,486,728
2041-2045	-	51,156	6,841	1,590,498	78,307	1,726,803	-	187,475	29,025	689,016	2,107,029	241,541	78,307	3,332,393	1,605,590	BCR	1.77
2046-2050	-	52,156	2,168	1,820,336	80,553	1,955,214	-	205,915	36,161	1,112,377	3,401,678	389,954	80,553	5,226,639	3,271,426	Switching value costs	77%
Total		**300,190**	**35,131**	**5,444,856**	**584,464**	**6,364,641**	**-**	**659,237**	**101,895**	**2,086,637**	**6,380,989**	**731,490**	**584,464**	**10,544,711**	**4,180,070**	Switching value benefits	-44%

Table 5-11: All River Basins: Consolidated Costs and Benefits: HDMP Scenario 2 Hydropower, MPP, Groundwater and Gravity-pump Schemes, Economic NPR million Including Costs and Benefits of MPP

	Cost stream, **NPR million**						Benefit stream, **NPR million**										
	Irrigation Costs						Irrigation Benefits			Hydropower Generation Benefits							
	All MPP	Groundwater	Gravity/Pump Hill schemes	Development & Operation Costs of HP Scenario	Drinking water	Total	All MPP	Groundwater	Gravity/Pump Hill schemes	Domestic resource cost saving, NPR million	Domestic incremental benefits, NPR million	Export sales, NPR million	Drinking water	Total	Net benefit stream	Economic Indicators	
2021-2025	41,035	33,485	1,910	23,959	119,517	219,906	-	2,866	-	-	-	-	119,517	122,383	(97,523)	ENPV	506,534
2026-2030	87,314	40,225	13,325	150,951	156,211	448,026	16,958	40,818	1,052	5,408	16,537	1,928	156,211	238,911	(209,115)	EIRR	13.8%
2031-2035	46,195	52,856	5,592	340,650	73,815	519,108	65,555	86,808	12,184	23,629	72,257	8,283	73,815	342,531	(176,577)	NPV benefit	1,639,929
2036-2040	49,786	70,311	6,133	642,574	76,061	844,865	158,297	135,356	23,473	97,883	299,328	34,314	76,061	824,711	(20,154)	NPV costs	1,133,394
2041-2045	19,952	51,156	6,884	909,862	78,307	1,066,161	215,214	187,475	29,025	279,307	854,128	97,914	78,307	1,741,369	675,208	BCR	1.45
2046-2050	19,634	52,156	2,168	1,042,111	80,553	1,196,622	244,125	205,915	36,161	509,661	1,558,557	178,666	80,553	2,813,638	1,617,016	Switching value costs	45%
Total	**263,916**	**300,190**	**36,012**	**3,110,107**	**584,464**	**4,294,688**	**700,148**	**659,237**	**101,895**	**915,887**	**2,800,807**	**321,105**	**584,464**	**6,083,543**	**1,788,855**	**Switching value benefits**	**-31%**

Table 5-12: All River Basin: Consolidated Costs and Benefits: HDMP Scenario 2, Groundwater and Gravity-Pump Schemes, Economic NPR million Excluding Costs and Benefits of MPP

	Cost stream, NPR million						**Benefit stream, NPR million**									Economic Indicators	
	Irrigation Costs						**Irrigation Benefits**			**Hydropower Generation Benefits**							
	All MPP	Groundwater	Gravity/Pump Hill schemes	Development & Operation Costs of HP Scenario	Drinking water	Total	All MPP	Groundwater	Gravity/Pump Hill schemes	Domestic resource cost saving, NPR million	Domestic incremental benefits, NPR million	Export sales, NPR million	Drinking water	Total	Net benefit stream		
2021-2025	-	33,485	863	-	119,517	153,865	-	2,866	-	-	-	-	119,517	122,383	(31,482)	ENPV	441,268
2026-2030	-	40,225	6,151	5,190	156,211	207,777	-	40,818	1,052	-	-	-	156,211	198,081	(9,696)	EIRR	17.5%
2031-2035	-	52,856	6,074	141,090	73,815	273,835	-	86,808	12,184	1,208	3,695	424	73,815	178,133	(95,702)	NPV benefit	1,210,377
2036-2040	-	70,311	12,977	419,420	76,061	578,769	-	135,356	23,473	38,517	117,787	13,503	76,061	404,696	(174,073)	NPV costs	769,109
2041-2045	-	51,156	4,311	754,925	78,307	888,699	-	187,475	29,025	180,012	550,483	63,105	78,307	1,088,406	199,707	BCR	1.57
2046-2050	-	52,156	2,002	924,186	80,553	1,058,897	-	205,915	36,161	403,839	1,234,951	141,570	80,553	2,102,990	1,044,092	Switching value costs	57%
Total	**-**	**300,190**	**32,376**	**2,244,811**	**584,464**	**3,161,842**	**-**	**659,237**	**101,895**	**623,577**	**1,906,915**	**218,601**	**584,464**	**4,094,690**	**932,848**	Switching value benefits	-36%

5.4.3 Financing Plan for Preferred Scenario

Table 5-9 and Table 5-13 show the economic valuation of a consolidated economic analysis of water infrastructure assuming HDMP Scenario 1 (high demand for electricity) and Scenario 2 (lower demand) respectively. Converting costs to financial prices and disaggregating into fund flows for both scenarios, an indicative financial plan was prepared. This is shown in Table 5-13 and Table 5-14 for HDMP Scenario 1 and 2 respectively. The plan assumes:

- GoN will arrange for concessional financing of surface irrigation works associated with all MPP
- Irrigators will pay all O&M costs associated with surface water irrigation
- Irrigators will pay all MOM and replacement costs associated with groundwater irrigation
- GoN will either fund or arrange for concessionary financing for capital cost of pump and gravity schemes in the Hills and Mountains
- Irrigators will pay for O&M for pump and gravity schemes
- A concessionaire will be responsible for the construction and MOM of all infrastructure pertaining to hydropower development (not irrigation: any costs below the tunnel outlet of MPP schemes is assigned to irrigation); this will include raising equity, financing loans and paying taxes
- Government will receive from the concessionaire generation royalties based on installation capacity and distribute them to Provincial accounts
- Electricity consumers (including, for simplicity foreign consumers of exported power) will pay the concessionaire for power consumed through the appropriate tariffs (via NEA).

The overall flow of funds is substantially greater than the economic value of the programme, mainly because it includes financing charges on the construction of major infrastructure. For this reason the financing plan is extended to 2064, to show the completion of the financing cycle for construction of hydroplants.

Some funding flows are slightly less than when expressed in economic values. This difference is a result of the adjustments made to calculate financial from economic values, such as the addition of taxes and other transfer costs, adjusting for the premium placed on foreign exchange and applying the full cost of unskilled labour (or the converse when adjusting financial to economic).

If the programme is financed according to these guidelines, GoN would be responsible for a very small proportion of programme financial costs. The major investment in the basin is intended to be financed through hydropower site concessionaires who will be reimbursed by sales of electricity to consumers (via NEA). Consumers of water services are expected to be pay at least for O&M. Groundwater irrigators and consumers of potable water are expected to pay for MOM and replacement in full, because consumption can be metered.

GoN may seek concessionary financing for some investment. Groundwater irrigation is amenable to external financing. Larger gravity-pump irrigation schemes and drinking water supply projects may also attract donor interest. But Government may have to pay replacement and management costs on smaller schemes, and if water charging is not secure, some or all of O&M. But a higher contribution by Government is a necessary condition of investment and operation in more remote river basins.

Compare this with investment in major hydropower infrastructure, constructed under the assumption that cost recovery of MOM and replacement is met by consumers of services. Construction costs are increased by the need of concessionaires to borrow at commercial rates and these costs are passed on to electricity consumers,

The consumers of program services are expected to pay about 66% of programme costs through water charges and electricity tariffs. The concessionaires will pay 32% of costs but be reimbursed by generators' tariffs. Even at commercial rates of interest on construction, the greenfield sites identified under HDMP Scenario 1 are overall attractive to investors. A 16% return on the development of all 92 sites identified under HPMP Scenario 1 is expected which would be a return greater than the opportunity cost of concessionaires' capital. However, there will be good and less good sites. The MPP are estimated to return only 9% on investors' capital, which is lower than their opportunity cost of capital. For that reason, the investment costs of some or all MPP may have to be funded through government finance and concessionary loans.

Table 5-13: Indicative Financial Plan for All basins Water Infrastructure Investment, HDMP Scenario 1, Current NPR million

Financial Flow NPR million																											
	Irrigation Costs										Operator's Expenditure & Revenue NPR million						Drinking water			Irrigation		Hydropower generation			Drinking water		Total
	MPP Irrigation Costs		Tubewell investment and Operation			Tubewell Support and Supervision			Gravity/Pump Hill schemes investment costs	Gravity/Pump Hill schemes O&M	Equity	Loan Repayment	Taxes	O&M	Royalty payment	Sales Revenue	Investment cost	O&M	Total	GoN/Concessional Finance	Irrigators	Conncession-aire	GoN	Electricity consumers	GoN	Water consumers	
	All MPP, investment	All MPP, O&M	Investment costs	Replacement, costs tubewe...	MOM costs at site	Investment costs	Replacement costs, tubewell	MOM costs																			
2021	4,054	-	-		-	-	-	-	-	-	-	-					20,968	-	25,022	4,054	-	-		-	20,968	-	25,022
2022	4,054	-	23		-	-		-	215	-	-						20,968	1,468	26,728	4,292	-	-		-	20,968	1,468	26,728
2023	5,231	-	4,071		212	331		73	568	-	1,970						20,968	2,936	36,360	10,201	285	1,970		-	20,968	2,936	36,360
2024	11,090	0	12,075		839	687		271	949	0	4,925						20,968	4,403	56,207	24,801	1,110	4,925		-	20,968	4,403	56,207
2025	25,548	135	14,981		1,605	297		480	1,010	7	4,925						20,968	5,871	75,826	41,836	2,227	4,925		-	20,968	5,871	75,826
2026	20,564	135	10,654		2,136	55		595	1,233	18	7,095						20,968	7,339	70,792	32,506	2,884	7,095		-	20,968	7,339	70,792
2027	23,809	243	3,943		2,320	156		612	1,080	52	23,667			422			20,968	8,807	86,080	28,989	3,227	24,089		-	20,968	8,807	86,080
2028	24,118	243	5,481	347	2,601	305		625	1,274	52	49,702		305	422	63	3,231	20,968	10,274	120,012	31,178	3,869	50,493		3,231	20,968	10,274	120,012
2029	26,432	269	6,091	1,028	2,911	79	238	586	1,388	67	70,786		328	422	65	3,328	20,968	11,742	146,729	33,991	5,099	71,602		3,328	20,968	11,742	146,729
2030	22,231	645	7,897	1,259	3,314	334	543	674	1,537	87	94,812	3,490	344	887	67	3,425	20,968	13,210	175,724	31,999	6,522	99,601		3,425	20,968	13,210	175,724
2031	18,364	645	5,236	873	3,574	119	296	728	1,512	87	76,571	3,490	433	4,939	117	5,970	1,284	13,300	137,538	25,230	6,204	85,551		5,970	1,284	13,300	137,538
2032	7,084	2,294	5,175	303	3,837	20	47	765	1,633	138	56,372	3,490	3,666	4,939	1,072	54,648	1,284	13,389	160,156	13,911	7,384	69,539		54,648	1,284	13,389	160,156
2033	7,400	2,294	605	780	3,857	1	112	695	1,772	173	66,533	7,330	4,101	7,312	1,102	56,177	1,284	13,479	175,007	9,778	7,912	86,377		56,177	1,284	13,479	175,007
2034	3,142	2,620	1,231	1,781	3,919	97	247	715	2,333	175	76,283	55,090	6,484	7,312	1,758	89,656	1,284	13,569	267,695	6,802	9,457	146,927		89,656	1,284	13,569	267,695
2035	2,339	3,455	8,299	2,810	4,353	593	337	793	2,380	189	83,639	55,090	7,026	9,690	1,807	92,143	1,284	13,659	289,887	13,612	11,937	157,252		92,143	1,284	13,659	289,887
2036	2,339	3,455	9,698	2,478	4,848	163	781	920	2,120	233	83,652	60,390	9,420	12,714	2,324	118,518	1,284	13,749	329,086	14,320	12,715	168,501		118,518	1,284	13,749	329,086
2037	7,803	3,904	8,382	1,583	5,271	21	432	1,022	1,253	312	148,652	60,390	12,705	13,357	3,345	170,590	1,284	13,839	454,144	17,459	12,524	238,449		170,590	1,284	13,839	454,144
2038	11,852	3,904	336	752	5,271		62	985	1,055	312	225,019	80,030	14,430	13,357	3,571	182,133	1,284	13,929	558,281	13,243	11,285	336,407		182,133	1,284	13,929	558,281
2039	7,669	3,904	-	1,013	5,271		112	965	1,326	312	274,323	105,010	14,856	13,357	3,620	184,615	1,284	14,018	631,655	8,995	11,578	411,165		184,615	1,284	14,018	631,655
2040	7,669	3,904	-	2,156	5,271		413	850	832	354	294,982	106,830	15,269	13,357	3,669	187,096	1,284	14,108	658,043	8,501	12,947	434,107		187,096	1,284	14,108	658,043
2041	872	3,904	-	2,846	5,271		875	850	552	368	138,847	106,830	15,563	37,287	3,703	188,858	1,284	14,198	522,107	1,424	14,114	302,229		188,858	1,284	14,198	522,107
2042		3,904	-	2,769	5,271		924	850	166	393	84,311	132,360	37,862	37,287	10,531	537,057	1,284	14,288	869,255	166	14,110	302,350		537,057	1,284	14,288	869,255
2043		3,904	-	1,655	5,271		569	850		393	151,438	128,520	41,053	37,287	10,735	547,496	1,284	14,378	944,831	-	12,641	369,032		547,496	1,284	14,378	944,831
2044		3,904	-	1,365	5,271		331	850		393	186,353	252,860	42,723	37,287	10,940	557,934	1,284	14,468	1,115,962	-	12,114	530,162		557,934	1,284	14,468	1,115,962
2045		3,904	-	2,348	5,271		391	850		393	207,248	252,860	44,463	37,287	11,145	568,373	1,284	14,558	1,150,372	-	13,157	553,002		568,373	1,284	14,558	1,150,372
2046		3,904	-	3,062	5,271		608	850		393		247,560	46,293	53,051	11,349	578,811	1,284	14,647	967,082	-	14,087	358,253		578,811	1,284	14,647	967,082
2047		3,904	-	3,369	5,271		1,254	850		393		275,870	60,764	53,051	16,438	838,347	1,284	14,737	1,275,531	-	15,040	406,123		838,347	1,284	14,737	1,275,531
2048		3,904	-	2,796	5,271		1,094	850		393		256,230	61,510	53,051	16,591	846,133	1,284	14,827	1,263,934	-	14,308	387,382		846,133	1,284	14,827	1,263,934
2049		3,904	-	1,770	5,271		765	850		393		333,160	63,895	53,051	16,744	853,919	1,284	14,917	1,349,922	-	12,953	466,850		853,919	1,284	14,917	1,349,922
2050		3,904	-	936	5,271		505	850		393		327,850	63,978	53,051	16,896	861,705	1,284	15,007	1,351,629	-	11,858	461,775		861,705	1,284	15,007	1,351,629
2051		3,904	-	934	5,271		674	850		393		327,850	65,929	67,758	17,049	869,491		15,007	1,375,109	-	12,026	478,586		869,491		15,007	1,375,109
2052		3,904	-	1,585	4,564		885	736		393		315,190	81,006	67,758	21,848	1,114,236		15,007	1,627,111	-	12,067	485,801		1,114,236		15,007	1,627,111
2053		3,904	-	1,489	3,298		745	532		393		315,190	81,436	67,758	21,992	1,121,578		15,007	1,633,321	-	10,361	486,376		1,121,578		15,007	1,633,321
2054		3,904	-	1,214	3,048		620	491		393		251,690	82,540	67,758	22,136	1,128,920		15,007	1,577,720	-	9,669	424,124		1,128,920		15,007	1,577,720
2055		3,904	-	1,086	3,048		496	491		393		251,690	83,764	67,758	22,280	1,136,263		15,007	1,586,178	-	9,417	425,491		1,136,263		15,007	1,586,178
2056		3,904	-	778	2,724		376	439		393		251,690	84,988	67,758	22,424	1,143,605		15,007	1,594,085	-	8,614	426,859		1,143,605		15,007	1,594,085
2057		3,904	-	732	2,164		255	349		393		223,380	96,851	67,758	22,424	1,143,605		15,007	1,576,820	-	7,796	410,412		1,143,605		15,007	1,576,820
2058		3,904	-	681	2,164		533	349		393		223,380	83,599	67,758	22,424	1,143,605		15,007	1,563,797	-	8,024	397,161		1,143,605		15,007	1,563,797
2059		3,904	-	814	1,472		433	237		393		121,470	83,599	67,758	22,424	1,143,605		15,007	1,461,115	-	7,253	295,251		1,143,605		15,007	1,461,115
2060		3,904	-	695	1,413		347	228		393		121,470	83,599	67,758	22,424	1,143,605		15,007	1,460,843	-	6,980	295,251		1,143,605	-	15,007	1,460,843
2061		3,904	-	-	1,413		152	228		393		121,470	83,599	67,758	22,424	1,143,605		15,007	1,459,952	-	6,090	295,251		1,143,605	-	15,007	1,459,952
2062		3,904	-	-	1,413		176	228		393		108,600	93,671	67,758	22,424	1,143,605		15,007	1,457,178	-	6,114	292,453		1,143,605	-	15,007	1,457,178
2063		3,904	-	-	1,207		295	195		393		108,600	82,419	67,758	22,424	1,143,605		15,007	1,445,806	-	5,993	281,201		1,143,605	-	15,007	1,445,806
2064		3,904	-	-	1,207		295	195		393		-	82,419	67,758	22,424	1,143,605		15,007	1,337,206	-	5,993	172,601		1,143,605	-	15,007	1,337,206
																			Share of funds flow, NPR million	**377,287**	**379,947**	**11,702,950**	-	**23,193,095**	**235,351**	**559,209**	**36,447,839**
																			% of programme funds flow	**1.0%**	**1.0%**	**32.1%**	**0.0%**	**63.6%**	**0.6%**	**1.5%**	

Table 5-14: Indicative Financial Plan for All basins Water Infrastructure Investment, HDMP Scenario 2, Current NPR million

Financial Flow																											
	Irrigation Costs										Operator's Expenditure & Revenue						Drinking water			Irrigation		Hydropower generation			Drinking water		Total
	MPP Irrigation Costs		Tubewell investment and Operation			Tubewell Support and Supervision																					
	All MPP, investment	All MPP, O&M	Investment costs	Replacement, costs tubewells	MOM costs at site	Investment costs	Replacement costs, tubewell support	MOM costs	Gravity/Pump Hill schemes investment costs	Gravity/Pump Hill schemes O&M	Equity	Loan Repayment	Taxes	O&M	Royalty payment	Sales Revenue	Investment cost	O&M	Total	GoN/ Concessional Finance	Irrigators	Conncessionaire	GoN	Electricity consumers	GoN	Water consumers	
2021	4,054	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20,968	-	25,022	4,054	-	-		-	20,968	-	25,022
2022	4,054	-	23	-	-	-	-	•	112	-	-	-	-	-	-	-	20,968	1,468	26,625	4,189	-	-		-	20,968	1,468	26,625
2023	5,231	-	4,071	-	212	331	-	73	443	-	1,970	-	-	-	-	-	20,968	2,936	36,235	10,076	285	1,970		-	20,968	2,936	36,235
2024	11,090	0	12,075	-	839	687	-	271	1,091	0	4,925	-	-	-	-	-	20,968	4,403	56,350	24,944	1,110	4,925		-	20,968	4,403	56,350
2025	25,548	135	14,981	-	1,605	297	-	480	1,551	0	4,925	-	-	-	-	-	20,968	5,871	76,361	42,377	2,219	4,925		-	20,968	5,871	76,361
2026	20,564	135	10,654	-	2,136	55	-	595	1,871	7	7,095	-	-	-	-	-	20,968	7,339	71,418	33,144	2,872	7,095		-	20,968	7,339	71,418
2027	23,809	243	3,943	-	2,320	156	-	612	2,092	18	13,554	-	-	422	-	-	20,968	8,807	76,945	30,001	3,194	13,976		-	20,968	8,807	76,945
2028	24,118	243	5,481	347	2,601	305	-	625	1,825	52	18,358	-	305	422	63	3,231	20,968	10,274	89,220	31,729	3,868	19,149		3,231	20,968	10,274	89,220
2029	26,432	269	6,091	1,028	2,911	79	238	586	1,140	119	23,142	-	328	422	65	3,328	20,968	11,742	98,889	33,743	5,150	23,957		3,328	20,968	11,742	98,889
2030	22,231	645	7,897	1,259	3,314	334	543	674	763	147	25,755	3,490	344	887	67	3,425	20,968	13,210	105,952	31,225	6,582	30,543		3,425	20,968	13,210	105,952
2031	18,364	645	5,236	873	3,574	119	296	728	945	159	30,931	3,490	433	1,996	117	5,970	1,284	13,300	88,460	24,664	6,276	36,967		5,970	1,284	13,300	88,460
2032	7,084	2,294	5,175	303	3,837	20	47	765	1,167	164	31,739	3,490	1,177	1,996	239	12,203	1,284	13,389	86,373	13,445	7,410	38,642		12,203	1,284	13,389	86,373
2033	7,400	2,294	605	780	3,857	1	112	695	1,262	172	55,948	7,330	1,229	1,996	244	12,458	1,284	13,479	111,147	9,269	7,910	66,746		12,458	1,284	13,479	111,147
2034	3,142	2,620	1,231	1,781	3,919	97	247	715	1,133	192	60,446	16,490	1,272	1,996	249	12,713	1,284	13,569	123,095	5,602	9,474	80,453		12,713	1,284	13,569	123,095
2035	2,339	3,455	8,299	2,810	4,353	593	337	793	1,078	219	51,709	16,490	1,314	4,374	254	12,969	1,284	13,659	126,330	12,310	11,967	74,142		12,969	1,284	13,659	126,330
2036	2,339	3,455	9,698	2,478	4,848	163	781	920	920	234	40,491	16,490	3,336	6,747	728	37,112	1,284	13,749	145,772	13,120	12,716	67,792		37,112	1,284	13,749	145,772
2037	7,803	3,904	8,382	1,583	5,271	21	432	1,022	1,027	239	62,239	30,790	5,660	7,390	1,368	69,781	1,284	13,839	222,035	17,233	12,451	107,447		69,781	1,284	13,839	222,035
2038	11,852	3,904	336	752	5,271	-	62	985	1,070	272	87,648	50,430	7,060	7,390	1,565	79,812	1,284	13,929	273,621	13,258	11,246	154,093		79,812	1,284	13,929	273,621
2039	7,669	3,904	-	1,013	5,271	-	112	965	1,402	274	102,881	55,730	7,393	7,390	1,603	81,740	1,284	14,018	292,649	9,071	11,540	174,997		81,740	1,284	14,018	292,649
2040	7,669	3,904	-	2,156	5,271	-	413	850	1,488	294	110,092	57,550	7,715	7,390	1,641	83,668	1,284	14,108	305,491	9,157	12,887	184,387		83,668	1,284	14,108	305,491
2041	872	3,904	-	2,846	5,271	-	875	850	1,507	294	52,209	57,550	7,916	16,530	1,664	84,877	1,284	14,198	252,648	2,379	14,040	135,870		84,877	1,284	14,198	252,648
2042		3,904	-	2,769	5,271	-	924	850	1,159	333	47,726	57,550	16,307	16,530	3,924	200,133	1,284	14,288	372,951	1,159	14,050	142,038		200,133	1,284	14,288	372,951
2043		3,904	-	1,655	5,271	-	569	850	870	333	97,637	53,710	17,358	16,530	3,992	203,584	1,284	14,378	421,923	870	12,581	189,227		203,584	1,284	14,378	421,923
2044		3,904	-	1,365	5,271	-	331	850	268	393	122,106	120,050	17,863	16,530	4,059	207,034	1,284	14,468	515,776	268	12,114	280,609		207,034	1,284	14,468	515,776
2045		3,904	-	2,348	5,271	-	391	850	-	393	134,502	120,050	18,438	16,530	4,127	210,484	1,284	14,558	533,130	-	13,157	293,648		210,484	1,284	14,558	533,130
2046		3,904	-	3,062	5,271	-	608	850	-	393		120,050	19,104	26,474	4,195	213,934	1,284	14,647	413,775	-	14,087	169,823		213,934	1,284	14,647	413,775
2047		3,904	-	3,369	5,271	-	1,254	850	-	393		105,750	27,963	26,474	7,064	360,263	1,284	14,737	558,576	-	15,040	167,252		360,263	1,284	14,737	558,576
2048		3,904	-	2,796	5,271	-	1,094	850	-	393		86,110	29,208	26,474	7,150	364,653	1,284	14,827	544,014	-	14,308	148,942		364,653	1,284	14,827	544,014
2049		3,904	-	1,770	5,271	-	765	850	-	393		162,940	29,939	26,474	7,236	369,043	1,284	14,917	624,787	-	12,953	226,590		369,043	1,284	14,917	624,787
2050		3,904	-	936	5,271	-	505	850	-	393		157,630	30,671	26,474	7,322	373,433	1,284	15,007	623,679	-	11,858	222,098		373,433	1,284	15,007	623,679
2051		3,904	-	934	5,271	-	674	850	-	393		157,630	32,056	36,816	7,408	377,823		15,007	638,766	-	12,026	233,911		377,823		15,007	638,766
2052		3,904	-	1,585	4,564	-	885	736	-	393		185,930	41,339	36,816	10,780	549,798		15,007	851,736	-	12,067	274,865		549,798		15,007	851,736
2053		3,904	-	1,489	3,298	-	745	532	-	393		185,930	41,867	36,816	10,882	554,957		15,007	855,819	-	10,361	275,495		554,957		15,007	855,819
2054		3,904	-	1,214	3,048	-	620	491	-	393		167,540	42,607	36,816	10,983	560,116		15,007	842,738	-	9,669	257,946		560,116		15,007	842,738
2055		3,904	-	1,086	3,048	-	496	491	-	393		167,540	43,467	36,816	11,084	565,275		15,007	848,606	-	9,417	258,907		565,275		15,007	848,606
2056		3,904	-	778	2,724	-	376	439	-	393		167,540	44,327	36,816	11,185	570,435		15,007	853,923	-	8,614	259,868		570,435		15,007	853,923
2057		3,904	-	732	2,164	-	255	349	-	393		167,540	47,871	36,816	11,185	570,435		15,007	856,650	-	7,796	263,412		570,435		15,007	856,650
2058		3,904	-	681	2,164	-	533	349	-	393		167,540	43,913	36,816	11,185	570,435		15,007	852,920	-	8,024	259,454		570,435		15,007	852,920
2059		3,904	-	814	1,472	-	433	237	-	393		85,410	43,913	36,816	11,185	570,435		15,007	770,018	-	7,253	177,324		570,435		15,007	770,018
2060		3,904	-	695	1,413	-	347	228	-	393		85,410	43,913	36,816	11,185	570,435		15,007	769,746	-	6,980	177,324		570,435		15,007	769,746
2061		3,904	-	-	1,413	-	152	228	-	393		85,410	43,913	36,816	11,185	570,435		15,007	768,855	-	6,090	177,324		570,435		15,007	768,855
2062		3,904	-	-	1,413	-	176	228	-	393		57,110	49,074	36,816	11,185	570,435		15,007	745,740	-	6,114	154,184		570,435	-	15,007	745,740
2063		3,904	-	-	1,207	-	295	195	-	393		57,110	43,309	36,816	11,185	570,435		15,007	739,855	-	5,993	148,420		570,435	-	15,007	739,855
2064		3,904	-	-	1,207	-	295	195	-	393		-	43,309	36,816	11,185	570,435		15,007	682,745	-	5,993	91,310		570,435	-	15,007	682,745
																			Share of funds flow, NPR million	**377,287**	**379,746**	**6,078,042**	**-**	**10,747,731**	**235,351**	**559,209**	**18,377,366**
																			% of programme funds flow	**2.1%**	**2.1%**	**33.1%**	**0%**	**58.5%**	**1.3%**	**3.0%**	

5.5 Consolidated Financial Plan

5.5.1 Potable Water Supply

The Consolidated Financial Plan for all basins was prepared to show that investment in water infrastructure in Nepal's river basins need not be a permanent burden on Government finance if consumers of water services pay for a reasonable proportion of the costs of management, operation, maintenance and replacement.

For drinking water services, The National Water Supply and Sanitation Sector Policy 2017-30 [24] acknowledges that coverage and quality of service in existing schemes is poor, tariffs do not cover basic operational costs and consumer participation in management is low. To address these issues the policy includes the objectives of increasing provincial and private sector involvement, including concessional financing, service regulation and tariff setting and benchmarking. The objective is to not only to improve cover and service quality but also to relieve Government and financing agencies of at least some of the responsibility of financing new schemes and subsidizing existing ones.

Tariffing aims to give access to essential potable water to the poorest, while extracting the consumer surplus (what they would pay over and above the cost of supplying potable water) of the more affluent. If water utilities are to survive and expand without government subsidy, the aggregate income from consumers' tariff must cover MOM and allow the utility manager to accumulate capital to expand and improve the service offered. The financial plan for all basins assumes that investment costs are paid by the government, possibly through concessionary finance, while MOM is charged at 7% of accumulated investment costs per annum. Over the life of the incremental investment in water supply, 2023-2050 GoN pays NPR 24.5 billion in investment costs, while consumers' payments allow the accumulation of NPR 36.8 billion to cover annual MOM and capital accumulation to expand and improve utility services. It also conforms to the aspirations of The National Water Supply and Sanitation Sector Policy.

5.5.2 Groundwater Irrigation

Pumping groundwater for irrigation is an important part of the recommendations of the IMP, to increase productivity in those parts of the (lower) Terai which will benefit only partly or not all from water transfer MPP. Groundwater irrigation provides an opportunity to achieve the recovery of MOM and replacement costs in full by adjusting the water charge, which is levied volumetrically (or by time) to cover these costs. Of course, the charge must be affordable to irrigators and provide a better standard of service than alternative sources of supply (shallow tubewells, canal irrigation etc.). The costs can be transparently calculated though the operational accounts of individual tubewells.

Government is in negotiations with Asian Development Bank (2023) for the development and financing of a groundwater project (20,000 ha in Rautahat and Siraha District). The scheme would be managed by a Design, Build and Operate contractor, supported by an Irrigation Management Company. If the project is sustainable, or may be adapted to become sustainable, it is likely to be replicated. Sustainability in economic terms implies that replacement costs are paid as scheduled and in theory the project remains in an "as built" condition.

The consolidated Financial Plan for All basins shows that of the total costs of groundwater irrigation, only 31% is for investment. The balance is for replacement and MOM. The cost relationship is similar for potable water: in the long term, MOM and replacement are more expensive than the original investment. Government, perhaps with concessionary financing, will pay for the initial investment costs but subsequent costs, including replacement, will be paid for by irrigators.

5.5.3 Surface Water Irrigation

Surface water irrigation presents problems for recharging farmers for investment and operational costs because service varies through the system (head, middle and tail effects) and the reliability of water deliveries (sufficient, timely and controllable) is inferior to that provided by a groundwater scheme. The older surface irrigation systems on the Terai were designed for emergency use for the paddy crop during the monsoon.

[24] https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/ eng_wss_po icy_2014_draft-1.pdf

Given these constraints, it has proved very difficult to manage surface water irrigation centrally. Farmer organizations (water user groups) are favoured, but such groups seldom manage to accumulate funds to pay for replacement.

The Financial Plan below therefore assumes that irrigators pay no more than the O&M costs of surface irrigation. That implies that the schemes will deteriorate over time and eventually must be replaced. The Financial Plan focusses on investment and does not calculate surface water scheme depreciation, because there is no reliable way of making it good.

5.5.4 Hydropower Investment and Operation

Government have developed a system for financing hydropower development by granting concessions to private operators. The Financial Plan assumes that this system is followed and as a result Government contributions to financing are avoided. About 95% of funds flow through the Plan are accounted by HP concessionaires

Table 5-15: Consolidated Financial Plan: All Basins, 2023-2050, HDMP Scenario 1, Current NPR million

	Financial Flow, NPR million																		
	Irrigation Costs										Operator' s Expenditure & Revenue, NPR million						Drinking water		Total
	MPP Irrigation Costs		Tubewell investment and Operation			Tubewell Support and Supervision													
	All MPP Investment	All MPP O&M	Investment costs	Replacement costs, tubewells	MOM costs at site	Investment costs	Replacement costs, tubewell support	MOM costs	Gravity/Pump Hill schemes investment costs	Gravity/Pump Hill schemes O&M	Equity	Loan Repayment	Taxes	O&M	Royalty payment	Sales Revenue	Investment cost	O&M	
2021-2025	49,978	135	31,150	-	2,656	1,315	-	823	1,423	-	-	-	-	-	-	-	104,840	14,678	206,998
2026-2030	117,154	1,535	34,066	2,633	13,282	929	781	3,093	7,625	209	147,669	-	-	-	-	-	104,840	51,371	485,188
2031-2035	38,330	11,309	20,546	6,548	19,541	829	1,038	3,697	9,212	722	227,804	77,220	15,545	20,237	4,545	231,786	6,418	67,397	762,723
2036-2040	37,333	19,071	18,416	7,983	25,931	184	1,800	4,742	6,992	1,485	868,137	251,140	44,546	40,133	12,077	615,942	6,418	69,643	2,031,972
2041-2045	872	19,521	-	10,984	26,353	-	3,090	4,249	932	1,933	753,325	641,720	145,802	141,950	40,035	2,041,805	6,418	71,889	3,910,879
2046-2050	-	19,521	-	11,933	26,353	-	4,226	4,249	-	1,964	-	1,238,370	256,260	220,774	70,305	3,585,533	6,418	74,136	5,520,041
Total	**243,668**	**71,091**	**104,178**	**40,081**	**114,116**	**3,257**	**10,936**	**20,852**	**26,184**	**6,313**	**1,996,935**	**2,208,450**	**462,154**	**423,094**	**126,962**	**6,475,066**	**235,351**	**349,113**	**12,917,802**

Table 5-16: Consolidated Financing: All Basins, 2023-2050, HDMP Scenario 1, Current NPR million

	Irrigation		Hydropower generation			Drinking water		Total
	GoN/Concessional Finance	Irrigators	Conncessionaire	GoN	Electricity consumers	GoN	Water consumers	
2021-2025	83,867	3,614	-	-	-	104,840	14,678	206,998
2026-2030	159,775	21,533	147,669	-	-	104,840	51,371	485,188
2031-2035	68,917	42,854	345,352	-	231,786	6,418	67,397	762,723
2036-2040	62,924	61,011	1,216,033	-	615,942	6,418	69,643	2,031,972
2041-2045	1,805	66,130	1,722,832	-	2,041,805	6,418	71,889	3,910,879
2046-2050	-	68,247	1,785,708	-	3,585,533	6,418	74,136	5,520,041
Total	**377,287**	**263,389**	**5,217,595**	-	**6,475,066**	**235,351**	**349,113**	**12,917,802**

Table 5-17: Consolidated Financial Plan: All Basins, 2023-2050, HDMP Scenario 2, Current NPR million

	Financial Flow, NPR million																		
	Irrigation Costs										Operator' s Expenditure & Revenue, NPR million						Drinking water		Total
	MPP Irrigation Costs		Tubewell investment and Operation			Tubewell Support and Supervision			Gravity/Pump Hill schemes investment costs	Gravity/Pump Hill schemes O&M	Equity	Loan Repayment	Taxes	O&M	Royalty payment	Sales Revenue	Investment cost	O&M	
	All MPP Investment	All MPP O&M	Investment costs	Replacement costs, tubewells	MOM costs at site	Investment costs	Replacement costs, tubewell support	MOM costs											
2021-2025	49,978	135	31,150	-	2,656	1,315	-	823	3,198	0	11,820	-	-	-	-	-	104,840	14,678	220,593
2026-2030	117,154	1,535	34,066	2,633	13,282	929	781	3,093	7,691	342	87,904	3,490	977	2,154	196	9,985	104,840	51,371	442,424
2031-2035	38,330	11,309	20,546	6,548	19,541	829	1,038	3,697	5,585	906	230,773	47,290	5,425	12,357	1,104	56,313	6,418	67,397	535,404
2036-2040	37,333	19,071	18,416	7,983	25,931	184	1,800	4,742	5,907	1,314	403,351	210,990	31,164	36,306	6,904	352,113	6,418	69,643	1,239,569
2041-2045	872	19,521	-	10,984	26,353	-	3,090	4,249	3,803	1,745	454,180	408,910	77,882	82,652	17,767	906,112	6,418	71,889	2,096,428
2046-2050	-	19,521	-	11,933	26,353	-	4,226	4,249	-	1,964	-	632,480	136,886	132,371	32,967	1,681,327	6,418	74,136	2,764,831
Total	**243,668**	**71,091**	**104,178**	**40,081**	**114,116**	**3,257**	**10,936**	**20,852**	**26,184**	**6,270**	**1,188,027**	**1,303,160**	**252,334**	**265,840**	**58,938**	**3,005,850**	**235,351**	**349,113**	**7,299,248**

Table 5-18: Consolidated Financing: All Basins, 2023-2050, HDMP Scenario 2, Current NPR million

	Irrigation		Hydropower generation			Drinking water		Total
	GoN/Concessional Finance	Irrigators	Conncessionaire	GoN	Electricity consumers	GoN	Water consumers	
2021-2025	85,641	3,614	11,820	-	-	104,840	14,678	220,593
2026-2030	159,841	21,666	94,720	-	9,985	104,840	51,371	442,424
2031-2035	65,290	43,037	296,949	-	56,313	6,418	67,397	535,404
2036-2040	61,840	60,840	688,715	-	352,113	6,418	69,643	1,239,569
2041-2045	4,675	65,942	1,041,391	-	906,112	6,418	71,889	2,096,428
2046-2050	-	68,247	934,704	-	1,681,327	6,418	74,136	2,764,831
Total	**377,287**	**263,347**	**3,068,300**	**-**	**3,005,850**	**235,351**	**349,113**	**7,299,248**

6 Policy Interventions and Institutional Requirements

The development and effective management of water resources are governed by sound and pragmatic policy combined with an enforceable regulatory framework with support from appropriate institutional mechanisms. These three components combined play a crucial role in Nepal's sustainable development and overall welfare through the water resources sector. Legal frameworks serve as the cornerstone for governing water access, distribution, and use while guaranteeing fair distribution among various sectors and stakeholders. To maintain Nepal's water security and stop overuse, pollution, and disputes over water resources, clear and enforced regulations are necessary. Robust institutions are indispensable for translating legal and policy frameworks into actionable initiatives. They play a pivotal role in coordinating and implementing water management strategies, ensuring accountability, and fostering collaboration among various governmental and non-governmental entities. Moreover, institutions facilitate engagement with international organizations and neighbouring countries, enabling Nepal to navigate transboundary water management challenges and foster regional cooperation. Thus, the effective integration of these elements is crucial to ensure the responsible and equitable management of Nepal's precious water resources, thereby benefiting both the nation and its people.

In developing the river basin plans, the legal, policy, and institutions influencing water resources have been reviewed, and recommendations provided on how to strengthen these frameworks and institutions. This chapter provides an overview of the policies, legal acts, and institutions that influence the development and management of water resources and freshwater ecosystems. The summary information herein is based on the project technical notes *TN 6 (Policy), TN 8 (Legal), and TN 18 (Institution)*.

6.1 Policy Context and Requirements

The Water Resources Development Plans provide guidance on how to fulfil the responsibilities of the State and achieve a balance between sectoral uses of water, the plans have to be in the hands of a governmental organization that has clear and explicit responsibilities and powers to ensure that coordination and any such regulation is undertaken. In other words, without a suitably empowered lead agency (or "Champion") to guide the country in the overall development and implementation of its water resources master plans the State will fail to fulfil its responsibilities, the master plans will become redundant and water resource development is likely to be ad hoc and piecemeal – project by project-based - and fail to secure the optimal benefits for the country and the people and fail to prevent the broader and deeper environmental impacts which can arise in large rivers.

The National Water Resources Policy 2020 provides the guidance and vision for:

Section 10. Strategy (3) Institutional arrangements will be made for the protection, development, management, and regulation of the water resources sector.

Policies and Strategies

- For the study, research, data collection, analysis, archiving, regulation, and protection of the water resources sector there shall be Water and Energy Commission and other offices can be set up under it as per the need**.**

Section 13. Monitoring and Evaluation:

The implementation of the provisions of this water resources policy shall be monitored and evaluated at various levels. Its overall monitoring shall be done by the Ministry of Energy, Water Resources and Irrigation, and the Water and Energy Commission. In addition, the province and local levels shall also monitor policy implementation in their areas. The relevance, effectiveness, and potential impact of the implementation status of this policy shall be assessed through the National Planning Commission directly or with the involvement of a third party.

The Water Resources Policy specifically places WECS in a high-level central role, it is argued here that the description of that role in policy does not fully encompass what is going to be required of such an agency to be the "champion," to lead the proper and effective safeguarding of the Nations water resources at the national level.

Having such a lead agency or champion, with a clearly defined role and the relevant power needed, is of such critical importance in ensuring that the State can safeguard the nation's water resources that **the paramount recommendation arising from the present work is that the Role of WECS must be fully and explicitly defined and establish and as necessary supported by law**.

This recommendation is essentially a "gatekeeper" recommendation, a key to the door giving access to implementing the other recommendations. Thus, for example, and as is explained elsewhere, WECS would be responsible for leading the effort across agencies, ministries, and local administrations to come up with a properly practical way forward regarding River Basin planning and the three tiers of government. It is worth pointing out here that the existing river basins of Nepal will not change their boundaries even in the distant future – administrative boundaries may well change numerous times. The State therefore will continue to undertake national-level planning based on river basins and their boundaries.

6.2 Legal Landscape and Requirements

Acts and Policies impact on water management by providing the legal framework and regulations necessary to govern the access, allocation, and conservation of water resources. The keyways these legal acts are instrumental in shaping policies, practices, and institutions related to water management include:

1. Resource Allocation: Laws and policies establish criteria for allocating water for domestic, agricultural, industrial, and environmental uses, ensuring fair distribution and preventing overexploitation. They also define the rights and obligations of various stakeholders regarding water resources.

2. Environmental Protection: These laws and policies frequently include clauses aimed at preserving aquatic habitats and safeguarding water quality. To protect both human health and the environment, they establish norms and laws to stop pollution and the deterioration of water bodies.

3. Infrastructure Development: The design, approval, and building of water-related infrastructure, including dams, irrigation systems, and hydropower projects, are governed by legal provisions and policies. To ensure responsible development, they describe the application procedure, environmental impact analyses, and compliance requirements.

4. Disaster Risk Reduction: Legal acts address disaster risk reduction techniques relating to water management including procedures for handling situations including floods, landslides, and other bodies of water.

5. Transboundary Cooperation: Transboundary water agreements are governed by legal acts, which encourage collaboration and negotiation to guarantee that water resources are managed cooperatively and avoid conflicts with China and India.

Thus, when managing water resources, it is important to comprehend the legal and policy framework governing the use and preservation of the resource.

6.2.1 River Basin Plan

The *Water Resources Act* (1992) is to be revised to include the prioritization of water use for religious/ cultural/ environmental purposes, while also considering the licensing requirements for drinking water and irrigation. Additionally, the Act incorporates provisions for ensuring dam safety, managing groundwater, and promoting multipurpose water use. These provisions are to be implemented when granting licenses and constructing projects.

To establish a comprehensive framework, the River Basin Plan, Hydropower Master Plan, and SESA are to be interconnected under the Act. This can be achieved by introducing specific provisions that make these plans enforceable and mandatory, while also implementing a basin-level licensing regime. The implementation of federalism and the fair distribution of water resources pose challenges. Ownership issues and the distribution of water resources between or among tiers of government are to be addressed. Furthermore, water quality and pollution concerns to be considered to achieve optimal efficiency. It may be necessary to establish a clear regulatory regime for restricted lands or buffer zones and define the right of way for rivers or water resources.

Under the *Water Supply and Sanitation Act* (WSSA) (2022) it may be necessary to implement a water use license, which is to be regulated by the Water Resources Act, or the WSSA could exclusively handle licenses for drinking water purposes across the three tiers of government. Moreover, when it comes to site-specific discharge permits concerning sanitation, it is the responsibility of the WSSA to address them, rather than the WRA, as the WSSA has jurisdiction over sanitation matters.

The *Environment Protection Act* (2019) considers environmental assessment compliance as a supportive instrument for project development and completion, ensuring a mindful approach throughout the process. This may involve the involvement of the environmental agency, rather than relying solely on the Ministry, for the final approval of projects. For instance, in Japan, the power-related approval agency relies on the energy ministry for its decision-making process.

The *Federation, Province, and Local Level (Coordination and Interrelation) Act* (2020) in conjunction with the *Inter-Governmental Fiscal Management Act* (2017) aims to address royalty issues through its interconnected provisions based on the principles of coexistence, coordination, and cooperation. However, certain matters, such as the extent of investments solely made by provincial or local governments and, the *Natural Resources and Fiscal Commission Act* (2017) from the natural resources need to be further elaborated upon to minimize potential disputes among the governments involved.

Within the draft *Water Resources Bill* provisions are made to establish basin offices, enabling efficient management at the basin level. The Bill's provision for a robust regulatory and licensing regime aims to maximize efficiency in water resource management under the purview of these basin offices.

To establish an effective plan for the major three basins (RBO), it is essential to have a legally defined jurisdiction within the legally defined or any other appropriate legal framework to prevent overlapping jurisdiction with the basin office.

6.2.2 Hydropower Development Master Plan

To establish an interconnection between the HDMP and the *Electricity Act* (1992) specific provisions are to be introduced to ensure the Hydropower Master Plan's enforceability and make it mandatory under the Act. Likewise, the *Electricity Authority Act* (1984) includes provisions that are designed to align with the Nepal Electricity Regulatory Commissions. These provisions aim to foster compatibility and enable smooth functioning between the Act and the regulatory commissions.

The *Public Private Partnership (PPP) and Investment Act* (2019) may encounter challenges related to procurement modalities for PPP projects. To address these challenges, it may be necessary to develop a legal instrument that facilitates private sector participation in small-scale IWRM projects and includes partnerships along with goods, services, and construction. Similarly, the Act might need to incorporate a provision stating that a party who challenges the contract awarding authority can only bid for another project after a final decision is made by the court or a dispute resolution board, agency, or organization.

Considering the constitutional mandates for provincial legal frameworks and the provisions outlined in the *Local Government Operation Act*, of 2017, local governments are given with the power to grant licenses for electricity generation projects up to one MW. This grant of authority enables local governments to maintain jurisdiction over several critical aspects, such as policy formulation, establishment of standards, project planning and execution, and monitoring and evaluation. Notably, local governments can exercise this authority without facing regulatory hurdles from federal or provincial regulatory agencies.

The *Nepal Electricity Regulatory Commission Act* (2017) is crucial to grant the Commission organizational autonomy to ensure an effective institutional structure. The Commission's future objectives are to focus on infrastructure and distribution levels, aiming to unbundle networks and harness the positive impacts of a competitive market. Additionally, the Commission is responsible for establishing performance standards, efficiency-based incentives, and yardstick competition for benchmarking purposes. Furthermore, the Commission can play a vital role in reviewing market-based versus negotiated prices and setting specific regulations for flat-rate electricity generation. Effective price regulation is crucial for fostering market fairness. The NERC is tasked with bringing all relevant issues under its purview, including cross-border dispute resolution. It is important to establish cross-country authorization for the execution of decisions made by another country, thereby ensuring harmonious legislation and legal proceedings during the decision-making phase.

6.2.3 Social and Environment Relevant Acts

For environmental compliance, *Environment Protection Act* (2019) and consideration may be given to involving environmental agencies, rather than solely relying on the Ministry for the final approval of projects. Regarding the Forest Act, 2019, it is suggested that instead of the Ministry assuming the role of the regulating agency for environmental compliance, an efficient and independent environment regulatory agency to be established. This would ensure competency and independence in addressing environmental compliance matters and promoting overall efficiency.

The *Immovable Property Requisition Act* (1956) may conflict with the Land Acquisition Act, of 1977. The Act may be necessary to prioritize national or large-scale projects in such cases. Under the *Land Acquisition Act* (1977) the government is granted broad powers to acquire any land in the name of public works. However, the Act does not specify the procedures for private companies to acquire land for projects serving the public interest. There are limited provisions for land acquisition, thus it is recommended to broaden the definition of public interest to allow acquisition by any of the three tiers of government, public entities, and private sectors. It is also suggested to include an ex-ante evaluation process for acquired land. The *Guthi Corporation Act* (1976) allows for the acquisition of Guthi Land, with reimbursement offered in the form of land instead of monetary compensation. However, this provision can pose a barrier to nationally prioritized projects.

The *National Parks and Wildlife Conservation Act* (1973) emphasizes the importance of harmonizing with the *Environmental Protection Act* and the *Forest Act* (2019) to prevent any adverse environmental impact during the construction of infrastructure within and beyond areas affecting water resources, forest areas, national parks, and heritage sites.

According to the *Working Policy on Construction and Operation of Development Projects in Protected Areas* (2009), all hydropower components are to be constructed outside of national parks. Per the Hydropower Policy of 2021, a minimum of 10% of the monthly discharge, or as determined by the Environmental Report shall be released as environmental flow from all hydropower projects. Per the new working policy under consideration, there is a provision for the projects utilizing water from streams and rivers that pass through National Parks and/or Reserves, at least 50% of the natural flow of monthly discharge is to be considered a minimum environmental flow release. It would be more prudent to consider environmental compliances of individual project studies instead blanket approach of restriction.

For further clarity and detailed information, the recommendations are provided in the Technical Report (Technical Note -8 Working Paper on Legal Issues) and the Status Reports (Vol-I).

6.2.4 Recommendations

It is imperative to incorporate legal recommendations into the binding legal instruments. In Table 6-1, recommendations have been categorized as urgent, moderate, and standard, prioritizing their application to facilitate the implementation of the River Basin Plan, Hydropower Master Plan, and Strategic Environmental and Social Assessment Plan as detailed below:

Table 6-1: Binding Legal Instruments (Acts) impacting water management in Nepal

Legal Instrument	Recommendations	Prioritized Recommendation
River Basin Plan		
Water Resources Act, 1992	Water use priority on 'religious' purpose needs to consider	S
	River Basin Plan and SESA Plan to be interlinked under the Act by having certain provision to make enforceable and mandatory	U
	May require making clear regulatory regime for restricted land or buffer zone and RoW for river or water resources	U
	Water use license must be updated in federalization context	U
Draft Water Resources Bill	Site specific discharge permits to be provisioned	U
	Licensing not only for hydropower but also other uses to be implemented	U
	WECS at Federal level and Provincial and Local Government related to be interlinked with RBOs, its need to be legally defined and mandated	U
	Binding Legal Instrument: Act(s)	U
	'Technical' approval of water use license to be obtained from basin offices, led by the commission from the as stated in the Draft, water use license issued from federal, provincial and local level	U
	Whether the government or others, required to have water use license	U
	To be ensured multipurpose and optimal water use from the beginning	U
	Right of way for rivers or water resources	U
	Prioritization of water use and (or) IWRM 'further' thin lines (licensing etc.) to be determined	U
	To be determined: Water tribunal or WECS as semi-judicial body	U
Water Supply and Sanitation Act, 2022	Require having water use license under Water Resources Act or may exclude to WSSA to use only drinking water purpose to three tiers of government	U
	Site-specific discharge permits related to sanitation, the WSSA is responsible for addressing them instead of the WRA, as sanitation falls under the jurisdiction of the WSSA	S
Environment Protection Act, 2019	EIA compliances to be supportive instrument to develop project by having mindful on project development and completion	S
	Incentives needs to reintroduce	U
	Need to have thoughts on requirement of environmental agencies instead Ministry for final approval	S
Inter-Governmental Fiscal Management Act, 2017	Royalty issues such as absolute investment from provincial or local government to be elaborated to minimize the disputes among government (s) in line with Natural Resources and Fiscal Commission Act, 2017	M
Federation, Province, and Local Level (Coordination and Interrelation) Act, 2020	Conjunction with the Inter-Governmental Fiscal Management Act, 2017	S
Local Government Operation Act, 2017	Local government is empowered to conserve river basin and cap for the basin to be determined with licensing regime.	U
Ship Registration Act, 1971	Connect to the provincial government authority as per the Constitution	M

Legal Instrument	Recommendations	Prioritized Recommendation
Bilateral agreements: Koshi, Gandak and Mahakali	Framework Treaties may require for neighboring countries for water resources issues for transboundary water sharing	S
	Basin Level treaties may require for wider understanding in the future in terms of transboundary water sharing	S
UN Convention on Non-Navigation of user International Water Course, 1997	Voted in favor but not ratified: Nepal	S
	Transboundary water law to be addressed and initiated by having general agreement in the beginning which may lead to framework treaty	S
Hydropower Development Master Plan		
Electricity Act, 1992	Hydropower Master Plan to be interlinked under the Act by having provision to make enforceable and mandatory	U
Electricity Authority Act, 1984	Act provisions for the Nepal Electricity Regulatory Commissions entail to compatible together	M
Local Government Operation Act, 2017	Local government to be empowered to issues the license for HPP to be harmonized with Electricity Act	S
Public Private Partnership (PPP) and Investment Act, 2019	Issues of procurement under modalities for any PPP projects. May be need of legal instrument for private sector participation (PSP) in small scaled IWRM related projects.	M
	For the long run PPP Procurement either exempted from Public Procurement Act or include within PPPI Act	S
Nepal Electricity Regulatory Commission Act, 2017	Commission may need organizational autonomy for their institutional structure. The future goal of the Commission should direct towards infrastructure and distribution levels to unbundle the networks to achieve positive effects of competitive market.	S
	Commission to set performance standards and efficiency-based incentives, where it comes with settings of yardstick competition to set bench marking in between public and private sector for lowering the prices	S
	Commission to review market-based v. negotiated prices and flat rate of electricity generation by establishing specific regulation to contribute proper price regulation and fairness on the market	S
	Cross border dispute resolution should be specified. Need of a cross country authorization to execute the cross-border decisions to bring harmony into legislation and legal proceedings in the decision-making phase	M
Public Procurement Act 2007	May require introducing provision into the Act such as the Party who has challenge to the contract awarding authority may not be able to bid for the other project and only after final decision made from the court or dispute resolution board/ agency/or organization	U
Strategic Environmental and Social Assessment		
Forest Act, 2019	Rather Ministry to be as Regulating agency for environmental compliances, competent and independent environment regulatory agency required to obtain efficiency.	S
Guthi Corporation Act, 1976	May acquire any Guthi land and to be reimburse a land instead of the amount of compensation of that acquired land may need some level of flexibility to national prioritized projects	S
Immovable Property Requisition Act, 1956	May contradict with Land Acquisition Act, 1977 It may be given national prioritized or large scaled project *(The Act has limited the raising of any inquiry concerning the requisition order in any court.)*	M

Legal Instrument	Recommendations	Prioritized Recommendation
Land Acquisition Act, 1977	Need to have provision on proceedings of private companies to acquire the land to develop the projects to serve the public interest	M
	Limited access for land acquisition, therefore it is entails to broaden public interest to acquire initiated by any three tiers of government, public entity and private sectors	M
	Suggested to limit ex-ante evaluation of acquired land thorough the legal instruments	U
Land Use Act, 2019	Classified lands into 10 categories to provision for three tiers of government to formulate land use plan based on the condition of land, population growth, and requirements of land for various purposes	M
National Parks and Wildlife Conservation Act, 1973	Entails harmonizing with EPA, FA to avoid environmental concern while constructing infrastructures within and beyond affected areas of water recourses, forest areas and national parks and heritage sites.	S

U	Urgent Recommendation	**M**	Moderate Recommendation	**S**	Standard Recommendation

6.3 Institutional Landscape and Requirements

Institutions in Nepal provide the administrative structure and governance required for the effective and equitable use of water resources. These organizations oversee putting legal and policy measures into effect, organizing numerous stakeholders, and dealing with the problems the nation faces with water management. Important elements of institutional influence on Nepal's water management include:

- **Coordination and Governance:** Institutions manage the distribution and allotment of water resources, ensuring fair access and avoiding conflicts. They make it easier for local communities, government organizations, and other parties participating in water management efforts and projects to coordinate. WECS at the federal level and proposed RBOs at the basin level will be appropriate agencies to take an overseeing role in water resources development and management.
- **Development of Infrastructure:** Institutions coordinate the planning and construction of crucial water infrastructure, such as irrigation systems and hydropower projects, to increase the availability of water and maximize the potential for energy and economic development. Roll of e.g., DoWRI, DoED, development projects
- **Capacity Building:** Institutions empower local governments and non-profit organizations to implement sustainable water management strategies.
- **Transboundary Cooperation:** Institutions play a crucial role in negotiating and putting into effect transboundary water agreements with China and India. These agreements guarantee the cooperative management of water resources, lowering the possibility of conflicts and promoting regional stability.

Given their importance, a summary of the institution impacting water resources development and management is described below.

At the federal level, the following ministries and agencies are directly or indirectly related to water resources:

- Ministry of Energy, Water Resources and Irrigation (MoEWRI)
- Ministry of Agriculture and Livestock Development (MoALD)-Ministry of Health and Population (MoHP)
- Ministry of Forests and Environment (MoFE)
- Ministry of Water Supplies (MoWS)
- Investment Board, Nepal (IBN) under the Prime Minister’s Office

Besides, the Water and Energy Commission (WEC) supported by its secretariat WECS is considered as custodian of the water resources and energy sector overseeing and coordinating work with various ministries mentioned above at the federal level.

In addition, there are various departments, centers, authorities, and companies under MoEWRI doing their respective works according to their formation orders:

- Department of Water Resources and Irrigation (DWRI)
- Department of Electricity Development (DoED)
- Department of Hydrology and Meteorology (DHM)
- Nepal Electricity Authority (NEA)
- Groundwater Resources Development Board (GWRDB)
- Alternative Energy Promotion Centre (AEPC)
- Water Resources Research and Development Centre (WRRDC)
- Vidhyut Utpadan Co Ltd (Electricity Generation Co Ltd)
- Rashtriya Prasharan Grid Co Ltd (National Transmission Grid Co Ltd)
- Hydroelectricity Investment and Development Co Ltd
- Nepal Energy Efficiency Programme

In the context of a federated structure of governance, in the water resources sector, there are concerned ministries and departments at the provincial level and sections at the local governmental level. They are supposed to oversee and operate various water resources-related projects and programs. This calls for strong vertical and horizontal linkages among concerned institutions with clear jurisdiction, responsibilities, and positive intent to coordinate.

Major Institutional Findings and Recommendations

Major institutional hurdles facing Nepal's water resources sector as underlined by various past and present policy documents can be summarized below:

- Lack of an effective central institution that can meaningfully oversee the planning, implementation, and regulation of projects and programs related to the water resources sector. This has resulted in a piecemeal approach to development rather than taking an integrated approach overlooking long accepted principle of IWRM. This is further reinforced during the conduction of Province level workshops where participants also vocally pointed out it.
- Blurred responsibilities in terms of policy formulation, planning, implementation, operation, and regulation among various organizations and various levels.
- Lack of clarity in jurisdiction results in problems of coordination.

Major recommendation in terms of institutional back up for effective planning and management of water resources sector are summarized as below:

- A clear institutional mechanism for taking custodian role in terms of all river basin planning which will be performed by WECS as has been underlined by past and present policy documents.
- Preparation of policy regarding jurisdiction among 3 tiers of governments and appropriate mechanism therein to ensure coordination for the optimal benefits from the development of water resources and enhanced management with due consideration of lesser environmental impact.
- Reinforcement of WECS to effectively address above mentioned recommendations.
- Refinement of Policy, Act, and Regulations to instil dynamism in the development of the sector.
- Promotion of International Water Law to prepare Nepal for undertaking mutual understanding with neighbouring countries as per international law and practices.

The entry points to effectively implement RBP and the above-mentioned institutional recommendations are:

- **Reinforcing WECS** through its institutional strengthening that to consolidate present tasks of a) Prepare Policies, Strategies and Legislation; b) Recommending Mega/Medium Projects; and c) Advice on International Issues; to be enlarged and encompass a) Electrical Studies-forecast, transmission, efficiency; b) Hydro-data Centre task; c) River Basin Plans-preparation, implementation and audit; d) Projects related task-national standards and codes; pre-license consent for central level projects; monitor safety of basins, infrastructures and SESA issues.

- **Setting up the River Basin Offices (RBOs)** to implement the mandate of WECS at provincial and local levels and will have a role a) to act as a local data centre; b) support regulation through issuance of pre-license consent at provincial and local levels, regulating sand and gravel extraction from rivers; c) audit of RBPs including quality assurance and RBP update; d) communicative role on sharing and explaining RBPs, good practice, guidelines; e) supportive role in terms of sharing information, support investment development and training as required.
- **Moving Forward:** a) WEC as Steering body for inter-ministry coordination in policy and planning; b) WECS as planning and regulating agency, providing pre-license consent to federal level projects and programs; c) RBO as implementing arms for WECS mandate at basin level; and d) RBOs provide pre-license consent on projects and programs at basin level.

7 Capacity Building

The key tasks under the capacity building component included:

i.) Preparation of the capacity building plan

ii.) Enhance capacity of WECS and other related agencies in hydrological modelling, river basin modelling and development and maintenance of the DSS (Table 7-1)

iii.) Exposure visit for WECS and other related GoN staff (undertaken in 2020)

Table 7-1: List of trainings for WECS capacity building

No.	Theme	Training Module	Contents	Dates	No of days	No of trainees
1	GIS and Database	Basic GIS Training (GIS Training-1)	Basic GIS training in Open source GIS software (QGIS)	6th to 22nd Jan 2019	15	12
2		Advance GIS Training (GIS Training-2)	Advance GIS (Analysis functions) in Open source GIS software (QGIS)	25th Feb to 18th Mar 2019	15	9
3		GIS Training on Database Development and Analysis (GIS Training - 3)	GIS Training on database development and analysis using ArcGIS software	26th Dec 2022 to 1st Jan 2023	5	15
4	Hydrological Modelling	Hydrological modelling -1	Rainfall-runoff modelling concepts, various models, NAM model setup and simulation, interpreting model results, hands-on exercises	11th to 29th Nov 2019	15	9
5		Hydrological modelling -2	Data preparation for models, distributed hydrological modelling, MIKE SHE model set up, calibration and allocations, hands-on exercises	2nd to 6th Jan 2023	5	14
6		Hydrological modelling -3	Advanced topics in integrated hydrological modelling using distributed model, Data inputs, MIKE SHE model setup, calibration, simulation and result interpretation.	9th to 13th Jan 2023	5	15
7	River Basin Planning (RBP)	River system planning -1	IWRM concepts, RBP Overview, Theoretical Concepts, Approaches and Models, Data	16th to 20th Jul 2023	5	13

No.	Theme	Training Module	Contents	Dates	No of days	No of trainees
			Preparation, hands-on exercises			
8		River system planning -2	Advanced River basin modelling using MIKE Hydro Basin, hands-on exercise	20th to 24th Aug 2023	5	14
9		River system planning -3	Multipurpose water resources systems modelling, Reservoir operation modelling, using MIKE Hydro Basin	25th to 29th Aug 2023 and 20th to 22nd Feb, 2024	5	21
10	Decision Support System (DSS)	DSS modelling -1	Overview and Concepts on DSS, Framework, Web-based Graphical User Inter-face (GUI); and hands-on exercises	31st Jan to 5th Feb, 2024	5	16
11		DSS modelling -2	Decision Support System (DSS), applications; Backend development process and coding; hands-on exercises	6th to 11th Feb, 2024	5	16
12		DSS modelling -3	Advanced Decision Support System (DSS), applications and hands-on exercises	12th to 16th 2024	5	16

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Annex A: Development Scenarios

Table A. 1: Simulations Used in the Analysis of Development Futures for the Mahakali Basin

No	Simulations	Year	DWS	IRRG	IMP/HP Development	Scenarios			
Scenario Analysis									
1	D325BaseBDV-01	2025	DWS:25	IRRG:25	OP-HP	1	2	3	4
2	D330BaseBDV-01	2030	DWS:30	IRRG:30	OP-HP	1			
3	D330BaseMAH-02	2030	DWS:30	IRRG:30	OP-HP, CL-HP		2		
4	D330BaseMAH-03	2030	DWS:30	IRRG:30	OP-HP			3	
5	D330BaseMAH-04	2030	DWS:30	IRRG:30	OP-HP, CL-HP, Pancheshwar Dam				4
6	D335BaseBDV-01	2035	DWS:35	IRRG:35	OP-HP	1			
7	D335BaseMAH-02	2035	DWS:35	IRRG:35	OP-HP, CL-HP		2		
8	D335BaseMAH-03	2035	DWS:35	IRRG:35	OP-HP			3	
9	D335BaseMAH-04	2035	DWS:35	IRRG:35	OP-HP, CL-HP, Pancheshwar Dam				4
10	D340BaseBDV-01	2040	DWS:40	IRRG:40	OP-HP	1			
11	D340BaseMAH-02	2040	DWS:40	IRRG:40	OP-HP, CL-HP		2		
12	D340BaseMAH-03	2040	DWS:40	IRRG:40	OP-HP			3	
13	D340BaseMAH-04	2040	DWS:40	IRRG:40	OP-HP, CL-HP, Pancheshwar Dam				4
14	D345BaseBDV-01	2045	DWS:45	IRRG:45	OP-HP	1			
15	D345BaseMAH-02	2045	DWS:45	IRRG:45	OP-HP, CL-HP		2		
16	D345BaseMAH-03	2045	DWS:45	IRRG:45	OP-HP, Pancheshwar Dam			3	
17	D345BaseMAH-04	2045	DWS:45	IRRG:45	OP-HP, CL-HP, Pancheshwar Dam				4
18	D350BaseBDV-01	2050	DWS:50	IRRG:50	OP-HP	1			
19	D350BaseMAH-02	2050	DWS:50	IRRG:50	OP-HP, CL-HP		2		
20	D350BaseMAH-03	2050	DWS:50	IRRG:50	OP-HP, Pancheshwar Dam			3	
21	D350BaseMAH-04	2050	DWS:50	IRRG:50	OP-HP, CL-HP, Pancheshwar Dam, Chameliya_05 HPP				4
Climate Variability									
22	D350Q-20MAH-05	2050	DWS:50	IRRG:50	OP-HP, CL-HP, Pancheshwar Dam, Chameliya_05 HPP -20% Inflow				4
23	D350Q-10MAH-06	2050	DWS:50	IRRG:50	OP-HP, CL-HP, Pancheshwar Dam, Chameliya_05 HPP -10% Inflow				4
24	D350Q+10MAH-07	2050	DWS:50	IRRG:50	OP-HP, CL-HP, Pancheshwar Dam, Chameliya_05 HPP +10% Inflow				4
25	D350Q+20MAH-08	2050	DWS:50	IRRG:50	OP-HP, CL-HP, Pancheshwar Dam, Chameliya_05 HPP +20% Inflow				4

OP-HP = Operating HPP, CL-HP = Construction License HPP, MG-HP = Mega HPP, GF-HP = Greenfield HPP

Table A. 2: Development scenarios evaluated in the Karnali Basin

No	Simulations	Year	DWS	IRRG	IMP/HP Development	Scenarios				
1	D325BaseBDV-01	2025	DWS:25	IRRG:25	OP-HP	1	2	3	4	
2	D330BaseBDV-01	2030	DWS:30	IRRG:30	OP-HP	1				
3	D330BaseKAR-02	2030	DWS:30	IRRG:30	OP-HP, West Seti		2			
4	D330BaseKAR-03	2030	DWS:30	IRRG:30	OP-HP, Nalgad + Karnali IBT			3		
5	D330BaseKAR-04	2030	DWS:30	IRRG:30	OP-HP, West Seti, Nalgad + Karnali IBT				4	
6	D335BaseBDV-01	2035	DWS:35	IRRG:35	OP-HP	1				
7	D335BaseKAR-02	2035	DWS:35	IRRG:35	OP-HP, West Seti		2			
8	D335BaseKAR-03	2035	DWS:35	IRRG:35	OP-HP, Nalgad + Karnali IBT			3		
9	D335BaseKAR-04	2035	DWS:35	IRRG:35	OP-HP, West Seti, Nalgad + Karnali IBT				4	
10	D340BaseBDV-01	2040	DWS:40	IRRG:40	OP-HP	1				
11	D340BaseKAR-02	2040	DWS:40	IRRG:40	OP-HP, West Seti		2			
12	D340BaseKAR-03	2040	DWS:40	IRRG:40	OP-HP, Nalgad + Karnali IBT			3		
13	D340BaseKAR-04	2040	DWS:40	IRRG:40	OP-HP, West Seti, Nalgad + Karnali IBT				4	
14	D345BaseBDV-01	2045	DWS:45	IRRG:45	OP-HP,	1				
15	D345BaseKAR-02	2045	DWS:45	IRRG:45	OP-HP, West Seti		2			
16	D345BaseKAR-03	2045	DWS:45	IRRG:45	OP-HP, Nalgad + Karnali IBT			3		
17	D345BaseKAR-04	2045	DWS:45	IRRG:45	OP-HP, West Seti, Nalgad + Karnali IBT				4	
18	D350BaseBDV-01	2050	DWS:50	IRRG:50	OP-HP	1				
19	D350BaseKAR-02	2050	DWS:50	IRRG:50	OP-HP, West Seti		2			
20	D350BaseKAR-03	2050	DWS:50	IRRG:50	OP-HP, Nalgad + Karnali IBT			3		
21	D350BaseKAR-04	2050	DWS:50	IRRG:50	OP-HP, West Seti, Nalgad + Karnali IBT				4	
22	D350Q-20KAR-05	2050	DWS:50	IRRG:50	OP-HP, West Seti, Nalgad + Karnali IBT, Karnali High Dam					5
23	D350Q-20KAR-06	2050	DWS:50	IRRG:50	OP-HP, West Seti, Nalgad + Karnali IBT + Karnali High Dam, Inflow -20%					5
24	D350Q-10KAR-07	2050	DWS:50	IRRG:50	OP-HP, West Seti, Nalgad + Karnali IBT + Karnali High Dam, Inflow - 10%					5
25	D350Q+10KAR-08	2050	DWS:50	IRRG:50	OP-HP, West Seti, Nalgad + Karnali IBT + Karnali High Dam, Inflow +10%					5
26	D350Q+20KAR-09	2050	DWS:50	IRRG:50	OP-HP, West Seti, Nalgad + Karnali IBT + Karnali High Dam, Inflow +20%					5

OP-HP = Operating HPP, CL-HP = Construction License HPP, MG-HP = Mega HPP, GF-HP = Greenfield HPP

Table A. 3: Development scenarios evaluated in the Babai Basin

No	Simulations	Year	DWS	IRR	IBT Development	Scenarios	
1	D325BaseBDV-01	2025	DWS:25	IRR:25		1	
2	D330BaseBDV-01	2030	DWS:30	IRR:30		1	
3	D330BaseBAB-02	2030	DWS:30	IRR:30	Madi Dang IBT		2
4	D335BaseBDV-01	2035	DWS:35	IRR:35		1	
5	D335BaseBAB-02	2035	DWS:35	IRR:35	Madi Dang IBT		2
6	D340BaseBDV-01	2040	DWS:40	IRR:40		1	
7	D340BaseBAB-02	2040	DWS:40	IRR:40	Madi Dang IBT		2
8	D345BaseBDV-01	2045	DWS:45	IRR:45		1	
9	D345BaseBAB-02	2045	DWS:45	IRR:45	Madi Dang IBT		2
10	D350BaseBDV-01	2050	DWS:50	IRR:50		1	
11	D350BaseBAB-02	2050	DWS:50	IRR:50	Madi Dang IBT		2
12	D350Q-20BAB-03	2050	DWS:50	IRR:50	Madi Dang IBT, Inflow -20%		2
13	D350Q-10BAB-04	2050	DWS:50	IRR:51	Madi Dang IBT, Inflow -10%		2
14	D350Q+10BAB-05	2050	DWS:50	IRR:52	Madi Dang IBT, Inflow +10%		2
15	D350Q+20BAB-06	2050	DWS:50	IRR:50	Madi Dang IBT, Inflow +20%		2

Table A. 4: Development scenarios evaluated in the West Rapti Basin

No	Simulations	Year	DWS	IRR	HP Development	Scenarios			
1	D325BaseBDV-01	2025	DWS:25	IRR:25	OP	1	2	3	4
2	D330BaseBDV-01	2030	DWS:30	IRR:30	OP	1			
3	D330BaseWRT-02	2030	DWS:30	IRR:30	OP, Madi Dang Dam-IBT		2		
4	D330BaseWRT-03	2030	DWS:30	IRR:30	OP			3	
5	D330BaseWRT-04	2030	DWS:30	IRR:30	OP, Madi Dang Dam-IBT, Naumure Dam-Kapilbastu Diversion IBT				4
6	D335BaseBDV-01	2035	DWS:35	IRR:35	OP	1			
7	D335BaseWRT-02	2035	DWS:35	IRR:35	OP, Madi Dang Dam-IBT		2		
8	D335BaseWRT-03	2035	DWS:35	IRR:35	OP, Naumure Dam-Kapilbastu Diversion IBT			3	
9	D335BaseWRT-04	2035	DWS:35	IRR:35	OP, Madi Dang Dam-IBT, Naumure Dam-Kapilbastu Diversion IBT				4
10	D340BaseBDV-01	2040	DWS:40	IRR:40	OP	1			
11	D340BaseWRT-02	2040	DWS:40	IRR:40	OP, Madi Dang Dam-IBT		2		
12	D340BaseWRT-03	2040	DWS:40	IRR:40	OP, Naumure Dam-Kapilbastu Diversion IBT			3	
13	D340BaseWRT-04	2040	DWS:40	IRR:40	OP, Madi Dang Dam-IBT, Naumure Dam-Kapilbastu Diversion IBT				4
14	D345BaseBDV-01	2045	DWS:45	IRR:45	OP	1			
15	D345BaseWRT-02	2045	DWS:45	IRR:45	OP, Madi Dang Dam-IBT		2		
16	D345BaseWRT-03	2045	DWS:45	IRR:45	OP, Naumure Dam-Kapilbastu Diversion IBT			3	
17	D345BaseWRT-04	2045	DWS:45	IRR:45	OP, Madi Dang Dam-IBT, Naumure Dam-Kapilbastu Diversion IBT				4
18	D350BaseBDV-01	2050	DWS:50	IRR:50	OP	1			
19	D350BaseWRT-02	2050	DWS:50	IRR:50	OP, Madi Dang Dam-IBT		2		
20	D350BaseWRT-03	2050	DWS:50	IRR:50	OP, Naumure Dam-Kapilbastu Diversion IBT			3	
21	D350BaseWRT-04	2050	DWS:50	IRR:50	OP, Madi Dang Dam-IBT, Naumure Dam-Kapilbastu Diversion IBT				4

OP = Operating HPP, CL = Construction License HPP, MG = Mega HPP, GF = Greenfield HPP

Table A. 5: Development scenarios evaluated in the Gandaki Basin

No	Simulations	Year	DWS	IRR	IMP/HP Development	Scenarios			
1	D225BaseBDV-01	2025	DWS:25	IRR:25	OP	1	2	3	4
2	D230BaseBDV-01	2030	DWS:30	IRR:30	OP	1			
3	D230BaseGAN-02	2030	DWS:30	IRR:30	OP, CL		2		
4	D230BaseGAN-03	2030	DWS:30	IRR:30	OP, CL, GF			3	
5	D230BaseGAN-04	2030	DWS:30	IRR:30	OP, CL, GF				4
6	D235BaseBDV-01	2035	DWS:35	IRR:35	OP	1			
7	D235BaseGAN-02	2035	DWS:35	IRR:35	OP, CL, GF, Budhi Gandaki		2		
8	D235BaseGAN-03	2035	DWS:35	IRR:35	OP, CL, GF			3	
9	D235BaseGAN-04	2035	DWS:35	IRR:35	OP, CL, GF, Budhi Gandaki				4
10	D240BaseBDV-01	2040	DWS:40	IRR:40	OP	1			
11	D240BaseGAN-02	2040	DWS:40	IRR:40	OP, CL, GF, Budhi Gandaki		2		
12	D240BaseGAN-03	2040	DWS:40	IRR:40	OP, CL, GF			3	
13	D240BaseGAN-04	2040	DWS:40	IRR:40	OP, CL, GF, Budhi Gandaki				4
14	D245BaseBDV-01	2045	DWS:45	IRR:45	OP	1			
15	D245BaseGAN-02	2045	DWS:45	IRR:45	OP, CL, GF, Budhi Gandaki		2		
16	D245BaseGAN-03	2045	DWS:45	IRR:45	OP, CL, GF Kaligandaki-Tinau MPP			3	
17	D245BaseGAN-04	2045	DWS:45	IRR:45	OP, CL, GF, Budhi Gandaki, Kaligandaki-Tinau MPP				4
18	D250BaseBDV-01	2050	DWS:50	IRR:50	OP	1			
19	D250BaseGAN-02	2050	DWS:50	IRR:50	OP, CL, GF, Budhi Gandaki		2		
20	D250BaseGAN-03	2050	DWS:50	IRR:50	OP, CL, GF Kaligandaki-Tinau MPP			3	
21	D250BaseGAN-04	2050	DWS:50	IRR:50	OP, CL, GF, Budhi Gandaki, Kaligandaki-Tinau MPP				4
22	D250Q-20GAN-05	2050	DWS:50	IRR:50	OP, CL, GF, Budhi Gandaki, Kaligandaki-Tinau MPP, Inflow -20%				4
23	D250Q-10GAN-06	2050	DWS:50	IRR:50	OP, CL, GF, Budhi Gandaki, Kaligandaki-Tinau MPP, Inflow -10%				4
24	D250Q+10GAN-07	2050	DWS:50	IRR:50	OP, CL, GF, Budhi Gandaki, Kaligandaki-Tinau MPP, Inflow +10%				4

No	Simulations	Year	DWS	IRR	IMP/HP Development	Scenarios			
25	D250Q+20GAN-08	2050	DWS:50	IRR:50	OP, CL, GF, Budhi Gandaki, Kaligandaki-Tinau MPP, Inflow +20%				4

OP = Operating HPP, CL = Construction License HPP, MG = Mega HPP, GF = Greenfield HPP

Table A. 6: Development scenarios evaluated in the Kamala Basin

No	Simulations	Year	Code	DWS	IRRG	IMP/HP Development[1]	Scenarios
Scenarios Analysis							
1	D125BaseBDV-01	2025	25 BDV	DWS:25	IRRG:25		1
2	D130BaseBDV-01	2030	30 BDV	DWS:30	IRRG:30		1
3	D130BaseMEC-02	2030	30 MxDV	DWS:30	IRRG:30	Sunkoshi-Kamala IBT (SM IBT, SUNK220)	2
4	D135BaseBDV-01	2035	35 BDV	DWS:35	IRRG:35		1
5	D135BaseMEC-02	2035	35 MxDV	DWS:35	IRRG:35	Sunkoshi-Kamala IBT (SM IBT, SUNK220, DUDH031)	2
6	D140BaseBDV-01	2040	40 BDV	DWS:40	IRRG:40		1
7	D140BaseMEC-02	2040	40 MxDV	DWS:40	IRRG:40	Sunkoshi-Kamala IBT (SM IBT, SUNK220, DUDH031)	2
8	D145BaseBDV-01	2045	45 BDV	DWS:45	IRRG:45		1
9	D145BaseMEC-02	2045	45 MxDV	DWS:45	IRRG:45	Sunkoshi-Kamala IBT (SM IBT, SUNK220, DUDH031)	2
10	D150BaseBDV-01	2050	50 BDV	DWS:50	IRRG:50		1
11	D150BaseMEC-02	2050	50 MxDV	DWS:50	IRRG:50	Sunkoshi-Kamala IBT (SM IBT, SUNK220, DUDH031, SUNK158)	2
Climate Change							
12	D150Q-20MEC-06	2050	50 Q-20	DWS:50	IRRG:50	Sunkoshi-Kamala IBT (SM IBT, SUNK220, DUDH031, SUNK158)	3
13	D150Q-10MEC-07	2050	50 Q-10	DWS:50	IRRG:50	Sunkoshi-Kamala IBT (SM IBT, SUNK220, DUDH031, SUNK158)	3
14	D150Q+10MEC-08	2050	50 Q+10	DWS:50	IRRG:50	Sunkoshi-Kamala IBT (SM IBT, SUNK220, DUDH031, SUNK158)	3
15	D150Q+20MEC-09	2050	50 Q+20	DWS:50	IRRG:50	Sunkoshi-Kamala IBT (SM IBT, SUNK220, DUDH031, SUNK158)	3

[1] SM IBT = Sunkoshi-Marin IBT, SUNK220 = Sunkoshi-3 Dam, DUDH031 = Dudhkoshi Dam, SUNK158 = Sunkoshi-2 Dam

Table A. 7: Development scenarios evaluated in the Koshi Basin

No	Simulations	Year	DWS	IRRG	IMP/HP Development[1]	Scenarios
Scenarios Analysis						
1	D125BaseBDV-01	2025	DWS:25	IRRG:25	OP	1, 2, 3, 4
2	D130BaseBDV-01	2030	DWS:30	IRRG:30	OP	1
3	D130BaseKOS-02	2030	DWS:30	IRRG:30	OP, CL, Arun3	2
4	D130BaseKOS-03	2030	DWS:30	IRRG:30	OP, CL, Arun3	3
5	D130BaseKOS-04	2030	DWS:30	IRRG:30	OP, CL, Arun3, TAMOO6O, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SM IBT, SKIBT, TM IBT	4
6	D135BaseBDV-01	2035	DWS:35	IRRG:35	OP	1
7	D135BaseKOS-02	2035	DWS:35	IRRG:35	OP, CL, Arun3, Upper Arun, SUNK220, SM IBT	2
8	D135BaseKOS-03	2035	DWS:35	IRRG:35	OP, CL, Arun3, ARUN093, Upper Arun, SUNK220, SM IBT, SKIBT	3
9	D135BaseKOS-04	2035	DWS:35	IRRG:35	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SM IBT, SKIBT, TM IBT	4
10	D140BaseBDV-01	2040	DWS:40	IRRG:40	OP	1
11	D140BaseKOS-02	2040	DWS:40	IRRG:40	OP, CL, Arun3, TAMOO6O, DUDH031, Upper Arun, SUNK220, SM IBT, SKIBT	2
12	D140BaseKOS-03	2040	DWS:40	IRRG:40	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Upper Arun, SUNK220, SM IBT, SKIBT	3
13	D140BaseKOS-04	2040	DWS:40	IRRG:40	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SM IBT, SKIBT, TM IBT	4
14	D145BaseBDV-01	2045	DWS:45	IRRG:45	OP	1
15	D145BaseKOS-02	2045	DWS:45	IRRG:45	OP, CL, Arun3, TAMOO6O, DUDH031, Tamakoshi-3, Upper Arun, SUNK220, SM IBT, SKIBT, TM IBT	2
16	D145BaseKOS-03	2045	DWS:45	IRRG:45	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SM IBT, SK IBT, TM IBT	3
17	D145BaseKOS-04	2045	DWS:45	IRRG:45	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SUNK116, SM IBT, SK IBT, TM IBT	4
18	D150BaseBDV-01	2050	DWS:50	IRRG:50	OP	1

No	Simulations	Year	DWS	IRRG	IMP/HP Development[1]	Scenarios
19	D150BaseKOS-02	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SM IBT, SK IBT, TM IBT	2
20	D150BaseKOS-03	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SM IBT, SK IBT, TM IBT	3
21	D150BaseKOS-04	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SUNK116, SAPT056, SUNK158, SM IBT, SKIBT, TM IBT	4
Climate Change						
22	D150Q-20KOS-06	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SUNK116, SAPT056, SUNK158, SM IBT, SK IBT, Inflow -20%	5
23	D150Q-10KOS-07	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SUNK116, SAPT056, SUNK158, SM IBT, SK IBT, Inflow -10%	5
24	D150Q+10KOS-08	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SUNK116, SAPT056, SUNK158, SM IBT, SK IBT, Inflow +10%	5
25	D150Q+20KOS-09	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAMOO6O, DUDH031, ARUN093, Tamakoshi-3, Upper Arun, SUNK220, SUNK116, SAPT056, SUNK158, SM IBT, SK IBT, Inflow +20%	5
Test Cases						
26	D150BaseKOS-10	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAM IBT, SM IBT, SK IBT, SAPT	5
27	D150BaseKOS-11	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAM IBT, SM IBT, SK IBT, SAPT, SUNK220, TAM	5
28	D150BaseKOS-12	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAM IBT, SM IBT, SK IBT, SAPT, SUNK220, TAM, DUDH	5
29	D150BaseKOS-13	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAM IBT, SM IBT, SK IBT, SAPT, SUNK220, TAM, SUNK116	5
30	D150BaseKOS-14	2050	DWS:50	IRRG:50	OP, CL, Arun3, TAM IBT, SM IBT, SK IBT, SAPT, SUNK220, TAM, SUNK117, DUDH	5

[1] OP = Operating HPP, CL = Construction License HPP, MG = Mega HPP, GF = Greenfield HPP

Table A. 8: Development scenarios evaluated in the Kankai Basin

No	Simulations	Year	Code	DWS	IRRG	IMP/HP Development[1]	Scenarios
Scenarios Analysis							
1	D125BaseBDV-01	2025	25 BDV	DWS:25	IRRG:25	OP	1, 2, 3
2	D130BaseBDV-01	2030	30 BDV	DWS:30	IRRG:30	OP	1
3	D130BaseKAN-02	2030	30 SC1	DWS:30	IRRG:30	OP, CL	2
4	D130BaseKAN-04	2030	30 MxDV	DWS:30	IRRG:30	OP, CL, GF, Kankai MPP	3
5	D135BaseBDV-01	2035	35 BDV	DWS:35	IRRG:35	OP	1
6	D135BaseKAN-02	2035	35 SC1	DWS:35	IRRG:35	OP, CL	2
7	D135BaseKAN-04	2035	35 MxDV	DWS:35	IRRG:35	OP, CL, GF, Kankai MPP	3
8	D140BaseBDV-01	2040	40 BDV	DWS:40	IRRG:40	OP	1
9	D140BaseKAN-02	2040	40 SC1	DWS:40	IRRG:40	OP, CL, GF, Kankai MPP	2
10	D140BaseKAN-04	2040	40 MxDV	DWS:40	IRRG:40	OP, CL, GF, Kankai MPP	3
11	D145BaseBDV-01	2045	45 BDV	DWS:45	IRRG:45	OP	1
12	D145BaseKAN-02	2045	45 SC1	DWS:45	IRRG:45	OP, CL, GF, Kankai MPP	2
13	D145BaseKAN-04	2045	45 MxDV	DWS:45	IRRG:45	OP, CL, GF, Kankai MPP	3
14	D150BaseBDV-01	2050	50 BDV	DWS:50	IRRG:50	OP	1
15	D150BaseKAN-02	2050	50 SC1	DWS:50	IRRG:50	OP, CL, GF, Kankai MPP	2
16	D150BaseKAN-04	2050	50 MxDV	DWS:51	IRRG:50	OP, CL, GF, Kankai MPP	3
Climate Change							
17	D150Q-20KAN-06	2050	50 CC-20	DWS:50	IRRG:50	OP, CL, OP, CL, GF, Kankai MPP, -20 Inflow	5
18	D150Q-10KAN-07	2050	50 CC-10	DWS:50	IRRG:50	OP, CL, OP, CL, GF, Kankai MPP, -10 Inflow	5
19	D150Q+10KAN-08	2050	50 CC+10	DWS:50	IRRG:50	OP, CL, OP, CL, GF, Kankai MPP, +10 Inflow	5
20	D150Q+20KAN-09	2050	50 CC+20	DWS:50	IRRG:50	OP, CL, OP, CL, GF, Kankai MPP, +20 Inflow	5

[1] OP = Operating HPP, CL = Construction License HPP, MG = Mega HPP, GF = Greenfield HPP

Table A. 9: Development scenarios evaluated in the Mechi Basin

No	Simulations	Year	Code	DWS	IRRG	IMP/HP Development[1]	Scenarios
Scenarios Analysis							
1	D125BaseBDV-01	2025	25 BDV	DWS:25	IRRG:25		1
2	D130BaseBDV-01	2030	30 BDV	DWS:30	IRRG:30		1
3	D130BaseMEC-02	2030	30 MxDV	DWS:30	IRRG:30	CL, Tamor-Morang IBT	2
4	D135BaseBDV-01	2035	35 BDV	DWS:35	IRRG:35		1
5	D135BaseMEC-02	2035	35 MxDV	DWS:35	IRRG:35	CL, Tamor-Morang IBT, Kankai MPP	2
6	D140BaseBDV-01	2040	40 BDV	DWS:40	IRRG:40		1
7	D140BaseMEC-02	2040	40 MxDV	DWS:40	IRRG:40	CL, Tamor-Morang IBT, Kankai MPP	2
8	D145BaseBDV-01	2045	45 BDV	DWS:45	IRRG:45		1
9	D145BaseMEC-02	2045	45 MxDV	DWS:45	IRRG:45	CL, Tamor-Morang IBT, Kankai MPP	2
10	D150BaseBDV-01	2050	50 BDV	DWS:50	IRRG:50		1
11	D150BaseMEC-02	2050	50 MxDV	DWS:50	IRRG:50	CL, Tamor-Morang IBT, Kankai MPP	2
Climate Change							
12	D150Q-20MEC-06	2050	50 Q-20	DWS:50	IRRG:50	CL, Tamor-Morang IBT, Kankai MPP	3
13	D150Q-10MEC-07	2050	50 Q-10	DWS:50	IRRG:50	CL, Tamor-Morang IBT, Kankai MPP	3
14	D150Q+10MEC-08	2050	50 Q+10	DWS:50	IRRG:50	CL, Tamor-Morang IBT, Kankai MPP	3
15	D150Q+20MEC-09	2050	50 Q+20	DWS:50	IRRG:50	CL, Tamor-Morang IBT, Kankai MPP	3

[1] OP = Operating HPP, CL = Construction License HPP, MG = Mega HPP, GF = Greenfield HPP

Annex B: Supporting Technical Reports

The following technical notes and reports provide the details description of the respective subjects covered in the River Basin Plans, Hydropower Development Master Plan and Strategic Environmental and Social Assessment.

No.	Title/content
1	*Technical Note* #3: Hydro-meteorological data analysis – data quality and gaps filling
2	*Technical Note* #2: Report on Baseline Data
3	*Technical Note* #6: Working paper on policy analysis
4	*Technical Note* #18: Working Paper on Institutional Analysis
5	*Technical Note* #8: Working paper on legal issues
6	Preliminary review of legal documents on river basin plans and hydropower development and strategic environmental and social assessment
7	Report on political economic analysis for basin planning
8	*Technical Note* #7: Socio-economic assessment
9	*Technical Note* #17: Report on socio-economic environment
10	Basin socio-economic profiles
11	Stakeholder analysis for basin planning
12	*Technical Note* #9: Paper on framework for DSS
13	*Technical Note* #19: Basin Planning Assessment Methodology
14	List of prospective irrigation projects that are included in the Irrigation Master Plan developed by DWRI
15	*Technical Note* #5a: Climate change assessment – Part 1
16	*Technical Note* #5b: Climate change assessment – Part 2
17	*Technical Note* #4: Hydrological modelling for Domain 1
18	*Technical Note* #12: River basin modelling for Domain 1
19	Report on Culture and Tourism Sites of Fourteen River Basins
20	Report on Indigenous peoples planning
21	Report on GESI planning
22	Report on community participation planning
23	Report on social and agricultural impacts of reservoirs in Koshi Basin
24	Report on policies and strategies for gender development
25	Report on policies and strategies for poverty reduction
26	*Technical Note* #16: Agriculture Sector Overview
27	*Technical Note* #10: Report on Water Supply Requirements
28	Status of Basin Reports (separate report for each river basin)
29	Power Market Assessment Report
30	*Technical Note* #13: Energy pricing and economics of hydropower
31	List of prospective hydropower projects for inclusion in the hydropower development plan
32	*Technical Note* #1: Hydropower plant design criteria
33	*Technical Note* #15: Site Visits Report
34	*Technical Note* #15a: Report on Site Visit to Koshi High Dam Site
35	*Technical Note* #15b: Report on Site Visit to Sunkoshi River Basin
36	*Technical Note* #15c: Report on Site Visit to Tamor Storage Dam
37	*Technical Note* #11: Draft hydropower plan for Koshi Basin

No.	Title/content
38	Stakeholder Analysis for SESA
39	*Technical Note* #17: Guiding Framework and Recommendations for ESIA
40	*Technical Note* #14: Working paper on SESA
41	Report on Training Needs Analysis and Capacity Building Plan
42	Training Report on Hydrological Modelling #1
	Final Reports
43	Volume 1 – Basin Status Report (separate volumes for 10 basins), February 2024
43	Volume 2 – Water Resources Development Plans (separate volumes for 10 basins), February 2024)
44	Volume 3 – Strategic Environmental and Social Assessment (separate volumes for 10 basins), February 2024
45	Volume 4 – River Basin Atlas, February 2024
46	Hydropower Development Master Plan, February 2024
47	SESA - Strategic Management Plan, February 2024

Government of Nepal

Water and Energy Commission Secretariat

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