

**Review of Existing Feasibility Study of Karnali Chisapani Hydro Power Project  
(10,800 MW) for Defining the Way Forward to Materialize its Development as a  
Regional Hydro Power Project**

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# CHAPTER-1: INTRODUCTION

# CHAPTER 1: INTRODUCTION

- This chapter gives a brief background of the Karnali (Chisapani) hydropower project.
- Studies carried out for implementation of the project over the past 50 years.
- It gives a brief overview of the project.
- The need for conducting a fresh Feasibility study in 1989 with the objective of developing it as a multipurpose project.
- The Scope of the Feasibility study conducted by a consortium of leading international hydropower consulting firms led by Himalayan Power Consultants.
- The execution of the study that began in 1986 and was completed in Dec. 1989.
- It gives the names of various consultants that worked on the different aspects of the HPC study and also the names of the reviewers, who reviewed the study.

# Various Studies conducted since 1966

- Karnali (Chisapani) Multipurpose Project is the largest storage project in Nepal.
- Feasibility Studies carried out in the past were conducted by:
  - Nippon Koei in 1966, (1800 MW)
  - Snowy Mountains Hydroelectric Authority in 1968 (3600MW)
  - Norconsult and Electrowatt in 1976 (3600MW)
  - Himalayan Power Consultants (HPC) consortium comprising Acres, Canada; Ebasco USA; Shawinigan, Canada; and SNC, Canada (10,800MW).
- All these studies established that the project is technically feasible and financially viable, as a multipurpose project with irrigation and electricity as main benefits from the project
- Irrigation potential of 191,000 ha in Nepal and 3200,000 ha in India.
- Other benefits considered were flood control and navigation.

# Nippon Koei Study 1966

- Nippon Koei of Japan conducted feasibility study in 1966.
- It proposed a concrete gravity – arch dam with height of about 200 m upstream site (same site as HPC recommended in 1990 study).
- The reservoir full supply level (FSL) was kept at el 370 m.
- Its estimated the generation capacity of 1800 MW.
- A surface power house at the base of the dam, and provision for future underground power plants on both banks of the river was proposed.
- Its capacity was selected in view of the limited size of the then projected power market in Northern India.

# SMHA Review study in 1968

- Snowy Mountains Hydropower Authority (SMHA) of Australia reviewed the study conducted by Nippon Koei in 1968.
- The review study questioned the feasibility of the project configuration and its arrangement and carried out alternative study of this arrangement with an embankment dam of similar height at downstream site.
- The review study also recommended the alternative development of a peaking project with higher capacity.

# Norconsult (Norway) and Electrowatt in 1977

- The 1977 Study conducted by Norconsult (Norway) and Electrowatt (Switzerland) carried out a further study, including investigations at the downstream site.
- This study recommended an embankment dam at the downstream site.
- The selected FSL was retained at el 370 m, the estimated installed capacity was doubled to 3600 MW.

# Feasibility Study by HPC in 1989

- A detailed feasibility study was conducted during 1986-1989, under the loan assistance from the IDA and the local costs provided by GoN.
- It was done by Himalayan Power Consultants (HPC), a joint venture of three Canadian consulting companies (Acres, SNC and Shawinigan/Lavalin) and Ebasco of the United States.
- General advice and direction for the study was provided by a bi-national Karnali Coordinating Committee (KCC), consisting of technical officials from Nepal and India.
- Overseas Bechtel Inc. (OBI) provided advisory services to the Government of Nepal on all aspects of the study.
- The Final Report was submitted in January 1990.
- Main features of the project as per this study are given in subsequent slides.

# Himalayan Power Consultants (HPC) Study

- Its scope included comprehensive field investigations, including topographic mapping, geologic investigation, seismicity and tectonic measurements and sedimentation and hydrologic data collection.
- Extensive investigation of two alternative dam sites in the Karnali gorge was carried out leading to the selection of the more upstream site.
- Project designs, cost estimates and benefits evaluation were carried out to determine the optimum scale of development, including consideration of future effect of potential upstream developments.
- Feasibility level design of the recommended development was completed.
- A construction plan for the entire project was prepared including special attention to diversion considerations, dam construction, transportation of major equipment through India and Nepal, access roads and general construction logistics.

# Himalayan Power Consultants (HPC) Study

- A detailed contractor's type cost estimate was prepared.
- Economic benefits of hydro power production, irrigation benefits, flood control and navigation were evaluated.
- Socioeconomic and resettlement studies were carried out, with special attention to resettlement strategies. This included a comprehensive field programme of data collection.
- An environmental assessment of the project, based on the field data collection programme was carried out.
- Assessment of the Karnali Irrigation Command project in Nepal was advanced to reconnaissance level, including evaluation of costs of irrigation infrastructure and associates economic benefits.

# Study Execution

- The study was started in June 1986 and was carried out in four stages.
- **Initial stage:** In this stage (June 1986 to July 1987), the main emphasis was on identifying the optimum project site and general arrangement of the civil works.
- **Optimization** (referred to as Stage A): In this stage (July 1987 to May 1988), the scale of development was optimized. This included selection of the reservoir full supply (FSL) and associated live storage and operating range, as well as installed generating capacity.
- **Final design:** (referred to as Stage B)-At this stage (May 1988 to June 1989) Feasibility level designs and costs estimates were prepared for the recommended development, and benefits evaluations were further refined. During this period, the result of the entire study were documented and submitted as a Final Draft Report.
- **Final Report:** In this stage (June 1989 to December 1989), the Final Draft Report was subject to extensive review by the Governments of Nepal and India, the World Bank, and Overseas Bechtel Inc. These reviews were incorporated as appropriate, and the report was finalized.

# Report Format of HPC Study

- This Main Report is organized and presented to reflect the analytical and chronological development of the study.
- Part I – Section 1 to 5- covers a brief summary description of the project introduction, general background and the project conclusions and recommendations.
- Part II – Section 6 to 11- covers site investigations and assessment of site conditions, topography, geology, seismology, construction materials, hydrology and sedimentation.
- Part III – Section 12 - covers the process of initial selection of the project site and dam type.
- Part IV – Sections 13 to 17- covers the Stage-A optimization study, including selection of the recommended reservoir full supply level, reservoir operating range and installed capacity.
- Part V- Section 18 to 25 - covers the engineering description of project facilities for the recommended development (Stage-B)
- Part VI – Section 26 to 27 - covers the construction plan and capital cost estimate for the recommended development.
- Part VII – Section 28 to 29- covers impact assessments, including socioeconomic, resettlement and environment.
- Part VIII – Section 30 - covers the economic evaluation of the recommended project.
- Annexures A to R

# Objectives of Conducting Fresh Feasibility Study

Following are the key objectives of review for conducting a fresh Feasibility study

- i. Review of existing feasibility studies of Karnali (Chisapani) Hydropower Project (1989).
- ii. Appropriately point out the requirements of upgrade/improvement in the data/information contained in the existing studies, where required.
- iii. Point out the need to incorporate necessary information which is missing in the existing studies, where required, especially from the point of view that the project is to be undertaken as regional hydro power project.
- iv. Make available detailed ToRs for updating the 1989 Feasibility Study.
- v. Sensitize the decision makers, professionals, investors and developers of a great opportunity to consider the construction of a regional hydropower project and considerably offsetting the electricity demand and supply gap.
- vi. Take another step for advocacy towards promoting regional energy cooperation for materializing the SAARC Energy Ring envisioned by the SAARC leaders.

# Summary of Conclusions/recommendations of Past Studies (1)

## Conclusions:

- Feasibility study of 1990 concludes that the project configuration defined is technically feasible and economically viable and very attractive.
- However, the study is unable to confirm environmental feasibility of the project; mainly, because of deficiencies in baseline data and field inventories.
- Three aspects of feasibility namely technical, economic and socio-environmental are summarized below.

## Technical Feasibility:

- A multipurpose water resources project on the Karnali River at Chisapani (upstream dam site) is technically feasible.
- It include a 270-m high gravel-fill dam, an underground powerhouse on the left bank with 18 x 600 MW generating units, a chute spillway on the right bank capable of discharging 19,200 m<sup>3</sup> /s, a downstream reregulating facility (which includes an 84-MW power plant and two irrigation outlets).
- Five 765 kV transmission lines from the Chisapani power plant, and a 220 kV transmission line from the Reregulating facility power plant into Northern India.
- However, more needs to be known on the geological and hydraulic conditions in the fan area affecting design and cost of the reregulating facility.
- The study also concludes that the upstream dam site (approximately in the middle of the gorge) is superior due to the more favourable topography and better geological conditions, and overall economy.

# Conclusions/recommendations of Past Studies (2)

## **Economic Viability:**

- The Chisapani project is economically viable and very attractive - without qualification, as the Consultant was aware of no comparable project offering such low generation costs.
- Based on normally accepted economic evaluation methodology, the gross benefits of the project were estimated at US \$16,780 million, compared with the associated economic cost estimated at US \$6,808 million.
- The resulting net economic benefit and B/C ratio was estimated at US \$9,972 and 2.46 respectively.
- For the entire range of sensitivity analyses, and even when examining a worst case scenario, the net economic benefits and the B/C ratio both remain high, thereby confirming the economic viability of the project.
- Furthermore, early implementation was desirable, as estimated economic opportunities foregone are US \$700 million (about US \$2 million/d) for each year of delay in implementation.

## **Socio-environmental Feasibility:**

- The study was not able to confirm environmental feasibility of the project through the study programme because of deficiencies in baseline data and field inventories.
- Additional field studies are required to define an adequate programme of mitigation, compensation, enhancement and management measures.
- Furthermore, The Consultant concluded that the time of completion of the study (early 1990) was a good time to proceed with the project from the view of the above technical and economic aspects covered in the study.
- The magnitude of the project net benefits are such that a reasonable proportion assigned to Nepal would provide a major boost to the national economy.

# Recommendations from HPC Study (1989)

- In view of the very favourable economic merits of the project, the Consultant recommended that Government of Nepal takes immediate steps to ensure implementation of the project at the earliest practical date.
- The Consultant recommended followings most urgent tasks to be undertaken:
  - Substantive discussion at appropriate government levels between the two countries, to at least initiate the process towards a Treaty of Implementation.
  - Continuing, and in some cases expanding the program of data gathering e.g. sedimentation, environmental and related studies including resettlement, to ensure that final design and definition of the project is made with full knowledge on conditions.
  - Full 'technical' involvement of the relevant Indian authorities to ensure that the definition of the project and its designed operating characteristics are fully appropriate for the 'market' conditions.

# **CHAPTER-2: THE PROJECT--KARNALI (CHISAPANI) MULTIPURPOSE PROJECT**

# Karnali (Chisapani) - Project Description (1)

- Located in Western Nepal (600 km from Kathmandu and 500 km from Delhi) in Karnali Gorge upstream of Terai part of Gangetic plains.
- The dam, sites at the narrowest, part of the gorge, is an embankment dam containing  $45 \times 10^6 \text{ m}^3$  of materials obtained from the alluvial fan area, 6 km downstream
- Reservoir will extend up to 100 km upstream and provide sufficient live storage to substantially regulate the river flow.
- Underground powerhouse, sited within the left abutment, contains 18 x 600 MW generating units.
- Power to be delivered to Northern grid of India by 5 x 765 kV transmission lines.

# Karnali (Chisapani) - Project Description (2)

- Power Plant was planned as a peaking facility for the North Indian power system.
- Capable of operating at about 20% PLF for firm energy and at about 25% for average energy production.
- Because of highly variable plant output over daily cycle, a reregulating facility is provided immediately downstream to ensure near-uniform downstream flows.
- This facility includes a low embankment dam and reservoir providing  $100 \times 10^6 \text{ m}^3$  of live storage, and a small 84 MW power plant.
- This Chapter gives the complete details of the project as discussed in subsequent slides.

# Project Features as per HPC study (1)

## i. Main Dam:

- The Main Dam is 270 m high from the lowest foundation level to crest elevation, Spillway, Diversion and Outlet facilities are conventional in concept.
- Peak discharges are reduced to about one third of peak inflow for both the spillway and diversion facilities.
- The spillway is an un-gated chute spillway capable of discharging a maximum flood flow of 19,200 m<sup>3</sup>/s. It is 860 m long.
- It terminates at a flip bucket and ultimately into the plunge pool.
- The large storage reservoir with live storage of 16.2 km<sup>2</sup> (equal to 37% of average annual runoff) created increases almost four-fold of the dry season flow in the Karnali River.
- This in turn increases agricultural production in Nepal and India.
- River Karnali will be diverted during construction through two 15 m diameter diversion tunnels, each 2400 m long.

# Project Features as per HPC study (2)

## ii. Power Facilities:

- The Power Facilities are located on the left bank of the damsite.
- The power facilities incorporate 18 generating units @ 600 MW each producing 20,842 million kWh/yr in-housed in an underground cavern of the size 705 m x 27.7 m x 50 m units and include six power tunnels of 15 m diameter connected to six bell mouthed intake structure with gate shaft.
- The power tunnels convey water into eighteen steel lined penstocks of 7.2 m dia through six vertical shafts of 14 m diameter.
- Transformers and valves are in-housed in a separate underground cavern some 700 m long.

# Project Features as per HPC study (3)

## iii. Regulating Dam:

The reregulating dam with maximum height of 24 m is located at about 8 km downstream of the main dam mainly for the following two reasons:

- to provide uniform daily flows downstream to ensure full irrigation benefits both in Nepal and India, and
- to maintain the natural riverine environment.

## iv. Power Evacuation:

- Evacuation of power from the main power plant (10,800 MW capacity) to the Indian system will be achieved through five 765 kV transmission lines, while the power from reregulating powerhouse would be transmitted to Indian system by one 220 kV line.

# Project Features as per HPC study (4)

## V. Socioeconomic and Environmental Issues:

- The study concluded that the project will cause substantial socioeconomic and environmental impacts, which require further investigations and studies for their effective mitigation.
- The project required resettlement of about 60,000 people. It was planned to resettle them, primarily into currently undeveloped areas within the Karnali irrigation command area.
- Environmental impact includes unavoidable encroachment into the existing Royal Bardiya Wildlife Reserve, located in the vicinity of the main dam and reregulating facilities and potential adverse impacts on the Gangetic Dolphin and Garial crocodile.
- A special consideration of these impacts is clearly an essential element of the decision to proceed with Kanali (Chisapani) project.

# Project Features as per HPC study (5)

## vi. Project Implementation:

- The study envisaged an implementation period of 17 years (5 years for pre-construction activities, nine and half years for project construction including generation from two units and 4 years for installation of remaining 16 units).
- A period of five years (1990 to 1994) was allowed for pre-construction activities, ending with the award of the major construction contract.
- Construction time was conservatively estimated at almost nine years i.e. from a January 1995 start to the on-power date for the first two (of eighteen) units, i.e. November 2003.
- Installation of the remaining units was tentatively planned at a rate of one every three months, terminating in November 2007.
- Annual cash flow distribution, beginning with expenditures in 1990, showed that about 3% (\$ 80 million) would be expended during the five year pre-construction period, and about 85% of the total would be expended before the initial on-power date and the remaining 12% during installation of 16 units.

# Project Features as per HPC study (6)

## vii. Capital Cost:

- The capital cost of the project at 1998 price level was estimated at US\$ 4,890 million consisting of US \$ 1,667 million for civil works, US \$ 1,907 for electromechanical works and transmission lines, and the remaining 1,316 million for access, infrastructures, resettlement and environmental mitigation, engineering and administration, etc.

## vii. Economic Evaluation:

- The equivalent economic cost of the project for the November 2003 in service date is US \$ 6,808 million.
- The corresponding gross economic benefit was US \$ 16,780 million and net economic benefit is US \$ 9,972 million.
- The benefit /cost ratio was 2.46 and the corresponding internal rate of return is 27%.
- The net economic benefit would be equivalent to about US\$ 1,000 million per year to be shared between the two countries.
- These economic measures demonstrate that the project is feasible and economically very attractive.

# The Need for 1989 Feasibility Study

- None of the earlier studies considered multipurpose aspects of development, though limited consideration was given to the potential for irrigation development in the Terai region in Nepal, but quantitative evaluation was not carried out.
- Although it was recognized that there would be significant variations in flow from the power plant, no studies were carried out to reregulate flows released downstream of Chisapani.
- Earlier studies recognized that the power plant capacity was largely controlled by the size of the Indian power market.
- Recognizing potential growth of Indian power system recommendations were made to make provision for increased generating capacity.
- However, none of the studies considered a development at Chisapani utilizing the full resource potential of this site.
- With continued interest of GON and GOI in Chisapani project; steps were taken during 1970s and 1980s to proceed with development of the project.
- A bi-national policy level committee named “Committee on Karnali” was formed in 1978 and subsequently, a technical level committee consisting of technical experts from Nepal and India named “Karnali Coordinating Committee (KCC)” was formed in 1983.

# The Need for 1989 Feasibility Study

- As a result a Final feasibility study was deemed necessary and GON decided to carry out a comprehensive Study to meet all requirements of a major multipurpose development, consistent with the norms of international lending institutions.
- Selection of suitable dam site in consideration to the relative merits of the two alternative dam sites.
- Optimum development as a multipurpose project in consideration of all possible water related benefits.
- Recognizing the role of the project in an integrated basin development, it was desirable to ensure that the selected development was reasonably compatible with the most likely overall development of the water resources potential of the entire Karnali basin.
- To address the need of comprehensive study of the project compatible with international norms for feasibility studies; more work was required on field investigations, engineering designs, cost estimates, benefit evaluations, socioeconomic resettlement and environmental studies.
- And above all, to address the technological changes in construction of major dams and hydro projects over the past 20 years.

**CHAPTER - 3: REVIEW OF FEASIBILITY STUDY**  
**DEC. 1989**

# Scope of Present Review

- The scope of this review, include the following:
  - i. Assessment of demand-supply in Nepal and in the regional countries,
  - ii. Updating of hydrological studies (using longer years of rive flow and meteorological data now available; refining the hydrological modelling using GIS and remote sensing technologies),
  - iii. Updating of geological, geotechnical and seismic studies/ investigations,
  - iv. Carrying out dam break/ safety studies
  - v. Project optimization (including dam height) to match the regional power market, and in light of the prevailing environmental and social, and safety concerns,
  - vi. Design of the structures (dam--RCC, rock fill, or concrete gravity dam, power house- - underground v/s surface),
  - vii. Project cost and benefit assessment (irrigation, flood control, navigation, and so on)
  - viii. Assessment of cost of generation,
  - ix. Studies on environmental and social safeguards,
  - x. Power evacuation related studies,
  - xi. Assessment of institutional, regulatory and legal issues of cross border power trade
  - xii. Study of the regional power market,
  - xiii. Design of the project governance structure for regional development of the project,
  - xiv. Implementation and financing modality,

# Documents Reviewed for this Study

Inter-alia previous studies and other reports, the main focus of this review were the following documents:

- Karnali (Chisapani) Multipurpose Project; Feasibility Study, Main Report, December 1989
- Karnali (Chisapani) Multipurpose Project; Feasibility Study, Executive Summary, January 1990
- Annexure:

Annex A: Geology and Site Investigation	Annex B: Construction Materials	Annex C: Seismology
Annex D: Hydrology	Annex E: Sedimentation	Annex F : Reservoir Simulation
Annex G: Power System Studies	Annex H: Project Optimization	Annex I : Main Dam
Annex J: Power Facilities	Annex K1: Spillway	Annex K2: Diversion and Outlet Facilities
Annex L: Reregulating Facilities	Annex M1: Irrigation Development within Nepal	Annex M2: Irrigation in India
Annex N: Environmental Impact and Mitigation	Annex O: Socioeconomic and Resettlement	Annex P: Construction Planning
Annex Q: Capital Cost Estimate	Annex R: Project Evaluation	

# OUTCOME OF THE REVIEW STUDY

# SITE INVESTIGATIONS

A comprehensive programme of field investigations were found to be executed by HPC as part of site investigation. The assessment is found to be based on interpretation of extensive data sets from site investigations during the study period by HPC and those investigations carried out under previsions studies carried out in 1966 and 1977.

■ **Topographic mapping** : Aerial photography, ground control surveying and topographic mapping were carried out in 1986 and 1987 by Kenting Earth Sciences Ltd. under subcontract to Himalayan Power Consultants (HPC) and the following topographic maps were found to be produced.

- 12.5 km<sup>2</sup> at the damsite at a scale of 1:10,000 with 1-m contours
- 460 km<sup>2</sup> of the reservoir area at a scale of 1:10,000 with 5-m contours
- 3901 km<sup>2</sup> of the western Terai at a scale of 1:10,000 with 1-m contours

■ **Observation:** *This information is generally sufficient given the nature of the project site. However, it is essential to update the topographic maps to take into account the recent infrastructure development in the area, using the latest technologies such as LIDAR mapping technologies.*

# Geological and Geotechnical Investigations

Carried out in two stages—Stage A, and Stage B. The Stage-A: for the selection of a damsite location and the Stage B investigation were concentrated at the selected upstream of the damsite, the area of the reregulation facility and the borrow areas to provide data for feasibility design.

The investigations carried out for the underground works comprised five elements: geological mapping, geophysical survey, core drilling, aditing and rock testing. The investigation includes about 3200 m of core drilling and almost 700 m of exploratory adits. Points of particular interest are angle core drilling under the river and deep holes and adits into the area of the underground powerhouse complex.

- **Observation:** *The investigations are generally comprehensive except investigation on geological and hydraulic conditions in the fan area. Investigation on geological and hydraulic conditions in the fan area affecting design and cost of the reregulating facility needs to be done. Besides, further geological/geotechnical investigations might be necessary for the detailed engineering design of the project. Such additional investigations may also include in situ tests. The consultant (to be hired for the updating of the feasibility study) will determine the scope of additional investigations, and carry out investigations subject to the approval of the Employer .*

# Investigation on Hydrology and Sedimentation

**Hydrology:** Station 280 located immediately downstream from the damsite was used for flow measurement, between July and September 1987. A shore-based system from the existing wire rope cableway was used for this purpose.

**Sedimentation:** Channel hydraulic characteristic and bed material sizes were determined in April and September 1987 along an 8 km stretch of the Karnali River upstream of the damsite and along the river Bheri. Three cross sections were surveyed on the Karnali River upstream of the damsite and four on the river Bheri. Water surface profiles were measured along both reaches. A total of 12 bed material samples were taken and their gradation determined. A total of 403 suspended sediment sample were taken and were analysed.

■ **Observation:** *In the past 20 years since the time HPC study was carried out, there are additional hydrological data available. Also, there has been significant change in the land use pattern in the river catchment, impacting the sediments concentration in the river. Supplementary data collection on hydrology and sedimentation during the study period to refine them, It is essential to review the hydrological data, and take sample measurements of suspended sediments in the river and that of the river bed sediments.*

# Environmental and Social Surveys

The baseline information on a variety of resources in the reservoir and downstream areas within Nepal was collected by a survey team travelling on foot and by boat.

Several helicopter and fixed-wing reconnaissance flights were made over the reservoir area and along the lower Karnali, to gain an overall impression of the geomorphology, and the extent and condition of the forest and agricultural resources.

Extensive socio-economic with a total of 7448 interviews were carried out to obtain a data base for socioeconomic studies and resettlement planning of the population living in the impact areas.

## ■ **Observation:**

- *Environmental survey has to be updated to reflect the current information on the condition of the forest and agricultural resources to conduct , full-fledged Environmental Impact Assessment (EIA), Cumulative Impact Assessment (CIA), Social Impact Assessment (SIA), Rehabilitation Action Plan (RAP).*
- *The social economic surveys (census and sampling) need to be redone as the population in project area has increased significantly in the past 20 years. Further, the socio economic conditions of the people have undergone significant transformation in that period, as people are moving away from the subsistence farming to other trade, foreign employment and so on.*

# Observation on Geology & Construction Materials

- **Geology:** *HPC has made conservative assumptions in the design of major structures and has recommended carrying out detailed geological investigation at these location during detailed design stage of the project.*
- *It is recommended that as part of the updating of the feasibility study, the consultant will review the geology at the reservoir, dam site and reregulating facility and update as necessary, and identify the additional geological and geotechnical investigations to be carried out and carry out the investigations.*
- **Construction Materials:** HPC study concludes that the material required for Chisapani project (A total of about 60 million m<sup>3</sup> of construction materials; consisting of 9 million m<sup>3</sup> of impervious materials, 39 million m<sup>3</sup> of shell fill, 6 million m<sup>3</sup> of filters, 4 million m<sup>3</sup> of aggregates, and 1.5 million m<sup>3</sup> of Riprap} should be obtained from terrace deposits extending downstream along the banks of the alluvial fan.
  - *The information on construction materials including the core fill materials needs to be updated during updated feasibility study of the project*

# Hydrology

- ❑ The existing 36 meteorological stations located within the Karnali basin and 21 stations from the adjacent basins form the basis of data network that were used for hydrometeorology studies.
- ❑ There are five principal gauging stations located in Karnali basin, operated by Department of Hydrology and Meteorology (DHM).
- ❑ A flow gauge was set up near the mouth of the gorge at the Chisapani damsite in 1961 and the flow records are available since then.
- ❑ HPC used 25 years of flow data from 1962 to 1986; and has opined that the 25 year flow sequence is quite adequate for feasibility study purposes.
- ❑ The average long-term flow is estimated at 1389 m<sup>3</sup>/s.
- ❑ There is a marked seasonal variation in flows with a distinct seasonal variation. Average monthly flows range from 309 m<sup>3</sup>/s in February up to 4359 m<sup>3</sup>/s in August.
- ❑ The peak flood recorded was about 21,000 m<sup>3</sup>/s in 1983. The PMF used for design of the spillway has a peak inflow of 63,000 m<sup>3</sup>/s.

## ■ **Observation:**

*The updated feasibility study requires reviewing the hydrology, and updates them to incorporating the additional flow information available in the intervening periods.*

# Sedimentation

A total of 403 samples of suspended sediment, representing on 318 occasions, were collected on average every 6 hours from July through September 1987. The suspended sediment measured load over the 3 months was estimated at 84 million tonnes. 1987 was a low flow and low flood year for Karnali River, thereby requiring some adjustment. HPC study estimated 260 million tonnes as the annual average applying sediment rating curve derived from the 1987 data and consideration of sediment loads measured for other basins in the subcontinent.

## ■ **Observation:**

- *The updated feasibility study requires reviewing the hydrology, and updates them incorporating additional information from the field investigations/measurements to assess the current status of the sediment load in the river induced by the changed land use pattern in the river catchment. Further, as suggested by the HPC study, the updated feasibility study will also require to carry out an assessment on the potential for river channel degradation downstream of Chisapani especially at the downstream of Girjapur barrage, quantify the likely impact and identify mitigation measures.*

# George and Dam type Selection

The Karnali gorge is 4 km long. Two dam sites identified at this gorge are:

- **Upstream Damsite:** situated 2 km upstream of the mouth of the gorge is narrowest and deepest section, providing specific site advantage. Both the embankment type and concrete gravity type dam are considered at this site.
- **Downstream Damsite:** with relatively wide gorge close to the existing access facilities and sources of construction materials. The river level is about 1 to 2 m lower, giving a small increase in head at the same reservoir level. Only embankment type dam is considered at this site.
- **Damsite Selection:** HPC study considered five different aspects of comparing dam type alternatives at both the sites; viz, cost comparison, technical acceptability, impact of possible optimization changes to reservoir levels and installed capacity, comparison with previous studies and concluded that the embankment dam at the upstream site was confidently selected in consideration to this analysis.
- **Observation:** *The consultants to be hired for updating of the feasibility study would review the location of the dam and the dam type and make recommendations on the location and the dam types.*

# Project Optimization

Objective : The objective of the optimization studies was to determine the optimum size of the project taking into account all the multipurpose benefits and the long-term potential for development in the Karnali River basin.

- The optimization was carried out comparing costs and benefits for the project; primarily as an economic analysis expressed net benefits (B-C) and benefit/cost (B/C) ratios. The project was optimized considering only power benefits in consideration to uncertainty in the value of additional irrigation benefits due to increased reservoir storage. However, the study confirmed that almost the entire reservoir sizes considered is capable of providing the maximum identifiable downstream irrigation flow demands.
- The range of alternatives considered in the optimization study are: (i) the FSL varying from el 370 masl to 430 masl, (ii) Drawdown varying from 40 m to 70m, and (iii) the installed capacity corresponding to 20% to 30% Capacity Factor (CF).
- The HPC study considered the range of project Capacity Factors from 20% to 30% as suggested by the Indian delegation to the Karnali Coordinating Committee (KCC)
- The evaluation of these three alternative generating capacities were studied and found that the most economic capacity is the maximum, 10 800 MW at 20% CF.

# Project Optimization (Contd.)

- After the initial optimization as an independent hydro project for power exports, the HPC study also evaluated the impact of upstream Karnali hydro project development on Chisapani project. Finally, the influence of other project benefits, such as irrigation and flood control on the optimum project size was considered.

Reservoir FSL	EI 415
Reservoir MOL	EI 355
Installed Capacity (18x600 MW)	10 800 MW
Firm plant capacity at MOL	9 000 MW
Extreme reservoir level at PMF	EI 443.6 m, although levels higher than 420 m are extremely rare
Tail water level	195 m ; 3 units running
	209 m; PMF conditions
Full plant discharge at MOL	5880 m <sup>3</sup> /s @ 327 m <sup>3</sup> /s/unit
Full Plant discharge at FSL	7110 m <sup>3</sup> /s @ 395 m <sup>3</sup> /s/unit

- **Observation:** *The updated feasibility study requires carrying out project optimization study in consideration to (i) multipurpose benefits (ii) the South Asian power market, (iii) financial and institutional concerns from the regional perspective.*

# Reservoir Simulation

- ❑ Reservoir simulations were used to define the power and energy capability for the numerous project combinations used in the Stage-A optimization studies and also, for the selected project arrangement at Stage B.
- ❑ Majority of the simulations considered Chisapani project reservoir alone.
- ❑ series of multi-reservoir simulations also analyzed the impact of the potential future development of upstream hydro project and ultimate full development of Karnali basin.
- ❑ Operation of Chisapani project would be influence by operation of other hydro projects connected in the system and vice versa.
- ❑ The normal result in such cases is that the capability of the system as a whole is greater than the sum of the individual project capabilities.
- ❑ A system simulation of the Northern India hydro system including Chisapani could not be performed in the absence of large amount of consistent data.
- ❑ A modest system simulation with Chisapani was carried out for the Nepal hydro system.
- *Observation: it is proposed that as part of the updated feasibility study, the consultant will carry out the system simulation in light of the upstream development in the Karnali river basin (on-going and proposed), and current generation capacities (in the regional countries and the demand for electricity). The other upstream storage type hydropower development (such as West Seti, Nausalgad) will further firm up the energy generation capacity of Karnali Chisapani. It is also required to consider the influence of these developments on project benefits such as irrigation and flood control.*

# Observation on Project Benefits

## ■ Power Benefits:

- The Chisapani project has been designed as a peaking hydro plant for power exports to the Northern Indian power region of India and hence it was optimised accordingly. *As only a few cost data was available from official Indian sources; unofficial sources and reasonable assumptions for comparative generation cost characteristics (capital cost, fuel costs, and Unit cost of generation) used in the feasibility study would result in to estimated power benefits less than the actual. The updated feasibility study needs to estimate the power and energy benefit by collecting information from official sources.*
- *Power Benefits: As the project is being optimised for reasonal power market, the updating of the feasibility study of the Karnali project requires to review the power market both in Nepal and in the region. For this, the consultant will prepare electricity demand forecasts in the regional countries, and the generation technologies that are likely to be displaced by the project and then determine the power benefits of the Karnali project.*

■ *Irrigation Benefits: As the pertinent data/information on irrigation potential was not available from relevant official sources, the benefit were evaluated both with and without the Chisapani project. The benefit estimation was made the available information from relevant Indian reports on water and land use concepts throughout the Ghagra/Ganga plain.*

# Observation on Project Benefits

- *Flood Benefits : The study has estimated flood benefits farther downstream in India and Bangladesh. It, however states that such benefit in India and Bangladesh are very uncertain due to lack of data. Thus the total flood control benefits appear to be far less than actual irrigation benefits. The updated feasibility study requires collecting relevant data in Nepal, Bangladesh and India and refining the flood control benefits.*

- *Navigation Benefits: the study has stated that downstream navigation benefits are not significant given the river transport is not economically competitive with alternative mode of transport, it may be worthwhile to revisit this conclusion backed up by a detailed analysis.*

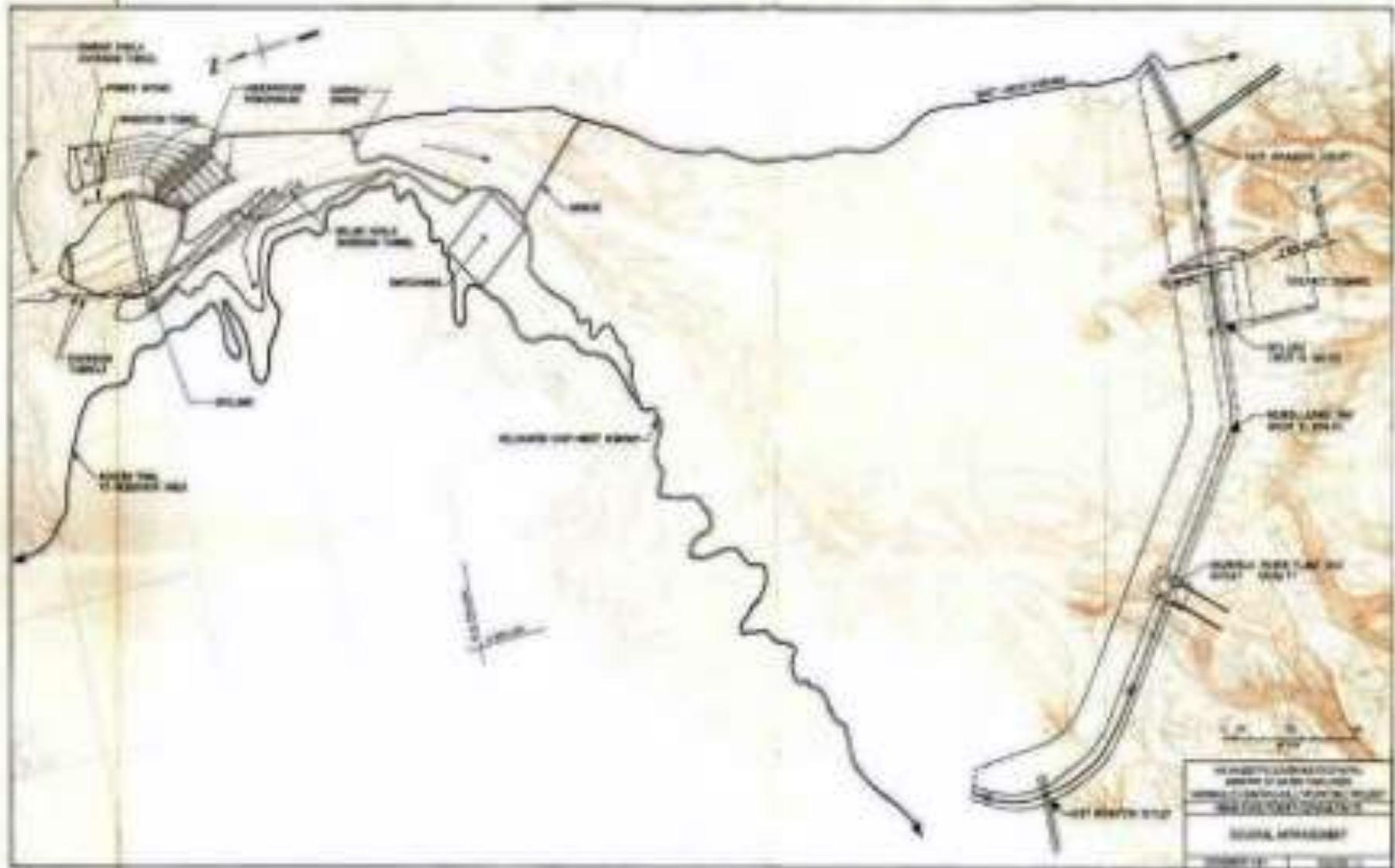
- *Observation: it is essential to estimate the power benefits, irrigation benefits, and flood control benefits using updated information from official sources of GOI.*

# Project General Arrangement

The general arrangement of Karnali (Chisapani) Multipurpose Project consists of the following five main features

- Main civil structures consisting of (i) the Dam and Spillway; (ii) Power Facilities including intake, power tunnels, penstock shafts together with penstock, powerhouse and tailrace
  - Hydromechanical equipment including gates, stoplogs, and penstock pipes, etc.
  - Electromechanical equipment including turbines, generators, power transformers, etc.
  - The transmission facilities which deliver the power to Indian power system
  - Reregulating facilities
- *Observation: The updated the feasibility study requires to review the project arrangement and dimensioning of various project structures and recommended improvements backed up by necessary physical and computational (numeric) hydraulic modelling exercises.*

# Project General Arrangement (Contd.)



# Power Facilities

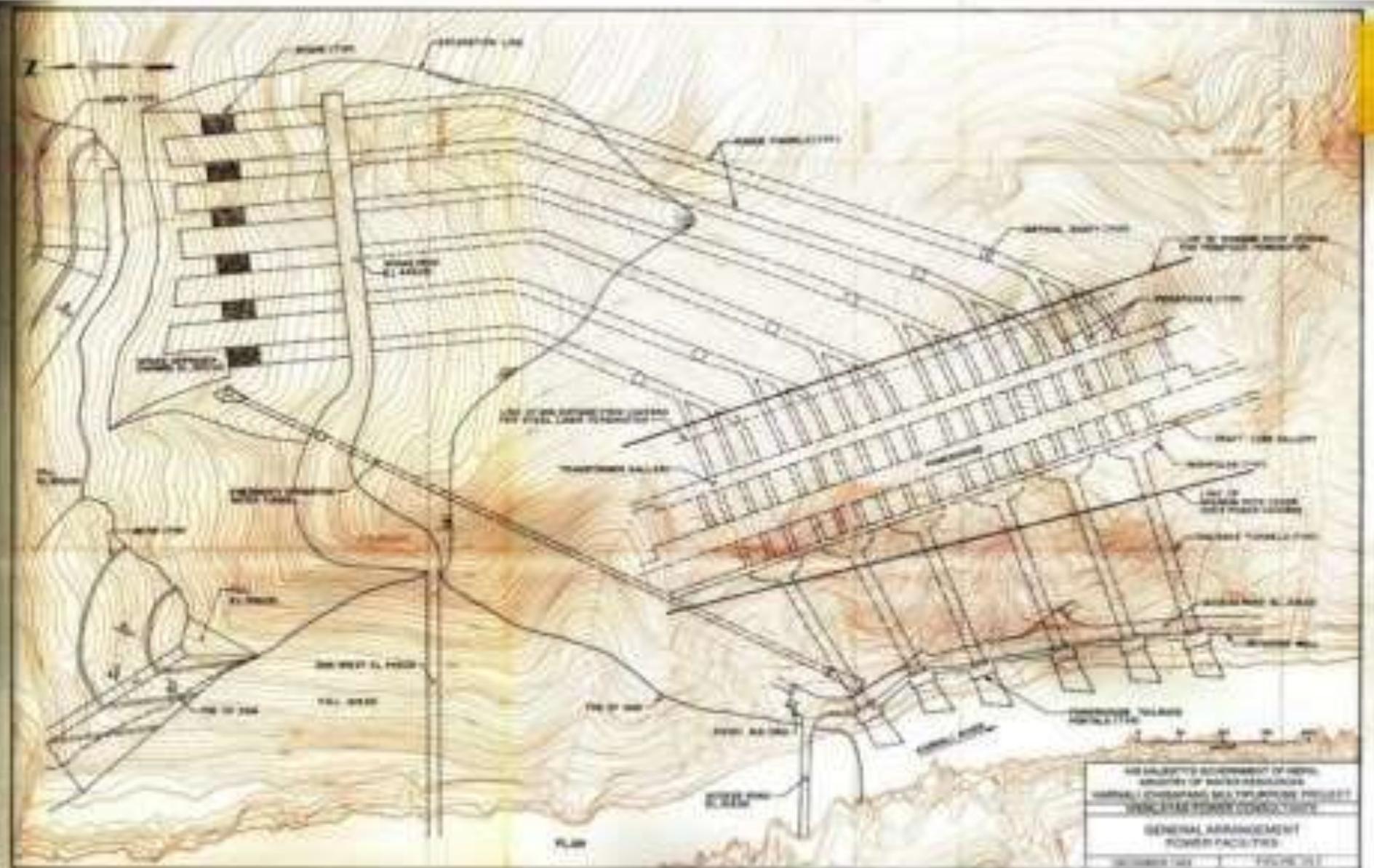
The main components are:

- The power intake
- Six horizontal power tunnels, vertical penstock shafts and penstock manifolds with 18 steel lined penstocks
- The underground powerhouse complex—the powerhouse cavern housing 18 units and an upstream transformer gallery, downstream draft tube gallery, associated cable and ventilation shafts and access tunnels
- Six tailrace tunnels exiting immediately downstream from the dam

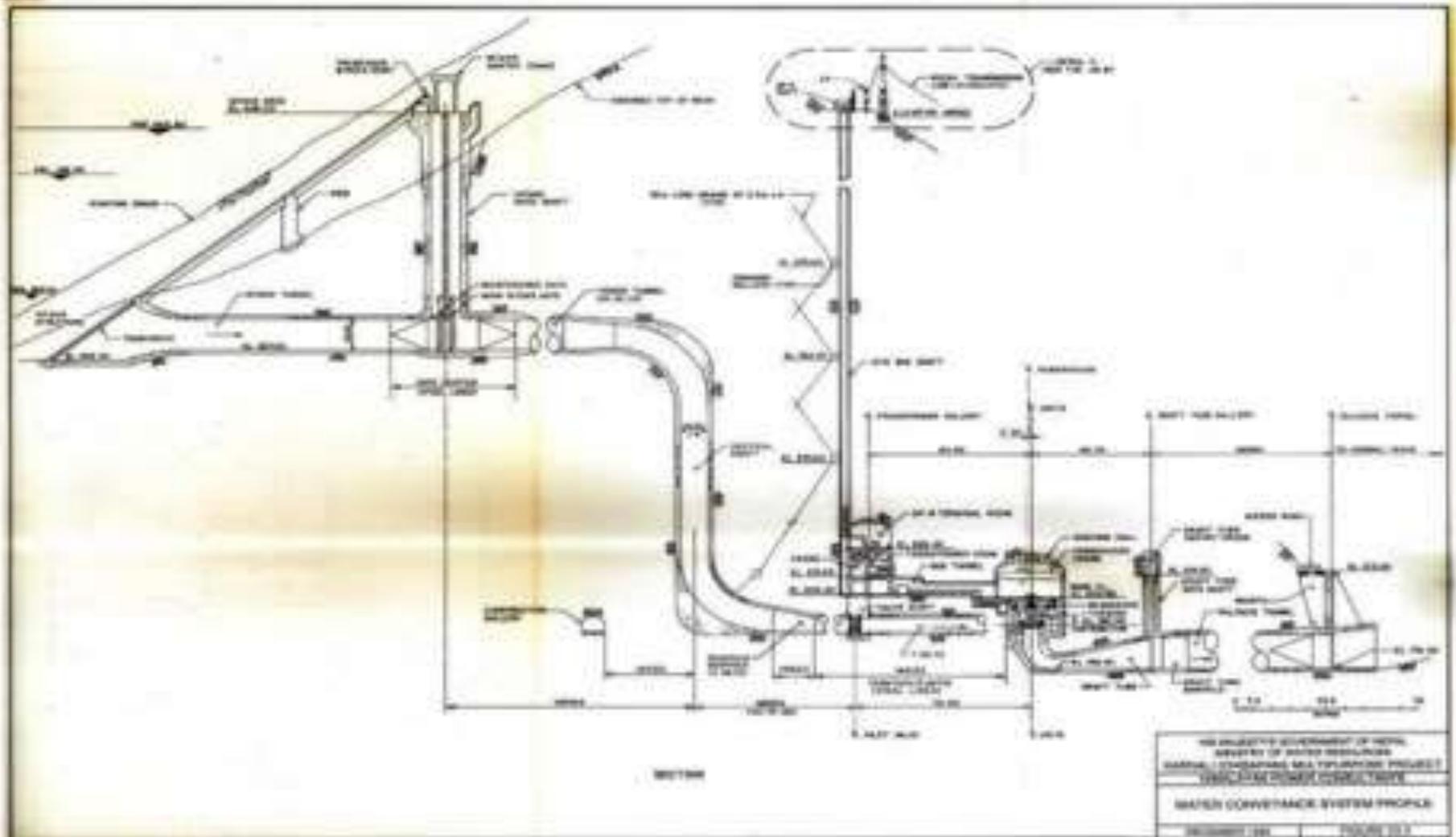
Description	Diameter (m)
Power Tunnels	15.0
Penstock shafts	14.0
Steel lined Penstocks	7.2
Tailrace tunnels (Width x Height)	15x18 (horseshoe)

- *Observation: A review of the power facilities (civil) is suggested to incorporate the most current design practices.*

# Power Facilities



# Power Facilities



# Power Facilities (Electrical – Mechanical)

- Operation : Mode of operation of the power plant (HPC study)
  - Peak system demands (North India) : Dec,- March & April-June, to produce 2074 MWc; no units would be scheduled for maintenance.
  - Remaining 8 months the target firm energy : 1602 MWc.
  - Monsoon (Aug, to Oct.), continuous generation at full capability possible.
  - Annual maintenance (lower demand months)of April and July to Nov. inclusive,
  - The large short duration plant discharges during peaking operation are regulated at the d/s regulating facility to maximize irrigation benefits in India and mitigate disturbance in the natural riverine environment.
  
- Observation: *it is likely that the current profile of electricity demand may have undergone some change as compared to the one prevailing at the time of the HPC study. For example, currently India experiences two peak periods, one in summer (April- June), and another in winter (December-March).Accordingly, the annual maintenance may be scheduled in the lower demand months outside of the peak periods. The consultant to be hired for updating the feasibility study will collect the information on the latest load profile and suggest maintenance schedule accordingly and also plan the reregulating facility for maximum irrigation benefits.*

# Power Facilities (Electrical – Mechanical)

- The report has described major power plant equipment such as turbine and governors, turbine inlet valves, power house cranes, generators, 18/400 kV transformers, exciters, auto transformers, switchgears, electrical auxiliary services, etc.

<b>Turbines</b>	<b>18 units @ 600 MW at design head of 185m</b>
<b>Generators</b>	<b>18 units @ 642 MVA; generating voltage : 18 kV</b>

- **Electrical Main Single-Line Scheme: Scheme B:** The second scheme (Scheme B) consists of a single stage transformation from 18 kV to 765 kV with a bank of three single-phase transformers, and utilization of GIS switchgears and bus ducts to supply five 765 kV single-circuit transmission lines to deliver power to India is recommended.
- *Observations: The updated feasibility shall review the technological options for the switchyard schemes in light of the current level of technology, and recommend the one which is technologically superior and economically feasible. The study should also look into the unit size of the turbine generators, as there is a possibility of having higher capacity Francis turbines.*
- *Observation: A review of the power facilities (civil) is suggested to incorporate the most current design practices.*

# Power Evacuation

- The power system study for the power evacuation to India was not carried out for lack of information, and was expected to be carried by Central Electricity Authority (CEA) in India. The system study for Nepal was however carried out.
- *Observation: The updated feasibility study should include carrying out of a comprehensive power system study of the regional countries to identify the system reinforcement needs for the power evacuation for Karnali Chisapani.*

## Construction Planning & Scheduling

- The Contract packages are basically envisaged in three Lots; one for access and Infrastructures construction/improvement/upgrading, the other for the main civil works and the third for equipment.
- *The consultant to be hired for the updating the feasibility study will suggest the construction methods in light of the current construction practices. The slicing of the contract packages shall also be reviewed and changes suggested if there is a possibility of reducing the project costs, implementation time and construction risks.*

# Environmental and Social Impact

- The most significant environmental impacts expected to result from the construction and implementation of the project and the proposed mitigation measures to mitigate the negative impacts is presented in the Feasibility study Report. No assessment of Environmental impacts within India has been made.
- The feasibility study has covered the environmental impact due to the reservoir and change in flow regime, impact on water quality, on agriculture forest resources, and wildlife.
- The report has proposed a number of mitigation, compensation and enhancement measures; proposed to reduce the environmental impacts of the project.
- **Resettlement** of some 60,000 people displaced by the project (mostly from the main reservoir area). Resettlement areas totalling 12,650 ha have been identified,
- *Observation: On the environmental impact assessment, a fresh study need to be done as part of the updated feasibility study to align the study in line with the requirements of the Environmental Protection Act (EPA) 1997 and Environmental Protection Rules (EPR), 1997,*

# Socioeconomic Impact and Resettlement

- The HPC report has identified the displacement the population of 38,000 persons within the area to be flooded by the Chisapani reservoir as a major socioeconomic impact.
- *Observation: The socioeconomic conditions of the population in the project-impacted areas have undergone a significant transformation in recent years, due to improved road, communication and other infrastructure, providing opportunities for alternative employment. Thus the HPC study on socioeconomic impact is now outdated. Resettlement of the people directly affected by the project will be a major issue to be looked at carefully and resettlement plans to be prepared in detail.*
- *The updated feasibility study requires to redo the socioeconomic impact assessment to reflect the current situation and meet the requirements of EPA and EPR. To enhance the acceptability of the social impact assessment to funding agencies, it is suggested that the social safeguard studies should be carried out in line with the environmental and social safeguard policies of the multilateral funding agencies.*

# Project Cost

- The project cost estimate at 1988 prices is presented in the table.

<b>Civil works cost</b>	<b>US \$1,667 million</b>
Electromechanical equipment	US \$1,575 million
Transmission Cost	US \$332 million
Access and infrastructure	US \$280 million
Engineering and management	US \$385 million
Resettlement and environment	US \$232 million
Contingencies	US \$419 million
Total project cost	US \$4,890 million

- *Observation:.. The consultant to be hired for updating the feasibility study shall review the project cost to reflect the current cost of materials, labor and equipment, and the costs of land acquisition and rehabilitation of the project affected people.*

# Economic and Financial Analysis

- The HPC study has evaluated and quantified the (i) power benefits, (ii) irrigation benefits; (iv) flood control benefits, and (iv) navigation benefits and performed economic analysis.
- *Observation: In the updated feasibility study, the consultants shall carry out benefits calculations of electricity taking into account the current opportunity cost of electricity in the regional countries from this project developed as a regional project. The current generation mix will determine the type of electricity generation, which will potentially be displaced by the Karnali Chisapani project, and hence the power benefits.*
- *The irrigation and flood control benefits should also be re-evaluated taking into account the current opportunities for the same.*
- *In respect of navigation benefits, the consultants may review if there are new opportunities for enhanced navigation upstream and downstream of the project.*
- *The consultants engaged for the updated feasibility analysis will have to carry out the economic analysis with updated cost and benefits calculation.*

# CHAPTER-4: DEVELOPING KARNALI CHISAPANI AS REGIONAL HYDROPOWER PROJECT

# Energy Resource Endowments of SAARC Countries

Country	Coal (mill. tons)	Oil (mill. .barrels)	Natural Gas (TCF)	Biomass (mill. tons)	Hydro (GW)	Solar Power (kWh/sqmts./day	Wind (MW)
Afghanistan	440	NA	15	18–27	25	NA	NA
Bangladesh	884	12	8	0.08	0.33	3.8-6.5	V. Ltd.
Bhutan	2	0	0	26.6	30	2.5-5	4,825
India	90,085	5,700	39	139	150	4-7	151,918
Maldives	0	0	0	0.06	0	NA	NA
Nepal*	NA	0	0	27.04	83	3.6-6.2	3,000
Pakistan	17,550	324	33	NA	59	5.3	24,000
Sri Lanka	NA	150	0	12	2	NA	25,000
<b>Total</b>	<b>108,961</b>	<b>5,906</b>	<b>95</b>	<b>223</b>	<b>349.33</b>		

# Electricity Generation Installed Capacity of SAARC Countries

S. No	Country	Installed Capacity (MW)
1	Afghanistan	1,341
2	Bhutan	1,614
3	Bangladesh	12,578
4	India	315,426
5	Nepal	898
6	Sri Lanka	4,050
7	Pakistan	24,829
8	Total	360,689

Source: SARI/E, Task Force 1 Report -IRADe Report on CBET in South Asia: Challenges and investment opportunities, etc.

\*DOED, MOE, GON

# Access to Electricity in South Asia

S. No	Country	Percentage of Population with Access to Electricity
1	Afghanistan	15.6%
2	Bangladesh	41%
3	Bhutan	60%
4	India	66.3%
5	Maldives	100%
6	Nepal	43.6%
7	Pakistan	62.4%
8.	Sri Lanka	88%

Source: [http://apod.nasa.gov/apod/image/0011/earthlights2\\_dmisp\\_big.jpg](http://apod.nasa.gov/apod/image/0011/earthlights2_dmisp_big.jpg)

# Per Capita electricity Consumption of SAARC Countries

S. No	Country	Per Capita Electricity Consumption Per Year (kWh/year)
1	Afghanistan	49
2	Bangladesh	259
3	Bhutan	977
4	India	684
5	Maldives	521
6	Nepal	106
7	Pakistan	449
8	Sri Lanka	490
9	World Average	2,782

Source: SEC; Development of a Potential Regional Hydropower Plant in South Asia: A Pre-feasibility Study

# Country Wise Hydropower Potential of SAARC Member States

S. No	Country	Potential (MW)	Techno-economically Feasible (MW)	Present Generation (MW)	Generation Capacity %
1	Afghanistan	23,000	18,400	298	1.625
2	Bangladesh	1,897	775	220	28.39
3	Bhutan	30,000	23760	1,484	6.25
4	India	150,000	84,400	40,195	47.62
5	Maldives	0	0	0	0
6	Nepal	83,000	42,130	743	1.76
7	Pakistan	100,000	60,000	6,928	11.54
8	Sri Lanka	4,000	2,423	1,628	67.19
9	Total	391,897	231,888	51,496	22.21

Source: SEC; Development of a Potential Regional Hydropower Plant in South Asia: A Pre-feasibility Study

# Developing Karnali Chisapani as a Regional HEP

- The project (10,800 MW Capacity) in addition to fully meeting **Nepal's demand** can meet significant part of the energy demand in SAARC Member States.
- **Joint development** by SAARC countries will facilitate early financing of the project.
- **Participating countries will Offtake 100% energy** generated, thereby assuring a steady stream of revenues and timely debt servicing.
- Spreading of risk through **multiple shareholding** will help reduce the financing costs.
- **DFIs** promoting regional energy cooperation in South Asia **will provide financing**, technical assistance and support in other forms.
- “*SAARC Framework Agreement on Energy Cooperation (Electricity)*” signed by the member states commits them to **facilitate electricity flows across SA**; obviating the need to obtain the right of way for transmission corridor for Karnali Chisapani HEP.

# Developing Karnali Chisapani as a Regional HEP

- **Energy cooperation** has the potential to encourage cooperation **in other sectors** as well, leading to long-lasting peace in South Asia.
- Following **further studies need** to be undertaken to fully assess the economic benefits:
  - **Power Market Study** of SAARC Member States.
  - **Willingness and affordability** of consumers to pay for power from Karnali Chisapani.
  - **Power System Studies** to evacuate energy from the project
- **“Energy Security for South Asia”** co-authored by D. N. Raina, et. al. highlighted the need to harness hydro resources in SA to meet the energy demand in the region.

# CHAPTER -5 : TERMS OF REFERENCE FOR HIRING CONSULTANTS

# OBJECTIVE FOR HIRING CONSULTANTS

- The main objective of hiring Consultant is to prepare the Project for implementation from the current level of Feasibility Study.
- The overall objective of the consulting service is to update the Feasibility Studies in considerations of the project as a regional project of multipurpose nature with storage for irrigation, electricity generation, flood mitigations, etc.: and
- Conduct environmental and social studies of KCMP in Phase I and carry out Detail Engineering Design along with detailed structural design of the project and preparation of construction drawings and schedules and to prepare tender documents inclusive of tender drawings and construction plan in Phase II.

# Phasing out of the Consultancy services

## ■ Phase-I:

- Review and update the HPC feasibility study, conduct environmental, social and associated studies relating to the power market, power systems and willingness of consumers to pay for the electricity from the Karnali project.
- Overall evaluation of the project in view of the changed electricity scenario in the region and assess the suitability of implementing the project based on the findings of the Phase-I studies
- Carryout financial structure and plan including potential source of financing along with the associated modalities for implementation of the project as a regional hydropower project
- Risk Analysis on quantitative as well as qualitative basis with respect to the implementation of the project as a regional hydropower project

# Phasing out of the Consultancy services (Contd.)

## ■ Phase-II:

- Carry out mathematical modelling and conduct physical modelling of dam, spillway and intake structures;
- Conduct Detail Engineering Design of the project components including detailed structural design and prepare detailed design drawings (construction drawings) and schedules.
- Refine project benefit streams inclusive of all downstream benefits.
- Refine project cost including cash flow and other details, construction schedule, economic and financial analysis; \Prepare complete tender documents and tender drawings, including tender drawings.

# Detail Scope of Services in Phase I

- Task 1 Inception Report on the Assignment
- Task 2 Review and Update Site Investigation and Studies
- Task 3 Review and Update Hydrological, Meteorological and Sedimentological Studies, etc.
- Task 4 A Regional Power Market and associated studies
- Task 4 B Willingness and affordability of consumers
- Task 5 Review and Update Power Evacuation Study
- Task 6 Review and update project configuration and project components
- Task 7 Review and Update Project optimization Study
- Task 8 Review and Update Reservoir simulation
- Task 9 Review/update and conduct Environmental Impact and Safeguard Studies
- Task 10 Review and update project benefit streams
- Task 11 Review and Update of Feasibility Studies
- Task 12 Analysis of Institutional Arrangement for Project Implementation

# Task 1: Inception Report on the Assignment

- Review of existing reports including Feasibility Study Report 1989, applicable guidelines/norms, available data
- Identify key areas, which will require additional field work or demand major efforts in data collection/ investigation
- Planning and initiation of the field work and up-dating of the work plan submitted with the proposal on the basis of the findings of the review
- Inception visit to the project site and carry out engineering studies with respect to the topographical and geographical features, hydrological, meteorological and sedimentological aspects, Geological, environmental and social aspects of the project area.
- Establish methods and procedures for further studies
- Preparation of Inception Report that summarizes the results of the review of existing data/ reports, summarize the results of the field reconnaissance, discuss the key data/information gaps requiring additional field work/investigation, and describe the approaches and methodology that the Consultant intends to follow in carrying out various activities to complete the assignment.

# Task 2: Review/Update Site Investigations and Studies

- **Objective:** Collect all reports of previous field studies and investigations of the project, then review and update them. Identifying the necessary data gaps to update the study based on refinements to the Project arrangement . The consultant shall then carry out required supplementary field investigation after getting approval from the client.
- **Topographical Survey :** Review the topographical maps prepared in the previous studies including feasibility study 1989 and conduct site verification works to identify any data gaps focusing on the planned engineering design changes under the scope of current study. LIDAR mapping of the project area including reservoir area with ground verification shall be carried out to update the topographical maps.
- **Hydrological, Meteorological and Sedimentological Investigation :** Review the hydrological, meteorological and sedimentological investigation carried out in the previous studies including feasibility study 1989 identify data gaps, if any, and acquire all relevant data from different secondary sources to update the feasibility study.
  - Supplementary data collection on hydrology and sedimentation during the study period
  - Investigation related to climate change
  - Investigation on possibility of aggravated erosion in the catchment area
  - A comprehensive investigation to reduce the long term reservoir sedimentation.

## Task 2: Review and Update Site Investigations and Studies

- **Geological, geotechnical and construction material Investigation:** Review the geotechnical; geological and geophysical investigation carried out in the previous studies including feasibility study 1989; identify data gaps, if any and carry out supplementary field investigation required for updated feasibility study in Phase I and detailed engineering design in Phase II.
- **Seismological investigations:** Determination of dynamic response profiles for accelerations and velocities applicable at different elevations shall be carried out for the Design Basis Earthquake (DBE) and Maximum Credible Earthquake (MCE). Investigation on possibility of reservoir induced seismicity
- **Investigation related to Glacier Lake Outburst Flood( GLOF).** and recommendation on the measures to minimize the risks of potential GLOF
- **Environmental and Socio-economic Survey:** Conduct full-fledged Environmental Impact Assessment (EIA), Cumulative Impact Assessment (CIA), Social Impact Assessment (SIA), Rehabilitation Action Plan (RAP) based on the current requirement of the Nepal environmental laws, and that of the multilateral funding agencies including World Bank(WB), Asian development Bank (ADB, etc. and the bilateral agencies.

# Task 3: Review and Update Hydrological & Sedimentological Study

- **Review the hydrological, meteorological and sedimentological studies** carried out in the previous studies including feasibility study 1989; assess the adequacy of available data and identify the gaps, if any and undertake the respective studies with the use of additional data series collected after the 1989 study to refine the long-term stream flow, flood frequency analysis including PMP and PMF, reservoir simulation, power potential, sediment flow assessment and climate change impacts which will be used for update of the Feasibility Study Report and subsequently in the Detailed Engineering Design in Phase II study.
- **Dam Break analysis** for the GLOF and PMF studies including recommendation of a framework for early warning system and evacuation plan.
- **Hydrological Study**
  - Long-term stream flow at Project site.
  - Flood frequency analysis and re-assessment of appropriate design flood.
- **Sedimentological Study:**
  - Assessment and estimation of sediment inflow , sediment yield to determine the capacity of dead storage and identification of the needs of sediment management measures
  - Investigation of alternative sediment management options including possibility of application of flushing, sluicing, density current venting etc. through mathematical calculations or numerical modeling
  - Qualitative analysis of Sediment

## Task 3: Review and Update Hydrological Study (Contd.)

- **Meteorological Study** : Assessment of meteorological aspects relevant during construction phase, such as length of the rainy season, rainfall characteristics, number and duration of rainfall events, dry interval between rainfall events, temperature etc
- Assessment of effect of dam construction on the river regime, particularly of downstream degradation and upstream aggradation and recommend appropriate measures to minimize the same.
- Assessment of meteorological aspects relevant during construction phase, such as length of the rainy season, rainfall characteristics, number and duration of rainfall events, dry interval between rainfall events, temperature etc.
- Reservoir simulation studies using appropriate computer model(s) in view of the seasonal power market, load pattern and future demand
- Assessment and estimation of flood flow due to Glacier Lake Outburst Floods (GLOFs), Cloud Outburst Floods (CLOFs) and Landslide Dam Floods (LDFs) for dam spillway design & safety.
- Determination of reservoir storage in consideration to load pattern and its growth potential, technical and economical aspects.
- Assessment of possible impact of upstream hydropower projects on the planned Karnali Chisapani Storage project
- **Climate Change Impact Study.** Assessment of possible impact of climate change on hydrological characteristics, erratic rainfall pattern on the availability of water and the water requirements using different scenarios (without climate change, low climate change and high climate change),

## **Task 4 (A) Regional Power Market study**

- Carry out the Power markets study of Nepal, Afghanistan, Bangladesh, India, Pakistan and Sri Lanka, the six beneficiary states of the project.

## **Task 4 (B) Review of willingness/affordability of consumers**

Examine willingness and affordability of consumers to pay for energy from Karnali Chisapani project, in participating Member States Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka.

## Task 5: Review and Update Power Evacuation Study

- Review of Power System Master Plans of Each SAARC Member State
- Identify the volume of cross border energy flows from Karnali Chisapani project that can be facilitated through the existing and proposed transmission systems in and between each of these countries and also identify the additional cross border interconnections required to facilitate energy flows from Karnali project.
- Associated transmission systems to wheel the energy from the Bus-Bars of Karnali Chisapani hydropower project to load centers in participating countries shall form an integral part of a feasibility study of the project.

## **Task-6: Review and update project configuration and project components**

- The objective of this Task is to confirm the optimum overall project configuration and the different project components general arrangement of Karnali (Chisapani)
- Multipurpose Project consisting of the following five main features and refine the design inconsideration to the field studies and investigations and study of different Tasks in Phase I of the study.
  - Main civil structures consisting of (i) the Dam and Spillway; (ii) Power Facilities including intake, power tunnels, penstock shafts together with penstock, powerhouse and tailrace
  - Hydromechanical equipment including gates, stoplogs, and penstock pipes, etc.
  - Electromechanical equipment including turbines, generators, power transformers, etc.
  - The transmission facilities which deliver the power to Indian power system
  - Reregulating facilities
- Review the project arrangement and dimensioning of various project structures and refine them by necessary physical and computational (numeric) hydraulic modelling exercises.
- Prepare engineering drawings of all the components of the project including hydro and electro-mechanical works, transmission lines and substations.

## Task-7: Review and update project Optimisation Study

- **Objective:** To determine the optimum size of the project taking into account all the multipurpose benefits and the long-term potential for development in the Karnali River basin.
- Review the optimization study performed in 1989 Feasibility study and update them adopting standard approach practiced in this industry,
- Carry out the optimization study in consideration of: (i) the South Asian power market, (ii) financial and institutional concerns from the regional perspective, in addition to accounting for all the multipurpose benefits and the long-term potential for development in the Karnali River basin.

## Task-8: Review and update Reservoir Simulation Study

- **Objective:** To assess the overall power and energy capability of KarnaliChisapani Project taking into account all the multipurpose benefits and the long-term potential for development in the Karnali River basin.
- Review the reservoir simulation study performed in 1989 Feasibility study and update them adopting standard approach practiced in this industry,
- Carry out the system simulation in light of the upstream development in the Karnali river basin (on-going and proposed), and current generation capacities (in the regional countries and the demand for electricity).
- Perform reservoir simulation considering the influence of these developments on project benefits such as irrigation and flood control.

# Task 9: Review/Update Environmental Impact and Safeguard Studies

- Review the environmental and social studies undertaken in 1989 Feasibility study and prepare a full-fledged EIA/SIA/RAP in accordance with the requirements of the Government of Nepal Environmental Protection Act, 1997 and Environmental Protection Rules, 1997 (with amendments), as well as latest World Bank (WB) and Asian Development Bank (ADB) guidelines with regard to environmental protection and resettlement. Terms of Reference (ToR) and Scoping documents as per the Environment Protection Act-1996 and Environment Protection Rules-1997.
- Baseline Survey in the entire project area including reservoir and its periphery
- Detailed qualitative and quantitative analysis of the anticipated changes to the baseline to determine the direct, indirect, induced and cumulative impacts of the project in construction, operation and maintenance phases.
- ACRP Preparation
- Buffer Zone and Affected Area Development Planning

## Task 9: Environmental Study (Contd.)

- Environmental and Social Management Plans:
- (i) Prepare Environmental Management Plan (EMP) covering, but not limited to, the following:
- (ii) Prepare a Resettlement Action Plan (RAP), and an Indigenous/Vulnerable People's/Community Development Plan (IPDP/VCDP) as part of Social Management Plan (SMP), with full participation of stakeholders. The plans shall, among others, include the following:
  - Full census survey including cadastral mapping
  - Environmental and Social Management Plans:
  - iii) Prepare Detailed Monitoring Framework to effectively monitor the implementation of various plans during construction and operation phase
  - f) Assess the capacity of the executing and implementing agencies to plan, manage, implement, finance, and monitor, and prepare capacity-building measures and training workshops for stakeholders.
  - g) Organize public hearings (at least two) in project affected area to discuss all the assessment done and mitigation measures suggested

# Task 10: Review and Update Project Benefit Streams

- **Objective:** Review the project benefits identified in the 1989 feasibility study and to estimate the multipurpose benefits including power benefits, irrigation benefits, and flood control benefits using updated information
- **Power Benefits:** Review the power benefits computed in the feasibility study 1989 and further study the current power market both in Nepal and in the region. For this, the consultant shall prepare electricity demand forecasts in the regional countries, and the generation technologies that are likely to be displaced by the project and then determine the power benefits of the Karnali project.
- **Irrigation Benefits:** Review the irrigation benefit computed in 1989 feasibility study and update them collecting relevant information on irrigation within the reach of the project both in India and Nepal from official sources.
- **Flood Control Benefits:** Review the irrigation benefit computed in 1989 feasibility study and refine them collecting relevant data in Nepal, Bangladesh and India
- **Navigation Benefits:** Carry out detailed analysis to compute navigation benefits in consideration to updated information within the reach of the project.

# Task 11: Review and Update Feasibility Study

■ Review and update shall include; among others; project optimisation study, reservoir simulation study, design of different project components including optimization of individual components, regional market study, estimation of updated cost, construction planning and economical and financial analysis of the project

- Review and Perform Design Studies
- Review and Update Construction Planning and Scheduling
- Review and Update Project Cost and Quantity Estimation
- Review and Update Economic and Financial Analysis of the Project

# Task 12: Analysis of Institutional Arrangement for Project Implementation

- Assessment of the institutional arrangement required for implementation of physical project of this size and complexity.
- Analyse financial structure and plan including potential source of financing (including investment by stake holder member states, international financial institutions, etc.) along with the associated modalities for implementation of the project as a regional hydropower project
- Analyze critically alternative institutional setups to smoothly carryout the implementation of the project
- Risk Analysis on quantitative as well as qualitative basis with respect to the implementation of the project as a regional hydropower project
- Propose organizational structure clearly defining the role of each position and responsibility and chain of command linking the entire organizational hierarchy.
- Identify the requirement of resources including Trainings, Workshops physical infrastructures, etc.

# Detail Scope of Services in Phase II

- Task 1 Inception Report on the Assignment
- Task 2 Review and update site investigation and associated studies including additional field investigations, if any
- Task 3 Detail Engineering Design, Specifications and Drawing
- Task 4 Model test study (Physical and Mathematical both)
- Task 5 Refinement of Project Cost & quantity estimation, Construction Planning and Scheduling, and Economic and financial evaluation
- Task 6 Preparation of Complete Tender Documents and Tender Drawings

## Task 2: Review and Update site investigation and associated studies

- **Objective:** Collect all reports of previous field studies and investigations of the project, then review and update them to use for detailed engineering study in Phase II.
- **Topographical Survey :** Review the topographical maps prepared in Phase I and update them, if needed; and incorporate them in the engineering studies in Phase II.
- **Hydrological, Meteorological and Sedimentological Investigation :** Review the hydrological, meteorological and sedimentological investigation carried out in Phase I study identify data gaps, if any, and acquire all relevant data from different secondary sources and refine the analysis to use in detailed engineering design in Phase II.
- **Geological/Geotechnical :** review the previous studies; identify data gaps, if any and conduct necessary investigations for detailed engineering study in Phase II study. after getting approval from the Client.
- **Seismological Investigation :** Review the seismological investigation performed in Phase I study and refine them for detailed engineering study.
- Review the GLOF study performed in Phase I study and refine them for detailed engineering study (Phase II).

# Task 3: Detailed Design, Specification and Drawings

- **Objective:** To prepare detailed design and drawings of the project configuration option finalized in the updated feasibility study.
- **Design Criteria:** For every component of the project the Consultant shall formulate, prior to detail designing, the design criteria on which a design will be developed. It shall establish the design and functional criteria, and prepare the layout and design concepts of all project facilities/ components; state the assumptions, parameters, and standards applied, loading conditions, factors of safety, allowable stresses, stability criteria, and all other factors which are necessary to fully carry out the detailed design. The design criteria shall describe in sufficient detail methodologies and analysis methods, data base and international standards or codes and prudent practices employed.
- **Detailed Design:** The detailed design including reinforcement details where applicable shall cover each component of major structures of the project including civil, hydro-mechanical, electro-mechanical works and transmission line and substations.
- **Detailed Drawings:** The detailed drawings shall be in sufficient detail based on the detailed design so that the contractor can prepare and place a bid for construction.
- **Specifications:** Technical specifications for the entire civil components, hydraulic structures based on the International practices. Technical and Performance Specifications for the hydromechanical and electromechanical works to a level of detail so as to enable contractors and suppliers to clearly interpret type and scope of works involved and to submit competitive tenders.

## Task 4: Model Test (Numerical and Hydraulic)

- **Objective:** carry out numeric modelling for the spillway, plunge pool, energy dissipating structures, weir (for reregulating dam), power intake, irrigation outlets, sediment flushing outlets, low level outlets, and so on. Carry out physical modelling of key hydraulic structures to confirm the result of numerical modelling,
- **Numeric Model:** Carryout 2D and 3D computational hydraulic model studies of dam, intake, overflow spillway and the plunge pool or stilling basin, energy dissipating structure, intake, sediment flushing outlet, irrigation outlets, and other structures if necessary to finalize the design, using Computational Fluid Dynamics (CFD) analysis method.
- **Hydraulic Model:** Following the computational CFD analysis, as confirmatory tests, the consultant shall carryout hydraulic model studies of dam, intake, overflow spillway and the plunge pool or stilling basin, sediment flushing outlet, irrigation outlets, and other structures as necessary to finalize the design.

# Task 5: Refinement of Project Cost , Construction Planning and Scheduling, and Economic and financial evaluation

- **Refine of Project Cost:** Refinement of the project cost involves the preparation of Project cost estimate from the detail engineering designs and Bill of Quantities (BoQ) for use in preparation of tender documents. Prepare detailed quantity estimate based on detailed design and tender drawings for the purpose of cost estimate and preparation of Bill of Quantities (BoQ).
  - Prepare an Engineer's cost estimate based on the tender documents and drawings and BoQ, consistent with the construction plan and schedule
  - Preparation of the BoQ shall be in accordance with recognized standard method of measurement of civil engineering works and shall be appropriate to the level of information available.
  - The cost estimates shall be prepared from a contractor's point of view using resource based costing and shall follow international standard practice (Cost and Performance Calculations of the Construction Industry) and Nepalese practices including other recognized estimating methods.
- **Refine Construction Planning and Scheduling:** Refinement and preparation of a realistic and practical construction and equipment procurement plan (Master Schedule) and schedule with milestones which aligns with detailed engineering design and cost estimate.
- **Refinement of Economical and Financial Evaluation:** Refine the Economic and Financial evaluation based on refined detailed cost estimates and refined project schedule and prepare cash flow.

# Task 6: Preparation of Complete Tender Documents

- Complete Tender/Bidding Documents complete with tender drawings with appropriate details and specifications, BoQ and other necessary documents for bidding purpose.
- The Tender Documents shall describe the works, including temporary works as necessary in sufficient detail to allow bidders to confidently determine the cost of construction and ensure competitive and comparable tenders.
- FIDIC Yellow book and Red book for bidding purpose.
- Recommendations and discuss in detail with SEC, the extent to which bidders should be permitted to suggest alternative designs, construction methods or temporary works.

# Reporting and Duration of services

## Reports in three Categories

- Management Reports,
- Technical Reports,
- Environmental reports and
- Combined Reports (Technical and Environmental both).

## Duration Of Services:

- Phase I : 24 months
- Phase II: 16 months

# TECHNICAL & COMBINED REPORTS (Phase I)

Inception Report

Topographical Survey and Mapping Report

Geological and Geotechnical Report

Hydrology and Sedimentation Study Report

Interim design report including Project optimization report

Upgraded Feasibility Study Report (Draft)

Water Resources Management Report

Power System Analysis Report

Geotechnical Baseline Report

Cost Estimation Report

Economic and Financial Analysis Report

Upgraded Feasibility Study Report (Draft Final)

Upgraded Feasibility Study Report (Final)

Draft Consolidated Report(Upgraded Feasibility Study and EIA) : Combined

Final Report - Consolidated Report (Upgraded Feasibility Study and EIA): Combined

# TECHNICAL & COMBINED REPORTS (Phase II)

Inception Report

Geological and Geotechnical Report

Hydrology and Sedimentation Study Report

Geotechnical Baseline Report

Cost Estimation Report

Physical Model Test Report

Geological and Geotechnical Report

Design Criteria Report

Draft Final Detailed Design report

Final Detailed Design report

Draft Final Tender Document

Final Tender Documents

Updated Financial Report

Design Criteria Report

Draft Final Detailed Design report

# Team Composition/Qualifications

- Composition of team of experts in each discipline, their qualifications, expertise, experience and other factors are given in para 5.7 of Chapter-5.
- Phase wise requirement of key experts, their engagement period, their disciplines, person months etc. too are given thereunder.
- It also gives the break up of professional requirements based on national and international expertise to ensure quality and contain costs.
- Detailed qualification against each team member, his/her area of expertise, experience have been stated therein.
- It also covers the inputs/support to be provided by the employer.

# CHAPTER -6:COST ESTIMATE FOR HIRING CONSULTANT

# Cost Estimates for Hiring the Consultants

- The cost estimate of the consulting assignment is based on the estimate of the person-months of each identified experts for the assignment and the estimated monthly rates, and the related direct cost components
- The monthly rates are based on the experience of the experts from recent procurement of consulting services for the two storage projects in Nepal--1200 MW Budhi Gandaki Hydropower Project, and 300 MW Dudh Koshi Hydropower Project
- While estimating the person-month inputs, the available information from the contract signed with the Himalayan Power Consultant for the Feasibility Study of the Karnali (Chisapani) Multipurpose project has also been utilized.
- The monthly rates of the national consultants is based on the suggested billing rates of Society of Consulting, Architectural & Engineering Firms (SCAEF, Nepal) (please see SCAEF website, <http://scaef.org.np>).

# Cost Estimates for Hiring the Consultants

Description	Amount in US\$	
	Phase I	Phase II
Remuneration	7,999,006	4,818,501
Out of Pocket Expenses		
i. Miscellaneous Expenses	1,787,540	1,215,620
ii. Lump Sum Competitive Items	2,740,000	550,000
Provisional Sum	2,500,000	1,500,000
Contingencies	547,134	332,908
<b>Sub-total</b>	<b>15,573,680</b>	<b>8,417,029</b>
<u>VAT@13%</u>	<b>2,024,578</b>	<b>1,094,214</b>
<b>TOTAL AMOUNT IN US\$</b>	<b>17,598,258</b>	<b>9,511,243</b>

# Chapter – 7: WAY FORWARD

# Way Forward

- Preparation of request for proposal (RFP) documents for the hiring of an international consultants thru quality based selection (QBS) or quality and cost based selection (QCBS) procedures with Time-Based Contract.
- The RFP document should be prepared in accordance with the procurement guideline of the funding agency, and the standard RFP document issued by the funding agency. (4 months including review)
- Short-listing of the consultant firms. This is normally done by issuing a notice inviting the eligible confirms to submit the expressions of interest (EOIs). (2 months)
- Issuing the RFP documents to the shortlisted consulting firms, and submission of the proposals (2 months)
- Evaluation of the technical and financial proposals (4-6 months including decision making and approval)
- Negotiations and award of the contract (2 months).
- Setting up of a contract administration office by SEC in Kathmandu.

# Way Forward

- Commencement of consulting assignments
- Submission of deliverables by the consultants (36 months from the date of commencement--for Phase I)
- Review of the updated feasibility report by SEC and participating regional countries.
- If the project is found feasible to extent the contract of the consultants for Phase II of the assignment.
- Road show to investors - multilateral, bilateral and private investors, may be with assistance of an excellent merchant banker (2-4 years)
- Construction of the Project (9 years).

# Way Forward (Contd.)

- **Threshold Criteria of International Consultants (Minimum Qualification of the Consultant to submit EOI Proposal)**
  - The Consultant must have extensive consulting experience in general and must have experience in carrying out feasibility study, environmental impact assessment and detailed design or construction supervision of large hydropower projects; and one of them should be a reservoir (storage capacity type hydropower plant of capacity 4200 MW (about 40% of the Karnali Chisapani capacity) preferably, with dam height of 180 m or higher (at least two third the height of planned Karnali Chisapani). The Consultant may have the above mentioned experience from different projects.

THANK YOU!