Luhri Hydro-electric Project - case for Planning of Geo-technically viable and Cost - effective Hydro Power Project in the Himalayas

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Abstract

For Planning a hydro power project, it is very important to asses optimum and full utilization of the available potential in a river valley. Stage wise development and identification of sites for schemes should be dealt with a prudent approach. Integrated approach of hydrological, geological and design parameters should be viewed in totality. Hasty and wrong decisions, if taken in the preliminary stage would not only force undesired layouts but would incur recurring power and financial losses.

Geological constraints for want of availability of sound foundation for safe design of dam, incomplete comprehension of hydro-logical data and structural designs, restricting heights of dams- at times due to environmental constraints,or in an attempt to reduce the initial cost of major civil structure, such as a diversion, or a desilting structures or impractical approach for tunnels, etc. may pose problems of cost overruns or operations in the long run. Should these be given importance?!, Remains a basic question to be answered.

A case study for evaluation of the layout of the Luhri H.E.Project, by way of five alternative layouts studied in Satluj basin,involving problems related to a burried channel at Kepu dam, presence of shallow rock cover for crossing Satluj at Nathan; two alternative proposals involving a 38 km long HRT crossing major thrust zones with a dam located at Neerth, has been discussed in the paper, to have a foresight in adopting the best possible option.A two stage development of the scheme with dam at Neerth -power house at Luhri (Stage-I) and a dam at Nathan having powerhouse at Morola (Stage-II) reducing the aggregate length of HRTs to only 25 km, also has been dicussed for a cost effective and geotechnically viable proposition.

Introduction

India has vast potential for hydroelectric project and there is adequate scope for increasing this cheap and vital resource in order to achieve a targeted power potential of 20386 MW in Himachal Pradesh alone. Planning and identification of hydro power potential is necessary in a river valley to provide optimum and full utilization of the available head. Thus identification of of stage wise development of schemes should be viewed in totality. There need to be a thorough knowledge of hydrological, geological and design parameters, and these studies should be taken up simultaneously while planning various schemes/ hydro-electric projects, in a particular river valley. Wrong decisions taken in the preliminary stage would not only incur recurring financial loss but would force us to opt for undesired schemes, having been restricted by, either topographical constraints, or being relegated to potentially inviable schemes,or their layouts being restricted due to other existing schemes.

Geological studies are jointly required along with the hydrological studies for identification of major dam sites, alternative tunnel alignments and power houses. Geological constraints are non-availability of site for safely founding a dam. Locating dam sites in glacial terrains, burried valleys and with unsound abutments, would lead to failures,

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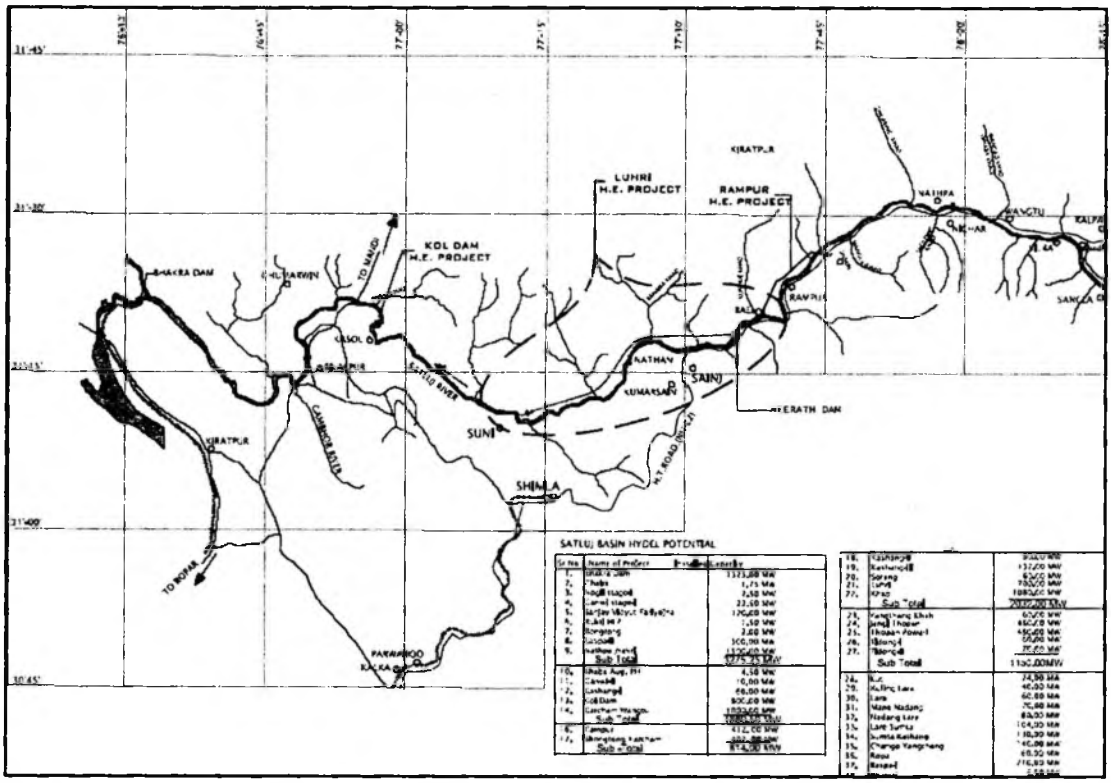

Fig. 1: Index map showing layout of Luhri H.E.Project In Satluj Basin H.P.

if adequate design measures are not provided. The suitability of a dam site on preliminary surveys and hydro-graphs may help in deciding the yield within a catchment and on the basis of area capacity curves, would optimise height of the structure. At times due to environmental constraints the type of the diversion structures and their heights are restricted. Should this be given importance, remains a basic question. Restricting heights of diversion structures for hydroelectric projects may at times lead to siltation problems or silt erosion problems. This situation has been faced in a large number of hydroelectric project in the Himalayas. While freezing out project layouts, assessments in the preliminary stage, considerable importance to major geological imponderables should also be given due weightage in comparison to the initial cost estimate of a project.

In Himachal Pradesh, in Satluj basin, geotechnical feasiblity of a 750 M.W. Luhri Hydro-electric project, situated between Rampur and Seoni has been considered as a case for discussion,(Fig. 1);

Decending from Karchham to Rampur, the rocks exposed in the area are the granite, augen gneiss, amphibolite and quartz-mica schist of the Jeori-Wangtu Group, that have a thrusted contact with the Rampur Quartzite having easterly dips and overlain by the gneissic rocks near Jhakri along Barauni Khad . Further towards the west the Rampur quartzite are overlain conformably by the green slates chlorite phyllite and phyllite with interbeds of phyllite and intruded by amphibolite bodies(called the penicomtemporaneous basaltic and mafic volcanics). From Rampur, beyond Nogli Khad, the older Rampur Group is overthrusted by the Kullu Group of rocks characterised by the streaky gneisses, the earthy brown to grey phyllite and phyllitic quartzite with bands of limestone and calcareous rocks successively named as the Garh and

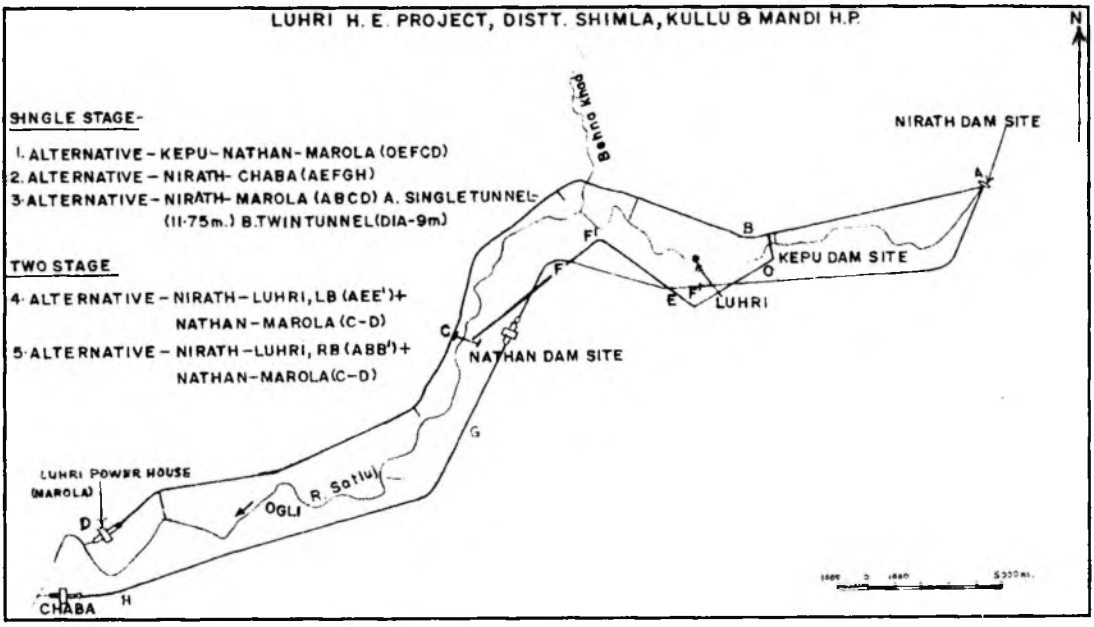

Fig. 2: Layout plan of alternative proposals

Regional Geological Set up

In this part of the Satluj Basin of the Lesser Himalayas. The general geological setup of the Luhri H.E.project (Fig. 2)(after Sharma, 1977) Srikantia, and Bargava, 1998; Srikantia, and Sharma, 1998.) is as follows:

Khamrada members. These occupy valley floors of Satluj upto Kotlu and a little upstream of Nathan. At higher levels rocks of Khokhan formations are exposed in the river section. A small inlier of Shalis forms a thrusted contact with the older Jutogs in Behna Khad on the right bank side of river Satluj. Jutog Thurst is also present in Kotlu Khad area and is characterised by fractured schists bands with limonitisation and mylonite. From Nathan towards west upto Chaba a thick sequence of rock formations of Shali Group, comprising of grey dolomites, pink and variegated limestone, puple quartzite etc. occur in the valley section of river Satluj.

Alternative Proposals

Five alternative proposals for Luhri Hydro-electric Project were examined on geotechnical and engineering consideration.(Fig. 2&3). The various layouts studied have been grouped as under:

Single Stage Development

1. Kepu-Marola scheme – O-E'-F'-C-D -lies partly on left bank and partly on right bank of R.Satluj
2. Nirath-Chaba scheme – A-E-F-G-H -Lies on left bank of R. Satluj
3. Nirath-Marola scheme – A-B-C-D - Lies on right bank of R. Satluj (with single or twin Tunnel)

Two Stage Development

4. Nirath-Luhri-Nathan-Marola (with Stage I on left bank)
   - 4a. Nirath – Luhri scheme -A-E-F"- Lies on left bank of R.Satluj
   - 4b. Nathan- Marola scheme -C-D- Lies on right bank of R.Satluj
5. Nirath-Luhri-Nathan-Marola (with Stage I on Right bank)
   - 5a. Nirath – Luhri scheme -A-B-B'- Lies on right bank of R.Satluj

Regional Geological Map of Satluj Basin showing alternative layouts

Geological Age	*Group Formation*	*Lithology*
Holocene	**Newer Alluvium**	Boulder,pebble,coarse sand -younger terrace (T1) and river channels
Middle to Upper Pleistocene	**Older Alluvium**	Boulder,pebble,coarse sand -Older terrace (T2)
Pleistocene to Early Eocene	**Subathu (Kakra)**	Basal Pisolitic laterite, quartz arenite, variegated shales& massive to thin bedded limestone
	Jutogh (Kullu)	Quartzite,quartzchlorite and quartz biotitew schist; slate, phyllite and schist, garnetiferous schist;locally associated with amphibolite.
	Khokan	Streaky mylonitic gneiss,banded and augen gneisses.
	Garh-Manjrot	Carbonaceous to graphitic schist and phyllite locally garnetiferous;lenticular greyish blue and cream coloured platy limestone and calc schist
Mesoproterozoic to Neoproterozoic	*Khamrada*	
(II)	**Simla**	Quartzite-shale-limestone at the base, shale and siltstone alternations with limestone interbeds;shale and siltstone alterations with ortho-quartzite and greywacke; greywacke sandstone, siltstone, shale alternations, orthoquartzite; conglomerate, arkosic sandstone, protoquartzite, grey and purple shale at top.
	Rampur	Quartzite with penecontemporaneous mafic meta-volcanics intruded by Bandal Granitoid Gneiss
	Shali/Larji	Green and purple shale, slate, siltstone earthy limestone bedded orthoquartzite.
	Bandla Formation	Cherty dolomite,grey limestone& white quartzarenite
	Parnali Formation	Grey,green,black and purple shale and slate thin bedded limestone,arenite with or without dolomite;
	Makri Formation	Mainly pink & grey cream limestone;cherty dolomite, grey & pink phyllitised shale ;
Paleoproterozoic	*Tattapani Formation*	Pink & grey cream limestone with shale partings
	Sorghwari Formation	Massive dolomite sporadic quartzarenite and thin red shale;
	Kathpul Formation	Mainly pink and purple& white quartzarenite;
	Khaira Formation	Brick red shale and siltstone with grey dolomite;
	Ropri formation	Quartzite with penecontemporaneous mafic volcanics (Mandi-Darla Volcanics)
	Sunder Nagar	Augen gneisses,mylonite gneiss, porphyroblastic biotite gneiss with intercalated biotite,garnet,kyanite, silliminite bearing schist bands intruded by porphyritic and tourmaline bearing granite, pegmatite and aplite.
Archaean	**Jeori -Wangtu Granitoid Gneiss**	

5b. Nathan- Marola scheme -C-D - Lies on right bank of R.Satluj

Single Stage Development

Dam at Kepu and UGPH at Marola: - HRT partly on left bank and partly on right bank of Satluj (A-E'-F'-C-D):

This proposal includes a 78m high dam at Kepu on Staluj. The river bed level is 770.4m for the 78m high and a 342.5m long proposed concrete dam, a 29 km long HRT partly on left bank and partly on right bank of Satluj (fig2). A surface desilting structure is proposed on left bank on overburden . The main rocks at dam site are the gneisses with biotite schist. The proposed tunnel (HRT) crosses the river Satluj to the right bank at Nathan, passes through a sequence of rocks belonging to Shali Group, to finally join an underground powerhouse at Bindla/ Marola on the right bank of Satluj to generate 700MW power. Preliminary studies by reconnaissance and limited subsurface drilling were carried out at the Kepu dam site by way of five boreholes and one borehole

Table 1 : Comparative study of different layouts

	Discription of Component	Schemel	Scheme II	Scheme III	SchemeIIIa	SchemeIV-a/Va	Scheme IV-b/Vb
		Dam at Kepu PH at Marola HRT partly on Left Bank	Dam at Nirath PH at Chaba-Single HRT	Dam at Nirath PH at Marola-Single HRT	Dam at Nirath PH at Marola-Twin HRT	Dam at Nirath PH near Luhri	Dam at NathanPH at Marola
1	River bed level at Dam	770.40m	795.00 m	795.00 m	795.00 m	795.00 m	674.50 m
2	Height of Dam	78 m	71.0 m	71.0 m	71.0 m	71.0 m	98.0 m
3	Length of Dam	342.5m	230.5 m	230.5 m	230.5 m	230.5 m	160 m
4	Dam width at Top	8 m	8 m	8 m	8m	8m	8m
5	Length of HRT	29 km	39 km	38.44 km	76.88 km	9.7 km/ same (appx)	15.6 km
6	Dia of HRT	10.50m	11.75 m	11.75 m	9.0 m	9.0 m	11.75 m
7	No. of Adits	6	6	9	9	2	3
8	Gross Head	180 m	221.0 m	221.0 m	221.0 m	91 m	131.0 m
9	Installed capacity	700MW	725 MW	725 MW	775 MW	325 MW	450 MW
11	Length of Reservoir	-	7 km	7 km	7 km	7.0 km	13.7 km
12	PH location	Right bank	Left bank	Right bank	Right bank	L bank/R bank	Right bank

put down at the river crossing at Nathan.

Nirath-Chaba scheme Lies on left bank of R. Satluj (A-E-F-G-H)

A 71m high dam at Nirath, has been proposed as one of the alternative site.The river bed level is 795.00 m,.. The total length of 11.75m dia HRT, aligned on the left bank is 39.00 km, and the proposed underground powerhouse is located near Chaba village, a little upstream of Nauti Khad. On the left bank the tunnel shall have to negotiate nine major khads, namely Behra Khad, Gharal nala, Khanet Khad, Kiongal ki Khad,Teshan Nala, Kunda Nal, Chapala Nala, Sal-Ser Nala, Pandoa Khad, Bathora Nala, Ogli Khad, Jud ka Nal and Khaira Khad. A power generation of 775 MW is envisaged.The rock types present along the HRT are granite gneiss with amphibolite bands and carbonaceous zones, quartzite and phyllite belonging to Kullu and Shimla Group and limestone, dolomite and quartz arenite of ShaliGroup. The dam site is located in the gneisses while the porposed UGPH lies in the highly fractured dolomite with cavities.

Nirath-Marola scheme Lies on right bank of R. Satluj(A-B-C-D)

This alternative includes a 71m high dam proposed at Nirath as in above proposal. The intake of HRT is proposed on the right bank .The HRT lies entirely on the right bank and is 38 km long. It crosses a number of major khads viz.Tani nala, Gutidhar nala opposite Bithal,Luhri Khad, Behna (Baba) Khad, Kotlu Khad, Jhajhar Khad, Khunali Nal, Chainre Khad, Jakrali ka Nal, and Gumma Khad. The tunnels is expected to have low rock cover in some of these nala crossings particularly at Behna Khad, Jhajhar Khad, Chainre Khad and Gumma Khad. An underground power house to generate 775 MW is proposed at Marola.

Two Stage Development

The two stage schemes proposed for the Luhri Project, listed as 4 and 5 above, have two

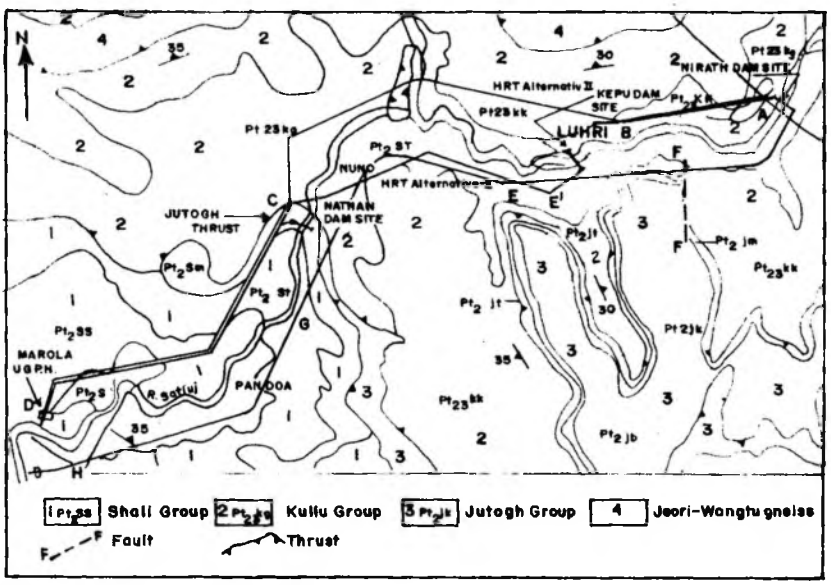

Fig. 3 : Layout plan of Alternative Proposals

damsites. In these one of the dam at Nirath is proposed for the upstream stage while another dam at Nathan is proposed for the downstream stage. These alternatives are under consideration because the length of HRT in single stage was too long.

Nirath – Luhri scheme -A-E-F"- Lies on left bank of R.Satluj

This stage includes a 71m high at Nirath.The 7.9km long HRT is located on the left bank of Satluj to generate a power of 325MW. A powerhouse is proposed at Baha near Luhri. On the left bank the tunnel shall have to negotiate four major khads, namely Behra Khad, Gharal nala, Khanet Khad, Kiongal ki Khad. The entire tunnel alignment would lie within the geisses and quartzite and phyllites of Kullu Group of rocks.

Nathan- Marola scheme C-D - Lies on right bank of R.Satluj

This is a downstream proposal of the two stage development scheme (Fig. 2).The proposed 98 m high dam is located within the pink and creamy limestones of Shali Group. Both the abutments are in sound rock.The river section is narrow in this reach and the length of the dam at the top would be around 160m. A proposal of a high dam was studied earlier by the HPSEB in the year 2004. A15.6km long HRT on the right bank will be used to generate 450MW at the proposed under ground Marola Power House.

Nirath – Luhri scheme A-B-B'- Lies on right bank of R.Satluj

In this proposal, suggested by the Geological Survey of India, the proposed 71m high dam location was at Nirath (Fig2 &3). The intake and tunnel was proposed on the right bank of Satluj.The scheme included an underground power house just upstream of Luhri village.The dam , HRT and the proposed power house lie in the granite gneiss, quartzite and phyllites with occaissional limestone and carbonaceous zones of Garh and Khokhan formations of the Kullu Group.

Nathan- Marola scheme C-D-Lies on right bank of R.Satluj

The lay out of this downstream proposal is the same as alternative 4b(fig.2).

Geotechnical Assessment

The main geological constraints at the dam site under proposal No. 1, were non availability of bed rock at reasonable depth,

since a burried channel of Satluj existed on the left bank extending for a considerable length of over 800m towards the hill on the left bank.Moreover limited rock outcrop of less than 100m length was present adjecent to the river channel on the left bank indicating inadequate sound dam abutment on the left bank . The had rock on left abutment of the dam width was inadequate to support the concrete dam. Founding of a highly reinforced surface desilting structure on the left bank over a burried river course where over 500 m of unconsolidated material was present, involved very deep cutting, posing instability and seepage problems, would also have incurred huge cost . This and the seepage at the tunnel crossing on river at Nathan , where over 35 m of river deposits existed, did not favour the alternative. Moreover, their was an additional loss of 91m unutilized head for power generation between the tail end of Rampur H.E.Project and the proposed dam at Kepu, near Luhri.

Keeping these aspects in mind an alternative dam site was identified in 2005, for which recconnaissance and preliminary studies were initiated for the proposed 38 to 39km long single stage and two stage alternative proposals.As discussed in the previous chapters two single stage and two two-stage proposals were considered. The merits and demerits of single stage proposals with one HRT and twin HRT were carried out by the project authorities.

Although in all these proposals the dam site at Nirath finds favour on both engineering and geological considerations, the relative merits of layout of tunnels, and powerhouse is of significance.The single stage proposal No.2 and No.3 located on the left and right bank of river Satluj respectively involve 38 to 39 km long HRT. The rock condition on the northern slopes are more prone to deeper weathering because these slopes are covered with snow for longer duration of the year as can be seen by the pattern of thick vegitation and cultivated lands. The rock formations by and large remain the same . Presence of thrust zones are similarly disposed along the HRT, but their locations are controlled by the regional geological setup (fig 3). In case of Alternative 2, however the rock conditions at the proposed Chaba UGPH being highly fractured and jointed due to proximity of a local fault running NNW-SSE along Satluj, the site does not apprear suitable. On the said demerits the right bank proposal No3 that includes a UGPH at Marola is located in dolomites and bedded limestone in which lesser jointed nature of rock and fracturing has been recorded . The slopes expose better rock conditions, on the right bank side for the obvious reason that snow cover remains for shorter period over the year. In both of these alternatives , however, the power benefits remain the same.

Studies on engineering considerations revealed that a dam at Kepu would have a 20 to 30% greater capital cost than a dam at Nirath, even with a reduced length of tunnel with Kepu site.They have also found that for a two stage development 10 to 20% greater capital cost than a single stage development. The two stage development scheme would involve construction of two powerhouses one near Luhri and the other at Marola. An additional desilting chamber would be requied for the second Downstream Stage. But in these cases, length of HRTs could be reduced by 14.5km for a single HRT and about 29 km in case of twin tunnels. On getechnical grounds not only reduction in tunnel length would be achieved in the two stage development but the tunnelling through Jutogh thrust in the highly fractured rocks would also be avoided.

Therefore, on geotechnical consideration and above merits, proposals for two stage development were studied.. The downstream proposal No,4b and 5b are the same scheme that is located on the right bank of Satluj with a 98m high dam at Nathan. Of these two upstream proposals Nos 4a and 5a lie on the left and right bank of Satluj respectively, these involve construction of a gravity concrete dam at Nirath. The tunnel alignment on the left bank lies entirely in the augen gneiss, streaky gneiss with phyllite and quartzite of Kullu

formation. Similarly the right bank tunnel alignment lies in the gneisses and quartzite with phyllite rock of Kullu Group. However on the nature of weathering and construction constraints due to vehicular movement and other problems, the right bank proposal would be better suited.

As regard to the d/s proposal (Dam at Nathan), as studuied earlier by the HPSEB a power output of 465 MW was envisage with a dam at Nathan and UGPH at Chaba. Since in the revised proposal with a 98m high dam at Nathan and a reservoir extending just d/s of Luhri bridge, the overall head for generation for the combined two stages would remain same as that for the Single stage proposal. However, as detailed in the project report a total power output of only 775 MW has been shown. These figure would definitly change as additional pondage, including discharges from Behna, Chainre,Kiongal ki Khad,Teshan Nala, Kunda Nal, Chapala Nala, Sal-Ser Nala, Pandoa Khad, Bathora Nala, Ogli Khad, at Nathan would provide additional power benefits. Moreover with the combined two stage development extra tunnelling of over 14.5km would be avoided, that too within the highly fractured zone at the contact of the regional Thrust. Besides this an added advantage of indepenendly developing the two stages could be possible, therby considerably reducing the gestation period of the entire scheme when compared to a single stage development.Thus two stage development appears geotechnically more viable.

Conclusions

After having made a detailed comparative geotechnical assessment of a project, only the best possible proposal on geotechnical and enginnering consideration should therefore, be accepted. The choice and decision of the same lies with the authority who accepts the proposal. Hence utmost care and information should be gathered to acertain that the particular layout is found feasible before finalising the DPR of a given project. Although cost of initial project proposal may appear acceptable but if geological or engineering conditions prevail, a judicious approach should be made. In the case of Luhri H.E. Project, it would be, therefore, prudent to analyse in detail all the techno economical aspects in order to finalise the best possible layout.

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