Tectonic and environmental control in shaping the layout of the Jakhol Sankri HE Project, District Uttarkashi, Uttarakhand

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Abstract

The 45 MW Jakhol Sankri HE Project across the Supin river, a major tributary of the Tons river, is another revelation of the geotechnical and environmental constraints in projects located in the mighty Himalayas. It has had its share of gnawing teething troubles in the PFR investigations itself and has landed up facing two important tectonic features- the Main Central Thrust and the Purola Thrust- across its layout, besides the tightrope walking in adjusting the layout so that it stays clear of the widespread wildlife sanctuary area.

Located largely within the Lesser Himalaya, this scheme transgresses into the Great Himalaya as the diversion structure is proposed about 300m beyond the MCT, within Central Crystallines. The underground powerhouse is proposed within interbedded quartzite and schist of the Jaunsar Group, separated by the Purola Crystallines along the Purola Thrust. Owing to the wildlife sanctuary stipulations, tectonic setting and optimization of power generation, the project layout has been drastically modified at the PFR stage itself.

The paper deals with the role of geological investigations in arriving at the optimal layout of the project and advocates a relook at the environmental restrictions so that both the nature as well as the developmental projects of national interest flourish side by side.

Introduction

The Jakhol Sankri Hydroelectric Project is located in Uttarkashi District in the state of Uttarakhand. It is a run of the river scheme on river Supin which is a major tributary of Tons river. The scheme envisages construction of a barrage/raised trench weir near Jakhol village, a head race tunnel from Jakhol to Sankri along the left bank and an underground powerhouse near Sankri. It is expected to generate 45MW of installed capacity, utilizing an available head of ~456m.

The project in its prefeasibility stage itself has had its share of troubles and has landed up facing two important tectonic features- the Main Central Thrust and the Purola Thrust- across its water conductor system, besides the tightrope walking in adjusting the layout so that it stays clear of the widespread wildlife sanctuary area. The environmental restrictions imposed have gone a bit too far as even the deep seated subsurface structures like the HRT are not allowed even to be aligned through the restricted wildlife sanctuary area.

Owing to the wildlife sanctuary stipulations, tectonic setting and optimization of power generation, the project layout has been drastically modified from its initial proposal. The diversion structure site has been shifted ~2.5 km upstream. The new site, proved to

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be an excellent location for the structure, but as it fell in wildlife sanctuary, it had to be relocated ~300m downstream. The TRT outfall needed to be kept clear of the wildlife sanctuary and has been shifted upstream marginally, along with the underground powerhouse site by ~ 500m. The powerhouse complex has also been proposed to be relocated within Purola Crystallines as the pressure shaft intersects the Purola Thrust. The thrust would now be negotiated in the TRT. The HRT alignment may also undergo slight changes in view of the changes brought about in the citing of other project components.

Detailed geological investigations have been taken up for the project to arrive at the optimal layout considering the environmental and geotechnical restrictions attached with it.

Project Features

The scheme envisages construction of a barrage/raised trench weir, near village Jakhol. The river bed level at diversion site is El 1956m with FRL of 1970m. The length of barrage is expected to be 41m with radial gates. The water would be diverted into a tunnel having a diameter 3m.This will be equipped with a desilting chamber to extract coarse sediment. The HRT will have a length of 6.508 km with a design discharge of 11.41 cumec. The HRT would lead to a pressure shaft of 2m diameter. The underground powerhouse at El ±1539m would have a dimension of 66m x 14.6m x 29.7m with vertical shaft pelton turbine. The maximum gross head is expected to be 456m with an installed capacity of 45MW.The normal Tail water Level in turbine pit would be 1509.9m.

Proposed Project Layout

Originally, the project envisaged construction of a barrage upstream of bridge near Jakhol village on river Supin with an underground powerhouse near Sankri. This tentative barrage site location had been proposed by GSI after preliminary assessment. The site fell immediately west of village Dhara, just upstream of a major left bank tributary of Supin river flowing in between village Jakhol and Dhara. The Sankri power house however was coming under the purview of wild life reserve which required shifting of the powerhouse location much upstream. This would have resulted in loss in head and overall generation.

The project authorities thus identified a barrage site location ~2.3 km upstream of this site. GSI carried out geotechnical assessment of the new site which was found to be feasible, as hard and compact gneissic rocks of the Central Crystalline Group occupied the site area and both the abutments were found to be rocky. However it was later discovered by the project authorities that even this location fell in the purview of reserve forest area and hence had to be forfeited. The diversion structures site location thus had to be shifted ~300m d/s of the earlier location. The shifting of the barrage site to its present location resulted in the loss of a very good diversion site.

The alignment of HRT also cuts through patches of wild life cover and hence has to be so aligned in order to avoid encroaching these prohibited areas demarcated on the surface. It was brought out that the State wild life authorities would not permit even subsurface structures like HRT or powerhouse cavern under the protected wildlife areas. It was thus bound to have an impact on the preferred HRT alignment.

A similar issue affected the location of the powerhouse cavern. Initially it had been decided to keep the powerhouse cavern entirely within the thick quartzite unit of the Jaunsars comprising of uniformly dipping, thick and competent beds. But, the TRT outfall was needed to be kept clear of the wildlife sanctuary and was thus shifted upstream marginally, along with the underground powerhouse site. It was decided, that the powerhouse complex would be located between wildlife protected area boundary on the western side and Purola Thrust on the eastern side. The geological

setting would be defined on this zone and the best possible rock mass would be utilized for locating the powerhouse unit.

Site Conditions

Physiography

The Supin river on which the project is located originates from Kimlog glacier and flows south westerly making a confluence with Tons river near Sankri. The project area is bounded by Bharasar Dhar (4642m) in the north, Chansil Dhar (4058m) in the west, Haridwar Dhar (5050m) in the east and Tons river in the south.

Physiographically, the area forms mountaneous terrain characterized by rugged topography with steep slopes, narrow valleys and deep gorges. The general altitude varies from El ±1513 near confluence of Tons and Supin river to El ±2660m near Jakhol village. In general the ground elevations along HRT vary from El ±1750m - El ±2450m. The maximum vertical rock cover is ~ 500m and the minimum is ~100m.The drainage pattern in the area is dendritic. The area remains snow bound during peak winters. Glacial evidences like glacial valleys and moraine sediments are common.

The HRT slopes in general are overburden covered. The outcrops are however exposed in lensoidal pattern at frequent intervals along the HRT.

Regional Geology

The project cuts across two major tectonic planes namely Main Central Thrust (MCT) towards the barrage and Purola Thrust towards the powerhouse site. The zone of MCT has been marked ~300m downstream of the proposed diversion structure site which implies that the HRT would cut across the MCT zone.

The area around the project is covered by Proterozoic rocks represented by the Central Crystallines, Purola Crystallines and the Jaunsar Group.

The Central Crystallines are the oldest rocks in the area and are represented by intercalated sequence of grey micaceous quartzite, quartz mica schist, garnetiferous biotite schist, biotite and porphyroblastic gneiss sillamanite- kyanite bearing schist and gneiss, garnetiferous biotite schist, migmatite, micaceous quartzite and basic intrusives.

The rocks of Purola Crystalline comprises of biotite schist, quartz mica schist, garnetiferous biotite schist, biotite gneiss, porphyroblastic gneiss, quartzite and amphibolite occurring as a thrusted mass, over the rocks of Jaunsar Group.

The rocks of undifferentiated Jaunsar Group of Neoproterozoic age, tectonically underlie the Purola Crystalline and consist of grey, green phyllite, sericite quartzite with local carbonaceous phyllite, schist and basic rocks (Fig. I & II).

The Main Central Thrust

The Main Central Thrust is the most important tectonic feature of the area. In the Tons valley, the MCT is exposed near Taluka, where Gangar Formation of the Central Crystallines is thrust over Sankri Formation of the Garhwal Group. It is slightly displaced by a cross fault. From Taluka, the MCT extends northward overriding the Naitwar Group and Jutogh group. The MCT trends NW-SE towards NE.

In the area of interest, the zone of MCT has been marked ~300m downstream of the proposed diversion structure site which implies that the HRT is likely to cut across the MCT zone.

The Purola Thrust

The Purola Thrust may be understood as a synformal thrust along which the rocks of Purola Crystalline have moved over the rocks of Jaunsar Group. Around the area of investigation it truncates against the MCT near Taluka having a roughly east west trend and dipping in the northerly direction. It cuts

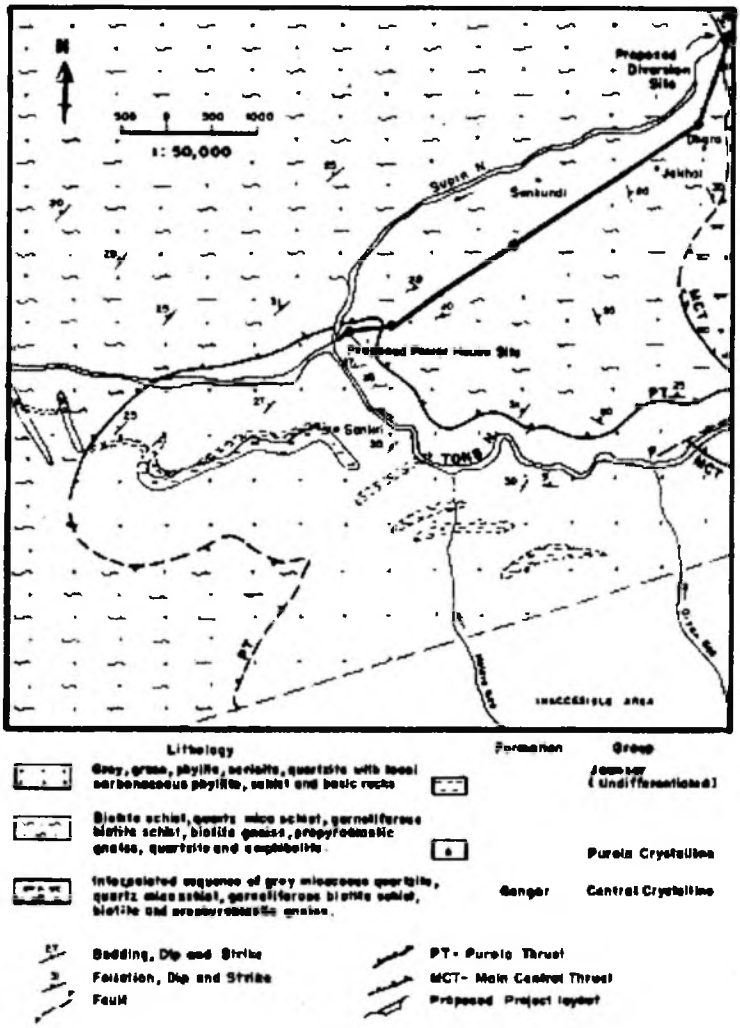


Fig. 1: Regional Geological Map of the Jakhol Sankri H.E. Project

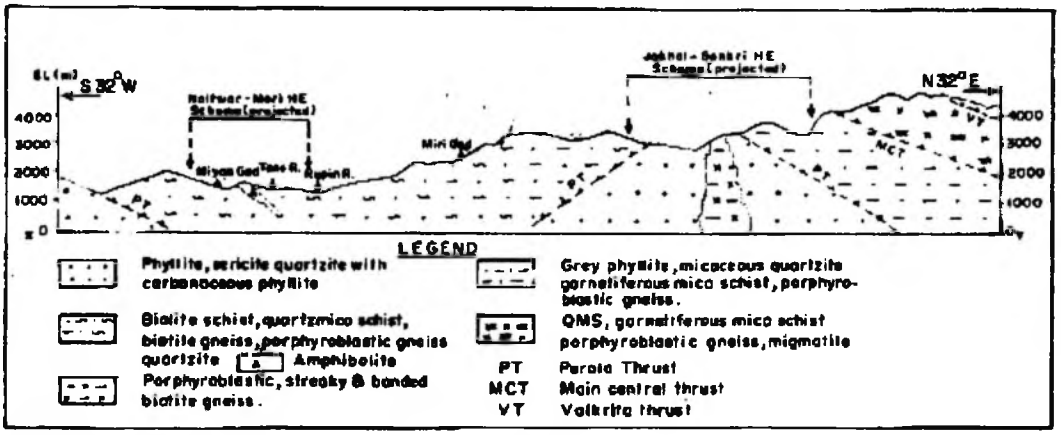


Fig. 2: Geological Section depicting the regional geology along the Jakhol - Sankri and Naitwar-Mori HE scheme, district Uttarkashi, Uttarakhand

across Supin river just upstream of its confluence with Tons river. It follows the right bank of Tons river downstream of Sankri village cutting across the river upstream of its confluence with Mautar Gad. Here it follows a northeast- southwest trend with dips in the north westerly direction.

The Purola Thrust separates the rocks of Jaunsar group with that of the Purola Crystalline. The Purola Thrust has an arcuate disposition at site. It is important to mention that the present layout of the scheme intersects the Purola Thrust probably in the Surge shaft area and may pose obvious construction and stabilization problems depending on its nature where it is intersected.

Site Geology

Geologically, the area of investigation is occupied by low to high grade metamorphic rocks of Central Crystalline Group, characterized by presence of quartz mica schist, chlorite mica schist, high grade biotite rich banded gneiss, and "clasts" dominated porphyroblastic gneiss. These are exposed around the proposed barrage site near villages Dhara and Jakhol.

These rocks are thrusted upon the rocks of Purola Crystalline represented by green schist metamorphites comprising quartz mica schist, chlorite mica schist, biotite rich banded gneiss and "clast" rich porphyroblastic gneiss. The gneisses and the schistose rocks depict an inter layered sequence and are undifferentiated.

The rocks of Purola Crystalline are thrusted upon the rocks of Jaunsar Group represented by white sericitised Quartzite with numerous interspersed schist bands of variable thickness. Grayish green, mafic, fine grained foliated rock with gneissic appearance has also been observed as an inter layered sequence within the rocks of Jaunsar Group.

Structure

The rocks in the area generally trend northwest- southeast with moderate to gentle dips towards north east. But general swing in the strike is common as in the case near Sankri powerhouse area where trend of the formations is northeast- southwest. The various tectonic planes include Main Central Thrust and the Purola Thrust which are present within the purview of the project layout.

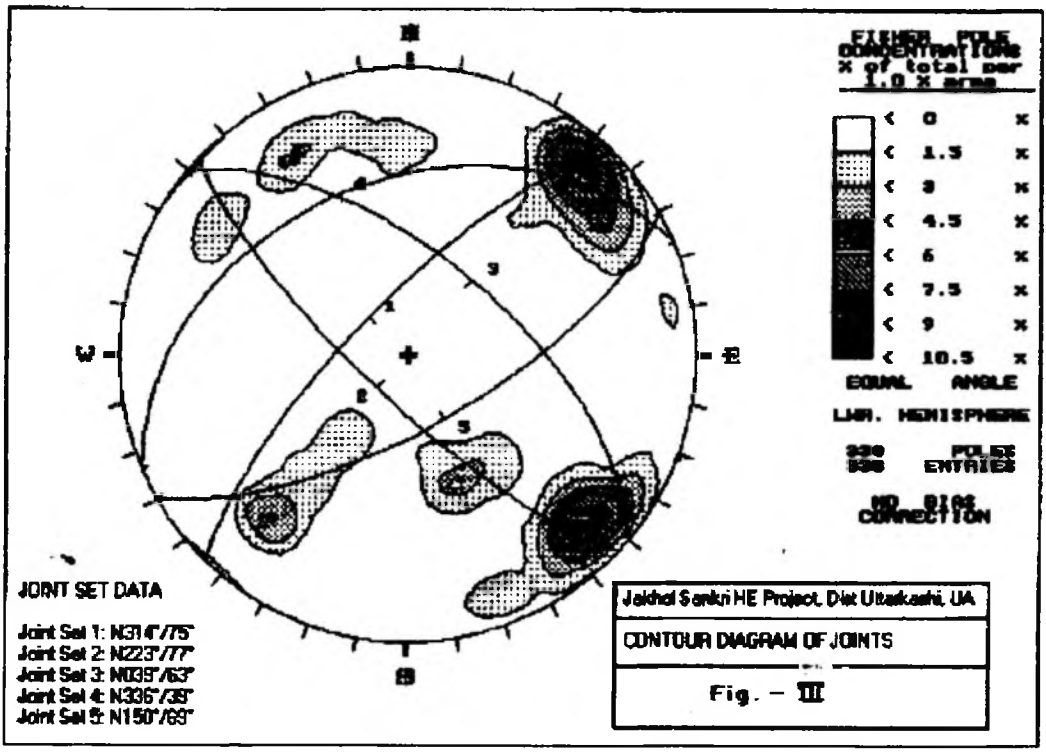
The formations have foliation dipping N330°-N348°/ 28-45° as observed around powerhouse area. There is a swing in the strike of the formations as we move upstream of the powerhouse site. The change gets apparent east of Nichia Panva village where the strike becomes northwest-southeast with dips in the north easterly direction. This trend continues upto the diversion structure site with local variations. The dips are moderate, but become slightly steeper as one goes into the Central Crystallines. In general the rocks have been dissected by four prominent sets of joint. Joint Set (J1) having dip N310°-N350°/ 40-83°, Joint Set (J2) having dip N210°-N260°/ 45-80°, Joint Set (J3) having dip N120°- N160°/ 45-85°, Joint Set (J4) having dip N030°- N050°/ 28-50°.

It may be interpreted that the foliation joints are the main controlling joints in the area. However the southwesterly and southeasterly dipping joints are also prominent and have high density throughout the project area. There is uniformity in the disposition of joints and very few randomly occurring joints are present (Fig. III).

Wildlife sanctuary

The project area has been discreetly outlined into sanctuary and non sanctuary limits (Figure IV). The laws as laid down under the Wildlife Preservation Act are quite stringent which do not permit any surface or subsurface construction activity within the areas delimited under wildlife. Thus wild life cover in the project area is a major constraint in deciding the project layout.

It can be seen that the project is sandwiched by wild life boundaries and any decision on



the layout has to be taken in the light of wild life constraints. An excellent diversion site had to be forfeited as it could not comply with the permissible boundary limits, leaving little option but to shift ~300m downstream on a geologically inferior site. Similarly, the powerhouse site had to be shifted upstream by about ~500m as it was barely stepping into the non permissible limits of wildlife protected zone.

Even the HRT alignment cuts through patches of wild life cover and hence has to be so aligned in order to avoid interference with the prohibited areas demarcated on the surface.

Apprehensions vis-à-vis Layout Modification

As a result of the change in location of the various project components the following apprehensions have been found associated with the new sites.

a) On Social Consideration

As mentioned earlier, a very good diversion site location had to be forfeited in view of the wild life coverage area. It resulted in shifting of site ~300m downstream to a geologically inferior site with associated geotechnical constraints.

The New Diversion Structure Site

The site faces limitations in view of the major debris cone on the right bank and availability of limited outcrop (±35m) on the left abutment. The spillway discharge would be hitting the toe of the debris cone directly and would call for elaborate slope stabilization measures along with a heavily reinforced toe wall.

The diversion structure may have to be a structure which needn't intercept the runoff so as to avoid flooding and disturb the debris cone structure downstream of the cave. As there is limited room for intake on the left abutment a choice of surface desilting chamber may need to be considered as per site conditions.

The gneisses exposed around the site area belong to the Central Crystallines and the

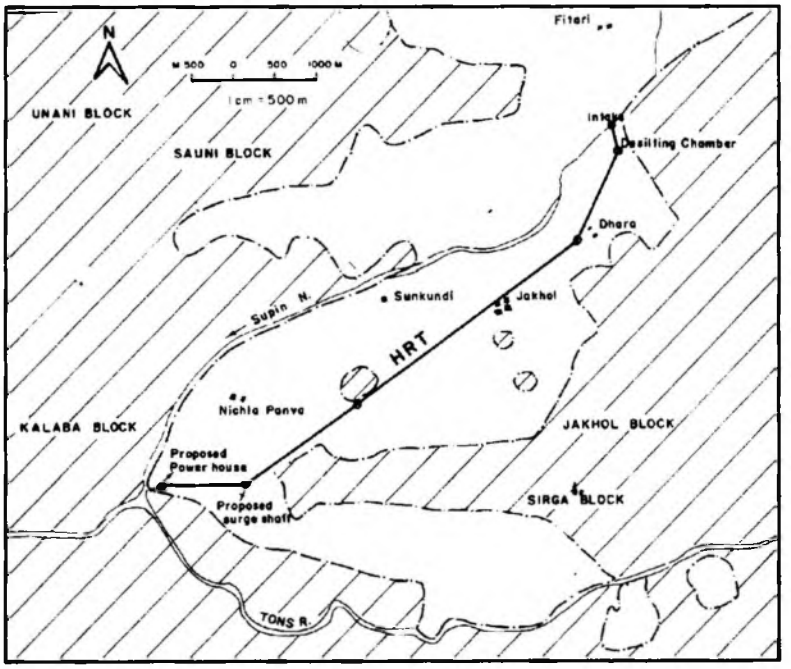


Fig. IV: Map showing restricted wild life sanctuary area around JSHE project.

MCT is interpreted to be located ~200m downstream of the site. This may have implications on the engineering structure being designed in the near vicinity of a major tectonic plane.

b) On Geotechnical Consideration

As per the present layout, the Purola Thrust is likely to intersect in the penstock area and may pose construction and stabilization problems depending upon its location where it is intersected. Therefore, a geologically better option would be to totally avoid the Purola Thrust from cutting across any of the major project components.

The Powerhouse Site

An underground powerhouse structure has been proposed for the scheme. The area around the powerhouse site comprises rocks of Purola Crystallines and Jaunsar group. The rocks of these two groups are separated by Purola Thrust that appears to have an arcuate disposition at site. The quartz -schist sequence is uniformally dipping and is found very well exposed in a 250m high section on the right bank of the Tons river at its confluence with the Supin nadi.

Preliminary analysis of bed disposition vis-a-vis the proposed layout of the underground powerhouse complex indicates that it may fall within a 150m thick quartzite- schist sequence comprising a 12-15m thick schist bed sandwiched between an underlying 100m thick bed of quartzite and an overlying 35m thick bed of quartzite.

An interpreted geological section around the powerhouse area was developed to see the disposition of bed and where the powerhouse cavern was falling as per the present layout. As per the available powerhouse elevation at 1530m provided by the project authorities, the powerhouse cavern is falling into the ~100m thick underlying quartzite sequence. (Fig. V)

The interpreted geological cross section reveals that due to bed thickness limitations, it may not be possible to accommodate the powerhouse cavern in the overlying quartzite which may be more appropriate from the point of view of the ideal layout of the Main Access

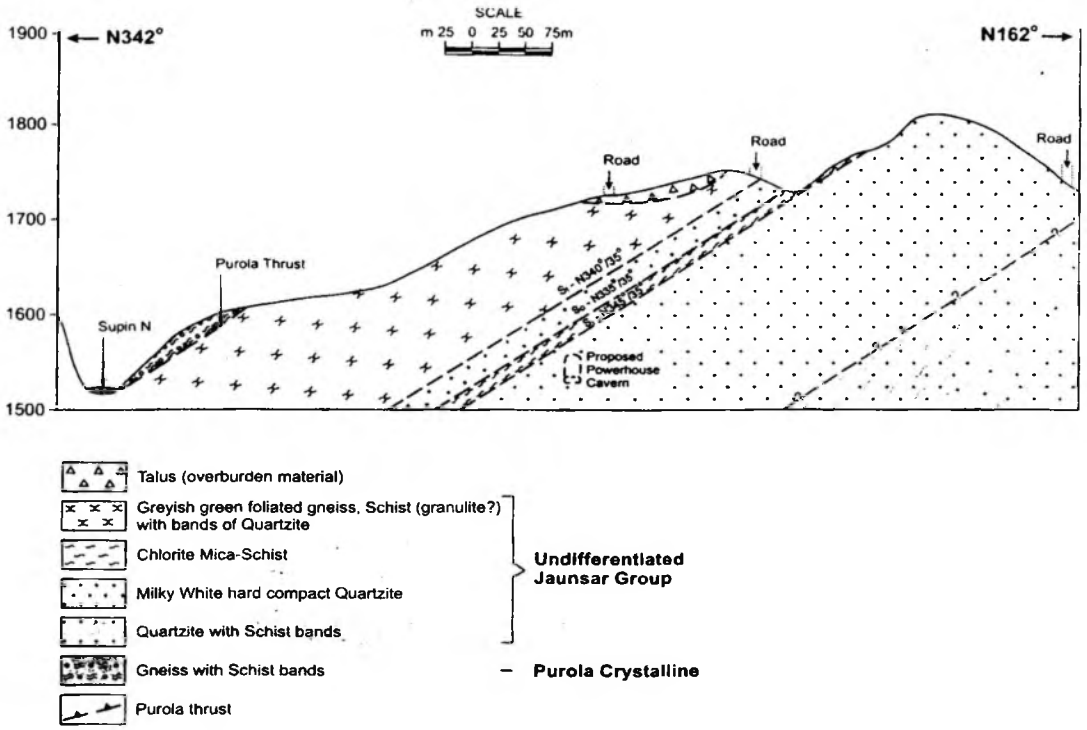


Fig. V: Geological section of power house area of JSHE project.

Tunnel. Locating the complex within the underlying thick quartzite bed may be geologically a better option but pushes the cavern deeper into the hill and may render the layout very complex. The present layout would also intersect the Purola Thrust in the penstock area and may pose construction and stabilization problems depending upon its location where it is intersected. These features reveal that the Sankri Power House complex is located in a heterogeneous lithological complex being subject to problems associated with it.

As a better geological alternative, a powerhouse complex, along with the surge shaft and the Pressure Shaft, may be located entirely in a nearly uniform lithological assemblage of quartz biotite gneiss on the other side of Purola Thrust (Fig. VI). This would lead to lengthening of the TRT by a few hundred meters with consequent head loss that may not be much. The complex lithological assemblage of the Jaunsars and the Purola Thrust, in this case, would be intersected in the much smaller opening of the TRT. The siting of the powerhouse complex in Purola Crystallines would however be in the consideration of the dip of the thrust zone.

Head Race Tunnel

The approximately 6.5km long HRT is likely to be cut across by two major tectonic features namely the Main Central Thrust and Purola Thrust. Broadly, the MCT marks the upstream end of the scheme and Purola Thrust marks the downstream end of the scheme. There may be serious implications because of these regional planes, depending upon their nature at the location where they are intersected. However, disturbance because of these major tectonic planes on the surface is not much visible.

Discussions

1. Project planning and layout modification on sound technical findings is a welcome aspect as it leads to development of the

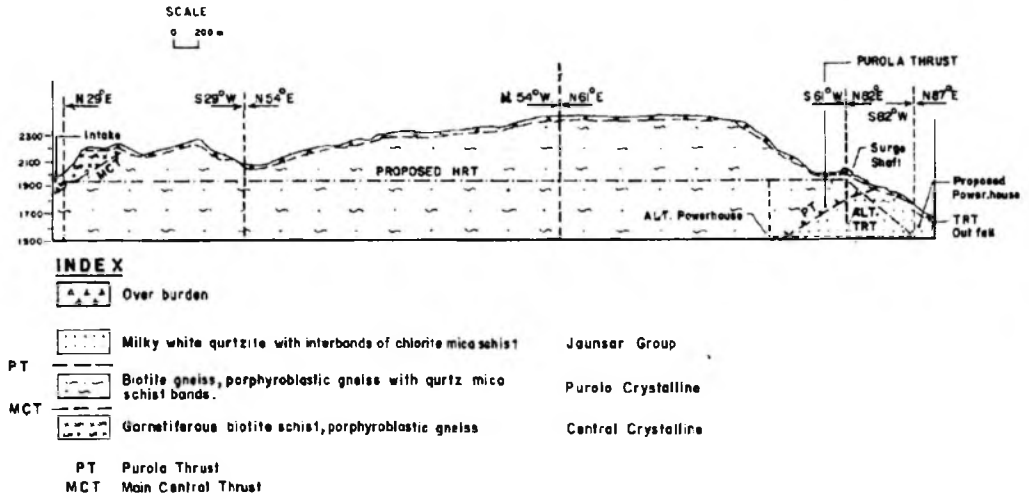


Fig. VI: Geological section along proposed HRT alignment of Jakhol Sankri HE project.

project as the best possible techno economic unit. In the case of Jakhol Sankri Hydroelectric Project, upstream shifting of the powerhouse complex, thus avoiding the Purola Thrust across the penstock alignment, besides providing a better subsurface excavation media, is considered a reasonable modification.

2. It is of paramount importance that execution of projects causes no disturbance of any kind whatsoever to the designated wild life reserved areas, directly or indirectly. Whereas uncontrolled development activities on ground may lead to impact on wild life, the influence of subsurface development may be much restricted. Technically, construction of a deep seated tunnel within the wild life area may not make a difference even if the imaginary line of the tunnel alignment on the surface passes through a wild life designated area or close to it. Similarly, construction of a deep seated underground powerhouse also may not lead to such problems. Hence, the HRT and underground powerhouses of the JSHEP are not expected to have much influence on the wild life. Despite this, however, the restrictions posed due to the wild life have led to serious modifications in the project layout and may have even affected the overall power output.

3. Valley optimization for power development is a well known fact and should clearly be a prerogative of the Government. The development of hydropower through multiple independent agencies is proving a deterrent in the optimization of power generation. In case of conflicts between agencies, the Government must act as a moderator and take decisions in the overall long term interests.

In the light of the above, it may be prudent to reassess the wild life conservation Acts on the technical grounds. In this reference, besides the clearance on ground around the wild life sanctuary, the clearance of depth underneath it, may also be relevant. Such a reassessment may lead to approval of deep sub surface structure like tunnels and caverns even in wild life reserved areas.

In the case of Naitwar-Mori Hydroelectric Project, downstream of JSHEP and belonging to the same owner, probably the Government of Uttarakhand is loosing a good layout wherein the diversion structure is kept clear of the notoriously unstable and slided slopes downstream of the Naitwar village, the penstock slopes are rocky and stable, and

the powerhouse is located on stable terraces close to Mori township. This, however, cannot be had as the backwaters of Mori- Hanoi HE Scheme, with a different private owner, transgresses into the powerhouse area and beyond. A compromise between these two projects cannot be reached as the project owners are different entities. Only the Uttarakhand Government can use its power and make the parties agree to necessary modifications in the layouts of the two schemes so that the overall generation is not harmed in any way.

Conclusions

Layout modifications due to major geological features in the Himalaya are evident in case of the JSHEP, where upstream shifting of the powerhouse complex avoids the Purola Thrust across the pressure shaft alignment and provide a better subsurface excavation media. Keeping adverse geotechnical influence of the Purola Thrust away from important project components like the pressure shafts, may be a welcome step.

Senso-stricto adherence to statutory demands may lead to unnecessary losses in project planning and execution. Restrictions on locating even the deep seated sub surface structures like HRT and underground powerhouse of the JSHEP in the wild life sanctuary area have led to tightrope walking while planning the project layout and loss of good sites for placing major structures. Reassessment of wild life and Environment Conservation Acts on technical grounds may be the need of the hour.

Valley optimization should be the prerogative of the Government. In case of conflicts of interest between independent schemes, the Government may act as a moderator and take decisions in the overall long term interests.

Acknowledgements

The authors express their sincere thanks to Shri P.N Razdan, Senior Deputy Director General, GSI, NR and Shri Deepak Srivastava, Deputy Director General, Operation UP&UA, GSI, NR for providing their support in preparation of the paper. The first two authors also express their sincere thanks to Shri Yogendra Deva, Director, Engineering Geology, Op:UP&UA, GSI, under whose guidance and supervision the present work has been carried out.

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