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HYDROPOWER POTENTIAL OF PAKISTAN

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INTRODUCTION

Pakistan does not have large proven reserves of fossil fuels but is fortunate to have been endowed with considerable hydroelectric potential. The gross hydropower potential available in Pakistan is about 3300 MW. There are number of suitable sites available on Indus, Jhelum, Swat, Panjkora and Chitral Rivers which can be developed to meet the growing power demand of the country for many decades to come. In addition the existing barrages and link canals offer attractive sites for the development of low head hydroelectric plants of medium capacity. The availability of this natural resource combined with the country's large balance of payment deficit, caused to a great extent by its substantial imports of, oil makes hydroelectric development a logical choice. This article discusses the Hydro power potential available on major rivers, their tributanis, barrages and link canals in Pakistan.

EXISTING GENERATING PLANTS

The present total installed capacity of power generating plants in the country is 6624 MW out of which 44 percent (2897 MW) is hydel and the rest (3727 MW) 56 percent is thermal. Of this Pakistan Water and Power Development Authority owns 81% while 19% is supplied by Karachi Electric Supply Corporation. All the hydel plants are located in WAPDA's Power System. Major Hydroelectric plant in the country are at Tarbela, Mangla and Warsak dams located in the Northern parts of the Country. Fig.1 (Plan of Pakistan) shows location of rivers, dams, barrages and link canals. The Tarbela Power Station has an installed capacity of 1750 MW having 10 units of 175 MW each. The project envisages installation of another four units of 432 MW capacity each on tunnel No.3 by October, 1991. The Mangla Power Station has an installed capacity of 800 MW with 8 units of 100 MW each. Two additional units of 100 MW each will be installed by December, 1991 increasing its capacity to 1000 MW.

The Warsak Power Station has an installed capacity of 240 MW. In addition there are small hydel plants at Dargai (20 MW), Jabban (19.6 MW), Rasul (22 MW), Shadiwal (13.5 MW), Chichoki Mallian (13.2 MW), Nandipur (13.8 MW) Renala (1.1 MW), Kurram Garhi (4 MW) and Chitral (1 MW) with a total installed capacity of 108 MW. Table-I shows the installed and actual

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effective capacity of existing hydel power stations. The total energy produced in 1987- 88 amounted to 23439 Gwh out of which 65% was hydel and 35% was thermal. Table-1 (continued) gives the addition in progress at Mangla and Tarbela Power Projects.

An important aspect relating to hydel power plants which has to be taken into account is the system's generating characteristics. The capability of hydel stations does not remain the same throughout the year. During the high water months hydroelectric plants produce optimal energy whereas in lean winter months the production is reduced to about one third of the installed capacity. Over and above, this, the hydel generation is largely dependent upon vagaries of nature. The drought conditions will change the normal pattern. The major reservoirs in Pakistan were built primarily for supplementing irrigation supply and power generation is only an incidental benefit. During the early summar months the reservoirs are drawn to their lowest level due to continued draft for irrigation and the output of associated power plants is very low. This period concides with the peak load demand due to rising summer temperatures. Thermal plants are therefore required not only to fill the gap in generation capability of hydel power stations but also to meet the increasing load demand. Pakistan has very limited deposits of gas, coal and some oil. The present sources of thermal generation are distillate high speed diesel oil, natural gas and coal. Thermal generation is not only very expensive but import of oil and coal is a big drain on the financial resources of the country. A comparison of unit cost of generation from thermal plants and hydel plants is given in the following Table.

Thermal Plants:

	Fuel Type	Thermal Efficiency	Heating Value	Qty/Kwh	Rate	Fuel Cost
i.	Furnace Oil	34%	18500 Btu/Lbs	0.54 Lbs	Rs. 1980 per Mt.	49 Ps
ii.	High Speed diesel Oil	27%	19500 Btu/Lbs	0.65 Lbs	Rs. 3.85 per litre	137 Ps
iii.	Natural Gas	32%	930 Btu/Cft	12 Cft	10.11/1000 Cft	12 Ps
iv.	Natural Gas Purified	32%	975 Btu/Cft	12 Cft	47.45/1000 Cft	57 Ps
v.	Coal	34%	8500 Btu/Lbs	1.18 Lbs	728 Mt.	39 Ps
		Hydel Plants (Costs 1987)				
i.	Tarlala	53% Plant Factor		8 Ps		
ii.	Mangla	76%		2 Ps		
iii.	Renala	27%		15 Ps		
iv.	Chitral	46%		53 Ps		

WAPDA and Northern Area Works Organization have also built some mini hydel plants in the Northern areas of Pakistan mainly in the Gilgit, Dir, Chitral and Kohistan districts. These are small plants varying in size from 50 to 600 KW meeting the local power needs of isolated and

remote villages in the mountains. Their total installed capacity is 2.71 MW. Another hydel power station of 3 MW capacity is now under construction by WAPDA on Kargah Nullah at Gilgit.

HYDROELECTRIC POTENTIAL

Of the total hydrolelectric potential of 33000 MW, 10% would be ultimately obtained at Tarbela, Mangla and Warsak. A total of 1928 MW of hydel capacity is at present under various stages of installation at Tarbela and Mangla. A third major dam at Kalabagh has been planned on Indus River.

KALABAGH DAM : The Kalabagh dam is planned to be located 120 miles downstream of Tarbela. The main objective of Kalabagh dam is to generate large quantity of low cost hydel power near the load centre and increase the efficiency of generation of power at Tarbela through conjuctive operation. It would provide storage of about 7 MAF of water for irrigation and generate 3600 MW of power. In-order to minimise environmental effects, the design of the dam has been modified and conservation level has been reduced from El.925 to El.915. The main dam would be a rolled fill embankment of earth and rock about 5000 feet long and 257 feet high. It shall have two spillways each capable of passing about one million cusecs. Initially the main power station will house 8 units of 300 MW capacity each with ultimate provision for expansion to 3600 MW capacity. Feasibility report prepared by WAPDA and approved by World Bank shows that the project is economically attractive. Detailed design and Tender documents have already been prepared.

HYDEL RANKING : Hydel ranking studies have indicated that 12400 MW power can be obtained from development in the Upper Indus basin at Basha, Dasu and Thakot upstream of Tarbela which will meet the country's need well upto 2000. The major hydroelectric projects are not only highly capital intensive but require long periods for planning & design. The power load forecasts indicate that at the current rate of load growth the power demand will increase to nearly 20,000 MW by the year 2001-2002. This is a very high rate of growth and requires tremendous efforts on national level and mobilization of huge finances.

The three major watersheds in Pakistan which provide substantial potential for hydroelectric development are the upper Indus basin, Jhelum river above Mangla and parts of Kabul, Swat and Chitral basins in Pakistan. It has been estimated that ultimate installed capacity at hydropower schemes in these areas which is now economically attractive (compared with thermal alternative) is about 18000 MW. An additional 4300 MW can be installed at schemes which might become competitive in the near future. Due to combination of large available discharges and high heads, the Indus river above Tarbela has by far the largest hydroelectric potential in the country. Average run-off in the Indus river is almost three times that in the Jhelum River. In addition because of the poor geological conditions encountered in most of the Jhelum basin, generally dam heights would be restricted to about 70 meter. Also tunneling in the Jhelum basin would be more difficult and expensive than in the Indus. Consequently schemes on the Jhelum River are smaller and less cost effective than those on the Indus. The power potential of schemes in Kabul, Swat and Chitral basin is relatively modest.

Due to large seasonal variation in river flows, the primary need of Pakistan is the energy which can be stored in high summer months and subsequently utilized during low winter months. The storage schemes are therefore more valuable to the system. For schemes without

any storage potential the firm energy available during the lowest winter months of January is the primary energy which contributes towards the country's load growth. The secondary energy produced in other months which can be absorbed by the system is equal to the total average energy delivered by a scheme to the system with a plant installation equal to Index capacity minus the corresponding primary energy. The index capacity for scheme is defined as the firm energy produced over a year and delivered to the system at 60% load factor and with 11% allowance for reserve. The index capacity however does not represent the optimum installed capacity at a scheme but provides a consistent means of comparing the scheme adopted by MECO for ranking. The schemes on Jhelum rivers and its tributaries due to their early rising characteristic (flood seasons starts in the mid March) provide maximum output during the early summer months and should therefore be ranked according to their peaking capability in the month of May and not on the basis of minimum energy produced in January. For instance Kohala Hydroelectric project on Jhelum River has a firm power potential of 80 MW in January but provides a peaking capability of 300 to 576 MW from March to May.

The major project like Kalabagh and Basha are long gestation projects and require long period for planning and execution and huge mobilization of funds. In the interim period the existing irrigation barrages and link canals offer very attractive sites for installation of low head hydel plants. In a preliminary survey carried out by WAPDA nine sites were identified on the Indus barrages and large link canals (where medium size 10 to 200 MW plants can be installed) with a total installed capacity of 644 MW. However there are many other sites available on major irrigation canals where small hydel projects generally under 10 MW can be installed. Irrigation and Power Department has already carried out feasibility studies for five such schemes on branch canals in Punjab. According to a survey carried out by WAPDA in 1974, small streams in Northern Areas have a potential of 30 MW mainly in Dir, Chitral, Gilgit and Kohistan districts where small hydel plants ranging in capacity from 50 to 400 KW can be installed.

GHAZI GHARIALA : A diversion canal type project on Indus river below Tarbela dam known as Ghazi Gariala Project is presently under active investigation with WAPDA. The water would be diverted from Indus below Tarbela th ough a barrage and a large capaity canal running upto Attock where the water would be dropped into Haro river thus utilizing the large available head 600 ft. at this point to generte 500 MW of power.

GOMAL ZAM : The scheme envisages construction of 443 ft. high double arch concrete gravity dam at Khajuri Kach about 3 miles downstream of confluence of rivers Zhob and Gomal. This dam would eliminate the flood hazard in Dera Ismail Khan district and utilize the stored water for irrigation of 100,000 acresa of land. The project has potential to generate 117 GWrH of hydel energy. The firm capacity depends upon duty assigned to power station as follows: 115 MW for 4 hour dauly peaking operation, 75 MW for 6 hour daily peaking operation, 17 MW for 24 hours base load operation.

Upper Indus Basis

The hydroelectric inventory and ranking studies show that an ultimate installed capacity at major schemes in Upper Indus basin which is at present competative with alternative thermal installation is in the range of 13500 MW. In addition the major planned projects at Basha and Kalabagh have an installed capacity of 3600 MW each. Table-2 shows the list of identified sites on

Upper Indus river. The Upper Indus includes the reach of the river from proposed Kalabagh dam site to the control line upstream of its confluence with Shyok River. Sixteen potential hydropower sites in this reach were identified and studied by MECO in various configurations. Fig.2 and 3 show the proposed hydroelectric schemes in the Upper Indus Basin. From the control line to the confluence with the Shyok, the Indus River has a modest power potential due to low river flows and generally narrow valley unsuitable for a large storage reservoir.

The Yugo dam site is located in this reach on Shyok River. The valley around Khaplu which would be flooded by a dam at Yugo has considerable physical storage potential. However the amount of live storage is restricted by the low dependable flows in the Shyok River. A 542 feet high dam will provide a gross storage of 7.30 MAF. In the reach from the mouth of Shyok River to a site downstream of Skardu, the wide Skardu flood plain provides excellent site for a storage reservoir, but it would inundate the town of Skardu. The average annual run-off at Skardu is 24 MAF. An earth rockfill dam at Skardu located some 40 miles downstream of confluence with Shigar river would provide a gross storage of 20.25 MAF.

The river valley from Skardu to its confluence with Gilgit is generally narrow, with little or no storage potential. In such conditions power head could be developed by tunnels cutting across river bends. The Rakhiot schemes is located in this reach. An exceptionally high dam at Rakhiot would be required to develop any significant storage. The river valley about 61 miles below at Basha is relatively wide and has considerable storage potential with an average annual run-off of 62 MAF. A storage reservoir at Basha with a 700 feet high dam provides considerable power potential. The river after Basha drops a further 1541 feet to enter Tarbela reservoir. The valley is narrow in this reach and offers sites for the development of run-of river plants at Dasu, Pattan and Thakot. With the exception of storage at Yogu, Skardu, Basha and Rakhiot all new hydroelectric schemes on the Indus river would be run-off river projects which would benefit from regulation at the upstream reservoirs.

Gilgit has a rather steep average gradient and the river valley is relatively wider. Good dam sites are not available in Gilgit valley. The Gilgit valley is also known to have been exposed to floods caused by glacier dam bursts. The river carries an average annual run-off of 6 MAF at Gilgit town. Kanch and Sher Qila both run-of-river shcemes are located on Gilgit river.

There are three other large tributaries in the upper Indus basin, viz Shigar, Hunza and Astor which are not suitable for major hydropower projects. Hunza carries the heaviest sediment loads of all rivers in this basin. Due to its very steep gradient it has no storage capabilities. In addition a large number of glacier outburst floods on record have originated from the Hunza valley. The geology of upper Indus basin is very diverse. The rock types include various metasediments, granites, quartzites and slates in the south and granodiorite gneisses and marbles to the north. In general the rocks are massive, hard and suitable for tunneling and therefore large underground power houses can be built at most of the sites.

The most suitable type of dams which can be constructed in the narrow gorge of upper Indus basin are earth rockfill dam and concrete arch or gravity dam placed on the bed rock. There are abundant quantities of granular material and scattered deposits of clayey silt on terraces. However, their suitability as an impervious core for a rockfill dam needs further investigations. If concete dams are selected deep excavations upto 200 feet would be required in the river bed to found a concrete dam on the bed rock. The same applies to concrete faced rockfill dams. Although

earth rockfill dam would make maximum utilization of local available materials, they would pose the difficult problem of providing a cut-off under the dam through the alluvium and also blending of clayey material to obtain large quantity of core material. In the narrow and steep sided valley of Indus River underground power house provides better protection against the dangers of rockfalls, mud slides and flood waters. Underground power houses are also more cost-effective than the above ground type since the later requires a large volume of excavation. Due to range of head available, vertical axis Franeis type turbines would be suitable at most of the sites. However, the maximum size of key equipment would be limited by the width of Korakoram highway.

BASHA DAM : The hydroelectric ranking study by MECO indicated that after Kalabagh dam first ranked scheme in Pakistan is a Project providing both storage and power located at Basha on Indus river 195 miles upstream of Tarbela, with a strorage potential of 7.5 MAF. Basha would supplement water storage, replenish the storage lost at Tarbela due to sedimentation and help raising the minimum draw down at Terbela thus raising the peaking capabillity in the month of May. Basha would produce 3600 MW of power and give additional power benefits at d/s dams. Basha dam would be 700 ft. high earth and rockfill embankment. No doubt it is an excellent site but still some studies are required for optimisation of the project. This would also require relocation of the Korrakorram highway falling in the reservoir and also upgradation of the highway leading to the site. If work is started right away on the project, it can supply power in the start of 21st century. The run-of-river projects located downstream between Basha and Tarbela will benefit from the stream flow regulations provided by Basha reservoir. The schemes with the lowest index cost after Basha are Dasu, Bunji, Thakot and Pattan (refer Figure-2). The head between Dasu tail-race and Tarbela full supply level could be developed by either one scheme-high Thakot, or two schemes at Pattan and low Thakot. The second alternative is less disruptive to the social infrastructure but is somewhat less cost effective. The two additional storage sites at Yugo and Skardu can be regarded only as long term prospects to be developed only after some of the more accessible sites have been built. Skardu is more cost effective than Yugo due to large available storage.

Jhelum River Basin:

The Jhelum basin is considerably less attractive than Indus. The Hydroelectric schemes identified in Jhelum River basin are shown in Table-3 and Fig.4. The estimated average annual runoff in the Jhelum reach upstream of Mangla reservoir is about 21 MAF or 35 percent of that in Indus River. Because of the poor foundation conditions resulting from the discontinuous beds of shales and sandstones of the Murree formations, dam heights would be generally limited to 230 feet or about one third those of Indus. The three main rivers of this basin are the Jhelum main, and its tributaries the Neelum and the Kunhar rivers. These rivers generaly flow in deep gorges and at a very steep slope and there are few locations where the valleys are wider. Hence the sites available in Jhelum basin have limited storage potential and require very high dams to achieve economical storage capacity.

A storage site on the Upper Jhelum at Chikar upstream of Kohala provides only a live storage of 0.16 MAF with a 460 feet high dam. A storage site on the Neelum river at Dhudnial provides a storage of 1.1 MAF with a 700 feet high dam. On Kunnhar river storage sites at Naran, Suki Kinari in the upper Kunhar basin and at Patrind and Lohari Gali in the lower valley

are available. Although these storages are small yet they are significant in terms of the average annual run-off in the Kunhar river and afford a reasonable degree of regulation. Apart from these schemes on the Kunhar river all hydroelectric projects in the Jhelum basin would operate on a run-off-river basis. The two lower schemes on Kunhar river and the four projects in the middle Jhelum would operate assuming complete development of upstream storage on the Kunhar. In addition several combination schemes could be developed on the three rivers in which the water could be diverted from one river through a transmountain tunnel to the other river and the head thus available could be exploited at more than one location. These schemes have been listed in Table- 3.

The poor and complex geological conditions in the Jhelum and Neelum valleys do not favour construction of high dams. The geological formations comprise weak friable sandstones and limestones with frequent out-crops of shales. Repeated cycles of wetting and drying cause these to disintegrate and form steep slopes which become unstable in wet conditions. In addition the sandstone beds are not wide enough to provide continuous rock foundations for spillway or intakes. The practical solution appears to be the construction of low concrete gravity dams in the river channel with as little excavation as possible in the abutments. The tunneling operation in Jhelum and Neelum basin would be more difficult due to poor geology. The Jhelum valley is consistently narrow throughout its length. No sites are available where the spillway and power intakes could be contained within the width of the valley. Sites are therefore, located near nullah openings where more space would be available and where valley sides rise to lower elevations.

In the Upper reaches of Kunhar river the gological conditions are favourable for higher dams. The conditions are similar to those in the upper Indus basin except for the fact that the depth of river bed alluvium is much less consequently concrete dams are also cost effective. Underground power house would be the ideal choice for the developments on Jhelum river, since land slides are common and exceptionally large floods have been reported. However, the sandstone beds are not thick enough for large under- ground caverns and therefore semi out door power houses would be adopted for these schemes. Because of abnormally high design floods, a power house would typically require a massive substructure to counteract flotation.

In Jhelum basin rivers are in high flow in the early summer months from March to May thus providing ample opportunity to generate substantial power in the critical power deficit period on the national grid thus replacing the costly thermal generation. The volume of sediment carried by Jhelum river is generally less than that of Indus river. The reservoirs at Naran and Suki Kinari on the Kunhar basin have storages of only 0.28 MAF and 0.13 MAF but have long lives of 1500 years. However, the life of Patrind reservoir near the Jhelum confluence with a storage of 0.42 MAF would be about 100 years.

Kabul, Swat and Chitral Basis

The Kabul, Swat and Chitral basins have better foundation conditions than the Jhelum watershed. However the average flows available in Swat river below its confluence with the Panjkora and in the Chitral river are only about 7 MAF in each case. Hence the hydro power potential of these rivers is relatively modest. The schemes identified in Kabul, Swat and Chitral basins alongwith their power potential are shown in Table-4 and Fig-5. All the schemes on Swat River are associated with storage reservoirs. The portion of the runoff from the Swat river which

is in excess of existing irrigation requirements in the Swat and lower Kabul basins will in future help meet irrigation demands in the Indus basin as a whole and in dry years there will be no water remaining to fill the storage reservoirs in Swat basin. The four schemes therefore compete for the same water to fill their reservoirs. They are therefore mutually exclusive in their present configuration. The Swat schemes are benefitted with regulation from upstream storage reservoirs. All the schemes on Swat were studied individually as well as assuming diversion of 1.0 MAF annually from Chitral river at Mirkhani into Panjkora to supplement their flow. The diversions would however be only for four high flow months.

The Kabul river which rises in the mountains of Afghanistan and the Chitral river carry very large sediment. On the other hand the Swat basin where all the power sites are located is relatively free of sediment. Because of the low sediment yield in the Swat basin, the lives of the reservoirs at Kalam and Khazana have been estimated to be about 200 years, while the life of Kalangai reservoir would exceed 300 years. At Munda the reservoir life would be 1000 years.

The Swat river from Kalam to Bahrain drops at an average gradient of 32 ft. per mile and flows through a relatively wide valley known as Upper Swat gorge. The average annual runoff is 2.3 MAF. The steep slopes, wide open valley and limited flow in this reach (about 2.3 MAF) preclude major hydroelectric development at a reasonable cost. From Bahrain to confluence with the Panjkora alluvial river, valley is considerably wider. Although there is potential for considerable storage, the valley is well populated and cultivated. Below Panjkora confluence the river flows through the narrow lower Swat Gorge. The gradient here is only a few feet per mile. Large storage however cannot be developed due to very narrow width of the valley. Rockfil dams with impervious core are feasible at all the sites. The geology of the area is complex and includes a wide variety of igneous and metamorphic rocks which have undergone extensive deformations. Valley slopes in the basin are more stable than those of either the Jhelum or Indus Valleys. At all sites geological conditions are favourable for the construction of underground power houses with the exception of Munda and Kalangai.

Low Head Hydel Plants:

Due to recent advances made in the development of low head turbines suitable for minimum 10 feet head, there has been great stress in other countries on exploiting the under-developed and low head hydro-power sites which were previously considered uneconomical. The economy of such a decision depends upon changing economic conditions in the world and rising demand for electric energy. To cope with the fast rising power demand in a short period it is quite attractive to look into the short gestation low head hydroelectric projects existing on irrigation barrages and large canals in Pakistan. These power stations produce power at a cheaper rate than the thermal plants.

WAPDA in 1984 identified nine sites on barrages and large link canals for feasibility studies. The sites considered have generally capacities of about 10 MW. The nine sites selected for studies by WAPDA on irrigation barrages are at Jinnah, Chashma, Taunsa and Guddu Barrages and five on link canals Chashma - Jhelum link one site and at two existing falls on Balloki-Sulemanki Link and on Rohri canal at two canal falls. The list of identified sites is shown in Table-5. The Chashma Low Head Project on Indus River shall have installed capacity of 220 MW.

The total generation capacity available from the nine low head sites identified so far on the

existing barrages and canal falls has been estimated to 644 MW. In view of the low available head (generally between 15 to 30 feet) and great variation in head and discharge, suitable types of turbines for low heads are bulb turbines. The bulb type unit is especially suited where the variation in head and discharge is great and water carries large amount of silt. From construction point of view, it requires a smaller power house with civil works reduced by 30 percent. The layout for a power plant on an existing irrigation barrage requires that there is a minimum of disturbance in the existing regime of the river and least modification in existing river training works. This is particularly true for alluvial rivers in the Indus plain like Indus or its tributaries.

In addition to the proposed low head hydel plants on existing barrages and two major links canals M/s. ACE have prepared feasibility studies for five small hydels schemes on major irrigation canals of the Punjab Province. The capacity of these plants range between 3 to 5 MW. It is believed many more locations on existing irrigation canals in the Indus plain can be developed for small power plants of less than 5 MW capacity.

Small Hydel Scheme

The northern part of Pakistan abounds in hilly streams with steep gradient and therefore offers a large potential of small hydroelectric sites. The area has scattered sparse population along nullahs. As it is not connected to the national grid system, it is feasible to build small hydel schemes with indigenous material for the local supply of electricity. At present the following organizations are working on the development of small hydro power schemes:

Appropriate Technology Organization (ATDO) Small Hydroelectric Development Organization NWFP Northern Area PWD

Govt. of Azad Jammu and Kashmir.

In 1973-74 Surface Water Hydrology Project of WAPDA carried out a stream gauging survey of 100 small streams in Gilgit, Dir, Chitral Swat and Kohistan districts to identify suitable sites for small hydel generation to supply electric power to remote isolated villages in these mountaineous terrain. According to this survey it was estimated that 10 MW of power is possible at small power plants ranging in size from 50 to 600 KW in Gilgit and Baltistan Districts of Northern areas and about 20 MV of power potential is available in Dir, Chitral, Swat and Kohistan districts.

NAWO has so far constructed 64 small schemes with a total generation potential of 18.325 KVA ranging in size from 50 to 2000 KVA in major villages of Gilgit, Hunza and Chilas valley.Some of the schemes completed upto 1987, those under construction and identified for future construction are given in Table-6. Fifteen schemes with a total potential of 11 MVA are proposed for construction during the year 1987-88 (Table-7) In addition Kohistan Development Board has constructed a number of small hydel schemes to supply electric power to important towns in Kohistan areas located mainly along the Karakoram Highway. The total potential of these stations is about 1 MW. A few small hydel schemes from 100 to 500 KW have also been constructed in Dir, Chitral and Swat districts by Government of NWFP.

In addition Government of Azad Jammu and Kashmir had identified sixteen sites on hill torrents of AJK where micro hydel power stations could be installed. M/s. Crescent group of

services have prepared Kundal Shahi Hydel Scheme of 1200 KW installed capacity on Jagran Nullah about 2 KM upstream of its confluence with Neelum River.

CONCLUSIONS

Previously the Goverment policies have been short termed. We must have long term planning and policies in addition to short term policies. Pakistan does not have enough sources of fossil fuel. Moreover these sources are short lived. Pakistan is endowed with Hydro Power Potential of about 33000 MW out of which only 10% has been exploited. The remaining potential at Mangla and Tarbela is being exploited by installing addtional units. In order to make up the fast depleting capacity of Mangla and Tarbela reservoirs due to sediments at least one storage type hydel; power station is necessary. Kalabagh which provides both storage and power, is near the load centre and is ready for construction, should be started immediately. Kalabagh's conjunctive use with Tarbela would produce additional power at Tarbela and help in raising its minimum pool level.

Basha dam's feasibility should be firmed up and construction undertaken at an date so that it come on line by the turn of the centry. In addition to the above major dams we can have additional 12500 MW on the run of river projects on river Indus such as Dasu, Bungi and Pattan . Early investigations on these projects should be started. Jhelum & its tributaries due to their early rising feature provide maximum power output in the early summer season and can help to firm up the hydel power in critical months. Low Head Hydel Power Stations at existing barrages and canal falls should be taken up. In northern areas of Pakistan which are not connected with the National Grid System, mini hydel power station should be built with the indigenous material.

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Table 1

HYDEL POWER

INSTALLED CAPACITY AND EFFECTIVE CAPABILITY

(In MW)

Sr. No.	Name of Power Station	Date of Commiss-ioning	No. and Capacity of Units	Total Installed Capacity	Effective Capability	
					Maximum	Minimum
1.	Tarbela	May 1977	2x175			
		June 1977	1x175			
		July 1977	1x175			
		Aug. 1982	1x175	1750	200	570
		Oct. 1982	1x175			
		Dec. 1982	1x175			
		Feb. 1985	1x175			
		May 1985	1x175			
2.	Mangla	July 1967	2x100			
		Mar. 1968	1x100			
		Jun. 1969	1x100	800	920	400
		Dec. 1973	1x100			
		Mar. 1974	1x100			
		Jun. 1981	2x100			
3.	Warsak	May 1960	2x40			
		Jun. 1960	1x40	240	240	80
		July 1960	1x40			
		Mar. 1981	2x40			
		Sub-Total		2790	3160	1050
4.	Dargai	Apr. 1954	4x5	20		
5.	Malakand	1938	3x3.2	20		
		1951	2x5			
6.	Rasul	May 1951	2x11	22		
7.	Chichoki Malian	May 1959	1x4.4			
		June 1959	1x4.4	13		
		Aug. 1959	1x4.4		70	40
8.	Shadiwal	June 1961	2x6.75	13		
9.	Nandipur	Mar. 1963	3x4.6	14		
10.	Kurram Garhi	Feb. 1958	4x1	4		
11.	Renala	1925	5x0.22	1		
		Sub-Total (Small Hydels)		107	70	40
		Total Hydel:		2897	3230	1090

TABLE-1 (Continued)

ADDITION AT TARBELA AND MANGLA POWER PROJECTS

S.No.	Power Station	Capacity in MW
1.	Tarbela	
	Unit 11	432
	Unit 12	432
	Unit 13	432
	Unit 14	432
	Total:	1728
2.	Mangla	
	Unit 9	100
	Unit 10	100
		200

TABLE - 2

INVENTORY OF HYDROELECTRIC SCHEME - INDUS RIVER BASIN

No.	Name	River	Gross Head (M)	Height of Dam (M)	Live Storage Volume Volume	Live Storage Volume % of Flow	Average Flow M^3/s	Index capacity at plant	Index cost Rs./Unit
			FIRST - ADDED SCHEME AFTER BASHA AND KALABAGH						
1.	YUGO	SHYOK	-	165	5.9	55.4	338	-	-
2.	SKARDU	INDUS	-	230	19.0	63.3	951	-	-
3.	TUNGAS	"	214	127	-	-	962	625	0.202
4.	YULBO	"	238	140	-	-	990	710	0.135
5.	BUNJI	"	402	210	-	-	1025	1290	0.058
6.	KANCH	GILGIT	190	200	-	-	207	122	0.871
7.	SHER QILA	"	121	130	-	-	234	88	1.517
8.	RAKHIOT	INDUS	120	140	-	-	1858	670	0.097
9.	DASU	"	215	235	-	-	2099	2712	0.027
10.	PATAN	"	150	104	-	-	2254	1172	0.071
11.	THAKOT	"	138	60	-	-	2337	1043	0.069
12.	THAKOT	"	288	205	-	-	2337	2415	0.064

TABLE - 3

INVENTORY OF SCHEMES - JHELUM RIVER BASIN

No.	Name	River	Gross Head (M)	Height of Dam (M)	Live Storage Volume Volume Km³	% of Annual Flow	Average Flow M³/s	Index capacity at plant	Index cost Rs./Unit
					FIRST-ADDED SCHEME				
1.	NEELUM	NEELUM	156	30	-	-	316	76	0.284
2.	KOHALA	JHELUM	167	36	-	-	349	85	0.114
3.	NARAN	KUNHAR	352	195	0.306	19.8	49	177	0.192
4.	SUKI KINARI	"	940	160	0.149	6.9	64	332	0.196
5.	PATRINO	"	105	130	0.320	9.6	106	133	0.215
6.	ABBASIAN	JHELUM	53	80	-	-	809	90	0.333
7.	MAHL	"	53	75	-	-	825	93	0.292
8.	AZAD PATAN	"	48	70	-	-	833	86	0.250
9.	KAROT	"	52	70	-	-	834	93	0.173
					COMBINATION SCHEME				
10.	NEELUM	NEELUM	842	30	-	-	67	76	
	KOHALA	JHELUM	610	36	-	-	349	187	0.140
	Combined				-	-	416	263	
11.	NARAN	KUNHAR	2208	195	0.306		-	177	
	SUKI-KINARI	KUNHAR	1268	160	0.146	22.5	64	609	0.140
	Combined				0.455		64	786	
12.	U/S STOR-AGE	KUNHAR	838	130	0.455		-	744	
	PATRINO	KUNHAR			0.320	23.5	106	199	0.145
	Combined				0.775		106	985	
13.	U/S STOR-AGE	KUNHAR JHELUM	610	80	0.775		-	985	
	ABBASIAN				-	3.0	809	167	0.155
	Combined				0.775		809	1152	
14.	U/S STOR-AGE	KUNHAR JHELUM	557	75	0.775		-	985	
	NAHAL				-	3.0	825	169	0.152
	Combined				0.775		825	1154	
15.	U/S STOR-AGE	KUNHAR JHELUM	481	70	0.775		-	985	
	AZAD PATAN				-	3.0	833	156	0.149
					0.775		833	1141	
16.	U/S STOR-AGE	KUNHAR JHELUM	433	70	0.775		-	985	
	KAROT				-	2.9	834	169	0.140
	Combined				0.775		834	1154	
								6635	

TABLE - 4

INVENTORY OF SCHEMES - KABUL, SWAT, CHITRAL BASIN

		River	Gross Head (M)	Height of Dam (M)	Live Storage Volume		Average Flow M^3/s	Index Capacity at plant	Index cost Rs./Unit
					Volume	% of Annual Flow			
				FIRST - ADDED SCHEME					
1.	KALAM	SWAT	139	160	0.316	11.4	88.1	116	0.524
2.	MIRKHANI	CHITRAL	-	125	-	-	307	-	-
3.	KHAZANA	PANJKORA	111	115	0.682	29.3	73.9	110	0.208
4.	KALAM	SWAT	131	145	1.436	17.9	254	256	0.143
5.	MONDA	SWAT	198	205	1.468	16.3	285	492	0.161
				COMBINATION SCHEMES					
6.	MIRKHANI/	CHITRAL	111	120	1.272		40	-	0.812
	KHAZANA	PANJ-			1.272	35.4	74	221	
	Combined	KORA					114	221	
7.	MIRKHANI	CHITRAL	131	145	1.950		40	-	0.479
	KALANGAI	SWAT			1.950	21,00	254	350	
	Combined						294	350	
8.	MIRKHANI	CHITRAL	198	205	1.858	18.1	40	-	0.396
	MONDA	SWAT			1.855		285	728	
	Combined						325	728	

TABLE - 5

LOW HEAD HYDEROPOWER AT BARRAGES AND UNIT ENERGY COST

	PROJECT		JINNAH	CHASHMA	TAUNSA	GUDDU
1.	Design Discharge	m^3/s	4 000	4 000	3 100	2 600
		ft^3/s	141 200	141 200	109 000	91 800
2.	Rated Head	m	4.3	7.8	5.9	2.5
		ft	14.2	25.7	19.3	8.2
3.	No. of Units		16	16	12	10
4.	Runner Diameter	m	6	6	6	6
		ft	19.7	19.7	19.7	19.7
5.	Installed Capacity	MW	141	255	144	51
6	Annual Energy Output	GWh	817	1 250	785	269
7.	Total Cost*	U.S.$ M.	160	195	150	105
		Rs. M.	2 210	2 710	2 050	1 460
7.1	F.E.C	U.S.$ M	80	105	75	55
7.2	Local	U.S.$ M.	80	90	75	50
		Rs. M.	1 090	1 450	1 020	700
8.	Cost Per Kwh	U.S.$	1 425	1 038	1 374	261
		Rs.	21 400	15 570	20 600	39 200
9.	Cost Per Kwh*	U.S.$	0.026	0.022	0.027	0.053
		Rs.	0.40	0.33	0.40	0.80

* Exclusive of custom duties and I.D.C. for ranking purposes.

TABLE - 5 (Continued)

LOW HEAD HYDROPOWER AT CANALS AND UNIT ENERGY COST

	Project		C-J Link Tail	B.S. Link-1 RD 106	B.S. Link-1 Tail	Rohri Canal RD 15	Rohri Canal RD 117	Rohri Canal Comb.
1.	Design	m^3/s	385	330	230	375	375	375
	Discharge	ft^3/s	13 600	11 650	8 120	13 240	13 240	13 240
2.	Design Head	m	12.7	3.4	3.3	2.6	1.6	4.0
		ft.	41.7	11.2	10.8	8.5	5.2	13.24
3.	No. of Units		4	4	4	6	6	5
4.	Runner Dia	m	3.8	3.5	3	3	3	3.5
		ft.						
5.	Installed Capacity	MW	40	9	6	8	5	12
6.	Annual Energy Output	GWh	311	71	46	69	46	108
7.	Total Cost	U.S.$ M.	35	19	16	23	25	31
		Rs. M	490	266	225	324	343	428
7.1	F.E.C.	U.S.$ M.	17	10	7	11	11	14
7.2	Local	U.S.$ M	18	9	9	12	14	17
		Rs. M	250	135	125	175	195	235
8.	Cost per Kw	U.S.$	852	2 580	3 160	3 534	5 700	2 874
		Rs.	12 776	38 600	47 400	53 000	85 500	43 100
9.	Cost per KWH	U.S.$	0.016	0.036	0.046	0.044	0.070	0.037
		Rs.	0.24	0.64	0.69	0.66	1.05	0.55

TABLE - 6

EXISTING HYDEL STATIONS ENDING JUNE 1987

GILGIT DISTRICT		Capacity in KVA
1.	Gilgit Phase-I	400 KVA
2.	Gilgit Phase-II	560 KVA
3.	Gilgit Phase-III	375 KVA
4.	Gilgit Phase-IV	375 KVA
5.	Dormoshko	250 KVA
6.	Juglote	135 KVA
7.	Single	125 KVA
8.	Sherqillah	135 KVA
9.	Nomal	135 KVA
10.	Naltar	100 KVA
11.	Chalt	50 KVA
12.	Hassanabad Phase-I	200 KVA
13.	Minapin	125 KVA
14.	Sumayar	125 KVA
15.	Chatorkhand	200 KVA
16.	Hassanabad Phase-II	500 KVA
17.	Danyore	200 KVA
18.	Khyber	500 KVA
19.	Gupis	750 KVA
20.	Bodulas	750 KVA
		4792 KW = 5990 KVA
DIAMER DISTRICT		
1.	Chilas	200 KVA
2.	Astore	270 KVA
3.	Thore	125 KVA
4.	Tangir	200 KVA
5.	Darel	250 KVA

TABLE - 6 (Continued)

HYDEL PROJECT IDENTIFIED FOR FUTURE CONSTRUCTION

Sr. No.	Name of Project	Capacity
	GILGIT	
1.	Const. of 250 KVA H/Scheme Phase-II Sumayer	250 KVA
2.	Const. of 500 KVA H/Scheme Pisson	500 KVA
3.	Const. of 500 KVA H/Scheme Sher Qillah Phase-II	500 KVA
4.	750 KVA H/Scheme Darmadar	750 KVA
5.	1 MW H/Scheme Juglote Phase-II	1250 KVA
6.	200 KVA H/Scheme Bargo	200 KVA
7.	Const. of 500 KVA H/Scheme Haramosh	500 KVA
		3160 KW
		3950 KVA
	DIAMER	
1.	Const. of 800 KVA H/Scheme Bulashber	800 KVA
		800 KVA
	BALTISTAN	
1.	Const. of H/Scheme at Tolti Phase-II	250 KVA
2.	2 MW H/Scheme at Kachura Phase-III	2500 KVA
3.	Const. of H/Scheme at Baraldo Shigar	500 KVA
4.	Const. of 500 KVA H/Scheme Ganji	500 KVA
5.	500 KVA H/Scheme at Hassanabad (Khaplu)	500 KVA
6.	1 KVA H/Scheme at Mehdi Abad	1000 KVA
7.	Const. of 1 MWA H/Scheme at Hargosil (Kharmong)	1000 KVA
		6250 KVA
	Total:	11,000 KVA

TABLE - 6 (Continued)

6.	Parshing	200 KVA
7.	Rattu	200 KVA
8.	Gurikot	250 KVA
		1695 KVA

BALTISTAN DISTRICT

1.	Skardu Phase-I	400 KVA
2.	Skardu Phase-II	800 KVA
3.	Khaplu	135 KVA
4.	Parkuta (Mehdi Abad)	135 KVA
5.	Sirmik	125 KVA
6.	Shigar	135 KVA
7.	Kachura	250 KVA
8.	Tolti	250 KVA
9.	Olding	125 KVA
10.	Hoshopi	100 KVA
11.	Stak	200 KVA
12.	Mendi	200 KVA
		2855 KVA

Total: 10,540 KVA

TABLE - 6 (Continued)

UNDER CONSTRUCTION HYDEL PROJECTS

		Capacity in KVA
GILGIT		
1.	Danyore Hydel Project (for additional unit)	200 KVA
2.	Rehabilitation Kargah Complex Gilgit	1250 KVA
3.	1 MW Hydel Project at Jalalabad	1250 KVA
4.	1 MW Hydel project at Nazber (Yasin)	1250 KVA
5.	Hydel project at Ishkomen	1250 KVA
6.	Hydel project at Single Phase-II	250 KVA
		5450 KVA
DIAMER		
1.	Hydel project Chilas Phase-II	500 KVA
2.	1 MW Hydel project at Bunner	1250 KVA
3.	1 MW Hydel project at Phase-II Darel	1250 KVA
4.	Loss Hydel Project	600 KVA
5.	Shankergar Hydel project	250 KVA
		3850 KVA
BALTISTAN		
1.	Hydel Station manthoka	250 KVA
2.	Hydel Station Kayo	125 KVA
3.	Hydel Station Garboching	250 KVA
4.	Hydel Station Keris	200 KVA
5.	Hydel Station Thally	200 KVA
6.	Hydel Station Phase-II Kachura	250 KVA
7.	Hydel Station Gundus	2000 KVA
8.	1 MWA Hydel Station at Kharko Daghoney	1000 KVA
9.	1.5 MWA Hydel Station Balogun	1500 KVA
10.	1. MWA Hydel Station Dumsum	1500 KVA
11.	1 MVA Hydel Station at Basho	1000 KVA
12.	500 KVA Hydel Station Harpo	500 KVA
13.	Hydel Station Niasolo	250 KVA
		9025 KVA
		18,325 KVA

TABLE - 7

NEW HYDEL PROJECTS INCLUDED ADP 1987-88

		Capacity in KVA
GILGIT		
1.	Hydel Scheme at Juglote	1250 KVA
2.	Hydel Scheme at Misger (Hunza)	200 KVA
3.	Hydel Scheme at Nagar	1250 KVA
4.	Hydel Scheme at Phander	1250 KVA
		3950 KVA
DIAMER		
1.	1.6 MW Hydel Scheme Thack Chilas	2000 KVA
2.	Hydel Scheme Gudia Astore	500 KVA
3.	Hydel Scheme Horcho Astore	300 KVA
		2800 KVA
BALTISTAN		
1.	Hydel Scheme Turnic	1000 KVA
2.	Hydel Scheme Pion	1000 KVA
3.	Hydel Scheme Shirting	1000 KVA
4.	Hydel Scheme Shigar Phase-II	1000 KVA
5.	Hydel Scheme Gole	500 KVA
		4500 KVA
		11,250KVA
SCHEME IN OPERATION DIR CHITRAL KOHISTAN		
1.	Garam Chash	50 KVA
2.	Patika	100 KVA
3.	Chamare	100 KVA
		250 KW
4.	Basham	200
5.	Dir	360
6.	Korora	400
7.	Dober	300
		1260 KW

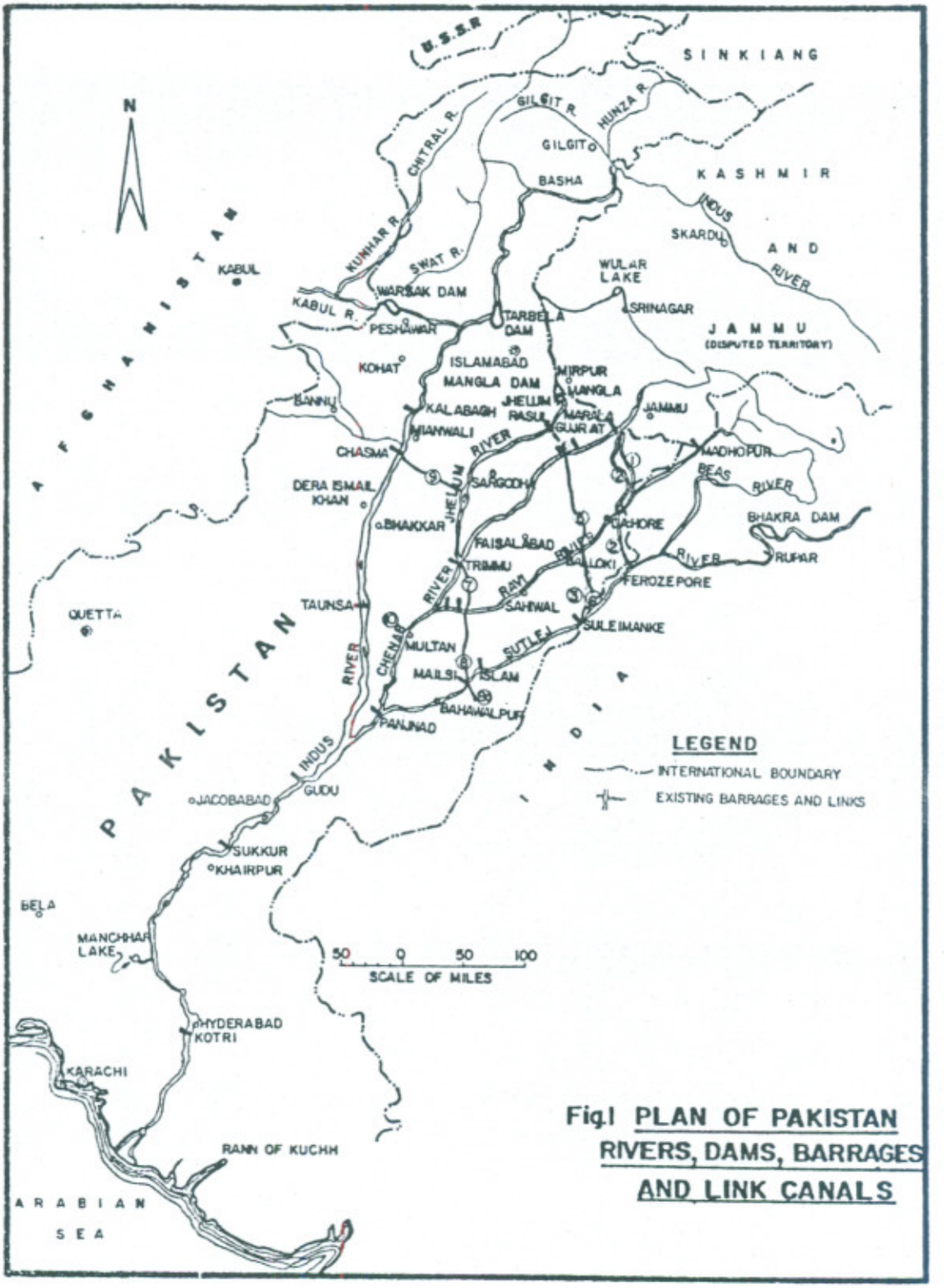


Fig.1 PLAN OF PAKISTAN RIVERS, DAMS, BARRAGES AND LINK CANALS

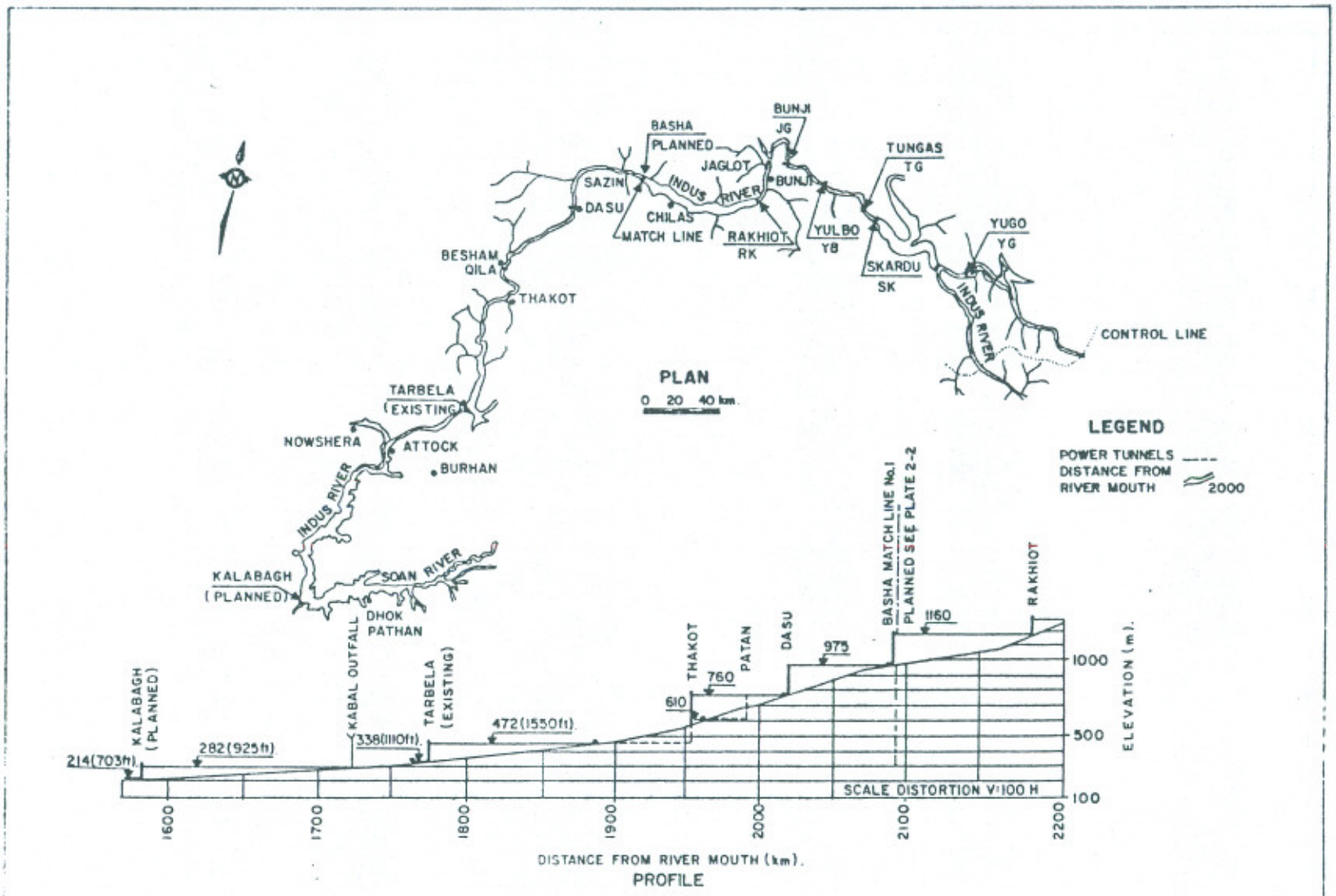


Fig. 2 HYDROELECTRIC SITES
INDUS RIVER RAKHIOT TO KALABAGH
PLAN & PROFILE

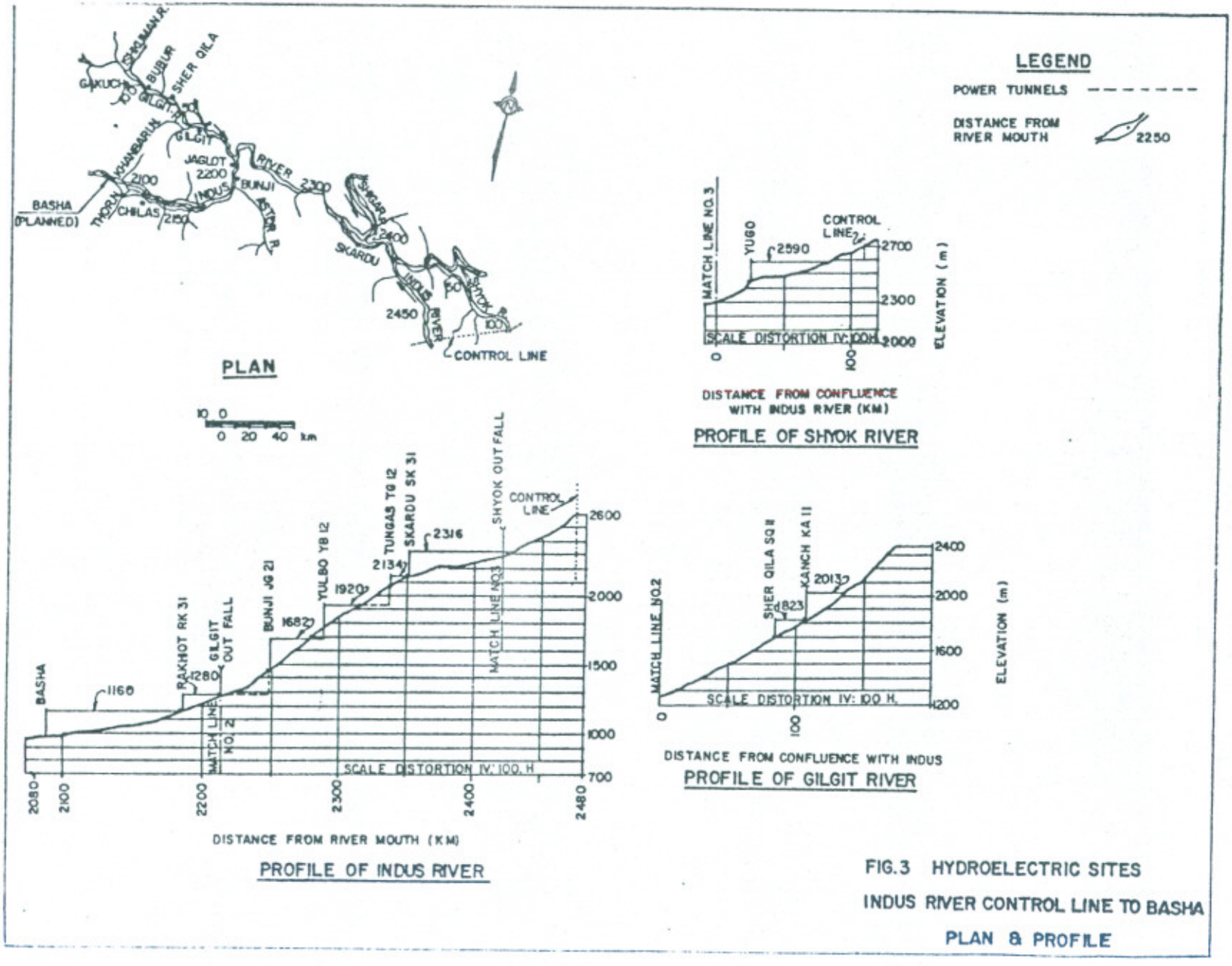


FIG.3 HYDROELECTRIC SITES
INDUS RIVER CONTROL LINE TO BASHA
PLAN & PROFILE

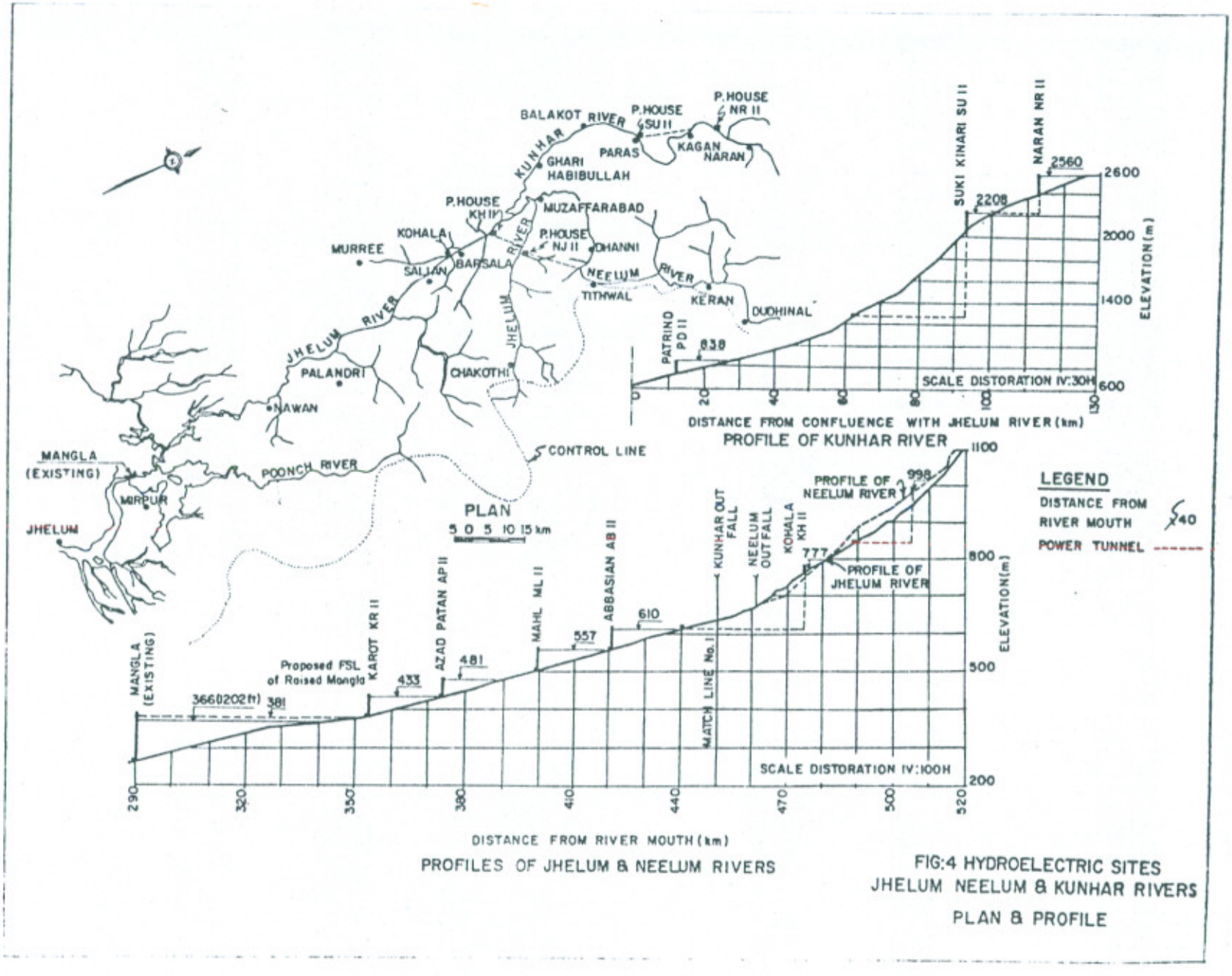


FIG:4 HYDROELECTRIC SITES
JHELUM NEELUM & KUNHAR RIVERS
PLAN & PROFILE

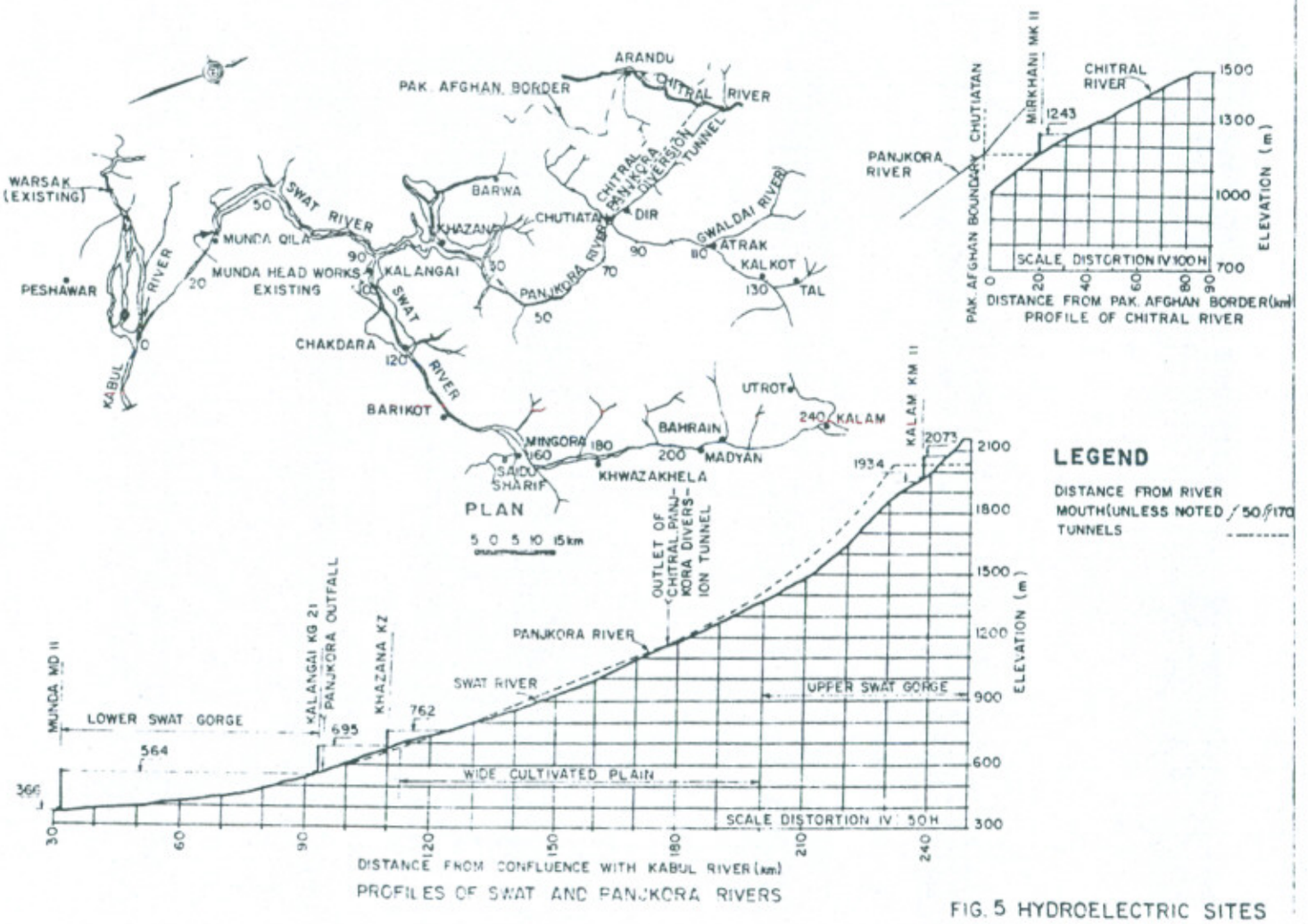


FIG. 5 HYDROELECTRIC SITES
SWAT, PANJKORA & CHITRAL RIVERS
PLAN & PROFILE