PAKISTAN GEOGRAPHICAL REVIEW

1956

VOL. XI
NO. 2

ANNUAL SUBSCRIPTION:

INLAND	..	**Rs. 4**
FOREIGN	..	**Rs. 6**

All Communications to be addressed to the Manager, Pakistan Geographical Review, Department of Geography, University of the Panjab, Lahore.

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HYDROELECTRIC DEVELOPMENT IN PAKISTAN

BY

KAZI S. AHMAD

Water Power

Falling water has been used for a long time to drive water-wheels on perennial hill torrents both in Pakistan and India, mainly for grinding food grains. They are often met with in the hilly areas even today. With the advent of the canals, flour mills worked by water were installed at many places. Later, electricity produced from water introduced a new factor. Its transmission has enabled the water-power to be used at a distance from its source.

Hydel power has now acquired a value which no country can afford to neglect if it has the means for it. It represents an increasing percentage of the total power used in the world. With the increasing demand for power and gradual exhaustion of their coal resources, today even countries like United States and Russia which have plenty of coal, have been looking to alternative supplies, mainly white coal. All the progressive countries have been developing the water-power as far as possible to relieve pressure in local or imported fuels, the supply of which is obviously limited. Each horse-power generated from water saves 4 tons of coal a year.

Water-power ensures a perennial supply and does not suffer from the danger of exhaustion unless there is such a great change in the climatic elements as to turn the perennial rivers into seasonal or earth movements interfere with gradients.

Unlike petroleum, gas or coal, nothing is consumed in it but simply gravity of water is used to produce power. For this reason water-power is much cheaper than fuels. On account of its low cost of production and cheap transmission its development not only accelerates the pace of industrial development but also helps in a more rational distribution of industry. It is no longer necessary to take the factory to coal or oil or carry fuel to it from long distances. With the help of hydro-electricity it could be established at a suitable point in relation to transport and markets, comparatively much more economically as it would save the capital expenditure in power-generating plants. Spreading over a network in the rural area it promotes the dispersal of the industry to raw materials and thus reduces the cost of production.

Hydel-power is important not only for industry and house-hold purposes but also for the development of agriculture by increasing the yield of old lands and breaking new lands through lift irrigation, processing of crops and manufacturing fertilizers.

Significance of water power to Pakistan

Water power is of special significance to countries like Pakistan which lack in conventional fuels, coal and petroleum. Being the most efficient substitute of coal, whether as a fuel or as a source of power, it is bound to play a vital role in her economy. It had to build up her industry almost from a scratch and for it, it had to import fuel by spending her hard-earned foreign exchange. Still her industry was subservient to foreign supplies. For its full growth hydel-power has to be developed as much as possible. Not only the present deficiency of coal and oil has to be made up but Pakistan has to provide for the growing needs of power for development programmes.

At the time of independence there were only a few factories in either wing and majority of them had been damaged in the disturbances. Of those which continued to function, the source of main fuel, the coal, which lay in Bharat was cut off. With a deficiency in coal and oil cheap energy in the form of hydro-electricity became of immense importance for the economic and industrial planning and development. In 1954 the total production of coal was over 525,000 tons[1] and that of petroleum 1,700,000 barrels[2]. In spite of the great increase in their production, they are but a fraction of their requirement. Since the bulk of all the coal and oil consumed is a foreign origin and has to be transported to long distances fuel prices are very high. Before devaluation coal at power stations in West Pakistan costed Rs. 70 to Rs. 90 per ton and in East Pakistan the cost was still higher. Bunker coal suitable for burning under boilers costed about Rs. 115 per ton in the Lahore area and Rs. 75 per ton at Chittagong. Now the prices are about 33% higher.

Under the circumstances hydro-electricity is the only hope for industrial progress if it was not to be dependent upon foreign countries. Even otherwise, cheap power, as the vital force behind industrial development, is an important factor in the solution of Pakistan's economic problems. Accordingly while the Government took steps to increase the output of coal and oil and to locate new areas it paid particular attention to the development of hydro-electricity as rapidly as possible and to make this development as widespread as practicable so that industry may not remain confined to a few centres.

1. Against 30,000 tons in 1947.
2. Representing a five-fold increase over that in 1947.

In the search of oil Pakistan was lucky to find gas at Sui[1] which is now estimated to contain 2,250,000 million c. ft., equivalent in effective heating to approximately 1,600,000 tons per year of imported coal. It is specially important for the reason that it will supply cheap power to lower Indus Valley, an area outside the range of the sources of supply of hydro-electric power. Wind also offers some possibilities for power in the lower Indus Valley, where they are quite regular in force and direction[2]. Practically nothing has been done in Pakistan in respect of atomic energy or tidal power.

With the development of hydro-electricity at Malakand and Dargai a great industrial region has grown in the Peshawar and Mardan Districts centred at Nowshera. Similarly the Rasul Hydro-electricity is now feeding numerous plants right upto the Lahore Industrial region. The famous Cement Factory at Wah and Premier Sugar Mills at Mardan are powered from Malakand while the great Engineering Workshop of Beco gets its power from Rasul. Apart from large factories the hydel-power is being supplied to numerous smaller units.

In Pakistan as in India small Cottage industries occupy a very important position in the industrial structure. The extension of hydro-electricity to smaller towns and some rural areas is likely to be of substantial help to the smaller industrial consumers. Availability of cheap hydro-electricity is bound to promote village aid programmes to some extent and bring new life into the countryside. Without hydro-electricity the rural electrification even though on a small scale would be impossible.

Development of hydro-electricity is also likely to promote the mineral industry. Inaccessibility of many areas and lack of power has stood in the way of location and exploitation of mineral wealth. Hydro-electricity will greatly help in mineral surveys and mining operations. The Power Stations at Malakand and Dargai are very advantageously placed for it, particularly in realtion to the highly mineralised region of Chitral. The Hydel-power from Warsak Project will open further mining factories in the western mountains and so will the Kunhar Project when it comes into function. Thus the development of hydro-electricity will have a significant role to play in the new orientation of Pakistan's economy—the change from purely agricultural to semi-industrial.

Pakistan has been so far mainly an agricultural country. Its agricultural prosperity is based on irrigation and its progress is correlated with extension in

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1. This is sufficient to supply 100 million c. ft. per day for 60 years. It is also proposed to establish a Power Station at Multan for producing electricity.

2. The Meteorlogical Department is making investigations in this connection.

irrigation. In West Pakistan even these parts of the Indus plain, which have a magnificient system of canals, there are large areas which are not commanded by them, where water cannot reach by gravity. Water-table being low percolation wells are difficult to construct. Water has to be lifted from great depths. The construction of tube-wells will be greatly facilitated by the development of water-power. These wells wil also ensure water-supply during the closure of canals. With the help of cheap power water-supply may also be augmented in gravity canals by lift irrigation if the flow of water is reduced in them.

As a result of many years of irrigation, the sub-soil water-table shows a considerable rise and at many places reaches a point when much land is either completely water-logged (Sem land) or has been salt encrusted because of the extensive surface evaporation of water raised by capillary action (Thur land). In either case it becomes useless. The malady has already become so serious and thousands of acres of land go out of cultivation every year. It has been estimated that about 50,000 acres of land have been water-logged and 2 million acres rendered barren by salinity in West Pakistan.

The evil is not unique in West Pakistan but is met with in other parts of the world where extensive irrigation is practised. In United States of America and Egypt it appears that a solution has been found to lie in developing land drainage to a point of equal efficiency with land irrigation, with ultimate removal of the drained water from a low-lying drain sump by pumping where necessary. In West Pakistan the solution is being sought in the sinking of a large number of tube-wells with the help of hydel-power. These are generally aligned parallel to the main canals. After reducing the water-table to a suitable level they will maintain it there by returning the further leakage to the canals as it occurs. It so happens that the areas in which such dewatering is needed are generally the same as those at which the supplementing of canal flows is required. Thus the pumping would serve double purpose.

Hydro-electricity may relieve the pressure on soil not only by increasing agricultural production through irrigation and land reclamation but also by diverting a part of rural population to industry.

In East Pakistan there is mostly lift irrigation. The water is to be pumped up from innumerable rivers and *bhils*. Under the Karnafuli project cheap hydel-power will be available for pumping over a large part of the plain. It will open a new era of agricultural development by bringing large areas under cultivation during Rabi season. There is also a great scope for developing industries utilizing local agricultural and forest products as well as for the manufacture of common consumers' goods. These industries could be established in several towns if power was available. Boiler fuel is virtually absent except for some deposits of lignite. So hydro-electricity is the only practicable source of power. It would create great interest and give impetus to development which would not occur if steam power was used as an alternative.

Besides water, manure is an important need of agriculture in Pakistan as in India. Calcium Cynamide (Ca CN)2 and Calcium Nitrate (Ca No3) can be produced on a large scale if cheap power is available. The former can be utilized in the manufacturing of nitric acid which has to be imported for various purposes.

The high locomotive fuel cost and low hydro-electricity expenses may justify electrification of railways in areas of high traffic density in the plains as more and more hydel-power is available and grid becomes closer.

The following is the estimate of power requirements of Pakistan as worked out by M. R. V. P. :—

1955	.. ..	292,000 KW	1970	.. ..	700,000 KW
1960	.. ..	325,000 KW	1975	.. ..	1,025,000 KW
1965	.. ..	475,000 KW	1980	.. ..	1,510,000 KW

Geographic Control of Water-Power

The main geographic factors which control the development of water-power are (*i*) configuration of the land and geological structure and (*ii*) perennial supply of water. This itself depends upon (*a*) precipitation and (*b*) catchment area of the river.

Configuration of Land and Geological Structure

The configuration of land and geological structure determine the site and feasibility of the development of hydro-electricity. There should be a fall of ground sufficient to admit of an easy diversion of water from the river to the turbine below. In West Pakistan, mountains and valleys which carry perennial rivers occupy a large area in the north as well as in the west of the Indus plain. But its power resources are mainly concentrated in the north. Most of the Western hills lie in the dry zone. Some of the rivers like Kurram, Tochi and Gomal have quite large catchment areas but on account of the backwardness of the people it is not likely that power-sites, howsoever good, could be utilised there for a long time to come. Similarly there are falls in the northern rivers which are not suitable on account of remoteness of location in almost uninhabited regions. Minor schemes may be feasible like those of Swat or Gilgit.

As there are no natural falls in the southern parts of the Himalayas on rivers having perennial flow an artificial fall has to be created by making tunnels to connect the different reaches of rivers at different levels. From the point of view of configuration the best site for hydro-electric projects are near-about the point where a river comes out of the mountains so as to be near the centres of population or markets.

The Himalayan region in the north may be sub-divided into four zones (1) The trans-Himalayas, lying behind the main Himalayan axis (2) The great or snowy Himalayas or the main Himalayan axis (3) The outer or lesser Himalayas, on the south of the main exis and (4) The outer-most Himalayas which border the plain The Indus and the Sutlej rise beyond the main Himalayas while the Jhelum and Chenab, Ravi and Beas rise between them and the sub-Himalayas. The first two zones are useless for power sites on account of their remoteness.

The Dhauladhar and the Pir Panjal are the main ranges which constitute the outer-Himalayas in the north of West Pakistan. These ranges usually consist of crystalline or volcanic rocks while there are spurs of unfossiliferous sediments—conglomerates of slates, shales, quartzites, schists and limestones.

The sub-Himalayas consist of two ranges, the Sirmur Range and the Siwalik Range, corresponding to the Sirmur and Siwalik series respectively. The upper Sirmur beds consist of a number of alternate layers of hard sand-stone and red marl, varying from 10 to 50 ft. in thickness, with their strike running generally parallel to the direction of the range. The lower or Sabathu beds consist of nummulitic limestones and shales.

The Siwaliks may be divided into two distinct types, (*i*) the upper and middle Siwaliks consisting of soft sand-stones and clays of recent alluvial formation and (*ii*) the lower Siwaliks consisting of hard well consolidated Nahan Sandstones, calcareous clays and conglomerates. The latter are often indistinguishable from the upper beds of Sirmur series.

From the power point of view the Sirmur range is of great significance as with it are associated most of the important potential sites. The Siwalik range is structurally not suitable for a natural site. One thousand foot contour may be taken as a demarcation line between the plain and the mountain area in the north and it is quite significant in the location of dam sites and the development of artificial falls in the sub-mountain area. It passes by Kalabagh, Mangla, Rasul and Madhopur.

Apart from the Sirmur some other hills on either side of the river Indus provide a few useful sites in the north-west. The principal of them are:—

(*i*) The Hazara Hills.

(*ii*) The Swat Hills,

(*iii*) The Murree Hills.

(*iv*) The Kala Chitta Hills, traversing the northern part of the Potwar Plateau and

(*v*) The Salt Range.

The prospective sites in these hills on various rivers are given later in this paper.

The construction of structures, head race and tail race canals and making of a reservoir upstream of a fall would also depend upon the configuration of the land and the geological structure of the site. The storage of water above the fall should form part of all good hydel projects so that its flow could be regulated. It has the further advantage of making use of surplus water and controlling the flood.

In the plain area the gradients are generally low and the river flows sluggishly. The geological structure of the river valleys generally does not offer suitable sites for the storage of water and the constructions of dams.

The doab uplands between the Sutlej and the Jhelum drain south-westward and the canals on them have a number of falls but they are of small height. There are very few falls of even 10 ft., a few of 8 ft. but most of them only about 5 ft. The turbines to be used have, therefore, to be large and expensive. The falls that are likely to be developed for hydel-power would probably have a head from 5 to 15 ft. But on account of the high and rising cost of fuel in West Pakistan even some of these low falls could be locally economically used for power purposes, while others could be combined. Such falls, however, are likely to suffer from the disadvantage that the flow of water would not be constant but fluctuate with the amount of water in the feeding river.

In East Pakistan configuration presents very limited opportunities for the generation of hydro-electricity. Mountains in the north and north-east lie just outside the frontier and those in the south-east in Chittagang District and Hill Tract have practically no easily accessible streams of any significance for power, except the Karnafuli. The geological structure is not generally suitable. There are numerous folds of losely consolidated sedimentary formations. Even on the Karnafuli a suitable site for the dam could be found fairly far from the coast.

The plain is drained by innumerable rivers, big and small, with loose banks and shifting channels, flooding hundreds of square miles during the rains. The gradient is low. It has not been possible to construct even bridges on the major rivers. The question of a barrage for power does not arise.

Perennial supply of water

West Pakistan is fortunate in having several big rivers which carry a perennial flow of water. They are fed by a well-distributed rainfall in the mountain area and the melting water of the glaciers. The minimum and maximum discharge of the rivers is given below:—

TABLE I

RIVER DISCHARGES EVER RECORDED

River	Site	Date	Maximum discharge	Date	Minimum dischaage
Indus ..	Attock ..	..	10,00,000	..	18,000
	Kalabagh ..	12-7-42	9,17,015	17-12-36	17,304
	Ghazighat ..	7-8-50	8,27,998	5,2-41	15,836
Jhelum ..	Mangla (above) ..	29-8-28	7,60,000	9-1-17	3,943
					2,944
Chenab ..	Marala (above) ..	29-8-29	7,18,000	25-1-39	3,618
Ravi ..	Madhopur (above) ..	5-10-55	6,50,000	..	1,300
Beas ..	Pang ..	4-8-27	4,36,529	7-3-32	1,925
Sutlej ..	Rupar ..	..	2,60,000	..	2,818
	Ferozpur (above) ..	15-8-25	3,53,960	23-3-32	2,651

Precipitation

Precipation determines the natural flow of water in a river. The amount of rainfall in the catchment area and its seasonal distribution and variability affect the discharge of a river during various months of a year and are important geographical considerations in assessing the value of a river for the development of water-power. Similarly the amount of snowfall in the catchment area has significant bearing on stabilizing and regulating the flow of a river. The water is gradually released from the melting snow in spring and summer and keeps the river running.

In the northern catchment areas of West Pakistan, the rainfall though not very heavy is fairly well distributed during the year. Late summer rains from the s. w. monsoons are followed by winter rains from western disturbances which continue into spring and early summer over a large area. Thus the rainfall from the western disturbances is complementary to that of the monsoons. Though the rainfall from these disturbances is much lower its effectiveness is greater on account of lesser evaporation during the cold season. The higher monsoon rainfall is characteristic of the outer Himalayas.

TABLE II

MEAN MONTHLY RAINFALL (INCHES)

Station	Jan.	Feb.	March	April	May	June	July	August	Sep.	Oct.	Nov.	Dec.	Annual
Drosh	1.37	1.55	3.73	4.08	1.91	0.65	0.60	0.65	0.69	1.27	0.34	1.20	18.04
Skardu	0.8 8	0.69	1.02	0.97	0.79	0.24	0.39	0.34	0.40	0.14	0.06	0.38	6.30
Gilgit	0.25	0.26	0.80	0.96	0.80	0.37	0.39	0. 55	0.40	0.24	005	0 11	5,18
Srinagar	2.90	2·84	3.61	3.65	2.38	1.40	2.33	2.42	1.53	1.17	0.14	1.32	25.99
Jammu	2.29	2.43	2.03	1.29	0.93	2.80	12.79	11.75	3.51	0.76	0.28	1.24	42.1
Murree	3.79	4.31	4.81	4.13	2.62	3.98	12.40	13.81	5.42	1.56	0.73	1180	59.36
Peshawar	1.44	1.53	2.44	1.76	0.77	0.31	1.26	2.03	0.81	0.23	0.31	0167	13.56

With the advent of the s. w. monsoon heavy rains start in the outer Himalayas in June which last till September and early October. Late October, November and December are the driest months of the year in the Himalayas and this is also the most critical period from the point of view of water-supply but still the flow is generally not less than 2,000 cusecs in any of the major rivers when they emerge from the Himalayas. From January to May more or less rains occur throughout the Himalayan region, and the northern areas get more rain during this part of the year. The rainfall regime is, therefore, conducive to the maintenance of river flow practically all the year round. From the point of view of power the monsoon rainfall is of importance only where seasonal storage may be involved in so far as it affects the summer discharges due to the melting of snow deposited on the higher ranges. Most of the lowest readings of discharge occur during the winter months when the catchments are frozen up. This is the consequence of the combined effect of winter rains and minimum temperatures. The temperatures are more important at higher elevations and the winter rains at the lower. The sites which are not snow-fed generally get their minimum discharge in summer just before the monsoon breaks.

In East Pakistan there is quite a heavy and well distributed rainfall in the Chittagong hill area in the south-east and the adjacents parts of Bharat and Burma. The rainy season is also quite long on account of the pre-monsoon and post-monsoon storms. January and February are the only two months which can be called dry though they are not without rain.

In addition to periodicity and amount, the variability of the rainfall is also quite important. As a rule the variability of rainfall is lesser when the rainfall is heavier and *vice-versa*. According to Williamson and Clark the variability of rainfall is less than 15% in the Chittagong hill tracts and 15 to 25% in the outer Himalayas. There is thus not likely to be any shortage of water for any storage scheme.

In the West Pakistan heavy snowfall in the Himalayas in which all the major rivers rise or pass through is an important factor in maintaining the flow of water.

According to Elliot Smiths' estimate there is a snowfall of 100 ft. in a year on higher peaks.

The average permanent snowline in the n. w. Himalayas lies approximately at 15,000 ft. during summer and at about 9,000 ft. in winter. Occasionally the storms bring down the snowline to 4,000 ft. Peaks on the lesser Himalayas will usually be clear of snow a month or so before the monsoon, and are often covered again before the end of july.

Catchment area

Major rivers in Pakistan have large catchment areas in mountains. These areas mostly lie obliquely across the region. Although the rainfall varies in various sections it is quite high near about where the rivers emerge into the plain and here are also found suitable sites for the construction of reservoirs. The following table gives the area of the catchment basins of the principal rivers in the hills.

TABLE III

RIVER SLOPES AND CATCHMENT AREAS

RIVER	Length in miles from the source to 1,000 ft. contour	Average slope in feet from the source to 1,000 ft. contour	Catchment area in sq. miles, above 1,000 ft. contour
Indus	1,100	15	103,823
Jhelum	400	37	13,030
Chenab	380	40	10,588
Ravi	130	115	3,123
Beas	250	48	5,663
Sutlej	560	30	18,554

RIVER	Catchment area (Sq. Miles)	RIVER	Catchment area (Sq. Miles)
Kabul	35,000	Karnafuli ..	4,250
Gilgit	10,000	....	

The catchment areas of the Ravi and the Beas which are comparatively smaller lie mostly in the outer zone of the Himalayas with heavier rainfall. Similarly Karnafuli basin has not only much higher rainfall but a long rainy season.

Economic considerations

For the development of water power economic considerations are no less important than the physical. As has already been pointed out above, on account of the deficiency of other sources of power it is necessary to develop hydro-electricity in Pakistan as far as possible. Luckily in West Pakistan the main sites for hydel power, actual and potential, located on the outer fringes of the Himalayas, lie quite close to the area where the population is densest. The sub-montane belt of the Indus plain is an old settled area where there is a chain of towns, big and small, which offer a good market for electricity for domestic, commercial, and industrial purposes.

The high intial costs for setting up a hydro-electric plant could be partly offest by combining it with irrigation projects, the water to be first used for driving turbines at the generating stations and then distributed on the field. Practically the whole of the plain needs irrigation at one or the other time of the year. This is a great advantage in developing water-power in West Pakistan. Even in East Pakistan irrigation is needed for the winter or Rabi crops. So it is that our new schemes of hydel power are part of the multi-purpose projects. The two old projects that have been nearly completed are also associated with irrigation canals.

Although some of the falls in canals provide valuable sites for the hydro-electric power, there are many which are too small for it. When these canals were built there was no question of development of water-power. But now when the new canals are made they should be so graded as to provide head sufficient for the economic development of hydro-electricity. Besides utilising the high grade between upper and lower Jhelum canals at Rasul and the upper Swat Canal at Malakand-Dargai, Pakistan has now schemes to make use of some smaller heads in canals in upper and lower Chenab and upper Jhelum canals. Closure of canals either for clearing, repair or due to short supplies of water from the feeding rivers has been the main objection against the use of canal heads for electricity. But if such a power station was connected with the general grid, the closure of the canals could be regulated and clearing could be done in turn. The additional power available from these falls would be of great use in seasonal factories like cotton-ginning. The thermal stations working within the area could also be connected with the grid to make up the temporary shortage of power required. In case of Rasul, every effort has been made so far to keep up the upper Jhelum canal constantly in flow. Another difficulty experienced has been that as the canals were constructed mainly for irrigation, a proper supply of water for it is not always available if used for the generation of power.

Economic considerations, therefore, demand that, as far as possible, our canals should in future be so constructed as to be useful for irrigation as well as the development of power. Hydro-electricity being one of the most important things of public utility, its production should be properly organised and rationalised. There should be little scope for great profits.

Resources

The potential supply of hydro-electric power in Pakistan is quite great but at present only a small fraction of it is developed, the most substantial increase having taken place since independence. At the time of partition the total generating capacity in Pakistan, both thermal and hydro, was 78,621 K. W., which represents 3 % of what existed in undivided India. It worked out to about 1 K. W. per thousand of population. Of this only 11,000 K. W. consisted of hydel power. The old province of Punjab largely depended upon electricity supplied from Jogindernagar now in Indian territory. There was the risk of the supply being reduced or cut off. Several thermal stations were closed on account of the demage done to them during disturbances.

The Central Government assumed responsibility under the development of Industries (FederalControl) Act 1949 to plan and regulate the development of electricity and set up the central Engineering Authority. To assist the authority in technical problems, Messrs. Rendel and Vattab (Pakistan), a combine of three firms of international repute, were appointed as consulting Engineers. The six years development plan (July, 1951—July 1957) which now forms part of the Colombo plan, amongst other things also provided for the development of hydro-electric power. New schemes have been sanctioned to increase the capacity by 718,400 K. W. at a total estimated cost of Rs. 10,85.6 million. Of these the Malakand extension, Dargai Hydel projects and Rasul Hydel scheme have so far been completed. They have increased the hydel capacity from 11,000 K. W. to 62,000 K. W. in 1954-55. Other projects are under various stages of development. These include (1) Warsak Hydro-electric Schame, (2) Mangala multi-purpose Dam Project, (3) Gilgit multi-purpose Project, (4) Mianwali Hydro-electric project, (5) Canal falls hydel projects including (*a*) Mangla Hydro-electric Project, (*b*) Shadiwal Hydro-electric Project, (*c*) Gujranwala Hydro-electric Project, (*d*) Chichoki Malian Hydro-electric Project, (*e*) Khanki Hydro-electric Project, (6) Karnafuli multi-purpose project. The existing and most of the projected power stations will be inter-connected in a big grid extending over a large northern part of West Pakistan with a modern system, incorporating a number of 132,000 K. W. sub-stations among the largest in the sub-continent. Malakand and Rasul stations have already been connected together by Wah-Jhelum link. The potential water-power in Pakistan has been estimated between 5 to 6 million K. W.

Recently two reputed firms of consulting Engineers Messrs International Engineering Company of U. S. A. for East Pakistan and Messers H. G. Acres for West Pakistan have completed their detailed surveys of power requirements of the country. These reports are under examination. The government have also entrusted to these firms the work of preparation of separate detailed plans for generation of power in the two zones and its use in various fields during the next ten years. It is also proposed to set up a separate Electricity Commission. It will be the precursor of a power development corporation.

RASUL HYDRO-ELECTRIC SCHEME

Rasul is a small village in the Gujrat District, near which the head-works of the the Lower Jhelum Canal are situated. It has recently grown into prominence on account of its Hydro-Electric power station. The Head-works of the Lower Jhelum Canal existed here for a long time before this scheme was contemplated. The survey on this scheme was started before independence in 1946 but due to disturbances the work was held up though most of the material had arrived at Rasul. The work began in full earnest in 1948. The Government gave great priority to the project to provide power to the growing needs of industry. After partition the old province of Punjab had only one thermal station at Shahdra with a firm generating capacity of 8,000 K. W. and 21 diesel electric supply undertakings abandoned by the non-Muslims who migrated to India. These were capable of generating 942 K. W. Some of these undertakings ceased to function altogether and had to be sealed. What remained could meet but a fraction of the demand. An agreement was made with India by which electricity to the extent of 14,000 K. W.* was supplied to Punjab from the Jogindarnagar Power Station in Mandi. It was essential to make alternative arrangement as soon as possible from a permanent source.

Two great difficulties were experienced in the beginning. The first was in the construction of the foundation of the Power-house building. For reaching the foundation level many crores of c.ft. of earth had to be excavated under difficult conditions as this level lay 40 ft. below the sub-soil water. At one time 5,000 labourers and almost an equal number of donkeys were employed for the purpose. The second difficulty was in getting 150 ton crane which was ultimately obtained from W. Germany in July, 1950. The work was completed early in 1952 and the Commissioning ceremony was done in April the same year. By the end of 1953 all the 128 miles of 132 K. W. line and 206 miles of 66 K. W. lines were completed. About 400 miles of 11 K. W. lines have since been laid. The grid has been connected with that of Malakand by the construction of 116 miles Wah-Jhelum link. The entire work including the distribution of power is expected to be completed by 1959.

*This supply has now been reduced to 4,000 K.W.

The project utilizes the difference of Head between the Upper and Lower Jhelum Canals near Rasul. The maximum available head is 85′ and minimum 81′ while the discharge varies from 1,400 cusecs to 4,000 cusecs. The head race canal for the power house is drawn at a point 40 miles lower down the Upper Jhelum Canal.

Two generators of 11,000 K. W. each have been installed and a firm demand of 11,900 K. W. will be met at all times. Maximum power of 22,000 K. W. will be available for about six months. The annual output of energy will be 1,525 million K. W. H. equivalent to 1,30,000 tons of coal.

Although the Rasul Hydel Scheme was undertaken with the primary object to supply power for tube-well pumping, the changed circumstances after partition have made it necessary to ear-mark most of the output of Rasul for industrial purposes. Under the revised scheme, electricity will be supplied to 28 towns for industrial and domestic purposes out of which 20 towns have already got it. Ultimately it is hoped to supply electricity to every town with a population of 5,000 persons and over. Of the principal industrial recepients of electricity today are Batala Engineering Company, North Western Railway Workshops, Lahore, Lyallpur Koh-i-Noor Textile Mills, Lyallpur Cotton Textile Mills, Koh-i-Noor Textile Mills, Rawalpindi, Rawalpindi Electric Co., Wah Cement Factory, Lawrencepur Woollen Mills and Fauji Textile Mill, Kala (Jhelum).

A portion of the electricity will also be supplied to energize 1,860 tube-wells in the Ghej and Rechna doabs, as a means of solving the problems of water-logging and salinity of agricultural lands by lowering the water table. 1,300 of these wells have already been supplied. The total cost of the scheme is estimated at Rs. 857.370 lakhs including Rs. 330.395 lakhs on transmission lines, about 700 lakhs have already been spent on it. As regards the price, one unit at busines costs only 1.9 pies which is quite cheap.

The following figures show the progress in the production of electricity :—

Year					*Units Generated*
1952-53	..	..	..	..	5,11,81 000
1953-54	..	..	..	..	9,46,54,300
1954-55	..	..	..	..	13,71,31,233

MANGLA MULTI PURPOSE DAM PROJECT

The river Jhelum rises in Kashmir at an elevation of 17,000 ft. in the south of the Great Himalayas. It crosses the Pir Panjal range by a narrow defile, and flowing past Uri and Muzaffarabad, it breaks through the outer folds of the Siwaliks into the plain by a neck about 9,000 ft. wide near Mangla, just north of the present upper Jhelum Canal head-works. The catchment area above Mangla is 13,030 sq. miles. The river is mostly rainfed, the glacier area being only 142 sq. miles. The rainfall in the catchment is mostly limited to the monsoon period, July to September. Only about 40% of the catchment area above Mangla receives an annual rainfall of more than 20 inches. It is an early rising river. After the middle of March the discharge increases rapidly. Towards the middle of September the discharge drops rapidly. Between October and February it varies between 6,000 to 9,000 cusecs.

The idea of this project was first mooted about 1952, to provide firm storage supplies mainly for irrigation and subsequently for the development of power.

It is proposed to build in the first phase a dam on the Jhelum above the neck near Mangla. Both geologically and geographically the site is ideal for an irrigation-cum-power project. Located in the outer-most part of the hills, a canal could be economically constructed to link it with the Jhelum canal and a good head obtained on it for the hydel power, quite near the trunk of the grid of the province in a fairly densely populated and progressive region.

The dam will be an earth rolled-filled type. The construction material for it is available in large quantity within a reasonable distance. It will be 360 ft. high and 9,000 ft. long and will be designed to pass a maximum flood discharge of one million cusecs.

Above it will be formed a reservoir of 75 sq. miles in area with a maximum depth of about 300 ft. It will store 4.1 million acre ft. of water with the effective storage capacity of 6 million acre ft. The water thus made available could irrigate 3 million acres of land.

The second phase envisages the production of hydro-electricity. There will be an installed capacity of 3,00,000 k.w. with four units of 75,000 k. w. each. The power house will be located in the left abutment and the tunnels will be about 3,000 ft. long, carrying about 2,500 cusecs of water to the power house to be subsequently discharged into the Upper Jhelum Canal. The total cost of the project will be about 73 crore of rupees of which the first phase will cost 55 crores. It has been recently sanctioned by the economic Council and the work is proceeding apace. It will be linked with the super grid of West Pakistan.

MANGLA HYDRO ELECTRIC PROJECT

The Mangla-hydro-electric Project is a power-cum-irrigation project. Its main purpose, however, is power production, irrigation being only a secondary object.

The Upper Jhelum Canal takes off from the Jhelum near the Mangla village. At the head regulator of the canal there is a fall which varies from a minimum of

6 ft. to a maximum of 60 ft. In addition there is a drop of nealy 28 ft. in the first six miles of the canal due to steep slope of its bed. It is proposed to utilize this drop for th e generation of power. A reservoir with a capacity of 75,000 acre ft. will be made which will be useful not only to firm up the power but also to provide water for irrigation during the rabi season. Between the Pabbi hills which run continuously on the left side of the canal and the low terrace on the right side there is a valley varying in width from 1/2 to 1 1/2 miles which provides a good site for a reservoir. A six-mile long bund, with a height upto 58 ft., will be constructed along the existing canal railway line for the purpose.

The power-station will be situated near the Bong rest-house. Available drop at the power house will vary from 32 ft. to 48 ft. The maximum discharge utilized will be 12,000 cusecs which corresponds to the ultimate capacity of the Upper Jhelum canal. It will be available for seven months from March to September. There will be a minimum supply at all times of 7,500 cusecs in an avaerage year and 5,500 in a bad year.

The power station will have an installed capacity of 45,000 K. W. with three generators of 15,000 K. W. each. The minimum power demand that can be met in bad year is 27,000 K. W. H. The total utilizable out-put will be 226.75 million K. W. H. The annual firm power output at 50 % load factor works out 118.26 million K. W. H. The total estimated cost is 425.38 lakhs. The firm power is expected to be sold for 6 pies per K. W. H. at the generation end.

The main object of the Mangla project is to provide cheap power for the operation of tubewells. By 1955, 3,350 tubewells with a minimum demand of 66,210 K. W. were expected to be installed by the Government in addition to private ones.

It will be thus possible to supply water to about 53 1/2 thousand acres in the Rabi season and to bring 14 1/2 thousand acres of most fertile but high land under irrigation situated at the foot of the Pabbi hills, not commanded by the Upper Jhelum Canal.

Unlike other canal hydro-electric schemes, this project provides a reservoir up-stream of the canal. It is possible to meet firm power demand of 33,610 by proper regulation of the reservoir. It will also be useful for fish breeding. The additional supplies available could be used not only for irrigation but also for providing power at other stations lower down.

SHADIWAL HYDRO ELECTRIC PROJECT

The Upper Jhelum Canal outfalls into the Chenab river about 6 miles up-stream of Khanki head-works. It is mainly a feeder canal for the Lower Chenab Canal, which takes off at Khanki, and for the Rasul Power house. In addition it irrigates a small area in the Gujrat district.

The idea of producing power on this canal was under consideration since 1950. In the present Shadiwal project it is proposed to combine two existing falls of 3.3 ft. and 10 ft. and modify the slope of the canal in the up-stream reach where a net head varying from 21.2 to 24 ft. will be available for producing power. The available discharge at the tail of the Upper Jhelum Canal varies from 3,500 to 7,860 cusecs. It is proposed to take off a lined loop canal of 7,250 cusec's capacity. The water producing power will be escaped through a 1,725 long tail race canal which will outfall back into the Upper Jhelum Canal. The power station will have an installed capacity of 12,000 K. W. consisting of three units of 4,000 K. W. each. The 132,000 K. W. sub-station at Gujrat is only 5 miles from the site of the power-station and the latter will be connected with the main transmission grid. If it is possible to augment the Jhelum supply in future, a fourth set of 4,000 K.W. may be installed.

The main object of the Project is to supply power to the tube-wells that are being installed in Chej and Rechna doabs.

The total utilizable out-put from the Shadiwal power station will be 82.85 million K. W. H. leading to an annual saving of 74,000 tons of coal, costing about Rs. 49 lakhs. It will promote agriculture as the power will be utilized for tube-well pumping for reclaiming the water logged areas and for the extension of irrigation.

GUJRANWALA HYDRO ELECTRIC PROJECT

The Upper Chenab Canal takes off from the Chenab at Marala headworks where its full supply capacity is 18,000 cusecs. The canal ends at Bambanwala from where there take off two canals. One of them is the main line of the Upper Chenab Canal and the other is Bambanwala-Ravi Bedian link. The former is mainly a carrier canal for feeding the lower Bari Doab at Balloki. There are several falls 8 to 10 ft. on this canal which are proposed to be utilized for the generation of electricity.

The project envisages the setting up of a power house near Gujranwala which will utilize the head of 23—26 ft. Its installed capacity will be 12,000 K. W. with three units of 4,000 K. W. each.

A large part of the Rechna Doab is badly waterlogged and several schemes were proposed in the past to reclaim it. Tube-wells are now to be installed in this area to meet the wtater-logging menace. They will work from the hydel power to be available under this project. The power is to be injected into the Rasul-grid *via* Gujranwala-Daska-Sialkot line. The cost of the project is estimated at Rs. 180 lakhs.

RENALA LIFT IRRIGATION SCHEME

The scheme was organised about three decades ago as a private enterprise by Sir Ganga Ram, retired Chief Engineer. He entered into a lease with the Government for the purpose. The electricity produced was utilized mainly for lifting the water for irrigation. The Government took it over in 1945.

The scheme comprises the establishment of a power house near Renala railway station (District Montgomery), with five generating sets of 200 K. W. each, and a firm power of about 800 K.W. It makes use of a fall on the lower Bari Doab Canal. The power produced is given to Siran sub-station at a distance of about 7 to 8 miles when water is lifted by means of pumps. Water-lift is on the average 10 ft. and the pumping capacity is about 70—140 cusecs. Water so lifted is carried by several distributaries for irrigation to adjacent areas including Mitchels Fruit farm.

It is a minor project. The following is the amount of energy produced during the last three years.

1952-53	42,36,100 K. W. H.
1953-54	48,44,840 "
1954-55	44,27,630 "

CHICHOKI MALLIAN (OR JOYANWALA) HYDRO ELECTRIC PROJECT

On the Upper Chenab Canal Main Line Lower near Joyanwala, about 10 miles east of Sheikhupura, there are five low head falls within a distance of five miles which are proposed to be utilized for producing electricity. These falls are to be consolidated into one big fall on a diversion channel. The minimum head available at Chichoki-mallian power-station will be 22.07 ft. The available discharge varies from 7,600 cusecs, which will be available for at least seven months in a year, to 32,00 cusecs. The power-station will have a capacity of12,000 K.W. consisting of three units of 4,000 K.W. each, and is estimated to produce 87.5 million K.W.H. of energy in a year. The total cost will be about 13.2 million rupees. The proposed power station will be connected with the existing 66,000-volt sub-station at Sheikhupura and through it with the genral grid.

The main object of the project is to supply cheap power for the operation of tube-wells that are being installed in the Rechna Doab.

KHANKI HYDRO ELECTRIC PROJECT

The Lower Chenab Canal with a designed capacity of11,300 cusecs takes off from the Chenab on the left side of the Khanki Headworks.

Lower Chenab Canal

The canal has two head regulators. The main Head-regulator can pass a discharge of 13,500 cusecs. The second Head-regulator, called the subsidiary Head-regulator can pass a discharge of 6,000 cusecs. The drop at the regulators varies from 8.7 to 15.8 ft. depending upon the water levels in the canal and the river. It is proposed to utilize this drop for the generation of power. The power station will have an installed capacity of 8,176 K.W. consisting of four units of 2,044 K.W. each. It will be connected with the Shadiwal Hydel station by means of 8 miles long transmission lines at 132,000 volts.

With the power available from Khanki station it will be possible to operate 675 tube-wells of 1·6 to 2 cusecs capacity. Some of these wells are proposed to be located in the water-logged areas on both sides of the Lower Chenab Canal for their reclamation, while others on the left side of the Lower Chenab Canal may be used for irrigating a part of the area commanded by the Upper Chenab Canal, thus saving its water for use further down. It will also provide some lift irrigation. The project is estimated to cost about 130 lakh rupees.

GILGIT MULTIPURPOSE PROJECT

The project aims at the construction of a lined canal of about 150 cusecs from the Hunza river (tributary of Gilgit) near Nomal running west through a tunnel in Nattar range (about $3\frac{1}{2}$ miles long) to fall into the river Gilgit near the town of Gilgit. It will have a head of about 800 ft. at a short distance from the range. Besides providing water to irrigate 1,000 acres of land, it is proposed to construct a hydro-electric power station on the channel capable of generating 400K.W. of energy which will be used for heating and lighting purposes and for running light industries in Gilgit and its neighbourhood. The project was sanctioned by the Economic Council on 6th September 1952. The total cost is estimated at 687 thousand rupees.

MIANWALI HYDEL PROJECT

It is proposed to utilize a head of about 40 ft. between the main Thal canal and the river Indus. Although the scheme had been mooted for a long time, the Economic Council in its meeting held on 6th September, 1952 sanctioned the Mianwali Hydro-electric project for the generation of 100,000 K.W. of power subject to foreign aid and loans becoming available. The power house would be connected with the general grid at Lyallpur *via* Sargodha. Besides improving the position regarding electricity in old Punjab, the project would particularly benefit the industrial development of the Thal area and help in bringing under cultivation, by means of tube-well irrigation, an additional area of 300,000 acres which could not be covered by canal irrigation. The project was estimated ot cost Rs. 211.4 million. A sum of Rs. 1.6 million had been spent on preliminary work till September 1953. Although provision was made for the pondage of water, it would vary seasonally. The development of the Thal project would reduce the water available for power generation to nil at certain times of the year.

The Government of Canada did not approve of this scheme under the Colombo plan. The project, therefore, could not make much headway due to non-availability of foreign aid and has now been practically abandoned.

KUNHAR VALLEY HYDRO ELECTRIC PROJECT ✓

This project was recently suggested in 1951 and it envisages the development of hydro-electricity in seven stages by diverting the waters of the Kunhar river into Siran Valley. The main feature of the project is the development of about one million K.W.of power in easy stages as and when there is a demand for it and thus the capital expenditure required will be within the means of the country after the first expenditure of about 16 crores. Each step will start paying within a year of its completion as it will be undertaken only when there is demand for it.

1. The first stage comprises the construction of a tunnel 13.7 miles long from the proposed Paror dam near the village Kawai (above Balakot) into Siran near Shinkiari where the power house will be located. That will give a head of 1,000 ft. at Shinkiari with a peak discharge of 3,000 cusecs. The installed capacity of the power house will be 300,000 K.W. with a peak capacity of 200,000 K.W. It is estimated to cost 4.5 crores of rupees.

2. The second stage comprises the construction of a power house (No. 2) at Baffa about 4 miles further down on the Siran connecting it with a 4-mile tunnel from Shinkiari. The head will be 300 ft. with a discharge of 3,100 cusecs producing a firm power of approximately 62.000 K.W.

3. The third stage comprises the construction of a power house (No. 3) at Bairakund which is connected by a 3½-mile canal with Baffa. It will have a discharge of 3,100 cusecs and a head of 200 ft. The approximate power produced will be 41,000 K. W.

The construction of four or more power stations is contemplated between Bairakund and Turbela where the Siran joins the Indus. The exact location of these has not yet been determined. Provisionally the following sites have been suggested for dams. (*a*) Bhirina (*b*) Barila, (*c*) Bir (*d*) Turbela.

It will be seen that the waters flowing down Kunhar are to be utilized at several points on the Siran. In order to regulate the waters of the Kunhar it is proposed to construct a number of dams on it from Paror to Lulusar for the storage of water.

The power produced for the project is suggested to be utilized for developing heavy industries like the manufacture of alluminium and steel or for domestic purposes.

Canal Hydel schemes, (Lower Indus valley).

In the former province of Sind a few small canal hydel schemes were under consideration. (*i*) Rohri Canal Hydel scheme, 9,000 K.W. (*ii*) East Nara Canal 7,500 K.W.(*iii*) Yusaf Dhari Hydel scheme on Rohri canal, 5,000K.W.(*iv*) Kumb luma Hydel project on Rohri Canal, 2,000, K. W. A fair-sized hydel station associated with the Ghulam Muhammad (Lower Sind) barrage is also being worked out.

In the hydro-electric Survey of India by Mearres in the Preliminary and Triennial Reports, the following known and possible sites have been mentioned :

1. *Indus.*—The gradient averages about 17 ft. a mile for hundreds of miles above Attock. If development by lifting dams were possible it would provide continuous power on the main flow of the order of 20,000K.W.per mile run or over 2 million k. w. in the 120 miles between Attock and the entry of the river into Kashmir territory. The cost is, however, considered to be prohibitive. Above Kalabagh, the catchment areas are 50,400 sq. miles in the exterior Himalayas and 63,000 in the interior ranges with average rainfall of about 26.6″ and 7.6″ respectively. The maximum recorded flood discharge at Kalabagh is 100,000 cusecs and the lowest observed discharge 18,870 cusecs. The bed here is narrow and if a 100—ft. dam could be con structed the minimum power would be about 170,000 e. h. p Below it the bed widensout greatly, so the flood afflux would be small.

2. *Haro river.*—Near Hasan Abdal, Attock. There is said to be a fall of 50 ft. which can probably be increased by a lifting dam and a good perennial discharge. Rainfall 25 to 40 inches. It is believed that 1,850 K.W.continuous could be obtained.

3. *Kohat Toi.*—It is believed that power can be obtained from this hill stream near Kohat.

4. *Kunhar river.*—This snow-fed river joins the Jhelum not far from Abbottabad. It has many rapids and a large perennial flow and it could be developed on series of lifting dams.

5. *Sinan river.*—This tributary of the Indus had a small plant on one of its own tributaries near Mansehra during the Boer war. The Sinan itself could be dveloped by means of lifting dams and there may be sites where other methods of development on higher heads could be used.

Soan River.—near Rawalpindi. It is capable of supporting a plant of 2,000 K. W. This may be taken as the equivalent of about 700 K. W. continuously as storage is a part of the project.

Jhelum.—The river Jhelum takes a hair-pin bend near Muzaffarabad. Here Nicholson has suggested tunnelling through the ridge so as to short-circut a considerable length of the bend.

Siliaza Nullah.—in Baluchistan near Fort Sandeman. This nullah has gross of about 110 ft. capable of giving 70 e. h. p. continuously.

CANAL FALLS

Name of Channel	R. D.	Particulars	Head (ft.)	Normal discharge cusecs	Min. Dis.
Upper Jhelum Canal					
Main line	240,000	Fall	50	3,000	..
Do.	418,000	Fall	20	..	..
Gujrat Branch	600	Fall	8	2,033	..
Do.	1,350	Fall	8	1,866	..
Do.	2,000	Fall	8	1,850	..
Lower Jhelum Canal					
Northern Branch ..	342,080	Fall	8	294	..
Do.	343,080	Fall	8	294	..
Do.	343,580	Fall	100	294	..
Do.	34,080	Fall	5	294	..
Sulki Branch	13,526	Fall	6	357	..
Do.	14,000	Fall	515	341	..
Upper Chenab Canal					
Main Line Lower ..	715,000	Fall and bridge.	815	9,070	..
Do.	221,000	Do.	15	7,889	..
Lower Chenab Canal					
Bhawana Branch ..	7,500	Fall	10 912	423	..
Khewra Major	8,000	Fall	817	314	..
Burala Branch	164,000	Fall	812	350	..
Upper Gugera Branch ..	219,000	Fal	815	--	850
Lower Bari Doab Canal					
Main Line	329,058	Fall and bridge.	8	4,291	..
Do.	493,759	Do.	8	3,774	..

Upper Swat Canal (Branches)

By utilizing the existing falls considerable power may be available. There are frequent groups which will permit of 30 to 50 ft. drop, with a minimum discharge of several hundred cusecs during about 286 days in a year. Unless required for pumping there is, however, not likely to be much demand for power.

Lower Swat Channel

There are no falls suitable for power here, but near the head works power is generated for the works by dropping the water about 50 ft. down into the river area where there are small canals that require feeding. The site can be utilized later.

Kabul river Canal

A scheme has been considered for running water from one branch to another, near Peshawar, giving a 50 ft. drop.

Aylward in his hydro-electric surveys of the Punjab and adjacent territory made in 1922-24, has mentioned the following sites.

Indus

Few power sites exist on the main river in the accessible area, as its slope is very flat except in the south Himalayan zone. There are four sites, the northern most is Amb on the bend of the river, and the remaining three are further south below Attock. From north to south they are located (1) where the river cuts through the slate rocks of the eastern spurs of the Cherat hills, (2) where the river meets the foot of the Kalachitta range and flows around the hard Siwalik formation at Amanpura and (3) where the river cuts through the Kalachitta range, composed of hard nummulitic limestone. All the sites are formed by short circuiting the rapids in the river either by a tunnel or flumes and are at the points where the river changes its direction. They have natural heads of 43, 11, 17 and 28 ft. respectively. The minimum discharge can be taken at 15,000 cusecs for the first and 20,000 cusecs for the last three. The first third and 4th sites can develop peak load capacity of 48,000 K. W., 26,670 K. W. and 46,600 K. W.

Tributaries of the Indus

There are three accessible tributaries of value (1) Swat, a sub-tributary of the Kabul, (*ii*) The Haro and (*iii*) the Siran.

The first has already been utilized.

The Haro is a small snowfed stream. There is a valuable site on it within 5 miles of Murree, capable of yielding no less than 53,000 K. W. There is also an alternate site on the lower reaches near Campbellpur where the river cuts through a narrow gorge.

The Siran is an important snowfed stream which draining the western slopes of the hills divides its catchment area from that of Kunhar, a tributary of the Jhelum. It has three sites. Two of them are near Shinkiari, about 10 miles north-west of Garhi Habibullah. The third is about 20 miles further down from Shinkiari. These are estimated to have a capacity of 25,000 K. W.

Jhelum

There are two sites on the main river, one is already partially developed at Mahusa near Baramullah where the river cuts through the Pir Panjal range. The other site is on the Domel loop near Muzaffarabad where the river cuts through the Sirmur range, and sharply turns back to the south. Ten different alternates for the development of this loop have been suggested, the most promising being the one near Kohala.

Tributaries of Jhelum

There are two tributaries of value on the Jhelum, the Kunhar and the Poonch. The latter lies in Kashmir. The Kunhar joins the Jhelum below Domel. It has one valuable site made by tunnelling through the neck dividing its lower reaches, from the Jhelum. This loop is formed by a spur, barren and useless for any other purpose.

Chenab

The river has only one site, the well-known one at Riasi where the river makes a big loop capable of developing 40,000 K. W.

The following hydro-electric generation schemes have been suggested by M. R. V. P. to be developed later on.

1. *Attock.*—On the Indus gorge below Attock, ultimate out-put 200,000 K. W. The scheme calls for a dam across the Indus.

2. *Ghazi.*—On the Indus, 30 miles above Attock, ultimate output 200,000 K. W.

The Indus would be headed up by a barrage and 1,500 cusecs diverted through a canal which would debouch into the Indus about 9 miles below Attock. The total head available would be 190 ft. Estimated cost Rs. 25 crores.

3. *Darband.*—On the Indus, 25 miles above Ghazi ultimate output 2,500,000 K. W. A high dam would be built across the gorge of the Indus giving a maximum

head of over 750 ft. forming a reservoir about 60 miles long. This would enable the flow of the Indus to be controlled to a minimum of 400,000 cusecs. The output from the power station would be about 12,000 million K. W. H.

This scheme is a multipurpose one and would provide for the irrigation requirements of the Punjab as well as navigation in the lower reaches of the Indus. Estimated cost Rs. 220 crores very strongly recommended.

4. *Chilas.*—On the Indus, n. w. of Nanga Parbat. The proposal is to divert water from the Indus through a tunnel to the Kunhar river which lies to the south. There is no indication of its possible output.

5. *Khushal-garh.*—By the railway bridge over the Indus 30 miles east of Kohat, ultimate output, 200,000 K. W. The construction of a dam in the gorge above the railway bridge has been suggested but the banks of the river are of insufficient height to provide more than 60 ft. head above the highest flood level.

6. *Kalabagh.*—On the Indus, 40 miles north of Mianwali, ultimate output 200,000 k. w. There is a possible site for a dam upstream of the railway bridge at Kalabagh, where the Indus Gorge opens out into the plain. The dam could be built to height 150 ft. above the present highest flood level. The site is close to the Salt Range.

7. *Kashmor.*—On the Indus, near the old Punjab and Sind border ultimate output 70,000 K. W.

This is an extension of the Taunsa scheme and involves the enlargement of the Dera Ghazi Khan canal to take a further 10,000 cusecs from the Indus which would be dropped through two power stations, each with a head of about 50 ft. situated close together at the end of D. G. Khan canal. The water would be finally returned to the Indus near Kashmor, some 6 miles away. Estimated cost Rs. 14 crores.

8. *Bedian.*—15 miles s. s. e. of Lahore, estimated output 4,000 K. W. Bedian is on the Bambanwala-Sutlej canal which is now under construction. At this point the flow in the canal would be about 2,000 cusecs and a fall of 30 ft. would be available for power generation. As planned at present the canal is likely to stop short of the Sutlej, so that an extension of the canal is a prerequisite of this hydro-electric scheme.

9. *Thatta.*—60 miles east of Karachi, ultimate output 10,000 K. W. A canal scheme.

10. *Barrage schemes.*—(*a*) At the confluence of the Indus and the Sutlej (*b*) Lloyd barrage at Sukkur, (*c*) Downstream from Hyderabad.

It is possible that these three barrage schemes may be used for hydro-electric generation. No attempt has yet been made to do so at the existing Lloyd Barrage.

The country through which the Indus flows is very flat and in times of flood there would be very little head available for power generation.

11. *Kunhar.*—20 miles n. e. of Abbottabad, ultimate output 7,000 K. W.

At a point about 3 miles south of Muzaffarabad a tunnel 1¼ mile long can be driven on the Kunhar river towards the Jhelum river, where a drop of 150 ft. is available. The proposal visualised the diversion of about 600 cusecs from the Kunhar.

Riasi.—About 65 miles upstream from Gujrat, on the Chenab, ultimate output 500,000 K. W. Some preliminary work has been done on this dam site, where it may be possible to construct a dam, 700 ft. high for the production of 50,000 K. W.

The United Kingdom Industrial mission to Pakistan recommended in their report that attention should be given to possible development of hydro-electric power in the hilly regions north-west of Karachi in the Kalat Division, while in a memorandum on irrigation prepared by the Chairman, Central Engineering Authority, possible schemes still further west, in the highlands north of Pasrur, have been mentioned.

MALAKAND DARGAI HYDEL SCHEMES

1. **Malakand**

This is the oldest major hydel project in Pakistan, completed in 1938 utilising the waters of the Upper Swat Canal. The river Swat rises in Kohistan in the snows at an elevation of over 11,000 ft. The minimum discharge therefore, occurs during winter when the upper reaches are frozen. The normal winter discharge is 2,000 cusecs but in exceptionally cold dry winters it is less. The Upper Swat Canal takes off from it at Amandarra Head works near Chakdarra. The water is then taken through a Benton tunnel for about 2½ miles to the Mazah Khwar, the bed of which is followed for a short distance before the water is again taken into the canal for distribution.

The Hydro-electric scheme takes about 1,000 cusecs of water debouching from the Benton tunnel through another tunnel known as power tunnel, about 2,250 ft. in length, and then for a short distance along an open cut to a concrete masonary weir supporting the tops of three pipes down which the water falls about 250 ft. to drive turbines, situated on the right bank of the Upper Swat Canal. The power station is situated at Jabban. Some of this surplus water flows to rejoin the Upper Swat Canal by means of a natural nala.

The scheme originally had an installed capacity of 9,600 K. W. It was extended by another 10,000 K. W. during 1950.

The power is transmitted through a net work of transmission lines to a large area in the Peshawar Division right upto Mansehra, District Abbottabad.

With the help of this power Nowshera has grown into an important industrial centre, with many factories including those of caustic soda, DDT, card board and paper, cotton extile and tleather tanning.

It has been taken to Wah from where a link has been constructed to Jhelum to connect it with the Rasul grid.

There has been a progressive increase, since independence in the electricity produced as shown by the following table :

Years	*Units generated*
1947-48	1,96,80,400
1948-49	2,21,00,350
1949-50	4,13,79,100
1950-51	4,95,94,200
1951-52	5,84,81,600
1952-53	7,12,68,950
1953-54	9,66,99,400
1954-55	11,35,45,436

2. **Dargai Scheme**

The Dargai Hydro-electric scheme was first conceived in 1945. Under the scheme a tail race of the Malakand has been taken from Jabban along a falling contour on the adjoining hill-side at the end of which there is a fall of 250 ft back into Upper Swat Canal through a power house at Dargai. It has four turbine generators of 5,000 K.W. each thus giving it a total installed capacity of 20,000 K.W. The generating plant of the station has been obtained from U. S. A. The total cost of the Project is 15.55 million rupees. The power has been injected into the general grid. The most important recepient of the Dargai power is the ordnance factory at Wah.

WARSAK HYDRO ELECTRIC SCHEME

The Warsak Dam project is a multi-purpose project and includes a hydro-electirc scheme. The project consists of a dam (of the rockfill type) on the river Kabul, just above the village Warsak about 19 miles north-west of Peshawar. It is about 240 ft. high from the foundations and is designed to give an average head of about 130 ft. for an under-ground power-station generating approximately 150,000 K.W. It will have six turbines of 30,000 K.W. each. Besides providing the hydraulic head the dam would afford sufficient storage for daily and weekly regulation. There will be two overflow spillways having maximum discharge capacity of 3,85,000 cusecs and two diversion tunnels with discharge capacity of 65,000 cusecs.

The energy available from Warsak will vary considerably due to seasonal changes in the flow in the Kabul river. In the month of least flow, which may be any month from December to March, the energy produced would be no more than 27 million K. W. H., 77% of 34.6 million K.W. H.

It has been estimated that there will be an economic advantage from Warsak against thermal generation equal to Rs. 136 lakh per annum making a total of 27 crores over a period of 20 years.

It is proposed to transmit most of the power direct to Jhelum at a distance of about 170 miles for injection into the Rasul grid. A smaller part of the out-put will be injected into the Malakand grid. About 5,000 K.W. of power will be used in the centrifugal pumps to lift water into the lift canal, one of the two canals into which the high level right bank canal from the dam will bifurcate. The water will be pumped into it from the main canal through a lift of 150 ft. It will irrigate a large area in the Khyber Agency. The total cost is estimated to be 221 million rupees. Foreign aid has been secured for the project. The Government of Canada has so far provided 6.9 million dollars for this project under the Colombo Plan for the power-generating station and light construction equipment and has agreed to bear the entire dollar cost of the project. They have also agreed that sole proceeds of the wheat provided by them during 1952-53 and 1953-54, worth 10 million dollars, may be utilized to meet a part of the rupee cost of the project. H. G. Acres ltd., have been engaged by the Canada Government as Consulting Engineers for the purpose. About 15% of the civil works have been completed.

TAUNSA MULTI-PURPOSE PROJECT

A barrage across the Indus near Taunsa, District Dera Ghazi Khan about 85 miles downstream from Dera Ismail Khan, was proposed in 1936, but the project could not be persued due to other more important schemes of Punjab. In 1945 the Government of India was interested in a national highway from Lahore to Quetta. The railway department also wanted to reduce the length from Lahore to Quetta. So a multi-purpose project was sanctioned in 1952. Besides providing road and railway track between Dera Ghazi Khan and Muzaffargarh and weir-controlled irrigation in these districts, at present served by inundation canals, it is proposed to have a hydro-electric station from the canal off-taking on the left side of the barrage and out-falling into river Chenab near Muzaffargarh town. The length of the canal in about 45 miles. A drop of 39 to 44 ft. is available from this canal. The power house will have an installed capacity of 100,000 K.W. the firm power available being 89,500 K.W. It will be located at a distance of about 39 miles from Multan. The power will be used in operating 1,000 tube-wells in an area of high water table of these two districts besides electrification of the central area of the plain of West Pakistan. These tube-wells will not only lower the already high water-table here, reducing the water-logging, but also supplement perennial water supplied for irrigation. The discharge available from these tube-wells will be about 2,000 to 3,000 cusecs. This project is of special significance because hydro-electricity will be available in this central area which has lacked development for want of suitable source of power.

Sui gas pipe-line is also to be carried over the Taunsa Barrage for athermal station at Multan, with a capacity of 10,000 K.W. This power could act in conjunction with the hydel power when necessary or when there is a great demand for electricity with the development of industry. The whole project is estimated to cost thirty one crores of rupees. The electricity will be quite cheap, 3 pies per unit at busbars and the hydel scheme above 13.2 crores.

Karnafuli-Multipurpose Project.

The Project for harnessing the river Karnafuli and controlling its devastating floods in the lower reaches of the valley is about 50 years old. The Karnafuli valley has a catchment area of 5,500 sq. miles with an average rainfall of about 100 inches. The river was first examined in 1906-07 and then in 1922. It was, however, in 1946 that Mr. Moore, Superintending Engineer, submitted his preliminary report on the Karnafuli scheme.

East Pakistan's main natural wealth is an abundant supply of water. At present this water is not only running waste into the sea but very often it causes heavy floods with great misery to the people living nearby. This precious gift of nature could be utilised for the needs of irrigation, navigation and hydel-power. This would not only improve the food supply for the growing population but also raise their standard of living. Soon after the establishment of Pakistan the Government of East Bengal gave their earnest consideration to this problem and the project was given a concrete shape. This is the first great efforts to utilise on a large scale the water resources of East Pakistan. In it the development of hydel-electricity plays the major role as the main basis for future agricultural industrial and cultural progress.

After emerging from the Lushai Hills in Bharat, the river Karnafuli enters the Chittagong Hill Tract of East Pakistan at Thegamukh and passes through three hill ranges of Barkar, Chillardak and Silchari successively at a distance of 89, 69 and 40 miles respectively from Chittagong. Geological considerations demand that dam could be located on one of these sites only. A reservoir could be constructed at any one of these ranges. The Silchari gorge was finally selected for the dam site which is to be located at its mouth, 3 miles-up-stream of Kaptai* in the Kaptai forest. The river runs through this gorge for 10 to 12 miles.

The works include the construction of a reservoir for improving the river water by a dam 2,000 ft. long at the crest and 140 ft. high above the bed of the river. There shall be 3 spillways to pass the controlled flood of a lock suice, for navigational facilities and of a power-house for the generation of electricity. The dam will create a reservoir of 213 sq. miles. The average volume of water which passes annually through the river is 520,000,000,000 c. ft. of which 425,000,000,000 c. ft. will be controlled and utilised for the generation of hydroelectric power and navigation.

The Karnafuli valley ranks as one of the world's heaviest zones of rainfall. The maximum record at several stations is as much as 138.25 inches. The normal floods have an intensity of 1,50,000 cusecs while the catchment is considered to be quite capable of bringing flood upto 3,00,000 cusecs. The spillway has been designed for a maximum surplus discharge of 5,23,000 cusecs.

The Hydro-power station will be located near Kaptai. The maximum discharge through the power-house will be 10,000 cusecs and the minimum about 5,000 cusecs at tail water level. The maximum head of discharge will be nearly a fall at full reservoir level. The power-station will be equipped with 120,000 K.W. of generation plant in 3 units of 40,000 each, and adding one spare unit to be installed later the station's installed capacity will be 1,60,000 K. W. By the time this power station starts operation there will be steam and diesel generating sets of about 60,000 K.W. capacity within this area as a part of the project. This hydro-power station will work in combination with these thermal stations at Chittagong, Narayanganj and Dacca which will come into existence before it. This combination will be able to supply upto 1,60,000 K.W. of peak demand. The total extent of power generated at the ultimate load conditions will be 655,000,000 K.W. from hydro and 75,000,000 K. W. from steam. If all this energy is used for lighting purposes it will be sufficient to light every house in the whole of East Pakistan.

In this project a fuel and hydro combination has been envisaged with a view to obtain maximum possible development of hydro-power. The fuel plants will serve as a stand-by for meeting the dificinecies in years of low yield and will also meet the heavy peak load demands during the lighting period.

*19 miles below Rangameti and 28 miles from Chittagong.

With 730 million K.W.H. of electrical generation, it will be possible to serve the needs of 18,150,000 people living within an area of 15,000 sq. miles of Chittagong, Noakhali, Tippera, Dacca, Mymensingh, Sylhet and Khulna Districts or 27.6 p.c. of the total area of East Pakistan. There will be three main sub-stations at Chittagong, Narayanganj and Khulna and for the subsidiary rural electrification lines the sub-stations will be spread all over the country-side.

The object of the project is an over-all balanced development. Apart from providing protection from floods and facilities for navigation and exploitation of forests in the Karnafuli basin, its main aspect is the development of industry as well as agriculture in the plains both by pump irrigation and drainage by means of hydro-electric power. Approximate distribution of this power between various uses is estimated as :—

		K. W. H.	*Percent*
1.	Industrial and urban lighting ..	304,160,667	$41\frac{2}{3}$
2.	Village lighting and cottage industries	243,333,333	$33\frac{1}{3}$
3.	Irrigation and drainage	109,500,000	15%
4.	Losses in distribution and transmission	73,000,000	10%
	Total	730,000,000	100%

It is proposed to distribute the power in such a way that average concumption per head of population is 40 K. W. H. per annum. An idea as to what actually this 40 K. W. H. per head of population means, can be obtained from the following :—

1. Average strength of one family .. .. 6 members.
2. Over all average consumption per family .. 40 K.W.H. or 240,000 Watt Hours per annum.

This is distributed as below :—

1. (*a*) Rural lighting 2 lights per family, each of 25 watts, working for 3 hours .. .. 54,750 Watts.

   (*b*) About 50% extra for other domestic uses and cottage industries .. .. .. 25,250 Watts per annum.

   Total consumption for rural lighting and cottage industries .. .. 80,000 Watts per annum or 33%

2. In the case of drainage and irrigation pumping load in order to irrigate 1,500 sq. miles or about 1,000,000 acres of second crop the power required is equivalent to a continous energy of 11,300K.W. which involves a consumption of 99 millionK.W.H. per annum or on the population basis it will mean per family of 6 an average consumption of about 36 K.W.H. or 36,000 Watt. hours or 15%.

3. The industrial and urban lighting load by the end of 1960 is expected to be 277.7 million K.W.H. or on the population basis it will mean per family of 6 an average consumption of 100 K.W.H. or 100,000 Watt hours per annum or 41.67%.

4. Losses in distribution and transmission per family of 6—24 K.W.H. or 24,000 Watt Hours per annum or 10%.

2,40,000 Watt Hours per annum or 100%

Chittagong, Naryanganj-Dacca and Khulna are three chief centres of industry in East Pakistan which are at present based on thermal power. It all comes from imported fuel, as East Bengal neither produces coal nor oil at present. The little that is produced in West Pakistan is consumed locally. Hydro-power will meet the full requirements of industry, big and small, not only for the existing factories but also for those planned for future. It will be a great boom to jute industry and facilitates the exploitation of forests. East Pakistan had very few industries before partition. Their expansion is induspensible as an alternative source of income to the already dense and growing population as well as to provide consumers' goods, now available only in limited quantities on account of exchange difficulties. Industry complementry to agriculture will bring wealth and prosperity to the country and increase the general standard of life of a large but poor population.

Hydro-power will also be available to most of the villages and homesteads at such low rates that better lighting will be obtained at cost much cheaper than that of kerosene. It will thus not be the privilege of the urban population only. The cheap power could also be utilised in cottage industries like small power-looms, flour or rice mills. This will increase rural prosperity by enhancing the per-capita income and is likely to transform completely the character of villages. Many of the dispersed homesteads are likeby to develop into nucleated settlements.

Whatever may be the progress of industry in the years to come, agriculture will always remain the predominent occupation of the people and the principal source of income. Although the annual rainfall is abundant, water is needed for the irrigation of rabi crops in winter. To meet the requirements of the growing population swampy lands are to be reclaimed by drainage and culturable wastes are to be brought under cultivation and more than one crop is to be obtained from the same field whenever possible. During the monsoon a large part of East Bengal is covered by water. Flooding of the rivers also fills many low lying areas which are so low that when the water retreats they remain as lakes known as bhils or haors. Is is proposed to instal 2,500 pumps having an average capacity of 24 horse-power spread out to drain these low areas. They will be capable of removing 4 ft. depth of water from 5,000 sq. miles It means one pump for each 6 sq. miles or about 4,000 acres. The drainage will increase the production of foodgrains by about one million tons from such lowlying areas which are useless at present. But for the exceptionally cheap hydro-electric power pumping would not be possible. A great deal of secondary power could be generated by passing the rain water through the spare unit instead of over the spillways. More power could thus be available at the same time when there is a great demand for drainage.

When the monsoons are over these pumps would be utilised for lifting water on to the field and irrigating the second crop which may cover 1,000,000 acres. The extra yield from only one crop can be taken roughly at 500,000 tons. If the average price of crops so produced is taken as Rs. 10 per maund, the extra gross annual income to the nation will be about 14 crore rupee from it, and the pumps will be available for service for the whole year.

The national income from the value of crops raised due to better drainage and irrigation and cultivation, in one year alone, will pay for about the entire cost of the first stage of the scheme.

An account of the Karnafuli Project would be incomplete without mentioning the fluctuations of sea-level due to the tides, which could be a further source of power. The capacity of the tidal basin between the dam site and its outfall is 3,425 million c. ft. Assuming that for 12 hours an average head of 15 ft. is available for the generation of power, it will be possible to obtain an output of 80,000 K. W. H. of enargy. The Karnafuli reservoir can be very efficiently operated in conjunction with such a scheme. Though it is premature to provide any electric gear to meet the requirements, yet an extra tunnel and open space in the power-house have been provided so as to accomodate such a contingency in future.

The total estimated cost of the project is approximately Rs. 26.65 crores, 18.57 crores in the first stage and 8.08 crores in the second stage. The power would be delivered at sub-station at 0.5 annas per unit. The scheme promises to be a productive concern, even with rates for the supply of energy which can be compared favourabley with those of any other scheme. The direct revenue accruing to the Government from the project will not only meet its interest and other liabilities but will be sufficient payto back the capital cost of the scheme within a period of 4 decades.

The Economic Council, on 6th September, 1952, approved the first stage of the project subject to the availability of foreign aid or loans. The Government of East Bengal proceeded on their own in autumn 1952 with the execution of the project rather hurriedly. Two coffer dams and a diversion channel road and labour camp were constructed. The flood in the summar of 1953 which came before the works on the coffer dams was complete did considerable demage to them.

An agreement was signed with F. O. A. of U. S. A. for the provision of the Engineering services of a value of $.75 million. The work is now proceeding satisfactorily. About seven thousand persons are working on the site and the camp has a population of about 15,000. The first stage of the work is expected to be completed by June, 1956. Other subsidiary transmission lines and pumping installations will proceed for one or two more years.

The scheme when completed is sure to make a great improvement in the economic condition of nearly 40 % of the population of East Pakistan.

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Vols—1-X (1942-1955)

Compile it by A.R. GHANI

Punjab Geographical Review:—

Vol. I, 1942, No. 1.

Vol. II, 1947, No. 1.

Vol. III, 1948, Nos. 1-2.

Pakistan Geographical Review:—

Vol. IV, 1949, Nos. 1-2.

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