CHAPTER VIII.

THE KOSI.*

KOSI RIVER, ITS CATCHMENT AND TRIBUTARIES.

The Kosi known as Kaushiki in Sanskrit books is one of the most ancient rivers of India. It rises in the Himalayas and drains generally an area in the hills to the east of Kathmandu in Nepal, roughly between the longitudes 85°20′ and 88°. Its three tributaries within the Himalayas the Sun-Kosi, Arun and Tamur join together at Tribeni some six miles above Chatra, to form the Sapt Kosi, which flows thereafter through a gorge past Barahkshetra and debouches into the plain at Chatra. The Sun-Kosi takes its source near Kathmandu. The Arun rises into Tibet, where it is called Phingchue, cuts through a deep gorge across the great Himalayan Ranges and flows south to Tribeni. The Tamur comes from east to Tribeni. Two highest peaks in the world, Mt. Everest and Mt. Kanchanjunga are situated within the catchment of the Kosi. The chief tributaries that join the river in the plains are Tiljuga, Bhati Balan, Sugarwe, Soni or Jangar Balan, Kamla and Bagmati. All of them join the main river on its right side. There are no major tributaries joining the river from the left.

The details of the catchment for the Sapt Kosi at Chatra are given in the following table:—

TABLE NO. I.

River.	Catchment (sq. miles).	Percentage to total.
The Sun	7,330	32
The Arun	13,330	58
The Tamur	2,228	10
The Sapt Kosi below the Tribeni	112	23,000 square miles.

VAGARIES OF THE KOSI RIVER.

Though very little known outside, the Kosi has been one of the problem rivers of the world. It is notorious for its vagaries and has preferred to change its bed very often. During the last two centuries, for which records are available the river has been changing its course in a westerly direction and it has laterally moved nearly 70 miles. About 125 years back, the river was flowing just west of Forbesganj, Purnea and Katihar. It may be pointed out that the movement of the river has not been gradual one, as the river has been taking sudden jumps from one course to

* Contributed by Sri Debesh Mookerjea, Chief Engineer, Kosi Project (P. C. R. C.).

another from time to time. The river has been known to have shifted by as much as 12 miles to the west in the course of a single year. During each of these westward shifts, the river has generally moved along a straight course in the new direction until it met another stream-course, which it thereafter appropriated to itself and enlarged. The river has been swinging about a pivotal point situated near the Belka-hill nose. In 1937 the river was flowing just near Supaul and joined the Bagmati course above Dhamhara-ghat and thereafter flowed eastward up to Kursela where it joined the Ganga. Today the river is flowing along a more westerly course near Nirmali and Madhepur.

During these peregrinations, the river has laid waste vast tracts of what were once rich and fertile lands. For this reason and for the reason that during floods the river used to overflow its banks and inundate wide areas, it is often called "Bihar's River of Sorrow". During the floods, the river spilled over a large tract of land on the eastern side up to a north-south line passing through Pipra and Madhepura and submerged generally, most of the area over which it has shifted in the recent past. On the western side, the flood waters used to cover relatively a very narrow area, up to a maximum of about 5 miles to the west near Nirmali and Madhepura.

Heavy silt load.

The vagaries of the river are to be ascribed to the heavy coarse sediment load and bed load, the river brings down from the Himalayas. As regards total discharge and bed falls the Kosi is comparable to the neighbouring river Gandak. The hydrographs show that the flows in both the rivers are generally in step with each other, indicating thereby that the incidence of rainfall is generally similar in time, intensity and duration in both the catchments. But the Gandak is generally under better regime, the reason being that it carries much smaller quantities of coarse sediment and bed load as compared to the Kosi.

The comparatively excessive coarse sediment carried down by the Kosi is to be ascribed to the fact, that in its catchment the Himalayas is much more compressed. The valleys are narrower, the sides are steeper and there are no wider basins in the hill region for the river to spillover its flood waters and deposit its coarse sediment load. Moreover, on account of the steep and high sides, frequent slips occur in the river, and that adds considerably to the coarse sediment load of the river. Boulders, pebbles and shingles are also brought down into the river, which are thereafter rolled down into the plains.

Geologically, it is known that a wide area on either side of the Sapt Kosi between the Tribeni and Chatra is a "Thrust Zone", wherein, due to folding and faulting accompanying the mountain

building activity the older rock strata underneath have slided over and covered the much younger rich formations above. This overthrust is itself a direct consequence of the highly compressed nature of the Himalayas in this region. This reversal of the older rocks riding over the younger ones has brought to bear excessive stresses which has resulted in considerable shattering of the rocks over the area and on its margins. In addition, the frequent seismic disturbances, more especially the very intense earthquake of 1934, should have further accentuated the loosening up and disintegration of the already shattered rocks in the region. This shattered zone extends over the area through which the Sun-Kosi and the Tamur flow and constitutes a major contributary factor for the excessive sediment and bed loads carried down by the river. The chief reasons for excessive silt discharge may be attributed to—

(*i*) the concentration and uneven distribution of very high rainfall;

(*ii*) the exposed young rocks with high sediment loads subject to easy erosion;

(*iii*) the frequent seismic disturbances of great magnitude;

(*iv*) the steep slope of the river; and

(*v*) the afforestation and cultivation in unscientific way.

SEDIMENT DATA.

To get a quantitative estimate of the total amount of sediment brought down the river during each year and of the sediment intensities, gauging and sediment load determinations were started systematically from the year 1943 onwards. The silt quantity brought down by the river in each year from 1948 to 1961 are given in Table 2 below:—

TABLE NO. 2.

Year.	Run off in million acre ft.	Sediment load in 1,000 acre ft.				Percentage of sediment to run off.
		Coarse.	Medium.	Fine.	Total.	
1948	49.2	10.4	28.0	45.6	84.0	0.17
1949	47.1	9.5	37.6	76.1	123.2	0.28
1950	42.6	12.1	21.3	42.2	75.6	0.18
1951	36.3	16.2	24.2	43.0	83.3	0.23
1952	36.5	16.2	21.8	42.1	80.1	0.22
1953	35.8	13.4	18.7	34.0	66.1	0.18
1954	49.1	37.2	56.7	135.9	229.8	0.47
1955	34.3	13.4	13.9	28.9	56.2	0.16
1956	34.3	7.1	15.7	32.9	55.7	0.16
1957	34.3	6.5	15.7	26.2	48.4	0.14
1958	40.1	19.0	29.6	36.7	85.3	0.21
1959	36.8	11.9	22.3	36.7	70.9	0.19
1960	41.7	8.2	16.9	33.4	58.5	0.14
1961	39.3	8.2	13.1	26.6	47.9	0.12
Average 1948 to 1961	39.8	13.5	24.0	45.7	83.2	0.20

The monthwise contributions of the silt load for each year has been tabulated in Table no. 3.

TABLE NO. 3.

Monthly total sediment load in Kosi at Barahkshetra for the years 1948–61.

Month.	1948.	1949.	1950.	1951.	1952.	1953.	1954.	1955.
1	2	3	4	5	6	7	8	9
January ..	0.11	0.12	0.12	0.07	0.06	0.06	0.04	0.11
February ..	0.05	0.11	0.08	0.05	0.07	0.05	0.06	0.08
March ..	0.16	.09	0.09	0.07	0.08	0.49	0.08	0.09
April ..	0.77	1.08	0.10	0.12	0.28	0.53	0.69	0.29
May ..	2.58	3.36	1.40	5.07	3.01	3.45	3.16	1.42
June ..	9.21	14.99	9.47	13.61	7.56	11.07	31.92	7.99
July ..	28.16	43.05	16.23	25.07	24.93	20.76	67.65	17.90
August ..	20.46	28.42	31.43	26.33	22.99	15.33	101.61	17.20
September ..	15.57	28.00	14.96	8.96	18.61	11.74	20.43	8.36
October ..	6.00	3.17	1.18	3.07	2.04	2.24	3.45	2.23
November ..	0.70	0.58	0.33	0.60	0.36	0.23	0.52	0.45
December ..	0.25	0.14	0.14	0.18	0.11	0.09	0.27	0.12
Total years ..	84.02	123.11	75.53	83.20	80.10	66.04	229.85	..
(*a*) ..	0.25	0.14	0.14	0.18	0.11	0.09	0.27	61.21
June to October (*b*).	79.40	117.63	73.27	77.00	76.13	61.14	225.03	53.68
Percentage of *b*/*a*	94.5	95.6	97.0	92.6	95.0	92.6	97.9	95.5

Month.	1956.	1957.	1958.	1959.	1960.	1961.	Average, 1948—61.
1	10	11	12	13	14	15	16
January ..	0.10	0.11	0.05	0.25	0.06	0.04	0.09
February ..	0.06	0.04	0.04	0.18	0.06	0.06	0.07
March ..	0.14	0.07	0.05	0.28	0.08	0.11	0.14
April ..	0.88	0.09	0.42	0.67	0.07	0.18	0.45
May ..	6.78	0.37	1.00	2.31	1.14	1.05	2.58
June ..	14.70	6.81	10.62	11.16	9.13	6.34	11.75
July ..	11.74	12.28	16.89	18.50	13.15	8.12	23.18
August ..	12.47	21.31	37.49	20.95	17.78	18.04	27.99
September ..	5.97	5.58	13.11	11.33	14.02	9.98	13.33
October ..	2.23	1.23	4.42	4.42	2.53	3.50	2.98
November ..	0.45	0.26	0.85	0.75	0.33	0.44	0.49
December ..	0.12	0.09	0.40	0.18	0.10	0.10	0.17
Total years ..	55.64	48.24	83.34	70.96	58.45	47.96	83.22
(*a*) ..	0.12	..	..	..	..	..	..
June to October (*b*)	47.11	47.21	82.53	67.34	56.61	45.98	79.23
Percentage of *b*/*a* ..	84.6	87.9	96.7	93.5	96.9	95.9	95.2

From the table it will appear that about 95 per cent of the silt load comes down to the river during the monsoon floods only, i.e., from the months of June to October. The sediment load as percentage of run off has also been indicated in Table no. 2. The maximum sediment load of 0.47 per cent of the annual run off was recorded in the year 1954 when there was maximum discharge and when 98 per cent of the total sediment was contributed during monsoon months only and 2 per cent during the next of the months. It is evident that greater the magnitude of the flood the greater is also the sediment load.

DISCHARGE.

The annual rainfall in the main catchment within the Himalayas varies from 60″ near the foot hills to as much as 160″ on the southern slopes of the central Himalayan ranges. Further north, the rainfall rapidly decreases. Even the lower Arun catchment is a region of comparatively low rainfall, only about 40″ per year. In the upper Arun catchment, the rainfall is still less, decreasing to about 10″ only to the north of the greater Himalayas. The average annual rainfall for the Kosi catchment has been estimated to be 67″ excluding the upper Arun catchment and only 45″ for the whole Kosi catchment.

The main monsoon season extends over the months of June, July, August, September and October. In all the tributaries and in the main river the discharges increase rapidly with deep and rapid fluctuations in flow. June is the month when the discharges generally increase rapidly. Late September and October are the months when the discharges begin to fall down rapidly to nearly off-monsoon flows. The fluctuations in the flow are very marked in all the rivers during this period. There are instances when the discharges have increased and then fallen by as much as a lakh of cusecs in a day in the Sun-Kosi or Arun, about 75,000 cusecs in a day in the Tamur and as much as two lakh cusecs in a day in the Sapt Kosi.

Peak flow for the year is generally recorded either in July or August, though there are instances when it was recorded as late as September. Peak flows result naturally after very heavy rainfall in the catchment, which occur generally during the tail end of the monsoon season. Excessively heavy rainfall intensity in the catchment is meteorologically associated with either of the following two major factors:—

(*i*) A bay depression breaking over the Nepal Himalayas during the later monsoon season; or

(*ii*) The incidence of westerly winds over the region associated with what is called a "break" in the monsoon, when the axis of monsoon trough shifts to the Himalayas.

The monthly run off of the Sapt Kosi from 1948–61 is given in Table no. 4. From the table it is seen that the total annual run off averages to 40 millions acre ft., of which 81 per cent is usually contributed from June to October and balance in the rest of the months. The run off is found generally low during the months from December to March. The contribution of run off from each of the major distributaries is as below:–

(*i*) The Sun Kosi–43.8%;

(*ii*) The Arun Kosi–36.6%; and

(*iii*) The Tamur–19.6%.

TABLE NO. 4.

Monthly run off in the Sapt Kosi from 1948 *to* 1961.

(In million acre ft.)

Month.	1948.	1949.	1950.	1951.	1952.	1953.	1954.	1955.
1	2	3	4	5	6	7	8	9
January ..	0.88	1.05	0.94	0.79	0.81	0.84	0.77	0.74
February ..	0.67	0.90	0.73	0.64	0.69	0.66	0.62	0.75
March ..	0.69	0.85	0.71	0.69	0.75	0.91	0.65	0.86
April ..	0.89	1.16	0.73	0.67	0.88	0.80	0.81	0.73
May ..	1.77	2.02	1.22	1.52	1.63	1.36	1.49	1.17
June ..	3.90	4.55	4.30	4.16	3.17	3.33	5.64	3.20
July ..	10.17	9.52	7.86	7.42	6.84	8.39	12.01	7.42
August ..	11.36	11.20	12.21	9.05	8.04	7.76	13.20	7.78
September ..	9.87	8.52	8.40	5.85	7.62	7.16	7.91	5.48
October ..	5.49	4.17	2.91	2.80	3.21	3.00	3.31	3.42
November ..	2.11	1.95	1.52	1.62	1.69	1.50	1.57	1.66
December ..	1.44	1.22	1.01	1.08	1.16	1.05	1.10	1.19
Total for the year (*a*).	49.24	47.11	42.54	36.29	36.49	35.76	49.08	34.33
Total June to October (*b*).	40.79	37.96	35.68	29.28	28.88	28.64	42.07	27.30
Percentage of *b*/*a*.	82.8	80.6	83.8	80.7	79.1	80.1	85.7	79.5

Month.	1956.	1957.	1958.	1959.	1960.	1961.	Average for 1948—61.
1	10	11	12	13	14	15	16
January ..	0.92	1.06	0.82	0.87	0.88	0.95	0.88
February ..	0.71	0.76	0.63	0.69	0.75	0.78	0.71
March ..	0.76	0.81	0.69	0.82	0.78	0.89	0.77
April ..	0.85	0.84	0.86	0.94	0.75	1.03	0.85
May ..	2.24	1.19	1.43	1.40	1.40	1.52	1.53
June ..	4.67	2.62	3.11	3.51	4.31	4.47	3.92
July ..	5.80	6.92	6.93	6.45	7.93	6.18	7.85
August ..	6.86	9.47	11.58	7.70	9.31	9.54	9.65
September ..	5.26	5.23	7.08	6.54	7.87	6.60	7.03
October ..	3.25	2.79	3.99	4.68	4.42	4.19	3.69
November ..	1.76	1.45	1.74	2.03	1.93	1.96	1.75
December ..	1.24	1.05	1.20	1.15	1.34	1.22	1.17
Total for the year (*a*).	34.32	34.24	40.05	36.78	41.67	39.32	39.80
Total June to October (*b*).	25.84	27.08	32.69	28.88	33.84	30.97	32.14
Percentage of *b*/*a*.	75.3	79.1	81.6	78.5	81.2	78.8	80.8

The maximum and minimum discharge of the Sapt Kosi from 1948—61 with date of occurrence is given below in Table no. 5.

TABLE NO. 5.

Year.	Maximum.		Minimum.	
	Discharge.	Date.	Discharge.	Date.
1948	4,78,422	July 13 ..	9,016	March 18.
1949	3,95,640	July 19 ..	12,415	March 26.
1950 . ..	3,40,661	August 20 ..	9,603	March 30.
1951 . ..	2,56,284	August 24 ..	9,325	March 24.
1952	3,06,443	September 24	10,843	February 27.
1953	1,91,413	July 30 ..	10,988	February 27.
1954	8,55,237	August 24 ..	9,481	March 19.
1955	2,50,000	August 7 ..	10,114	February 3.
1956	1,92,000	August 29	10,794	March 20.
1957	2,66,000	August 12 ..	11,261	March 2.
1958	3,73,000	August 25 ..	10,348	March 17.
1959	2,11,000	August 10 ..	11,339	February 19.
1960	2,54,000	September 28	11,102	April 19.
1961	2,93,000	August 20 ..	12,519	February 21.

The maximum discharge so far observed is 8.55 lacs cusecs in the year 1954 which is considered as a crucial year in the districts of Darbhanga, Saharsa and Purnea.

The main problems of the Kosi.

The river causes annually a large destruction by--

(*i*) flooding a wide stretch of land;

(*ii*) depositing coarse silt on fertile lands; and

(*iii*) shifting its course forming numerous *dhars* and destroying buildings and gardens in its way.

The annual loss in terms of money was estimated at ten crores of rupees. The amount of human suffering and the instability of life caused was immense.

The basic factors causing the lateral movement of the river and other troubles are well recognised. These are--

(*i*) excessive bed load and coarse silt discharge;

(*ii*) excessive river or valley slopes even below gorge;

(*iii*) absence of strong high banks; erodable low banks are ineffective for confining flood waters or maintaining a definite channel;

(*iv*) large discharge; and

(*v*) lateral slope of terrain assists the movement of the river by inducing pendulam action starting at bends.

Attempts were made in the distant past to prevent the movement of the river by building an embankment on western side. These might have been effective in distant past but in the recent past they were not at all effective. The various attempts made to control the river are discussed in subsequent paragraphs.

History of different proposals.

The first attempt to tackle the problem was made in a conference in 1896-97, in Calcutta, when the question of building extensive embankments to control the river and prevent its swinging to the west was considered. The conference was presided over by the Secretary to the Government of India in the Public Works Department. However, the proposal was considered to be of doubtful efficacy and it was concluded that no steps were feasible for controlling the course of this big river with its numerous channels and wide and elevated beds, beyond protecting by short lengths of embankments isolated tracks exposed to its floods.

1937 *Patna Flood Conference.*—In 1937, a conference of officials and non-officials was called by the then provincial Ministry of Bihar, to discuss the problem of floods in North Bihar. At this conference the controversy centered mainly round "embankments or no embankments".

The Chief Engineer, Bihar, was for an all out policy of removing all embankments public and private, on the plea that the embankments did more harm than good, that they merely transferred trouble from one area to another and that they gave rise to a false sense of security.

Dr. Rajendra Pd., in dealing with the flood problem of Bihar, asked among others, the following questions:—

> "Is it possible to control the North Bihar rivers as to make them efficient for draining away the surplus water without causing devastation?
>
> "Is it possible to create artificial reservoirs where the surplus water may be stored and let off for irrigational purposes when required? What would be the cost of such a scheme?"

A member referring to the Kosi Flood problems said that the only possible means to check the Kosi river was to dam it where it left the hills and regulate the flow past the river, but there were two obstacles. The dam site lay in Nepal territory and the cost would be enormous. Nevertheless, he considered the project worthwhile as he visualised the installation of hydro-electric plant, the opening of the river to navigation and the development of irrigation.

The deliberations of this conference, however, do not appear to have led to any constructive approach towards the solution of the flood problems of North Bihar.

Claude Inglis's report.—In 1941, Mr. C. C. Inglis, Director, Central Irrigation and Hydrodynamic Research Station, made a comprehensive inspection of the Kosi river both in Nepal and Bihar and submitted a report on the "factors affecting the westerly movement of the Kosi river with suggestions for further investigation". His conclusions were—

> "(*i*) The river is now held firm along the right bank and will continue to fill up the trough of low land which is now occupied by Tiljuga and Balan rivers, until its westward translation is stopped by the somewhat higher land running south from Tamuria, along which an embankment probably be required to prevent still further westward movement.

"(*ii*) The cause of the movement is the building up of the sub-montane delta due to an excess charge of sand. This sand is stated to be due to a considerable extent to landslides and erosion which occurs as a result of removal of forest trees and undergrowth from the steep hill sides in order to secure short term cultivation."

He wanted some more data to be collected for the lower reaches of the river but no action was taken by the Government on his report.

The Bihar Post-war Development Plan.—Owing to shortage of personnel and equipment during the war years no further action seems to have been taken in dealing with the problem of the Kosi beyond including in the Bihar post-war plan a proposal for the construction of marginal embankments, right from the Nepal foot hills to the Ganga to control the river by confining to a definite channel. The scheme was estimated to cost roughly Rs. 10 crores.

Report of the Central Waterways Irrigation and Navigation Commission (1946).—The above proposal of marginal embankments was considered by the Labour Department of the Government of India; the Secretary referred it to the Chairman of the then Central Waterways Irrigation and Navigation Commission (Now Central Water and Power Commission), who opined that a more effective control would be secured by the construction of storage reservoir in the hills which would give effective control of floods in the river and in addition provide water for use in irrigation, navigation, power generation, etc. As a result of correspondence with the Government of Bihar, a further note was recorded in August, 1946 to the effect that no satisfactory scheme for the control of the Kosi and its flood damage can be prepared except after a comprehensive survey of the entire field of possibilities, viz., the construction of a high dam across the Chatra gorge, training the Kosi in the lower reaches and exclusion of floods from the low lying areas which are susceptible to water logging.

The Kosi river was inspected up to its junction with the Tamur tributary by officers of the Commission and Geological Survey of India, and of the Governments of Bihar and Nepal. The party led by the Chairman, C. W. I. N. C. (now C. W. P. C.)*, carried out the reconnaissance between the 24th and 31st January, 1946 under difficult conditions. There was great paucity and in most cases complete absence of basic data in respect of rainfall, flood discharge, minimum and normal flows, silt load, surface contours, subsoil water levels and the correct magnitude of the damage caused by the vagaries of the river. The Chairman gathered such information as possible as a result of inspection, discussions and investigation and prepared the preliminary report on the project in March, 1946.

* C. W. P. C.—Central Water and Power Commission.

As the dam site and several other works lay in Nepal, the Chairman visited Kathmandu accompanied by the Superintendent Meteorologist. Together with H. M.'s* Charge-d'affaires in Nepal, they had discussions with that Government between the 24th May and 3rd June, 1946. The Government of Nepal kindly accepted the recommendations concerning Nepal and authorised the C. W. P. C.† and other organisations working under its direction or control to carry out the full programme of surveys and investigations required for the Kosi Dam Project in the Nepal territory. This was followed by discussions between the Government of India and the Government of Bihar and investigations were taken in hand thereafter.

The Original Multi-purpose Scheme.

Thus though the problem of Kosi had been engaging the attention of the authorities since a long time, the work of surveys and investigations for the purpose of preparing a project for the control of this dangerous river, which has been rightly called the "Sorrow of Bihar", was only started in 1946. As a result of these surveys, a Multi-purpose Scheme costing Rs. 177 crores was evolved which comprised the construction of—

(*a*) a dam, at Barahkshetra, of an unprecedented height of 873 feet above foundation rock to impound 6.9 million acre feet in the reservoir of which 3.1 million acre feet was dead storage to provide silt reserve and minimum head for power generation, the remaining 3.8 million acre feet providing flood absorption, capacity to regulate floods so as not to let them exceed a safe maximum of 2 lakh cusecs to generate hydro-electric power to the extent of 1.8 million Kilo Watts, and to provide navigation facilities in the reservoir and the river below; and

(*b*) a barrage at Chatra and canals for irrigating annually 38.4 lakh acres of land in Nepal and Bihar flushing drainage channels and siltation of low lying areas and for generating 90,000 K.W. hydro-electric power on the eastern canal.

In view of the huge cost of the project and the limited financial and material resources available in the country, the scheme was divided into seven easy stages, each self-supporting and independent in itself and yet capable of being super-imposed on the preceding one without involving any engineering difficulty or wasteful expenditure.

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* H. M.'s—His Majesty's.

† C. W. P. C.—Central Water and Power Commission.

Advisory Committee Report (1951).

When the Report on Stage I of the above Multi-purpose Scheme was submitted to the Government of India for sanction, they, vide Resolution no. DW21, dated the 5th June, 1951, appointed an Advisory Committee consisting of five Engineers to go into the details of the project and to advise them on the general soundness of the Scheme, on its adaptability to staging and as to the economies of the project as a whole. The Committee submitted their report in September, 1951, suggesting certain modifications and recommended the construction of Belka dam.

The Belka reservoir would impound 1.75 million acre feet of water of which 0.78 million acre feet will be dead storage, to provide silt reserve and minimum head for power generation, the remaining 0.97 million acre feet providing flood absorption capacity for regulation and moderation of flood. Hydro-electric power could be generated to the extent of 90,000 K.W. at the falls in the canals. The spillway portion was recommended to be of concrete and the rest of the dam in earth. The western end was to be enclosed into the Belka hills and the eastern dam on the eastern flank was recommended to be tied into the high ground at the foot hills. The maximum hydraulic height of the dam was 85 feet.

The Committee recommended further the construction of the Eastern Kosi Canal taking off from the tail race of the power house at the dam. This canal will have a discharge of 19,821 cusecs at the head and will irrigate annually 14.36 lakh acres of land in Purnea and Saharsa districts of North Bihar.

The construction of the Eastern Nepal Branch taking off, like the Eastern Kosi Canal, from the tail race of the Power House at the dam for irrigating areas in the Morang district of Nepal. This canal will have a discharge of 1,369 cusecs and will irrigate annually 1.82 lakh acres of land.

The construction of the Western Flood Protective Embankment running parallel and some distance away on the west of the present main channel of the Kosi and extending from right bank of the Ghati Balan to Bhit Bhagwanpur, opposite Supaul, a length of some 23 miles. This embankment was intended to prevent further westward movement of the Kosi.

C. W. and P. C.* Proposals (1953).

Based on investigations at Belka site, estimates were prepared for the Belka dam. The estimates were far in excess of the figures assumed by the Belka Advisory Committee. The Central Water and Power Commission, therefore made alternative studies which was a low detention dam at Belka with F. R. L. 350. The proposal requiring the low detention dam at Belka was discussed with some

*C. W. & P. C.—Central Water and Power Commission.

of the members of the Advisory Committee (1951) and the Planning Commission in 1953. Estimates were asked to be prepared. Meanwhile the Chairman, Central Water and Power Commission, inspected the Kosi area and as a result of this inspection and comprehensive study of the data collected, formulated the present scheme described below.

THE PRESENT SCHEME.

The scheme consists of the following three units:—

Unit I.—Construction of 3,770 feet long R. C. C. Barrage across the river 3 miles above Hanumannagar in Nepal with Eastern and Western Earth Dams of 6,200 feet and 12,500 feet lengths respectively tagged with Eastern and Western Afflux *Bunds* each nearly 8 miles long;

Unit II.—Construction of flood protection banks on either side below the Barrage—75½ miles in length on western side from Bharda to Bhanthi including ring *bunds* around Nirmali and Mahadeo Math, Tiljuga Marginal and Balan Marginal Embankments and 62 miles on the eastern side and also a flood bank of 12 miles length above the Eastern Afflux *Bund;* and

Unit III.—Eastern Canal System for irrigating about 14 lakh acres of land annually.

Estimate.

Originally, in 1953, the Central Water and Power Commission had estimated that the Scheme might cost Rs. 37.32 crores although, the Project Engineers felt that the cost might be much more. On detailed examination by the Central Water and Power Commission, an estimate for Rs. 45.92 crores was administratively approved in December, 1957. Later on, this was revised to Rs. 44.76 crores and the administrative approval accorded in June, 1960. Since the sanction of the Project estimate, there have been lot of further changes. Some inadequate provisions in the estimate came to light in course of execution, the cost of labour and materials increased as also the scope of the various components of the work. The revised estimated cost (proposed) of the project now stands at Rs. 52.82 crores as per details given below:—

Unit I—Rs. 22.95 crores.

Unit II—Rs. 9.40 crores.

Unit III—Rs. 20.47 crores.

Total—Rs. 52.82 crores.

This estimate is under examination by the Government of India and will be sanctioned as soon as their clearance is received.

New Schemes.

The original scheme did not provide for the irrigation on the western side and also the land in the district of Saharsa between the Bhenga *dhar* and Eastern Kosi Embankment. There was persistent demand from the public of these areas to give them also the benefit of irrigation. The following new schemes were later on sanctioned; works in these schemes have also been taken up:—

(1) Western Canal System—Rs. 13.4939 crores.

(2) Rajpur Canal System—Rs. 4.6680 crores.

(3) Extension of the Eastern and Western Embankments—Rs. 0.80 crore.

Indo-Nepal Agreement.

A substantial portion of the project work falls in the Nepal territory. So that the next necessary step, after the preparation of the scheme in 1953, was to obtain the consent of the Nepal Government for carrying out work in their territory. A delegation, headed by Shri Gulzarilal Nanda, the then Union Minister for Planning, Irrigation and Power, visited Kathmandu and Indo-Nepal Agreement on the Kosi was signed between the Government of Nepal and the Union Government on the 25th April, 1954. The agreement provided for acquisition of land, construction of work camps, laying lines of communication in Nepal subject to the full recognition of the sovereignty rights of the Nepal Government. It also provided for further investigations, soil conservation, distribution of electricity when generated and other matter as may be of mutual benefit to both the countries. In pursuance of the Agreement a Co-ordination Committee of six persons consisting of three nominees of the Union Government, three of the Nepal Government with the Minister of the Nepal Government as the Chairman, was set up in order to deal expeditiously with matters arising out of the agreement. The Chief Administrator of the Kosi Project was made the Secretary to the Committee.

Function of the Barrage.

The Barrage has been planned to discharge the following functions:—

(1) To flatten the excessive river gradient upstream of Barrage and ensure effective reduction in coarse silt charge downstream. As the river emerges from the gorge at Chatra, its slope is very steep enabling to carry its full coarse charge, into plains below. The high velocities further cause bank erosion thus

enhancing its silt load. The river carries this high charge until Hanumannagar, below which the natural country slope is too flat to maintain the velocities necessary for charge transportation. This results in deposition of coarse charge which is depicted by splitting of Kosi into large number of interlacing channels below Hanumannagar.

If coarse silt can be reduced above this reach, the trouble causing river instability will be overcome and flood control will become a relatively much simple problem.

The Kosi Barrage has been constructed to discharge this function. The Barrage raises, the normal flood level by about 12 feet (from R. L.* 243 to R. L.* 255). This causes the steep gradient between Belka and Hanumannagar, to reduce from an average of 3.5 feet per mile to less than 3 feet per mile from the known principles of sediment transportation. This means reduction of silt carrying capacity as under:—

(*i*) Quantity of silt carried is reduced to 63 per cent.

(*ii*) Capacity to erode is reduced to 58 per cent.

(*iii*) Maximum-size of the particles that can be carried is reduced to 58 per cent.

(2) To tie down the river immediately upstream of reach where the Kosi splits into large numbers of interlacing channels.

A central structure was found necessary above the unstable reach (Hanumannagar to Jhamta) to ensure flow at the same place.

(3) To feed supplies to irrigation channels, the Kosi Barrage will divert necessary irrigation supplies to the east and west sides.

(4) Another incidental advantage of the Barrage would be the generation of hydro-power.

Preliminaries for the construction of the Barrage and Appurtenant work.

Before the actual construction of the Barrage, lot of preliminary works had to be done for access to the site of the Barrage, viz., carriage of materials for the construction of the Barrage from the rail head at Bathnaha Station (N. F. Rly.) to the site of work, setting of camps for the housing of the staff at various places, etc. A 27-mile long *pucca* road with several bridges big and small between

* R. L.—River Level.

Bathnaha and Bhimnagar was constructed. Seventy-six miles of narrow gauge railway line was laid to link Bathnaha, Bhimnagar, Chakarghati, Chatra and Dharan. A township for the staff was constructed at Birpur. Along with offices it contains a well equipped hospital, a High school, a Sub-Treasury, a Post Office and a Telephone Exchange buildings. The colony has the facilities of water-supply, electrification and drainage, etc. A colony for the skilled workmen has been constructed near Bhimnagar. Camps at Dharan, Chatra, Chakarghati Haripur and Bharda in Nepal were also constructed.

Construction Materials and the bottlenecks in feeding the same to the works.

One of the great problems which the Project Engineers had to face was feeding the works with the requisite type and quantity of materials. This can be well understood if we visualise the location of the Kosi Barrage which is situated in Nepal territory at a distance of about 30 miles from Bathnaha, the nearest Rail Head on N. F. Railway.

Out of the several construction materials like cement, steel and stone, etc., the first two namely, cement and steel had to be transported from far off places, lying on the other side of the river Ganga. Due to transhipment from broad to meter gauge at Barauni, Pahleza and other points and other usual difficulties, it always remained a problem as to how to ensure timely and programmed delivery of these vitally important materials.

The sand for the construction of Barrage was transported from Gangajali located in Nepal at a distance of 17 miles from the western bank of the river. For speedy transport tram-track was laid from Bharda Ghat to Gangajali and boats were used for crossing the river and then on the left bank also, it was carried by tipping wagons working with the help of locos from the river bank to the work site. This cumbersome process of transport necessitated frequent loading and unloading during transport from quarry area at Gangajali to work site. But there was no other alternative left. In all about 34 lac cft. of Gangajali sand was transported for use in concrete of the main Barrage.

The total requirement of stone materials for the Barrage works out to roughly 5 crore cft. The entire requirement for construction had to be met by quarrying stones in Chatra and Dharan areas in the Morang district of Nepal. The quarrying operation for coarse aggregate involved screening the materials by electrically operated screens to which the raw materials were fed by pushing with the help of dozers and then the screened aggregate was transported by aerial rope-way to a place called Ghopa where they were loaded direct from the bunkers into either railway wagons or tippers which transported it to the Barrage construction site.

The quarrying operation at Chatra was very simple. Machines were not used. The boulders of requisite sizes and specifications were manually picked up from the bed of the main river or other small Kholas in the neighbouring jungle areas. The work of collection and the transport to the railway loading yard was done through the contractors. But the loading into railway wagons was partly done through the contractors and partly departmental.

The immediate need for execution of the Project on the one hand, coupled with natural difficulties in procurement of construction of materials on the other, posed a baffling problem. But due to advance planning and accurate assessments, not a single occasion arose when progress could be marred due to inadequate supply of materials.

SALIENT FEATURES.

The work involved a 3,770 feet long R. C. C. Barrage of the floating raft type with 56 clear spans of 60 feet each. On either side of the concrete Barrage there are earthen dams, connecting the flood levees, thus covering the entire width of the river. The length of the Western Earth Dam is 12,500 feet and that of the Eastern Earth Dam 6,500 feet. On the upstream of the Barrage there are Afflux Bunds of the lengths of 8 miles on each bank in continuation of the flood levees. The Eastern Afflux Bund is further continued for another 12 miles as flood embankment. The following are the salient features of the Barrage and appurtenant works:—

A—Barrage—

(*i*) Designed discharge—9.50 lakh cusecs.

(*ii*) Length of the Barrage—3,770 feet.

(*iii*) Looseness factor of the Barrage—1.45.

(*iv*) Silt factor—1.3.

(*v*) No. of bays—6.

(*vi*) Left undersluices—6.
Spillway—46.
Right undersluices—4.

(*vii*) Intensity of discharge—
Undersluices—397 cusecs.
Spillways—358 inches.

(*viii*) Length of stilling basin with friction blocks—89 feet 6 inches.

(*ix*) Lacy's scour depths—
Spillways—38.6 feet.
Undersluices—41.2 feet

(*x*) Bottom levels of sheet piles—

Undersluices—

(*a*) Upstream—201.00
(*b*) Downstream—187.50

Spillway—

(*a*) Upstream—201.00
(*b*) Downstream—191.00

(*xi*) Present pond level—245

(*xii*) Future pond level—255

(*xiii*) Crest level—

(*a*) Undersluices—230
(*b*) Spillways—235

(*xiv*) Top level of cistern—

(*a*) Undersluices—218
(*b*) Spillways—222

(*xv*) Size of gates—

(*a*) Undersluices—60 feet×26 feet
(*b*) Spillways—60 feet×21 feet

(*xvi*) Width of piers—

(*a*) Main piers—7 feet
(*b*) Double piers—10 feet
(*c*) Dummy piers—5 feet

(*xvii*) Quantity of important items of works involved—

(*a*) Concreting—85 lakh cft.
(*b*) Earthwork in excavation—470 lakh cft.
(*c*) Sheet piling—4,400 tons.
(*d*) Rip Rap work—30.84 lakh cft.

B—Guide Bunds—	Left guide bund.	Right guide bund.
(*i*) Lengths—		
(*a*) Straight portion ..	3,000 feet	3,000 feet.
(*b*) Curved portion ..	1,832 feet	3,446 feet.
(*ii*) Radius of curvature of nose—		
(*a*) Upstream	500 feet	1,700 feet.
(*b*) Downstream	500 feet	500 feet.
(*iii*) Top widths	21 feet	21 feet.
(*iv*) Side slopes—		
(*a*) River side	2:1	2:1
(*b*) Country side	3:1	2:1
(*v*) Quantities of work involved—		
(*a*) Earthwork	65,78,000 cft.	1,09,18,000 cft.
(*b*) Concreting	10,10,000 cft.	16,22,500 cft.
(*c*) Stone work	19 lakh cft.	35 lakh cft.

Earth Dams—	Eastern.	Western.
Lengths	6,200 feet	12,500 feet.
Earthwork of all types ..	173 lakh cft.	420 lakh cft.

CONSTRUCTION OF THE BARRAGE AND APPURTENANT WORK.

To begin with, the construction of Eastern Afflux Bund and Eastern Earth Dam were taken first. The Project Engineers had to face lot of difficulties as no contractors and skilled labourers were available in the area at that time. The initial difficulties were, however, overcome by constant vigilance of the department.

In 1958, active construction of Barrage work started. The foundation stone was laid by His Majesty, the King of Nepal in presence of our late Prime Minister on the 30th April, 1959. The Barrage has been constructed on an island. The construction of left and right guide *bunds* were taken up first which served as coffer dams also for the main Barrage. In the upstream and downstream of the Barrage site, *bunds* spanning between the left and right guide *bunds* were also constructed. These two *bunds* and guide *bunds* thus boxed the Barrage site area and gave protection to the machines and materials against any sudden flood in the river. This also facilitated the communication system for transport of men and materials up to the Barrage construction site. The channels on the east of the Barrage were also blocked.

Contract for the concreting portion of the Kosi Barrage was awarded to M|s. National Projects Construction Corporation, a Government of India undertaking. The stone materials and sand were supplied by the department in the bins specially constructed for the purpose. Several one-cubic yard electrically operated mixers were installed near the bins. The coarse aggregate, sand and cement were fed to these mixers manually as per design. The finished concrete used to be poured in tipping wagons which used to be pushed by labourers and dumped near the actual place of concreting. In addition there were 10 to 12 mixers of smaller capacity also and were installed at places of convenience.

The excavation of the Barrage foundation was done by machines like dozer-scrappers and dragline dumper combination. The sinking of the wells was done manually as well by clam shells. Due to great depth and diameter of wells, machine sinking was found to be cheaper. In the Barrage, a lot of sheet-piling job had to be done. The depth of the piles varied from 12 feet to 30 feet. This was done by pile-driving plants run by compressed air or steam.

The biggest problem presented during the Barrage construction work was the dewatering of the Barrage foundation. The average level of the ground water at the site of the Barrage was 237.00 cusecs. The water level during construction had to be lowered down to R. L. 215 in the spillway section and even 5 feet deeper in the undersluices.

Dewatering of the Kosi Barrage foundation was done merely by open pumping through 12 feet diameter brick masonry sump-wells consisting of 20 inches thick steening set in cement mortar

1 : 6 with nominal reinforcement. These sumpwells were approximately taken down to five feet below the deepest bed of the Barrage foundation and bottom of the wells were properly plugged with cement concrete 1 : 3 : 6. The average distance between two sumps was varying to suit the local conditions; but on the average these sumps were 200 feet apart. These sumps were connected with the Barrage pit by open drains. The pumps installed were mostly electrically driven ones as these were comparatively trouble free, though engine-driven pumps were also used for stray and local dewatering. During the peak period of construction when there was a maximum installation of pumps of about 120, the power used in dewatering was of the order of 2,200 K. W. Flow more, Power mac, Hor-land, Worthington Simpson end flow and Hydraulically balanced 5 L and 5½ series Worthington Simpson pumps of size 6″×6″, 8″×8″ and 4″ *plus* 4″, etc., were mostly used for dewatering. The maximum rate of dewatering in different working seasons is given below:—

TABLE NO. 6.

Serial no.	Working season.	Peripherial area of excavated pit in lac sft.	Effective wetted area.	Total no. of pumps working.	Maximum discharge in cusecs.	Discharge per lakh cft. of peripherial area.
1	2	3	4	5	6	7
1	1958-59 ..	0.60	0.60	66	90.00	150.00
2	1959-60 ..	0.95	0.95	91	133.00	140.00
3	1960-61 ..	1.80	1.30	110	162.62	125.00
4	1961-62 ..	2.40	1.90	118	199.95	105.00

The construction of the Barrage was covered in four working seasons.

RIVER DIVERSION.

After the construction of the Barrage the river had to be diverted from its age old course to follow certain predetermined channels, through the Barrage. The diversion of the Kosi river was linked up with the erection of gates and some other ancillary works specially wanted by H. M. G.* of Nepal. There was considerable handicap and delay in the transport of gate parts from Calcutta which involved transhipment from broad gauge to meter gauge, crossing the Ganga at Farakka or Bhagalpur or Mokameh and then transhipment from meter gauge to narrow gauge Project Railway or by road from the nearest rail head to the site of work a distance of nearly 28 miles.

* H. M. G.—His Majesty's Government.

There was certain controversy on whether the diversion of the river should be done in one or two seasons. At the instance of the Chief Engineer it was decided to complete the diversion in one season and final decision to take up the work came as late as 15th February, 1963. The Central Water and Power Research Station, Poona, was requested to conduct certain field model experiments to test certain proposals made by the Project Engineers. Their comments were also received.

The scheme of the diversion in short comprised the excavation of four pilot cuts leading from the upstream channel, through the Barrage and out falling into the downstream channel and construction of a coffer dam across the river at the off-take point of the pilot cuts to facilitate diversion of the river and construction of the Western Earth Dam. The depth of water in the river at the start of the construction varied from a foot to eight feet. As the coffer dam was built up, the depth of flow and velocity correspondingly increased. When the gap was reduced from 15,000 feet to nearly 1,500 feet, ordinary sand embankment could not stand. A non-erodible bed was, therefore, made by dumping stones. By this, the gap could be reduced to 700 feet. At that stage, the velocity and the depth of the scour started developing considerably. A small stone dam had to be built forming some sort of a rock toe and sand was being dumped in front by dumpers and dozers. In closing one of the deep channels, dumping of stone also could not bear fruit. Stones in mild steel crates of size 20 feet $\times$ 5 feet $\times$ 3 feet had to be put in. The gap was thus reduced to 180 feet. The depth of scour then went to 30 feet and the crates full of stones could not be placed in position even by cranes. At that stage two or three crates piled together were pushed by H. D. 21 dozer. Ultimately, when the gap was reduced to 20 feet or so, piles of crates heaped and tied together on both banks were pushed into the gap.

The final closure took place at 11 P.M., on the 31st March 1963, after continuous fight with the river for nearly $1\frac{1}{2}$ months. The entire operation was extremely risky and dangerous, as operation and control of cranes, dumpers, dozers and other machines on a small crest of Coffer Dam presented serious problems which required minute observation, perfect control and well thoughtout synchronisation. The diversion of a river like the Kosi carrying a minimum discharge of over 12,000 cusecs and spreading over a fine sand bed for nearly $\frac{3}{4}$ mile, is the first of its kind in India and perhaps in the world. Diversion of rivers during construction of dams is, of course, a common feature but the significant difference is that in such cases the river carrying a smaller discharge is confined within definite high banks and rocky bed. In the present case the work had to be carried out in a shifting and turbulent river with fine sand and wide bed, in very unfavourable climatic conditions with heavy sand storms.

The Embankments.

Unit two of the Project consisted of the construction of about 150 miles of embankment on both sides of the river. Inauguration ceremony of this work was done on the 14th January, 1955, by late Dr. S. K. Sinha, Chief Minister, Bihar, who cut the first sod of earth near Nirmali for the embankment, amidst tumultuous applause and great enthusiasm of the local people.

The work was started with great handicap on account of extreme shortage of technical personnel and unfavourable conditions prevailing in the working area on account of jungles, unhealthy climate, want of suitable communications and marketing facilities but all these odds were boldly faced and the work was pushed through vigorously. A remarkable feature of the work has been an extensive enlistment of public co-operation and local participation through the Bharat Sewak Samaj. This aspect has been separately discussed under the head "Public Co-operation".

Several active Kosi *dhars* falling in the alignment of the embankments presented special difficulties. These *dhars* take off from the main river and wind their way downward in the shape of numerous interlacing channels meeting the main channel once again in the lower reaches. All the *dhars* were successfully tackled.

The top width of the embankments has been kept 15 feet with side slopes of 1:2 to 1:3, depending upon the nature of the soil. A free board of 6 feet over the designed flood level with a discharge of 9.5 lakh cusecs has been allowed in fixing the crest level of the embankment. The entire earthwork was done by manual labour and compaction was ensured by watering and ramming the soil in 9 inches layers by wooden rammers. The side slopes of the embankments have been turfed with *dub* grass in the entire length.

The embankments on both sides have been completed and have given protection to $6\frac{1}{2}$ lakh acres of land in North Bihar and Nepal. Further extension of Eastern and Western Embankments by 16 miles and $2\frac{1}{2}$ miles respectively to give protection from flood to an additional area of 37,600 acres has also been taken up and has already made sufficient progress.

The crucial danger in this river is that the break in levees would be not so much due to pressure of water or sudden draw down effect but due to rapid erosion of the banks of the river in the floods, then leading the levees to initial collapse soon after the bank erosion extends to the body of the levees. To prevent such bank erosion and formation of parallel channels, spurs, both permeable and impermeable have been constructed at vulnerable points. Annual cross sections of the river channels are being taken from Chatra downwards since 1955, to study the changes in the river.

The control of a river by embankments requires adequate supervision to provide careful and efficient maintenance and keen

watch specially during floods when a slight negligence or delay in this direction can precipitate catastrophical results. A systematic and efficient patrolling of the flood banks is, therefore, regularly arranged during the flood season for very prompt attention to weak spots when detected. The discharge of the river Kosi recorded at Barahkshetra is regularly transmitted by wireless and telegrams to concerned offices. This serves as a forewarning and enables to anticipate the conditions of the river. *Khalasis* are placed all along the embankment for day and night vigil by patrolling in small stretches. Surprise check by Overseers, Subdivisional Officers and Executive Engineers is continuously done. It is because of the vigilance exercised by the Kosi Project authority that no serious damage has so far occurred on the embankments.

Public co-operation in the Kosi.

One of the important features of works in the Kosi Project is the materialisation of people's participation in the execution of the Project. The underlying idea behind mass participation in the Kosi was not just to induce an alternative agency for execution of the Project works but also to enthuse in the people a spirit of co-operation and partnership in the developmental activities of the State. This bold experiment was launched in pursuance of one of the basic principles of the First Five-Year Plan, to mobilise active popular support for large projects.

The decision to get a portion of the Kosi Project work done through public co-operation was taken by the Kosi Control Board on the 2nd December, 1954. The organisation of public co-operation was to be entrusted to establish institutions of non-political character. Accordingly, the Bharat Sewak Samaj came forward and took the responsibility of giving a shape to the scheme.

The work of the construction of Western Kosi Flood Embankment was inaugurated by Dr. S. K. Sinha, the late Chief Minister of Bihar, on the 14th January, 1955. He laid the first basket of earth at village Bhutaha near Nirmali in the district of Saharsa. Work on the Eastern Embankment was inaugurated after a few days near Supal on 3rd February, 1955. This was followed by allotment of further works to the Bharat Sewak Samaj in the construction of Western and Eastern Kosi Flood Embankments which were completed between 1955—1959. Subsequently, some works were allotted in the excavation of Eastern Kosi Main Canal and its branches and distributaries. By this time the Bharat Sewak Samaj had developed suitable organisation for handling bigger and more complicated jobs, like construction of buildings and canal structures and also supply of bricks. At present they are doing earthwork in canals and embankments, supply of bricks, construction of small and medium type and canal structures and buildings.

Three forms of public co-operation were arranged for the execution of the Project works, namely, (*i*) *shramdan*, i.e., unpaid

voluntary labour, (*ii*) the execution of the work through *Gram Panchayats* and labour co-operation and (*iii*) the execution of the work by the individuals selected by the Bharat Sewak Samaj not necessarily from the labour co-operatives and *Gram Panchayats.*

The organisational pattern of the *Bharat Sewak Samaj* in the Kosi has been changing from time to time according to the adjustment demanded by the changing conditions of work and also from the experience gained in course of execution of the various works allotted to the *Bharat Sewak Samaj.* To start with, work was taken up on the Kosi Embankments and to execute the same, the *Bharat Sewak Samaj* set up a Central Committee, styled as the Project Construction Committee, a 12 men body with the convenor, the *Bharat Sewak Samaj,* Bihar, as the Chairman and a member as the Secretary. This Committee had a Technical Adviser and included representatives of the State *Panchayat Parishad* and the district wings of the *Bharat Sewak Samaj* and the *Panchayat Parishad.* It was a policy-making body which in consultation with the Project authorities, framed the programme of the work and the annual budget of the organisation. The field executive responsibility was discharged by the Secretary, assisted by two influential local organisers, each in charge of the Eastern and Western Kosi Embankments. They were assisted by the Advisory Committees of the leading public workers. The work on each embankment was divided into a number of points. Each point-in-charge who was a local public worker of repute, held charge of two to three miles of the embankments and was responsible for co-ordinating activities of the unit leaders in his charge and for ensuring progress of work.

Mobilisation of local resources could be done most effectively through *Gram Panchayats,* Co-operative Societies and other institutions. While the scheme of public co-operation was being discussed, the Project administration got a drive launched for the formation of *Gram Panchayats* and within 6 months from October, 1954 to March, 1955, a network of these institutions covered the area of work. The work was allotted to the accredited Societies and the *Bharat Sewak Samaj* also set up their own units in some places. The representatives to whom work was allotted were denominated as unit leaders.

In the approved scheme of work of the *Bharat Sewak Samaj* 90 per cent earnings is to be paid to the individual labourers, 5 per cent spent on organisation expenses and the remaining 5 per cent over social objectives, like provision of drinking water, schools and roads, etc., in the village homes of the labourers working for the Project.

In the first working season the *Bharat Sewak Samaj* was allotted eight miles of the Embankment on the western side and nine miles on the eastern side, out of which half mile near Bhutaha was reserved for work through *shramdan,* on the western side and

one mile near Bairia on the eastern side. The rest of the work was distributed among 29 *Gram Panchayats* on the western side and 27 *Gram Panchayats* and labour co-operatives on the eastern side. In the first working season, i.e., 1954-55, the total earthwork involved was 668 lakh cft., out of which 451 lakh cft. was done. In the 2nd working season the *Bharat Sewak Samaj* took up the residual work along with new work in 11 miles on the Western and 10 miles in the Eastern Embankments. This involved about 1,324 lakh cft. out of which about 1,037 lakh cft. was done in that season. The residual work was completed in the subsequent year. In the subsequent working seasons, i.e., 1956-57 and 1957-58 the *Bharat Sewak Samaj* did 749 lakh cft., and 937 lakh cft., out of the total quantity of 1,676 and 1,004 lakh cft. The balance work were completed in all respect by 1959. This relates to the construction of Eastern and Western Flood Embankments only.

The *Bharat Sewak Samaj* switched on to the excavation of canals from the working season 1957-58. Their output was 542 lakh cft., 1,040 lakh cft., 814 lakh cft. and 1,456 lakh cft., in 1957-58, 1958-59, 1959-60 and 1960-61, respectively.

In the beginning, tools and implements were supplied by the Project Administration free of charge to the unit leaders. The unit leaders were, however, required to reimburse the Project for tools and implements lost or damaged beyond normal depreciation.

The Project Administration undertook to provide labour amenities such as hutted accommodations, drinking water-supply, lighting, sanitation, medical treatment and recreation, etc.; the details are—

(*i*) hutted accommodation—28 hutments were provided in each mile of the embankments;

(*ii*) water-supply—ten hand tube-wells were sunk in each mile of the embankments;

(*iii*) sanitation—ten bore hole latrines were provided in each mile of the embankments;

(*iv*) lighting—every hutment was supplied two hurricane lanterns for lighting purposes, besides two for street lighting;

(*v*) medical and public health facilities—a six-bedded indoor hospital was set up for each of the embankments. Besides, medical centres under a compounder or a dresser were established at every four miles of the embankments. First aid medicine chests were also distributed in every two miles of the embankments. To control epidemics mass inoculation was arranged; and

(*vi*) recreation—a community centre in every two miles of the embankment was established fitted with a radio set, amplifiers, information books, daily newspapers, indoor and outdoor games, etc. Cinema shows were also arranged by the Kosi Project Department.

A very remarkable feature of the work on the public co-operation sector was the mustering of a large labour force particularly in the construction of embankments in the years 1955 to 1957, which was a rush job and there was virtually a race between the rising embankment and rising flood. The peak labour strength of 20,000 per day (average) was achieved at one time in February, 1956, out of which the *Bharat Sevak Samaj* contributed about 10,000, i.e., 50 per cent of the total labour force engaged in the embankment.

The public co-operation programme in the Kosi Project has resulted in inculcating a spirit of self-help and co-operative action among the people. Other obvious benefits from the public co-operation programme in the Kosi were (*i*) creating a sense of partnership between the people and the plan, (*ii*) producing local organising and taking work from labour and (*iii*) social well being of the community.

Apart from the above the very existence of public co-operation agency in the field of execution was instrumental in exercising a control on the rising rates of works. This has generally resulted from a sense of keen competition between the *Bharat Sevak Samaj* and other contracting agencies who were not allowed to have their monopoly in the field of project construction. Incidentally the local leadership engaged in the public co-operation venture was also of immense help in getting amicable possession of land for the construction of embankments and canals.

Rehabilitation.

The rehabilitation poses a very complicated problem for all River Valley Projects. The main difficulty is in obtaining possession of land for the rehabilitation sites. Formal land acquisition proceedings are quite dilatory and usually there is considerable resistance from the land owners when their lands are taken for rehabilitating the people affected by floods. The other most important cause of delay is the inevitable inertia of the people in leaving their old hearths and homes for practical as well as sentimental considerations. Even when the people shift outside the danger zone to the rehabilitation sites, there is an inherent human tendency to go back to the original places of habitation as soon as the danger is minimised. This problem was faced by the Kosi Project authorities also. This was, however, tackled to a good degree of success by building up the public opinion in favour of scheme and availing the house building grants.

Unfortunately, the embanked space, an area of about 2,60,000 acres contains 300 villages with a population of 1,15,000 souls. All possible future changes in the channel configuration are bound to take place in the limited embanked areas, resulting in greater pressure on the villages situated therein. Keeping these in view, the Kosi Control Board sanctioned the rehabilitation scheme costing Rs. 2.12 crores in 1957.

The entire embanked area of about 2,60,000 acres is not likely to become unfit for cultivation. In riverine tracts, while some lands get sanded or eroded, some land is formed and some get improved in quality. From the practical standpoint, payment of compensation for the cultivable lands within the embankments does not help, because it will not be possible to find elsewhere the necessary cultivable area for such a larger population. Moreover, if the total value (of Rs. 10 to 11.5 crores) of all the assets has to be paid for, the Project cost would increase disproportionately.

The rehabilitation scheme has, therefore, been drawn up keeping the above points in view. Our scheme consists of two aspects, viz., permanent rehabilitation and temporary rehabilitation.

(I) The scheme of permanent rehabilitation is—

(*a*) equivalent area of homestead land at a reasonable distance from the embankments on the land side so that the villagers may live as close as possible to their cultivable land within the embankments;

(*b*) acquisition of an additional area equal to 40 per cent for common purposes like roads, lands for schemes, shelter for cattle and playground, etc.;

(*c*) house building grants equivalent to the full value of house left on the river side;

(*d*) drinking water facilities in the form of wells, tube-wells, tanks, etc.; and

(*e*) boats to be used as means of communication to and from the agricultural lands on the river side.

(II) The scheme for temporary rehabilitation provides temporary shelter to villagers living in the river side whose houses are affected by the flood water during the rainy season. The villagers so rehabilitated temporarily on safer sites return to their respective old houses after the floods recede. This arrangement of temporary rehabilitation has to be made only for a year or so, i.e., until rehabilitation at a permanent site is settled for the people.

Out of 300 villages lying between the embankments 47 have shifted outside the embanked space on the eastern and western sides. A sum of Rs. 74.79 lakhs has so far been spent on rehabilitation till March, 1963.

Necessity of Irrigation.

Excepting for a small area in the Champaran district, North Bihar mainly depends on rainfall in corresponding failure of crops. The failure of the rainfall is not infrequent and hence there is acute need for irrigation in the North Bihar.

Aghani rice is the main crop in this area and it requires a good rainfall at the end of May and beginning of June to facilitate preparation of grounds and for growth of seedlings. More rain is required in July and August for transplantation. Good rainfall is again required during *Hathia Nakshatra* (end of September and beginning of October) for maturing of the crop. Failure of rains during *Hathia* results in serious loss and damage to crops, causing scarcity and famine. That there is shortage of rainfall in October in this area will be apparent from the following statistics for Purnea district for a period of 48 years:—

(*i*) Number of years with rainfall less than an inch—11.

(*ii*) Number of years with rainfall between 1 and 2 inches—10.

(*iii*) Number of years with rainfall between 2 and 3 inches—3.

(*iv*) Number of years with rainfall between 3 to 4 inches—8.

(*v*) Number of years with rainfall over 4 inches—16.

Thus, out of 48 years, 32 years have rainfall less than 4″ in the month of October, or failure occurs for a year in every three years. This shows great necessity of providing irrigational facilities to this area for protecting it against scarcity or famine conditions.

Apart from the consideration of the needs of the foodgrains in the locality or the desirability of providing protection against famines in the Kosi area, the position of foodgrains in India as a whole calls for vigorous measures to make up the progressively increasing shortage in the country. The increase in food production can be achieved by the use of fertilisers in larger quantities, by using improved seeds or by bringing fresh areas under cultivation but above all by the introduction of irrigation in areas that are already under cultivation but depend upon rain as the only source of water.

Besides foodgrains, India is greatly in need of raw jute and this need has become acute since the partition of the country as bulk of the jute-producing area has gone out to Pakistan. This area is eminently suited for jute cultivation, but for want of assured irrigation and improved drainage a considerable increase in jute cultivation is expected as water will be available not only for irrigation but also for steeping the jute. That will go a long way to obviate the present shortage and will greatly help in earning the much needed dollars.

Possibility of Irrigation.

The Kosi Eastern Main Canal taking off from the Hanumannagar Barrage will be capable of irrigating the whole of Saharsa and Purnea districts on the east bank of the Kosi excepting a small strip at the northern extremeties of the two districts. The originally sanctioned Project was designed to irrigate the area up to the Panar river on the east and up to Bhenga *dhar* on the west. The area between Bhenga *dhar* and Eastern Embankment was left out of command as it was thought that the old *dhars* of the Kosi river flowing in this area would be resuscitated for diverting about 50,000 cusecs of flood water for reducing the peak flood in the Kosi. Later investigations reveal that there will be little advantage in resuscitating these old *dhars*. Hence, it was considered that this area should also be brought under command in the Third Plan period. The new scheme was sanctioned under the name of Rajpur Canal System. Including the Rajpur Canal system the eastern canal will irrigate the following areas:—

District.	Gross commanded area in lakh acre.	Culturable commandable area in lakh acre.	Annual irrigation.
Purnea	12.00	8.00	9.27
Saharsa—			
(*i*) Original Scheme ..	6.23	4.08	4.77
(*ii*) Rajpur Canal System	4.91	3.27	3.97
	23.14	15.35	18.01

The Existing and Future Crop Pattern.

Aghani rice is the principal crop of this area. The distribution and percentage of different kinds of crops in relation to gross area and culturable commandable area in the Purnea district, is as below:—

Crops.	Percentage over gross area.	Percentage over culturable commandable area.
1. *Bhadai* paddy	7.06	10.60
2. Maize	4.93	7.40
3. Jute	5.49	8.02
4. Sugarcane	0.08	0.10
5. Tobacco	0.21	0.30
6. Other *Bhadai* and hot weather crops	0.83	1.30
7. *Aghani* rice	34.35	51.50
8. Other *Aghani* crops	2.35	3.50
9. *Rabi* (wheat and barley), etc. ..	6.20	9.30
10. Other *rabi* crops	12.30	18.50
11. Orchards	1.20	1.80
Total	75.00	112.50

With the introduction of Irrigation, the crop pattern is to be as below:—

Crops.	Existing percentage to culturable commandable area.	Expected percentage after introduction of irrigation.
1. *Bhadai* paddy	10.60	12.00
2. Jute	8.20	15.00
3. Sugarcane	0.10	3.00*
4. *Aghani* paddy	51.50	65.00
5. *Rabi*	9.30	20.00
6. Maize and other crops not requiring irrigation.	32.80	20.00
Total	112.50	135.00

Experience on Sone and Tribeni canals has shown that with canal irrigation cultivators tend to grow more of *aghani* paddy, therefore, the intensity of *aghani* paddy has been taken as 65 per cent of the irrigable area. Jute is in great demand and, hence, it will develop much with assured irrigation. Therefore, intensity for jute has been doubled. Similarly, there is possibility of increased cultivation in sugarcane and *rabi* crops, hence, the intensity has been increased.

The Canal System.

The main canal, 27 miles long after taking off from the Kosi Barrage, runs in south-east direction for a length of 10 miles, and then terminates into the river Parman on the east of Jogbani-Katihar Railway line. It crosses the major *dhars* Haiya, Bochaha, Sursar, Kajra, besides, about 12 smaller *dhars*.

Irrigation will be effected through 5 branch canals including the Rajpur Branch Canal. A small belt of about 1½ miles width will also be irrigated on the north of the main canal by distributaries taking off directly from the main canal. The branch canals are—

(*i*) *Murliganj Branch Canal.*—This canal takes off from the main canal at R. D. 43.80. It is about 40 miles long. This will irrigate 1.96 lakh acres of land in Saharsa district between the two old *dhars* of the Kosi, known as Bhenga *dhar* and Murliganj *dhar*.

(*ii*) *Jankinagar Branch Canal.*—This takes off from the main canal at R. D. 78.60. It is about 51 miles long. This will irrigate 4.81 lakh acres of land in Saharsa and Purnea districts, between the rivers Sursar and Fariane.

(*iii*) *Purnea Branch Canal.*—This takes off from the main canal at R. D. 131.20. It is about 40 miles long. This will irrigate about 4.18 lakh acres of land in Purnea district, between the rivers Fariane and the Jogbani-Katihar Railway line.

(*iv*) *Araria Branch Canal.*—This takes off from the tail end of the canal. It is 36 miles long. This will irrigate about 1.82 lakh acres of land in the Purnea district, between Jogbani-Katihar Railway line and river Panar.

(*v*) *Rajpur Branch Canal.*—This canal takes off from the main canal at R. D. 14.50 below the proposed Power House. The canal has been aligned straight up to 13 R. D. and then it takes a turn towards west. Four sub-branch canals namely Madhepura, Gamharia, Saharsa and Supaul respectively take off from here. The canal passes through Kalaiya, Samada, Baisi Chahala and Kailanpura. This will provide irrigation to an area of 3.97 lakh acres of land in Saharsa district.

Progress of Canal Works.

Eastern Kosi Canal System.

The total quantity of the earthwork involved in the eastern Kosi Canal System is 237.60 crores cft. This is nearing completion. There are about 1,650 canal structures of various types out of which 900 are either completed or are in progress. There has been some difficulty in making better progress with regard to canal structures. This has been due to the difficult nature of the work, bad transport and communication facilities and dearth of contractors and skilled labourers. The Chinese attack added fuel to the fire as we had to relieve some of our resources for more important work of the Nation. The situation is, however, being tackled and some irrigation will be given in 1964, as programmed.

Originally the idea was that the Project would dig canals up to 5 cusecs discharge only, beyond which the cultivators would take over and construct the field channels for irrigating their lands. Later on it was considered that this would present immense difficulties because the people of Purnea, Saharsa and Darbhanga who are not accustomed to artificial irrigation practices would be reluctant to do their part of the jobs. The Planning Commission have, therefore, advised the Project to go down to 1 cusec channels. This would cost an additional sum of about Rs. 6 crores which was not provided in the Project estimate. The construction of village channels will have to be tackled in a phased sequence so that their completion is well synchronised with the completion of the individual branch canals and their distributary systems.

Necessary legislation for their construction as well as for levy of irrigation cess and betterment has been initiated. Compulsory irrigation cess is proposed to be levied as a part of the water rate with a view to inducing the people to make use of the irrigation facilities extended to them thereby accelerating the pace of utilisation of the irrigation potential.

Rajpur Canal System.

As said earlier, this comes under new scheme and has been sanctioned for Third Five-Year Plan. In the initial stages there could not be as much progress as the Project Engineers wanted for want of funds. But as soon as this problem was solved the work was taken in full swing. Earthwork in excavation of Rajpur Branch Canals and its 4 sub-branches is in progress. More than 50 per cent of the earthwork has already been done. Out of the total 206 of canal structures, work in 28 has already been taken up.

Additional yield.

As a result of the completion of the originally sanctioned Eastern Kosi Canal System and Rajpur Canal System the districts of Saharsa and Purnea will get the additional yield of 123.48 lakh maunds as detailed below:—

Name of the system.	Crop.	Additional yield in lakh maunds.	Monetary value in lakh rupees.
(*i*) Eastern Kosi Canal System.	Jute ..	11.95	298.75
	Paddy ..	41.71	552.66
	Rabi ..	8.64	120.06
	Sugarcane ..	45.00	112.50
	Total of (*i*) ..	107.30	1084.87
(*ii*) Rajpur Canal System	Jute ..	1.30	32.50
	Paddy ..	6.71	88.91
	Rabi ..	3.92	54.88
	Sugarcane ..	4.25	10.63
	Total of (*ii*) ..	16.18	186.92
	Grand Total	123.48	1271.79

Western Canal.

For further utilisation of the irrigation potential created by the construction of the Kosi Barrage, as already stated, two schemes namely, the Western Kosi Canal Scheme and the Rajpur Canal Scheme were sanctioned for Third Five-Year Plan. Enough has

already been said about the Rajpur Canal System. A few words may be said about the Western Kosi Canal System also. The Western Kosi Canal takes off from the Kosi Barrage to irrigate the land in the district of Darbhanga of North Bihar and the district of Saptari in Nepal. Its salient features are given below:—

(*i*) Cost of the scheme—Rs. 13,49,39,000.

(*ii*) Discharge in the main canal—7,000 cusecs.

(*iii*) Length of the main canal—70 miles.

(*iv*) Irrigation and yield to Nepal—

(*a*) C. C. A.*—0.35 lakh acres.

(*b*) C. C. A.—0.23 lakh acres.

(*c*) Annual irrigation—0.26 lakh acres.

(*d*) Additional yield expected annually—

Aghani paddy—0.44 lakh maunds valued at Rs. 5.83 lakhs.

Bhadai paddy—0.06 lakh maunds valued at Rs. 0.80 lakh.

Rabi—0.12 lakh maunds valued at Rs. 1.68 lakhs.

Jute—0.10 maunds valued at Rs. 2.50 lakhs.

Sugarcane—0.09 lakh maunds valued at Rs. 0.15 lakhs.

Total—1.31 lakh maunds valued at Rs. 10.96 lakhs.

(*v*) Irrigation and yield to Darbhanga district—

(*a*) C. C. A.—9.76 lakh acres.

(*b*) C. C. A.—6.45 lakh acres.

(*c*) Annual irrigation—8.03 lakh acres.

(*d*) Additional yield expected annually—

Jute—3.90 lakh maunds valued at Rs. 97.50 lakhs.

Paddy—30.64 lakh maunds valued at Rs. 405.98 lakhs.

Rabi—7.76 lakh maunds valued at Rs. 108.64 lakhs.

Maize—0.60 lakh maunds valued at Rs. 7.20 lakhs.

Sugarcane—12.00 lakh maunds valued at Rs. 30.00 lakhs.

Total—60.90 lakh maunds valued at Rs. 6,49.32.

Irrigation schemes for Nepal.

There are two schemes to provide irrigational facilities to Nepal. It is proposed to provide irrigation to an area of 36,000 acres of land in the district of Saptari by the Western Canal. Facts and figures about this have already been given. There is another scheme known as Chatra Canal Scheme estimated at a cost of Rs. 4 crores

* C. C. A.—Culturable Commandable Area.

for irrigating 1,83,000 acres of land in the district of Morang and yield additional produce valued at Rs. 85 lakhs (approximately). The main canal takes off from the foot of hills of the Himalayan range close to Chatra Bazar in Nepal. The main canal itself is about 35 miles long. The total length of the distributaries would be nearly 165 miles. The canal system will necessitate construction of about 600 numbers of canal structures big and small. Work on the scheme has made good progress. The entire cost of this scheme is being borne by the Government of India but the execution is being done by the Kosi Project Administration as an agent of the Government of India under the Indo-Nepal Aid Programme. Liaison between the Project Administration and His Majesty's Government of Nepal is maintained through the Indian Aid Mission and the Indian Embassy at Kathmandu.

Power generation.

Owing to the persistent demand of the people of the area, the Government have decided to set up a hydro-electric power house with an installed capacity of 20,000 K. W. in the eastern main canals. Though the power output from the station would be small, yet it would go a long way to meet the immediate needs of small village industries which cannot develop for want of power. Fifty per cent of the power generated would be supplied to His Majesty's Government of Nepal and 50 per cent will be utilised in the Bihar portion. Many industries like paper, sugar and jute and other small industries are expected to develop in these areas.

The allotment of the construction of the power house has already been made and the work will shortly start.

THE ORGANISATIONAL SET UP OF THE KOSI PROJECT.

The Kosi Control Board.

The Kosi Control Board has been constituted by the State Government in consultation with the Government of India. It consists of the following:—

(*a*) State—(*i*) Chief Minister, (*ii*) Irrigation Minister, (*iii*) Deputy Irrigation Minister, (*iv*) Development Commissioner, (*v*) Chief Engineer and (*vi*) Chief Administrator.

(*b*) Centre—(*i*) A representative of the Ministry of Irrigation and Power, (*ii*) a representative of the Ministry of Finance, and (*iii*) a representative of Central Water and Power Commission.

Chief Secretary, Finance Secretary and Irrigation Secretary of the State and representative of the Planning Commission and Financial Adviser are invited to attend the meetings. Chief Administrator of the Project functions as Member-Secretary.

The Control Board initiates and discusses fully important matters like programmes, targets and economy of construction. It reviews the position in regard to these matters and gives suitable directions to the Chief Engineer and the Chief Administrator.

Chief Administrator.—In this Project, there is a Chief Administrator of the status of a Divisional Commissioner. He is a member of the Control Board. To relieve the Chief Engineer of non-technical work like land acquisition, rehabilitation, medical, welfare and purchase, etc., departments concerned with these subjects function directly under him. Of course, the Chief Engineer is consulted on all important issues.

The Chief Administrator functions as the Secretary to the Government also. He is assisted by an Additional Secretary, two Deputy Secretaries and an Under-Secretary. In addition there are separate Directorates for Land Acquisition, Rehabilitation and Purchase, etc., directly under the Chief Administrator.

Chief Accounts Officer-cum-Financial Adviser.—In the Kosi Project there is a Financial Adviser-*cum*-Chief Accounts Officer. He functions as Financial Adviser of the Project Administration and is appointed by the State Government in consultation with the Government of India. The Chief Accounts Officer is assisted by seven Accounts Officers who audit the papers of the officers of the Project and advise them in regard to financial matters.

The Engineering set-up.—There is a Chief Engineer of the Project with his headquarters at Patna. He is the over-all incharge of the execution of the Project and is assisted by several Superintending Engineers and his subordinate Engineers. For the technical matters he is the final authority but generally he seeks advice from the Central Water and Power Commission also on important matters. There is a Directorate of Designs at Patna under his direct guidance.

Present scheme is not the final solution of the Kosi.

It must be mentioned here that the present scheme is not the final reply of the Kosi problems. The final and lasting answer lies in the construction of a dam across the Kosi as well as some check dams across its tributaries. The construction of the dam must immediately follow to make the gradient control more effective and levees to serve the purpose for which they have been put up. A suitable site for the dam has already been located at Kothar. The site is located in a highly seismic zone of Bihar-Nepal Earthquake of 1934. It is also about 200 miles from the epicentre of the great Assam Earthquake of 1897. Now, that a number of dams have been built in similar seismic areas in U. S. A., Italy and Japan, it should not be at all difficult to put up a structure

with necessary precautions and provisions for safeguards against the probable earthquake effects. It is hoped that this project will be included in the Fourth Plan so that the present construction unit may be put on to this new job.

A 510 feet high dam at Kothar can store about 3.71 million acre ft. of water of which 1.62 million acre ft. will form the dead storage to provide silt reserve and minimum head for power generation, the remaining 1.69 million acre ft. being available for power generation, irrigation and navigation. The structure will roughly cost Rs. 50 crores. The following benefits are expected to be derived from the dam:—

(*i*) To trap all the harmful silt behind the dam and increase the life of the Barrage to the extent of 70 years or more.

(*ii*) To generate about 1 million K. W. cheap hydro-electric power.

Investigations are on way to finalise the scheme. It is expected that a preliminary project report will be drawn up by the Central Water and Power Commission in the near future for which the required data are being sent as and when required.

Chatra Research Station.

A few words are required about a Soil Conservation Research Station which has a bearing on the Kosi problems.

There is a Research Station working under the Soil Conservation Board, Ministry of Food and Agriculture, Government of India at Chatra on the bank of the Kosi just where the river debouches from a gorge along the foot-hills to enter the plains. Although the location of the Research Centre is in Nepal, a coverage is necessary as they are doing extremely valuable work. The following quotation summarises:—

> "The aim of the Research Station is to collect data and educate the people of Nepal in understanding their special problems. There was immediate need for restoring Nature's balance and preserving the cushion of vegetation along the slopes that protects the friable upper crust of the soil. In many places the friability runs deep into the hill sides that bring about land-slides under the pressure of heavy rains and floods.
>
> "At the Chatra centre, in the midst of a dense forest with a steep hill on one side and the plains rolling out on the other, I found extensive model experiments on a cross section of the terrain from the foothills to the plains including the bhawar, terrains and plains.

"Here the soil scientists at the centre gauge the run-off and sediment movement over the valley to measured scales. This was later correlated with rainfall for quantitative relationship between watershed, sediment and movement.

"Since man could not improve upon Nature's mosaic of vegetation that it provides against erosion the best he could do was to select plants with an eye to their adaptability and economic utility. Several species of legumes and grasses, some of them well known in the line of soil conservation, were being tried out in difficult and varying conditions. The pine-apple plant was one of them that was found very useful in this region.

"Data on agriculture, grass-land and forestry practice were being collected for complete scientific reconnaissance over the Kosi watersheds.

"The Chatra Soil Conservation Research Centre runs a free advisory service for the benefit of individuals and organization and provides a working knowledge of the various techniques in a complicated work in the widest possible areas and the largest possible number of people. It was doing its very best to bring home to the people of Nepal the truth of their well-known folklore *'Nepal Ko dhan hario van'* (Nepal's wealth—its green forests).

"Properly managed, the forests in Nepal as everywhere else yield timber and food for man, provides grazing ground for livestock and protect the soil against the battering force of rain drops and corrosive flow of water. The forest litter and humus are effective absorbents that were beneficial to vegetation and soil alike. Nepal forests sustain the kholas or gulley streams as perennial rivulets and prevent them from turning into flashy hill streams that go dry within hours of the heaviest rain.

"It was necessary for the Nepalese peasant than any other to know his land and the means of protecting it against the conditions and forces of erosion. He could then draw up a blueprint for conservation, sustenance and abundance"*.

* *Statesman*, Calcutta, July 22nd 1963. (Published with permission).