PAPER No. 372

Diversion of the River Jhelum at Mangla

By
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One of the essential requirements towards the early and successful completion of the gigantic Mangla Dam Project was the timely and safe diversion of the mighty river Jhelum, at a place about half a mile upstream of the existing Upper Jhelum Canal Headworks. As is always the case with river projects, diversion of the river Jhelum was also an essential component of the project. River diversions are normally spectacular events as it happened to be in the case of diversion of the Kabul river for the WARSAK Multipurpose project, but it was not so in the case of Mangla, though it was an exciting event. Exciting because of the unpredictable nature of the river and the none too certain date on which the diversion was proposed and achieved.

Whatever the case may be, the timely and safe diversion of the river Jhelum on the 16th of September, 1965, would go in the history of the project as a great event achieved under abnormal and emergent circumstances in the country. While so many, both outside as well as inside the country, had worked so hard towards the successful achievement of this goal and so many had wished to see it, only so few were fortunate to watch the great event. It was fascinating, indeed to see the river readily obeying man and turning its course with the least possible trouble.

A well devised plan was drawn up fairly in advance for the diversion of the river, keeping in view the safety of the works already completed as well as the works in hand during and after diversion. This plan also envisaged the safety of human lives, construction materials, and construction equipment etc. Adequate precautions were taken and facilities made available for handling the river during diversion.

Considerable studies were essentially required for the diversion of the river. These studies were based on the stream hydrographs and metereological datas of the past forty years. During the critical period *i.e.*, from July to Sptember, weather forecasting was intelligently followed. According to the tentatively agreed programme, a date beyond the 25th of September had to

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be chosen for diverting the river. This was done keeping in view the monsoon period and safety against floods which could be expected during the months of September and October.

For the diversion of the river Jhelum at Mangla extensive model studies were also carried out at the Irrigation Research Station, Nandipur. It was observed from the model tests that the river could be diverted safely, up to a discharge of about 50,000 cusecs and the contractor was prepared and had arranged for diversion of that much flow of the river. Among other things, he had stockpiled about 25,000 cu. yds. of sand-stone boulders, each stone weighing, on the average, from half to two tons and about 100,000 cu. yds. of gravel fill material. It was further observed from these studies that for safe diversion the upstream dyke had to be raised to elevation 910 S.P.D. as fast as possible and up to 930 S.P.D. by early October, 1965.

The discharge capacity of the tunnels was estimated to be 85,000 cusecs with a reservoir level at 910 S.P.D., and 132,000 cusecs at 930 S.P.D. There was, therefore, a risk of higher discharges over-topping and breaching the closure dyke. The flow-record of the river for the past 40 years (reference Appendix 'A') also confirmed our observations that the closure section had to be raised up to 930 S.P.D. as quickly as possible, in order to avoid over-topping in the early stages. In the second half of September five floods exceeding 85,000 cusecs have been recorded, the maximum being 224,000 cusecs in 1954. In October one flood exceeding 85,000 cusecs has been recorded, the maximum being 97,000 cusecs. The estimated probability of a flood which would overtop the dam in October was, however, one in 90 years.

Mangla Dam Contractor, according to his construction schedule—"Diversion Programme" (See Plate 2) had fixed the 12th of September as the date for final diversion. As this date appeared to be a bit too early, having an element of risk involved, a lot of discussions took place from the middle of August to the 1st week of September as to whether a go-ahead signal should be given to the contractor on his proposal or to change the date. As the contractor was confident of achieving the diversion on the scheduled date, he could not be persuaded much to change the date. The contractual position was such that he could not be ordered to change the date. Nonetheless, the date was shifted by four days and the final date of the 16th of September was agreed to for final diversion of the river. While the final date was still under-discussion, India treacherously attacked Pakistan and war broke out. During the war, the swing and grave-yard shifts were almost abandoned, due to observance of black-out, and partial dwindling of the contractor's labour force had already taken place; but in spite of these unexpected difficulties, the final date for diversion remained unchanged.

Diversion of the river Jhelum, at Mangla, was carried out through the five diversion tunnels constructed in the left bank of the river upstream of the famous Mangla Fort. Diversion of the river Jhelum at Mangla may differ in some respects and aspects from diversions elesewhere. In this particular case, the diversion was not confined to a single day operation, as was the case of the river Kabul at WARSAK, but, as may be noted, remained operative from the 21st of August, 1965, through the 16th of September, 1965. Contractually, this period, rather, extends up to the date of impounding *i.e.*, say from September, 1965 to September, 1966.

Again the diversion of the river was subject to certain conditions involving some works to be fully completed while some works completed to certain stages. As required under the contract, it was obligatory on the part of the contractor to comply with the following requirements for and before the river diversion.

STAGE No. I (REQUIREMENTS)

(1) Completion of the main embankment (except the river bed portion in its full section to 1100 S.P.D. for its entire length. This required a fill of about 39 m. cu. yds. to be placed before diversion.

(2) Construction of the five, 30-feet finished diameter diversion tunnels *i.e.*, excavation by Mole, concreting and steel lining, along with their culvert and intake sections.

(3) Excavation of the diversion intake channel involving about 7.35 m. cu. yds. of excavation and completion of the intake structures as required under "works to be completed before diversion".

(4) Construction of the five intake structures, installation and placing in position of the bulk-head diversion gates to the five diversion intakes, as required under "works to be completed before diversion".

(5) Complete erection of the power intake gates, gate rails, screens, screen rails, and air vent-pipes up to elevation 1100 S.P.D.

(6) Completion of the intake embankment to its full section up to elevation 1100 S.P.D. for its entire length.

(7) Construction of certain works such as the D/S prestressed wall, west coffer dam, baffle wall, portal walls, stilling basin floor slab and concreting up to spiral casing for sets No. 1 and No. 2. This required placement of at least 75% of the total estimated quantity of 230,000 cu. yds. of concrete in the power-station.

In addition, placing in position the 30 feet diameter diversion pipe on tunnel No. 1, a bulk head gate on its downstream end, installation and testing of the 8 feet diameter irrigation relief values and draft-tube gates were essentially required to be in position before diversion.

(8) All the works in the Tail-race area, such as given below were required to be completed before diversion.

(*i*) An estimated total excavation of 13 m. cu. yds.

(*ii*) Concreting of the friction blocks and the splitter pier

(*iii*) Placing of Gabions and rip-rap on the slopes.

(*iv*) Completion of the tailrace escape coffer dam up to 925 S.P.D.

(*v*) Installation of Irrigation Valves for sets No. 1 & 2, draft-tubes, draft-tube gates, diversion pipe and its stop log gate.

(9) Completion of the Fabridam in all respects and capable of being operated.

(10) Satisfactory completion of the alluvial grouting required in the river bed to provide part of the cut off in the alluvial overburden beneath the closure dam.

(11) Excavation and removal of the rock-plug in the intake area. This involved an excavation of about 350,000 cu. yds.

(12) Laying and concreting part of the cable-trench.

(13) Construction of eastern and western coffer dams to 918 and 915 S.P.D. elevation, respectively for enclosure of the power-station.

In spite of certain difficulties, particularly in the Power-station area, where some mechanical and civil works had to be taken concurrently in the limited available space, it would be of interest to know how closely and critically the construction schedule was followed during the previous three years. The revised construction programme, already running ahead by one year of the contract date, was further improved upon as may be judged from the progress of works achieved before the September diversion of the river.

(A) Main Dam, Closure Dam and Intake Embankment

The main dam section from its junction with the main spillway to the right bank of the river was raised to a general level of 1120 S.P.D. by July 1965 as against 1100 S.P.D. of the Contract requirements.

The closure dam section (except the river gap) was raised to its full height of 1083 S.P.D. by the end of July, 1965.

The intake embankment which was required to be raised to 1100 S.P.D. before diversion, was raised to 1110 S.P.D. by the end of August, 1965. Concreting for the tracks of the intake gates, trash racks, and air-vents for the tunnels were also completed to this level.

About 40,000,000 cu. yds. of fill was placed in the above three sections before diversion. This quantity of fill was more than 100% required to be placed before diversion and about 51% of the total estimated quantity of fill required to be placed for completion. The fill was placed at an average rate of about 2,000,000 cu. yds. per month.

(B) Closure Dam Cut-off

The grout-curtain under the closure dam section in the river bed, which called for specialised alluvial cut off, was completed and tested for the desired permeability of about 10^{-5} cm/sec. towards the first week of April, 1965. This alluvial grouting was done in the right half portion of the river channel only, with the help of a Jetty formed on that bank. For the left half section of the river bed, it was proposed to have a slurry trench immediately after diversion. However, it may be of interest to know, that the proposed slurry trench was not resorted to. In fact, no need arose for it. After the closure it was found that the depth of the over-burden at this section was too insignificant to warrant the provision of a slurry trench. The small overburden of approximately 10 ft. to 12 ft. depth was removed and the bed rock exposed, cleaned and fill material placed on the same.

(C) Tunnels (See Plate 4)

Excavation of all the five tunnels, concreting as well as steel lining, (tunnels 1 to 3 were about half-length steel lined and the rest of the portion concrete lined) and fully concrete lining No. 4 & 5 were completed towards the middle of 1964. The additional steel lining of about 866 feet in tunnel No. 2 required to be placed before diversion was also completed by early 1965.

Except for the removal of the bed-rock plug coffer dam in the intake area, involving about 350,000 cu. yds. of excavation, the rest of the 7,000,000 cu. yds. of excavation was already completed.

(D) Intake Structures (See Plate 4 and Photograph No. 3)

Installation and testing of the five bulk head diversion gates was completed by June, 1965. Installation of the power intake gates, trash racks, air-vents and concreting of the tracks upto 1110 S.P.D. was completed by August, 1965.

(E) Power-Station (See Plate 6 and Photograph No. 4)

In the Power-station area the following works were completed fairly ahead of the diversion:—

(*i*) Installation of the 30 feet diversion pipe on tunel No. 1.

(*ii*) Construction and raising of the downstream prestressed wall up to 910 S.P.D.

(*iii*) Construction and raising of the Western Wall to 846 elevation and the baffle wall to 834 S.P.D.

(*iv*) Installation of stop-log gate and draft-tube gates on the two sets and irrigation relief pipes and valves, and enclosing the power station area with the help of coffer dams on the eastern and western sides.

(*v*) Construction of a splitter pier in front of the diversion pipe and the rest of the works as required before diversion.

All the above works were completed towards the end of August, 1965.

(F) **Tailrace Works** (See Plates 5 and 6)

The estimated 13,500,000 cu. yds. of bulk excavation, in the tailrace area, was completed towards the middle of 1965. Rest of the tailrace works, such as construction of the baffle wall, concreting of the tailrace slabs, friction blocks, and placing of gabions and rip-rap on the slopes were completed much ahead of time.

(G) **Fabri Dam** (See Plate 5 and Photograph No. 1)

Installation of the Fabri Dam in the tailrace area for controlling the tailrace water level has been, perhaps, adopted for the first time for such a purpose in such a big way. This Fabri Dam, which has been named by the Patentees as such, is made of rubberised fabric similar to that used in the tyres of motor cars. It is a flexible material and could be anchored to suitable foundation. The Fabri Dam at Mangla consists of three bags with a total length of about 700 feet. This dam is capable of being inflated to a height of 10 feet and could be completely deflated when it is so required. The purpose of its application at Mangla is to maintain certain water level in the tailrace in order to avoid hydraulic jumps in the tunnels during the diversion period. The Fabri Dam would remain inflated when the discharge is either less than 20,000 or more than 130,000 cusecs through the tunnels.

(H) **Tailrace Coffer Dam** (See Plate 5 and Photograph No. 1)

A coffer dam had to be constructed at the tailrace, with a crest level up to 925 S.P.D., for protecting the tail-race working area against the monsoon floods of 1965. This dam was completed by February/March of 1965. A dam of this much height would have protected the power station and tailrace area from being flooded if a record flood had taken place in the monsoon season of 1965.

(Highest recorded flood: 1.1 million cusecs in 1929)

(I) Construction of Log-Boom

Before the river was diverted a log boom was placed in position in order to safeguard the tunnels from damage on account of stray logs going into the tunnels. The log-boom has been installed in the river section, a couple of hundred yards upstream of the tunnels intake, by the first week of September, 1965.

STAGE No. 2—ACTUAL DIVERSION

In spite of some difference of opinion, the 16th of September was fixed as the date for the final diversion of the river through the tunnels and it was achieved on the same day. Some of us, no doubt, had some apprehensions about the element of risk involved, in the advancement of the date, but fortunately the whole operation turned out to be quite easy, peaceful and smooth.

The diversion operations were carried out in different stages on different dates, a summarised version of which is given below:—

August 21st, 1965

Bulk-head gate No. 1 of tunnel No. 1, was raised at about 10.45 a.m. and flooding of the tailrace area commenced. To start with, the gate was raised up to 6″ and the discharge through the tunnel was about 350 cusecs. (See Photograph No. 4).

August 22nd, 1965

Flooding of the tailrace area continued. Diversion bulk head gate was further raised by about 4″ and the whole area of the tailrace was flooded upto 867 S.P.D. Further flooding was temporarily stopped by closing the gate.

September 5th, 1965

Preparations were in hand for the piloting of the upstream dyke towards the river from the right bank, and preliminary work continued on the same.

September 8th, 1965

Filling on the closure dyke commenced in the river section from the right bank side. The discharge of the river, as observed in the morning, was about 25,000 cusecs and the gap with this much flow was about 300 feet (See Plate 1).

Excavation for removal of the tailrace coffer dam (original level 925 S.P.D.) was started and remained continue.

September 10th to 11th, 1965

Removal of tailrace coffer dam, and extension of upstream closure dyke continued. Work on the downstream coffer dam (downstream of the haul bridge) also started this date and continued. The downstream coffer dam had to be constructed up to 900 S.P.D. elevation, having a top width of 60 feet, side slopes of 1: 1.75; and consuming about 70,000 cu.yds. of material.

September 12th, 1965

Work continued, as usual, on the breaching of the tailrace coffer dam; construction of the downstream closure dyke and extension of the upstream closure dyke. By the end of the day, the remaining river gap was reduced to about 230 feet.

September 13th, 1965

Work continued at a faster speed on the breaching section of the tailrace coffer dam and extension of the closure dyke. The river gap was reduced to about 200 feet by the evening.

September 14th, 1965

The breach in the tailrace coffer dam was completed by about 12.30 p.m. and the bulk head gate of tunnel No. 1 was raised again at 2 p.m. At about 2.25 p.m. water started flowing from the tailrace area into the river through the gap, over-topping partially, the fabri dam. (See Photograph No. 1). Thus, the river was partially diverted through tunnel No. 1 and put back into the original bed, upstream of the present Upper Jhelum Canal Headworks. Meanwhile, work continued on removal of the tailrace coffer dam with the help of two drag lines, one on each bank. The discharge of the river as observed in the morning was about 19,300 cusecs. At 3.30 p.m. bulk-head gate of tunnel No. 2 was also opened. Materials continued to be pushed across the closure dyke in the remaining river gap of about 200 feet.

September 15th, 1965

While work continued on widening of the gap in the tailrace coffer dam with the help of drag lines, bulk head gate of tunnel No. 3 was raised at about 9 a.m. and that of tunnel No. 4 at about 10.30 a.m. and finally gate No. 5 was also raised at about 12.15 p.m. So by 12.15 p.m. on September the 15th, all the five gates remained opened and part of the river flows passed through the five diversion tunnels, while part still continued to flow in the origianl river bed. (See Photograph No. 3).

Meanwhile, work also continued on both the upstream closure dyke and the downstream dyke at a fairly high speed. The river gap was about 150 feet at 9 a.m. This was reduced to about 125 feet at about 2 p.m. and to 100 feet at about 5 p.m. respectively. Thus, out of a total discharge of about 19,000 cusecs, about 7,000 cusecs was now flowing in the old river bed, while remaining 12,000 cusecs was passing through the tunnels.

September 16th, 1965

All the five bulk-head diversion gates of the tunnels remained open, ready to take the entire river discharge of about 18,000 cusecs as observed in the morning. Work on the closure of the remaining 100 feet of the river gap started at about 6.30 a.m. and by about 11.30 a.m. the river section was entirely closed. It was an interesting and fascinating operation to see the original river bed closed for ever and the river water completely diverted through the tunnels. The river gap was gradually reduced as under. (See Photograph No. 2).

At about	6.30 a.m. the gap was			100	feet
,,	9.20	,,	,, ..	58	,,
,,	9.35	,,	,, ..	55	,,
,,	10.00	,,	,, ..	49	,,
,,	10.50	,,	,, ..	30	,,
,,	11.00	,,	,, ..	25	,,
,,	11.20	,,	,, ..	15	,,
,,	11.30	,,	,, ..	0	ft.

For the final push and closing the remaining river gap, the contractor had stockpiled about 25,000 cubic yards of sandstone boulders, mostly won over from excavation, each weighing about half ton to two tons and about 100,000 cu. yds. of gravel, conforming to the standard gravel fill specifications at Mangla. These materials were stockpiled at about 1200 feet away from the right bank of the river (start of the closure dyke).

Thus, the remaining 100 feet wide gap of the river was closed in about 5 hours time, with complete calm, and ease. Because of the unexpectedly low discharge, it obeyed our command with least resistance. About 61 different pieces of equipment (*vide* Appendix B) remained busy in closing the river gap. With an average rate of fill of 1500 cu. yds. per hour, about 9,200 cu. yds. were placed in the final closure gap in the first shift from 6.30 a.m. to 11.30 a.m. (*vide* Appendix C).

As the discharge of 18,000 cusecs was unexpectedly low, the head across during diversion did not create much difficulty in the closure operation. (*vide* Appendix D).

It was essentially required that the contractor should raise the entire closure dyke (see Plate 3) up to 910 S.P.D. as fast as possible and the downstream dyke to a level of 900 S.P.D. The downstream coffer dam was to follow closely behind the closure dyke in order to maintain a high tail water and minimise on erosion. This, however, did not prove necessary because of the low river discharge.

By the 18th September, the entire closure section was raised to the general level of 910 S.P.D. consuming the following quantities of different materials. (See Plate 3, Details M).

Sandstone Boulders	.. 1,000 cu. yds.
Gravel fill	.. 350,000 ,,
Washed gravel fill	.. 60,000 ,,
Free draining gravel	.. 20,000 ,,
Seal Blanket (Sand & Clay mixed)	.. 20,000 ,,
Rip-Rap	.. 16,000 ,,

Materials were placed at a maximum rate of about 2,000 cu.yds. per hour at the peak of the closure.

Dewatering and controlling of Seepage Flow

Immediately after the diversion of the river stream, arrangements were made for installation of pumping units for dewatering the area of the old river bed between the upstream and the downstream dykes as well as to control the seepage flow. By the afternoon of the 18th September, three pumps were placed in position downstream of the upstream dyke and dewatering operation commenced.

On the 20th of the month, about 5 feet of the surface water was pumped out by the three pumps already installed. Three more pumps were added to the three pumping sets already commissioned, while another four pumps were installed at the various water pockets on the upstream of the downstream coffer dam. Thus, by the afternoon of the 20th September, ten pumps, a description of which is briefly given below, were in position to take care of the surface as well as the seepage water. From now onwards, pumping continued almost round the clock. By the evening of the 22nd September, 1965, almost the whole standing water was pumped out and excavation for the coretrench started in a big way on the morning of the 23rd September, 1965.

With the pumping out of the standing water, only seepage flow had to be taken care of. For this purpose three of the six pumps were shifted further to the downstream toe of the upstream dyke, while the remaining pumps continued to take care of the small pockets of water still remaining plus part of the seepage flow.

Pumps installed on the downstream of the upstream dyke

Number of pumps	.. 6
Horse Power of each pump	.. 150
Lift	.. 120 ft.
Manufacturers	.. Johnston-Vertical-Turbine Pumps.
Static Head start of pumping	.. 45 ft.
Static Head dewatered condition	.. 70 ft.
Estimated total headstart of pumping	.. 70 ft.
Average measured discharge for all the pumps	.. 15,000 gallons per minute.

Pumps installed on the upstream of the downstream Coffer Dam

(A)	Number of pumps	.. 2
	Horse Power of each pump	.. 100
	Lift	.. 120 ft.
	Manufacturers	.. Johnston-Vertical-Turbine Pumps.
(B)	Number of pumps	.. 2
	Horse Power of each pump	.. 50
	Lift	.. 120 ft.
	Manufacturers	.. Johnston-Vertical Turbine Pumps.
	Average Measured Discharge from Pumps (A) and (B)	.. 16,800 gallons per minute.

The total average measured discharge from all the ten pumping units installed in the river bed was approximately 32,000 gallons per minute. Each pump had 12″ columns (Suction) and 12″ discharge pipes (Delivery).

The three pumps installed for controlling the leakage through the upstream dyke were encased in 36″ diameter slotted sheet pipes. When the height of the fill was raised up to about 890 S.P.D. further pumping was discontinued and the pumps were removed from the casings. The casings were sealed off with lean concrete mix. Thus, the seepage problem was finally controlled.

It would be interesting to describe briefly the manner in which the seepage through the closure dyke was reduced to the minimum. Once closure was secured the contractor started immediately sealing the closure dyke from the upstream side while installing pumps on the downstream side. With reference to Plate No. 3 Details M, it would be observed that a sealing blanket of sandstone/clay was placed on the upstream toe of the dyke, immdeiately on the upstream side of the sandstone boulders. A trench was cut with the help of a drag line in the river bed and sealing material was pushed into the same. This seal blanket worked wonderfully well. The effectiveness of the seal made was demonstrated by the fact that after pumping out the surface water, only three 150-H.P. pumps installed immediately downstream of the closure dyke and one 100-H. P. pump installed upstream of the downstream coffer dam, controlled the entire leakage of the river. The maximum leakage was about 8,000 gallons per minute. Pumping of leakage continued till the closure dyke was raised to 890 S.P.D.

In order to minimise on the sloughing of the gravel fill (reference plate No. 3) due to saturation, washed gravel was placed immediately downstream of the gravel fill in a width of about 50 feet. The 910 S.P.D. elevation of the closure dyke was reached on the 18th of September, 1965; while the 930 S.P.D. level was attained by the 2nd of October, 1965.

STAGE No. 3

Contractually it is incumbent on the part of the Contractor to complete some of the works immediately after diversion while some to be carried to certain stages on or before scheduled period of time, as briefly described below: (Reference Plate No. 1 and 3).

(*i*) Immediately after river diversion, complete removal of the tailrace coffer dam was required and work continued on the same. This was completely removed by the middle of October, 1965.

(*ii*) Raising of the closure section to certain levels by certain dates (see plate No. 3) as given below:—

(*a*) up to 930 S.P.D. by 1st November, 1965. This was achieved a few days earlier than the date specified.

(*b*) up to elevation 980 S.P.D. by 1st February, 1966. This was achieved by the middle of December, 1965.

(*c*) up to elevation 1020 S.P.D. by 1st March, 1966.

(*d*) up to elevation 1083 S.P.D. by 1st June, 1966.

(*iii*) It is required of the Contractor to excavate the core-trench in the river bed portion and complete back-filling up to the river bed by 1st July, 1966. With the easy control of leakage, almost the entire excavation in the river bed was completed towards the end of the 3rd week of the month of November and clay fill was commenced from the 23rd of November, 1965. By the middle of December clay in the core-trench was back-filled up to an average elevation of 840 S.P.D. starting from a minimum of 796 S.P.D. By the end of the year, 1965, the general level of the fill was as much as 860 S.P.D., against the level of 880 S.P.D.; of the original bed of the river.

(*iv*) Closing of tunnel No. 1 and dewatering the same was required to be done by the 1st of November for installation of the additional steel lining there-after, so that the same is ready again by the 15th of June, 1966 for taking water. The tunnel was closed 10 days ahead of the target date *i.e.*, by the 20th of October, 1965 and work of removal part of the diversion pipe, laying a rail track inside the tunnel etc. were completed by the middle of November, 1965. Towards the end of December, 1965, 320 feet of the additional liners were placed in position and concrete back-filled.

DIVERSION PERIOD AND THE RISKS INVOLVED

The diversion period practically extends from the date the river is diverted *i.e.*, 16th September, 1965 to the time impounding is started. The closure section of the dam would, therefore, be subject to the risk of being overtopped during the diversion year of 1966. The chances of overtopping of the closure dam were the highest at the beginning and also at the end of its construction. If the closure dam would have been overtopped, say in September, 1965, the damage downstream would have been relatively small. We were confident that the contractor would have been in a position to make another attempt at closing the river gap till about the middle of October. However, if the dam had been overtopped during the months of November or December, 1965, the damage thus caused would not have been so great, but this could have caused a serious delay. It would have been unlikely for the contractor to attempt another closure because there would not have been much time left for him to raise the closure dam as fast as possible. This could have delayed the project by almost a year. The contractor would have thus lost the chances of earning his bonus and we would have lost the benefits derived from the early commissioning of the Power-Station and utilization of the water for irrigation.

According to the probability analysis, there are chances that the closure dam is overtopped during the period from January, 1966 to June, 1966; though, in this case, the freeboard available for the flood period would be sufficiently large. The most critical period will, however, be the monsoon period of 1966 *i.e.*, the period from July 1966 to September, 1966. During this period a free-board of only 6½ feet will be available against the record flood of 1.1 million cusecs. Chances against overtopping at this time are estimated to be 90 to 1 in July; 73 to 1 in August and 123 to 1 in September. Nonetheless, God forbid, if the closure dam is overtopped the following would be the consequential losses. (See Appendix E & F):

(1) The contract programme for completion will have a set back of at least a year. The contractor would lose a bonus of about 25 million plus the additional cost of overheads for the extended period of construction. The employer would lose revenues for one year's supply of electricity and water for irrigation. This loss may amount to Rs. 100,000,000 for one year's delay.

(2) **Damage at Site.** The extent of damage as a result of the closure dam being overtopped will depend upon the time of the year and the height of the closure dam at that time. Supposing if the closure dam is at its full height of 1083 S.P.D., the loss caused, may be as much as Rs. 150,000,000. This loss would, however, be covered under the contractors "all risk policy".

Judging from our experience of the performance of the contractor, for the last 3½ years, we have every reason to hope that reservoir impounding should take place by early 1967, reservoir works and turbo-alternator sets Nos. 1 and 2 to be commissioned before July, 1967 and the whole project to be completed by end of 1967 or early 1968. This would entitle the contractor for a bonus of over 30 million rupees and the Employer would get the benefit from the early commissioning of the power-station, producing 300,000 K. W. of power and early utilization of the water for irrigation.

Thus, the September, 1965 diversion of the river Jhelum has a lot of bearing on the future programme of completion of the project. This timely and successful diversion has made us fully confident of the early and successful completion of the remaining works and if all goes well there is no reason why Mangla Dam Project should not be completed in all respects by the middle of the year 1967.

APPENDIX 'A'

Closure Dam Crest Elevation

Estimated flows which would have overtopped the upstream closure dam at various crest elevations during September and October, 1965.

Crest elevation	Flow in cusecs
900 S.P.D.	55,000
910 ,,	85,000
920 ,,	112,000
930 ,,	132,000

Out of the 40 years of record, the number of years during which at least one day's recorded discharge, in cusecs, was greater than the "Over-topping Flow" are tabulated below:—

Period	Flow Greater than 132,000	Flow Greater than 112,000	Flow Greater than 85,000	Flow Greater than 55,000
1st to 15th Sept.	2	4	5	20
16th to 30th Sept.	1	1	2	5
1st to 15th Oct.	0	0	1	2

APPENDIX 'B'

Details of Machinery Deployed on the Closure of the River

Gap on the 16th September, 1965

Name of Equipment	No.	Max. Carriage Capacity	Normal Loading Capacity
Bottom dump trucks ..	7	40 cu. yds.	35 cu. yds.
Side dump trucks ..	5	25 ,,	20 ,,
Rear dump trucks ..	11	18 ,,	13 ,,
Rear dump trucks ..	4	11 ,,	10 ,,
Water trucks ..	3	7500 gallons	6250 gallons
Dozers (D8, & D9) ..	20		
Shovels (71-B & 38-B) ..	7		
Motor Graders (D14) ..	2		
Vibro-Pactors ..	1		Static weight 8 tons
Front end Loader ..	1		

APPENDIX 'C'

River Closure Fill Quantities

Working Hours on the 16th September, 1965, for Fill Operations

1st Shift	6.00 a.m.	—	12.30 p.m.	(No break)
2nd Shift	1.00 p.m.	—	7.30 p.m.	(No break)

Material Placed in Upstream Closure Dyke in the 1st Shift.

		All Materials
Bottom Dumps	173 No. × 35 c.y. =	6,055 cu.yds.
Side Dumps	44 No. × 20 ,, =	880 ,,
Rear Dumps (R27)	129 No. × 13 ,, =	1,677 ,,
Rear Dumps (R18)	54 No. × 10 ,, =	540 ,,
		9,152

Closure effected at 11.30 a.m. in the 1st Shift.

At 6 hours effective working time, average rate of placing was 1,500 cu.yds. per hour.

Total Material Placed in day from Dawn to Dusk.

	Gravel Fill	Washed Gravel Fill (Plant Run)	Free Draining Gravel
1st Shift	5,868 cu.yds.	3,284 cu.yds.	. .
2nd ,,	10,386 ,,	2,555 ,,	455 cu.yds.
	16,254 cu.yds.	5,839 cu.yds.	455 cu.yds.
	Total . .	22,548 cu.yds.	

At 6 hours effective working time, average rate of placing for 2nd Shift was 2,200 cu.yds. per hour.

APPENDIX 'D'

Mangla Dam Project—River Closure—September, 1965.

Total River Flow × 18,000 *cusecs.*

Date	Water Gap	Closure Dyke			Intake Area		D/S Cofferdam	
		U/S	D/S	Head	Left	Centre	U/S	D/S
8 Sept.	300′	890.26	890.26	..	890.50	890.50	..	..
11 ,,	250′	890.15	889.80	0.35	890.25	890.25	889.85	888.77
14 ,,	200′	890.29	889.34	0.95	890.00	890.00	889.78	888.28
15 ,,	150′	888.53	888.05	0.48	887.00	887.80	888.79	887.32
16 ,,	100′	889.02	886.16	2.86	887.90	887.50	..	..
16 ,,	75′	889.13	885.36	3.77	888.00	887.30	..	..
16 ,,	50′	889.36	884.70	4.66	888.00	886.50	..	..
16 ,,	25′	889.47	884.63	4.84	888.50	886.50	..	..

APPENDIX 'E'

Free-Board Available During Diversion Season.

The Free-board which would be available against the record floods of the past 40 years are tabulated below, based on the maximum likely co-efficient of friction for the tunnel flows.

Flood of Record	Maximum W.S. Elevation in Reservoir				
	Nov. (1959)	Feb. (1954)	Mar. (1948)	July (1959)	Aug. (1929)
November to June: 4 tunnels 1—26 ft dia 3—30 ft dia	924	947	966	..	..
July to September: 5 tunnels 2—26 ft dia 3—30 ft dia	..	..	..	1071.0	1076.5
Closure Dam levels required by Specification.	930	980	1020	1083	1083
Available Free-board (in feet)	6.0	33	24	12	6.5

Floods of record during the past 40 years as referred to above, are given below:—

March	1948	..	258,000 cusecs
Feb.,	1954	..	151,000 ,,
July	1959	..	827,000 ,,
Aug.,	1929	..	1,100,000 ,,
Nov.,	1959	..	105,000 ,,

APPENDIX 'F'

Raising of Closure Dam and Critical Floods.

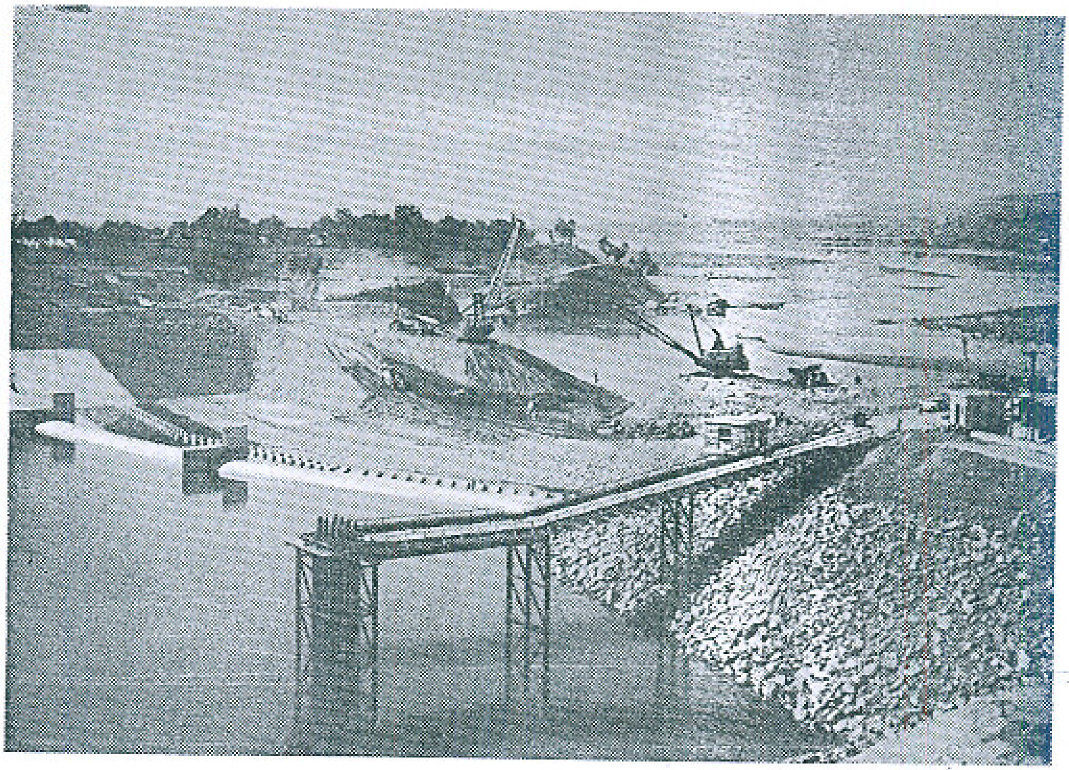
Month	Assumed Closure Dam Crest S.P.D.	Flood Peak which would overtop Closure Dam Cusecs	Return Period Years
October 1965	930	149,000	90
November 1965	939	163,000	420
December 1965	955	217,000	240
January 1966	972	253,000	72
February 1966	1,000	357,000	83
March 1966	1,030	372,000	59
April 1966	1,050	321,000	190
May 1966	1,070	318,000	550
June 1966	1,083	980,000	1,000
July 1966	1,083	880,000	90
August 1966	1,083	1,242,000	73
September 1966	1,083	1,008,000	183

The above table is based on the following tunnels being in operation:

October 1965—5 tunnels .. One tunnel 26′ diameter; four tunnels 30′ diameter

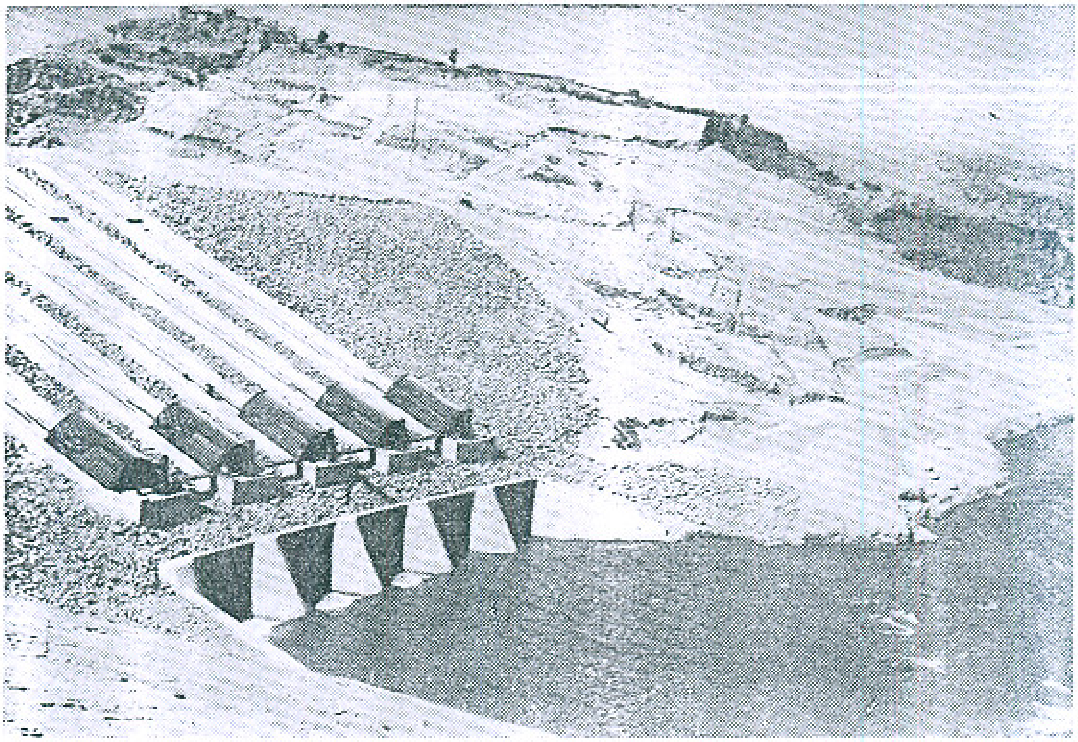
November 1965—June 1966—4 tunnels .. One tunnel 26′ diameter; three tunnels 30′ diameter

July 1966—September 1966—5 tunnels .. Two tunnels 26′ diameter; three tunnels 30′ diameter.

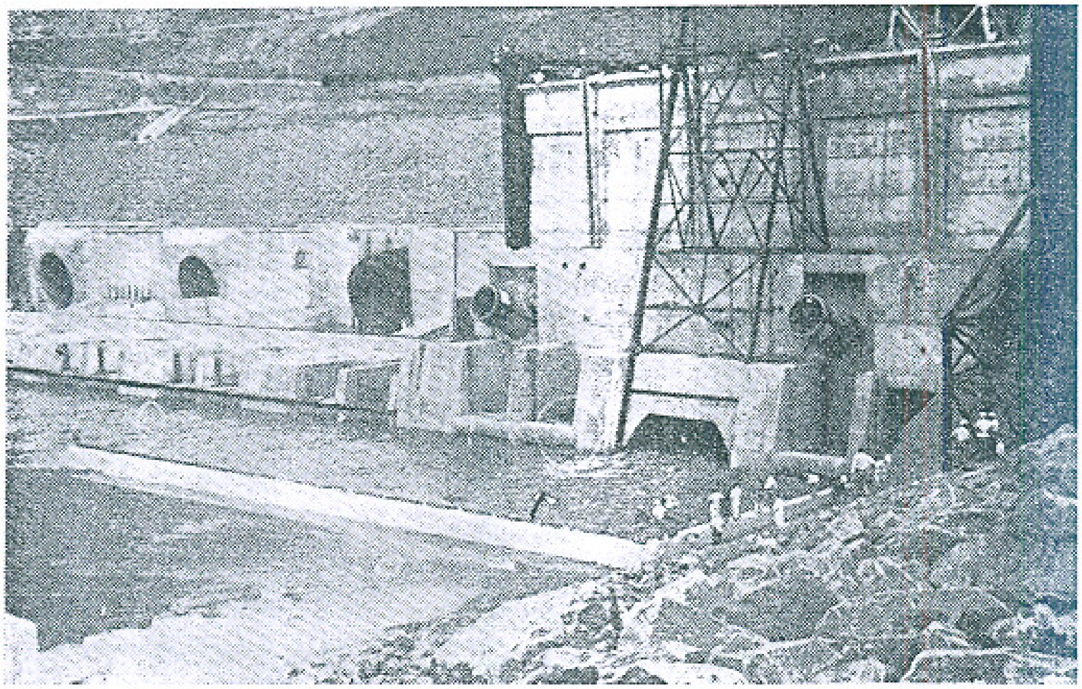


1 Looking from East to West, the Fabri Dam, the Downstream Blocks and excavation of the tailrace coffer dam can be seen. The Upper Jhelum Canal Headworks is visible on the far left side. Part of the rip rap for the slope protection is also visible on the right side.

2 Another View of the Closure Operations. The gap is reduced from 58 ft. to 30 ft. The heavy boulders are seen being pushed across by a Dozer. The gravel can be seen immediately on the downstream of the boulders.



3 Water is seen entering the five diversion tunnels. Power intake gates and trash racks are visible on the top left side. Part of the river water is still flowing in the old coarse. Excavation for the core trench of the Main Dam is also visible on the far side.



4 Water is seen coming out of the diversion pipe at tunnel No. 1 on the 21st of August, 1965. The irrigation relief-valves can be seen on the downstream pre-stressed wall of the Power-station.

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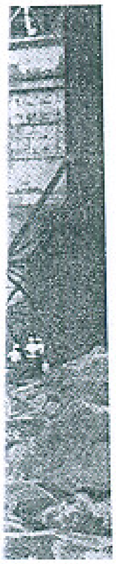

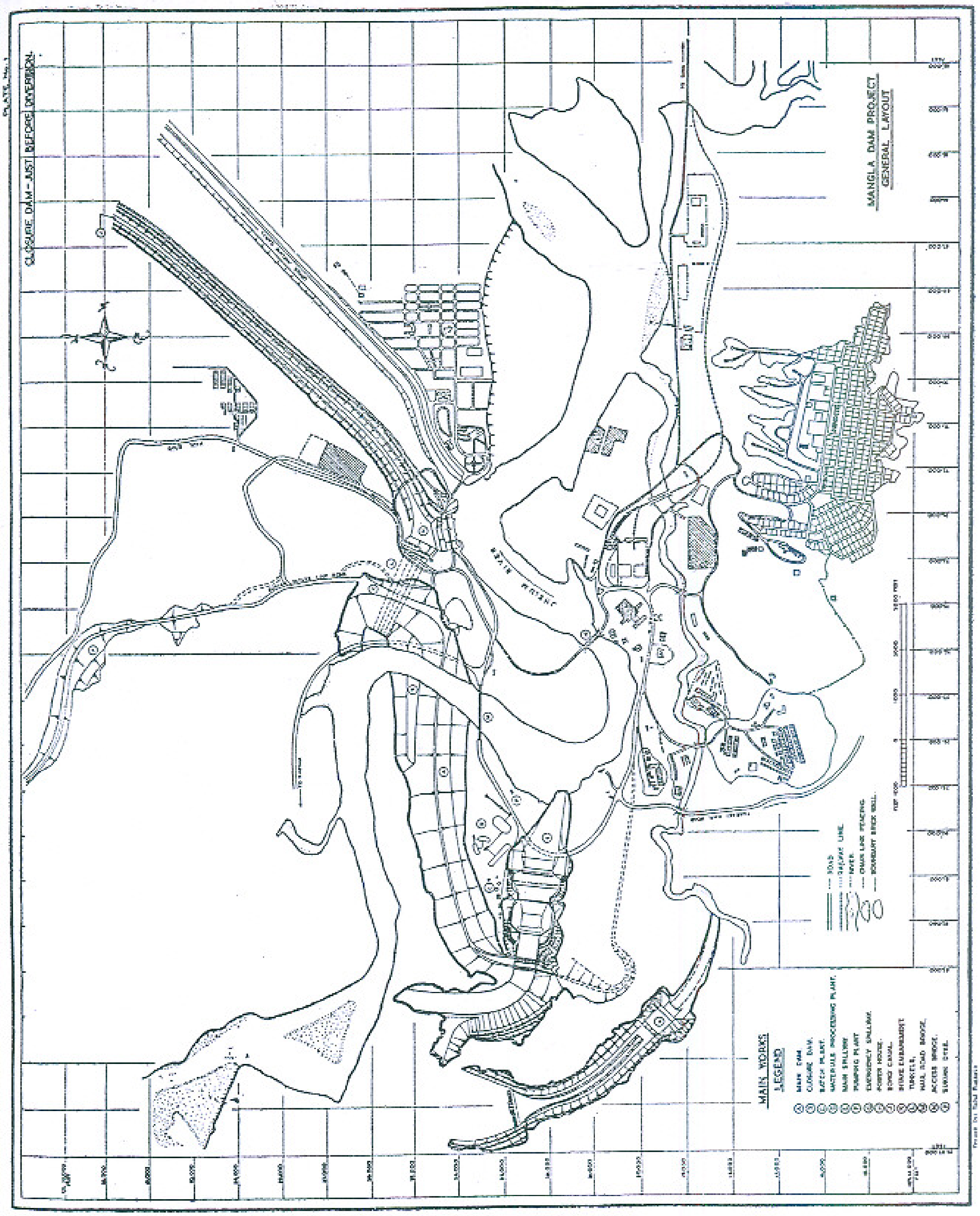

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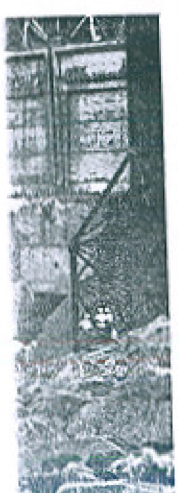

No. 1
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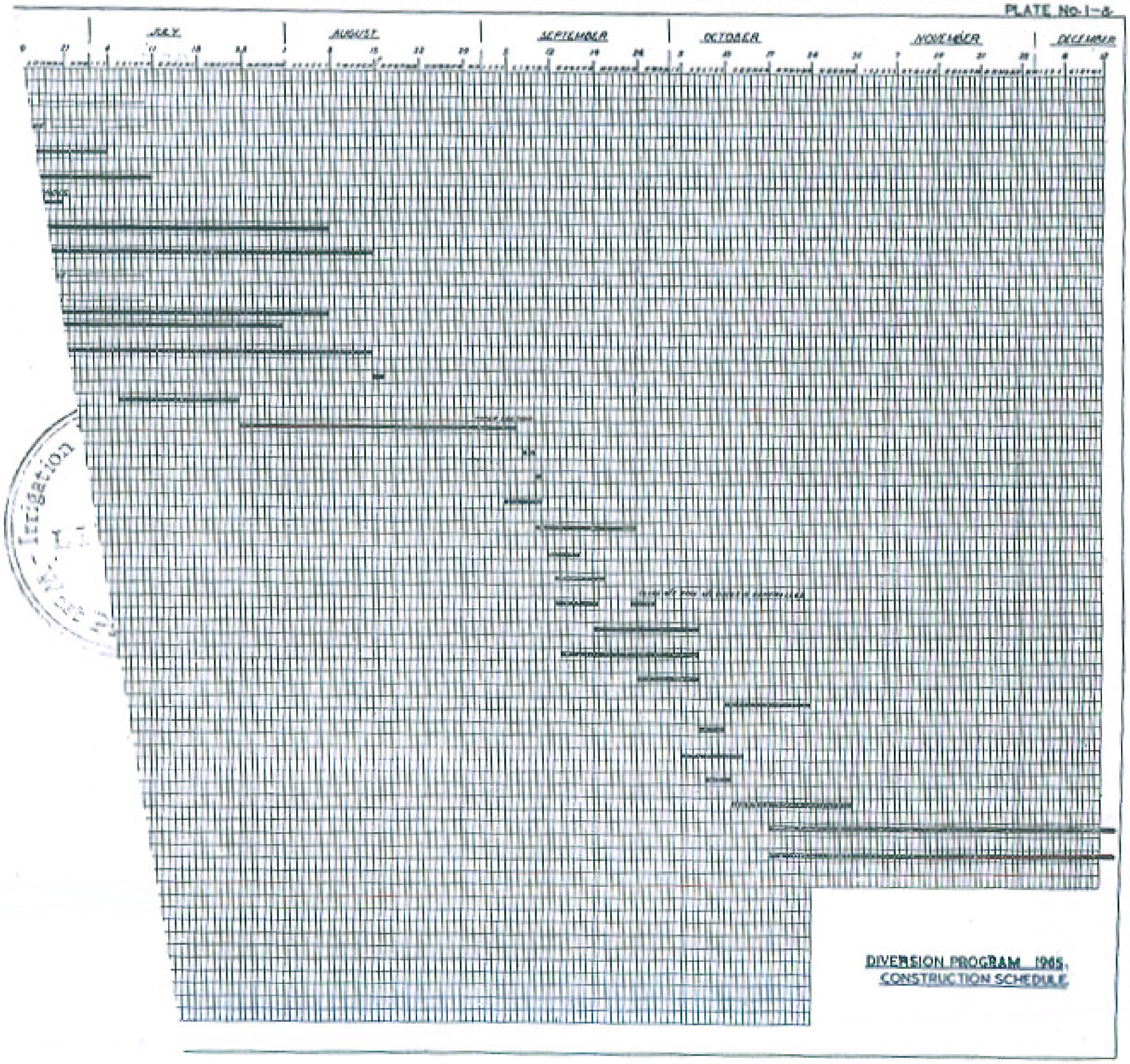
PLATE No-1-a



DIVERSION PROGRAM 1965,
CONSTRUCTION SCHEDULE

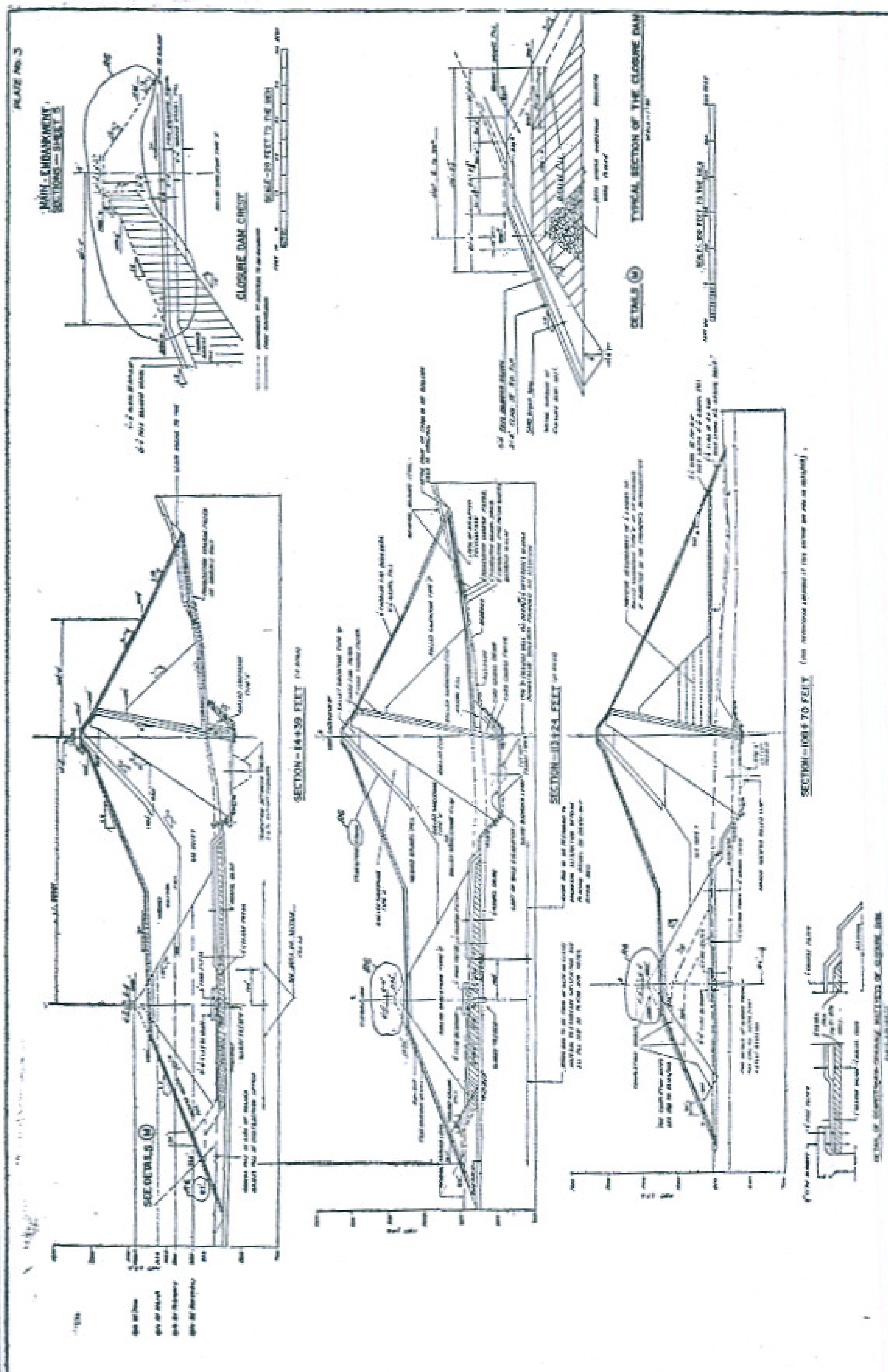


PLATE No. 3
MAIN EMBANKMENT SECTIONS—SHEET 5
CLOSURE DAM CREST
TYPICAL SECTION OF THE CLOSURE DAM

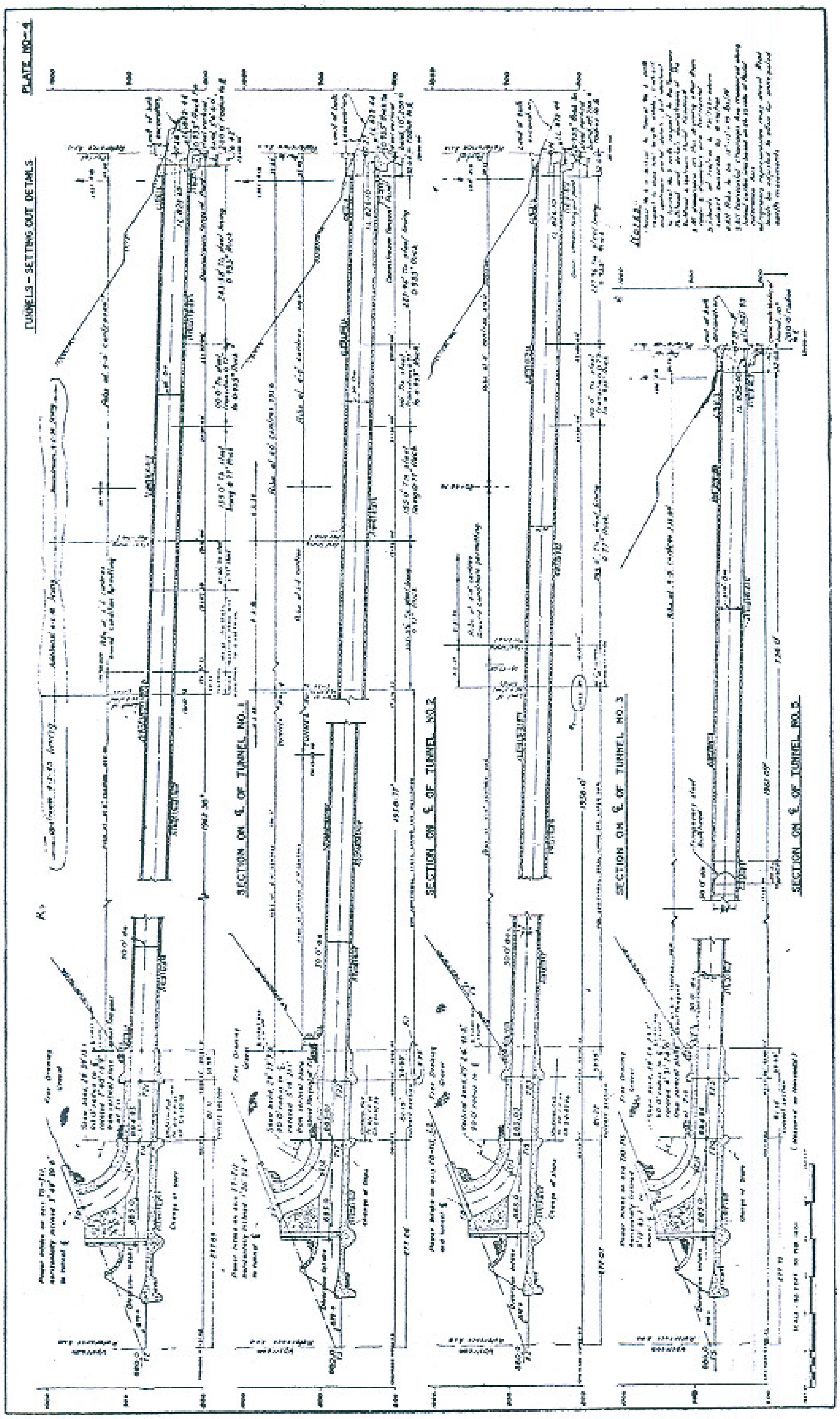
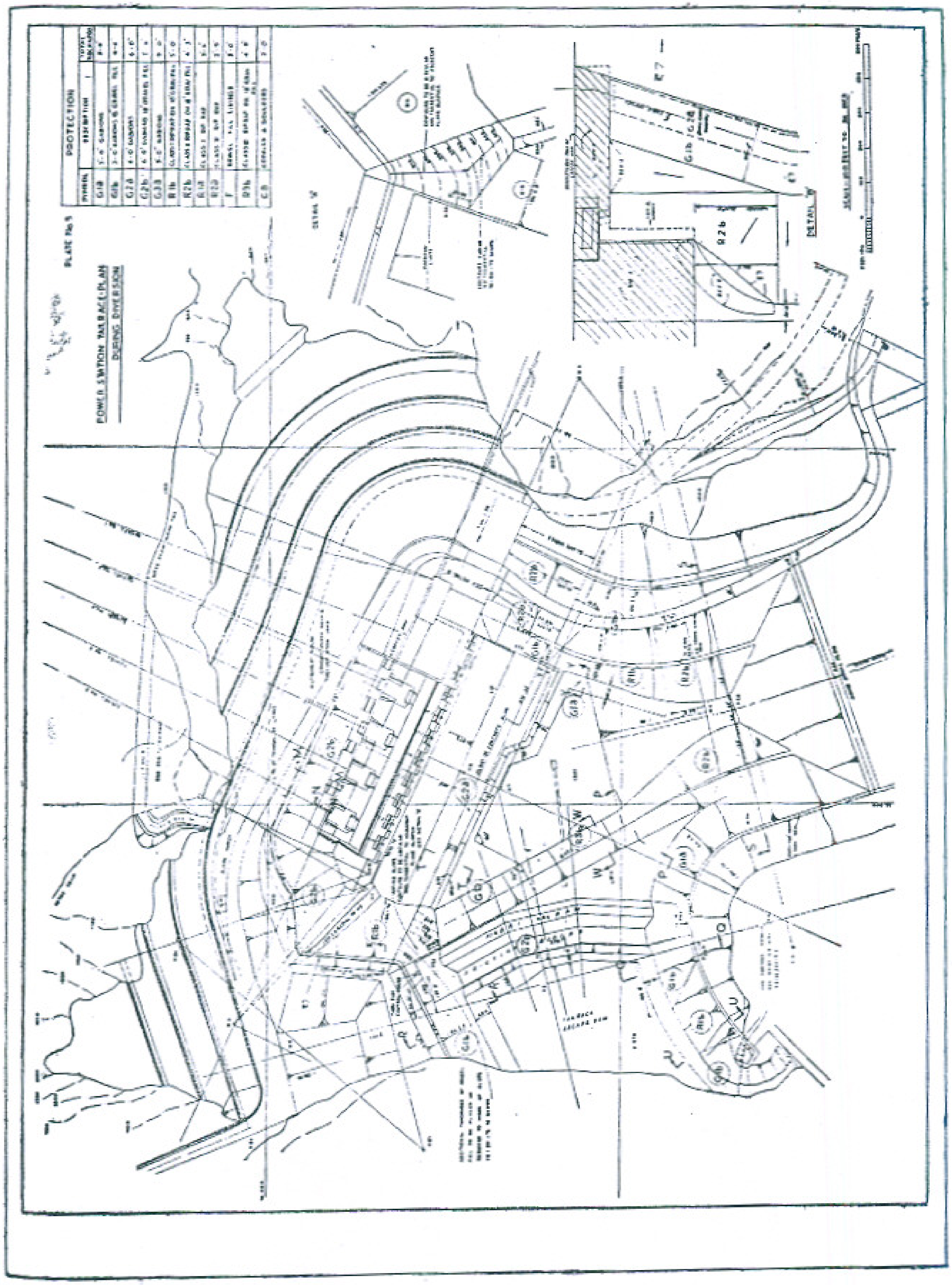


PLATE NO-4
TUNNELS - SETTING OUT DETAILS
SECTION ON ℄ OF TUNNEL NO.1
SECTION ON ℄ OF TUNNEL NO.2
SECTION ON ℄ OF TUNNEL NO.3
SECTION ON ℄ OF TUNNEL NO.5


POWER STATION TAILRACE PLAN
DURING DIVERSION
PROTECTION

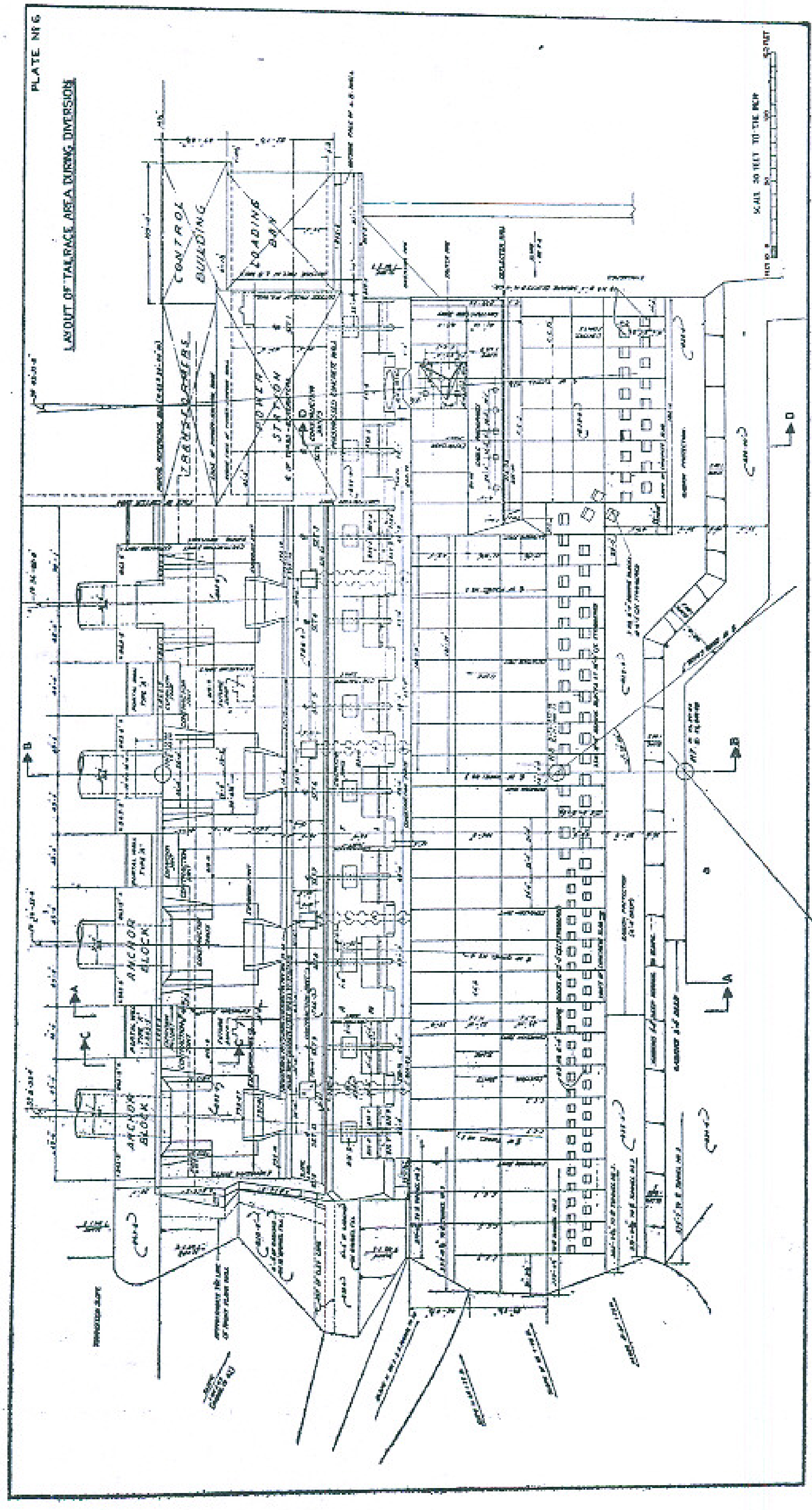


PLATE No 6
LAYOUT OF TAILRACE AREA DURING DIVERSION
CONTROL BUILDING
LOADING BAY
TRANSFORMERS
POWER STATION
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
SCALE 20 FEET TO THE INCH