Remodelling Balloki Headworks

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INTRODUCTION

Balloki Headworks across River Ravi is situated at a short distance of 42 miles in south-west direction from Lahore. It was constructed during the years 1911-13 as a part of the Triple Canal Project System to take Upper Chenab Canal water across the Headworks for feeding the Lower Bari Doab Canal.

The construction of Balloki-Sulemanki Link Canal after Independence, for a designed capacity of 15,182 cusecs, thrust an additional responsibility on this Headworks for the transference of water to the Eastern Rivers. This Link Canal forms an important limb of the Indus Basin Replacement Plan and is being remodelled to cater for an increased discharge of 18,500 cusecs.

The Barrage consists of 35 bays of 40 ft. span each, having 34 piers of 7.25 ft. thickness with manually operated counterbalanced steel gates for heading up the river supplies. It has two Head Regulators on the left side for feeding Lower Bari Doab and Balloki-Sulemanki Link Canals. There is a road bridge 10 ft. wide across the river which forms an important link between the Lahore-Multan and Lahore-Lyallpur highways.

Existing Structure Unreliable

The Barrage was constructed with lime mortar about 50 years back, when the theory of sub-soil flow under the Hydraulic Structures had not sufficiently advanced. Its design features therefore did not incorporate the modern concepts of Barrage design. The existing weir based on unconventional design had a long upstream floor, flat glacis, shallow well line cut-offs, inadequate loose protections and was devoid of energy dissipation devices.
(Refer Plate No. 5).

The high floods of the years 1929, 1954, and 1956 washed off a sufficient length of floor and cut-off on the upstream and in the succeeding years, settlements and cracks developed further. The structure therefore stood in a deplorable condition (as depicted in Plate No. 4) and its safe working could not be relied upon.

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The peculiar shape and location of floors coupled with absence of energy dissipation devices did not provide favourable conditions for the formation of hydraulic jump, as a consequence of which during floods, heavy damages to the loose protections used to occur which were set right by incurring huge expenditure almost every year. This state of affairs was not desirable for the safety of this vital structure.

Distorted River Approach

Up to the year 1954, the river had an approach favourable for the training works and off-taking channel. On coming into operation of B. S. Link in 1954, the withdrawal on the left increased enormously which had a consequential effect in changing the meanders of the river upstream, thereby badly damaging the river training works. The meandering tendency of the river particularly near the Headworks was posing a serious threat of River outflanking the Barrage.

Inadequate Flood Capacity

The Headworks was designed to cater for a maximum flood discharge of 1,39,500 cusecs. This limit has increased many a time, thereby causing damage to the structure and the training works. Flood Commission recommended a discharge of 2,25,000 cusecs across the weir which *inter alia* required remodelling of the Headworks.

Heavy Withdrawals

Balloki Headworks was originally required to handle withdrawal of the order of 6900 cusecs for the L.B.D.C. system. After construction of B.S. Link for a discharge of 15182 cusecs during the year 1954-55, the withdrawals increased considerably which effected the approach conditions and the working of the Barrage. This Link is now being remodelled to cater for a discharge of 18500 cusecs which cannot be accomplished at normal pond level. The additional withdrawals call for a rise in pond level by 1.0 ft. which in turn demands overhauling the structure.

A brief description in the preceding paragraphs would reveal that the Headworks under the prevailing conditions could not be entrusted with the heavy responsibility imposed on it, as a result of the Indus Waters Treaty 1960. It was, therefore, imperative to remodel the structure and the connected works against all hazards.

The salient features of Remodelling have been grouped as:—

I. Correcting River Approach.
II. Flood Control.
III. Remodelling the Barrage.

A brief account of these operations is given below:—

I. CORRECTING RIVER APPROACH

Except during floods, the Ravi contributes very little discharge for escapage on the down-stream to keep the Barrage flushed. This had been keeping the right side of the weir dormant, which steadily masked a considerable portion of the Barrage and rendered the same ineffective during floods. Repeated efforts were made before Independence to activate the masked weir bays on the right by way of regulation and excavating channels etc. but all such attempts proved abortive as the leading channels did not develop being situated on the inside of the curve near the Headworks.

The increased withdrawals on the left after the construction of B.S. Link in 1954, caused more concentration of River flow towards the left side, thereby further choking up the right side of the Barrage with silt. As a result of this, the floods of 1954-59 could not be passed without seriously damaging the upstream floor and allied protections.

Pitched Island

Extensive model study was conducted which, during the year 1956-57, led to the construction of a 1500 ft. long Pitched Island butting against Weir Bays No. 20 and 21 and having a 400 ft. diameter stone protected semi-circular head. A leading channel in the masked bela was also excavated to join the main River on the left with the weir bays on the right. The system coupled with judicious regulation successfully activated the masked weir bays and during floods a much better distribution of water throughout the Barrage width was attained. Experience gained in the following years established retention of Pitched Island on a permanent basis and accordingly the work was renovated in the following manner:—

(*i*) Stone pitching and aprons of semi-circular nose which stood badly damaged by repeated floods of the preceding years were properly designed and rebuilt during the winter season of 1963-64.

(*ii*) Model tests indicated necessity for protection of earthen shank in a length of 900′ as this reach was liable to come under river action during floods. Accordingly at the time of Remodelling the Barrage, during the year 1964-65, both sides of the earthen shank adjacent the gate line in a length of 900 ft. were protected with stone pitchings and aprons.

The extent of the work executed is depicted in Plate No. 13.

Spurs

Up to the year 1954, the River had an approach confined between spurs on the Right and Left Flood Embankments. Near the Headworks the River used to flow along Left Guide Bank and the off-takes were fed from outer side of the curve. This pattern of flow although well suited for withdrawal of relatively silt free water into the off-taking channels, was not very conducive to flood disposal across the Barrage as it tended to choke up the bays on right side of the Barrage with silt.

On construction of B.S. Link, the withdrawals on the Left increased which changed the meanders of the river upstream (refer Plate No. 2). Spurs No. 9 & 4 were hit badly by advancing meanders in the years 1955 and 1956 and ultimately the River made its way through the shanks during the year 1957-58. As the meander advanced further, Spur No. 3 also came under attack during the year 1959 and ultimately the River cut through its shank the same year. This tendency of the River, particularly very near the Barrage, was dangerous and had been posing a serious threat of River outflanking the Barrage.

The problem of improving the approach was tested on models and it was established that the river taking a sinocidal turn from Right to Left some distance above the Pitched Island Nose would be ideally suited for withdrawal of relatively silt-free waters into the off-taking channels and to help in favourable distribution of flood water throughout the width of the Barrage. To achieve this, the recommendations of Irrigation Research Institute were to:—

(*i*) Reconstruct Spur No. 4 in its original position by restoring shank in the form of a curve thereby minimising the recurrence of such damages in future. River conditions being favourable, the work was executed before the flood season of 1962.

(*ii*) Restore damaged earthen shank of Spur No. 9 in the form of a curve to minimise recurrence of future damages. This was done before the floods of 1963.

(*iii*) Reconstruct Spur No. 3 on the lines of Spur No. 4 in a retarded position and to maintain its old isolated T Head in order to form an 800 ft. wide gorge. The idea being to provide sufficient water-way in allowing normal flood waters to predominantly pass through the artificially created gorge for holding the River on right at this site. The gorge was proclaimed to be helpful in minimising the chances of River taking a sweep and re-adopt the old course along left guide bank during normal river floods. River conditions being favourable the work was executed before the flood season of 1963.

(*iv*) Construct a new hockey Spur No. 10 some distance Downstream of Spur No. 3. The idea was to rule out chances for development of a short loop (which is a common behaviour of River Ravi) in the zone, brighten chances of River flowing through artificially created gorge and to afford turning point for the River from Right to Left after striking its stone protected Nose. The work was constructed before the floods of 1963.

The extent of works executed is shown in Plate No. 2.

Ever since construction of these works, the chances of outflanking the Barrage seem to have been averted. The present set of River approach maintained since 1961 is giving best results ever achieved by way of a uniform disposal of Flood water across the Barrage and feeding relatively silt-free water into the off-taking channels. The results are remarkable as the bed of B. S. Link which was silted up to average depth of 3.35 ft. in the year 1960 has progressively scoured to+1.76, +1.72—0.52, +0.35 ft. depth during the years 1961, 62, 63 and 64 respectively.

II. FLOOD CONTROL

Balloki Headworks was originally designed to cater for a maximum flood discharge of 1,39,500 cusecs. This limit has exceeded many a time (particularly after Independence) thereby causing serious damages to the upstream floor, loose protection and the training works etc.

Flood Commission conducted an elaborate study and they recommended to cater for a maximum discharge of 2,75,000 cusecs. A series of alternative proposals to handle the increased discharge are discussed below.

Depressing Weir Crest

The weir crest being only 1.5′ above the existing Upstream floor, did not provide any margin for its further lowering. Apart from this, the accretionary trend of river on Downstream of the Barrage was already affecting the drowning ratio and the proposed lowering of the weir crest would have on the contrary worsened the situation. This alternative was therefore not considered worth-while.

Annexe Bays

The off-taking channels being situated on the left, the additional bays could only be added towards right side of the Barrage. The initial proposal was to convert existing Right Guide Bank into a divide groyne and add a few Annexe Bays by re-aligning a new guide bank on the right. Model tests revealed that the Annexe Bays in this manner would not enhance appreciably the discharging capacity as these were to be located on the inner side of the river

bend near the Barrage. The proposal of adding Annexe Bays was therefore not considered worth execution.

Spill Channel

Construction of a spill weir near Spur No. 3 and excavation of a spill channel connecting the river on the downstream of the Barrage was tested on models but the same was found to develop excessively and disturbed the approach conditions of the off-taking channels. The spill weir when converted into a controlled spill regulator also did not give better results as its mouth got silted on recurrence of a few consecutive dry seasons. The proposal being extremely costly, involving construction of a spill weir, spill channel and an arterial road bridge was not considered fit for execution.

Raising Weir Crest and Flood Embankments

Phenomena of flood cycles would reveal that a flood of magnitude higher than 2,25,000 cusecs may not recur more than once or twice in a century. Having this consideration in view, the Flood Commission at one stage suggested strengthening of the existing Barrage to cater for a discharge of 2,25,000 cusecs and to provide a breaching section in the Right Flood Embankment for the disposal of remaining 50,000 cusecs. It was accordingly decided to remodel the existing Barrage for a maximum flood discharge of 2,25,000 cusecs, leaving 50,000 cusecs to pass through Right Flood Embankment at sites considered suitable depending upon the river approach conditions at the time of a rare high flood of this magnitude.

In order to increase the intensity of discharge across the weir, it was established by model studies to raise the weir crest by 2.0 ft. from R. L. 622.50 to R. L. 624.50. The proposed modification improved the drowning ratio and consequently the coefficient of discharge across the weir. The increased discharge also warranted rise of flood heights on upstream of the Barrage by 1.0 ft. from existing R. L. 637.00 to R. L. 638.00. The anticipated rise in flood levels at the Barrage was apt to have a corresponding effect all along the flood embankments which in turn required raising and strengthening.

The raising of the weir crest was done while remodelling the Barrage (as discussed later) during the year 1964-65. The strengthening of the Flood Embankments was also accomplished the same year under a separate Contract by providing 5.0 ft. Free Board above the anticipated high flood levels and adding pushta (wherever necessary) to cover the hydraulic gradient line of 1 : 5.

III. REMODELLING THE BARRAGE

A brief narration of different remodelling proposals (refer Plate No. 5) is given below:—

Proposal No. I

This proposal was contemplated in 1960 by the Irrigation Department for undertaking mass repairs to the structure. It was then thought that the damages occur mainly due to upstream floor at higher elevation and the cut-off at the Upstream end being inadequate. The proposal involved depressing the upstream floor in a width of 100 ft. from R. L. 621.00 to R. L. 617.25 and to provide 25 ft. deep steel sheet pile cut-off with bottom R. L. 590.25 at its end. The proposal had to be shelved as it did not cater for all the shortcomings.

Proposal No. II

Design experts were of the view that the damages to the upstream floor occurred due to floor being too long and having been located at higher elevation. The damages on the downstream were attributed to flatter glacis and non-existence of a cistern. The proposal framed in 1961 therefore envisaged:—

(*a*) Raising of the crest by 2 ft.

(*b*) Dismantling and relaying the downstream floor to form a cistern and to modify the downstream glacis.

(*c*) Curtailing width of upstream floor to about 100 ft. and relaying the same by depressing to R. L. 617.25.

(*d*) Providing steel sheet pile cut-offs with bottom R. L. 595.00 & R. L. 592.00 at the tail ends of floors on upstream and downstream sides respectively.

The proposed remodelling with a view to improving the hydraulic and structural features of the barrage tantamounted to dismantling and rebuilding the whole weir. The proposal was given up due to radical changes in the downstream floor and high costs involved.

Proposal No. III

In order to eliminate extensive dismantling of upstream and downstream floors, fresh model study was conducted which indicated that (*a*) damage on the downstream can be controlled by modification of the piers and by providing a set of properly shaped friction blocks, (*b*) the damages recurring on the upstream can be overcome and flow pattern across the weir improved by simply raising the crest. The proposals in 1962 and 1964 therefore comprised:—

(*i*) On the barrage proper, raise pond level by 1′.

(*ii*) Provide steel sheet pile line cut-offs at the end of upstream floor after restricting the floor up to 122′.

(*iii*) Dismantle the upstream floor beyond 122′, and provide a suitable width of flexible blocks and stone aprons.

(*iv*) Raise the crest by 2′ and adjust upstream and downstream glacis accordingly.

(*v*) Provide steel pile cut-offs and inverted filter at the downstream floor end.

(*vi*) Provide measures required for dissipation of energy after model tests. Downstream piers to be made into cut waters.

(*vii*) Provide sheet pile at the end of downstream floor of Lower Bari Doab Canal Head Regulator.

(*viii*) Grouting of upsteam and downstream impervious floors to ensure against any crevices.

The proposals were considered reasonable.

Remodelling Operations for the Barrage can be grouped under the following main Heads:—

A. Preliminaries.

B. Feeding Arrangements.

C. Remodelling Operations.

A brief account of these operations is given in the following pages.

A. PRELIMINARIES

Projects conceived under Indus Basin Replacement Plan are executed according to the procedure approved by its Financier, *viz.* "THE WORLD BANK". The system generally involves entrusting the whole work along with the arrangements for all types of materials, machinery, equipment etc. necessary for its implementation to a single agency.

Documentation

Contract Documents on the pattern of International Contracts were prepared but looking at the peculiar nature of remodelling involving innumerable limitations and uncertainties, it was apprehended that the system will not have a favourable response on invitation of a single contract. It was argued that even if some firms might be attracted, the same would demand a huge amount of foreign exchange for import of a big fleet of earth-moving machinery, pumping plants and sheet piling equipments. Such a heavy investment would in no way be justified for a small contract of six to eight months' duration and in addition tantamounted to putting off the work for another year, as import of huge machinery would have been pretty time-consuming.

Keeping all these factors in view, it was decided to invite tenders for Civil Works only and to entrust mechanical jobs to the Machinery Pool

Organization who possess the requisite plant, machinery and technical know-how. The Contract Documents were accordingly re-drafted and Civil Works were awarded to M/s. M. A. Rashid Said Alam Khan, Contractors. The mechanical jobs like (*i*) erection of the coffer dams to enclose the working area, (*ii*) pumping and dewatering of the working area and (*iii*) steel sheet piling were given to Machinery Pool Organization WAPDA and the rates negotiated with them.

In this arrangement, the operations of Civil Contractors and Machinery Pool Organization were interdependent and the system was apt to fail, in case the two agencies did not co-operate with each other. However, by judicious planning for each item of work, such an eventuality was avoided.

Stock Piling

As the time for completing the remodelling of the Barrage was short and limited, its successful completion within the schedule, depended to a large extent on the timely supply of construction materials. It was therefore decided to stock pile in advance the following main construction materials for supply to the Contractors near the site of work.

1. Stone	..	From Sikhanwali Quarry of Irrigation Department.
2. Shingle	..	From Chak Daulat Quarry WAPDA.
3. Manufactured Sand	..	From Chak Daulat Quarry WAPDA.
4. Sill Girders	..	By inviting tenders.
5. Steel sheet Piles	..	Tenders were invited but the supply could not mature in time. Larssen type 111*n* & 111 sheet piles of size 32′ & 20′ respectively available with the Irrigation Department at Jallo Railway Station were therefore obtained on replacement basis. These sheet piles were cut to sizes to suit the requirements.

Initially stock piling of cement was also conceived but its loss during rains and storage was feared. It was therefore decided to leave the procurement of cement with the Contractor from Ismail Cement Industries, Gharibwal, WAPDA. However, a Store Godown having a storage capacity of about 500 tons was constructed near the site of work to facilitate storage by the Contractor.

The list of materials stock piled and consumed is attached as Annexure A.

Railway Track

Balloki Headworks is connected by a Canal Railway Track with Chhanga Manga Railway Station. Ever since the construction of the track in 1911,

no major repairs or replacements of the track materials seemed to have been done. The track stood in a highly deplorable condition and could not therefore be depended for safe handling of the increased rolling loads. The track being deficient in many respects was renovated as below:—

(*a*) The drainage across the Railway Track between R. D. 30-34 had been blocked after construction of Balloki Sulemanki Link in 1952. The rain water and the flow in the old Hudiara Nallah Creek accumulated along the Railway Track, thereby causing breaches into the same. The flow would then breach the left bank of Balloki-Sulemanki Link situated at a distance of about half a mile downstream, resulting into soil erosion, which with progressive retrogression had developed into deep ravines over a long belt. Assessing the catchment of the area, an inlet into Balloki Sulemanki Link at R.D. 25800 Left with a crest elevation of R. L. 630.00 for a discharge of 2400 Cs. was constructed during the year 1962-63. The higher crest of the inlet as compared to the bed of the Nallah at the Railway Track resulted into accumulation of water which made the track vulnerable to attack throughout the year. In order to ensure the safety of the track and to handle the drainage of the area, it was considered essential to construct a bridge at the crossing of the Hudiara Nallah Creek for a corresponding discharge of 2400 Cs. The bridge has been constructed in two spans of 20 ft. each and provided with steel girder decking.

(*b*) There existed no siding, and the terminus near the Headworks was being utilized for handling the normal loads for maintenance works. A siding was therefore constructed to accommodate the huge in-coming construction materials.

(*c*) The track in its entirety was renovated by replacement of worn out and unserviceable track materials like sleepers, dog spikes, fish plates, bolts, nuts and bearing plates etc.

(*d*) The embankment was strengthened and grades eased out for smooth working of the traffic.

Buildings

On opening of Balloki Remodelling Division at Balloki in 1961, a few buildings were spared by the Irrigation Department but the same did not meet

the entire demand. In due course of time, the following buildings were constructed:—

3 Roomed Quarters for office staff in Balloki Canal Colony	4 No.
2 Roomed Quarters for office staff in Balloki Canal Colony	6 No.
2 Roomed Quarters for field staff at Balloki Headworks	6 No.
1 Roomed Quarters for field staff at Balloki Headworks	7 No.
Officers' Flat in Balloki Canal Colony	1 No.
Field Office at Balloki Headworks	1 No.
Small Store Godown in Balloki Workshop (for preliminary works)	1 No.
Store Godown at Balloki Headworks (for use by the Civil Contractors)	1 No.

Electric Power

Electric supply to Balloki Headworks for its normal maintenance is fed from the distribution lines connected with the Grid at Bhaipheru. The power requirements for Remodelling Works were huge and could not be handled by the existing distribution lines. It was therefore envisaged to connect the Headworks by an independent 11 K.V. High Tension Line with Grid Station at Bhaipheru. The power requirements were originally estimated at 1000 K. Watts but had to be increased initially to 2000 K.W. and then to 3000 K.W. on the demand of Machinery Pool Organization. In order to reduce the transmission losses and to guard against mishaps, the 11 K.V. was stepped down to 400-440 Volts at a number of Sub-Stations spread over the entire working area as shown in Plate No. 3.

Stand-by Power Arrangements

The work in the river bed with headed up supplies all around (for feeding the off-takes) required continuous pumping to maintain the area dry. The failure of electric supply even for short durations could result in the disturbance of sub-soil strata, submergence of the working area, damage to the machinery, materials etc. It was suggested that a combination of Diesel and Electric pumps should be provided but Machinery Pool Organization had not sufficient stock of diesel pumping sets. In order to guard against failure of electric supply, stand-by power arrangements were considered inevitable.

Assessment of resources revealed that Generating Sets of adequate capacity were not readily available in the country. Import thereof and construction of a big Power Station at the site was time-consuming and a huge expenditure was not justifiable for a small-sized Project. With great efforts, Machinery

Pool Org. could arrange small mobile generating sets to cater for a maximum of 400 K.W. This fell too short of the basic requirements and necessitated alternative considerations. In order to ensure continuous flow of Power, the Electricity Department connected:—

(*a*) Grid station at Bhaipheru (Prime Feeder) presently fed from Montgomery side with Lahore side as well. This minimized the chances of breakdown on the Prime Feeder.

(*b*) Tapped power supply directly from 132 K.V. Main Feeder line crossing just upstream of the Headworks and connected the same with the Prime Feeder from Bhaipheru.

All the 11 K. W. Sub-Stations spread over the working area were fed from dual source and with these arrangements, no electric breakdown had been experienced on this Project.

B. FEEDING ARRANGEMENTS

L.B.D.C. is a perennial channel and runs all the year round while Balloki-Sulemanki Link is a Carrier Channel and runs during the period from 1st of March to 15th October each year. The programme of construction had thus to be devised in a manner so that both the off-takes could be fed according to their periods of flow. Flood season from middle of June to middle of October prohibited continuation of Remodelling Operations as the whole of the Barrage had to be kept clear for disposal of floods in this period. Complete blockade of the Barrage could not be done even in the remaining period (from 16th October to 15th June) unless some way was provided for escapage of winter freshets. The construction schedule and lay-out of Coffer dams had therefore to be planned by keeping in view the operational limitations of the Barrage and off-taking channels. In order to discharge these obligations, the following aspects were considered:—

Winter Freshets

Construction of a spill weir or spill regulator in connection with increasing the flood capacity of the Headworks could be utilized for disposal of winter freshets thereby allowing complete enclosure of the Barrage for remodelling operations. The proposal having been ruled out as a flood control measure, the construction thereof simply for disposal of winter freshets was not considered to be an economical proposition.

The existence of Pitched Island on Upstream and fish ladder on the Downstream almost in the middle of the Barrage was found to overcome the difficulty, as the remodelling of the Barrage when planned in two different phases (for the left and right sides) could in turn make available a number of

weir bays for disposal of winter freshets. It was therefore decided to enclose weir bays 1 to 17 on left in the 1st Phase and leave weir bays 21 to 35 on the right for winter freshets. Likewise weir bays 18 to 35 were to be enclosed in the 2nd Phase by leaving weir bays 1 to 10 or 1 to 17 (as the case may be) on the left to handle the freshets.

Feeding Off-Takes

Weir bays 5 to 15 had been badly damaged during the preceding years. The quantum of work in the 1st Phase which included complete remodelling of the L.B.D.C. Head Regulator and weir bay 1 to 17 was extensive and considered to be extremely tricky and time-consuming. It was apprehended initially that the work in the 1st Phase would not be finished by the time Balloki-Sulemanki Link was required to be opened and this called for making alternative arrangements to feed the Link as well. It was also found that the coffer dams while resting over the stone apron, pacca floor and butting against a masonry wall would not be safe and this warranted its location at some distance Upstream of the Balloki Sulemanki Link Head Regulator. The proposal for feeding the off-takes during Remodelling Operation in the 1st Phase therefore envisaged excavation of a combined channel leading from left guide Bund Upstream up to pacca road crossing wherefrom two independent channels for L.B.D.C. and Balloki-Sulemanki Link would be emanating after constructing a combined temporary Head Regulator. The arrangements are shown in Plate No. 6 and were roughly estimated to cost Rs. 52,84,000. The proposal was discussed with the Consultants and Senior Irrigation Officers in a number of meetings and in view of excessive cost, it was decided to thrash out the problems for devising relatively cheaper system for feeding the off-takes.

It was opined that if the coffer dams for enclosing the working area upstream could be located some distance downward, then Balloki-Sulemanki Link Head Regulator may be utilized for feeding L.B.D.C. and a part supply could be delivered into Balloki-Sulemanki Link as well. Balloki Sulemanki Link Head Regulator with raised pond level of 633.0 can deliver 18500 Cs. and if some system for regulating the supply for both the off-takes could be devised about 10900 cusecs were available for feeding Balloki-Sulemanki Link after running L.B.D.C. to its full requirements of 7600 cusecs. The modified proposal was therefore to erect coffer dam Downstream of Balloki-Sulemanki Link Head Regulator, construct a temporary Head Regulator at R.D. 3000 Balloki-Sulemanki Link and to excavate therefrom a leading channel into L.B.D.C. The proposal is shown in Plate No. 7 and roughly estimated to cost Rs. 15,00,000. The temporary regulator was required to escape all surplus water into Balloki-Sulemanki Link after meeting the requirements of L.B.D.C.

Even this system of feeding the off-takes was considered costly and the proposal was revised to achieve a system of regulation for both the off-takes from the existing Balloki-Sulemanki Link Head Regulator. This involved construction of a pacca divide wall on the Downstream for segregating 6 No. bays on the left side for Balloki-Sulemanki Link and the remaining 5 No. bays on the right for feeding L.B.D.C. A curved transition for the proposed divide wall bounded by steel sheet piles was planned for diverting the supplies into L.B.D.C. after puncturing the common bank. The arrangements are shown on Plate No. 8 and were roughly estimated to cost Rs. 7,23,000.

The arrangements for feeding both the off-takes from the Balloki-Sulemanki Link Head Regulator in the aforementioned manner demanded erection of the Coffer dam for enclosing the Upstream area clear of the B. S. Link Head Regulator. The Coffer dam could thus be located by blocking a few bays of L.B.D.C. Head Regulator thereby making provision for sheet piling on Upstream of this Regulator impracticable. Subsequent study showed that the erection of sheet piling on the Upstream of Lower Bari Doab Canal Head Regulator could not be omitted and this called for a further revision in the proposed Plan.

It was stressed that howsoever intricate the remodelling operations might be, efforts should be made to complete the remodelling works in the 1st Phase from weir bay 1 to 15 by the time Balloki-Sulemanki Link was required to be opened. The idea was to locate coffer dam some distance upward clear of Lower Bari Doab Canal Head Regulator by allowing a few bays of Balloki-Sulemanki Link Head Regulator to be blocked, because even 5 to 6 bays of this Head Regulator were sufficient to feed Lower Bari Doab Canal to its full requirements. The proposal was full of risks in regard to:—

(*i*) the safety of the coffer dam in the portion resting on stone apron, pacca floor and butting against masonry wall;

(*ii*) being too near the active flow of water for feeding the canal through a tight waterway and

(*iii*) deep excavation for driving the sheet pile just at the toe of the coffer dam.

After prolonged study a bold decision in favour of the last alternative costing Rs. 260,000 as shown in Plate No. 9 was taken. The details of the work and the manner of executing is discussed in subsequent chapters.

C. REMODELLING OPERATIONS

In view of operational limitations of off-taking channels and coming flood season, the programme of remodelling the Barrage was drawn out as per

Plate No. 14 and the work divided into two phases as under:—

Phase I

All works connected with weir bays 1 to 15 including L.B.D.C. Head Regulator—scheduled for completion by 15-2-65.

Phase II

All works connected with weir bay 16 to 35—scheduled for completion by 15-6-65.

PHASE I

Canal Closure

Location of a network of Coffer Dams (as shown in Plate No. 9) for enclosing the working area in 1st Phase threw L.B.D.C. Head Regulator out of action. During this period, Head Regulator of B. S. Link (which closes normally from 16th October each year) was scheduled to be utilized for maintaining flow into L.B.D.C. Remodelling works on the left being intricate and time-consuming warranted enclosing the working area soon on closure of B. S. Link. With this objective in view, a canal closure of about 3-4 weeks from 16th October 1964 for erection of coffer dams and to accomplish alternative feeding arrangements for L.B.D.C. was demanded but in the interest of irrigation, closure in the month of October was not allowed. Closure in the month of December was suggested by Lower Bari Doab Canal Irrigation Circle but it did not meet the requirements for completing the work in time. After detailed deliberations, one-month closure from 11-11-64 was agreed.

Traffic Diversion

Balloki Headworks on its left and right connects the two important highways—Lahore-Multan and Lahore-Lyallpur—respectively and provides the shortest link to the busy markets of Okara and Montgomery with Lyallpur and hence could not afford any disruption of traffic. Coffer dam No. 3 on the Upstream of the Barrage connecting left flank with the Pitched Island shank being located between Lower Bari Doab Canal and Balloki-Sulemanki Link Head Regulators required movement of heavy earth-moving machinery in the direct route of public traffic. Since there was no other source by which Coffer dam No. 3 could be erected and as the roadway was extremely tight, alternative temporary diversion arrangements for movement of public traffic were required. A service road (shown in Plate No. 9) connecting pacca road opposite Workshop at Balloki leading to Left Bank of Lower Bari Doab Canal, across Balloki-Sulemanki Link and over Coffer dam No. 1-A was constructed. The service road thereafter approached the Headworks along Right Bank of Lower Bari Doab Canal by crossing the same over Bridge at R. D. 8573 to follow the normal route.

Soon on closure of Balloki-Sulemanki Link, Coffer dam No. 1-A was erected and service road about 4 miles long made ready before commencing movement of earth-moving machinery for erection of Coffer dam No. 3 during Canal closure from 10-11-65.

Coffer Dams

Taking the advantage of nil flow Downstream Coffer dam No. 3-A was commenced ahead of schedule by borrowing earth from the adjoining fallow land. The working area on the Downstream was thus enclosed before releasing the ponded up supplies down below. Coffer dams No. 1 & 1-A in Balloki-Sulemanki Link were also constructed in advance on closure of Balloki-Sulemanki Link in 10/64.

For erection of Coffer Dam No. 3 on Upstream, the pond was depleted and canal closure effected on 10-11-64. The public traffic was diverted along the alternative route and all the Earth Moving Machinery available with Machinery Pool Organization deployed on the job. Protection of this Coffer dam for its safety in the reach resting over the pacca floor, stone apron and junction with the masonry wall had been attracting lot of attention. Originally it had been planned to grout the sub-strata or remove the stone apron for making an earth to earth joint and to provide a masonry retaining wall in alignment with pier No. 7 of Balloki-Sulemanki Link Head Regulator, for curtailing the base width of Coffer dam, but the proposal had to be ruled out as being time-consuming and necessitating a long canal closure. Therefore a simple solution in the following manner (as shown in Plate No. 10) was applied:—

(*a*) A retaining wall made from earth filled jute bags was provided to curtail the upstream slopes in the immediate vicinity of Balloki-Sulemanki Link Head Regulator. This was essential to locate the coffer dam clear of Lower Bari Doab Canal Head Regulator and to make available a reasonable number of Balloki-Sulemanki Link Head Regulator bays for alternative feeding of Lower Bari Doab Canal.

(*b*) Upstream slopes vulnerable to flowing water were protected by providing a layer of Earth filled jute bags.

(*c*) The pacca floor under the base of coffer dam was cleared to provide a few dwarf walls for protection against slipping.

(*d*) The stone apron on Upstream of Balloki-Sulemanki Link Head Regulator originally proposed to be removed was found to be fully packed and launched to deep levels. Its removal was therefore not considered advisable.

To accomplish these arrangements, as a first step, a small enclosure bund in front of Balloki-Sulemanki Link Head Regulator was erected and the area dewatered by open pumping. After providing the protections enumerated above, the Coffer dams in this reach were built up by compacting earth in layers. While the protection works were proceeding in this zone, the erection of main Coffer dam proceeded uninterrupted. The limited space between the two Head Regulators had been imposing serious restrictions in the movement of the machinery but judicious planning coupled with day and night work, the Coffer dam along with its allied protections was made ready in a short period of 15 days.

Coffer dam No. 2 in L.B.D.C. was also erected during the canal closure and its upstream face protected with a layer of earth-filled jute bags to prevent against back swirls, erosion and wave-wash.

Diversion Channel

On closing down of Balloki-Sulemanki Link in October 1964, a portion of common berm between the two channels was excavated for diverting water into L.B.D.C. as its own Head Regulator had been thrown out of action by virtue of its having been enclosed within the Coffer dams. Since the diversion channel happened to be very near to the Head Regulators and as sharp bends were involved, the sides of the excavated common berm and right side of L.B.D.C. below Coffer Dam No. 2 were protected with stone pitching and aprons. The disturbances created by sharp bends were thus taken care of in these protected zones upstream of Pacca Flume at R.D. 954 L.B.D.C. and flow into the canal lower down remained trouble-free and normal.

Having completed these alternative arrangements to feed Lower Bari Doab Canal, the canal was re-opened with effect from 1-12-64 thereby availing a closure of only 20 days as against stipulated period of one month. By so doing 47000 acre feet of precious water for sowing rabi crop were saved.

Dewatering Arrangements

Having regard to the prevalent conditions and the type of work, Irrigation Research Institute established seepage of the order of 30 to 40 cusecs in each phase. Accordingly two rows of tubewells (with 30′ of strainer and 20′ blind pipe), one near the toe of coffer dams to check the seepage lines and another close to the working area for depression of the water table were planned both on Upstream and Downstream of the Barrage.

(*a*) *Upstream.*—On the Upstream, Coffer Dam No. 3 blocked the River channel on 15-11-64 when manually operated percussion type boring for sinking of tubewells close to the working area at a distance of about 275′ from the gate

line was started. Obstructions in the form of stone were encountered at depths ranging from 15-25' ft. and sub-strata also found unfavourable. The well line was then shifted some distance Upstream but here too sub-strata was not desirable and tubewells did not give satisfactory results.

The boring operations with the customary percussion type were time consuming and it was feared that within the limited period of canal closure, the bores as per requirements could not be made. Guidance from WASID was taken and they suggested Rotary type of boring. Cyclones were at once put on the job but peculiar enough, the bentonite lining did not collapse and the tubewells installed in these bores did not give any relief. The cyclones were then improvised to work as percussion type and the progress of boring thus expedited. As a further precaution a few open pumps were installed to prevent flooding of the area on building up of pond and to allow for surface drainage during rains.

In spite of Installation of a big number of tube-wells, the area was not drying and on the spot study revealed the following:—

(*i*) Sub-strata being heterogeneous and mostly clayey at top, did not allow the water from upper layers to travel down the zone of strainer. Thus, howsoever efficient the pumps had been working, no relief at site was noticed. As a remedial measure, the blind pipes were altogether omitted and instead strainers provided right up to the base of the pumps. This effectively drained off water from the upper layers.

(*ii*) Old floor resting on a thick layer of very fine clay prevented drainage of the over-burden. The removal of the overburden being extremely slushy, thus became very difficult. Similarly the trench excavated for sheet piling always remained full of water thereby hindering the operations of dismantling, excavating and pile driving. To overcome these bottlenecks, drains leading to the open pumps were excavated, small open pumps provided in the trench and a few tube wells installed right on the zone of work by dismantling the existing floor.

(*iii*) The machinery with Machinery Pool Organization was pretty old and unreliable. The suctions, deliveries, bends, junctions etc. were profusely leaking. This coupled with unfavourable sub-strata, marred the efficiency of the pumping. To effect economy and to expedite laying of delivery lines, a few bores were coupled and deliveries for these pumps combined together.

In the early stages, the pumping remained a constant source of worry and even the progress of work suffered, but on overcoming the difficulties in the aforementioned manner, the work later on progressed satisfactorily. The network of tubewells, open pumps etc. is exhibited in Plate No. 3.

(*b*) *Downstream.*—On enclosing the area Downstream, big depressions at a distance from the zone of work opposite bays No. 2 & 13 to 15 were noticed. Open pumps were installed in these depressions which lowered the water table in the adjoining area, but substantial relief could not be achieved in the zone of excavation and dismantling. Installation of tubewells failed due to obstructions encountered in the form of settled stone. Leading channels towards the depressions were then excavated, which considerably eased the situation but still the water level in the working area could not be lowered beyond R. L. 612.50. All excavations and dismantling below this level had therefore to be done in water. A few small pumps were however installed at suitable sites to control water locally. In the meantime, efforts to sink tubewells were also continued and the network of pumping arrangements is shown in Plate No. 3.

On the average approximately a discharge of 10 to 15 Cs. on the upstream and 5 to 8 Cs. on the downstream of the Barrage had to be constantly pumped out to maintain working condition in the pit.

Remodelling L.B.D.C. Head Regulator

All the hydraulic structures require a deep cut-off at the tail end of impervious floor to guard against excessive scour and exit gradient. Such a cut-off was lacking in the case of L.B.D.C. Head Regulator. The excessive scours were of course controlled by lining the bed in a sufficient width, but the exit gradient still warranted consideration. Having regard to the existing thickness of the floor, 10 ft. deep steel sheet pile line with bottom at R.L. 611.90 was considered adequate. During annual closures when pond used to be depleted, it had been noticed in the past that the downstream floor of this regulator remained dry. In order to save pumping and to expedite the remodelling works in Phase I, the dismantling of the floor was started on 13-11-64 and after assembly of the piling rig, sheet piling followed from 15-11-64. As soon as piling had advanced in a sufficient length, the sheet pile was provided with concrete cap duly bonded with the existing floor. A small open pump proved sufficient to check the accumulation of water in the trench.

No significant obstruction was noticed except that the sheet piling at the ends had to be done by drop hammer held by a small crane as the adjoining vertical flank walls did not permit the piling rig to work in such nearness. The end piles were made to butt with the well foundation of the flank walls and the

adjacent zone thoroughly grouted with neat cement up to the bottom of the sheet pile for making the cut-off fully effective.

The whole job was accomplished by 26-11-64, the piling rig etc. dismantled and area cleared before re-opening of the canal from 1-12-64. The extent of work is shown in Plate No. 11.

Raising Weir Crest

As already explained, the accretionary trend on the Downstream and river-approaches being on the left side both on Upstream and Downstream of the Headworks, rendered tne Barrage to work non-modularly particularly in the right half, and had an adverse effect on the discharging capacity. In addition, the location of Upstream floor at R. L. 621.00 (lower by only 1.5 ft. from the existing crest) was considered unsafe and deserved a more cushioning effect to obviate recurrence of damages. All these factors combined together necessitated raising of the crest. Excessive raising was more beneficial, but it was apt to have a corresponding effect in increasing flood levels and greater submergence of the surrounding areas. The raising of crest was therefore restricted by 2.0 ft. (from R.L. 622.50 to R.L. 624.50) which in turn raised the high flood level at Barrage from R.L. 637.00 to R.L. 638.00 corresponding to a discharge of 2,25,000 cusecs as advised by the Flood Commission. The raising of the crest as shown in Plate No. 12 involved:—

(*i*) *Providing anchorage with the existing floor.*—This was done by drilling holes one foot deep spaced at 5 ft. interval with the pneumatic drills. Anchor bars were then fitted and holes properly grouted with concrete. The old surface was thoroughly washed, cleaned with wire brushes, joints raked out, surface chiselled and rubbish blown off with air jets.

(*ii*) *Providing bond with piers.*—This was accomplished by providing grooves by removing alternative layers of pier masonry. Masonry surfaces liable to come in contact with the concrete were then thoroughly washed, cleaned with wire brushes and nicked to provide adequate bond.

(*iii*) *Providing appropriate thickness of concrete at the ends of glacis.*—The Upstream and Downstream glacis with slopes of 1 : 5 and 1 : 12.62 respectively were normally to end in very small thickness at the toes. It was argued that thickness of concrete less than 9″ would not be stable. Accordingly a layer of stone masonry and cement concrete on Upstream and Downstream sides of the existing floor were dismantled to provide stable keys at the tail ends of the modified glacis. As a further precaution, the lime

concrete under the stone masonry on Upstream was excavated in a width of 4″—6″ to provide a bed sleeper for making a better union with the thin Upstream floor.

(*iv*) *Providing sill girders.*—The existing structure did not have any sill girders for resting the weir gates which resulted in heavy leakages and waste of precious water. On raising of crest in reinforced cement concrete 1 : 2 : 4, opportunity for providing sill girders was also availed of Rectangular bed blocks with anchor bolts, were precast and placed at suitable intervals in each bay. Two number sill girders (Mild steel I-Section Girders 12″×5″—each 21′—2″ long) were then seated over the bed blocks in each bay levelled properly and adjusted in the alignment of weir gate before concreting for raising of the crest.

After preparing the ground in the aforementioned manner, the top reinforcement was bound with the anchor bars and concreting done at the rate of one weir bay per day.

Extending Piers

The existing piers with rounded Downstream ends give a poor velocity distribution which affect the formation of the hydraulic jump and create undesirable swirls. Experiments revealed that unstable jump formation was largely eliminated with stream lined extension of the piers tapering in a slope of 1:6 on the downstream.

Monolithic extension at site was not possible as the well foundations did not exist any distance beyond the bottom end of the existing piers. Puncturing of the floor for providing additional wells for monolithic extension of the pier was not considered safe in view of excessive differential head. It was therefore decided to:—

(*i*) Extend the pier up to tail end of the well foundation (1st stage) monolithic with the existing pier.

(*ii*) Provide an expansion joint and

(*iii*) Extend the balance portion (Second stage) resting over an independent reinforced concrete raft built after dismantling upper layer of existing stone masonry.

Taking advantage of the Nil flow Downstream, the dismantling work for extension in the 1st stage was started in October 1964. Alternate courses of the existing masonry were removed, surfaces cleaned, brushed and washed for providing good bond with the new masonry.

The extension in the 1st stage was soon completed but 2nd stage extension had to be deferred till closure when the effect of uplift pressure had been eliminated on depletion of upstream pond. The upper layer of stone masonry was then dismantled and suitable number of anchor bars were provided in the manner discussed under "Raising Weir Crest". After laying the R.C.C. raft, the balance portion of pier extension was then built over the same by providing one inch wide expansion joint in between. The detail of the work is shown in Plate No. 12.

Friction Blocks

Flatter glacis, non-existence of a deep cistern and friction blocks on the Downstream of the Barrage did not create favourable conditions for the formation of a defined hydraulic jump. In the absence of proper energy dissipation, huge scours occurred which resulted in dislocation of stone apron and concrete blocks. These scours at times approached as far as the Downstream well line and could result into colossal damage. The phenomena recurring almost every year was a big burden on the maintenance of the Headworks and thus demanded immediate remedial measures.

Irrigation Research Institute conducted a series of model tests and initially suggested replacement of the existing baffle wall with 2 rows of blocks 3 ft. cube. Knocking down of the baffle wall was ruled out as being a safety factor against uplift. Further experiments were therefore continued and the final results were to:—

(*i*) Extend the baffle towards Upstream and provide a row of blocks 2 ft. cube on its top.

(*ii*) Provide another row of triangular blocks $3' \times 2' \times 1.5'$ at the Downstream end of the existing baffle.

For the extension of baffle and first row of friction blocks, holes were again drilled in the existing floor, anchor bars grouted, joints raked out, surfaces nicked, cleaned and washed for making proper bond of new concrete with the old work.

The 2nd row of triangular blocks was more tricky, as construction of simply a triangular portion, howsoever nicely jointed by anchor bars with the existing sloping surface would not have been a solid structure. Sloping surfaces of the existing baffle at the site of triangular blocks were therefore completely dismantled, anchor bars provided in the top layer of the existing floor and recessed rectangular blocks built up to get a protection of desired triangular shape.

The construction of the friction blocks was commenced soon on depletion of the Upstream pond and completed simultaneously with concreting for the Downstream steel sheet pile cap.

Upstream Floor

Floods of the past years had badly damaged the floor Upstream of the well line and restoration thereof without a deep cut off would not have been of any use. Location of sheet pile cut-off Upstream of the existing floor and loose protections would have further widened the floor which apart from being costly was technically not required. The damaged nature of the floor and subsequent heterogeneous protections did not permit location of sheet pile cut-off away from the well line. It was therefore decided to:—

(*i*) Have no reliance on the 100 ft. width of damaged floor Upstream the well line.

(*ii*) Provide steel sheet pile line cut-off with bottom R.L. 602.50 just Upstream of the well line and restrict width of impervious floor up to this end.

(*iii*) Protect the cut-off and impervious floor by providing a few rows of concrete blocks followed by stone apron to guard against anticipated scours.

After construction of Coffer Dam No. 3 and pumping the surface water, removal of over-burden deposited over the floor area was commenced. This was followed by dismantling and excavation for sheet piling, concrete blocks and stone apron. After driving the sheet piles to designated levels, the same was covered with concrete cap duly jointed with the existing floor by forming steps over the well masonry. Shells of cement masonry 1: 4 were then built over one ft. thick layer of stone and filled with 1 : 3 : 6 concrete to form concrete blocks.

Sheet Piling on Upstream

A row of 10 ft. deep masonry wells (with gaps in between) at the end of modified width of Upstream floor was neither considered a reliable cut-off nor deep enough to guard against anticipated scours. It was therefore proposed to provide 16 ft. deep steel sheet pile cut-off with bottom R.L. 602.50 just Upstream of the existing shallow wells by enclosing the Lower Bari Doab Canal Head Regulator on the Left and butting against the flank wall on the right.

The piling rigs normally give good performance, if the top of sheet piles after driving does not go lower than the top of its rail track. To create such situation, excavations up to R.L. 617.00 were needed right from the start. Since the pumping arrangements in the beginning had not been very satisfactory and as firm soil to stable the heavy piling rig was not available even at R.L. 617.00, alternative proposals had to be considered.

Advantage of the nearness of well line was taken as the same could accommodate the heavy load of the piling rig and take care of the jerks on its

hammerings. The track was therefore laid over the well line and 2 No. piling rigs assembled over it.

On driving the sheet piles it was noticed that the top of pile would not go lower than R.L. 621.00. Further lowering was then managed by drop hammer supported by a small crane, but the process was found to be extremely cumbersome, risky and gave very low progress. The piling rigs were then improvised by elongating the guides of the monkeys to afford hammering at elevations lower than the rail top and thereafter the system worked very well. The end piles were made to butt against the well foundations of the flank walls and the adjoining zone grouted thoroughly with neat cement up to the bottom of the sheet piles for making the cut-off fully effective.

Remodelling Downstream Floor

The downstream well line having gaps in between could not be termed as an effective cut-off. Springs used to be noticed in the past which led to the desirability for providing a steel sheet pile cut-off at the tail end of the impervious structure to check the exit gradient. Zone of inverted filter at the end of impervious floor for the release of residual pressures was also missing. During floods, the scour approached close to the well line which was least desirable for safe function of the structure. The old blocks had mostly been washed off or were deeply settled and the huge scours used to be filled up after floods by haphazard dumping of the stone. A situation of this type could not be allowed for such a vital structure and the need for adequate protections was gravely felt. The downstream protections were therefore provided on modern concepts in the following manner:—

(*i*) 30′—9″ wide inverted filter was provided downstream of the impervious floor segregated from the loose protection by constructing 3′ wide concrete toe wall. The inverted filter was to have the following composition:—

After preparation of the base and spreading a layer of 3″ coarse sand, 6″ layer of graded shingle followed by another layer of 6″ rock spawl were laid. A layer of 9″ thick revetment stone was then provided and on its top brick masonry shells for concrete blocks having intervening jharries of 3″ were constructed. The concreting of the shells was then done by providing at the bottom a layer of building paper and the gaps between the blocks filled with shingle. With these arrangements, it is expected that the residual pressures shall be effectively released in this zone and in turn blowing up of the sub-strata would automatically be controlled.

(*ii*) Beyond concrete toe wall, an adequate width of loose protection to guard against anticipated scours was provided in the form of:—

3 rows of concrete blocks laid over 1.5 thick revetment stone in a width of 15.75 ft. and 4′ thick stone apron in a width of 60 ft.

After enclosing the working area on the downstream of the Barrage and its dewatering, excavation and dismantling operations were started. The stone encountered was salvaged for reuse and earth dumped at the inner toe of the coffer dam for additional safety. On inspection of the area, it was noticed that in certain reaches the old blocks were in good shape and dismantling thereof simply for laying of the inverted filter was not considered desirable. In such cases old blocks were kept in position and the intervening gaps (Jharries) fully opened, cleaned, washed and refilled with shingle to affect drainage of the area. At other places where old blocks had either been washed off or got settled, new concrete blocks were rebuilt after preparation of the inverted filter as discussed earlier. After building concrete blocks and concrete toe walls, the loose stone apron was constructed mostly by the reuse of salvaged material.

As the water table could not be depressed beyond R. L. 612.50, all excavations and dismantling at lower levels were done in water. This retarded the progress to some extent, but did not effect the overall plan of completing the work.

It would be worthwhile to mention here that all excavation and dismantling operations were tackled by manual labour and no machinery had been engaged to surmount such a difficult job.

Sheet Piling on Downstream

It was proposed to provide 16 ft. deep steel sheet pile cut off with bottom at R.L. 597.00 on the Downstream of the existing wells. Having regard to the settled concrete blocks and apron in the past many years, it was feared that the driving of sheet piles in the zone of loose protection would not be possible. Certain quarters suggested location of the pile line on upstream of the existing wells. Conscientious opinion was not in favour of puncturing the impervious floor at the tail end, as, such a junction would have remained a permanent weak spot. It was opined that the 1st row of concrete blocks might not have settled at deeper elevations under scour, as the loose protection generally rolls down in a slope. Although nothing could be said with certainty, yet a bold decision was taken to drive the sheet pile just on the Downstream of the existing well line,

Like upstream, the piling rigs could not be stabled over the well line at the sloping end of downstream floor. The piling rigs had therefore to be run downstream of the well line and erection of 2 such machines started accordingly. Anticipating difficulties in sheet piling, it was desirable to locate the rail track at stable ground after excavation to designated levels, but this involved dismantling of at least 3 rows of existing blocks. Such a wasteful dismantling and rebuilding afterwards was not desirable, and the piling rigs had to be assembled on the top of 2nd and 3rd row of existing blocks. The work was started with such odd limitations from a central place to proceed outwards in both directions.

A further problem arose as to the location of the piling rigs in the zone where existing blocks had been settled or washed off. In such cases the piling rigs were lowered by construction of a ramp and relocation of the track at lower levels. Obstructions in the form of odd settled blocks were however overcome by temporarily bridging such spans with the sheet piles.

The trench for the sheet piles was normally lower from the top of the blocks by about 5.5 ft. and while hammering, the loose base under 2.5′ thick existing blocks got disturbed, which put the whole driving operations into danger. The piling rigs had therefore to be kept always secured by jacking all the four corners and in spite of best efforts, one of the piling rigs turned turtle in the 2nd Phase of the work. Luckily the rig got stuck with an adjoining obstruction and a major accident was averted.

While excavating the trench, old settled blocks at elevations lower than the bed of the trench were also noticed. These blocks were removed as much as they could be dismantled in standing water and the rest used to give way on repeated hammering of the heavy sheet pile. Similar obstructions in the form of odd settled stone were overcome by excessive hammering of the sheet pile.

As in the case of Upstream, the end of piles were made to butt with the well foundations of the flank walls and the adjoining zones grouted with neat cement up to the bottom of the sheet pile to make the cut off fully effective.

Grouting

Sand blowing springs had been noticed in the past and the structure being old, possibility of cavities and runnels underneath the same could not be ruled out. Likewise, the Downstream floor consisting of laminations of lime concrete, lime masonry, cement masonry, cement concrete etc. placed in stages from time to time was structurally weak and cavities in certain layers could exist. On clearance of the Upstream floor, a few cracks particularly at the junction of the stone masonry with concrete floor repaired in 1954-55

had been noticed. Grouting of the impervious floor and sub-strata underneath was therefore considered desirable to make the structure reliable.

The floor area was cleared of overburden, thoroughly washed and cleaned with wire brushes to obtain bare surface. All visible crevices were opened out, nicked properly and filled with rich cement mortar.

Holes at 40′ interval were then drilled with the pneumatic drill and the sub-strata grouted with fine sand at pressures of 4 and 5 lbs./sq. inch on Upstream and Downstream of the Barrage, respectively. Another series of holes-2 rows on the Upstream (one near the Upstream well line and another near the toe of glacis) and 2 rows on the Downstream (one near the end of existing piers and another near the friction blocks) were drilled at variable depths and neat cement grouted into the impervious floor.

Repairing Roller Boxes and Sill Gates of L.B.D.C. Head Regulator

The upper gates of Lower Bari Doab Canal Head Regulator did not rest properly on the rising sill gates as with the constant use, the roller boxes of the latter had been badly damaged. This resulted into heavy leakages during closure of the canal which was least desirable for effective regulation.

The replacement or repairs of the roller boxes involved removal of the sill gates which could only be accomplished on dismantling of its superstructure. The process being tricky, laborious and time-consuming could not be handled during normal closures of short duration and it seemed that ever since the construction of the Headworks, no repairs or replacement of these roller boxes had been done.

The opportunity afforded by the long closure of L.B.D.C. Head Regulator during Remodelling Operations in the 1st Phase was therefore availed of. During this period, the whole of the superstructure was dismantled, sill gates taken out, new plates welded by removing the patches corroded by constant water action and roller boxes repaired and replaced for effective regulation of the canal.

Completing 1st Phase

The various operations of the work were carefully planned, organized and most of the items commenced in advance. This coupled with day and night work enabled completion of the difficult task (fitted in a tight schedule), 19 days ahead of the programme on 27-1-65. The commencement and completion for different phases of the work as compared to the schedule are shown in Plate No. 14.

While remodelling weir bays No. 12 & 13, concrete toe walls connecting the impervious floor and extending up to the end of stone aprons on Upstream and

Downstream were constructed under the base of coffer dam No. 5 to prevent leakage of water on enclosing the area for the 2nd Phase. To ensure further stability, the zone of stone apron and concrete blocks were grouted with clay and a few masonry dwarf walls constructed on the pacca floor. The construction of coffer dam No. 5 opposite weir bays No. 12 & 13 thus created an auxiliary pocket between bays No. 13 to 19 into which materials and machinery were shifted for works in the 2nd Phase.

The left portion of the Barrage having been remodelled, the Lower Bari Doab Canal could now be fed through its own Head Regulator and weir bays Nos. 1—11 could be utilized for the disposal of winter freshets on enclosing the right side of the Barrage for the 2nd Phase.

In order to reactivate the normal system of regulating both the off-taking channels from their own Head Regulators, it was essential to remove the Coffer dams from the canals, the river on the left side and to close the cut in the common bank between L.B.D.C. and B. S. Link. The work was originally contemplated by availing a short closure from 21—28-2-65. A closure in the month of February being not suited to the cropping pattern was reluctantly agreed by the Irrigation Department.

Remodelling works of the 1st Phase had been completed ahead of schedule, and as there was ample time for the stipulated opening of Balloki-Sulemanki Link from 1-3-65, it was in the interest of irrigation to explore ways and means by which removal of the coffer dams and closing the common bank could be manipulated without affecting a canal closure. With this objective in view, the operations were replanned as below:—

(*i*) Dislodge bagged protection along Coffer Dams No. 3 & 2 in standing water with the help of a Drag Line.

(*ii*) Scrape coffer dam No. 2 on the top and make a few cuts to enable flow into the canal on opening from L.B.D.C. Head Regulator.

(*iii*) Scrape coffer dam No. 3 and make a few cuts for allowing the river water to head up against weir bays 1—11 for disposal of winter freshets.

(*iv*) Steadily close bays 1 to 7 Balloki-Sulemanki Link Head Regulator, feed L.B.D.C. through the remaining bays 8 to 11, and wash down a portion of Coffer Dam No. 3 to clear the Head Regulator for opening of Balloki-Sulemanki Link with effect from 1-3-65.

(*v*) Close all the gates of Balloki-Sulemanki Link Head Regulator and open Lower Bari Doab Canal from its own Head Regulator thereby creating a pool of water in Balloki-Sulemanki Link up to Coffer Dam No. 1-A.

(*vi*) Close common bank between Lower Bari Doab Canal and Balloki-Sulemanki Link in the standing water and strengthen to full width for safety against failure on releasing the trapped supply of Balloki-Sulemanki Link.

(*vii*) Dislodge bagged protection of Upsteam face of Coffer Dam No. 1-A with the help of a Drag line and make a few cuts for releasing the trapped supply.

All the operations were manipulated in the sequence given above without affecting a canal closure and thus 126,000 acre feet of precious water was utilized for benefit of Irrigation.

PHASE II

Anticipating advance completion of work in 1st Phase by the end of January 1965, steps for undertaking the work in the 2nd Phase were also initiated well ahead of schedule as below:—

Enclosing the Working Area

Construction of Coffer Dam No. 4 Upstream of weir bays 20-35 was started from Pitched Island side in the last week of January 1965 by utilizing earth scraped from Coffer Dam No. 3 and by removal of river deposits rendered dry while working in the 1st Phase. This provided dual benefit of cleaning the area in the 1st Phase and simultaneous construction of Coffer dams for the 2nd Phase. For safety against leakage at its junction with Right Guide Bank Upstream, it was originally planned to remove stone pitching and stone apron for making an earth to earth joint. This could only be done on depletion of pond level which involved another canal closure. As removal of Coffer dams of 1st Phase and restoration of common bank were manipulated without affecting canal closure, therefore depletion of pond simply for making a better junction with the guide bank was not considered advisable. Past history revealed that no fresh dumping of stone along Right Guide Bank Upstream had been done since last many years. A sufficient width of stone apron was noticed to have been covered by the formation of silty berms which led to believe that the crevices between the stone pitching and apron would be fully packed. Although nothing could be said with certainty, yet decision was taken to butt the Coffer dam with the Right Guide Bank Upstream without adopting the planned protective measures. The coffer dam was, however, widened at its junction with the Right Guide Bank as a further safety measure and the arrangements worked satisfactorily. After completing coffer dam No. 4 in the 1st week of February 1965, the weir gates in the right half were raised to drain off the headed up supplies.

Immediately thereafter the erection of coffer dam No. 4-A on the Downstream was started by scraping coffer dam No. 3-A and the area in the 2nd Phase completely enclosed by the middle of February 1965.

Dewatering Arrangements

The main rush of sinking Tubewells in the 1st Phase was over by the end of December 1964. Sinking of tube-wells for works in the 2nd Phase was therefore started much in advance as discussed below:—

(*a*) *Upstream.* A sufficient number of Tubewells had already been sunk in the auxiliary pocket and along the pitched Island shank for blocking the seepage line on heading up supply against coffer dam No. 5. A wide berm on the right side of Pitched Island shank afforded further opportunity for sinking more Tubewells before enclosing the working area in the 2nd Phase. After construction of coffer dam No. 4 and release of headed-up supply a row of Tubewells was sunk near the toe of coffer dams and another row sunk in the zone of concrete blocks. This effectively lowered the water table to designated levels and created dry working conditions on the Upstream of weir.

(*b*) *Downstream.*—The river bed opposite weir bays 20—32 was found to have been silted up at higher levels and the sinking of tubewells in this area could be done before erecting coffer dam No. 4-A on the downstream. Luckily no stone obstruction was encountered and a sufficient number of tubewells were ready for lowering the water table even before enclosing the working area. The surface water collected in a natural depression formed by the river along Right Guide Bank was disposed of by open pumping. The tubewell pumping helped by open pumps effectively depressed the water table thus enabling all dismantling operations in dry.

Remodelling Operations

After enclosing the working area and depression of water table, the shank of pitched island and Coffer Dam No. 3-A downstream opposite weir bays 19 & 20 were punctured to connect the auxiliary pocket with the weir bays on the right. All the operations like raising the crest, extending piers, constructing friction blocks, sheet piling remodelling Upstream and Downstream floors, grouting etc. were then continued as in the case of 1st Phase. After remodelling the Upstream floor, the punctured shank of Pitched Island was again restored.

Pitched Island Shank

Pitched Island shank standing almost in the middle of the Barrage was liable to river attack during high floods. The top of the shank was 13 ft. wide and had been placed just one foot above the last designed High Flood Level. With the remodelling of the Barrage for increased flood discharge of 225,000 cusecs and proposed rise of High Flood Level by one ft. the work necessitated some treatment for future reliability. The problem was tested on model and it had been established that both sides of the shank should be protected with stone pitching and apron up to a distance of 900 ft. from the gate line. The shank

was therefore raised by providing 2 ft. free board above the modified High Flood Level. The portion of the shank up to 400 ft. from the gate line (within the zone of Coffer dams) liable to severe river action was protected by excavating the silty berms up to the Upstream floor level. The balance portion of 500 ft. (outside the enclosure bunds) being less vulnerable to river attack was protected at higher elevation as shown in Plate No. 13.

After completing all the remodelling works, in the 2nd Phase a few cuts were made in the coffer dams and the whole of Barrage opened to river from 17-5-65 *i.e.*, 30 days ahead of schedule.

QUALITY CONTROL

Sample of concrete aggregates and sand as manufactured at WAPDA Quarry along with local sand were sent for analysis to determine admixture of various ingredients in the concrete work. It was observed that mixing of aggregates size 3/16″ to 3/4″ with aggregates size 3/4″ to 1½″ in the ratio of 4:1 gave results conforming to American Standard of Testing Materials. For ascertaining admixtures of manufactured sand with the local sand, a series of compression tests were made and mixing of aggregates done as below:—

(*a*) Aggregates size 3/16″—3/4″ and size 3/4″—1½″ mixed in the ratio of 4 : 1 for all types of concrete work.

(*b*) Manufactured sand mixed with local sand for different types of work as below:—

(*i*) 1:3:6 Plain Concrete : 20% manufactured sand

(*ii*) 1:2:4 Reinforced cement concrete : 80% manufactured sand

(*iii*) 1:2:4 Plain concrete for Cap of sheet pile on U/S. 20% manufactured sand.

(*iv*) 1:2:4 Plain concrete for cap of sheet pile on D/S. 80% manufactured sand.

While concreting, representative samples of the mixes were taken at regular intervals and compression tests thereof gave results as contemplated.

All mixing was done in concrete mixers and no concreting was allowed to proceed without the use of pneumatic wrigglers.

ACKNOWLEDGEMENTS

The Remodelling of the Balloki Headworks was an intricate job and the successful completion in a single working season ahead of schedule was a result of judicious planning, concerted efforts and hard work. This was rendered possible due to close collaboration of all agencies associated with the Project.

Thanks are due to the Irrigation Department, Chief Engineer, I.B.P., WAPDA: Chief Engineer, Remodelling Organisation, Project Director, Links Construction Project, WAPDA, and Messrs T & K, WAPDA Consultants whose personal efforts and active guidance paved the way to success.

Annexure

REMODELLING

STATEMENT OF EXPENDITURE

S. No.	Description of work	Total cost of the work	
		Estimated	Actual (Approximate)
		Rs.	Rs.
1.	Survey and investigations ..	15,000	2,000
2.	Providing one No. siding at Balloki and renovating Railway Track from Chhanga Manga to Balloki. ..	10,65,165	8,97,000
3.	Constructing temporary buildings for staff and store for materials. ..	4,40,000	2,40,000
4.	Making feeding arrangements for L.B.D.C. during remodelling operations. ..	5,35,870	2,60,000
5.	Installation of power transmission lines and Sub-stations. ..	6,00,000	6,00,000
6.	Reconstructing Spur No. 4 at Balloki Headworks. ..	6,79,764	6,80,000
7.	Reconstructing Spur No. 3 at Balloki Headworks. ..	8,68,614	6,80,000
8.	Constructing Spur No. 10 at Balloki Headworks. ..	4,61,280	3,40,000
9.	Remodelling pitched island (nose) ..	2,75,282	2,46,000
	Upstream Balloki Headworks. (shank) ..	4,66,253	4,70,000
10.	Remodelling upstream floor and providing sheet-piles at Balloki Headworks. ..	22,97,496	15,50,000
11.	Raising Crest and modification of upstream and downstream glacis of Balloki Barrage. ..	18,82,323	14,60,000
12.	Remodelling downstream floor protection and providing sheet piles at Balloki Headworks. ..	36,39,715	27,10,000
13.	Extending piers downstream Balloki Barrage ..	2,34,185	2,80,000
14.	Grouting U/s & D/s impervious floor of Balloki Barrage. ..	5,08,435	42,000
15.	Remodelling L.B.D.C. Head Regulator ..	1,91,735	1,27,000
16.	Raising and Strengthening marginal bunds and other protective works at Balloki Headworks. ..	11,75,000	11,00,000
17.	Constructing Coffer dams for enclosing the working area at Balloki Headworks. ..	26,39,915	11,30,000
18.	Dewatering of working area at Balloki Headworks. ..	23,94,000	13,90,000
19.	Repairing and examination of damaged floor at Balloki Headworks. ..	6,38,422	3,42,000
	Total ..	2,10,08,454	1,45,46,000

"A"

BALLOKI BARRAGE

AND MATERIALS CONSUMED

Stone & spawl salvaged from the work	Salvaged stone and spawl re-used on the work	New Materials				Remarks
		Shingle	Manufac-tured sand	Pitching stone and spawl	Steel sheet piles	
Cft.	Cft.	Cft.	Cft.	Cft.	Ton	
..	..	..	..	..	..	
..	..	..	..	..	..	
..	..	..	..	..	..	
29,596	..	2,139	..	63,500	..	
..	..	..	..	..	..	
..	..	..	..	3,18,000	..	
..	..	..	..	4,81,000	..	
..	..	..	..	3,00,000	..	
..	..	..	..	2,08,000	..	
51,748	3,38,244	..	..	..	..	
1,07,751	76,025	96,485	9,054	..	483.11	
15,000	..	1,04,630	41,800	..	..	
4,06,312	4,48,125	2,08,628	42,482	16,000	395.30	
6,300	..	9,581	3,330	..	..	
..	..	..	..	..	..	
..	..	5,500	540	..	52.02	
..	..	..	..	..	..	
57,228	9,450	2,260	250	67,867	..	
..	..	..	..	..	..	
10,453	12,530	8,506	850	..	..	
6,84,388	6,84,374	4,37,729	98,326	14,54,367	930.43	

Annexure "B"

REMODELLING BALLOKI BARRAGE

A. Machinery Engaged

	No.
Dozers	6
Scrapers	13
Pumping sets	40
Sheet piling rigs	4
Cranes	2
Grader	1
Water Tankers	2
Cyclone Drill Machine	1
Drag lines	2
Compressors	4
Low Bed Trailors	2
Trucks	6
Concrete mixers	6

B. Labour Engaged

Skilled coolies	200
Unskilled coolies	1500
Semi-skilled coolies	100
Donkeys	1100
Camels	100

Annexure "C"

REMODELLING BALLOKI HEADWORKS

PERTINENT DATA

	Last designed	Remodelled	
1. Capacity (cusecs)			
(*a*) Barrage	139500	225000	
(*b*) L.B.D.C.	6300	8650	
(*c*) B. S. Link	15182	18500	
2. Highest flood level (Upstream)	637.00	638.00	
3. Highest flood level (Downstream)	634.40	635.20	
4. Width between abutments (feet)	1646.5	1646.5	
5. Waterway (feet)	1400	1400	
6. Pond level	632.0	633.0	
7. Crest level	622.41	624.50	
8. Number of bays	35	35	
9. Width of bay (feet)	40.0	40.0	
10. Crest width (feet)	11.0	5.0	
11. Upstream floor level	621.0	621.0	
12. Downstream floor level	615.5	615.5	
13. Upstream cut-off (feet)	10.0 (wells)	18.5	Steel sheet pile.
14. Downstream cut-off (feet)	15.0 (wells)	18.5	
15. Length of Upstream impervious floor (feet)	214.0	119.50	
16. Length of Downstream impervious floor (feet)	103.78	116.28	
17. Differential Head across Weir (feet)			
Designed	17.93	17.50	
Restricted to	13.00		

Annexure "D"

REMODELLING BALLOKI HEADWORKS EXECUTED FOR THE GOVERNMENT OF PAKISTAN

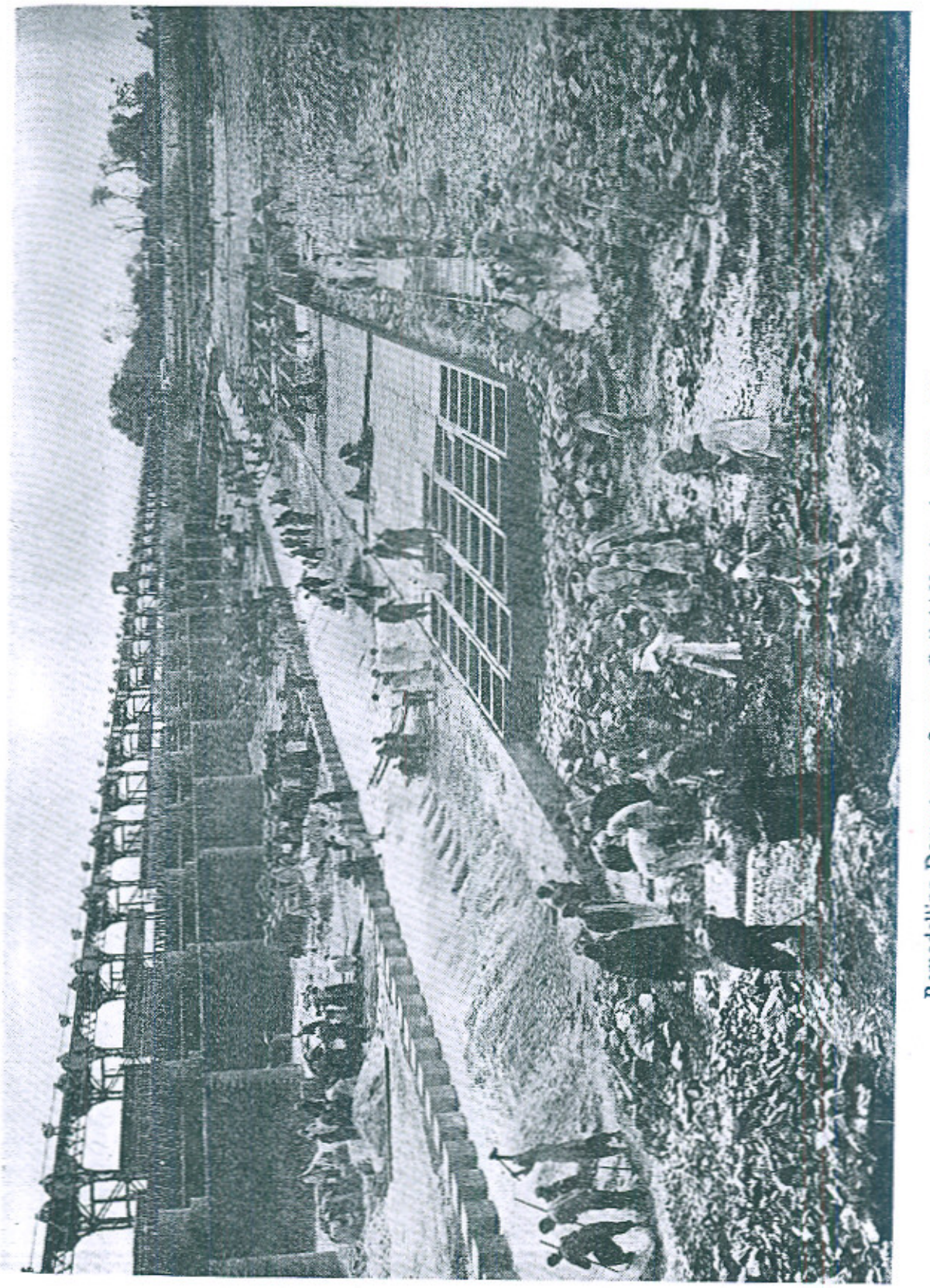
BY THE

WEST PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

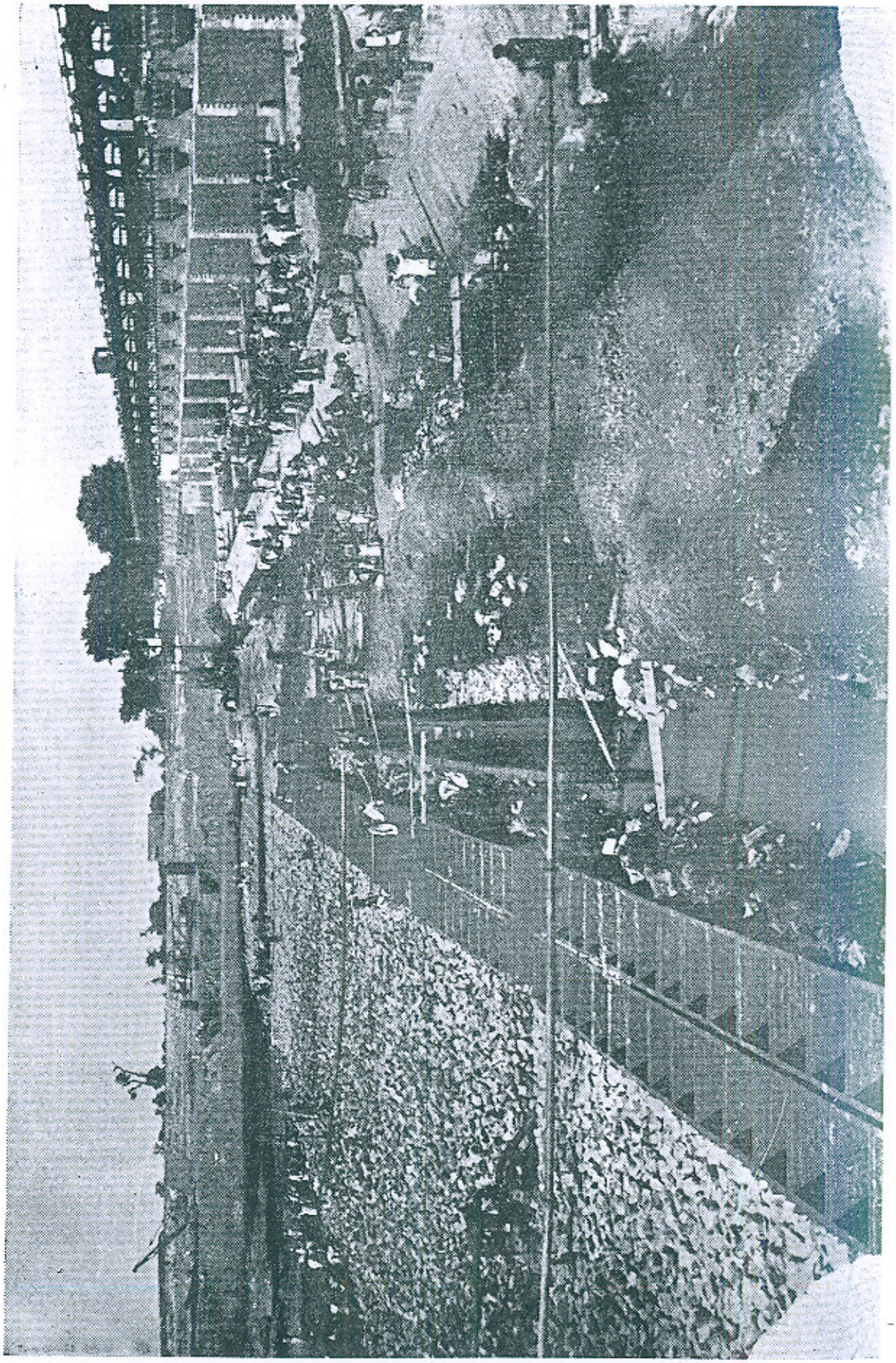
UNDER

INDUS BASIN DEVELOPMENT FUND

Name of Project	..	Remodelling Balloki Headworks.
Financed by	..	The International Bank for Reconstruction and Development.
Engineers	..	1. Remodelling Organization, WAPDA (For Design, Drawings and Documentation)
		2. Links Construction Directorate, WAPDA. (For Construction)
Contractors	..	1. M/s. M. A. Rashid Said Alam Khan (For Civil Works).
		2. Machinery Pool Organization, WAPDA (For Mechanical Works)
Review Consultants	..	M/s. Tipton and Kalmbach Inc. Engineers, Denver, Colorado, U.S.A.
General Consultants	..	M/s. Harza Engineering Company (International), Chicago, U.S.A.

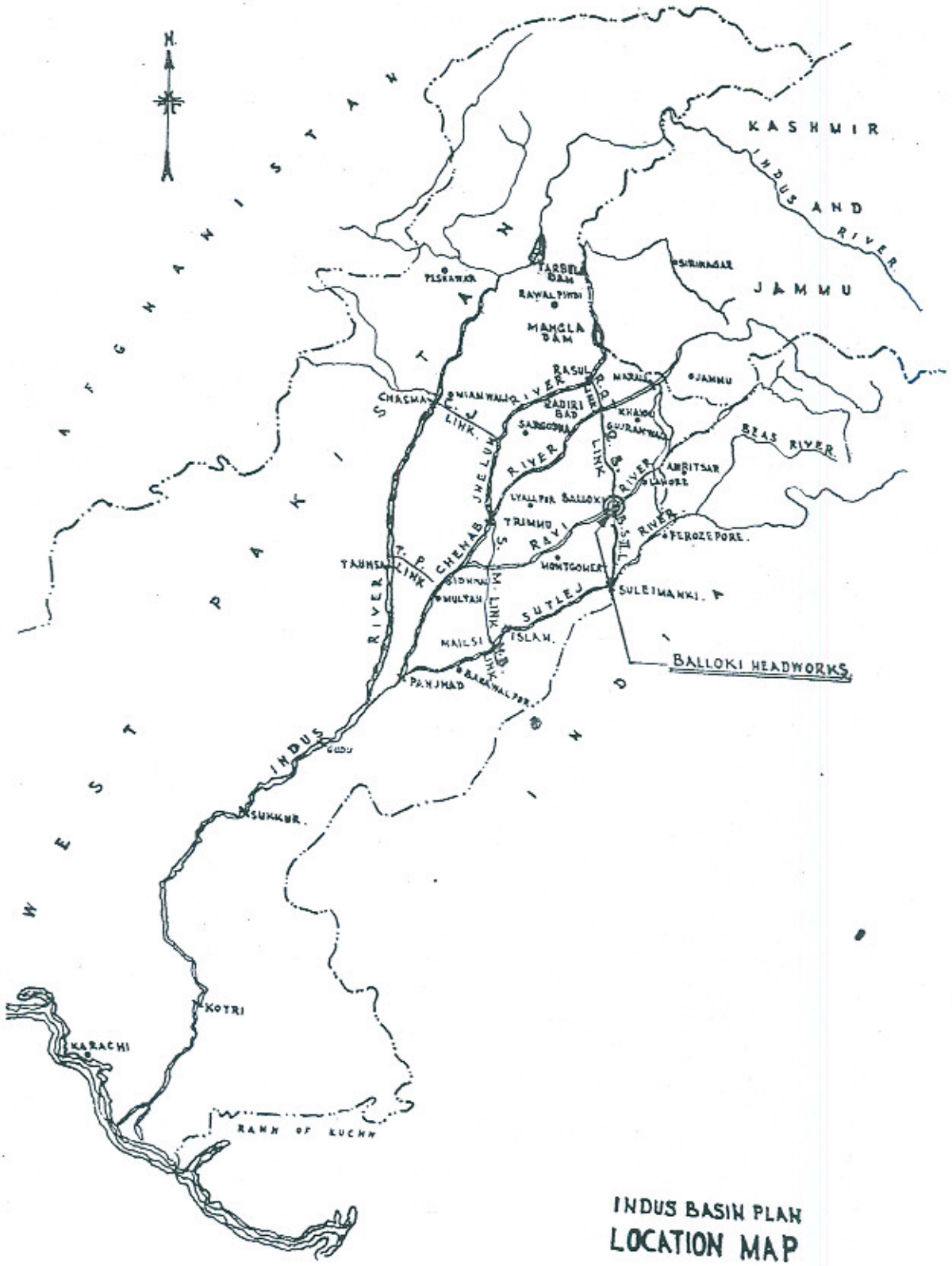


Remodelling Downstream floor at Balloki Headworks (Right side)

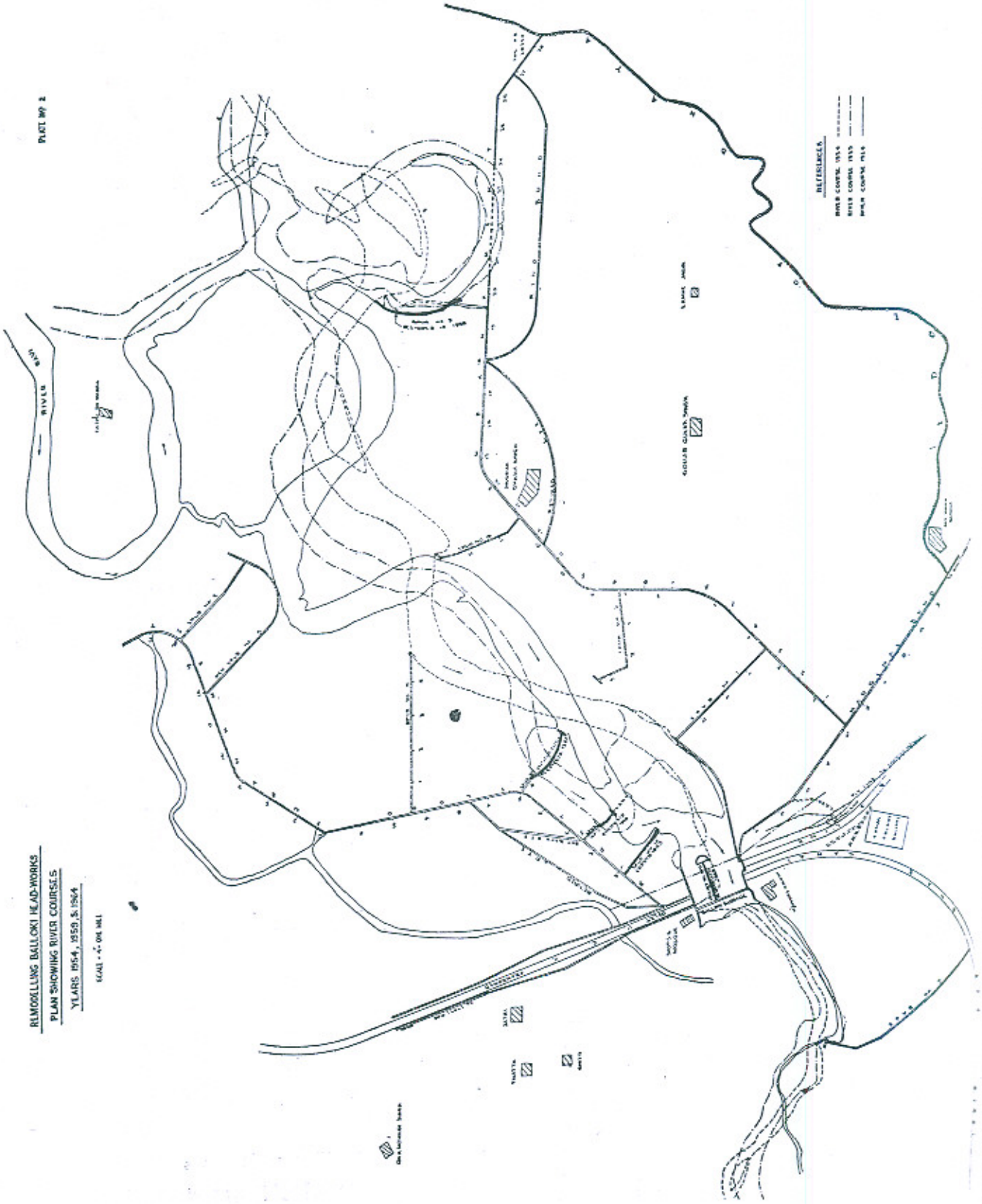


Remodelling Downstream floor at Bailoki Headworks (Left side)

PLATE No 1.



INDUS BASIN PLAN
LOCATION MAP


REMODELLING BALLOKI HEAD-WORKS
PLAN SHOWING RIVER COURSES
YEARS 1954, 1959 & 1964
REFERENCES

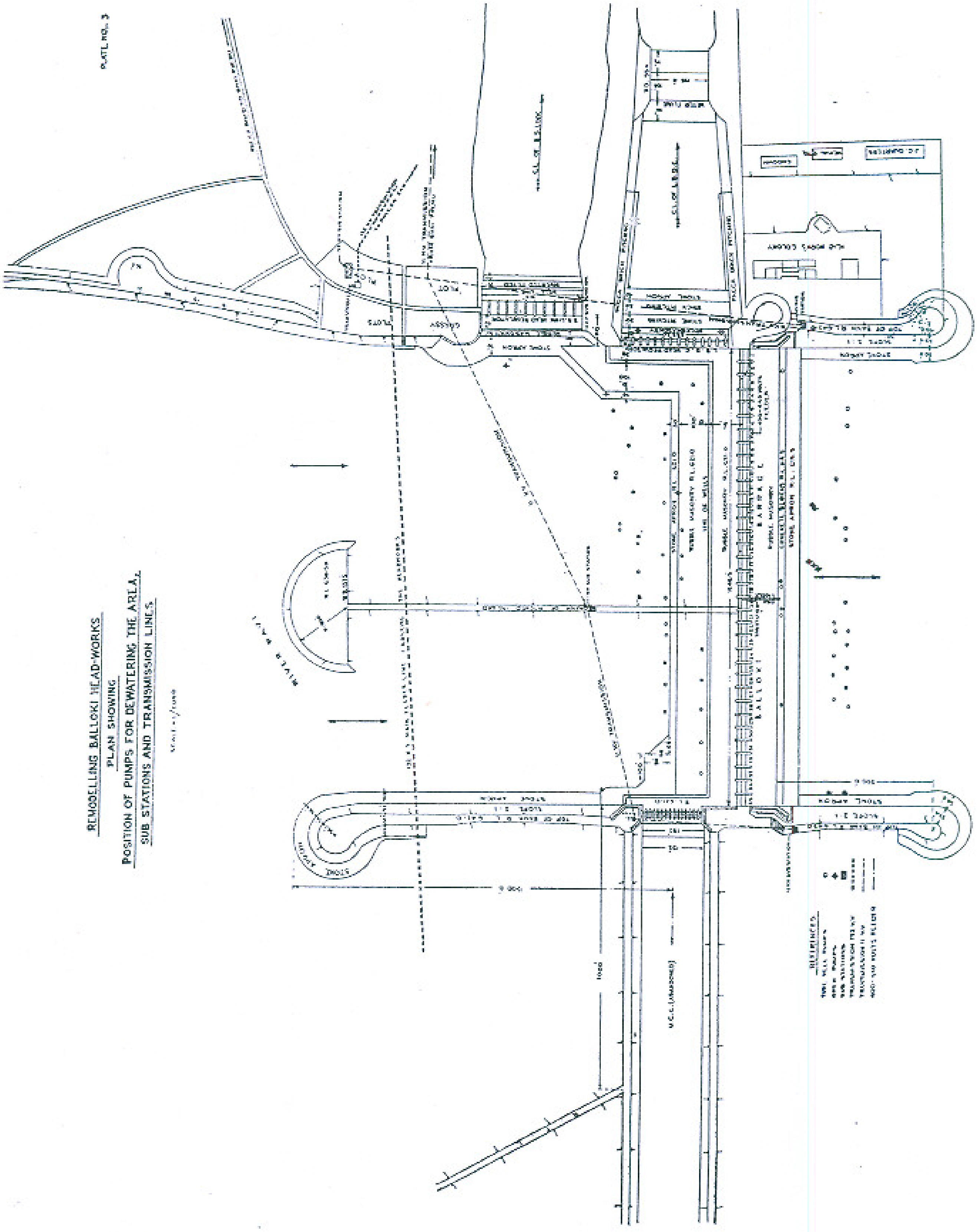


PLATE No. 3
REMODELLING BALLOKI HEAD-WORKS
PLAN SHOWING
POSITION OF PUMPS FOR DEWATERING THE AREA,
SUB STATIONS AND TRANSMISSION LINES
BALLOKI BARRAGE
REFERENCES

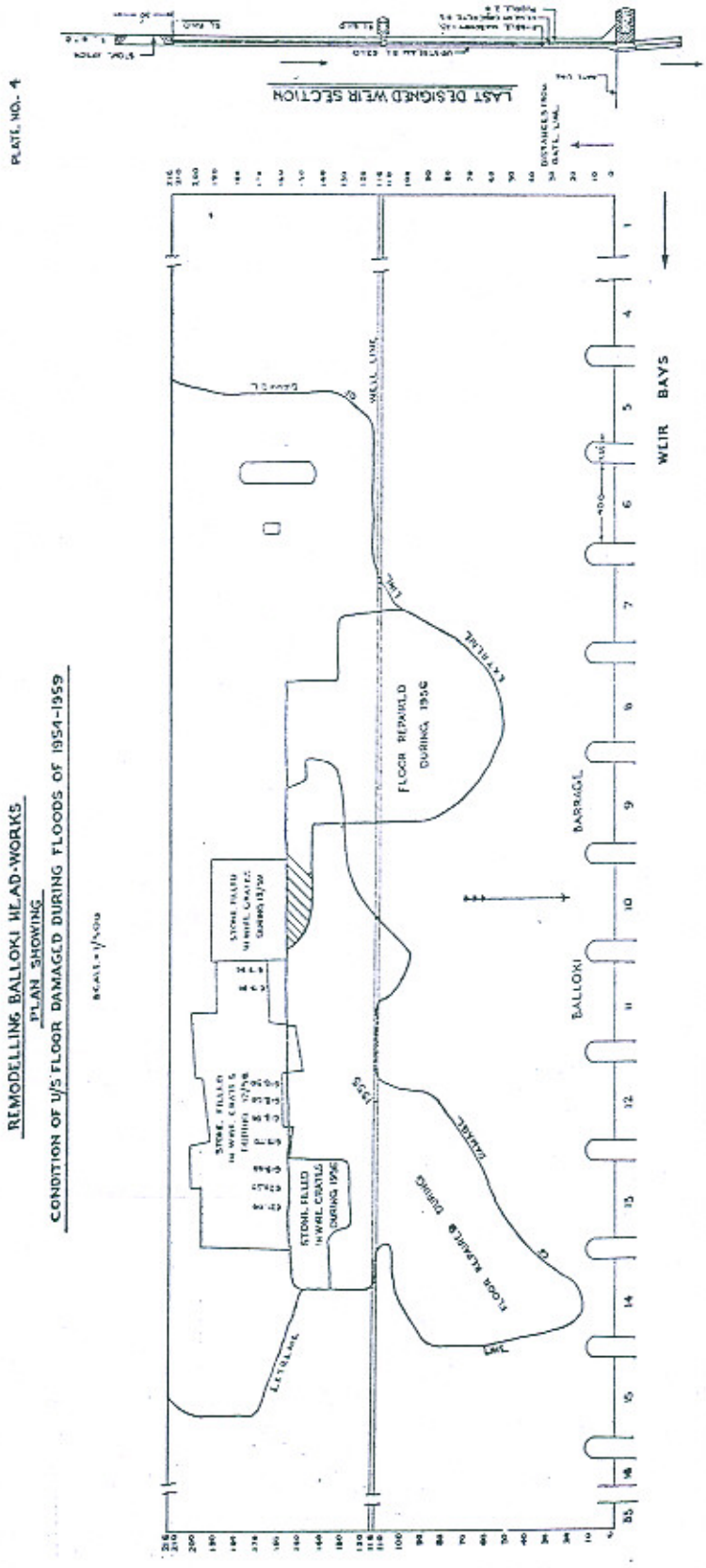
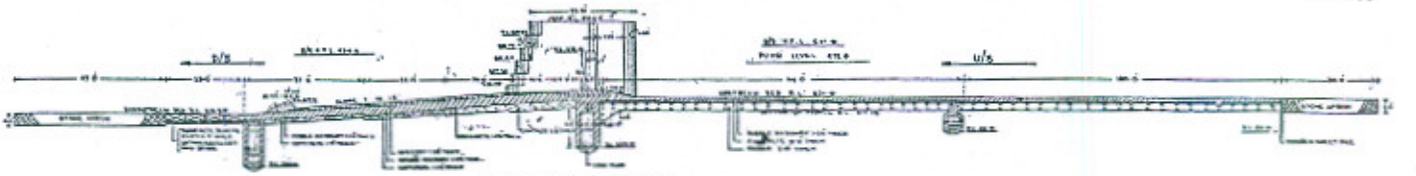


PLATE NO. 4
REMODELLING BALLOKI HEAD-WORKS
PLAN SHOWING
CONDITION OF U/S FLOOR DAMAGED DURING FLOODS OF 1954-1959
LAST DESIGNED WEIR SECTION
WEIR BAYS
BARRAGE
BALLOKI
FLOOR REPAIRED DURING 1956
FLOOR DAMAGED DURING 1956
STONE FILLED IN WIRE CRATES DURING 1956
STONE FILLED IN WIRE CRATES DURING 1958
EXTERNAL
WELL LINE

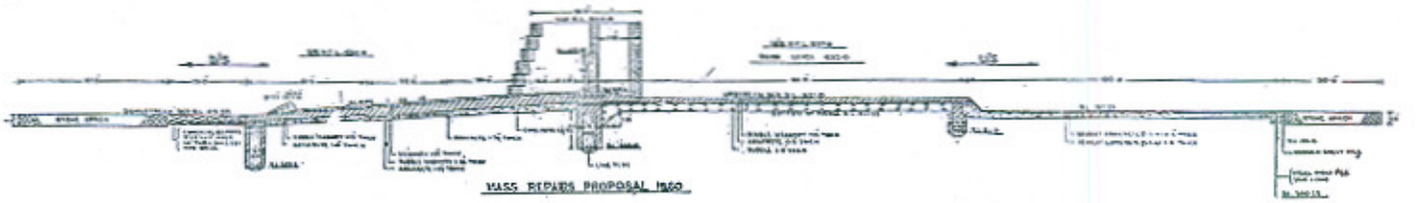
REMODELLING SALLOKI HEAD-WORKS.

SCALE-1/200

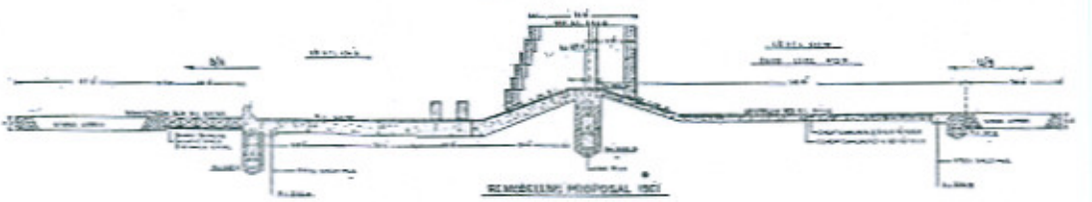
PLATE NO 5



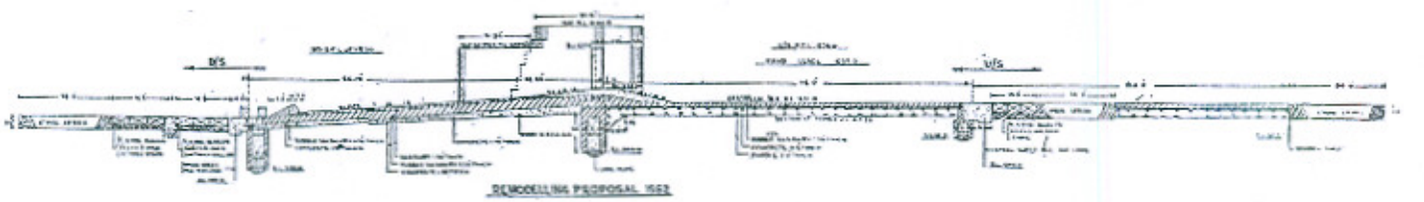
LAST WORKS WEIR SECTION



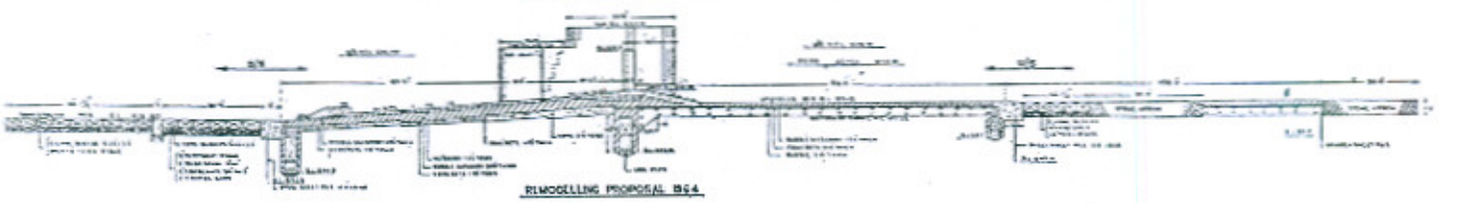
MASS REPAIRS PROPOSAL 1960



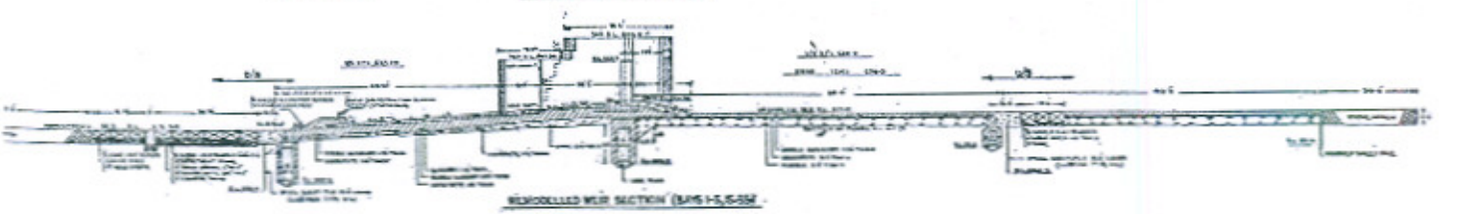
REMODELLING PROPOSAL 1961



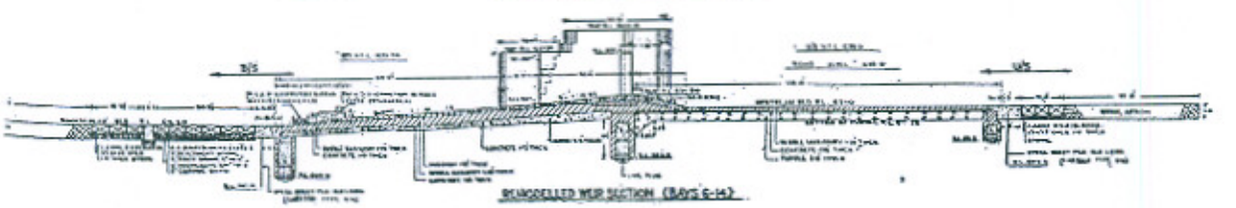
REMODELLING PROPOSAL 1963



REMODELLING PROPOSAL 1964



REMODELLED WEIR SECTION (BAYS 1-5, 8-15)



REMODELLED WEIR SECTION (BAYS 6-14)

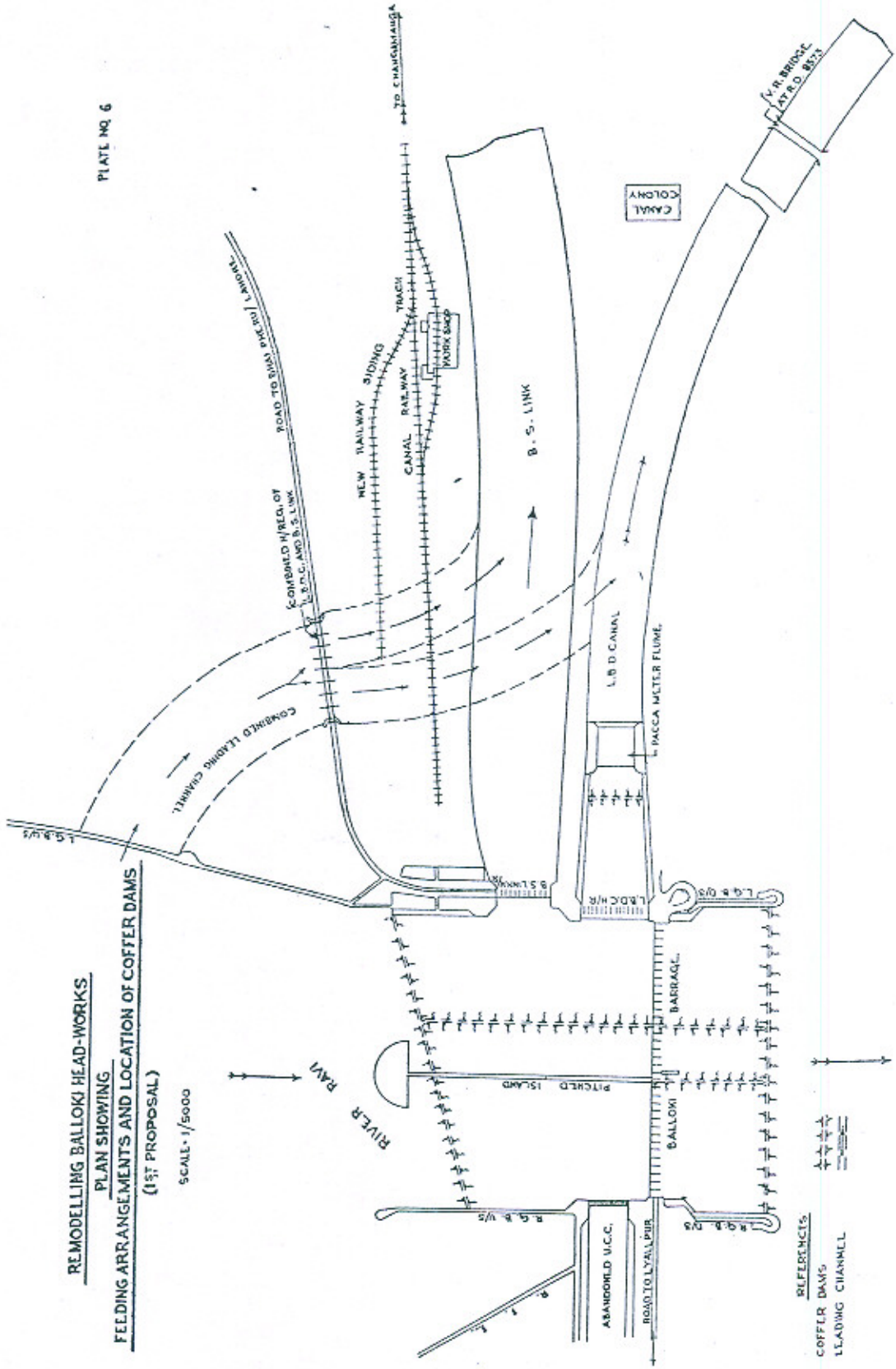
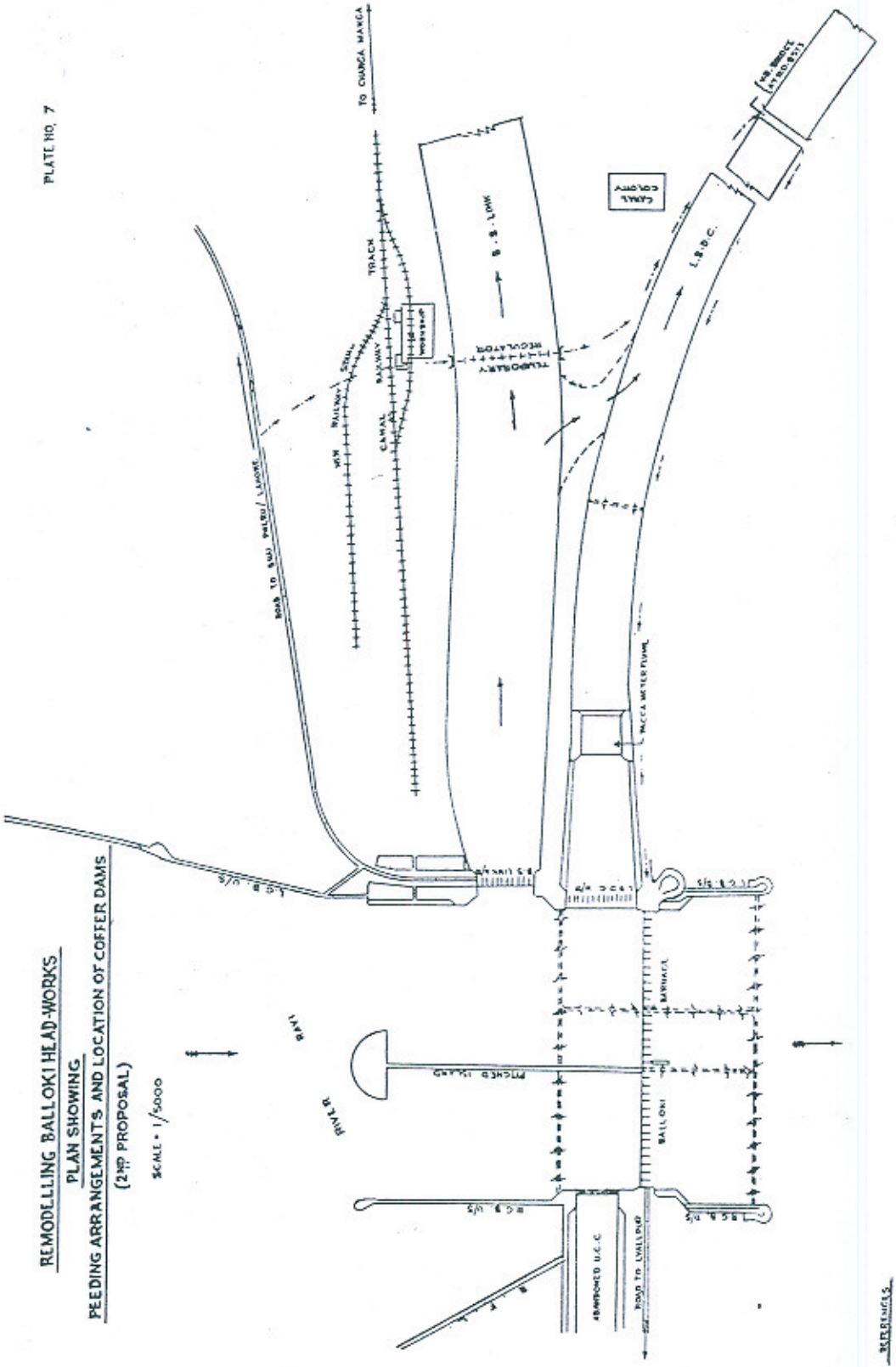


PLATE NO 6
REMODELLING BALLOKI HEAD-WORKS
PLAN SHOWING
FEEDING ARRANGEMENTS AND LOCATION OF COFFER DAMS
(1ST PROPOSAL)
SCALE 1/5000
TO CHUNIANWALA
V.R. BRIDGE AT R.D. 85.5
CANAL COLONY
ROAD TO BHAI PHERU
NEW RAILWAY SIDING
CANAL RAILWAY TRACK
WORK SHOP
B.S. LINK
L.B.D. CANAL
PACCA WATER FLUME
COMBINED L.B.D.C. AND B.S. LINK
COMBINED L.B.D.C. AND B.S. LINK
L.B.D.C. H/R
B.S.L. H/R
L.B.D.C. U/S
L.B.D.C. D/S
BARRAGE
PITCHED ISLAND
BALLOKI
RIVER RAVI
R.B.D.C. U/S
R.B.D.C. D/S
ABANDONED U.C.C.
ROAD TO LYALLPUR
REFERENCES
COFFER DAMS
LEADING CHANNEL

PLATE NO. 7



REMODELLING BALLOKI HEAD-WORKS

PLAN SHOWING

PEEDING ARRANGEMENTS AND LOCATION OF COFFER DAMS

(2ND PROPOSAL)

SCALE - 1/5000

PLATE No. 8

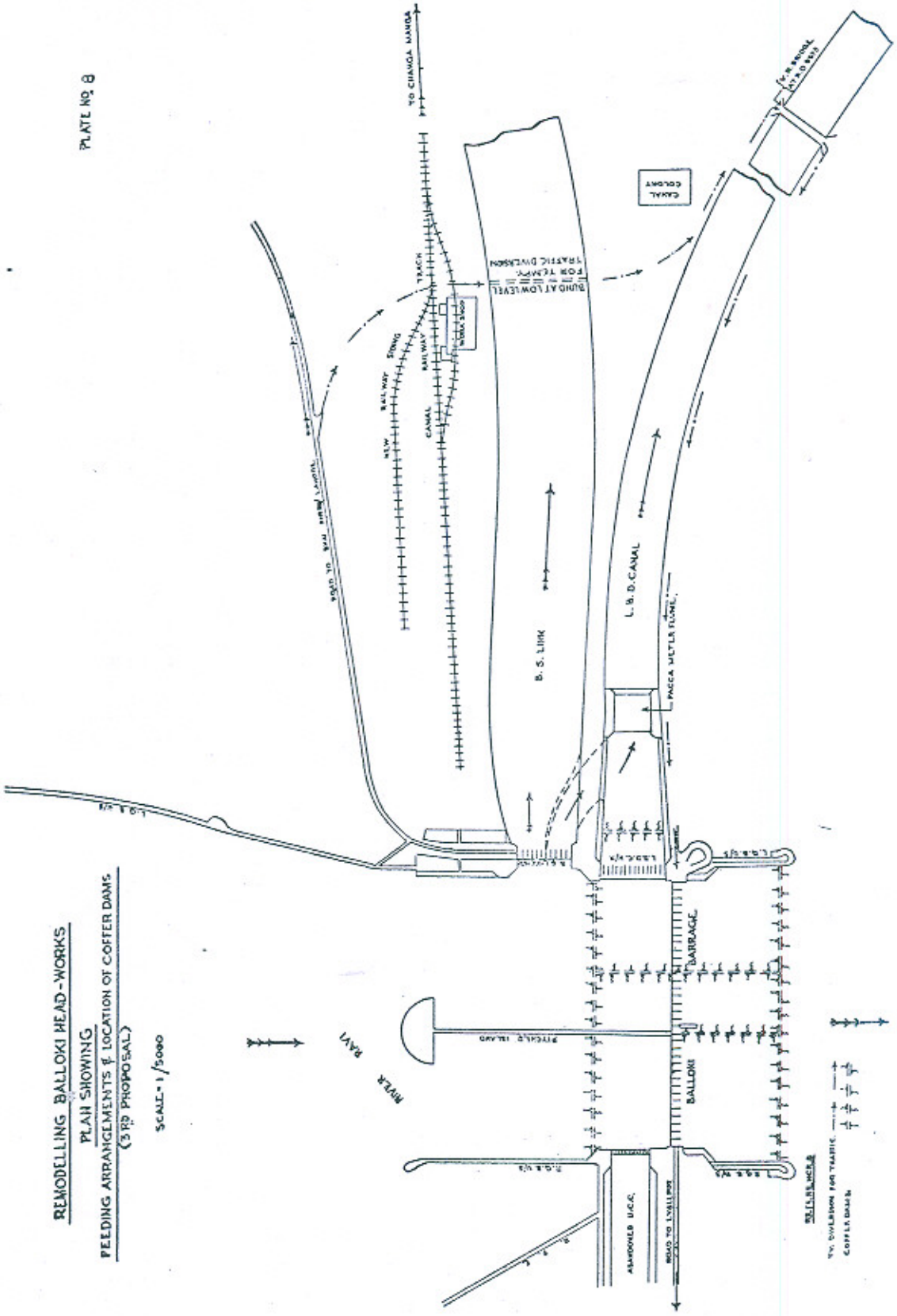
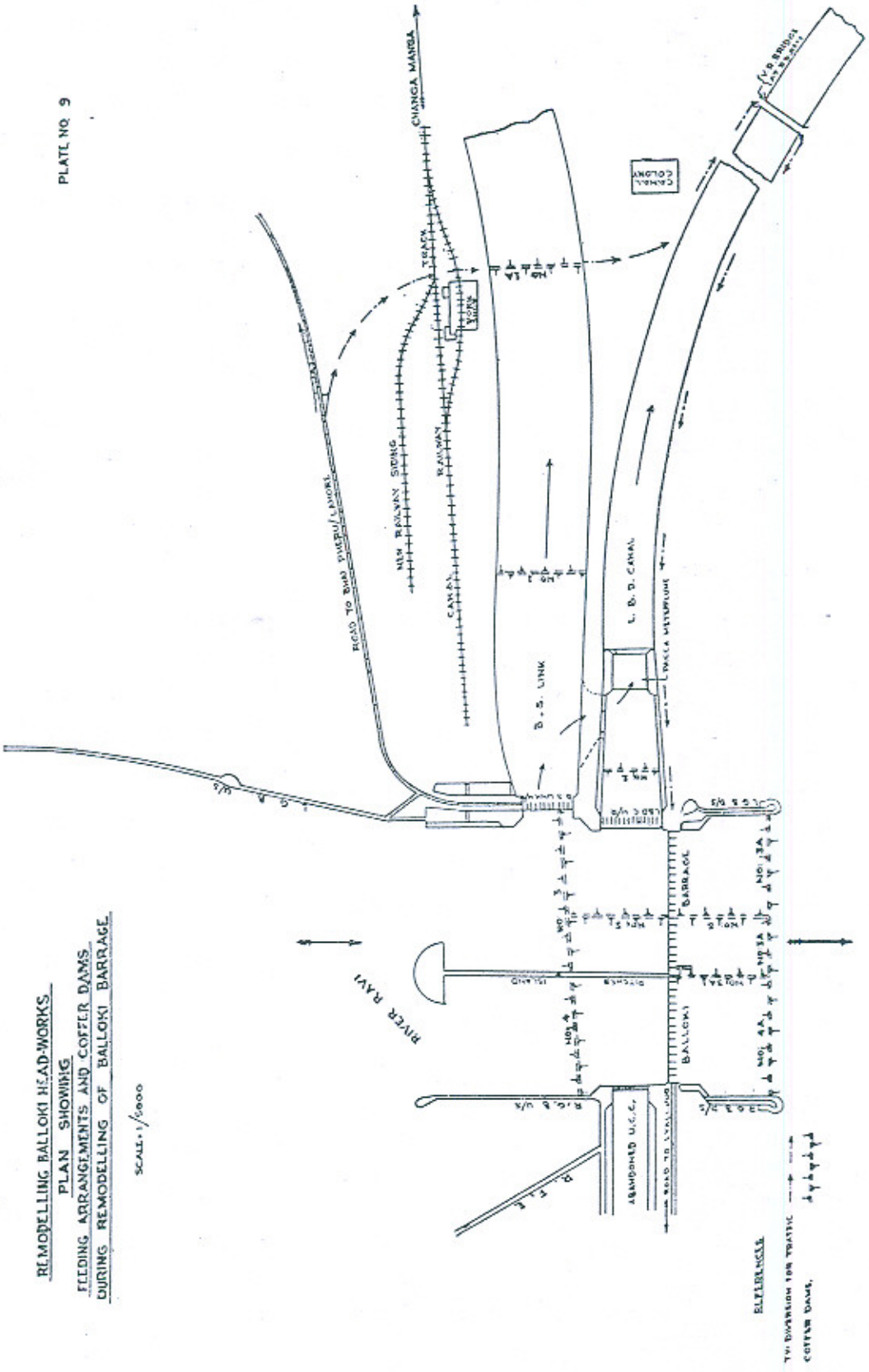

REMODELLING BALLOKI HEAD-WORKS
PLAN SHOWING
FEEDING ARRANGEMENTS & LOCATION OF COFFER DAMS
(3RD PROPOSAL)
SCALE-1/5000
TO CHANGA MANGA
BUND AT LOW LEVEL FOR TEMPY. TRAFFIC DIVERSION
NEW RAILWAY SIDING
RAILWAY TRACK
CANAL
ROAD TO KASUR
B. S. LINK
L. B. D. CANAL
CANAL COLONY
PACCA MUTLA FLUME
BARRAGE
BALLOKI
RIVER RAVI
ATCHISON ISLAND
ABANDONED U.C.C.
ROAD TO LYALLPUR
TEMPORARY TRAFFIC DIVERSION
COFFER DAMS

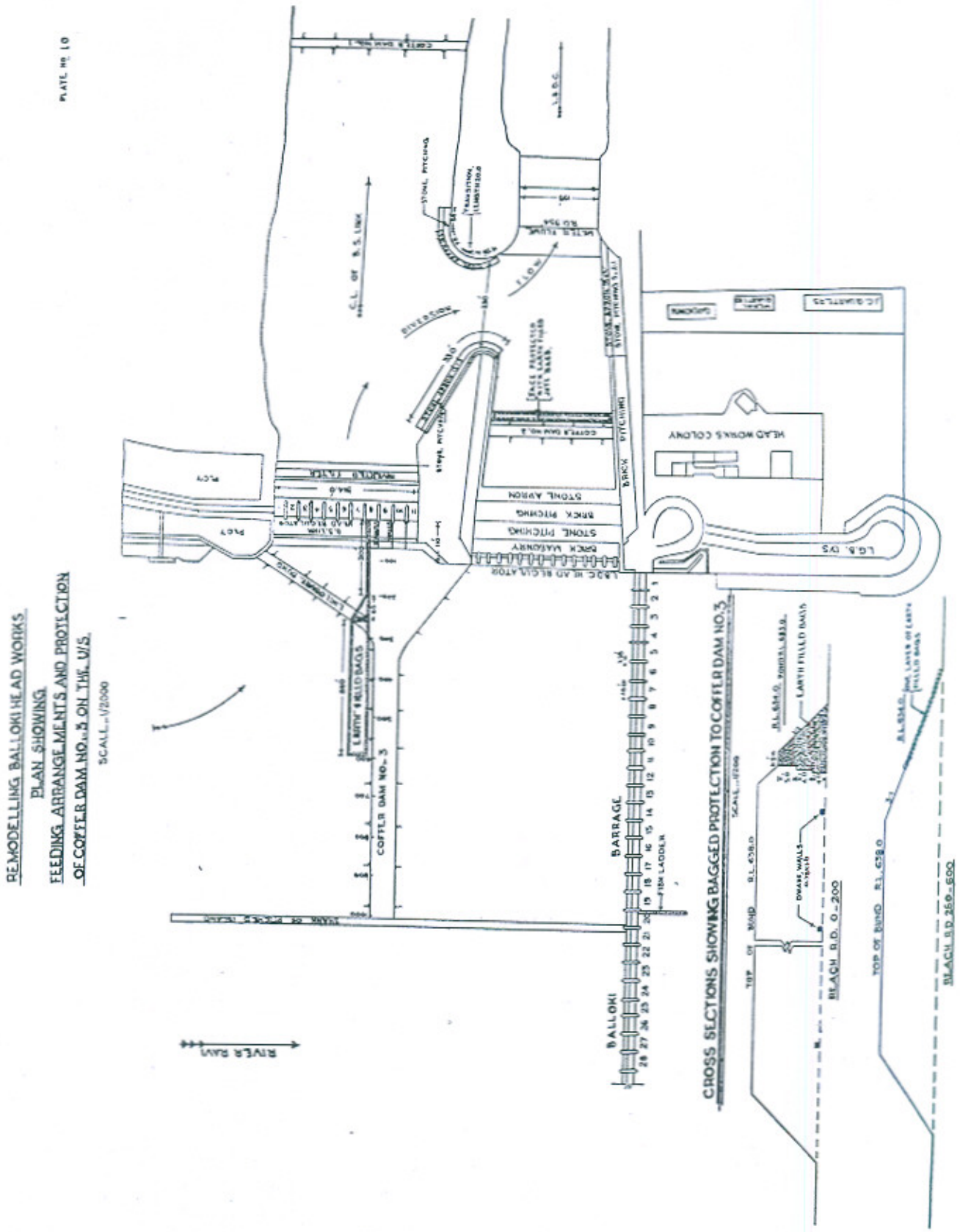
PLATE NO. 9

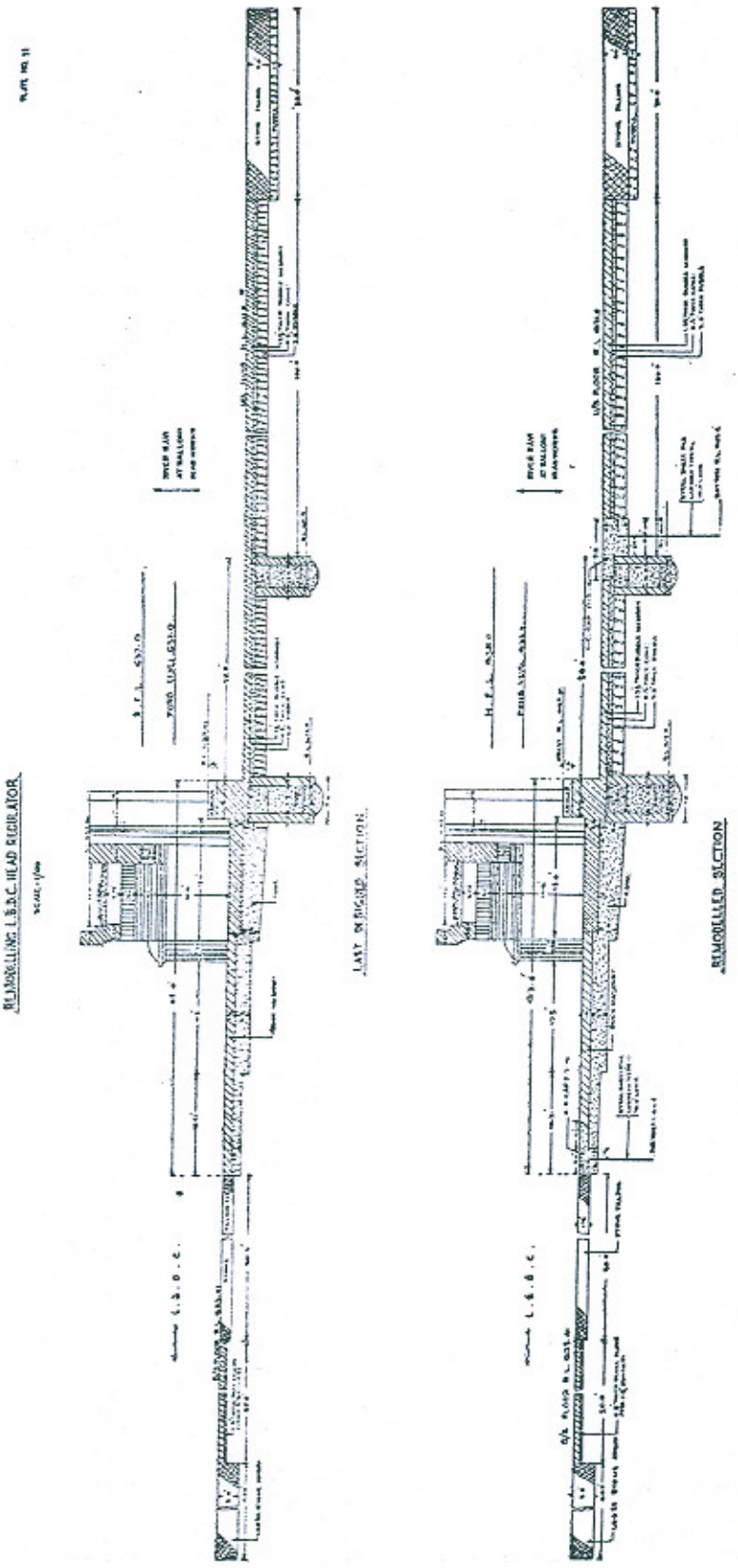


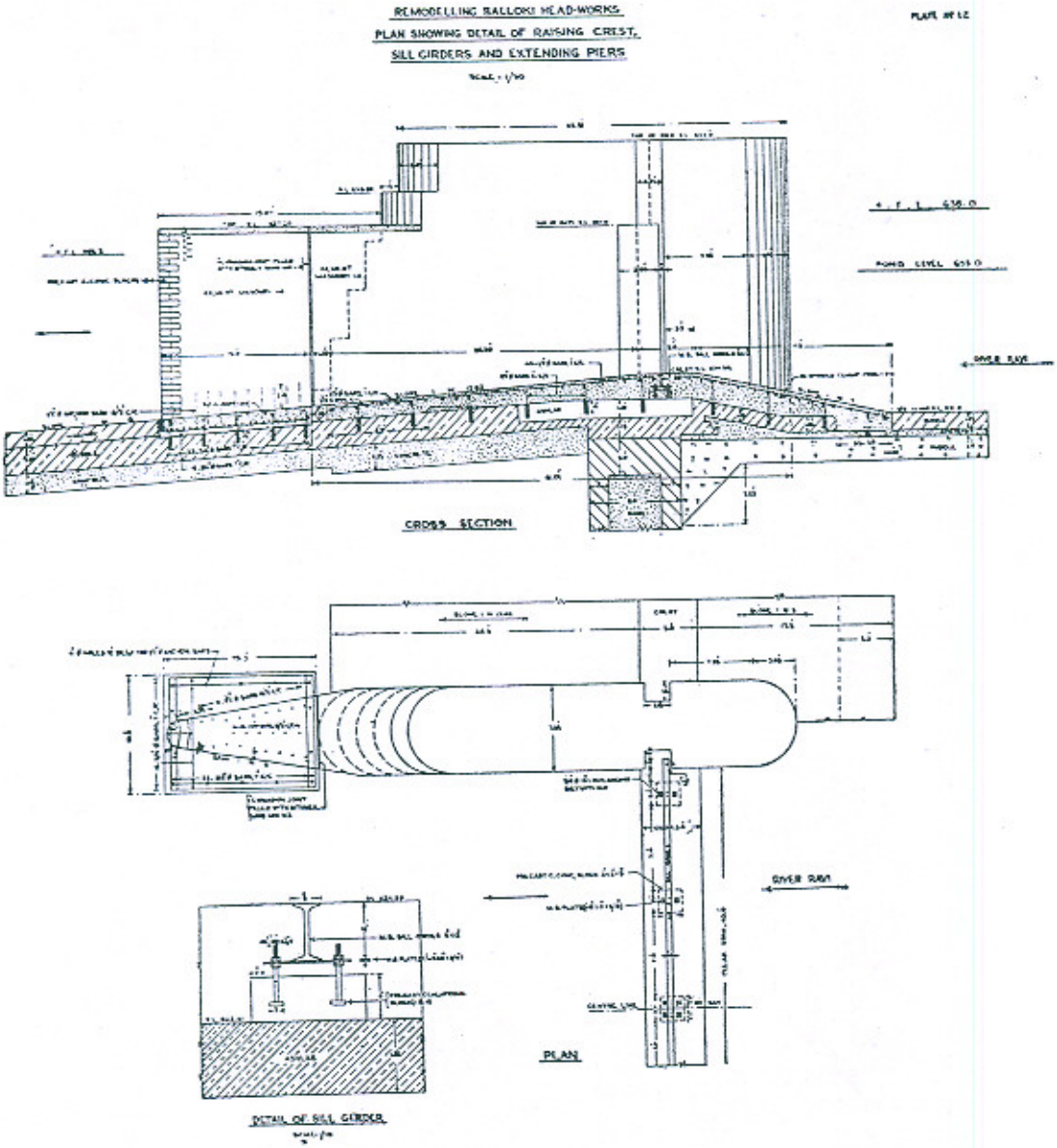
REMODELLING BALLOKI HEAD-WORKS
PLAN SHOWING
FEEDING ARRANGEMENTS AND COFFER DAMS
DURING REMODELLING OF BALLOKI BARRAGE

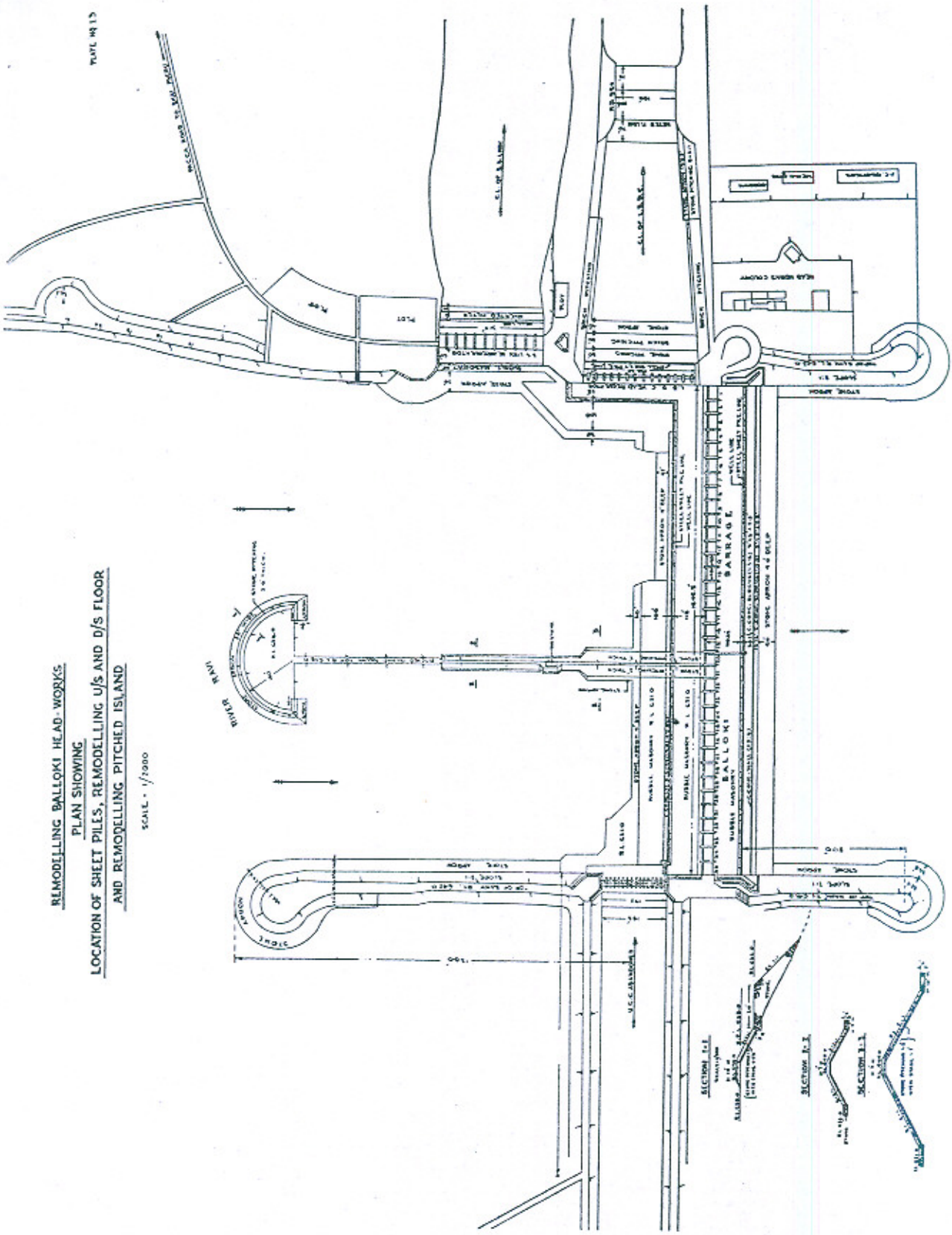
SCALE 1/6000

PLATE No 10


REMODELLING BALLOKI HEAD WORKS
PLAN SHOWING
FEEDING ARRANGEMENTS AND PROTECTION
OF COFFER DAM NO. 3 ON THE U/S.
SCALE 1/2000
RIVER RAVI
COFFER DAM NO. 3
EARTH FILLED BAGS
BARRAGE
BALLOKI
HEAD WORKS COLONY
L.B.B. D/S
STONE APRON
BRICK PITCHING
STONE PITCHING
BRICK MASONRY
DIVERSION
CROSS SECTIONS SHOWING BAGGED PROTECTION TO COFFER DAM NO. 3
TOP OF BUND R.L. 638.0
BEACH R.D. 0-200
BEACH R.D. 250-600


REMODELLING L.B.D.C. HEAD REGULATOR
LAST IN ENGINE SECTION
REMODELLED SECTION


REMODELLING BALLOKI HEAD-WORKS.
PLAN SHOWING DETAIL OF RAISING CREST,
SILL GIRDERS AND EXTENDING PIERS
CROSS SECTION
RIVER RUN
PLAN
DETAIL OF SILL GIRDER



REMODELLING BALLOKI HEAD-WORKS
PLAN SHOWING
LOCATION OF SHEET PILES, REMODELLING U/S AND D/S FLOOR
AND REMODELLING PITCHED ISLAND

SCALE - 1/2000

CONSTRUCTION PROGRAMME OF REMODELLING BALLOKI HEAD-WORKS

PROPOSED SCHEDULE ——— ACTUAL PROGRESS ———

PLATE N°14

S.NO.	DESCRIPTION OF WORK	APPROXIMATE QUANTITY OF WORK: QUANTITY	UNIT
I	DIVERSION & PREPARATION OF SITE AREA.		
	i CONSTRUCTION AND MAINTENANCE OF DIVERSION ROAD	4.0	MILE
	ii EARTH WORK IN COMMON BANK BETWEEN R.D. 0.00 & 9.6	5.0	LAC CFT
	iii ERECTION OF COFFER DAM NOS. I & 1-A IN R.D. 0.00	12.0	LAC CFT
	iv PROVIDING STONE PROTECTION AT DIVERSION CHANNEL AND BANK OPP. OF L.B.B.C.	70.0	% CFT
	v CONSTRUCTING COFFER DAM NO. 2-A ON THE D/S SIDE	35.0	LAC CFT
	vi CONSTRUCTING COFFER DAM NO. 3 ON THE U/S SIDE	24.0	LAC CFT
	vii CONSTRUCTING COFFER DAM NO. 3 IN L.B.D.C.	10.0	LAC CFT
	viii ERECTING COFFER DAM NO. 5 OPPOSITE EAST NO. 13 & 14 ON U/S R.D.	10.0	LAC CFT
	ix ERECTING COFFER DAM NO. 4 ON U/S SIDE	10.0	LAC CFT
	x ERECTING COFFER DAM NO. 4-A ON D/S SIDE	12.0	LAC CFT
	xi PART REMOVAL OF COFFER DAM NOS. 2, 3 & 3-A	10.0	LAC CFT
	xii RESTORING COMMON BANK BETWEEN L.B.D.C AND R.D. 0.00	15.0	LAC CFT
	xiii PART REMOVAL OF COFFER DAMS NOS. 2 & 2-A IN R.D. 0.00	3.0	LAC CFT
	xiv PART REMOVAL OF COFFER DAMS NOS. 4 & 4-A AND MAKING LEADING CUTS WITH EXCAVATION.	10.0	LAC CFT
II.	DEWATERING AND DEPRESSION OF WATER TABLE.	1.25	DAY
III	REMODELLING L.B.D.C. HEAD REGULATOR	DAILY PROGRESS CONSIDERED	LFT % CFT
IV	EXTENDING PIERS.	34	PIER
V	RAISING SILLS AND MODIFICATION TO GLACIS.	35	DAY
VI	EXAMINATION AND REPAIRING FLOOR.	35	DAY
VII	REMODELLING U/S FLOOR.		
	i EXCAVATION	1930	% CFT
	ii SHOT PILING	2000	LFT
	iii CONCRETING AND STONE APRON	1500	% CFT
VIII	REMODELLING D/S FLOOR.		
	i EXCAVATION	5544	% CFT
	ii SHEET PILING	1650	LFT
	iii CONCRETING AND STONE APRONS	6000	% CFT
IX	GROUTING U/S AND D/S FLOORS.	35	DAY
X	REMODELLING PITCHED ISLAND SHANK.		
	i EARTH WORK	5.0	LAC CFT
	ii STONE WORK	600	% CFT

10/64 | 11/64 | 12/64 | 1/65 | 2/65 | 3/65 | 4/65 | 5/65 | 6/65

REMARKS

DATES SHOWN SUBJECTED TO FINAL SANCTION OF GOVERNMENT.

CANAL CLOSURES

SCHEDULED ... [11.11.64 TO 10.12.64 / 22.2.65 TO 28.2.65

ACTUAL ... (11.11.64 TO 30.11.64)