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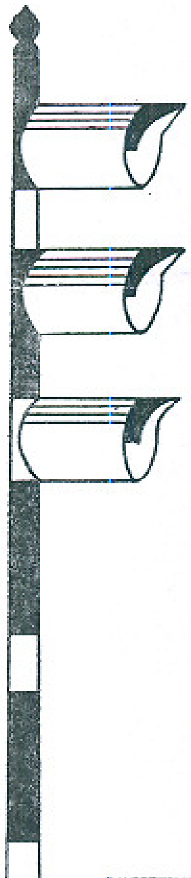
PANJAB UNIVERSITY HALL—THE VENUE OF 15TH ALL PAKISTAN SCIENCE CONFERENCE



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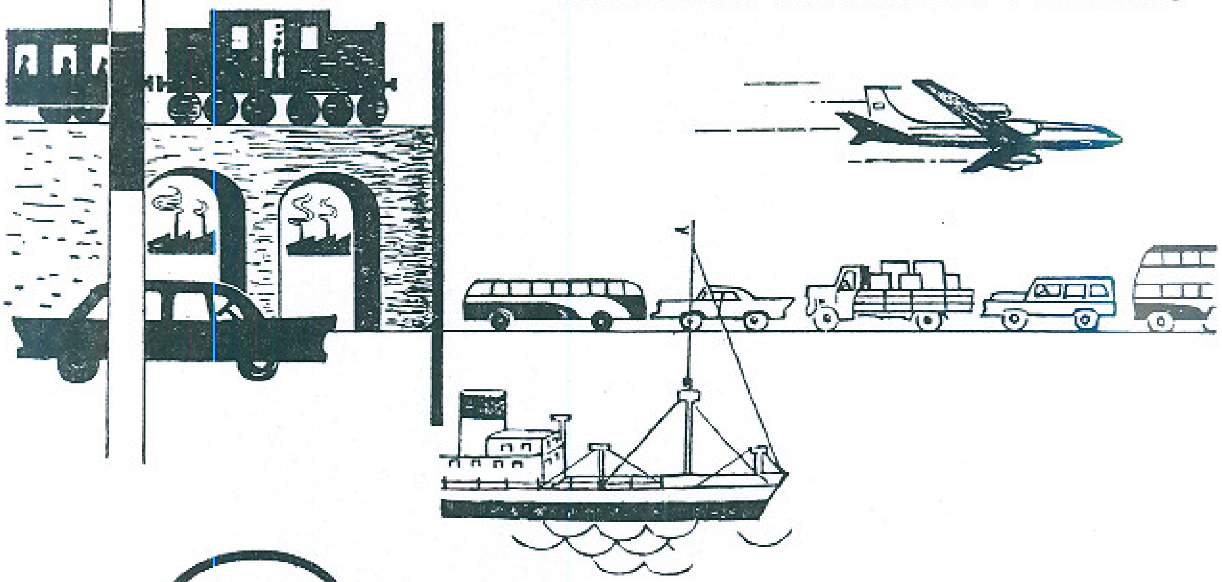

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In this issue

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Encourage Young Writers

With the publication of this issue of the "Engineering News", the magazine completes the seventh year of its existence. With all its failings, it has served at least a section of the profession by publishing a large number of informative and technical articles. Out of the several useful services which the engineers of this country rendered to the nation, one was the establishment of the Engineering Congress; which provides an effective platform for the discussion of engineering problems, and review of achievements and progress. For nearly fifty years it has served the country's engineers. It has helped them in pooling the gains of their knowledge, the findings of their research and the fruits of their experience, for everybody to share; and we are confident that as a result, their efficiency, individually and collectively, has increased.

After the establishment of Pakistan, the Executive Committee of the Congress decided to hold annual symposia on important subjects. This decision too has been of great importance in collecting available information on a particular subject at a given stage, and the coming generations will certainly appreciate the usefulness of this decision of the Council. The bringing out of the "Engineering News" was a step in the same direction. How ardently we wish to make it a monthly, so that it may become a more effective medium of the dissemination of engineering knowledge in this country. Sooner or later this step will have to be taken, as has been done by other engineering societies of the world. The Institute of Civil Engineers, London and the American Institute of Civil Engineers, publish the "Civil Engineer", London and the "Civil Engineers Public Review" respectively, besides the publication of their proceedings and transactions.

A monthly magazine needs a full-fledged organization and cannot be run by Honorary Editors; but the real hindrance is the non-availability of engineering articles. Now that we have a large number of development works in progress, far more complicated engineering problems are being solved and many more engineers are engaged on the application of engineering science, there should be no dearth of articles on this science. Our elder engineers are of course patronizing our magazine, but what is needed is a little encouragement and guidance to the younger engineers. A young engineer, fresh from college and with fresh knowledge, only needs a little encouragement and guidance to be able to write scientifically. At present some bashfulness, a certain diffidence, are the two major hindrances. A little help from those who have experience and knowledge can overcome these.

The development of a scientific atmosphere by holding scientific meetings, lectures and seminars is another necessity. Our nationals should be afforded opportunities for describing their own experience of the problems facing our country. Here again, a lead by the elders is necessary. Once the proper atmosphere is created, many useful results of observations, calculations and new conceptions of design will be forth-coming; and not only will the "Engineering News" appear monthly, contributions will also be available for other engineering journals of the country, although small in number, are starved of contributions.

We are sure the Engineering Congress will take the lead in solving this problem also.

Concrete Lining of Warsak Irrigation Tunnel

by **MOHAMMAD YUNAS Chaudhry**
Superintending Engineer (WAPDA).

In this paper the author describes the method adopted to concrete the lining of 3½ miles long Irrigation Tunnel at Warsak. The engineering details of planning, excavation and completion are put forth.

Data about the Tunnel

The tunnel is Horse-shoe shaped with nominal diameter equal to ..	10 ft.
Its designed thickness of lining was ..	9 inches
Length Inlet Portal to I.P. was ..	9,820 ft. and
From I.P. to Outlet Portal was ..	7,160 ft.
Making a total length of the tunnel equal to ..	16,980 ft.
The elevations of the Head-water was ..	1,269 ft. and
Tail water ..	1,244 ft.
Design capacity of the tunnel was ..	850 cusecs
The water will irrigate an area equal to ..	100,000 acres

Alignment

The intake of the tunnel is sited a couple of hundred feet to the south of the intake of the Power Tunnel. It is so aligned that the greater part of it lies in granite gneiss. For reaching the plains, the tunnel turns through an angle of approximately 15 degrees (14°-46′-32.8″) to the South East at a point 9,820 ft. from the Inlet. From the intersection point to the Outlet the tunnel passes through a succession of different strata, most of which are well weathered, decomposed and usually water bearing. A constant slope of 0.04925 per cent was provided throughout the length of the tunnel leading from an invert at an elevation of 1,240 ft. at the Intake to 1,231.5 ft. at the Outlet.

During the excavation of the tunnel, wherever the rock was loose, standard 5 inches wide flange, 18.5 lbs/ft. steel ribs were used throughout for roof support. The ribs were supplied from Canada, rolled to shape to allow 9 inches clearance between their underside and the finished surface of the concrete. Normal spacing of the ribs was 4.0 ft. although it was reduced to 2.0 ft. or increased to 6.0 ft. as the rock conditions warranted. The ribs were spiked to 12 inches longitudinal runners, which being notched at each end, interlocked and became continuous. Approximately 1,400 ribs were placed in the whole tunnel. A typical cross-section of the tunnel showing the dimensions, the steel ribs together with the Curbs, the Arch and the Invert are shown in Diagram 1.

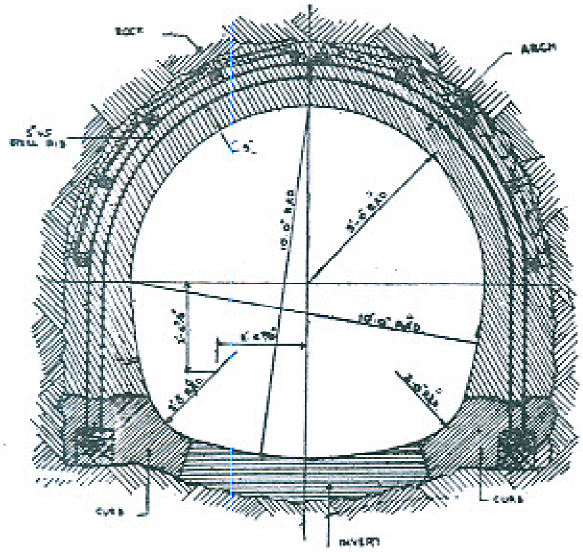


Diagram 1. Typical Cross Section
Warsak Dam Project Concrete Operations in Irrigation Tunnel

Concreting

The tunnel forms supplied for the job were designed for the concreting to be done in three operations, *i.e.* Curbs, Arch and Invert.

A brief description of how the concrete was placed in each of the three sections is given as follows:—

Curb Concreting

The first operation in the lining of the tunnel was the placing of two longitudinal sections of concrete known as the Curbs. Unlike the diversion and power tunnels the curbs in Irrigation Tunnel were to be an integral part of the tunnel. These had also to serve as the base for the main arch form and the controlling guide for the rest of the tunnel.

When the excavation had advanced about 5,000 feet, concreting of the curbs was commenced and carried on simultaneously with the excavation. The design of the curb forms incorporated horizontal braces between the two forms. It was, however, found necessary to make slight modifications and remove these braces, to allow traffic to pass between the forms when they were set in position. After some experimentation it was found easier to make two operations of the mucking and concreting, and to pour a "Flood Pour" to level up the uneven ground beneath the curbs. It also provided an even seat for the curb forms and minimised the cleaning operations at the time of pouring curbs.

Concrete saddles 1.5 ft. long, and shaped to the profile of the curbs were set accurately to line and grade at 50.0 ft. centres on both sides of the tunnel to provide alignment for the curbs. These proved to be very effective, being permanent and easy to follow and were much better than any type of batter boards which were constantly being stolen or knocked down by muck trains.

The curb form in 10 feet sections was made out of $\frac{1}{8}$ inch iron sheet, bent to 2.0 ft. radius and strengthened by angle irons, detail of which is shown in diagram 2.

The setting of forms was done by means of horizontal as well as vertical screw props provided in the forms. The horizontal props helped in setting the forms to correct alignment and the vertical props took care of the grade and elevations. The props were placed at 5 ft. centres and checking at 5 ft. intervals ensured great accuracy in laying the curbs. Holes of 1-1/16 inches in size were provided in the form at 30 inches centre to accommodate 5/8 inch screw anchors meant for the dual purpose of holding the curb forms rigidly in position while pouring concrete and subsequently to rest the main arch form as shown in Diagram 3.

On hundred feet of curb form was used in two lengths of 50 ft. each, two alternative lengths being set up and concreted at one time. On an average one pour was completed every 36 hours, though on occasion it was possible to complete a cycle in 24 hours over a short period.

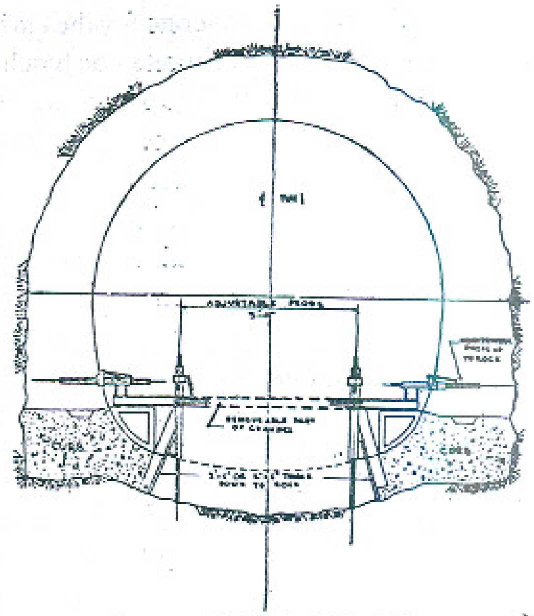


Diagram 2. Detail of Curb Form
Warsak Irrigation Tunnel Concrete Operations
in Irrigation Tunnel

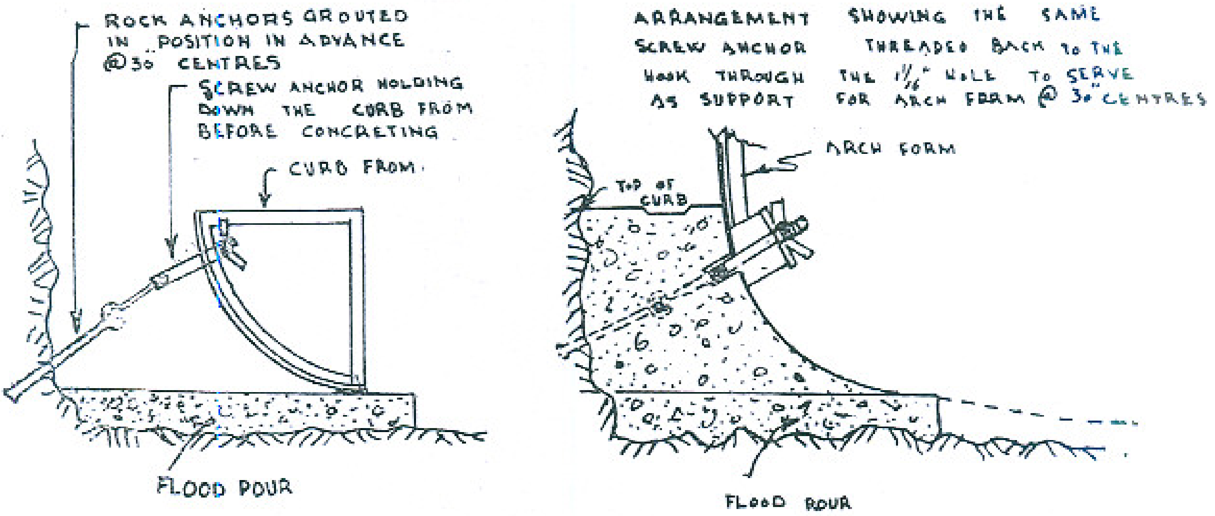


Diagram 3.

Concrete was provided from one cubic yard mixer set up near the portal at the Inlet end and batching was done volumetrically. The wet mixed concrete was transported into the tunnel in 8-1/4 yards concrete boggies which had been divested of wheels and mounted on trestles on top of muck car chassis so as to side tip direct into the forms.

Concreting of the curbs commenced at the Inlet in the second week of January, 1959 and continued until 9th October. During this period 4,650 feet of curbs on both sides of the tunnel were concreted. At this point, signs of segregation were becoming evident and concreting was stopped, until such time as the tunnelling operations were over. Concreting was recommenced on 11th July, 1960 and completed up to the Inter-section point in the beginning of May.

A small mixer had been set up above the

outlet portal to provide concrete for the curbs, but the major part of the concrete was batched at the 2 cu. yds. plant at the Dam site and transported over a distance of seven miles to the outlet in transit mixers. From the portal, the concrete was taken into the tunnel inside tipping buggies as had been used at the Inlet. For some reasons which was never really ascertained, segregation was not so pronounced at the outlet end and it was possible to complete 6,835 feet of curbs before concreting was stopped.

Sub-Invert Concreting

Due to the large overbreaks in the invert, it was necessary to make a separate operation of its cleaning, the standard of which was specified as follows:—

> "Rock surface to be cleaned with blow pipe only to remove loose material. A nominal amount of localised water in deep pockets permitted. No hand cleaning required."

In actual practice, the standard of clean up was still better than the one specified above. The compacted muck was first broken up with paving breakers and hand loaded into muck cars for transporting to the outlet dump. A 2 inches diameter blow pipe was then used to remove muck from the rock surface and this was usually followed up by a final "blow" and a gang hand cleaning pockets of mud.

The Sub-invert Concrete was actually poured and completed before the pouring of remaining curbs *i.e.*, beyond 4,650′ at the Inlet end and 6,835′ at the Outlet end, was taken in hand. This base section was poured to minimise the final cleaning operations, reduce the quantity of concrete in the final pour for invert to a minimum of 9 inches and to have an even surface at a given grade for laying the track to run the locomotives and concrete batch cars at a high speed so as to get the maximum work in the given time. The Sub-invert pour called for the dismantling of mucking track excavating, mucking and blowing the area to be concreted down to the solid rock concreting the Sub-Invert and the remaining Curbs and relaying the track.

The concreting of Sub-Invert was first done between the curbs already completed. At the point where no curbs were laid, the concreting of Sub-Invert and Curb was done simultaneously by keeping the Sub-Invert pour at least 200 ft. ahead of curb forms. This was followed by the relaying of track in the first instance at an approximate elevation to keep up the flow of concrete. After the completion of curbs it was packed to proper elevation on a gravel bed and brought to exact centre of the tunnel.

The pouring of concrete in the sub-invert and curbs was started from both ends of the tunnel. The method of supplying concrete inside the tunnel at outlet end was the same as before but the concrete at Inlet end was poured by means of the Arch Concreting Train.

The concrete car employed for this job had two compartments, each having an independent hand operated sliding gate underneath to discharge its contents. The designed capacity of each compartment being one cubic yard so that each car carried 2 cu. yds. of concrete. Two cars attached to one locomotive made one train. The number of trains employed depended on the distance each had to travel but a maximum of only 3 trains could be employed at a time.

Wet concrete was supplied from the 6 cubic yds. mixing plant in Transit mixers. By this time the Inlet portal had been closed off to permit raising of head pond, so the only access to the tunnel for mucking trains was through the outlet portal and for concrete supply through a 50 ft. shaft constructed just behind the gate at the Inlet. Eight 12 inches diameter feed pipes each having a capacity to hold one cubic yard concrete were placed in the shaft. Each pipe had a hopper at top and a hand operated discharge gate at its lower end. Concrete brought in transit mixers was discharged into the hopper until the pipe was full and on receiving a light signal from top, the contents was discharged into the batch car down below. Having filled 2 cars at a time the loco drove them to the concrete train where these were emptied in turn. By the time the loco returned with the empty cars two more were filled and kept waiting and thus the supply was continued until the portion of Sub-Invert or Curbs in hand was completed.

During the excavation process, loop lines with points and crossing were provided at each portal as well as at every 2,000 ft. distance throughout the length of the tunnel, which were now used for allowing the incoming full cars to cross the returning empty cars from opposite direction at any one of these crossings. At each cross a telephone was installed so that the position of trains moving in the tunnel be easily enquired and traffic controlled.

Leaving aside the digging, mucking and cleaning operations, the concreting of sub-invert and the remaining curbs including the dismantling and re-laying of track was commenced on 12th April, 1960 and completed on 15th July. This gave an average daily progress of pouring sub-invert and curbs as 230 ft. and 160 ft., respectively.

During the excavation of the tunnel and blowing for the sub-invert pour, considerable deposit of dust and debris had accumulated on the sides and crown of the tunnel. Therefore before the concreting of the arch was commenced, the whole tunnel was washed with water hoses to remove these deposits.

Arch Concreting

The original arch form supplied for the job was intended to be used as a static form which, with 100 ft. of form supplied, would have permitted an absolute maximum progress of about 100 ft. per day. In view of the very tight time schedule obtaining towards the end of the job, it was decided that the only way in which the Schedule could be met was to use a Telescopic form of continuous concreting. Accordingly, the contractor on this job designed a collapsable form into which the original form could be converted and at the same time fabricated another 100 ft. of form from material salvaged from the arch form used in the Diversion Tunnel. A total length of 200 ft. of form was considered necessary for a progress of 10 ft. per hour and a 12-hour stripping time.

The collapsable form, made in 10 ft. lengths, was designed to hinge at the crown and the spring line, so that when the form carrier (Jumbo) was in position, the skirts could be folded inwards and the whole section of form lowered on the Hydraulic Jacks mounted in the Jumbo.

At first it was feared that the form might prove too flexible. However, with locking pins at the crown, and bolts inserted in the Channels forming the hinge at the spring line it was found that the form was strong enough for the job it had to do. When in position, the form was supported on form bolts inserted at two-and-a-half feet centres in the curb, and additional support was provided by 4″×6″ timber struts wedged between the rail and the underside of the form. The form sections under erection are shown in the Photograph No. 4.

To collapse a 10 feet section of form, move it on the Jumbo through 190 ft. of arch

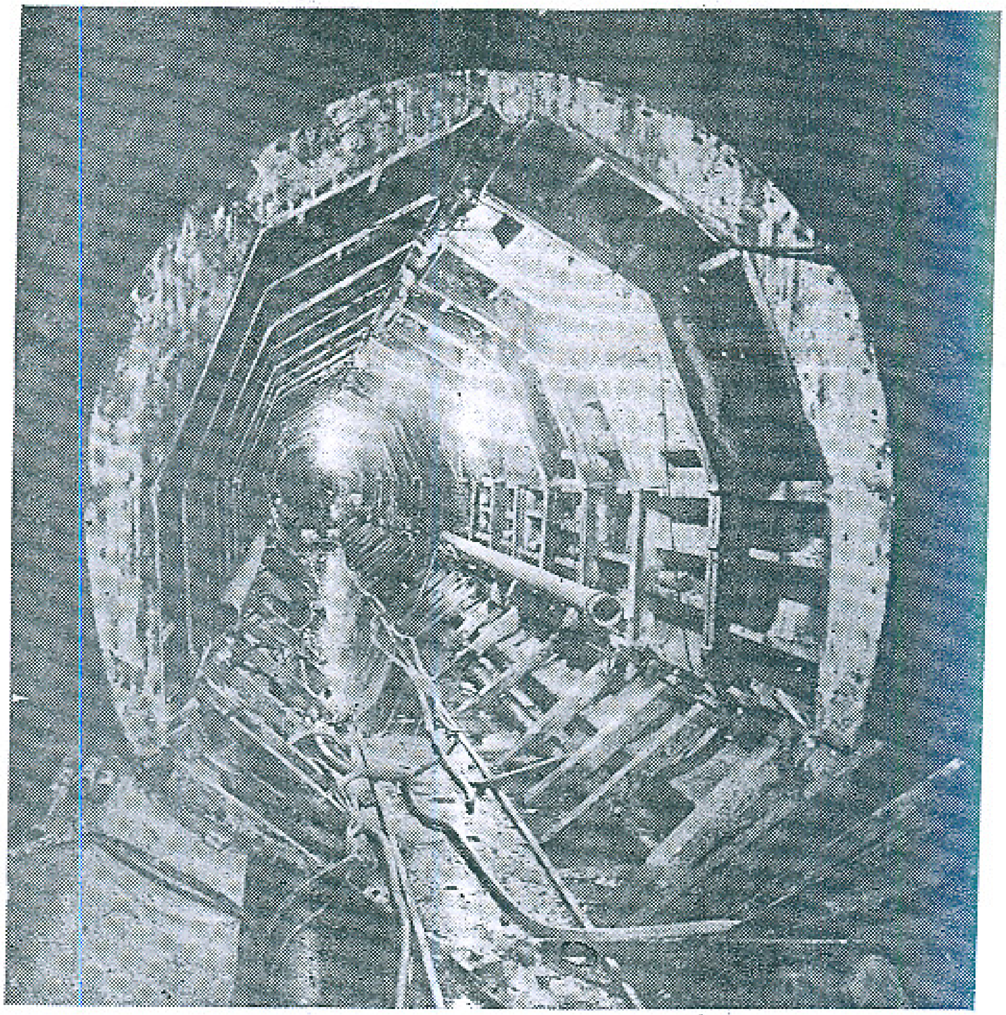


Fig. 4. The Form Sections Under Erection

form and to re-erect it in its new position took approximately 45 minutes.

The working of Jumbo (Fig. 5) over which the form sections were collapsed, was shifted and re-erected.

The Jumbo carried 4 hydraulic rams built in two sets and spaced apart to receive one 10 ft. section of form. Each set was made in such a way that one ram slide over the other. The top ram was used to hold the form section and it worked up and down. The other ram which slide over the top one, and carried 2 arms, one on either side, also worked up and down, but when working upwards, it spread the form sideways with the help of the arms.

Both the rams worked on hydraulic system and the oil required to work them was supplied through a pump which was coupled to an air motor. The pressure of oil was controlled by a small controlling unit assembled on the Jumbo. The motor when started, worked the pump which in turn fed the oil to both the rams through the supply lines. Independent valves were provided to work each ram. The valve for the top ram was first opened which worked the ram upwards, carrying the form section with it, until it reached the correct elevation, where the form was held in position. Having attached the arms to the form section, the valve for the second ram was then opened, which lifted and spread the form sideways, until completely set with the curbs. To provide concrete for the Arch, the concreting train was fabricated. The units consisted of a combined ramp and transfer car platform, a conveyor to feed the aggregate into a one cubic yard mixer and a second discharge conveyor to supply the concrete to a Rex 200, single stroke pumpcrete machine, capable of pumping 30 cubic yards of concrete per hour, through an 8 inches pipe line. All units were mounted on disused nine car boggies which ran on the central rail track.

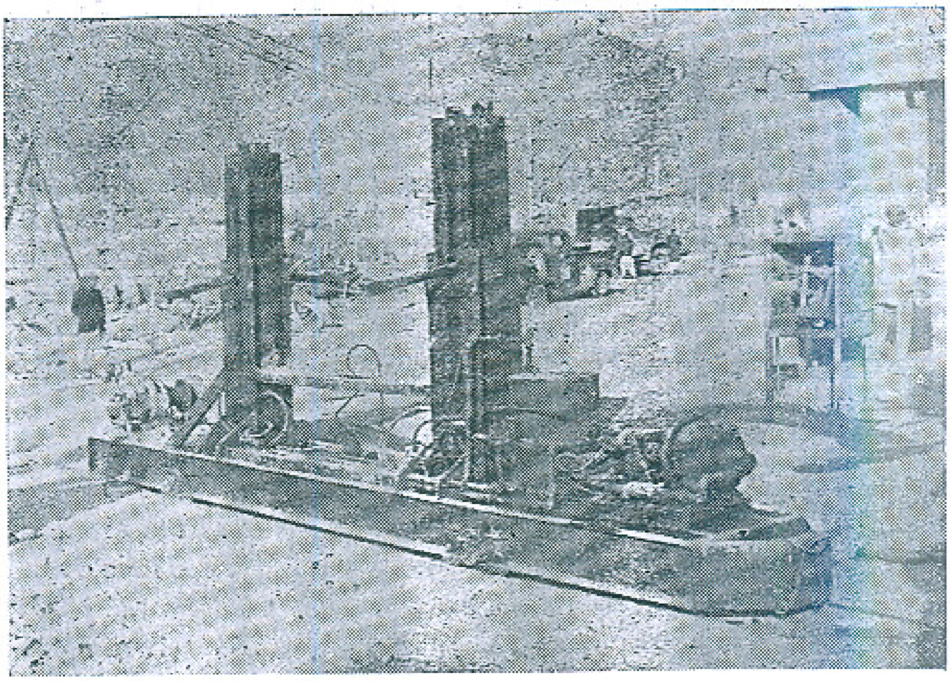


Fig. 5. The Jumbo

Prior to commencing concreting of the arch, the rail track throughout the length of the tunnel was accurately relaid to line and grade. This was done as it had been found that a very little variation in the track threw the "form moving Jumbo" off the line. It was also considered necessary for the full speed operation of the aggregate trains.

On account of the long haul over which the concrete had to be supplied and in order to get uniformity in the mixes, dry weighed batches of aggregate and cement were brought in and mixed in the one cubic yard mixer at the train.

Aggregate was dry batched in a weigh batcher. The batches were discharged into 12 inches diameter pipes with bottom opening gates arranged in such a position, that batches could be discharged simultaneously into each compartment of the batch cars. Due to the confined working area on the portal, cement was batched volumetrically from a central pipe leading down the shaft. The cement batches were not entirely satisfactory owing to leakage of cement—past the gates as the batchers were being filled. Cement also tended to hang up in the main feed pipe and unless the operator exercised proper care there was a tendency to underbatch the cement. Specimen batches of cement were checked on two or three occasions and were found to be within the specified limit of 5 percent variation from the theoretical quantity.

The dry batches were transported from the Inlet to the concreting train in bottom dumped cars as already explained. Whereas each car was designed to take two cubic yards of wet concrete, it could hold only 1.6 cu. yds. of dry aggregate *viz.* 2 batches of 0.8 cu. yds. each, and with 2 cars to a loco and with three locos in the tunnel it was found to be a relatively easy matter to keep the pumpcrete machine supplied. It was estimated that 12.5 cubic yards per hour would be the average rate for supplying concrete, with a possible maximum of 15 cubic yards an hour. However, in practice, it proved possible to keep up an average of over 18 cubic yards per hour for long periods. The main bottleneck was getting the cars switched around on the unloading platform and in dumping the aggregate. To facilitate the latter, air vibrators were fixed to the side of each car and thereafter the time taken for discharging the cars was greatly reduced.

A 93 feet length of 8 inches diameter heavy duty pipe was used as a slick line. With this length of line, and using concrete with 3-1/2 inches to 3-3/4 inches slump it was found that there was plenty of time to strip a 10 feet section of form, take it through and reset it. A stripping time of 12 hours had been specified but it was found to be perfectly satisfactory to reduce this to 10 hours when occasion demanded. The overall average stripping time was approximately 14-1/2 hours.

In general, the slick line was kept buried a minimum of 2-3 feet in the concrete. Pulling of the slick line was effected by pulling the whole train with two large tugger hoists (air winches) mounted on the front of the train. In areas of large overbreaks, it was possible to continue pumpcreting until the slick line could be pulled 10 feet, this being a convenient length for moving the arch form. In ribbed sections and areas of no overbreak, shorter pulls of 4-5 feet were made in order to "Slug" as much concrete as possible between the ribs. A 40 ft. double pipe line 2 inches dia. was run along the slick line on either side and connected to a pin type compressed air booster valve "A" shown in Fig. 6. The booster was used to permit injection of intermittent shots of air when filling the arch. When the booster valve at "A" was opened it released a sudden pressure of air in the slick line and helped materially in thrusting the concrete laterally into the shoulders of the arch. The injection of air or "slugging" period was based on experience and varied between half to one minute.

To start the pour 8 sections of form (80 ft.) were bolted together, whereas 12 sections were kept loose, waiting to be moved ahead in turn. A timber bulk-head was provided at one end of the form and concret-

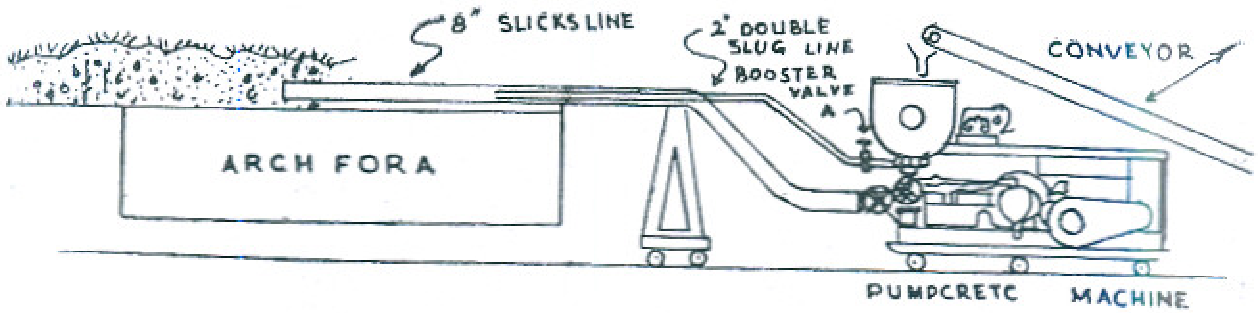


Fig. 6.

ing started. When the concrete had advanced by about 25 ft. from the bulk-head, the shifting of the 12 waiting sections was started. Each time concrete advanced by 10 ft. One section was brought forward through the forms and fitted ahead, until all the 20 sections *i.e.*, 200 ft. of form was in position.

Before each section was shifted the whole train had to be moved by 10 ft. to make room for the section, making sure that a minimum distance of 8 ft. was maintained between the newly erected section and the train. Vibration of the arch form was provided by inserting 2 inches poker type air vibrators into lengths of 2 inches pipe welded to the inside of the form. Vibration with four vibrators, two on each side of the form, was carried out parallel to the advance of the concrete, the lower vibrators being ahead of the upper one. It was found that there was superficial segregation of the aggregates and that usually the concrete was sound within 1/4 inch of the surface. These marks were repaired by trowelling 3 : 1 sand/cement mortar into the interstices and finishing with a gunny bag.

Curing of the arch was carried out for a minimum of seven days after removal of the forms by lightly spraying the surface with water from garden hose spray nozzles. A crew of masons followed up the curing to repair any marks or honey-combed area appearing on the surface. In ribbed sections there were one or two instances where the concrete got hung up on the tie rods between the ribs causing a void. In these cases, all loose or poor concrete was chipped out and the void made good with well rammed dry pack sand/cement mortar.

Necessity of a Draught Tunnel

In spite of the fact that 18 inches ventilation duct supplied fresh air inside the tunnel, when the stripping of forms and curing of arch was started, the temperature in the tunnel specially around the arch forms rose as high as 90 degree with humidity of 85 per cent and this made work inside the tunnel humanly impossible. In fact some of the workers actually fainted on the job and therefore further pouring of concrete was immediately stopped within one week of its start. To overcome this difficulty it was considered necessary to create a draught in the tunnel, bringing in fresh air, by making the whole tunnel section to act as a ventilation duct. For this purpose two exhaust fans 48 inches diameter, running with a 5 H.P., 724 R.P.M. electric motor, were installed in the centre of the tunnel, in a built in wooden bulk head, blocking the whole tunnel and leaving a central hole for the fan and provided with a wicket gate on one side. One fan was fixed permanently at the I. P. from where the arch concreting was started and the other was mounted on a trolly to run on wheels, so that this could be moved to follow the arch form keeping a distance of two to three hundred feet. The two fans were made to draw air from the Inlet and discharge towards the Outlet. Each fan was capable of displacing 20,000 cubic feet of air per minute and when put to action, a tremendous draught was created in the tunnel bringing in fresh air from Inlet shaft and thus reducing the temperature as well as humidity almost equivalent to the outside atmosphere and making it possible for the workmen to resume the work once again.

Bonus Scheme

With better conditions and all defects ironed out, the concreting got into its stride. As soon as things came into control a Bonus Scheme was introduced, based on the yardage placed rather than on the footage completed. This somewhat unusual procedure was adopted to encourage the concreting crews to place as much concrete as possible in the arch which would reduce the quantity of grouting. The bonus was based on a minimum rate of 10 cubic yards placed per hour, the first 2-1/2 cu. yds. placed above this rate being paid for at Rs. 20 and thereafter Rs. 25 per cu. yd. All breakdowns were to be included in the time on which bonus was to be calculated but stoppages for concreting of curbs and removal of transformers, etc. were to be excluded. In practice, the target proved to be too low, and for concreting of the arch at the Outlet, the minimum target was raised to 12-1/2 cubic yards per hour or 100 cu. yds. per shift. At the Inlet the crews became so enthusiastic that the number of batches batched per shift had to be restricted to 200. As each batch consisted of 0.8 cu. yds. this corresponded to a maximum rate of 20 cu. yds. per hour. The average rate of placing amounted to almost 18 cub. yds. per hour while concreting of the arch was in progress. Having completed the arch on the Inlet end the train was disconnected and taken out to the Outlet end through the tunnel, reversed and brought back at I.P. Exactly the same equipment and crews employed to pour the arch at the Inlet were employed for the Outlet side. While concreting at the Inlet was in progress an aggregate plant was set up at the Outlet portal to batch and supply the dry batches for the remaining concreting operations at this end. A section of the completed arch at the Inlet end is shown in Figure 7.

Invert

The completion of arch at the Inlet was immediately followed by the concreting of the last component part of the tunnel, *i.e.* the Invert. A different set-up for concreting of invert was used which eliminated the use of both the belt conveyors, mixer, as well as the pumpcrete. Wet Concrete at the rate of 1.5 cu. yds. per batch car was brought from the Inlet portal and the cars emptied in turn through the transfer switch provided over the platform. The pushing of boggy in the start was done manually but later on an air tugger was provided which made the movement of the boggy forward and backward fairly easy.

As there were no sidings left in the tunnel except the one at each portal, the concreting of invert required very careful planning and a thorough cleaning.

It was aimed to clean not less than 300 ft. each time the concrete was poured, though at times it was possible to clean and concrete as much as 500 ft.

One loco and 6 batch cars were employed for this job and wet concrete was used throughout. The concreting of invert at the Inlet side was started on 24th October, 1960 and completed on 12th November. Total length poured was 5,424 ft. and this gave an average progress of 271 ft. per day. Total quantity of concrete poured was 990 cubic yards which gave a figure of 0.183 cu. yds. per ft.

Grouting

In all except the most solid rock there is always a disturbed area surrounding the concrete section, more particularly over the upper portion. As a tunnel is excavated, the existing stresses in the rock have to adjust themselves to the new conditions and a natural arch of varying stability is formed. If the rock is of a disintegrated and highly jointed nature, falls from roof will tend to take place and this is especially liable to happen where the rock is charged with water and is of a rapidly weathering nature. The construction of

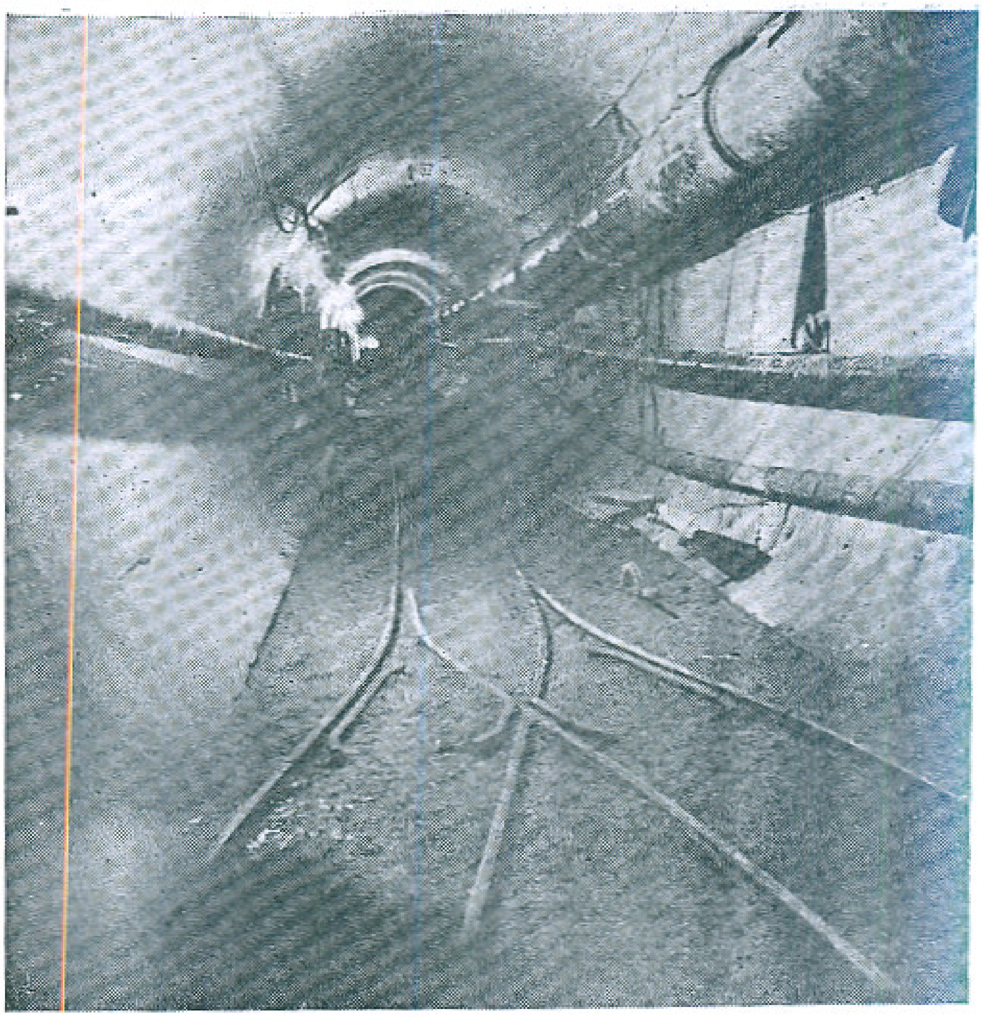


Fig. 7. A Section of completed Arch

a concrete arched lining will go far to give stability but if any hollows are left above the lining it is obvious that rock movement is possible and hence the development of heavy pressure may not be entirely prevented. The roof of a tunnel is always more or less uneven and it is not possible to ensure that the concrete lining at the crown invariably makes close contact with the rock. It is here that the grouting is indispensable and affords a simple means of filling the voids.

After the concrete lining or roof arch of the irrigation tunnel had been completed and attained sufficient strength the grouting into the rock of liquid mixtures of cement, sand and water in varying proportions was extensively applied throughout the tunnel. The purpose of grouting was to bond spilling, ribs, and timbers, wherever present, to the concrete lining, to thicken and strengthen the concrete arch where large voids existed, to fill small voids between the joints, fissures and other rock imperfections as was practicable and necessary. Grouting operations in the tunnel were started on 14th Nov. 1960 and completed in the middle of March, 1961.

This marked the completion of the gigantic Warsak Multipurpose Project, the first of its kind in Pakistan.

Determination of Sedimentation in Reservoirs

by **PIR MOHAMMAD IBRAHIM,**
Chief Engineer, Small Dam Organization, Rawalpindi.

Pir Mohammad Ibrahim Qureshi, Chief of Small Dam Organization has studied the existing data of sediment carried by streams of West Pakistan and have worked out suitable figures to estimate the life of storages. These figures have been adopted by his Organization for the dam being constructed. The sediment deposit in a reservoir depends on the silt entering the reservoir and that leaving through the outlet and the spill-way of the dam. Based upon this method developed by the author, the life expectancy of storage of Chichali Dam has been worked out.

A. Determination of Silt Entering Into a Reservoir

Khosla in his silting of reservoirs has estimated that for small reservoirs with catchment area below 1,000 sq. miles, the sediment carried by water is 0.75 acre feet per sq. mile. Mr. G. A. N. Starmans, Hydrological Adviser of F.A.O. has put forth the following three figures for soil erosion in Indus Basin.

(*i*) High Lands ..	426 tons (or 0.24 acre feet) per sq. mile per year.
(*ii*) Areas between 8,000 ft. to 1,000 ft. above sea level	2835 tons (or 1.59 acre-feet) per sq. mile per year.
(*iii*) Plains up to 1,000 ft. above the mean sea level.	260 to 536 tons (or 0.14 to 0.30 acre-feet) per sq. mile per year.

Assuming that the soil weighs 90 lbs. per cu. ft., the above figures in tons have been converted into acre-feet and are given above within brackets. This enables comparison of Mr. Starmans finding with that of Mr. Khosla.

Data Examined by the Author

There are 18 sites in Indus Basin where the silt observations were made by the Irrigation Research Institute for several years. The abstract of the observations as prepared by Dr. Nazir Ahmad are reproduced in Statement I. Out of these 18 sites full data for Beas and Sutlej rivers are not available. Ten streams namely Siran, Swat, Indus (two sites), (Jhelum), Kishan Ganga, Kunhar, Poonch and Chenab, originate above the snow line. Their contribution to sediment is by the irregular movement of glaciers. As it is not easy to predict the glacier movement, the present calculations were restricted to the remaining six sites.

While analysing these data of the six sites it was noted that there was some difference in the catchment areas as given in Statement I. In the calculation the revised corrected values of catchment areas were adopted. The fall from the divide near the origin of the longest channel to the point of interest was also determined for each stream as correctly as possible from the available plans. These values are given in Statement II.

According to the Laws of Liquid Flow the silt content is a function of Reynolds Number which in turn neglecting the temperature variations, is a function of (Velocity)×(Depth). Now velocity is $\sqrt{(\text{Slope}) \times (\text{Depth})}$, so that the Reynolds Number can be assumed to vary as $\sqrt{(\text{Slope})} \times (\text{Depth})^{3/2}$.

Slope of a catchment, H/L is the difference between the levels of the divide nearest to the origin of the longest channel and to the point of interest, divided by the length of the longest channel. The depth is the run off D. in acre feet divided by area A, of the catchment. A statement, giving the necessary data of the six streams, in the above stated form, were prepared and was noted in Statement II. The Reynolds Number $\sqrt{H/L}\,(D/A)^{3/2}$ and the silt as a result of the erosion E were plotted on logarithmic scale. It was noted (Figure 1) that a straight line having the following relations fitted these points satisfactorily.

(*a*) $E = C\left(\frac{D}{A}\right)^{0.705}\left(\frac{H}{L}\right)^{0.235}$

Where

E = Erosion in acre-feet per square mile of catchment area.

C = Erosion factor depending on the composition and weathering property of the soil. For the area of Indus basin its average value is equal to 0.0096.

D = Run off of the stream in acre-feet.

A = Area of the catchment in sq. miles.

H = Difference in the level of the divide of the stream near the origin of the longest channel and the point of interest.

L = Length of the longest stream up to the point of interest.

Suitable Value of C for different Catchments

The erosion from soil and addition to river stream depends upon the site so that—

(*i*) Above the snow-line there is practically no soil erosion excepting that added by the glacier movement.

(*ii*) Below the snow line the erosion depends on

(*a*) the run off $\left(\frac{D}{A}\right)$ per square mile of the catchment area,

(*b*) the slope $\left(\frac{H}{L}\right)$ of the catchment area, and

(*c*) the value of erosion factor (C) depends upon the erodibility of the soil of the catchment.

(*a*) For average area the value of C is equal to 0.0096 which gives very accurate results.

(*b*) For areas well stocked with vegetation, like that of Harrow River, the suitable value of C is 0.0014.

(*c*) For areas with poor vegetation and erodable soil like that of river Kurram, the mean value is 0.0519.

(*d*) Estimation of soil erosion

STATE

Sediment of the

Serial No.	River	Site	Catchment area in sq. miles upto site	Average Dis. in million acre-feet	SEDIMENT IN			
					Sand	Silt	Clay	Total
1	2	3	4	5	6	7	8	9
1	Indus	Durband	63,600	59.5	45,852	24,451	15,138	85,421
2	Siran	Thapla	1,100	0.141	88.1	548.8	27.1	664
3	Kabul	Warsak	26,000	12.9	14,893	6,445	3,403	24,742
4	Swat	Munda	4,800	2.86	556	1,400	468	2,424
5	Harrow	G. T. Road	2,400	0.82	26.1	68.4	50.3	1,044.8
6	Soan	Mukhad	4,800	0.8	463.3	4,317.9	153	4,934.2
		Total	102,710	77.021	61,878.5	38,131.1	16,176.7	128,733.2
7	Indus	Kalabagh	103,800	89	58,919	68,134	16,691	143,744
8	Kurrum	Kurrum Garhi	2,633	0.97	3,746.5	8,800.7	330.9	12,878.3
9	Gomal	Gul Katch	15,400	0.027	408.5	133.6	8.6	550.4
		Total	121,833	89,997	62,674	77,068.3	17,030.5	157,172.7
							Sediment of the	
1	Jhelum	Domel	5,280	11.42	3,002	3,710	1,765	8,477
2	Kishan Ganga	Muzaffarabad	2,600	6.42	1,998	1,485	869	4,353
3	Kunhar	Garhi	1,080	2.06	994	1,031	325	2,350
4	Poonch	Palak	1,520	2.53	1,475	2,055	656	4,186
5	Kanshi	G. T. Road	696	0.03	11.1	224.1	3.7	238.9
		Total	11,176	22.46	7,430.1	8,505.1	2,818.7	19,604.9
6	Jhelum	Mangla	13,180	24.9	15,500	16,584	4,742	36,827
7	Kahan	Rohtas	470	0.04	19.1	305.5	28.6	353.2
		Total	13,650	24.04	15,519.1	16,889.5	4,770	37,180.2
						Sediment	*Observation Data*	
1	Chenab	Chiniot	26,078	14.3	13,435	14,102.5	4115.7	31,653.2
2	Ravi	Shahdara	3,123	11.6	635.3	19,332.4	5,530	25,497.7
3	Beas	Balahue	2,320	9	...	...	...	4,224.0
4	Sutlej	Bhakra	21,965	16	...	...	...	19,500

Indus and its Tributaries

ACRE FEET								
Bed load at 20% of suspended	Total sand bed load and sand	Silt and Clay	Total sediment with bed load	Percentage of sed./dis.	Total sediment in million tons including bed load	Sediment in tons per sq. mile per year	Erosion in ft. per sq. mile per year	REMARKS
10	11	12	13	14	15	16	17	18
17,085	62,937	39,589	102,506	0.172	179.38	2,820	25.0	
133	221.1	575.9	797	0.565	1.37	1,250	11.3	
4,948	19,841	9,848.3	29,690	0.225	51.96	1,998	18.0	
485	1,041	1,868	2,909	0.102	50.90	1,058	9.5	
208.9	235	1,018.7	1,254	0.153	2.19	916	8.3	
987	1,450.3	4,470.9	5,721	0.74	9.36	1,950.4	17.6	
23,846.9	85,725.4	58,070.8	144,077	0.2	295.16	...	...	% sed. to dis. in column 14 is the ratio of 13 to 5.
2,8749	87,668	84,825	172,493	0.193	301.86	2,908	26.2	
2,576	6,321.5	9,131.6	15,454	1.59	27.04	10,272	92.5	
110	518.5	142.2	660	2.44	1.15	75	0.675	
31,438	94,508	94,099.8	187,947	0.2	330.07	...	...	
Jhelum and its Tributaries								
1,695	4,797	5,475	10,172	0.089	17.80	3,371	32.0	
871	2,869	2,354	5,224	0.081	9.142	3,516	31.6	
470	1,464	1,356	2,820	0.137	4.935	4,569	41.0	
837	2,312	2,711	5,023	0.198	8.790	5,783	52.0	% sediment to discharge in column 14 is the ratio of columns 13 to 5.
47.8	58.9	227.8	2,877	0 957	0.502	722	6.5	
3,870.8	14,440.9	12,123.8	26,116	0.1	41.169	...	...	
7,365	22,865	21,326	44,192	0.18	77.336	5,868	52.8	
70.6	89.7	334.1	423.8	1.06	0.742	1,578	14.2	
7,438.6	22,954.7	21,660.1	44,615.8	0.19	78.078	7,446	...	
of Chenab, Ravi, Beas and Sutlej								
6,331	19,766	18,218.2	37,984	0.265	66.47	(1) 2,549 (2) 4,228	(1) 20.0 (2) 38.0	Values are after including sediment, load of floods.
5,099	5,734.3	24,862.4	30,596.7	0.263	53.54	17,145	150*	
845	...	...	5,069	0.013	8.87	3,824	30	
3,920	...	...	23,520	0.261	41.16	1,875	16	

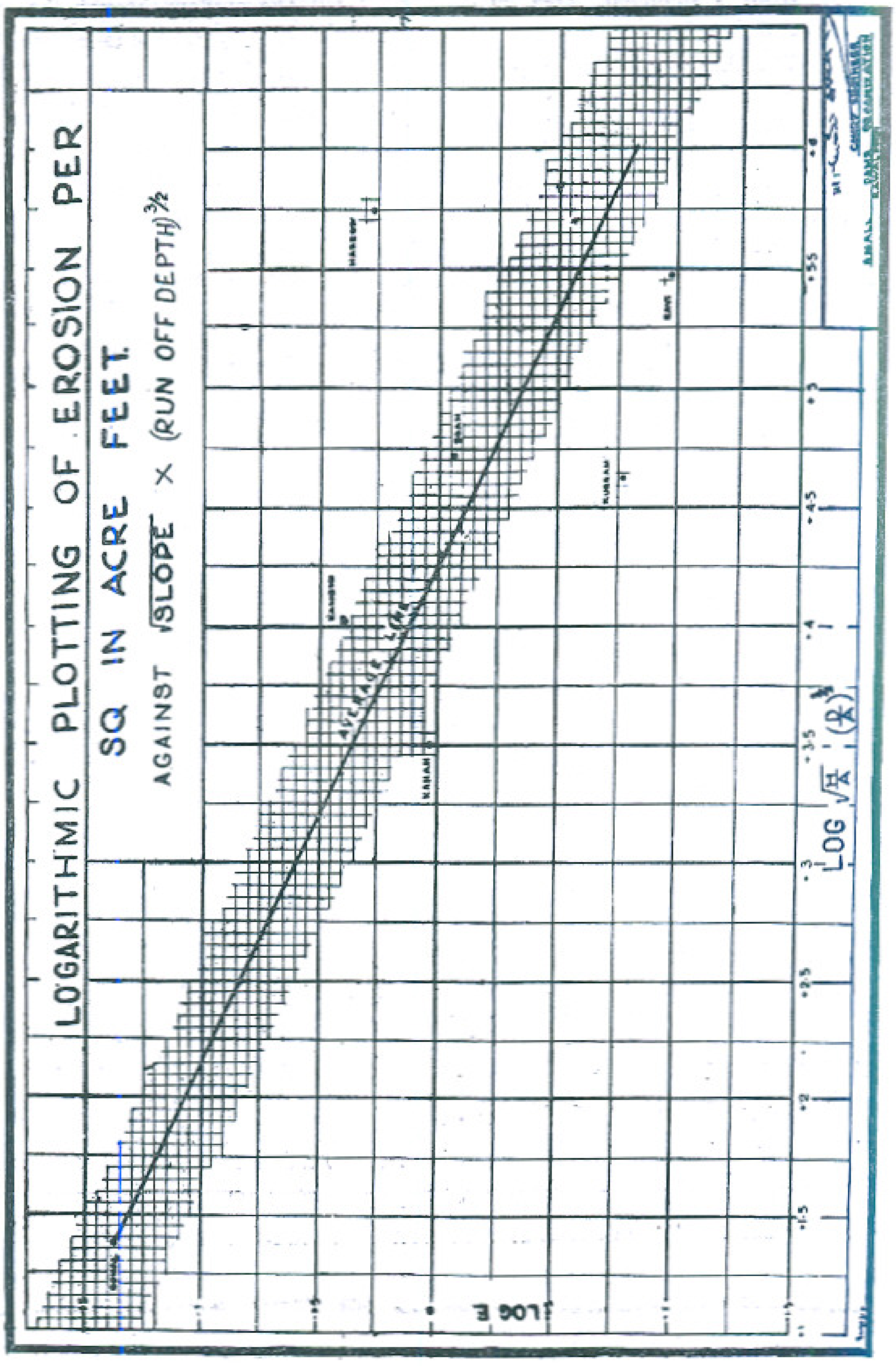
*Data are for 18th July to 10th Oct. 1958.

STATEMENT No. II

Stream & Sites	H in feet	L in miles	D in acre-feet	A in sq. miles	E in feet	SLOPE			
						Log H	Log L	Log H/L	Log $\sqrt{H/L}$
Comal at Gul Katch	8,827	182	27,000	11,850	0.0000675	3.94581	2.26007	1.68574	0.84287
Kanshi at G. T. Road	1,300	28	30,000	225	0.00065	3.11394	1.44716	1.66678	0.83339
Harrow at G. T. Road	7,988	50	8,20,000	650	0.00083	3.90244	1.69897	2.20347	1.10173
Kahan at Rohtas	905	28	40,000	600	0.00142	2 95665	1.41497	1.54168	0.77084
Soan at Makhad	5,734	96	8,00,000	2,050	0.00176	3.75845	1.98227	1.77618	0.88809
Kurrum at Kurrum Ghari	13,600	108	9,70,000	4,100	0.00925	4.13354	2.03342	2.10012	1.05006
Ravi at Shahdara	6,294	208	16,00,000	8,150	0.015	3.79893	2.31806	1.48087	0.74044

Streams & Site	DEPTH OF FLOW				LOG BY REYNOLDS	LOG EROSION	
	Log D	Log A	Log D/A	Log $^{3}/_{2}$ (D/A)	Log $\sqrt{H/L}\,(D/A)^{3/2}$	Log E erosion in feet	Log (E+2.80618)
Comal at Gul Katch	4.43136	4.07373	0.35763	0.53645	1.37932	5.82930	2.63548 (−1.36452)
Kanshi at G. T. Road	4.47712	2.35218	2.12494	3.18741	4.02080	4.81291	1.61909 (−0.38091)
Harrow at G. T. Road	5.91381	2.81291	3.10090	4.65135	5.75308	4.91908	1.72526 (−0.27473)
Kahan at Rohtas	4.60206	2.77815	1.82391	2.73587	3.50671	3.15229	1.95847 (0.04153)
Soan at Makhad	5.90309	3.31175	2.59134	3.83701	4.72510	3.24551	0.05169
Kurrum at Kurrum Ghari	5.98677	3.61278	2.37399	3.56098	4.41104	3.96614	0.77232
Ravi at Shahdara	7.06446	3.91116	3.15330	4.72995	5.47039	2.17609	0.98227

Note.—1. Sites for which full data is not available are: Beas and Sutlej.
2. Sites where part contribution is from snow regions:—Siran, Swat, Indus, Jhelum, Kishanganga, Kunhar, Punch, Chenab.


LOGARITHMIC PLOTTING OF EROSION PER
SQ IN ACRE FEET
AGAINST √SLOPE × (RUN OFF DEPTH)3/2
AVERAGE LINE
LOG E
LOG

from Catchment Area of Chichali Dam :

The data available for this dam are the following :

H =3,569 feet.

L =13.86 miles.

D =12,233 acre-feet.

A =66.52 sq. miles.

Assuming the soil of the catchment to be of average erodibility, E (the erosion per sq. mile per year) works out equal to 1.4411 acre-feet. Therefore the erosion for 66.52 square miles is found equal to 95.86 acre feet per annum.

B. Life Expectancy of Chichali Dam

(*a*) The data of the Chichali Dam is as under :—

(*i*) Spill over the weir is 15.4%. This will take away 7.6% of silt.

(*ii*) The outflow through the outlet is 73%. This will take away 18.25% of silt and

(*iii*) Evaporation is 19.4% which will not take away any silt. Hence the silt which will deposit in pond per year will be 74.15% or 71 acre-feet.

Although the detail of exact information will be made available when the Dam is put in operation but for the above stated estimate it is assumed that 25 to 50% of the silt entering the storage is passed over outlet or spillway. Under this condition the life expectancy of the dam was worked out as under.

Dead storage of the dam is 4,989 acre-feet. It will take 70 years to be got filled. The total storage is 8,872 acre-feet so that the total period to fill the dam will take 124 years and hence the average life is assumed at 96 years.

Freedom from Hunger Campaign of F.A.O.

Food and Agriculture Organization of Rome, in several countries of the world, has started measures to increase the food production under the campaign of Freedom from Hunger. A large number of F.A.O. experts have been sent out to work with local scientists. Generally this campaign is to last three years during which, improvement in agricultural production, finding new sources of water, improving agricultural lands and forests, etc. is being attempted by giving financial aids to augment the resources of a country. Brief news of this programme being conducted in East Pakistan, Syria, Turkey and Lebanon is put forth.

PREPARING EAST PAKISTAN FARMERS TO CHANGE FROM TRADITIONAL CROPPING PRACTICES

The long and difficult task of persuading farmers in the Ganges-Kobadak area of East Pakistan to turn from traditional agricultural practices that have remained virtually unchanged from biblical times and adopt modern, irrigated farming techniques has been started by experts of the Food and Agriculture Organization (FAO) who are working on the Ganges-Kobadak Irrigation Project. This ambitious project, being carried out under the control of the Government of East Pakistan Water and Power Development Authority, embraces an area of some 488,000 acres in the districts of Kushtia and Jessore, lying between the Ganges and the river Kobadak. It is an area, like most of the delta region of East Pakistan, that is subject to yearly inundations by the floods from the network of rivers that crisscross the countryside, followed by periods of drought. The failure of the vital rice crop due to unseasonable floods and droughts is always a threat which may bring with it privation, perhaps famine. The aim of the project is to build a system of main irrigation canals to feed into secondary and tertiary canals that will carry the water to the farmers' fields. Drainage of the fields is also part of the scheme. Much of the construction work which involves building hundreds of miles of canals to complete phase I of the project has been done but there are many difficult engineering problems to be overcome before the irrigation and drainage system becomes fully operative.

Farmers Must be Taught New Practices

But before irrigated farming can be introduced, the farmers of this densely populated region must be persuaded of the benefits to be derived from the new system and be taught the required farming practices.

Under the general direction of Mr. W. J. Blackie, the FAO team leader and senior agronomist, Pakistani agricultural extension officers and instructors, who will work at the village level among the farmers, are being trained and sent into the field. At the same time, a wide range of experimental crop growing under irrigated farming conditions is being carried out at the Amla Experimental Farm. The farm is under the management of an experienced Pakistani agriculturist, Mr. A. E. Mia, who is assisted and advised by a FAO agronomist, Mr. C. H. Huang. Servicing the project generally is a FAO irrigation agronomist, Mr. J. N. van der Zijpp, while a fellow Dutchman, Mr. T. J. Bos, is FAO's civil engineer responsible for advising the Authority and their construction engineers of the problems of building and operating the irrigation system.

Many of the improved varieties and new varieties grown on the farm provide yields of two, three and four times those obtained by local farmers. Gradually, the farmers come to believe and understand that they, too, could achieve similar results if they adopt the same practices. The first of the newly trained Pakistani extension officers have already started work in the villages. It is estimated that some 13 million rupees have already been spent and much more will have to be spent before the project becomes fully operative. But, however, distant the prospect may be today, there is the promise of prosperity in the future to beckon on the poor farmers of this part of East Pakistan and to encourage them to learn the modern skills and techniques brought to them by the international team working on this FAO project.

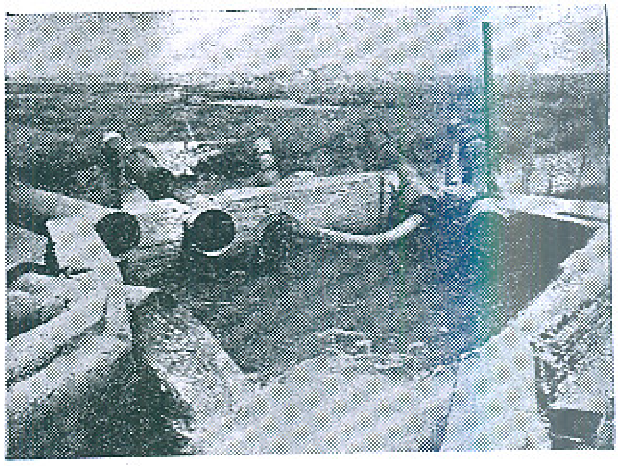
FINDING WATER IN THE SYRIAN SEMI DESERT

The vast plain which stretches southwards from the Taurus Mountains to the Persian Gulf, and which embraces what is now called Syria, Iran and Iraq—formerly Mesopotamia—has been the birthplace of civilizations since man inhabited the earth.

The existence of these civilizations—Sumerians, Assyrians, Persians—depended upon the mighty rivers flowing from North to South, notably the Tigris and Euphrates.

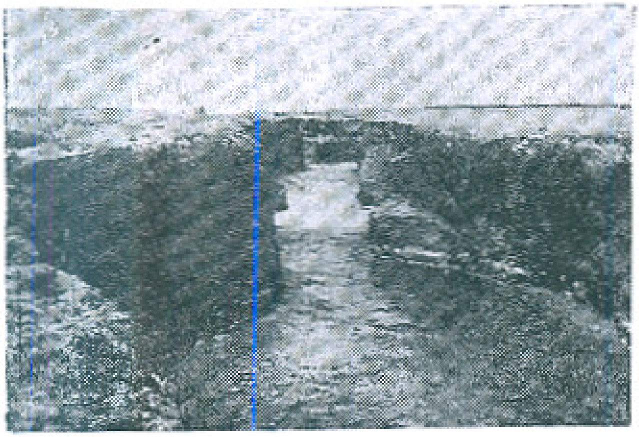
In earlier times the area must have been much more fertile than it is today. It was part of the granary which fed the Roman Empire, and the remains of vast irrigation and drainage systems can be found throughout. Now, wheat and cotton are the main crops but are grown only in limited areas of irrigation. For the rest, the tribesmen barely scratch a living in the dusty soil, while their villages porch on top of successive buried cities which once thrived amidst greenery.

Water is desperately needed throughout this region and yet, paradoxically, it is there



A large pumping station along the Khabour River (Syria) supplies water to a basin from which it is led by Canal to Irrigated Fields.

underground but, until now, unreachable. A team of Syrian Government and FAO (Food and Agriculture Organization) geologists, geophysicists, hydrologists and agronomists have been investigating these groundwater resources over the past under a project of the United Nations Special Fund for Economic Development. They have found out how the Khabour river is formed from 13 springs welling out of the ground at Ras-el-Ain, midway between the Tigris and the Euphrates in a region of open rolling plains. Here the world's largest limestone spring suddenly appeared a few months ago in the middle of a meadow. This blue sulphurous water is rushing into the Khabour at a rate of 3 cubic meters per second, swelling the existing flow of 38 cubic meters per second from the other 13 springs. An artesian water supply has been located below 200 metres, occupying



This spring suddenly appeared in 1961 in the middle of a meadow at Ras-el-Ain in the upper Jezireh (Syria).

a considerable part of the Jozireh. This prospecting, which is using all the modern techniques of hydrogeology, geophysics and hydrochemistry, is being supplemented by the drilling of some 30 prospecting boreholes. The Project is concerned with determining the depth of the groundwater, its extent, its degree of salinity, the yield which can be expected from tapping this underground supply and the use to which it can be put. Dr. Francois Mortier, a French groundwater specialist is project manager, working with Dr. Chafik Safadi, his counterpart who is head of the Syrian Hydrogeology Service. Dr. Donald Gear, a British hydro-geologist is working with Dr. John Khouri, head of the Geology Section of the Syrian Department of Irrigation and Hydraulic Power. Gerard Fery, a French geophysicist is in charge of the Compagnia Generale Geophysica team, who are sub-contracting this part of the project. Two Italian geophysicists, Messrs. Benvenuti and Andreotto are working with Mr. Fery. A second team of Syrian geophysicists is working with Mr. Fery under Dr. Habib el Hauch. The sub-contract for hydrometeorology is being handled by the French firm, Sogreah.

Dennis Noble, a British groundwater development specialist is working with Nizar Mourtada, his Syrian counterpart, and the Yugoslav drilling company, Geoistrazivanja, which is subcontracting this work. Dr. Benetti is the Italian irrigation agronomist with the team. Two FAO consultants have been steering the course of the investigations, Mr. Robert Ambroggi, a French hydrogeologist who is also the project supervisor, and Dr. A. Burden, an Irish groundwater specialist who have been undertaking similar work in this region under the UN technical assistance programme for many years.

DEVELOPMENT OF TURKEY'S ANTALYA REGION

New industry, invigorated forests and expansion of irrigated agriculture planned for Antalya by Turkish-FAO team. The Turkish Government is trying to put a stop to the problems of erosion, flooding and inadequate drainage which plague the Antalya region; and to bring about increased agricultural production, coupled with forestry and industrial development. To this end a three-year preinvestment survey of the Antalya region is being carried out, within the framework of the national development plan, by the Turkish Government with the assistance of the Food and Agriculture Organization (FAO) as a U. N. Special Fund project.

Antalya is a pleasant market town on the Mediterranean coast of Turkey where the gulf of Antalya bites into the Taurus mountains. The project area, some 36,000 square kilometres, includes the three provinces of Antalya, Burdur and Isparta, and is approximately the size of the Netherlands, 850,000 people live in the region, 70% of them in the highlands.

Land suitable for agriculture is limited to the coastal plains and the ancient lake beds and basins which form the highland valleys.

Expanding Irrigated Land

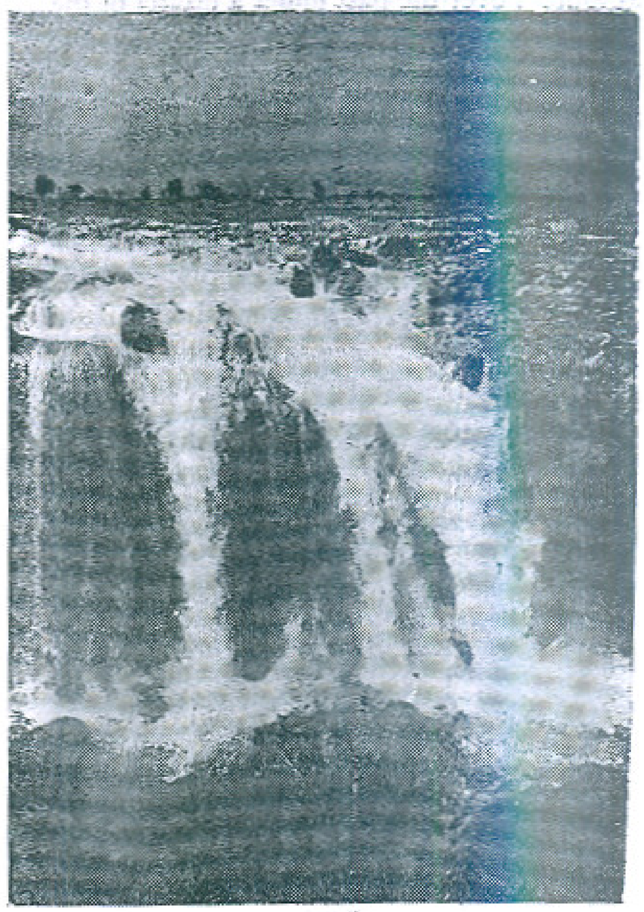
Present fully irrigated land, covering 40,000 hectares within the Antalya region, cannot be extended beyond an additional 65,000 hectares using the available water supply. The expansion of irrigation in addition to newly reforested areas means that the present 480,000 hectares of dryland will have to be reduced by about 80,000 hectares. However, a shift to higher-value crops and improved growing methods mean that, even with this reduction in area, the total value of production can be raised.

Improving Livestock

A great deal can be done to improve the lot of the livestock, which numbers about four million in the three main provinces.

Increasing Forest Yield

The present yield of the high forests is about one cubic metre of wood per hectare per year. However, under intensive management this figure could rise to 3 to 5 cubic metres with traditional species; while the potential increment of fastgrowing species, such as poplar and eucalyptus, could be two or three times higher again.



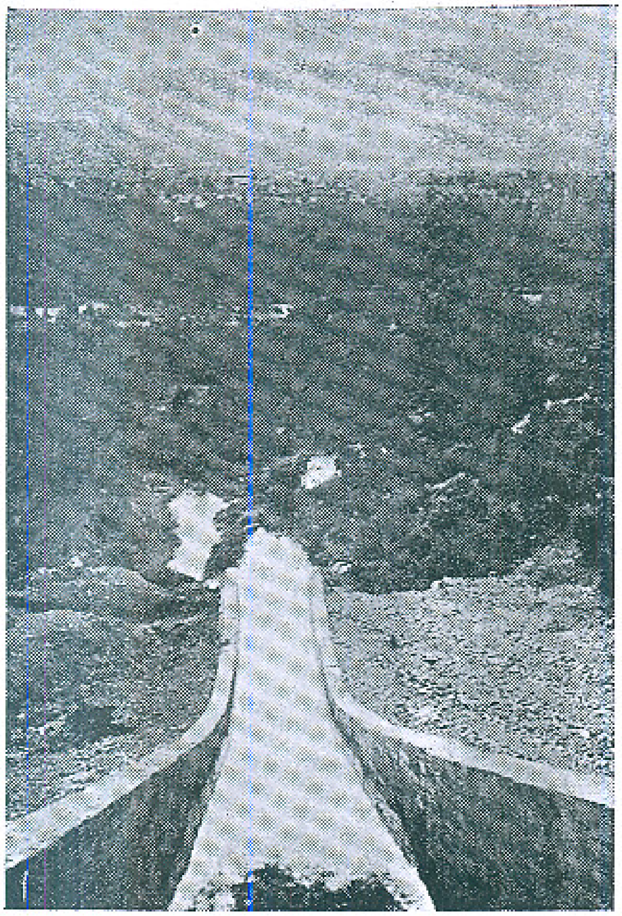
Springs welling out of the ground in the upper plateau of Antalya, Turkey.

WATER—THE VITAL ELEMENT

'Watershed Management Centre held by FAO to combat land misuse and water wastage in the Near East.'

Centre held in Lebanon

A recent meeting was organized in the Near East to combat land misuse and water wastage in the region. Mr. Talat Eren, a Turkish Forestry Officer, was co-director of FAO's Near East Watershed Management Centre, hosted by the Lebanese Government in September. The other co-director was



Water from springs is led by canal across and down to the lower plateau, where it joins the source of the Duden Cai (River-Turkey).

Dr. M. Basbous Director, Forestry and Natural Resources Department, Lebanon.

The aim of the centre was to train forestry agricultural and range officials of the region to plan and carry through watershed management and improvement programmes; as well as to consider regional problems of watershed management, particularly the social and economic aspects. This was the second in a series of such centres; the first having been held in India in 1957.

What is a Watershed?

"A watershed is a catchment area in which water, whether from rainfall or condensation, flows down towards a common point," stated Mr. Eren. "This may range from thousands of square miles of a larger river basin down to the few acres of land supporting a rivulet within the larger area. In this way all the multiple forms of land-use-wildlife, grazing animals, nomadic tribesmen, villages, fields of wheat, forests—all can come within the field of watershed management. The watershed management programme might then be aimed at collecting all available water, both surface and underground, for this purpose. Elsewhere, heavy rainfall might lead to seasonal flooding and crop spoilage; here efforts might be aimed at covering the bare hillside to absorb the deluge, and storing the torrential flow for future needs.

Too many goats spoil the landscape

A great number of people in the Near and Middle East are nomadic, wandering over the hills with their flocks. This could lead to excessive grazing, consequent disappearance of the vegetative cover, and subsequent soil erosion and flooding. One has only to see a herd of goats in action, nibbling the green shoots, and even standing on their hind legs to gnaw saplings, to appreciate this. Here, protection of certain areas, cutting down on the number of goats, forest plantations or even interesting the nomads in settled agriculture might be ways out of the dilemma.

"Watershed improvement and management is therefore an important part of overall land-use planning, and should be linked with the development of power, irrigation, water storage or navigation. Watershed management is necessary if soil erosion, flooding and crop spoilage and the silting-up of rivers, dams or reservoirs are to be avoided."

STORM DRAINAGE

by **RAFI AHMAD**
Sanitary Engineer

Insufficient Studies on Rainfall run off

Any design for storm drainage requires a serious study of precipitation at the place under consideration. Rainfall figures of as many previous years as possible must be collected. If possible, formulae for Intensity-Duration, Quantity-Duration and Intensity-Frequency should be developed. It is usually possible to express these relationships in mathematical terms by drawing graphs and by application of statistical methods.

Very few attempts have been made in this country in this direction. Khungar and Gulati developed a formula for storm run-off of Punjab plains while Naqvi[1] attempted formulation of these relationships. Both these are incomplete studies and need further studies.

Studies have been made in great details of rainfalls in various parts of Britain[2]. The usual British formulae for Intensity-Duration relationship are:—

(*i*) $R=\frac{30}{t+10}$ When t is 5—20 min.

(*ii*) $R=\frac{40}{t+20}$ When t is 20—100 min.

R=Rate of rainfall in inches/hour.

t=Duration in minutes.

Naqvi has worked out similar formula for Lahore and it is expressed as

$I=7.2 - 0.16\ t$

where, in terms of R & t, it is expressed as

$R=\frac{60}{100}(7.2-0.16\ t)$

$R=4.32-0.096\ t$

where I=Intensity in Cents/Min.

t=Duration in Min.

where R=rate of fall in inches/hour.

This formula for Lahore is, however, applicable only to maximum intensity rainfalls and is limited to a duration of 45 minutes. Further studies are very necessary to elaborate this formula for wider applications.

Probability—Intensity relation of Naqvi

Naqvi has worked out the probability of various intensities and his findings are given below:—

Intensity (Inches/hr.)	*Probability (Percentage of falls)*
0.48—0.74	31
0.75—0.99	22
1.00—1.24	16
1.25—1.49	11
1.50—1.74	6
3.75	15/1000
5	7/10,000

According to him maximum rainfall in cents is equal to $(7.2\,t - 0.08\,t^2)$. This holds good for duration up to 45 minutes.

From the study of graphs based on recorded data for 5 year, period of 1945—1950, Naqvi has given the following table of lower limits of Intense Rainfall.

	Noteworthy falls		*Remarkable falls*	
Duration (Mins.)	Quantity Inches	Intensity (Inches/hr.)	Quantity Inches	Intensity (Inches/hr.)
5	0.05	0.6	0.12	1.44
10	0.10	0.6	0.24	1.44
15	0.15	0.6	0.34	1.36
20	0.20	0.6	0.43	1.29
25	0.25	0.6	0.51	1.22
30	0.34	0.58	0.64	1.16
35	0.39	0.58	0.69	1.10
40	0.43	0.57	0.74	1.03
45	0.47	0.51	0.79	0.98
50	0.50	0.56	0.84	0.95
55	0.54	0.54	0.88	0.92
60	0.57	0.53	0.93	0.88
65	0.60	0.51	0.97	0.86
70	0.63	0.50	1.01	0.83
75	0.65	0.49	1.05	0.81
80	0.67	0.47	1.08	0.79
85	0.69	0.46	1.11	0.76
95	0.71	0.45	1.14	0.74

It has been observed that the intensity is lower for longer durations. It is clear from the study of foregoing tables that if storm drainage system is designed for hourly intensity of 1.5 inches then 80 per cent of the rainfalls are covered. If one inch per hour is taken as the intensity, then only 53 per cent of rainfalls are covered while the figure of 1.24 inches per hour will take care of 69 per cent of rainfalls. Before deciding on the figure for Lahore, let us study the facts stated by Naqvi regarding the number and intensity of heavy downpours during 1945—50.

Discussion of Naqvi's Figure of Intensity

In 1945 three storms of duration 15 to 45 min. occurred and the intensity ranged from 1.36 to 0.99 inches/hr. In the same year two rare storms of 5 and 50 minutes took place and their intensities were 3.6 and 1.92 inches/hr.

In 1946, there were seven remarkable storms of 5—60 minutes durations and intensities ranged from 2.28 to 1.35 inches/hr. There was no rare storm.

In 1947 there took place five remarkable rainfalls of 5—40 min. duration and intensity range of 2.16 to 1.35. There was one storm of intensity 3.38 inches/hr. for 5 minutes.

In 1948, eleven falls of duration 5.45 with intensities of 2.16 to 1.4 took place. There were two storms of 25 min. with intensity of 2.21 inches/hr.

The year 1949 saw seven falls of 5.30 min. having intensities equal to 2.64 to 1.13 inches/hr. Also there took place one rare storm of 3.48 inches/hr. for 5 mins.

The last year of study witnessed no rare storm but there were 10 rains of 5.35 min. with intensities ranging from 2.4 to 1.25 inches/hr. It is evident that to adopt a figure of less than 1—5 inches/hr. for Lahore would be a dangerous policy resulting into very inadequate works.

Hence, the formula $I = 7.2 - 0.16\,t$

or $R = 4.32 - 0.096\,t$

be used for concentration times up to 25 min. and a uniform rate of fall of 1.5 inches/hr. be taken for longer periods.

For the purpose of storage of storm water till it could all be pumped away the flood commission recommendation of 6″ of total rain in a day may be considered as adequate. The figure of intensity ½ inch./hr. which is being recommended by some authorities is perhaps too low to be acceptable for a rational design of any system of storm water channels. The system should, however, be designed to allow a good flow at low rates up to ¼ inch/hr. over the whole catchment for a duration equal to the total time of flow. This will ensure minimum self cleaning velocity at low flows.

Estimation of Run off

The amount of run off from a given locality depends on the area, the Type of surface, the Intensity and the Duration of rainfall. The rate of run off or the floor discharge also depends on these very factors in addition to the slope.

In this estimate, the area and the surface are determined by actual survey and is based on experience. The run off from an area having depressions, fields and previous surface is much less than an area of the same size with paved streets, roads and buildings. The co-efficient of impermeability has, therefore, to be fixed judiciously.

If Q = Discharge in cusecs.

r = Total rainfall in inches during the time of concentration in minutes.

t = Time of concentration, inclusive of time of entry in min.

p = Proportion of rainfall flowing off after allowing soakage, collection in pits and evaporation.

A = Area in acres.

Then: $Q = \dfrac{60.5 \times r \times 60 \times A \times P}{T \times 60}$

$= \dfrac{60.5r}{T}$ AP where 60.5 is the discharge in cft./min.

For rain of 1 inch per hour over one acre, if 'I' be the intensity in inches/hr.

then $\dfrac{I \times T}{60}\ r$

$Q = 60.5 \times \dfrac{I \times T}{60} \times \dfrac{I}{T} AP$

$= \dfrac{60.5}{60} \times I \times A \times P$ cusecs (roughly $I \times A \times P$ cusecs).

Or Q in c. ft./min = 60.5 IAP

When rain falls on the ground, a part is absorbed in the soil, collects in pits, evaporates, and a certain part is held by vegetation. The remaining portion flows off. The proportion 'P' can therefore be expressed also as "impervious factor" of a given area:

Usual values of 'P' are:—

Metal, glazed tile or slate roofs ..	0.95
Tiled roofs ..	0.90
Asphatic pavements ..	0.85—0.90
Close jointed pavement ..	0.80—0.85
Open jointed pavement ..	0.50—0.70
Cable stone pavement ..	0.40—0.50
Macadam road way ..	0.25—0.45
Gravel roads ..	0.15—0.30
Densely built city areas ..	0.70—0.90
Densely residence districts	0.40—0.70
Open built residences ..	0.25—0.50
Parks and open spaces ..	0.10—0.30
Lawns and gardens ..	0.05—0.25
Wooded areas ..	0.01—0.20

These figures were formulated by Fruhling for a surface wetted by previous rainfall.

Time of Entry

This is the time required for the first rain drops to travel to the point of entry into the system. Usual values are:—

(*a*) Large mansions in very large plot .. 1 min.
(*b*) Semi detached houses .. 1 min.
(*c*) Closely built areas .. 1/2 min.

Concentration Time

It is the time taken for water to flow through the limits of area under study, to the point under consideration and includes time of entry, which is the time taken for the flow to enter the system from the beginning of a storm.

It is hoped that with these figures and suggestions in view the designof a storm drainage system can be framed with greater accuracy rather than follow the old method of assuming an intensity of 1/2 inch or so per hour over a whole area and calculating the run off after applying a suitable run off factor. Since the intensity of rainfall decreases with increasing durations, the time of concentration must be considered at every point along a system and discharge worked afresh at every point.

This discussion will perhaps become more clear by solution of examples which will follow in the next instalment.

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Subsidiary Outfall of M. R. Link R. D. 313,500, an Outline of Design

by **ALI ABBAS NAMI**
Asstt. Design Engineer Remodelling.

Retrogression Endangers Outfall at R.D. 302,495

The Marala Ravi Link has assumed the role of a problem child of the Irrigation Department. Its heavy silt intake, its fast dying physical capacity, the threat of a meandering channel to the safety of its bridges, the shattering of its banks by swollen Aiks and Degs and last but not the least, its outfall into river Ravi has posed problems by attaining a full supply level seven feet lower than anticipated by the designers.

The M. R. Link is designed to deliver to river Ravi about 20,000 cusecs through its Mirowal Creak. The original outfall at R. D. 302,495 of the link envisaged a river stage corresponding to a full supply level of 744.68 immediately below the structure. The canal of course reflected its misbehaviour in this aspect also and began to retrograde its bed. The full supply level fell down to 737.65. The retrograded channel exposed to danger the bridge at R.D. 310,650 and jeopardised the safety of the outfall itself. The conditions prevailing at the end of 1961 flow season as compared to the design conditions at R.D. 302,495 were as follows:—

	Designed	*Existing at site*
Full Supply Level ..	744.62	737.65
Bed Level ..	731.48	724.45

This called for an immediate action. It was decided to construct a subsidiary outfall to restore the designed conditions at the original outfall and to absorb the entire anticipated retrogression. A site at R.D. 313,500 was selected with reference to facilities of construction and diversion. The anticipated retrogressed level at this site was worked out by assuming a flat slope from the recorded lowest river stage in Ravi upstream of Ravi Syphon. The design data as finally approved for the outfall is:—

	Upstream	*Downstream*
Q	20,000 Cusecs	20,000 Cusecs
B	330 feet	330 feet
D	13.3 feet	13.3 feet
F.S.L.	741.0	Existing 736.0 Ultimate 731.0
Bed Level	727.7	„ 717.7

Design Considerations

The M. R. Link is a big Canal and being a feeder channel it runs with fluctuating discharges and behaves more like a river than a channel. The bed width of the canal is designed for a discharge of 20,000 cusecs. Fluctuations in the supplies set meanders within the canal which give rise to oblique approaches to falls and bridges, or the concentration of flow in one bay or the other. The problem, therefore, was to design a fall which may cater for both the upstream approach variations and downstream retrogression.

The other aspect of the problem is the fluctuating tail supply level depending upon the river stage in the Ravi. The fall has, therefore, to work occasionally against accredited levels also. To design a structure conforming to the requirements of extreme conditions of retrogression and accretion at the same time is the most difficult task. A structure was, therefore, to be designed which may be safe within reasonable fluctuations of downstream level. The practical considerations limited the range of fluctuations of downstream levels within 741.12 to 731.0.

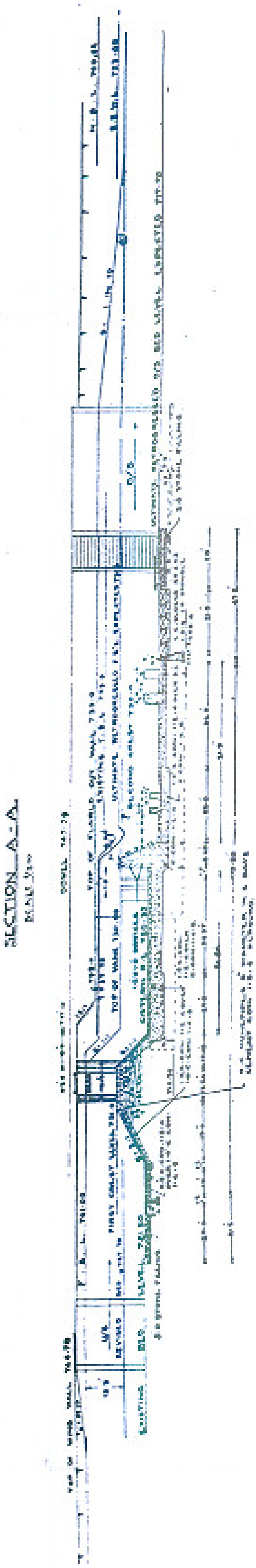
Single Versus Double Fall

These considerations rule out the adoption of conventional type single fall which fail to work efficiently in case of oblique or heavily concentrating flow on one side, and in cases of increased retrogression or accretion. In the case of big falls on feeder canals outfalling into rivers with greatly varying water stages, provision of a double fall is an advantageous proposition. Splitting the fall into two components, allows the downstream floor to be laid higher than in the case of a single fall. The double fall caters better for the retrogression and accretion of levels simultaneously, and the intermediate cistern formed above the baffle, rectifies to some extent the upstream approach variation and helps to even out distribution of flow. The model experiments carried out to check the efficacy of design established that double fall has a definite superiority over single stage falls in case of outfalls into rivers. It provides more flexibility and wider range of downstream levels up to which the structure remains safe.

The double fall has further constructional advantages as the dewatering level is comparatively high. This advantage is very substantial in case of outfalls where subsoil water level is invariably very high.

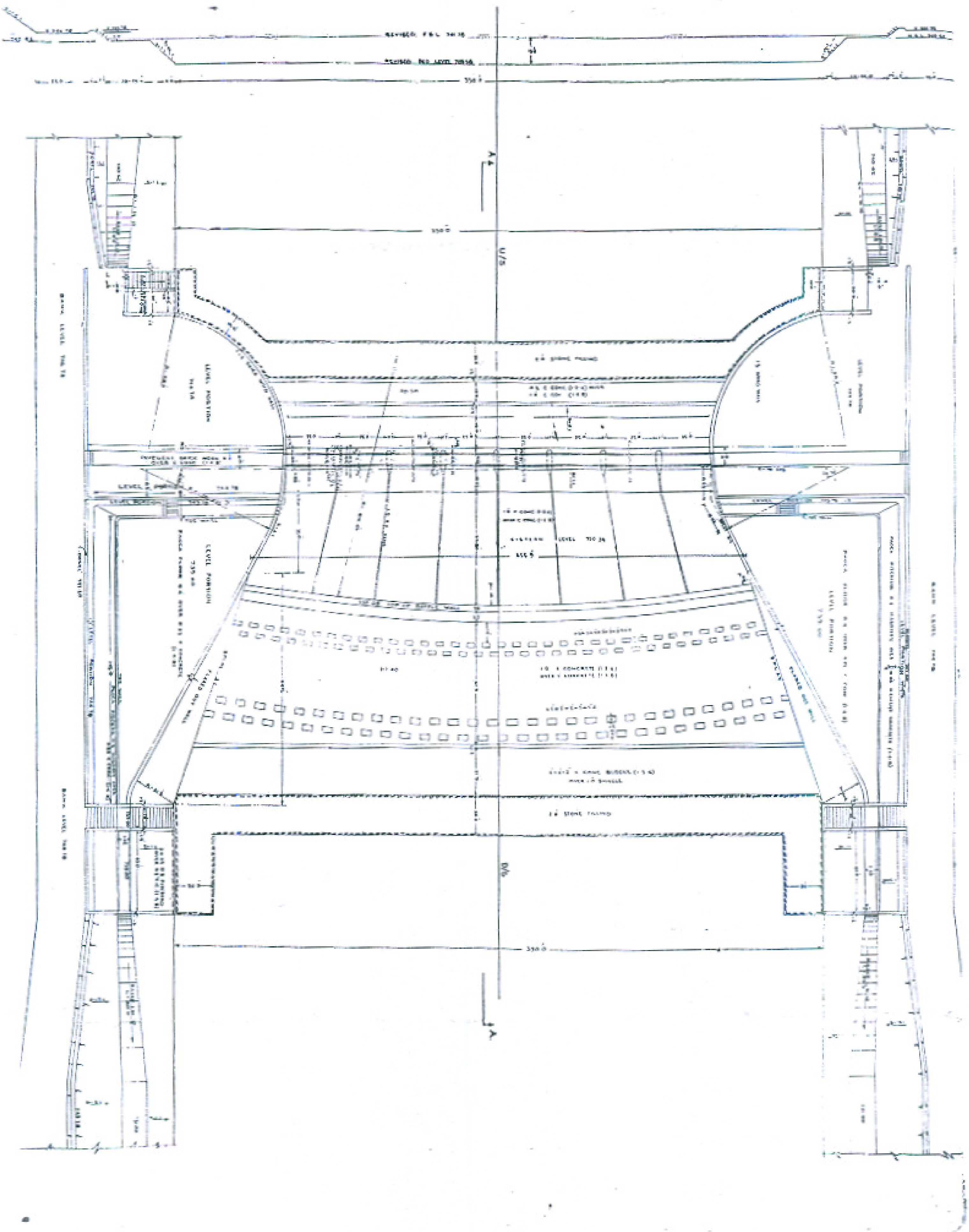
Water-way

Providing 60% fluming, 8 bays of 25 feet each with 7 piers of 2.7 feet thickness were adopted for the first weir thereby giving a discharge per foot of 100 cusecs. This intensity of discharge was advantageously re-



Out Fall of M. R. Link R-D 313,500

NORMAL CROSS SECTION



duced to 79 cusecs at the baffle wall, by giving a splay of 2 :1 starting 5 feet beyond the toe of the first weir for a length of 35 feet along the centre line of the fall. To ensure uniform distribution of flow below the first weir, radial vanes, reinforced to resist differential pressure and with top at R.L. 730.08 were provided dividing the first cistern into 8 compartments. For further distribution of flow below the baffle wall under the retrogressed conditions are also with a view to drain off the water in the first cistern, double rows of staggard rectangular perfections 1.5′×1′ with 3 ft. spacing in between were provided. The baffle wall was curved in plan with upstream face having a radius of 816.25 feet with a view to spread the flow evenly through out the section downstream of the fall.

Crest Levels

The surface flow conditions were checked with downstream full supply level at 736.0 and at the ultimate retrogressed full supply level of 731.0. The Full Supply Level over the baffle wall was fixed as 738.0 to provide modularity with downstream full supply level under accreted conditions as 736.75 thereby fixing the level of the top of the baffle wall as 730.08. The R. L. of the top of the second cistern was worked out as 717.4 after allowing for 20% concentration of flow and the length of the cistern was kept equal to $5E_{f2}$ $=65.3$ ft.

The retrogressed full supply level downstream of the outfall at R.D. 302,495 M. R. Link was restored to R. L. 742.65 as against 744.68 originally designed. This was the lowest that could be permitted by the existing structure and was utilized to reduce the fall lower down. With a slope of 1 in 6,666 the designed full supply level over the subsidiary outfall was fixed as 741.0 which in turn fixed the crest level of the first weir as 731.0. The R. L. of the top of the intermediate cistern as worked out from the energy of flow considerations was 723.9 which, however, was advantageously lowered to 720.35 being the lowest level to which the dewatering for the second cistern had to be done. The length of the intermediate cistern was economically restricted to about 3.5 E_{f2} in a view of the flow being confined in the pucca concrete floor.

Length of the Impervious Floor

A total length of 184.23 feet of impervious floor was provided to accommodate the double fall and ensure a safe exit gradient. Drawing of the outfall gives the detail.

Upstream and Downstream Cut Offs

A 5.0 feet deep curtain wall upstream and 9.0′ deep well line downstream were provided to check against scour.

Thickness of Floor

The thickness of the floor was designed for a maximum head across of 10.0 feet based on the method of independent variables as outlined in the Central Board of Irrigation Publication No. 12.

Flexible Apron

20 feet length of concrete cement blocks 4′×4′×2′ in size and with mix of 1 : 3 : 6 were laid over 1.0 foot of shingle. These were provided after the pucca floor.

Friction Blocks

Two rows of staggard blocks 5′×5′×3′, parallel to the baffle wall are provided at the two ends of the 2nd cistern.

Weep Holes

Two rows of weep holes were provided in the flared out walls and wing walls to relieve back pressures.

Flayed out Wall

Flayed out walls with side splay of 1 in 3 are used to spread the flow from the baffle wall on the full width of the downstream channel.

Water-logging—Causes and Remedial Measures Therefor

by **SHRI O. P. GUPTA**

Extracted from ICID Annual Bulletin 1962.

This article of paramount importance has appeared in the Annual Bulletin 1962 *issued by International Commission on Irrigation and Drainage, New Delhi. The Causes as put forth are very informative and those dealing with this problem in our country may have the opportunity to study carefully the ideas advanced by Mr. Gupta.*

In this issue we have reproduced the salient features of the article. In some later issue we shall try to reproduce the full article after obtaining permission from ICID organization.

The paper deals with the problem of waterlogging in general, with particular reference to the conditions of Uttar Pardesh and Ganga Yamuna Doab. The various causes contributing to water-logging conditions are analysed and remedial measures are suggested.

GROWTH OF PLANT LIFE

The growth of plants depends upon the the rate of the liberation of plant food which, in turn, depends upon:—

(*i*) quantity of organic matter present in the soil.

(*ii*) temperature of the soil and

(*iii*) the amount of water and air present in the soil.

After the elements of the plant food have been changed into soluble salts through bacterial action, they are dissolved by the capillary water and held in solution as films of moisture surrounding the soil particles. All plants have clusters of fine hair growing at tips of their young roots and these root-hair are immersed in moisture films. The food laden water surrounding the soil particles is taken into the plant by osmosis and after entering the roots, it moves upwards into the plant where the water is transpired through the pores in the leaves and the food remains in the plant and causes its growth.

EFFECT OF WATER-LOGGING IN IMPEDING PLANT GROWTH

(*i*) Inhibiting activity of soil bacteria

The liberation of plant food is dependent upon the activity of soil bacteria, which requires adequate amount of oxygen for proper functioning. The conditions of saturation produced in water-logged soils result in exclusion of air by water causing impediment to or the stoppage of the activity of soil bacteria and the decrease in the availability of plant food.

The depth of watertable at which it tends to make the soil water-logged and harmful to the growth and sustenance of plant life depends upon the height of the capillary fringe which is the height to which water will rise due to capillary action. The height of the capillary fringe is more for fine-grained soils and less for coarse-grained ones. The normal height of the capillary fringe met with in agricultural soils of India varies from 3 feet to 5 feet. The crop-yield is adversely affected when the capillary meniscus surface rises to within 2 feet of the ground surface. The land will, therefore, be water-logged when the water-table is within 5 feet (*i.e.* 2 feet+3 feet) to 7 feet (*i.e.* 2 feet+5 feet) below the ground surface. For fine grained soils with capillary fringe height of say, 8 feet, the land will be water-logged when the water-table rises to within 10 feet (*i.e.* 2 feet+8 feet) approximately beneath the ground surface.

The adverse effects of high water-table upon the yield of crops is also dependent upon the nature of crops grown. Plants with the longer roots going deeper are more susceptible to high water-table than those with smaller roots. The depth of water-table below ground level which adversely affects the growth of different Indian crops is as below:—

Crop	*Depth of water-table*
(*a*) Wheat	3 feet to 4 feet.
(*b*) Cotton	5 feet to 6 feet.
(*c*) Rice	2 feet.
(*d*) Sugar-cane	3 feet.
(*e*) Fodder crops	4 feet.
(*f*) Lucerne	7 feet to 8 feet.

The adverse effects of high water-table on plant life thus seems to be a function of the nature of the soil and the nature of crops grown. Availability of precise data in this respect will help in designing proper water-logging measures. It will indicate the proper level to which the watertable should be lowered in order to allow satisfactory growth of crops and in cases where water-table is not too high, it will indicate suitable crop pattern which will flourish with a minimum of expenditure as anti-waterlogging measures.

(*ii*) Decrease in available capillary water

If the water-table is high the roots of plants are confined to the top layer of soil above the water-table while if water-table is deeper, the roots of the plants have more room for growth.

In this case due to deeper and longer length of roots, more water is available to plants. The rise of water-table decreases the amount of plant food available to plant life.

(*iii*) Fall in soil temperature

A water-logged soil warms up slowly and due to lower temperature, action of soil bacteria is sluggish and plant food available is less.

(*iv*) Defective duration of soil

A well drained soil has about 25 per cent capillary water and 15 per cent pores are filled with air. The roots of plants require oxygen for their growth and bacteria need oxygen for their activity. Oxygen is taken into the plants through root-hair and carbon-dioxide is given out. The latter forms carbonic acid with water and dissolves mineral elements of the soil. In properly drained soils, the water percolating through the soil dissolves carbon-dioxide forming carbonic acid and thus fresh air with oxygen is drawn from outside. In improperly drained soils, percolation is stopped and as carbon-dioxide is not dissolved, its concentration rises. Consequently fresh air containing oxygen is not drawn in, growth of plant roots and activity of its absorption by plant roots falls appreciably.

(*v*) **Rise of salts**

In normal soils, the root solution round the hair roots of plants is stronger than the soil solution (containing plant food) round the soil particles. Due to osmosis, the soil solution is drawn into the roots and contributes to the growth of the plant. In strongly alkaline soils, the soil solution and water is thus drawn from the plants leading to their death. Soils with pH value 7.0 to 8.5 give normal yields. With pH value 8.5 to 9.0 the yield decreases. When pH value rises to 11.0, the soil becomes infertile.

(*vi*) The other defects as a result of high water-table are delay in ploughing and mulching operation, growth of weeds and stagnant water is a source for breeding of Malarial parasite.

CAUSES OF WATER-LOGGING

The causes enumerated include the inadequate surface drainage and the seepage from canal system.

The seepage from unlined canals in terms of percentage are given as under:—

	Upper Ganga Canal	*Upper Bari Doab Canal*
Main line & branches	15	12.2
Distributaries & Minors	7	9.2
Water courses	22	12.5
Evaporation	1	..

In Western U.S.A. losses in transit are 37 per cent and waste 14 percent.

During 40 years from 1918 to 1958, water-table in Kali Nadi Ganga and Hidan Kali Nadi Doabs has risen by 6 to 7 ft. and in Arind Pandu, Arind Sengar, Sengar Yamuna Doab by about 10 ft.

OVER-IRRIGATION OF FIELDS

As long as the amount of water supplied to the land for any crop is such that it is either used in the root zone or retained in the capillary fringe from which the plants draw their supply, there is not much rise to the water-table. But if the supply is in excess of capillary water, it is retained in gravitational zone and when water-table rises, gravitational zone reaches the root zone and saturates it, expelling all air and thus causing water-logging.

The losses in canal Irrigation in Utter Pardesh are assessed as below:—

Sandy soil	25 to 50
Sandy loam	15 to 25
Fine sandy loam	10 to 20
Heavy clay loam	5 to 15

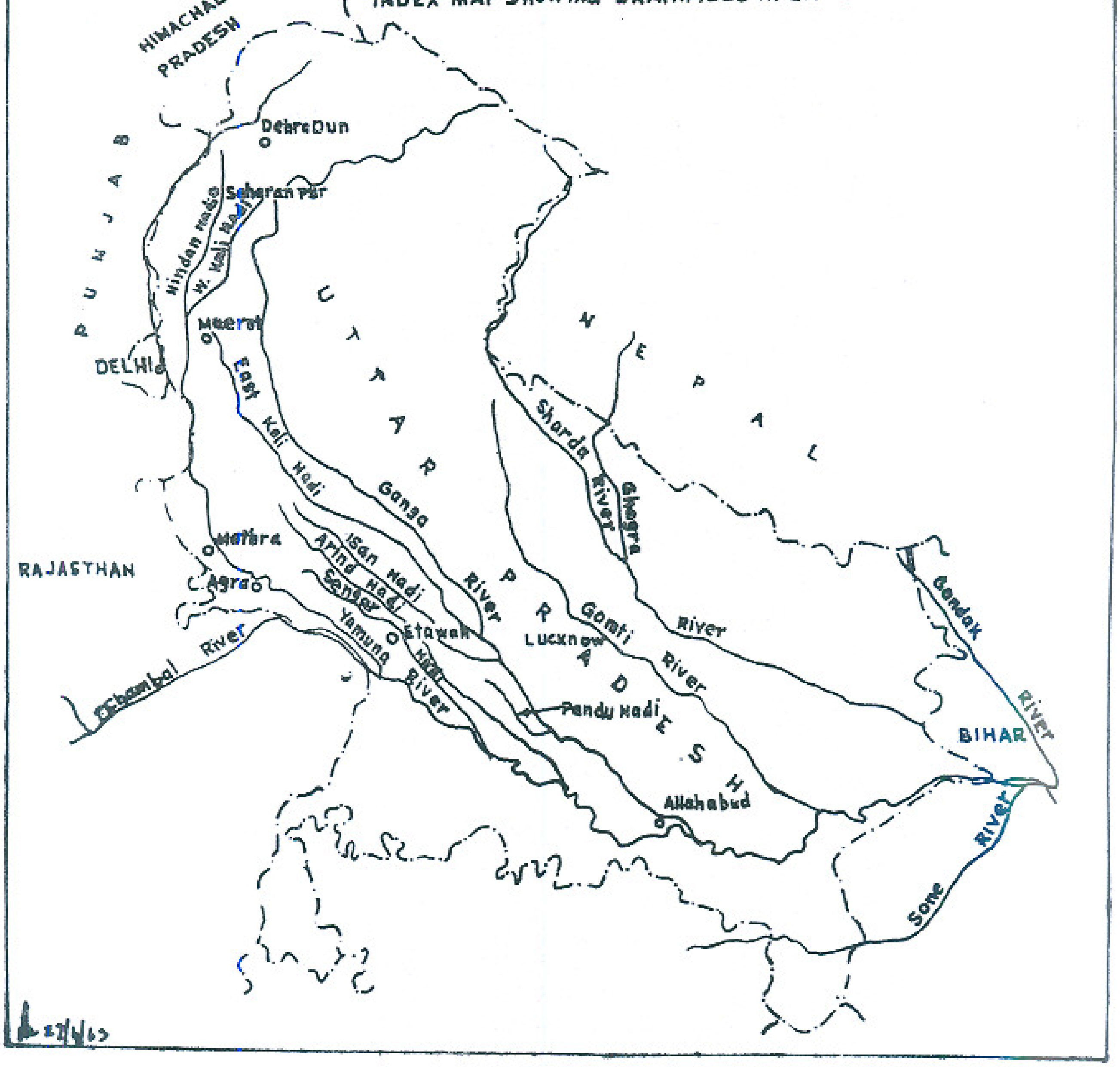
This deep percolation contributes tremendously to the rise in water-table and it is essential that this indiscriminate use of canal water should be checked. Other causes include obstruction to flow of natural drainage by construction of embankments, cultivation of natural drainage beds, inadequacy of artificial drains and seepage from reservoirs. Sometimes there is natural impervious obstruction in the way of laterally flowing sub-soil water. Sub-soil flow from canals and reservoirs on the upstream is obstructed and watertable rises.

REMEDIAL MEASURES

(*a*) **Efficient Surface Drainage**

The efficiency of surface drains depends entirely upon satisfactory annual maintenance which after a lapse of two or three years is neither satisfactory nor economical. The efficiency of the drain is lowered by 30 to 50 per cent if it is not maintained in any year. The growth of water-hyacinth in the bed of the drain creates a very serious problem. A bed slope of 1.6 feet to 3.2 feet per mile is considered satisfactory for the drain depending upon soil conditions and the available country slopes.

FIG. 1.
INDEX MAP SHOWING DRAINAGES IN GANGA-YAMUNA DOAB



(*b*) **Under Drainage by Tile Drain**

Large initial cost has, however, prevented its use in this country. It is to be expected that when Co-operative Farming is introduced, the Co-operative Farms themselves will lay tile drain systems in their water-logged areas at their cost, thereby increasing their production greatly.

(*c*) **Reducing percolation from canals**

This is possible by undertaking the following measures:—

(*i*) Lining of irrigation channels.

(*ii*) Lowering of full supply level of irrigation channels.

(*iii*) Construction of intercepting drains which are constructed along the canals and at short distance from it.

(*iv*) Restriction of irrigation.

Irrigation during Kharif and use of well or tube-well during Rabi is recommended.

(*v*) Lining of water courses.

(*vi*) Removing obstruction of natural drainage.

(*vii*) Depletion of ground water by pumping which is suggested to be undertaken by two systems of pumping, shallow well and deep well.

In this connection the author, considering all the various parameters has tried to work out the number of tube-wells for a given Doab to keep the rising ground water under check.

For the irrigated Doabs of Arind-Sengar, Sengar-Yamrina, Iran-Pandu, Karon Yamrina (see the map) using 6.0 inches diameter strainer well with 100 ft. length of strainer and working with a depression of 20 ft. for 4,000 hours in a year, the number of tube-wells needed have been worked out. These are as under:—

Name of Doab	*Equivalent No. of T/W*	*Equivalent No. of T/W to cope with Seasonal rise*
1. Sengar-Yamuna	19	230
2. Sengar Arind	81	560
3. Isan Pandu	21	176
4. Karon-Yamuna	21	254

A fourth measure to control water-logging suggested by the author is the encouragement of masonry wells, changes in crop pattern and sprinkler method of irrigation.

News and Notes

WATER-LOGGING AND SALINITY REPORTS

President Kinnedy's Science Advisory Committee of White House Interior Panel has sent first draft of the report on Water-logging and Salinity in West Pakistan. This report was sent by President Kennedy to the President of Pakistan and a few copies were circulated in Pakistan for Study and Comments. Dr. Roger Revelle, Head of the Panel of Scientists was in Pakistan recently discussing some of the salient features of the report. The report which is not for publication is separated into seven chapters dealing with—

The Problem.

Physical means of achieving increased agricultural production.

The Plan.

Productivity increase in million acre development.

Cost and uses of Fertilizer.

Hydrology.

Research and Development.

The report is accompanied by four short appendices and a Bibliography.

Dr. Revelle Plans to visit Pakistan again with his team of scientists before finalising the report.

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ALL PAKISTAN SCIENCE CONFERENCE

Brisk preparations are afoot to hold the 15th All-Pakistan Science Conference in Lahore. The University of the Panjab is acting as host. The venue of the conference will be the Panjab University Hall, a true exposition of the cultural heritage of the region. It is expected that President Ayub Khan will inaugurate the conference. Dr. Usmani is the President elect for the conference of this year. Intimation is being received from about a dozen countries which will be sending their scientists to participate in the deliberations. Three or four hundred delegates from all over Pakistan are expected to participate. For five days from 19th to 23rd March, the Panjab University and its hall will be the centre of considerable activity.

SEATO GRADUATE SCHOOL OF ENGINEERING

Special Scholarship Programme, Facility for Pakistani Teachers.

The new Special Scholarship programme of the SEATO Graduate School of Engineering, to provide short-term training for engineers and educators who cannot or need not spend the time to obtain an advanced degree, is now underway. Scholars are selected on the basis of promise, capability, and the potential value of the training to the profession in terms of current and anticipated requirements. The improvement of the teaching of engineering is one of the most significant objectives of the Special Scholarship programme. In response to requests from engineering colleges in South East Asia, Special Scholarships were granted to members of their faculties; three such awards have been made for the current semester. The first Special Scholars are all from West Pakistan; they are Mr. Iqbal Ali of the University of Engineering and Technology, Lahore; Mr. Mohammad Attaullah of the University of Peshawar; and Mr. Nazar Muhammad Awan of the West Pakistan University of Engineering, Lahore.

Visitors to Seato School

Dr. Mushtaq Ahmad, Director of the Irrigation Research Institute of Pakistan at Lahore, in May delivered in Manila a Special Lecture on "The Design of Alluvial Channels as Influenced by Sediment Charge." In Bangkok later in the month, Dr. Ahmad visited the SEATO's Hydraulics Laboratory and delivered two lectures. The first lecture was titled "The Design of Fluvial Regime Channels as influenced by Sediment Charge" and the second dealt with "Localized Scour and Design of Spur Dikes." Dr. Ahmad has gained renown for his research on channels subjected to heavy silt charges.

Mr. Frederick A. Camp, Design Engineer of the Department of Water and Power, City of Los Angeles, U.S.A. in a lecture in early June sponsored jointly by the Engineering Institute of Thailand and the SEATO Graduate School, reported the results of his research on Hydrological Processes of Water, Snow, and Ice at High Altitudes.

Mr. A. Linne Tholin, Technical Consultant to the Municipality of Bangkok and formerly the Engineer of Public Works of the city of Chicago, U.S.A. delivered a lecture in Bangkok on 29th June titled "Engineering Problems of Metropolitan Areas."

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AIR TRANSPORT ENGINEERING CONFERENCES

A three days conference on air transport engineering was held in Bangkok from 8th to 10th August, 1962. Special Engineering addresses on the following subjects were delivered:

1. Selected airports in South East Asia—A study of characteristics for Bangkok, Hong-Kong, Dacca and Manila.
2. Aeronautic Ground Service.
   - (*a*) Aeronautical Communications and Navigation Aid Facilities and Usage by Norman M. Jones.
   - (*b*) Historical aspects and Progress in Air Communication and Navigation Facilities by Elmer C. Butler.
   - (*c*) Air Cargo, an analysis of Air Cargo Potential for the Region by M. C. Kachorn C. Chiraprawat.

Airport Construction Management

Management of Contracts for Airport Construction Mr. A. Linne Tholin.

Transport to and from the Airport

(*a*) Economic Potential for Helicopter Service between Don Muang Airport and Bangkok, Mr. Somnuk Kulprapha, SEATO Graduate School of Engineering.

(*b*) Ground Transport on Exclusive Rights-of-Way Mr. Edward Sue, Planner, Presbyterian Mission, Bangkok.

(*c*) Ground Transport on Public Rights-of-Way, Mr. William E. Queckett, Manager, the Borneo Company, Bangkok.

Air Carriers

(*a*) Regional Passenger Potential Estimates.

(*b*) Terminal Facilities Requirements of Air Carriers Mr. Val Morehouse.

(*c*) The Economic Importance of Integrated Domestic Airline Systems.

Research on Air Transport Problems

(*a*) Aviation Research and Development in the United States Relating to Airports.

(*b*) Future Plans for Bangkok Airport. Mr. Boonmee Sookchareon.

Aircraft Characteristics as Affecting Airport Design

(*a*) Development Report by an European Aircraft Manufacturer.

(*b*) Future Civil Transport Aircraft-Report by an American Manufacturer.

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STATISTICAL INFORMATION RELATING TO IRRIGATION IN INDIA.

SOURCE: *IC and ID Annual Bulletin*, 1962

(1) Total area of India including inland waterways is 806.27 million acres.

(2) Total cultivable area is 435 million acres.

(3) Total population as per 1961 census was 438 million.

(4) Total cultivated area during a year (area which bear two crops in a year counted twice):

	1955-56	1956-57
(*a*) ..	362.56	368.38
(*b*) ..	318.19	322.46

(5) Net irrigated area in million acres by—

(*a*) Government canals.	19.83	19.5
(*b*) Private canals	3.36	3.35
(*c*) Tanks	10.93	11.10
(*d*) Wells (including tube-wells).	16.65	16.23
(*e*) Other sources	5.46	5.44
Total	56.23	55.68

(6) Maintenance expenses direct and indirect, during 1955-56 on some of the important Irrigation works were as under—

Name of scheme	State	Working expenses during 1955-56	Area irrigated in acres	Working expenses per acre
		(In Rupees)		Rupees
Sone Project ..	Bihar ..	26,69,119	683,891	3.90
Cauvery Delta Scheme ..	Madras ..	13,20,564	1,059,667	1.25
Sarda Canal ..	Uttar Pradesh ..	68,41,411	953,245	7.18
Gang Canal ..	Rajasthan ..	12,12,456	650,412	1.86
Nizam Sagar Project ..	Andhra Pradesh ..	7,41,256	177,759	4.17
Eastern Jamuna Canal ..	Uttar Pradesh ..	23,33,411	454,170	5.14

Extract from I.C.I.D. Annual Bulletin 1962.

(7) Cost of construction per acre as estimated for some important projects of the first (1950-51 to 1955-56) and second (1955-56 to 1960-61), five years plan is shown below:—

Name of Project	Name of State	Actual or estimated cost for irrigation alone (million rupees)	Total area irrigated or to be irrigated in mill. acres	Cost of project in per acre of irrigated area	Year of commencement completion
Western Jamuna (Diversion)	Punjab	36.685	1.332	28	NA/1886
Krishna Rajsagar Dam and Visveswaraya Canal (Multi-purpose) ..	Mysore	55.00	0.12	458	1911/1930
Cauvery Mettur Project (Storage) ..	Madras	66.291	0.332	200	1911/1934
Hirakund Dam (Multi-purpose) ..	Orissa	252.8	0.449	563	1948/1956
Matatila (1st Stage) (Storage)	Uttar Pradesh	48.125	0.265	182	1952/1956
Kakrapar (Division) ..	Gujrat	116.507	0.652	179	1949/1957
Bhakra Nangal (Multi-purpose) ..	Punjab	1,142.181	3.203	357	1946/1960
Nagarijunasagar (Multi-purpose) ..	Andhra Pradesh	1,220.2	3.183	383	1955/1964

(8) Gross revenue for existing State-owned works and Projects included in the First Five-Year Plan (1951-52 to 1955-56) which have started yielding benefits by 1954-55 is as below:—

Gross receipts (Direct and Indirect)

	million Rs.
1. Total productive works ...	137.65
2. Total unproductive works (including Navigation, etc.)	40.99
Total ...	178.64

(9) Maximum and average yields per acre of crops during 1959-60 is as under—

Name of Crop		*Yield* (lbs per acre)
Rice	...	808
Wheat	...	692
Jowar	...	424
Bajra	...	292
Maize	...	774
Gram	...	482
Sugar-cane	...	3,279
Ground-nut	...	643
Cotton	...	78
Jute	...	1,066

Some Interesting Papers for Engineers

PAPERS, DISCUSSED IN THE PROCEEDINGS OF THE SEVENTH HIGH DAM CONFERENCE HELD IN 1961, AT ROME (ITALY)

JAEGER (CR)
Recent British experience on underground work and rock mechanics.
Q-25, R-6.

ABOU WAFA (T)
Field tests for grouting Nile alluvials under the ASWAN High Dam.
Q-25, R-13.

LANE (R.G.T.), ROFF (J. W.)
Kariba underground works. Design and construction methods.
Q-25, R-16.

FREY-BAER (O)
Sub-Soil exploration for Zervreila arch dam by means of borings, exploratory tunnels and cement injections in bed rocks.
Q-25, R-34.

LAURILA
The Pirttikoski tailrace tunnel.
Q-25, R-41.

OTTESEN (J. P.), BURNETT (R. E.)
Underground water conduits for Niagara power project, Power Authority of the state of New York.
Q-25, R-54.

UNDERWOOD (L. B)
Tunneling by mechanical miners in faulted shale at Oahe dam.
Q-25, R-55.

WHINNERAH (R. W.), JABARA (M.A.)
Whiskey town dam spillway and outlet works tunnels.
Q-25, R-56.

SCHULZ (W. G.), THAYER (D. P.) & DOODY (J. J.)
Oroville underground power plant.
Q-25, R-57.

SYNDER (D)
Geological problems in the construction of Hills Greek Dam, Middle Fork Willamette river, OREGON.
Q-25, R-58.

AASTRUP (A), SALISTROM (A)
Berge for Sen—A Swedish power plant built on non-resistant rock.
Q-25, R-69.

PRESS (H)
Foundation work in connection with the Construction of large dams.
Q-25, R-72.

KOENIG (H. W.)
Sub Soil works at construction of large dams.
Q-25, R-74.

NONVEILLER (E), HABEKOVIC (M)
Properties of clay-cement suspension for grouting.
Q-25, R-86.

MULLER (L)
Safety of Rock-abutments on concrete dams.
Q-25, R-90.

LAUFER (H), SEEBER (G).
Design and control of linings of pressure tunnels and shafts based on measurements of the deformability of the rock.
Q-25, R-91.

RAO (K. L.)
Modern trends in design and construction of dams in India.
Q-26, R-15.

COLEBATCH (G.T.), WILKINS (J. K.)
Design of catagumya prestressed dam.
Q-26, R-17.

GRONER (F)
Modern technique of concrete dams for wide valleys and auxiliary works.
Q-26, R-21.

DICKERSON (L.H.), MORTON (R.R.)
Review of some recent dams built for scottish conditions.
Q-26, R-25.

KORVENKONTIO (O), KILPELANEN (J) & ARHIPPAINEN (E).
The regulating dam of Petajajaskoski power plant.
Q-26, R-42.

SMITH (S. N.)
Diversion of Saint-Lawrence river for construction of Long sault dam.
Q-26, R-53.

ZIENKIEWICZ (O. C.), VELTROP (J.A.) & SHIEH (W.Y.J.)
Stresses at the base of long spillway and other cantilever walls.
Q-26, R-59.

GOODHUE (H. W.)
Crops of Engineers planning and over-all design of concrete dams in wide valleys.
Q-26, R-60.

FAIRBANKS (H.K.), SUTHERLAND (R.A.)
Design features for safety and economy in dams for wide valleys.
Q-26, R-61.

SCHULTZ (E.R.), SCRIVNER (L.R.) & COPEN (M.D.)
Study of a curved dam in a wide valley.
Q-26, R-62.

RICHARDSON (G.C.)
Ancillary work for dams of the crops of Engineers in the pacific north west.
Q-26, R-63.

ELDER (H.B.)
Diversion and construction techniques of the crops of Engineers for concrete dams in wide valleys.
Q-26, R-64.

BUCHMANN (P), HAUTUM (F).
Study of the safety factor of an arch-gravity dam with a height length ratio 1 : 6 : 5
Q-26, R-75.

KRAUS (A)
Continuous production of concrete at the arlik dam.
Q-26, R-100.

ROUSSEAUX (G.A.), LIKHACHEY (V.P.)
Experience of designing and construction of large dams on rivers of the plains in the U.S.S.R.
Q-26, R-111.

VELTROP (J.A.)
Curved dams in wide valleys. Effects of hinges on stresses in dam.
Q-26, R-113.

GUITART (J.L.)
An examination of the methods of calculating buttress dams.
Q-26, R-122.

VAN ASBECK (W.F.)
The use of asphaltic bitumen for sealing earth and rock fill dams.
Q-27, R-5.

DIXON (H.H.), PERROTT (W.E.)
Investigation and preliminary foundation treatment at the site of the proposed Guma dam, Sierra Leone.
Q-26, R-9.

LANE (K.S.), WOHLT (P.E.)
Performance of sheet piling and blankets for sealing Missouri river reservoirs.
Q-27, R-65.

BROWN (F.S.)
Service behaviour of blankets as a method of sealing dams.
Q-27, R-67.

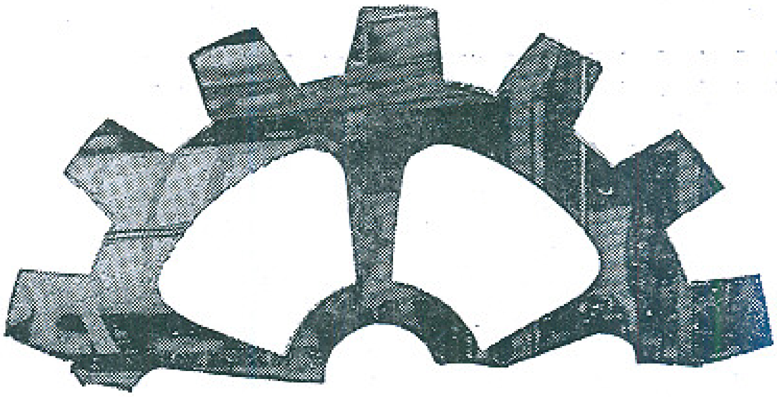
LOHR.
Problems encountered in the construction of fill dams with bituminous sealing elements.
Q-27, R-77.

KJAERNSLI (B) & TORBIAA (I)
Compaction of moraine in three feet layers.
Q-27, R-81.

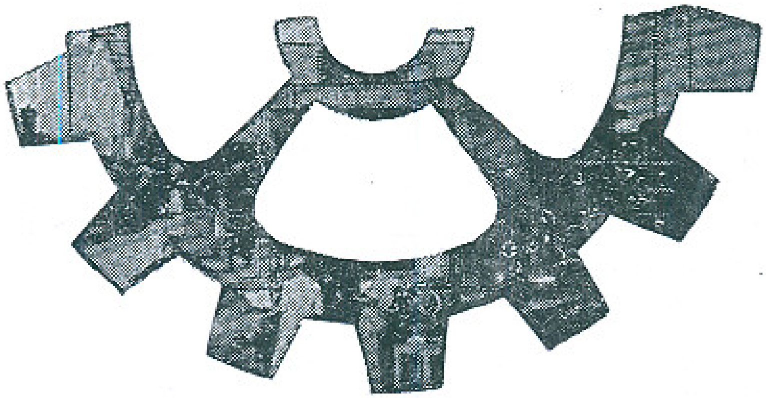
LAUFFER (H) & SCHOBER (W)
Investigations for earth core of the Gepatsch rock fill dam with a height of 150 m. (500 ft.)
Q-27, R-92.

HOBST (L)
The sealing of rock fill and earth dams by precast elements and P.V.C. film liners.
Q-27, R-97.

NITCHIPOROVITCH (A.A.) & SIDOROV (A.A.)
Anti-seepage installations in earth and rock fill dam based on experience in the U.S.S.R.
Q-27, R-123.



BREAKDOWNS?



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