MODERN TECHNIQUES OF VIGILENCE AND REPAIRS ON LARGE DAM

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Modern Techniques of Vigilence and Repairs on Large Dam

1. In Pakistan many modern techniques of vigilence and repairs have been used on Tarbela Dam. This dam on River Indus is one of the largest rock fill dams of the world. The principle element of the project is an embankment dam 9000 ft. long with a maximum height of 485 ft. On the river's Right Bank there is a Power House and 5 Tunnels following a curved alignment through the right abutment of the dam. On the left Bank two saddle spillways discharge into a side valley and 2 auxiliary dams close the upstream end of the side valley and one Irrigation Tunnel. The main embankment dam and two auxiliary embankment dams had a fill of 186 mil ion cubic yard of the earth and rock or about 2/3 as much as the initial excavation of Panama Canal. The reservoir capacity is 11.1 million acre feet on elevation 1550. The maximum draw-down elevation assumed is 1300 giving a net useable capacity of 9.3 MAF.

2. The Project was being completed according to the schedule and filling of reservoir was started in summer of 1974 when due to sudden damages the whole of the reservoir had to be dumped. Although this resu.ted in heavy loss to Pakistan yet there was a lot to learn from this debacle. It high-lighted the importance of vigilence and also brought into focus some of the modern techniques adopted for vigilence and repairs, This paper briefly describes some of the salient features on both these aspects.

3. A brief narration of the subsequent events might be o interest to fully appreciate the aspect of vigilence and the subsequent repairs that were then carried. Tunnel Nos. 1 and 2 have 3 intake gates each. Gates were expected to be operated

simultaneously to the same height. Specially it was expected that if only 2 gates were to be operated then it would only be the side gates. The actual operation of the gates had been somewhat different as given in the sketch enclosed. Due to the middle gate having been stuck under force of circumstances about 40,000 cusecs of water continued flowing in undesirable conditions. On 30th July occasional debris in the form of stone and concrete were observed in water discharging from tunnel No. 2. Another attempt was made on August 7 to lower centre gate of tunnel No. 2 but it could only go down a few feet further. Further attemps were made to close the centre gate on succeeding dates but all without success. In order to keep the water level in the reservoir low, tunnels 3 and 4 outlet gates were opened on August 28th with openings of 24 ft. and 11.5 ft. respectively. Damage caused to gates would be clear from the photographs.

4. On 13th August the steel liner in outlet gate paasage 3A failed. Immediately thereafter all 4 outlet control gates were ciosed. It was then discovered that concrete erosion has occured in varying degree in 4 chutes downstream of the steel liner section. On August 15th, the centre gate of tunnel No. 2 was raised from 25 feet open position to full open position, in order to permit passing of the supplies for irrigation purpose as gates of Tunnels 3 and 4 had to be closed. However as soon as the gate was opened stones were seen passing through the tunnel therefore centre gate was closed again as far as it would go i.e. to the 28 ft. open position. The discharge in that position was about 40,000 cusecs.

5. On August 16th, Tunnel No. 1 left side gate was opened to 10 ft. This gate also was stuck at 2.5 ft. open position and remained in that position till August 22nd.

6. On 21st August at about 23.30 hours a loud explosive noise emanated from the tunnel inlet area. The discharge from Tunnel 2 increased from about 42,000 cusecs to 1,42,000 cusecs. The water was very dirty and contained a lot of stones. A strong thumping type vibration having a frequency of about 2 cycles per second occured in the portal area of tunnel No. 2.

7. On 22nd August the reservoir had attained an elevation of 1463. It was evident that serious damage has taken place to

tunnel No. 2 and decision was taken to deplete the reservoir completely. Intake gates of Tunnel 1 and 2 were opened to various heights viz. Gate 1, 7 ft. Gate 2, 8 ft; and Gate 3, 8 ft. On 23rd August these gates however opened to 7 ft. 24 ft. and 38 ft. respectively. On August 24 gate 3 B was also put in full open position and on Augnst 24 gate 4 B. On 28th August Gate 3 of Tunnel 1 was raised to fully open position and on September 4 gate 2 followed by gate 1 were raised to fully open position. The reservoir draw down was thus completed on 16th September with a total draw down of 327 ft.

8. **Damages**:

(i) Right side of 200 ft. long section of tunnel No. 2 had collapsed immediately downstream of the portal to the tunnel. Rock fill overlain the tunnel was eroded away above this section as well as a distance of 80 ft. farther into the abutment. About 500,000 cubic yard of a rock and fill which formerly overlay tunnel 2 had passed through tunnel 2. The sounding indicated that the natural rock between intakes 1 and 2 was eroded to about elevation 1040 which is about 30 ft. below foundation level of the intakes.

(ii) Serious erosion had also taken place inside Tunnel No. 1 specially at intake piers.

(iii) The liner in 3 A had been very badly damaged.

(iv) There has been severe erosion of concrete in all the chutes 3A, 3B, 4A and 4B.

(v) When the upstream blanket portion was exposed it was revealed that there are number of sinkholes in the whole area over 400 in number. There were also some continuous cracks. Some of the sinkholes were about 6 to 10 feet deep even, and the diameter varied.

(vi) There has been quite a substantial seepage to the right abutment. It was apparent that the grout curtain was not functioning very efficiently.

(vii) Heavy damage was detected in the stilling Basin in May 1975. Concrete in Stilling Basin of tunnel 3 specially has been badly eroded and resulting in big cavities.

(viii) Relief Wells. It was also noticed that some relief wells were flowing more than their normal discharge.

(ix) Piezometer behaviour.

The piezometer readings on various instruments between August 2nd and 10th rose and fell erratically till one of tha piezometer failed on August 15 and another on August 21st. All other piezometer readings returned to normal on 22nd August. This was explained by a direct connection to the tunnel in the upstream area which periodically became partially blocked due to fall in the lime stone.

9. The above narration of events would bring out the importance of vigilence in such big structures. The each individual component might be very small but it has very important role to play while working under such high heads. The minutest details have got to be observed and the design criteria strictly followed. The bolts having not been properly keyed or welded, the gates being operated in unsymmetrical manner, the presence of sugary lime stone and it having not been properly estimated in the intake area, the concrete surface of the chute in outlet area having not been properly smoothen and some patches of concrete sticking out, the air supply being not proper might be considered as some of the essential components of the vigilence which if had been attended to properly at the appropriate time might have to some extent avoided the sudden and unfortunate debacle at Tarbela. The objective of this paper is however not to consider the past events but to examine them with an objective of taking lessons for the future vigilence and to high light the modern techniques in vigilence and repairs that has been adopted at Tarbela.

Modern Technique of Vigilence :

10. One of the mojor worry was about the behaviour of the upstream blanket. This had been strengthen by placing another 4.2 million cubic yard of loose material yet no body could be sure of its adequacy and its behaviour at the time of the next filling. The unusual behaviour of the blanket or development of any connection between the reservoir and the "Open work" could cause a major collapse of the dam. The causes of formation of sink holes and cracks were also not

fully established although there were different theories. The situation was quite confusing. It was therefore very essential to have a proper vigilence on the formation on the sink holes after the blanket area was submerged under water.

11. For this purpose advantage was taken of the Side Scan Sonar Survey System. The Side Scan Sonar has proved to be the most effective means for bottom search. The fine resolution in the system recordings has enabled the users to identify aircraft parts, small vessels, well heads and numerous other search objects. As a complementary device to conventional echo sounding methods, EG&G's side scan sonar can detect bottom irregularities upto a distance of 500 meters on either side of the vessel track.

12. For Tarbela, the Mark IB system as designed and manufactured by EG&G environment Div. was obtained. It consists of a dual channel graphic recorder a tone fish and associated cables. The system is battery powered and fully portable. The system configuration is given in the sketch Enclosure 'A'.

13. The system employes a stable towed transducer (as opposed to hull mounted transducer) to minimize distortion of recorded data by allowing the transducer to be used below the thermocline. Also, the towed transducer is mechanically decoupled from the hull, which reduces distortion caused by vessel roll, pitch, and yaw, The tow fish is usually towed to the side or astern of a vessel, and can be launched or retrieved by one man. It contains two sets of transducers which aim fan-shaped beams to either side of the tow fish perpendicular to the direction of fish motion. In addition the tow fish contains the transducer driver and preamplifiers for received signals. The transducers are line arrays of piezoeletrict crystals which are molded in sound-conducting plastic. Breakaway tailfins are provided to minimize the possibility of snagging the fish on an obstruction. The tow fish is usually operated at a distance above the sea floor equal to 10-20 percent of the range scale in use. In every shallow water, however, successful work can be done with the tow fish only three feet above the sea fioor.

14. Depth of the transducer tow fish is controlled by the length of cable deployed, vessel towing speed, and vessel

course (sharp turns cause the tow fish to go deeper). Tow depth can be increased further by the use of a depressor or suitable weights.

15. The graphic recorder contains most of the electronics for the system as well as the graphic mechanism. The recorder runs from batteries or a D.C. power supply. For small boat operation two fully charged 12-volt automobile batteries can operate the system for more than eight hours. The recorder is mounted in its own tough fiberglass suitcase with removable cover for ease of transportation and handling. The electronic functions include a trigger generator, two amplifiers, two print amplifiers, and a D.C. to A.C. converter. Except for power supplies and line filters, all electronics are on easily accessible plug-in printed wiring boards. An "extender" board is provided for ease of servicing. The recorder used dual helix electrodes which sweep out from the centre of the recording drum. The port and starboard received signals are amplified and ultimately applied to the port and starboard helices of the graphic printer as a varying current. This current passes through specifically treated paper to the printer blade to ground. As the current passes through the paper, iron ions are formed on the paper producing marks of varied intensity (in proportion to the strength of the received signal) forming a graphic representation of the ocean floor. The helix on the right prints echoes from the starboard side of the tow fish while the helix on the left prints echoes from the port side. New "wireless" helices are used for improved performance and reliability.

16. The interpretation of the Side Scan records requires a clear understanding of the basic record-making technique generating of side scan and basic knowledge of the Sonar equation. The side Scan recorder receives the return signals amplifies them and then records on paper a mark of each signal. Their intensity is related to the strength of the signal as received back at the tow fish. The stronger the signal the darker the mark on the paper. The target strength of the given target depends on its size reflectivity and aspect to the Sonar Beam.

17. This instrument has been used with great success at

Tarbela. Exceptionally clear pictures have been obtained of the blanket area and have been improved in the various surveys that have been carried out to locate sinkholes, the cracks and even the minutest details. The unevenness was clearly reflected in the picture. One such sample picture is enclosed. As a result of the various surveys carried out on various depth the following sink holes were noticed :—

		Date	Reservoir level
Survey No. 1 :	70	28/5/1975	1257.87
Survey No. 2 :	58	11/6/1975	1265.30
Survey No. 3 :	27	16/6/1975	1270.35
Survey No. 4 :	12	15/7/1975	1380.4
Survey No. 5 :	61	9/8/1975	1514.0
Survey No. 6 :	41		
Survey No. 7 :	20		
Survey No. 8 :	0	24/8/75	1530.88
		29/8/75	1531.11
Total :—	289		

Only four surveys for the blanket extension have been completed and 97 sink holes were spotted. The break down is as under :—

Survey No. 1 :	57	3/6/1975	1262.15
Survey No. 2 :	25	19/6/1975	1299.64
Survey No. 3 :	8	4/7/1975	1345.8
Survey No. 4 :	7	6/8/1975	1502.0
Total :—	97		

Some sink holes have enlarged after initial detection, One sink hole (Ch : 58+00—775') upstream of the toe of MED) had enlarged from 5' to 16' diameter between survey 1 & 2. Another sink hole (Ch. 56+50-2200') upstream of the toe of MED) enlarged from 4' to 10' diameter between survey 2&3.

None of the sink holes enlarged between survey 3 and 4. Sink holes which enlarged between Survey 4 & 5 are the following.

18. It was also noticed that the following sink holes have increased in size.

Sink Hole No.	Distance from U/S toe of dam	Chart Co-ordinates	Size Survey IV	Size Survey V
6	2500 ft.	612,999 N 412,580 E	4′ dia	20′×8′
22	1600 ft.	611,770 N 421,640 E	15′ dia	30′×15′
44	1700 ft.	611,490 N 422,180 E	6′ dia	35′×8′(Lead 2′otheren
47	1250 ft.	611,300 N 421,680 E	6′ dia	15′×6′
59	700 ft.	610,410 N 422,100 E	6′ dia	22′×9′
o5	1800 ft.	611,560 N 422,660 E	15′ dia	30′×15′(Lead 5′
103	1700 ft.	611,360 N 422,830 E	5′ dia	25′×2′(other end)

19. Effort has also been made to determine the depth of the sink-holes. It is possible to determine the depth but in view of the limited time as more number of surveys had to be carried out this aspect was not measured. Similarly it is possible to determine the velocities of the flow of water through the sink holes if in any one of the surveys it was noticed that in one area the instrument indicated the minimum velocity that could be detected on the ir strument of 0.5 ft. per second and in all others there was hardly indication of velocity.

20. Therefore, with this instrument and the surveys being regularly carried out it is now possible to know precisely as to what is happening under the 400 to 500 ft. depth of water. The results are very accurate, reliable and clear.

21. Second important aspect was to precisely determine the location of the sink holes in order to accurately determining the position of Barges etc. for having treatment of the sink holes. For this purpose the mini ranger III system (MRS III) is used to accurately determine the position of the mobile unit.

This position is determined with respect to Radar Transponder reference stations located at known fixed point. This operates on the basic principle of pulse radars use a transmiter (located on the mobile unit) to interrog te the reference station transponder. The elapsed time between the transmitted interogation produced by MRS III transmiter and the reply received from each transponder is used as the basis for determing the range to each transponder. This range information, displaced by the MRS III together with the known locatien of each fix transponder can be trilaterated to provide a position of mobile unit.

22. The 3rd important aspect was with regard to observed pressures by piezometer and thormometers. For this purpose number of piezometer/Thermometers have been installed of varying the depth in the blanket areas at the various locations, These piezometers are being read, analysed and interpreted. Their behaviour is strictly watched and compared with the results obtained from side Scan Sonar, The result of one of the study is reproduced below.

23. During the first 4 to 6 days of observations after the 18th August the potentials as measured at the upstream piezometers dropped slightly. The largest of these potential drops occurred in area of the upstream end of the open work on the right and the centre of the river hence suggesting some migration of sand from this area. However. after 4 to 6 days the potential stopped decreasing hence a stable situation was achieved. It is also quite probably that part of the decrease in potential was due to changed tail water condition. Table 1·1 shows day to day potential values of all deep and shallow piezometers in the alluvial foundation upstream of the Main Embankment Dam for the report period, Ground water equipotential contours for August 9, 15, 22 and 31 are included on Figures 1.9 thru 1.12. For the purpose of comparison equipotential contours from piezometers at shallow depth (5 ft. into the alluvium below bottom of blanket) have also been included on Figure 1.12. It should be noted that the shallow potentials are based only on readings on the lines of piezometers at the downstream of cofferdam C and at the upstream toe of the MED and are therefore, of limited accuracy in betwcen these lines Piezometer 201 A has been neglected as we believe

its high potential is a local effect due to sink holes in the immediate vicinity. Shallow and deep potentials are much the same at the upstream toe of the dam. Generally the shallow piezometers show higher potentials than the deep piezometers indicating a general downward flow of water. The maximum gradient is about 2/3 in several locations. There is a zone in the centre where the deep potentials are apparently higher than the shallow indicating an upward flow of water. This seems rather doubtful but could occur in a foundation as variable as one at Tarbela.

24. Cassagrande piezometers installed in BP 24, BB-160, BB 166 and BB-200 (routed to MXI House) started reading during this period. On 31st August electric and Cassagrande piezometers read 1304 and 1308 respectively in BP-24 and 1212/1215 (two electric cells) and 1200 respectively in BB-200. As electric piezometers is BB-160 and BB-166 are not operative, the readings are measured by the two types cannot be compared.

The sedimentation piezometers show that there is still little head loss through the sediment.

The thermometers did not show any significant change during this period.

Thus any increase in pressure at any place can be immediately noticed and its causes determined for having remedial measures.

25. The fourth important aspect is flow measurements in the alluvial foundation, left abutment and right abutment. Constant observations are taken of the seepage in the relief wells from the right abutment and the left abutment. Their approximate value as observed at an elevation of 1530 is as below :—

(i) Through Dam	275 Cusecs.
(ii) Right abutment	46-50 Cusecs.
(iii) Left abutment	12 Cusecs.

The total number of wells running is about 188 and the maximum discharge through one well has been 1.7 cusecs.

26. Sand has also been observed in the drainage channel. Regular measurements were taken of the sand coming out

through wells and other sources. In some of the wells discharging large quantity of sand T. V. camera was used to find the causes. In one of the wells it was revealed that well scrone had broken and TV Camera would not go beyond 75 ft. This well had to be subsequently plugged. In another well clear picture would come upto about 110 ft. depth but beyond that water still became merky and although the TV Camera would go down by another 100 ft. into the water but no picture would be available. Thus by the help of TV Camera clear picture is being obtained of the conditions of the relief wells except in a few exceptional cases. The total quantity of sand measured is about 3 cubic yards. Such a small quantity can have no adverse effect on the foundation.

27. The fifth important aspect is with regard to vibration problems. They are of two kinds. The heavy structures like intake structure and outlet works are likely to be affected by the vibrations. Second due to impounding the adjoining area experiences sesmic activities. Such frequencies were measured by 211 Tektronix oscilloscope (Lamont unit). On the concrete outlet structure the predominant frequency was about 100 CPS although some of 40-50 cps and 7-10 cps were also obtained. Measurement taken at the dam crest showed predominant frequency of 4 CPS although some 25-40 cps was noted in the vertical mode.

28. Certain seismological stations were set up in the vicinity by 70 miles away and they have picked up a frequency of about 1.0-1.3 cps. It is planned to adopt a Sprengnether smoked-Drum seismograph (Lamont equipment) so it may produce a continuous record of vibration. This record can be studied and even low frequency vibrations can be identified. In addition to the fixed seismographic station portable recording equipment has also been made available at site for recording vibrations at known potential travel spots. Predominent record from this equipment would be important in evaluating the affects of modified flow operations of the tunnels.

29. Regular soundings are required to be taken of the plung pools of the spillways. This would determine the extent of scour that is taking place in the area and whether it is within the designed and anticipated limits. It was noticed that in the

Auxiliary spillway there was an out crop of hard rock due to which the striking jet was reflected to the left and big scour was taking place. Not the same subject soundings in the stilling basin area by expert divers have revealed heavy damages. It has not been possible to use the TV Camera because of the darkness to see the extent of the damage. While the down-stream water level in the stilling basin is being maintained at 1090 the divers have gone in and located the scan upto depth of elevation 950. The wall between Tunnel No. 3 and 4 had been damaged to the extent that divers can enter from one side and get out at the other. The wall is 80 ft. thick. The damages as observed by soundings and by means of divers is shown in one of the sketches as enclosed. It would be appreciated that this work is carried out while the upstream water level in the reservoir is on the elevation 1530 and the maximum pit is at elevation RL 950. There is a constant discharge of 3000 gallons per minute. This is being pumped out but its source is not known.

30. While filling operation was continuing suddenly a hole was noticed in the upstream slope of the dam in the intake area where the stone fill had suddenly gone down in shape of a verticle hole. Immediate soundings in the water were taken and it was noticed that this hole was exactly above remanent portion of the air duct which had been left open and had not been plugged. With the rise of the water level the stone was perhaps got sucked in the air duck thus causing this cavity.

31. The above techniques of vigilence by observations, soundings, photography, the pizometer observations are all being carried out when the reservoir is practically full. It would be noticed that any effect on the dam or its other permanent structures is noticed or known as soon as it occures. No where it is considered necessary to find out any effectry lowering of the water level. A clear picture is known of every thing, that is happening and the situation is under constant observations. Simultantously as would be explained in the following paragraphs most of the remedial works have been carried out in water and the shortest possible time with modern techniques and there is no problem in the proper operation and functioning of the dam.

Modern techniques of remedial measures and repairs

32. (i) In order to treat the sink holes 2 dumping barges were imported. They have the capacity of 75 cubic yard each. Special dumping material was designed which would result in maximum placing of the dump on the sink holes by various experiments that mix was evolved which could result in a very good efficiency. Its spread was about 28 meters. By 24 hours working it was possible to attain on average 20 dumps and any resulting placing of 3000 cubic yard of dump material in a day. In this way about 30 sink holes have already been treated. The location of the sink holes and direction to barges for placing is given by MRS III. As revealed by the subsequent Side Scan Sonar survey the dump has treated the sink holes very effectively. The piezometer observations have also shown very encouraging results. It has, therefore, become very clear that even with a depth of water about 500 feet it is possible to clearly spot out any damage or any defect and then have it treated properly. This is a very big achievement of the modern technology.

33. (ii) About 500,000 cubic yards of the rock mostly sugary lime stone had been completely eroded in the intake area in the right abutment. It was important to rebuild the right abutment in the damaged portion of the intake in the shortest possible time and of sufficient strength to withstand the pressures. The mountain had also to be cut to remove as far as possible any weak geology of sugary lime stone and weak carbonaceous schist. It was also important that while this mountain was being rebuilt the work on repairing of tunnel No. 2 must also proceed simultaneously.

34. It was then decided to built up the mountain of right abutment by adopting "Roll-crete", as a fill material from bed rock upto an elevation of 1230 to cover and support the upstream portions of tunnels 1 and 2 and buttress the Intake cut Slopes upto elevation 1250. It is estimated that total of 460,000 cubic yard of Rollcrete was placed as a continuous operation without any intervals between the pours. This was achieved in a period of 6 to 8 weeks. The "Roll-Crete" is a lean zero slump concrete. It is placed like any other earth and rock fill material and compacted with rubber tyre or vibratory

rollers. Roll-crete requires no horizontal or vertical construction joint nor any extensive curing. The cement/aggregate ratio is generally 1/15 to 1/20 with a 2 to 5 percent water content. Natural aggregates of maximum size of 9" boulder gravel having 20% to 30% sand was used. In one cubic yard of RBG 1 to 2 cubic feet of cement was mixed. The consumption of cement for roll crete operation was about 700 tons to 1200 tons per day which was a record of consumption on any work. The cement was hauled in covered belli-dumpers (about 50 tons) from Tarbela Railway siding to roll-crete plant. The belli-dumpers open their bellies to unload the cement in cement hopper of roll crete plant. It is so arranged that for one cubic yard an aggregate of 2 cubic feet cement is placed while the conveyer belt is running. Water is added at the highest point of the main conveyer belt prior to its falling on the lader used for mixing. The quantity of water is controlled in such a way that the roll-crete has a zero slump. The water content was kept about 2 to 5 percent of volume depending upon the moisture present in the incoming RVG. The whole roll-crete operation was completed in 6 weeks and it has had withstood very well. This operation can successfully employed in any other repair.

35. (iii) Some repairs have to be done under water like in the intake area and in the stilling basin area. In this "Tremie Concrete is used. This is a concrete mix with 6" to 7" slump, 42% sand, $1\frac{1}{2}$" size aggregate mix; water content 0.6 and Aggregate cement rated 6: 1. It is pumped by pipes to the desired depth and the cavities are filled up. The operation was quite successful in tunnel No. 2 and intake area and would be carried in the stilling basin.

36. (iv) Repairs to outlet chamber of 3A was problem because stainless steel liner could not be put in the short time available. The floor and sides were reconstructed with a epoxy concrete and then epoxy paint was put on it. All the repairs carried out with epoxy have stood very well. The idea of putting in the stainless steel plates have been given a second thought in view of the fact that epoxy has stood very well. About 14 number transducers were also put in the Chamber 3A and regular observations are being carried out. Apparently it appears that epoxy concrete can be very useful material for such repairs where there are likely chance of having erosion.

37. (v) In order to cope with the seepage additional 77 number of relief wells were added. There was problem with regard to the availability of the strainers and therefore small size screens $4\frac{1}{2}$" dia were used without any shrouding material to expedite the construction. The Becker drilling rigs have proved very effective and the work was carried out in the record time.

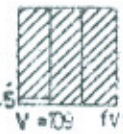
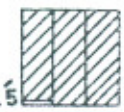
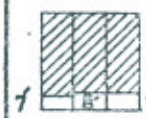
38. It would be apparent from the description given above that practically all the repairs have been carried without in any way necessitating lowering of the water level in the reservoir. The modern technology has developed so much that all repairs can be carried out even in water. Tarbela has been a very good example where most of modern techniques had been used for vigilence as well as repairs. Advantage should be taken of this by all the Engineers of the world and it should be very clear that the out-dated practices of completely depleting the reservoir for inspection or of having the work done unless surface was exposed, are discarded.

SHEET: 1 OF 3

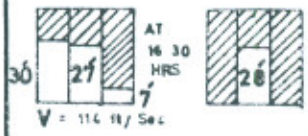
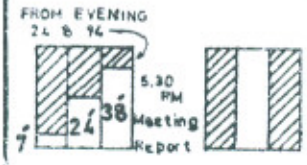
OPERATION OF TUNNELS NO 1 AND 2

DATE	POND LEVEL	TUNNEL 1 TUNNEL 2	REMARKS
4.7.74			4/7 TUNNEL – 4 CLOSED C. 11.30 TO REDUCE OUTFLOW
5.7.74	1178.50	1134.5 / 1089.5 / 45'	11/7 TUNNEL – 3 CLOSED AT 11.30 TO 1300
12.7.74	1183.20		DO
			INLET T-3 & T-4 70.5' HIGHER i.e 1160.00
13.7.74	1189.80		
15.7.74	1208 10		
15.7.74 (EVE.)			
20.7.74	1277.60		EARLY HOURS OF 20/7 INSTRUCTIONS RECEIVED FROM MINISTER TO INTERUPT FILLING. GATES OF T-3 & T-4 DECIDED TO BE RAISED.
24.7.74	1313 50		
27.7.74	1336.50		AS PER CONSULTANTS REPORT DATED 14.8.74, ATTEMPT MADE TO CLOSE CENTRE GATE OF T-2. BOTH SIDE GATES IN POSITION AND ALL T-1 GATES WERE FULLY CLOSED. RESERVOIR EL. 1300.?
31.7.74	1350.48		
6.8.74	1379 50		ROCK FRAGMENT & CONCRETE FRAGMENTS BEING WASHED UP ON SPRAY DEFLECTOR DECK. IT CONTINUED TILL 11.8.74 – REPORT DATED 14.8.74. WATER DEPTH OVER GATE CREST = 280' V = 92.3 FT./SEC.
7.8.74	1385.90	26'	
8.8.74	1391.80	28'	AND THEN ATTEMPTED TO CLOSE CENTRE GATE OF T-2
9.8.74	1394.70	26'	EFFORTS TO CLOSE CENTRE GATE CONTINUE. WATER DEPTH = 305.20'

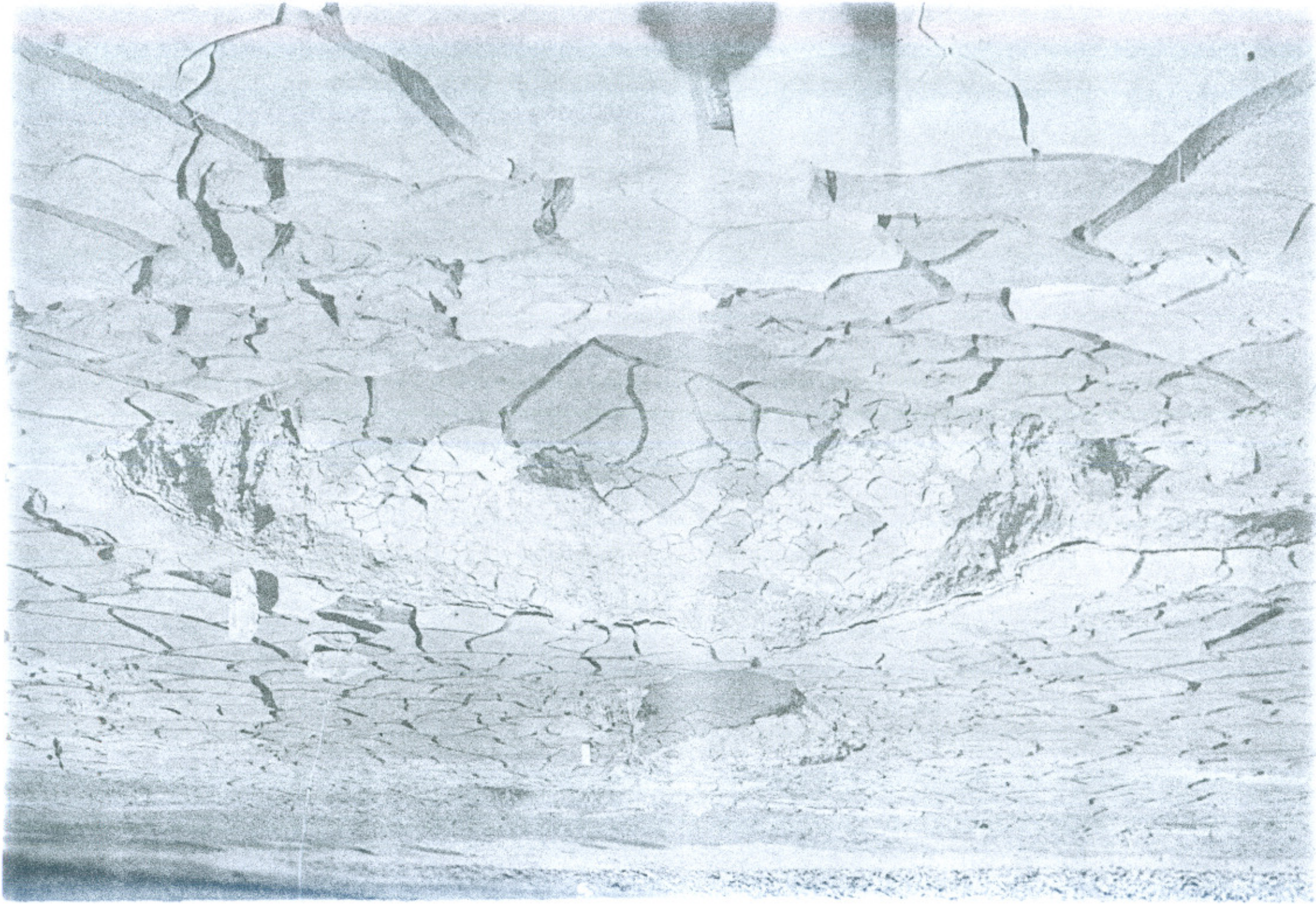
SHEET 2 OF 3

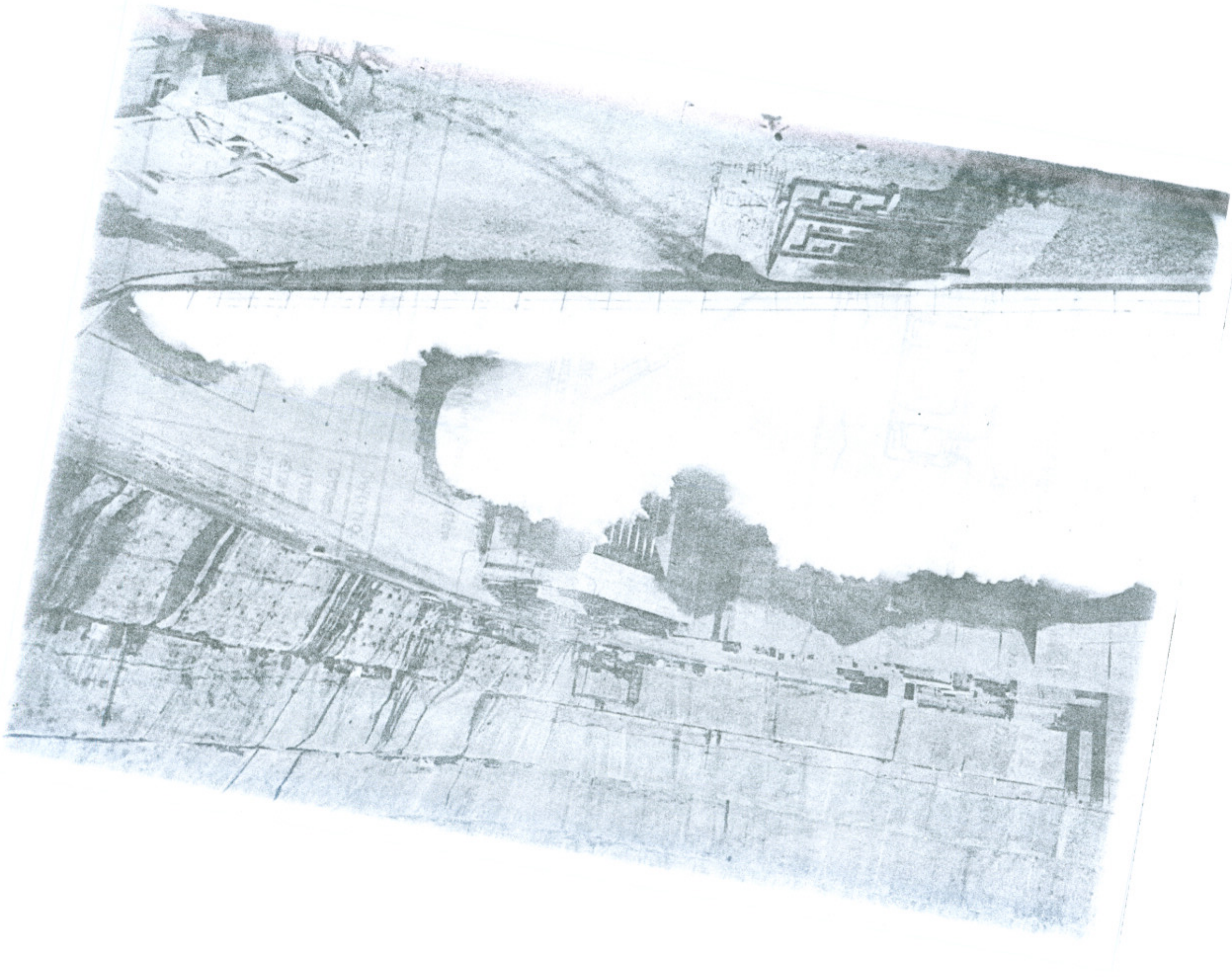
DATE	POND LEVEL	TUNNEL 1	TUNNEL 2	REMARKS
10.8.74	1396.40			WATER THROUGH T-2 NOTICEABLY DARKER.
11.8.74	1398.30			EFFORTS TO CLOSE CENTRE GATE OF T-2 CONTINUE
13.8.74	1407 00			T-3 & T-4 CLOSED AT 15.30 HRS. S. STEEL CLAD, LINER PLATE ON SIDE AND FLOOR OF T-3 RIPPED OUT.
14 8 74	1416 50			CONSULTANTS REPORT WITH ONLY T-2 CENTRE GATE AT 25.5′ OPENING AVAILABLE OUTFLOW CAPACITY ESTIMATED AT 2′ 1410 41,000 CFS. AT 5′ 1490 46,000 " NOTE: VELOCITIES WORK OUT TO 107 FT/SEC. AND 121 FT/SEC.
15.8.74	1426 50			FULL OPEN 11.00 HRS.
15.8.74				2 RESTEEL BARS NOTICED, THEN RECLOSED TO 28′ OPEN POSITION OF CENTRAL GATE, AT 16.00 HRS V = 118.8 FT/SEC.
16.8.74	1435 55			
17.8.74	1442.15			
19.8.74	1452 10			
20 8 74	1456.30			EFFORTS TO CLOSE 1.5 CONTINUE V = 117 FT/SEC
22.8.74	1461 50			WATER DEPTH OVER CILL 37.6′ REPORT THAT CENTRE GATE & RIGHT SIDE GATE FAILED AT 00.30 HRS. OUTFLOW INCREASED FROM 42,500 TO 146,000 CFS. DECIDED TO EMPTY THE DAM RESERVOIR BY OPENING T-1 FIRST STAGE OPENING WAS ACCOMPLISHED ON 22ND AND AN INCREMENTAL OPENING WAS MADE ON 28.8.74 BY RISING THE RIGHT GATE TO FULL OPEN LOCKED POSITION.
23.8.74	1460 30			

SHEET 3 OF 3

DATE	POND LEVEL	TUNNEL 1 TUNNEL 2	REMARKS
23 . 8 . 74	1459.15		
24 . 8 . 74	1455 . 50		OPENED T-3 B & T-4 B TO EMPTY RESERVOIR DAILY MEETINGS AT 5 . 30 P.M START.
25 . 8 . 74	1442 . 60		ASSUMED 2 GATES FULL OPEN. 5.30 P.M MEETING RECORD.
26 . 8 . 74	1433 . 00		
27 . 8 . 74	1422 , 60		
28 . 8 . 74	1413 . 35		SEE REPORT OF SP. CONSULTANTS DATED 1 . 9 . 74.
29 . 8 . 74	1401 . 00		RIGHT GATE FULL OPEN DETERMIN LEFT AND CENTRE GATE WHETHER OPERABLE
30 . 8 . 74	1388 . 00		WHEN POOL REACHES 1300.0
31 . 8 . 74	1375 . 70		THEN OPERATE EITHER OR BOTH PARTIALLY
1 . 9 . 74	1363 70		TO MAINTAIN T-1 DISCHARGE APPROXIMAT.. ELY EQUAL TO T-2 IN ORDER TO OBTAIN UNIFORM DISCHARGE ACROSS D/S APRON.
2 . 9 . 74	1349 . 65		
3 . 9 . 74	1334 . 90		
4 . 9 . 74	1318 . 55		
5 . 9 . 74	1296 . 76		
6 . 9 . 74	1274 . 40		
7 . 9 . 74	1251 . 40		
8 . 9 . 74	1231 . 05		
9 . 9 . 74	1218 . 70		
10 . 9 . 74	1194 . 60		SILTY WATER IN T-1
11 . 9 . 74	1180 . 70		
12 . 9 . 74	1169 . 40		
13 . 9 . 74	1158 . 95		
14 . 9 . 74	1151 . 85		

Pervaiz Akhtar





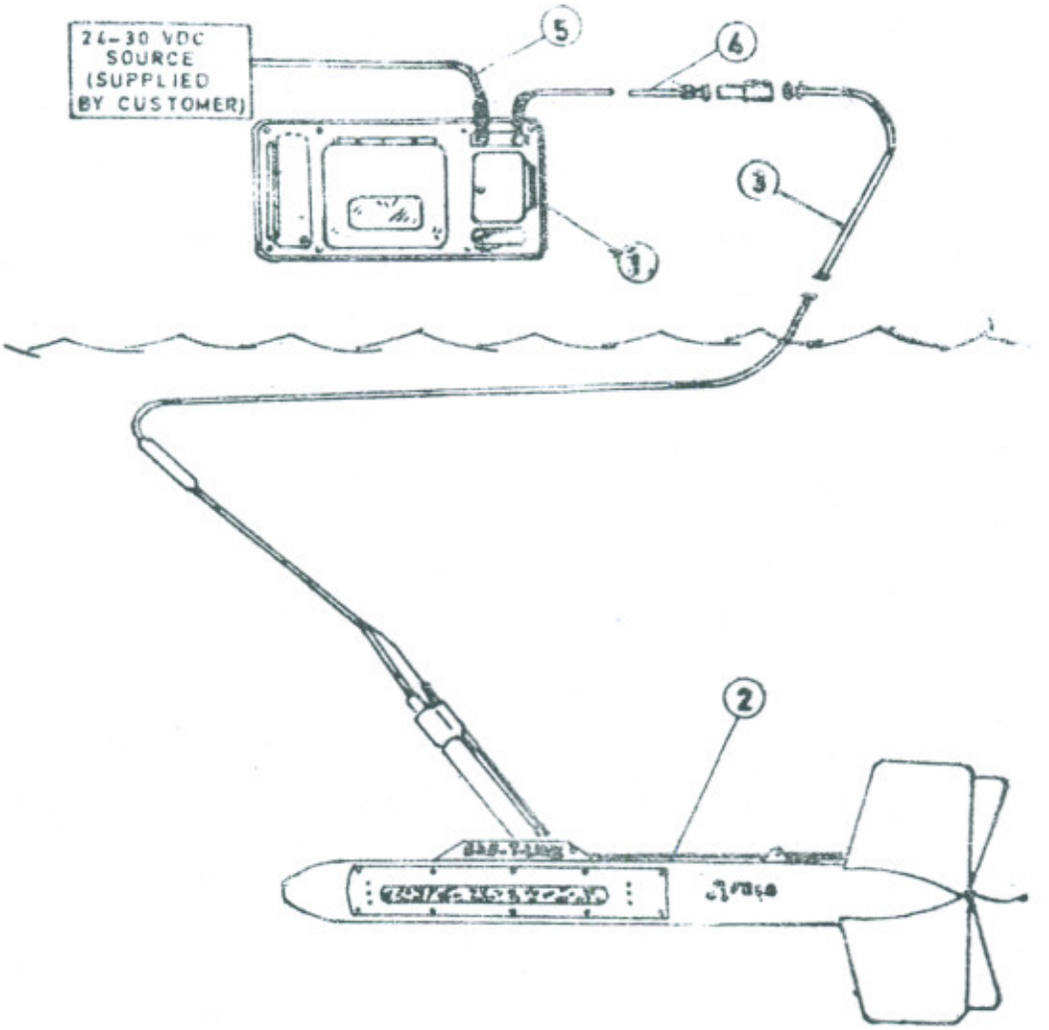


Figure 1-1. System Configuration

ITEM	DESCRIPTION	DWG NO.	REMARKS
1	RECORDER, MODEL 259-3	C17208	
2	SAF-T-LINK TOW FISH, MODEL 272	J17588	
3	TOW CABLE, MAIN TOW(600 meters) TOW CABLE, MAIN TOW(150 meters) TOW CABLE, MAIN TOW(50 meters)	E17859 F17858 D17858	OPTION 1 OPTION 2 OPTION 3
4	INTERCONNECTING CABLE, RECORDED TO MAIN TOW CABLE (15 meters)	C16594	NOT USED WITH OPTION 3
5	CABLE, POWER (2 -1/2 meters)	C 210674	
6	DEPTH DEPRESSOR		OPTION 4
7	INSTRUCTION MANUAL	TM 73-241B	

Table 1-1 Mark 18 side scan sonar System Components