11.4.1 Sloping Glacis

Sloping glacis starting at RL 1820, 20 ft. d/s of bucket was taken down to R.L.1780. It is a 5 feet thick concrete lining with reinforcement in the top layer. The cutoff wall at the end of glacis was taken down to RL 1770. The apron was tied to foundation with steel rock anchors. This would protect the bucket and chute structure against the impact of back rollers.

11.4.2 The Pool

The channel beyond the glacis was excavated to conform to scour for a discharge of 30,000 cusecs. It was necessary for proper energy dissipation of the falling jet for different range of discharges. The channel was excavated to RL 1780 upto RD 1130 and then taken to RL 1825 on a slope of 2H:1V.

11.4.3 Right Flank Protection

Right flank shale bed was protected by a retaining wall upto RL 1840 and RD 1050 ending in a return wall into the hill. Below RL 1820, the foundation of the wall, the channel is sloping at 1V:1H and provided with 2 ft. thick concrete lining and a concrete cutoff upto EL 1770. Beyond the right flank wall the channel slope was protected with 2 ft. thick concrete lining. The rock slopes on this flank were also protected by stone masonry pitching.

11.4.4 Left Flank Protection

An R.C.C. wall similar to the right flank was designed on the left flank. The wall was founded at RL 1820 on limestone. The concrete work upto RL 1100 was completed but beyond this work was abdicated due to rise of water level in the reservoir and thereby in the pool inspite of pumping for dewatering. After the water level

in the reservoir goes down, it is proposed that left over protection works between RD 1100 and RD 1250 be carried out. As it would be quite difficult to dewater the plunge pool completely it is proposed to protect the excavation from RL 1740 to RL 1750 by gabions and above RL 1750 concreting would be done.

11.4.5 Spur Dyke

A spur dyke was provided on the left flank so that the water does not come back towards the toe of main dam.

According to the model studies, flows higher than 50,000 cusecs may scour the plunge pool beds and also the flanks beyond RD 1100. However, such scour is not expected to cause any damage to the spillway structure.

12.0 CLOSURE SCHEME

The unit hydrograph studies indicated that a probable non-monsoon flood peak was of the order of 19,500 cusecs. Flood routing study for the above discharge with a 10 ft. dia tunnel available for discharge showed that the maximum water level reached was 1883.5. With a free board of 4.5 feet, the crest of coffer dam was fixed as 1888.

The construction sequence of blanket in the two stream beds was co-ordinated with the target date of construction of coffer dam. This was done by putting temporary bunds across the river courses and diverting the two streams through the diversion tunnel. The closure operation consisted of:

1. Diversion of Nilan Kas through the diversion channel already blanketed.
2. Diversion of Haro River through the diversion channel.

3. Diversion of both the above through the diversion tunnel.

4. Construction of upstream impervious blanket in the active stream beds.

5. Construction of coffer dam and upstream slope protection works.

6. Construction of Stage-II closure section of Main Dam upto RL 1960 including slope protection works.

7. Stage-III construction of Main Dam upto RL 1992 with slope protection works.

13.0 DIVERSION TUNNEL

The tunnel is located in the left abutment. It started 500 ft. upstream of main dam axis after following a curved alignment opened into the river about 940 ft. downstream of the dam axis. Originally the inlet portal of the tunnel was proposed at R.D. 375 but due to a large slide in the tunnel it had to be shifted to R.D. 525. A cut and cover conduit was provided in this reach.

The tunnel is 10 ft. diameter, horse shoe shaped with an R.C.C. lining of 15 inches in limestone and 24 inches in shale reaches.

The invert level at R.D. 425 was R.L.1829.89 and at outlet portal it was 1826.75. The longitudinal slope of the tunnel was 1 in 500.

The tunnel traversed through three main rock units namely shale, massive limestone and nodular limestone. The properties of these rocks and the reaches in which they were exposed were as follows: From R.D. 225 to 608 shale reddish brown to greenish grey and black, soft, splintery, highly weathered and sheared.

From R.D. 608 to 819, from 864 to 1261 and from 1546 to the end of the tunnel, well bedded massive limestone was encountered. The rock was hard, dark grey, compact, moderately jointed and fractured.

From R.D. 819 to 864 and from 1261 to 1546 of the tunnel, nodular limestone was encountered. The nodular limestone was greyish brown, slightly to moderately weathered and compact. This rock was comparatively weaker than massive limestone and contained argillaceous partings around the nodules.

Grout sleeves were left at the time of concreting by embedding pipe pieces at regular intervals for contact grouting. Consolidation grouting was also carried out in the plug area by drilling 16 ft. deep radial holes. The tunnel was designed to withstand a head of 130 ft. and velocity of 28 ft./sec.

14.0 INSTRUMENTATION AND MONITORING

Instrumentation is needed to monitor the performance of a structure during and after construction and to provide evidence that design criteria are satisfied. The instrumentation of Khanpur Dam Project has been designed for the main dam, abutments, u/s blanket and spillway as follows:

MAIN DAM

Thirty piezometers were installed at ch. 6+40, out of which six are electrical and twenty four are hydraulic. Twenty two piezometers are working presently. Four piezometers were proposed to be installed at ch.9+50. Seven Casagrande type piezometers are in operation at the toe of main dam. Review of performance and monitoring studies indicates that all the piezometers are behaving almost

in harmony with the reservoir level. Higher residual pressures were observed at the toe of main dam.

ABUTMENTS

About twenty six piezometers were proposed to be installed in the abutments. At present three have been installed and are working. Higher pressures have been indicated in the left abutment.

BLANKET

Twenty five electrical piezometers were installed out of which thirteen are in operation. Except two piezometers which showed higher potential, the others recorded normal pressures.

SPILLWAY

Thirteen Casagrande type piezometers were installed and all of them are in operation. The head of water was just above the spillway crest. The behaviour of foundation would be tested when the water reaches the max. level to be impounded.

MOVEMENT CONTROL

Surface markers, slope indicators and settlement plates are being installed for movement control.

IMPOUNDING OF RESERVOIR

The flood of April 1983 in which water level rose to 1900.8 for a brief period provided an opportunity to review the underseepage control measures. The diversion tunnel was closed on 25th July 1983, the reservoir started impounding and the water level reached the spillway crest on 25th August and remained at that level till end of November 1983 after which it started lowering due to working of outlet.

SEEPAGE STUDIES AND RELIEF WELLS

No seepage has developed through the core of the dam as yet. The relief wells at d/s toe of Main Dam were installed at 100 ft. spacing as initially envisaged but they were found insufficient. All the installed relief wells were overflowing. Seepage was emerging from the d/s toe of closure section and the Main Dam. Higher pressures were recorded in the piezometers installed in the d/s shell and foundation. Sand boiling was noticed near the relief wells although minor in quantity.

Based on the field observations and instrumental behaviour it was considered necessary to provide immediately the following seepage control and disposal arrangement.

i) Extension of weighted toe berm initially provided during the temporary impounding of April 1983. The berm comprised of free draining material.

ii) Additional relief wells to provide drainage and reduce uplift. Starting from left abutment spacing in between RW1 to RW4 was reduced to 25 ft. and between RW4 and RW17 it was 50 ft. A second line of relief wells at 50 ft. d/s to supplement the existing ones shall be installed.

iii) Collector drain to intercept seepage and provide means of shallow drainage to carry away water coming out from the d/s filter blanket and relief wells.

iv) Additional piezometers shall be installed d/s of relief wells to monitor the behaviour of foundation.

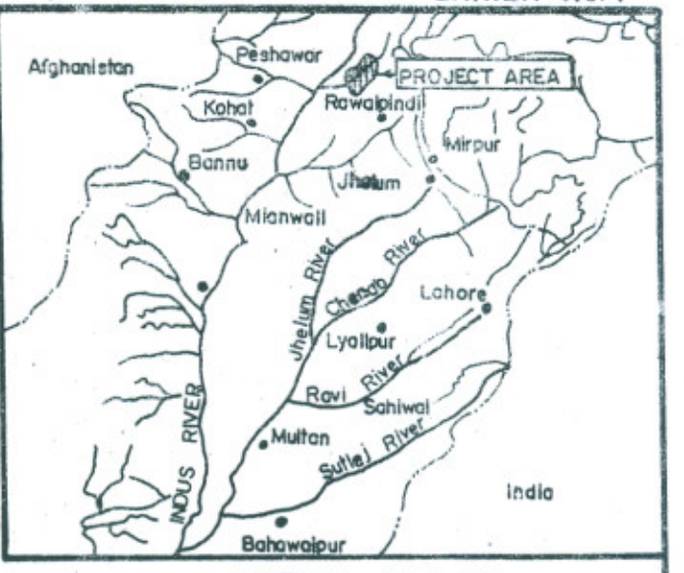
Dr. Izhar-ul-Haq

The total quantity of seepage at the d/s toe of Main Dam through the foundation alluvium was 20 cusecs when the reservoir level was RL ± 1947. After a period of about 4 months, it decreased to about 3 cusecs when the reservoir level dropped down to RL 1910 showing improvement in the blanket.

LIST OF FIGURES

Figure No.	Title
Exhibit No.1	General Layout of Structures.
Exhibit No.2	Subsurface Exploration Plan.
Exhibit No.3	Surface Geology.
Exhibit No.4.	Geology Section Along Dam Axis.
Exhibit No.5.	Gradation Limits of Construction Material.
Exhibit No.6.	Typical Sections of Main Dam.
Exhibit No.7.	Geological Plan of Left Bank Saddle.
Exhibit No.8.	Typical Section of Check Dam and Left Bank Saddle Embankment.
Exhibit No.9.	Typical Cross Section of Right Bank Saddle Embankment No.1 and No.2.
Exhibit No.10.	Outlet Works Plan and X-Section.
Exhibit No.11.	United Hydrograph.
Exhibit No.12.	Plan and X-Section of Spillway.
Exhibit No.13.	Spillway Plunge Pool Plan and X-Section.

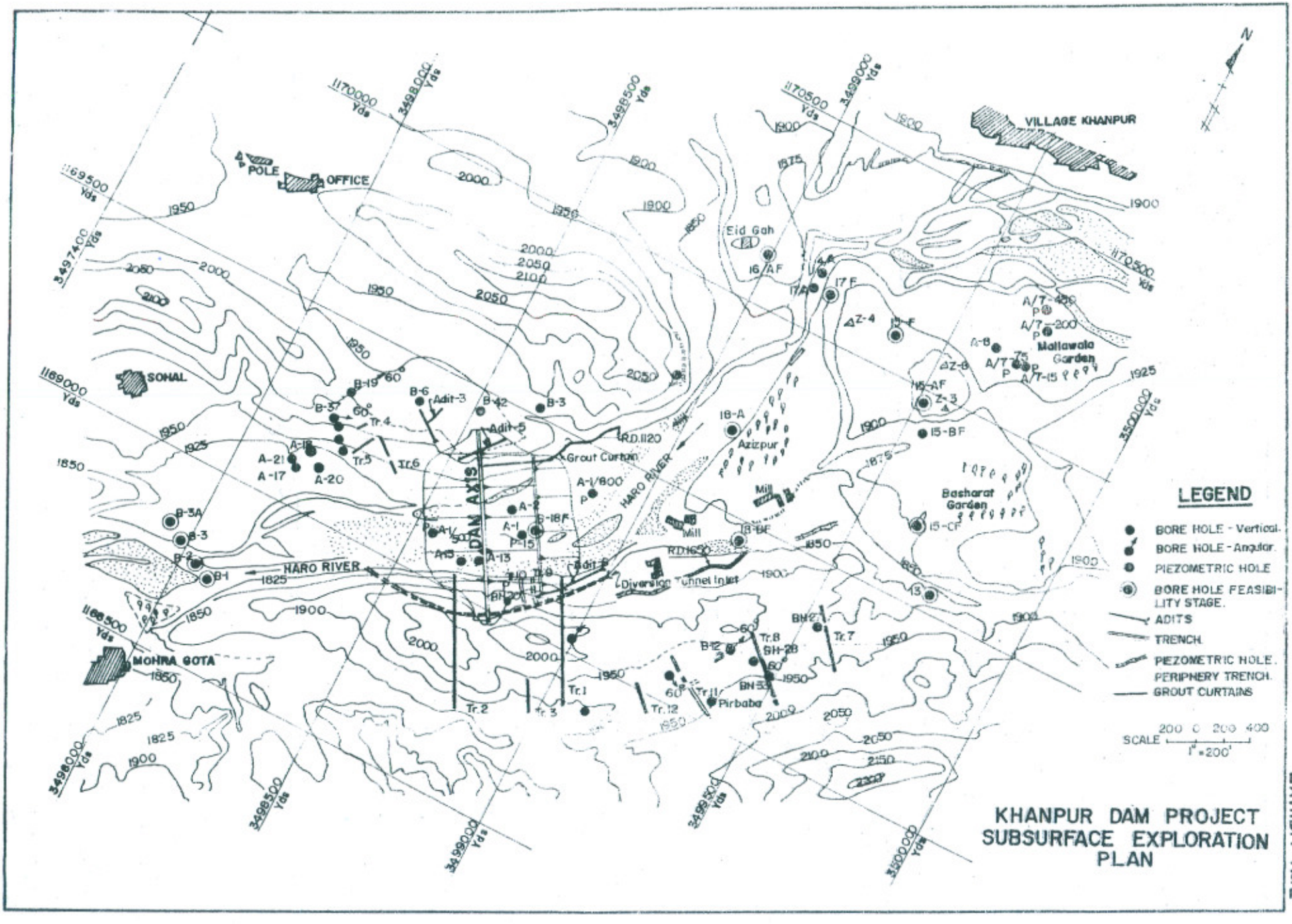
EXHIBIT No. I



LOCATION MAP OF
KHANPUR DAM

GENERAL LAYOUT OF STRUCTURES
KHANPUR DAM

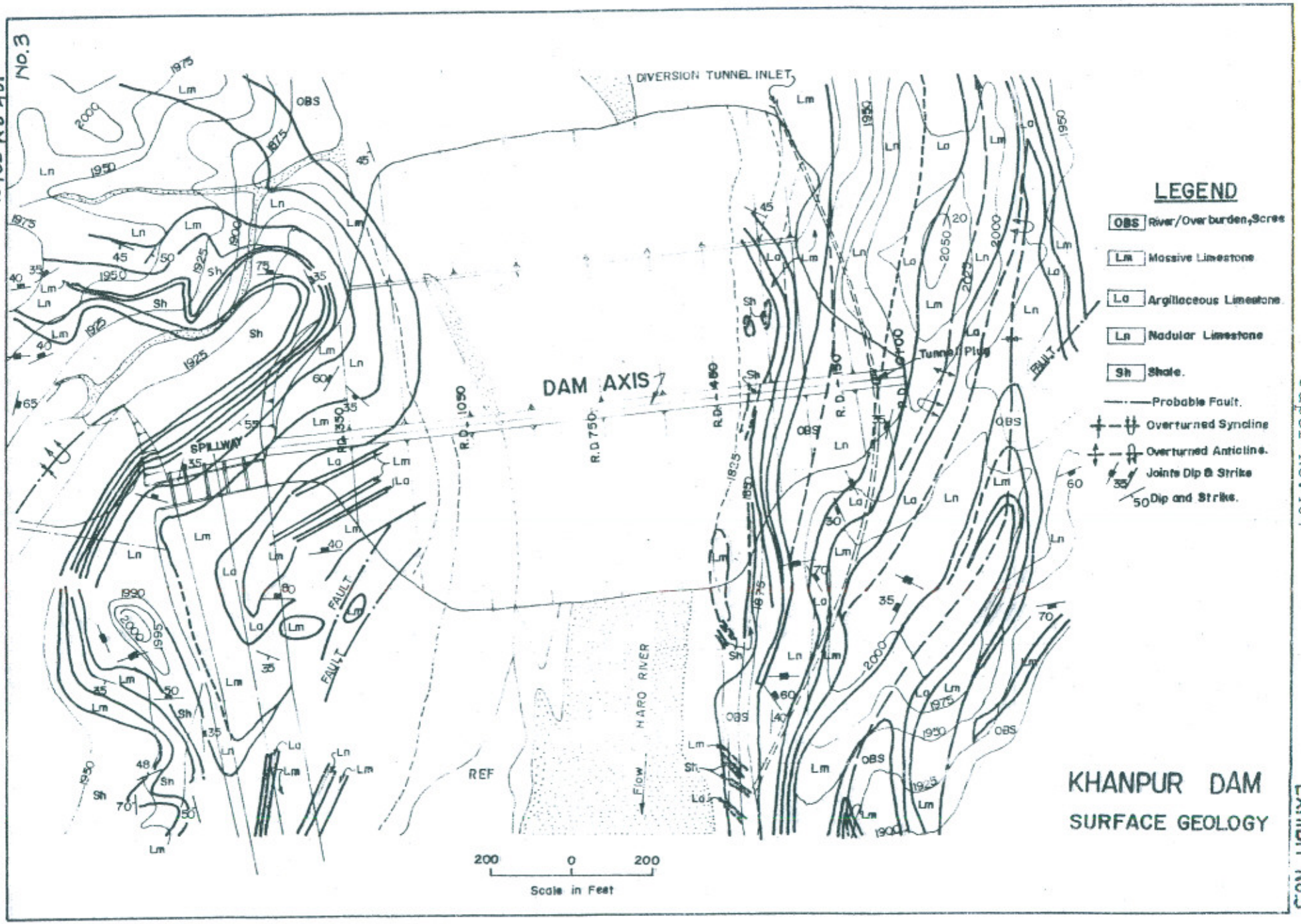
0 500 1000
Scale Feet



Paper No. 461

EXHIBIT No. 2

Paper No 461 No.3

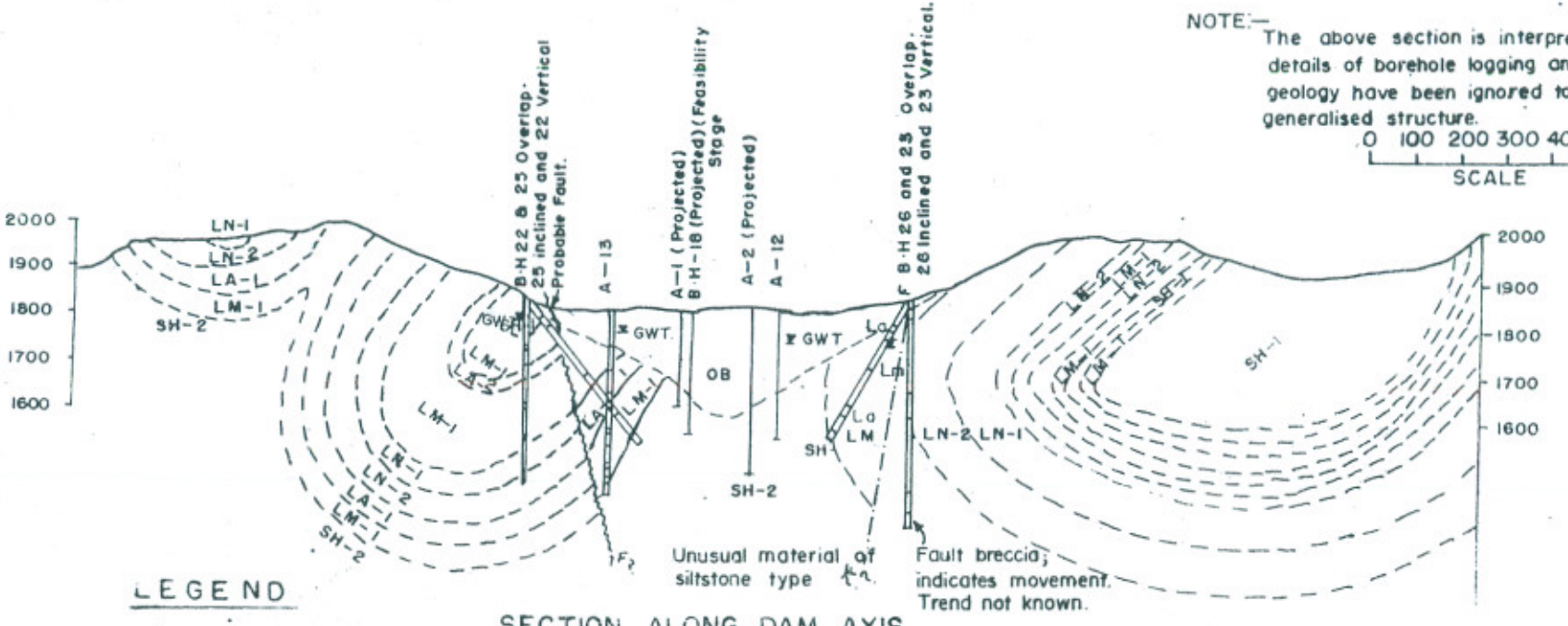


Paper No. 461

EXHIBIT No.3

NOTE:— The above section is interpretive. Minor details of borehole logging and surface geology have been ignored to give a generalised structure.

0 100 200 300 400 500
SCALE



SECTION ALONG DAM AXIS

LEGEND

SHALE, SH-1

Sh-1 — Brown to greenish grey in colour, soft generally calcareous & splintery with well laminations, A few bands of mudstone and limestone generally 4"–1½ thick, mostly highly weathered and sheared.

MASSIVE LIMESTONE, Lm-1

Lm-1 — Generally dark grey, medium hard massive with rare argillaceous layers, fossiliferous.

MASSIVE LIMESTONE, Lm-2

Lm-2 — Main component of the unit similar to Lm-1 with frequent intercalations of argillaceous limestone 2"–12" thick spaced generally 6" to 1½" apart.

NODULAR LIMESTONE, Ln-1

Ln-1 — Light grey to dark grey, medium soft to medium hard having argillaceous layers 1"–6" thick, generally irregular giving it conspicuous nodular appearance at certain places with elongated nodules 6"–2' in size, which apparently appears to be embedded in argillaceous partings. Nodular structure may be the result of shearing along compartively soft arg. layers. The apparently massive looking limestone in this zone is generally argillaceous in nature. Due to its argillaceous characteristic this unit is quite susceptible to surface weathering and mostly it is covered with residual soil. Mostly difficult to differentiate between lm-1 and Ln-1 in the core from the borehole.

Ln-2 — **NODULAR LIMESTONE, Ln-2**

Almost similar to Lm-1 as encountered in boreholes and adits but generally appears to be nodular on the surface due to weathering.

La-1 — **ARGILLACEOUS LIMESTONE, La-1**

Brownish grey to dark grey, medium soft, laminated & fossiliferous, Some interbeds of medium hard dark coloured massive limestone. At places this unit represents highly weathered and disintegrated material with indication of well developed laminations which can also be called as calcareous shale. It shows nodular structure due to weathering at certain places.

La-2 — **ARGILLACEOUS LIMESTONE, La-2 or TRANSITION ZONE**

Soft to medium soft, brownish grey, generally weathered and sheared, Nodular in appearance having medium hard elongated Lst, nodules 1¼–4" in size embedded in 2"–9" thick argillaceous Lst. Partings. It represents transition zone as mapped in some of the adits.

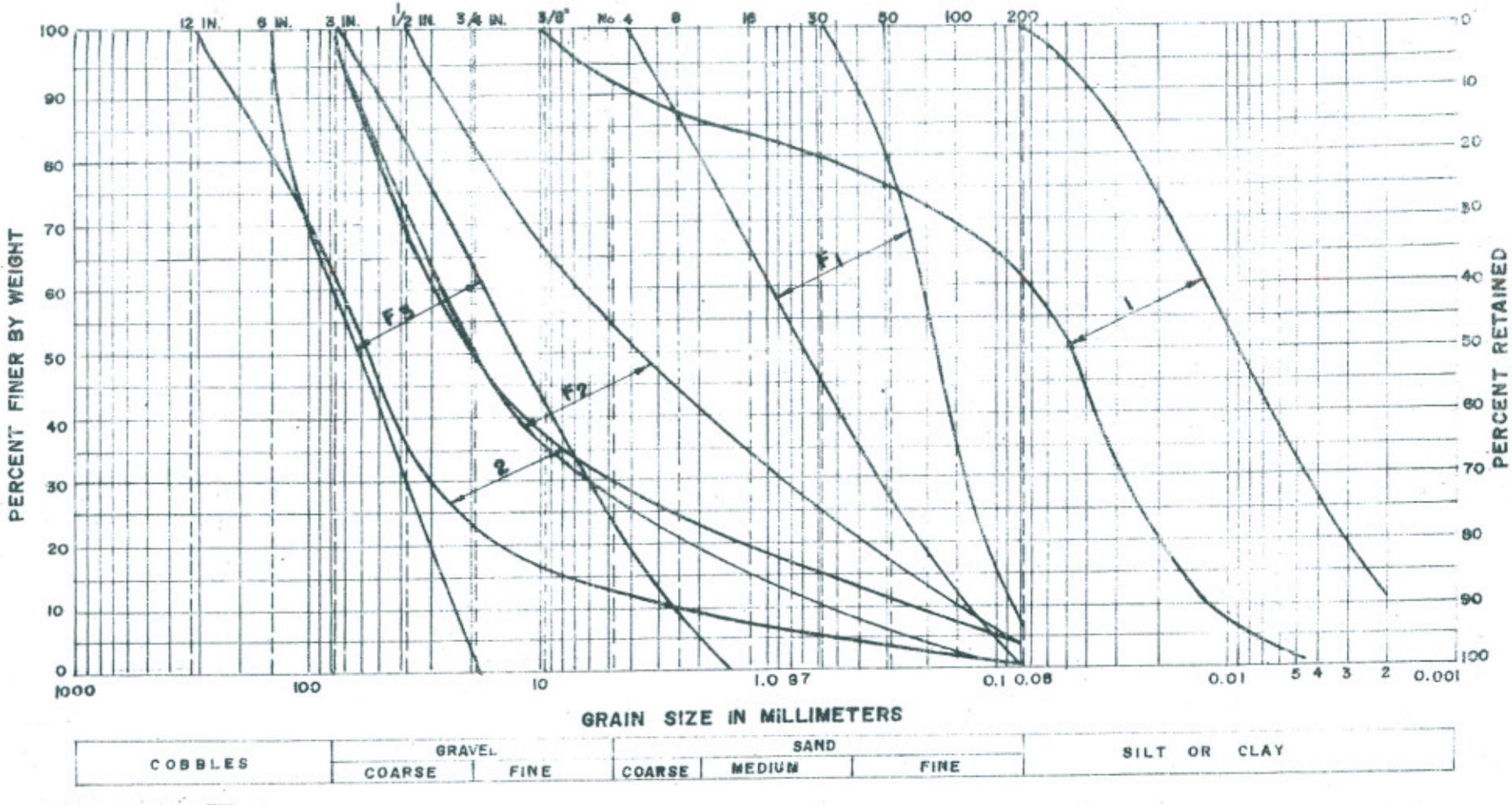
Sh-2 — **SHALE, Sh-2**

This is similar to sh-2 as exposed on the surface as well as in the trench probably due to weathering but it may be conformably under lain by an older horizon which is quite dark coloured as encountered in the boreholes.

KHANPUR DAM SITE
GEOLOGY SECTION ALONG DAM AXIS

Paper No. 461

EXHIBIT No. 4



1. Impervious Fill
2. River Gravels

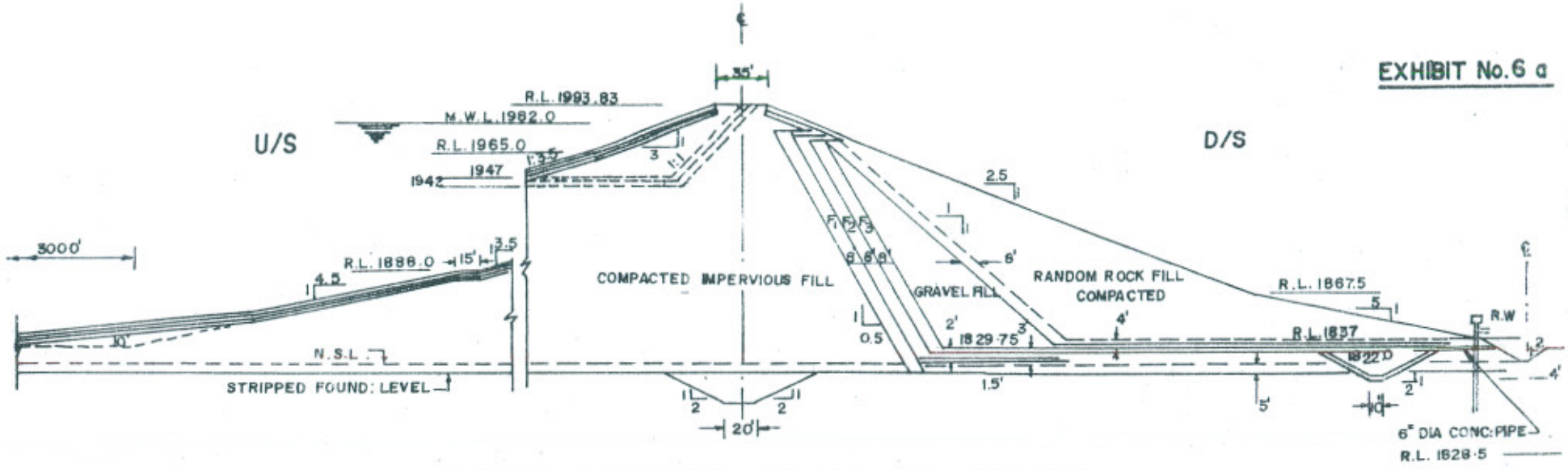
F1, F2, F3 } Filters

KHANPUR DAM PROJECT
GRADATION LIMITS OF
CONSTRUCTION MATERIAL

Paper No. 461

EXHIBIT No. 5

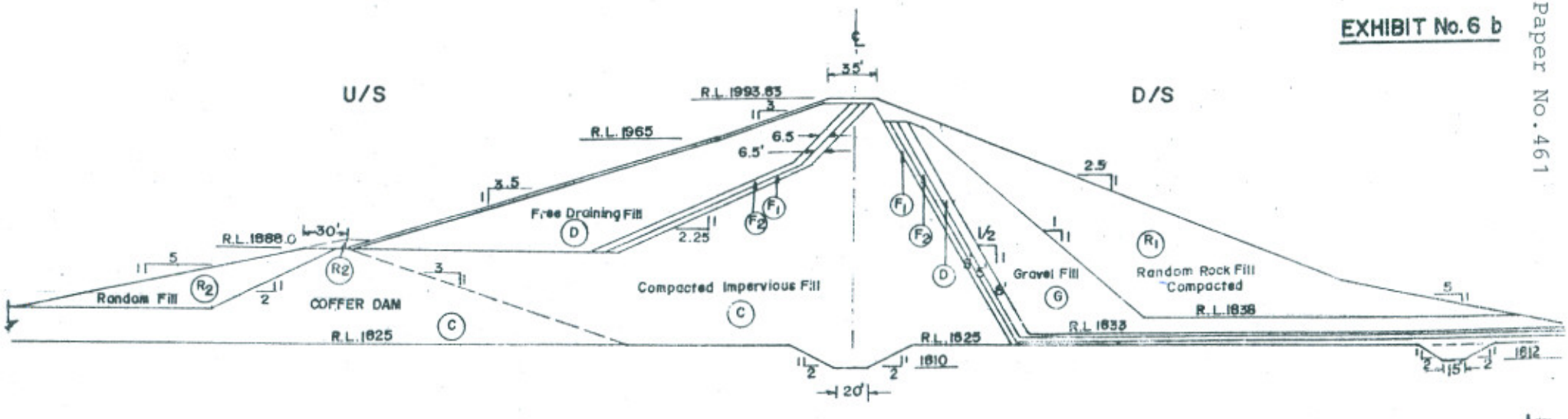
EXHIBIT No.6 a



MAIN DAM X-SECTION KHANPUR DAM PROJECT

SCALE :- 1" = 100'

EXHIBIT No.6 b



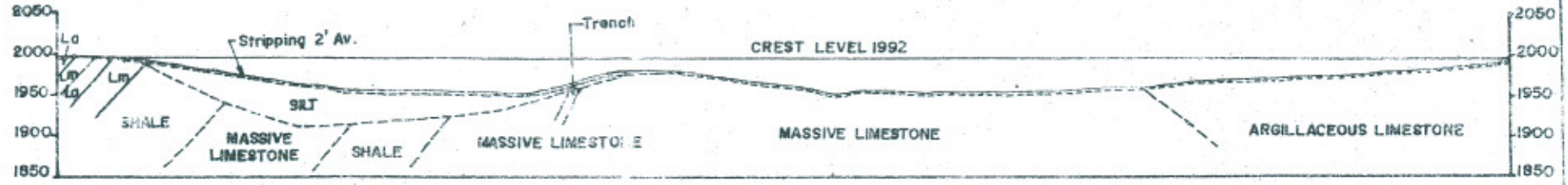
TYPICAL CLOSURE SECTION OF MAIN DAM

SCALE: 1" = 100'

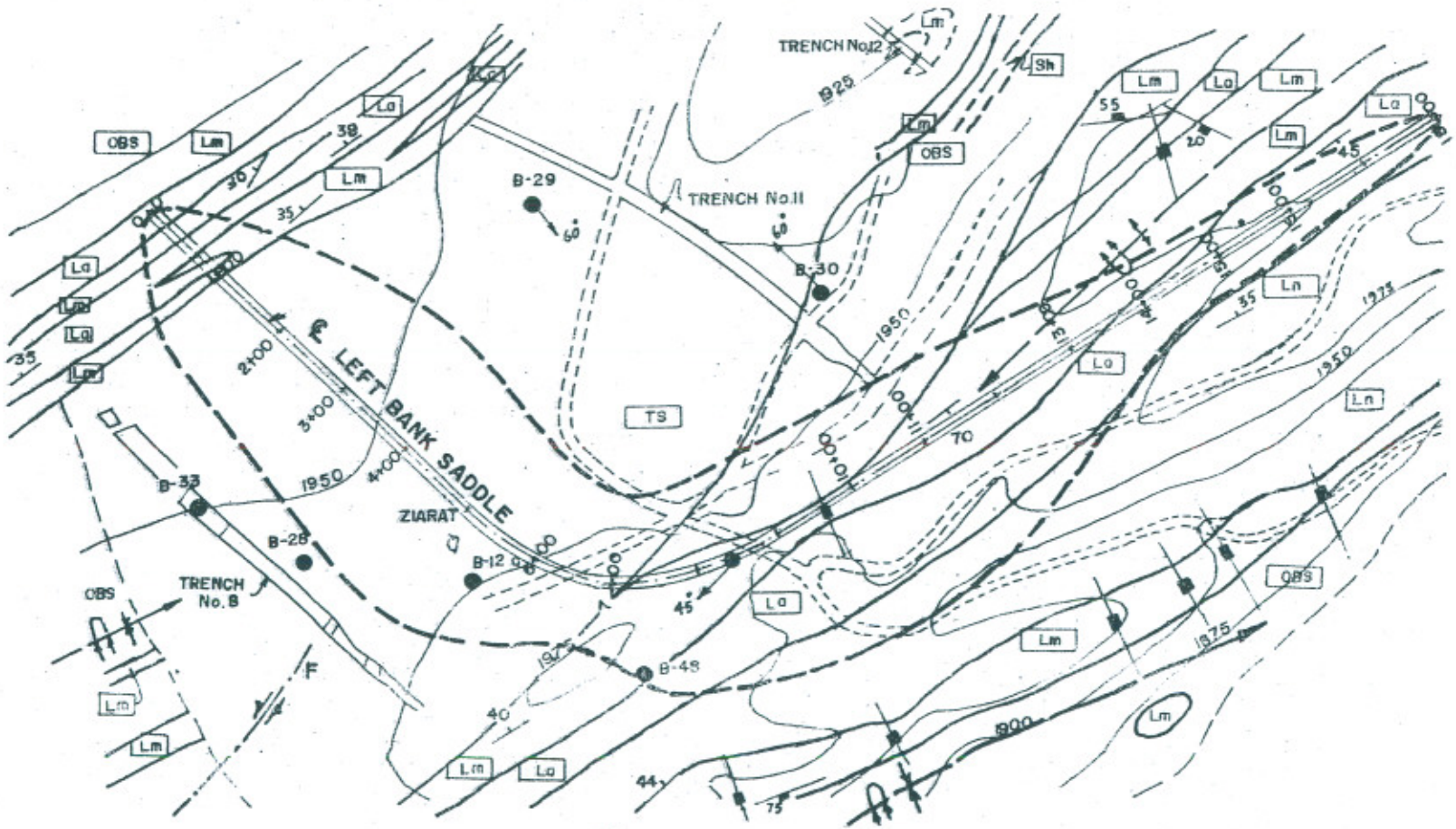
Paper No. 461

EXHIBIT No.6

No. 7a



L-SECTION OF SADDLE EMBANKMENT



KHANPUR DAM PROJECT

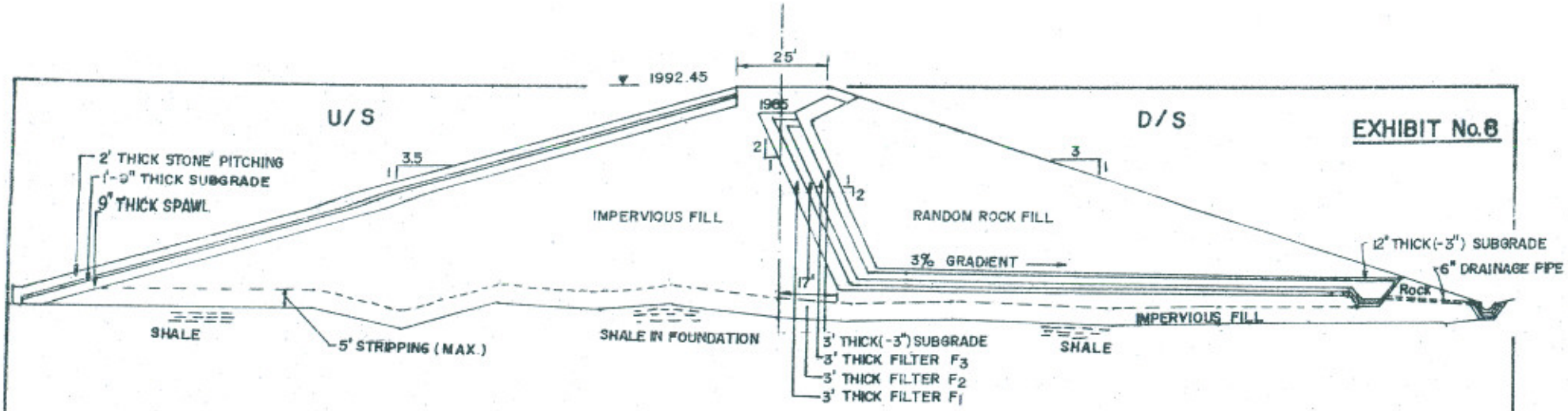
GEOLOGICAL PLAN OF LEFT BANK SADDLE

SCALE: 1"=200'

Paper No 461

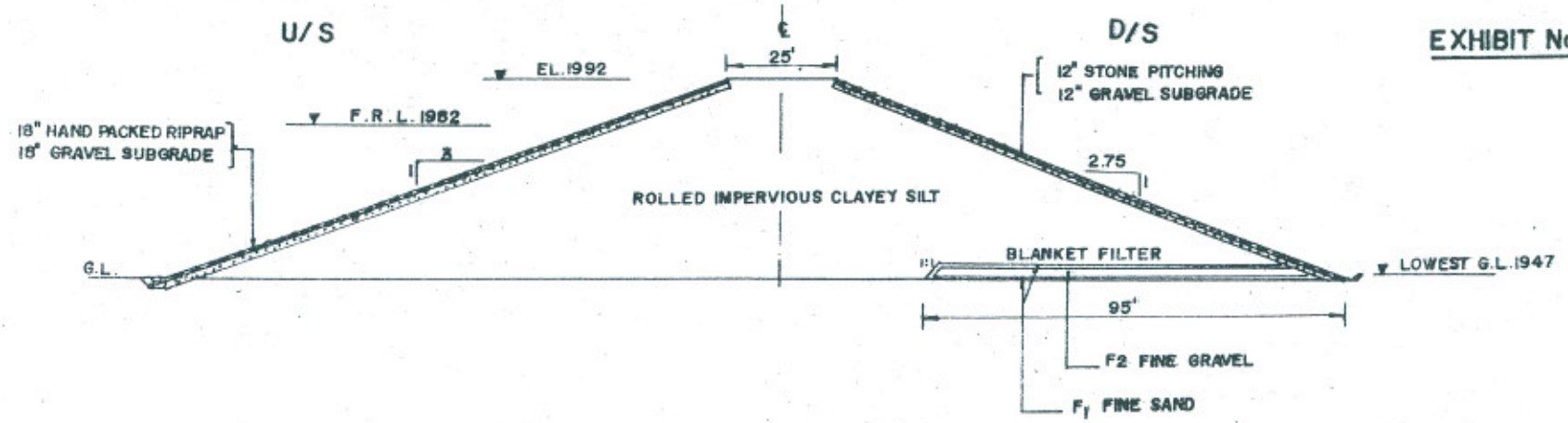
Paper No. 461

EXHIBIT No. 7



TYPICAL SECTION OF CHECK DAM

SCALE: 1"=40'



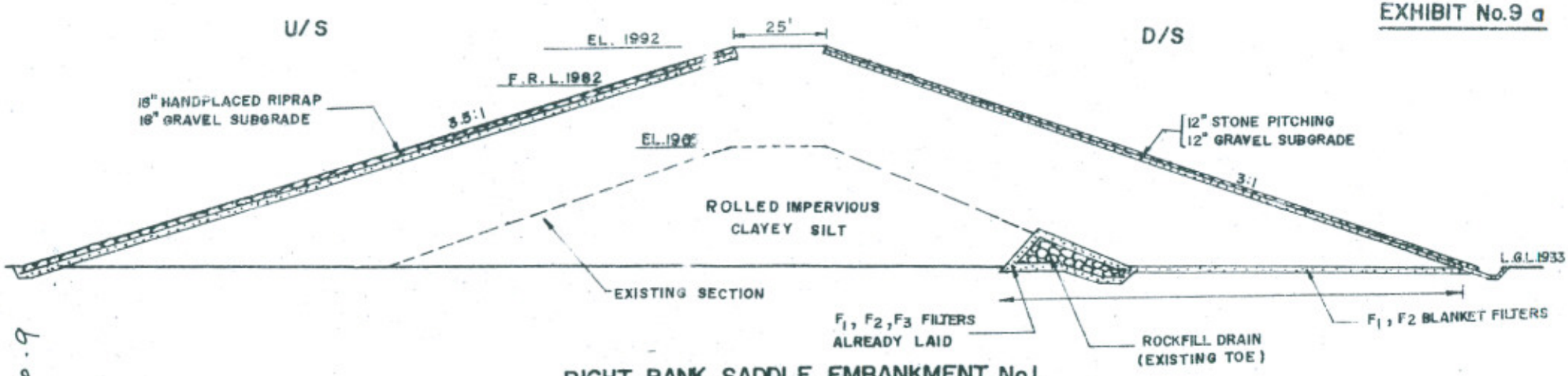
LEFT BANK SADDLE EMBANKMENT

SCALE: 1"= 40'

Paper No.461

EXHIBIT No.8

EXHIBIT No.9 a

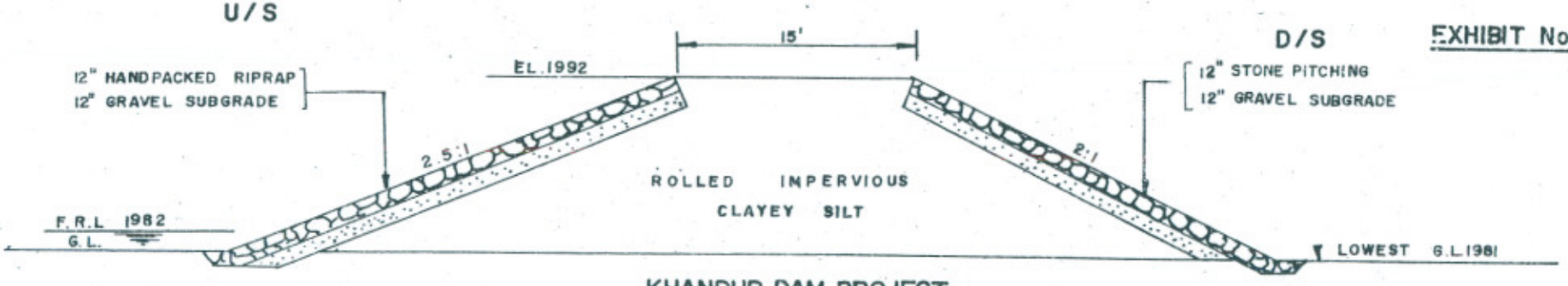


RIGHT BANK SADDLE EMBANKMENT No.1

SCALE: 1" = 40'

Papers No. 461 No. 9

EXHIBIT No.9 b



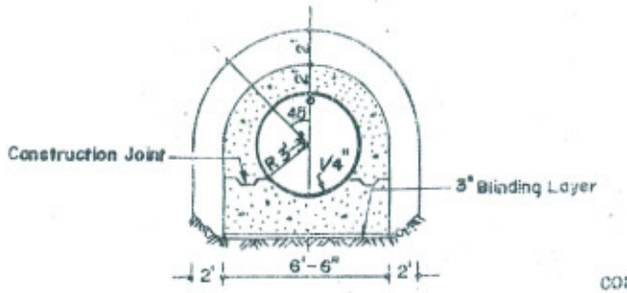
KHANPUR DAM PROJECT

RIGHT BANK SADDLE EMBANKMENT No.2

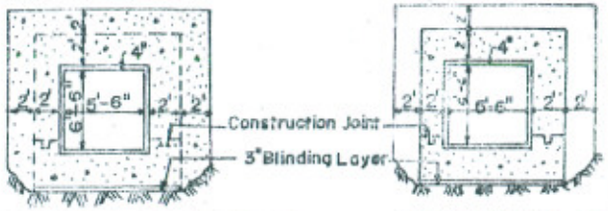
SCALE: 1" = 10'

Paper No. 461

EXHIBIT N

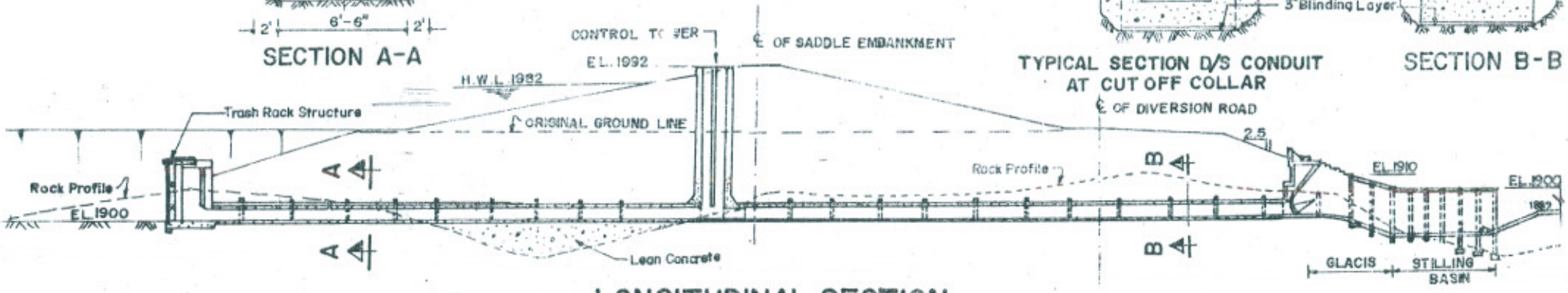


SECTION A-A

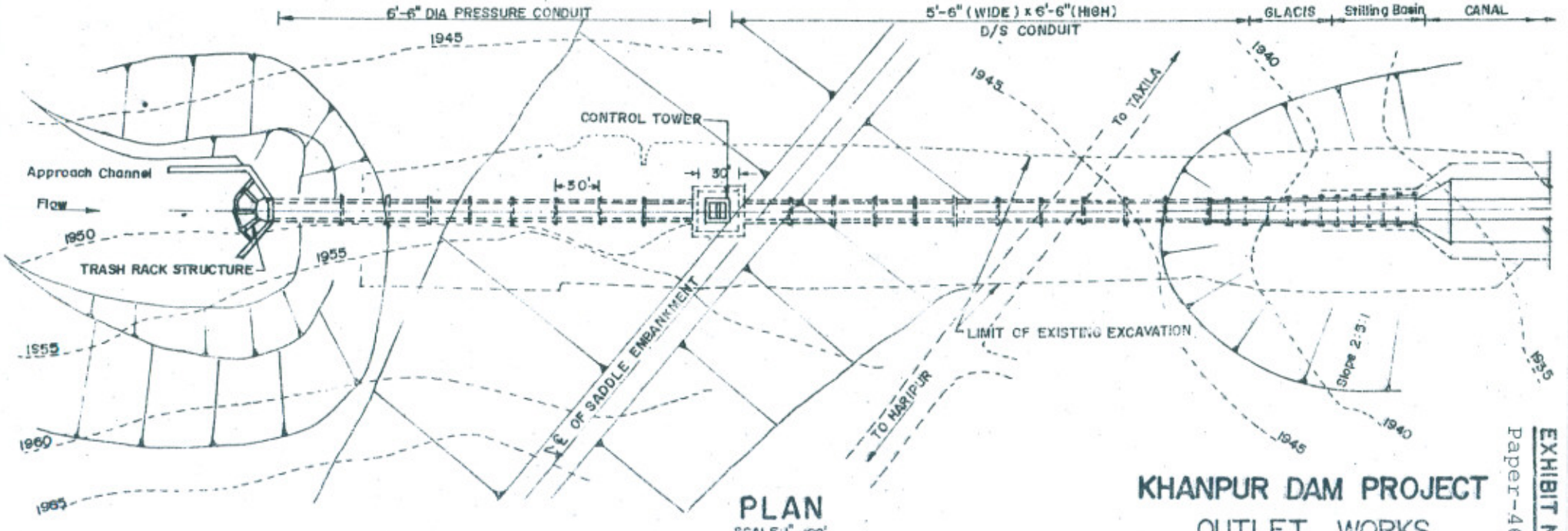


TYPICAL SECTION D/S CONDUIT AT CUT OFF COLLAR

SECTION B-B



LONGITUDINAL SECTION

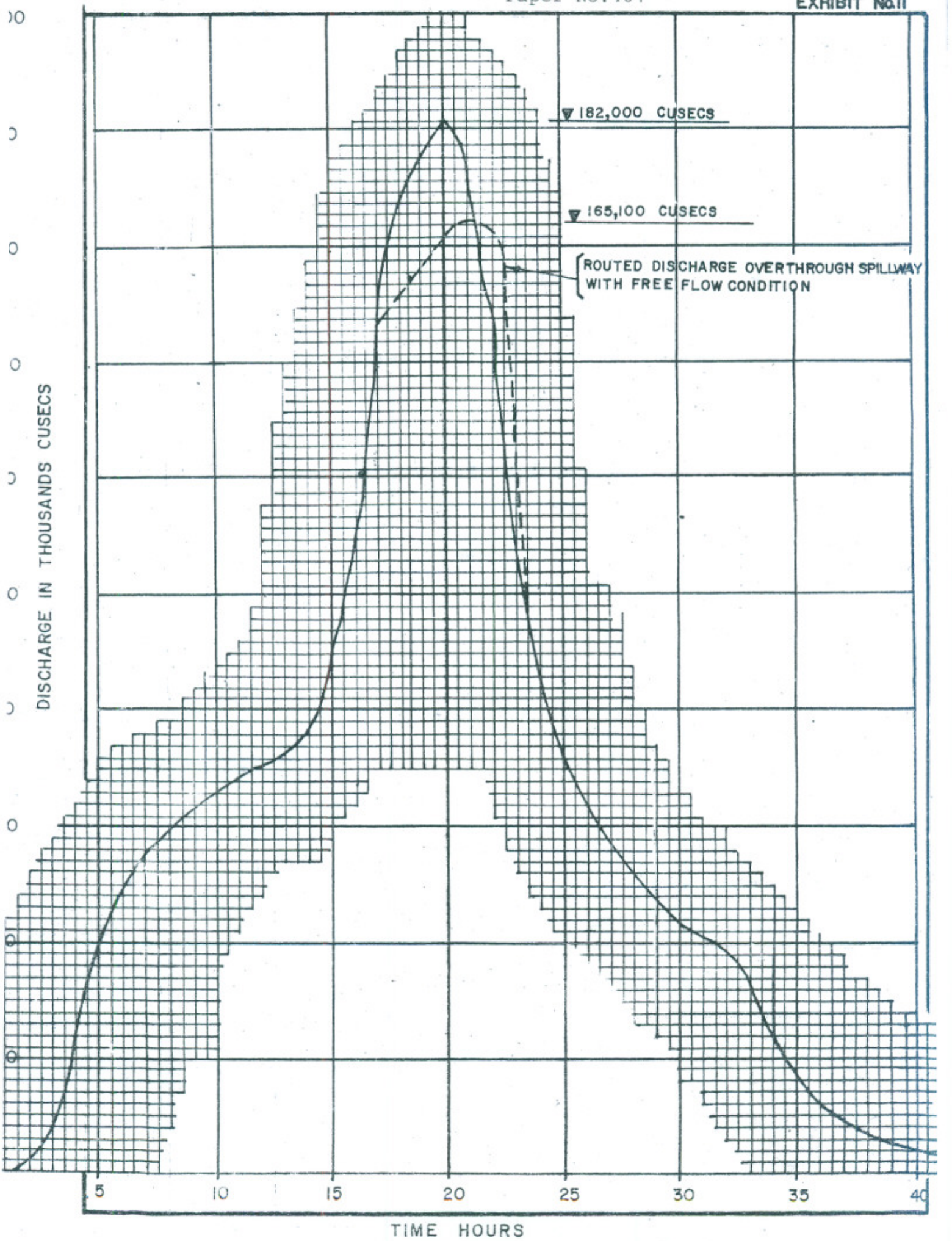


PLAN
SCALE: 1" = 100'

KHANPUR DAM PROJECT
OUTLET WORKS

EXHIBIT No.10
Paper-461

EXHIBIT No.II



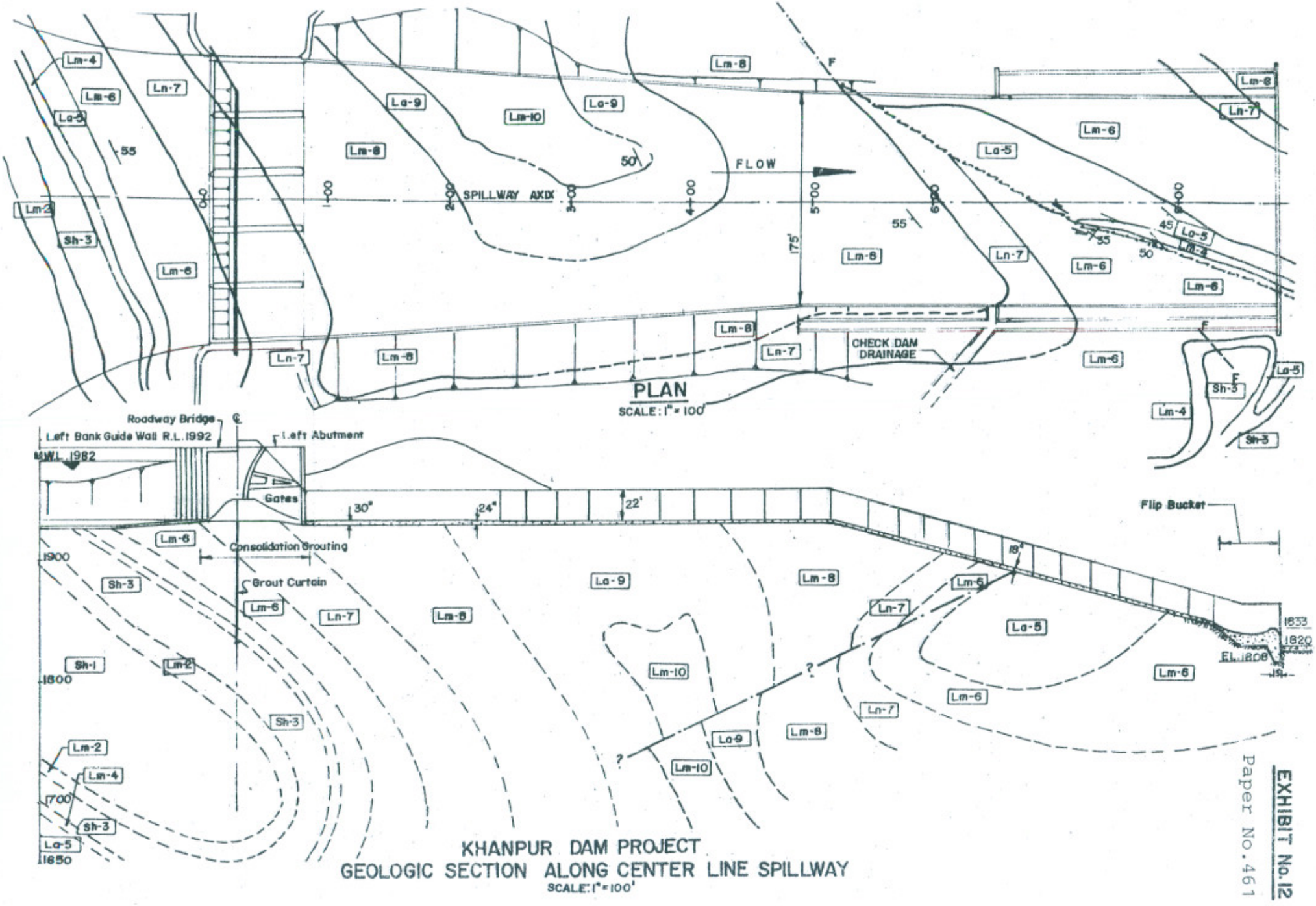
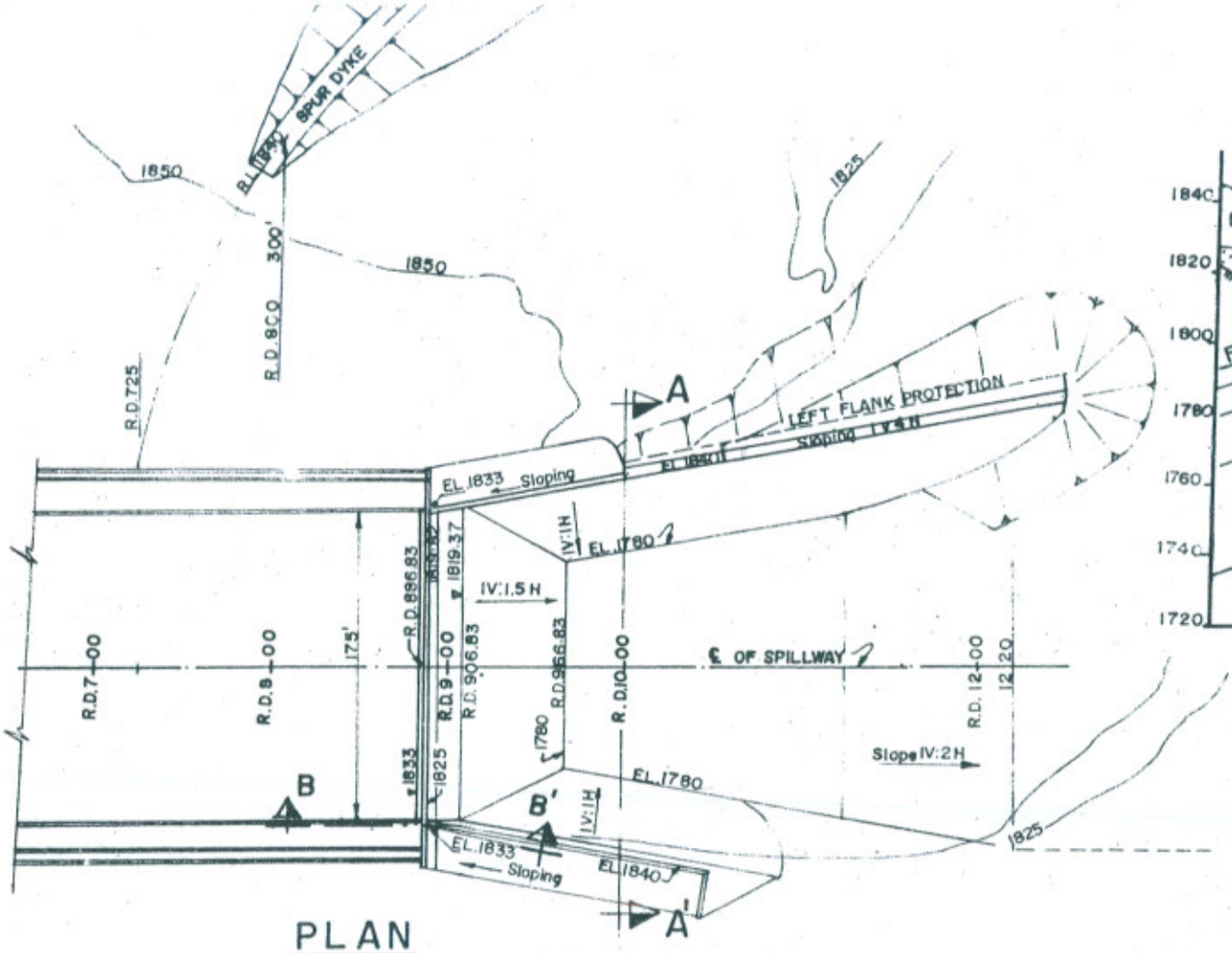


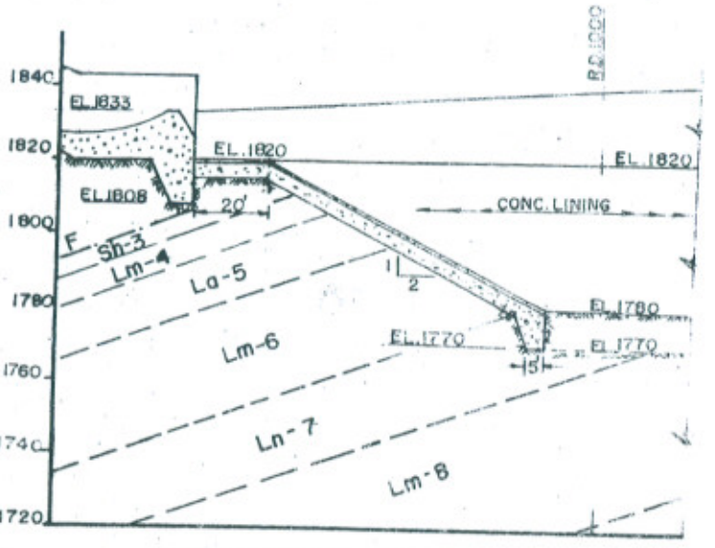
EXHIBIT No. 12

Paper No. 461



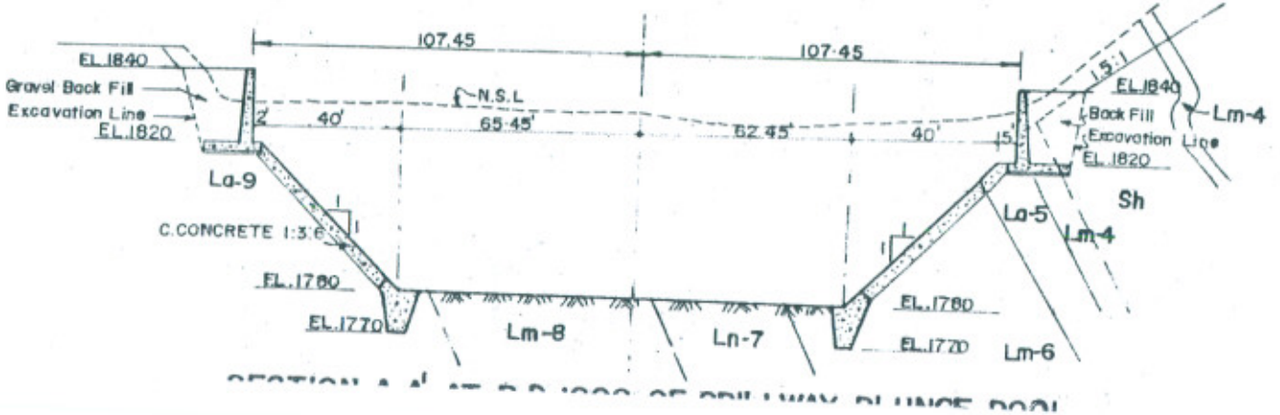
PLAN

SCALE: 1"= 100'



LONGITUDINAL SECTION B-B'
ALONG RIGHT CUT SLOPE

SCALE: 1"= 50'



KHANPUR DAM PROJECT
SPILLWAY PLUNGE POOL

EXHIBIT N

Paper No. 461