PAPER NO.608

DESIGN AND CONSTRUCTION OF SCARP SUKH BEAS SUKHNAI OUTFALL CHANNEL PROJECT

BY
Ch. Ghulam Hussain

DESIGN AND CONSTRUCTION OF

SCARP SUKH BEAS - SUKH NAI OUTFALL CHANNEL PROJECT

Engr. Ch. Ghulam Hussain[1]

1.0 INTRODUCTION

1.1 SCARP SUKH BEAS

SCARP Sukh Beas is located in the Bari Doab of the Punjab Province of Pakistan as shown in Project Area location Map (Fig.1). It comprises the drainage basin of Sukh Beas extending from downstream of Balloki-Sulemanki Link Canal upto Sidhnai-Mailsi Link Canal. Other boundaries of the area are defined by the Lower Bari Doab Canal in the North-West, Depalpur and Pakpattan Canals in the South-East. The Sukh Beas Nullah runs along the lowest contours of the catchment area and forms the irrigation boundaries between these two groups of canal commands, except for some channels which cut across the Sukh Beas to irrigate on the other side.

The Project entitled "SCARP Sukh Beas" as a whole is envisaged to provide an efficient surface drainage system to 5,180 square miles of cultivated land in the Bari Doab of the Punjab Province. In accordance with the Recommended Plan, WAPDA has taken up phase-wise implementation of SCARP Sukh Beas as mentioned below:-

1.	CBDC SCARP Phase I.....	This has already been completed by WAPDA
2.	CBDC SCARP (Remaining).....	The Project is at Planning stage with WAPDA
3.	Sukh Nai Outfall Channel Project	To which this Paper pertains.
4.	Channelization of Sukh Beas Nullah and Construction of Tributary Drains	To be taken up in future phase

1.2 SUKH NAI OUTFALL CHANNEL (SNOC) PROJECT

Sukh Nai Outfall Channel which is one of the components of SCARP Sukh Beas, lies between longitudes 72°-20' to 72°-40' E and latitudes 29° -40' to 30° -20' N. Administratively, the Sukh Nai Outfall falls in Tehsils Burewala and Vehari of District Vehari, refer Vicinity Map (Fig.2). Sukh

---

[1] **Project Manager - NDC-TECHRED Joint Venture, Consultants for SCARP Sukh Beas - Sukh Nai Outfall Channel Project and Partner National Development Consultants (NDC)**

Nai Outfall Channel envisages to fulfil the following functions:-

(i) To receive and carry the seepage and storm water from Sukh Beas drain.

(ii) To discharge the effluent from (1) above into the Sutlej river about 16 kilometers below Islam Headworks, refer Fig. 2.

(iii) In addition to the uses enumerated as (1) & (2) above, Sukh Nai Outfall Channel will receive the overland flow and interflow generated by rainfall over adjoining lands and convey the same into the Sutlej river, 16 kilometers below Islam Headworks, refer Fig.2.

1.2.1 Pre-Project Conditions

(i) Drainage and Groundwater

Locally, there are no requirements of subsoil drainage, because of subsoil water level lying at a depth of more than 40 feet below the ground level in most of the Project Area. However, this outfall channel will carry primarily seepage and storm runoff from Sukh Beas Nullah and discharge it into the Sutlej river. the groundwater quality is generally good in the Project Area and fit for construction purposes.

(ii) Climatology

The climate of the Project area is primarily characteristic of subtropical continental and is arid to semi-arid. Monsoon season prevails from July-September. South-Easterlies from Bay of Bengal area being mainly responsible for rainfall during the monsoon. During winter, South-Westerlies emanating from the Caspian Sea bring scanty rainfall. The temperature varies from minimum of 3°C (in winter) to maximum of 46°C (in summer).

(iii) Geology

Sukh Nai Outfall Channel, situated in the Indus Valley alluvial plain consists, in general, of fine sand to medium to coarse grained sand and silt, in great depths except the top strata comprising silty loam soils. The Entire formation is interspersed with occasional layers or lenses of kanker nodules and clays.

2.0 ORGANIZATION

The project preparation of the SNOC project was done by the General Manager (Water), Central Division, WAPDA, Lahore. PC-I was prepared by Planning an Design (P&D) Directorate (Central), WAPDA, Lahore. Topographic Surveys and Geo-technical investigations were carried out by Project Preparation Circle (PPC) (Central) WAPDA, Lahore. The responsibility of construction was entrusted to Chief Engineer (Water), Faisalabad Region, WAPDA, through SCARP Construction Circle, WAPDA, Lahore. A construction division with its headquarter at Burewala was created under this Circle for providing resident supervision for the construction of works.

A Joint Venture Comprising M/s National.Development Consultants (NDC) and Technology Resources Development (TECHRED) were engaged by WAPDA as their Consultants for the preparation of detailed design, drawings and tender documents and for providing top construction supervision of the Project Works.

Later, it was decided that one half of the SNOC project would be executed through Irrigation and Power Department (I&P Department) Punjab. As a consequence, Superintending Engineer, Drainage and Floods Circle, Lahore, Irrigation and Power Department was entrusted with the onus of execution of SNOC from R.D. 90+000 to R.D. 180+000 alongwith its related structures. Unluckily, Finance Department of the Government of Punjab did not agree to sanction a new construction Division for this project and, hence, Executive Engineer, Khairwala Drainage Division, Faisalabad, was made responsible for its execution. Notwithstanding the fore stated division of assignment between WAPDA and I&P Department, M/s NDC-TECHRED Joint Venture rendered consultancy services for whole of the Project.

3.0 PROJECT IMPLEMENTATION

3.1 Surveys and Investigations

The setting-out of alignment of the channel, collection of hydraulic and hydrological data, and performance of geo-technical investigations was taken in hand by the Project Director, Project Planning Circle (Central), WAPDA, Lahore, in the middle of the year 1986 and continued upto December 1987. Nevertheless, the works of making augur holes along the centre-line of the channel and bore-logs with standard Penetration Test (SPT) values at important structure sites continued concurrently with the design phase during the year 1988. Only a few of these augur holes and bore-logs are depicted as a sample in Fig.3 due to constraint of space in the Paper.

3.2 Acquisition of Land and Properties

The acquisition of land and properties falling within the right-of-way of Channel was started by Project Director, SCARP Construction Circle, WAPDA, Lahore, in early 1988 and continued through out the currency of the design and construction period. The land owners took legal stay-orders which caused inordinate delays in the acquisition of land and the affected properties.

3.3 Design and Construction

M/s NDC-TECHRED Joint Venture, started preparation of design, drawings and tender documents in February 1988 and completed this assignment in accordance with the envisaged time-schedule in February 1989.

Fig.4 shows the schedule and actual completion dates of the major activities of the Project.

4.0 DESIGN OF THE OUTFALL CHANNEL AND STRUCTURES

The following is a brief summary of the design of principal features of the Project.

4.1 PARAMETERS OF CHANNEL DESIGN

4.1.1 Channel Capacity

The capacity of the Sukh Nai Outfall Channel for the purposes of design has been adopted as 2000 cusecs throughout its length. This capacity is considered to be adequate to carry run-off of 5 years frequency and 24 hour duration storm anticipated to enter this channel from the Sukh Beas Main Drain. The structures are, however, designed to pass run-off of 10 Years frequency (about 4000 cusecs) by partially encroaching the free-board.

4.1.2 Cross-Sectional Geometry

(a) Inside Slope for Cut or Fill within waterway

The nature of material forming the body of the channel is mostly silty loam to silty sand. Generally side slopes of 1.5:1 to 2:1 are proposed for these classes of soils. But in order to minimize the land width to be acquired a trapezoidal section with a side-slope of 1.5:1 was designed. It is anticipated that this slope will be adequate for all the conditions to which the channel flow will be subjected during its operation. Nevertheless, the position of banks have been determined by assuming sloughing of side slope of channel at 2 horizontal to 1 vertical. Typical cross-sections are shown in Fig.5.

(b) Spoil Banks

Spoil Banks were placed far enough from the edge of the drain to assure that the material will not be carried back into the drain either by the direct action of rain water or by being undermined by minor shifts in the alignment of the channel over an extended period of time. Spoil banks are of any reasonable height and their side slopes are as steep as the soils permits.

(c) Berms and Banks

4 feet wide berms were provided after the free-board edge of the anticipated sloughing line (with 2:1 side slope) on service road side and 12 feet wide berm on the left side for dragline operation during maintenance. Nevertheless, a 15 feet wide service road, with a minimum compacted filling of 1.50 ft. above N.S.L., and 5 feet wide dowel are provided on right side of the channel, as shown on the typical sections of the channel. (refer Fig.5).

(d) Free-Board

A free-board of 2.5 feet for the banks of the channel above its Full Capacity Level (F.C.L.) was adopted.

(e) Design of Section

Because of comparatively silt-free discharge flowing in the channel, the Manning's formula given hereafter was used for the design of the section.

$V = \frac{1.486}{n} x R^{2/3} x S^{1/2}$ V = Mean Velocity in fee per second R = Hydraulic mean radius

S = Water surface slope n = Co-efficient depending upon roughness of bank and bed within water prism. (0.027 representing a channel with grass and weed growth was adopted for the design).

4.1.3 Minimum Permissible Velocities

The lowest velocity that can cause sedimentation and induce weed growth should be avoided as far as possible. To achieve this objective it was ensured that mean velocities, slightly higher than the critical velocity for a corresponding depth and silt grade, based on the following kennedy's equation, are produced:

Where $V_0 = K d^{0.64}$ V_0 = Critical velocity in feet/sec.
d = Depth of water in feet K = A constant taken equal to 0.63 for fine silt grade

Critical velocity as determined by this formula comes to be 2.38 ft/sec. and therefore minimum velocity considered for design was 2.5 ft/sec.

4.1.4 Maximum Permissible Non-Erodible Velocity

The velocity which does not cause scour in the channel is identified as maximum velocity. This value is variable depending upon the size and quantum of sediment load transported by the channel. Such a velocity ranges from 2.5 to 3 feet per second for the soil texture in the Project area. Therefore, while designing the section it was be kept in view that the mean velocity in the channel should not exceed 3 feet per second.

4.1.5 Slope

The outfall channel generally follows the slope somewhat higher than the ground surface, along its alignment, so as to generate slightly higher velocities to avoid weed growth in the bed of the channel. An average channel slope varies from 1 in 5,800 to 1 in 6000 which is commensurate with the intended limits of the velocities within the channel prism. For brevity considerations, only some of the as-built plan and profile of the channel are exhibited as a sample in Fig.6.

4.1.6 Cunette Section

As the channel runs most of the period with very low discharges as compared to the full capacity of 2000 cusecs, a trapezoidal cunette was provided in the bed of the channel in order to carry, 100 cusecs, which is about the perennial flows of Sukh Beas spine drain. The cunette is 32 ft wide and 2.3 ft deep. The typical cross-section of the Cunette is shown in Fig.6.

The cunette effectively safeguarded against the meandering tendency caused by varying low discharges in larger sections.

4.2 DESIGN OF CURVES IN ALIGNMENT

As SNOC traverses highly valuable agricultural and inhabited areas, there was considerable public resistence in the acquisition of land and properties to be affected by its construction. The radii of the curves was, therefore, required to be kept as short as technically possible. Following criteria were adopted to determine the radii of the curves.

(i) According to Practice of irrigation Department, in special circumstances where the procurement of right-of-way or the avoidance of existing cultural features would appreciably increase the cost of construction the radii given below may be adopted.

Radii for Sharp Curves

Capacity of Channels	Minimum Radii
under 10 cusecs	100 feet
10 to 100 cusecs	200 feet
100 to 500 cusecs	500 feet
500 to 1000 cusecs	1000 feet
over 1000 cusecs	1 foot per cusec

Hence according to this practice, which is just empirical, minimum radius for SNOC should be 2000 ft.

(ii) Ven Te Chow, vide para 16.6 of book "Open channel hydraulics" recommends radius on concave side (ro) to curvature, as ro > $40\sqrt{A}$, where A is the x-sectional area of flow. Hence ro for SNOC = $40\sqrt{656}$ = 1024 feet

(iii) USBR recommends minimum radius of curvature at the centre of the curved channel as rc = 7T, where, T is the top width. So rc for SNOC would be rc = 7x94 = 658 say 700 feet

Based on the above criteria, radii of curves of SNOC alignment were kept between 2000 ft to 700 feet suiting to the topographic feature of the site. It has been observed that the sharp curves of 700 feet radius, as determined by USBR criterion, have not created any operational problem during the last four years.

4.3 DESIGN OF STRUCTURES

The execution of SNOC involved construction of 128 structures.

A number of existing roads, paths, railway line and irrigation channels are intercepted by the SNOC .(refer Fig.2). Structures were required to maintain routes of travel and conveyance at the point of intersection with the outfall channel. Integrated list of project appurtenant structures constructed in connection with the SNOC is given at the next page.

INTEGRATED LIST OF PROJECT APPURTENANT STRUCTURES

TYPES	NUMBERS
• Outfall structure	1 No.
• Canal aqueduct	1 No.
• Disty aqueduct	6 No.
• District road bridges	5 No.
• Arterial road bridges	2 No.
• Railway bridge	1 No.
• Village road bridges	22 No.
• Water course aqueducts	40 No.
• Canal road bridges	2 No.
• Pipe Drainage inlets	46 No.
• Box Drainage inlets	2 No.
Total	128 No.

4.3.1 Basic Criteria-Structural

Following design criteria, coefficients and constants, design codes, allowable stresses, unit loads, weights and stability criteria were used in the design of all structures. The supplement design criteria applicable to specific structures has been mentioned in the relevant paragraphs.

(a) Design Codes

The following published codes and standards were used, where applicable, in the design of all structures, unless otherwise specifically stated in the section on the design of a particular structure.

- Reinforced Concrete - Reinforced concrete design was done in accordance with the "Building Code Requirements for reinforced Concrete" (ACI, 318-83) of the American Concrete Institute, generally known as "ACI Code".
- "Standard Specifications for Highway Bridges" of the American Association of State Highway and Transportation Officials were duly applied during design of bridges.

(b) Allowable Stresses and Unit Loads

The applicable allowable stresses, unit loads used for the design of the concrete, steel and masonry structures are shown in Table 1, 2, 3 and 4.

TABLE-1 - WORKING STRESSES FOR CONCRETE

Description	Allowable Stresses: For any strength of concrete	Allowable Stresses: For strength of concrete shown below fc' = 3000 Psi
- Modulus of elasticity ratio: n		
For concrete weighing 145' lbs per cu ft	$n = \frac{29.000.000}{w^{1.5}33\sqrt{fc}}$	9
- Flexure: fc		
Extreme fibre stress in compression for bridges.	fc = 0.40 fc'	1200
Extreme fibre stress in compression. other structures	fc = 0.45 fc'	1350
Extreme fibre stress in tension in plain concrete footings and walls	fc = 1.6 $\sqrt{fc'}$	88
- Shear: v (as a measure of dia- gonal tension at a distance of d from the face of the support)		
Beams with no web reinforcement	ve = 1.1 $\sqrt{fc'}$	60
Joints with no web reinforcement	ve = 1.2 $\sqrt{fc'}$	66
Members with vertical or inclined web reinforcement or properly combined bent bars and vertical stirrups	ve = 5 $\sqrt{fc'}$	274
Slabs and footings (peripheral shear)	ve = 2 $\sqrt{fc'}$	110
- Bearing fc on full area	0.25 fc'	750
On one-third area or less	0.375 fc'	1125

TABLE-2 - WORKING STRESSES FOR REINFORCEMENT

	Pounds per Square Inch
REINFORCEMENT (Intermediate grade steel)	
Tension in flexural members with or without axial loads	$f_s = 20,000$
Tension in web reinforcement	$f_s = 20,000$
Compression in column verticals and flexural members (or as allowed in ACI Code and AASHTO)	$f_s = 16,000$

TABLE-3 - UNIT LOADS AND WEIGHTS

Material or Force	Unit Weight or Intensity
Concrete	150 pounds per cubic foot
Water	62.5 pounds per cubic foot
Dry earth	100 pounds per cubic foot
Compacted earth	110 pounds per cubic foot
Saturated earth	135 pounds per cubic foot
Active Horizontal pressure, dry earth	30 pounds per square foot per foot
Active Horizontal pressure, compacted earth	35 pounds per square foot per foot
Active Horizontal pressure, saturated earth	85 pounds per square foot per foot
Wind load on structures	20 pounds per square foot. Transverse 4 pounds per square foot longitudinal
Horizontal earthquake acceleration	0.10 times gravity intensity
Brick masonry	120 pounds per cubic foot
Stone masonry	150 pounds per cubic foot
Live loads	depending on structure
Angle of internal friction	33 degrees
Wind load on live loads	100 pounds per linear foot. Transverse, applied 6 foot above deck level.
	40 pounds per linear foot. Longitudinal, applied 6 foot above deck level.

TABLE-4 - STABILITY CRITERIA

NORMAL LOADS

	Outfall Regulator and Other Structures
Allowable foundation bearing pressure	3,000 pounds per square foot
Maximum sliding-friction factor	0.40
Location of resultant of forces acting at the base	Within middle third of base
Allowable compression in concrete	750 pounds per square inch

Allowable tension in concrete	None

Brick Masonry Walls

Allowable compression - brick	150 pounds per square inch
Allowable tension-brick	25 pounds per square inch
Allowable compression concrete	1,000 pounds per square inch
Allowable tension concrete	100 pounds per square inch
foundation bearing pressure	4,000 pounds per square foot
Sliding factor	0.40
Location of resultant of forces acting at the base	Within middle 1/3 of base

EARTHQUAKE LOADS AND EXTREME LOADS

Outfall Regulator and Other Structures

Allowable foundation bearing pressure	4,000 pounds per square foot
Maximum sliding-friction factor	0.50
Location of resultant of forces acting at the base	Within middle ½ of base
Allowable compression in concrete	1,000 pounds per square inch
Allowable tension in concrete	100 pounds per square inch

Brick Masonry Walls

Earthquake loading	None

4.3.2 Roadway and Foot Bridges

Some 31 roadway bridges are provided across the outfall channel. The placement of the various bridges was determined by the location of existing road crossings. Wherever practicable and for reasons of economy, bridges were incorporated as a part of other structures such as aqueducts.

The roadway bridges are of the following five general classification.

Type	Roadway	Description/ Live Loading
Arterial (A.R)	28' clear.	Main arteries of transportation and communication, generally metalled subjected to Motor Vehicle transport inclusive of 70-ton army tank loading and/or NLC loadings. Walkway on both sides of the drive-way designed for 100 lbs per square foot loading. Designed to conform to AASHTO and/or Highway Department, Government of the Punjab Specifications.

District (D.R)	24' clear	All other details are similar to A.R. bridges described above.
Village (V.R.)	12' clear	Minor roads (earthen or brick - paved) leading from village to village and subjected generally to traffic comprising comparatively light motor vehicle transport, inclusive of 30-ton army tank loading. Are also commonly used by farm-tractors, bullock carts, camels, donkeys and pedestrians.
Canal (C.R.)	12' clear	Minor roads running along the edge of canals. These are earthen tracks meant relatively for light motor vehicles. Can be subjected to 30-ton army tank loading. Generally closed to public and heavy vehicular traffic other than the department and army.
Foot (F.B.)	4' clear	Limited to pedestrians only. Designed for a live load of 100 lbs per sq. foot.

4.3.3 Irrigation Cross-Channels

SNOC crosses a number of existing irrigation channels and watercourses enroute. Several of these irrigation channels which were severed by the construction of the outfall channel are provided exclusively with aqueducts to carry the irrigation flows across the outfall channel. Fig.7 shows D.R. Bridge Cum Allahabad Disty and Fig.8 shown Pakpattan Canal Aqueduct.

4.4.4 Outfall Structure

The Outfall Structure is located at R.D. 9+609 of the outfall channel. An aqueduct for carrying Ghulam Wah Disty across the outfall channel is combined with the outfall structure. Apart from the reasons of economy, the topographical environments of the terrain are best suited for the present location of the outfall structure. Fig.9 shows the outfall structure cum Ghulam Wah disty aqueduct at R.D. 9+609.

4.3.5 Surface Drainage

Keeping in view the discharge of run off from rain or other sources, both during and after construction, provision for the construction of appropriate drainage works was made. It ensures safety of necessary Irrigation outlets, water courses, diversion channel, culverts and other drainage works.

On account of the crest levels set lower than full supply level of the channel, all the drainage pipe lines were provided with flap valves except the two at R.Ds. 10+014-L and 132+177-L which are box inlets fitted with regulation gates. Water from the country side will have to stand for sometime during monsoon rains, till the channel supplies can be drawn down to such an extent that the inlets start working. The inlets have their crest elevations at natural surface levels which are below the full supply level of the link.

The drainage inlet consists of a single, 2.0 ft. dia R.C. pipe culvert under the canal road with a chute to convey run-off into the channel. Large fan shaped intake weir is provided upstream to carry the run-off into the culvert as rapidly as practicable with a minimum depth of ponding. A stilling pool for energy dissipation is provided at the downstream end of the chute to prevent erosion of the channel bed at the time of low discharge in the outfall channel.

5.0 CONSTRUCTION

5.1 General

Sukh Nai Outfall Channel Project involved the construction of an earthen carrier channel and 128 appurtenant structures. The work of earthen carrier channel comprised a length of ± R.D.180+000 ft. The 1st half (R.D. 0+000 to R.D. 90+000 ±) was executed by WAPDA. The construction of the 2nd half (R.D. 90+000 ± to R.D. 180+000 ±) was taken up by the Irrigation and Power Department, Government of the Punjab.

For ease of the construction, the project was divided into four major contract packages for execution through local competitive bidding (LCB). Following contractors were awarded the contracts.

WAPDA Component Packages	**Name of Contractors**
SNOC-01 (R.D. -8+000 to R.D. 45+000)	M/s Hudda Joint Venture, 38-A, 1, Ghausul-Azam Road, Lahore.
SNOC-02 (R.D. 45+000 to R.D. 90+000)	M/s Saifoor Khan Muzaffar Khan (Pvt.) Ltd. Lahore.
I&P Department Component Packages	
SNOC-03 (R.D. 90+000 to R.D. 140+000)	M/s Ejaz Ahmad and Co. 223-Ahmad Block, New Garden Town, Lahore.
SNOC-04 (R.D. 140+000 to R.D. 180+000)	M/s Hudda Joint Venture, 38-A, 1, Ghausul-Azam Road, Lahore.

5.1.1 Construction Camps

Both WAPDA and Irrigation and Power Department did not build their own construction camps because of paucity of funds. Both the agencies made use of rented accommodation for their offices and to house their staff.

The contractors also made their own arrangements to accommodate their working crew as well as workshops for repairs to their machinery, tools and plants.

5.2 CONSTRUCTION PLANT AND EQUIPMENT

In order to obviate delays in the commencement of construction activities, the contractors moved to the construction sites with their own construction equipment and plant and also hired some constructional plants and other equipments like farm tractors etc. The contractors possessed both

new and used equipments most of which were manufactured in Pakistan. The construction techniques adopted by the contractors were by and large labour-oriented as none of them possessed major earth moving, compacting, and concreting equipments essentially required for use of mechanized construction techniques. The worth mentioning equipments, contract-wise deployed at the work sites by the contractors including earth moving and compacting equipments, concreting equipments, transport and hauling units, electrical generating sets and lighting equipment are summarized in Table-5.

All the contractors had their own workshops at site for regular maintenance and upkeep of their equipments. Minor repairs were only available at near cities of Burewala and Sahiwal and major repairs were got done only at Lahore, the nearest big city.

TABLE-5 - LIST OF CONSTRUCTIONAL EQUIPMENT

Sr. No.	Equipment	SNOC-1	SNOC-2	SNOC-3	SNOC-4	Total
1	Farm Tractors. (hired)	18	14	44	30	106
2	Bulldozer		1	5		6
3	Sheep foot roller, drag type	3	2		1	6
4	Water tanker on wheel base, 4000 Gallons.	1		2	1	4
5	Water tanker on wheel base, 3000 Gallons.	1	2			3
6	Concrete mixer, without weigh batching, 5 cft. capacity	3	2			5
7	Concrete mixer (Single load)			2	2	4
8	Truck 5 ton capacity	1				1
9	Vibrators	4	2	2	6	14
10	Generator set, portable	2	1		1	4
11	Generator set, heavy duty	2				2
12	Workshop (complete unit)	1	1	1	1	4
13	Water pumps	6	4	2	2	14
14	Welding plant single phase	1				1
15	Welding plant 3 phase	3				3
16	Steel shuttering (4'x2' standard size)	5000 ft^2	2000 ft^2	2000 ft^2	2000 ft^2	11000 ft^2
17	Scaffolding pipes	6000 Rft	1000 Rft	2000 Rft	4000 Rft	13000 Rft
18	Coupler/ Joints	500	200	500	1000	2200
19	Hiace pick up	1	1	1		3

Sr. No.	Equipment	SNOC-1	SNOC-2	SNOC-3	SNOC-4	Total
20	Pajero Jeep	1				1
21	Suzuki Jeep		1	1		2
22	Motor Car		2			2
23	Tractor trolley		2	2		4

5.3 MATERIALS AND SUPPLIES

A significant part of the cost of work was the cost of construction materials, fuel oil and lubricants for equipment operation. Some of these materials required in large quantities and spread over the entire construction period, were designated "Specified Materials", Provisions were made in the Contract Documents to vary payments to the contractors to correspond to price escalations of such materials during the relatively long construction period. The Specified Materials, for which escalation on basic prices was allowed were as given below:

(i) Cement (ii) Mild Steel Reinforcement Bars,
(iii) Intermediate Grade-40, Deformed Reinforcement Bars
(iv) Petrol (i) Regular (ii) Super (v) Diesel.

5.3.1 Procurement of Materials

The contractors procured concrete coarse aggregates from Blund Hill Quarries, near Sargodha, for all the four contracts and fine aggregates were procured from the bed of the Haro River, near Lawrence Pur and Sakhi Sarwar Nullah near D.G. Khan. Sand from both these locations fulfilled the contract specifications for fine aggregate. Revetment material was procured from Railway Quarry near Chiniot. The contractors were responsible for all types of handling and processing of these materials.

The contractors procured cement from local market in Vehari/Burewala on daily consumption basis. Sulphate resistant (SR) cement was arranged from Falcon, Karachi or State Cement, Rohri, on monthly consumption basis. No arrangement of large quantity stock/ storage was available with any of the contractors at SNOC Project. In case of non-availability of SRC, contractor had been given the option of using 11% additional OPC in 1:2:4 concrete in order to give high cement content in lieu of SRC.

Water for construction purpose was arranged by drilling bores upto a depth of 70 ft. near the sites of construction. Sub-soil water encountered was fit for use for R.C.C. construction of the project. Good soil deposits for making bricks were locally available, hence, burnt bricks were available locally and were arranged from the best quality available in the Project area at different approved kilns.

All the contractors of four contracts procured various sizes of deformed steel bars from PECO/AFCO, Lahore.

Fuels and lubricants, used by the contractors, were purchased from the open market at Burewala/ Sahiwal.

24" dia R.C.C. Pipes were specially got manufactured according to Contract Specifications at a private pipe factory at Hasal Pur. Flap valves for inlets were fabricated in a local workshop at Burewala.

PVC water stops, both for 9-inch-3 bulbs and 6 inch-2 bulbs types were arranged from Pakistan Rubber, Branderth Road Lahore, for use on WAPDA as well as on Irrigation component. Neoprene bearing pads were also arranged from Pakistan Rubber, Branderth Road, Lahore, for use on all the four contracts. All of these materials conformed to Contract Specifications.

5.4 EXCAVATION AND OTHER EARTHWORK

SNOC Channel was constructed according to the lines and grades shown on the drawings.

The Outfall Channel was mainly in cut and fill except for few patches where the depth of the cut along the outfall channel exceeded the full supply depth of the channel. The sub-soil water levels along the entire length of the channel, were substantially lower than the invert levels of the channel. The low sub-soil water levels facilitated the excavation operations and did not pose any problem of water handling.

The excavation of the Outfall Channel was accomplished exclusively by farm tractors/ bulldozers equipped with locally manufactured scrapping units. Farm tractors with improvised scrapping units substituted conventional donkey labour used for dry excavations. For the lengths of the channel covered under contract Nrs. SNOC-01, SNOC-2 and SNOC-04, tractor drawn scrapping units were used for excavation. The reach under Contract Nr. SNOC-03 was excavated both by bulldozers-drawn and tractors-drawn scrapping units.

Inasmuch as the purchase of new earthmoving equipment involved heavy sums of foreign exchange, the contractors preferred to make use of the old tractor-drawn scrapping units already available with them. The shortfall was made good by hiring the additional numbers from the local farmers. Requisite number of bulldozers used by the Contractor of the Contract Nr. SNOC-03 was acquired by him from the Agriculture Department.

The excavated materials were placed in the channel embankments or spoil piles. The shaping and grading of the excavated materials were done by bulldozers and tractors. The excavation was normally carried out on a one shift, six-day week basis during the peak operation period by the bulldozers/ tractors.

Photograph of excavation in progress and completed cross-sections are added on the subsequent pages.

5.5 CONCRETE

All of the concrete used in structures was cast-in-situ except the concrete block aprons and concrete pipes, which were precast. To ensure the requisite quality of concrete, materials were proportioned by volume. The concrete mixing and placing procedures were specified in detail. Curing of all concrete was done with water. Other materials that were incorporated in the

concrete structures were expansion joint filler, hot poured elastic joint sealer, polyvinyl-chloride (PVC) water stop and neoprene bearing pads.

The preparation of concrete of all the structures was carried out by concrete mixers, where stock piles of mixing components were maintained to ensure the continuous production of concrete.

Concrete was placed both by concrete chutes and by traditional head baskets. Gasoline driven vibrators were used to consolidate the concrete.

Batching, mixing and placing of the concrete was carried out without unusual difficulties. During hot weather it was felt feasible to place concrete during comparatively mild temperature hours. Occasionally placement of concrete for longer durations at sites of bigger structures, where larger quantities of concrete were required to be consumed, work was done during night. In order to ensure that the concrete temperature did not exceed the allowable maximum, when it was placed, the aggregate piles were sprinkled with water and the mixing water was cooled by adding ice where considered necessary.

Reusable steel panel forms were used for casting concrete. Forms were held in position by conventional wooden supports and male and female type steel ties. The concrete finish after stripping the forms was usually good and only a minimum of hand finishing work was required.

The contractor procured the precast concrete pipes from a manufacturer in Hasilpure and transported them to the various structure sites by trucks.

Placement of concrete in permanent works was started by the contractor of the Contract Nr. SNOC-01, during April 1989. For contract Nrs. SNOC-01 and SNOC-02, concrete work in permanent structures was completed on 15-12-1993 and 30-11-1993 respectively, whereas the completion of structures of SNOC-03 and SNOC-04 was delayed upto 1997.

Photographs of concreting in progress and completed structures are added in the sub-sequent pages.

5.6 INORDINATE EXTENSION IN CONSTRUCTION PERIODS

The construction period envisaged for each of the four contracts was two years. For Contract No.SNOC-1 and 2, the legal stay orders taken by land owners were vacated after the expiry of the original completion dates of these contracts. Accordingly, new MOUS had to be signed with the contractors for revised rates of BOQ for completion of the remaining works. The construction of these contracts was delayed by about two years due to the land acquisition problems, whereas completion of Contract No. SNOC-3 & 4 was extended by four years. These inordinate extensions in the construction periods resulted in substantial increase in the cost of the Project.

The following reasons were responsible for the aforementioned delays in the completion of the Project.

- Legal stay-orders by the owners of lands/ properties
- Non-provisions of proportionately adequate funds by the Government.

5.7 QUALITY CONTROL

Tests were made of the various materials used in construction of the permanent works by the WAPDA / I&P Department site supervision staff. Notwithstanding the consistent follow-up of the Consultants for establishing field laboratory at Burewala, neither WAPDA nor I&P Department could establish any field laboratory. Real objective of quality control, which can be better achieved through a field laboratory, did suffer due to the non-availability of some of the testing facilities at the site. Nevertheless, field compaction tests were carried out by the equipment provided by the Consultants and concrete cylinders were tested mostly in the material testing laboratory of Drainage-IV, Project, WAPDA, at Faisalabad.

The adequacy of compaction of embankments and compacted backfill was checked by Standard Proctor Compaction Tests performed in accordance with ASTM Designation: D-698.

The Contractors obtained coarse sand from the Haro river near Lawarancepur or Sakhi Sarwar near D.G. Khan. Aggregates meeting specification requirements were obtained from the Bulland Hill quarries near Sargodha. These materials were transported to the site and stockpiled in advance of their use. the sand and aggregates were periodically tested prior to batching to check their conformity to the grading requirement as given in Contract Specifications.

Trial concrete mixes were prepared in the laboratory and the concrete mix design for use in different components of works were furnished to the Contractor of the concrete mix designs used throughout the construction of the project. Table-6 contains summary of the concrete mix designs used for different structures of SNOC. Standard 6-inch diameter by 12-inch cylinders were cast from concrete produced at the contractor's concrete mixers and were tested in the laboratory for compressive strength. All the concrete strengths determined by the concrete cylinders tests conformed to the requirement of the specifications.

Samples of brick manufactured by the several private kilns were selected at random from the stacks offered for inspection and were tested in the laboratory. The bricks were manufactured from suitable soil deposits consisting generally of silty or sandy clay.

Samples from the different consignments of reinforcing steel bars were taken and tested in Building Research Station (Punjab) Lahore. The average of test results conforms to the specifications.

5.8 COST OF TE PROJECT

The overall cost of constructing SNOC, as included in approved PC-I prepared by WAPDA in May 1987, was 393.40 million rupees. Due to the extension in construction period by about 5 Years, as mentioned in para 5.6, the total expenses incurred upto December 2000, rose to Rs. 562 million and there are still some liabilities, including payments of land acquisition, which need to be met with. The overall costs as approved in revised PC-I are now Rs. 617.327 millions.

TABLE-6 - CONCRETE MIX DESIGNS

MIX	PERIOD		CEMENT CONTENTS lbs/cft	WATER CEMENT RATIO	SLUMP IN INCHES	UNIT WEIGHT TO MIX lbs/cft	AGGREGATE (PROPORTIONS) %				REMARKS
NO.	FROM	TO					SAND	C. Agg ½"	C. Agg 3/4"	C. Agg 1 ½"	
1	2	3	4	5	6	7	8	9	10	11	12
1	June 1989	Oct. 1989	19.71	0.60	3.0	145.00	38	16	16	30	Mostly used in foundation blocks.
2	Nov. 1989	April 1990	19.71	0.54	2.75	144.70	36	25	25	14	Used in columns and caps.
3	May 1990	Oct. 1990	20.00	0.59	2.50	145.00	36	25	25	14	Used in columns caps and girders.
4	Nov. 1990	March 1991	20.00	0.58	3.00	146.00	36	32	32	-	Used in aqueduct troughs and deck slabs and other structures
5	April 1991	Sep. 1991	20.00	0.58	2.50	145.80	36	32	32	-	- do -
6	Oct. 1991	Dec. 1991	20.00	0.58	2.50	146.00	36	32	32	-	- do -

Notes:

(a) All Cement used on the Project was, OPC from State Cement Factory D.G. Khan and S.R. Cement from State Cement Factory Rohri.

(b) No additives were used.

6.0 CONCLUSIONS AND RECOMMENDATIONS

On the basis of the experiences gained through implementation of Sukh Nai Outfall Channel (SNOC) Project, following conclusions and recommendations are be made for consideration in planning, design and construction of similar future projects.

(i) The channels which are liable to run for most of the period with very low discharges as compared to their full capacity discharges, need to be provided with a cunette in the central portion of their sections to carry the anticipated perennial discharges. The depth in the cunette may be kept about 1/3 of the computed overall depth of the channel for its full capacity. The cunette will keep the low discharges flowing in the central portion of the channel and help in controlling the side erosion associated with secondary meandering triggered by varying low discharges in the channel.

(ii) The criterion of U.S.B.R for determining minimum radius of curves is related with the top width of the channel cross-section. It determines curve radii shorter than those given by the criteria of Ven Te Chow, wherein curve radius is related to the under-root of the cross-sectional area of the channel and Irrigation Department criterion relating by curve radius with the maximum discharge of the channel. (refer paragraph 4.2).

- In special circumstances where procurement of right-of-way or the avoidance of the existing cultural features would appreciably increase the cost of construction, the criterion of U.S.B.R for determining minimum radius of curvature is deemed reasonable.

- However, the characteristics of the bank soils and ground topography may sometimes require some adjustments.

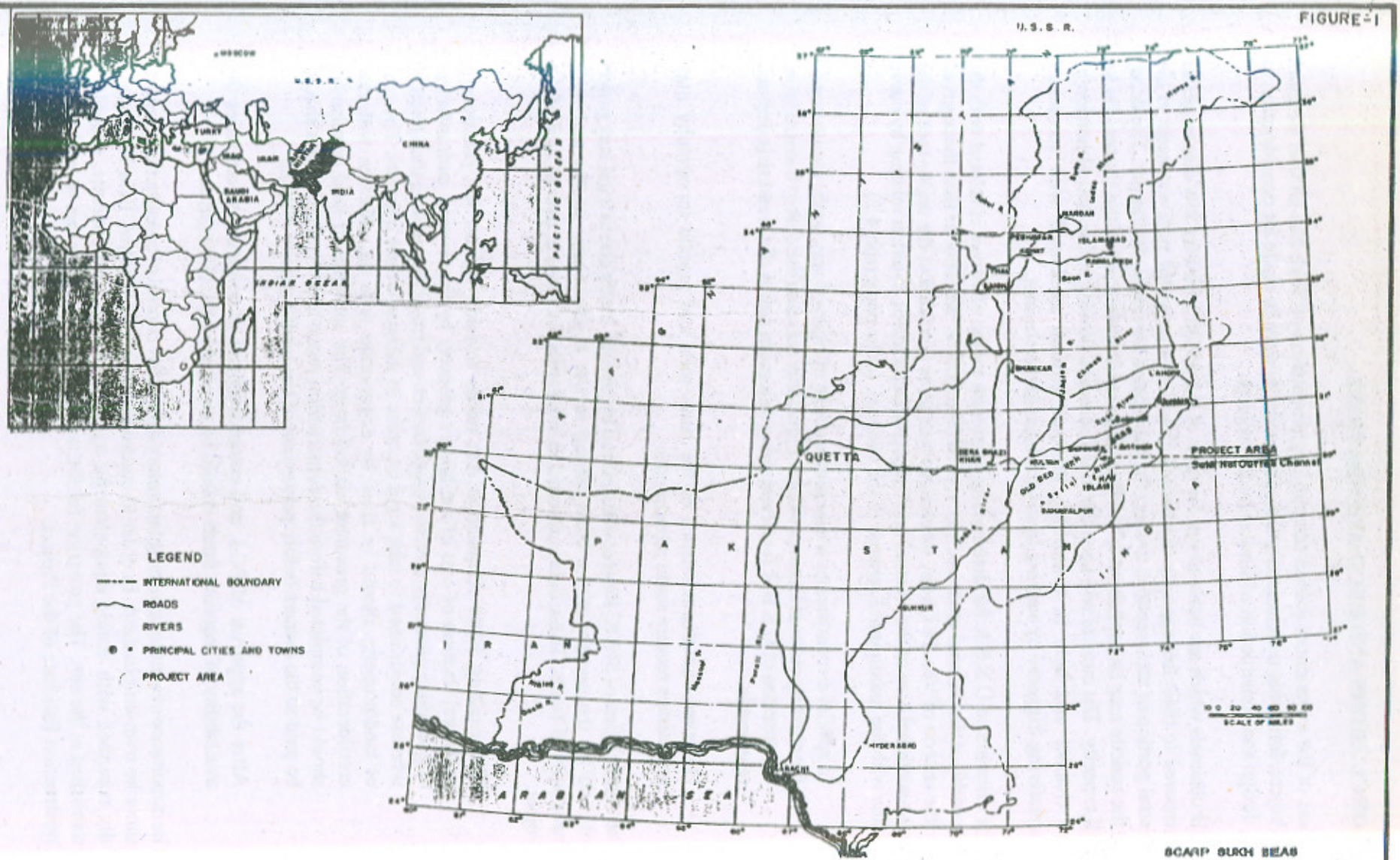
(iii) The construction of SNOC Project was delayed by about 5 Years due to legal stay orders obtained by the owners of the lands falling in the Right-of-way widths and non-availability of funds. These delays resulted in substantial increase in overall cost of the Project.

- The existing Land Acquisition Act needs revision against the practice of unilateral fixation of cost of the lands / property by the revenue authorities in vogue which generally creates dissatisfaction and frustration among the affectees who are constrained to take legal recourse to safeguard their interests. The cost of land/property should be fixed by negotiation with the affectees with due consideration of the prevalent market rates. The activities of land acquisition should be completed before the construction phase and the agreed costs should be paid to the owners before possession of the land/ property is taken.

- After the approval of PC-I, and commencement of construction activities the availability of requisite funds should be ensured by the Government.

(iv) The importance of a material testing laboratory for quality control of construction projects cannot be over-emphasized. In order to ensure proper quality control, field laboratory, fully equipped with testing equipment for aggregates, soils, and concrete, should be established at the site. The provision for the cost of such laboratory can be made in the Construction Estimate of the Project.

FIGURE-1



SCARP SUKH SEAS
SUKH NAI OUTFALL CHANNEL PROJECT
PROJECT AREA LOCATION MAP

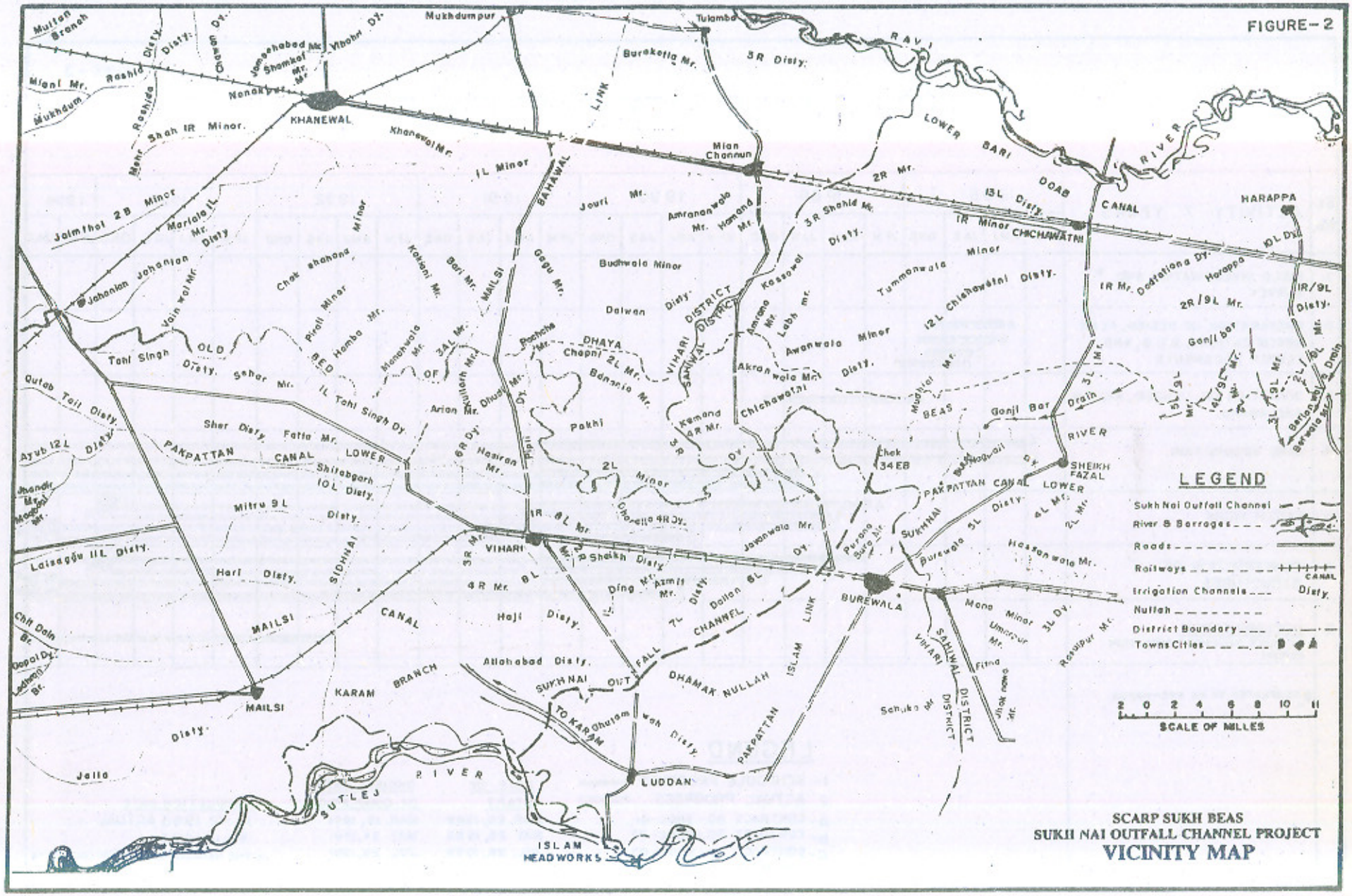


FIGURE-2
KHANEWAL
Mian Channun
HARAPPA
MAILSI
LUDDAN
BUREWALA
SHEIKH FAZAL
RAVI RIVER
SUTLEJ RIVER
LOWER BARI DOAB CANAL
PAKPATTAN CANAL LOWER
SIDHNAI CANAL
MAILSI CANAL
KARAM BRANCH
ISLAM HEADWORKS
SCARP SUKH BEAS
SUKH NAI OUTFALL CHANNEL PROJECT
VICINITY MAP
LEGEND
Sukh Nai Outfall Channel
River & Barrages
Roads
Railways
Irrigation Channels
Nullah
District Boundary
Towns Cities
SCALE OF MILLES

FIGURE - 3

PROJECT IMPLEMENTATION SCHEDULE

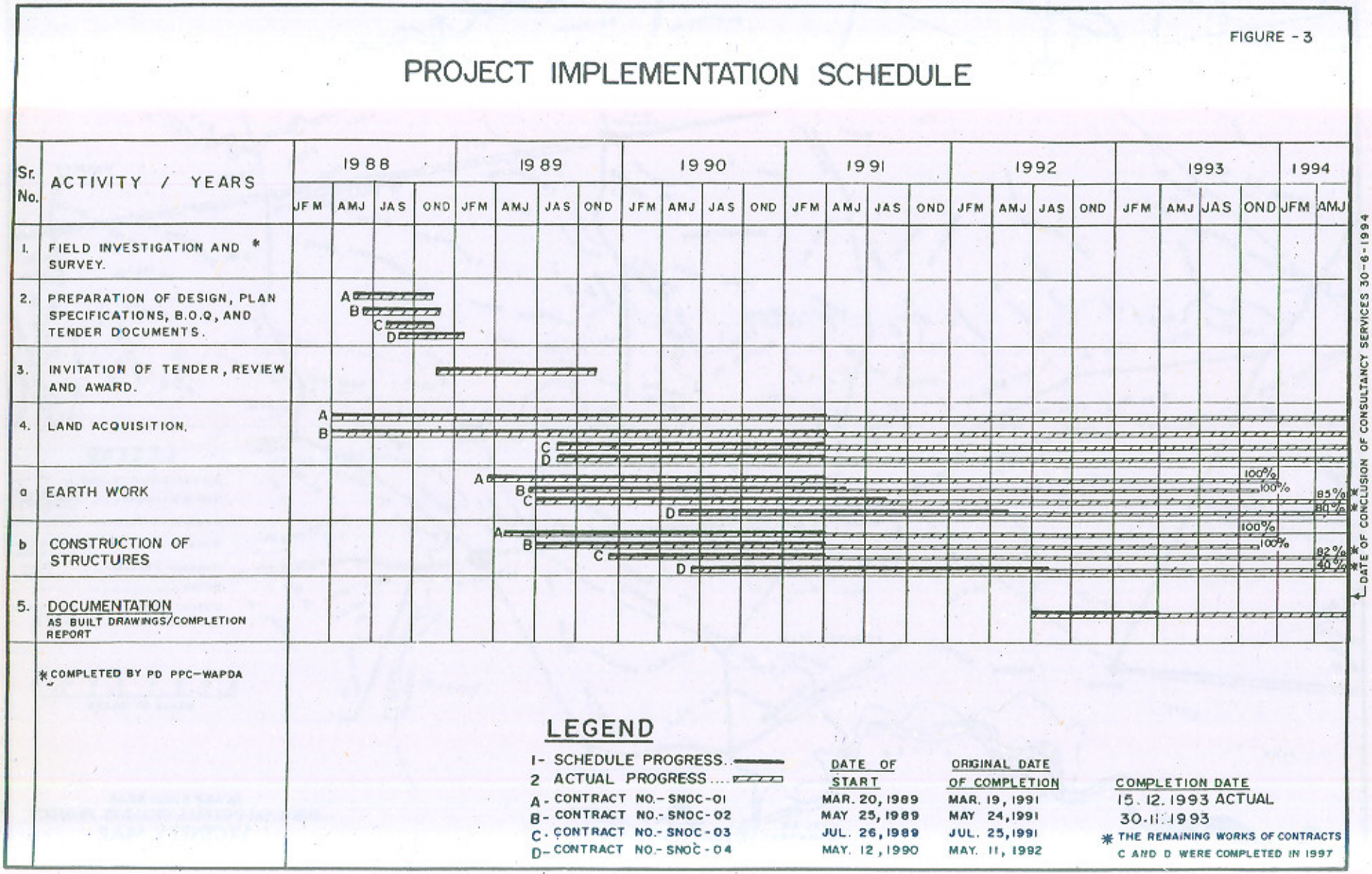
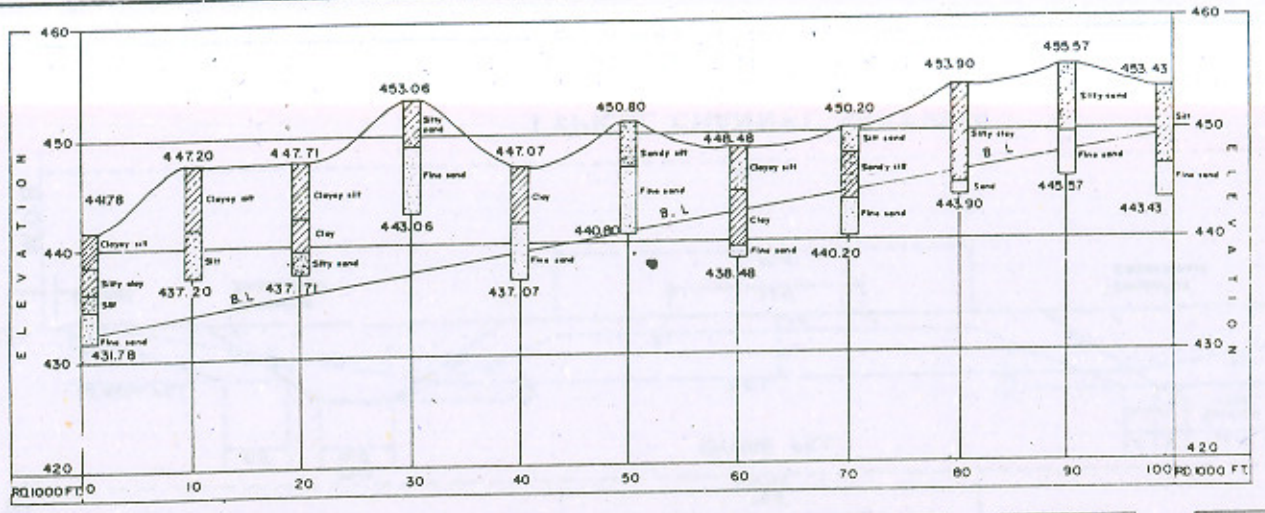


FIGURE - 4

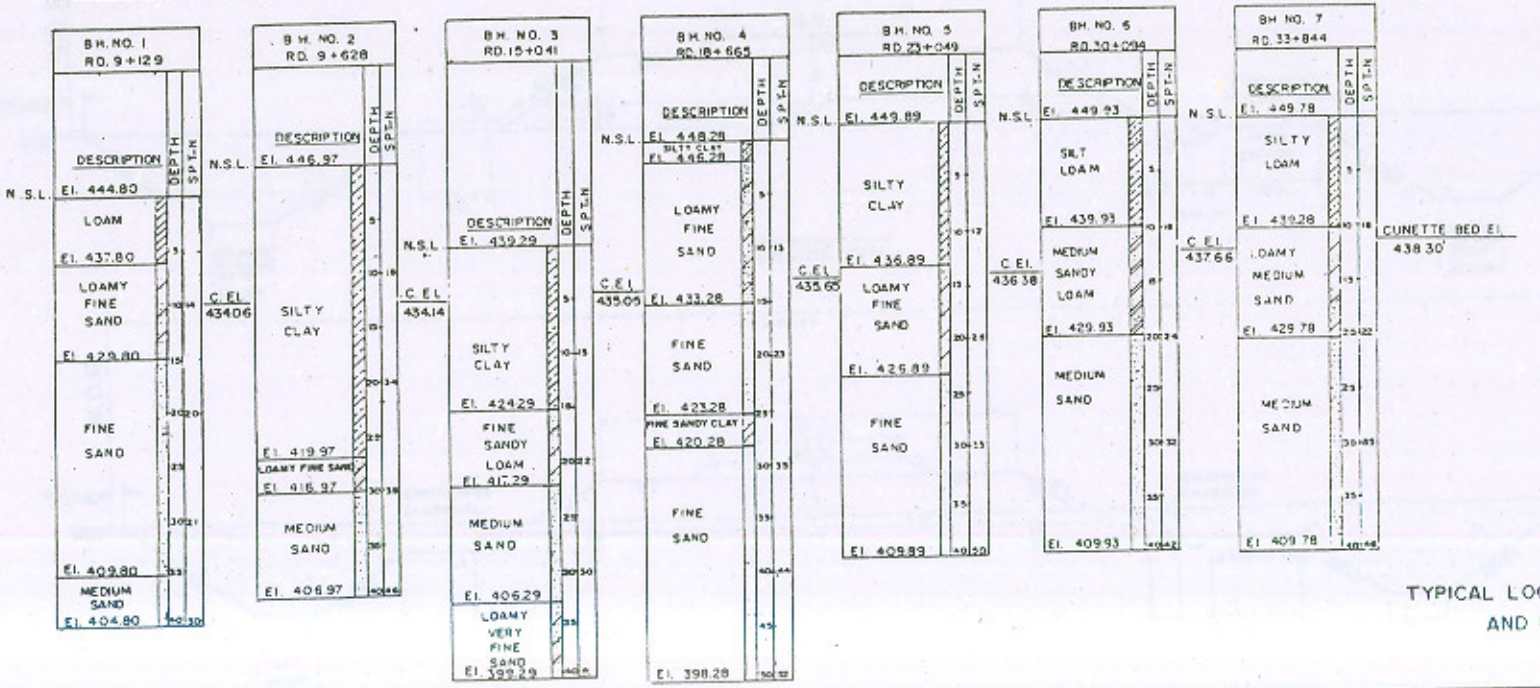


LEGEND

- CLAY
- SILTY CLAY
- CLAYEY SILT
- SILT
- SANDY SILT
- SILTY SAND
- SANDY CLAY
- CLAYEY SAND
- SAND

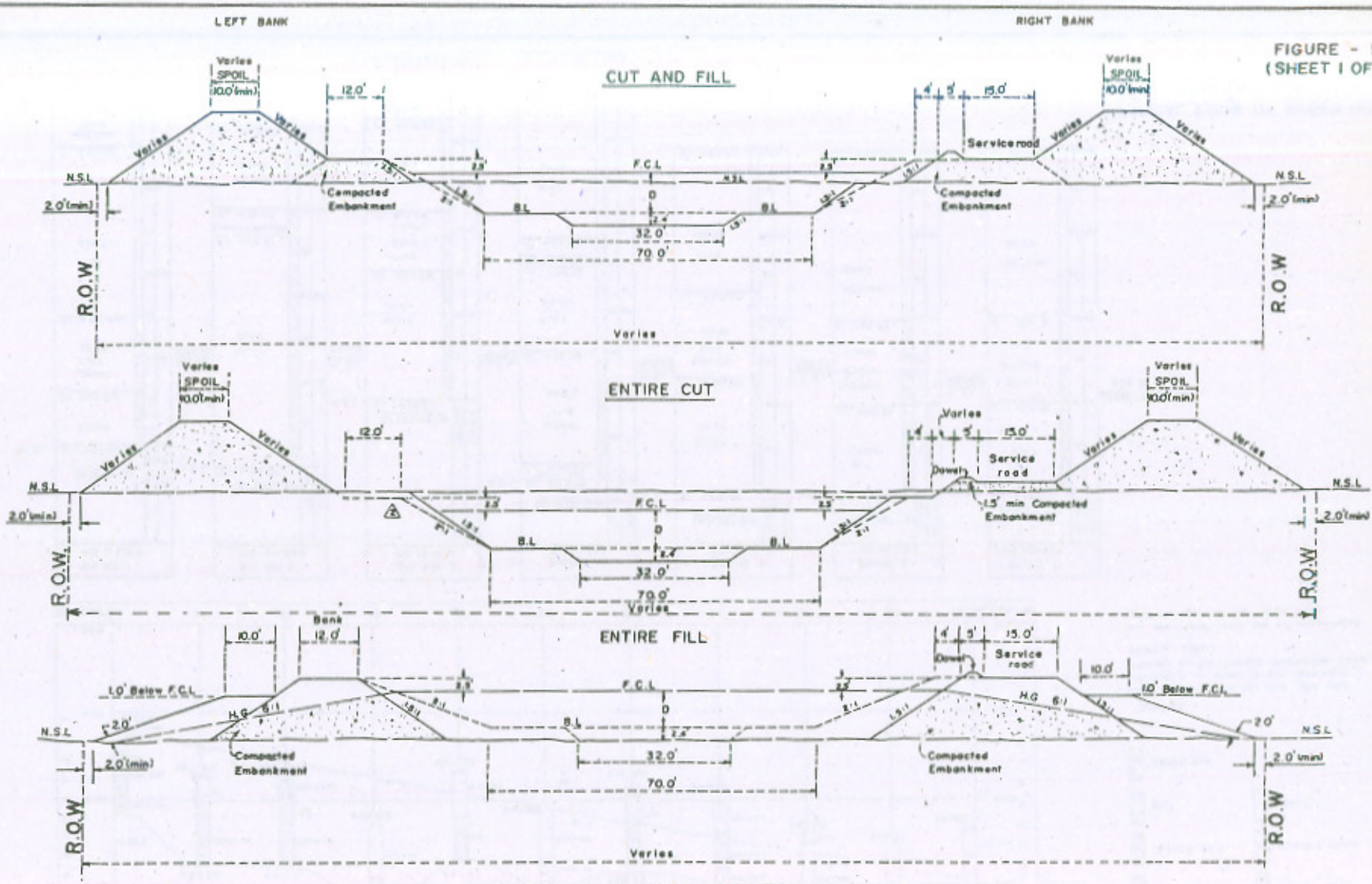
NOTES –

- The elevation, bore log data and other information as shown herein have been provided by the Project Preparation Circle, WAPDA, Lahore
- Sub soil water level was not encountered up to the depth of the Auger holes



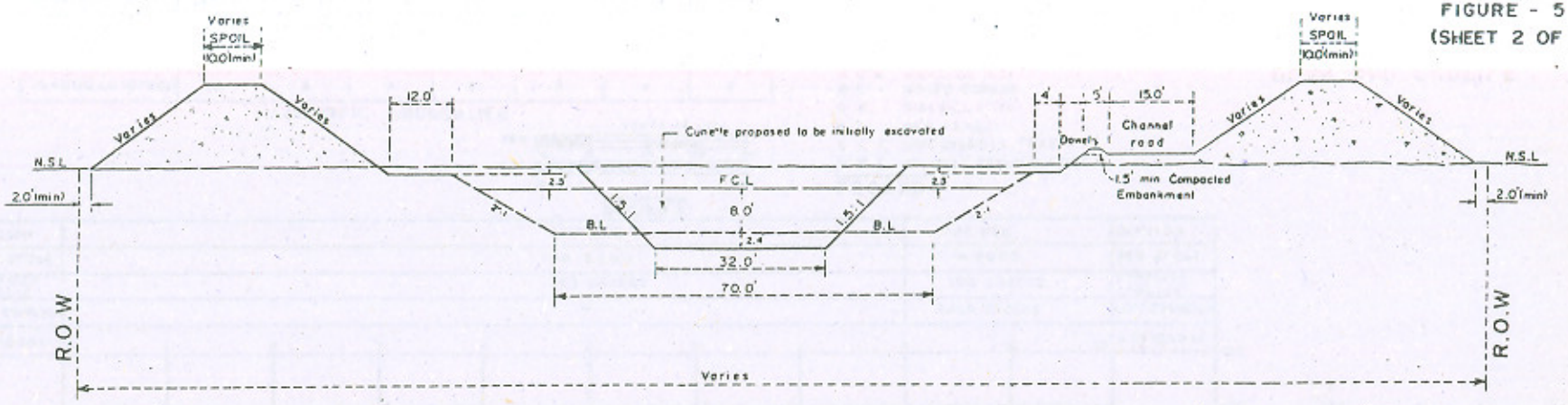
TYPICAL LOGS OF AUGER HOLES AND BORE HOLES

FIGURE - 5
(SHEET I OF 2)



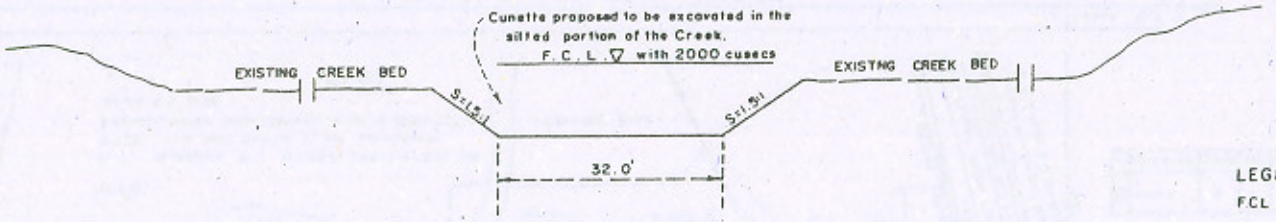
TYPICAL CHANNEL SECTIONS
CUT AND FILL REACHES
ENTIRE CUT AND ENTIRE FILL

FIGURE - 5
(SHEET 2 OF 2)



PILOT CUT

OUTFALL STRUCTURE R.D. 9+609 TO R.D 0+000



CROSS SECTION

CREEK LEADING

TO

RIVER SUTLEJ

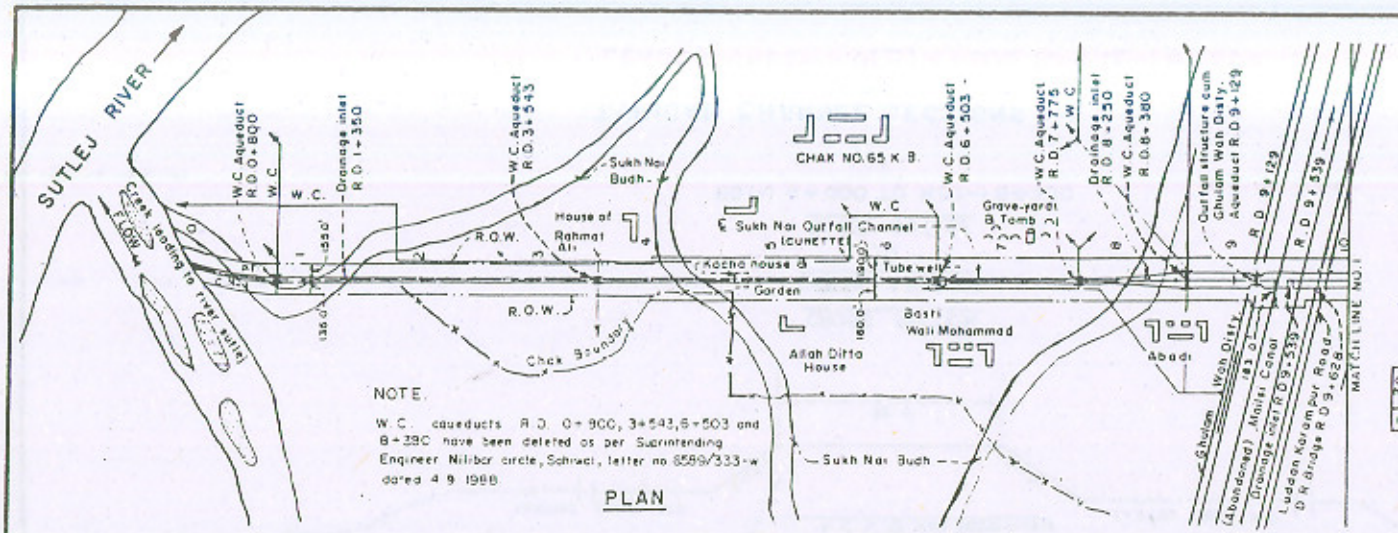
RD.(–) 4+600 TO RD.(–) 8+350

LEGEND

F.C.L	FULL CAPACITY LEVEL
B.L	BED LEVEL
R.O.W	RIGHT OF WAY
F.B	FREE BOARD
D	FULL CAPACITY DEPTH

TYPICAL CHANNEL SECTIONS
OUTFALL STRUCTURE TO R.D 0+000
LEADING CREEK R.D(±) 4+600 TO R.D(–) 8+350

FIGURE - 6
(SHEET 1 OF 2)



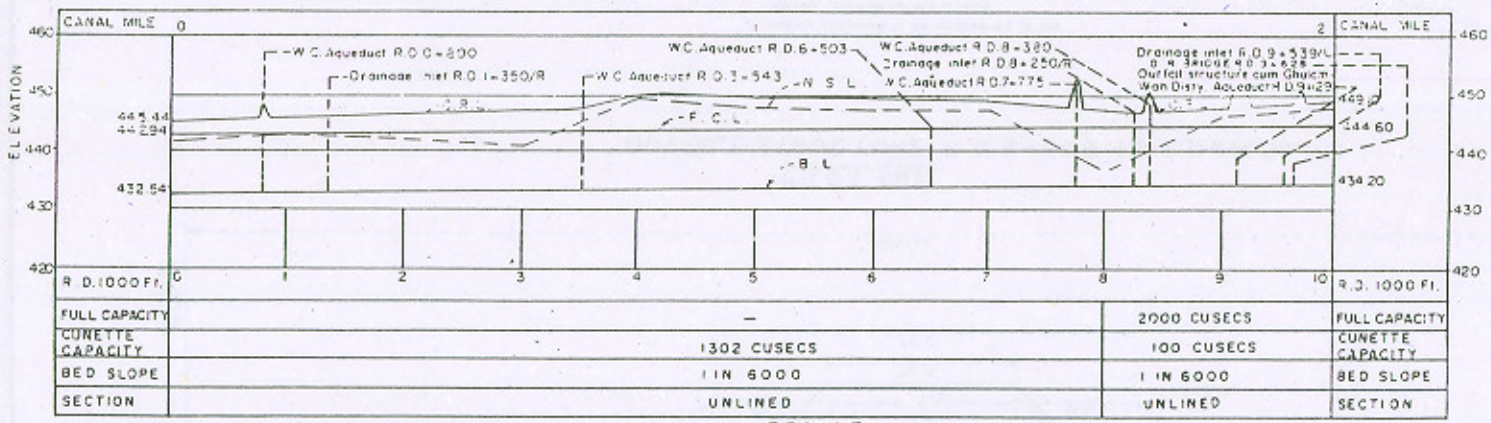
NOTE:

W.C. aqueducts R.D. 0+800, 3+543, 6+503 and 8+380 have been deleted as per Superintending Engineer Nilibar circle, Schiwal, letter no 8589/333-w dated 4.9.1988

PLAN

CURVE DATA

P.I.	ANGLE	R	T	L	E	REDUCED DISTANCE PC	REDUCED DISTANCE PT	STRAIGHT DISTANCE PC	STRAIGHT DISTANCE PI	STRAIGHT DISTANCE PT	DISTANCE PI to PI
1	25°58'-35"	2000	461	907	52	-478	429	-493	-32	429	12080

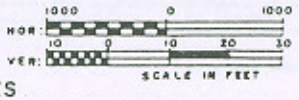


FULL CAPACITY	—	2000 CUSECS	FULL CAPACITY
CUNETTE CAPACITY	1302 CUSECS	100 CUSECS	CUNETTE CAPACITY
BED SLOPE	1 IN 6000	1 IN 6000	BED SLOPE
SECTION	UNLINED	UNLINED	SECTION

LEGEND

- CENTRE LINE OF CHANNEL
- TOP WIDTH OF CHANNEL
- RIGHT OF WAY
- ROAD BRIDGE
- DRAINAGE INLET
- ROAD BRIDGE WITH AQUEDUCT
- AQUEDUCT
- OUTFALL STRUCTURE

PROFILE



HYDRAULIC PROPERTIES

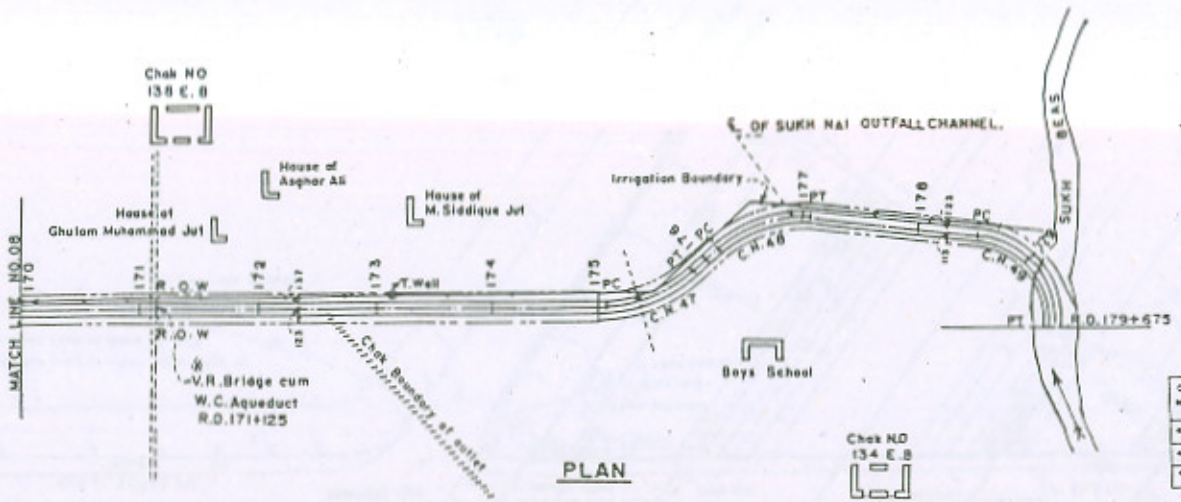
0+000 TO 10+000	Q	A	V	B	D	n	S
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Channel 0+000 to 8+000	1302	495.04	2.63	32	10.4	0.027	1 IN 6000
Channel 8+500 to 10+000	2000	741.44	2.70	70	8.0	0.027	1 IN 6000
Cunette 8+500 to 10+000	100	85.44	1.17	32	2.4	0.027	1 IN 6000

LEGEND

- N.S.L. NATURAL SURFACE LEVEL
- F.C.L. FULL CAPACITY LEVEL
- B.L. BED LEVEL
- D.R. DISTRICT ROAD
- W.C. WATER COURSE
- R.O.W. RIGHT OF WAY
- C.R.L. CHANNEL ROAD LEVEL

PLAN AND PROFILE
R.D. 0+000 TO R.D. 10+000

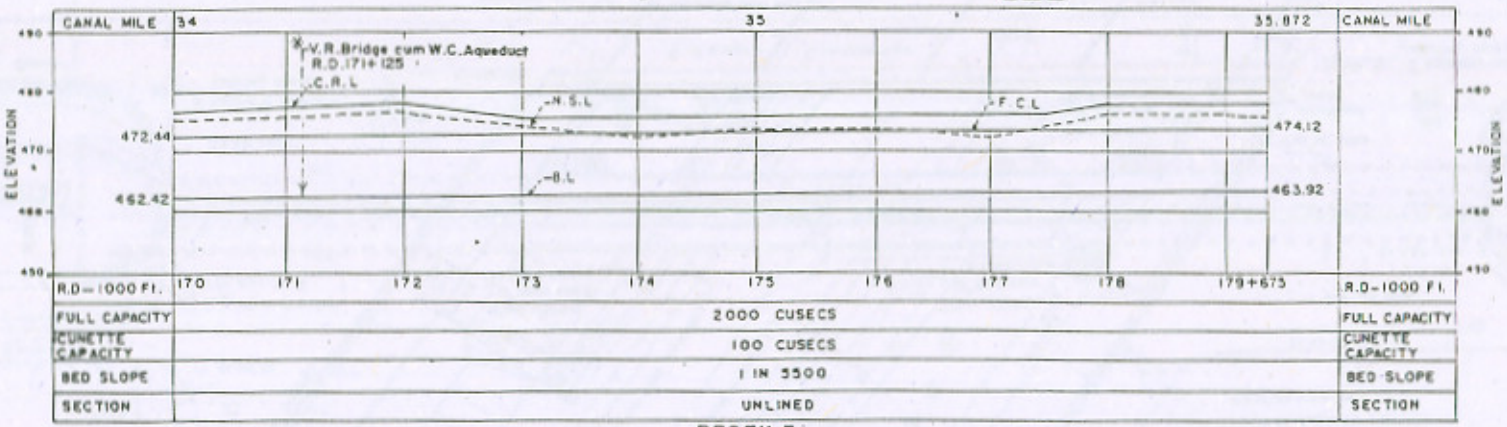
FIGURE - 6
(SHEET 2 OF 2)



PLAN

CURVE DATA

C. NO.	ANGLE	R	T	L	E	REDUCED DISTANCE PC	REDUCED DISTANCE PT	STRAIGHT DISTANCE PC	STRAIGHT DISTANCE PI	STRAIGHT DISTANCE PT	DISTANCE PI to PI
47	45°-1-0/1	2200	475	904	81	174845	175847	181958	182453	182908	1810
48	41°-33-46/1	2200	455	871	84	178147	177018	183188	183643	184098	2712
49	90-0-0/1	700	700	1100	250	176575	178872	186833	186333	187033	—



FULL CAPACITY	2000 CUSECS
CUNETTE CAPACITY	100 CUSECS
BED SLOPE	1 IN 5500
SECTION	UNLINED

PROFILE

HORIZ: 1000 500 0 1000
VERT: 10 5 0 10 20 30
SCALE OF FEET

HYDRAULIC PROPERTIES

170+000 TO 180+000	Q	A	V	B	D	n	S
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CHANNEL	2000	722.70'	2.78'	70.0'	7.8'	0.027	1 IN 5500
CUNETTE	100	85.44'	1.22'	32.0'	2.4'	0.027	1 IN 5500

PLAN AND PROFILE
R.D.170 + 000 TO R.D.180 + 000(±)

FIGURE - 7
(SHEET 1 OF 2)

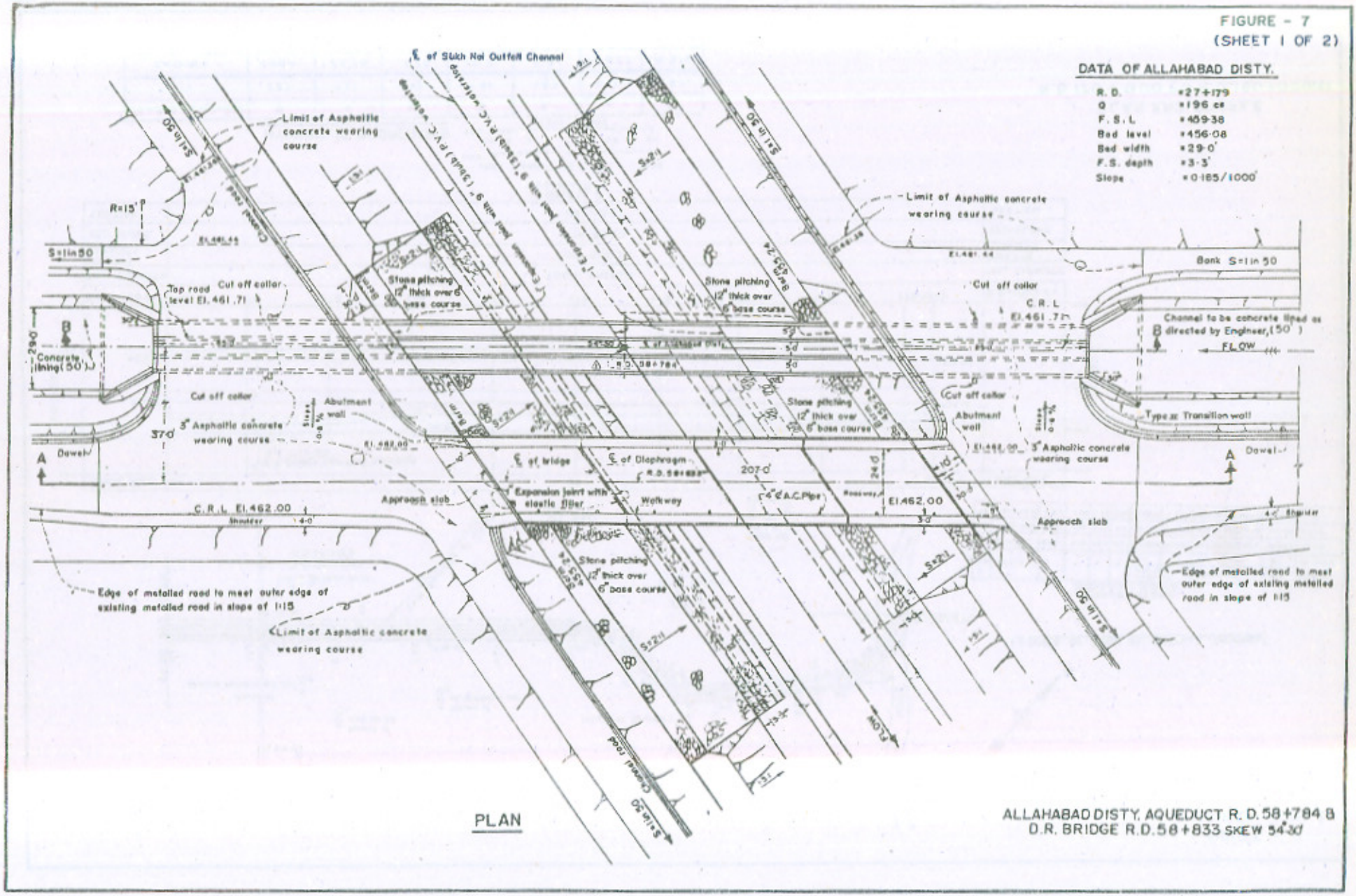
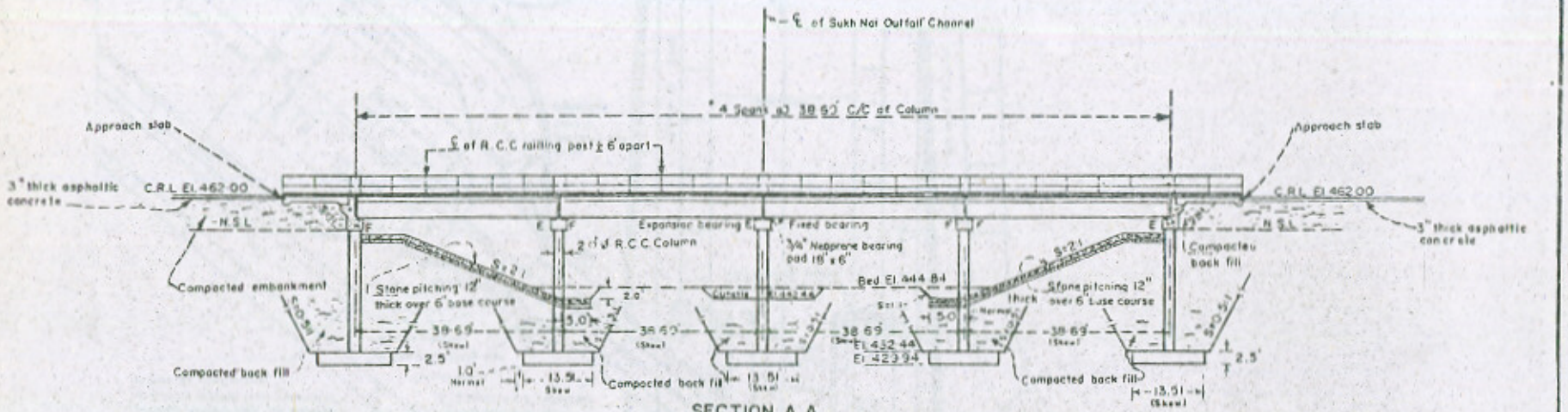


FIGURE – 7
(SHEET 2 OF 2)



ALLAHABAD DISTY. AQUEDUCT R.D. 58+784 &
D.R. BRIDGE R.D. 58+833 SKEW 54°30'
ELEVATIONAL SECTIONS

FIGURE -8
(SHEET 1 OF 2)

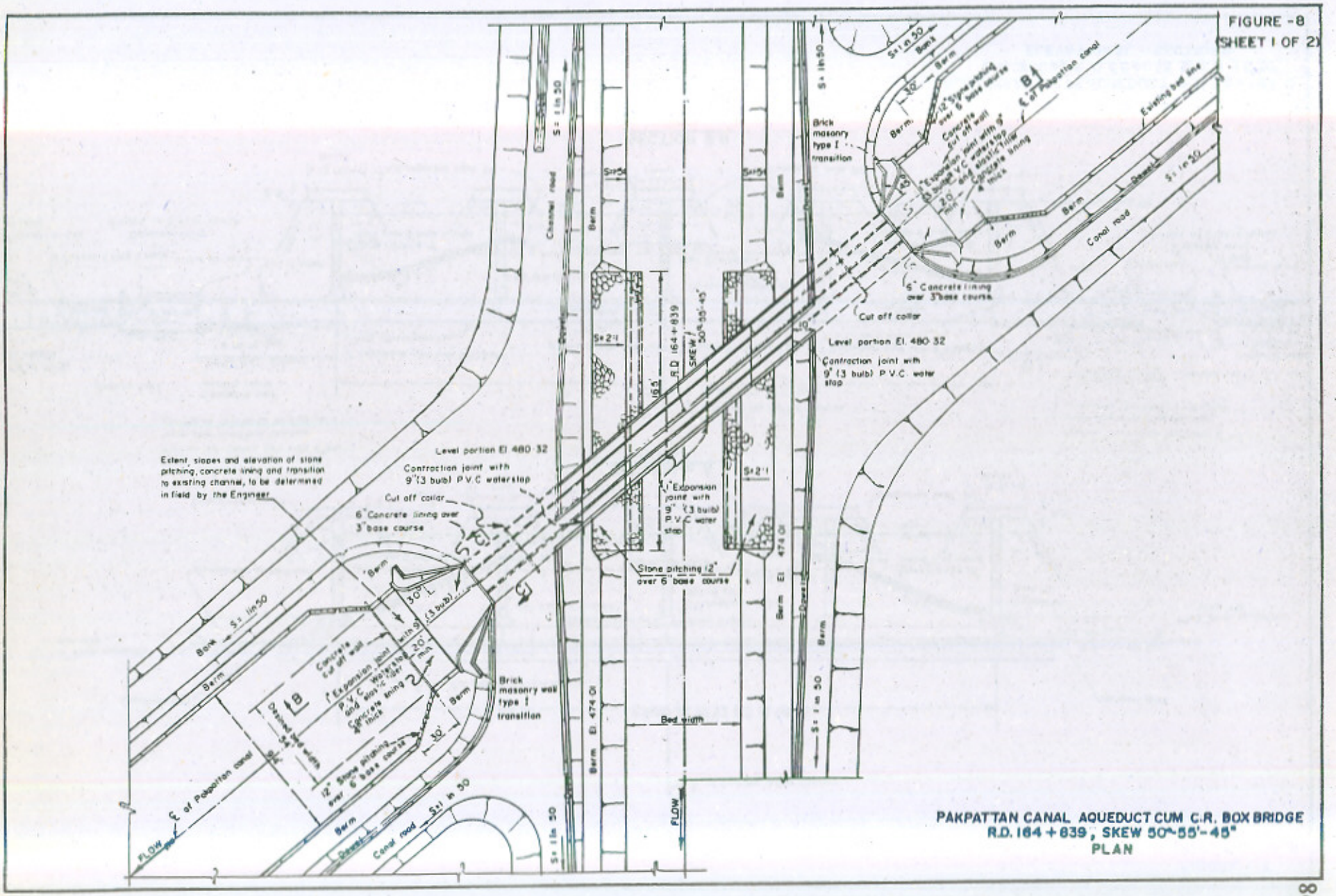
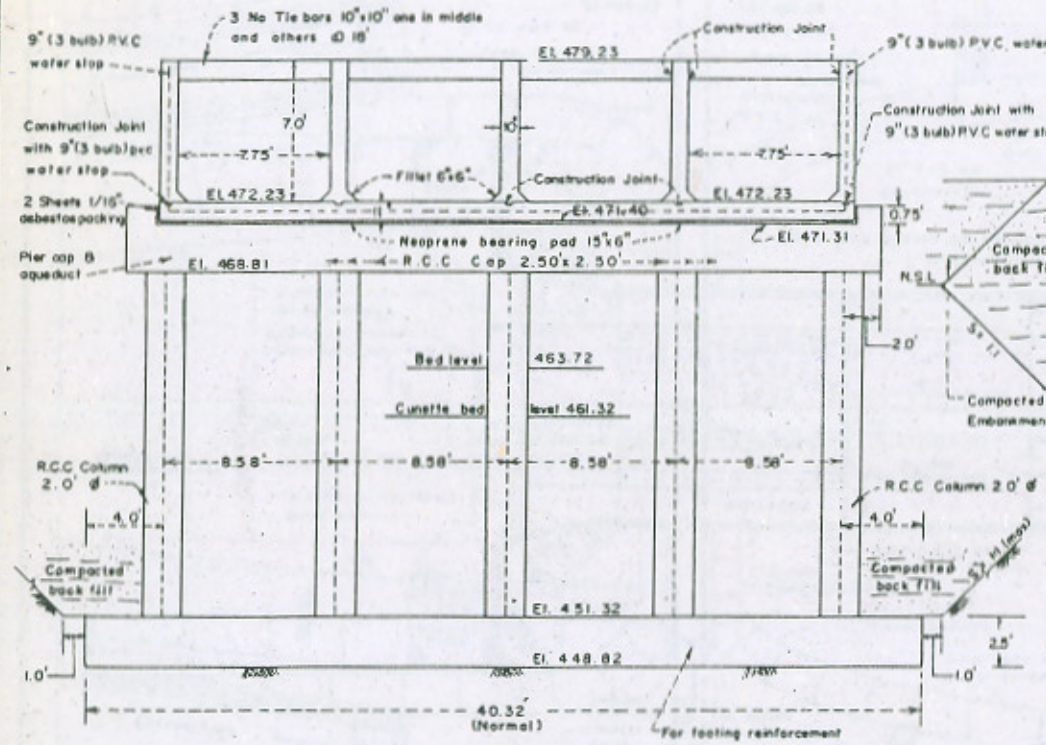
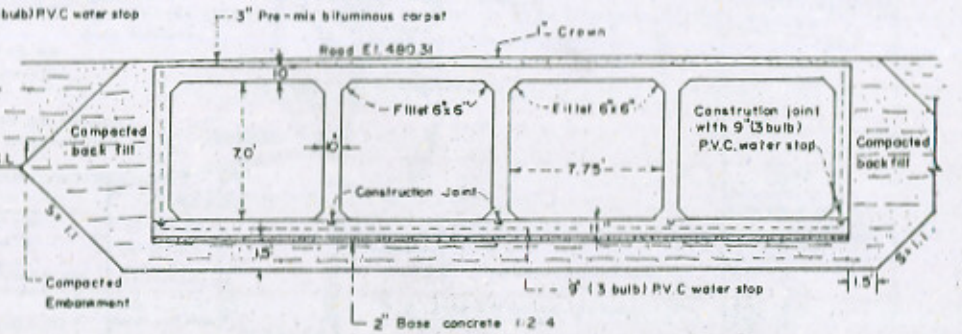


FIGURE - 8
(SHEET 2 OF 2)



SECTION C-C



SECTION B-B
CULVERT

PAKPATTAN CANAL AQUEDUCT
R.D.164+875 SKEW 49°-07'-32"
SECTIONS

FIGURE - 9
(SHEET 1 OF 2)

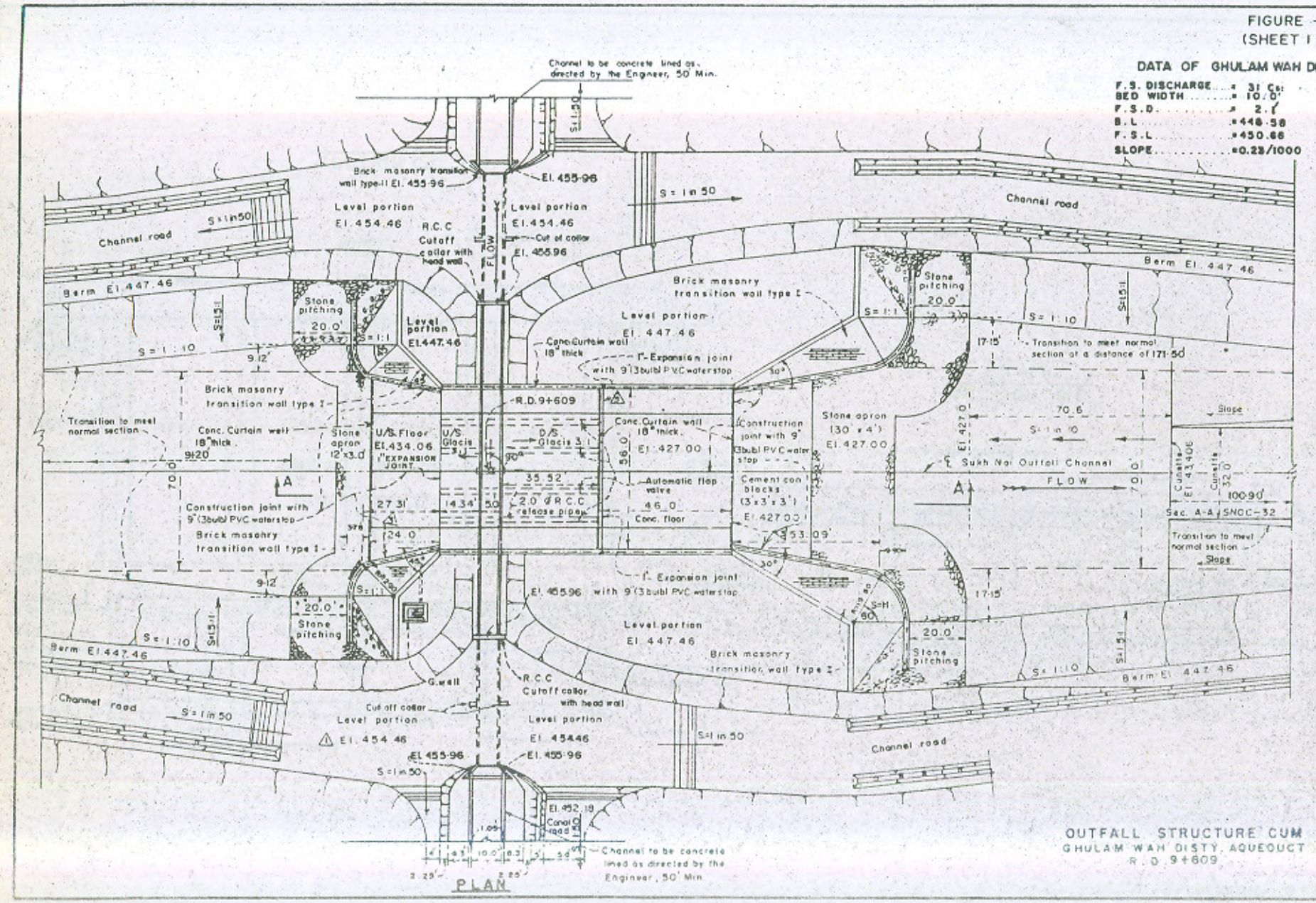
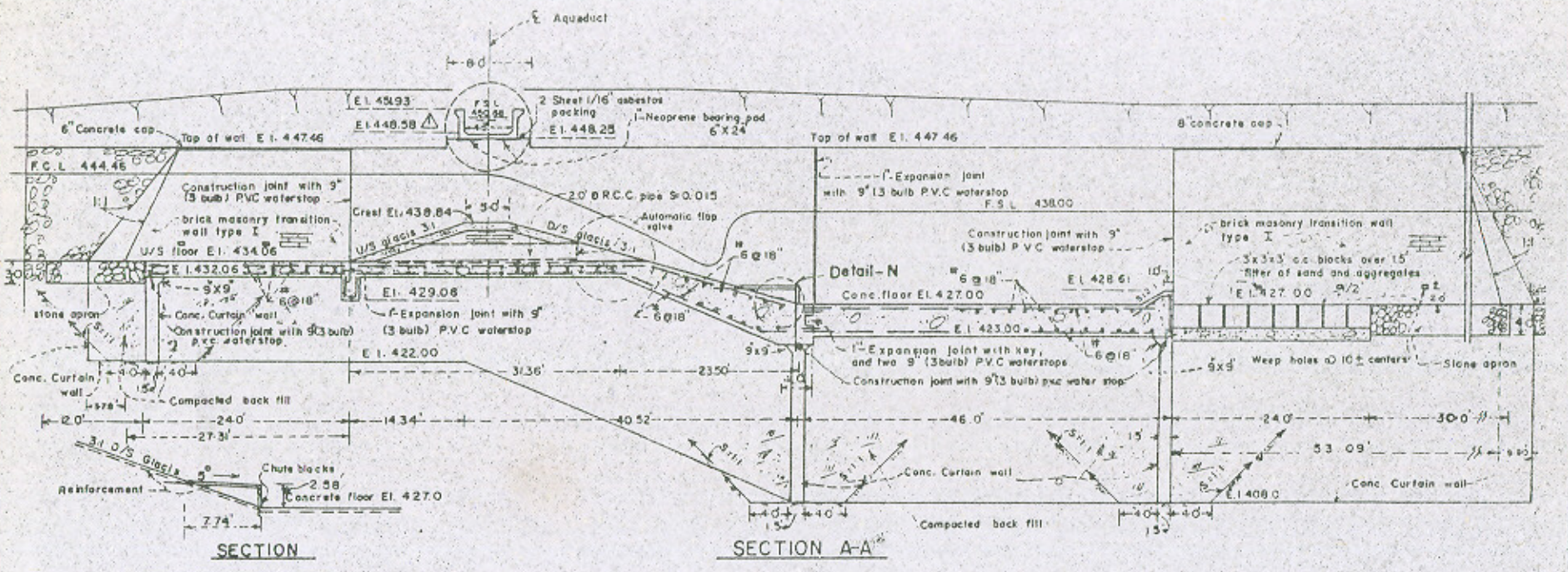


FIGURE - 9
(SHEET 2 OF 2)



OUTFALL STRUCTURE CUM
GHULAM WAH DISTY AQUEDUCT
R. D. 91+609
SECTION

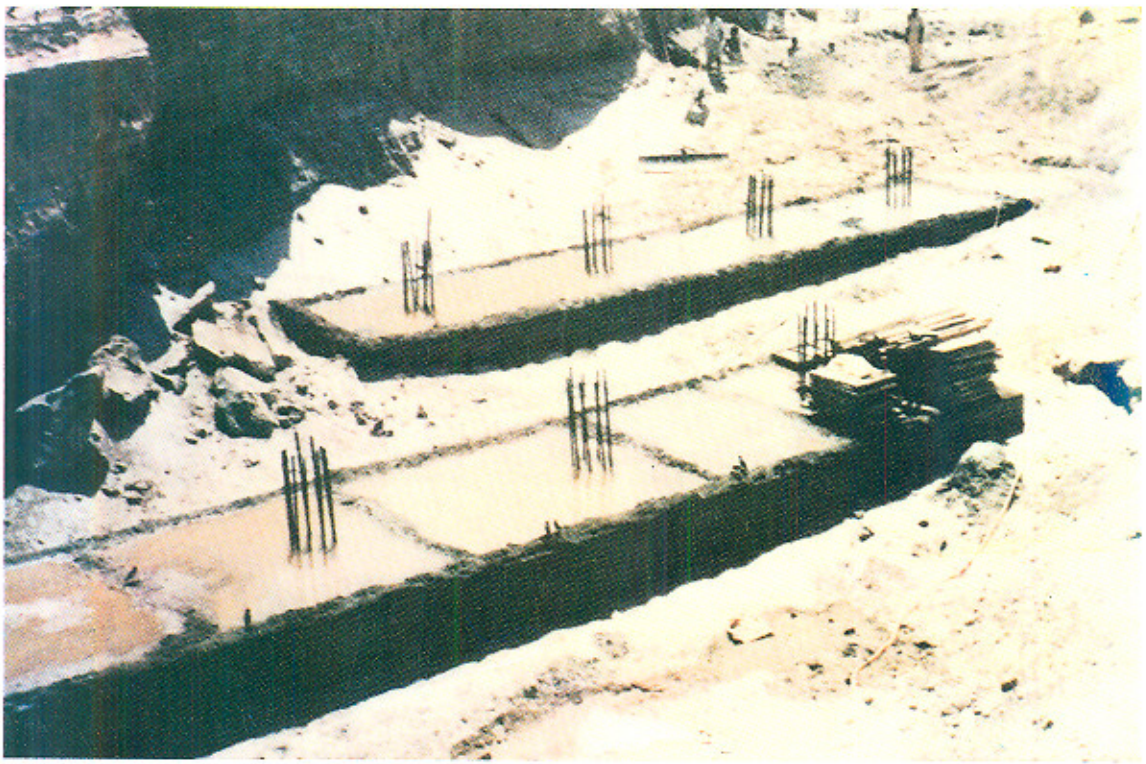
EARTHWORK EXCAVATION, UNCLASSIFIED, FOR THE 6-L DISTY AQUEDUCT AT R.D. 156+165, IN PROGRESS

EXCAVATION WORK IN PROGRESS IN R.D. 127+000 TO R.D. 128+000 - SNOC-03

(6' X 4') BARREL TYPE DRAINAGE INLET AT R.D. 10+014

COMPLETED SECTION OF SNOC INDICATING DOWEL REACH R.D. 18-19
(CONTRACT NO. SNOC-01)

ALLAHABAD DISTY AQUEDUCT CUM DISTRICT ROAD BRIDGE
R.D. (57+845) +
CONSTRUCTION OF R.C.C. COLUMNS FOR SUPPORTING THE AQUEDUCT



DISTRICT ROAD BRIDGE AT R.D. 144+310
COMMENCEMENT OF ERECTION OF STEEL REINFORCEMENT ABOVE THE BASE SLABS.

D.R. BRIDGE CUM ALLAHABAD DISTY AQUEDUCT AT R.D. 57+845
VIEW FROM AQUEDUCT SIDE (UPSTREAM SIDE)

COMPLETED HAJI DISTY AQUEDUCT CUM BOX-GIRDER BRIDGE
AT R.D. 90+240