STUDY OF THE LOSSES IN AN IRRIGATION SYSTEM - A CASE STUDY

A DISSERTATION

submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
IRRIGATION WATER MANAGEMENT

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By
C. L. JATAV

WATER RESOURCES DEVELOPMENT TRAINING CENTRE
INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE
ROORKEE - 247 667 (INDIA)

JANUARY, 2002

CANDIDATE'S DECLARATION

I hereby declare that work which is presented in this dissertation entitled **"STUDY OF LOSSES IN AN IRRIGATION SYSTEM - A CASE STUDY"** in partial fulfillment of the requirement for the award of the degree of **Master of Technology In Irrigation Water Management,** submitted in Water Resources Development Training Centre, I.I.T, Roorkee, Roorkee is a record of my own work carryout during the period from July 16th, 2001 to 28th January 2002, under supervision of **Prof. R. P. Singh, Emeritus Fallow, Dr. Deepak Khare Associate Professor,** WRDTC, I.I.T., Roorkee, and **Er. D. C. Sharma, Superintending Engineer,** I.R.I Roorkee (India).

The matter embodied in this dissertation has not been submitted by me for the award of my other degree.

(C. L. JATAV)
Trainee Officer

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

(Dr. Deepak Khare)
Associate Professor
WRDTC, I.I.T. Roorkee
Roorkee -247667 India

(Er. D. C. Sharma)
Superintending Engineer
Irrigation Research Institute
Roorkee -247667 India

(Prof. R. P. Singh)
Emeritus Fellow
WRDTC, I.I.T. Roorkee
Roorkee -247667 India

ACKNOWLEDGEMENT

I would like to express my deep gratitude and my sincere thanks to **Prof. Raj Pal Singh**, **Emeritus Fallow,** Water Resources Development Training Centre, I.I.T. Roorkee, **Dr. Deepak Khare, Associate Professor,** Water Resources Development Training Centre, I.I.T. Roorkee, and **Er. D. C. Sharma, S.E**, I.R.I. Roorkee, Roorkee for their valuable guidance, inspiration and encouragement during the preparation of this dissertation work.

In particular, also would like to extend my sincere thanks to **Prof. Deva Dutta Das,** H.O.D. of Water Resources Development Training Centre, I.I.T. Roorkee, for extending various facilities for this work.

I extend my thanks to **Dr. S.K.Tripathi Professor, Er. V. K. Bairathi Visiting Professor, Dr. B. N. Asthana Professor, Dr. G. C. Mishra Professor,** W.R.D.T.C., I.I.T Roorkee and **Er. Satendra Kumar R.O. and Sh. S. S. Chhabra A.R.O.,** I.R.I. Roorkee, for their kind cooperation in making the data available.

Also my thank to all faculty member of WRDTC, I.I.T., Roorkee, and all colleagues for their help and inspiration during the study at WRDTC, I.I.T., Roorkee.

I am extremely grateful to the **Water Resources Department, Government of Madhya Pradesh** for providing me the opportunity to participate in the course.

Finally, I acknowledge the inspiration and cooperation, which I have always received from my parents and all family members.

Place: Roorkee
Date: January 28th, 2002

(C. L. JATAV)
Trainee Officer

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ABBREVIATIONS

B.C.	Black cotton soil
Br	Branch canal
C	Constant
Cumecs	Cubic metre per second
Cusecs	Cubic feet per second
CCA	Culturable Command Area
C_s	Cubic feet per second
Cumecs/M.sq.m.	Cubic meter per second per million square meter
Cusec/M.sq.ft.	Cubic feet per second per million square feet
CWC	Central Water Commission
Cum	Cubic meter
Cm	Centimeter(s)
C.P.S.	Counter per second
CWPRS	Central Water and Power Research Station (Pune)
Ch.	Chainage
CL	Central Line
d	Effective size of particle in mm
Dy.	Distributary
etc.	Extra
Fig.	Figure
FSL	Full Supply Level
ft	Foot, feet
GCA	Gross Command Area
G.O.I.	Government of India
ha.	Hectares
INCHR	Indian National Committee on Hydraulic Research (Pune)
IRI	Irrigation Research Institute (Roorkee)
Km.	Kilometer
K	Coefficient of permeability in feet/minute

L	Length
LB	Left Bank
m	Meter
M.ha	Million hectares
m^3/sec	Cubic meter per second
mm/day	Milimeter per day
M.P.	Madhya Pradesh
Mr.	Minor
N	Void ratio
P	Loss due to seepage
P.E.	Potential evapotranspiration
%	Percentage
Q	Discharge
R.B.	Right Bank
RD	Reduced distance
S	Seepage loss
sq.ft	Square feet
U.G.S	Upper Ganga Canal
U.S.A.	United States of America
USSR	Union of Soviet Social Republic
US	United States
UP	Uttar Pradesh
V	Velocity of flow
Vo	Coefficient of viscosity
Vt	Coefficient of viscosity at temperature t
Vf	Filtration velocity
WRDTC	Water Resources Development Training Centre
WAPCS	Water and Power Consultancy Services (India) Ltd.
W/c	Water courses
WS	Water Surface

SYNOPSIS

The seepage losses in irrigation system (head to outlets), specially with large conveyance system in alluvial plain in India, are quite substantial, nearly 1/3rd of Head discharge. The seepage losses depends upon many factors which vary from system to system.

Earlier the irrigation system is considered from head to outlet. But as per Govt. of India, command area development program, the concept of irrigation system is now extended up to water course and field channels. Therefore now watercourses are the ultimate links of conveyance network of irrigation system. The losses on watercourse constitute a major portion of the transit losses, during conveyance of irrigation water from source of farmers field. Hence for getting optimum utilization of valuable water the saving of these losses are essential.

The conveyance losses also vary from one element to another in the same system i.e. main canal, Branch canal distributory channel and minor channels. Besides these, substantial losses are also observed below outlet in watercourse and field channel and application of water in fields. They also constitute nearly 1/3rd of supply at the head.

The present study would involve the critical review of actual distribution of these losses in different reaches of network i.e. conveyance, distribution and then delivery to field water application in different crops, so that realistic estimation be made of the total losses and suitable reaches in the system be identified for saving the losses, to conserve the valuable resource at economical cost.

As a case study, the irrigable command of Upper Ganga Canal is proposed to be use to carry out the critical review of losses observed and estimated from time to time.

C. L. JATAV
Trainee Officer
IWM 21st Batch

INTRODUCTION

1.1 IRRIGATION SYSTEM

An irrigation system generally consist entire system, starting from development of source of water to the application of water in the field. The irrigation system can be divided in following two categories mainly on the basis of nature of irrigation structure to feed the water supply into the system.

1. Diversion irrigation system
2. Storage irrigation system.

In diversion irrigation system the irrigation water is obtained directly from river without creating any storage of water. In this system a weir or a barrage is constructed across a river to raise the water level in the river and facilitate its diversion to irrigation canals

In storage irrigation system, a device is constructed across the river, and water is stored behind it and a canal carries irrigation water.

On the basis of flow of canal, the irrigation system can be further divided into perennial irrigation system and non-perennial irrigation system. Both the above types of works can have a perennial or a non-perennial canal.

The above system can be of different magnitude from small to very large in size, therefore, their canal system depends on their magnitude. The system or scheme can be from 40 hectares to million of hectares.

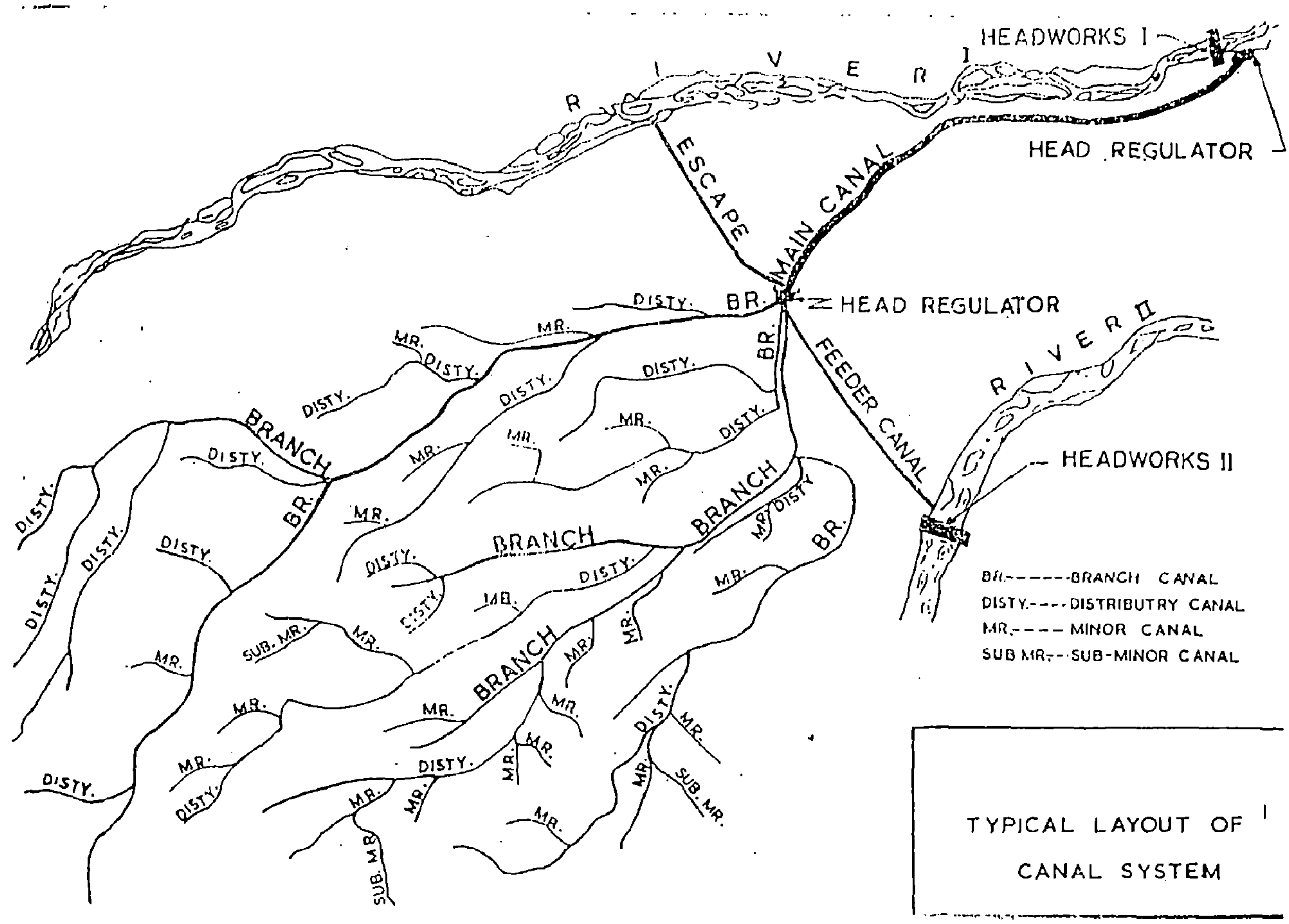

Fig. 1.1 : Typical layout of canal system

Canal System:

The entire network of irrigation channels in called a canal system. The canal system consists of the main canal, branch canal, distributaries, minors / subminors, water courses, field channels and farm channels. The typical layout of a canal system is shown in fig. 1.1.

Main Canal:

In case of a weir or a barrage is constructed across the river and the water is diverted into the main canal by means of a diversion weir, a head regulator is provided at the head of main canal, so as to regulate the flow of water into the main canal. Normally no direct outlets are provided for irrigation from main canal.

Branch Canal Branch:

Branch canal takes of from a main canal and having head discharge of not less than 30 cumecs. In general, branch canals also do not carryout any direct irrigation. Branch canals are usually feeder channels for major and minor distributaries.

Distributaries:

Distributary or Rajbaha is a channel which takes off from a main canal or branch canal and from which water is supplied to cultivators for irrigation purpose through outlets into minors, sub-minors or water courses, are called distributaries. They are aligned either as water shed channels or as side slope channels. A major distributaries under 30 cumecs and above 2.50 cumecs.

Minors:

Minors is a small irrigating channel usually discharge in one cumecs or less discharge and may take off from main canal, branch canal, or distributaries, so as to supply water to the cultivators at the point nearer to their fields.

Sub-Minors:

A channel taking-off from a minor which delivers water to more than one water course.

Water Courses:

These are small channels which carries water from an outlet of a distributaries or minors to the holding of a afarmer in known as a watersourse, it is generally an earthen channel and is located between the boundries of holdings in ordrer to avoid their bifurcation. its capicity is seldom less then 30 liters/sec.

Field Channels:

A channel taking-off from the outlet and leading to the farm gate.

Farm Channel:

A channel to carry water from the farm gate to the field.

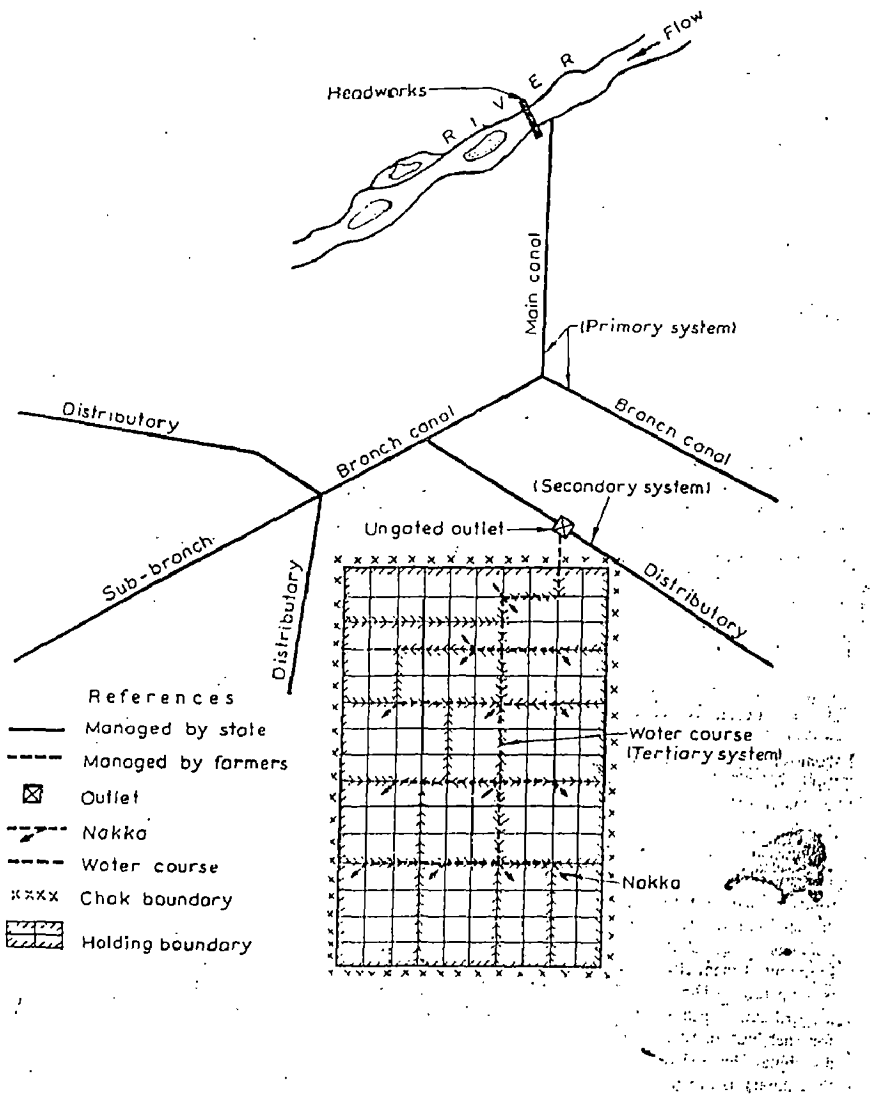

Fig. 1.2 : Distribution System

Upper Ganga Canal System:

The Upper Ganga Canal System (Fig. 1.3) is a prestigious large irrigation system in India. The canal take-off from the river Ganga at Haridwar, to carry a discharge of 297 cumecs from the head. The actual irrigated area is 0.925 million hacters as against the CCA on outlets of 1.086 million ha. The gross command area of Upper Ganga Canal System in 1.95 million ha. The canal network spread over the district Meerut, Ghaziabad, Bulandshahar, Aligarh, and parts of districts of Saharanpur, Muzaffarnagar, Mathura, Agra, Etah and Mainpuri of Uttar Pradesh and Hardwar District of Uttarnachal.

The Upper Ganga Canal system is fed through the headwork complex with the head regulator at Mayapur and the diversion weir at Bhimgoda across the river ganga. The project was initiated to examine the feasibility in 1837-38 and put to use in 1854. The main canal is 291.91 km long up to Kanpur stump to the lower ganga canal system. The important branches of the system are Deoband branch (about 80 km long, with head discharge of 24.794 cumecs) taking-off on right bank at km. 35.0, Anup Shahr branch(about 206 km long, with head discharge of 46.755 cumecs) taking-off on left bank at km 80, Mat Branch (about 128 km long, with head discharge of 55.256 cumecs) taking-off on right bank at km. 176, the Hathras Branch (about 74 km long) taking off from Mat Branch on left bank at km. 80. The entire system is unlined except parallel canal upto Roorkee and has a network of about 115 major distributories with 3315 km length. The surface water diversion made through the head regulators in the main / branch canals are later controlled at the distributory head in order to regulate the flow for irrigation in distributory command area. The salient features of U.G.C. are shown in Table 1.3.

The canal system is connected with natural drains / rivers by escapes where surplus water of canal, if any, is discharged. The cost of construction in the 32 km of canal was nearly 30% of the cost of entire canal system of 1412 km at that time. (Source: Report on U.G.C and its modernization, 1838 -1988, December 1988).

The U.G.C. was aimed to cover as much area under its command as well as technically and economically feasible. The protective irrigation was provided to cover nearly 35% of gross command area during the rabi season. The details of distribution network of the above system is given in Table 1.1.
(Source: Report NIH, TN2-1981-82).

Although being the first major canal system in the world with no precedents any where regarding the magnitude of the works and scope of the system, yet this project was considered unique due to the following main reasons.

1. The project remained under scrutiny and technical examination for almost 10 years from 1838 to 1848, all the related documents were thoroughly seen and all the aspects were carefully examined.
2. The major aspect of salubrity in the large command was specially examined by a special committee of engineers and a doctor.

3. This committee recommended the following safe guard and limitations in the projection of the canal system and these are as follows.

> *"1st, That the ganges canal be kept as much as possible within soil; i.e., that its ordinary surface-level should be below that of the country.*
>
> *"2nd, That earth wanted to complete embankments be never obtained from excavations made outside the canal, except in such localities as will readily admit of drainage.*
>
> *"3rd, That the canal and its branches be taken as much as possible along the water-shed line of the country, so as not to interfere with drainage; and in all cases where such interference may be unavoidable, that the executive officers be instructed to provide otherwise for the drainage.*
>
> *"4th, That masonry drains be constructed under all main watercourses or bridge ramps, whenever these cross the drainage of the country.*
>
> *"5th, That no private watercourses from the canal be allowed, but that irrigation be practiced exclusively from main water courses.*
>
> *"6th, That irrigation be prohibited within five miles of a military station, and within one or two miles of large native towns.*
>
> *"7th, That in clearing embankments, the grass, weeds, & c., be not suffered to rot on the ground, but that they be burned as soon as possible after they are cut.*
>
> *"8th, That irrigation be altogether prohibited in localities which appear naturally to possess a malarious character.*

(Source: Italian irrigation by R. Baird Smith, F.G.S, Vol. II-1855)

After receiving and examining the report of the committee and visiting the off take point of canal at Haridwar and major crossing across Solani river by an aquduct near Roorkee Lord Hardinge GOVERNOR GENERAL OF INDIA approved the vigorous prosecute of this project in March 1847.

The restrictions imposed by the committee called for a very careful alignment of the canal network and also the layout of major works, with these special care taken the seepage losses on this system were observed of lesser degree then other similar canal systems subsequently projected in India and else where. However after establishment of hydel power stations by utilizing the various falls, some of the reaches on main canal have been converted to embankment reaches, with substantial losses.

The canal system was initially projected for 6750 cusecs (189 cumecs) but its head discharge was increased to 8500 cusmecs (240.50 cumecs) in 1938 and again to 10500 cusecs (297 cumecs) in 1951-52 without carrying over any significant remodeling or change in canal cross section. This alongwith the change in hydraulics of flow in main canal due is power stations have caused much widening of canal section with serious erosion of banks, resulting into substantial increase in the losses, over its use for a long period.

The U.G.C started irrigation during the year 1855-56. The distribution of water on ganga canal started with simple measure irrigate 220 acres from 1 cusec for wheat with four watering of 12.50 inches adding 20% for absorption and evaporation making a water depth of 15 inches, with high duty and limited irrigation intensity (35%) providing thin spread of water over large areas.

Main canal was a continuous running canal but its off takes were alternative running channel according to predetermined and pre-decided roster. For better distribution and management of water within an outlet command, practice of warabandi or osrabandi was introduced in this canal system as back as 1880. In order to run this system, the Northern Indian canal and drainage act of 1873 was introduced for the intensive irrigated agriculture developing in the command of U.G.C.

The main crops in the command area the sugarcane, paddy an wheat which contribute to more than 75 percent of the irrigation revenue. Other crops such as maize, bajra, mustered, pulses, gram, groundnut, potato, vegetables fodder crops etc. are also grown in the command under irrigated and unimagined condition. The command area being in alluvial plains.

The existing system conveys water to distributaries canal heads through the main canal and three major branches, which have the following characteristics as shown in Table No. 1.1.

Table 1.1
Details of Conveyance Channels of U.G.C. System

Major conveyance channel	No. of Distributary	CCA on outlets (M.ha)
Main canal	46	0.47
Anupshahr Branch	31	0.141
Deoband Branch	23	0.1942
Mat & Hathras Branch	15	0.1998
Total	**115**	**0.925**

An index plan of U.G.C. system has been given in Fig. 1.3. The U.G.C. system has length of 6540 km of irrigating channels of varying sizes and 4400 km of drains and escape channels.

In addition to irrigation other existing non-irrigation requirement have been fulfilled through Upper Ganga Canal. These are briefly given below:

1. The supply of 5.67 m^3/sec drinking water for Delhi administration from km. 160.90 of U.G.C. (against Ramganga project)
2. Drinking water supply for Meerut city from near Bhola Power House.
3. The supply of 2.834 m^3/sec water for cooling purposes in Kasimpur thermal power station.
4. The supply of 5.67 m^3 /sec to be delivered at km 160.90 of UGC for Delhi water supply against Tehri Dam Project.
5. Supply of 1.415 m^3/sec (50 cusecs) of water from upper Ganga canal system to Noida and Gaziabad Domestic water supply.
6. There is a proposal under serious consideration for allowing 5.67 m^3/sec of additional water supply to Delhi administration from upper Ganga canal after generating same quantity of water resource by saving in losses. The above details do reveal that a old canal system (U.G.C) primarily constrict for irrigation in large agricultural tract has been gradually converted to a carrier of substantial quantity of drinking water supply for capital town (New Delhi) of country. This calls for the constant running of the main canal (U.G.C) with least or no interruption by normal closures for inspections and maintenance. Thus the main canal should be free of normal deficiencies and capable to carry it authorized discharge constantly with their dependability.

The important events in the History of U.G.C are presented in Table 1.2, whereas salient feature U.G.C are given in Table 1.3.

Table 1.2

IMPORTANT EVENTS IN THE HISTORY OF GANGA CANAL

1.	Date of commission the Project	8th April, 1854
2.	Date of start if irrigation	1 may, 1855
3.	Establishment of Govt. workshop at Roorkee	1845
4.	Establishment of Thomson College of Civil Engineering at Roorkee	Ist Jan, 1848
5.	First major remodeling of the canal (to improve initial deficiencies)	1868
6.	Construction of Lower Ganges Canal	1874-1878
7.	Start of Osrabandi on the system	1880
8.	Heavy damage to head-works at Hardwar (Gohna Floods)	1894
9.	Construction of first Hydel power station on the system, as well as in the state	1912-1915
10.	Settlement with British Government for leaving free-gaps in Bhimagoda Weir and Mayapur Dam for passing on uninterrupted flow of Ganga to the Ghats	1917
11.	Addition of permanent Head-Works (Bhimgoda Weir)	1917-1922
12.	Major damages to the Head-Works and other important structures on the canal (Damages at Dhanauri Works)	1924
13.	Addition of subsequent Hydel Power Stations	1930-1955
14.	Increase in the head discharge of the canal (6750 $C_{S.}$ to 8500 $C_{S.}$)	1938
15.	Further increase in head-discharge (8500 Cusecs to 10500 Cusecs)	1951-1952
16.	Centenary celebrations of Upper Ganga Canal	1954-1955
17.	Silting in the head reach of canal requiring desilting operations on account of Alakananda Calamity	1970
18.	Addition of New Head-Works (Bhimgoda Barrage)	1978-1984
19.	Addition of sill ejecting drain (silt ejecter km 22)	1975-1977
20.	Strengthning pathri superpassage (major remodelling km 16)	1986-1988
21.	Start of parallel canal upto down stream of solani aqueduct	Nov. 2001

Table 1.3

SALIENT FEATURES OF UPPER GANGA CANAL

1	Formulation of the Project and Preliminary arrangement	1838-1842
2.	Detailed Examination of the project report	1842-1845
3.	Scrutinizing and examination of the project	1845 -48
4.	Main construction period	1848-54
5.	Initial Gross Command Area	0.607 M.ha.(15 Lac Acre)
6.	Present culturable command area	0.925 M.ha. (25 Lac Acre)
7.	Initially head discharge	189 cumecs (6750 cusec)
8.	Present head discharge	297 cumecs (10500cusec)
9.	Initial capital investment	Rs. 140 lacs
10.	Initial length of the canal and branches in the system	1400 km (878 miles)
11.	Total length of channels in present system	6540 kms
12.	Design concept of channels	Protective rabi irrigation designed on 3-4 core weeks with av. Duty of nearly 200 acre/cusec
13.	Design concept for major works	Massive structures with simple and bold designs mainlywith brick arches in lime-surkhi mortar
14.	Important major structures	Ranipur super passage, Pathri Power Hgouse, Pathri super passage, Dhanuri level crossing, Solani Aqueduct.
15.	Other important features	First major and large canal system of country as wells as a remarkable major irrigation system in whole of the world in mid of nineteenth century

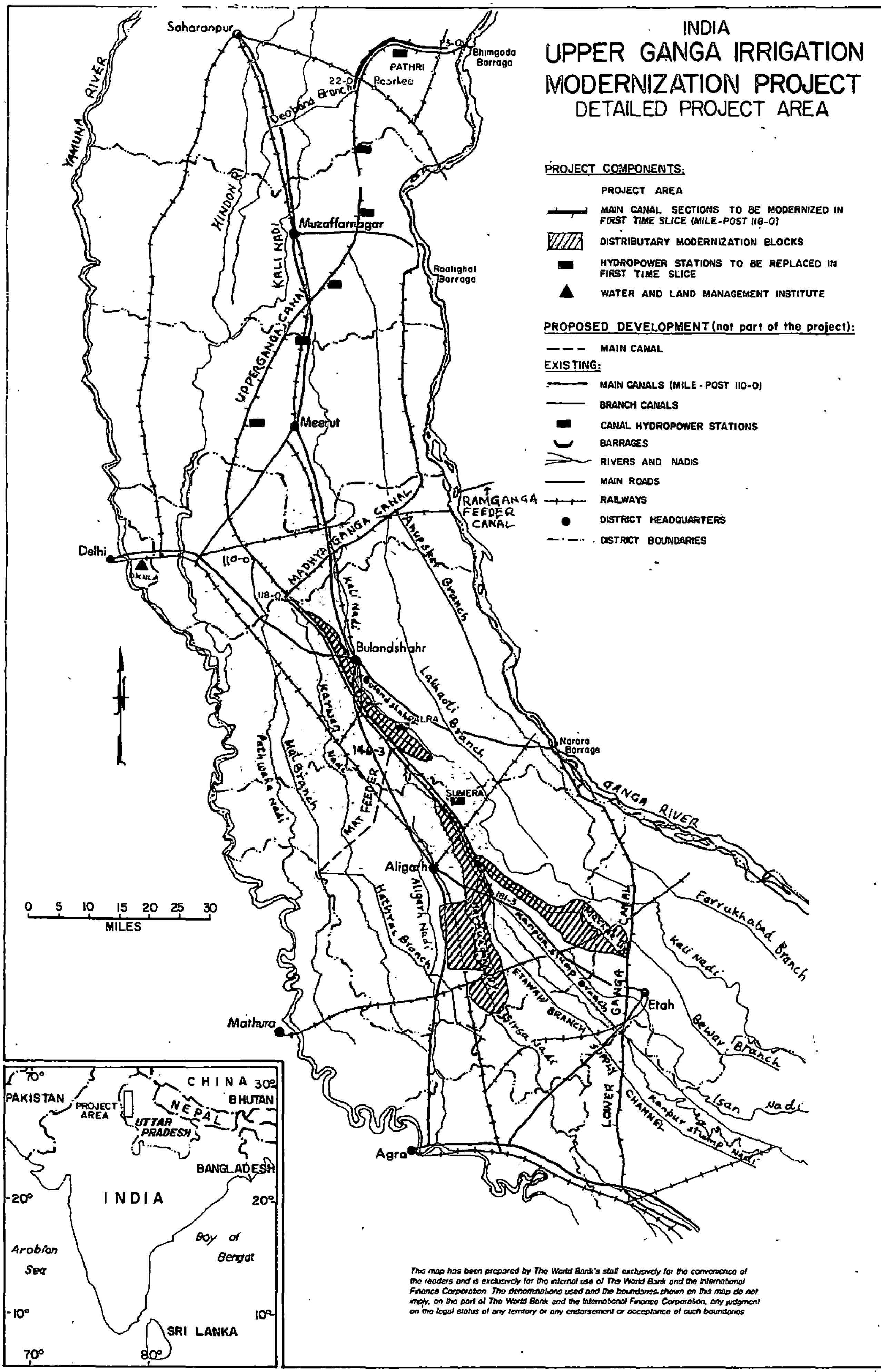
INDIA
UPPER GANGA IRRIGATION
MODERNIZATION PROJECT
DETAILED PROJECT AREA
PROJECT COMPONENTS:
PROJECT AREA
MAIN CANAL SECTIONS TO BE MODERNIZED IN FIRST TIME SLICE (MILE-POST 118-0)
DISTRIBUTARY MODERNIZATION BLOCKS
HYDROPOWER STATIONS TO BE REPLACED IN FIRST TIME SLICE
WATER AND LAND MANAGEMENT INSTITUTE
PROPOSED DEVELOPMENT (not part of the project):
MAIN CANAL
EXISTING:
MAIN CANALS (MILE-POST 110-0)
BRANCH CANALS
CANAL HYDROPOWER STATIONS
BARRAGES
RIVERS AND NADIS
MAIN ROADS
RAILWAYS
DISTRICT HEADQUARTERS
DISTRICT BOUNDARIES
Saharanpur
Bhimgoda Barrage
PATHRI
Roorkee
Deoband Branch
YAMUNA RIVER
HINDON R.
KALI NADI
Muzaffarnagar
Raolighat Barrage
UPPER GANGA CANAL
Meerut
RAMGANGA FEEDER CANAL
MADHYA GANGA CANAL
Anupshahr Branch
Delhi
OKHLA
Kali Nadi
Bulandshahr
Lakhaoti Branch
Narora Barrage
GANGA RIVER
SUMERA
Mat Branch
MAT FEEDER
Aligarh
Aligarh Nadi
Hathras Branch
Farrukhabad Branch
Kali Nadi
Kanpur Branch
ETAWAH BRANCH
Etah
Bewar Branch
Isan Nadi
LOWER GANGA CANAL
Mathura
Agra
Kanpur Branch
0 5 10 15 20 25 30
MILES
70°
PAKISTAN
PROJECT AREA
CHINA
NEPAL
BHUTAN
UTTAR PRADESH
BANGLADESH
INDIA
20°
Arabian Sea
Bay of Bengal
10°
SRI LANKA
80°
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Fig. 1.3

TYPE OF LOSSES IN IRRIGAITON SYSTEM

2.1 EVAPORATION LOSSES:

Evaporation is the process in which a water changes to the vapour state at the free surface, below the boiling point through the transfer of heat energy. The molecules of water are in constant motion with a wide range of instantaneous velocities. The net escape of water molecules from the liquid state to the gaseous state constitutes evaporation.

The rate of evaporation depends upon the vapour pressure on the body of water and that of the air. This vapour pressure depends on temperatures of the water, air, wind and atmospheric pressure, quality of water and the nature and shape of the water surface.

Evaporation rate is India is more during summer seasons, when temperature is rise and wind velocity increases during the month of April and May, when winds are slight and temperatures low, evaporation is low.

Evapo-transpiration is controlled by different factors, namely, the availability of moisture at the earth's surface, and the ability of the atmosphere to supply energy to vaporise the water in vapour form. The loss of water in the form of evaporation and transpiration form an extensive cover of vegetation will depend on the atmospheric conditions. This loss is called potential evapo-transpiration (PE).

The annual PE ranges between 140 to 180 cm. Over most parts of the country and is highest over the extreme west Rajasthan in the Jaislmer area. Part of Mysore, Andhrapradesh and Tamil Nadu show high values, exceeding 180 cm. PE less then east of Uttar Pradesh and Assam.

The evaporation losses in U. G. C. system have been estimated to be less than one percent of head discharge of main canal.

Source: Irrigation Commission Report 1972.

2.1.1 Factors Affecting the Evaporation Losses

Temperature: When temperature is raised the vapour pressure of a body of water increases because of kinetic energy of after molecules is raised with increasing temperature. As evaporation is proportional to the vapour pressure difference between the water and the air. Thus for the same mean temperature it is possible to have evaporation to different degrees.

Wind: The rate of evaporation increases with the wind speed up to a critical speed, beyond which any further increase in the wind speed has no influence on the evaporation rate. This critical wind speep value is function of the size of the water surface.

Atmospheric pressure: The atmospheric pressure is decreases with respect to increased altitude. Therefore the rate of evaporation in more in high altitudes.

Soluble solids: When soluble salts is desolved in water, the vapour pressure of the solution is less than that of pure water and hence causes reduction in the rate and evaporation. The rate of evaporation is proportional to the difference in vapour pressure between the water and atmosphere. Hence the rate of evaporation is reduced when soluble salts are there.

Nature and shape of water bodies: Deep water bodies have more heat storage then shallow. Therefore during summer the evaporation losses are less in deep water bodies than the shallow water bodies.

Vapour pressure: The rate of evaporation is proportional to the difference between the saturation vapour pressure at the water temperature e_w and the actual vapour pressure in the air e_a. Thus

$$E_L = C\,(e_w - e_a)$$

Where E_L = rate of evaporation (mm / day)

C = a constant

e_w = Vapour pressure at the water temperature in mm of mercury

e_a = Actual vapour pressure in the air in mm mercury evaporation is continued fill $e_w = e_a$.

The evaporation losses include all the evaporation losses from surface of flowing water in canal and distribution network. Evaporation losses generally of the order of 2 to 3% of total losses in summer season.

On the Upper Ganga Canal system evaporation losses have been estimated at less than one percent.

Source: ICID Annual Bulletin 1962.

2.2 TRANSPIRATION LOSSES:

The water is taken up by the plant root system and escapes through leaves. The important factors affecting transpiration are: Atmospheric vapour pressure, temperature, wind, light intensity and characteristics of the plants, and leaf system. The rate of transpiration also depends upon the growth period of vegetation along the water surface of canal banks and berms.

The transpiration losses in canal can be minimize in the following ways:

(1) by removal of vegetation regularly

(2) by burning of weed when channel is dry,

(3) by increasing the velocity of flow in the channel

(4) by adopting rush rotation method. In this method the channel is run with full supply discharge for the received period and stopped the channel for considerable period.

2.3 SEEPAGE LOSSES:

Seepage losses constitute the seepage as well as percolation losses from the canal cross-section and vary from system to system and also on different network of the system. They also depends upon design, alignment maintenance of the canal system, type of soil, ground water table and many other factors related to the canal system.

The commonly accepted seepage losses is the alluvial plains of northern India are 17 percent for main canal and branch canals, 8 percent for distributaries, and 20 percent for water courses. The total losses comes to 45 percent of the head discharge of canal.

2.4 WATER APPLICATION LOSSES:

Water losses on irrigation land is called water application losses. These losses are due to slippage by over topping by accidental or deliberate. The water application losses are due to uneven levels of farms which is to be irrigated in respect of full supply level of water course, excess supply of water. Unreliable water supply in canals also the causes of excess irrigation. The farmers used farm inlets an enter length of channel but its proper closing in not ensure after using. The ineffective method of irrigation is also the one of the reason.

These are the following reason behind water application losses.

1. Unawareness of farmers
2. Undulating fields
3. On reliable water supply in canals
4. Un-effective method of irrigation
5. Due to saline and degraded soil.

The field application losses have been estimated at 30 percent of the supply reaches to the field, or 17 percent of the head discharge of the canal.

Source: Controlling Seepage Losses from Irrigation Canals, ICID 1967.

The water application losses occurs deep percolation losses, increase the saline water logging, ground water pollution due to fertilizer washing, raise in ground water table, distraction of natural vegetation due to salnization processes. The improved method of irrigation would centrally control the water application losses.

2.5 UNIT OF SEEPAGE LOSSES AND METHOD OF EXPRESSION:

The seepage losses is generally expressed in the following different ways:

(1) As cumecs / million square metres of wetted perimeter. (cumecs / Million Sq. M)

(2) As a depth of water lost in 24 hours over the area of wetted perimeter (feet/day or meters /day)

(3) As a percentage of the head discharge of the canal.

(4) As a percentage per km. length of the canal.

(5) As a cubic meters / sq.m / day of seepage through the wetted perimeter.

(Source: Frederick L. et al. C)

FACTORS AFFECTING THE CANAL SEEPAGE

3.1 FACTORS AFFECTING THE CANAL SEEPAGE

The seepage of water from irrigation canals is a complex process and it depends on following factors:

(1) Soil characteristics of the canal bed and slopes

(2) Position of ground water table in relation to canal

(3) Position of impermeable layer in relation to canal

(4) Drainage levels of nearby drain and its location

(5) Temperature of water and soil

(6) Entrained air in the soil

(7) Soil moisture tension

(8) Ground slope at right angle to canal

(9) Velocity of flow of under ground water

(10) Other geological factors

(11) Depth of water in the canal

(12) Velocity of flow in the canal

(13) Age of the canal

(14) Amount of sediment and its grade

(15) Salt concentration in the canal water and soil

(16) Surrounding vegetation of canal

(17) Wetted area or shape of the canal

(18) Frequency of canal uses.

3.1.1 Soil characteristics of Canal Bed and Slopes:

The amount of seepage losses depends on the texture of soil and extent of absorbing medium. It also depends on porosity of soil through which canal runs and on the nature of material of which the canal banks are formed.

3.1.2 Position of Ground Water Table in Relation to Canal

The seepage rate decreases as the ground water table approaches the surface of the ground. The lowering of ground water table would result in increase in seepage rate. Depending upon the permeability of the soil and the position of water table the seepage from a unlined canal may occur in the two ways. (a) Percolation (b) Adsorption

(a) Percolation:

When the water table is close to the ground surface a direct flow from the channel to the ground water reservoir is set up and hence there is a zone of continuous saturation from the channel to the water table as shown in Figure 3.1 below. In this case almost all the water lost from the cannel joints the ground water reservoir. The seepage loss will depend on the total seepage head H. i.e. the different between the water surface level in the channel and the water table, and will independent of the water depth in the channel.

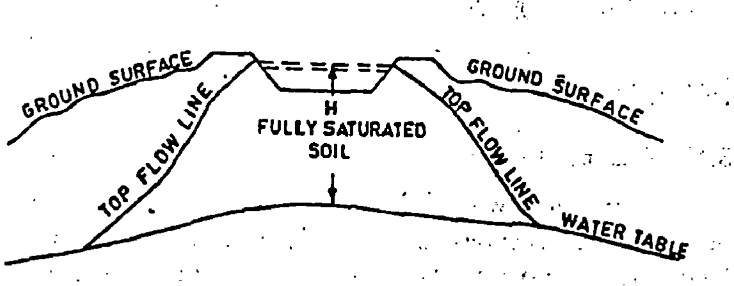

Fig. 3.1 : Percolation from an Earthen Channel

(b) Absorption:

In 'absorption' there is a small zone of complete saturation round the canal section surrounded by zones of decreasing saturation ratio (i.e. percentage of void space occupied by water). Above the water table, there will be a zone of soil saturated by capillary action and on top of that, soil of decreasing moisture content again. Between the soil saturated by the canal water at top and the soil saturated by ground water at the base, there is a layer of unsaturated soil which has decreasing moisture content from the two ends towards the centre. The water lost from the canal by seepage is initially utilized in filling up the pores of the soil around it and after that it trickles through the saturated layer to the water table below, the quantity of seepage being too small to saturate the intermediate zone. Obviously, this condition is more likely to occur where there is a zone of lower permeability near the canal bed and a zone of higher permeability from canal bed downwards. Some of the water is also lost by the evaporation and transpiration of the seepage water re-emerging at the surface by capillary action. The water trickling down through the unsaturated zone forms what is known as a 'water mound' under the canal. The mound stabilizes when the increased gradients result in a balance between outflow and inflow.

In this case the rate of loss will be independent of 'seepage head' (or the difference in water surface level of the canal and the level of the ground water table) but will be dependent on the water head, h_c from the water surface in the canal to the bottom of the saturated zone plus the capillary head he for the soil at the boundary of the saturated zone as shown in Figure 3.2.

Source: Bharat Singh1997.

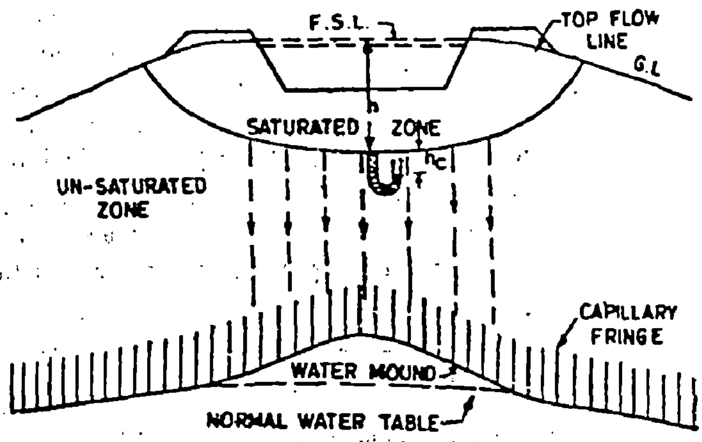

Fig. 3.2. Absorption from an earthen channel

Fig. 3.2 : Absorption from an Earthen Channel

In both cases the losses are large at first as the water is utilized in filling the pores of the soil and reduce afterwards as equilibrium is reached. An important factor working in the same direction is the deposition of fine silt carried by the water on the canal section which reduces the soil permeability.

3.1.3 Position of Impermeable Layer in Relation to Canal

If impervious layer is deep below the canal bed seepage will be more. Therefore seepage is inversely proportional to impervious layer below the canal bed.

3.1.4 Drainage Level of Nearby Drain and its Location:

The canal is running through a composite section will also influence the seepage rate. The canal may be constructed with zonal or composite section because of non-availability of imperious soil etc.

3.1.5 Temperature of Water and Soil:

At high temperature there are more loss due to seepage. Viscosity of the liquid increases as the temperature decreases, hence the seepage not should decreases when the temperature drops.

By Kori Torzoghi's formula

$$K = (8\, to\, 6)\frac{V_0}{V_t}\left[\frac{N-0.13}{3}\right]^2 d^2$$

Where K = coefficient of permissibility in ft/min.

N = void ratio

V_0 = coefficient of viscosity at 10^0C

V_t = coefficient of viscosity at t^0C

d = effective size of particles in mm

3.1.6 Entrapped Air in the Soil

The entrapped air in the soil is more, soil is porous resulting the seepage will be more.

3.1.7 Soil Moisture Tension

Soil moisture tension is defined as the force per unit area that must be exerted in order to extract water from the soil. Soil moisture tension is usually expressed in terms of atmospheres. The soil moisture tension for almost all the soils is in the range of 7 to 32 atmospheres.

3.1.8 Ground Slope at Right Angle to Canal

If ground slope at right angle to the canal is high the seepage losses are more because flow line touches the ground. There is no soil cover, therefore seepage loss is more.

3.1.9 Velocity of Flow of Under Ground Water

If flow of underground water is more, seepage is more. Therefore seepage directly proportional to the velocity of flow of under ground water.

3.1.10 Other Geological Factors

If canal is running from geologically fissures, faults and weak shear zone the seepage will be more.

3.1.11 Depth of Water in the Canal:

The seepage rate increases with the increase of depth of water in canal. This further depends on the relative permeability of sides and bottom of the canal in most of the cases it is observed that the seepage rate varies in a straight line relationship as per dyas

$$P = C\sqrt{d}$$

where P = Loss due to seepage in cusecs in a length L of canal

d = Depth of water in canal

C = Constant

Thus, according to dyas the seepage loss in proportional to the square root of depth of water in canal.

3.1.12 Velocity of Flow in the Canal:

The more the velocity, less will be the percentage of seepage loss. However as per tests conducted American society of civil engineering irrigation and drainage division. It is observed that velocity in a canal has no direct effect on seepage.

3.1.13 Age of the Canal

The losses due to seepage decrease with the age of canal. The silt of water gets filled up in the soil pores as time passes. Thus the rate of flow decreases with time as the same head is used to overcome the continuously increasing frictional resistance because of infiltration of silt in the soil pores. The Table 3.1 shows the seepage losses in different type of soils.

Table 3.1 : Seepage Loss Characteristics of Different Soil

S.No.	Nature of soil	Average loss in cumecs/million sq.m
1.	Imperious clay loam	0.92 to 1.20
2.	Medium clay loam with a hard pan layer at 2 to 3 ft depth	1.2 to 1.80
3.	Ordinary clay loam silt, soil, or lavash loam	1.8 to 2.7
4.	Gravelly or sandy clay loam cemented gravel sand and clay	2.70 to 3.60
5.	Sandy loam	3.60 to 5.20
6.	Loose sandy soil	5.20 to 6.10
7.	Gravely sandy soil	7.00 to 8.80
8.	Porous gravelly soil	8.00 to 10.70
9.	Very gravelly soil	10.70 to 21.30

Source : 1. Central Water Commission
2. Bharat Singh, 1997.

3.1.14 Amount of Sediment and its Grade

The purer the water more the losses due to seepage. The silt particles carried by water get silted where velocity is low or came in contact with the rough surface of the canal and get into the soil pores. This reduces the pore spaces and hence seepage rate reduces.

3.1.15 Salt Concentration in the Canal Water and Soil

Suspended silt and dissolved salts conveyed by the water will settle and seal the wetted perimeter, in some cases small soil particles in layers around the bed will move and creating a water proof layer in the ground some time silt. Clay and fine sand particles carried by the water will also soak in to the soil surrounding the bed, so that scaling will occur not only along eh surface of the perimeter but in the deeper soil layer as well . All these conditions are under favourable for reducing the seepage losses if salt concentration in the canal water & soil.

3.1.16 Surrounding Vegetation of Canal

Seepage in canal depends upon the characteristics of plants if plants having deep roots and more leaf system if will increasing the seepage.

3.1.17 Wetted Area or Shape of the Canal

The seepage rate is proportional to the wetted surface. As the wetted surface of canal increases the seepage rate also increases. It is one of the reason that the canal is designed for least wetted perimeter.

3.1.18 Frequency of Canal Uses

If, the frequency of canal uses is more, seepage losses will be more. Therefore frequent closing and opening of canal should be avoided, for best performs canal should run with full discharge for minimum time and keep it closed for long time.

LITERATURE REVIEW

In developed countries like U.S.A. which is supposed to have better management of irrigation system, at least 23% of the supplies are lost in transit through seepage.

In US.S.R. the Kara-Kum Canal, which runs through sand hills, occurrence of high seepage losses was observed during the first few years of its operation. The initial seepage losses at the rate of 43% get reduced as the canal reach in stable condition.

In Australia, the losses in channel constructed in clay loam, were estimated at 0.13 cusec per million sq. feet, as against 35 cusec per million sq feet. in a newly constructed channel in Acolian sand, were 80 percent of the particles were in the range of 0.15 to 0.60 mm.

(Source: Report of irrigation commission, Vol. I, 1972).

In Cyprus where canals are usually smaller the seepage loss in a mile of unlined canals ranges from 20 to 45% depending on the nature of soil.

In Greece, where most canals are unlined earthen channels, the losses reported in the order of 40 to 50% of the initial discharge.

In Czechosolvakia, the Research Institute of Prague places the seepage losses in a clayey soil at only 7 to 10% of the Head discharge.

In India in 1881 Kennedy worked out the nearly 47% of the supply entering at the canal head was lost in transit (20% in Main canal, 6% in distributaries and 21% in water courses). The corresponding total loss observed in Ganges Canal was of the order of 44%. In 1907 Khandesh Region in Bombay were also obtained same result of seepage loss.

In Nagarjun Sagar Canal System seepage losses varies from 1.58 to 2.98 cumecs / M.sq.m. of wetted perimeter, WAPCOS have also collected data on canal losses from Maharashtra, Andra Pradesh and Madhya Pradesh.

Losses due to seepage and evaporation allowed for in design of channels by some of the states of India and CWC area as under.

Table No. 4.1

Sl. No.	Name of State	Transmission losses in Cumecs/M.Sq.m.	Remarks
1.	Maharashtra	3.05 & 4.58	Unlined main and branch canal
2.	Madhya Pradesh	2.4 & 3.05	Unlined main canal & distributaries
		1.22 & 1.83	Lined main canal & distributaries
3.	Andhra Pradesh	1.83	Unlined canal
4.	Bihar	2.44	Unlined canal
5.	Gujarat	2.44 to 3.96	Main and branch canal
6.	Kerala	2.44	Unlined canal
7.	C.W.C.	0.61	Lined canal
		0.91	Rock
		1.83	Black cotton soil
		2.74	Alluvial soil
		3.05	Decayed rock or Gravel
8.	Orissa	2.44	Unlined
9.	Tamil Nadu	1.52	B.C. Soil
10.	Karnataka	1.52	Lined canal
		2.44	Unlined canal

Source : Report on Problem No. 2.7.5 (XXXVIII) Seepage Losses in Irrigation Canals of M.P. Bhopal, Feb. 1982.

The factors affecting seepage losses include the nature of soil transversed by the canal, deposition of silt, depth of water in canal, location of water table relative to the canal, ground slope at right angles to the direction of canal flow etc.

Colonel Dyas (1863) and Higham (1864) conducted experiments on seepage losses in Punjab. The seepage losses from the main canal of the Upper Bari Doab Canal were noticed to be 20% of head discharge.

(Source: Report on Problem No. 2.7.5 (XXX VIII) of M.P., Feb. 1982)

Kennedy in 1881 showed that out of every 2.83 cumecs (100 cusecs) of water entered at head, nearly 1.34 cumecs (47 cusecs) were lost in conveyance system. The correct calculation on the basis of Mr. Kennedyi figures is as follows

Out of 100 cusecs (2.83 cumecs) head of canal

80 cusecs (2.264 cumecs) enter the distributaries head of canal

74 cusecs (2.094 cumecs) enter the watercourse

53 cumecs (1.499 cumecs) are taken out of the watercourse

It means 47% of head discharge was wasted as conveyance losses. The 25 cusecs (0.707 cumecs) further waste in application losses. Out of 100 cusec only 28 cusec (0.792 cumec)are actually employed to maturing the crops. **(Source: Additional note no. 98 dated 19th March 1892, by T. Higham, Esq. S. E., Sirhind Circle, Irrigation Work Punjab).**

In 1883 Kennedy worked out absorption losses as different rates of sinkage per hour for main canal, branch canal, distribution and water courses. In his result the losses in cusecs per million sq.ft were 9.75, 2.2, 2.3 and 9.4 respectively.

Kanwar Sain report on saving of water in irrigation canals; pointed out that canal losses due to seepage, leakage and evaporation varying from 10 to 50% of the supplies entering at the heads. It was known that out of 17.76 million cum of water diverted for use in 36 Bureau of Reclamation projects during 1946, approximate 57% was lost in transit.

In 1950 loss was reported to be 36% on canal. Improvement including lining the loss was reported 32% in decrease of 4%.

In 1959, census of agriculture showed that 90 million cum of water conveyed in 17 Western States of Lousiana, 21.7% was lost in conveyance.

In proceedings of seepage symposium 1963 published by U.S. Deptt. Of Agriculture, C.W. Lauritzen explained in his paper on "Conveyance Losses in Irrigation System and Measures for Control", it appeared that about one third of water diverted for irrigation purposes was lost in conveyance and that only one half of what was left; when applied, was stored in root zone.

Studies conducted by Maharashtra Engineering Research Institute also conform to the values as indicated in note prepared by WAPCOS, through their studies would be finalized by March 1983. The observed losses are in very-very wide range which is 10 to 50% of head discharge.

In 1989, Central Water & Power Research Station, Pune has recommend, a uniform seepage rate for all states in India for preliminary canal design after actual observations of the seepage losses in different states, the results were compared with the design practices and found 90 percent of the observed data with the range of design practice.

The recommended seepage rates are as under

i. For Lined Channel = 0.80 cumecs per million Sq. m. of wetted parameter

ii. For Unlined Channel = 2.50 cumecs per million Sq. m. of wetted parameter

Source: 55th R & D Session, 25-26 July 1989, CWPRS, Pune.

A channel taking off from a branch canal, distributory, minor or sub minor, which conveys water to the turn out. Therefore the watercourses are the ultimate links of conveyance network of irrigation system. The losses in the water courses and field channels constitute a major portion of the transit loss during conveyance of irrigation water from out let to farmers field. The study of seepage losses in water course and field channels has been carried out in Northern India from 1892 to 1920 by the than field engineers. The study shows that the improvement of watercourse and field channel is essential for batter management of irrigation water.

In major irrigation systems about 45% of water diverted for irrigation is lost in transit indifferent component of conveyance network connecting the source of water to farmers fields. Out of this loss nearly 40% to 50% in lost in water course and field channels. Therefore improvement of water course and field channel is essential to minimize the transit losses.

Field observations on losses of water courses:

U. P. Irrigation Branch circular collection No. 1 on puddling of irrigation water course gives lot of information on losses observed by experienced canal engineers in Punjab and U. P. in the last two decades of 19th century. The problem of losses was quite serious in Punjab and Sindh specially large capacity watercourse extending over large lengths and passing through sandy soil with large seepage and percolation losses.

Mr. R. G. Kennedy, Executive Engineer, Bari Doad Canal, Irrigation Works, Punjab (1892), laid down that the average loss of water in a water-course is 21 percent of head discharge of canal or nearly 43 percent at outlet head.

Another Engineer, Mr. Dempster, who has made number of experiments, commented that the loss is possibly well over 30 percent of head discharge.

As per Mr. Kennedy's 21 percent was on supply entering the canal, whereas Mr. Dempster's 30 percent was on the supply entering the watercourse, the correct calculation as the basis of Mr. Kennedy's figures is as follows:

Out of 100 cubic feet entering head of canal

80 cubic feet enter the distributaries
74 cubic feet enter the watercourses
53 cubic feet are taken out of the watercourses
25 cubic feet are dissipated by wastefull
28 cubic feet are actually employed in maturing the crops.

Mr. Kennedy in his memorandum also given the rate of absorption in different kind of channels. He has given the surface area in square feet on which the loss is cubic foot per second and the proportion of branch canal: constant distributaries: tatited distributaries: water courses is as 45:30:17:8, i.e. the proportionate loss is greatest on watercourses, less on distributaries and least on canals (Ref. Irrigation Branch Collection No.1).

Normally, the greater the depth of water, the greater the absorption, we might have expected the absorption per square foot of wetted surface to be greatest in canals, next on distributaries and least on watercourses.

In an another observation on Chenab Canal on a representative watercourse with capacity of 5 cusecs (2 ft bed width). Main watercourse for a representative village with 1712 acres C.C.A. was on an average 12000 running ft. long, with eight branch watercourses of 37500 feet in length.

The field channels were found in a length of 584010 feet. This gives over 100 miles of channels in a single village. Thus on chenab canal main watercourse were equivalent to a minor and branch water course to a watercourse (nearly 0.60 cusecs). We can very well imagine the quantum of loss over these three set of channels.

Attempts were also made for comparative study of water losses on the above set of channels.

The wetted area on main water course = 12000 x 8	= 96000 sq ft.
Wetted area on branch water course = 37500 x 4	= 150000 sq.ft.
Wetted area on minor channels (field channels)	= 584010 x 2
	= 1, 168,020 sq ft.

The main watercourse normally run continuously the branch watercourse might possibly run constant or by turns, say half time.

The field channel may only run at time of irrigation, say at twelfth of them running always.

The proportionate losses (based on wetted perimeters) would be as 96 :150/2 : 1168/12 or 96 : 75 : 97

Or roughly the loss is equal in each of these cases. Of course as the loss is only on the amounts which enter at the heads of the channel, then with the same percentage of loss the final set of channels would have the least loss. But as the main channel would run constantly and the other channel intermittently, this would tend to increase the absorption in the minor channels, which are often dry.

On another recent studies on losses in field channels the losses in unlined water courses, during running period, were observed as 4 percent per 100 meter length.

The steady state losses in unlined watercourses have been observed to be 20 to 30 cusecs per million square feet of wetted area. During the first 24 hours of running, after usual 7-days closure, the losses have been found to be as high as 50 to 100 cusecs per million square feet of wetted area, depending on nature of soil and seasonal temperature.

The study on modernization of canal water courses in Haryana was conducted since 1973, the detailed study on seepage losses in an unlined. Watercourses was done, the result shows that the seepage losses in an unlined water courses go on increasing as the distance of delivery point from the outlet on the irrigation canal increases. The study state losses in unlined watercourses have been observed to be 20 to 30 cusecs per million sq. feet of wetted perimeter. During the first 24 hrs. of running, after a usual 7 days closures, the losses have been found to be as high as 50 to 100 cusecs per million sq. feet of wetted perimeter depending upon the type of soil. In a lived water course the seepage losses in study state condition was 3 to 6 cusec / million sq. feet,, as in first 24 hours of running after 7 days closer were only 4 to 8 cusec per million sq. feet.

Determination of water course length to be lined:

It was realized from study on water course, the 50 percent lined length would lead to the reduction of 85 percent seepage losses. Based on this concept, a curve was developed, which is shown in fig. 4.1.

Studies by W.R.D.T.C. (University of Roorkee) on improvement of watercourses of Jarijokhar Minor of U.G.C. system was done and found that the watercourse efficiency was on an average 75 percent in the field.

An analysis was also made to estimate seepage losses on water courses of U.G.C. system for a specific check of 60 ha. Served by a 6 inch diameter outlet. Water course characteristics are summarized below:

Water courses	Water course length in (m)	Proportion of chek served	Area served location factor	Average W/C run (m)
Main	100	1	1	100
Left 1	380	0.15	0.6	34
Left 2	480	0.20	0.6	56
Right 1	950	0.30	0.8	228
Right 2	950	0.35	0.8	226
	2860 m			686 m

Average water course run as percentage of total length 686/2860 = 23.98

Say 24%

Average water course run per ha. Of C.C.A (60 Ha) 11 m.

Adopting a typical figure water losses on unlined water course of 4% per 100 m run, then the weighted average loss would be 24% of the volume passed through the outlet after the entire check area had been served (Ref. Upper Ganga Irrigation Modernization Project Annexure No. 6, page 7).

In 1995, a field study has been carried out by the U.P. Irrigation Research Institute, Roorkee to measure seepage losses from Easter Yamuna Canal System, Jaunpur Branch Canal System and other canals of U.P. Irrigation Department under the programme of fundamental and Basic Research sponsored by Indian National Committee on Hydraulic Research (INCHR), Pune, Ministry of Water Resources, Government of India, New Delhi. The average losses in main canal is 2.479 cumecs/m.sq.m, in branch canal is 2.11 cumecs/m.sq.m., in distributaries is 2.495 cumecs/m.sq.m and in minors is 1.96 cumecs/m.sq.m.

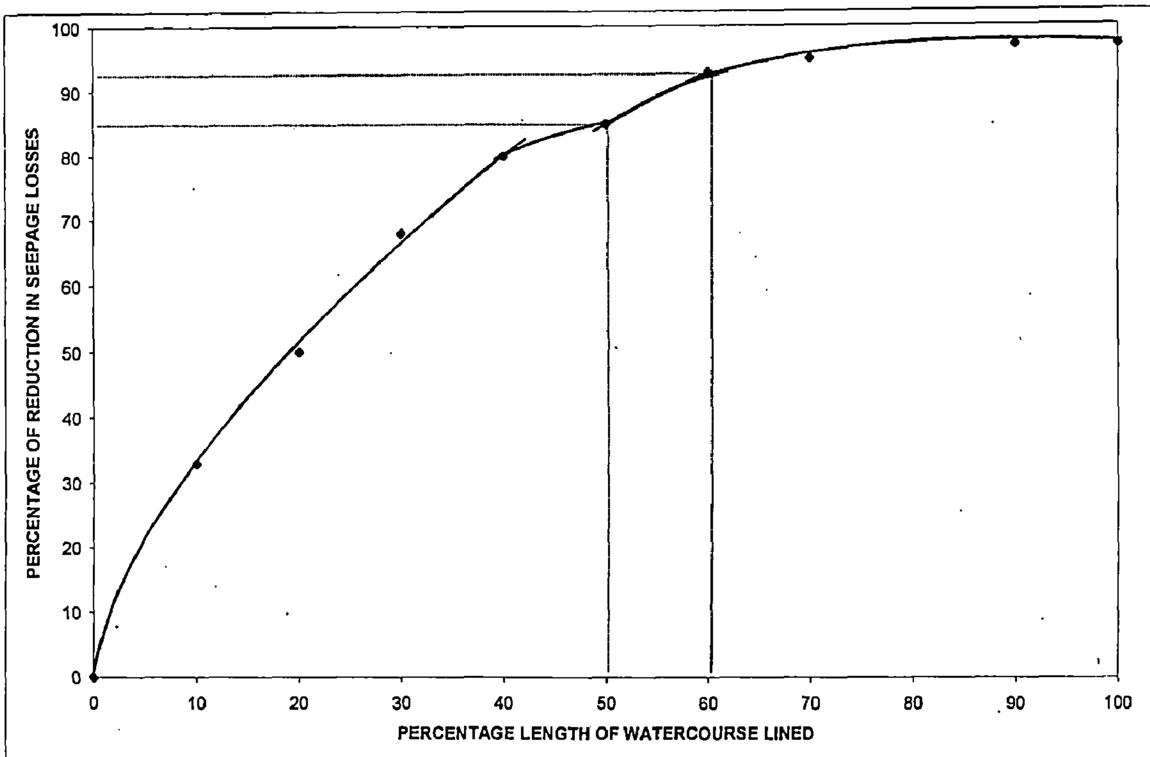

Fig. No.4.1 RELATION BETWEEN REDUCTION IN SEEPAGE LOSSES AND LENGHT OF WATERCOURSES LINED

MEASUREMENT / ASSESSMENT OF SEEPAGE LOSSES

5.1 GENERAL

The seepage losses in a canal system are generally estimated by the following methods:

1. Empirical formulae
2. Theoretical methods (indirect measurement)
3. Experimental methods (direct measurements).

5.1.1 Empirical Formulae

Several different empirical formulae have been used in different countries and also in different parts of India. These formulae are commonly used for estimation of seepage losses.

(a) Punjab Formula (India)

(i) $\Delta Q = 1.9\ Q^{1/6}$

where ΔQ =losses in cumecs per million sq.m of wetted perimeter

Q = discharge in cumecs.

This formula have been used in U.S.A, Pakistan and Punjab in India.

Punjab Formula (India)

(ii) Transmission losses in Punjab(India) and Pakistan

The losses due to conveyance is also work out from the following formula:

$a_{(L)} = 5\ Q^{0.0625}$ for Unlined

$a_{(L)} = 1.25\ Q^{0.056}$ for Lined

where

$a_{(L)}$ = absorption loss in cusecs / million sq. feet of W. P.

Q = discharge of canal in cusecs

The above formula is also converted to give the loss per foot length of the canal using Lacey's equation for wetted perimeter viz. $P_{(W)} = 2.67\ Q^{1/2}$, and the formulated derived is $a_{(L)} = 0.0122\ L\ Q^{0.5625}$ cusecs / 1000 ft length

L = Length of canal in 1000 ft

Q = discharge in cusecs

Note: Both formula derived with the assumption of conveyance losses very from 6 to 8 cusec per million sq. feet or 1.83 to 2.44 cumecs per sq. m. of wetted perimeter for 2000 cusec (56.60 cumecs) canal capacity.

Graphical solution of the formulae for the losses are given in fig.No. 5(a), 5(b) & 5(c).

(b) Merit Formula / Moritz Formula

Loss $S = 0.2\ C\ (Q/V)^{1/2}$

Where,

S = Seepage loss in cusecs per mile of canal

Q = Discharge of canal in cusec

V = Mean velocity of flow in ft/sec.

C = Coefficient which is taken as

= 0.34 for gravel and hard pan with sandy loam

= 0.41 for clay and clayey loam

= 0.66 for sandy loams

= 1.68 for sandy loams with rocks / boulders.

= 2.20 for sandy and gravelly soils.

This formulae is also used in U.S.A(United States in America).

(c) Uttar Pradesh, (India)

(i) $\Delta Q = \frac{C}{200}(B + D)^{2/3}$ (MKS unit)

where ΔQ = channel losses in cumecs/Km length of channel

C = constant, 1 for intermittent running canal and 0.75 for constant running canals

B = Bed width of channel in meters

D = depth of water in the channel in meters

This formula is generally used in U.P. in planning and design of irrigation channels.

(ii) $a_{(L)} = \frac{C'(B + D)^{2/3}}{8}$ (FPS unit)

where

$a_{(L)}$ = absorption loss in cusec per mile

B = bed width in feet

D = water depth in feet

C' = coefficient generally equal to 0.75 for main and branch canal constantly running and unity for all other canals.

Note: This formula based on the assumption of evaporation and seepage losses as 10 cusec / million sq. ft. (3.05 cumecs / million sq. m)

The graphical solution of the above formula is given in Fig. No. 5(d).

(d) In India Following Formulae Is Also Used:

Seepage loss S = c.a.d.

Where,

S = total loss in cusecs

a = area of wetted perimeter

d = depth of flow in ft.

c = a constant (range 1.10 to 1.80)

(e) Highham's formula

$$S = 0.55\ C.\frac{BL}{10^6}\sqrt{d}$$

where:

S = seepage in cusecs for a length L ft. of canal

C = coefficient, average value being 0.45

B = water surface width of canal in ft

L = length of canal in ft.

d = depth of water in ft.

This formula suggested by Sir Highham for Punjab canals.

(f) Davis and Wilson formula

(i) $$S = C\ \sqrt[3]{d}.\frac{PL}{4000000 + 2000\sqrt{v}}$$ (FPS unit)

where:

S = seepage in cusecs in length L ft. of canal

C = coefficient varying 1 to 30

d = mean depth of water in canal ft.

P = wetted perimeter in ft1.

L = length of canal in ft.

v = mean velocity of water in canal

(ii) $$q = 8.64 \times 10^{-3}\ C.P.\ (H)^{1/3}$$

where:

q = seepage rate m^3/day/m length

p = wetted perimeter in meters

H = water depth in canal in meters

C = soil coefficient, 12 for loams and 70 for sand gravels.

(g) Muskat's formula:

$S = K. L. (B + 2d)$ (F.P.S unit)

where:

S = seepage loss in cuft.

K = coefficient of permeability

L= length of canal in ft.

B = width of water surface in canal in ft.

d = canal water depth in ft.

Note: This formula is applicable in deep water table condition only.

(h) Molesworth and Yennidumia formula (Egypt's Irrigation Dept.)

$S = C\,L\,P\,(R)^{1/2}$

where:

S = conveyance losses (m^3/sec length L of canal)

L = length of canal in km

P = wetted perimeter (m)

R = hydraulic mean depth in (m)

C = coefficient depending upon nature and temperature of soil

for clay = 0.0015, for sand = 0.003

(i) U.S.S.R formula

$$S = \frac{1.16}{Q} \times K \times q_r$$

where:

S = loss in percentage of canal discharge per km of canal length

Q = canal discharge (m^3/sec)

K = saturated permeability (m/days)

q_r = reduced specific seepage loss i.e. ratio of seepage velocity of standard permeability of bed material.

(j) Pavolvsky's formula (USSR)

Seepage losses, in absence of high ground water table, are estimated as under: (Source: Design practices of irrigation canals in the world, 1972. ICID)

$$S_{eL} = 0.0116\, B_{(ws)} + 2y\, C_I \text{ cumecs/km}$$

where:

$S_{e(L)}$= seepage loss in cumecs / km of canal

$B_{(ws)}$ = canal width at water edge in meter

y = depth of flow in meter

C_I = coefficient and soil infiltration in m/day

= 0.05 for heavy loam

= 0.05 to 0.10 for medium and light loam

= 0.10 to 0.50 for sandy loam

= 0.50 to 1.00 for dusty sand

= 1.00 to 5.00 for fine sand

= 5.00 to 20.00 for medium grained sand

(k) Offengenden Equation:

Offengenden proposed the equation for estimating seepage losses from unlined canals

$$S = s \, x \, \frac{Q \, x \, L}{100} \text{ cumecs}$$

where:

S = water losses per km of canal length in percentage

Q = discharge in cuemcs

L = length of canal in km

s = A/Q^m, A & m are the empirical constants depending on permeability of soil

	Low permeability	**Medium permeability**	**High permeability**
A	0.70	1.90	3.40
m	0.30	0.40	0.50

Seepage losses of 6 cusecs per million sq.ft. for channels upto 120 cusecs discharge and loss of 8 cusecs per million sq. ft. for channel upto 2000 cusecs discharge are taken for design purpose, as per practice recommended by CWC (GOI).

5.2 SEEPAGE LOSSES MEASUREMENT BY DIRECT METHOD

Seepage losses of canals can be measured by inflow-outflow method, ponding method, seepage meter method and tracer techniques method.

5.2.1 *Inflow - Outflow Method:*

In this method the quantity of water flowing into and out of the reach of canal are carefully measured and the difference is taken as seepage loss from the reach. The inflow-outflow method gives the seepage losses from a canal section under normal operating condition. Existing calibrated weirs and flumes in the canals can be used for measuring flows. The ideal gauging site would be where canal has rectangular cross-section. Current meters are used at gauging stations to measure the velocity from which the rate of flow is derived (Ref. Humt. B.W. (1972), Crebas J.I. et al (1984).

Limitation

The method is not very accurate as the order of error involved in measurement of canal discharge may be of the same order or even higher than the quantum of seepage loss involved. When large reach of the canal is involved, the steady state condition may be established after a long time and the leakage and outflow of the off-taking canal would have to be evaluated to determined the seepage losses. This method is more suitable for main and branch canals.

5.2.2 Ponding Method:

This method consists in measuring the rate of drop in a pool formed in the section of the canal to be tested. This method can be applied in smaller reaches of a canal. Since observation can be made accurately the results should be a good indication of the average loss from the reach with the reservation that the still water in the pool may seep out at a different rate than the flowing water in the canal. This can be caused due to sealing effect of the suspended material settling in the still water. To isolate a reach of a canal for ponding tests, watertight dikes or bulk heads have to be built. Whenever, possible, existing structures such as weirs and regulators should be utilized for this purpose all structural leaks should be carefully measured and since the testing may take considerable time, evaporation and rainfall should be recorded so that the drop in water surface can be corrected accordingly

$$\text{Seepage rate } S = \frac{W(d_1 - d_2)L}{PL}$$

Where,

S = Seepage in (m^3/m^2/ 24 h or ft^3/ft^2/24 h) over distance L.

W = Average width of water surface of the ponding reach

d_1 = Depth of water at beginning of measurement

d_2 = Depth of water after 24 hours.

P = Averaged wetted perimeter

L = Length of the canal reach.

A modification of the ponding method consist in adding water to the pond to maintain a constant water surface elevation. The accurately measured volume of added water is considered equal to the total losses, and the elapsed time established the rate of loss. [details showing in Fig. 5.1(a) and 5.1 (b)].

Limitations

Ponding tests can be made only when the canal is not in use. Watertight bunds to form the pools is expensive. Ponding water to fill the pools sometimes involves difficulties, particularly because the pools must be filled several times before the seepage rate becomes stabilized which may take considerable time. Filling of ponds also is a problem. The ponding method gives the average seepage from a pool, it does not show what the variation in the seepage rate from different parts of the pool may be. The suspended sediment may also affect the normal seepage rate.

5.2.3 Seepage Meter Method:

Seepage meter devices is suitable for measurement of local seepage rates in canal and ponds. This device originally developed by Regional Stability Laboratory, soil conservation services, river-side California and was adopted by USIBR. This is the simplest and cheapest device as regards construction as well as operation, it consists of the watertight seepage cup connected by a hose to a flexible water bag a floating on the water surface (as shown in Fig. 5.2).

Water flows from the bag into the cup, where it seeps through the canal sub guide area isolated by the cup. By keeping the water bag sub-merged it will adopt itself to the shrinking volume so that the head on the areas within and outside the cup are equal. The seepage rate is computed from the weight of water loss in a known period of time and the area covered by the meter (As shown in Fig. 5.2).

Working of seepage meter : The cylinder should be pushed only a small distance into the sub-grade in order to avoid, as far as possible disturbance of the existing soil texture. After pushing the cylinder into the sub-soil, the hose is kept open at its upper end to allow air and excess water from the cylinder to escape. When equilibrium is achieved, the hose is connected to the plastic bag. Containing the weighed quantity of water. The accuracy of measurement depends largely on the maintaining of an exact balance of pressure on the canal bottom inside and out side the meters.

5.2.4 U.P. I.R.I. Type Seepage Meter:

This type of seepage meter consist of following component parts as shown in Fig. 5. 3.

(a) seepage cup (b) constant head vessel, (c) the swivel head joint.

An iron cylinder of 34.50 cm in diameter open at bottom and closed at top act as seepage cup. The top lid has been provided with two open of 'A' & B, A is for release of entrapped air and later to serve as an enter for water into the cup. Opening B is connected to the constant head vessel by a plastic tube. For controlling penetration of the cup, 17.0 cm wide baffle steel plate 'C' has been provided around the cup. The constant had vessel consist of Marriotte's tube and is clamped to a stand pipe 'S' which is connected to the seepage cup through a Swivel head 'B' containing a ball and a socket joint. This seepage meter can be installed on side slopes of the canal (Ref. TM No. 65 (1995).

Working of Seepage Meter:

First seepage meter cup is lowered in the canal water where seepage is to be measured. Valve A is opened and all entrapped air is removed. The valve is than closed. The constant head vessel is than fixed on stand pipe 'S' and is adjusted in such a way that the point Q coincides with the water surface. Tube 'T' inserted to the original level, keeping it closed at the top. Valve 'V' is than opened and water allowed to move down the plastic tube into the seepage cup. Reading of the gauge 'G' are taken for a know period of time. Area of seepage cup is known, seepage is calculated from gauge readings.

The losses by seepage meter should be measured at various suitably located points especially where the strata appears to change.

5.3 TRACER TECHNIQUE:

This method is suitable for homogeneous and isotropic formation, economical in cost consideration and independent for the determination of filtration velocity and direction of flow.

A radio-active tracer is a mixture of isotopes of an element which may be incorporated into a sample to make possible observation, through a chemical, biological or physical process. The observations are done by measuring radio-activity, the minutest concentration i.e. 10^{-10} to 10^{-11} milligram of radio-active substance per litre volume of water is required, it does not disturb the ground flow pattern. These radio active directly detected with the help of detecting equipment. Disintegration of radio-tracer does not involve any temperature, chemical and bio-chemical reactions and do not get precipitated or absorbed in sub-soil.

The following factors generally considered for selection of radio-tracer for seepage measurements.

(i) The radio isotope should be gamma emitting to enable efficient detection in water.

(ii) It should be available in highly water soluble form and should be stable in water medium.

(iii) It should be easily detectable at site.

(iv) It should have higher concentration of radio-tracer.

(v) It's half life should reasonably be high so that observations may be continued for a reasonable time.

The following type of radio-isotopes are generally used:

Table 5.1: Radio-Isotopes, Generally Used

Isotope	Half Life	Max. permissible concentration in drinking water (μ CI/ml)	Min. amount detectable in water (μ CI/ml)
^{3}H (Tritium)	12.26 yrs	3×10^{-3}	1×10^{-6}
^{24}Na (Sodium)	15.0 hours	2×10^{-4}	1×10^{-8}
^{51}Cr (Chromium)	27.8 days	2×10^{-3}	8×10^{-7}
^{58}Co (Cobalt)	71.0 days	1×10^{-4}	6×10^{-8}
^{82}Br (Bromine)	35.7 hrs	3×10^{-4}	2×10^{-8}
^{116m}Ag (Silver)	249 days	3×10^{-5}	3×10^{-8}
^{131}I (Iodine)	8.05 days	2×10^{-6}	8×10^{-8}
^{198}Au (Gold)	64.8 hrs	5×10^{-5}	1×10^{-7}

Source : IRI Research Paper (April 2000)

Quantity of Radio – Tracers : Following factors are considered to decide the quantity of radio-tracer.

1. *The quantity of water involved in diluting the tracer*
2. The fraction of the tracer lost.
3. The sensitivity of the detecting unit
4. The maximum permissible concentration in drinking water to used by the puble at large.

A rough estimate made, taking into account the above factors give a value of 1.20 / μc/litre as the required specific activity for these types of experiments.

These are the following methods of tracer-technique generally used to measure seepage losses.

(i) Double well method

(ii) Single well pumping method

(iii) Single well dilution method.

5.3.1 Double Well Method :

In this method the tracer is injected in one well and observations for the tracer – are made in another well located down gradient at a known distance. The velocity of flow can be calculated with the help of travel time of tracer concentration and the distance between the injected well and observed well. The time of travel of the tracer in the bore holes is determined by lowering a water tight G.M. or scintillation probe. This method is suitable for high permeable soil or when velocity of flow is large.

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5.3.2 Single Well Pumping Method:

This method is also known as pulse technique. The procedure is to add a small quantity of tracer into the aquifer through a well and the tracer is left to move with natural flow for a prefixed interval. Then the tracer is recovered by pumping water from the same injection well. The pumped water continuously monitored for radio activity. For known time between injection and pumping, pumping rate and the pattern of activity flowing out during pumping the sub-surface flow rate can be calculated. This technique is adopted where the volume of water in the well is large, high permeability is encountered and then more than one well can not be economically drilled.

5.3.3 Single Well Dilution of Method

This method is used for localized velocity and direction of ground water flow. In this method the radio tracer is injected in a single well and its dilution is noted with time after injection, this will give the concentration decreases with time, because the well entercepts the sub-soil water flow, when fresh water enter in the well and water concentrated with isotope leaves the well uniformly in the direction of sub-soil flow. Thus the water in the well gets diluted. Total volume of water in the well remains the same and as the fresh water flows in to the well at a constant rate, the decrease in concentration follows a simple exponential law (Fig. 5.4).

The filtration velocity V_f of the horizontal water flow in the absence of all other flows through the bore hole is given by

$$V_f = \frac{\pi D \ln Co/C}{4\phi t}$$

Where,

V_f = Filtration velocity of flow (m/sec)

D = Diameter of bore hole (m)

t = interval of initial and final concentration

C_o = Initial concentration (CPS)

C = Concentration after time t

ϕ = Correction factor for the distortion of horizontal flow due to the pressure of bore hole (constant)

Once the filtration velocity of flow is known, then the rate of seepage loss may be evaluated knowing the wetted perimeter distance of bore hole by the following formula

q = velocity x area

$q = V_f . \operatorname{cosec} \theta \times 2 d \theta$

$q = 2 V_f . d \theta \operatorname{cosec} \theta$

where,

q = the rate of seepage loss ($m^3/sec/10^6 m^2$)

d = distance from centre line of canal to bore hole in m.

θ = angle with phreatic line at the point under consideration makes with vertical.

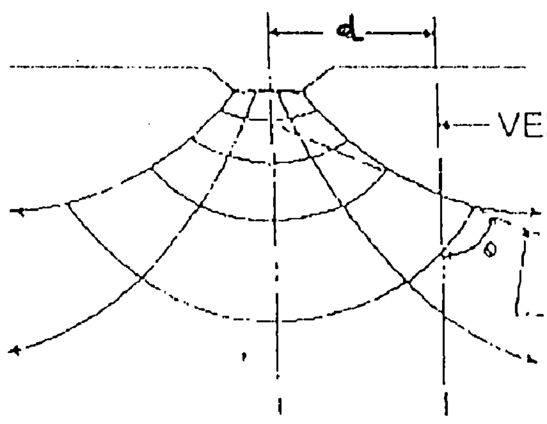


FIG. 5.0 : IDEALISED FLOW CONFIGURATION

As regards radio active tracer, tritium (tritiated water HTO) has been used because it behaves like ordinary water and moves freely with it through the soil mass, it is least hazardous to health and can be detected even in very small concentrations.

5.4 THEORETICAL METHODS: (INDIRECT MEASUREMENT)

The seepage losses from unlined canals depend on the different parameter like wetted perimeter, the permeability of the sub-soil, distance of the drainages and the head difference. Initially the seepage losses are high due to steep gradients, but, as the sub-soil becomes saturated, the gradients flatten and ultimately stabilize if the channel is continuously running. The discharge given by theoretical formulae corresponds to steady state conditions which are difficult to attain in practice due to fluctuations of water level in the canal and the water table. Thus except for cases of canals where steady condition can be obtained early as for instance in soils of high permeability with main drainage located close to the canal, the discharge as computed from theoretical formulae may be poor estimate of the likely losses and only serve to indicate the order of seepage losses for deciding the necessity or otherwise of the lining.

Analytical solutions are available for evaluating seepage losses from canals under steady conditions for the following cases:

(i) Canal located in homogeneous and isotropic medium extending up to infinite depth with shallow water table.

(ii) Canal located in homogeneous and isotropic medium extending to finite depths with shallow water table.

(iii) Canal located in homogeneous and isotropic medium extending up to infinite depth with very deep water table (Ref. Research, Report of IRI TM.No.72 RR (GW-03).

5.4.1 Infinite Depth of Permeable Medium:

The seepage from canal flows to the drains in a direction approximately transverse to the direction of flow in canal and drains. The line of flow from canal meet the drains at various slopes, depending upon the cross-section of the canal. The problem can be simplified by consideration of the following two extreme conditions Fig. 5.5 (A) & 5.5 (B).

Horizontal drainage : If the drain is shallow and wide the stream lines from the canal may joints the bottom of the drain at various points along its width as shown in fig. 5.5 (A).

Vertical drainage: If the drain is narrow, the seepage may enter into it from both sides. In this case the streamlines from the canal on both the flanks of the drain would reach the drain in a horizontal direction as shown in fig.5.5 (B).

In practice the flow may not fall distinctly into either a horizontal or a vertical drainage but may be a combination of the two. In such cases a fair idea of the flow can be obtained by a study of the two extreme cases.

However, the results are plotted in the form of curves which make it easy to obtain the seepage discharge and the phreatic surface for any channel size. The procedure for horizontal and vertical drainage conditions is given below.

Horizontal drainage: Knowing the dimensions of the system in the physical plane, the two parameters β and γ are determined as follows :

(i) The bed width B, the slope angle, the distance upto drainage L, and the water depth inside the canal H are recorded for the subject case.

(ii) Figure 5.6(a) can be used to obtain initial value of β and γ from these quantities. In these curves in addition to L/H, the quantities b/H and α' which corresponds to B/H and α respectively are to be used. The value of B/H and α are not for different from b/H and α' respectively, and former can be used as a first approximation.

(iii) After reading of the values of β and γ corresponding to these ratios, the value of α' and b/H are read off from the curves in Fig. (5.7) & (5.8).

(iv) With these values better approximations to β and γ are determined from Fig. 5.6(a) and the process is repeated until variation in the value β and γ from one trial to another is negligible. This condition is normally achieved within two or three trials.

Seepage discharge : Knowing β and γ the seepage discharge in terms of Kh is obtained from Fig. (5.9).

Free surface : Fig. 5.6(a) and Fig. 5.6(b) can be used parameterically to obtain x and y coordinates of the free surface. For any assumed value of the variable t between 0 and γ, a ratio t/γ is determined and Fig. 5.10 yields the value of γ/h. For the same value of t and the known value of a B the value of x/H can be obtained from Fig. 5.6(a).

Vertical drainage : The procedure with vertical drainage is similar. The differences is that Fig. 5.6 (b). For determining β and γ, and x/H.

5.4.2 Finite Permeable Medium with Shallow Watertable

Dechler combined both model experiments and approximate analysis to give a simple procedure for computing the seepage discharge and finding free surface of the system. The flow system is divided into two separate regions, the region I of curved flow extending up to a distance of $\frac{(B+H_2)}{2}$ from the axis of the canal and the region II extending beyond it in which this is taken as approximately linear, where B = surface width of canal H_2 = depth of impermeable layer below canal F.S.L. Fig. 5.11. Equating the discharge in two regions, the following equation is obtained:

$$Q = 2ke(H_2 + eL_1)\sqrt{H_2 - eL_1)^2 - H_2^2 + H_0^2} \qquad (5.2)$$

where, k is coefficient of permeability, H_0 = depth of impermeable layer below drain water-level, L = distance of drainage form the centre line of canal

L_1 = L- $\frac{(b+H_2)}{2}$ and e is from factor. The value of e which depends upon the geometry of the canal and the region in its vicinity, is obtained from Fig. 5.12.

Knowing the discharge q, the elevation of free surface at the dividing line can be obtained by evaluating H, being the height of free surface above impermeable boundary, from the following equation:

$$Q/2 = ke\ (H_2 - H_1)$$

Knowing H_1, the approximate position of phreatic line can be obtained by joining the point M at the inter-section of the phreatic surface and the dividing line with the canal and drainage water lines respectively.

5.4.3 Infinite Depth of Permeable, Medium with Very Deep Water Table

The solution for this boundary condition was obtained by Vedernikov with the help of conformal mapping. The seepage discharge, q per unit length of channel.

$$q = k\ (B^{-} + AH) \qquad (5.3)$$

Where, B = surface width of channel; H = water depth inside channel; and A is function of geometry of canal. The value of A is obtained from figure 5.13 for the known values of B/H and m, where m = cot α and α = side slope angle.

5.4.4 Seepage from Lined Canal

The seepage losses from lined canal can be made by theoretical method with the assumption of steady state condition. These losses depends upon the thickness of lining, permeability of lining material in addition to the factors on which the seepage from unlined canal depends. Details of losses effect of lining on free surface shown in Fig. 5.14.

$$q = P.K_1 \frac{h_1}{t} \tag{5.4}$$

where,

P	= perimeter of the channel
K_1	= permeability of lining
t	= thickness of lining
h_1	= head loss through the lining.

This quantity of seepage discharge through the sub-soil under the residual head $(h-h_1)$.

$$\frac{q}{(k(h-h_1)} = f\left(\frac{\beta}{\gamma}\right) = C \tag{5.5}$$

where,

k = permeability of sub-soil material and value of c is obtained from Fig. 5.9

By eliminating h_1 from eq. (5.4) & (5.5)

$$q = \frac{C\,P\,Kh}{C\gamma\,t + P} \tag{5.6}$$

where,

$\gamma = \frac{K}{K_1}$ knowing values of P, γ, t and c seepage discharge q is obtained.

5.5 ANALOGY MODAL TECHNICAL (EHDA TECHNICAL)

The EHDA technical can be applied to any problem involving the solution of La Place's equation –

$$\frac{\partial^2\phi}{\partial x^2}+\frac{\partial\phi}{\partial y^2} = 0 \text{ (for two dimensional)} \qquad (5.7)$$

Under a given set of boundary conditions, ϕ in equation (1) is the potential function governing the phenomenon under study.

This analogy is possible, because for the case of flow of a current through a homogeneous conductor, a similar La Place equation holds good, ϕ in this case being the strength of the electrical field.

For the case of subsoil flow, the analogy can be visualized more directly, since the flow of water in homogeneous and pervious medium viz. the Darcy's Law, and law of flow of electricity a homogenous medium viz. the Law can expressed as

Darcy's Law

$$Q=\frac{\mathrm{KAH}}{\mathrm{L}} \qquad (5.8)$$

Where,

Q = rate of flow of water

K = coefficient of permeability of soil

A = cross-sectional area for the flow of sub-soil water

H = Head producing flow

L = Length of path of percolation

Ohm's Law

$$I = \frac{K'A'V}{L'} \quad (5.9)$$

where,

I	= current (rate of flow of electricity)
K′	= coefficient of conductivity
A′	= cross-sectional are for the fow of electricty
V	= voltage producing current
L′	= length of path of current

5.6 FLOW NET

The La Place's equation (1) represent two sets of surfaces, the stream surfaces and the equipotential surfaces represented by $\psi(x, y)$ = constant and $\psi(x, y)$ = constant respectively. These two sets are mutually orthogonal and comprise what is technically called a flow net. For the case of a two-dimensional problem, these surfaces become lines.

A flow net gives a vivid picture of the flow conditions in a region specified by definite boundary conditions. A report from the electrical analogy methods the flow net can be drawn by analytical procedure, relaxation method, photoelastic method or by the method of source and sinks. But, the best method is the electrical analogy method.

5.6.1 Uses of Flow Net

A correct knowledge and study of flow net enables the computation of –

1. Loss of water through dams and their foundations by seepage.

2. Uplift pressures on the foundations of hydraulic structures with which the seepage water comes in contact.

3. The exit gradient and safety against of seepage is given by

$$Q = K.H\frac{N_1}{N_d} \tag{5.10}$$

Where,

Q = quantity of seepage flow

H = head producing flow

K = coefficient of permeability

N_1 = number of flow tubes and

N_d = number of potential drops in the flow net.

5.6.2 Construction of Flow – Net

A graphical representation of the family of streamlines and their corresponding equipotential lines within a flow region is called a flow net. The orthogonal network represents such a system. Although the graphical construction of a flow net often requires tedious trial and error adjustments, it is one of the more valuable method employed in two dimensional flow problems.

The following procedure is suggested for the construction of flow net.

(i) Draw the boundaries of the flow region to scale so that all equipotential lines & streamlines that are drawn can be terminated on these boundaries.

(ii) Sketch lightly three of four stream lines, keeping in mine that they are only a few of the infinite number of curves that must provide a smooth transition between the boundary streamlines. As an aid in the spacing of these lines, it should be noted that the noted that the distance between adjacent stream lines increases in the direction of the larger radius of curvature.

(iii) Sketch the equipotential lines, keeping in mind that they must intersect all streamlines, including the boundary streamlines, at right angles of enclosed figures must be squares.

5.7 MATHEMATICAL MODELLING TECHNIQUE

The seepage rate has also been computed by Mathematical Modelling Technique using numerous approach with the use of iteration technique. This is a theoretical approach where Numerov's has considered the shape of the channel to be semi-elliptical with semi-axis as 0.5 (B-q / K) and H and with origin at the centre Fig. 5.15(b).

The following equations for perimeter of the channel and the shape of the phreatic curve as

$$x = -(\psi/K) - 0.5\,(B - q/K)\sin\ \pi\psi/q \qquad (5.11)$$

$$y = H\cos \pi\psi/q \qquad (5.12)$$

$$x = q/2K + 0.5\,(B\text{-}q/K)\ \mathrm{Cos\,h}\pi Ky/q\ H\ \sin h\ \pi ky/q \qquad (5.13)$$

The value of seepage loss q can thus be determined by measuring the coordinates x and y of any point of the phreatic line and also the water surface width (B) and maximum water depth (H) in the channel. However, the above equation(s) fails to give the value of q at the point (B/2,O). Therefore the point on the phreatic line should be so chosen that y is always greater than zero.

Here K is the horizontal permeability of the soil medium and should be determined in-situ. In the present study the value of K has been obtained by dividing the filtration velocity (Vf) by the hydraulic gradient (i) of the phreatic line both of the point under consideration.

$$K = \frac{Vf}{i} \qquad (5.14)$$

A computer program was developed to compute the seepage loss by Numerov's approach. The program computes the seepage loss (q) with the use of iteration technique using equation 5.10 . The input data for analysis are water surface with (B), maximum water depth (H), horizontal permeability (K) and X and Y coordinates of any point of the phreatic line.

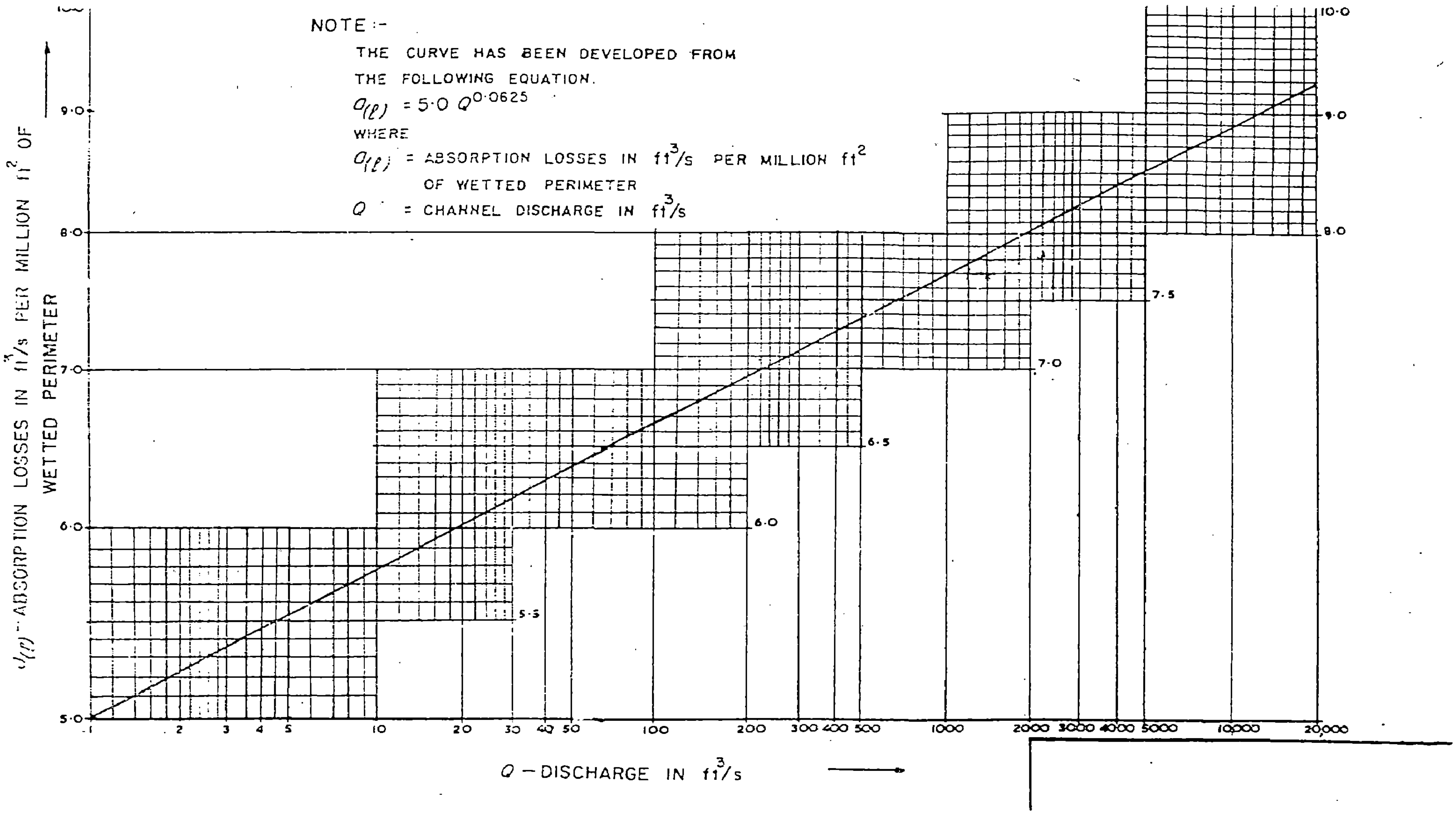
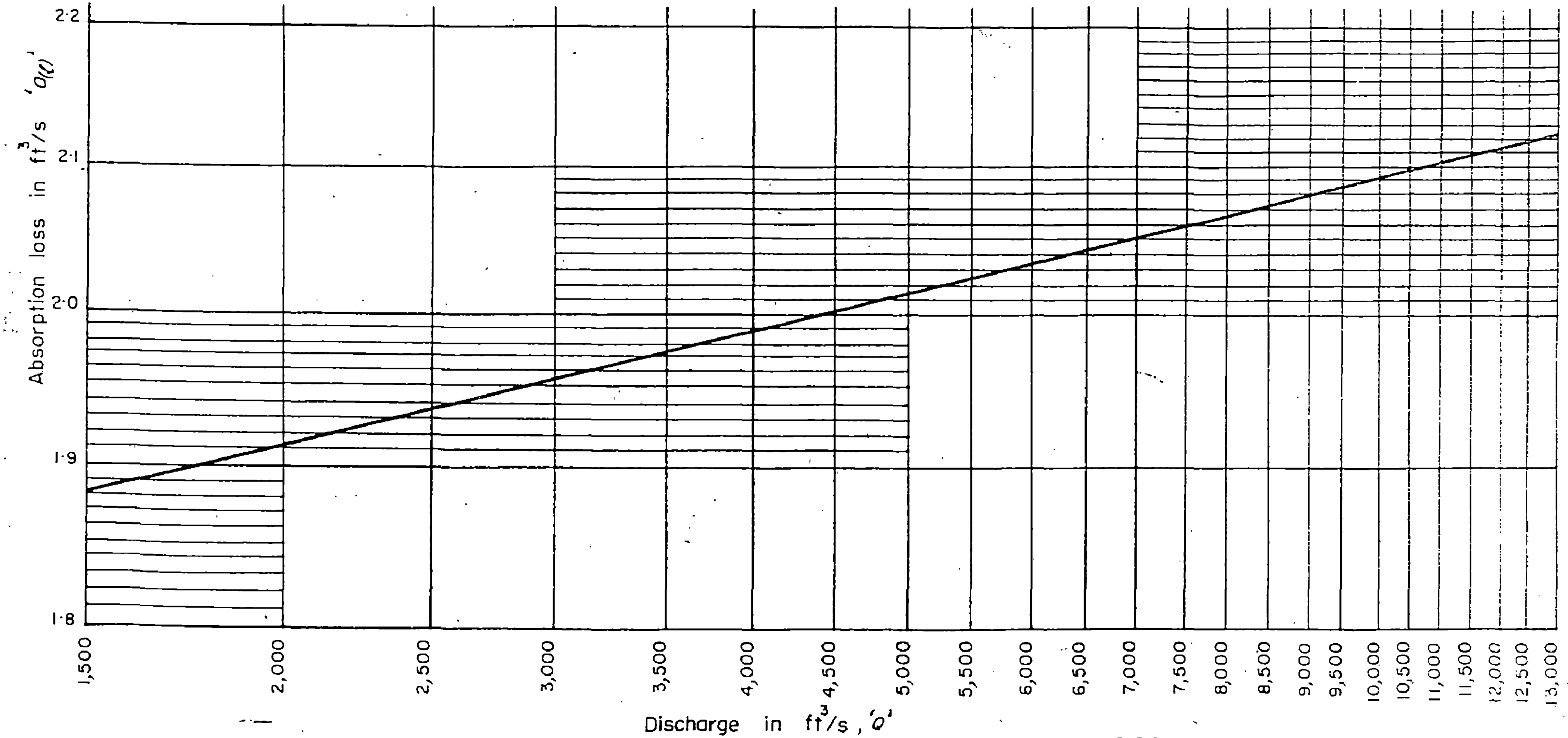


Fig. 5(a) Absorption Losses Curve, Discharge V/S Absorption Losses



Showing value of $a_{(l)}$ in the formula $a_{(l)} = 1{\cdot}25\ Q^{0{\cdot}056}$

Fig. 5(b) Absorption Losses Curve, Discharge V/S Losses in Cusecs

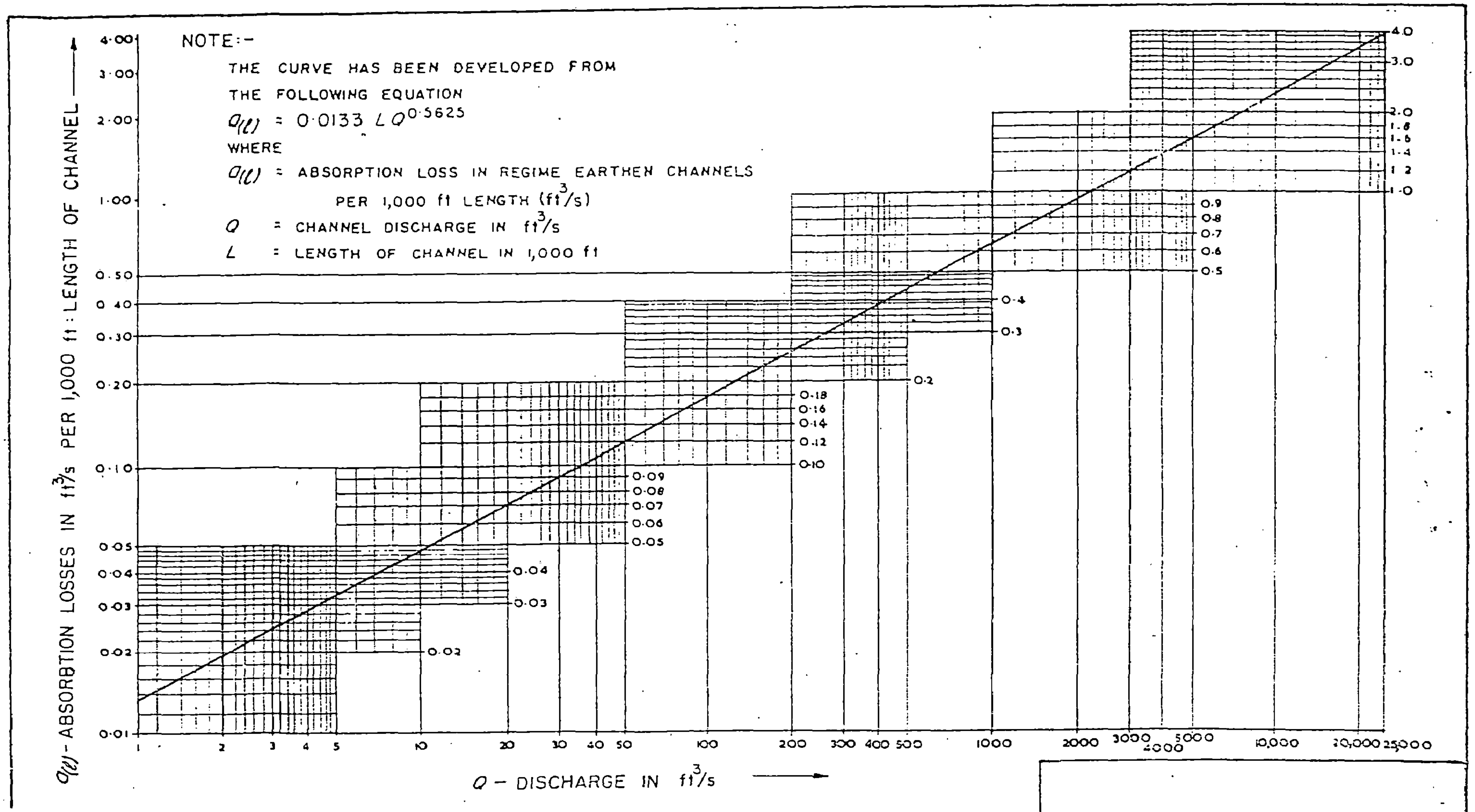


Fig. 5(c) Absorption Losses Curve, Discharge V/S Absorption Losses in Cusec/1000 ft. of Length of channel

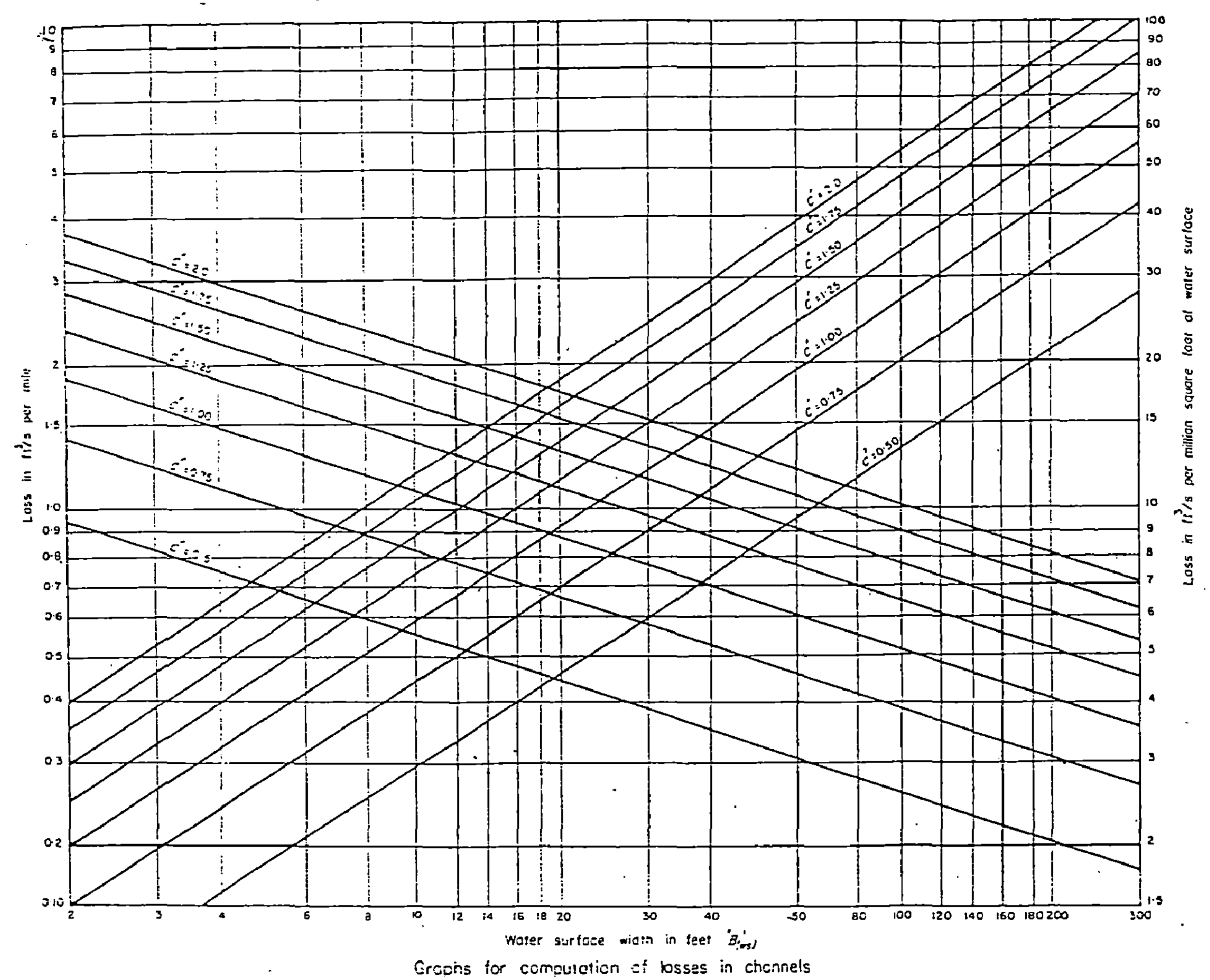


Fig. 5(d) Curve Showing Water Surface Width in ft. V/S Losses in Cusec / Mile and Losses in Cusec/M. sq. ft. of W.P.

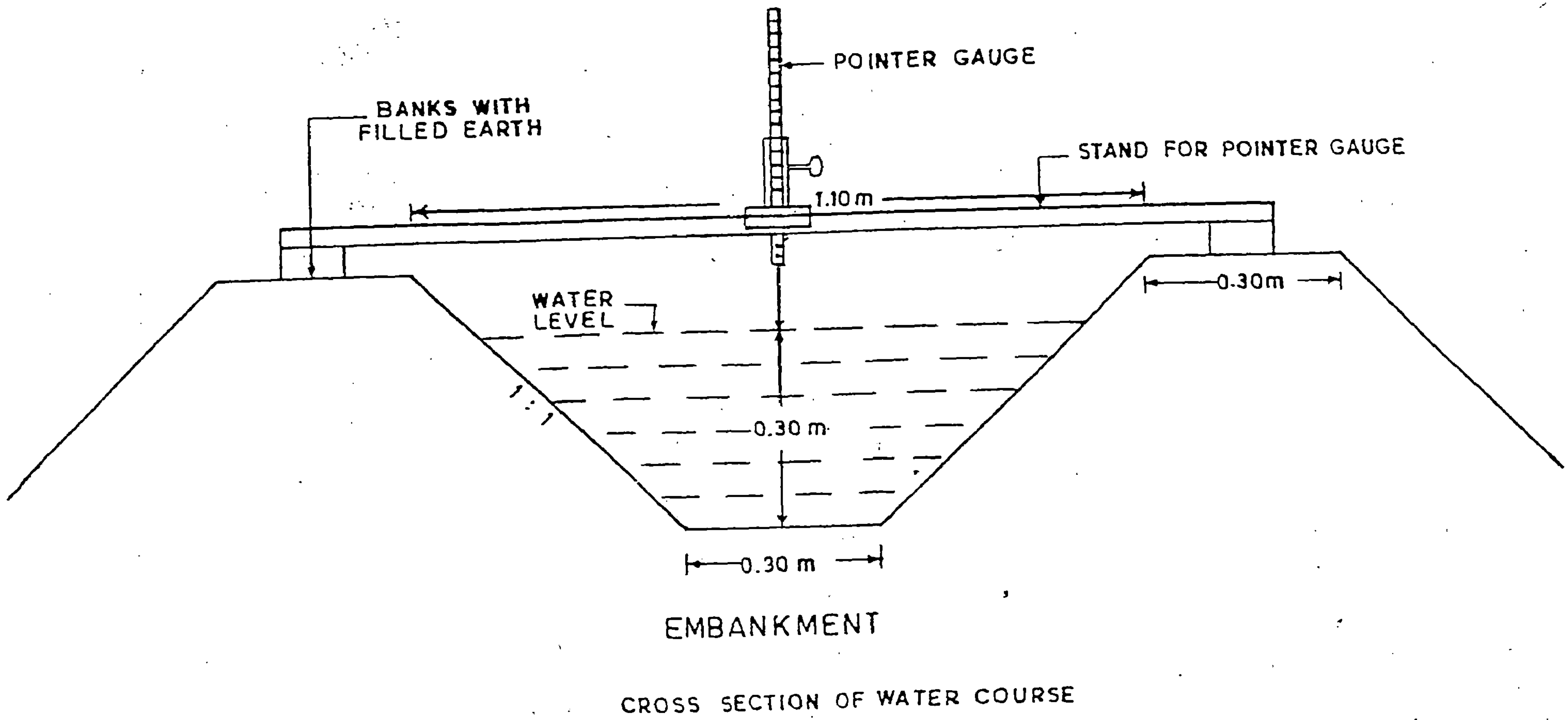


Fig. 5.1(a) Showing Ponding Method Gauging

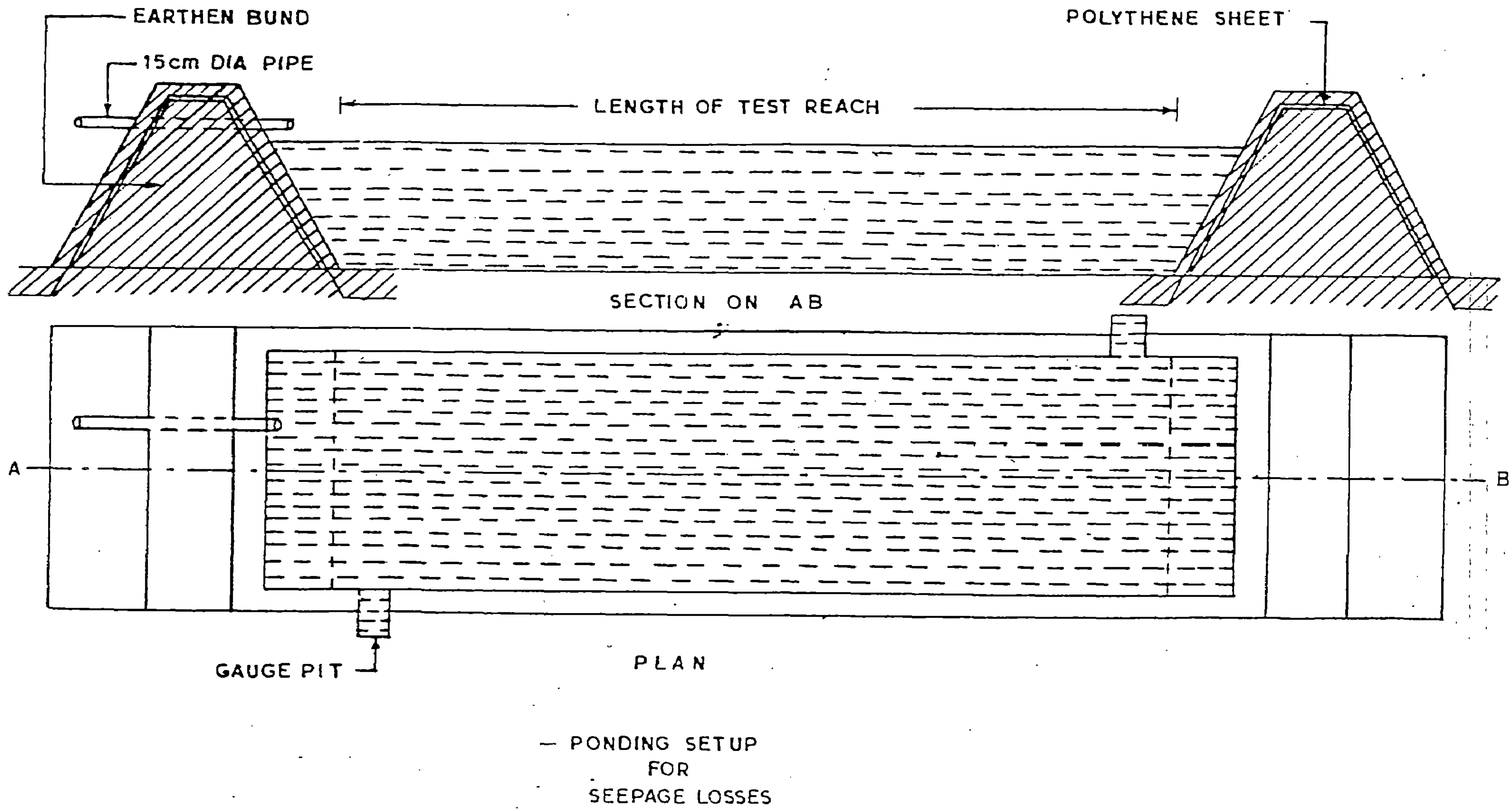


Fig. 5.1(b) Ponding Setup for Seepage Losses

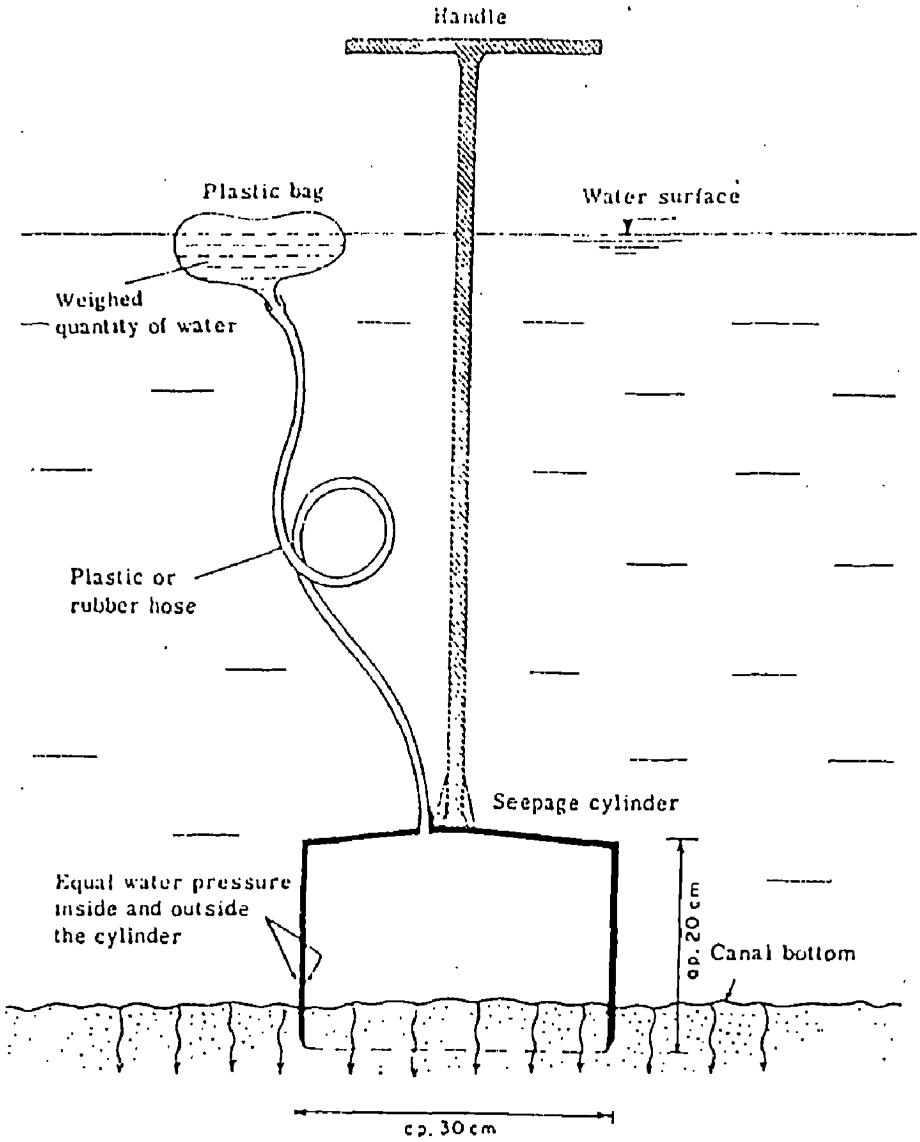


Fig. 5.2 Seepage Meter with Submerged Plastic Bag

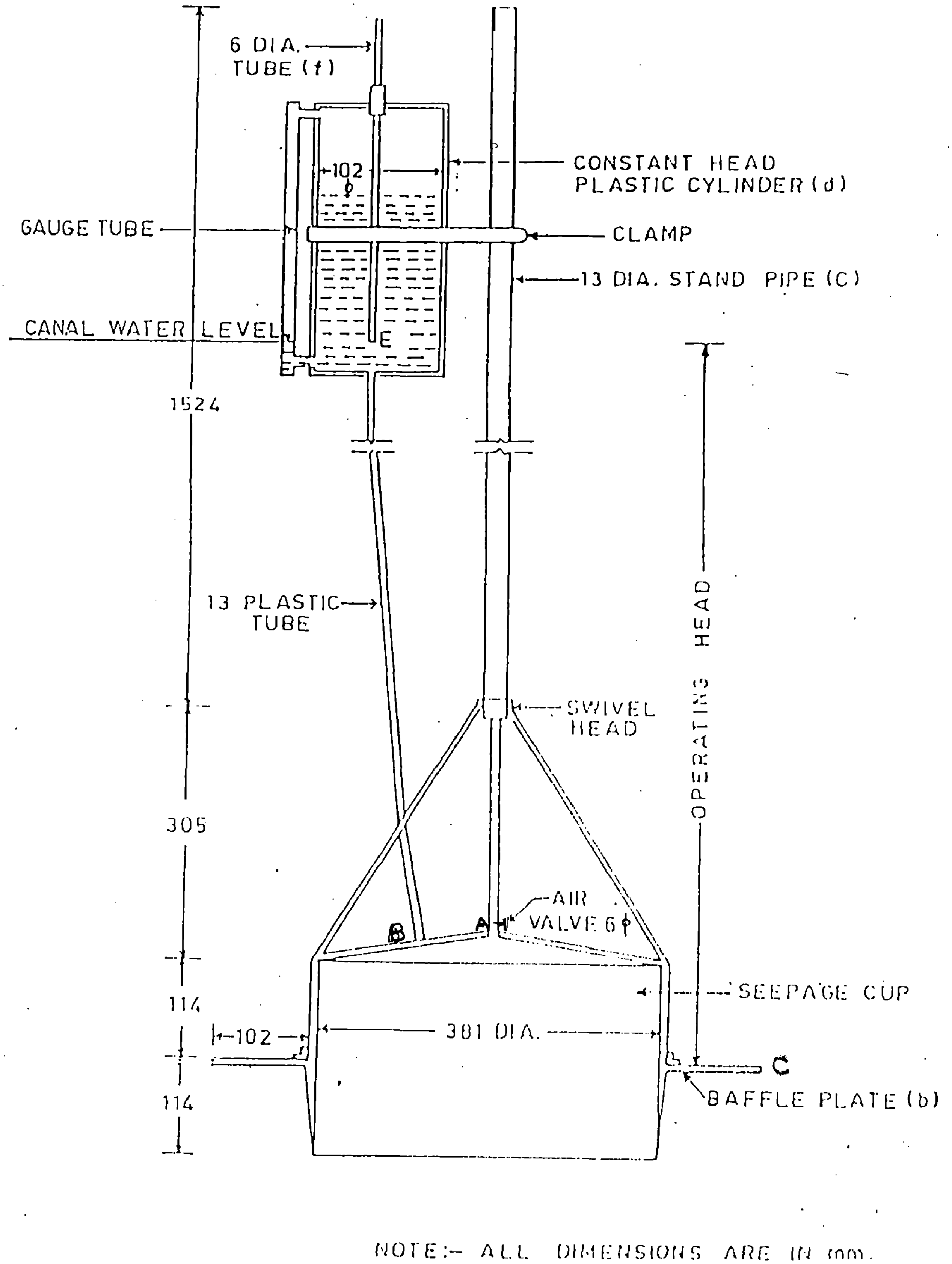


Fig. 5.3 U.P.I.R.I Type Seepage Meter

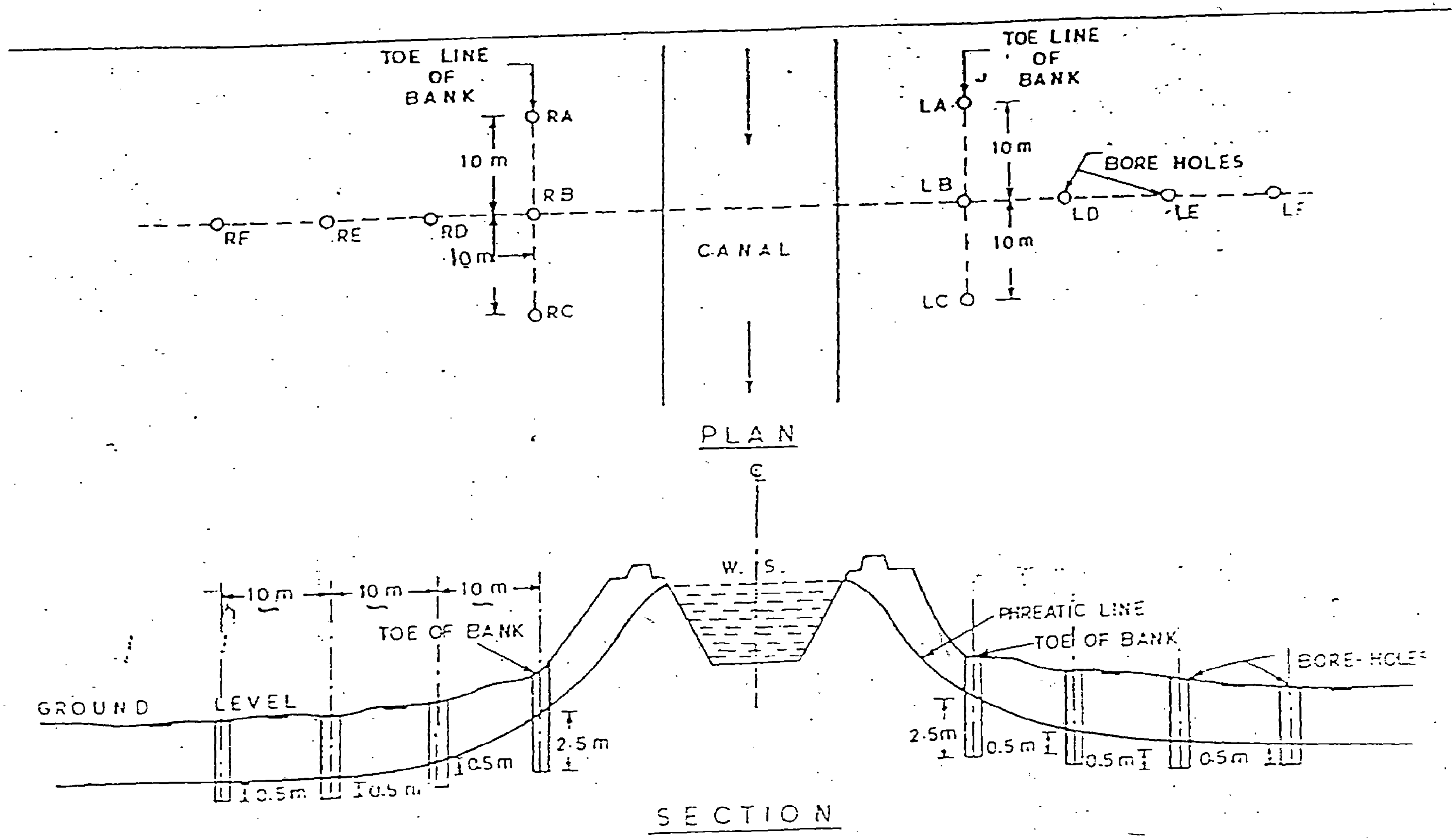


Fig. 5.4 Layout Plan of Borehole Setup for Seepage Measurement

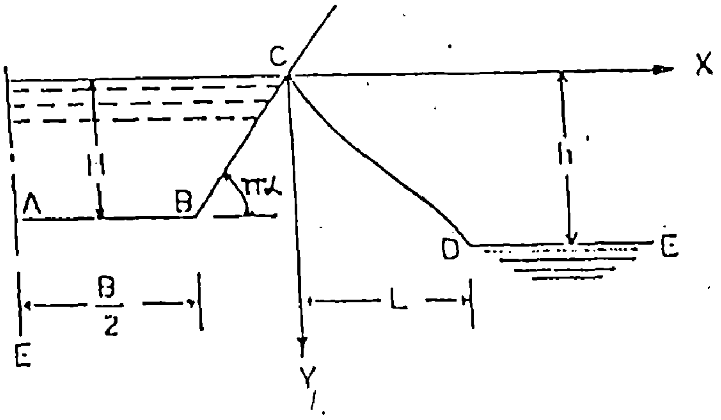


Fig. 5.5(A) Horizontal Drainage

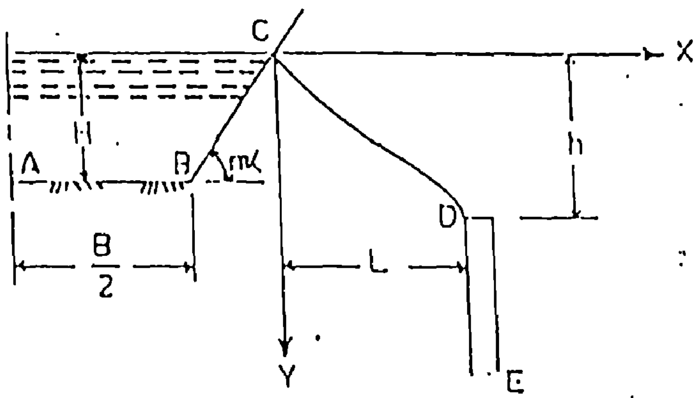


Fig. 5.5(B) Vertical Drainage

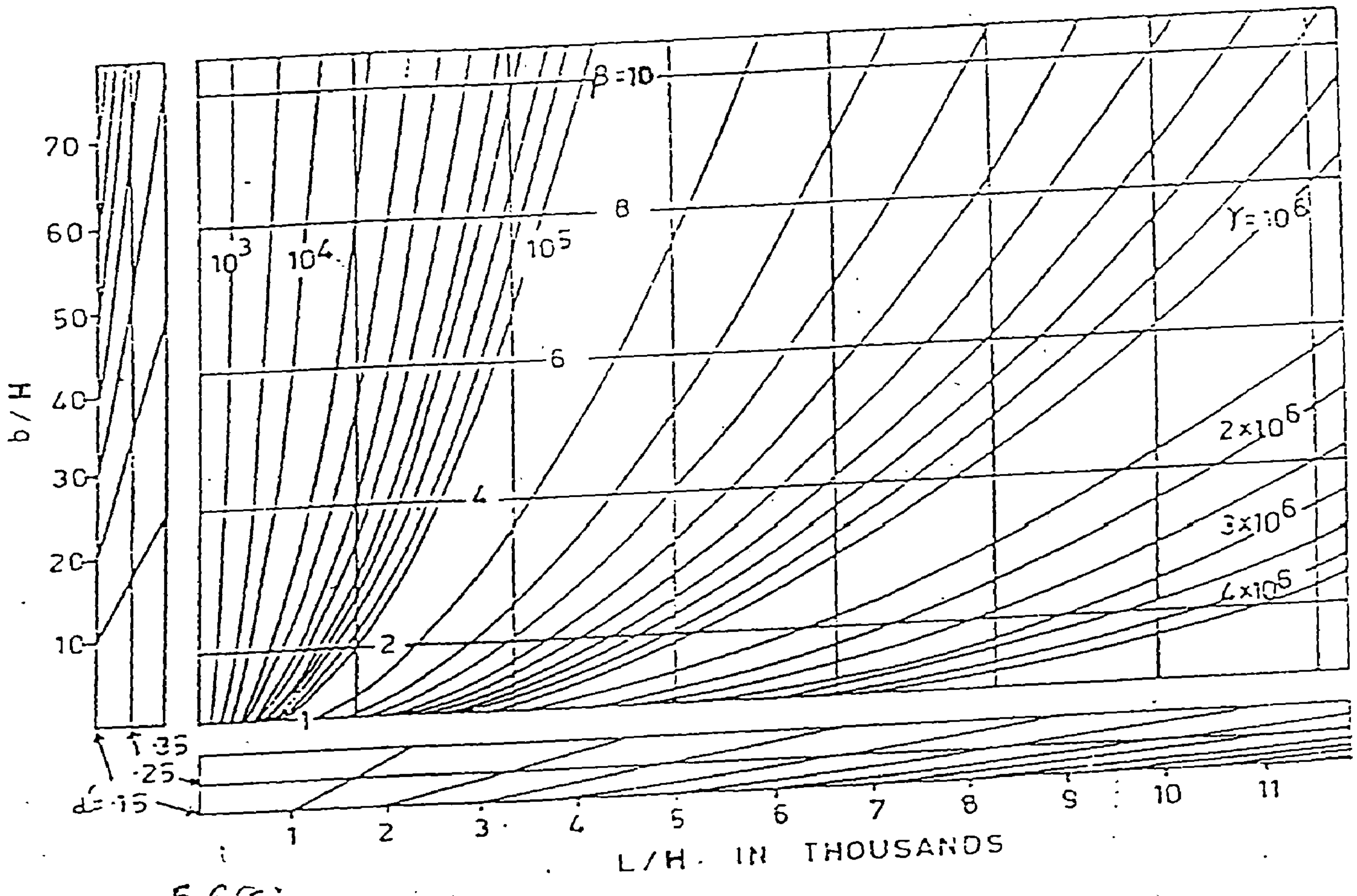
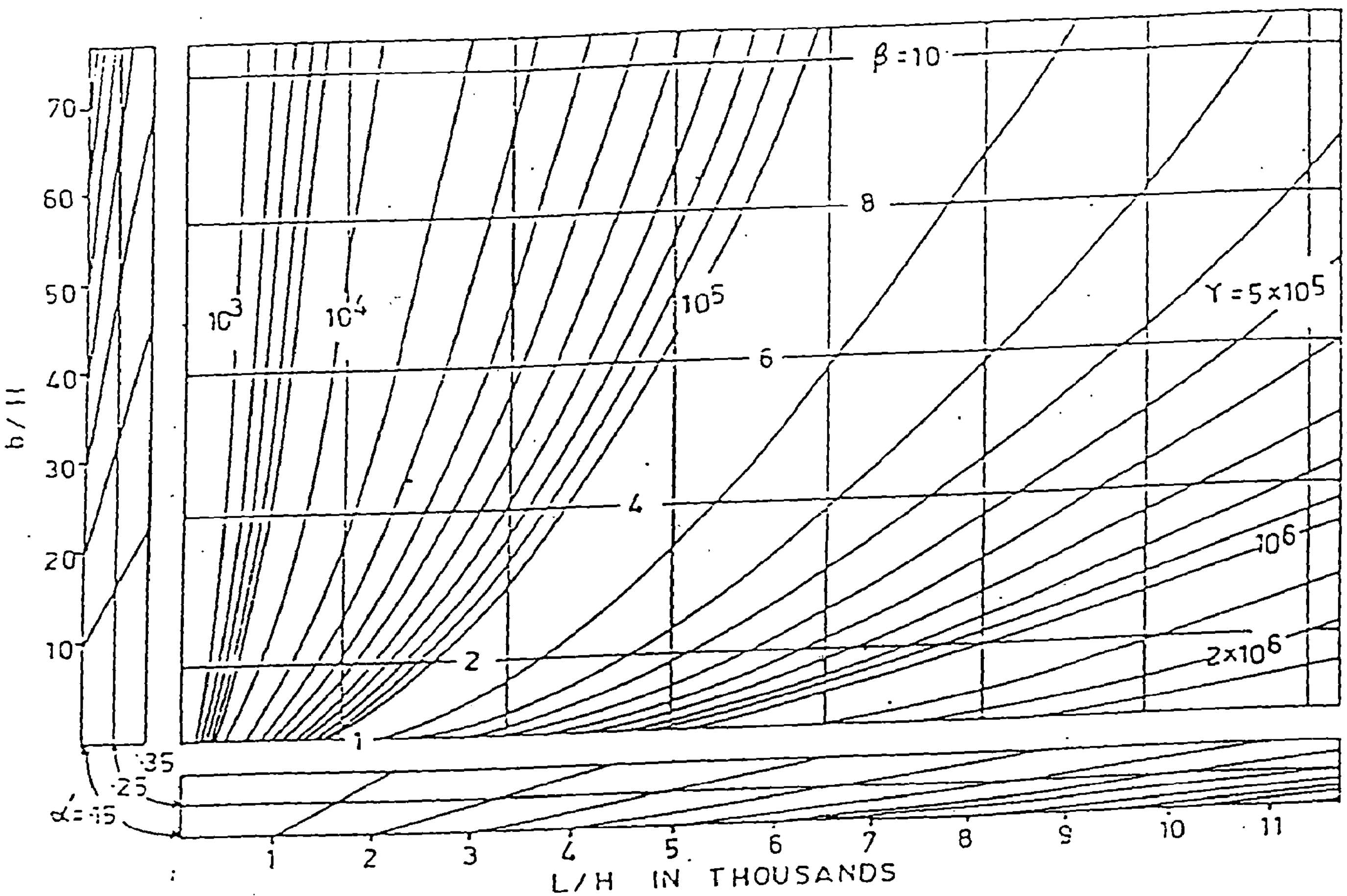


Fig. 5.6(a) Values of β and γ - Horizontal Drainage



5.6

Fig. 5.6(b) Values of β and γ - Vertical Drainage

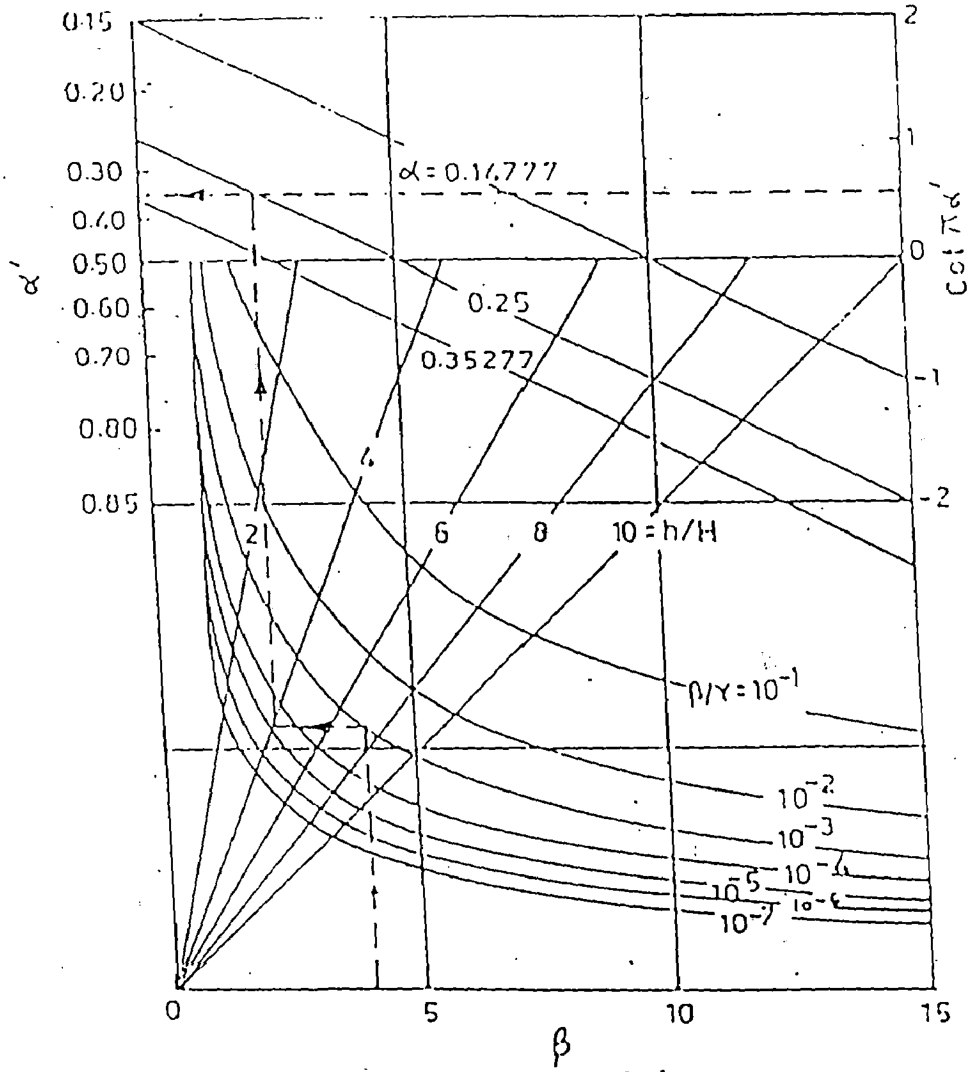


Fig. 5.7 Relation Between α and α'

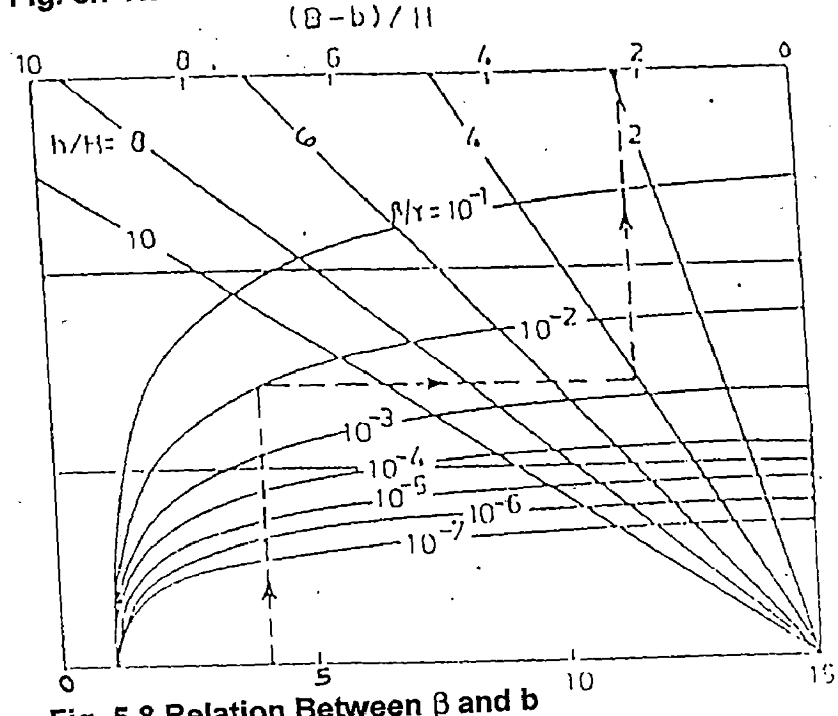


Fig. 5.8 Relation Between β and b

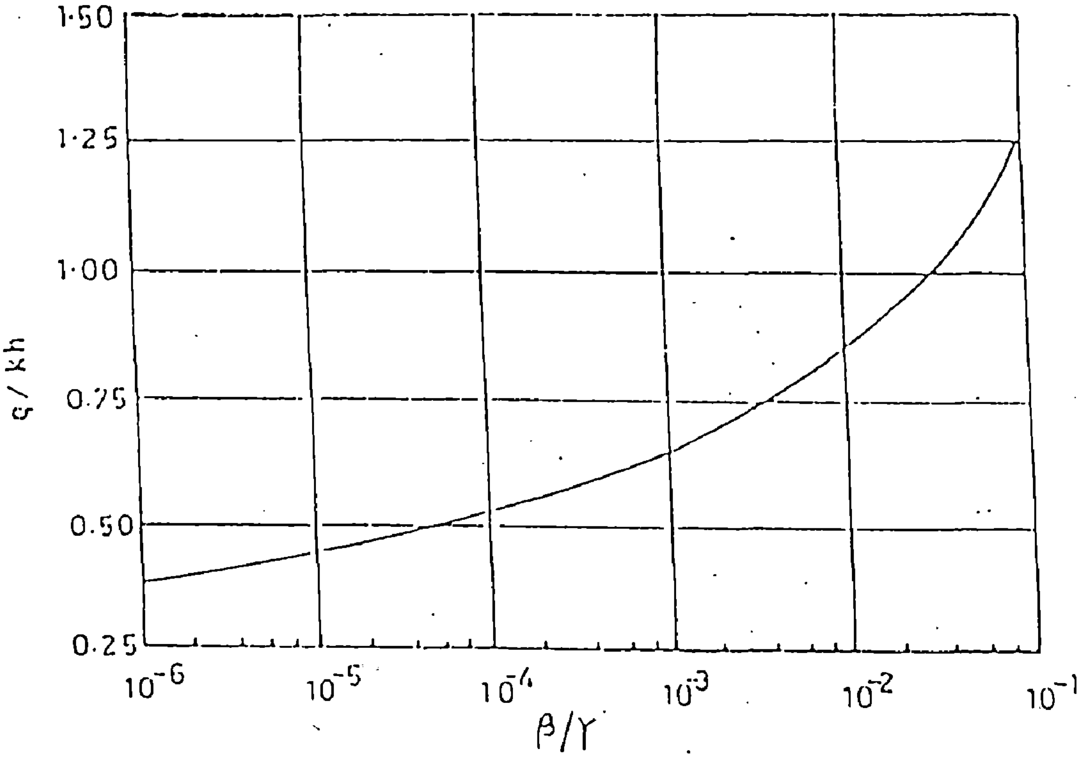


Fig. 5.9 Seepage Discharge q / kh

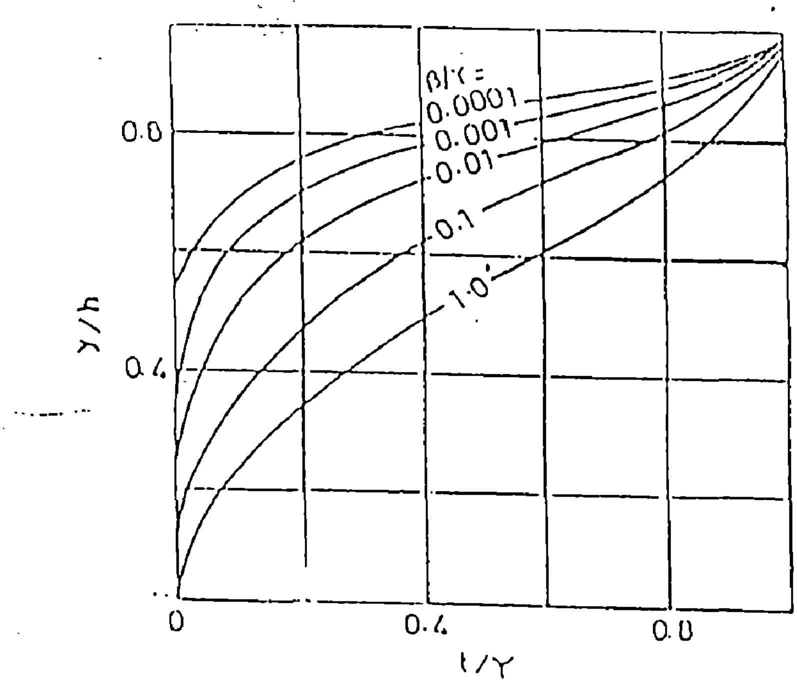


Fig. 5.10 Ordinates of Free Surface

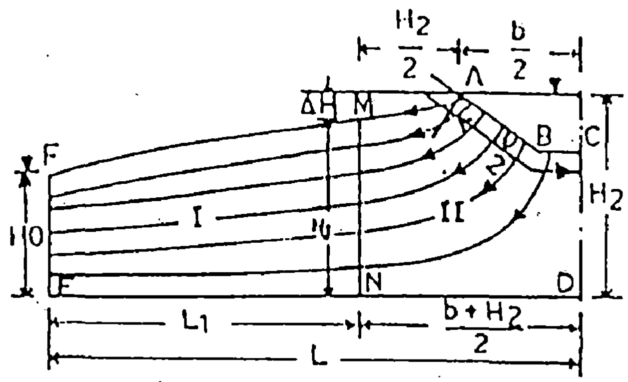


Fig. 5.11 Diagrammatic Representation of the Seepage from a Canal which Overlies a Shallow Water Table

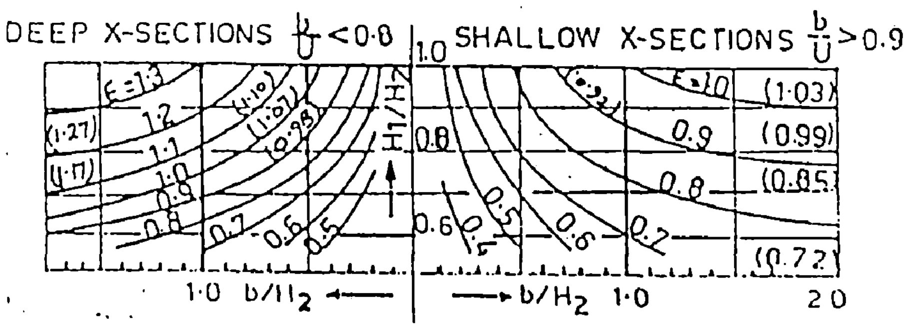


Fig. 5.12 Curve of Constant E as Calculated from the Potential and Streamline Distributions

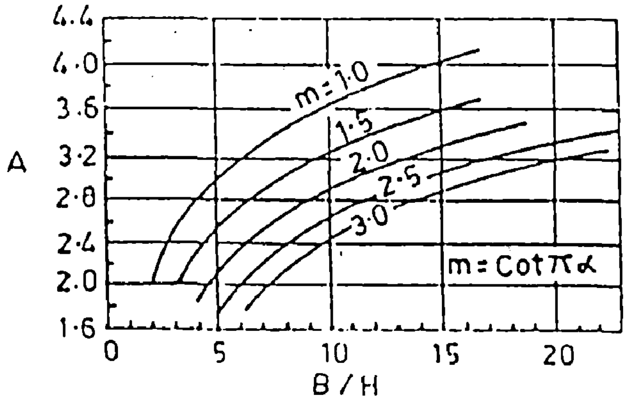


Fig. 5.13 Curve B/H V/S A

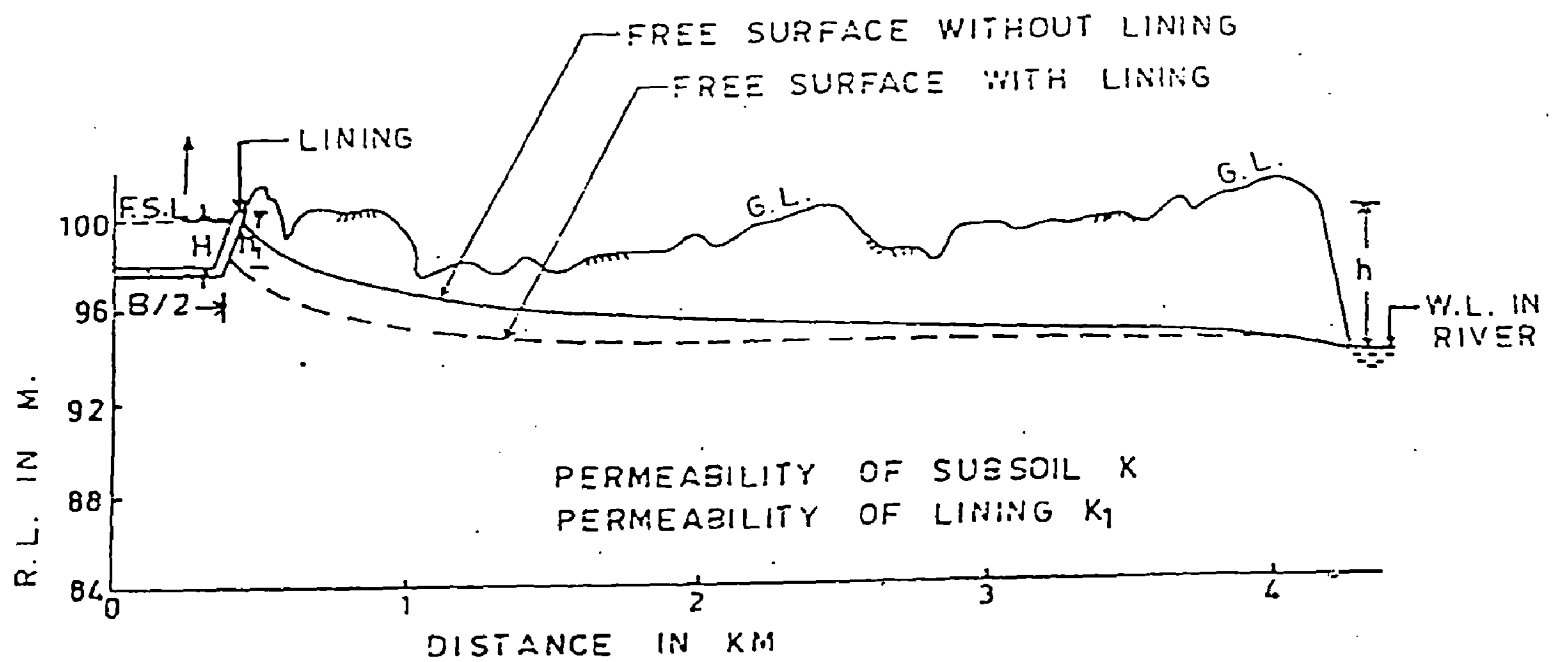


Fig. 5.14 Effect of Lining in Free Surface

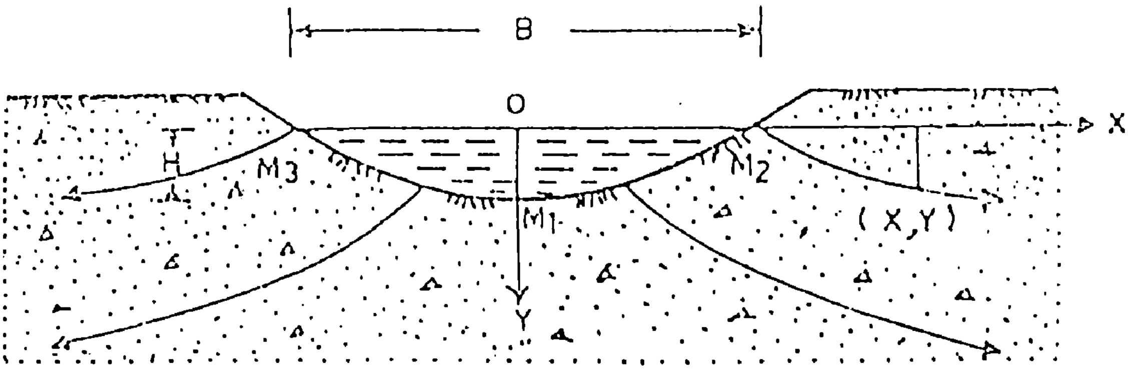
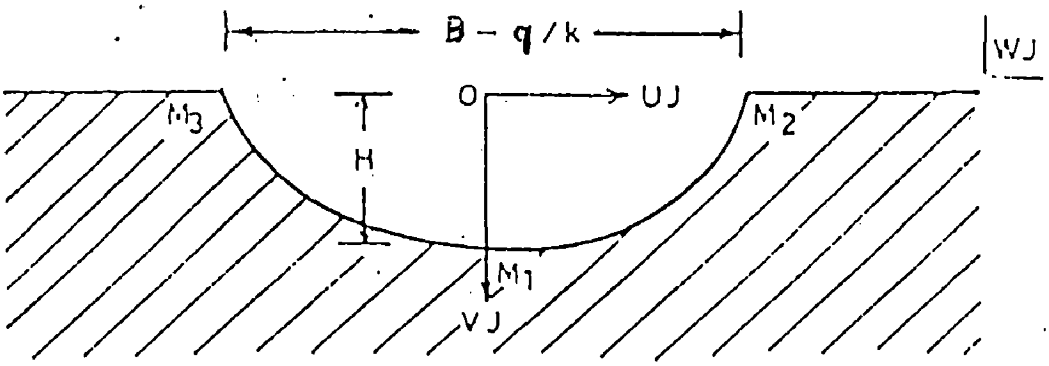


Fig. 5.15(a) Pond with Literally Spreading Seepage



$$UJ = X + \frac{U}{K} \quad \text{AND} \quad VJ = Y - \frac{V}{K}$$

Fig. 5.15(b) Zhukovsky's Region as a Semiellipse

ESTIMATION OF SEEPAGE LOSSES IN UGC SYSTEM

6.1 GENERAL

The seepage losses which constitute the major part of transmission losses, could be found on measurement from time to time by various methods, and were of the order of 45% of head discharge of the system, from its head up to delivery point to the field including losses on main canal, branch canal, distributary minor channels and water courses carrying water from outlet to the fields.

The distribution of seepage losses in Upper Ganga Canal system can be recorded as follows and these losses represent the normal losses in unlined canal system in alluvial plain in Northern India.

(a)	Losses on main canal	- 11 percent of head discharge
(b)	Losses on branch canal	- 8 percent of head discharge
(c)	Losses on distributory & minors	- 10 percent of head distributory
(d)	Losses on water courses	- 16 percent of head discharge.

The total losses works out to 45 percent of the head discharge of main canal, in the system.

6.2 LOSSES IN MAIN CANAL

In the Upper Ganga Canal during operation at full supply level, the wetted surface for seepage is about 15.13 million square meter, with wetted perimeters ranging from about 73 meter near head to about 30.50 meter at the tail. As the canal has been flowing almost continuously from many years, the ground water conditions in its vicinity are essentially in dynamic equilibrium.

Seepage losses have been estimated by the inflow-outflow method, seepage meter method and tracer technique method in different reaches of the canal by U.P. Irrigation Research Institute, Roorkee since 1980 onward, and are shown in Table 6.1(a), 6.1(b) & 6.1(c). All these observations provide consistent estimates of seepage losses of about 1.5 to 3 cumecs per million square meter of wetted perimeter, equivalent to flow rates of 200 – 225 mm/day. Accepting an average seepage loss rate of 2.1 cumecs / million sq.m. and the total wetted perimeter at F.S.L. for entire U.G.C. main canal of 13.135 million sq. meter, this implies a loss rate of 31.78 cumecs when canal is running full. Expressed as a proportion of the diversion capacity at the head (297 cumecs), this loss represents 10.70% or nearly 11 percent of the diverted water, the conveyance efficiency of main canal is about 90% when running full.

6.3 LOSSES IN BRANCH CANAL

The major branch canals carry water for extended periods flowing for long periods throughout the year. The average seepage loss rate on long reaches of branch canals were estimated to be about 2.40 cumecs / million square meter of the wetted perimeter. The total wetted surface of all major branch canals at

F.S.L. is 9.9225 million sq. meter which gives an estimated seepage loss about 17.62 cumecs, when all the branches are running. Losses for (the Anupshahr branch an the Mat-Hathras) combined branch system are nearly 5.9% of the discharge of main canal head. Seepage test results of different branch canals are shown in Table 6.2.

6.4 LOSSES IN DISTRIBUTORIES AND MINORS

Total length of distributories and minors of U.G.C. system is about 5384 km and those total wetted surface is about 45.764 million sq. m. The seepage rate on distributaries and minors is believed to be average about 1.20 cumecs million/sq m. The seepage losses in distributaries and minors would average about 10.7 percent of the head discharge of main canal. The seepage loss observation on distributaries and minors of U.G.C. was done by U.P. Irrigation Research Institute, Roorkee from 1980 to till date are tabulated in Table 6.3(a), 6.3(b).

6.5 LOSSES IN WATER COURSES:

Seepage losses have been estimated by the U. P. Irrigation Depth., under modernization project of Upper Ganga Canal during 1989 to 1991. The selection of representative outlets, stratified sampling procedure was adopted for these studies, for different conation of command area on the following basis:

(i) Three outlets in each of the head, middle and tail reaches of main distributaries.

(ii) One outlet each in head, middle and tail reaches of each of the minors of distributaries.

Thus on Bulandshahr Distributary, 33 outlets were selected which was about 9% of total outlet i.e. 369, similarly on Harduaganj Distributary.

45 no. outlets were selected out of 439 outlets that is about 10% of total outlets.

The average percentage of seepage losses in 24 hours on unlined water courses during Kharif and Rabi on Bulandshahr distributary system was to be of in the order of 28% of outlet head discharge.

The average percentage losses in unlined water courses Harduaganj distributary system during Kharif and Rabi have been assessed as 30% of outlet head discharge.

Effect of soil type on seepage losses in unlined watercourses. According to the study on both distributary there is no effective role in seepage due to the following reasons.

(i) There is very minors variation in the type of soils, (predominant soils are loam or silly loams) of different grain size. Thus there is minor variation in their permeability in the command.

(ii) The fine canal silt flowing with water gets deposited due to low velocity on the inner section / surface of water courses and plays very effective role in rendering the inner surface of water courses of low permeability in comparatively more permeable soils.

(iii) The variation in losses is more dependant on the quality of maintenance and repair of water courses.

Source: Study report on evaluation of agricultural performance in command of Bulandshar & Harduaganj distributary system, vol. I, Nov. 1991.

An another study were made on Janjokhar minor of Dabthua Distributary of U. G. C. system during 1977 to 1983.

On the basis of above study in the head reaches of different water courses, it was found that the seepage rate varied from 4 cumecs / million sq. m. to 7 cumecs / million sq. m.

Source: Paper on design of field channel on farm development by K. R. Thiruvenkataswamy.

A field study have been done by U. P. I.R.I., Roorkee to observe the seepage losses from unlined water courses constructed on compacted embankment in clayey soil (having 80% fine below 75 microns) is found in order of 1.904 cumecs / M. sq. m., and in sand mixed clayey soil is 2.483 cumecs / M. sq. m.

The figures showing the cumulative drop of water level v/s time and rate of seepage v/s time for both type of soil is enclosed in fig. No. 6(a) and 6(b), a detail of seepage rate in both type of soil is shown in Table 6.4(a) and 6.4(b).

The comparative study of seepage losses on mechanically compacted and manually compacted watercourses were also made under U.N.D.P. Project by U.P. I.R.I. Roorkee. The rate of seepage loss was observed at the end of each week in both the watercourses. The results indicate that the rate of seepage loss is inversely proportional to the running period. The seepage loss observed in these watercourses are given in Table 6.4(c).

Source: U.P, I.R.I., Roorkee, UNDP Project IND/84/006 Oct.1986 and April 1987.

The evaluation of modernized watercourses in Pilot Projects of Upper Ganga canal modernization project in U.P. observation of seepage loss in 24 numbers unlined watercourses in kharif and 20 nos. in rabi on Bulandshahr Distributory System. The average percentage seepage losses in unlined water courses during kharif and rabi were found 28 percent of head discharge.

On Harduaganj Distributory System, the average losses in unlined watercourses during kharif have been observed as 32 percent and during rabi as 28 percent.

The variation in losses on unlined watercourses on a particular channel in the same area, normally depends on the quality of maintenance of watercourses, culverts and other structures and water management by farmers.

Also the percentage seepage losses on both distributary systems an unlined watercourses were found higher during wet kharif period than during hot weather rabi. This may be due to slake demand and wastage of water.

6.6 IDENTIFICATION OF REACHES FOR ECONOMICAL SAVING OF LOSSES

The canal data of Upper Ganga Canal system were collected from irrigation department UP and the efforts have been made to identify the suitable reaches where the losses can be curtailed substantially at economical cost and by measure which can be practically implemented in the system.

6.6.1 Main Canal

Suitable reaches in main canal are identified and the value of seepage losses in cumecs/km and cusecs/km has been tabulated in Table 6.5.

6.6.2 Branch Canal

There are four main branch canal in the U.G.C. system out of which three branch canals i.e. Deoband branch, Anupshahr branch and Mat branch are selected for study, the best suitable reaches in each branch canal has been identified the seepage loss in comecs/km and cusecs/km has been calculated in branch wise and tabulated in Table 6.6, 6.7 and 6.8 respectively.

6.6.3 Distributaries and Minors

There are 115 major distributaries in the U.G.C. command out of which two distributaries from main canal i.e. left main distributary and right Mohammadpur distributary and 12 distributious from Anupshahr branch system, and few minors are selected for study and suitable filling reaches are specified for which seepage losses in cumecs/km. and cusecs/km. Have been estimated and tabulated in table no. 6.9(a), 6.9(b), 6.9(c), 6.9(d) and table no. 6.10.

The general abstract of seepage losses and cost/unit of seepage losses in each component of U. G. C. have been computed and in closed as table no. 6.11 and 6.12.

Table 6.1 (a)

Observed Seepage Losses in Upper Ganga Main Canal

Name of channel	Chainage in km.	Type of channel and soil	Seepage losses in m^3/sec / M.Sq.M				Ref. If any
			Tracer technique	Ponding method	Inflow out flow	Seepage meter / Conventional Method	
1	2	3	4	5	6	7	8
Upper Ganga Canal System (U.G.C-1981)		**Unlined**					UP IRI TM No. 51-RR (G-8) March 1981
	40.40	Silty clay	0.81				
	42.40	Sandy clay	1.54				
	45.80	Silty clay	1.34				
	159.60	-do-	0.50				
	164.86	-do-	0.67				
	206.00	-do-	1.16				
	212.00	-do-	0.91				
1984	40.40	Sandy clay	0.77				UP IRI TM No. 54-RR (G-15) March 1984
	42.40	Silty clay	1.09				
	45.80	-do-	1.11				
	159.60	sandy,silty, clay	0.58				
	164.80	-do-	0.72				
	206.00	silty clay	0.75				
	212.80	-do-	0.79				
1988	178.62	Sandy, silty clay		-	-	-	TM. No. 59 RR(G-6) 1988-89, RR (G-7)
	Left Bank		1.562				
	Right Bank		1.585				
	185.06	-do-		-	-	-	
	Left Bank		1.570				
	Right Bank		1.610				
	194.72	-do-		-	-	-	
	Left Bank		1.630				
	Right Bank		1.290				
	202.28	-do-		-	-	-	
	Left Bank		1.610				
	Right Bank		1.350				
	210.81	-do-		-	-	-	
	Left Bank		1.610				
	Right Bank		1.780				
	214.67	-do-		-	-	-	
	Left Bank		1.550				
	Right Bank		1.690				
	224.49	-do-		-	-	-	
	Left Bank		1.820				
	Right Bank		1.590				
	236.56	-do-		-	-	-	
	Left Bank		1.460				
	Right Bank		1.630				
1988	0-21.40	Sand, silt, clay	-	-	3.800	-	U.P. I.R.I TM No. 67 RR (G-10)
	40-48.0	-do-	-	-	2.694	2.519	
	128-154.2	-do-	-	-	3.280	-	
	154.2-164.6	-do-	-	-	2.300	-	
	128-164.6	-do-	-	-	2.700	-	
	154.2-164.6	-do-	-	-	2.430	2.412	
	249-267.6	-do-	-	-	2.330	2.603	

Table 6.1 (b)

1989	7.00	Sandy clay		-	-	-	U.P. I.R.I TM No. 60 RR (G-1) & (G-2) 1989-90
	Left Bank		0.711				
	Right Bank		0.715				
	9.00	-do-		-	-	-	
	Left Bank		1.194				
	Right Bank		1.155				
	11.00	-do-		-	-	-	
	Left Bank		0.877				
	Right Bank		0.870				
	13.00	-do-		-	-	-	
	Left Bank		0.470				
	Right Bank		0.567				
	16.00	-do-		-	-	-	
	Left Bank		0.625				
	Right Bank		0.631				
	19.20	-do-		-	-	-	
	Left Bank		0.701				
	Right Bank		0.687				
	21.70	-do-		-	-	-	
	Left Bank		3.636				
	21.90	-do-		-	-	-	
	Left Bank		3.999				
	22.10	-do-		-	-	-	
	Left Bank		4.155				
1990	40.00	Silty clay		-	-	-	U.P. I.R.I TM No. 61 RR (G-3)
	Left Bank		1.780				
	Right Bank		1.880				
	50.50	-do-		-	-	-	
	Left Bank		1.870				
	Right Bank		1.950				
	60.40	-do-		-	-	-	
	Left Bank		2.010				
	Right Bank		2.120				
	69.40	-do-		-	-	-	
	Left Bank		1.980				
	Right Bank		2.100				
1991	2.20 (cutting)			-	-	-	
	Left Bank	Sandy silty	1.970				U.P. I.R.I TM No. 62 RR (G-3) 1991
	Right Bank		1.920				
	7.80(cutting)			-	-	-	
	Left Bank	-do-	1.980				
	Right Bank		1.860				
	12.90(cutting)			-	-	-	
	Left Bank	-do-	1.920				
	Right Bank		1.840				
	19.70(cut+fill)			-	-	-	
	Left Bank	-do-	2.980				
	Right Bank		2.560				
	24.15(filling)			-	-	-	
	Left Bank	-do-	2.500				
	Right Bank		2.300				
	28.00(filling)			-	-	-	
	Left Bank	sandy silt soil	2.100				
	Right Bank		2.300				
	34.45(cut+fill)			-	-	-	
	Left Bank	-do-	2.020				
	Right Bank		1.960				
	41.40 (cut+fill			-	-	-	
	Left Bank	silty clay	2.100				
	Right Bank		1.960				

Table 6.1 (c)

1991	50.50(cut+fill)	Silt soil					U.P. I.R.I
	Left Bank		2.000				TM No. 62
	Right Bank		2.080				RR (G-3)
	60.40(cut+fill)	-do-					5/1991
	Left Bank		1.960				
	Right Bank		2.160				
	70.80(cut+fill)	-do-					
	Left Bank		2.002				
	Right Bank		1.860				
	77.80(cut+fill)	sandy silty soil					
	Left Bank		2.090				
	Right Bank		1.970				
	88.20(cut+fill)	-do-					
	Left Bank		2.080				
	Right Bank		1.960				
	103.0(cut+fill)	-do-					
	Left Bank		2.312				
	Right Bank		1.980				
	115.6(cut+fill)	sandy soil					
	Left Bank		1.960				
	Right Bank		1.980				
	128.0 (cut+fill)	silty soil					
	Left Bank		2.120				
	Right Bank		2.000				
	135.2(cut+fill)	-do-					
	Left Bank		2.020				
	Right Bank		1.960				
	148(cut+fill)	-do-					
	Left Bank		1.980				
	Right Bank		1.900				
	158(cut+fill)	-do-					
	Left Bank		1.980				
	Right Bank		1.940				
1994	40.40	Silty	1.550	-	-	-	U.P. I.R.I
	42.40	Sandy clay	2.176	-	-	-	TM No. 65
	45.80	Silty clay	2.220	-	-	-	RR (G-9)
	40.00-48.00	-do-	-	-	2.894	2.500	
	159.00	-do-	1.160	-	-	-	
	152.2-164.6	-do-	-	-	2.300	2.412	
	164.80	sandy silty	1.434	-	-	-	
	206.00	sticky clay	1.504	-	-	-	
	212.00	silty clay	1.584	-	-	-	
	233.60	sandy clay	1.014	-	-	-	
	248.0-257.6	-do-	-	-	2.330	2.603	
	258.20	-do-	2.732	-	-	-	
	260.40	-do-	2.660	-	-	-	
1995-1999	45.80	Silty clay	1.052	-	-	0.961*	U.P. I.R.I
	206.0	Sandy silty clay	0.905	-	-	0.992*	TM No. 70
	233.6	-do-	0.383	-	-	0.380*	RR (Gw'-9)
	260.4	-do-	1.442	-	-	1.298*	1995-99
							*Numerov's approach

Table 6.2

Observed Seepage Losses in Upper Ganga Canal Network

(Branch Canals)

Name of channel	Chainage in km.	Type of channel and soil	Seepage losses in m^3/sec / M.Sq.M				Ref. If any
			Tracer technique	Ponding method	Inflow out flow	Seepage meter / Conventional Method	
Upper		**Unlined**					Seminar
Ganga							report of
Canal							canal lining
System	2.40	Clay silt	1.767	-	-	-	Nov. 1988
Deoband	6.40	-do-	2.143	-	-	-	IDARO
Br.	8.80	-do-	1.375	-	-	-	Roorkee
(1980-81)	23.50	-do-	1.523	-	-	-	U.P. I.R.I
	24.40	-do-	1.626	--	-	-	TM No. 65
	49.10	-do-	0.880	-	-	-	RR (G-9)
	50.0	-do-	0.846	-	-	-	
	73.70	-do-	1.060	-	-	-	
	6.40	-do-	2.006	-	-	-	
	23.50	-do-	1.529	-	-	-	
1995	73.70	-do-	1.282	-	-	-	TM No. 70
							RR(Gw1-9)
							1995
Anup	3.70-9.97	Sand silt clay	-	-	2.430	1.957	TM No. 65
Shahar Br.	0-123.91	-do-	-	-	2.500	3.32-	RR(G-9)
1981	123.9-tail	-do-	-	-	2.520	5.22*	
	0-32				2.430	-	TM No. 67
	3.80-10				2.430	1.957	RR(G-10)
						1.957	
Mat Br.	53.91-73.38	Clay silt	-	-	1.710	-	TM No. 70
	83.68-95.59	-do-	-	-	1.243	1.536	RR(Gw1-9)
	0-128.74	-do-	-	-	-	2.21-	
	43.8-74.8	-do-	-	-	1.700	3.19*	
	53.80-73.20	-do-	-	-	1.700	-	TM No. 67
	83.20-95.20	-do-	-	-	1.242	-	RR(G-10)
						1.536	
Hathras Br.	0-32.18	Sand silty clay	-	-	1.697	1.697	
	16.09-29.61	-do-	-	-	2.100	-	
	0-74.02	-do-	-	-	-	2.46-	* conventional
	0-32	-do-	-	-	1.340	2.85*	method
	16-29.6	-do-	-	-	2.100	2.054	
						-	

Table 6.3 (a)

Observed Seepage Losses in Upper Ganga Canal Network

(Distributaries and Minors)

Name of channel	Chainage in km.	Type of channel and soil	Seepage losses in m³/sec / M.Sq.M				Ref. If any
			Tracer technique	Ponding method	Inflow out flow	Seepage meter / Conventional Method	
Upper							From seminar
Ganga Canal							report CBI&P
System							Ooty UP I.R.I.
Deoband Br.		**Unlined**					Roorkee
System	Near head	Sand, silt clay	-	1.380	-	-	1980-83
(1980)	-do-	-do-	-	1.080	-	-	
Sidhauli Mr.	-do-	-do-	-	1.980	-	-	
Kulsath Mr.	-do-	-do-	-	0.990	-	-	
Rankandi Mr.	-do-	-do-	-	1.120	-	-	
Tansipur Dy.	-do-	-do-	-	0.640	-	-	
Siadpur Mr.	-do-	-do-	-	1.020	-	-	
Charthawal	-do-	-do-	-	0.990	-	-	
Dy.	-do-	-do-	-	1.590	-	-	
Saloni Mr.	-do-	-do-	-	1.540	-	-	
Gadar Judda							
Mr.	0.06-11.26	Unlined	-	-	1.830	2.06-2.72	
Majhol Mr.	0.36-7.6	Unlined	-	-	-	-	
Tansipur Dy.	Head reach	Unlined	-	1.760	-	-	
1981	-do-	Sand, silt ,clay	-	1.000	-	-	
Bokarkery	-do-	-do-	-	1.000	-	-	
Dy.	-do-	-do-	-	0.640	-	-	
	-do-	-do-	-	1.120	-	-	
Kulsath Mr.	-do-	-do-	-	1.380	-	-	
Gadarguda	-do-	-do-	-	1.590	-	-	
Saloni	-do-	-do-	-	1.880	-	-	
Chahthwal	-do-	-do-	-	1.960	-	-	
Dy.	-do-	-do-	-	3.920	-	-	
Saidpur	Near head	-do-	-	1.960	--	-	
Sadhauli	1.21	-do-	-	-	-	1.50-4.04	
Majhot Mr.	2.012	-do-	-	-	-	3.334	
Dabuthawa	2.816	-do-	-	-	-	4.150	
Dy.	3.621	-do-	-	-	-	2.621	
Rankhandi	3.621-5.23	-do-	-	-	-	1.091	
Mr.	4.426	-do-		-	-	1.207	
Birpur Dy.							
Tansipur Dy.							

Table 6.3 (b)

Upper Ganga Canal System Deoband Br. System (1982)		**Unlined**					U.P. I.R.I TM No. 65 RR (G-9)
Gaderjuda Mr.	Near Head	Sand, silt, clay	-	0.990	-	-	
Majhol Mr.	-do-	-do-	-	1.590	-	-	
Solani Mr.	-do-	-do-	-	1.020	-	-	
Sidhali Mr.	-do-	-do-	-	1.380	-	-	
Kulsath Mr.	-do-	-do-	-	1.080	-	-	
Saidpur Mr.	-do-	-do-	-	1.120	-	-	
1994		**Unlined**					
Guderjuda Mr.	Near Head	Sand, silt, clay	-	0.990	-	-	
Mahhol Mr.	-do-	-do-	-	1.590	-	-	
Saloni Mr.	-do-	-do-	-	1.020	-	-	
Sidhauli Mr.	-do-	-do-	-	1.380	-	-	
Kulsath Mr.	-do-	-do-	-	1.080	-	-	
Tansipur Dy.	-do-	-do-	-	1.960	-	-	
Saidpur Dy.	-do-	-do-	-	1.120	-	-	
Chartawal Dy.	-do-	-do-	-	0.640	-	-	
Anup Shahar Br. System		**Unlined**					
(1980 & 1994)	Head Reach	Sand silt clay	-	2.330	-	-	
U. Churmula Dy.	-do-	-do-	-	2.070	-	-	
L. Churmula Dy.	-do-	-do-	-	2.420	-	-	
Dhirauli Dy.	-do-	-do-	-	2.600	-	-	
L.ParichatgarhDy	-do-	-do-	-	2.780	-	-	
Khanauda Dy.	-do-	-do-	-	2.320	-	-	
Charura Dy.							
Mat Br. System		**Unlined**					
(1982 &1994)	Near Head	Sand, silt, clay	-	1.950	-	-	
Mahaban Dy.	-do-	-do-	-	2.330	-	-	
Khera Mr.	-do-	-do-	-	2.370	-	-	
Kasison Mr.	-do-	-do-	-	1.760	-	-	
Bhalai Mr.	-do-	-do-	-	2.130	-	-	
Surja Mr.	-do-	-do-	-	2.180	-	-	
Dahrua Mr.	-do-	-do-	-	1.080	-	-	
Katela Mr.							
1982		**Unlined**					
Khera Mr.	Near Head	Sand, silt, clay	-	2.330	-	-	
Kasison Mr.	-do-	-do-	-	2.370	-	-	
Bjhalai Mr.	-do-	-do-	-	1.760	-	-	
Surja Mr.	-do-	-do-	-	2.130	-	-	
Dahrua Mr.	-do-	-do-	-	2.180	-	-	
Katela Mr.	-do-	-do-	-	1.080	-	-	
Upper Ganga Canal System BulandshahrDy.		**Unlined**					UP I.R.I TM No. 61 RR (G-3)
1990	4.20	Sand silt	1.530	-	-	-	1990-91
	15.4	-do-	1.550	-	-	-	
	26.0	-do-	1.530	-	-	-	
	36.0	-do-	1.530	-	-	-	
1991	1.35	-do-	1.680	-	-	-	UP I.R.I
	9.6	-do-	1.490	-	-	-	TM No. 62
	15.9	-do-	1.820	-	-	-	RR (G-10) 1992
Harduaganj Dy.		**Unlined**					UP I.R.I
1990	11.60	Sand, silt	1.480	-	-	-	TM No. 61
	20.50	-do-	1.900	-	-	-	RR (G-3)
	24.80	-do-	1.980	-	-	-	1990-91

TABLE 6.4 (a)

Observed seepage losses in Upper Ganga Canal Network

(Water Courses)

Calculation for computing seepage losses from unlined water course (Clayey Soil)

Length of the test reach = 50.0 m **Average water surface width = 0.824 m**

Average bed width = 0.30 m **Average Depth of water = 0.208**

Sl. No.	Time hours	Accumulated time hours	Drop of water level cm.	Evaporation correction cm.	Corrected drop of water level cm.	Water surface width m	Volume lost m^3	Wetted perimeter m	Wetted surface area m^2	Seepage rate cumecs per million square meter of wetted surface area
1	2	3	4	5	6	7	8	9	10	11
1.	0	0	-	-	-	0.824	-	0.970	48.50	-
2.	1	1	1.19	0.02	1.17	0.809	0.473	0.951	47.55	2.763
3.	2	2	0.98	0.02	0.96	0.782	0.375	0.917	45.85	2.772
4.	3	3	0.90	0.02	0.88	0.759	0.334	0.887	44.35	2.092
5.	4	4	0.84	0.02	0.82	0.738	0.303	0.860	43.00	1.957
6.	5	5	0.79	0.02	0.77	0.718	0.276	0.834	41.70	1.839
7.	6	6	0.74	0.02	0.72	0.699	0.252	0.810	40.50	1.728

Average seepage losses after two hours = 1.904 cumecs per million square meter of wetter surface.

TABLE 6.4 (b)

Observed seepage losses in Upper Ganga Canal Network

(Water Courses)

Calculation for computing seepage losses from unlined water course (Sand Mixed Clayey Soil)

Length of the test reach = 50.0 m **Average water surface width = 0.850 m**

Average bed width = 0.30 m **Average Depth of water = 0.240**

Sl. No.	Time hours	Accumulated time hours	Drop of water level cm.	Evaporation correction cm.	Corrected drop of water level cm.	Water surface width m	Volume lost m^3	Wetted perimeter m	Wetted surface area m^2	Seepage rate cumecs per million square meter of wetted surface area
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1.	0	0	-	-	-	0.850	-	1.030	51.50	-
2.	1	1	1.41	0.02	1.39	0.834	0.580	1.009	50.45	3.193
3.	2	2	1.28	0.02	1.26	0.804	0.507	0.969	48.45	2.907
4.	3	3	1.14	0.02	1.12	0.776	0.435	0.932	46.60	2.593
5.	4	4	1.11	0.02	1.09	0.751	0.409	0.899	44.95	2.527
6.	5	5	1.06	0.02	1.01	0.727	0.378	0.866	43.30	2.425
7.	6	6	1.04	0.02	1.02	0.703	0.359	0.835	41.75	2.389

Average seepage losses after two hours = 2.483 cumecs per million square meter of wetter surface.

TABLE 6.4 (c)

Observed seepage losses in Upper Ganga Canal Network

(Water Courses)

Observed seepage losses in water courses with different period of running

(Cumecs per million square meter of wetted surface area)

Time in hours	Seepage losses observed in manually compacted unlined water course					Seepage losses observed in mechanically compacted unlined watercourse				
	(Clavey soil) Period of running					(Clavey soil) Period of running				
	One Week	Two Week	Three Week	Four Week	Six Week	One Week	Two Week	Three Week	Four Week	Six Week
1.	2.763	2.139	1.508	1.072	0.980	2.143	1.368	1.234	0.855	0.806
2.	2.272	2.031	1.391	1.067	0.978	2.032	1.325	1.148	0.828	0.792
3.	2.992	1.990	1.203	0.990	0.876	1.995	1.215	1.036	0.812	0.784
4.	1.957	1.529	1.130	0.950	0.840	1.932	1.176	1.061	0.795	0.706
5.	1.639	1.496	1.161	0.948	0.823	1.815	1.162	0.996	0.771	0.663
6.	1.726	1.435	1.124	0.947	0.815	1.750	1.124	0.976	0.749	0.637
7.	-	1.409	1.111	0.943	0.805	1.710	1.111	0.934	0.745	0.619
8.	-	1.400	1.111	0.943	0.711	1.693	1.116	0.934	0.695	0.613
Average	**1.904**	**1.544**	**1.143**	**0.953**	**0.812**	**1.816**	**1.151**	**0.990**	**0.761**	**0.670**

Average seepage losses after two hours during observation period.

TABLE NO. 6.5

STEMATION OF SEEPAGE LOSSES IN U. G. C. (MAIN CANAL)

Name of channel	Discharge	Detail of reach	Length of reach	Wetted perimeter	Area of wetted perimeter in	Observed rate of seepage	Total loss	Losses in		Remark
	Cumecs	KM.	Meter	Meter	SQ. M.	M^3/sec./M sq.m	Cumecs	Cumecs /KM.	Cusecs /KM.	B / D
Main canal	274.51	37.0 - 50.50	13500	78.88	1064880	2.00	2.129	0.157	5.57	67.16/3.44
	251.87	74.8 - 93.30	18500	70.77	1309245	2.03	2.657	0.143	5.07	60.96/3.47
	140.55	93.3 - 124.8	31500	58.60	1845900	2.146	3.961	0.125	4.44	49.98/3.05
		124.8 - 128.6	3800	54.07	205466	2.1	0.43	0.113	4.00	44.80/3.28
		128.6 - 135.80	7200	60	432000	2.1	0.90	0.126	4.40	57.90 /2.90

Average seepage losses = 0.137 cumecs per km. or 4.83 cusecs per km.

TABLE NO. 6.6

ESTIMATION OF SEEPAGE LOSSES IN U. G. C. (DEOBAND BRANCH)

Name of channel	Discharge	Detail of reach	Length of reach	Wetted perimeter	Area of wetted perimeter in	Observed rate of seepage	Total loss	Losses in		Remark
	Cumecs	KM.	Meter	Meter	SQ. M.	M^3/sec./M sq.m	Cumecs	Cumecs /KM.	Cusecs /KM.	B / D
Deoband Branch	21.238	6.30 - 9.70	3400	21.33	72528	2.143	0.155	0.045	1.609	16.76/1.61
		18.70 - 21.10	2400	18.282	43877	1.529	0.067	0.028	0.985	13.71/1.61
		24.95 - 26	1050	16.37	17191	1.626	0.028	0.026	0.940	12.19/1.47
	12.318	36.00 - 42.00	6000	15.416	92500	0.88	0.081	0.013	0.476	11.58/1.35
	10.052	47.00 - 49.00	2000	13.37	26744	0.88	0.023	0.012	0.415	9.75/1.28
	1.981	73.35 - 76.45	3100	5.89	18266	1.06	0.019	0.006	0.22	3.95/0.68
	0.509	80.00 - 82.80	2800	3.67	10284	1.282	0.013	0.004	0.166	2.4/0.45
							Average	0.019	0.687	

TABLE NO. 6.7

ESTIMATION OF SEEPAGE LOSSES IN U. G. C. (ANUPSHAHR BRANCH)

Name of channel	Discharge	Detail of reach	Length of reach	Wetted perimeter	Area of wetted perimeter in	Observed rate of seepage	Total loss	Losses in		Remark
	Cumecs	KM.	Meter	Meter	SQ. M.	M^3/sec./M sq.m	Cumecs	Cumecs /KM.	Cusecs /KM.	B / D
Anupshahr Branch	44.29	0-3.50	3500	30.425	106487	2.43	0.258	0.0739	2.609	25.9/1.61
		3.50-12.00	8500	30.425	258612	2.43	0.628	0.0739	2.609	25.9/1.61
		12.00-24.00	12000	30.425	365100	2.43	0.887	0.0739	2.609	25.9/1.61
		24.00-31.50	7500	27.89	209175	2.43	0.508	0.0677	2.39	24.38/1.64
		31.50-36.00	4500	26.86	120870	2.42	0.293	0.0652	2.30	24.38/1.64
		36.00-39.00	3000	26.86	80580	2.5	0.201	0.067	2.366	24.38/1.64
		39.00-56.00	17000	26.435	449395	2.43	1.092	0.064	2.26	22.86/1.35
		56.00-261.5	5500	26.01	143055	2.5	0.357	0.065	2.295	22.86/1.09
		61.50-63.50	2000	26.01	52020	2.43	0.126	0.063	2.224	21.33/1.21
		63.50-81.00	17500	25.4	444500	2.5	1.111	0.0635	2.242	21.33/1.3
		81.00-99.00	18000	24.79	446220	2.43	1.084	0.0600	2.118	18.28/1.4
		19.99-113.50	14500	20.75	300875	2.5	0.752	0.051	1.80	15.24/1.3
		113.50-126.00	12500	18.97	237125	2.43	0.576	0.046	1.624	15.24/1.3
		126.00-131.94	5940	18.97	112682	2.52	0.284	0.478	1.688	15.24/1.3

Average seepage losses = 0.0629 cumecs per km or 2.222 cusec per km.

TABLE NO. 6.8

ESTIMATION OF SEEPAGE LOSSES IN U. G. C. (MAT BRANCH)

Name of channel	Discharge	Detail of reach	Length of reach	Wetted perimeter	Area of wetted perimeter in	Observed rate of seepage	Total loss	Losses in		Remark
	Cumecs	KM.	Meter	Meter	SQ. M.	M^3/sec./M sq.m	Cumecs	Cumecs /KM.	Cusecs /KM.	B / D
Mat Branch	46.196	44.60 - 47.00	2400	31.00	74400	1.71	0.127	0.052	1.86	25.9/1.92
		47.00 - 48.80 C								
		48.80 - 52.00	3200	31.27	100064	1.71	0.171	0.053	1.88	25.9/1.90
		52.00 - 54.70 C								
		54.70 - 58.30	3600	31.27	112572	1.71	0.192	0.053	1.88	25.9/1.90
		58.30 - 60.00 C								
		60.00 - 64.00	4000	30.4	121600	1.71	0.207	0.051	1.82	25.9/1.90
		64.00 - 70.80 C								
		70.80 - 75.60	4800	29.50	141600	1.71	0.242	0.05	1.78	24.4/1.80
		75.60 - 84.30	8700	19.62	170729	1.71	0.291	0.033	1.18	15.24/1.55
		84.30 - 86.00 C								
		86.00 - 92.00	6000	19.11	114660	1.242	0.142	0.023	0.835	15.24/1.37
		92.00 - 99.80 C								
		99.80 - 104.00	4200	20.00	84000	1.242	0.104	0.024	0.874	15.84/1.47
		104.00 - 106.4 C								
		106.4 - 111.30	4900	20	98000	2.7	0.264	0.053	1.90	15.84/1.47
		111.30 - 113.40 C								
		113.40 - 119.00	5600	17.5	98000	2.7	0.264	0.047	1.66	13.4/1.46
		119.0 - 122.6 C								
		122.6 - 128.80	6200	13.62	84444	2.7	0.227	0.036	1.29	9.75/1.37

Average seepage losses = 0.0431 cumecs per km or 1.524 cusec per km.

TABLE NO. 6.9 (A)

ESTIMATION OF SEEPAGE LOSSES IN U. G. C. (DITRIBUTARIES)

Name of channel	Discharge	Detail of reach	Length of reach	Wetted perimeter	Area of wetted perimeter in	Observed rate of seepage	Total loss	Losses in		Remark
	Cumecs	KM.	Meter	Meter	SQ. M.	M^3/sec./M sq.m	Cumecs	Cumecs /KM.	Cusecs /KM.	B / D
1. LEFT MAIN	3.29	0 - 7.50	7500	9.27	69525	1.5	0.104	0.014	0.49	6.7/0.91
DY. OF	2.60	7.50 - 8.85	1350	8.2	11075	1.5	0.0166	0.123	0.434	5.8/0.85
U. G. C.	2.05	8.85 - 13.5	4650	7.35	34177	1.5	0.0512	0.011	0.389	5.2/0.76
(29.70KM)	1.845	13.50 - 17.70	4200	6.90	28980	1.5	0.0437	0.01	0.365	4.72/0.76
	1.67	17.70 - 24.00	6300	6.66	41988	1.5	0.0629	0.0099	0.353	4.6/0.73
	1.37	24.00 - 29.70	5700	6.00	34200	1.5	0.0513	0.009	0.317	4.1/0.70
2. Rt. Md. PUR	5.377	6.50 - 23.134	16634	10.69	109160	1.5	0.163	0.0098	0.347	7.30/1.20
DY.										
(23.134KM)										
3. SALARPUR	4.99	11.00 - 12.20	1200	5.945	7134	2.33	0.044	0.011	0.386	
DY.		15.60 - 17.50	1900	4.38	8322	2.33				
(20.18KM)		18.70 19.60	900	3.78	3402	2.33				

TABLE NO. 6.9 (B)

ESTIMATION OF SEEPAGE LOSSES IN U. G. C. (DITRIBUTARIES)

Name of channel	Discharge	Detail of reach	Length of reach	Wetted perimeter	Area of wetted perimeter in	Observed rate of seepage	Total loss	Losses in		Remark
	Cumecs	KM.	Meter	Meter	SQ. M.	M^3/sec./M sq.m	Cumecs	Cumecs /KM.	Cusecs /KM.	B / D
4. UPPER CHURIALA DY. (15.00KM)	1.49	2.00 - 4.50	2500	4.98	12450	2.33	0.072	0.0083	0.292	
		8.00 - 9.70	1700	3.50	5950	2.33				
		10.50 - 15.00	4500	2.81	12645	2.33				
5. LOWER CHURILA DY. (17,90KM)	1.42	2.80 - 3.60	800	5.68	4544	2.07	0.053	0.0079	0.279	
		5.80 - 7.60	1800	4.40	7920					
		9.70 - 11.30	3100	3.80	11780					
		16.90 - 17.90	1000	1.40	1400					
6. RIGHT AKBARPUR DY. (31.72KM)	4.14	0.60 - 1.20	600	8.83	5298	2.42	0.076	0.016	0.57	
		1.80 - 3.20	1400	8.63	12082	2.33				
		4.60 - 5.30	700	8.63	6041					
		23.00 - 24.00	1000	4.38	4380					
		27.80 - 29.00	1200	2.91	3492					
7. LEFT AKBARPUR DY. (26.59KM)	3.63	2.00 - 5.00	3300	8.01	26433	2.42	0.076	0.015	0.546	
		15.20 - 15.70	500	6.83	3415					
		25.30 - 25.70	400	4.36	1744					
8. DHIKOLI DY. (11.47KM)	1.07	5.40 - 11.30	5900	2.91	17169	2.42	0.041	0.007	0.248	

TABLE NO. 6.9 (C)

ESTIMATION OF SEEPAGE LOSSES IN U. G. C. (DITRIBUTARIES)

Name of channel	Discharge	Detail of reach	Length of reach	Wetted perimeter	Area of wetted perimeter in	Observed rate of seepage	Total loss	Losses in		Remark
	Cumecs	KM.	Meter	Meter	SQ. M.	M^3/sec./M sq.m	Cumecs	Cumecs /KM.	Cusecs /KM.	B / D
9. GARH M. DY. (33.79KM)	3.06	3.60 - 6.40	2800	8.31	23268	2.42	0.063	0.016	0.566	
		18.30 - 18.90	600	4.94	2964					
10. UP. GARH DY.(40.23KM)	6.80	0.0 - 4.20	4200	12.94	54348	2.42	0.222	0.0258	0.911	
		15.3 - 16.1	800	11.06	8848					
		24.70 - 25.70	1000	9.28	9280					
		34.40 - 37.00	2600	7.48	19448					
11. KITHORE DY. (60.43KM)	8.05	4.80 - 5.60	600	14.13	8478	2.42	0.108	0.0216	0.762	
		15.30 - 16.90	1600	12.33	19728					
		28.4 - 29.8	1400	6.86	9604					
		38.60 - 40.00	1400	5.10	7140					
12. L. P. GARH DY. (28.94KM)	1.98	8.20 - 9.10	900	6.23	5607	2.60	0.077	0.0135	0.477	
		16.10 - 20.90	4800	5.06	24288					
13. CHARAURA DY. (22.06KM)	2.15	0.0 - 3.00	3000	8.08	24240	2.32	0.129	0.0126	0.446	
		10.50 - 17.70	7200	4.41	31752					
14. KHANAUDA DY. (19.91KM)	1.38	0.0 - 0.80	800	7.24	5792	2.78	0.046	0.0127	0.451	
		6.80 - 8.00	1200	4.30	5160					
		14.50	16.10	1600	3.50	5600				

Average seepage losses in distributaries = 0.01168 cumec / km or 0.412 cusec /km.

TABLE NO. 6.9 (D)

ESTIMATION OF SEEPAGE LOSSES IN U. G. C. (DITRIBUTARIES)

Name of channel	Discharge	Detail of reach	Length of reach	Wetted perimeter	Area of wetted perimeter in	Observed rate of seepage	Total loss	Losses in		Remark
	Cumecs	KM.	Meter	Meter	SQ. M.	M^3/sec./M sq.m	Cumecs	Cumecs /KM.	Cusecs /KM.	B / D
15. RT. BHOLA DY. (18.30KM)	3.93	0 - 5.00	5000	8.95	44750	1.22	0.0545	0.01	0.385	5.5/1.22
		5.0 - 7.00	2000	8.61	17220	1.22	0.021	0.01	0.385	5.5/1.1
		7.0 - 18.30	11300	7.32	82716	1.22	0.1009	0.0089	0.315	4.5/1.0
							Average	0.0096	0.34	
16. Lt. .SALAWA DY. (33.20KM)	6.31	0.0 - 1.60	1600	12.448	19917	2.42	0.048	0.03	1.06	9.45/1.06
		1.60 - 6.40	4800	9.398	45110	2.42	0.109	0.022	0.80	6.40/1.06
		6.40 - 11.20	4800	6.833	32798	2.42	0.079	0.016	0.583	4.26/0.91
		11.20 - 17.60	6400	6.449	41273	2.42	0.099	0.015	0.551	3.96/0.88
		17.60 - 27.20	9600	5.454	52358	2.42	0.126	0.013	0.466	3.65/0.85
		27.20 - 29.60	2400	5.284	12681	2.42	0.03	0.012	0.451	3.05/0.79
		29.60 - 33.20	3600	2.472	8899	2.42	0.021	0.006	0.211	1.7/0.45
							Average	0.015	0.544	
17. Rt. JOLLY DY. (47.87KM)	6.509	0.0 - 27.35	27350	9.92	271298	2.40	0.651	0.023	0.84	5.79/1.46
		27.35 - 31.78	4430	8.22	36452	2.40	0.087	0.019	0.697	5.4/1.0
		31.78 - 36.60	4820	7.487	36087	2.40	0.086	0.018	0.634	4.8/0.95
		36.60 - 40.20	3600	6.946	25006	2.40	0.06	0.017	0.588	4.8/0.93
		40.20 - 47.87	7670	6.728	51647	2.40	0.123	0.016	0.57	3.9/1.0
							Average	0.021	0.742	

TABLE NO. 6.10

ESTIMATION OF SEEPAGE LOSSES IN U. G. C. (MINORS)

Name of channel	Discharge	Detail of reach	Length of reach	Wetted perimeter	Area of wetted perimeter in	Observed rate of seepage	Total loss	Losses in		Remark
	Cumecs	KM.	Meter	Meter	SQ. M.	M^3/sec./M sq.m	Cumecs	Cumecs /KM.	Cusecs /KM.	B / D
1. FULAT MR.	0.622	0.0 - 8.44	8440	4.16	35155	1.20	0.042	0.005	0.176	2.44/0.61
		8.44 - 11.90	1.69	1.98	6850	1.20	0.008	0.0048	0.171	0.91/0.38
2. GYAS PUR MR. (9.99KM)	0.792	0.0 - 5.60	5600	3.78	21189	1.20	0.025	0.0045	0.160	1.21/0.91
		5.60 - 9.99	4.39	2.60	11401	1.20	0.013	0.0031	0.110	0.9/0.60
3. SULTAN PUR MR. (7.50KM)	0.70	0.0 - 1.20	1200	3.89	4650	1.20	0.0056	0.0046	0.164	1.98/0.67
		1.20 - 6.40	5200	3.63	18877	1.20	0.022	0.0043	0.153	1.82/0.64
		6.40 - 7.50	1100	3.32	3652	1.20	0.004	0.0039	0.140	1.68/0.58
4. ROHTA MR. (12.31KM)	0.76	0.0 - 1.6	1600	3.71	5944	1.20	0.0071	0.0044	0.157	1.82/0.67
		1.60 - 5.40	3800	3.11	11818	1.20	0.014	0.0037	0.131	1.22/0.67
		5.40 - 7.20	1800	2.72	9896	1.20	0.011	0.0066	0.233	0.91/0.64
		7.20 - 8.80	1600	2.60	4171	1.20	0.005	0.0031	0.110	0.91/0.60
		8.80 - 12.31	3510	2.38	8333	1.20	0.009	0.0028	0.10	0.91/0.52
5. UJHERA MR. (12.00KM)	0.76	0.0 - 5.47	5470	3.96	21714	1.20	0.026	0.0047	0.168	1.82/0.76
		5.47 - 9.65	4180	3.66	15299	1.20	0.018	0.0043	0.155	1.52/0.76
		9.65 - 12.00	2350	2.91	6855	1.20	0.008	0.0035	0.123	1.22/0.60

Average Losses 0.004 cumecs per km or 0.15 cusec per k

TABLE NO. 6.11

ABSTRACT OF SEEPAGE LOSSES IN U.G.C. SYSTEM

S. NO.	Details	Unit	Main canal	Branch canals	Distributaries and minors	Watercourses
1	2	3	4	5	6	7
1.	Head discharge	Cumecs	297	127	146	215
2.	Length	KM	291.91	490	5384	38990*
3.	Canal running days	Days	357	266	210	210
4.	Rnning days factors	Percentage	100	74	58	58
5.	Wetted perimeter	Meter				
	(i) At head		73.20	30.50	14.50	1.30
	(ii) At tail		30.50	10.00	2.50	1.20
	(iii) Average		51.85	20.25	8.5	1.25
6.	Average wetted area	M. Sq. meter	15.135	9.9225	45.764	48.50
7.	Average rate seepage	Cumecs /M. sq. m	2.10	2.40	1.20	2.48
8.	Total losses	Cumecs	31.78	17.62	31.85	52.32
9.	Losses / Km.	Cumecs / km.	0.108	0.036	0.006	0.0013
10.	Losses in percentage of head discharge	Percentage	10.70	5.90	10.70	17.00
11.	**Over all losses in system**	**44.30 Percentage**				

* As per unit length of watercourse 45.50 meter / ha. of C.C.A. (0.857 M.Ha) and consider 75% length of w/c running during watering

TABLE NO. 6.12
STATEMENT SHWOING THE ECONOMICAL COST OF LINING IN U. G.C. SYSTEM

Name of channel	Discharge in cumecs	Length in km.	Average wetted perimeter /km. (sq. m.)	Av. Rate of losses in cumecs / M. sq. m	Losses/km. In cumecs	Canal running days	Running days factor %	Lining efficiency %	Loses to be saved/ km.	Approx. rate of lining/ sq.m. in Rs.	Cost of lining /km. In lac.	Cost /unit saving of losses in lac.
1	2	3	4	5	6	7	8	9	10	11	12	13
Main canal	297	291.91	51830	2.1	0.10	357	100	75	0.075	200	103.66	1382*
Branch canals	30 - 60	70 - 210	20400	2.40	0.049	310	74	75	0.027	150	30.60	1133
Distrubutries	2.5 - 10	10 -60	7570	1.2	0.009	210	58	75	0.0039	100	7.57	1941
Minors	0.5 - 1.0	7.5 -15	3260	1.2	0.004	210	58	75	0.0017	100	3.26	1917
Watercourses	0.028	0.5 - 1.5	1250	2.48	0.003	210	58	75	0.0013	75	0.94	723

- **If the suitable measure for controlling the losses such as laying clay in the bed and controlling the section to the designed requirement, the cost of saving the losses in the main canal substantially reduced.**

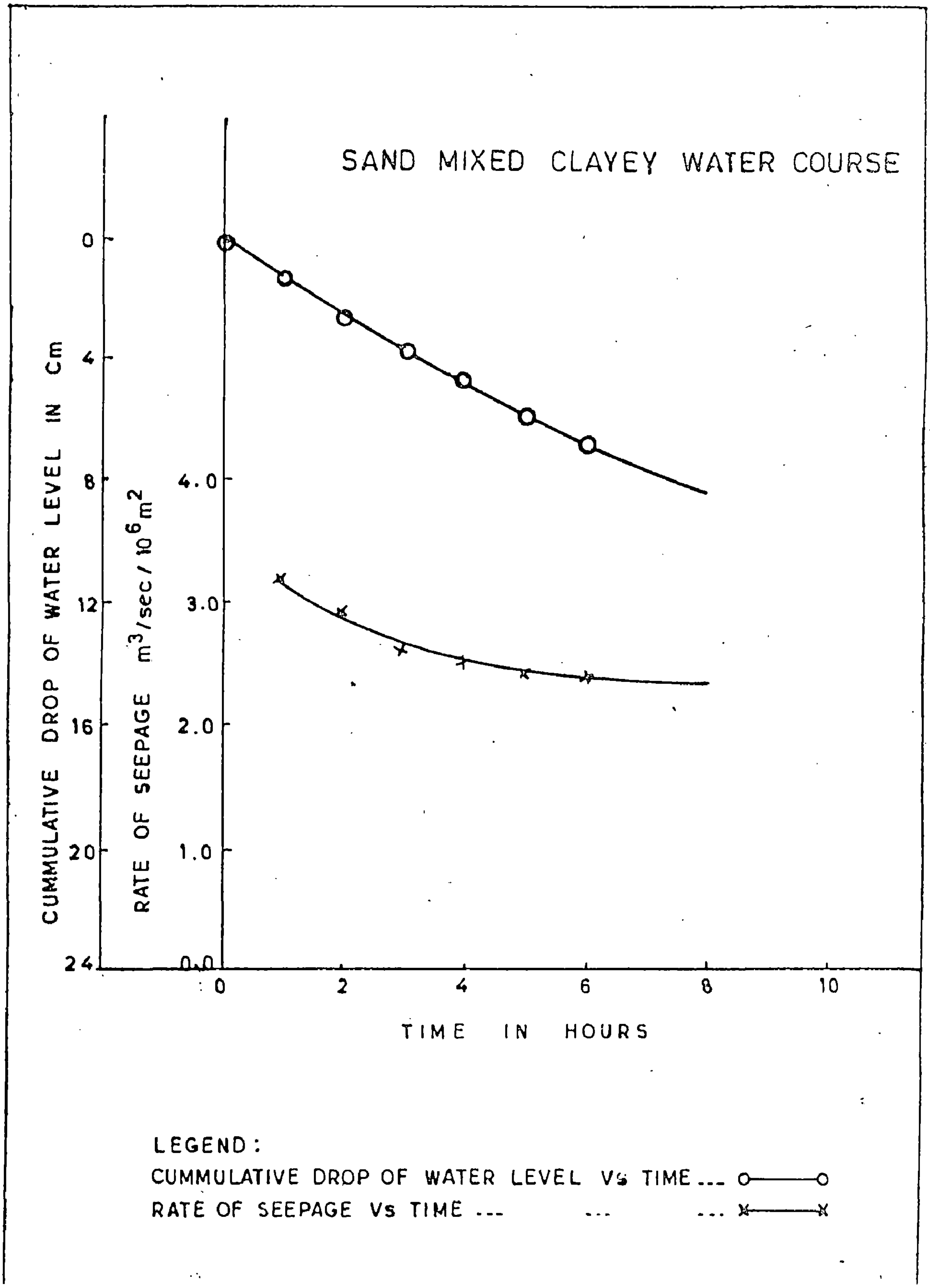


Fig. 6(a) Curve Showing Cumulative Drop of Water Level V/S Time and Rate of Seepage V/S Time in Clayey Soil

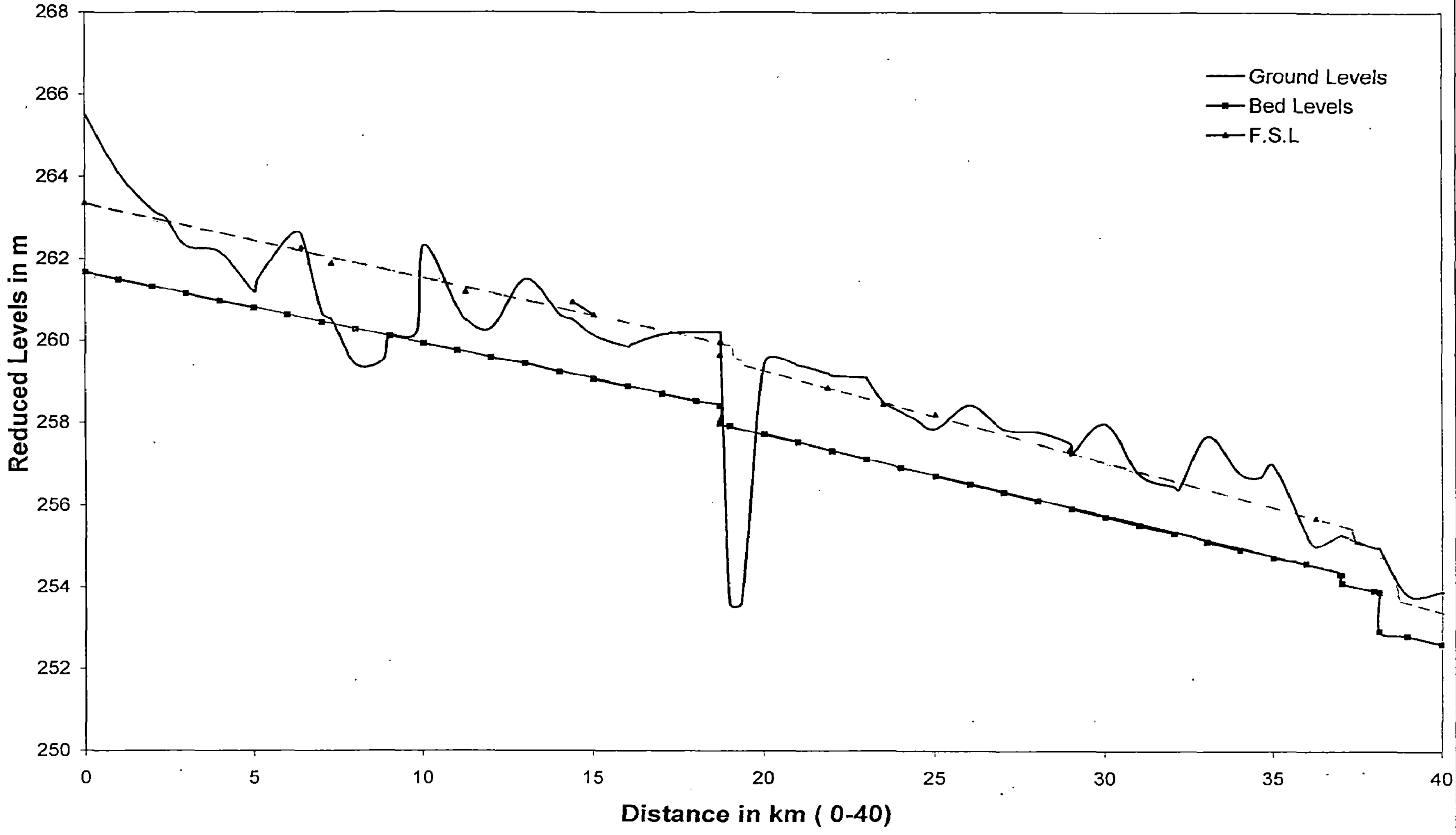


Fig.no. 6.4(a) Deoband Branch

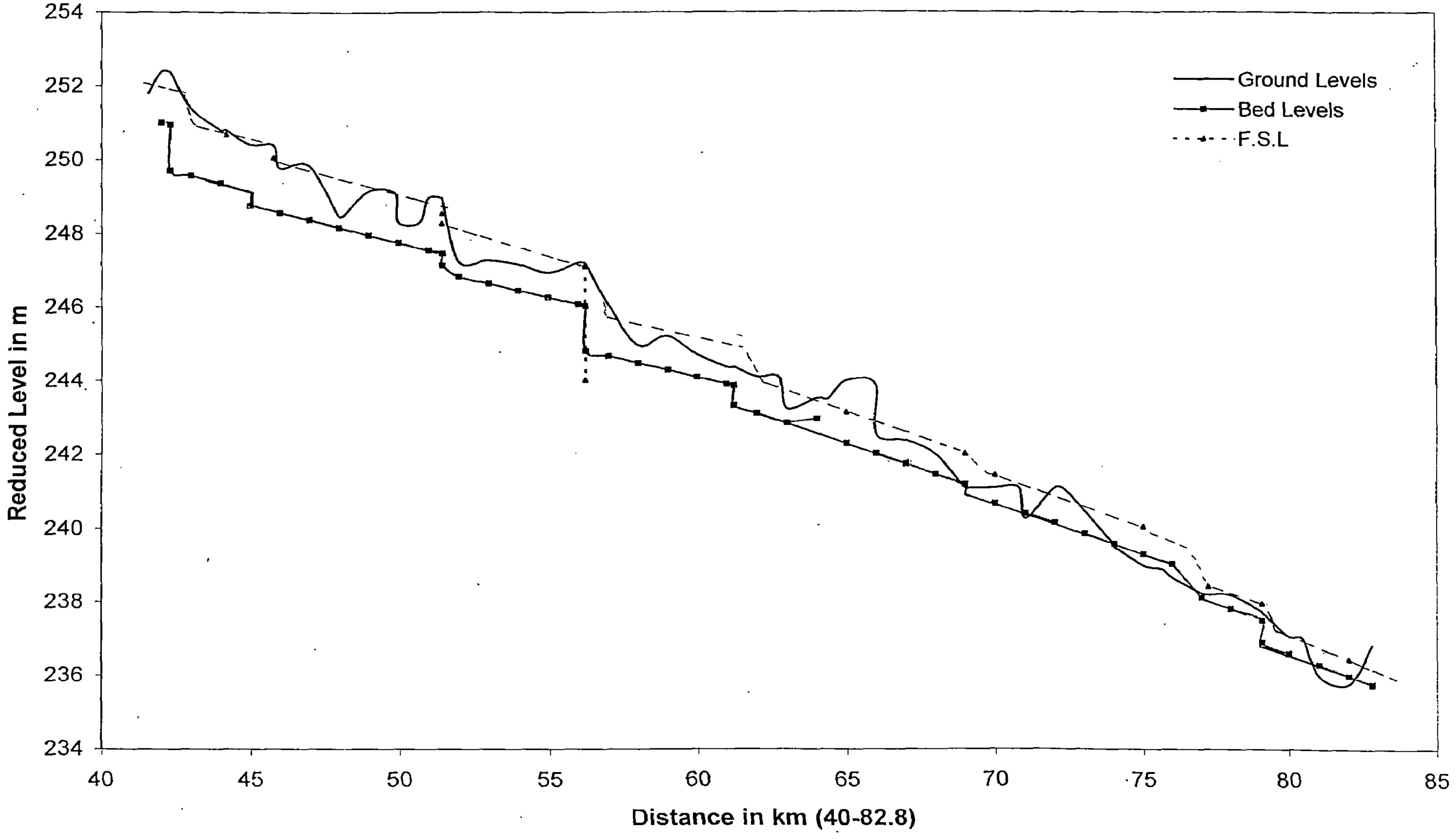


Fig.no. 6.4(b) Deoband Branch

TABLE NO. 6.12
STATEMENT SHWOING THE ECONOMICAL COST OF LINING IN U. G.C. SYSTEM

Name of channel	Discharge in cumecs	Length in km.	Average wetted perimeter /km. (sq. m.)	Av. Rate of losses in cumecs / M. sq. m	Losses/km. In cumecs	Canal running days	Running days factor %	Lining efficiency %	Loses to be saved/ km.	Approx. rate of lining/ sq.m. in Rs.	Cost of lining /km. In lac.	Cost /unit saving of losses in lac.
1	2	3	4	5	6	7	8	9	10	11	12	13
Main canal	297	291.91	51830	2.1	0.10	357	100	75	0.075	200	103.66	1382*
Branch canals	30 - 60	70 - 210	20400	2.40	0.049	310	74	75	0.027	150	30.60	1133
Distrubutries	2.5 - 10	10 -60	7570	1.2	0.009	210	58	75	0.0039	100	7.57	1941
Minors	0.5 - 1.0	7.5 -15	3260	1.2	0.004	210	58	75	0.0017	100	3.26	1917
Watercourses	0.028	0.5 - 1.5	1250	2.48	0.003	210	58	75	0.0013	75	0.94	723

- **If the suitable measure for controlling the losses such as laying clay in the bed and controlling the section to the designed requirement, the cost of saving the losses in the main canal substantially reduced.**

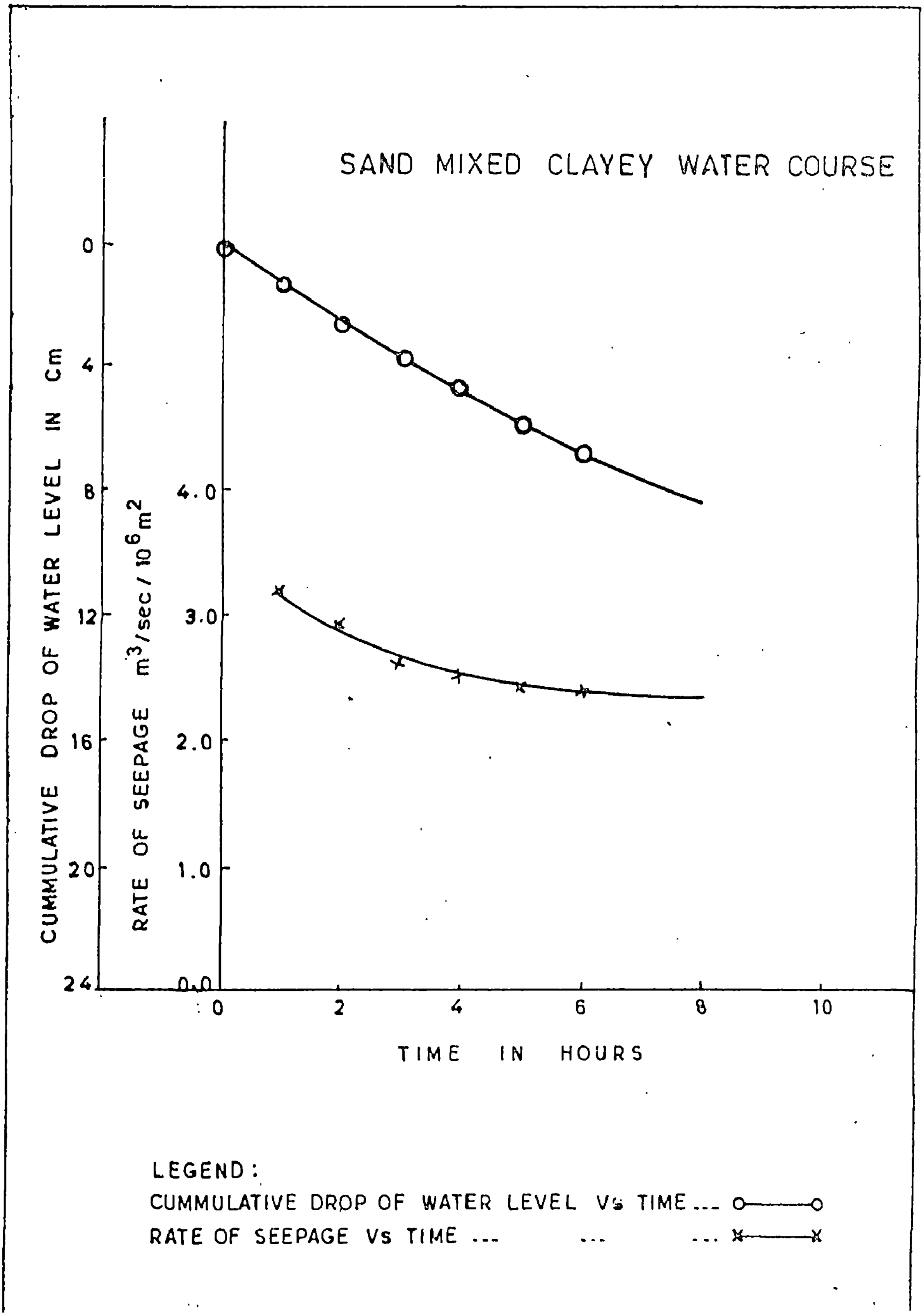


Fig. 6(a) Curve Showing Cumulative Drop of Water Level V/S Time and Rate of Seepage V/S Time in Clayey Soil

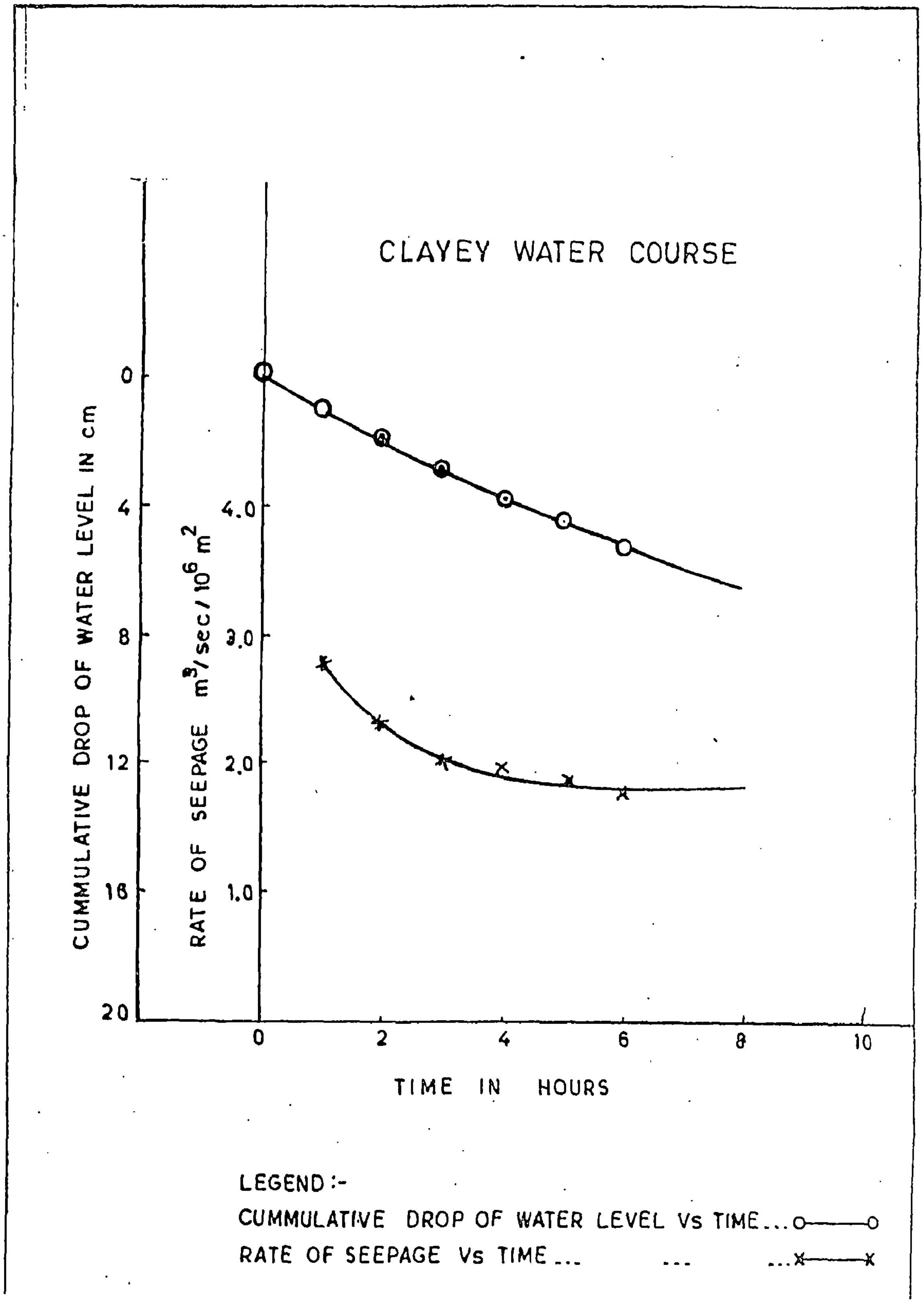


Fig. 6(b) Curve Showing Cumulative Drop of Water Level V/S Time and Rate of Seepage V/S Time in Sand Mixed Clayey Soil

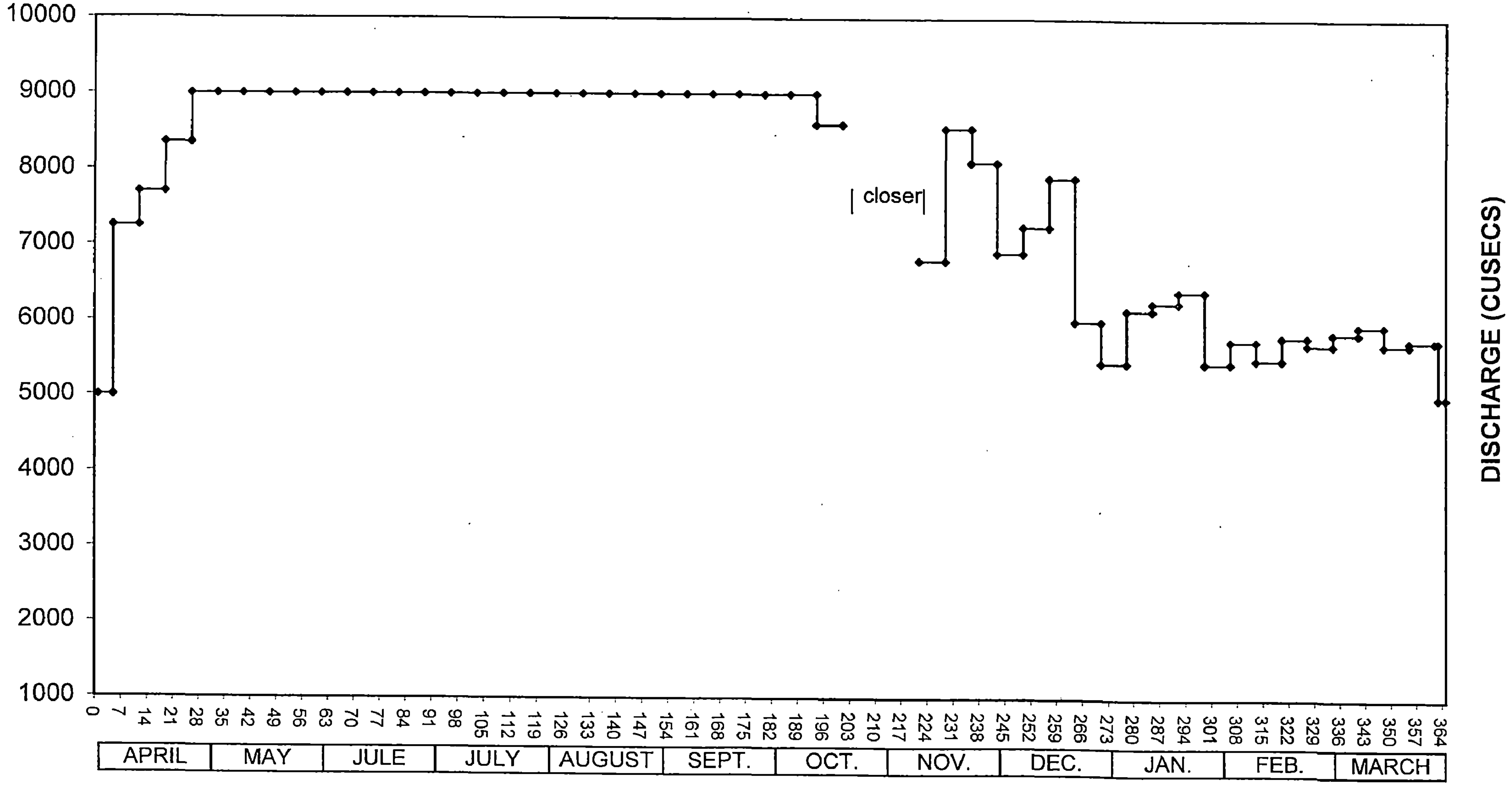


Fig.no. 6.1 ROSTER OF UPPER GANGA CANAL

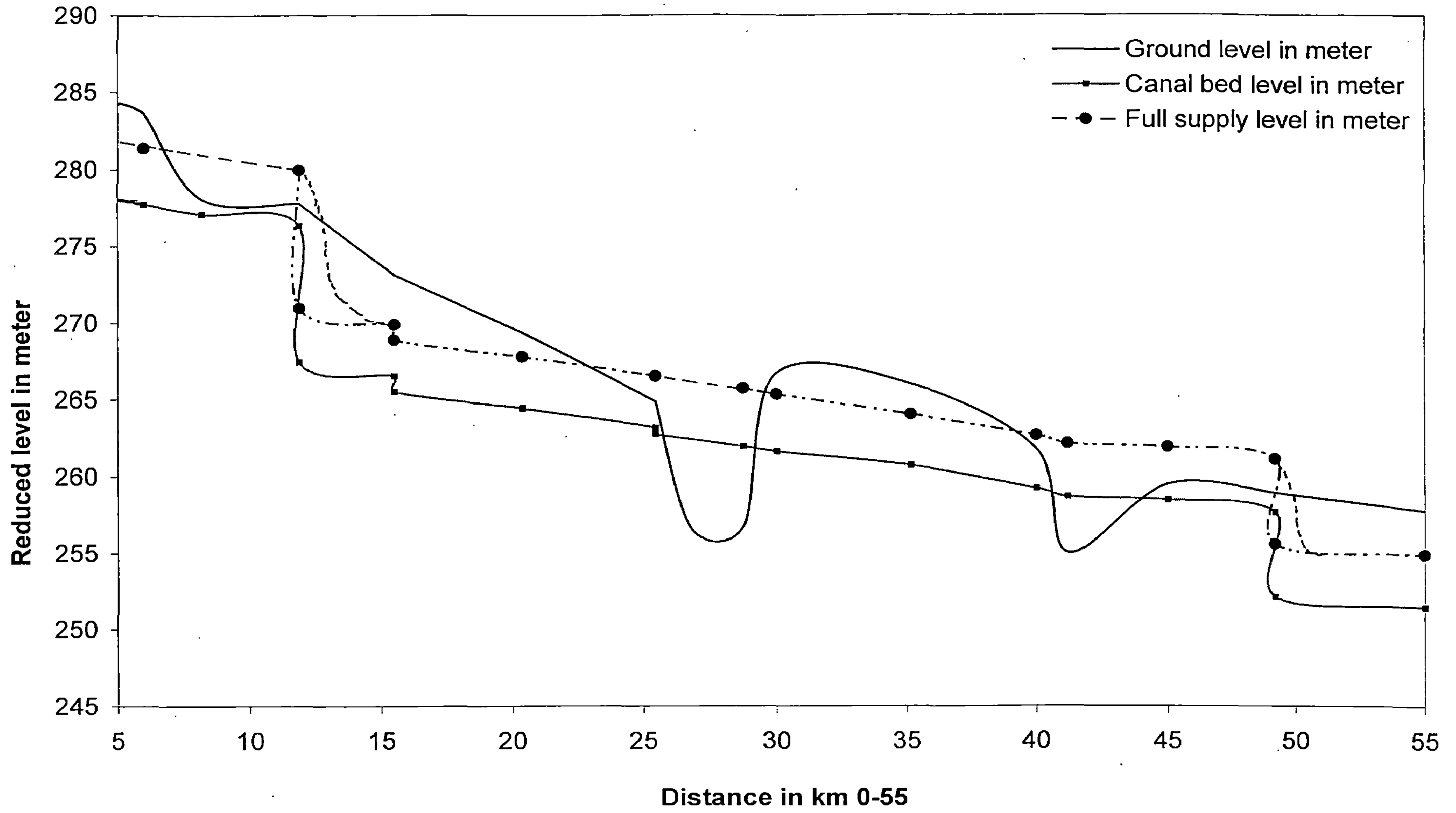


Fig.no. 6.2(a) Condensed L-section of U. G. C

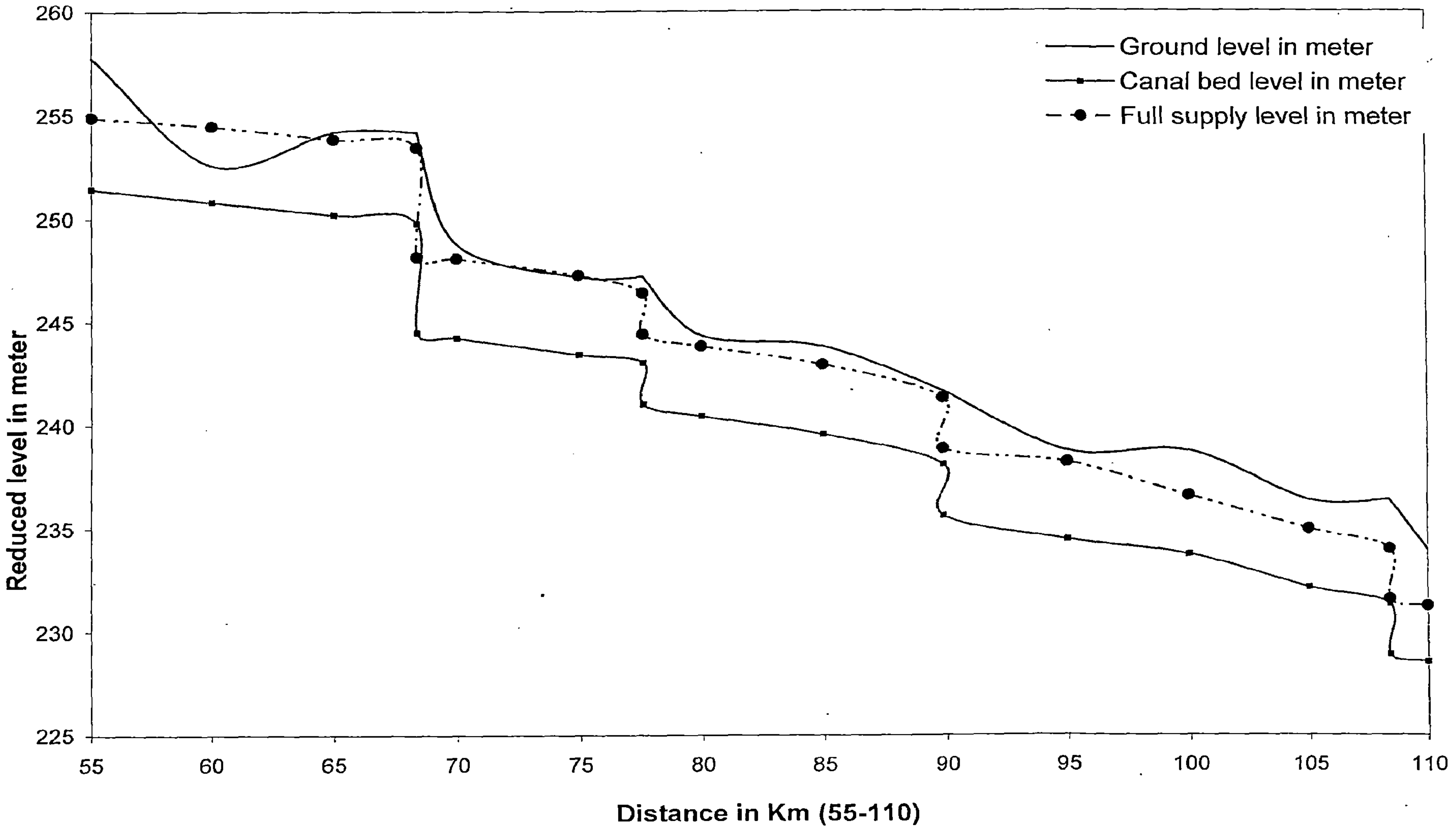


Fig.no. 6.2(b) Condensed L-section of upper Ganga canal

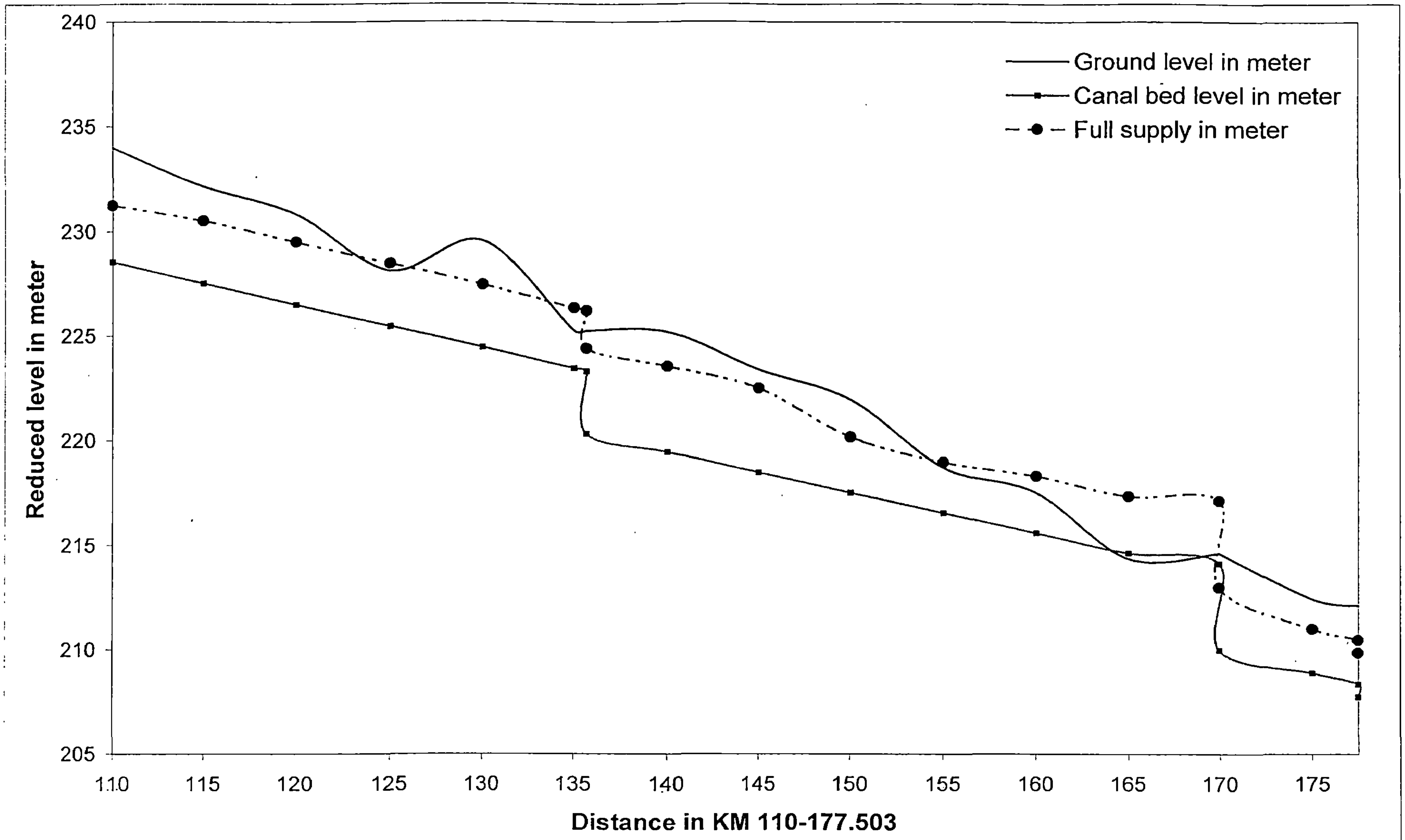


Fig.no. 6.2(c) Condensed L-section of U.G.C

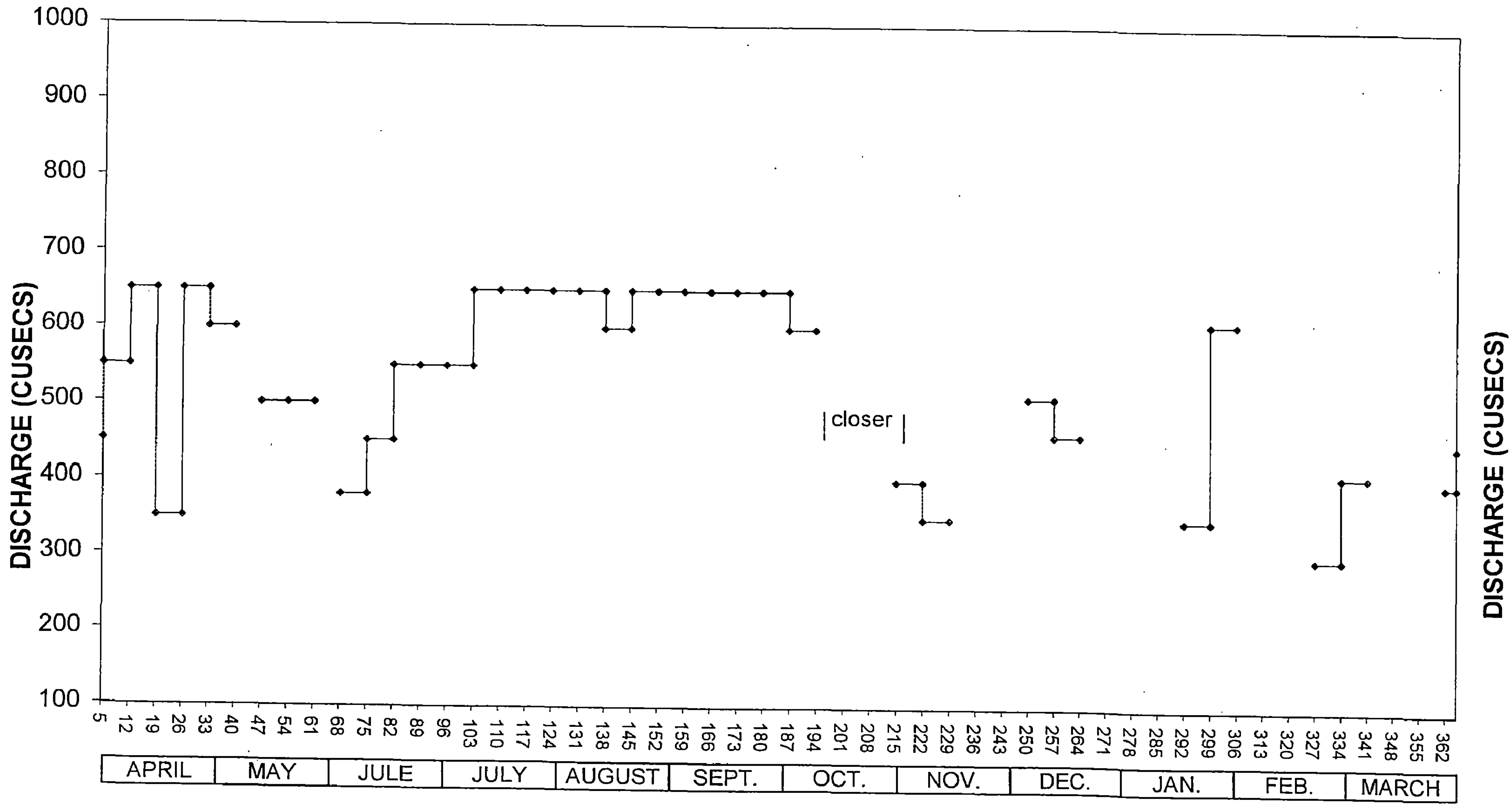


Fig.no.6.3 ROSTER OF DEOBAND BRANCH

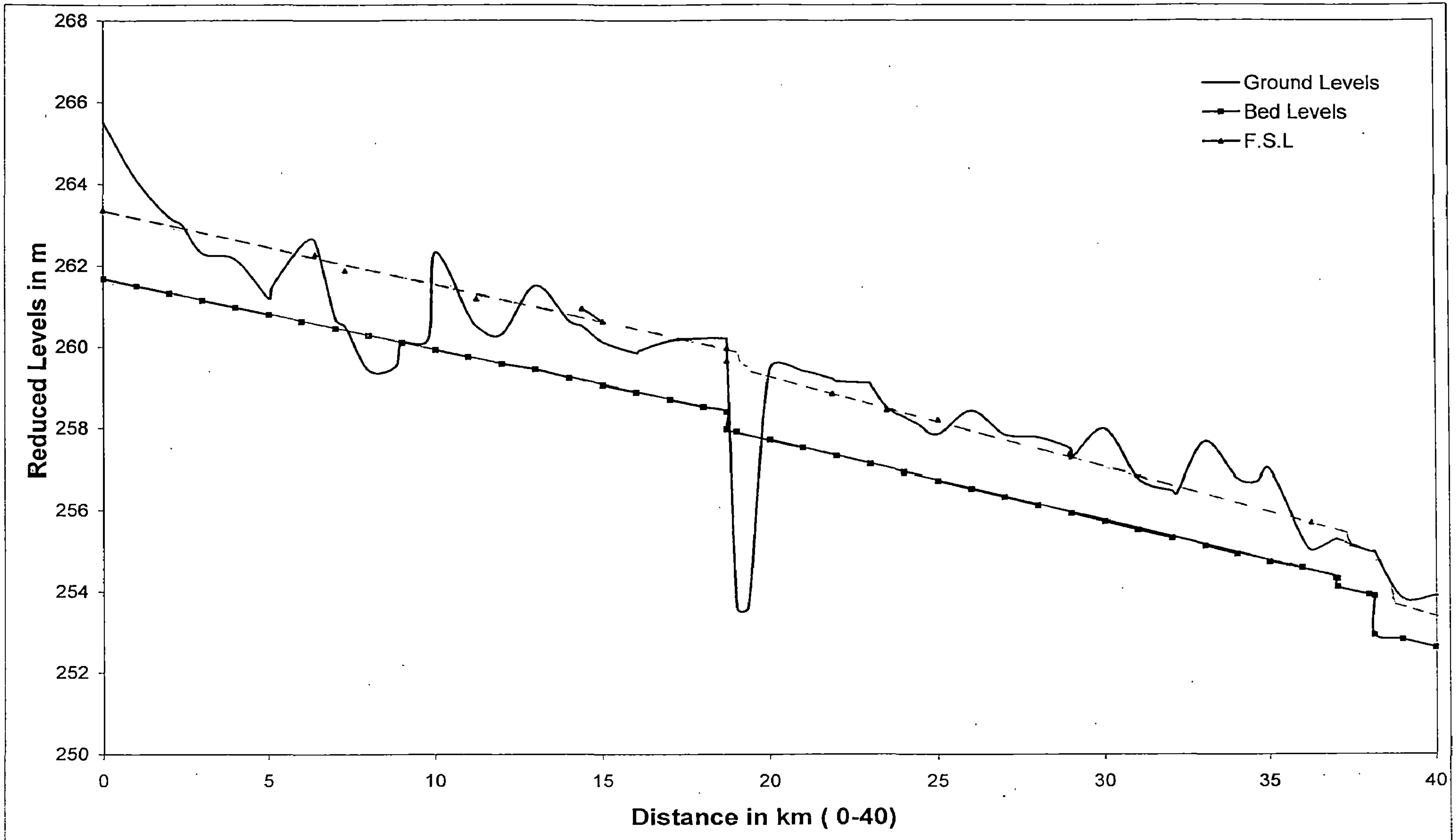


Fig.no. 6.4(a) Deoband Branch

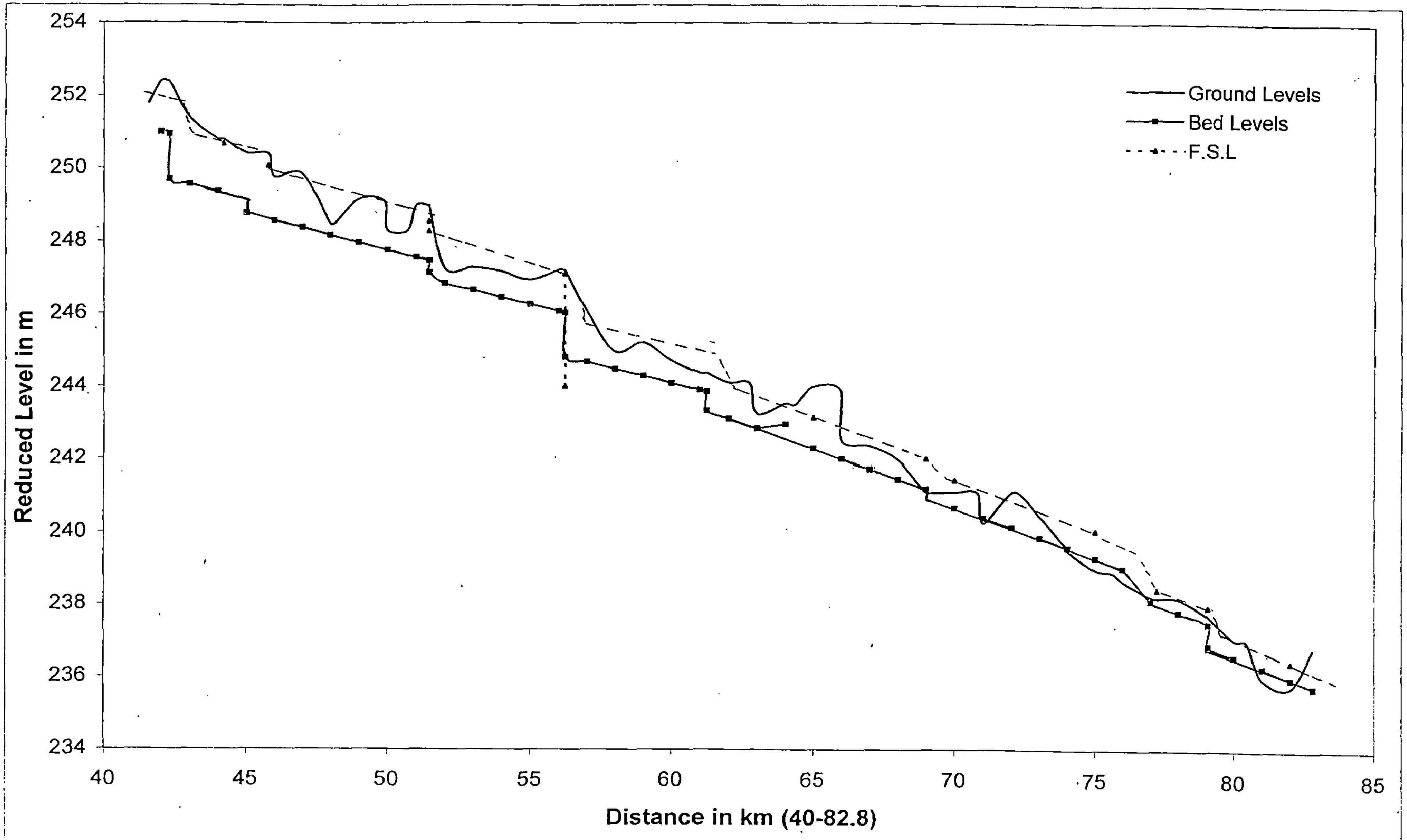


Fig.no. 6.4(b) Deoband Branch

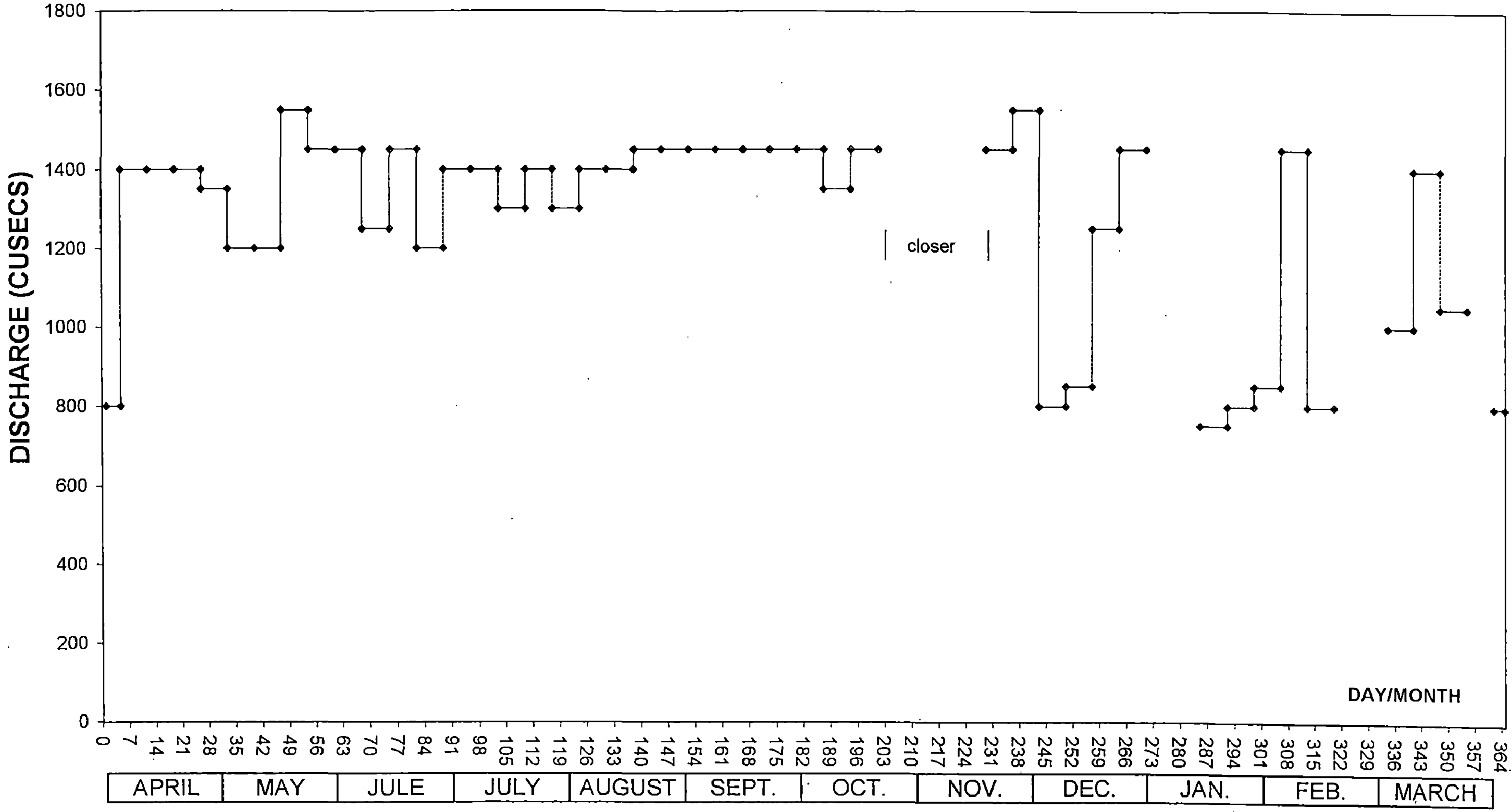


Fig.No.6.5 ROSTER OF ANUPSHAHR BRANCH

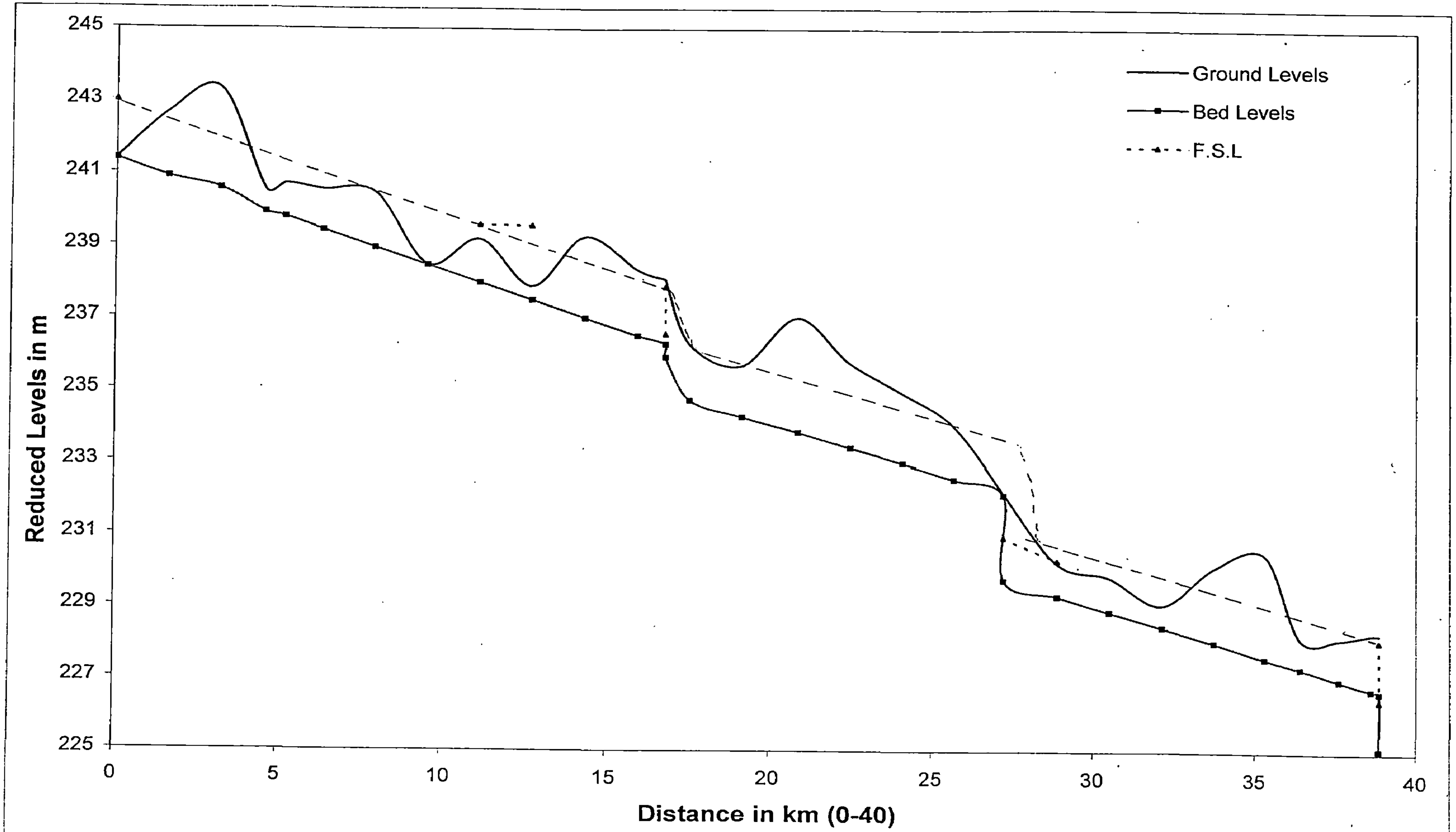


Fig.no. 6.6(a) Anup Shahr Branch

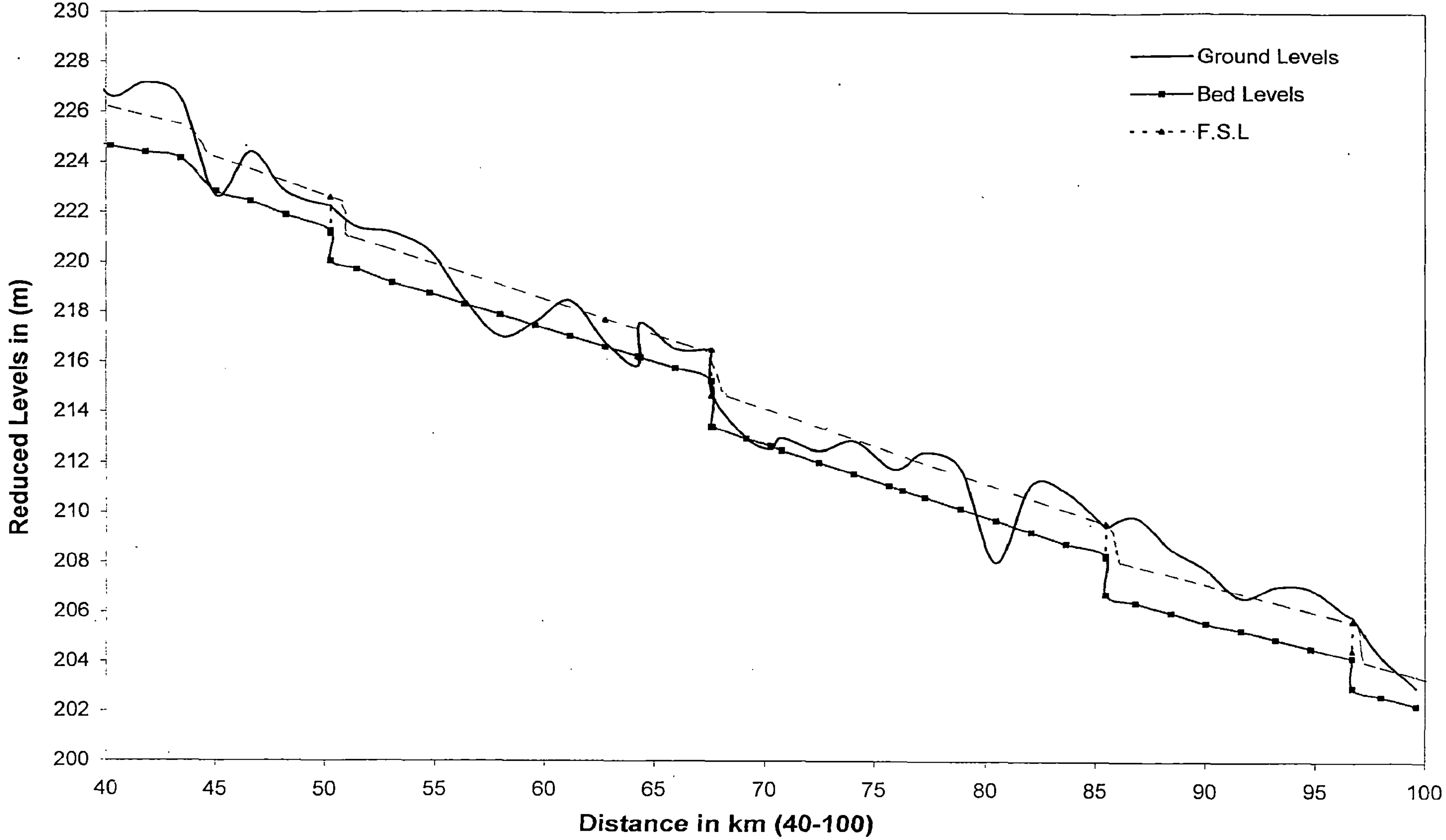


Fig.no. 6.6(b) Anup Shahr Branch

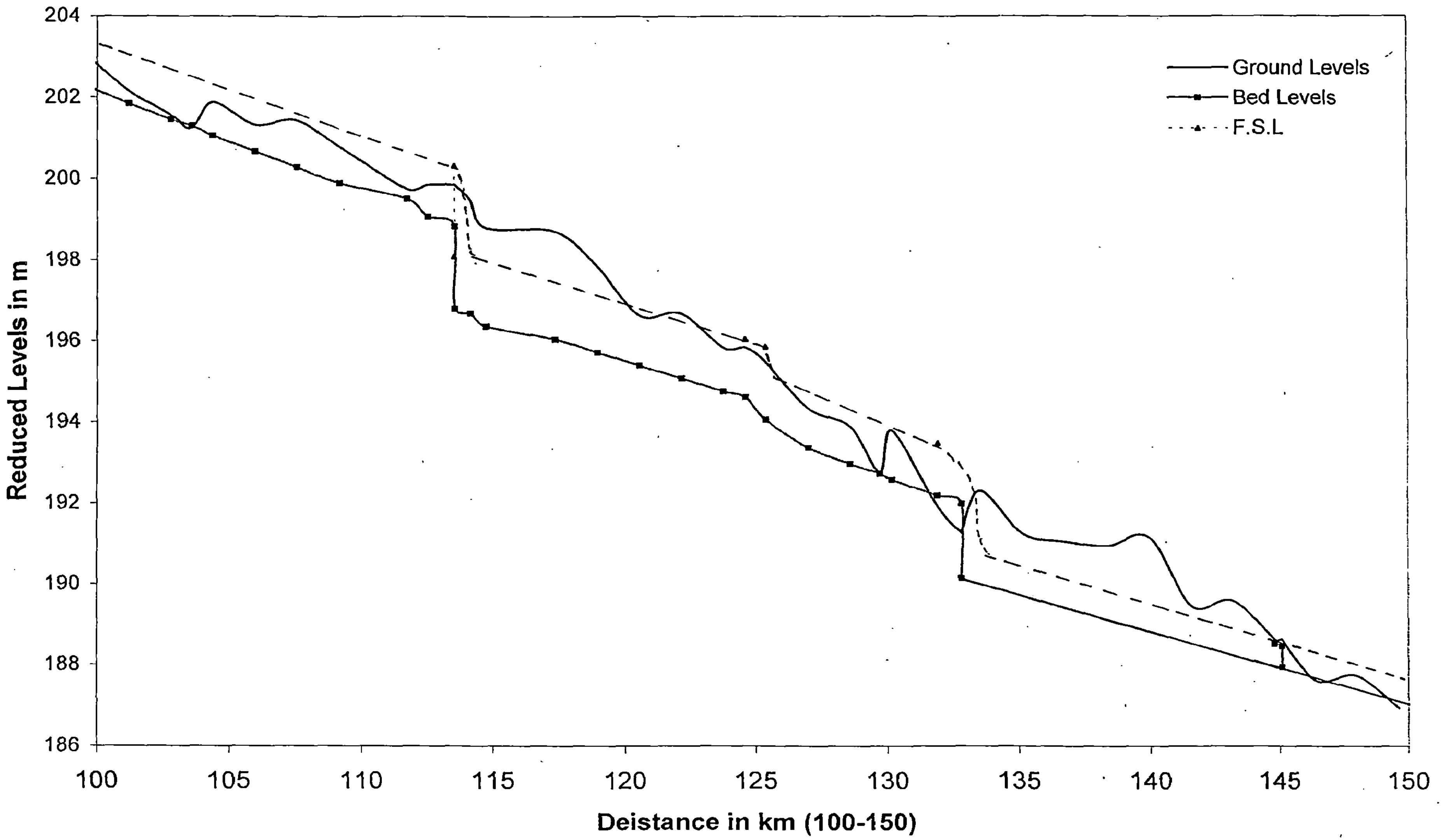


Fig.no. 6.6(c) Anup Shahr Branch

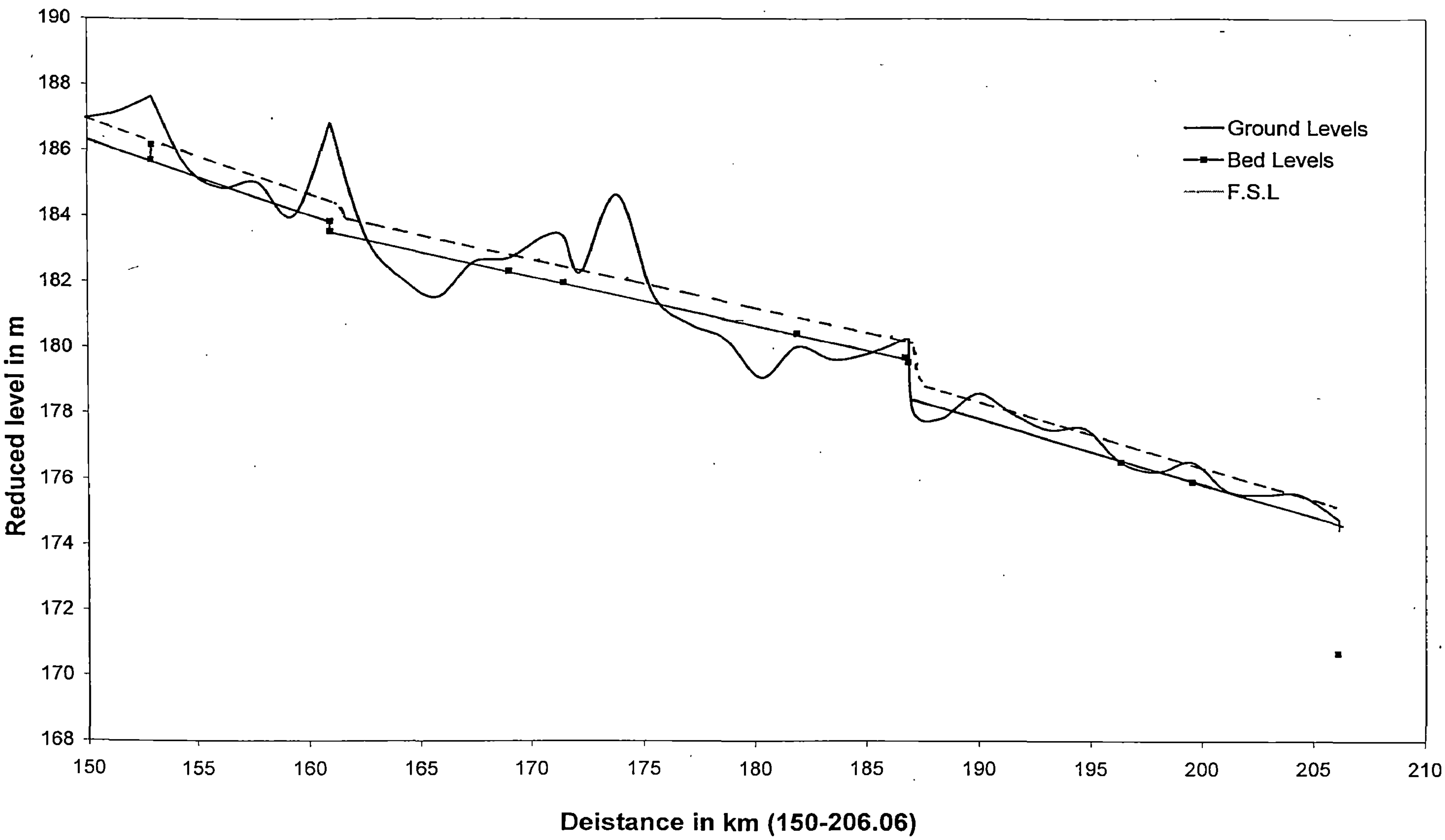


Fig.no. 6.6(d) Anup Shahr Branch

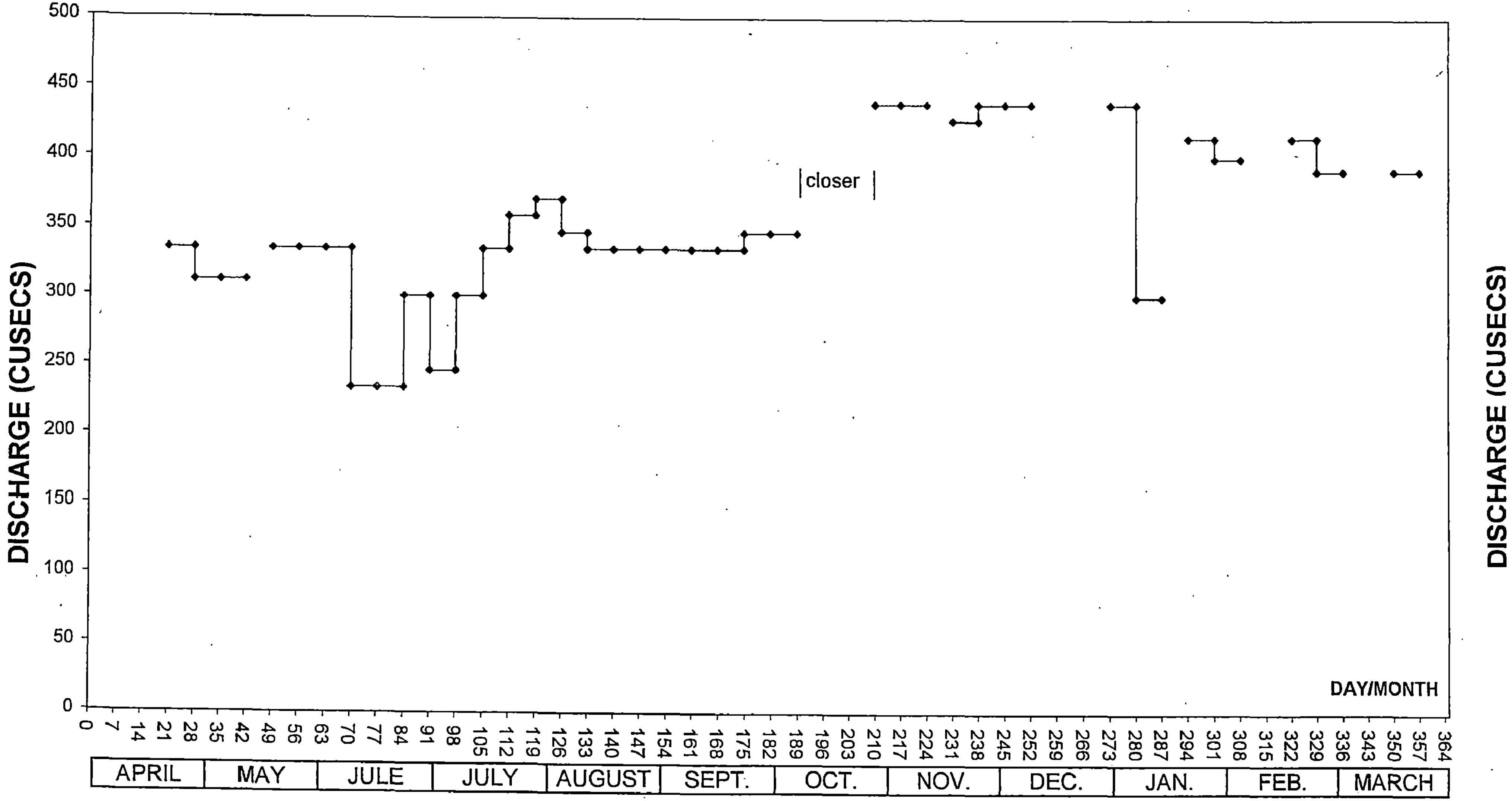


Fig.no. 6.7 ROSTER OF UPPER MAT BRANCH

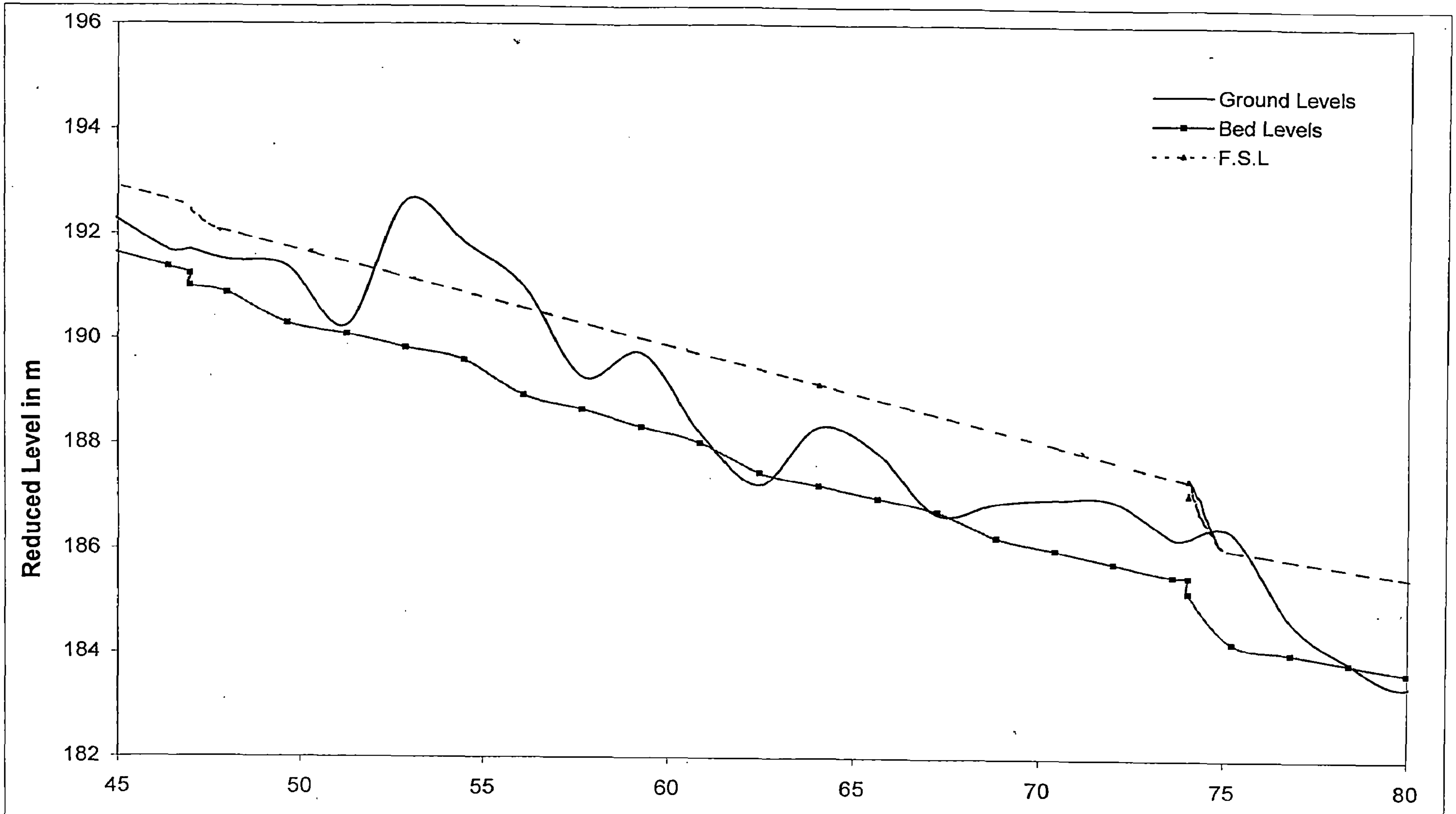


Fig.no. 6.8(a) Mat Branch

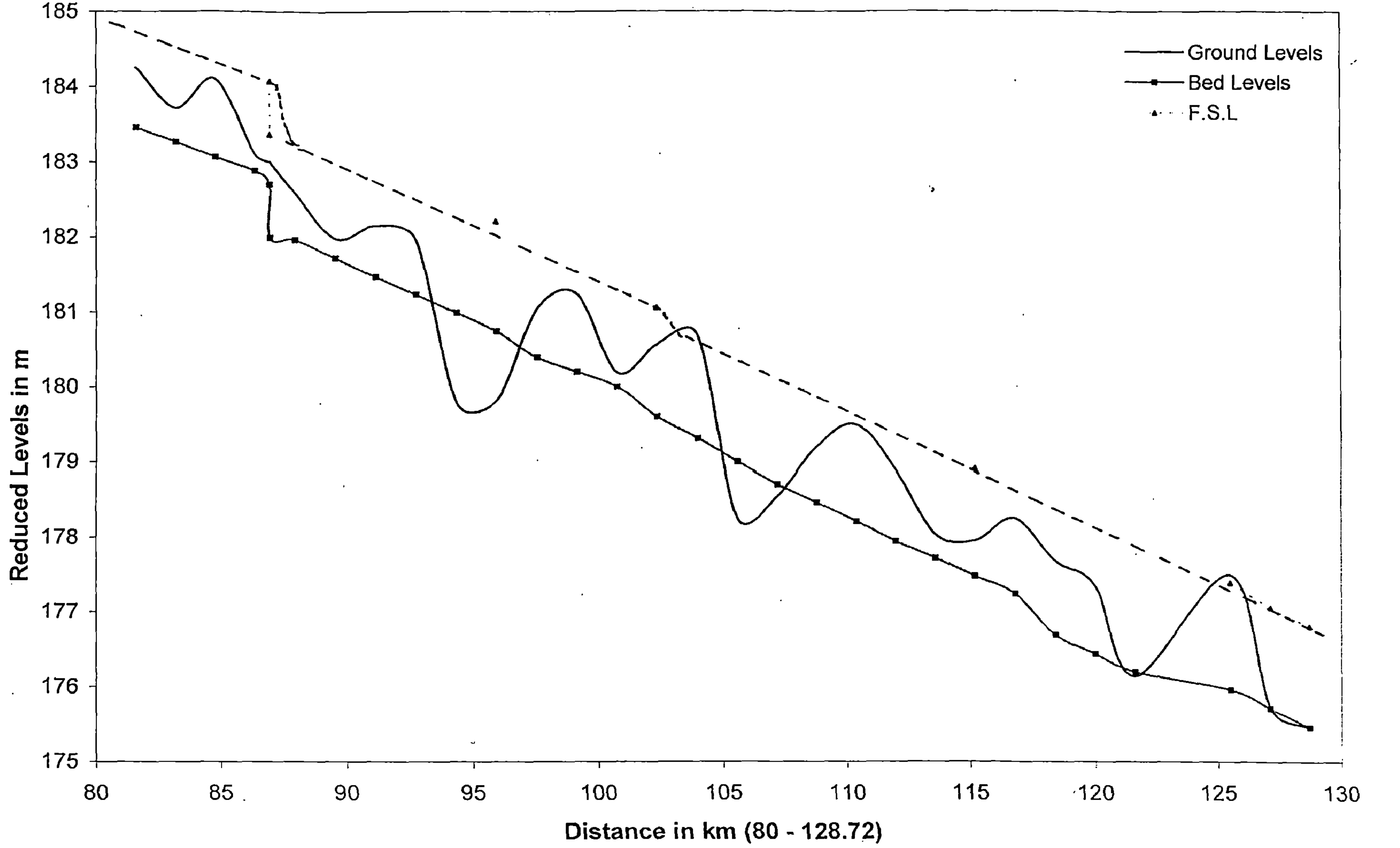


Fig.no. 6.8(b) Mat Branch

DISCUSSIONS, CONCLUSIONS & RECOMMENDATION

7.1 DISCUSSIONS

The dissertation deals with the study of losses in an irrigation system. The irrigation system may be of small in size to very large in size, like Upper Ganga Canal (UGC) system. The UGC system is an unique system to do any type of study related to the losses, in view of large irrigation command of alluvial soil and well laid channel network with the good availability of related technical details in view of its use over a long period.

The UGC system has a main canal of 291.91 km long with head discharge of 297 cumecs, the bed width of canal in the upper reaches is about 60 m and water depth is about 3.30 m. The initial reach of the canal is in deep cut and then passes through a four major cross-drainage works. The entire canal system had been projected normally along the water shed line of the command. The UGC has four major branch canals with total length of about 500 km, and 46 nos. direct off taking distributaries. Total distribution network of U.G.C system is about 6540 kms spread over nearly two million ha of total irrigable command.

The soils of the command area are alluvial, in Saharanpur and Meerut districts, they are deep, dark gray, loam to loamy sands. In the southern part (Aligarh and Etah Districts), they are slightly acidic loam, sand, sandy loams. Saline and alkaline efflorsences, known as 'usar' and 'reh' occur in Aligarh, Mainpuri and Etah districts (5-6% of the CCA) but are not major problems. Fertility levels are medium to high.

The different type of losses have been assessed & measured for the UGC system specially by IRI Roorkee. The estimation shows that evaporation losses have been about one percent of head discharge. Transpiration losses in the system depends upon the overall maintenance of the system and can be reduced by keeping the banks clear of weeds, the main loss is through percolation and seepage, depending on the permeability of the bed and bank materials of the channel.

The seepage loss in UGC system has been estimated against various projects through IRI Roorkee from time to time. The seepage losses in main canal vary from 1.5 to 3 cumecs/ million sq m of wetted perimeter. There is not much of the difference in cutting and filling reaches, because the canal is shallow one with comparatively wider cross section and major losses are from the bed of the canal. The substantial bed load carried by the canal normally get deposited in the bed. As the UGC normally carried below the ground surface and bed profile is close to the water table, there are more possibilities of direct percolation to the water table. With the establishment of Hydel Power Stations on the falls, some of the reaches have been converted to embankment with additional marked seepage from the embankments.

As the main canal normally runs continuously, there is rise in water table all along the canal alignment. Similar situation has been observed in case of branches. However the distributaries and minors have been used on rotation and with tight roster, where closure of the channels are quite frequent and extends for 2 to 3 weeks or over more. This has posed the conditions where delivery of the water to the fields is normally less than demand and over use is normally quite restricted. But, with the fading away of discipline and dilution in administration of distribution of water in the general and also over use of water in upper reaches of the channels with unauthorized out-letting, the wastage of water in upper reaches could not be controlled.

With the development of sugarcane zone in the upper portion of command with continuously increase in the intensity of sugarcane crop, the excessive use of water in this portion of command could not be controlled, in the management of irrigation water on this system.

However, with favorable water bearing strata and very convenient pumping of groundwater, the use of groundwater on large scale by farmers has been very well established specially after green revolution of 1960's. This has created a balancing condition for the groundwater table normally in the command of Upper Ganga Canal and inspite of irrigation over a long period of nearly 150 years, the water logging is almost not noticeable in the system. Inspite of the above use of surface and groundwater there is very good and effective drainage large irrigated command by drains as provided and with due care taken in the alignment of irrigation channels.

After study of the losses on main canal, observed from time to time against various projects, it could be observed that the losses along the length of the canal almost quite matches and are consistent inspite of variation of water surface profile with ground profile. The main canal has been showing substantial deposits of bed load at reaches up to Bhola falls at km. 134.35 and the bed profiles as observed are enclosed in Fig. 7.1. Infect, in almost the whole of above reach the losses from bed had outweighed the losses from banks and even limited embankment reaches.

Also the losses have been observed from the heavy and very thick growth of jhunds and other water weeds on inner slope of banks in most of the reaches of main canal specially from jaullifall (km. 77.66) to Bhola fall (km. 134.35) and also along the Anupshahr Branch, obviously looking to the growth of this vegetable with deep roots and fast annual growth, substantial loss of water through evapotranspiration can not be ruled out. This weed can be removed by mechanized means and for the control against regrowth by proper maintenance for few subsequent years the substantial loss of water cane be saved, besides improving the hydraulic efficiency of the channels.

Thus although the proposal of lining of the main canal running almost continuously except some short planned closer of 2 to 3 weeks for inspection and maintenance, is quite tedious from practical considerations but substantial losses in its present regime could be reduced by suitable measures as could be practically and properly implemented.

In case of watercourses, lots of studies were done, which shows that the conveyance losses are more in watercourses than the losses in other network of the system. The main reasons behind it, is due to low velocity of flow and lack of maintenance and repairs. An another study was done in state of Haryana, which shows that the 50% to 60% length of watercourse lining would reduce 80% to

85% seepage losses, it is because the head reaches of water courses are required to run for a longer periods then the middle and tail reaches.

The estimation of seepage losses in water courses made by manually compacted and mechanically compacted are discussed in chapter VI, the study shows that the seepage loss rate stabilized offer three week continuos running of manually compacted watercourse and after two week running of mechanically compacted watercourse. Therefore frequent running after short closures should be avoided to save the seepage loss in watercourses.

Thus there is a golden rule for saving the water in rotational distribution is to run the channel full for minimum time and keep it closer for long time to control the running time of channels as well as water courses.

The study made on command of Janjokhar minor of UGC system, gives an important recommendation that by lining a few meters in head reach, sometimes by making earthen renovation in next few meters and by regular cleaning and maintenance in remaining stretches of a water course network, the conveyance efficiency of water course can be substantially improved from 75 to 95 percent.

The data of some of the actual observations of the seepage losses in different states in India are presented and compared with the design practices by CW & PRS Pune, are shown in chapter 4, 90% of the observed data was found to fit in with the design practices.

The central water and power research station, Pune, has recommended uniform seepage rate for all state for design and preparation of project reports, which is 0.80 cumecs/million sq m. for lined canal and 2.50 cumecs/ million sq m of unlined canal, for alluvial and deltaic regions.

The correct measurement of seepage losses in various network is one of the most essential requirements for planning of any measure of saving water on the system. The different methods, which are generally used in different part of country and abroad, has been discussed with their limitation. The tracer technique is one of the best techniques to measure the seepage losses in main canal and branch canals and has been used by the expertise in IRI Roorkee. The seepage losses in distributaries and minors are measured normally by ponding methods. The seepage losses in main canal, branch canals, distributaries and minors by different methods are tabulated in table no. 6.1, 6.2 and 6.3 respectively.

For the identification of suitable reaches in the U. G. C. system for saving of the losses to conserve the valuable resource, the detailed study has been carried out by critical review of available data from various documents related to different project reports for rehabilitation and modernization and other purposes. The condensed L-Section of main canal and branch canals have been prepared and enclosed in Fig.6.2 (a, b & c), 6.4(a &b), 6.6 (a, b &c) and 6.8 (a & b) containing all relevant technical information on the channels in the system.

The rosters of main canal and its branches have specially been studied and the graphical representation of roster have prepared for main canal, branch canals for better presentation of the running of the channels as shown in the Fig. 6.1, 6.6, 6.7 & 6.8.

For identifying the specific elements of UGC system for economical saving of seepage losses the results of seepage loss measured at various points in the system have been critically studied and used and the saving in losses by lining per km length of main canal, branch canals, distributries and minors have been worked out as shown in Table 6.5, 6.6, 6.7, 6.8,, 6.9 and 6.10.

The study also include the estimation of overall seepage losses in the entire system based on the earlier studies as explained above. This estimation provides the valuable information on the total losses in the system depending upon the average rate of seepage and running time of channel for distribution of water in the command. The details are given in Table 6.11 and the estimated overall losses are quite consistent with the earlier estimation done on this system and available in report of II Irrigation Commission Govt. of India (1972).

Another study has also been attempted to work out the economical measure by lining the channels from main canal to watercourses in the system based on the observation from time to time on seepage losses (detail shown in table no. 6.12). It could be observed from the above study that for per unit saving of seepage losses in the system, it would be appropriate, to save the losses by suitable lining preferably on watercourses, on branch canals and their distributaries and minors. But as the lining of watercourses, are being taken up in command area development programme and on U.G.C system normally the average length of the individual watercourse, is comparatively much smaller than the length of watercourses, in Haryana and Punjab etc. and farmers can better maintain the unlined water courses instead of lined watercourses, the lining of watercourses may not be encouraged on U.G.C system due to maintenance and requirement of long time sustainability. It may be concluded that it would be more appropriate to save losses in critical reaches of main canal and branch canals if closure period and suitable materials of lining the canal section in limited restricted closer period, are available. Beyond the saving on main canal and branch canals, it would be better in the saving is exercised more on distributary channels by taking the longer distributaries for lining the whole length. As the loses on minors have been normally on lower side and minor also run for the least period during each fasal and also need more frequent maintenance and desilting etc. the lining on minors be taken on last priority.

During my study, I have got golden opportunity to see U.G.C system during closer period and running period with experienced engineers and senior professors during their visit, some critical reaches have been physically seen and the various aspect of seepage losses have been discussed at site. I could also get opportunity to see, most of the activities of Tracer Technique, used on Anupshahr Branch km. 69.187 during the seepage losses measurement, done by I.R.I Roorkee experts team. The data of field observations are enclosed in table No. 7.1, 7.2 & 7.3 and Fig. No. 7.2, 7.3, 7.4 and 7.5 respectively. This could provide me a good understanding of this prestigious system of Utter Pradesh and specially the recent and more deferrable practice of measurement of seepage by tracer technique method.

7.2 CONCLUSION

From the critical study of the seepage losses measured and assessed on the U.G.C. system as detailed out in chapter VI and also narrated in the discussion, the following conclusion can be recorded in brief as under:

1. The study of the losses in main canal does indicate, that the losses are quite matching and consistent all along the canal, inspite of variation of water surface profile with respect to the ground profile.
2. The study of the observation on branch canal also confirms the above conclusion.
3. The losses in the distributaries and minors are comparatively much less, than the main canal and branch canals. Obvious reason may be that, the distribution channels generally run above the ground profile to irrigating the large area commanded. Therefore, it appears that the seepage losses in these channels are mainly from banks instead of losses from bed.
4. The losses on watercourses are quite substantial and more than the other elements of the U.G.C. system. The length of individual watercourse on U.G.C. system is comparatively less then the other major irrigation system in Haryana and Punjab etc. The losses on watercourses, specially running on loamy soils in U.G.C. command, can be drastically reduced by thorough cleaning of vegetation and proper regular maintenance instead of the lining, infect the lining may create more maintenance problems to the watercourses.

5. The substantial losses form the heavy weed growth in the internal section of main canal and branch canals are not directly measured but they are quite sustain appreciable, these can be controlled by effective removal of water weed growth along the banks and also by the control against recurring growth, by proper maintenance for few subsequent years, the internal section as really should be maintained and this would also help in reduction of the over all losses.

6. During the site visit of the main canal and Anupshahr Branch Canal, it could be observed that there is heavy bed load (sand) and deposition in the bed of channels normally to the depth of one meter or even more, this bed load regularly deposited year after year, and alters the canal regime, and causing the banks erosion, resulting in the increased seepage losses. This bed load shall have to be taken care to maintain the designed carrying capacity and also to exercise control on seepage losses.

7. An attempt has also been made, to assess the over all seepage losses for the U.G.C system from the available details and irrigation scheduling and also the observed seepage losses, in different elements of the system. The running period of different channels play an important role in this study. From the study of rosters and the different running time of irrigation channels that is the main canal, branch canals, distributries, minors and watercourses, the loses has been workout, and it could be found that the over all seepage losses are 44.30 percent, of the head discharge of main canal which are quite consistent with the earlier

recorded seepage losses in U.G.C system (45%) mentioned in report of 2nd Irrigation Commission, Govt. of India (1972).

8. The requirement of the investment for saving of per unit water from U. G. C. system have also been compared it could be found that the water can economically be saved by suitable and cost effective lining on main canal, branch canals, because the channels run for long time during each fasal where as the distributries and minors are used on rotation with tight roster of short running. The losses on minors are comparatively less and lining may get the lower preference on these channels.

7.3 RECOMMENDATIONS FOR FUTURE STUDIES

For better water management in U. G. C. system and economical measures in saving the valuable water resource by controlling the losses, detailed studies on specific representative channels and other offtakes from the main canal should be carried out by critical review of the available technical data as well essential field observations on actual running of channels, real distribution of water in the command of the channel and detailed measurements on water used and the seepage losses occurring in different crops, with varying running schedules.

TABLE No. 7.1

TIME.CUM	CPM
HOURS	R5
0.0	-
16.1	50679.1
24.1	69634.9
41.1	116235.75
44.1	162836.6
48.1	108652.3
65.1	118274.2
68.4	118272.7
72.1	113616
89.1	105220.3
92.4	103997
96.1	100397.7
111.1	108076
115.1	81645.5
119.1	80050.3

TIME.CUM	CPM		
HOURS	R2	R3	R4
0.0	446512.8	380246.1	549729.0
16.1	301598.9	304816.5	444899.6
24.1	273180.7	298451.8	424469.7
41.1	213287.7	249098.6	398638.1
44.1	182558.3	243710.9	369654.7
48.1	184973.4	240668.3	412587.3
65.1	130269.9	213075.8	314702.4
68.4	120666.4	212097.4	306288.1
72.1	113333.6	241537.3	301083.0
89.1	60962.8	174878.6	260711.5
92.4	54289.1	155795.1	253980.1
96.1	51072.8	167731.7	242111.7
111.1	33741.7	168092.8	225023.2
115.1	28903.4	148642.7	217092.3
119.1	25982.4	174172.1	208805.4

TIME.CUM	CPM		
HOURS	L2	L3	L4
0.0	199258.9	752669.9	1445586.7
18.1	108279.2	205585.2	483604.7
25.1	102765.8	170258.3	400106.3
42.1	78615.0	82996.4	196374.8
46.4	85554.0	82369.2	172086.1
49.1	81849.8	150501.4	127400.1
66.1	74469.5	40552.6	82714.0
69.4	74467.6	39102.0	73271.3
73.1	72609.5	28970.1	62686.9
90.1	59828.0	18838.1	35288.6
93.4	67427.1	15473.5	31407.9
107.1	65799.7	16334.3	26023.3
112.1	60247.4	9164.9	15644.5
116.1	58081.4	7227.0	11352.7
120.1	58548.4	6601.0	11349.1

X	YL2	YL3	YL4	YR2	YR3	YR4
20	98856.262	440666.3329	211223.8362	339831.0438	293703.0555	452692.6
40	88381.873	214066.7697	107223.8179	206944.0701	257384.0279	387305.3
60	79017.306	103989.2964	54430.15968	126021.0006	225556.1751	331362.6
80	70644.969	50515.89172	27630.44947	76741.95531	197664.123	283500.4
100	63159.729	24539.59595	14026.07933	46732.90704	173221.1742	242551.3
120	56467.593	11920.83816	7120.076047	28458.54776	151800.8162	207517

TABLE 7.2

SEEPAGE LOSS CALCULATION BY TRACER TECHNIQUE METHOD

Bore no.	Initial conc. C_1	Final conc. C_2	Time t_1 Hrs.	Time t_2 Hrs.	Time $t = t_2 - t_1$ Hrs.	Log_e (C_1/C_2)	Deflection Coefficient ϕ Radian	Dia. Of Bore Hole (D) m	Seepage Velocity $V_f = \frac{\pi D \log_e C_1/C_2}{4 \Phi t}$ M/sec	Average Velocity V_f
Left bank										
L_2	98856	56467	20	120	100	0.56	1.0	0.075	0.91629×10^{-7}	
L_3	440666	11920	20	120	100	3.61	1.0	0.075	5.9068×10^{-7}	4.1232×10^{-7}
L_4	211223	7120	20	120	100	3.39	1.0	0.075	5.5468×10^{-7}	
Right bank										
R_2	339831	28458	20	120	100	2.48	1.0	0.075	4.0578×10^{-7}	
R_3	293703	151800	20	120	100	0.66	1.0	0.075	1.0799×10^{-7}	2.1379×10^{-7}
R_4	452692	207517	20	120	100	0.7799	1.0	0.075	1.2761×10^{-7}	

TABLE NO. 7.3

SEEPAGE LOSS CALCULATION BY TRACER TECHNIQUE METHOD

S. NO.	Borehole no.	Filtration velocity vf x10^{-6} m/sec.	Average Filtration velocity vf x10^{-6} m/sec.	Angle ϕ radian	Distance from centre line of canal (d) m	Seepage losses m^3 /sec/10^6 m^2 $q = 2vf\, d\, \phi \operatorname{cosec} \theta$	Av. Seepage losses m^3/sec/$10^6 m^2$
1.	L_2	0.091629					
2.	L_3	0.59068	0.41232	1.55	29.00	1.548	
3.	L_4	0.55468					
4.	R_2	0.40578					1.1838
5.	R_3	0.10799	0.21379	1.55	29.60	0.8197	
6.	R_4	0.12761					

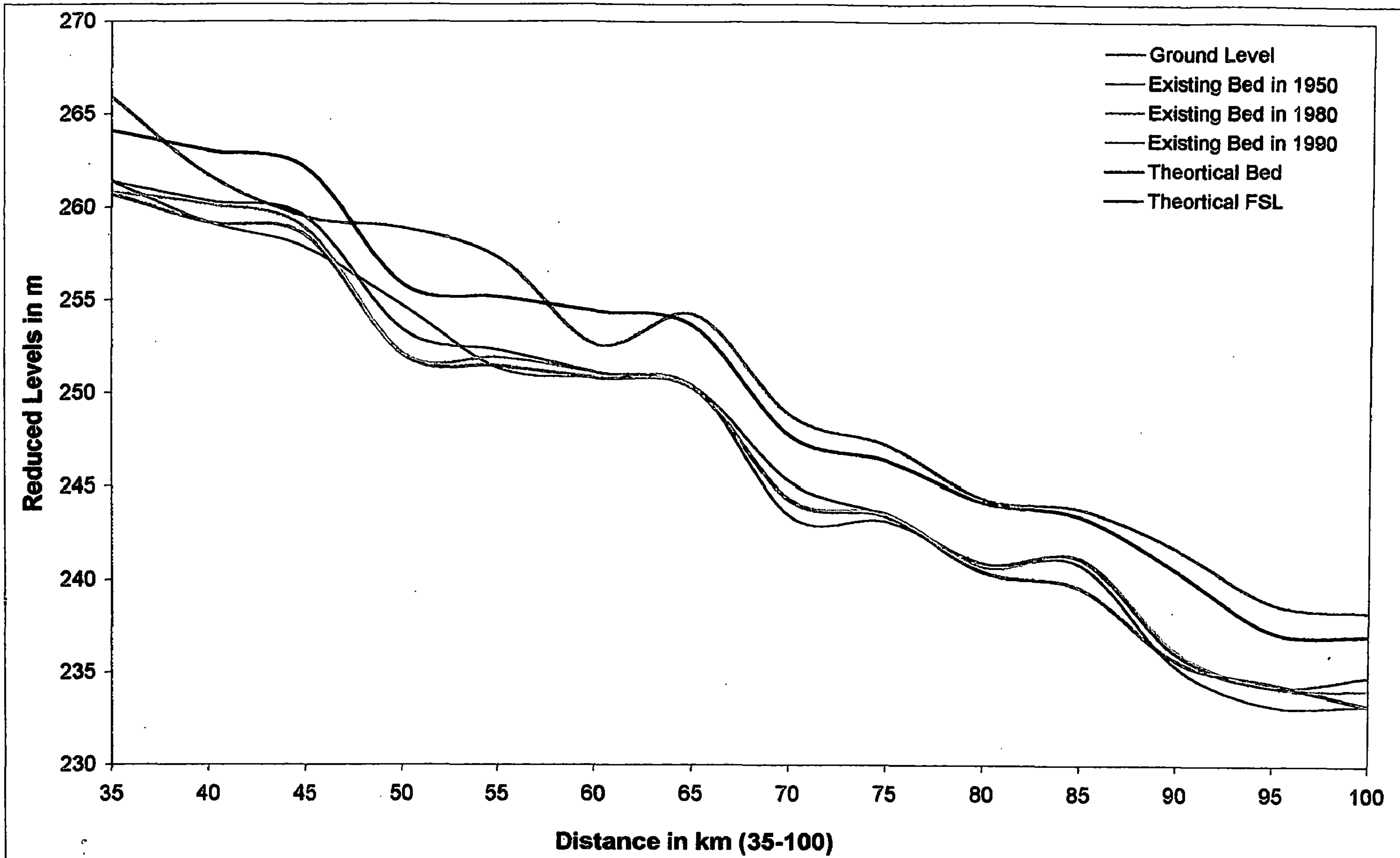


Fig.no.7.1(a)L Section of UGC Showing Profile Bed Duing Year 1950, 1980 & 1999

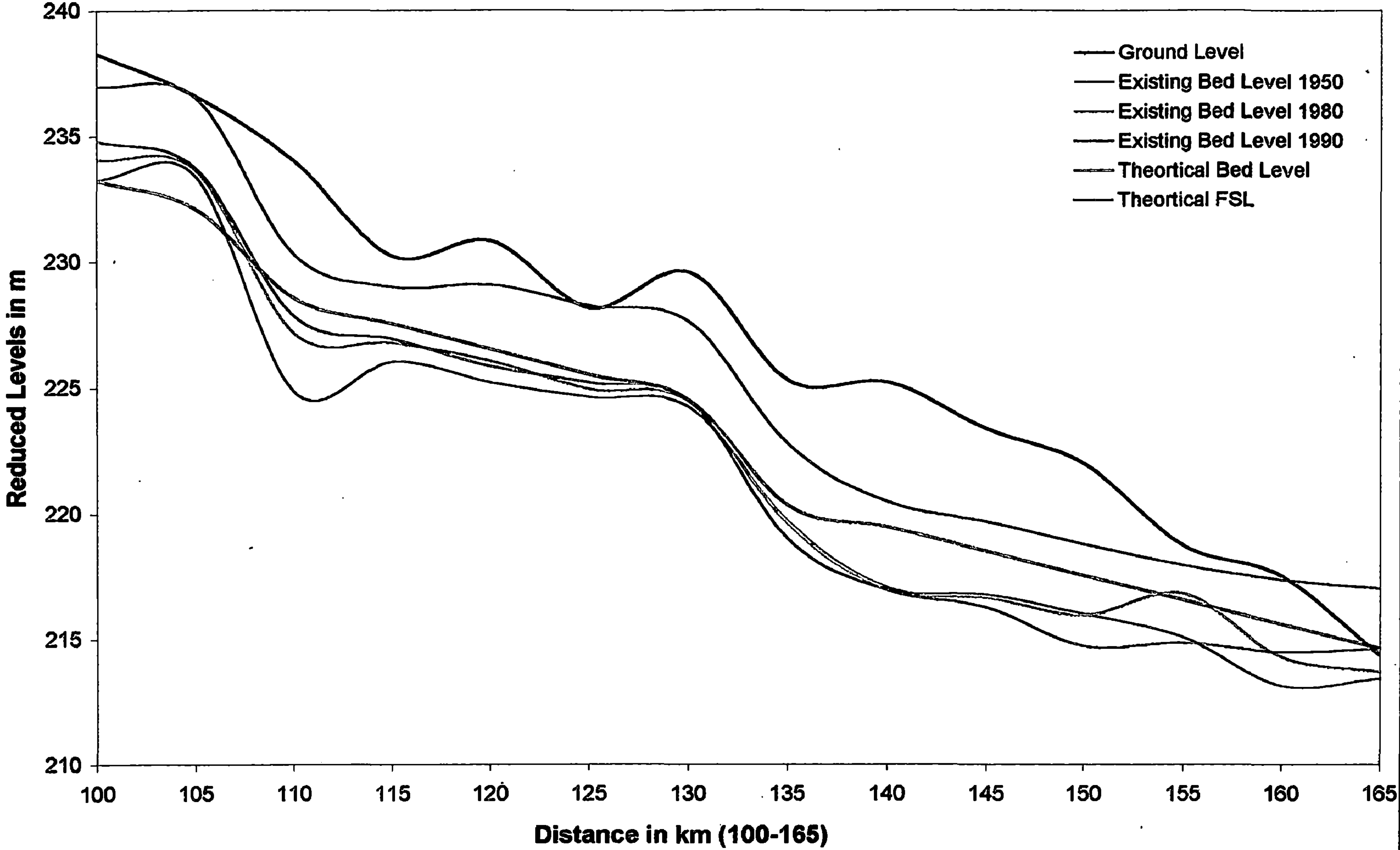
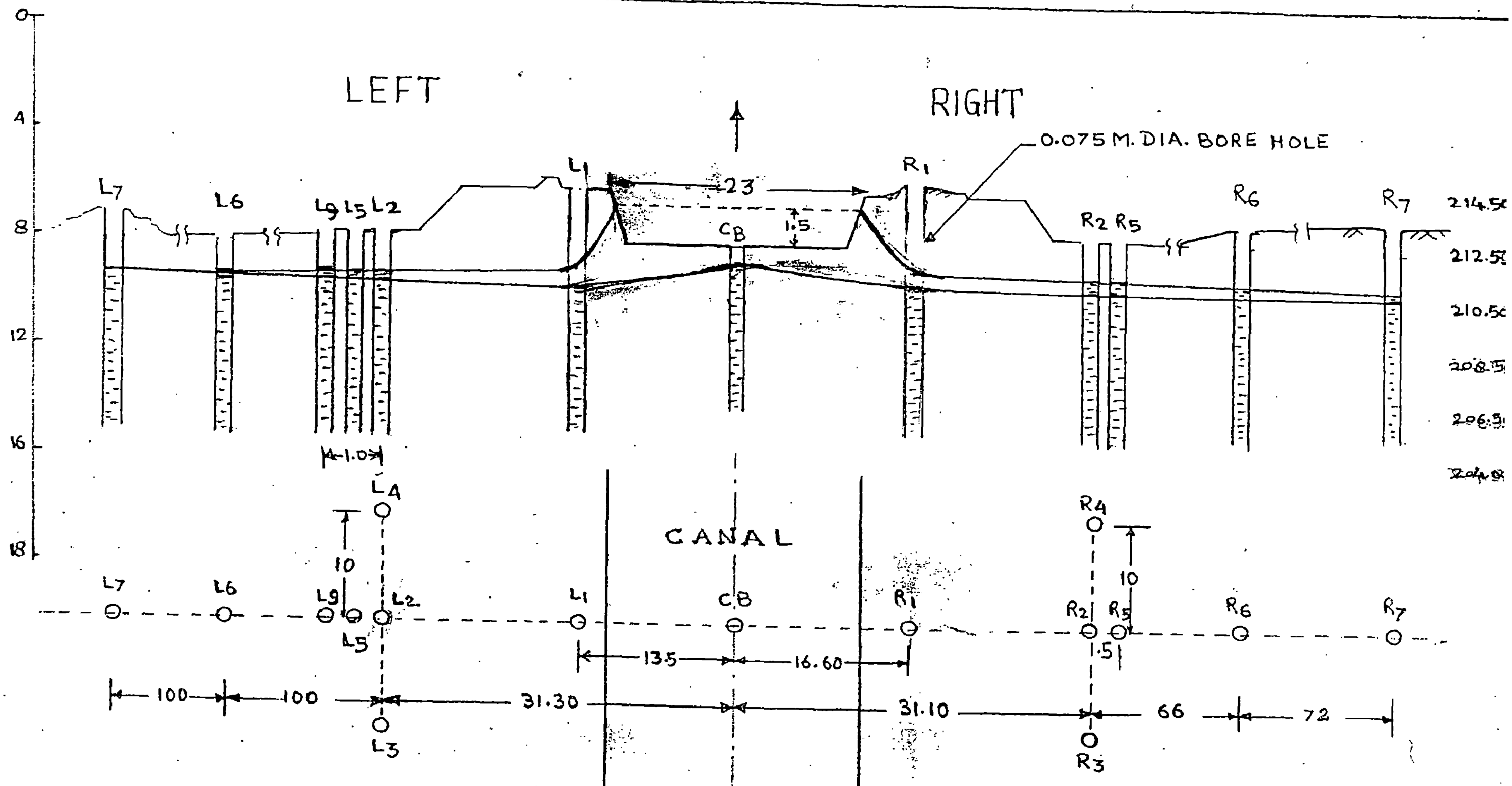


Fig.no.7.1(b)L Section of UGC Showing Profile Bed Duing Year 1950, 1980 & 1999



CROSS SECTION OF ANUP SHAHR BRANCH
AT KM. 69.187

ALL DIMENSIONS IN METERS

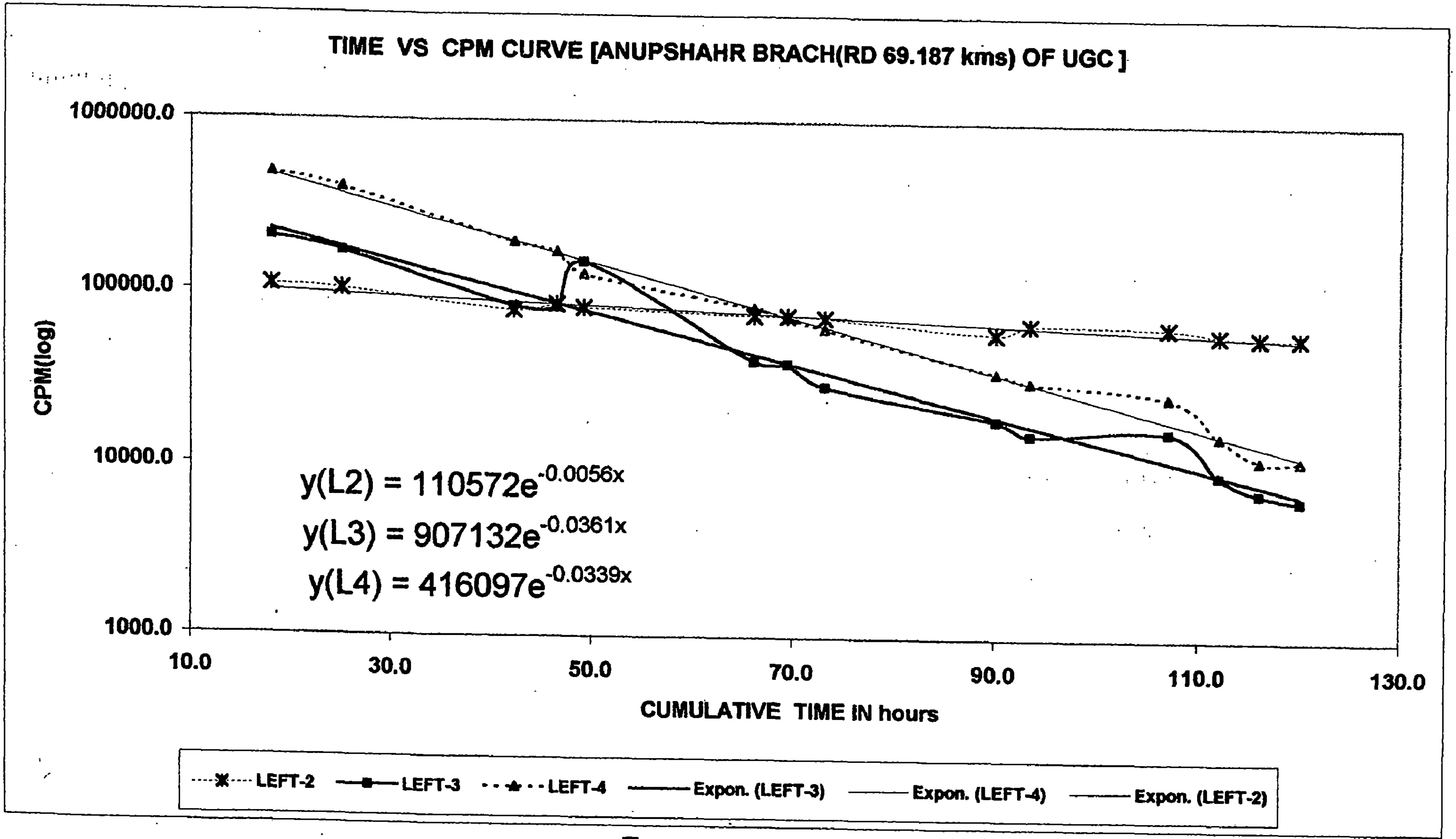

TIME VS CPM CURVE [ANUPSHAHR BRACH(RD 69.187 kms) OF UGC]
1000000.0
100000.0
10000.0
1000.0
CPM(log)
y(L2) = 110572e^-0.0056x
y(L3) = 907132e^-0.0361x
y(L4) = 416097e^-0.0339x
10.0
30.0
50.0
70.0
90.0
110.0
130.0
CUMULATIVE TIME IN hours
LEFT-2
LEFT-3
LEFT-4
Expon. (LEFT-3)
Expon. (LEFT-4)
Expon. (LEFT-2)

Fig. No. 7.3

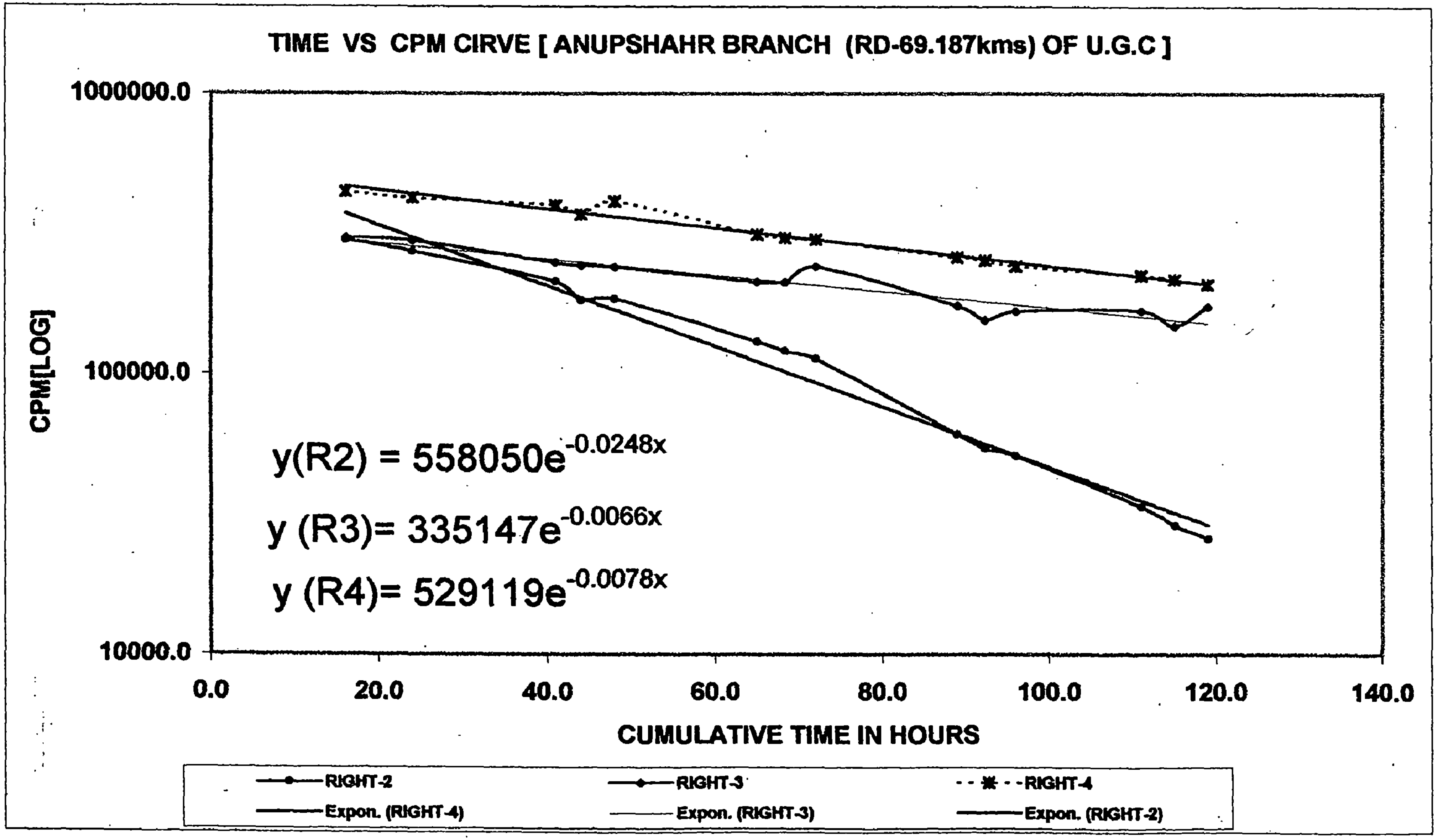

TIME VS CPM CIRVE [ANUPSHAHR BRANCH (RD-69.187kms) OF U.G.C]
1000000.0
100000.0
10000.0
CPM[LOG]
y(R2) = 558050e^-0.0248x
y (R3)= 335147e^-0.0066x
y (R4)= 529119e^-0.0078x
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
CUMULATIVE TIME IN HOURS
RIGHT-2
RIGHT-3
RIGHT-4
Expon. (RIGHT-4)
Expon. (RIGHT-3)
Expon. (RIGHT-2)

Fig. No 7.4

FIG, NO 7.5


BRANCH
FOR TESTING


ANUP SHAHR
TEST


BRANCH SEEPAGE
WATER LEVEL


TEST SITE

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