DETERMINATION OF THE MOST ECONOMICAL SUPPLY DEPTH FOR LINED CHANNELS

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CERTIFICATE

Certified that this dissertation entitled "DETERMINATION OF THE MOST ECONOMICAL SUPPLY DEPTH FOR LINED CHANNELS" is a record of bonafide work done by Shri A.C.Mehta, Post Graduate Student in the course of Master of Engineering (Water Resources Development) in the academic years 1966-67 and 1967-68. Shri A.C. Mehta has worked under our guidance on this dissertation for a period of 11½ months from 6th October,1967 to 21st September, 1968.

To the best of our knowledge and belief this dissertation has neither been published any where nor submitted for the award of any other degree.

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LIST OF ABBREVIATIONS AND SYMBOLS

A	Cross-Sectional area of channels;
Amt	amount;
B	bed width (B.W.);
b	top width of bank;
B.D.	balancing depth;
C	free board;
cusecs	cubic feet per second;
Cusec/msf	cubic per million square feet;
C.C.A.	culturable commanded area;
D=(F.S.D.)	full supply depth;
d=B.D.	balancing depth of cutting;
Ft (')	feet;
ft/sec.	feet per second;
Fig.	figure;
F.S.D.	full supply depth;
F.S.L.	full supply level;
fL	Lacey's silt factor;
i	longitudinal slope;
in (")	inch;
M/sec.	metre per second;
mm.	millimetre;
M.Sft.	million square feet;
N	coefficient of rugosity;
N.S.L.	natural surface level;
P	wetted perimeter;
Q	discharge;

Qty.	quantity;
R	hydraulic mean depth;
Rft.	per running foot;
Rs.	rupees;
S	side slope;
Sec.	second;
Sq.ft.	square foot;
V	velocity
2α	angle subtended by the arc at centre in degrees.

DETERMINATION OF THE MOST ECONOMICAL SUPPLY DEPTH FOR LINED CHANNELS

SYNOPSIS

In the present dissertation, a number of computations have been made to facilitate the design of lined channels. The section adopted is a trapezoidal one with rounded corners. Discharge range used is from 3,000 to 20,000 cusecs.

The study comprises of the following parts:-

1. A design chart for the section shown in figure 2.5 for the rugosity coefficient N equal to 0.017, side slopes (S:1) 2:1 and a bed slope of 1 in 12,000 is presented in figure 2.6 from which for a given discharge, the corresponding full supply depth and bed width can be read.
2. A Cost study for the most economical full supply depth, the bed slope remaining constant at 1 in 12,000, and channel running in balanced depth of cutting has been made. The results are presented in table No. 3.3 and figure 3.6.
3. A Cost study with variable depths of cutting and filling but with a constant slope of 1 in 12,000 has been made. The results of this study are presented in figures 3.7A(i) to 3.7(A)(xiii), 3.7(B)(i) to 3.7 (B)(xiii) and 3.8.

4. Using a limiting value of velocity of 6 ft./sec., a cost study for slopes assuming that channel remains in balanced cutting has been made. The results of this study are presented in table Nos. 3.7(i) to 3.7(xiii), Table 3.8 and figure 3.9.

It is hoped that these charts and curves will be found useful, not only for the Rajasthan Canal Project, but by any design engineer with the problem of designing a lined canal.

CHAPTER-I

INTRODUCTION

1.1 NEED FOR LINING :-

Water for irrigation is an expensive commodity; yet a large part of it is allowed to be wasted every year during its carriage from the reservoirs to the fields, principally through seepage in unlined canals. This loss may be as much as 25 to 50 percent of the water carried. If this water were saved, it would serve to irrigate more land and produce more crops.

Next to China, India has the largest area under irrigation in the World and this being steadily added to under sucessive Five Year Plans. In 1951, of a total cultivated area of 300 million acres (121.40 million hectares), 51.5 million acres(20.84 million hectares)was irrigated. By 1967, another 38.5 million acres (15.56 million hectares) had come under irrigation. It is expected that under the Fourth Five Year Plan the irrigated acreage of the country will be further increased. But such is the pressure of our growing population that we must bring yet more land under irrigation to ensure sufficient food production in the years to come. Indeed, it is expected that within the next few years we shall have over 100 million acres (40.47 million hectares) of land under irrigation.

It has been pointed out that irrigation of arable lands deficient in natural moisture is justified by the resulting benefits. In a like manner, the lining of an irrigation canal is justified economically when its cost can be repaid in monetary benefits accrued during the life of the lining. Some of the more important benefits to be considered in the economics of canal linings are prevention of seepage losses, reduction in required size of canal and lower maintenance costs. Usually there are additional benefits derived from lining of canals such as insurance against erosion and breaks in dykes, and reduction of the danger of water logging of adjacent lands. It may be difficult to place a fair monetary value on such benefits, but, nevertheless, they are important factors and should be given consideration when appraising the value of canal linings.

1.2 JUSTIFICATION OF LINING OF CANALS :-

To secure the benefits of irrigated land, a tremendous amount of capital has been invested ~~the~~ in the country in irrigation projects - the bulk of it since independence. As the water for irrigation is an expensive commodity, it is, all the more disappointing to note that a very large part of it is wasted every year during its carriage from the reservoirs to the fields, chiefly through seepage, as most of the length of canals is not lined. It is true that not all the canals which are unlined permit excessive seepage and there are regions where the soil is such that the absorption in canals is so small that no lining is justified. But by far the bulk of the unlined canals lose anything between 25 to 50 percent of the water they carry, mainly depending on the nature of the soil through which they pass. Observations carried out some years ago on the Ganges Canal System showed that water sent down it was accounted for as under[1] :-

Used actually for irrigation	..	56 percent.
Lost in the main canal and branches.	..	15 percent.
Lost in distributaries	..	7 percent.
Lost in field water courses.	..	22 percent.

It is thus been seen that not less than 44 percent of water was lost, chiefly by seepage, the loss being equally shared by the canal and its branches and distributaries and the field water courses. This is a very seriousloss and, in as much as only the water actually distributed over the land contributes to the raising of crops, this water loss represents a direct reduction in the potential productivity of the country. It represents, in effect, an uneconomic use of the capital sunk in irrigation projects as storage reservoirs and canal systems must have greater capacities and consequently cost more to provide for the water thus lost. This is substantiated by the studies which are being made at the moment for the lining of the Rajasthan Canal as given at Appendix-I.

A further serious consequence of seepage is the water logging of land adjacent to the canals and the consequent rise of salts in the top soil, which soon render the land unfit for cultivation. Thus, the very canals built to increase cultivable area and productivity have within a few years caused the ruin of a portion of the agricultural land under their command.

Fortunately, seepage losses can be greatly reduced by lining of canals and persuading farmers to use pipes and lined ditches for their field water courses. Experiments carried out at the Irrigation Research Institute at Amritsar have shown that under average conditions whilst seepage in unlined canals may be as much as 10 cusecs per million square feet of wetted area, it can be reduced to 1/10 of a cusec or less by lining.

The prevention of seepage losses and consequent reduction in the possibility of waterlogging, although very important, are by no means the only benefits which accrue from lining a canal. Other benefits are:-

1. Increase in the velocity of water and the consequent reduction in the required size of the canal.
2. Prevention of erosion or breaks in the canal bunds.
3. Lower maintenance costs.

The cost of lining a canal is no doubt a heavy item.

Nevertheless, to obtain a fair estimate of ultimate cost it is necessary to balance against the initial cost of lining, the large savings in terms of water which would have been wasted otherwise and land which would have been rendered unproductive.

It will thus seen that lining a canal makes for the most economic utilisation of irrigation water. In as much it requires a smaller section for the same carrying capacity, the excavation is appreciably less; in the case of the Rajasthan Canal the sectional area required for a lined canal has been estimated to be only a third of that required for the same discharge for an unlined canal. In as much as a greater slope is permitted than in an unlined canal, a better and more economical alignment of the canal can be selected. Both these factors lead to considerable savings in the cost of land acquisition and construction. The smaller section and shorter alignment of lined canal also effect economies in the size, number and cost of canal masonry works.

1.3 ADVANTAGES OF LINING CANALS :-

Efficiency of an irrigation system should be measured by the ratio of supply available to cultivators in the fields to the supply at its head. This figure is generally about 0.56 in alluvial Indian plains. This is not to be confused with efficiency of agricultural or cultivation systems. Irrigation efficiency of a canal system should be improved, consistent with overall economy so that the extra expenditure involved is less than the benefits received.

It is observed that the provision of linings reduces seepage losses to about 1% to 2% of the unlined section. The value of this saving in irrigation water in monetary terms will vary with place and season. A lined canal costs 2 to 2½ times as much as an unlined canal, but where seepage is heavy, the saving of irrigation water may, by itself, be sufficient to justify fully the expenditure on the lining. It must be remembered, however, that the additional water made available by lining results in additional production of crops, and the value of this additional production is also a benefit directly attributable to lining, though it does not directly increase the canal revenue. Alternatively, prevention of seepage by lining would reduce the volume of water to be impounded for irrigation of tho same area and thus reduce the capital investment.

1.4 REQUIREMENT OF CANAL LININGS:-

1.4.1 GENERAL:-

An ideal canal lining is one which satisfies the following requirements:-

(a) Impermeability

(b) Hydraulic efficiency.

(c) Reasonable durability

(d) Structural stability

(e) Economy.

These are briefly discussed below:-

1.4.2 IMPERMEABILITY:

A criterion commonly adopted in regard to impermeability is that a lining which limits the seepage losses to 0.015M^3/Sec per million square meters (0.5 cusecs/M. sft.) of wetted area should be considered satisfactory [redacted]

Note:- Cement concrete lining laid in situ and burnt clay tile lining with an intermediate layer of cement mortar satisfy this limit even after many years of operation in the field, but the reduction in seepage losses in the case of soil cement blocks is not very large compared to unlined canal. Some of the data from field measurements is quoted below:-

Type of lining 1.	Seepage loss in cusecs per M.Sft. of wetted area. 2.
1. Unlined channels.	0.26
2. Cement;lime;surkhi (1:5:12) mortar sandwiched between two layers of 12x6x2 in. brick tiles.	0.125
3. cement:sand (1:3) mortar sandwiched between two layers of 12x6x2 in.brick tiles.	0.027
4. 4 in.thick concrete of cement sand:brick ballast in 1:3:6 proportion.	0.02
5. 4 in. thick concrete of cement:lime:surkhi: brick ballast in 1:5:12:24 proportion.	0.39

Note:- All the linings were tested under a 6 ft. water depth and conditions approaching those obtainable in the field.

1.4.3 HYDRAULIC EFFICIENCY:-

The carrying capacity of a canal varies inversely with the value of the rugosity coefficient, and therefore the capacity of a canal is greatly increased by lining it. The rugosity coefficient of a particular type of lining may, however, undergo changes with passage of time. It may increase with time if the lining surface deteriorates thereby increasing relative roughness, or decrease with time due to the growth of algae.

The values of rugosity coefficients recommended for the various types of lining by Central Water & Power Commission [3] are:-

Nature of surface. 1.	Condition Good 2.	 Fair 3.	 Poor 4.
1. Cement plastered surface.	0.012	0.013	0.015
2. Brick work in cement mortar	0.013	0.015	0.017
3. Insitu concrete lining	0.014	0.016	0.018
4. Stone work	0.018	0.020	0.0225

However from practical considerations the rugosity coefficient 'N' should not be based on original surface but on surface that will exist after a few years. The value of N for, concrete and tile lining may be taken as 0.017, as adopted in the design of Rajasthan Canal.

1.4.4 REASONABLE DURABILITY:

The canal lining should be durable and should be able to withstand the effects of rain, sunshine, frost and thawing (if applicable). The material adopted for lining should not be very sensitive to moisture changes, chemical action of salts present in the soil, and should have a small coefficient of thermal expansion.

The different types of linings can be arranged in the ascending order of moisture absorption and hence of decreasing durability as follows [2] :-

(a) Burnt clay double tile lining with sand-wich layer of plaster.

(b) Burnt clay single tile lining with layer of plaster on top.

(c) Cement concrete lining both in situ and pre cast, and

(d) Soil cement block lining.

Based on the experience obtained from the projects where different types of linings have been used it can be concluded that:-

(a) Cement concrete lining is durable with life expectancy of about 40 years.

(b) Double tile lining with sandwich layer of cement plaster is also durablewith life expectancy of about 40 years.

(c) Single layer tile lining with layer of plaster on top surface has been used in the Rajasthan Feeder Canal project.

Evidence in regard to durability will be available after a few years when the canal comes into full scale use.

(d) Soil cement blocks have got a very small span of useful life.

1.4.5 STRUCTURAL STABILITY :-

The lining should be strong enough in flexural strength, and if it consists of several layers they should bond with each other well. Though supported by the subgrade in its entire length the lining may be subjected to external pressures due to a transient rise in sub-soil water table, the back filling getting saturated from seepage or by direct action of rain water. With variation of water level in the canal at a fast rate, differential hydraulic pressures of the order of about 5 to 6 in.(125 mm to 150 mm) have been noticed in large canals[2]. These forces test the strength of the lining and it should not crack under the action of these forces. It may, of course, be noted that no lining is designed to withstand soil or water pressures. Yet even with drainage arrangements, transient hydraulic pressures of limited magnitude cannot be ruled out.

1.4.6 ECONOMY:

This is the most important factor which governs the adoption of the type of lining on a project. The lining adopted should not only be economical in initial cost, but its repairs or annual maintenance cost should also be small. The initial cost of different types of linings depends upon the location of the project, particularly on the availability of different types of construction materials within the economical distance.

Other essential requirements of linings are:-

1. Resistence to mechanical damage.
2. Resistance to weakening and deterioration from biological activity.

3. Reasonably low investment and maintenance costs.

1.5 TYPES OF CANAL LININGS:

Appreciating the necessity of eliminating seepage losses, canal engineers have tried many materials and method for lining their canals. These are

a. Clay lining.

b. Earth lining with admixtures.

c. Asphaltic lining.

d. Hydraulic lime concrete lining.

e. Single brick tile lining.

f. Cement mortar sandwich brick tile lining.

g. Gunited or shotcrete lining.

h. Concrete lining - (i) Institu,(ii)Precast slabs.

i. Plastic membrance lining.

j. Boulder lining.

All these linings have their own advantages and disadvantages and none of these can be considered the best in all cases. A type can be selected with advantage for one locality whereas it may be less satisfactory for use at some other place. The most commonly adopted types of lining in India these days are, however, brick tile or cement concrete lining. This is shown by the following table:-

Name of the project	Type of lining adopted
1. Nangal Hydel Channel	1. Cement concrete (1:2:4) from R.D. 0 to R.D. 9500. 2. Cement concrete (1:3:6) from R.D. 9500 to 14450. 3. Brick tiles(12"x6"x2")& 5/8" thick cement, surkhi and sand mortar from R.D. 14450 to tail.
2. Sarda Power Channel (U.P.)	Two layers of brick tile (10"x5"x2½") in cement,sand and surkhi mortar (1:4) with a layer of plaster sandwiched and another on top.

1.	2.
3. Mahi Canal	Two layers of brick tiles (12"x6"x2") with 5/8" thick impervious layer of (1:3) red cement mortar sandwiched in between.
4. Bhakra Canals	Two layers of well burnt tiles with 5/8" thick layer of 1:3 cement surkhi and sand mortar, sandwiched between the tiles.
5. Rajasthan Canal	Two layers of brick tiles (12"x6"x2") with sandwich cement plaster in between.

Between these two types of rigid lining namely (1) Cement concrete lining, and (2) the brick tile lining with cement mortar sandwiched in between preference is being shown for the latter as it is found to have the same degree of watertightness, coupled with low intial cost as well as low cost for subsequent maintenance. Besides this, the construction methods are easy and quick, and manual labour can be largely employed without need of machinery. This type of lining develops numberous minute hair cracks which minimise the damage to the lining as against the large cracks likely to occur in cement concrete slabs by temperature variations if the joints are inadequate. Maximum use should be made of local materials while specifying a lining, and heavy transport should be avoided as far as possible. The same material need not be used for the whole cross section of channel; the material for lining the bed could be different from that used on the side slopes.

1.6 CHOICE OF A PARTICULAR TYPE OF LINING:-

The choice of a particular type of lining for a canal is govered by various factors such as

(a) Availability of construction materials at the site or nearby,

(b) The type and strength of labour available for the project at reasonable cost;.

(c) The degree of water tightness aimed,

(d) The maximum permissible velocity of flow in the canal and the hydraulic roughness of the lining,

(e) The life of the canal lining i.e. durability and finally,

(f) The standards of operation and maintenance charges.

The main criterion of selection of the type of lining would be economic. A low cost lining with maximum benefits in respect of water conservation and maintenance and operation charges would naturally be preferred to that whose cost is higher for the same benefits. The qualities of the different types of linings used in India have been discussed earlier in article 1.5.

1.7 FIELD CONDITIONS AFFECTING THE SELECTION :

The situations in which the different types of linings will be suitable are discussed below:-

1.7.1 CLAY LINING:-

This type of lining is generally found suitable where

(a) Large bands of clay deposit are available near or along the alignment of the canal.

(b) The aim of the lining is only to curtail the seepage losses. The rugosity coefficient available will be nearly the same as far unlined channels.

(c) Skilled labour is not available.

Under these condtions, this would be the cheapest type of lining. As wet clay will not stand on steep slopes, this type of lining could be provided in the bed, in conjunction with some other type on th the banks. Clay lining should be provided with an earth cover to prevent cracking.

1.7.2 EARTHLINING WITH ADMIXURES :-

This type of lining is generally suitable, where claying material is not available at site, nor can it be brought from within an economic distance. Practically all types of soils normally encountered during canal excavation can be used for this purpose, this long transport leads will not be involved. The most common admixure used is Portland cement. The percentage required varies from 2% to 8% depending on the nature and gradation of the soil. Such a lining is cheaper than the usual types of the cement mortar sandwich brick tile lining, and is specially useful under low heads in small channels. The velocity in such channels should be less than 4 ft/Sec. (1.22 metre/Sec.)

1.7.3 ASPHALTIC LINING :-

As asphalt is not available in adequate quantities in India, these linings have not been used in this country.

1.7.4 HYDRAULIC LIME CONCRETE LINING :-

This type of lining is generally suitable where Kanker lime is available in large quantities along the alignment of the canal. It has been used successfully for Gang Canal in Bikaner.

1.7.5 SINGLE BRICK TILE LINING :-

This type of lining will generally be found suitable for adoption only in the bed of canal and not on sides. It can be used where the subgrade below the lining is thoroughly compacted and there is no possibility of its subsequent settlement. The advantages of this type are enhanced if the aggregates for concrete are not available within economical lead and suitable soils are available for burning brick tiles. and also if skilled labour for manufacture and placing of concrete is not available.

1.7.6 CEMENT MORTAR SANDWICHED BRICK TILE LINING (DOUBLE LAYER TILE LINING WITH SANDWICH LAYER OF PLASTER) :-

As compared to single tile lining, this type has greater water tightness and strength. For this type the velocity ranges between 4-6 ft/Sec. (1.22 to 1.83 m/Sec.). It helps in preventing weed growth, stops burrowing animals and is more or less permanent.

1.7.7 GUNITED OR SHOT - CRETE LINING :-

This type of lining is suitable where there are small and widely scattered jobs. This has been used only for repair jobs in India.

1.7.8 CONCRETE LINING :-

(i) In situ (ii) Precast slabs.

(i) IN SITU :-

(a) Coarse and fine aggregates for concrete lining are available within relatively economical leads.

(b) The water transports considerable amount of coarse sediment which may damage by erosion other types of linings e.g. burnt clay tiles, soil cement blocks etc.

(c) High filling reaches adjoining cross drainage works and power houses in the case of hydel canals.

(d) Flat slopes are necessary to command maximum areas because it has got smaller coefficient of rugosity.

(e) The seepage losses are required to be restricted to the minimum.

(f) Velocity to be encountered in general is more than 6 ft./Sec. (1.83 M/sec.).

(g) Skilled supervision is available.

(ii) PRECAST CONCRETE SLABS :-

By precasting concrete tiles or slabs, the speed of the work can be improved and the problem of skilled work at site is reduced. If laid with open points, it would allow considerable seepage loss, but when laid in mortar, it would have the characteristics of a tile lining.

1.7.9 PLASTIC MEMBRANCE LINING :-

The experience on this type of lining is also limited. It would provide an efficient seepage cut off, but other properties of the section will not be changed as the plastic membrane hasto be protected by an earth cover.

1.7.10 BOULDER LINING :-

This type is generally found suitable where -

(a) Sub-soil water table outside the canal is high and it is necessary to release the pressures behind the lining. If portions of the lining are left without mortar, such relief will be obtained.

(b) The canal transports coarse sediment and the lining is required to resist abrasion.

(c) Boulder of required sizes are available within economical leads.

( ) The head loss in the canal is of no consideration.

(e) The velocity to be encountered is less than 5 ft/sec. (1.52 m/Sec.).

1.8 PROSPECTS OF CANAL LINING IN FUTURE PROJECTS :-

While the quantity of water available in nature is more or less limited, the demand for the same is increasing day by day.

The total annual run-off of India as a whole is plentiful. But it is distributed unevenly over the various States. Irrigation potential of the country depends upon two factors, the available water and cultivable land. There are some States which have more land potential than water resources for irrigation purposes. It will generally pay to conserve water by lining future canals in these States (which are deficient in water potential) as a long range policy.

Once a canal project is built without lining and put into operation, it becomes uneconomical to line the system subsquently. Hence on future projects, the provision of lining should be seriously considered right from the beginning.

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CHAPTER II.

DESIGN OF LINED CHANNELS.

A knowledge of the theory governing the design of lined channels is essential for a construction engineer also so that he fully realises the effects of his recommendations to modify sanctioned designs to suit his construction techniques in the field. He is likely, otherwise to over look some important design essentials and upset the carrying capacity of the channel concerned.

The purpose of an irrigation canal is to deliver impounded water to cultivable land at as low a cost as possible. All canals are costly to maintain and the first cost of lining is always a large percentage of the total cost of a canal system. Care is, therefore required to design the best and most economical section for a given set of data. That lined canal is cheapest which delivers a given quantity of water for the least annual cost; and annual cost includes depreciation of assets, interest on capital invested and annual maintenance and operation charges. Besides this, the design should fulfil all local requirements, such as adequate safety against a break through in weak spots in the alignment, satisfactory delivery to adjacent lands or high level lands, and the capacity to deliver the full quantity of water at peak demand.

2.1 CHANNEL GRADIENTS :-

After the discharge required for a canal has been determined, an engineer proceeds to fix gradients in its various reaches. If the natural falls in the ground level permit, maximum gradients should be allowed consistent with velocities permissible for the type of lining proposed. On the other hand, where the available fall is small or restricted by consideration of "command", the canal section should suit the minimum grades and the material for lining should be selected accordingly. The gradients usually vary from 1 in 5000 to 1 in 10,000 and are flatter for channels with higher capacities. gradients will affect velocities and, therefore, also materials for lining which could be varied for different reaches of a big canal system to suit local conditions.

2.2 DESIGN OF CROSS-SECTION OF A LINED CANAL:-

Most economical open channel section is semicircular. However, since the sides of channel should be selfsupporting as otherwise, the required thickness would be prohibitive. The banks of the channel have to be made at stable slopes. This rules out the provision of semicircular section. With this limitation a hydraulically efficient section is obtained with a circular bed and straight sides tangential to it as shown in figure 2.1. This type of section, however does

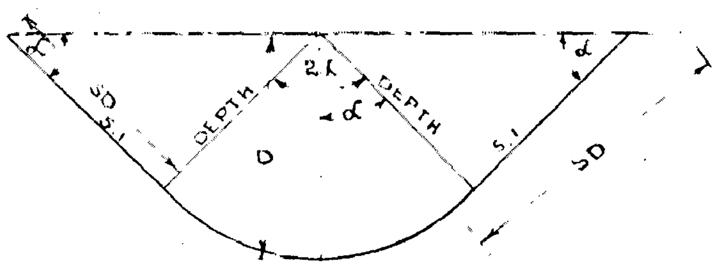


FIG. 2.1 SHOWING CIRCULAR LINED SECTION

not give any horizontal portion in the bed and for larger discharges, it will require too large a depth. It is, therefore, preferred for small channels only, carrying discharges upto 3000 cusecs. From practical consideration of avoiding very large depths it is advisable to use trapezoidal sections with rounded corners (figure 2.5) for discharges exceeding about 2,000 cusecs. The radius of this rounding curve is equal to full supply depth. Besides increasing the hydraulic mean depth of a channel for a given area it does away with the necessity of building toe walls for supporting side slopes.

According to sally [4] this section is also useful as it has a higher silt carrying capacity compared to a wide shallow section. During low supplies, heading up has to be done at off take sites which causes some silting. The silted bed, due to increase of rugosity, reduces the velocity in the canal. In the section proposed, however, the silt will deposit only on a relatively small central portion of the perimeter and hence cannot greatly affect the average coefficient of rugosity and, therefore, the design velocity.

The above figure 2.1 shows the ideal section for brick or concrete lined channels for discharges upto 3,000 cusecs. The limiting depth for such sections should be never more than 15 ft.

The sectional data for section shown in figure 2.1 with radius equal to full supply depth D and hydraulic mean depth R would be given by the following formulae:-

Side Slope (Horizontal/Vertical)	$S : 1 \ (= \cot\alpha)$
Hydraulic mean depth = R	$0.5D$
Angle subtended by the arc at the centre in degrees.	2α
Sectional area = A	$\frac{\pi D^2 \alpha}{180} + SD^2$
Wetted perimeter = P	$\frac{\pi D \alpha}{180} + 2SD$

Longitudinal slope i

Coefficient of rugosity N

The velocity according to Manning's formula

$$V = \frac{1.49R^{2/3}}{N} i^{\frac{1}{2}} = \frac{1.49}{N} (0.5D)^{2/3}(i)^{1/2}$$

Figure 2.2 [3] shows a graph for reading velocities in lined circular section using Manning's formula with N = 0.018.

$$\text{Discharge } Q = AV = \left(\frac{\pi D^2 \alpha}{360} + SD^2\right) \left(\frac{1.49}{N}\right) (i)^{\frac{1}{2}} (0.5D)^{2/3}$$

$$= D^{8/3}\left(\frac{\pi\alpha}{360}+S\right) \left(\frac{1.49}{N} \right)(0.63)(i)^{\frac{1}{2}}$$

$$= 0.936D^{8/3}\left(\frac{\pi\alpha}{360}+S\right) \left(\frac{i^{\frac{1}{2}}}{N}\right)$$

$$\alpha = 2 \tan^{-1} 1/S$$

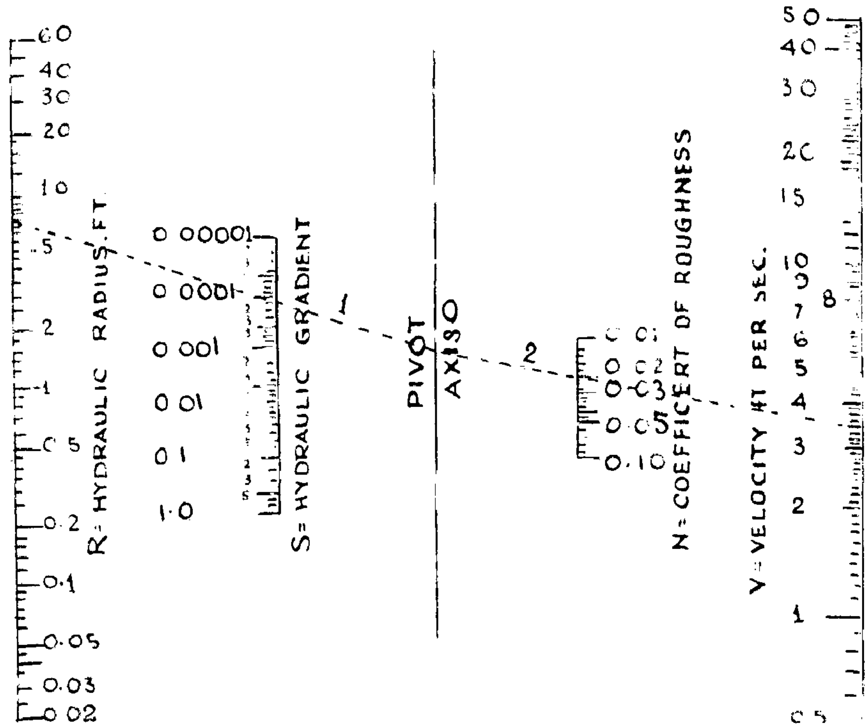
$$Q = 0.936\, D^{8/3} \left(\frac{\pi\, 2\tan^{-1} 1/S}{360} + S\right)\left(\frac{i^{\frac{1}{2}}}{N}\right) \quad \ldots(2.1)$$

For a given lining material choosing a proper value of 'N' i.e. rugosity coefficient needs judgement. Table in article 1.4.■ can be used for this purpose.

This formula (2.1) is used for calculating discharge for the circular lined section shown in figure 2.1.

Gradients may be kept the sttepest practical from topographical considerations subject to the maximum permissible velocity of about 6 ft/sec.

Graphs connecting Q,S,D,fL and V have been shown in figure 2.3 (a) and 2.3 (b) for N=0.018 and side slopes 1:1 and 1½:1 respectively [3]. These can be conveniently used for the design of circular sections for other values of



$$V = \frac{1.486}{N} R^{2/3} S^{1/2}$$

EXAMPLE.-

FIND THE VELOCITY FOR A CHANNEL FOR THE FOLLOWING DATA

R = 7.0

N = 0.02

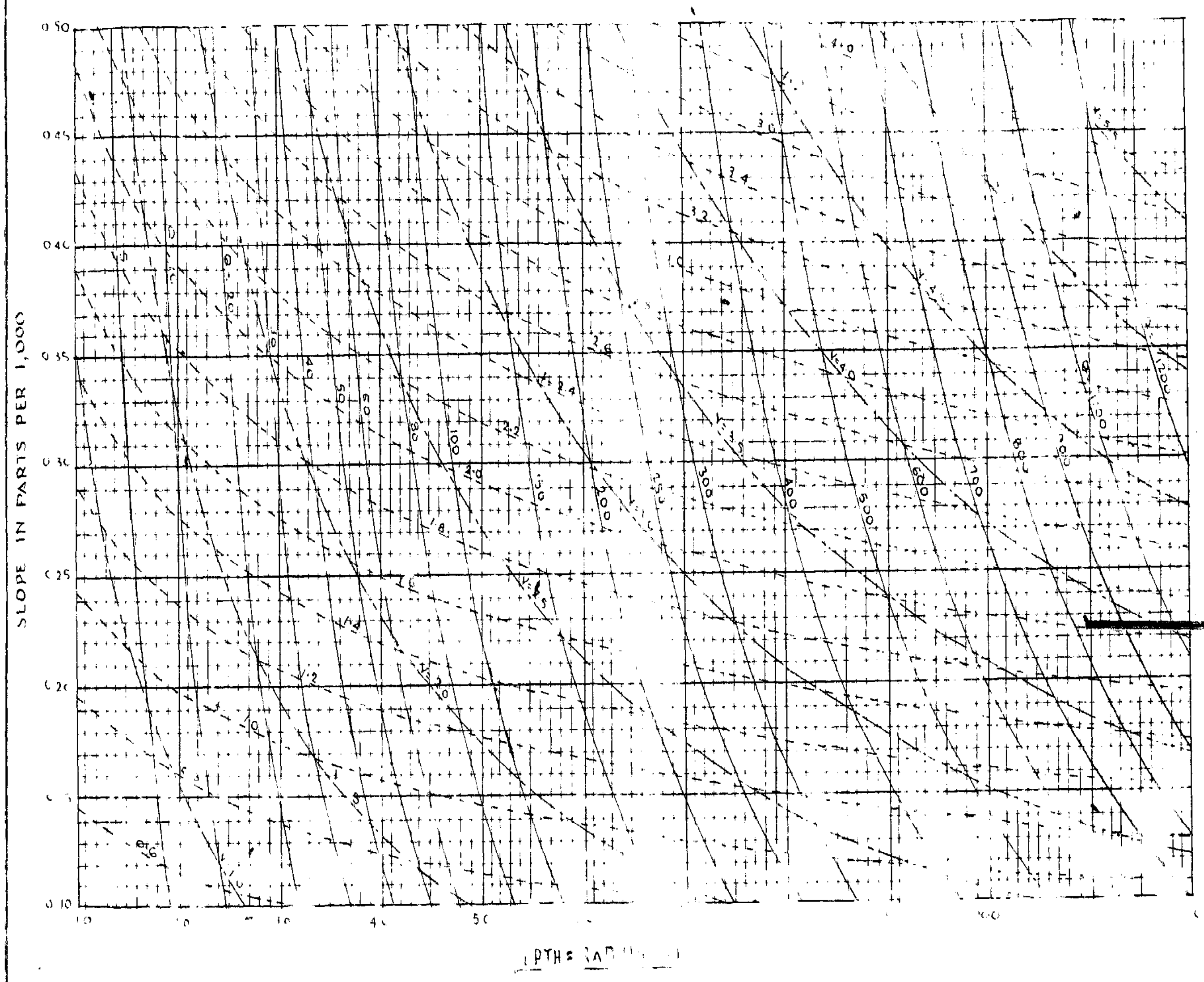
S = 0.15 PER o/oo

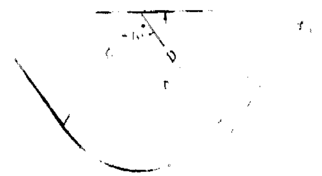
1. CONNECT R = 7.0 AND S = 0.15 AND PRODUCE TO INTERSECT THE PIVOT AXIS AT O

2. CONNECT O & N = 0.02 AND PRODUCE TO INTERSECT THE SCALE V THIS GIVES V = 3.33

TAKEN FROM DRAFT MANUAL ON IRRIGATION CHANNELS C.W. & P.C. (WATER WING.) NEW DELHI 1960

FIG 2.2 SHOWING GRAPH FOR READING VELOCITIES IN LINED CIRCULAR SECTION MANNING'S FORMULA





FOR OTHER VA...

(i) ...

N ... DISCHARGE MUL... BY $\frac{N_1}{N}$

N = 0

N_1 0.01 ... 020 ... 022

$\frac{N_1}{N}$ 0.833 ... 111

\# TO DETERMINE ...

READ FOR THE DISCHARGE CALCULATED ABOVE AND MUL... IT BY $\frac{N}{N_1}$

N = 0.018

N_1 = 0.015 0.016 ... 0.020 ... 022

$\frac{N}{N_1}$ 1.200 ... 1.0 ... 0.90 ...

(iii) TO DETERMINE ...

READ FOR THE DISCHARGE CAL... TRY...

N ... 018

N 0.015 0.016 ...

... 440 ...

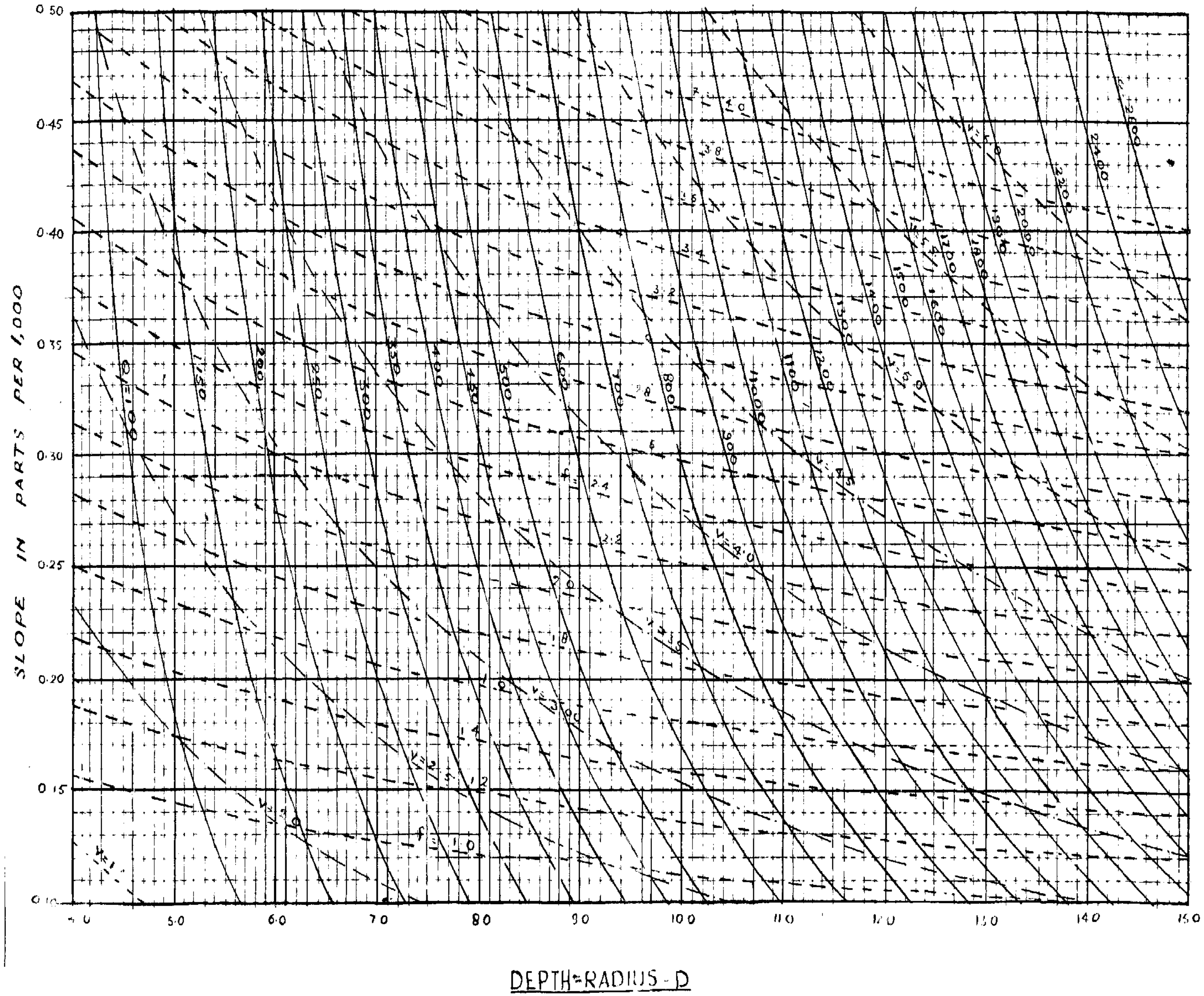
N.B. ...

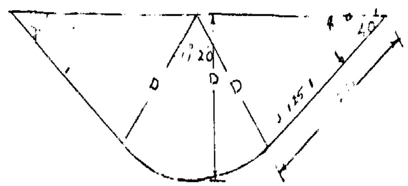
1. FIRM CURVES SHOW ... TAKEN ... IRRIGATION

2. DOTTED CURVES SHOW VALUE ... CHAN... ...

DOTTED CURVES ... W

FIG. 2.3(a) SHOWING CURVES FOR DESIGN OF CIRCULAR SECTION LINED CANALS WITH 1.5 TO 1 SIDE SLOPE & N = 0.018 MANNING'S FORMULA





FOR OTHER VALUES OF N

(i) TO DETERMINE Υ

READ AGAINST DISCHARGE MULTIPLIED BY $\frac{N_1}{N}$

N= 0.018

N_1=	0.015	0.016	0.020	0.022
$\frac{N_1}{N}$=	0.8333	0.8889	1.111	1.222

(ii) TO DETERMINE V

READ FOR THE DISCHARGE CALCULATED ABOVE & MULTIPLY IT BY $\frac{N}{N_1}$

N=0.018

N_1=	0.015	0.016	0.020	0.022
$\frac{N}{N_1}$	1.200	1.125	0.900	0.8182

(iii) TO DETERMINE Υ

READ FOR THE DISCHARGE CALCULATED ABOVE & MULTIPLY IT BY

N= 0.018

N_1=	0.015	0.016	0.020	0.022
$(\frac{N}{N_1})^2$=	1.440	1.2656	0.810	0.6696

N.B.
1. FIRM CURVES SHOW DISCHARGE IN CUSECS
2. DOTTED CURVES SHOW VALUE OF Υ
3. CHAIN DOTTED CURVES SHOW VALUE OF V

TAKEN FROM DRAFT MANUAL ON IRRIGATION CHANNELS-C.W.&P.C. (WATER WING) NEW DELHI 1960

[redacted]

FIG 2.3 (b) SHOWING CURVES FOR DESIGN OF CIRCULAR SECTION LINED CANALS WITH 1.25 TO 1 SIDE SLOPE & N=0.018 MANNING'S FORMULA

N as explained alongside the graphs.

Typical example has been worked out in appendix II.

2.2.1 <u>TRAPEZOIDAL SECTION</u> :-

For larger discharges, the required radius or maximum depth of the circular section becomes impractical. Very large depths involve excavation below the water table and large lifts for earthwork. Also, where machinery is used, operation becomes difficult in narrow deep sections, comparatively larger depths will be found to be economical in filling reaches as compared to those in the digging reaches. We have thus to adopt a trapezoidal section, with or without rounded corners.

The choice between a narrow and deep section or a wide and shallow one depends to a considerable extent on the position of sub soil water table with reference to designed bed level of the canal. To avoid construction difficulties and, later to avoid failure of lining by uplift pressures, it is desirable to keep the canal bed above the water table in foreseeable future. Economic base widths and depths for trapezoidal sections as accepted in American practice are given in figure 2.4 for discharges from 10 to 4,000 cusecs. The efficiency of type of section can be improved by replacing the corners by circular are as shown in figure 2.5.

For this type of cross-section the sectional data is given by the following formulae :-

Side slope (Horizontal/vertical)	S:1
Sectional area = A	$D(B+D(S+\frac{\tan^{-1} 1/s}{57.3})$
Wetted perimeter = P	$B+2D(S+\frac{\tan^{-1} 1/s}{57.3})$

TENTATIVE BASE ... THE ... WATER DEPTH ... CANALS IN RELATION TO CAPACITY

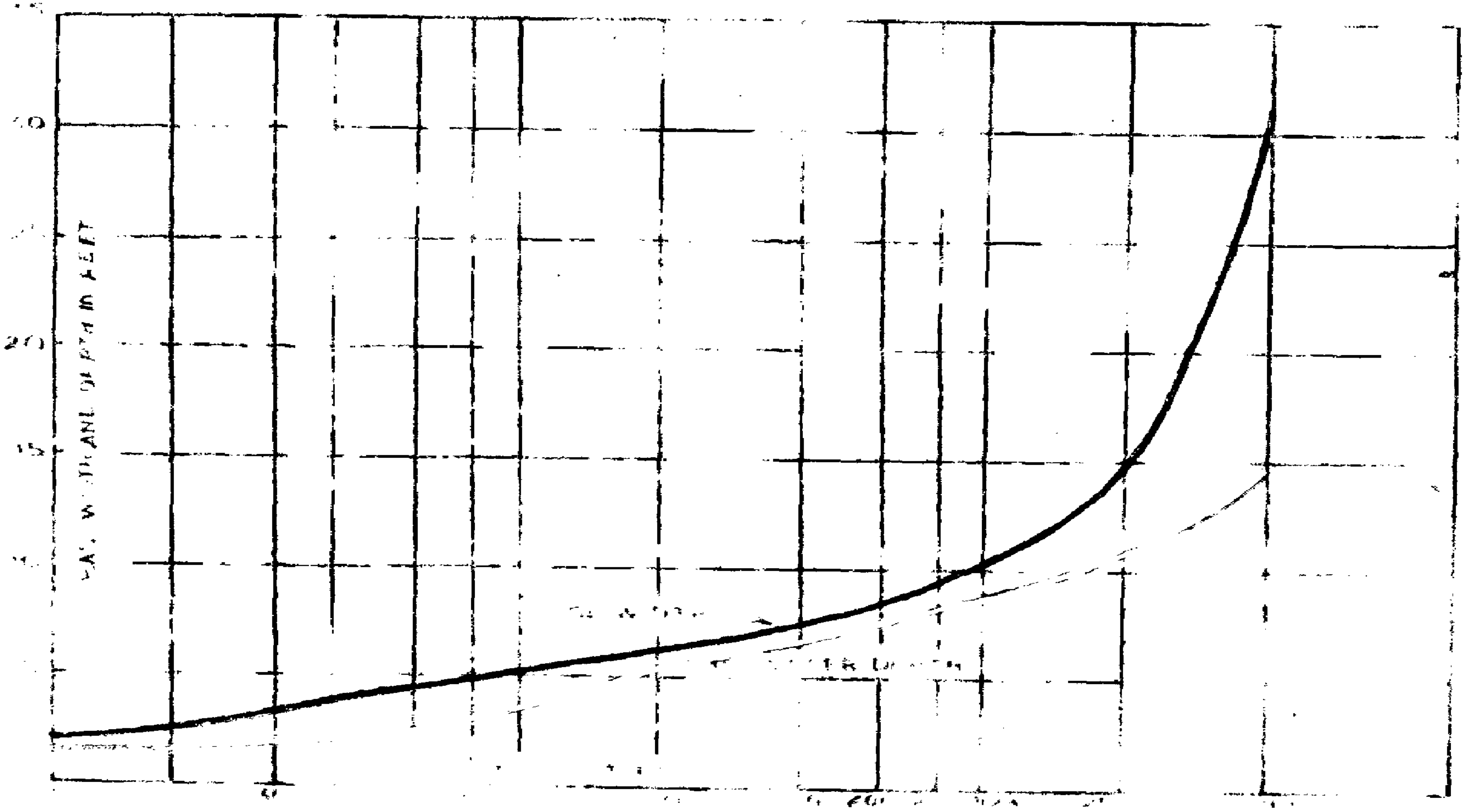
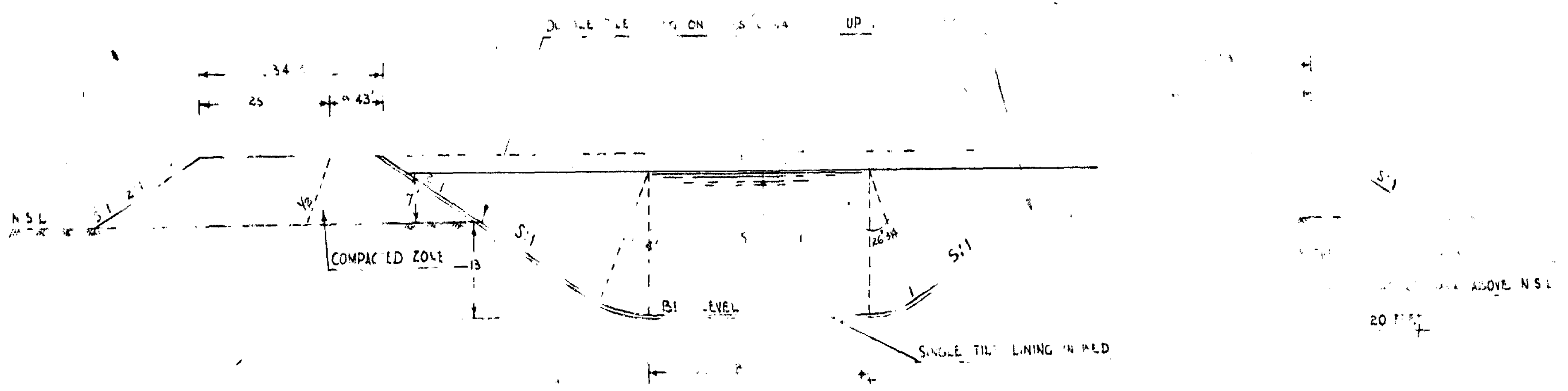


FIG. 2



TYPICAL CR SS SECTION OF CANAL

FIG.2·5 SHOWING TRAPEZOIDAL LINE ECTION

Longitudinal slope

velocity according to the Manning's formula

$$V = \frac{1.49}{N} R^{2/3} i^{\frac{1}{2}}$$

$$= \frac{1.49}{N} \frac{(D(B+D(S+\tan^{-1}1/S/57.3)))^{2/3}}{(B+2D(S+\tan^{-1}1/S/57.3))^{2/3}} i^{\frac{1}{2}}$$

Discharge Q $= AV$

$$= \frac{1.49}{N} i^{\frac{1}{2}} \frac{(D(B+D(S+\tan^{-1}1/S/57.3)))^{5/3}}{(B+2D(S+\tan^{-1}1/S/57.3))^{2/3}} \ldots\ldots(2.2)$$

Graphs with N = 0.017 for side slopes 2:1 and longitudinal slope 'i' equal to 1 in 12,000 have been plotted by the author relating the various data. These would be found useful in designing a suitable section for any value of 'N' with varying bed slopes vide instructions on chart in figure 2.6.

A section with rounded corners is better than a purely trapezoidal section, as it is hydraulically more efficient and also economical as it does away with the need of having a toe wall to support the side slopes.

2.3 FREE BOARDS:-

Free boards are primarily meant to prevent spilling over of water by wave action. This will depend on the water surface width of a canal. They also safe guard against danger from extra supplies passing down the canal by operational errors. A vertical free board of 2.0 to 2.5 ft. is quite ample for main canals and Branches. For channels upto 500 cusecs capacity, a margin of 1.0 to 1.5 ft. will, however, be ample.

It should never be less than one foot in distributaries or minors but could be reduced to 6 inches in case of laterals or water courses. The formula [4] given below is indicative of the free boards to be adopted.

Free Board in feet = $0.5D^{1/2}$ where D is F.S.D. of channel in feet. The height of the lining and bank above water surface is sometimes also controlled by the flood levels of drainage water intercepted by the canal bank.

2.4 SIDE SLOPES :-

The side slopes of lined channel (S:1) should more or less conform to the steepest stable slope for the supporting subgrade. For different materials the approximate stable angle are -

Material	Stable angles	Lining slopes
Firm clay well drained	45°	1:1
Clay loam and sandy loam	36°-33°	1¼:-1½:1
Sandy or gravelly soil	33°-25°	1½-2:1

In case appreciable seepage pressures develop in the bank behind the lining by rainstorm as canal seepage, these will not reduce simultaneously with the lowering of water level in the canal section. Thus the lining may be subjected to differential hydraulic pressures, and to avoid these drainage arrangements will be needed if the bank soil has a low permeability.

If side slopes are kept steeper than the stable angle the soil of sub grade, the thickness of the lining membrane has to be designed as that of sloping retaining wall with earth backing in a saturated condition. This would be found to be prohibitively expensive.

2.5 FULL SUPPLY DEPTH :-

The full supply depth is governed by the following considerations :-

1. Having fixed the alignment and full supply levels from the command point of view, the depth may be such as to give balancing depth as far as possible.

2. Velocity may not exceed permissible values.

3. The bed of the channel, may be higher than sub soil water level as far as possible ; so as to avoid pumping during construction and uplift pressures after closure of channel.

4. In case of main canal and branches the depth should be such that it gives enough bed width to provide convenient working space for the excavation equipment.

2.6 PERMISSIBLE VELOCITIES IN DIFFERENT TYPES OF LINING :-

The I.S.I. (Draft Indian Standard "Criteria for selection ~~for selection~~ of type of lining") has proposed the following limiting velocities for the different types of linings.

(a) Soil cement blocks	4ft/sec. (1.22M/Sec.)
(b) Boulder lining	5ft/Sec. (1.52M/Sec.)
(c) Burnt clay tile lining	6ft/Sec. (1.83M/Sec.)
(d) Cement concrete lining	7ft/Sec. (2.13M/Sec.)

2.7 PRESSURE RELIEFS :-

A canal sometimes passes through a tract of high sub soil water table. As lined channels are deep, the sub soil water level sometimes happens to be higher than the bed. Construction work becomes very difficult in such cases and very expensive at the same time. Sometimes sump wells are provided and water level kept below bed level by continuous pumping.

It is, however, desireable to ~~level~~ modify design of the section in these reaches to have a wider and shallower channel. This will reduce, if not eliminate, the necessity of pumping during construction. Pressure relief is provided in the bed to safe guard the lining against uplift pressures which later develop under the bed of these canals. These reliefs valve, are scattered all over the bed at suitable distance apart. They will also be helpful in draining the saturated banks behind the lining whenever water level in the canal drops suddenly.

Subsoil watertable sometimes rises in course of time by development of intensive irrigation in tracts adjoining the canal. This also creates the difficulty of uplift pressures under the canal bed. Pressure relief ~~may appear~~ provided at places of potential sub-soil w-atertable rise, may appear to be wasted, but it will be very helpful at some future date. These pressures can also be relieved by providing inverted filters under the bed and connecting them to a system of under ground drains connected to sump wells outside the canal. This will mean high maintenance costs and much work if the system gets choked up. Vertical pressure relief pipes are, therefore, always preferred. If valves are not provided, this has the disadvantage that during flow of canal it acts as a percolation pipe, partly reducing the advantage of lining. This disadvantage is eliminated by providing suitable one way flap valve at the top of the pipe so that it opens with pressure from below but gets tightly closed under pressure head when canal is in flow.

CHAPTER III.

STUDY FOR DETERMINING MOST ECONOMICAL FULL SUPPLY DEPTH

In this chapter description of the studies made to determine the most economical full supply depth is given. The studies have been done for discharges ranging from 3,000 cusecs to 20,000 cusecs with a discharge range of 1,000 cusecs upto 10,000 cusecs and 2,000 cusecs range thereafter. As described above in para 2.2, for discharges exceeding 2,000 cusecs trapezoidal sections with rounded corners are advisable from practical consideration of avoiding too large depths. This section has been adopted for the study. Although the study is general in nature and will be found useful in designing such sections for any project, some of the data (viz the side slopes and bed slope) assumed for the present study is as adopted for Rajasthan Canal, which is the longest canal in the world. At the same time it is in the Rajasthan State which is the parent state of the author. This study for different discharges has been made with the primary objective of affecting economy in designing the Rajasthan Canal. Similar studies can be conducted for other conditions also. The description of the Rajasthan Canal alongwith its salient features has been given in subsequent paras.

3.1 THE RAJASTHAN CANAL PROJECT:-

3.1.1 GENERAL :-

Legend has it that Western Rajasthan was once verdant and rich. The rivers which gave rise to its prosperity have since somehow vanished and the land reduced to a parched sandy waste. This arid tract is now inhabited by nomadic tribes which are continuously on the move in search for water.

The Rajasthan Canal Project seeks to transform a vast inhospitable stretch of desert land over 325 miles long by 27 miles wide with existing population in place as low as only six persons per square mile into a prosperous agricultural region. This very area, when developed, will be populated by two million people.

The Rajasthan Canal work has been planned to bring back prosperity to this area. It is being constructed to irrigate annually an area of about 30 lakh acres (12.10 lakh hectres) spread over a gross area of about 50 lakh acres (20.23 lakh hectres) on a portion of the great Indian Desert, situated in the North-west of Rajasthan. Besides providing irrigation facilities, the aim is to transform this desert tract in the districts of Sriganganagar, Bikaner and Jaisalmer into a prosperous fully developed region humming with people, agriculture, industry and commerce. This project thus opens out possibilities for resettlement of agriculturists, workers, tradesmen and many other categories of people from outside the area.

The rainfall in this area is only nominal. It varies from 3" to 8" in the Jaisalmer District and 8" to 12" in Bikaner and Ganganagar districts. The average depth of water in wells is 250 ft. below ground level and in places water is hardly available even at 500 ft. There is not enough water available even for drinking purposes. Every drop of rain is carefully collected in pucca shallow wells and tanks for the summer. After using up their on store of water, the villagers fetch water from surface ponds, miles out, till they dry out. Under such conditions of scarcity of water, it is evidently not possible to grow any worthwhile crops.

The Rajasthan Canal Project consists essentially of a 426 mile main canal taking off from the Harike head works at the confluence of the Sutlej and the Beas, and of storages on the Ravi and the Beas to collect surplus monsoon water. (Figure 3.1).

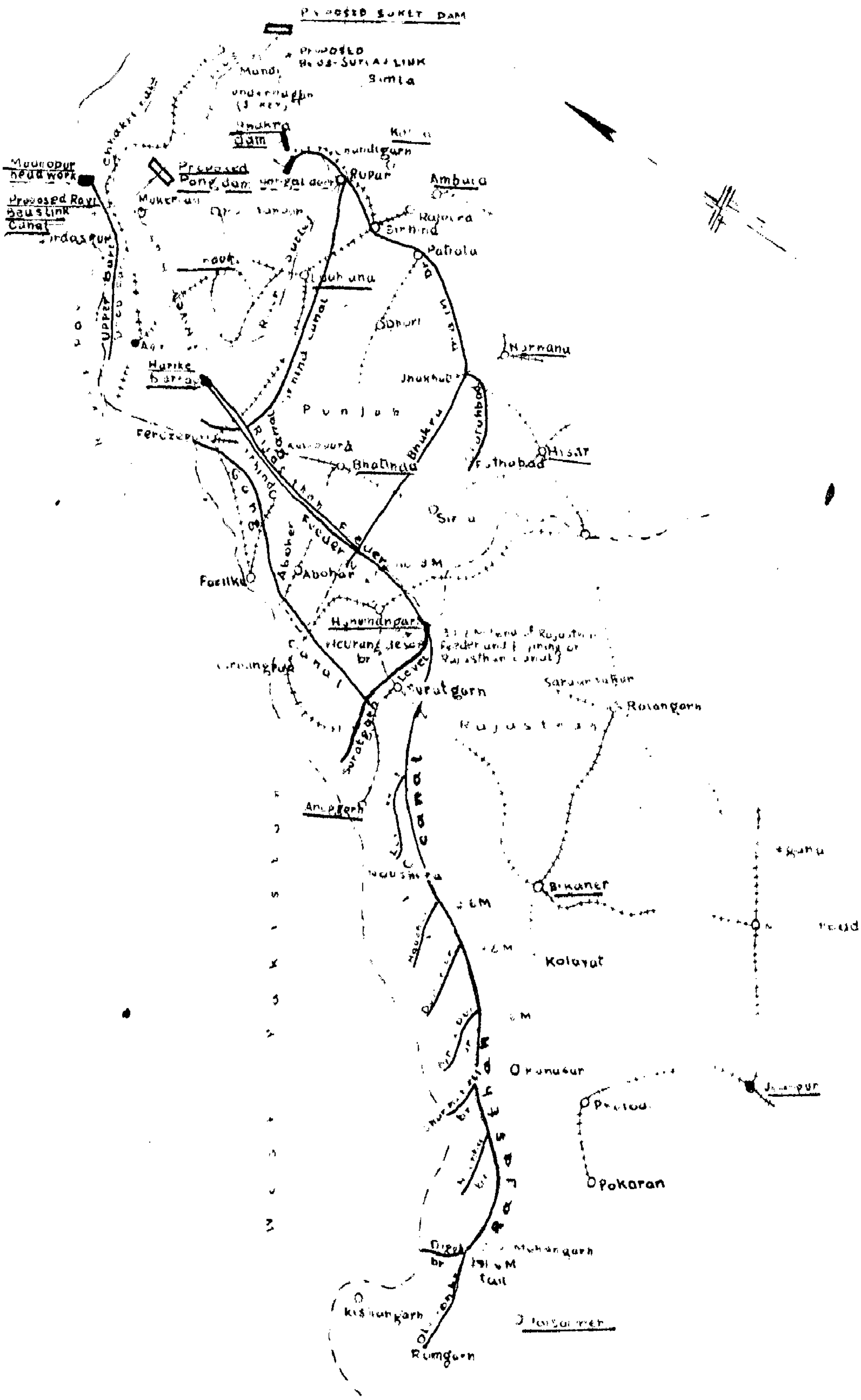


Fig. 3'1. A map of parts of the Punjab and Rajasthan showing the location of the Rajasthan Feeder and the Rajasthan Canal acres is cultivable. Irrigation is proposed to be carried out mainly in the 45 mile belt to the west of the canal, following natural gradients. On the eastern side, lift irrigation is also proposed to be done depending on the availability of power.

The canal is proposed to be constructed in two stages. Stage I comprises of the Rajasthan main canal upto 122 mile 122 and distribution systems of the main canal upto this point. The main canal below mile 122 and all the off taking channels in this reach are proposed to be taken up in the second stage.

The cost of the Rajasthan Canal Project including the share cost of the storage dam in the Beas River as estimated vide 1963 estimates is Rs.184.09 crores. This comprises of (i) Rs.45.39 crores as the share of the cost of the Madhopur Beas link, Harike Barrage and Pong Dam (ii) Rs.74.43 crores for the work of the Ist stage and (iii) Rs.63.97 crores for the work of the IInd stage of the project. Due to revision in the estimated cost of the Pong Dam currently in hand and increase in rates of materials and labour during the last five years, these figures are likely to be revised upwards. The above amount also includes a sum of about Rs.37.50 crores (about 20% of total cost) for lining the whole of the main canal and branches to conserve the water which would otherwise be lost in the sandy tracts through which the canal flows.

The Stage I which was earlier proposed to be completed by 1968-69 is now proposed to be completed by the year 1971-72 and Stage II by the year 1977-78.

3.1.2 <u>PRODUCTION POTENTIALITY OF THE PROJECT</u> :-

The total production of various crops on the full development of the Rajasthan Canal Project (Stages I and II) is estimated as 27.16 lakh tons amounting to Rs.123 crores.

The present annual food deficit at all India level is estimated at 100 lakh tons. It will thus be seen that the Rajasthan Canal alone would be able to meet at least 25 to 35% of this deficit on full development of irrigation. With improved agricultural practices and use of hybrid seeds, the production would increase considerably and in that case this project would have the capacity to cover upto 50% of the country's present food deficit.

3.1.3 PROGRESS OF CONSTRUCTION :-

The Rajasthan Canal (including the feeder in its entire length) has been completed in a length of 182 miles and work is in progress for another 32 miles below this reach. The Naurangdeser, Rawatsar, Zorawarpura, Khodawali distributaries and Suratgarh branch have already been completed. Work is in progress on the Anupgarh Branch system, Sardarpura, Khudan, Chuli and Jesabhati Distributaries.

3.1.4 INTENSITY OF IRRIGATION :-

Since increased supplies are now expected as Rajasthan's share of Indus River waters according to the latest water studies, there will be sufficient water for taking the canal upto Ramgarh in Jaisalmer district as originally planned. Further, it is also possible to give some water for improving the water allowance in the existing Gang Canal and Bhakra Canal systems.

3.1.5 NEED FOR EARLY COMPLETION OF THE PROJECT :-

The Rajasthan Canal Project is a national project and to meet the food deficit of the country as a whole it is essential to have it completed as early as possible. Some of the important considerations justifying the taking up of the project on a top priority basis are as under :-

(a) Under the Indus Water Treaty no waters of Rivers Ravi and Beas need flow to Pakistan after 31st March, 1970. In addition, winter supplies which are at present being allowed to flow to Pakistan are being gradually withdrawn from the year 1967. Advance construction is very necessary for the utilisation of these waters, which are being made available at such enormous cost to the country. If this is not done these waters would keep flowing into Pakistan unnecessarily.

(b) A sum of £ 6,20,000 (Rs.110 crores approximately at present rate of exchange) would have been paid by India to Pakistan for obtaining rights to use these supplies in India.

(c) The large investment made on Pong Dam which is presently estimated to cost Rs.130 crores will start bearing real fruit only when large areas are irrigated on the Rajasthan Canal.

(d) Almost all of the area in the Project is unoccupied and large numbers of people can be settled in this area.

(e) Area commanded by the Project borders the boundary between India and Pakistan and the development of the area will create a prosperous region, which would be a good buffer for any untoward activities by Pakistan. The project has therefore a definite defence value for the country.

(f) Nothing grows in the area at present which has rich potentialities. The estimated produce from the area is 27 lakh tons and the value of the agricultural produce will be Rs.123 crores per year.

(g) In addition, there would be inumerable indirect advantages and benefits both financially and socially, e.g. drinking water, establishment of new integrated communities from different parts of India, planned rural and urban development, and long term beneficial effects on climate.

It is, therefore, of utmost importance in the interest of the country that this project is completed as rapidly as possible.

If one visualises construction work going on in a desert (where there is no water even for drinking) where temperature ranges upto 125° F and where dust fills the air much of the time, one can then appreciate the extreme difficulties under which the project is being executed.

3.1.6 <u>LIFT IRRIGATION SCHEME</u> :-

The question of providing Lift Irrigation on Rajasthan Canal Project have been under consideration and different alternatives have been investigated from time to time. It has now been finally decided by the Government to construct a Lift channel of 500 to 600 cusecs capacity from mile 48 of Rajasthan Main Canal upto Bikaner via Lunkaransar. Besides providing irrigation facilities to an area of over 1 lakh acres near about Lunkaransar and Bikaner it will provide drinking water facilities to the age long water scarcity affected areas along its route upto Bikaner.

3.1.7 INCREASED INTENSITY OF IRRIGATION ANDLINING OF CHANNELS :-

The intensity of irrigation was originally fixed at 78%. With the availability of additional supplies, and less culturable commanded area in the middle reaches of the canal than earlier envisaged it has now been decided to increase the intensity of irrigation to 90%.

It has further been decided to line all the branches and distributaries of the system at an approximate cost of Rs.28 crores. The intensity of irrigation is likely to be increased to 110% due to saving in absorption losses on account of lining of the channels.

3.1.8 ECONOMICS OF LINING OF RAJASTHAN CANAL :-

With such a large expenditure on capital works to ensure perennial water supplies to the Rajasthan Canal, it will be appreciated that it is of paramount importance to save as much of this costly water as possible for actual irrigation and preventing its waste by seepage in the canal. This is done by lining the canals, and although the initial cost of lining is heavy, it can be fully justified by the great saving it eventually produces.

Let us study the case of the Rajasthan Canal. The factors primarily influencing seepage are the quality of soil through which the canal runs, the wetted perimeter, and the depth of water in the canal. It has been estimated that seepage losses in an unlined canal running through soil of the type found in Western Rajasthan is of the order of 8 cusecs per msft. of wetted area. At this rate the total losses in the system would be about 5,000 cusecs. Since the capital cost per cusec is about Rs. one lakh the ineffective investment would amount to Rs. 50 crores.

The recently constructed Bhakra Canal system has shown that a cusec of water will irrigate about 200 acres in Rajasthan. Then with, 5,000 cusecs saved, an additional 1 million acres would be brought under cultivation yielding 3,50,000 tons of food grains annually, valued at Rs.14 crores. Furthermore, taking a conservative assessment Rs. 10 per acre for water and land taxes, the revenue to Government from additional cultivation would amount to Rs. 1 crore.

From the foregoing it will be seen that lining a canal is a thoroughly economic preposition. Normally, the value of the water saved and the lower operational and maintenance expenditure should in themselves justify the adoption of lining.

These considerations led the Rajasthan Canal Board to decide to line the entire length of Rajasthan Main Canal including Rajasthan feeder. It has recently been decided by the Rajasthan Canal Board to line branches and distributaries at an additional cost of Rs. 28.00 crores.

3.1.9 SALIENT FEATURES :-

Salient features of the Rajasthan Canal are as below:-

(a) Gross commanded area	79.36 lakh acres.
(b) Culturable commanded area.	36.86 lakh acres.
(c) Discharge at Head of the Rajasthan Feeder.	18,500 cusecs.
(d) Water allowance.	
(i) Non perennial stage.	5 cusecs per thousand acres at disty head.
(ii) Perennial stage.	3.44 cusecs per thousand acres at disty head.

(e) Total area annually irrigated.	28.75 lakh acres.
(f) Length of feeder.	
In Punjab.	110.80 miles.
In Rajasthan.	23.2 miles.
(g) Length of main canal (in Rajasthan)	291.8 miles.
(h) Length of branches (discharge exceeding 360 cusecs.).	520 miles.
(i) Length of Distributaries (discharge less than 360 cusecs).	3,400 miles.
(j) Length of water courses.	40,000 miles.
(k) Full supply depth	
(i) Rajasthan feeder in Punjab.	21 ft.
(ii) Rajasthan feeder at Punjab/Rajasthan border.	21 ft.
(iii) At tail.	15 ft.
(l) Bed width.	
(i) Feeder in Punjab(lined)	125'
(ii) Feeder at Punjab/Rajasthan Border.	134'
(iii) At tail.	50'
(m) Estimated cost	
(a) Total cost.	Rs.184.09 crores.
(b) Per acre of C.C.A.	Rs.500.00
(n) Financial return on capital(irrigation).	
(i) 10th year after completion (excluding development costs).	5.06
(ii) 15th year after completion (excluding development costs).	5.91

3.1.10 TYPE OF LINING FOR RAJASTHAN CANAL :-

Shri Kanwar Sain, Ex-Chairman, Rajasthan Canal Board ivited some eminent and experienced engineers and Research workers for discussions on the necessity, the merits and best type of lining for the Rajasthan Canal and a group meeting was held on 7th and 8th February, 1959.

The main idea of calling this conference was to have the benefit of the experience of eminent engineers on the best method of tackling the problem of lining of the canal system. The group discussion was divided into four sub heads so that the deliberations were focused objectively. These four sub heads were :-

1. Necessity of lining.
2. Coefficient of Rugosity.
3. Type of lining.
4. Slopes.

A brief review of the deliberations [5] is given below:-

1. NECESSITY OF LINING :-

All the participants were of the opinion that the Rajasthan Canal should be lined.

2. COEFFICIENT OF RUGOSITY :-

Dr. Uppal starting the discussions regarding coefficient of rugosity brought out a lot of statistics on the basis of laboratory and field experiments. On the basis of extensive experience and 120 experiments conducted in the laboratory and field for the determination of coefficient of rugosity for different types of lining he revealed that whatever be the type of lining whether tile lining or concrete lining the coefficient of rugosity is not much different. Flow in any canal is such that very fine material, sticks to the sides. The type of lining and the deposition of that material give together the rugosity coefficient. The results actually obtained on the basis of measurements for different type of lining are as below:-

Earth lining.	0.021
Tile lining.	0.0185

Cement Concrete(1:3:6)	0.018
Cement sand mortar.	0.0145 (Good condition).

It had been observed that the cement concrete lining constructed in field does not significantly have a lower rugosity coefficient. It is the brick in cement mortar which gives the lower rugosity coefficient and not the concrete. In practice a value of 0.014 is never obtained in the field. Also when water flows in the channel, some abrasion occurs and concrete losses finer particles, the coarse particles remain behind and make the surface rough. This is a disadvantage in the concrete which is less in sand with moratar but it is there. It is absent in tile lining.

Mr. Siddhu opined that the normal coefficient of rugosity of bricks and tile lining with ordinary bricks and tiles can be taken as 0.018 but with compressed tiles at the top it is expected to improve between 0.016 and 0.017. Due to damage of Haveli canal lining, Engineers felt that the design value of rugosity coefficient should be fixed at a figure likely to be actually obtained under working conditions i.e. deteriorated lining, sand on the bed etc

3. TYPES OF LINING :-

Dr. Uppal expressed his strong opinion in favour of brick tile lining which has stood the test of time. The two most important aspects in selecting the type of lining are its imperviousness and its cost. In both these respects tile lining is superior to concrete lining. While constructing the Haveli and Bhakra canals, all the important points were discussed and it was considered that the lining is much better. The tiles in themselves are not impervious. It is the mortar in between which provides watertightness. Its thickness should be about 5/8". There is a base mortar of 3/8" before laying the first layer of tiles.

Experiments on Bhakra Canals revealed that the loss was only ½ cusecs per million square feet of wetted area. This type of double tile lining was evolved by Shri Kanwarsain in 1933 and adopted in 1937. It has stood the test of time and has proved itself in the field.

Mr. Uppal expressed that from the point of view of impermeability, temperature variations, reasonable co-efficient of rugosity, double tile lining should be adopted.

All the invitees were of the same opinion and decision was taken to use double layer tile lining on the sides of Rajasthan canal and single layer tile lining in the bed with 3/8" cement plaster on the top.

From the discussions held the following recommendations were accepted.

1. The main canal is to be lined.
2. Double tile lining as should be provided on the sides and single tile lining in the bed.
3. Value of coefficient of rugosity be adopted as 0.017.

For further details about the adoption of type of lining for Rajasthan Canal it is essential to refer "Canal Lining" published by Rajasthan Canal Board, Jaipur.

The composite type lining extensively used on the Bhakra and Rajasthan Canal is as shown in figure 3.3.

9.0 [illegible]

The main features assumed for the study are those of the Rajasthan canal.

1. Bed slope(S) 1 in 12,000

2. Side slopes of the channel (Z:1) 2:1

3. Type of lining. Single tiled lining in bed and double tiled lining on the sides.

4. Coefficient of rugosity 0.027

5. Thickness of single tile lining in bed. 0.20'

6. Thickness of double tile lining on the sides. 0.44'

7. Free board 2.5'

The study for the determination of most economical full supply depth has been done for discharges ranging from 3,000 cusecs to 20,000 cusecs with an interval of 1,000 cusecs upto 10,000 cusecs and 2,000 thereafter. A flat slope of 1 in 12,000 for the water surface line has been purposely provided to enable the canal to command the maximum possible area, and in accordance with the natural slope of the country. In the Rajasthan canal area the nature of the soil is sandy. The angle of repose for such soils ranges from 30° to 35°. As side slopes of lined channels should more or less conform to the stable angle of the natural soil, side slope of between 1½:1 and 2:1 had to be adopted. A side slope of 2:1 has been adopted for this study on the safe side. A free board of 2.5 ft. has been adopted for the studies ranging for the discharges from 3,000 cusecs to 20,000 which is in near conformity with the empirical formula for free board.

3.3 THICKNESS OF TILE LINING:-

(i) Double tile lining:-

It comprises of two layers of tiles with sand-wich cement plaster laid on a properly compacted sub-grade. The plaster checks the seepage and the tiles serve as protection cover for it. The total thickness of this type of lining is 0.44 ft (5.25") obtained as described below and is shown in figure 3.3.

The procedure for construction of lining is as below -

(a) Laying of 3/8" thick cement sand mortar (1:5) on the properly compacted sub-grade.

(b) Placing of first layer of 2" thick tiles on it in (1:5) cement sand mortar.

(c) Laying of 5/8" thick (1:3) cement sand mortar on the bottom layer of tiles, and curing it for 48 Hrs.

(d) Laying of 1/4" thick (1:3) cement sand mortar on the plaster.

(e) Placing of 2" thick tiles on its top in (1:3) cement sand mortar.

This procedure is adopted for lining the sides of the canal.

(ii) Single tile lining

In this case the cement plaster is done on single layer of tiles laid on the fully compacted sub-grade. This is cheaper than double tile lining. The total thickness of this type of lining is 0.26 ft.($3^{1/8"}$) as described below and shown in figure 3.4.

The construction of this type consists of the following steps -

(a) Laying of 3/8" thick cement sand mortar(1:5) on the properly compacted sub grade.

(b) Placing of a layer of tiles 2" thick on it in(1:5) cement sand mortar.

(c) Laying of 3/4" thick cement sand plaster (1:3) on the layer of tiles.

This is adopted for lining the bed of the canal.

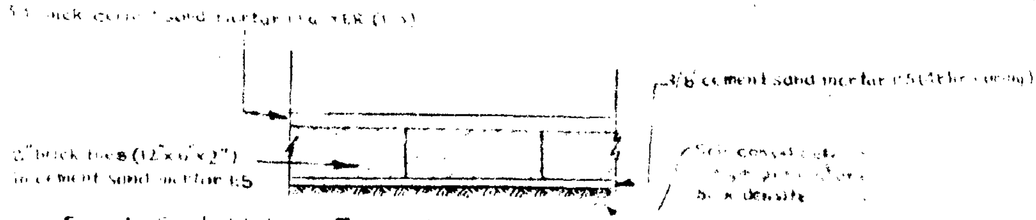


Fig. 3.4 Single tile lining. This consists of cement plaster done on [illegible] on the fully compacted sub grade

3.4 ADOPTED SHAPE OF SECTION

As described in 2.2, it is advisable to use trapezoidal section with rounded corners for discharges exceeding 2,000 cusecs and the same has been adopted for the detailed study. The cost per Rft of canal for discharges ranging from 3,000 to 20,000 cusecs has been worked out for both the circular (Fig. 2.1) and trapezoidal sections (Fig. 2.5) for balancing depth of cutting and it is concluded that trapezoidal section is economical compared to circular one for all the discharges ranging from 3,000 to 20,000 cusecs, which is clear from table 3.1. Statement of cost per Rft of canal for circular section for discharges ranging from 3,000 to 20,000 cusecs is given at table 3.2. Hence the trapezoidal section with rounded corners has been adopted for the detailed study. The section adopted is shown in figure 2.5.

3.5 UNIT RATES

The unit rates of earthwork and lining very depnding on the location, shape of canal section and availability of materials The analysis of rates of single tile lining in bed and double tile lining on side slopes have been given in appendices III and IV. The analysis is based on the average lead of materials and average

TABLE 3.1

STATEMENT OF COMPARATIVE COSTS FOR CIRCULAR AND TRAPEZOIDAL SECTION FOR VARIOUS DISCHARGES

S.No.	Discharge (Cusecs)	Cost per rft. of canal (Rs) Trapezoidal Section	Circular Section	Difference in cost per rft. (Rs.)	% saving with trapezoidal section over circular section.
1.	2.	3.	4.	5.	6.
1	20,000	228.38	236.83	8.45	3.57
2	18,000	218.53	226.88	8.35	3.68
3	16,000	208.00	216.74	7.74	3.54
4	14,000	196.56	203.92	7.36	3.61
5	12,000	184.62	191.32	6.70	3.50
6	10,000	171.45	177.50	6.05	3.41
7	9,000	164.14	170.02	5.90	3.47
8	8,000	156.44	162.19	5.75	3.54
9	7,000	149.40	153.47	5.07	3.30
10	6,000	139.39	144.57	5.18	3.60
11	5,000	130.07	134.51	4.44	3.30
12	4,000	119.41	123.43	4.02	3.26
13	3,000	107.01	110.64	3.63	3.28

TABLE 3.2

STATEMENT OF COST PER RFT. FOR CIRCULAR SECTION

S.No.	Canal dimensions				Cost per rft. of canal				
	Discharge (cusecs)	F.S.D. (ft.)	Balancing depth of cutting (ft.)	Velocity (ft./sec.)	Earth work Qty. (Cft.)	Earth work Amount (Rs.)	Double tile lining qty. (Sft.)	Double tile lining Amount (Rs.)	Total (Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1	20,000	37.8	26.01	5.676	1,802	63.07	197.45	173.76	236.83
2	18,000	36.4	25.22	5.535	1,691	59.19	190.56	167.69	226.88
3	16,000	34.8	24.31	5.392	1,571	54.99	182.67	160.75	215.74
4	14,000	33.1	23.35	5.195	1,444	50.54	174.29	153.38	203.92
5	12,000	31.25	22.30	5.000	1,313	45.96	165.18	145.36	191.32
6	10,000	29.20	21.13	4.779	1,175	41.13	155.08	136.47	177.60
7	9,000	28.05	20.47	4.653	1,101	38.54	149.41	131.48	170.02
8	8,000	26.85	19.78	4.519	1,026	35.91	143.50	126.28	162.19
9	7,000	25.50	19.00	4.366	944	33.04	136.85	120.43	153.47
10	6,000	24.10	18.19	4.205	863	30.21	129.95	114.36	144.57
11	5,000	22.50	17.26	4.017	774	27.09	122.07	107.42	134.51
12	4,000	20.70	16.20	3.800	678	23.73	113.30	99.70	123.43
13	3,000	18.60	14.95	3.538	575	20.13	102.85	90.51	110.64

conditions. These rates are generally taken as the current tendered rates received for various works on the Rajasthan canal in different reaches.

The average rates are work out as under and same have been assumed for the detailed study.

Earthwork	Rs.	35.00 per %o cft.
Single tile lining(0.26' thick)	Rs.	60.00 per % sft.
Double tile lining(0.44' thick)	Rs.	88.00 per % sft.

3.6 FULL SUPPLY DEPTH V/S DISCHARGE

For the adopted trapezoidal section with rounded corners with 2:1 side slopes, bed slope(i) equal to 1in 12,000 and rugosity coefficient(N) equal to 0.017 full supply depths have been assumed from 5' to 35' at intervals of 5'. For each assumed full supply depth, discharges are calculated for different bed widths varying from 10 ft to 900 ft. with intervals of 10 ft upto 100 ft., 20 ft. upto 200 ft., 50 ft.upto 300 ft., and then at 100 ft upto 900 ft. such that the discharge with each F.S.D. works out to near 20,000 cusecs by using formula(2.2). The corresponding velocities are also calculated. The method adopted is explained by the example given below:-

EXAMPLE

Let full supply depth considered(D)	=	15 ft.
Let bed width of the channel assumed (B)	=	100 ft.
Coefficient of rugosity for lined material(N)	=	0.017
Bed slope (i)	=	1 in 12,000
Side slopes of the channel(S:1)	=	2:1

Discharge Q according to formula (2.2)

$$Q = \frac{\left(D\left(B+D\left(S+\frac{\tan^{-1} 1/S}{57.3}\right)\right)\right)^{5/3}}{\left(B+2D\left(S+\frac{\tan^{-1} 1/S}{57.3}\right)\right)^{2/3}} \quad \frac{1.49}{N}\,(i)^{1/2}$$

$$= \frac{\left(15\left(100+15\left(2+\frac{26.57}{57.3}\right)\right)\right)^{5/3}}{\left(100+30\left(2+\frac{26.57}{57.3}\right)\right)^{2/3}} \quad \frac{1.49}{0.017}\left(\frac{1}{12,000}\right)^{1/2}$$

$= 8,530$ Cusecs.

Velocity V $= \frac{1.49}{N} R^{2/3} \; i^{1/2}$

$= \frac{1.49}{0.017} \left(\frac{1}{12,000}\right)^{\frac{1}{2}} \times 5.2$

$= 4.16$ ft/Sec.

The discharges and velocities for different values of full supply depth considered and bed widths adopted are worked out. The results obtained are plotted as two sets of curves - (i) between discharges and bed widths and (ii) between velocities and bed widths, for each full supply depth considred and are shown in figure 3.5. Firm curves are between discharges and bed widths, while dotted curves are between velocities and bed widths. The results are also plotted in a slightly different form (fig.2.6) for each given value of discharge curves have been plotted between bed widths and full supply depths, contours of equal velocity have then been interpolated on these curves. The graphs(fig.2.6) are with N = 0.017 and side slopes 2:1 for different disharges ranging from 3,000 cusecs to 20,000 cusecs for trapezoidal lined section with rounded corners. These curves are useful in designing a suitable section of the assumed shape for any value of N vide instructions on the chart in figure 2.6. Dotted curves give the velocities for different bed with and full supply depth combinations.

3.7 FULL SUPPLY DEPTH V/S COST

As a first step, a study has been made to work out the most economic full supply depth for the canal discharge range of 3,000 to 20,000 cusecs. The full supply depths considred are 5', 10', 15', 20', 25', 30' & 35'. For each assumed full supply depth,

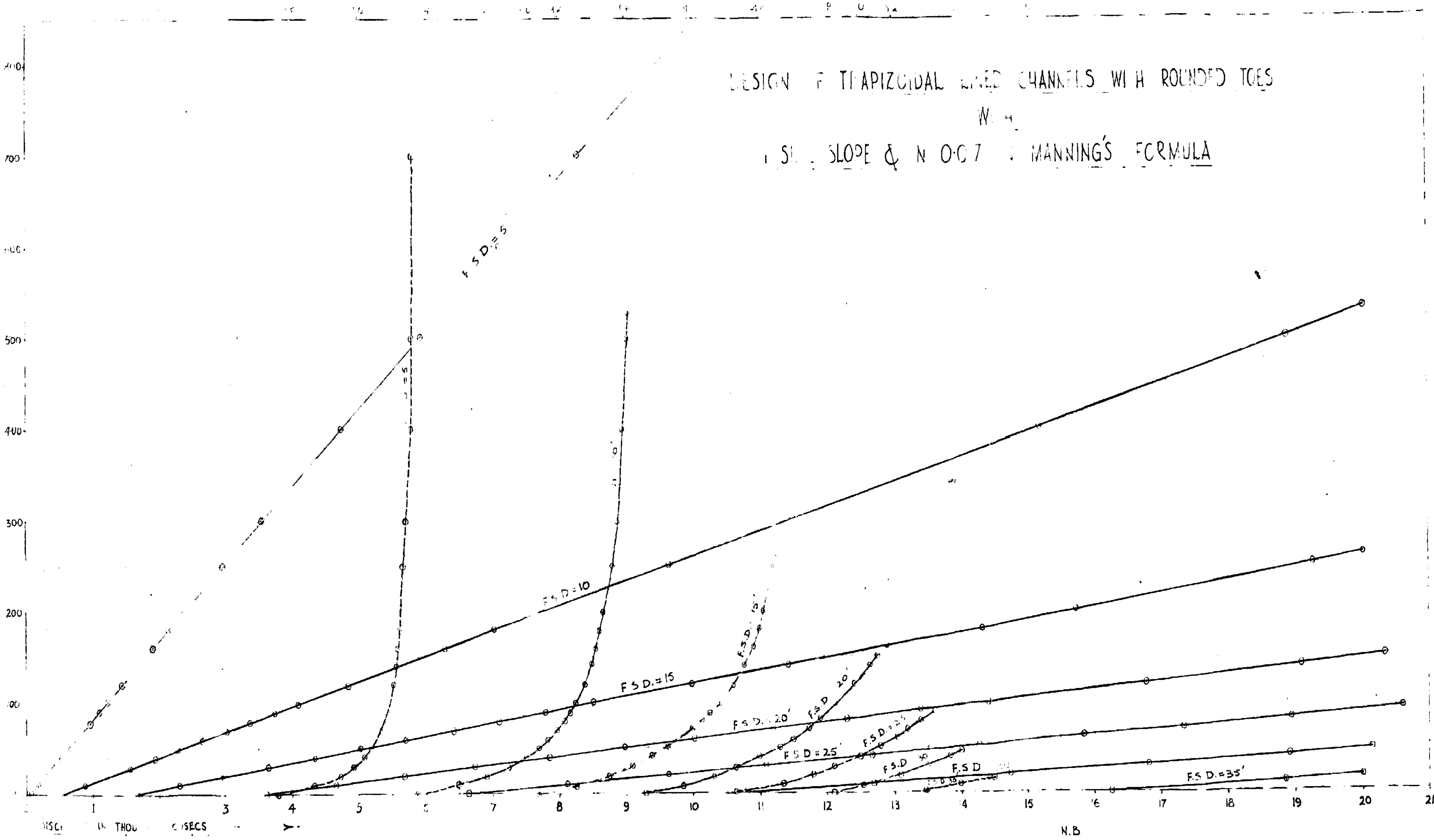

ESIGN F TRAPIZOIDAL CHANNELS WI H ROUNDED TOES
MANNING'S FORMULA
F.S.D.=5
F.S.D.=10
F.S.D.=15
F.S.D.=20'
F.S.D.=25
F.S.D.=35'
700
500
400
300
200
1
3
4
5
7
8
9
10
12
13
15
17
18
19
20
21
IN THOU
N.B
CURVES FOR DISCHARGE BED WIDTH
CURVES BED WIDTH AND

FIGURE. 3.5

bed width correspondaing to discharge has been worked out with the help of figure 3.5. For each set of full supply depth and bed with, balancing depth of cutting is first worked out. The quantities of earthwork, bed lining and side lining including that for curved portions are then estimated per ft. length of the canal. The costs of earthwork and lining are then calculated using the assumed unit rates, and the cost of the composite section is determined. The velocity corresponding to the section is also calculated using the Manning's formula. The procedure is explained by the example given below:-

EXAMPLE

Let discharge Q = 10,000 cusecs.

Let assumed full supply depth. = 20 ft.

The bed width corresponding to 10,000 cusecs and F.S.D. of 20 ft. from figure 3.5 is 60 ft. The cross-section of the channel is as shown in fig.(2.5).

The depth of bed below natural ground level at which the earth obtained from excavation in the bed of channel equals, that required for filling in the banks, is known as'balancing depth.' It is worked out as under:-

The side slopes of filling and cutting are 2:1.

Let d = balancing depth of cutting.

D = Full supply depth.

C = Free Board = 2.5 ft for the study.

b = Top width of the bank = 34.43 ft. for the study.

B = Bed width.

The area of dowel is neglected.

Area of cutting = [illegible]

= [illegible]

= [illegible]

= [illegible]

$$= 2d^2 + d(B+0.48D) - 0.01633D^2 \quad \text{.........} (3.1)$$

Area of filling = [illegible]

= [illegible]

= [illegible]

= [illegible]

= [illegible] ... (3.2)

Equating the areas of cutting and filling for balancing depth.

[illegible]

or [illegible] (3.3)

Solving equation (3.3) for a particular set of the full supply depth and bed width, the balancing depth of cutting 'd' can be worked out.

In the above example B = 60 ft and D=10 ft.

Substituting these values in equation (3.3)

[illegible] = 0

or [illegible] = 0

∴ d = 12.18 ft.

For balancing depth(d) = 12.18 ft. the earthwork per 1ft. of canal can be worked out by using formula (3.1) or (3.2) and in this example it works out to 1,133 cft. or cubic.

Using formula (3.1),

quantity of cutting per Rft. $= 2d^2 + d(B+0.48D) - 0.01683D^2$

Substituting = d=12.18 ft.

$= 2 \times 12.18^2 + 12.18(60+9.6) - 6.53$ Cft.

= 1,138 Cft.

The quantities for lining are:-

Bed lining (Single tile lining) = 60 Sft.

Side lining including for rounded corners (Double tile lining)

$= 4.92734D + 11.2$

= (98.55+11.2) Sft.

= 109.75 Sft.

The costs of earth work and linings per rft. are worked out with the assumed unit rates as below:-

Earthwork $\left(\frac{1,138 \times 35}{1,000}\right)$	=	Rs. 40
Single tile lining $\left(60 \times \frac{60}{100}\right)$	=	Rs. 36
Double tile lining $\left(109.75 \times \frac{88}{100}\right)$	=	Rs. 97
Total	=	Rs.173

Thus cost per rft. of canal for 10,000 cusecs for balancing depth works out to be Rs. 173/-. Similarly the cost per rft. of canal for balancing depth for different discharges and different combinations of bed width and F.S. depth is worked out.

The velocity corresponding to bed width of 60 ft. and F.S.D. of 20 ft. is directly read from velocity curves (dotted) corresponding to 20 ft. F.S.D. given in figure 3.5 against bed width of 60 ft. and it comes to 4.60 ft./sec.

The velocity range for discharge between 3,000 to 20,000 cusecs with assumed range of full supply depth from 5 ft to 35 ft will be between 2.304 to 5.676 ft/sec.

The results of the cost studies for the discharge range of 3,000 to 20,000 cusecs for different assumed F.S.D(s are shown in table 3.3 and figure 3.6.

These curves show that the most economical full supply depths for different discharge ranges work out as below -

Discharge range(Cusecs)	Economical F.S.D. ft.
18,000 - 20,000	30
10,000 - 18,000	25
6,000 - 10,000	20
3,000 - 5,000	15

3.9 (F.S.L - N.S.L.) AND F.S.D. V/S COST

It is realised that it would not be possible to adopt an alignment such that balancing depth of cutting is available every where. In fact deep cuttings and high fillings will have to be encountered even in the most suitable alignment. It is therefore necessary to consider the effect of variation in full supply depths for different conditions of cuttings and fillings. This study has been done for the same discharge range viz from 3,000 to 20,000 cusecs. The full supply depths considered are 5', 10', 15', 20', 25', 30' & 35' for different discharges ranging from 3,000 to 20,000 cusecs. For each assumed full supply depth and proposed discharge bed width and velocity are worked out from the curves in figure 3.5.

The values of full supply level minus natural surface level (F.S.L. - N.S.L.) considered are 30',25', 20', 15', 10', 5', 0', (-5'), (-10'). (-15'), (-20'), (-25') and (-30'),

STATEMENT OF COST PER RFT. OF CANAL FOR DISCHARGE RANGE OF 3,000 CUSECS TO 20,000 CUSECS (BALANCING DEPTH)

S.No.	Canal dimensions				Cost per rft. of canal						
	F.S.D.	Bed Width	Balancing depth of cutting	Velocity	Earth work		Single tile lining		Double tile lining		Total Amount
					Qty.	Amount	Qty.	Amount	Qty.	Amount	
	(ft.)	(ft.)	(ft.)	(ft./Sec.)	(Cft)	(Rs.)	(Sft.)	(Rs.)	(Sft.)	(Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
(i) For 3,000 Cusecs											
1.	15	20.50	11.38	3.494	574	20	20.50	12	85.11	75	107
2	10	70.00	6.45	3.178	564	20	70.00	42	60.47	53	115
(ii) For 4,000 cusecs											
1	20	3.50	15.49	3.797	679	24	3.50	2	109.75	97	123
2	15	35.50	10.56	3.696	671	24	35.50	21	85.11	75	120
3	10	97.25	5.73	3.285	650	23	97.25	58	60.47	53	134
(iii) For 5,000 cusecs											
1	20	13.50	14.79	3.99	773	27	13.50	8X	109.75	97	122
2	15	50.00	9.88	3.843	757	26	50.00	30	85.11	75	131
3	10	124.50	5.17	3.353	720	25	124.50	75	60.47	53	153
(iv) For 6,000 cusecs											
1	20	23	14.17	4.168	856	30	23	14	109.75	96	140
2	15	64	9.31	3.952	833	29	64	38	85.11	75	142
3	10	152	4.19	3.400	781	28	152	91	60.47	53	172

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
4	5	509	1.16	2.304	597	21	509	305	35.84	32	358
(v) For 7,000 cusecs											
1	20	32.5	13.57	4.304	934	33	32.5	20	109.75	96	149
2	15	78.5	8.79	4.04	904	32	78.5	47	85.11	75	154
3	10	180	4.31	3.44	832	29	180	108	60.47	53	190
4	5	594	1.03	2.308	616	22	594	356	35.84	32	410
(vi) For 8,000 cusecs											
1	25	9.50	17.96	4.512	1,027	36	9.50	6	134.38	118	160
2	20	41.25	13.10	4.424	1,003	35	41.25	25	109.75	96	157
3	15	93.00	8.32	4.120	969	34	93	56	85.11	75	165
4	10	208.00	3.95	3.480	881	31	208.00	125	60.47	53	209
5	5	680.00	0.915	2.320	627	22	680	408	35.84	32	462
(vii) For 9,000 cusecs											
1	25	16.25	17.47	4.636	1,094	38	16.25	10	134.38	118	166
2	20	50.5	12.65	4.514	1,074	38	50.5	30	109.75	96	164
3	15	107.0	7.92	4.188	1,027	36	107.0	64	85.11	75	176
4	10	234.0	3.72	3.488	914	32	234.0	140	60.47	53	225
(viii) For 10,000 cusecs											
1	25	22.75	17.02	4.746	1,161	41	22.75	14	134.38	118	173

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
2	20	60.00	12.18	4.[illegible]00	1,138	40	60.00	36	109.75	97	173
3	15	120.75	7.56	4.232	1,080	38	120.75	72	85.11	75	185
4	10	260.25	3.48	3.510	947	33	260.25	156	60.47	53	242
(ix) For 12,000 cusecs											
1	30	6.25	21.08	5.00	1,310	46	6.25	4	159.02	140	190
2	25	36.00	16.19	4.937	1,291	45	36.00	22	134.38	118	185
3	20	77.50	11.44	4.735	1,252	44	77.50	46	109.75	97.	187
4	15	148.75	6.90	4.331	1,179	41	148.75	89	85.11	75	205
5	10	314.00	3.09	3.543	1,003	35	314.00	188	60.47	53	276
(x) For 14,000 cusecs											
1	30	16.25	20.31	5.182	1,434	50	16.56	10	159.02	140	200
2	25	48.50	15.48	5.084	1,406	50	48.50	29	134.38	118	197
3	20	95.50	10.77	4.848	1,368	47	95.50	57	109.75	97	201
4	15	176.50	6.41	4.375	1,256	44	176.5	106	85.11	75	225
5	10	368.50	2.77	3.563	1,048	37	368.5	221	60.47	53	311
(xi) For 16,000 cusecs											
1	30	26	19.63	5.341	1,549	54	26.00	16	159.02	140	210
2	25	61.25	14.83	5.214	1,516	53	61.25	37	134.38	118.	208
3	20	113	10.20	4.939	1,452	51	113.00	68	109.75	97	216
4	15	204.25	6.96	4.423	1,328	47	204.25	122	85.11	75	245

1.	2	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
(xii) **For 18,000 cusecs**											
1	30	35.75	19.00	5.48	1,660	58	35.75	21	159.02	140	219
2	25	73.75	14.25	5.326	1,618	57	73.75	44	134.38	118	219
3	20	130.25	9.70	5.014	1,538	54	130.25	78	109.75	97	229
4	15	232.00	5.57	4.466	1,391	49	232.00	139	85.11	75	263
(xiii) **For 20,000 cusecs**											
1	35	15.00	23.23	5.676	1,798	63	15.00	9	183.66	162	234
2	30	45.50	18.41	5.600	1,766	62	45.50	27	159.02	140	229
3	25	86.00	13.71	5.421	1,710	60	86.00	52	134.38	118	230
4	20	147.75	9.94	5.080	1,616	57	147.75	88	109.75	97	242
5	15	259.50	5.23	4.600	1,447	51	259.50	156	85.11	75	232

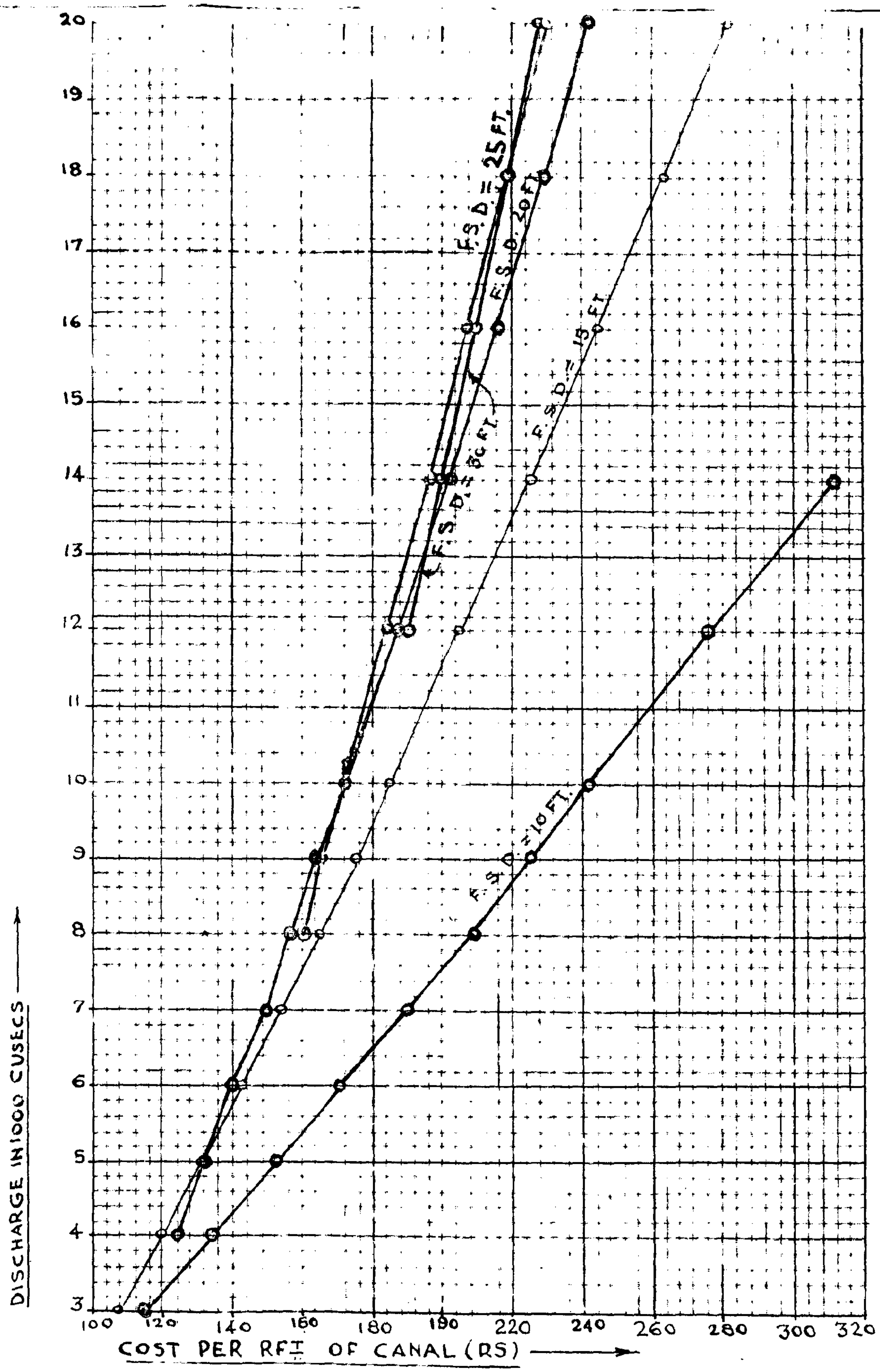


FIG. 3.6

COST PER RFT OF CANAL V/S DISCHARGE
FOR BALANCING DEPTH

for all the combinations of full supply depth and bed width corresponding to different discharges. The variation in the range of (F.S.L.-N.S.L.) considered is such that it covers practically the entire range of cutting and filling which can be usually encountered.

The costs of earthwork and both linings per rft have been worked for each case of (F.S.L. - N.S.L.) corresponding to each bed width and full supply depth combination for the adopted discharge range. These are then added to find the cost per running foot of the composite section in each case.

Considering the same example of 10,000 cusecs discharge as above.

Bed width	= 60 ft.
Full supply depth	= 20 ft.
Considering three cases.	
(i) N.S.L. above F.S.L. i.e. (F.S.L.-N.S.L.)	= - 5ft.
(ii) N.S.L. below F.S.L. but above bed level i.e. (F.S.L. - N.S.L.)	= 10 ft.
(iii) N.S.L. below bed i.e. (F.S.L. - N.S.L.)	= 30 ft.

The cost of lining per rft i.e. single tile lining and double tile lining will remain the same in all the three cases. The only difference will be in the cost of earthwork. The cost for the three cases has been worked out in the following table.

Sl.No.	F.S.L.-N.S.L. (ft.)	Cost per rft. of canal: Earthwork Qty. (Cft.)	Amt. (Rs.)	Single tile lining Qty. (Sft.)	Amt. (Rs.)	Double tile lining Qty. (Sft.)	Amt. (Rs.)	Total amount (Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	-5 (60+9.48+50)25 =	2,987	104	60	36	109.75	97	237
2.	10 2(34.43+2x12.5)12.5 = 1486 or 89.48x10 = 895 (Greater of two)	1,486	51	60	36	109.75	97	184
3.	30 2(60+9.48-20)10 = 495 + 2(34.43+65)32.5 = 6,463	6,958	243	60	36	109.75	97	376
4.	Balancing depth	As worked out in article 3.8						173

From the cost of canal per rft. calculated in three different cases of (F.S.L.-N.S.L.) equal to 30',10' and -5' and balancing depth of cutting of 12.18' (F.S.L-N.S.L.= 7.82'), it is seen that cost of canal per rft. is minimum for balancing depth of cutting i.e. Rs. 173/- per rft. But it is not possible to obtain the alignment such that balancing depth of cutting is available at all places. In such cases the alignment is to be laid under different conditions of natural surface levels and if possible, the most economical of the three alternatives is to be adopted for aligning the channel.

In order to have a ready reckoner of cost per rft. of canal for different conditions of (F.S.L.-N.S.L.) varying from 30' to (-30'), for each discharge the cost per rft. has been worked out as explained above for different combinations of full supply depths and bed widths. As a sample the results for a discharge of 10,000 cusecs are shown in table 3.4.

The (F.S.L.- N.S.L.) values for each value of F.S.D. are plotted against cost per rft of canal in order to obtain F.S.D. curves for each discharge ranging from 3,000 cusecs to 20,000 cusecs which are shown in figure 3.7(A)(i) to figure 3.7(A)(xiii).

For each discharge, from F.S.D. curves the economical F.S.D. corresponding to different values of (F.S.L.-N.S.L.) can be obtained. As an example the most economical F.S.D. for the range of (F.S.L - N.S.L) studied for discharge 10,000 is given in a foot note below table 3.4

The F.S.D. values for each value of (F.S.L.- N.S.L.) are plotted against cost per rft. of canal in order to obtain (F.S.L.- N.S.L.) curves for each discharge ranging from 3,000 cusecs to 20,000 cusecs which are shown in fig. 3.7(B)(i) to 3.7(B) (xiii).

Similarly for each discharge, from (F.S.L.- N.S.L.) curves the position of the ground relative to F.S.L. giving greatest economy can be obtained and a note regarding this is also given below table 3.4 for 10,000 cusecs. Obviously this would be that depth which is closest to balanced earthwork.

In some cases economic F.S. depths as determined above are not suitable as their corresponding bed widths are even less than the F.S. depths. This is undesirable from practical considerations

Thus from the present study of (F.S.L.- N.S.L.) and (F.S.D. V/s cost per rft of canal it is possible to say at a glance as to which particular full supply depth is mot economical corresponding to a given (F.S.L. - N.S.L.) value for a given discharge. Similarly

TABLE 3.4

STATEMENT OF COST PER RFT OF CANAL FOR 10,000 CUSECS

S. No.	F.S.L.-N.S.L.	Cost per rft. of canal						
		Earth work		Single tile lining		Double tile lining.		Total
	(Ft)	Qty (Cft.)	Amt. (Rs.)	Qty (Sft.)	Amt (Rs.)	Qty (Sft.)	Amt (Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.
(1) F.S.D.(D)=25',B.W.(B)=22.75', Velocity (V)=4.746'/Sec.								
a	30	6586	231	22.75	14	134.38	118	363
b	25	4919	172	22.75	14	134.38	118	304
c	20	3574	125	22.75	14	134.38	118	257
d	15	2430	85	22.75	14	134.38	118	217
e	10	1486	52	22.75	14	134.38	118	184
f	5	1492	52	22.75	14	134.38	118	184
g	0	2115	74	22.75	14	134.38	118	206
h	-5	2838	99	22.75	14	134.38	118	231
i	-10	3661	128	22.75	14	134.38	118	260
j	-15	4584	160	22.75	14	134.38	118	292
k	-20	5607	196	22.75	14	134.38	118	328
l	-25	6730	236	22.75	14	134.38	118	368
m	-30	7963	278	22.75	14	134.38	118	410
(2) F.S.D.(D)=20',B.W.(B)=60',Velocity (V)=4.6'/Sec.								
a	30	6958	243	60	36	109.75	97	376
b	25	5216	182	60	36	109.75	97	315
c	20	3574	125	60	36	109.75	97	258
d	15	2430	85	60	36	109.75	97	218
e	10	1486	52	60	36	109.75	97	185
f	5	1492	52	60	36	109.75	97	185
g	0	2190	76	60	36	109.75	97	209
h	-5	2987	104	60	36	109.75	97	237
i	-10	3884	136	60	36	109.75	97	269
j	-15	4882	171	60	36	109.75	97	304
k	-20	5979	209	60	36	109.75	97	342
l	-25	7177	251	60	36	109.75	97	384
m	-30	8474	306	60	36	109.75	97	439
(3)F.S.D.(D)=15',B.W.(B)=120.75',Velocity (v)=4.232'/Sec.								
a	30	7931	278	120.75	72	85.11	75	425
b	25	5998	210	120.75	72	85.11	75	357
c	20	4163	146	120.75	72	85.11	75	293

1.	2.	3.	4.	5.	6.	7.	8.	9.
d	15	2430	85	120.75	72	85.11	75	232
e	10	1486	52	120.75	72	85.11	75	199
f	5	1479	52	120.75	72	85.11	75	199
g	0	2368	83	120.75	72	85.11	75	230
h	-5	3357	118	120.75	72	85.11	75	265
i	-10	4447	156	120.75	72	85.11	75	303
j	-15	5636	197	120.75	72	85.11	75	344
k	-20	6925	243	120.75	72	85.11	75	390
l	-25	8314	291	120.75	72	85.11	75	438
m	-30	9804	343	120.75	72	85.11	75	490
(4)F.S.D.(D)=10',B.W.(B)=260.25', Velocity(V)=3.51'/Sec.								
a	30	10973	384	260.25	156	60.47	53	593
b	25	8451	296	260.25	156	60.47	53	505
c	20	6029	211	260.25	156	60.47	53	420
d	15	3707	130	260.25	156	60.47	53	339
e	10	1486	52	260.25	156	60.47	53	261
f	5	1377	48	260.25	156	60.47	53	257
g	0	2855	100	260.25	156	60.47	53	309
h	-5	4432	155	260.25	156	60.47	53	364
i	-10	6110	214	260.25	156	60.47	53	423
j	-15	7887	276	260.25	156	60.47	53	485
k	-20	9765	332	260.25	156	60.47	53	541
l	-25	11742	411	260.25	156	60.47	53	620
m	-30	13820	484	260.25	156	60.47	53	693

Note:- It can be concluded from these curves that

(i) full supply depth of 25' is most economical for the range of (F.S.L.-N.S.L.)from-30' to 30'; and

(ii) greatest economy is achieved when the ground level is between 5' to 10' below full supply level.

COST PER RFL V/S F.S.L N.S.L FOR DISCHARGE (Q) = 3000 CUSECS

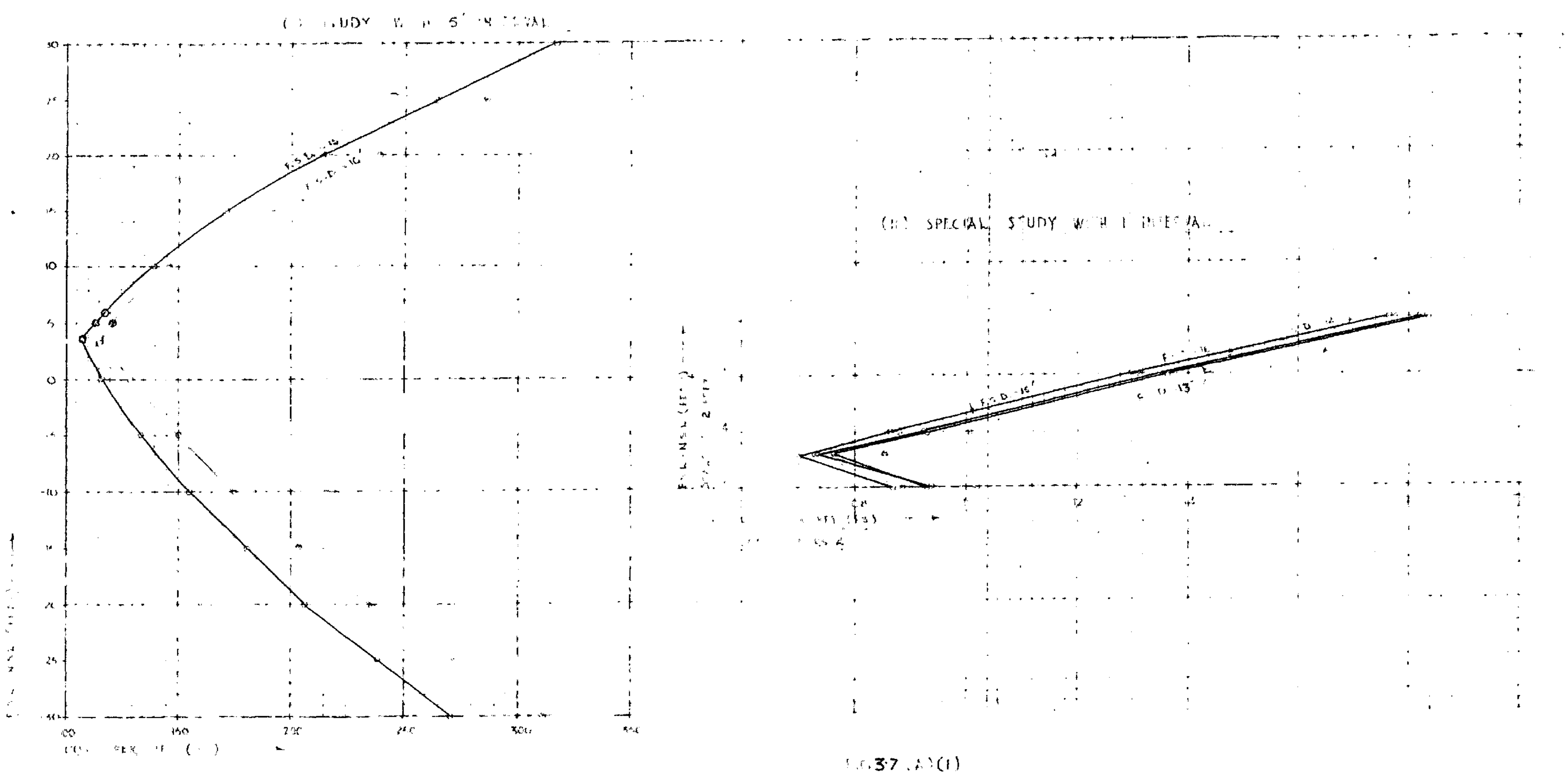
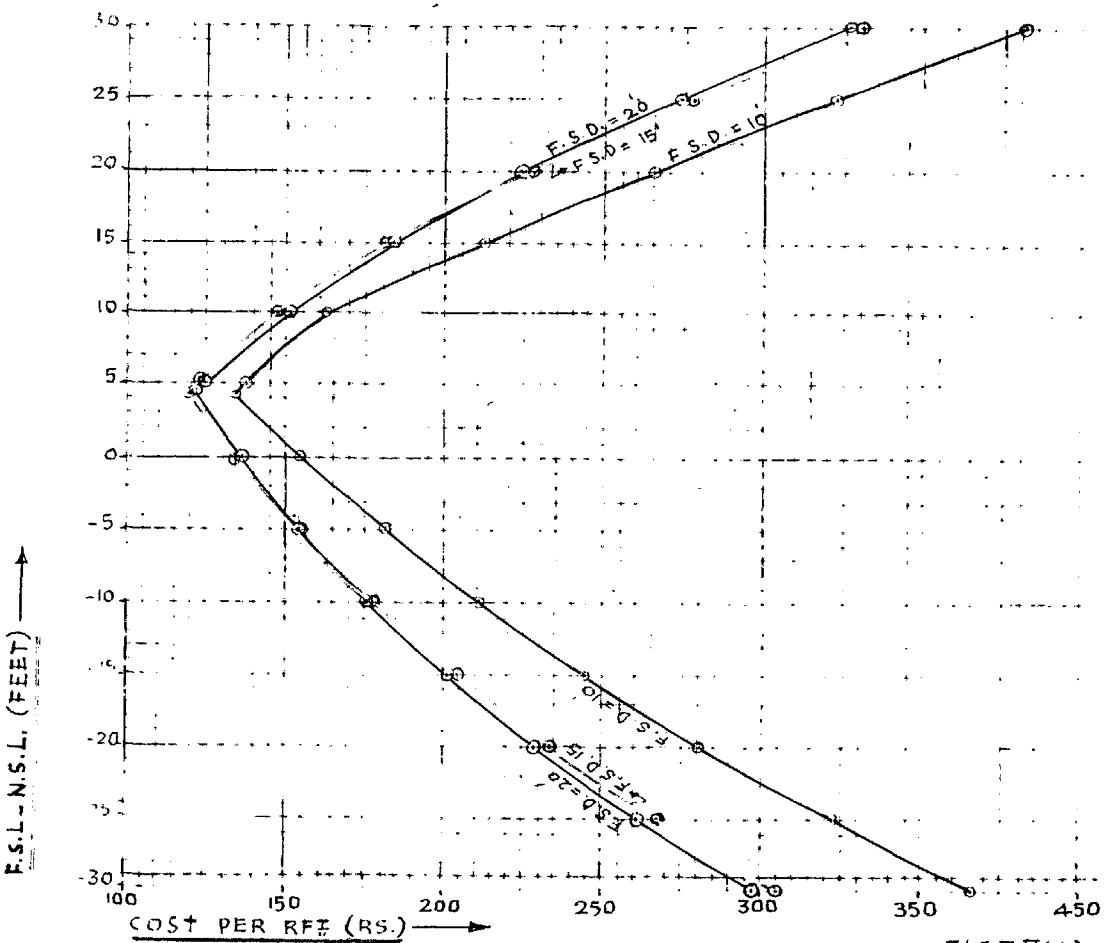


FIG 3.7 (A)(I)

COST PER RFT V/S F.S.L.-N.S.L. FOR DISCHARGE (Q) = 4,000 CUSECS

(i) STUDY WITH 5' INTERVAL



(ii) SPECIAL STUDY WITH 1' INTERVAL

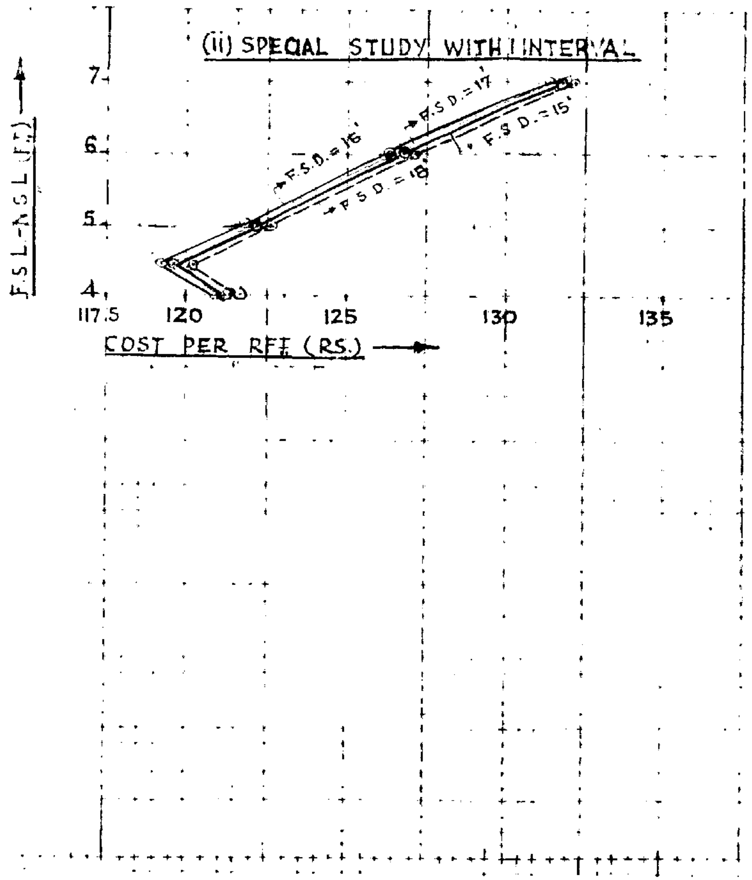


FIG 3·7(A)(ii)

COST PER RFT V/S F.S.L. - N.S.L. FOR DISCHARGE (Q) = 5,000 CUSECS

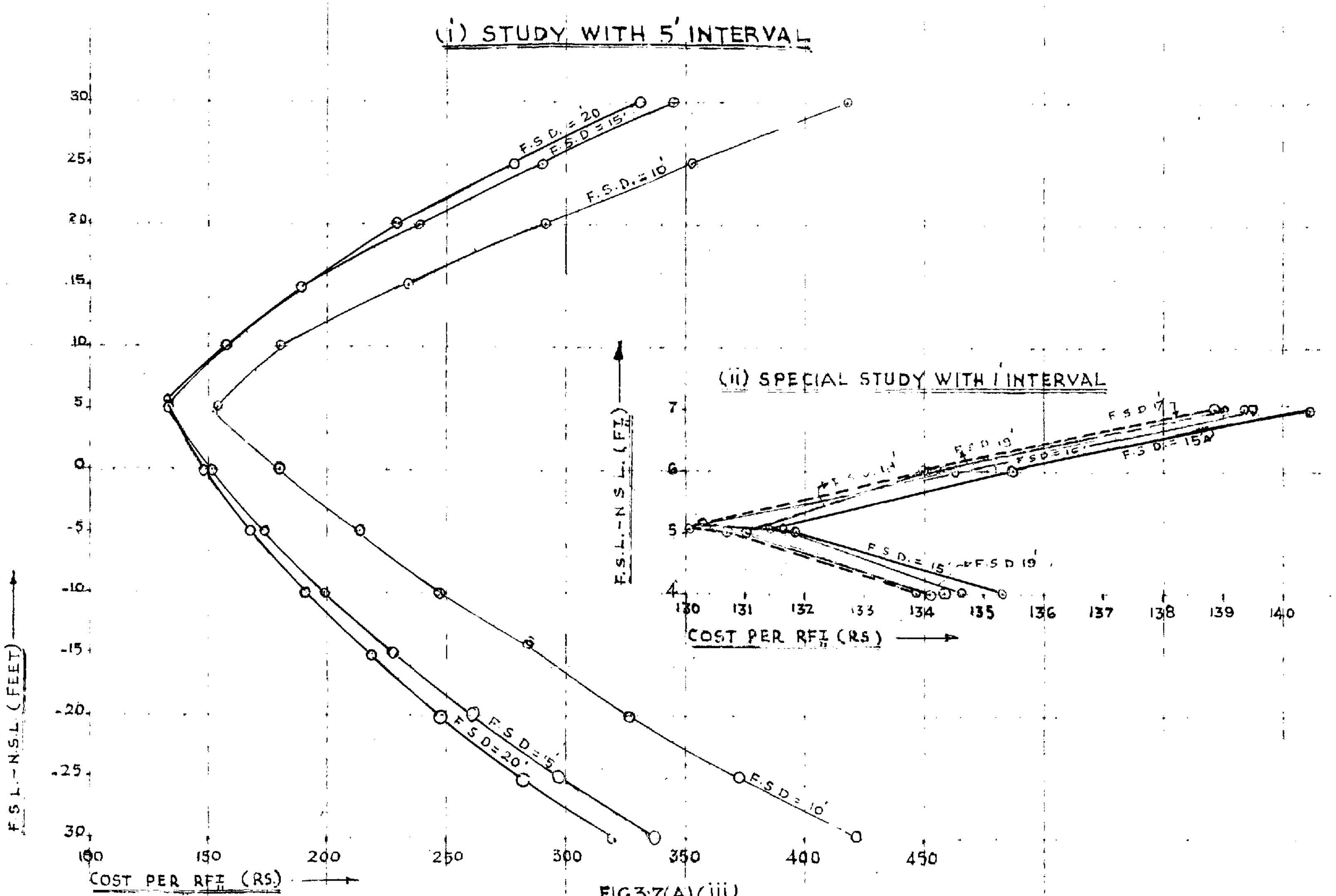


FIG. 3·7(A)(iii)

RFT V/S F.S.L- N.S.L FOR DISCHARGE (Q) = 6,000 CUSECS

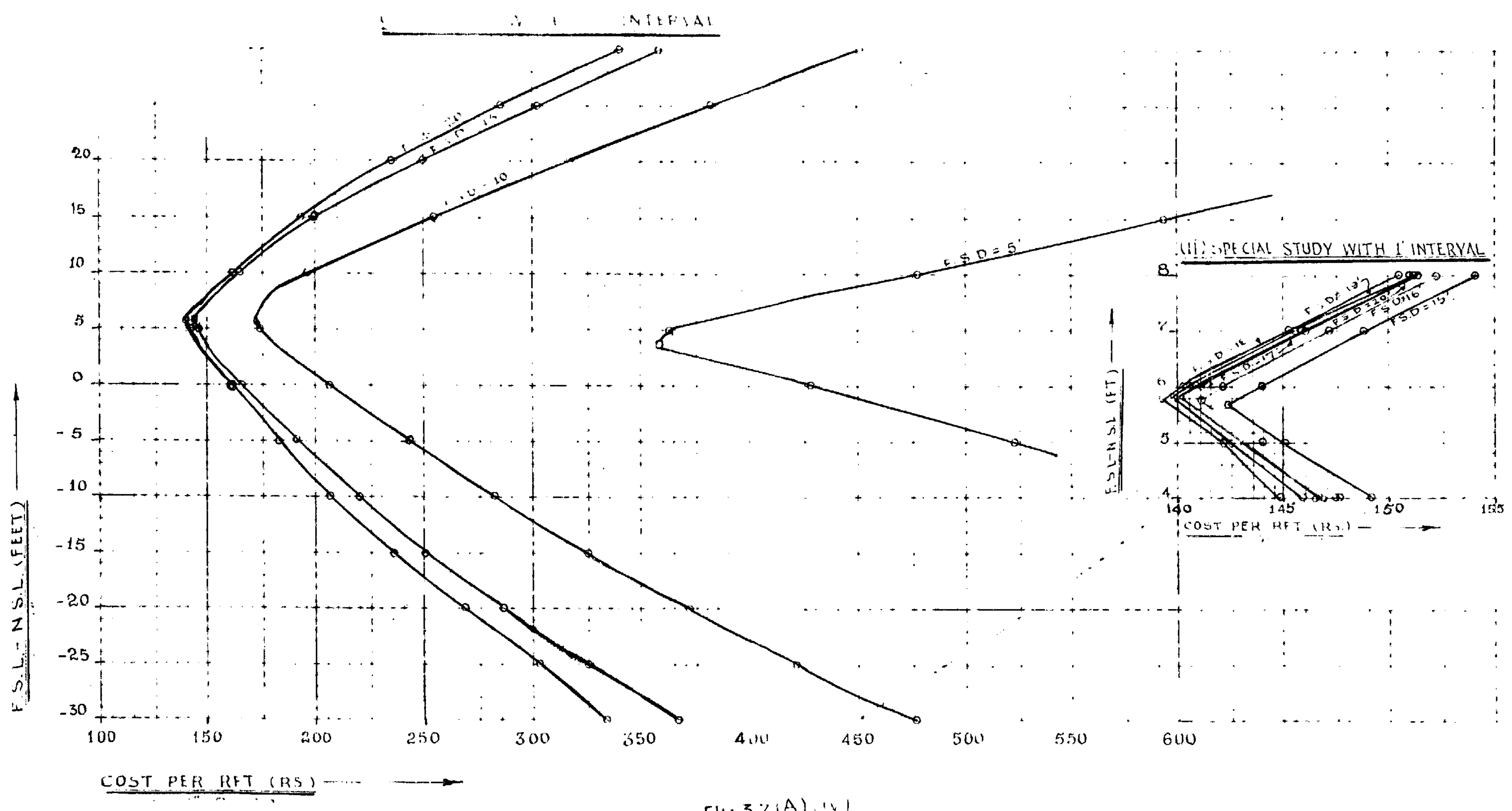
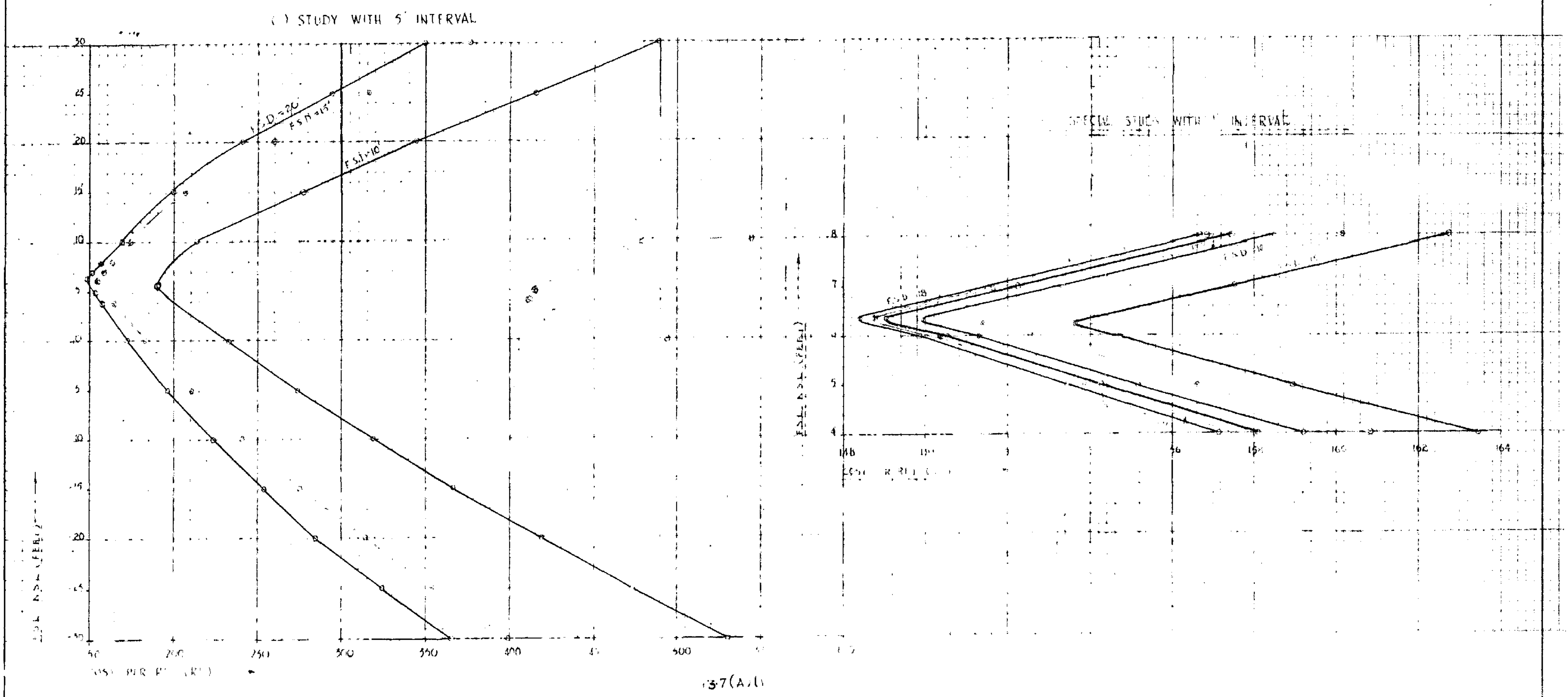


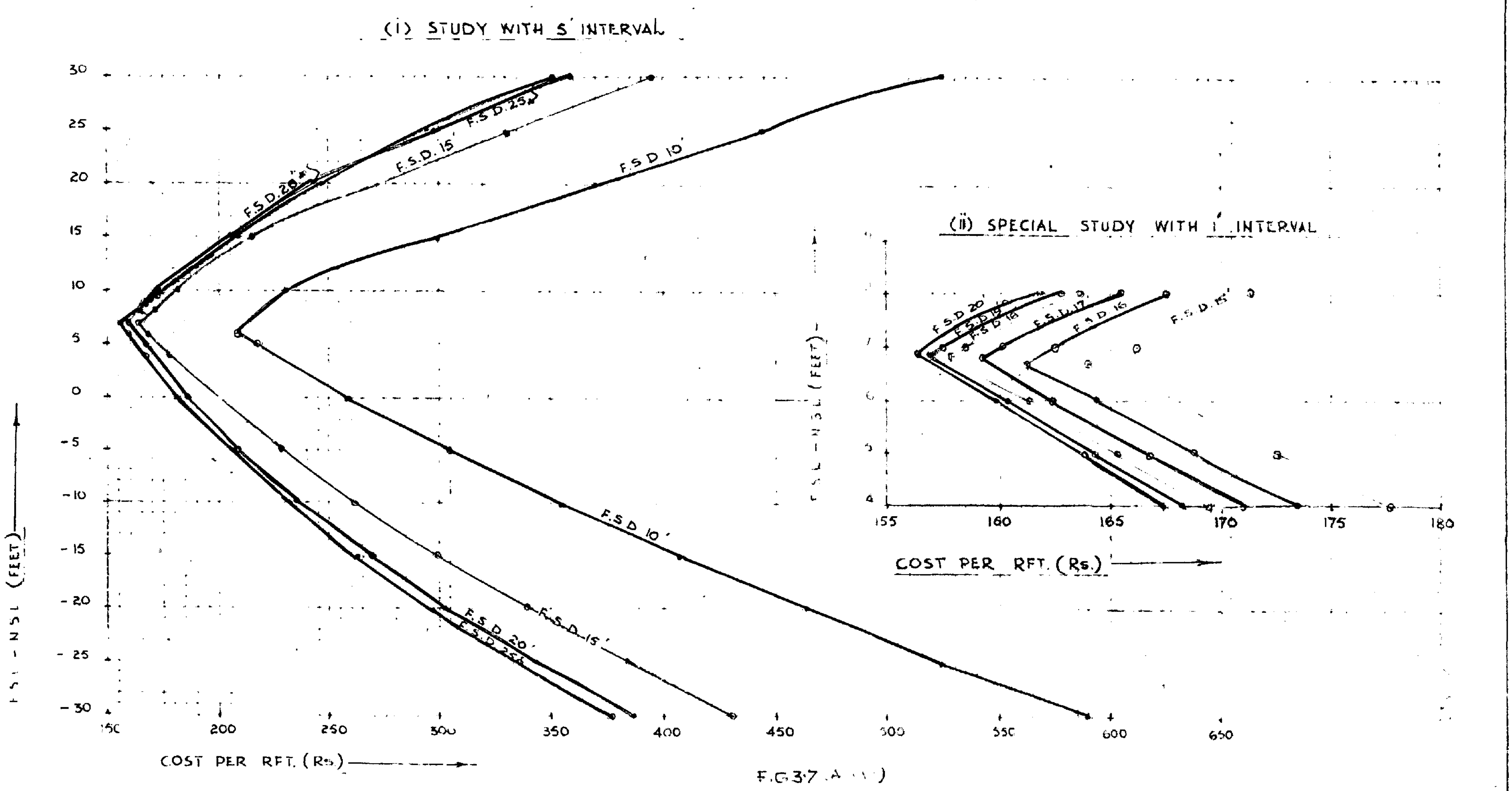
FIG 3.7 (A) (V)

COST PER RFT. V/S F.S.L. N.S.L. FOR [illegible] HARGE (C) = 700[illegible] CU[illegible]



37(A/1)

COST PER RFT V/S F.S.L - N.S.L. FOR DISCHARGE (Q) = 8,000 Cusecs



F.G.3.7 A

DISCHARGE (Q) - 9,000 CUSECS

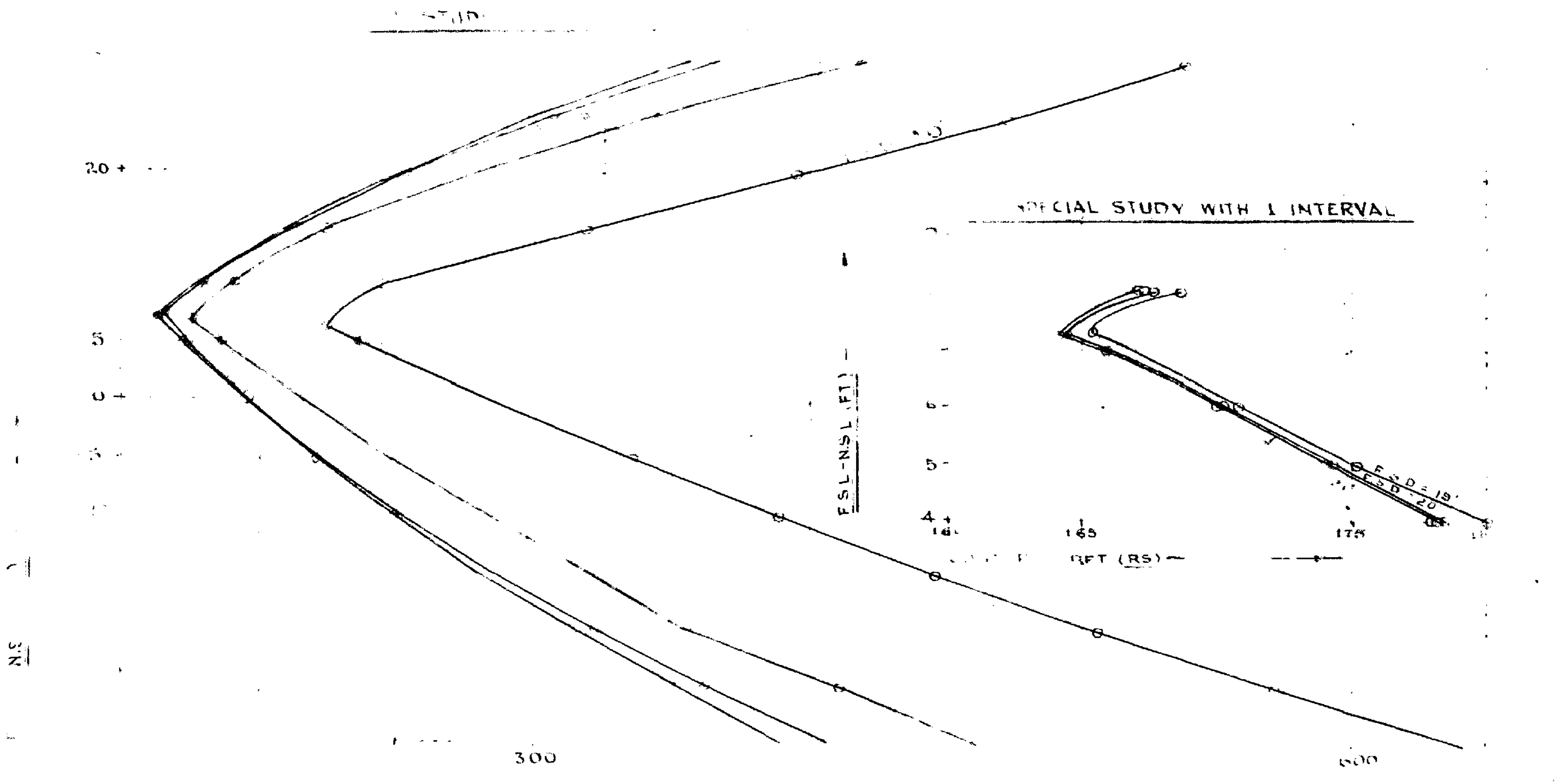


FIG 3.7(A)

COST PER RFT V/S F.S.L.-N.S.L. FOR DISCHARGE (Q) = 10,000 CUSECS.

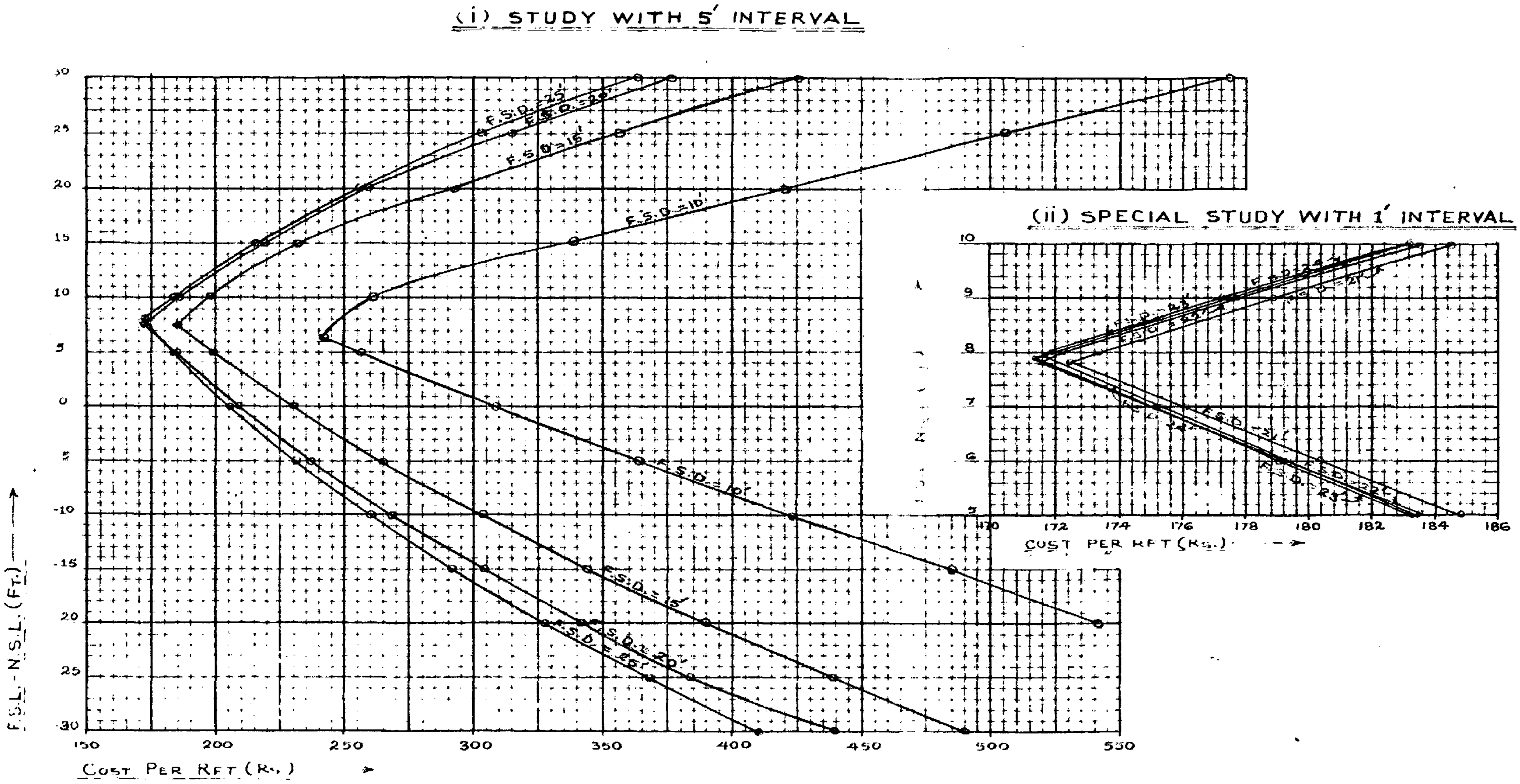


FIG 3.7(A) (VIII)

COST PER RFT V/S. F.S.L-N.S.L. FOR DISCHARGE (Q)= 12,000 CUSECS.

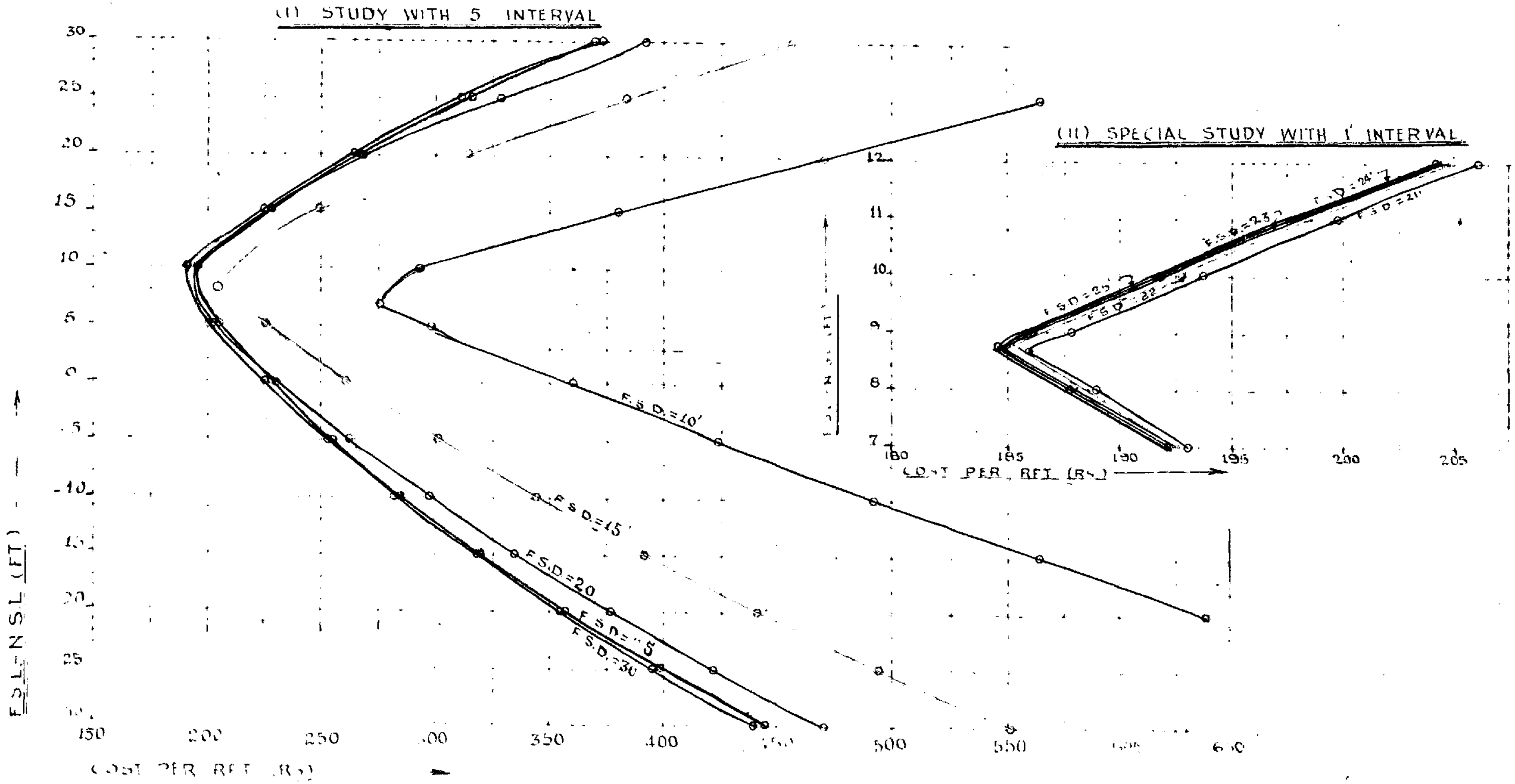


FIG 3·7(A)

COST PER RFT V/S F.S.L-N.S.L FOR DISCHARGE (Q) = 14,000 CUSECS

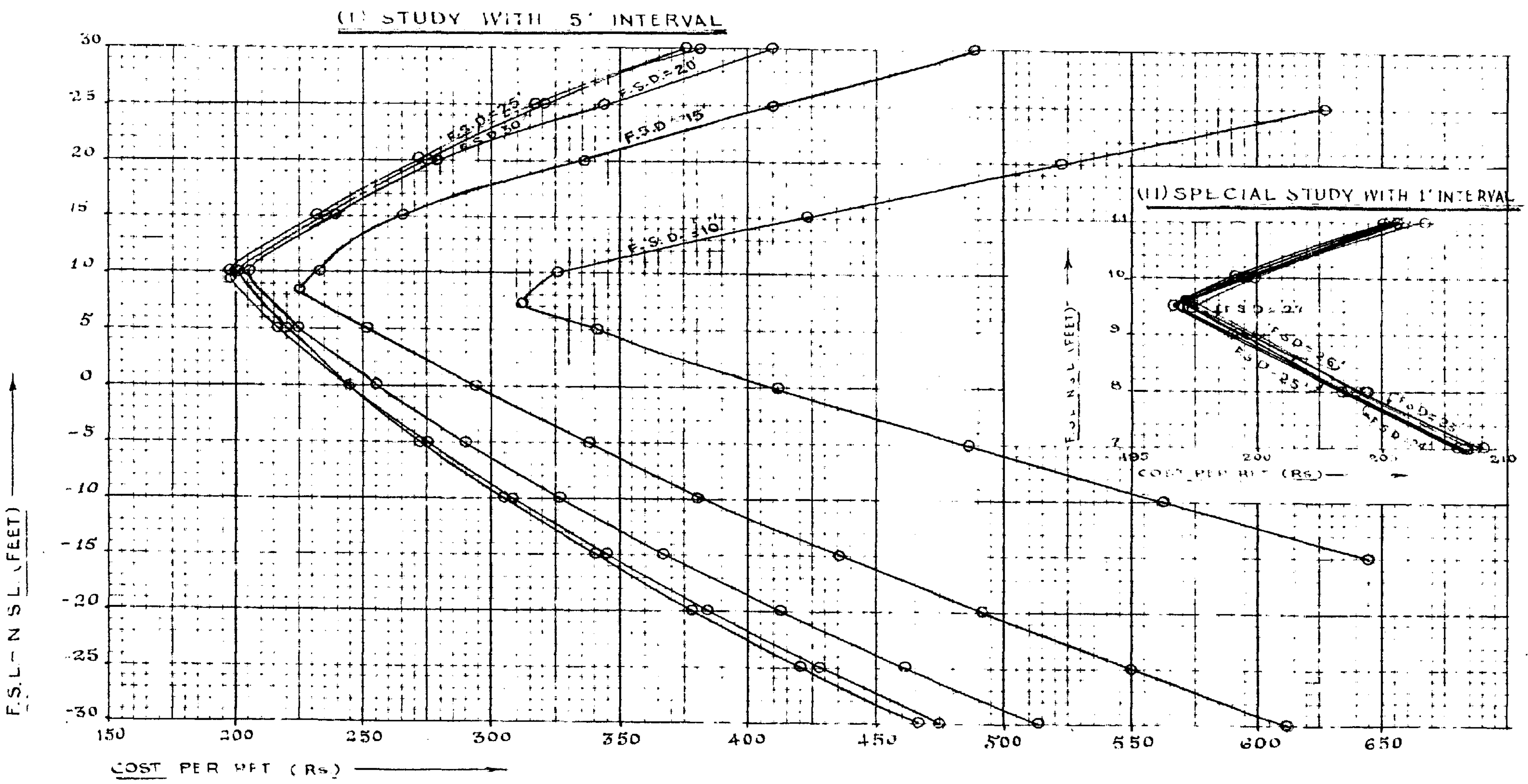
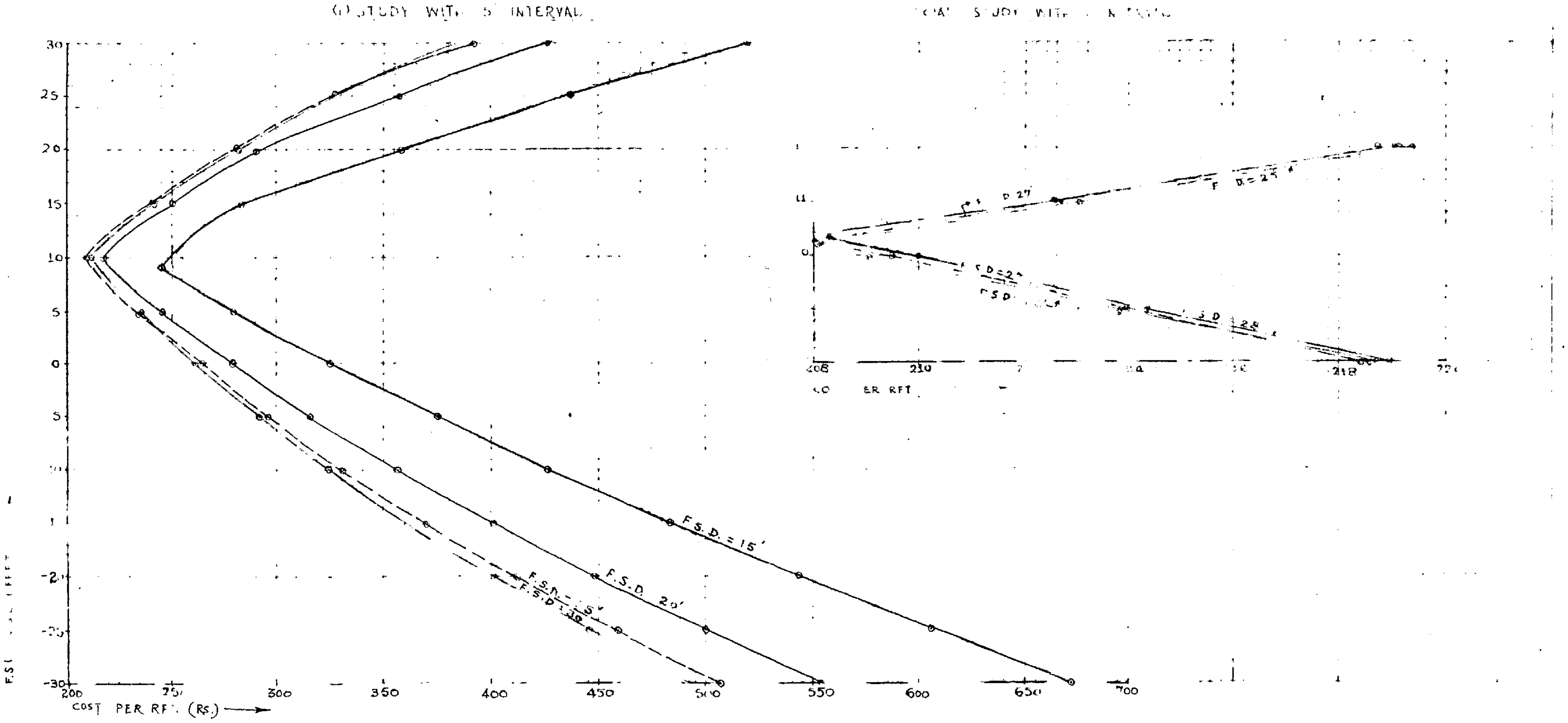


FIG 3.7 (A)(X

COST PER RFT. V/S F.S.L NS.. FOR ... (G) ... COC... ES



F 3.7(A)(XI)

COST PER RFT V/S F.S.L.-N.S.L. FOR DISCHARGE (Q) = 18,000 CUSECS

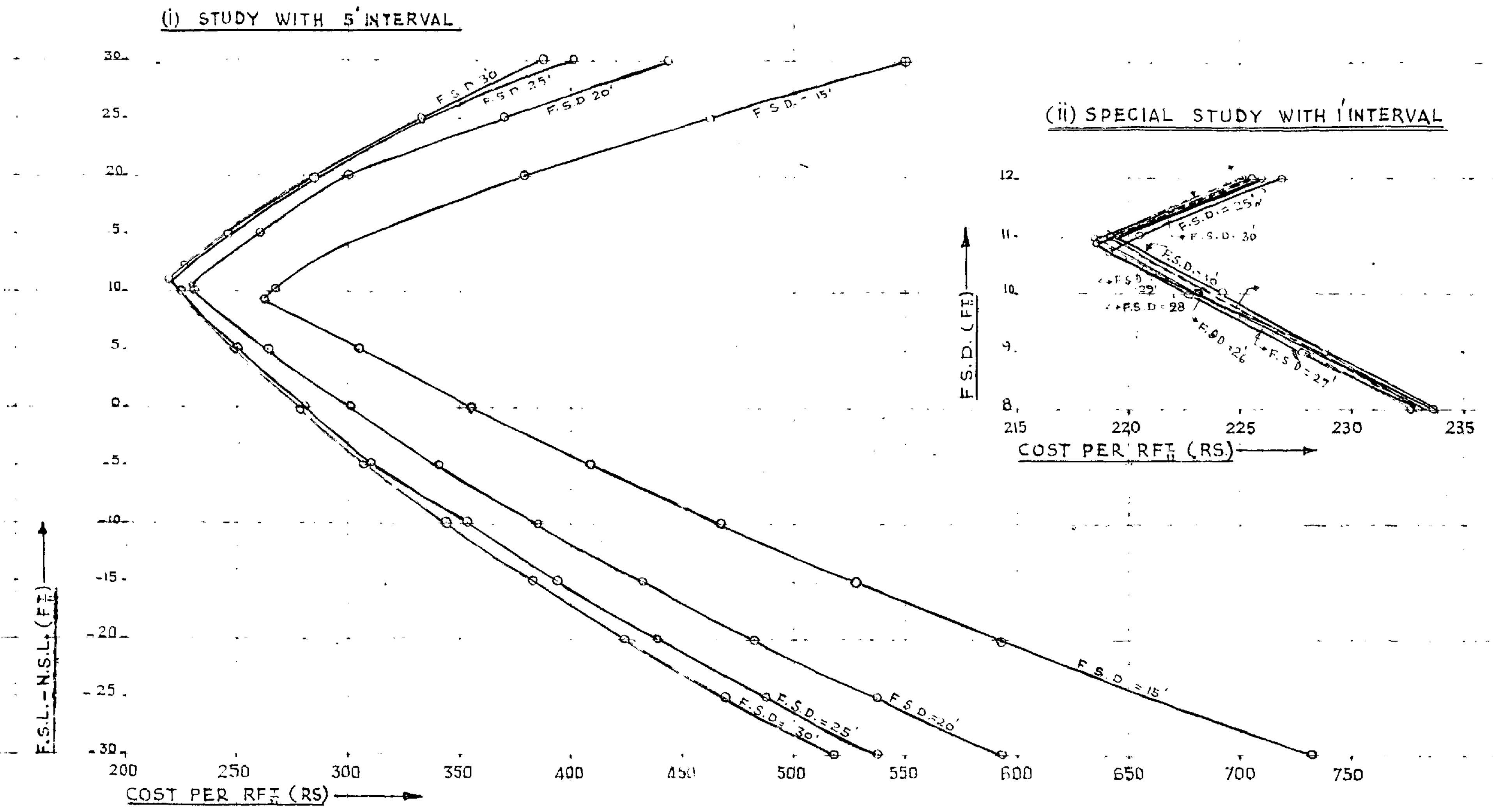
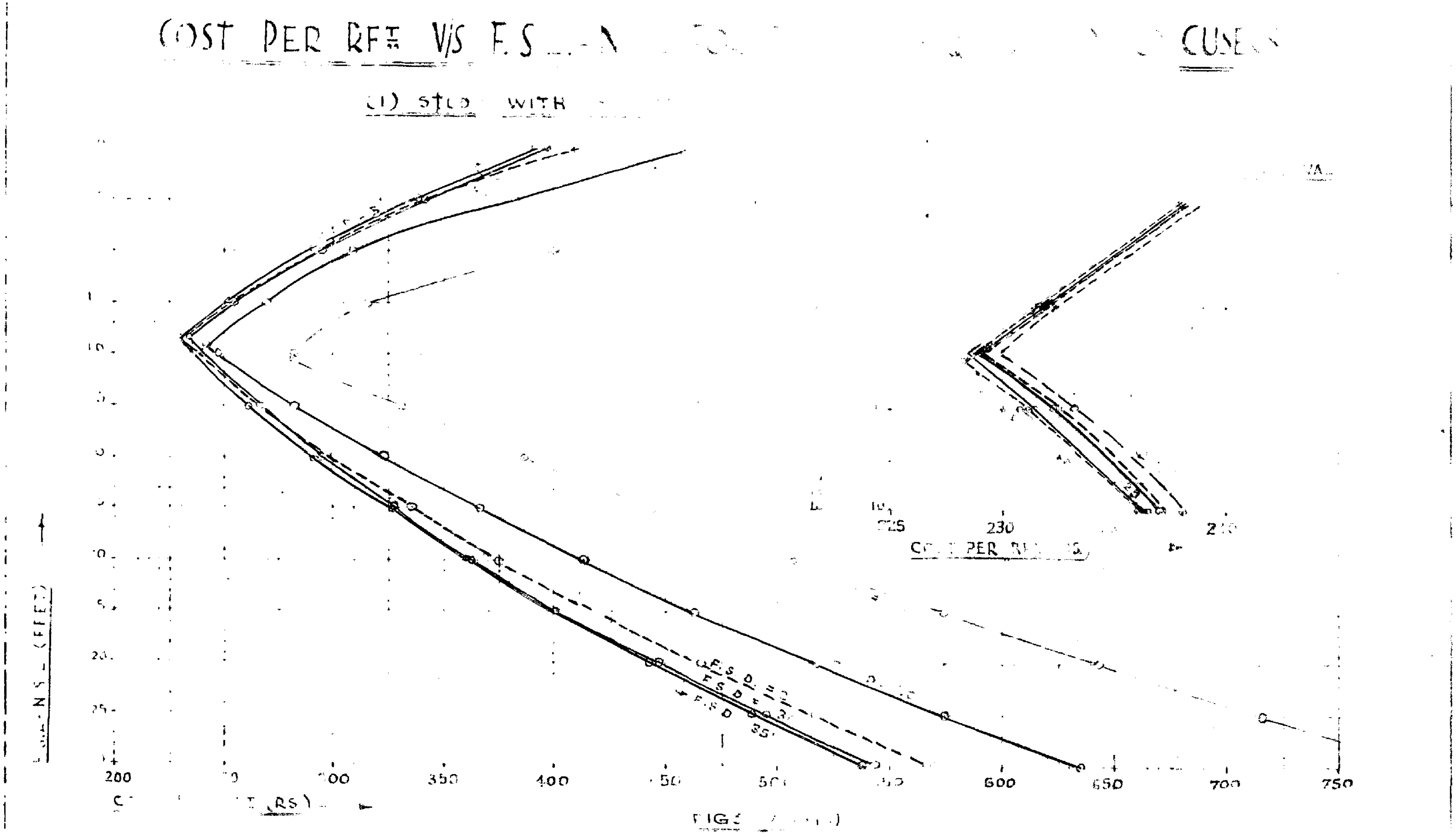


FIG 3.7 (A) (XII)



COST PER RFT V/S F.S
(I) STLD WITH
CUSEC
F.S.D. = 2
F.S.D.
F.S.D. 35'
200
350
400
500
600
650
700
750
225
230
COST PER
(RS)
(FEET)

FIG

COST PER RFT VS FSD FOR DISCHARGE ... COOC CUSECS

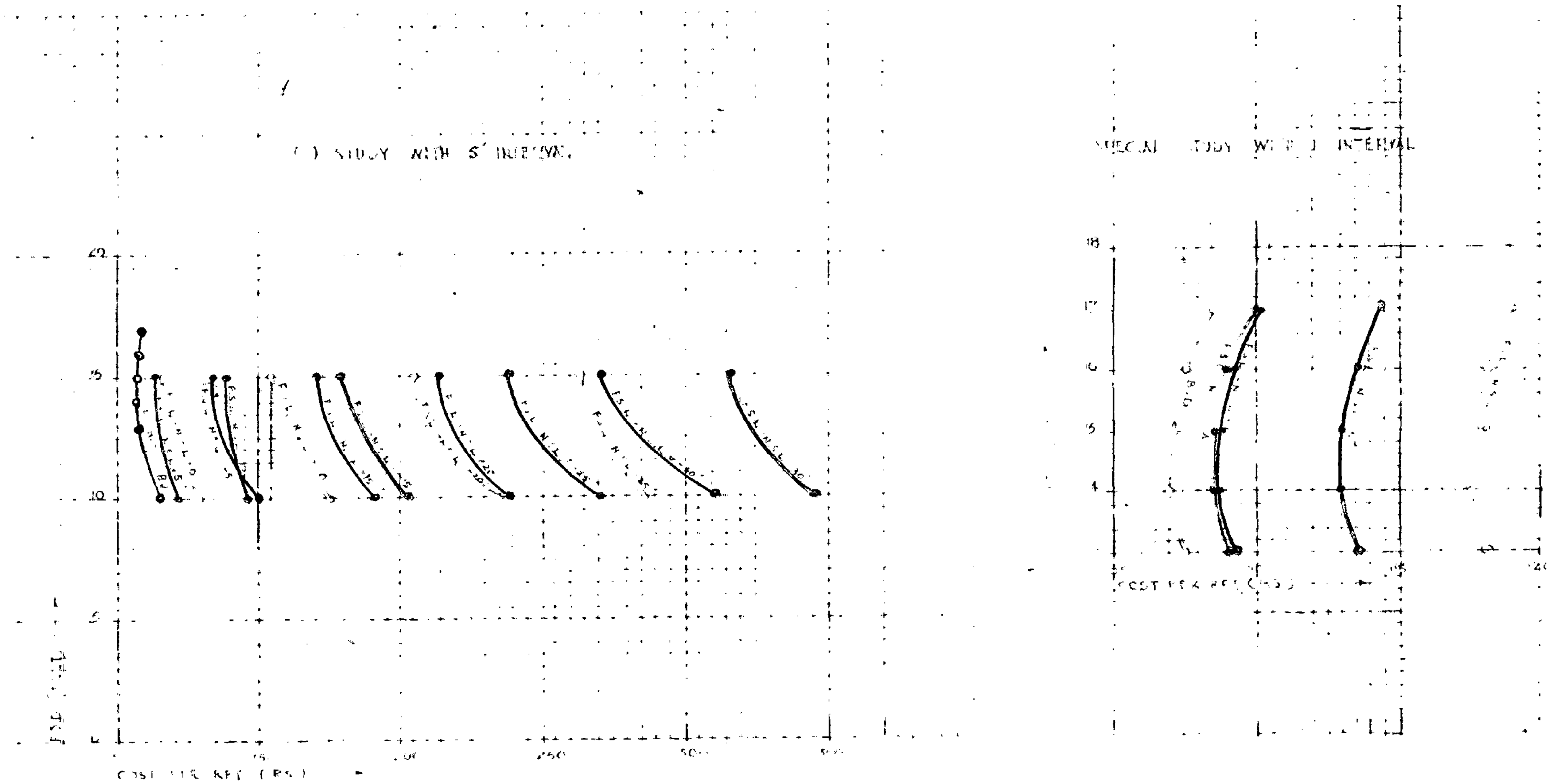
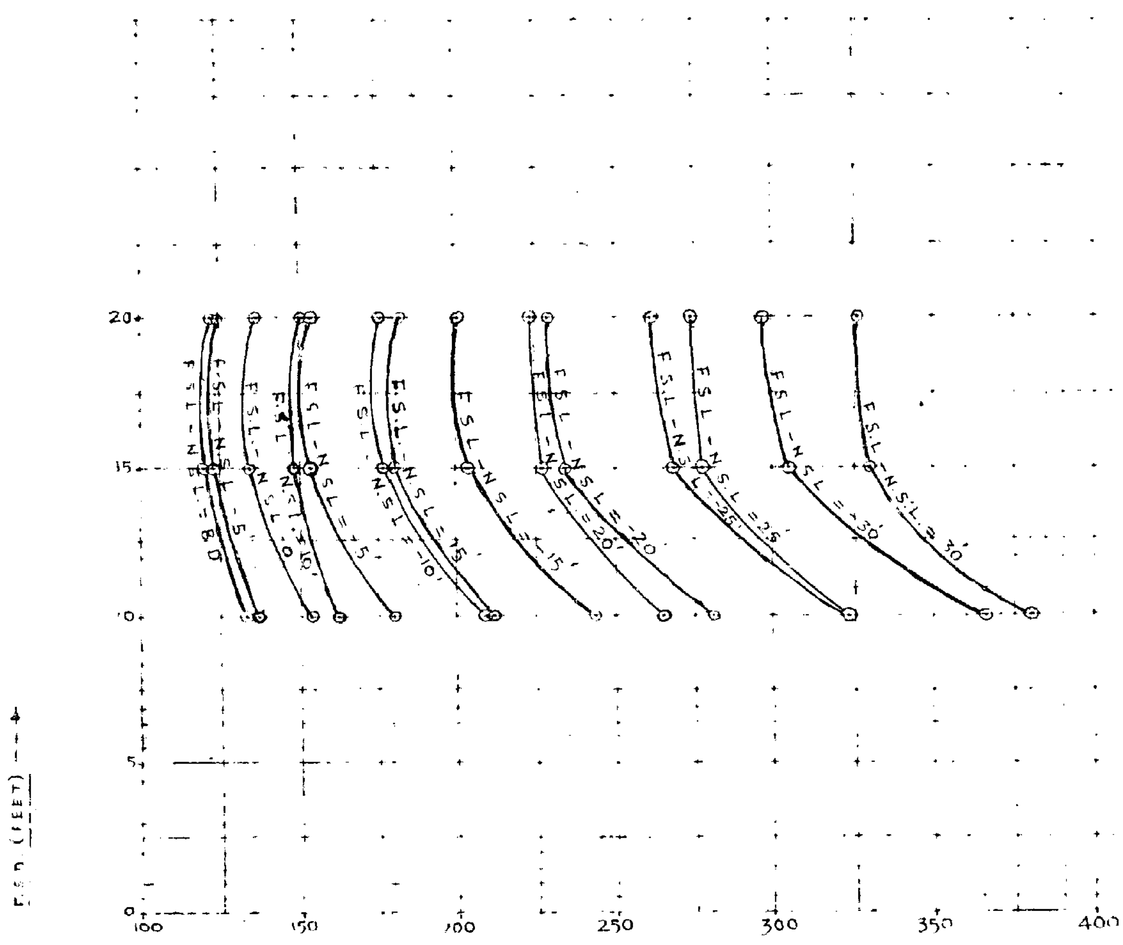


FIG.3.7(B)(I)

COST PER RFT. V/S F.S.D. FOR DISCHARGE (Q) = 4,000 CUSECS

(ii) STUDY WITH 5' INTERVAL



(ii) SPECIAL STUDY WITH 1' INTERVAL

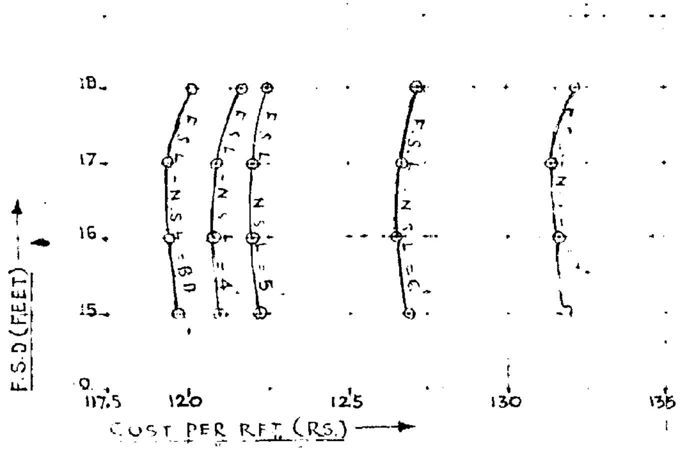


FIG 3·7(B)(II)

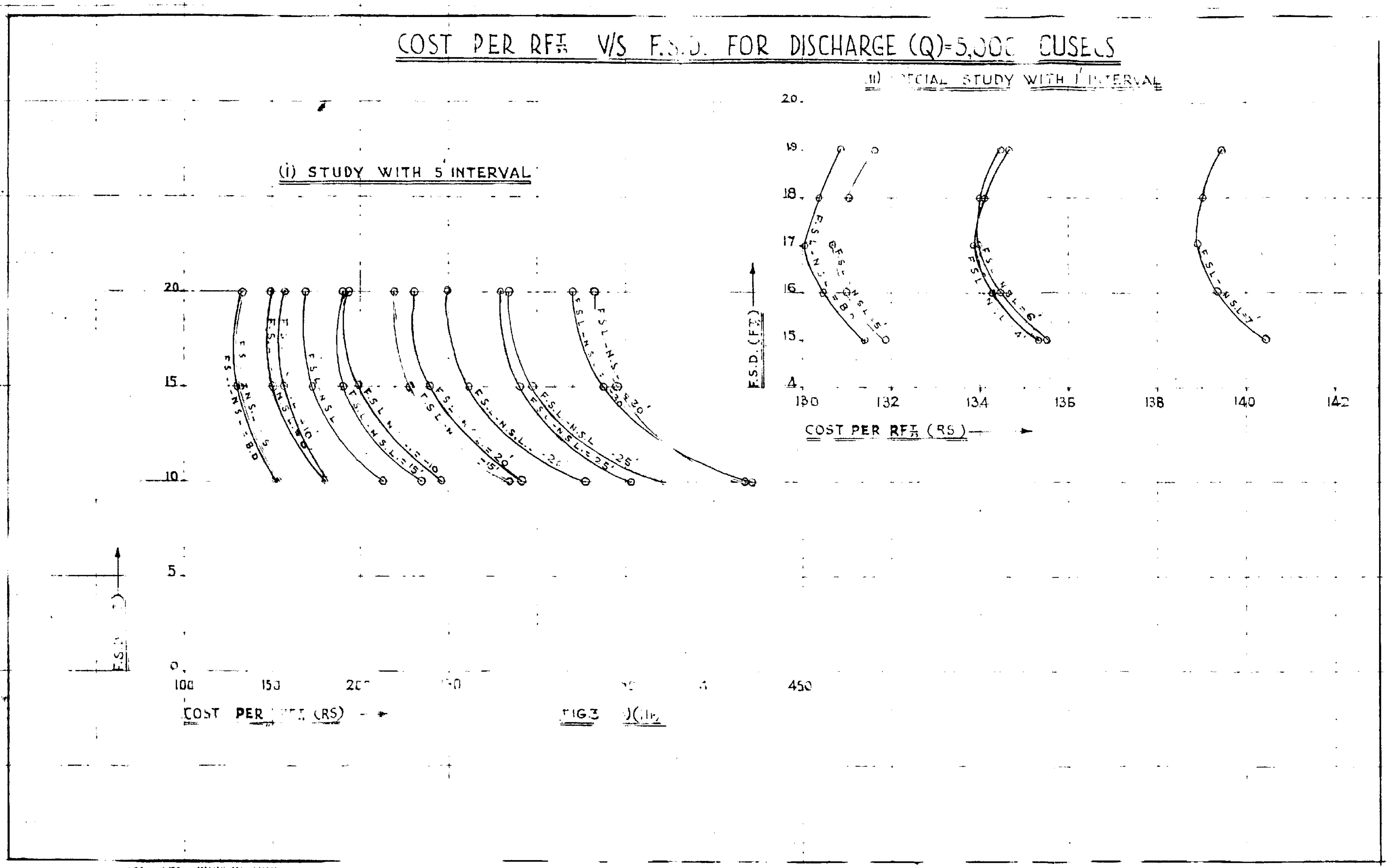
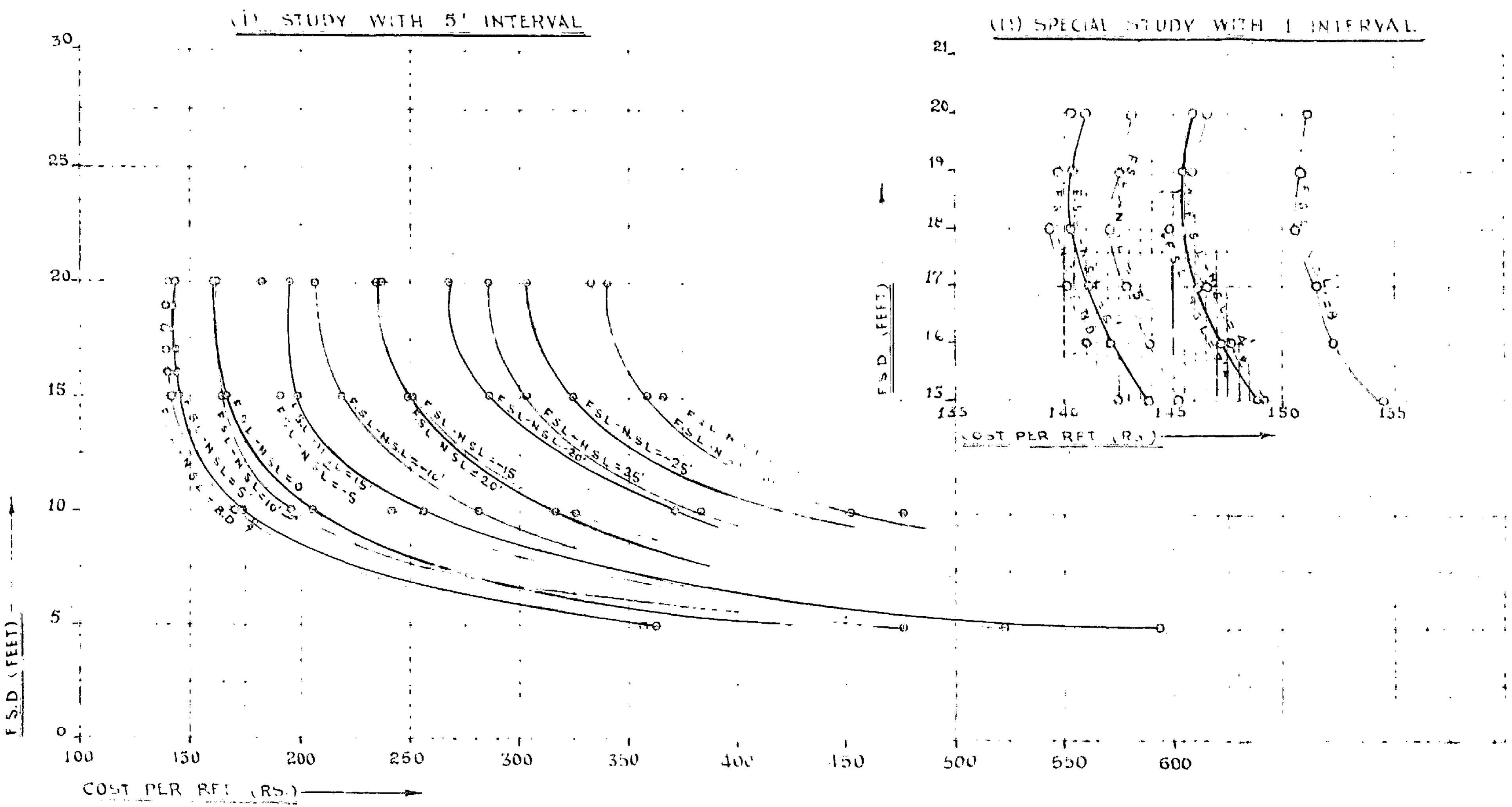

COST PER RFT V/S F.S.D. FOR DISCHARGE (Q)=5,000 CUSECS
(i) STUDY WITH 5' INTERVAL
F.S.D.
COST PER RFT (RS)
F.S.D. (FT)
COST PER RFT (RS)

FIG.3

Cost Per Rft V/s F.S.D. For Discharge (Q)- 6,000 Cusecs



(B)(IV)

COST PER RFT V/S FSD FOR DISCHARGE (Q) = 7,000 CUSECS

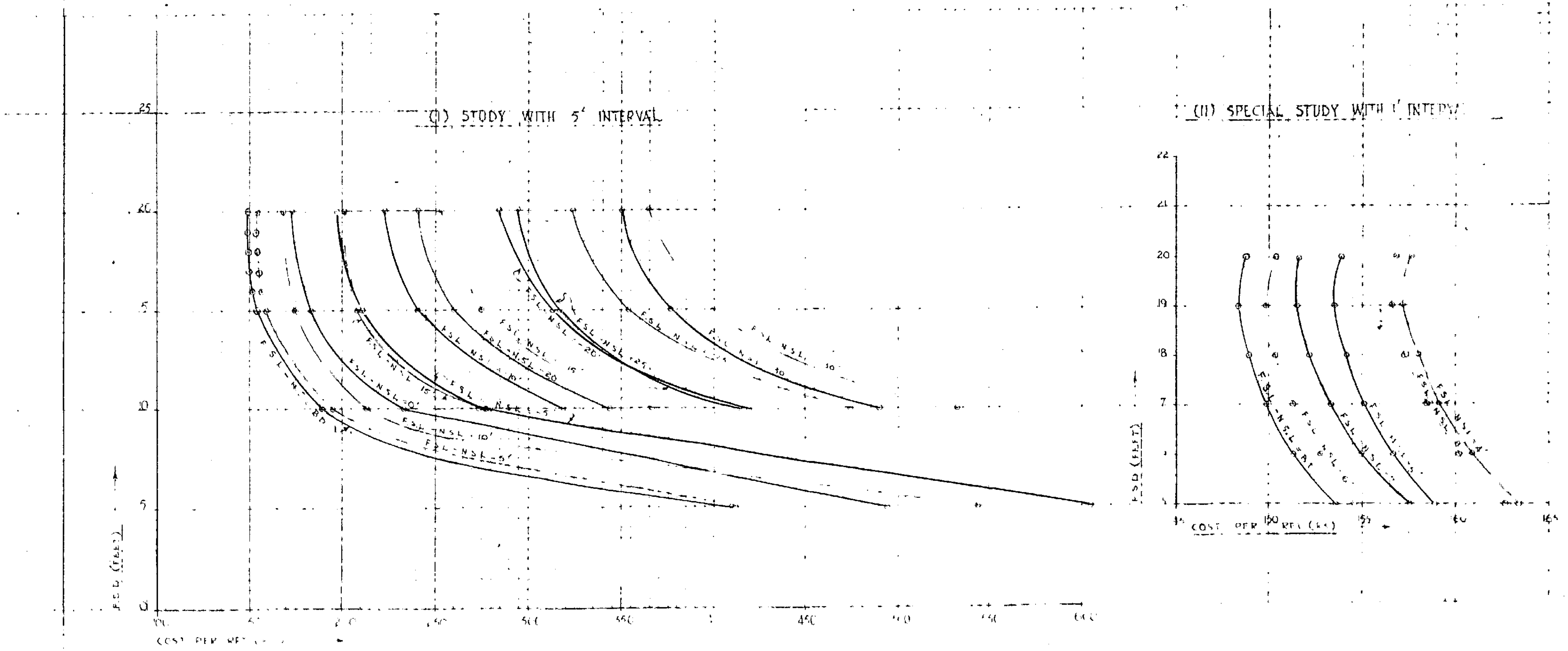


FIG 37(B)(V)

COST PER RFT V/S F.S.D. FOR DISCHARGE (Q) = 8,000 CUSECS

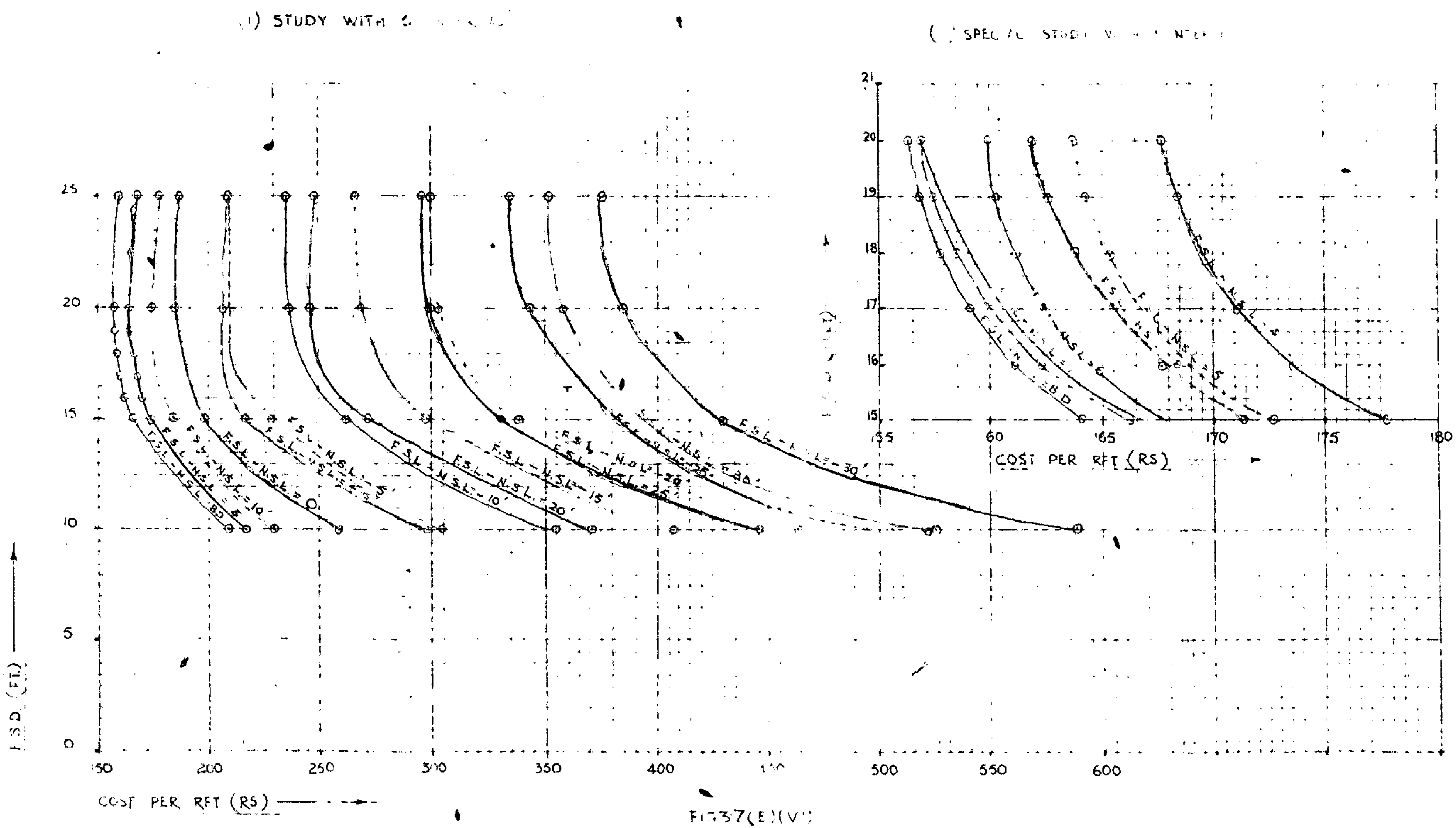


FIG 37(E)(V)

COST PER RFT V/S F.S.D FOR DISCHARGE (Q)= 9,000 CUSECS

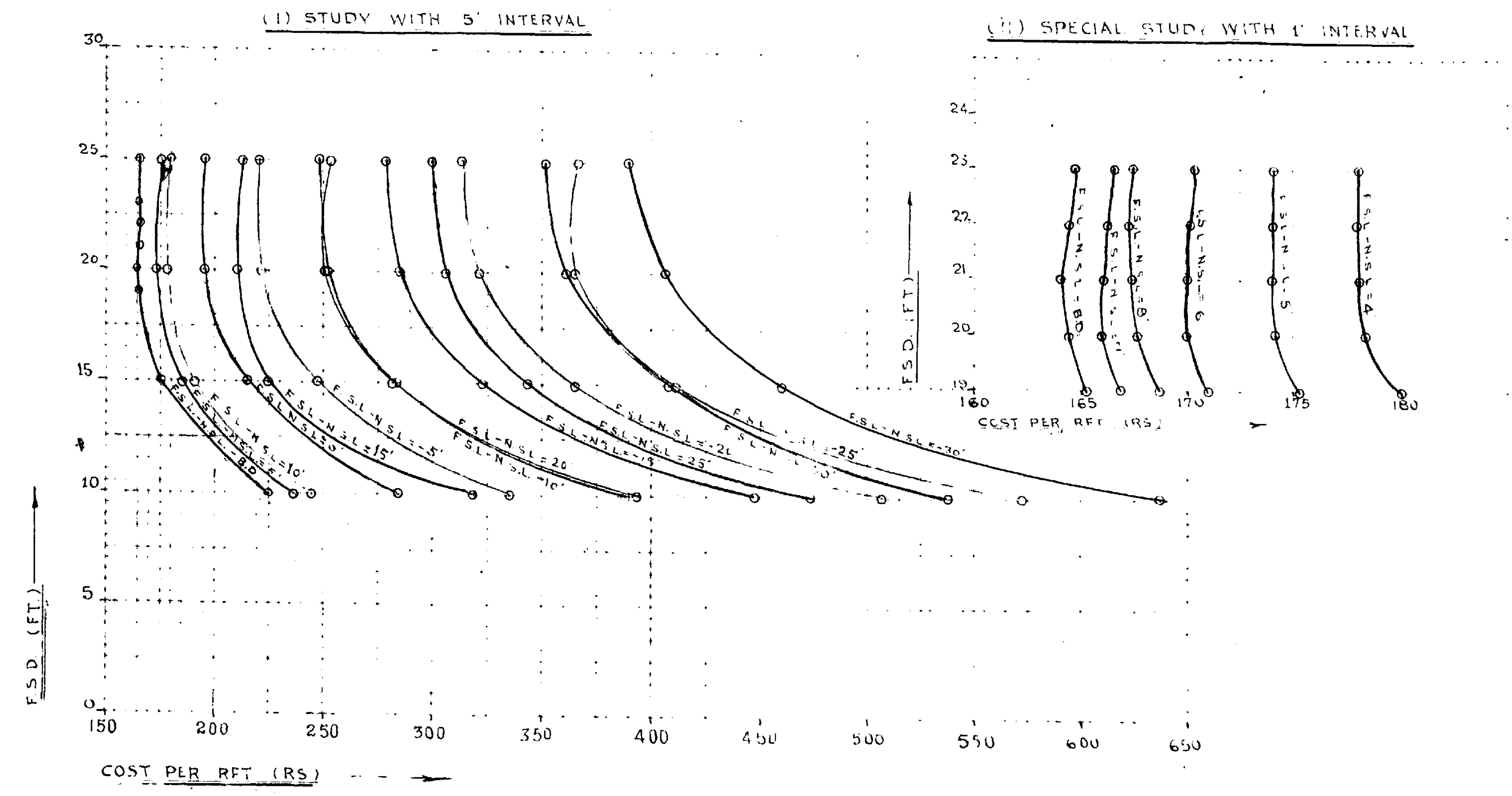
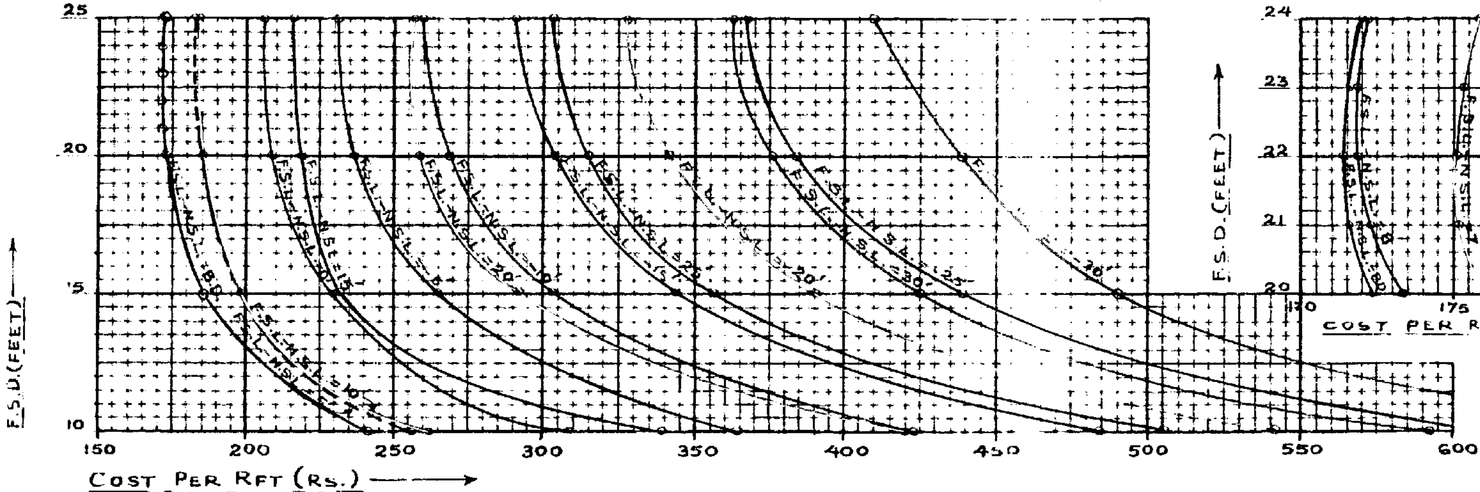


FIG 3.7 (B)

COST PER RFT V/S F.S.D. FOR DISCHARGE (Q) = 10,000 CUSECS.

(i) STUDY WITH 5' INTERVAL



(ii) SPECIAL STUDY WITH 1' INTERVAL

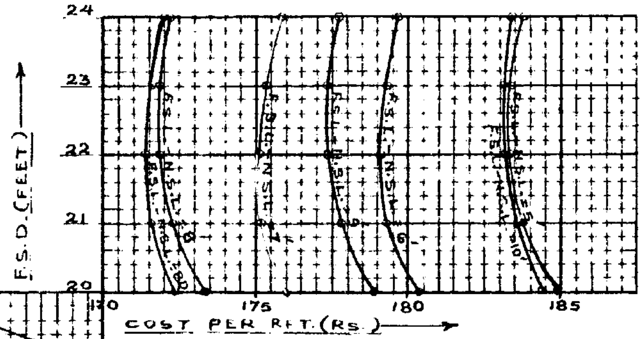


FIG 3·7 (B)(VIII)

COST PER RFT V/S F.S.D. FOR DISCHARGE (Q)= 12,000 CUSECS

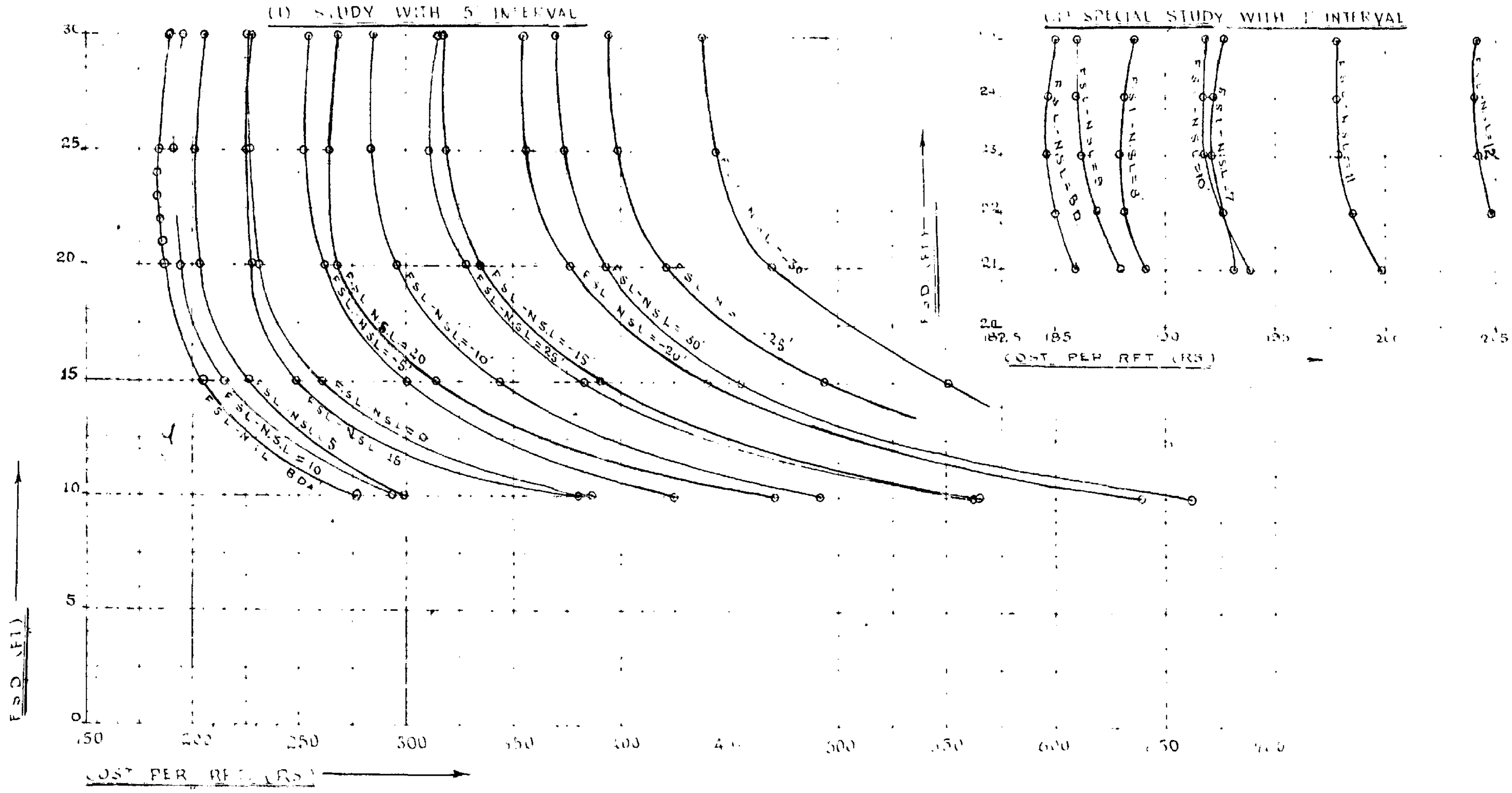


FIG. 3.7 (b)(IX)

COST PER RFT V/S FSD FOR DISCHARGE (Q)= 14,000 CUSECS

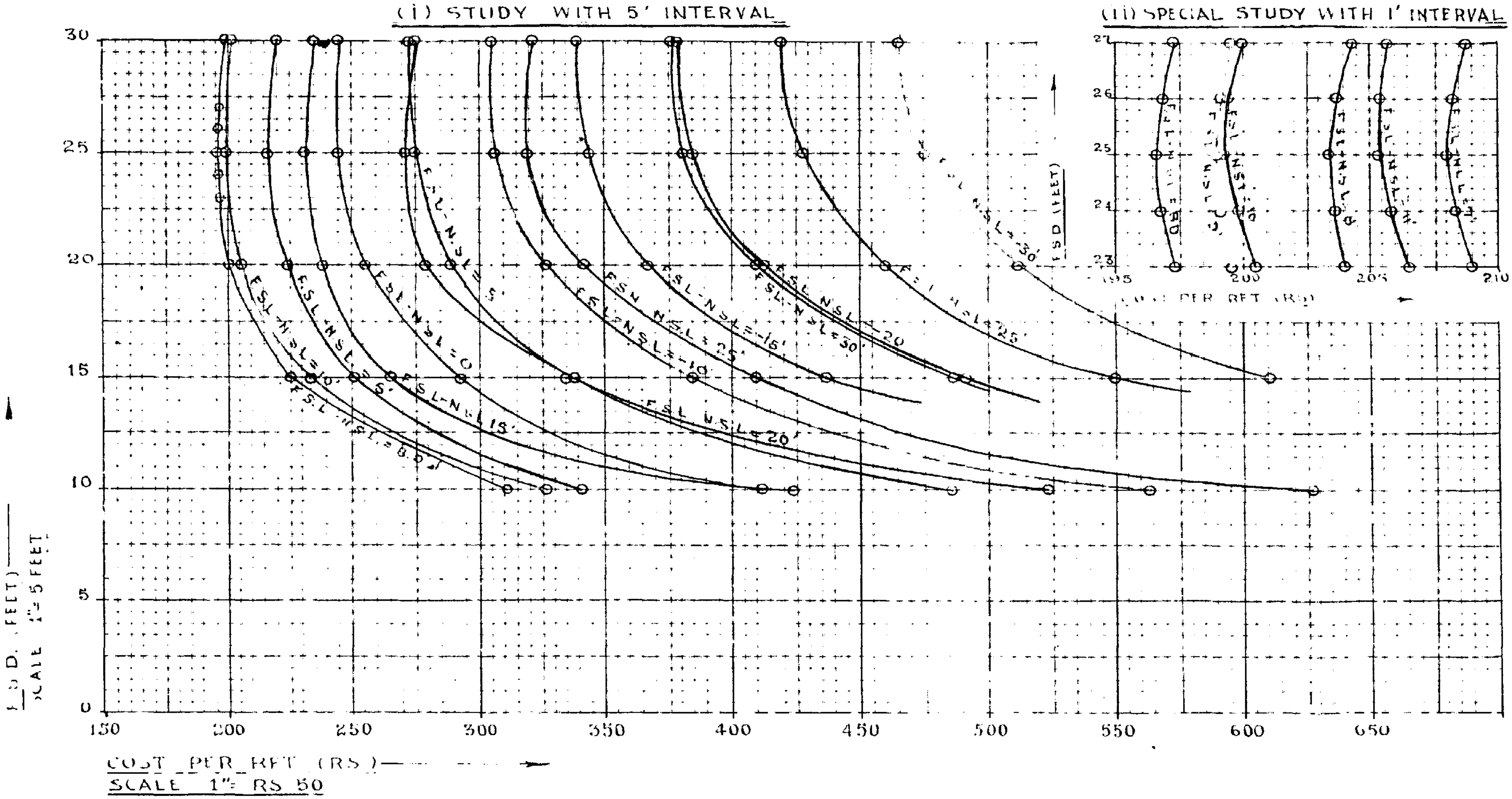


FIG.3.7(B)(x)

COST PER RFT V/S F.S.D FOR DISCHARC (Q) = 16,000 CUSCES

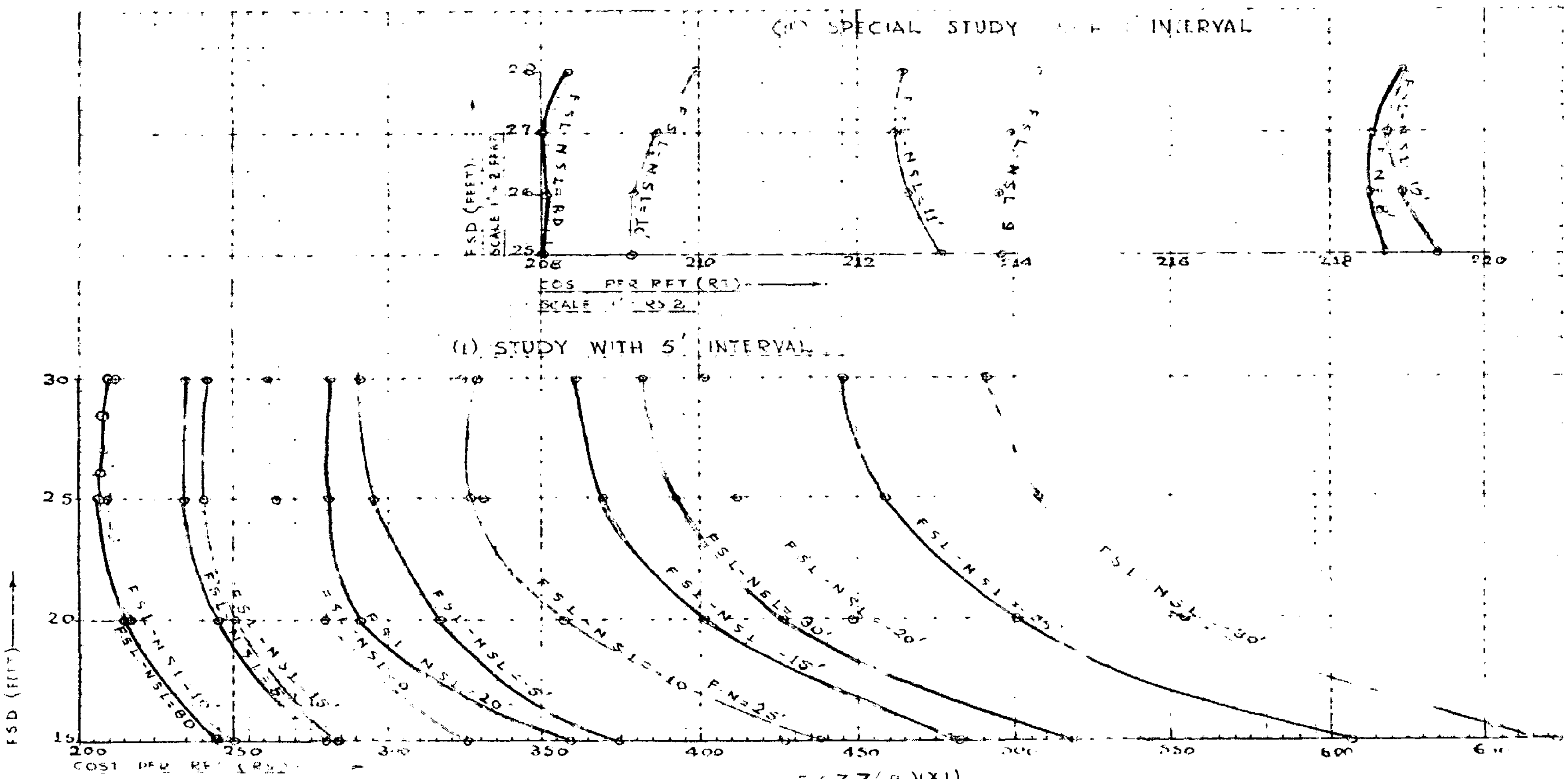


FIG 37(B)(XI)

COST PER RFT V/S F.S.D. FOR DISCHARGE (Q) ,000 CUSCES

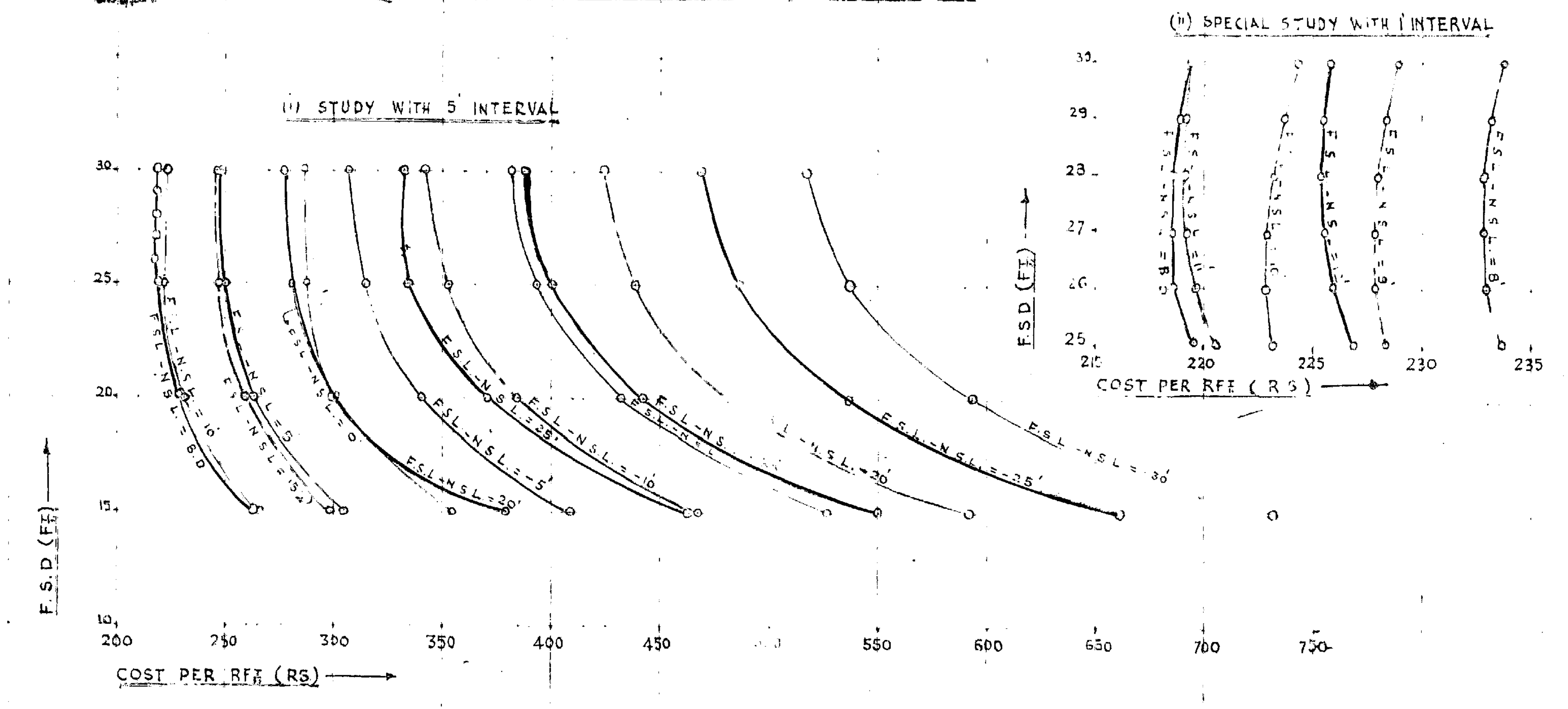


FIG 3·7

COST PER RFT. V/S F. S. D. FOR DISCHARGE (Q) = 20,000 CUSECS

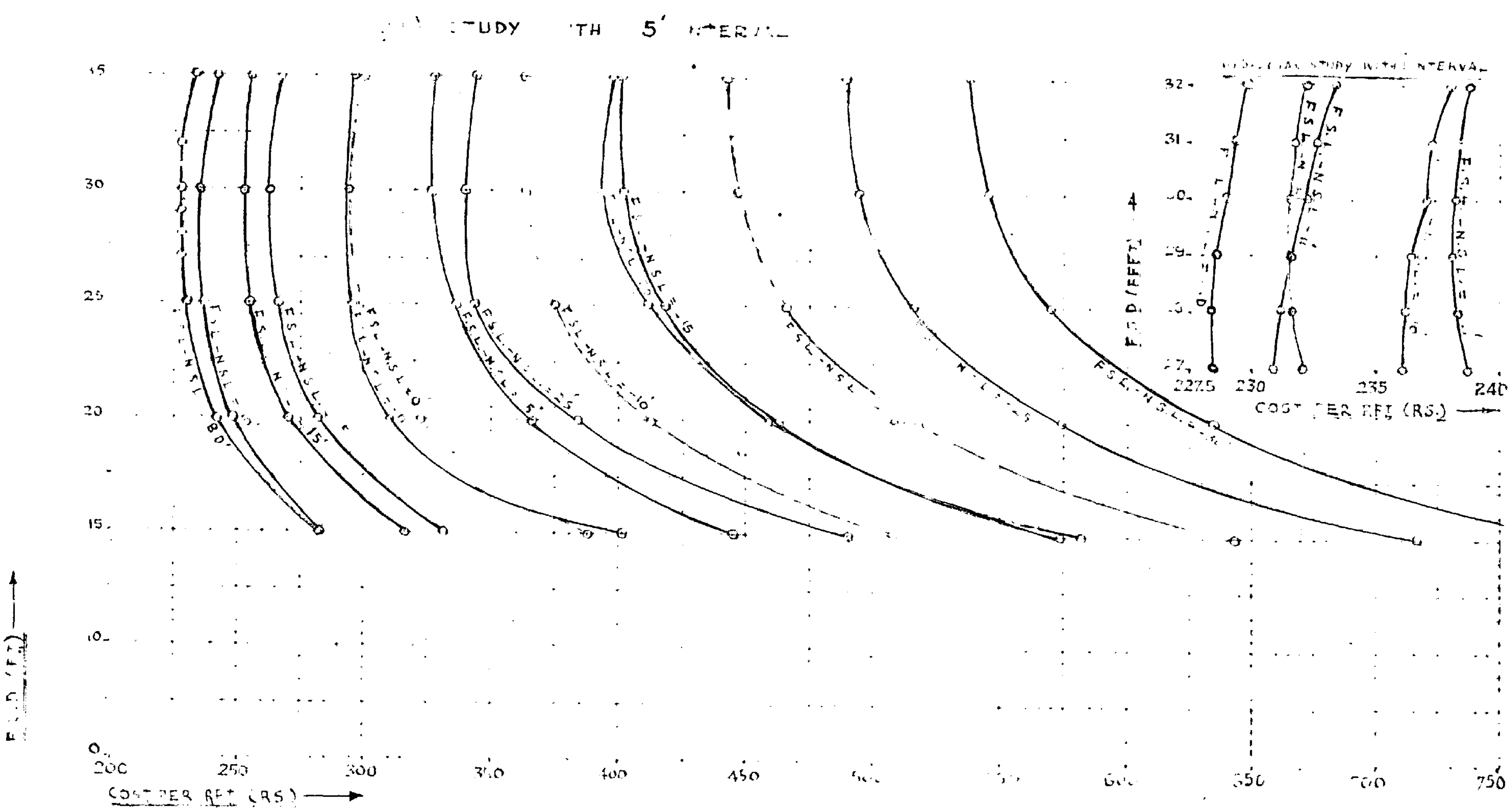


FIG 3·7(B)(XIII)

for a particular F.S.D. and for a given discharge it is possible to determine the most economical F.S.L. in relation to the level of the natural ground surface. The curves prepared are thus ready reckoners for the design engineer for deciding the full supply depth of a channel for a given discharge, and then its alignment for greatest economy.

3.9 SPECIAL STUDY WITH 1 FEET INTERVAL OF F.S.D. AND (F.S.L. - N.S.L.)

The above two studies were made with 5 ft. interval in the full supply depth and the (F.S.L.-N.S.L.) values. From the 5 ft. interval study for each discharge a conclusion for approximate economical full supply depth and ground position which gives minimum cost per rft. is drawn. For more accurate results, a closer interval of 1 ft. is taken. The above two studies for a range of 2 ft. to 3 ft. on either side of the full supply and (F.S.L.-N.S.L.) concluded to be economical in the earlier study.

In this case also, for each full supply depth considered for a particular discharge the bed width and velocity are worked out from the curves given in figure 2.6. The balancing depth is then calculated using equation (3.3) for each full supply depth and corresponding bed width. The earthwork & quantities of both the linings per rft. are then estimated for the balancing depth of cutting and other considered (F.S.L.-N.S.L.) values corresponding to the particular set of bed width and full supply depth combination. The cost of unit length of canal are worked out as before. The results obtained are plotted between (F.S.L-N.S.L.) & cost per rft. are shown separately on figures 3.7(A)(i) to 3.7(A)(xiii). As a sample the results for a discharge of 10000 Cs. are shown in table 3.5.

TABLE 3.5

STATEMENT OF COST PER RFT OF CANAL FOR 10,000 CUSECS.

S. No.	F.S.L.- N.S.L.	Cost per rft of canal: Earthwork		Single tile lining		Double tile lining		Total
	(Ft)	Qty. (Cft.)	Amt. (Rs.)	Qty. (Sft.)	Amt. (Rs.)	Qty. (Sft.)	Amt. (Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.
(i) F.S.D.(D)=20',B.W.(B)=60',Velocity(V)=4.6'/Sec.								
a	5	1492	52.22	60	36.0	109.75	96.58	184.80
b	6	1365	47.78	60	36.0	109.75	96.58	180.36
c	7	1241	43.44	60	36.0	109.75	96.58	176.02
d	7.82	1138	39.83	60	36.0	109.75	96.58	172.41
e	8	1164	40.74	60	36.0	109.75	96.58	173.32
(ii)F.S.D.(D)=21',B.W.(B)=51',Velocity(V)=4.638'/Sec.								
a	5	1487	52.05	51	30.60	114.68	100.92	183.57
b	6	1364	47.74	51	30.60	114.68	100.92	179.26
c	7	1246	43.61	51	30.60	114.68	100.92	175.13
d	7.84	1143	40.00	51	30.60	114.68	100.92	171.52
e	8	1164	40.74	51	30.60	114.68	100.92	172.26
(iii)F.S.D.(D)=22',B.W.(B)=43.25',Velocity 4.674/Sec.								
a	5	1491	52.19	43.25	25.95	119.61	105.25	183.39
b	6	1371	47.99	40.25	25.95	119.61	105.25	179.19
c	7	1255	43.93	43.25	25.95	119.61	105.25	175.13
d	7.89	1150	40.25	43.25	25.95	119.61	105.25	171.45
e	8	1164	40.74	43.25	25.95	119.61	105.25	171.94
f	9	1321	46.24	43.25	25.95	119.61	105.25	177.44
g	10	1486	52.01	43.25	25.95	119.61	105.25	183.21
(iv) F.S.D.(D)=23',B.W.(B)=36',Velocity (V)=4.708'/sec.								
a	5	1492	52.22	36.0	21.60	124.53	109.59	183.41
b	6	1375	48.13	36.0	21.60	124.53	109.59	179.32
c	7	1262	44.17	36.0	21.60	124.53	109.59	175.36
d	7.93	1155	40.43	36.0	21.60	124.53	109.59	171.62
e	8	1164	40.74	36.0	21.60	124.53	109.59	171.93

1.	2.	3.	4.	5.	6.	7.	8.	9.
(V) F.S.D.(D)=24',B.W.(B)=29.25', Velocity (V)=4.726'/sec.								
a	5	1494	52.29	29.25	17.55	129.46	113.92	183.76
b	6	1379	48.27	29.25	17.55	129.46	113.92	179.74
c	7	1269	44.42	29.25	17.55	129.46	113.92	175.89
d	7.97	1160	40.60	29.25	17.55	129.46	113.92	172.07
e	8	1164	40.74	29.25	17.55	129.46	113.92	172.21

Note:- It can be concluded from these curves that

(i) full supply depth of 22' is most economical for the range of (F.S.L.-N.S.L.)5' to 10'; and

(ii) greatest economy is achieved when ground level is about 8' below full supply level.

Similarly results are plotted between F.S.D. and cost per rft. of canal for each considered (F.S.L. - N.S.L.) and for each discharge and are shown separately on figure 3.7 (B) (i) to figure 3.7 (B) (xiii). The preparation of these curves is best explained by taking an example. The example is taken for a discharge of 10,000 cusecs.

EXAMPLE:-

From the F.S.D. curves in figure 3.7A (viii) for 10,000 cusecs it is concluded that full supply depth of 25 ft. is most economical for the range of (F.S.L-N.S.L.) 30' to -30'. Similarly from the (F.S.L.-N.S.L.) curves in figure 3.7B (viii) for 10,000 cusecs, it is concluded that greatest economy is achieved when ground level is between 5 ft. to 10 ft. and cost per rft. is minimum for balancing depth of cutting.

The fully supply depth and (F.S.L. - N.S.L.) considered for 1 ft. interval special study are 20 ft. to 25 ft. am 8 ft. to 8 ft. respectively.

For each considered fully supply depth of 20 ft. to 25 ft., the bed widths are obtained from the discharge curve of 10,000 cusecs given in figure 2.6 and are as below:-

F.S.D. (ft.) 1.	Corresponding bed width (ft.) 2.	Velocity (ft./Sec.) 3.	Balancing depth from equation(3.3) (ft.) 4.
20	60.00	4.600	12.18
21 ft.	51.00	4.638	13.16
22	43.25	4.674	14.11
23	36.00	4.708	15.07
24	29.25	4.726	16.03
[illegible]	[illegible]	4.746	17.02

The earthwork corresponding to (F.S.L-N.S.L.) values ranging from 5 ft. to 8 ft. including the balancing depth are worked out for each set of full supply depth ranging from 20 ft. to 25 ft. and corresponding discharge and cost of earth work worked out for each set, cost of lining will remain constant. The cost per rft. of canal is then worked out for each (F.S.L. - N.S.L.) value considered. The results are shown in table 3.5. The results are plotted and shown in figure 3.7A(viii) giving F.S.D. curves and 3.7B (viii) giving (F.S.L.-N.S.L.) curves under the heading special study with 1 ft. interval.

For each discharge, from F.S.D. curves the most economic F.S.D. corresponding to different values of (F.S.L.-N.S.L.) can be obtained. For an example considered the most economical full supply depth as obtained from F.S.D. curves is 22 ft. for the entire range of (F.S.L.-N.S.L.) 5' to 10'. Thus for 10,000 cusecs the most economical F.S.D. is 22 ft. The conclusion for the most economic F.S.D. for the range of (F.S.L.-N.S.L.) considered is given as a foot-note below table 3.5 for 10,000 cusecs discharge.

As described above the most economical F.S.D. for each discharge ranging from 3,000 to 20,000 cusecs and corresponding position of ground relative to F.S.L. are obtained from the figure 3.7A (i) to figure 3.7(A)(xiii) and figure 3.7(B) (i) to figure 3.7 (B) (xiii) respectively. These results showing the most economical F.S.D. corresponding to each discharge and respective ground position with respect to F.S.L. are shown in table 3.6. The table also

TABLE 3.6

STATEMENT SHOWING MOST ECONOMICAL F.S.D., BALANCING DEPTH AND CORRESPONDING CANAL DIMENSIONS FOR DIFFERENT DISCHARGES WITH BED SLOPE 1/12,000

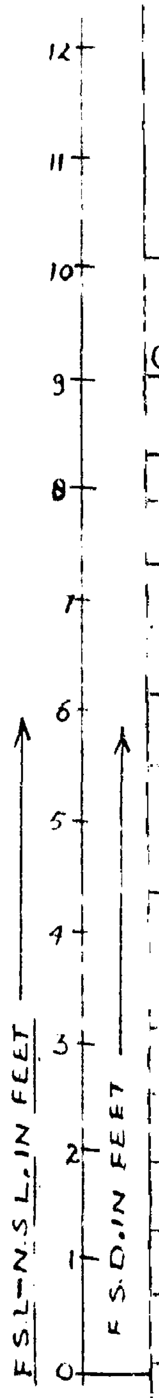
S.No.	Discharge	Canal Dimensions				F.S.D. -N.S.L.	Cost per rft. of canal
		Economical F.S.D.	Bed Width	Velocity	Balancing depth		
	(cusecs)	(ft.)	(ft.)	(ft./Sec.)	(ft.)	(ft.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.
1.	3,000	14	27.50	3.46	10.41	3.59	107.01
2.	4,000	16	27.75	3.734	11.55	4.45	119.41
3.	5,000	17	33.00	3.933	11.93	5.07	130.07
4.	6,000	18	36.50	4.112	12.22	5.78	139.39
5.	7,000	19	39.50	4.267	12.62	6.38	148.40
6.	8,000	20	41.25	4.42	13.10	6.90	156.44
7.	9,000	21	42.50	4.552	13.59	7.41	164.12
8.	10,000	22	43.25	4.674	14.11	7.89	171.45
9.	12,000	23	50.50	4.874	14.27	8.73	184.62
10.	14,000	25	[illegible]	5.084	15.48	9.52	196.56
11.	16,000	27	[illegible]	5.278	16.73	10.27	208.00
12.	18,000	27	[illegible]	5.402	16.09	10.91	218.53
13.	20,000	28	60.00	5.455	16.52	11.48	228.33

contains the canal dimension such as bed width and velocity and the cost per rft. of canal corresponding to the most economical F.S.D. The economical F.S.D., economical (F.S.L.-N.S.L.) and cost per rft. of canal are plotted against discharge in figure (3.8), which is thus an abstract of the earlier computations.

With the help of these curves shown in figure 3.8, it is possible to find the most economical full supply depth for any given discharge by reading the ordinate on economical full supply depth curve against a given discharge. These results are for the assumed unit rates of earth work and lining, bed slope of 1 in 12,000, sides slopes of 2:1 and rugosity coefficient of 0.017 in manning's formula. If any of the data adopted for design changes, the study can be repeated to determine the most economical F.S.D. in the same manner as the ratios between rates of different items of work are not likely to vary greatly, the present results will be useful for approximate estimation in other projects also. However, for accurate results, the procedure developed here could be used for the actual prevailing ~~for the~~ rates, or other conditions.

3.10 BED SLOPE AND F.S.D. V/S COST (ECONOMICAL BED SLOPE STUDY):-

In the above studies the variations of ground position corresponding to F.S.L. were considered for a particular bed slope. Now under this study the most economical bed slope has been determined for each discharge ranging from 3,000 to 20,000 cusecs and corresponding most economical F.S.D. is determined.



O	DISCHARGE (CUSECS)	ECONOMICAL F.S.D. FT	F.C.L. N. FT	COST PER ... OF CANAL (RS)
	2	3	4	5
	3,000	14	3 5[illegible]	[illegible]
	4,000	16	4·45	11[illegible] 1
	5,0[illegible]	17	5·07	130 [illegible]
	6,0[illegible]	18	5 78	139·39
	7,000	19	6 38	148 40
	8,000	20	6·90	[illegible]56·44
	9,000	21	7 41	164 12
	10,000	22	7 89	171 45
	12,000	23	8 73	184 62
	14,000	25	9 52	196 56
	16,000	27	10·27	208 00
	18,000	27	1[illegible] 91	[illegible]
	20,000	28	11·48	[illegible]28 38

DIAGRAM SHOWING MOST ECONOMICAL FULL SUPPLY DEPTH CORRESPONDING FSL-NSL AND COST PER RFT OF CANAL V/S DISCHARGE FOR TRAPEZOIDAL LINED CHANNELS WITH 2 TO 1 SIDE SLOPE & N=0·017 IN MANNING'S FORMULA WITH BED SLOPE OF 1 IN 12,000

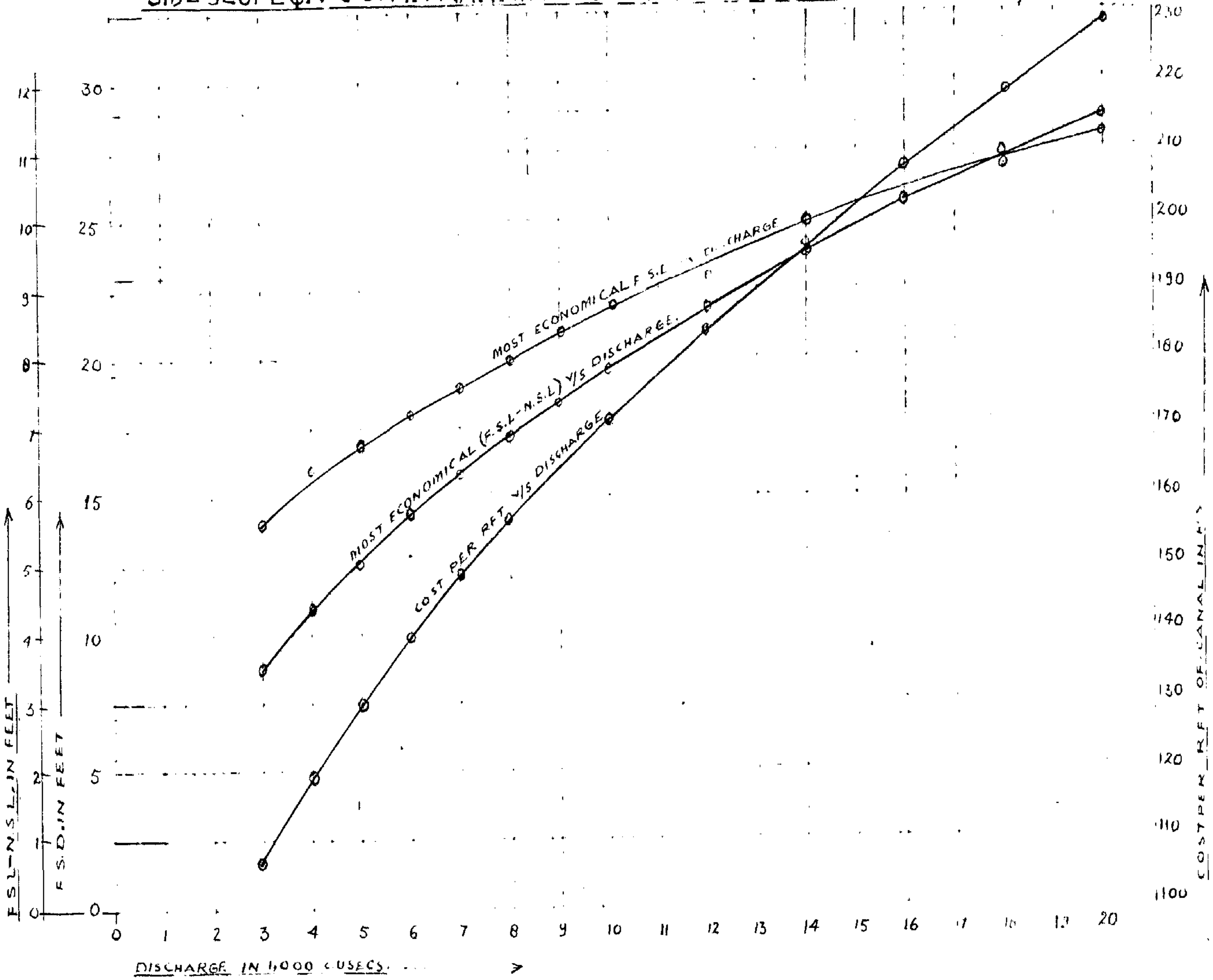


FIG. 3·8

S.NO	DISCHARGE (CUSECS)	ECONOMICAL F.S.D. FT	F.S.L-N.S.L FT	COST PER RFT OF CANAL (RS)
1	2	3	4	5
1	3,000	14	3.5[illegible]	[illegible]
2	4,000	16	4·45	115 [illegible]
3	5,0[illegible]	17	5 07	130 [illegible]
4	6,0[illegible]	18	5 78	139·39
5	7,000	19	6 38	148 40
6	8,000	20	6·90	56·44
7	9,000	21	7 41	164 12
8	10,000	22	7 89	171 45
9	12,000	23	8 73	184 62
10	14,000	25	9 52	96 56
11	16,[illegible]	27	10·27	[illegible]0 00
12	1[illegible],000	27	10 91	[illegible]
13	20,[illegible]	28	11 48	[illegible]28 38

For this study bed slope ranges considered are from 1 in 12,000 to 1 in 3,000 with an interval of 1 in 1,000. For each discharge bed slopes considered are from 1 in 12,000 to such value for which velocity in the channel may not exceed 6 ft./Sec. which is the permissible limit of velocity in tile lined channels.

For each discharge, full supply depths in a range of 2 ft. to 3 ft. on either side of the most economical F.S.D. as determined earlier are considered. The bed widths corresponding to each considered fully supply depth are determined for varying range of bed slopes such that the velocity in the channel may not exceed the permissible value of velocity in tile lined channel. For each set full supply depth and bed width, balancing depth is first worked out using equation (3.3). The cost of the composite section per rft. is then calculated as before. The velocities corresponding to the section and bed slope considered are also calculated by using manning's formula. The procedure is explained below by an example:-

EXAMPLE:-

Let discharge Q	=	10,000 cusecs
Let assumed full supply depth (D).	=	22 ft.
Bed slope considered (i)	=	1 in 10,000

The bed width corresponding to discharge of 10,000 cusecs for assumed full supply depth of 22 ft., bed slope (i) taken as 1 in 10,000, coefficient of rugosity (N) 0.017 and side slopes (S:1) (2:1) is determined using formula (2.2) as below:-

$$Q = \frac{(D(B+D(S+\tan^{-1}1/S/57.3))^{5/3}}{(B+2D(S+\tan^{-1}1/S/57.3)^{2/3}} \frac{1.49}{N} (i)^{\frac{1}{2}}$$

Substituting the known values of D, S, N, i & Q

$$\text{or } 10{,}000 = \frac{(22(B+22(2+26.57/57.3))^{5/3}}{(B+44(2+26.57/57.3))^{2/3}} \frac{1.49}{0.017} \left(\frac{1}{10{,}000}\right)^{\frac{1}{2}}$$

$$\text{or } \frac{10{,}000}{0.876} = 22\ (B+54.2)\ \left(\frac{2281.192.42}{B+108.4}\right)^{2/3}$$

This equation can be solved by trial and error for the value of B. It is found that B = 36.25 ft. satifies the equation. Corresponding value of velocity V = 5.03 ft./Sec.

The value of bed width and velocity can also be obtained from the curves given in figure 2.6 for discharge equal to the proposed discharge divided by $(S_1/S)^{\frac{1}{2}}$ where S_1 = 1 in 10,000 and S = 1 in 12,000 i.e. for a discharge of $10{,}000/\frac{(12{,}000)^{1/2}}{(10{,}000)^{1/2}} = 10{,}000/(1.2)^{\frac{1}{2}} = 10{,}000/1.0954 = 9130$ cusecs. For a discharge of 9,130 cusecs bed width can be read against the assumed F.S.D. of 22 ft. which gives a value of 36.25 ft. as before.

The velocity corresponding to a discharge of 9,130 cusecs as read from velocity curves is 4.6 ft./Sec.

This velocity corresponding to bed slope of 1 in 10,000 will be $4.6\ (\frac{S1}{S})^{\frac{1}{2}} = 4.6\ (\frac{1/10{,}000}{1/12{,}000})^{\frac{1}{2}} = 5.039$ ft./Sec. which is very near to the calculated velocity and of 5.03 ft./sec.

The section thus obtained is 36.25 ft. bed width and 22 ft. F.S.D. For this balancing depth of cutting can be determined by using equation (3.3) and comes to 14.49 ft.

Now for balancing depth (d) = 14.49 ft., the earth work per rft. of canal can be worked out using formula (3.1) or (3.2). In this example it works out to 1,090 Cft.

The cost of the canal per rft. then works out as below:-

Item	Cost per rft. of canal Quantity	Amount (Rs.)
1. Earthwork for balancing depth from formula (3.2)	1,090 Cft.	38.15
2. Single tile lining for bed	36.25 sft.	21.75
3. Double tile lining for sides and rounded corners. (4.92734x20+11.2)	119.61 sft.	105.25
	TOTAL Rs.	165.15

Thus cost per rft. of canal for 10,000 cusecs for a bed slope of 1 in 10,000 worked out to be Rs. 165.15.

Similarly the cost of canal per rft. for balancing depth for each bed slope considered for the discharge range of 3,000 to 20,000 cusecs is worked out.

The results are shown in table 3.7 (i) to 3.7 (xiii). The conclusion regarding most economical bed slope and corresponding most economical F.S.D. giving a velocity within the permissible limit are given in the form of a foot note below each table corresponding to each discharge. A note regarding most economic F.S.D. for different bed slopes is also given below each table.

For each discharge varying from 3,000 to 20,000 cusecs from tables 3.7 (i) to 3.7 (xiii) the most economical bed slopes and corresponding F.S.D. are found out and a

[illegible]

S.No.	Canal dimensions: F.S.D. (ft.)	Bed slope	Bed width (ft.)	Balancing depth (ft.)	Velocity ft./sec.	Cost per Rft. of the canal: Earth work Qty. (Cft.)	Earth work Amt. (Rs.)	Single tile lining Qty. (Sft.)	Single tile lining Amt. (Rs.)	Double tile lining Qty. (Sft.)	Double tile lining Amt. (Rs.)	Total amount (Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	10	1/3000	27.75	8.02	5.736	389	13.62	27.75	16.65	60.47	58.21	83.48
2.	11	1/6000	35.00	8.28	4.395	469	16.42	35.00	21.00	65.40	57.55	94.97
[illegible]		1/5000	30.50	8.48	4.739	446	15.61	30.50	18.30	65.40	57.55	91.46
		1/4000	25.50	8.73	5.192	419	14.67	25.50	15.30	65.40	57.55	87.53
		1/3000	20.00	9.02	5.844	389	13.62	20.00	12.00	65.40	57.55	83.17
3.	12	1/10000	39.50	8.66	3.62	540	18.90	39.50	23.70	70.33	61.89	104.49
		1/9000	36.50	8.79	3.785	524	18.34	36.50	21.90	70.33	61.89	102.13
		1/8000	33.50	8.93	3.975	508	17.78	33.50	20.10	70.33	61.89	99.77
		1/7000	30.25	9.08	4.198	491	17.19	30.25	18.15	70.33	61.89	97.23
		1/6000	26.50	9.28	4.471	469	16.42	26.50	15.90	70.33	61.89	94.21
		1/5000	22.50	9.49	4.814	446	15.61	22.50	13.50	70.33	61.89	91.00
		1/4000	18.00	9.74	5.263	419	14.67	18.00	10.80	70.33	61.89	87.36
		1/3000	13.00	10.04	5.905	388	13.[illegible]	13.00	7.80	70.33	61.89	83.27
4.	13	1/12000	35.75	9.40	3.418	569	19.92	35.75	21.45	75.25	66.22	107.59
		1/11000	33.25	9.52	3.532	555	19.43	33.25	19.95	75.25	66.22	105.60

		1/10000	30.75	9.65	3.68	540	18.90	30.75	18.45	75.25	66.22	103.57
		1/9000	28.00	9.79	3.843	524	18.34	28.00	16.80	75.25	66.22	101.36
		1/8000	25.25	9.93	4.03	508	17.78	25.25	15.15	75.25	66.22	99.15
		1/7000	22.50	10.08	4.254	491	17.19	22.50	13.50	75.25	66.22	96.91
		1/6000	19.25	10.27	4.524	470	16.45	19.25	11.55	75.25	66.22	94.22
		1/5000	15.75	10.47	4.865	448	15.68	15.75	9.45	75.25	66.22	91.35
		1/4000	11.75	10.72	5.31	421	14.74	11.75	7.05	75.25	66.22	88.01
5.	14	1/12000	27.50	10.41	3.46	570	19.65	27.50	16.50	80.18	70.56	107.01
		1/11000	25.25	10.52	3.585	555	19.43	25.25	15.15	80.18	70.56	105.14
		1/10000	23.25	10.63	3.72	542	18.97	23.25	13.95	80.18	70.56	103.48
		1/9000	20.75	10.78	3.885	525	18.38	20.75	12.45	80.18	70.56	101.39
		1/8000	18.25	10.93	4.098	509	17.82	18.25	10.95	80.18	70.56	99.33
		1/7000	15.50	11.09	4.289	490	17.15	15.50	9.30	80.18	70.56	96.01
6.	15	1/12000	20.50	11.38	3.494	574	20.09	20.50	12.30	85.11	74.90	107.29
		1/11000	18.75	11.49	3.618	559	19.57	18.75	11.25	85.11	74.90	105.72
		1/10000	16.50	10.63	3.754	542	18.97	16.50	9.90	85.11	74.90	103.77

Note:- It is concluded from above table that
(i) 11' F.S.D. is most economical for the bed slope of 1/3000;
(ii) 12' F.S.D. is most economical for the range of bed slope 1/4000 to 1/6000;
(iii) 13' F.S.D. is most economical for the range of bed slope 1/7000 to 1/9000;
(iv) 14' F.S.D. is most economical for the range of bed slope 1/10000 to 1/12000
(v) Greatest economy is achieved when ground has a slope of 1/3000; and
(vi) Most economical bed slope is 1/3000 with 11' F.S.D. giving a velocity of 5.844'/sec.

S.No.	Canal dimensions					Cost per rft. of the canal						Total
	F.S.D.	Bed slope	Bed width	Balancing depth	Velocity	Earth work		Single tile lining		Double tile lining		Amount
	(ft.)		(ft.)	(ft.)	ft./Sec.	Qty. (cft.)	Amt. (Rs.)	Qty. (sft.)	Amt. (Rs.)	Qty. (sft.)	Amt. (Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13
1.	[illegible]	[illegible]	[illegible]	[illegible]	5.562	492	17.22	30.50	18.30	70.33	61.89	97.41
2.	13	1/7000	36.75	9.36	4.486	575	20.13	36.75	22.05	75.25	66.22	108.40
		1/6000	32.50	9.56	4.781	556	19.25	32.50	19.50	75.25	66.22	104.97
		1/5000	28.00	9.79	5.152	524	18.34	28.00	16.80	75.25	66.22	101.36
		1/4000	22.75	10.07	5.635	492	17.22	22.75	13.65	75.25	66.22	97.09
		1/3000	17.00		6.328	-	Not considered -					
3.	14	1/10000	38.25	9.86	3.929	635	22.23	38.25	22.95	80.18	70.56	115.74
		1/9000	35.25	10.00	4.107	617	21.60	35.25	21.15	80.18	70.56	113.31
		1/8000	32.00	10.17	4.309	598	20.93	32.00	19.20	80.18	70.56	110.69
		1/7000	28.50	10.35	4.547	576	20.16	28.50	17.10	80.18	70.56	107.82
		1/6000	24.75	10.55	4.839	551	19.29	24.75	14.85	80.18	70.56	104.70
		1/5000	20.50	10.79	5.201	523	18.31	20.50	12.30	80.18	70.56	101.17
		1/4000	16.00	11.06	5.691	493	17.26	16.00	9.60	80.18	70.56	97.42
4.	15	1/12000	35.50	10.56	3.696	671	23.49	35.50	21.30	85.11	74.90	119.69
		1/11000	32.75	10.71	3.828	654	22.89	32.75	19.65	85.11	74.90	117.44
		1/10000	30.25	10.83	3.976	637	22.30	30.25	18.15	85.11	74.90	115.35

		1/9000	27.50	10.98	4.153	618	21.63	27.50	16.50	85.11	74.90	113.03
		1/8000	24.50	11.15	4.367	599	20.97	24.50	14.70	85.11	74.90	110.57
		1/7000	21.25	11.34	4.586	576	20.16	21.25	12.75	85.11	74.90	107.81
		1/6000	18.00	11.54	4.883	553	19.36	18.00	10.80	85.11	74.90	105.06
		1/5000	14.25	11.77	5.245	526	18.41	14.25	8.35	85.11	74.90	101.66
5.	16	1/12000	27.75	11.55	3.734	672	23.52	27.75	16.65	90.04	79.24	119.41
		1/11000	25.25	11.70	3.865	655	22.93	25.25	15.15	90.04	79.24	117.32
		1/10000	23.00	11.83	4.014	639	22.37	23.00	13.80	90.04	79.24	115.41
		1/9000	20.50	11.97	4.188	620	21.70	20.50	12.30	90.04	79.24	113.24
		1/8000	17.75	12.14	4.387	600	21.00	17.75	10.65	90.04	79.24	110.89
6.	17	1/12000	20.75	12.54	3.761	673	23.56	20.75	12.45	94.96	83.56	119.57
		1/11000	18.75	12.67	3.897	657	23.00	18.75	11.25	94.96	83.56	117.81

Note:- It is concluded from above table that-

(i) 13' F.S.D. is most economical for bed slope of 1/4000;
(ii) 14' F.S.D. is most economical for the range of bed slope of 1/5000 to 1/7000;
(iii) 15' F.S.D. is most economical for the range of bed slope of 1/8000 to 1/10000;
(iv) 16' F.S.D. is most economical for the range of bed slope of 1/11000 to 1/12000;
(v) greatest economy is achieved when ground has a slope of 1/4000; and
(vi) most economical bed slope is 1/4000 with 13' F.S.D. giving a velocity of 5.635'/sec.

S.No.	Canal dimensions					Cost per rft. of the canal						Total Amount
	F.S.D. (ft.)	Bed slope	Bed width (ft.)	Balancing depth (ft.)	Velocity ft./Sec.	Earth work Qty. (Cft)	Earth work Amt. (Rs.)	Single tile lining Qty. (Sft.)	Single tile lining Amt. (Rs.)	Double tile lining Qty. (Sft)	Double tile lining Amt. (Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	13	1/4000	33.50	9.61	5.877	556	1946	33.50	20.10	75.25	66.22	105.78
2.	14	1/6000	36.50	9.94	5.045	624	21.84	36.50	21.90	80.18	70.56	114.30
		1/5000	31.50	10.19	5.[illegible]	594	20.79	31.50	18.90	80.18	70.56	110.25
		1/4000	25.75	10.50	5.[illegible]	558	19.53	25.75	15.45	80.18	70.56	105.54
3.	15	1/12000	50.00	9.88	3.843	757	26.50	50.00	30.00	85.11	74.90	131.40
		1/9000	40.25	10.33	4.104	700	24.50	40.25	24.15	85.11	74.90	123.55
		1/8000	36.50	10.56	4.528	677	23.70	36.50	21.90	85.11	74.90	120.50
		1/7000	32.75	10.71	4.793	654	22.89	32.75	19.65	85.11	74.90	117.44
		1/6000	28.50	10.93	5.105	635	21.88	28.50	17.10	85.11	74.90	113.88
		1/5000	24.00	11.18	5.495	595	20.83	24.00	14.49	85.11	74.90	110.13
		1/4000	18.75	11.49	6.000	559	19.56	18.75	11.25	85.11	74.90	105.71
4.	16	1/12000	41.00	10.85	3.894	761	26.64	41.00	24.60	90.04	79.24	130.43
		1/11000	38.25	10.99	4.034	742	25.97	38.25	22.95	90.04	79.24	128.16
		1/10000	35.25	11.15	4.190	723	25.31	35.25	21.15	90.04	79.24	126.70
		1/9000	32.00	11.33	4.377	701	24.54	32.00	19.20	90.04	79.24	122.98
		1/8000	28.75	11.50	4.585	679	23.77	28.75	17.25	90.04	79.24	120.26

		1/7000	25.25	11.70	4.84	655	22.93	25.25	15.15	90.04	79.24	117.32
		1/6000	21.50	11.91	5.148	627	21.95	21.50	12.90	90.04	79.24	114.09
		1/5000	17.25	12.17	5.526	596	20.86	17.25	10.35	90.04	79.24	110.45
5.	17	1/12000	33.00	11.83	3.933	763	26.71	33.00	19.80	94.96	83.56	130.07
		1/11000	30.50	11.97	4.088	748	26.18	30.50	18.30	94.96	83.56	128.04
		1/10000	27.75	12.12	4.232	726	25.41	27.75	16.65	94.96	83.56	125.62
		1/9000	24.75	12.30	4.414	703	24.61	24.75	14.85	94.96	83.56	123.02
		1/8000	21.75	12.48	4.620	681	23.84	21.75	13.05	94.96	83.56	120.45
		1/7000	18.50	12.68	4.873	656	22.96	18.50	11.10	94.96	83.56	117.62
6.	18	1/12000	26.00	12.80	3.965	767	26.85	26.00	15.60	99.89	87.92	130.37
		1/11000	23.50	12.96	4.105	747	26.15	23.50	14.10	99.89	87.92	128.17
		1/10000	21.00	13.11	4.259	727	25.45	21.00	12.60	99.89	87.92	125.97

Note:- It is concluded from above table that

(i) 14' F.S.D. is most economical for bed slope of 1/4000;
(ii) 15' F.S.D. is most economical for bed slope range of 1/5000 to 1/6000;
(iii) 16' F.S.D. is most economical for the range of bed slope 1/7000 to 1/9000;
(iv) 17' F.S.D. is most economical for the range of bed slope 1/1000 to 1/12000;
(v) greatest economy is achieved when ground has a slope of 1/4000 and
(vi) most economical bed slope is 1/4000 with F.S.D. 14' giving a velocity of 5.955'/sec.

TABLE 3.7 (iv)

STATEMENT OF COST PER RFT. OF CANAL FOR 6,000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per rft. of canal						Total amount
	F.S.D.	Bed slope	Bed width	Balancing depth	Velocity ft./Sec.	Earthwork		Single tile lining		Double tile lining		
						Qty.	Amt.	Qty.	Amt.	Qty.	Amt.	
	(ft.)		(ft.)	(ft.)		Sft.	Rs.	Sft.	Rs.	Sft.	Rs.	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	15	1/12000	64.00	9.31	3.952	833	29.16	64.00	38.40	85.11	74.90	142.46
		1/7000	44.00	10.15	4.958	722	25.27	44.00	26.40	85.11	74.90	126.57
		1/6000	39.00	10.39	5.282	692	24.22	39.00	23.40	85. 11	74.90	122.52
		1/5000	33.50	10.67	5.690	657	23.00	33.50	20.10	85.11	74.90	1[illegible]8.00
2.	16	1/12000	54.00	10.26	4.016	839	29.37	54.00	32.40	90.04	79.[illegible]	141.00
		1/9000	43.50	10.74	4.586	776	27.16	43.50	26.10	[illegible]	[illegible]	[illegible]
		1/8000	39.50	10.93	4.749	750	26.25	39.50	23.70	90.04	79.24	129.19
		1/7000	35.25	11.15	5.017	723	25.31	35.25	21.15	90.04	79.24	125.70
		1/6000	31.00	11.37	5.341	694	24.29	31.00	18.60	90.04	79.24	122.13
		1/5000	26.00	11.65	5.[illegible]1	660	23.1[illegible]	26.00	15.60	90.04	79.24	1[illegible]7.9[illegible]
3.	17	1/12000	45.00	11.23	4.072	845	29.58	45.00	27.00	94.97	83.57	140.15
		1/11000	42.00	11.37	4.22	824	28.84	42.00	25.20	94.97	83.57	137.61
		1/10000	38.75	11.56	4.383	805	28.18	38.75	23.25	94.97	83.57	135.00
		1/9000	35.25	11.72	4.576	779	27.27	35.25	21.15	94.97	83.57	131.99
		1/8000	31.75	11.90	4.80	754	26.39	31.75	19.05	94.97	83.57	129.01

continued Table 32 (iv)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
		1/7000	28.00	12.11	5.062	728	25.48	28.00	16.80	94.97	83.57	125.85
		1/6000	23.75	12.37	5.382	696	24.36	23.75	14.25	94.97	83.57	122.18
		1/5000	19.25	12.64	5.787	661	23.14	19.25	11.55	94.97	83.57	118.26
4.	18	1/12000	36.50	12.22	4.112	845	29.58	36.50	21.90	99.90	87.91	139.39
		1/11000	34.00	12.36	4.257	827	28.95	34.00	20.40	99.90	87.91	137.26
		1/10000	31.25	12.50	4.42	807	28.25	31.25	18.75	99.90	87.91	134.91
		1/9000	28.00	12.69	4.609	782	27.37	28.00	16.80	99.90	87.91	132.08
		1/8000	24.75	12.88	4.835	757	26.50	24.75	14.85	99.90	87.91	129.26
		1/7000	21.25	13.09	5.096	730	25.55	21.28	12.75	99.90	87.91	126.21
		1/6000	17.50	13.33	5.40	699	24.47	17.50	10.50	99.90	87.91	122.88
		1/5000	13.00		5.789	Not practicable from construction						
5.	19	1/12000	29.50	13.18	4.14	851	29.79	29.50	17.70	104.83	92. 25	139.74
		1/11000	27.00	13.32	4.289	831	29.09	27.00	16.20	104.83	92.25	137.54
		1/10000	24.75	13.46	4.46	812	28.42	24.75	14.85	104.83	92.25	135.52

Note:- It is concluded from above table that -

(i) 16' F.S.D. is most economical for the range of bed slope from 1/5000 to 1/7000;
(ii) 17' F.S.D. is most economical for the range of bed slope 1/8000 to 1/9000;
(iii) 18' F.S.D. is most economical for the range of bed slope 1/10000 to 1/12000;
(iv) Greatest economy is achieved when ground has a slope of 1/5000; and
(v) most economical bed slope is 1/5000 with 16' F.S.D. giving a velocity of 5.751'/sec.

TABLE 3.7 (v)

STATEMENT OF COST PER RFT. OF CANAL FOR 7,000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per rft. of canal						Total amount (Rs.)
	F.S.D. (ft.)	Bed slope	Bed width (ft.)	Balancing depth (ft.)	Velocity ft./sec.	Earth work Qty. Cft.	Earth work Amt. Rs.	Single tile lining Qty. Cft.	Single tile lining Amt. Rs.	Double tile lining Qty. Cft.	Double tile lining Amt. Rs.	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	17	1/12000	57.00	10.68	4.176	919	32.17	57.00	34.20	94.97	83.57	149.94
		1/9000	45.76	11.18	4.71	850	29.75	45.75	27.45	94.37	83.57	140.77
		1/8000	41.50	11.40	4.94	821	28.74	41.50	24.90	94.37	83.57	137.21
		1/7000	37.25	11.62	5.216	793	27.76	37.25	22.35	94.37	83.57	133.68
		1/6000	32.50	11.87	5.539	761	26.64	32.50	19.50	94.37	83.57	129.71
2.	18	1/12000	48.00	11.64	4.232	924	32.34	48.00	28.80	99.90	87.92	149.06
		1/11000	44.50	11.81	4.382	901	31.54	44.50	26.70	99.90	87.92	146.16
		1/10000	41.25	11.98	4.55	879	30.77	41.25	24.75	99.90	87.92	143.44
		1/9000	37.50	12.17	4.7542	853	29.86	[illegible]	22.50	99.90	87.92	140.28
		1/8000	33.75	12.37	4.987	825	28.88	33.75	20.25	99.90	87.92	137.05
		1/7000	29.75	12.59	5.26	795	27.83	29.75	17.85	99.90	87.92	133.60
		1/6000	25.25	12.86	5.59	761	26.64	25.25	15.15	99.90	87.92	129.71
		1/5000	20.50		6.011							
3.	19	1/12000	39.50	12.62	4.269	927	32.45	39.50	23.70	104.83	92.25	148.40
		1/11000	36.50	12.79	4.421	905	31.68	36.50	21.90	104.83	92.25	145.83
		1/10000	33.50	12.95	4.592	881	30.84	33.50	20.10	104.83	92.25	143.19

continued Table 3.7 (v)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
		1/9000	30.[illegible]	13.13	4.793	857	30.00	30.25	18.15	104.83	92.25	140.40
		1/8000	26.50	13.36	5.022	827	28.95	26.50	15.90	104.83	92.25	137.10
		1/7000	23.00	13.57	5.294	798	27.93	23.00	13.80	104.83	92.25	133.98
		1/6000	18.75	13.84	5.628	763	26.71	18.75	11.25	104.83	92.25	130.21
4.	20	1/12000	32.50	13.57	4.304	933	32.66	32.50	19.50	109.75	96.58	148.74
		1/11000	29.25	13.77	4.454	908	31.78	29.25	17.55	109.75	96.58	145.91
		1/10000	26.50	13.93	4.622	884	30.94	[illegible].80	15.90	109.75	96.58	143.42

Note:- It is concluded from above table that -

(i) 18' F.S.D. is most economical for the range of bed slope from 1/6000 to 1/9000;
(ii) 19' F.S.D. is most economical for the range of bed slope from 1/10000 to 1/12000;
(iii) greatest economy is achieved when ground has a slope of 1/6000 and
(iv) most economical bed slope is 1/6000 with 17' [illegible].18' F.S.D. giving a velocity of 5.539'/Sec and 5.59' / Sec. respectively.

TABLE 3.7 (vi)

STATEMENT OF COST PER RFT. OF CANAL FOR 8,000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per rft. of canal						Total amount
	F.S.D.	Bed Slope	Bed width	Balancing depth	Velocity ft./sec.	Earth work		Single tile lining		Double tile lining		
	(ft.)		(ft.)	(ft.)		Qty. (Sft.)	Amt. (Rs.)	Qty. (Sft.)	Amt. (Rs.)	Qty. (Sft.)	Amt. (Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	18	1/12000	58.50	11.16	4.33	993	34.76	58.50	35.10	99.90	87.91	157.77
		1/8000	42.75	11.90	5.116	889	31.12	42.75	25.65	99.90	87.91	144.68
		1/7000	38.25	12.13	5.399	858	30.03	38.25	22.95	99.90	87.91	140.89
		1/6000	33.25	12.39	5.745	823	28.81	33.25	19.95	99.90	87.91	136.67
2.	19	1/12000	49.50	12.12	4.38	998	34.93	49.50	29.70	104.83	92.25	156.88
		1/11000	46.25	12.28	4.536	976	34.16	46.25	27.75	104.83	92.25	154.16
		1/10000	42.75	12.45	4.713	951	33.29	42.75	25.65	104.83	92.25	151.19
		1/9000	39.00	12.65	4.92	923	32.31	39.00	23.40	104.83	92.25	147.96
		1/8000	35.00	12.87	5.18	893	31.26	35.00	21.00	104.83	92.25	144.51
		1/7000	30.75	13.10	5.44	861	30.14	30.75	18.45	104.83	92.25	140.84
		1/6000	26.00	13.39	5.786	823	28.81	26.00	15.60	104.83	92.25	136.66
3.	20	1/12000	41.25	13.10	4.42	1003	35.11	41.25	24.75	109.75	96.58	156.44
		1/11000	38.25	13.25	4.575	979	34.27	38.25	22.95	109.75	96.58	153.80
		1/10000	35.00	13.44	4.748	954	33.39	35.00	21.00	109.75	96.58	150.97
		1/9000	31.50	13.64	4.956	926	32.41	31.50	18.90	109.75	96.58	147.89

continued Table 3.7 (vi)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
		1/8000	28.00	13.84	5.196	897	31. 40	28.00	16.80	109.75	96.58	144.78
		1/7000	24.00	14.08	5.475	863	30.21	24.00	14.40	109.75	96.58	141.19
		1/6000	19.75	14.35	5.816	827	28.95	19.75	11.85	109.75	96.58	137.38
4.	21	1/12000	34.00	14.05	4.444	1008	35.28	34.00	20.40	114.68	100.92	156.60
		1/11000	31.00	14.23	4.604	982	34.37	31.00	18.60	114.68	100.92	153.89
		1/10000	28.25	14.39	4.781	960	33.60	28.25	16.95	114.68	100.92	151.47
		1/9000	24.75	14.61	4.982	929	32.52	24.25	14.55	114.68	100.92	147.99

Note:- It is concluded from above curve that -

(i) 19' F.S.D. is most economical for the range of bed slope from 1/7000 to 1/8000;
(ii) 20' F.S.D. is most economical for the range of bed slope from 1/9000 to 1/12000;
(iii) greatest economy is achieved when ground has a slope of 1/6000 and
(iv) most economical bed slope is 1/6000 with 19' F.S.D. giving a velocity of 5.786'/Sec.

TABLE 3.7 (vii)

STATEMENT OF COST PER RFT. OF CANAL FOR 9000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per rft. of canal						Total amount
	P.S.D.	Bed Slope	Bed width	Balancing depth	Velocity ft./Sec.	Earth work		Single tile lining		Double tile lining		
						Qty.	Amt.	Qty.	Amt.	Qty.	Amt.	
	(ft.)		(ft.)	(ft.)		(Cft.)	(Rs.)	(Sft.)	(Rs.)	(Sft.)	(Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	19	1/12000	59.50	11.66	4.456	1066	37.31	59.50	35.70	104.83	92.75	165.26
		1/9000	47.50	12.22	5.027	985	34.48	47.50	28.50	104.83	92.75	155.73
		1/8000	43.25	12.44	5.284	952	33.32	43.25	25.95	104.83	92.75	152.02
		1/7000	38.50	12.68	5.576	919	32.17	38.50	23.10	104.83	92.75	148.02
		1/6000	33.25	12.97	5.924	879	30.77	33.25	19.95	104.83	92.75	143.47
2.	20	1/12000	50.50	12.65	4.514	1074	37.59	50.50	30.30	109.75	96.58	164.47
		1/11000	47.00	12.79	4.677	1048	36.68	47.00	28.20	109.75	96.58	161.47
		1/10000	43.50	12.98	4.859	1020	35.70	43.50	26.10	109.75	96.58	157.38
		1/9000	39.50	13.18	5.071	989	34.62	39.50	23.70	109.75	96.58	154.90
		1/8000	35.50	13.40	5.[illegible]2	958	33.53	35.50	21.30	109.75	96.5[illegible]	151.41
		1/7000	31.00	13.67	5.606	922	32.27	31.00	18.60	109.75	[illegible]	14[illegible].45
		1/6000	26.25	13.94	5.961	882	30.87	26.25	15.75	109.75	96.58	143.20
3.	21	1/12000	42.50	13.59	4. 552	1077	37.70	42.50	25.50	114.68	100.92	164.12
		1/11000	39.25	13.76	4.71	1050	36.75	39.25	23.65	114.68	100.92	161.22

continued Table 3.7 (vii)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
		1/10000	36.00	13.84	4.895	1024	35.84	36.00	21.68	114.68	100.92	$158.36
		1/9000	32.25	14.16	5.105	993	34.75	32.25	19.35	114.68	100.92	155.02
		1/8000	28.50	14.38	5.351	961	33.64	28.50	17.10	114.68	100.92	$151.66
		1/7000	24.50	14.62	5.642	927	32.45	24.50	14.70	114.68	100.92	148.07
		1/6000	20.00	14.91	5.994	887	31.05	20.00	12.00	114.68	100.92	143.97
4.	22	1/12000	35.50	14.53	4.584	1084	37.94	35.50	21.30	119.61	105.25	164.49
		1/11000	32.25	14.72	4.744	1056	36.96	32.25	19.35	119.61	105.25	161.56
		1/10000	29.00	14.92	4.92	1029	36.08	29.00	17.40	119.61	105.25	158.67

Note:- It is concluded from above table that -

(i) 20' F.S.D. is most economical for the range of bed slope 1/6000 to 1/9000;
(ii) 21' F.S.D. is most economic for the range of bed slope 1/10000 to 1/12000;
(iii) greatest economy is achieved when ground has a slope of 1/6000 and
(iv) most economical bed slope is 1/6000 with 20' F.S.D. giving a velocity of 5.961'/sec.

TABLE 3.7 (viii)

STATEMENT OF COST PER RFT. OF CANAL FOR 10000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per Rft. of canal						Total amount
	F.S.D.	Bed slope	Bed width	Balancing depth	Velocity ft./Sec.	Earth work		Single tile lining		Double tile lining		
						Qty.	Amt.	Qty.	Amt.	Qty.	Amt.	
	(ft.)		(ft.)	(ft.)		(Cft.)	(Rs.)	(Sft.)	(Rs.)	(Sft.)	(Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	19=	1/7000	45.00	12.29	5.678	974	34.09	46.00	27.60	104.83	92.25	153.94
2.	20	1/12000	60.00	12.18	4.60	1038	39.83	60.00	36.00	109.75	96.58	172.41
		1/9000	47.50	12.77	5.174	1050	36.75	47.50	28.50	109.75	96.58	161.83
		1/8000	43.00	13.00	5.43	1016	35.56	43.00	25.80	109.75	96.58	157.94
		1/7000	38.25	13.25	5.723	979	34.27	38.25	22.95	109.75	96.58	153.80
3.	21	1/12000	51.00	13.16	4.638	1143	40.00	51.00	30.60	114.68	100.92	171.52
		1/11000	47.50	13.33	4.81	1116	39.06	47.50	28.50	114.68	100.92	168.48
		1/10000	43.75	13.51	4.991	1087	38.05	43.75	26.25	114.68	100.92	165.22
		1/9000	39.75	13.74	5.218	1055	36.93	39.75	23.85	114.68	100.92	161.70
		1/8000	35.50	13.97	5.469	1020	35.70	35.50	21.30	114.68	100.92	157.92
		1/7000	31.00	14.23	5.765	982	34.37	31.00	18.60	114.68	100.92	153.89
		1/6000	26.00		6.124							
4.	22	1/12000	43.25	14.11	4.674	1150	40.25	43.25	25.95	119.61	105.25	171.45

continued Table 3.7 (viii)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
		1/11000	39.75	14.29	4.842	1120	39.20	39.75	23.85	119.61	105.25	168.30
		1/10000	36.25	14.[illegible]	5.026	1090	38.15	36.25	21.75	119.61	105.25	165.15
		1/9000	32.50	14.71	5.25	1058	37.03	32.50	19.50	119.61	105.25	161.78
		1/8000	28.50	14.95	5.499	1023	35.81	28.50	17.10	119.61	105.25	158.16
		1/7000	24.25	15.22	5.797	988	34.58	24.25	14.55	119.61	105.25	154.38
5.	23	1/12000	36.00	15.07	4.708	1155	40.[illegible]	36.00	21.60	124.53	109.59	171.62
		1/11000	32.75	15.26	4.874	1125	39.38	32.75	19.65	124.53	109.59	168.62
		1/10000	29.50	15.4[illegible]	5.0[illegible]	1096	38.36	29.50	17.70	124.53	109.59	165.65

Note:- It is concluded from the above table that -

(i) 20' F.S.D. is most economical for bed slope of 1/7000;
(ii) 21' F.S.D. is most economical for the range of bed slope 1/8000 and 1/9000;
(iii) 22' F.S.D. is most economical for the range of bed slope 1/10000 to 1/12000;
(iv) greatest economy is achieved when ground has a slope of 1/7000 and
(v) most economical bed slope is 1/7000 with 20' F.S.D. giving a velocity of 5.723'/Sec.

TABLE 3.7 (ix)

STATEMENT OF COST PER RFT. OF CANAL FOR 12000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per rft. of canal						Total amount
	F.S.D.	Bed slope	Bed width	Balancing depth	Velocity ft./sec.	Earth work		Single tile lining		Double tile lining		
						Qty.	Amt.	Qty.	Amt.	Qty.	Amt.	
	(ft.)		(ft.)	(ft.)		(Cft.)	(Rs.)	(Sft.)	(Rs.)	(Sft.)	(Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	22	1/12000	58.75	13.32	4.84	1271	44.49	58.75	36.25	119.61	105.25	184.99
		1/11000	54.75	13.51	5.016	1240	43.40	54.75	32.85	119.61	105.25	181.50
		1/10000	50.50	13.72	5.209	12072	42.25	50.50	30.30	119.61	105.25	177.80
		1/9000	46.25	13.94	5.439	1174	41.09	46.25	27.75	119.61	105.25	174.09
		1/8000	41.50	14.20	5.707	1135	39.73	41.50	24.90	119.61	105.25	169.88
		1/7000	36.50		6.014							
2.	23	1/12000	50.50	14.27	4.874	1278	44.73	50.50	30.30	124.53	109.59	184.62
		1/11000	46.75	14.47	5.053	1246	43.61	46.75	28.05	124.53	109.59	181.26
		1/10000	43.00	14.72	5.249	1207	42.25	43.00	25.80	124.53	109.59	177.64
		1/9000	38.75	14.90	5.48	1178	41.23	38.75	23.25	124.53	109.59	174.07
		1/8000	34.25	15.17	5.746	1139	39.87	34.25	20.55	124.53	109.59	170.01
3.	24	1/12000	43.00	15.22	4.897	1286	45.01	43.00	25.80	129.46	113.92	184.73
		1/11000	39.25	15.44	5.086	1251	43.79	39.25	23.55	129.46	113.92	181.26
		1/10000	35.75	15.64	5.273	1220	42.70	35.75	21.45	129.46	113.92	178.07

continued Table 3.7 (ix)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
		1/9000	31.75	15.88	5.495	118[illegible]	41.37	31.75	19.05	129.46	113.92	174.34
		1/8000	27.75	16.13	5.763	1144	40.04	27.75	16.65	129.46	113.92	170.61

Note:- It is concluded from above table that -

(i) 23' F.S.D. is most economical for the range of bed slope 1/8000 to 1/12000;
(ii) most economical bed slope is 1/8000 with 23' F.S.D. giving a velocity of 5.746'/Sec. and
(iii) greatest economy is achieved when ground has a slope of 1/8000.

TABLE 3.7 (x)

STATEMENT OF COST PER RFT. OF CANAL FOR 14000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per rft. of canal						Total amount
	F.S.D.	Bed slope	Bed width	Balancing depth	Velocity ft./sec.	Earthwork		Single tile lining		Double tile lining		
						Qty.	Amt.	Qty.	Amt.	Qty.	Amt.	
	(ft.)		(ft.)	(ft.)		(Cft.)	(Rs.)	(Sft.)	(Rs.)	(Sft.)	(Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	23	1/12000	65.00	13.57	5.016	1392	48.72	65.00	39.00	124.53	109.59	197.31
		1/11000	60.50	13.78	5.199	1357	47.50	60.50	36.30	124.53	109.59	193.39
		1/10000	56.25	13.98	5.404	1324	46.34	56.25	33.75	124.53	109.59	189.68
		1/9000	51.50	14.22	5.643	1286	45.01	51.50	30.90	124.53	109.59	185.60
		1/8000	46.50	14.48	5.920	1250	43.75	46.50	27.90	124.53	109.59	181.24
2.	24	1/12000	56.5	14.52	5.054	1400	49.00	56.50	33.90	129.46	113.92	196.82
		1/11000	52.25	14.73	5.259	1365	47.78	52.25	31.35	129.46	113.92	193.05
		1/10000	48.25	14.94	5.442	1330	46.55	48.25	28.95	129.46	113.92	189.42
		1/9000	43.75	15.19	5.677	1292	45.22	43.75	26.25	129.46	113.92	185.39
		1/8000	39.00	15.45	5.955	1249	43.72	39.00	23.40	129.46	113.92	181.04
3.	25	1/12000	48.50	15.48	5.084	1406	49.21	48.50	29.10	134.38	118.25	196.56
		1/11000	44.75	15.68	5.27	1373	48.06	44.75	26.85	134.38	118.25	193.16
		1/10000	41.00	15.90	5.474	1338	46.83	41.00	24.60	134.38	118.25	189.68

continued Table 3.7 (x)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
		1/9000	36.75	16.13	5.71	1300	45.50	36.75	22.05	134.33	118.25	185.80
		1/8000	32.00	16.43	5.982	1253	43.86	32.00	19.20	134.33	118.25	181.31

Note:- It is concluded from above table that -

(i) 24' F.S.D. is most economical for the range of bed slope 1/8000 to 1/12000;
(ii) 25' F.S.D. is most economical for the bed slope of 1/12000;
(iii) most economical bed slope is 1/8000 with 24' F.S.D. giving a velocity of 5.955'/Sec. and
(iv) greatest economy is achieved when ground has a bed slope of 1/8000.

TABLE 3.7 (xi)

STATEMENT OF COST PER RFT. OF CANAL FOR 6000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per rft. of canal						Total amount
	F.S.D. (ft.)	Bed slope	Bed width (ft.)	Balancing depth (ft.)	Velocity ft./sec.	Earth work Qty. (Cft.)	Earth work Amt. (Rs.)	Single tile lining Qty. (Sft.)	Single tile lining Amt. (Rs.)	Double tile lining Qty. (Sft.)	Double tile lining Amt. (Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	25	1/12000	61.25	14.73	5.214	1516	53.06	61.25	36.75	134.38	118.25	208.06
		1/11000	56.75	15.05	5.403	1478	51.73	56.75	34.05	134.38	118.25	204.03
		1/10000	52.00	15.29	5.611	1437	50.30	52.00	31.20	134.38	118.25	199.75
		1/9000	47.50	15.54	5.867	1397	48.90	47.50	28.50	134.38	118.25	195.65
2.	26	1/12000	53.25	15.77	5.254	1531	53.59	53.25	31.95	139.31	122.59	208.13
		1/11000	49.00	16.01	5.443	1490	52.15	49.00	29.40	139.31	122.59	204.14
		1/10000	44.50	16.25	5.639	1450	50.75	44.50	26.70	139.31	122.59	200.04
		1/9000	40.50	16.47	5.897	1406	49.21	40.50	24.30	139.31	122.59	196.10
3.	27	1/12000	45.75	16.73	5.278	1532	58.62	45.75	27.45	144.24	126.93	208.00
		1/11000	42.00	16.95	5.471	1494	52.99	42.00	25.20	144.24	126.93	204.42
		1/10000	37.50	17.22	5.671	1450	50.75	37.50	22.50	144.24	126.93	200.38
		1/9000	33.50	17.46	5.921	1409	49.31	33.50	20.10	144.24	126.93	196.34
4.	28	1/12000	38.75	17.70	5.304	1538	53.83	38.75	23.25	149.17	131.27	208.35
		1/11000	35.00	17.92	5.[illegible]	1499	52.47	35.00	21.00	149.17	131.27	204.74

continued Table 3.7 (xi)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
		1/10000	31.00	18.18	5.694	1456	50.96	31.00	18.60	149.17	131.27	200.83
		1/9000	27.25	18.42	5.940	1416	49.56	27.25	16.35	149.17	131.27	197.18
5.	24	1/12000	69.75	13.89	5.178	1506	52.68	69.75	41.85	129.46	113.92	208.45
		1/11000	65.25	14.10	5.368	1471	51.49	65.25	39.15	129.46	113.92	204.56
		1/10000	60.00	14.35	5.572	1429	50.02	[illegible].00	[illegible]00	129.46	113.92	199.94
		1/9000	55.50	14.57	5.818	1392	48.72	55.50	33.30	129.46	113.92	195.94

Note:- It is concluded from above table that -

(i) 25' F.S.D. is most economical for the range of bed slope 1/9000 to 1/12000;
(ii) most economical bed slope is 1/9000 with F.S.D. 25' giving a velocity of 5.867'/Sec. and
(iii) greatest economy is achieved when ground has a bed slope of 1/9000.

TABLE 3.7 (xii)

STATEMENT OF COST PER RFT. OF CANAL FOR 18000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per rft. of canal						Total amount.
	F.S.D.	Bed slope	Bed width	Balancing depth	Velocity ft./Sec.	Earth work		Single tile lining		Double tile lining		
						Qty.	Amt.	Qty.	Amt.	Qty.	Amt.	
	(ft.)		(ft.)	(ft.)		(Cft.)	(Rs.)	(Sft.)	(Rs.)	(Sft.)	(Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	25	1/12000	73.75	14.25	5.326	1618	56.63	73.75	44.25	134.38	118.25	219.13
		1/11000	69.00	14.45	5.520	1580	55.30	69.00	41.40	134.38	118.25	214.95
		1/10000	64.00	14.69	5.739	1538	53.83	64.00	38.40	134.38	118.25	210.48
		1/9000	58.50	14.97	5.993	1493	52.26	58.50	35.10	134.38	118.25	205.61
2.	26	1/12000	65.00	15.18	5.368	1627	56.95	65.00	39.00	139.31	122.59	218.54
		1/11000	60.50	15.43	5.562	1583	55.41	60.00	36.00	139.31	122.59	214.30
		1/10000	56.00	15.63	5.782	1549	54.22	56.00	33.60	139.31	122.59	210.41
		1/9000	50.75	15.91	6.032	1501	52.54	50.75	30.45	139.31	122.59	205.68
3.	27	1/12000	57.00	16.09	5.402	1640	57.40	57.00	34.20	144.24	126.93	218.53
		1/11000	52.50	16.36	5.597	1596	55.86	52.50	31.50	144.24	126.93	214.29
		1/10000	48.00	16.61	5.821	1552	54.32	48.00	28.80	144.24	126.93	210.05
4.	28	1/12000	49.50	17.07	5.437	1645	57.58	49.50	29.70	149.17	131.27	218.55

continued Table 3.7 (xii)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
	[illegible]	1/11000	45.50	17.30	5.629	1606	56.21	45.50	27.30	149.17	131.27	214.78
		1/10000	41.25	17.56	5.839	1560	54.60	41.25	24.75	149.17	131.27	210.62

Note:- It is concluded from above table that -

(i) 28' F.S.D. is most economical for the range of bed slope from 1/10000 to 1/12000;
(ii) most economical bed slope is 1/9000 with 26' F.S.D. giving a velocity of about 6'/Sec. and
(iii) greatest economy is achieved when ground has a slope of 1/9000.

TABLE 3.7 (xiii)

STATEMENT OF COST PER RFT. OF CANAL FOR 20,000 CUSECS DISCHARGE (BALANCING DEPTH)

S.No.	Canal dimensions					Cost per rft. of canal						Total amount
	F.S.D.	Bed slope	Bed width	Balancing depth	Velocity ft./Sec.	Earth work		Single tile lining		Double tile lining		
	(ft.)		(ft.)	(ft.)		Qty. (Cft.)	Amt. (Rs.)	Qty. (Sft.)	Amt. (Rs.)	Qty. (Sft.)	Amt. (Rs.)	(Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	26	1/12000	76.50	14.65	5.43	1722	60.27	76.50	45.90	139.31	122.59	228.76
		1/11000	71.50	14.87	5.671	1681	58.84	71.50	42.90	139.31	122.59	224.33
		1/10000	66.75	15.10	5.895	1641	57.44	66.75	40.05	139.31	122.59	220.08
2.	25	1/12000	86.00	13.71	5.421	1710	59.85	86.00	51.60	134.38	118.25	229.70
		1/11000	81.00	13.92	5.628	1673	58.56	81.00	48.60	134.38	118.25	225.41
		1/10000	75.50	14.16	5.848	1631	57.09	75.50	45.30	134.38	118.25	220.64
3.	27	1/12000	68.00	15.58	5.51	1735	60.73	68.00	40.80	144.24	126.93	228.45
		1/11000	63.25	15.81	5.708	1693	59.26	63.25	37.95	144.24	126.98	224.14
		1/10000	58.25	16.06	5.929	1648	57.68	58.25	34.95	144.24	126.93	219.56
4.	28	1/12000	60.00	16.52	5.545	1746	61.11	60.00	36.00	149.17	131.27	228.38
		1/11000	55.50	16.73	5.746	1701	59.54	55.50	33.30	149.17	131.27	224.11
		1/10000	50.50	17.02	5.97	1655	57.93	50.50	30.30	149.17	131.27	219.50

continued Table 3.7 (xiii)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
5.	29	1/12000	52.50	17.47	5.576	1757	61.50	52.50	32.50	154.09	135.60	228.60
		1/11000	48.00	17.71	5.773	1710	59.85	48.00	28.80	154.09	135.60	224.25

Note:- It is concluded from above table that -

(i) 28' F.S.D. is most economical for the range of bed slope 1/10000 to 1/12000;
(ii) most economical bed slope is 1/10000 with 28' F.S.D. giving a velocity of 5.97'/Sec. and
(iii) greatest economy is achieved when ground has a slope of 1/10000.

separate table prepared which is attached as table No. 3.8. This table shows most economical bed slope and corresponding F.S.D. for each discharge. In addition canal dimensions such as bed width and velocity, (F.S.L.-N.S.L.) giving minimum cost corresponding to most economical bed slope and F.S.D. and cost per rft. are also given in this table.

These results are plotted as most economical bed slope, most economical F.S.D., cost per rft. of canal and (F.S.L.-N.S.L.) against discharge and four curves obtained which are shown in figure 3.9.

It is possible to find out the most economical bed slope and full supply depth for a given discharge by using the curves given in figure 3.9

The use of curves can be explained by the following example.

EXAMPLE:-

Let Discharge Q = 11,000 cusecs.

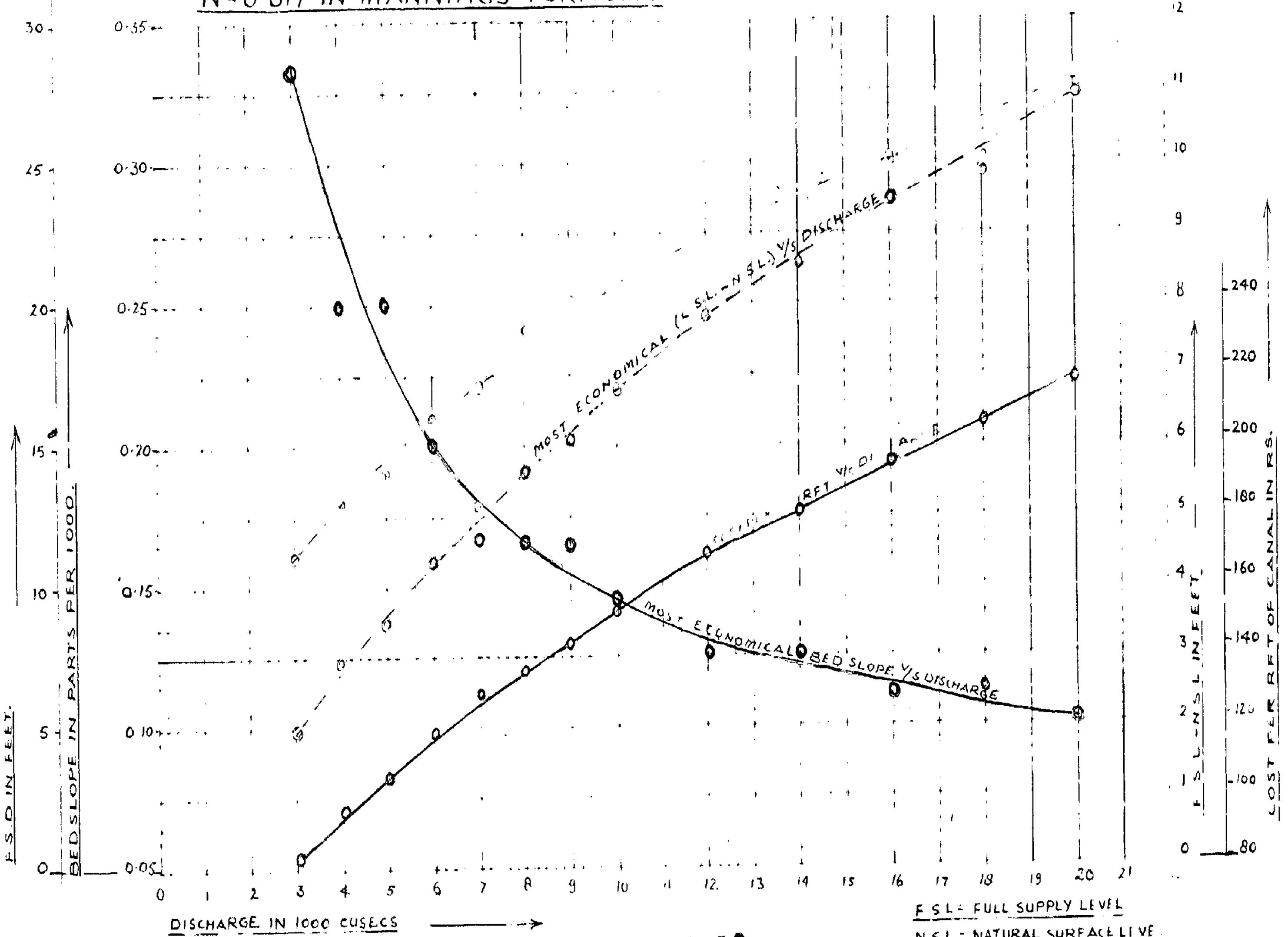
The most economical bed slope can be obtained by reading ordinate corresponding to discharge point on most economical bed slope line. The most economical bed slope corresponding to a discharge of 11,000 cusecs as read from the curves is 0.137 per 1,000 parts or 1 in 7,300 and most economical full supply depth is 21.80 ft. as read from most economical F.S.D. curve. The cost per rft. and (F.S.L.-N.S.L.) giving minimum cost are also determined by reading their value against 11,000 cusecs discharge. The cost per rft. as read is Rs. 162/- and value of (F.S.L.-N.S.L.) . for least cost is 7.3 ft.

TABLE 3.8

STATEMENT SHOWING MOST ECONOMICAL BED SLOPE AND CORRESPONDING F.S.D. FOR DIFFERENT DISCHARGES (BALANCING DEPTH)

S.No.	Discharge (cusecs)	Canal dimensions: Most economical Bed slope	Canal dimensions: F.S.D. (ft.)	Canal dimensions: Bed width (ft.)	Canal dimensions: Velocity (ft./Sec.)	Canal dimensions: Balancing depth (ft.)	F.S.L. - N.S.L. (ft.)	Cost per rft. of Canal (Rs.)
1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	3,000	1/3,000	11	20.00	5.844	9.02	1.98	83.12
2.	4,000	1/4,000	13	22.75	5.835	10.07	2.93	97.09
3.	5,000	1/4,000	14	25.75	5.955	10.50	3.50	10 .54
4.	6,000	1/5,000	16	26.00	5.781	11.65	4.35	117.94
5.	7,000	1/6,000	17	32.50	5.539	11.87	5.13	129.71
6.	8,000	1/6,000	19	26.00	5.786	13.39	5.61	136.66
7.	9,000	1/6,000	20	26.25	5.961	13.94	6.06	143.29
8.	10,000	1/7,000	20	28.25	5.723	13.25	6.75	153.80
9.	12,000	1/8,000	23	34.25	5.746	15.17	7.83	170.01
10.	14,000	1/8,000	24	39.00	5.955	15.45	8.55	181.04
11.	16,000	1/9,000	25	47.50	5.867	15.54	9.46	195.65
12.	18,000	1/9,000	25	58.50	5.993	14.97	10.03	205.61
13.	20,000	1/10,000	28	50.50	5. 97	17.02	10.98	219.50

DIAGRAM SHOWING MOST ECONOMICAL BED SLOPE CORRESPONDING FULL SUPPLY DEPTH, F.S.L.-N.S.L. AND COST PER RFT OF CANAL V/s DISCHARGE FOR TRAPEZOIDAL LINED CHANNELS WITH 2 TO 1 SIDE SLOPE AND N=0.017 IN MANNING'S FORMULA.



F.S.L.= FULL SUPPLY LEVEL
N.S.L.= NATURAL SURFACE LEVEL
F.S.D.= FULL SUPPLY DEPTH

FIG 3.9

S.NO	DISCHARGE (CUSECS)	CANAL DIMENSIONS MOST ECONOMICAL BED SLOPE	F.S.D. (FT.)	F.S.L.-N.S.L. (FT.)	COST PER RFT OF CANAL (RS.)
1	2	3	4	5	6
1	3,000	1/5,000	11	1.98	83.17
2	4,000	1/4,000	12	2.93	97.09
3	5,000	1/4,000	14	3.50	105.54
4	6,000	1/5,000	16	4.35	117.54
5	7,000	1/6,000	17	5.13	129.71
6	8,000	1/6,000	19	5.61	136.66
7	9,000	1/6,000	20	6.06	143.20
8	10,000	1/7,000	20	6.75	153.80
9	12,000	1/8,000	23	7.83	170.01
10	14,000	1/8,000	24	8.55	181.04
11	16,000	1/9,000	25	9.46	195.65
12	18,000	1/9,000	25	10.03	205.61
13	20,000	1/10,000	28	10.98	219.50

In this way the most economical bed slope and corresponding economical F.S.D. and (F.S.L.-N.S.L.) can be obtained for any discharge ranging between 3,000 to 20,000 cusecs.

It is realised that it is not possible to lay an alignment such that balancing depth of cutting is available at all sections, nor can the bed slope be adopted from considerations of cost alone. In some cases flatter slopes than economical one have to be adopted in order to have maximum command, which is purposely done in case of Rajasthan Canal Project. While in other cases steeper bed slopes than economic have to be used due to the nature of the topography of the area in which the canal is aligned. In the present study the influence of adopting slopes flatter or steeper than the economical slope on costs has not been worked out.

3.11 The curves given in figure 3.8 and 3.9 would be found useful for obtaining the most economical full supply depth corresponding to any discharge. The curves given in figure 3.7 (B) (i) to (xiii) are useful in choosing between two or more alternative alignments passing having different average depths of cutting or filling. With the aid of diagrams given in figure 3.7 (B) (i) to figure 3.7 (B) (xiii) one can even work out the likely difference in costs, for the different proposals.

CHAPTER IV

CONCLUSIONS AND LIMITATIONS

4.1 GENERAL

As discussed in chapter I canal lining offers undisputed advantages. The heavy cost of lining is, however, a major obstacle in the path of its wider adoption. The present study was aimed at determining the most economical design for lined canals from 3,000 to 20,000 cusecs capacity, with special reference to Rajasthan Canal.

These studies need revision when unit rates of items of earth work and lining are expected to vary. Whenever there is any change in the type of lining, the revision of studies is also essential. The studies are based on a trapezoidal section with rounded corners and the side slopes have been maintained 2:1 in all cases.

On basis of the work done, it would be possible to choose alignment, sections and slopes for minimum cost as shown below:-

(1) As far as possible, the Survey Engineer should try to align this canal to have depths of cutting as shown in table (3.6) and figure (3.8) for various discharges. These values are, however, applicable to the slope of 1/12,000 only.

(2) It is possible to choose a most economical slope from table 3.8 and figure 3.9 for a given discharge. For each such slope there is a different balanced depth of cutting. As an example if one has to align a canal carrying a discharge of 10,000 cusecs, then from table 3.8 and figure 3.9 the most economical bed slope is 1 in 7,000. Corresp

ponding (F.S.L.-N.S.L.) giving minimum cost is 6.75 ft.. One should so align the canal that as far as possible the depth of cutting is 6.75 ft.

(3) The curves shown in figure 3.7 (A) (i) to figure 3.7 (A) (xiii) and figure 3.7 (B) (i) to figure 3.7 (B) (xiii) can also be of help to the engineer in choosing between two or more alternative alignments, viz. he can judge whether an alignment having one (F.S.L.-N.S.L.) value is more economical than an alternative alignment having an-other (F.S.L.-N.S.L.) value. As an example for 8,000 cusecs, the alignment passing through with (F.S.L.-N.S.L.) value of (10') is more economical than an alternative alignment passing through ground with (F.S.L.-N.S.L.) value of (-15').

(4) With the aid of such F.S.D. and (F.S.L.-N.S.L.) curves, one can even work out the likely difference in cost between two or more alternative alignments.

Statements of comparative costs for the discharge range of 3,000 to 20,000 are given in table 3.9 (i) to (xiii).

Column No. 3 of these tables shows a comparision of cost of the canal with most economical F.S.D. correspon-ding to each discharge for various values of (F.S.L.-N.S.L.). Column No. 4 of same tables show the percentage increase in the cost of canal per rft. due to variation in values of (F.S.L.-N.S.L.) from the most economical.

As an example for 8,000 cusecs column No. 3 of table 3.9 (vi) shows the cost of canal per rft. with F.S.D. 20 ft. for various values of (F.S.L.-N.S.L.) ranging from

TABLE 3.9 (1)

STATEMENT OF COMPARATIVE COSTS (3,000 CUSECS)

S.No.	Value of (F.S.L. - N.S.L.) (ft.)	Cost per rft. of canal with 14' F.S.D. (ft.)	% increase in cost of canal due to variation of (F.S.L. - N.S.L.) from 3.59'
1.	2.	3.	4.
a	3	108.69	1.57
b	3.59	107.01	-
c	4	108.66	1.54
d	5	118.00	5.60
e	6	117.65	9.94

TABLE 3.9 (ii)

STATEMENT OF COMPARATIVE COSTS (4,000 CUSECS)

S.No.	Value of (F.S.L. - N.S.L.) (ft.)	Cost per rft. of canal with 16' F.S.D. (Rs.)	% increase in cost of canal due to variation of (F.S.L. - N.S.L.) from 4.45'
1.	2.	3.	4.
a	4	120.81	1.17
b	4.45	119.41	-
c	5	121.83	2.03
d	6	126.48	5.92
e	7	131.42	10.06

TABLE 3.9 (iii)

STATEMENT OF COMPARATIVE COSTS (5,000 CUSECS)

S.No.	Value of F.S.L. - N.S.L. (ft.)	Cost per rft. of canal with 17' F.S.D. (Rs.)	% increase in cost of canal due to variation of (F.S.L. - N.S.L.) from 5.17'	
1.	2.	3.	4.	5.
a	4	133.88	2.93	
b	5	130.70	0.48	
c	5.17	130.07	-	
d	6	133.95	2.98	
e	7	138.89	6.78	

TABLE 3.9 (iv)

STATEMENT OF COMPARATIVE COSTS(6,000 CUSECS)

S.No.	Value of F.S.L. - N.S.L. (ft.)	Cost per rft. of canal with 10' F.S.D. (Rs.)	% increase in cost of canal due to variation of F.S.L. - N.S.L. from 5.70'
1.	2.	3.	4.
a	4	144.88	3.94
b	5	142. 12	1.97
c	5.70	139.59	-
d	6	140.33	0.67
e	7	145.34	4.26
f	8	150.55	8.01

TABLE 3.9 (v)

STATEMENT OF COMPARATIVE COSTS (7,000 CUSECS)

S.No.	Value of F.S.L. - N.S.L. (ft.)	Cost per rft. of canal with 19' F.S.D. (Rs.)	[illegible]% increase in cost of canal due to variation of F.S.L. - N.S.L. from 6.38'
1.	2.	3.	4.
a	4	157.18	5.92
b	5	153.44	3.39
c	6	149.87	0.99
d	6.38	148.40	-
e	7	151.48	2.08
f	8	156.69	5.59

TABLE 3.9 (vi)

STATEMENT OF COMPARATIVE COSTS (8,000 CUSECS)

S.No.	Value of F.S.L. - N.S.L. (ft.)	Cost per rft. of canal with 30' F.S.D. (Rs.)	% increase in cost of canal due to variation of F.S.L. - N.S.L. from 6.9'
a	4	167.57	6.97
b	5	163.72	4.65
c	6	159.90	2.25
d	6.9	156.44	-
e	7	156.86	0.27
f	8	162.07	3.60

TABLE 3.9 (vii)

STATEMENT OF COMPARATIVE COSTS (9,000 CUSECS)

S.No.	Value of (F.S.L. - N.S.L.) (ft.)	Cost per rft. of canal with 20' F.S.D. (Rs.)	% Increase in cost of canal due to variation of (F.S.L. - N.S.L.) from 7.41'
1.	2.	3.	4.
a	4	177.87	8.38
b	5	173.71	5.85
c	6	169.72	3.41
d	7	165.83	1.04
e	7.41	164.12	-
f	8	167.16	1.85

TABLE 3.9 (viii)

STATEMENT OF COMPARATIVE COSTS (10,000 CUSECS)

S.No.	Value of (F.S.L. - N.S.L.) (ft.)	Cost per rft. of canal with 22' F.S.D. (Rs.)	% Increase in cost of canal due to variation of (F.S.L. - N.S.L.) from 7.89'
1.	2.	3.	4.
a	5	183.39	6.[illegible]
b	6	179.19	4.51
c	7	175.13	2.15
d	7.89	171.45	-
e	8	171.94	0.28
f	9	177.44	3.49

TABLE 3.9 (ix)

STATEMENT OF COMPARATIVE COSTS (12,000 CUSECS)

S.No.	Value of F.S.L. - M.S.L. (ft.)	Cost per rft. of canal (Rs.) With F.S.D. 23'	Cost per rft. of canal (Rs.) With F.S.D. 24'	% increase in cost of canal due to variation of (F.S.L. - N.S.L.) from 8.73' with F.S.D. 23'	% increase in cost of canal due to variation of (F.S.L. - N.S.L.) from 8.78' with F.S.D. 24'
1.	2	3a	3b	4a	4b
a	7	192.18	192.29	4.04	4.04
b	8	187.88	188.09	1.77	1.82
c1	8.73	184.62	-	-	-
c2	8.78	-	184.73	-	-
d	9	186.12	185.96	0.81	0.66
e	10	191.90	192.73	3.94	3.79
f	11	197.96	197.79	7.22	7.07
g	12	204.29	204.12	10.65	10.50

TABLE 3.9 (x)

STATEMENT OF COMPARATIVE COSTS (14,000 CUSECS)

S.No.	Value of F.S.L. - N.S.L. (ft.)	Cost per rft. of canal with F.S.D. 25' (Rs.)	% Increase in cost of canal due to variation of (F.S.L. - N.S.L.) from 9.52'
1.	2.	3.	4.
a	7	208.04	5.84
b	8	203.49	3.53
c	9	199.08	1.29
d	9.52	196.56	-
e	10	199.36	1.40
f	11	205.42	4.51

TABLE 3.9 (xi)

STATEMENT OF COMPARATIVE COSTS (16,000 CUSECS)

S.No.	Value of F.S.L. - N.S.L. (ft.)	Cost per rft. of canal Rs. With F.S.D. 26'	Cost per rft. of canal Rs. With F.S.D. 27'	% Increase in cost of canal due to variation of (F.S.L.-N.S.L.) from 10.23' with F.S.D. 26'	% Increase in cost of canal due to variation of (F.S.L.-N.S.L.) from 10.27' with F.S.D. 27'
1.	2.	3a	3b.	4a.	4b.
a	8	218.52	218.57	5.04	5.08
b	9	213.80	213.95	2.72	2.87
c	10	209.15	209.44	0.60	0.70
d	10.23	208.13	-	-	-
e	10.27	-	208.00	-	-
f	11	212.61	212.45	2.16	2.14
g	12	218.94	218.75	5.20	5.17

TABLE 3.9 (xii)

STATEMENT OF COMPARATIVE COSTS (18,000 CUSECS)

S.No.	Value of (F.S.L.-N.S.L.) (ft.)	Cost per rft. of canal (Rs.) With 26' F.S.D.	With 27' F.S.D.	With 28' F.S.D.	% increase in cost of canal due to variation of (F.S.L. - N.S.L.) from 10.82' with 26' F.S.D.	10.91' with 27' F.S.D.	10.93' with 28' F.S.D.
1.	2.	3a.	3b.	3c.	4a.	4b.	4c.
a	8	232.99	232.81	232.90	6.61	6.84	6.[illegible]
b	9	227.81	227.81	228.00	4.24	4.25	4.33
c	10	222.81	222.91	223.20	1.95	2.00	2.13
d	10.82	218.54	-	-	-	-	-
e	10.91	-	218.53	-	-	-	-
f	10.93	-	-	218.55	-	-	-
g	11	219.66	219.20	219.04	0.56	0.30	0.22
h	12	225.99	225.53	225.37	3.41	3.25	3.12

TABLE 3.9 (xiii)

STATEMENT OF COMPARATIVE COSTS (20,000 CUSECS)

S.No.	Value of (F.S.L.-N.S.L.) (ft.)	Cost per rft. of canal (Rs.)			% increase in cost of canal due to variation of (F.S.L.-N.S.L.) from		
		With 27' F.S.D.	With 28' F.S.D.	With 29' F.S.D.	11.42' with 27' F.S.D.	11.48' with 28' F.S.D.	11.53' with 29' F.S.D.
1.	2.	3a.	3b.	3c.	4a.	4b.	4c.
a	10	236.05	236.12	236.44	3.32	3.39	3.43
b	11	230.91	231.11	231.54	1.07	1.19	1.29
c	11.42	228.46	-	-	-	-	-
d	11.48	-	228.38	-	-	-	-
e	11.53	-	-	228.60	-	-	-
f	12	232.13	231.67	231.50	1.61	1.44	1.27
g	13	238.71	238.25	238.08	4.49	4.32	4.16

4 ft. including balancing depth of cutting equal to 6.9 ft. The column No. 4 of the same table shows the percentage increase in cost of canal per rft. from that with a value of (F.S.L. - N.S.L.) equal to 6.9 ft.

Similarly columns 3 and 4 of each table give the information for each discharge.

(5) The table Nos. 3.7 (i) to 3.7 (xiii) can be of the help ## the engineer in choosing between two or more alignments with different slopes.

4.2 CONCLUSIONS:-

(i) A most economical full supply depth for each discharge ranging from 3,000 to 20,000 cusecs with a bed slope of 1 in 12,000 is given in a table 3.6 and figure 3.8. The corresponding value of (F.S.L. - N.S.L.) for each discharge giving best results is also shown in the above table and figure. Thus figure 3.8 is most useful for finding out the most economical full supply depth corresponding to a given discharge with a bed slope in the channel equal to 1 in 12,000. Similarly, value of (F.S.L.-N.S.L.) giving minimum cost can be found out from figure 3.8.

(ii) A most economical bed slope and corresponding most economical full supply depth for each discharge ranging from 3,000 cusecs to 20,000 cusecs is given in table 3.8 and figure 3.9. The corresponding value of (F.S.L.-N.S.L.) giving a best result for each discharge is also shown in table 3.8 and figure 3.9.

(iii) The variation of cost due to change of (F.S.L.-N.S.L.) value from a value of (F.S.L.-N.S.L.) giving best results for each discharge is appreciable and varies from 0.22 to 10.65 percent.

(iv) These studies can be of much guidance to the survey and design engineers in fixing canal alignments and designing canal dimensions for lined canals.

4.3 LIMITATIONS:-

The work has been done for the conditions prevalent in Rajasthan Canal area and, to the extent that the assumed conditions change, these tables and figures cannot be used and require repetition of the calculation work. In many cases, however, the author's charts will be found directly useful atleast for preliminary studies. The procedure evolved will facilitate economic studies in all cases.

APPENDIX - I

ECONOMICS OF LINING THE CANALS

This is substantiated by the studies which are being made at the moment for the lining of the Rajasthan Canal. The canal having a full supply discharge of 18,500 cusecs, will take off from the Harike Head works at the confluence of the Sutlej and the Beas, cutting through the States of the Punjab and Rajasthan a total distance of 425 miles.

The estimated cost of the project without lining was Rs. 116.00 crores, the cost per cusec thus being Rs. 62,700 and when the same project with lined canal came to Rs. 152 crores including Rs. 12 crores for additional channels for distributing supply saved by lining. The total cost of the project includes the cost of the head works and appurtenant works at Harike and the share for the storage works above which is Rs. 45.39 crores.

It is estimated that seepage losses in an unlined canal in this territory is of the order of 8 cusecs per M.Sft. of wetted area. As at this rate 4,600 cusecs would have been lost in the canals and distributaries, an investment of Rs. 29 crores would not only have been wasted but x would also have added to the hazards of water logging.

Thus the cost of lining channels in the original project Rs. (152-12-116 = Rs. 24 crores) has been more than met by Rs. 29 crores cost of water saved for additional irrigation. After allowing for evaporation and reduced percolation through brick lining with sandwich cement mortar of 20% a net balance of 3,700 cusecs will be available for irrigation. At a rate of 200 acres per cusec (as the Bhakra Canal system has shown that 1 cusec of water is irrigating about 200 acres in Rajasthan), it will irrigate about 7,40,000 acres, yielding about 2.6 lakh tons of food grain valued at Rs. 9 crores annually. Assuming a conservative assessment of Rs. 10/- per acre for water and land taxes, additional annual revenue by Government will be of the order of Rs. 74 lakh. Further substantial gains can also be assured if the water courses which account for 20% losses are also lined. It is thus clear that lining of earthen irrigation channels, inspite of its apparent high cost is always an economy.

APPENDIX - II

TYPICAL EXAMPLE OF DESIGN OF CIRCULAR LINED SECTION

A circular lined Section is to be designed for the following data:-

DATA

Discharge (Q) .... 900 Cusecs

Rugosity co-efficient (N) 0.018

Bed slope (i) .... 1 in 4,000

Side slope (S:1) 1:1

DESIGN

The discharge curve for 900 cusecs in figure 2.3 (a) and the vertical ordinate through 1 in 4,000 bed slope intersect at a point which read radius or full supply depth 'D' at centre as 11.1 ft.

The same point reads an average velocity of 4.10 ft. /sec. as interpolated between velocity curve for 4.0 and 4.5ft./Sec.

Thus full supply depth for circular lined section 11.1 ft.

and velocity in the channel 4.1 ft./sec.

The curves given in figure 2.3(a) can also be utilised for other values of 'N' as explained along side the graph.

APPENDIX - III

ANALYSIS OF RATE OF TILE LINING (SINGLE TILE LINING) IN BED (100 SFT.) THICKNESS OF LINING = 3 1/8 INCHES OR 0.26 FEET

MATERIAL RATES

Following are the present rates of various materials required for lining the bed with tile.

Tile 12"x6"x2" at Kiln site (Present average rate)	Rs. 55.00 per %0 Nos.
Cement per bag at rail head (present market rate)	Rs. 8.00 per bag
Bajri at rail head	Rs. 80.00 per % cft.
Sand	Rs. 2.00 per % cft.

MATERIAL REQUIREMENT FOR 100 SFT.

Tiles	190 Nos.
Cement	2.80 bags
Bajri	3.36 cft.
Sand	7.84 cft.

AVERAGE CARRIAGE OF MATERIALS INVOLVED

Tiles	2 miles (katcha)
Cement	30 miles
Bajri	30 miles
Sand	2 miles

a) COST OF MATERIALS

190 Nos. tiles @ Rs. 55.00 per %0 Nos.	Rs. 10.45
2.80 bags of cement @ Rs. 8.00 per bag	Rs. 22.40
3.36 cft. of Bajri @ Rs. 80.00 per % cft.	Rs. 2.69
7.84 Cft. of sand @ Rs. 2.00 per % cft.	Rs. 0.16
	Rs. 35.70

b) <u>CARRIAGE OF MATERIALS</u>

190 Nos. tiles carriage distance 2 miles @ Rs. 12.90 per %0 Nos.	Rs. 2.45
2.80 bags cement carriage distance 30 miles @ Rs. 1.45 per bag.	Rs. 4.06
3.36 cft. of Bajri carriage distance 30 miles @ Rs. 48.90 per % cft.	Rs. 1.64
7.84 cft. of Sand carriage distance 2 miles @ Rs. 12.90 per % cft.	Rs. 1.01
Total	Rs. 9.16

c) <u>LABOUR</u>

19.79 cft. tile masonry @ Rs. 26.75 per % cft.	Rs. 5.29
100 sft. cement plaster @ Rs. 6.60 per % sft.	Rs. 6.60
100 sft. curing lining for 28 days @ Rs. 0.85 % sft.	Rs. 0.85
Pumping water	Rs. 0.50
Total	Rs. 13.24

Total (a)+(b)+(c) = Rs. (35.70+9.16+13.24)

= Rs. 59.10 per % sft.

The rate assumed for the study is Rs. 60.00 per % sft. which is also in conformity with the tenders received in various reaches of Rajasthan canal.

APPENDIX - IV

ANALYSIS OF RATE OF TILE LINING (DOUBLE TILE LINING) ON SIDE SLOPES INCLUDING ROUNDED CORNERS (100 SFT.)(THICKNESS OF DOUBLE TILE LINING = 5.25 INCHES OR 0.44 FEET)

MATERIAL RATES

Following are the present rates of various materials for lining the side slopes including rounded corners.

Tiles 12"x6"x2" at kiln site (present average rate)	Rs. 55.00 per %0
cement per bag at rail head (present market rate)	Rs. 8.00 per bag
Bajri at rail head	Rs. 80.00 per % cft.
Sand	Rs. 2.00 per % cft.

MATERIAL REQUIREMENT FOR 100 SFT.

Tiles	380 Nos.
Cement	3.50 bags
Bajri	4.11 cft.
sand	9.59 cft.

AVERAGE CARRIAGE OF MATERIAL INVOLVED

Tiles	2 miles (katcha)
cement	30 miles
Bajri	30 miles
Sand	2 miles

(a) COST OF MATERIALS

380 Nos. tiles @ Rs. 55/- per %0 Nos.	Rs. 20.90
3.50 bags of cement @ Rs. 8/- per bag	Rs. 28.00
4.11 Cft. of Bajri @ Rs. 80/- per % Cft.	Rs. 3.29
9.59 cft. of sand @ Rs. 2/- per % cft.	Rs. 0.19
Total	Rs. 52.38

(b) CARRIAGE OF MATERIALS

380 Nos. tiles carriage distance 2 miles @ Rs. 12.90 per %0 Nos.	Rs. 4.90
3.50 bags cement carriage distance 30 miles @ Rs. 1.45 per bag.	Rs. 5.08
4. 11 cft. of Bajri carriage distance 30 miles @ Rs. 48.90 per % cft.	Rs. 2.01
9.59 cft. of sand carriage distance 2 miles @ Rs. 12.90 per % cft.	Rs. 1.24
Total	Rs. 13.23

(c) LABOUR

44 cft. tile masonry @ Rs. 34.80 (Av. from 12' to 28' height) per % cft.	Rs. 15.31
100 sft. curing lining @ Rs. 0.85 per % sft.	Rs. 0.85
100 sft. scaffolding and template allowance @ Rs. 0.85 per % sft.	Rs. 0.85
Pumping Water	Rs. 0.50
Total	Rs. 17.51

Total (a)+(b)+(c) =Rs. (52.38+13.23+17.51)

= Rs. 83.12 per % sft.

The rate assumed for study is Rs. 88.00 per % sft. which is near to the cost calculated above. This assumed rate is also in conformity with the tenders received in various reaches of Rajasthan canal for double tile lining and hence adopted is all right.

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