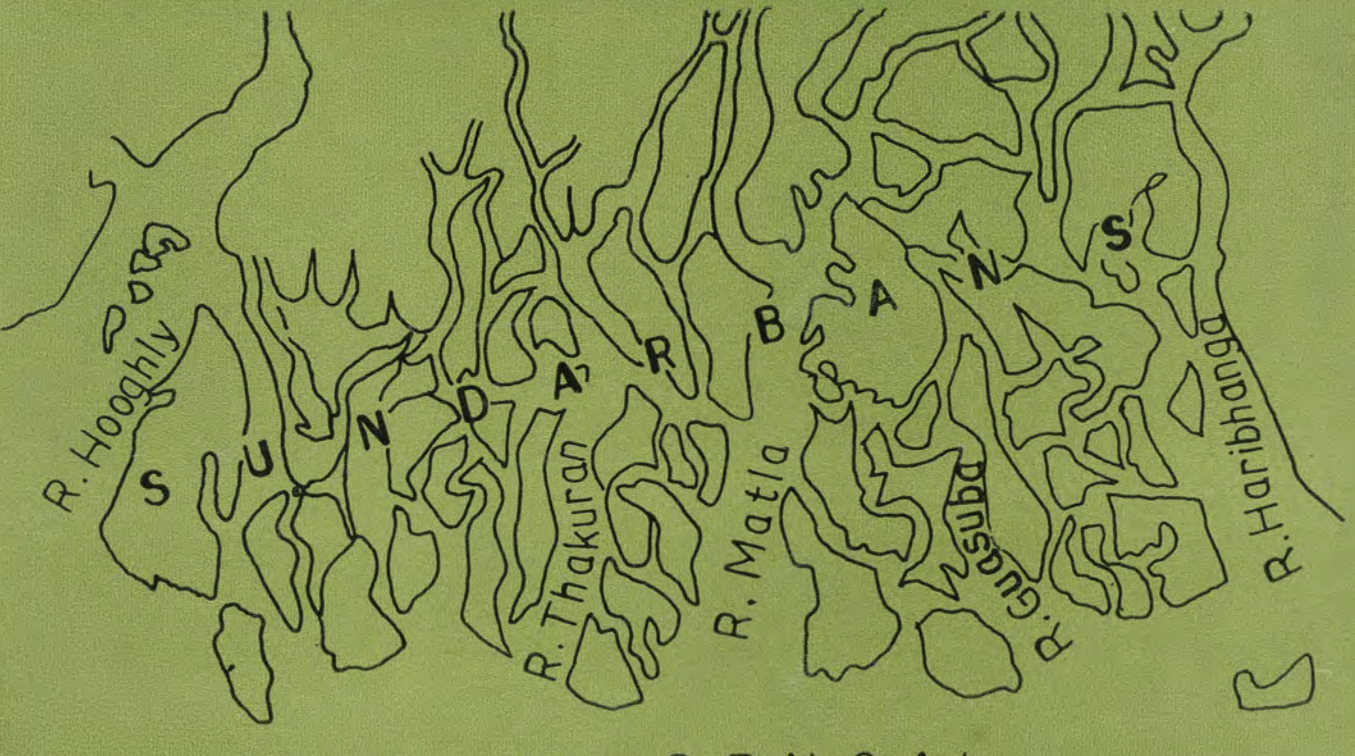
 

# Selection of site, survey, design and construction of Brackishwater Fish Farm with special reference to the islands of LOWER SUNDARBANS

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CENTRAL INLAND CAPTURE FISHERIES RESEARCH INSTITUTE
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# SELECTION OF SITE, SURVEY, DESIGN AND CONSTRUCTION OF BRACKISHWATER FISH FARM WITH SPECIAL REFERENCE TO THE ISLANDS OF LOWER SUNDARBANS


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# FOREWORD

*India is gifted with about 2 million hectares of low-lying land along the coast-line with rich resources of prawn and fish seed. Though in West Bengal and Kerala 24,000 hectares of land are utilised for prawn culture by traditional method, the rest are not fully utilised due to lack of adequate scientific know-how about the brackishwater aquaculture.*

*Small and big entrepreneurs of the country are constantly aspiring to enter this field of brackishwater farming but since no comprehensive methodology of constructing fish farm in these difficult terrains has been laid out so far, they are hesitant to invest on this venture.*

*Central Inland Fisheries Research Institute has been working for nearly two decades in lower Sunderbans, West Bengal to survey in detail the prospects of brackishwater fish farming, keeping in view all salient engineering and biological aspects of it. Valuable knowledge has been acquired regarding the various aspects of engineering problems to build and maintain brackishwater fish farm. This knowledge has been effectively put to use in designing and constructing a 500 acres brackishwater fish farm in Henry's Island, lower Sunderbans which is now functioning effeciently.*

*The present manual encompasses all these working experiences and synthesises them in the form of a comprehensive methodology which will be of immense help to the prospective aquaculturists for taking up brackishwater fish farming on a commercial scale.*

*ARUN G. JHINGRAN* 3.XII.87
*Director*

## C O N T E N T S

# SELECTION OF SITE, SURVEY, DESIGN AND CONSTRUCTION OF BRACKISHWATER FISH FARM WITH SPECIAL REFERENCE TO THE ISLANDS OF LOWER SUNDARBANS

Abhijit Sengupta & D.D. Halder

## INTRODUCTION

Brackishwater fish farming is an age-old practice in West Bengal and Kerala and fishermen of these areas raise bulk production of brackishwater fishes and prawns by following their traditional cultural practices.

The brackishwater fish farm are constructed in the low lying mud flats in the lower estuary which gets inundated by the tidal water during spring tide and the water again receeds back in the low tide.

The main working principle of the brackishwater fish farming is to enclose an area by constructing earthen dykes and to provide it with water gate by operating which water can be taken in to flood the impoundment with tidal water. Fish seeds carried in alongwith the tidal water and also stocked from other sources are reared in the impoundment and harvested after it attains the marketable size.

The water management is a very important part of the brackishwater farming and the farm should be such designed and constructed that regular water exchange is possible to maintain the quality of water and entire water of the farm can be drained out whenever necessary by operating the water gate.

An optimal depth of water should also be maintained in the impoundment which is most conducive to the growth of the brackishwater fishes and prawns and pond should be such designed that this optimal water depth is maintained also in the lean months when tidal rise is minimum. The work to be done starting from selection of site to the construction and operation of the farm is mentioned below :

1 Selection of site

a) Reconnaissance survey
b) Prismatic compass traversing
c) Detailed topographical survey
d) Tidal survey

2) Design

a) Farm layout
b) Design of the pond and canal
c) Design of the embankment
d) Design of the main water gate and secondary sluices

3) Construction

a) Construction of the embankment and pond
b) Construotion of the water gate

The forest deltas of lower Sundcrbans - the pro spect of brackishwater fish farming.

In the confluence of Hooghly Matla estuaries and Bay of Bengal there are innumerable deltas a few of which are only inhabited and almost all of the rest are thickly overgrown with wild mangroove forests invariably interspersed with numbers of meandering creeks entering deep into the island from the coast. The island ranges from quite small to very big sizes. These clusters of islands are widely known as Sunderbans.

The mangrooves mainly consisting of the species like geon (Excoecaria agallocha), Garan (Ceriops tagal), Hetal (Phoenix palludosa), Bani (Avicennia alfa, marina, A.officinalis) etc provide no quality timber but only fire wood and small poles for wooden hutments. Many of these forest islands can profitably be given shape to the brackishwater fish farm and lot of fish can be raised from these to meet up to a significant extent of protein requirement of the country.

With the said purpose the Sunderbans Survey Unit of Central Inland Fisheries Research Institute took up the detailed survey of some of the islands in lower Sunderbans in the year 1970 to study the prospect of constructing fish farm there and the engineering survey, design and construction of farms are carried up as per the guidelines mentioned earlier.

In the following pages the details of the steps needed to be taken up for selection of site, design and construction of the farm is narrated with the special reference to the work done in lower Sunderbans.

## A. Selection of site

Proper selection of the site is essentially needed before going to take up the design and construction of brackishwater farms. The basic factors needing attention in selection of site are as follows :

(i) Size and shape of the island (ii) Symptoms of erosion, (iii) Soil characteristics, (iv) Topography (v) Tidal phenomena.

To study the above aspects thorough survey should be carried out which can be broken up into following steps.

### (i) Reconnaissance survey

Reconnaissance survey is conducted by the surveyors by travelling around the islands by the country boat. This will give an overall idea about the size and shape of the island and also the symptoms of erosion if there are any and also about other important aspects which are needed to be known for proper selection of the site.

### (a) Size and shape of the island

If the size of the Island is too small or the shape is too elongated with a small breadth it may not be economically wise to build up fish farm there.

If the Island is too small it generally indicates that the Island is newly built and is still in the process of building up. The soil of the newly built-up island is generally very soft and have too low a bearing capacity to withstand the load of the dykes, watergates or other superstructures which are vital parts of the brackishwater farms. Besides that, if the island is too small construction of the farm will be difficult because required numbers of stocking, rearing and nursery ponds can not be constructed there to make the farm commercially viable and sometimes it may be difficult also to get required volume of earth from the pond excavation to construct the main marginal dykes for protecting the farm from tidal thrust.

If the shape of the island is too elongated then the ratio of the preimeter of the island to its area will become more and hence necessary volume of earth may not be available from the excavation of the pond to construct the perimeter or the marginal dykes around the island.

b) Erosion

As many new islands are rising up in Bay of Bengal due to the constant accumulation of the silt many old islands are also in the process of being rapidly eroded away due to the continually changing hydrodynamics of the bay. The erosion of the river or channel is a very complex phenomenon which can be analysed and estimated by sets of mathematical formulae involving a number of variable parameters. However one of the main reason of erosion is the transportation of the bed layers by tractive forces. As per Du Boys frictional resistance must depend on the effective weight of the overlying material, the coefficient of friction between layers being constant for the given material. It follows that movement of successive layers will occur down to that level at which the overlying material produces a resistance equal as magnitude to the tractive force of the stream, i.e.

$$\tau_o = \gamma_o S = \rho nd \; (Y_s - Y)$$

Where $\tau_o$ = Bed shear stress

$Y_o$ = Depth of the layer from the bed

$S$ = Energy gradient supplied to the layer

$\rho$ = Fluid density

$Y_s$ = Sp. gr. of the soil

$Y$ = Sp. gr. of water

$d$ = Thickness of each layer of the same order of magnitude as particles themselves.

$n$ = no. of layers.

By assuming the velocity of the layers to vary linearly (by equal increments $\Delta v$) from zero to maximum at the top the amount of solid material being transported per unit width per unit time is given by

$$q_b = nd \frac{(n-1)}{2} \Delta v$$

Though the above formulae present a theoretical aspect about erosion and sediment transport the practical observation in the field will give a clear picture about erosion.

During the primary survey of the Kakdwip sand opposite the existing fish farm of CIFRI, it was noticed that the Western bank of the island is getting eroded away due to the turbulent surf of the Muriganga river and this was one of the reasons that the island was not finally selected for farm construction.

c) Soil characteristics

If the soil contains high percentage of fine silt and clay it is very soft and unstable having a low bearing capacity and this type of soil will not be suitable for farm construction. On the other hand if the percentage of sand is too high than the soil will be stable but its water rretaining capacity will be low due to high permeability and such soil also will not be suitable for farm construction. A good soil will have roughly the following percentages of sand silt and clay for proper stability.

| | | |
|---|---|---|
| Sand | - | 60 p.c. by weight |
| Silt | - | 25 p.c. by weight |
| Clay | - | 15 p.c. by weight |

After the site is primarily selected soil at different layers should be tested elaborately in field and laboratory for knowing its suitability for the construction of pond dykes and sluices.

Generally soil upto 2 m from G.L. should be tested for knowing the suitability for dyke construction and its retentivity for holding the pond water. Soil from 2m upto 4 m (depending upon the site of main sluice) below G.L. should be tested for knowing the bearing capacity, silt factor etc for designing the sluice. For example the properties of Sunderbans soil can be referred. Though over a vast area of Sunderbans soil properties will vary remarkably from place to place still tests at some few spots give on an average the following properties of the soil at those spots

| | |
|---|---|
| Sand | 2.1 to 13.9% |
| Silt | 59.2 to 77.9% |
| Clay | 18.2 to 38.7% |
| Liquid limit | 52.5 to 55.0% |
| Plastic limit | 22.9 to 26.5% |
| Plasticity Index | 26.0 to 32.1 |
| Optimum moisture content | 15.3% |
| Dry Density | 1.22 to 1.75 (gms/cc) |
| Cohesion | 0.16 to 0.49 (kg/cm2) |
| Angle of Internal Friction | 4°44' - 8°19' |

d) Elevation:/*

Old and elevated islands, on the other hand, subject to infrequent submergence by tidal water are generally stable. But too much elevation causes a high expenditure on earthwork in excavation. Hence these factor should be given a thorough consideration before selecting the site.

/*Newly-built chars or islands have generally low elevation and due to the innundation by almost all the tides the top soil remains soft and slushy. This type of soil may not be suitable for the construction of the brackishwater farm dykes.

Trees, shrubs and herbs grown in the islands also present a first hand information about the elevation of the lands and during reconaissance survey the surveyor can have an rough idea about the elevation of the island by studying the flora grown on the soil.

Porterasia coarctata, locally named as dhani ghas, grows only in newly built soft and slushy soil. When the land will be more elevated by silt deposition then other shrubs like ketki (Acunthus ilicifolius) etc comes up. When the land is further more elevated then the trees like garan (Ceriops tayal), geon (Excoecaria agallocha) etc will grow up. Hetal (Phoenix palludosa) or bani (Avecinnia alba) grows up where the soil is further elevated.

e) Jungles and bushes

All the islands of the lower Sunderbans are invariably overgrown with thick mangrove vegetation. While constructing the farm a belt of mangroves should be left undisturbed all along the periphery of the island. It will play a significant role in protecting the earthen dykes by diminishing the striking energy of the short period wind waves which is generated in the adjacent open water and travel towards the dykes and which is mainly responsible for eroding away the dykes.

On the other hand very high incidence of bushes and jungles will incur greater cost for cutting and clearing the trees and many roots and stumps will remain in the soil which will spoil the dyke by gradual decaying and making internal tunnelling in the pond bottom or the dyke.

In some of the islands of Sunderbans it has been noticed while conducting survey that there is vast expanse of land devoid of growth of any sort of vegetations surrounded by thick jungles all around.

It is called blank which is locally named as 'dhal'. These blanks are formed, because the land has saucer-like depression in these places and tidal water accumulated in this depression during high tide will have no outlet to go out and will evaporate leaving salt behind and will act like a salt pan. Thus the soil in these blanks are too saline to allow any vegetation to grow. These blanks are ideal spaces for construction of farm.

In Henrys island on Bakkhali creek of lower Sunderbans almost 40% of area has been found to be blank. Also in Mahisani island a vast area remains blank.

ii) Prismatic compass Traversing

After the reconnaissance survey is over and the land has been primarily selected for farm construction it is essential to know the exact size and shape of the island for detailed contour surveying and mapping of the land.

Prismatic compass traversing is done along the circumference of the land and when the traverse is closed it gives the correct shape of the island. Traversing should be conducted during low tide so that prismatic compass stations can be fixed along the outer edge of the forest from where the consecutive stations are visible and no forest cutting will be needed. Since at the outer edge of the island soil will be soft and slushy additional care is needed to keep the compass-stand exactly on the station.

However, since to adopt the standard surveying and levelling practices in hazardous terrain like Sunderbans may be very much difficult, the help of the aerial photographs available with Survey of India may be taken as far as practicable for finding out the exact size and shape of any island.

iii) Plane Table Surveying

After the shape of the land is drawn by prismatic compass traversing the plane table survey is conducted to work out the details of the cluster of shrubs, big trees, blanks etc. It is to be noted here that since accurate chaining is very difficult on the slushy soil with thick growth of vegitation either resection or intersection method should be followed as far as practicable so that chaining can be avoided as much as possible.

iv) Detailed levelling

After the shape of the land is known and the island is primarily selected the contour survey should be taken up for detailed design. A suitable base line and also the perpendicular lines on the base lines are marked on the map. It is convenient if the base line can be ranged breadthwise in the mid position of the island. The perpendicular lines are ranged with the help of prismatic compass and the ranging rods. The lanes are ranged by cutting thick jungles. The distance from lane to lane depends upon the topography of the land. If the land is much undulated then the lines should be closely spaced. But the deltas of lower Sunderbans are formed of alluvial deposition and hence it is generally flat in nature. In surveying the Henrey's and Mahisani islands the perpendicular lanes are ranged 100' - 0" apart. The spot levels are also taken at every 100' - 0" distance along the line..

After the survey is over spot levels are plotted on the map and the contour lines are drawn by interpolation. Intervals of the contour lines are also fixed in conformity with the land undulation.

Before conducting the contour survey the permanant bench mark is fixed on the island and the reduced level of the bench mark is determined by drawing fly level from any known G.T.S. Bench Mark.

One of the major problem in surveying these thick forest deltas is that the soil is so densly interwoven with roots and stumps that it is often very difficult to find out the exact ground level. The staff-man should be very careful so that the levelling staff is placed exactly on the ground instead of any elevated roots and stumps so that the levelling becomes accurate.

v) Tidal Survey

Tidal survey is another essential pre-requisite for scientifically designing the various essential components of the fish farm like ponds, dykes, sluices etc. The tidal survey consists mainly the survey of (a) tidal rise and fall in spring tides round the year (b) tidal velocity in different phases of the tide.

(a) Tidal rise and fall

Generally there are two rises of flood tides and two falls of ebb tide every lunar day i.e. 24 hrs. 50 minutes. Thus the average interval between successive high tides is 12 hrs. 25 minutes. There are three types of tide (i) Semi-durnal tide which occur twice in a day (ii) Diurnal tide which occur only once a day (iii) Mixed diurnal type where one of the two high tides in a day do not reach the highest of the previous tides.

The tide in the Bay of Bengal are, for example, predominantly semi-diurnal with some influence of the diurnal constituents which result in the diurnal inequality between the heights of two daily high water levels or two daily low water levels.

Tidal observations are necessary for finding out the Highest High Water level of the year which is needed for designing the peripherial embankment.

The observations are also needed for knowing the spring tide levels in each fortnight of every month which will be useful in designing the depth of the ponds and the height of the dykes.

For these, long period observations over years are needed. The procedure that may be adopted is to establish a co-relation of tidal levels between the site and the place where long period of past records are available (Saugor in case of Sunderbans). Long period past data of the established site may be analysed to obtain Highest High Water level and Design Tide at the established site and to convert them to the project site value with the help of co-relation. The process is an involved one and beyond the scope of this note.

The tidal reading can be taken by either using automatic stage recorder or by using ordinary callibrated gauges which are less costly and easily available. The gauge is planted on the bed level of the feeding creek. The guage is callibrated and it is such driven into the ground that the zero mark of the tidal gauge flushes with the ground and the exact R.L. of the zero mark of the tidal gauge is known by drawing fly level from the known G.T.S. bench mark. The tidal readings are taken in the spring tides of both monsoon and lean months. Time interval between taking two tidal readings is to be decided as per the rate of tidal rise and fall;

To get the accurate curve of tidal fluctuation readings should be taken at least at every ten minutes.

After the tidal readings are recorded these are plotted against the time and the curve will give a clear picture of tidal height against the time and it is essentially needed for working out the detailed design of water gate. It has been observed during the survey of the Mahisani and Henry's island that the tidal amplitude from low low water level to high high water level varies from 2m to 4.5 m in the monsoon months and 1.5m to 2 metres in spring tides of lean months.

b) Tidal velocity

Tidal velocity observations are required to find out the discharge capacity of the creek on which the sluice gate is located in order to find out if the creek is capable of carrying the water for which the sluice has been designed.

For designing the efficient water gate it is essential to know the tidal velocity in the feeding creek in the different tidal phases. The velocity may be recorded by using half submerged float or the electric current meter which will give more precise result. The velocity varies with respect to time and the time velocity curve will give the volume of water ingressing through the water gate per unit width per unit time. It has been noted that the average velocity of spring the tidal creeks in the Bakkhali or Kakdwip creeks varies tide from 350 cm/sec in monsoon to 29.0 cm/sec in winter. It is better if the tidal survey is carried out for consecutive two or three years.

## B. Design of the farm

After the island is selected and the contour and tidal survey is completed the farm design is taken up. The design consists of the following parts.

### i) Farm layout

Farm layout and orientation of ponds and canals are most important part of the farm design. From the contour map the elevations and depressions of the land can be clearly visualised. Ponds should better be constructed on the land having low elevation and relatively elevated land should be marked for the construction of godown, watch sheds and other infrastructure. It will minimise the cost of earth work. Ponds should be such oriented that the maximum benefit can be extracted from existing canals and creeks for feeding the impoundment with water. This will also help in minimising the earthwork.

Forest belt of considerable width should be left undisturbed all along the outer margin of the farm. This will protect the farm from the direct thrust of the tidal wave.

In designing the fish farm in Henry's and Mahisani island forest belt of an average width of 200'-0" has been left.

### ii) Orientation of the ponds

The fish ponds are designed to be rectangular in shape. Its width should not be much which will make the netting difficult.

In the coast of Bay of Bengal there is high velocity of wind during summer and monsoon months and wind flows almost consistently from south to north. If the length of the ponds are oriented north-south wise then the wind will have a greater fetch length and it will cause bigger waves in the pond water which will result in erosion of dykes and ponds and pond sides. Hence the pond should be laid east-west wise as far as practicable. But, if the ponds are small wave height will be limited due to small fetch. These small waves may also help in aerating the pond water if the pond is oriented lengthwise in direction.

Design of ponds and the canals

a) Depth of pond

The bottom level of the pond should be such that at least a depth of 1 meter is maintained in the ponds even in the lean months when the tidal amplitudes is minimum. On the other hand , pond bottom should be at a higher level than the low/water level of the creek so that the pond water can/low be entirely drained out whenever it is necessary for washing the pond metabolites and preparing the pond bed. The depth of the pond excavation is calculated from the contour level and the tidal reading.

The depth and sizes of the individual ponds also should be such ascertained that the volume of earth obtained from the pond excavation is equal to the volume of earth required for constructing the dykes. In the most economic design these two volumes will be equal. Since pond depth is to be determined only on the criteria of contour level and tidal rise the area of the individual pond should be such designed that the condition of equality of earth volume in pond cutting and dyke filling is satisfied. In the case of rectengular ponds more the ratio of the longer to shorter sides more will be the length of the perimeter. For a given area square ponds will have minimum perimeter. These should be taken into consideration in designing the pond.

As the pond will be bigger in size the cost towards the lead for carrying earth to deposit to the dyke will be more and hence cost per unit area will increase. /on the other and perimeter varies linearly more in the individual ponds area less is the ratio of the perimeter to the area and hence the cost of dyke construction per unit area will come down. All these aspects are very much site specific and the best-suited economic design will have to be made satisfying the site conditions.

in
Since/the brackishwater farm practices fresh tidal water is taken into the ponds in every fortnight the loss of water due to seepage can be neglected. But if in any case the soil is very much previous and due to some reason or other water is not taken during consecutive fortnights there may be some appreciable losses due to seepage. Hence amount of seepage loss may be estimated in designing the pond depth.
/hand since area is propositional to square of the sides

Seepage loss may occur through the permeable dyke on impervious base when pond water will stand against the dyke and the rate of seepage flow per unit length will be given by

$$q = K \; Y_o$$

Where $q$ = flow rate per unit length in $m^3/day$

$K$ = Hydraulic conductivity in m/day

$Y_o$ = Focal distance of Kozeny's basic parabola in m

The parabola is represented by

$$X = \frac{Y^2 - Y_o^2}{2 Y_o}$$ with x and y as coordinates and origin at the focus

In the case of ponds and canals often seepage occurs through sides and bottom and when water table is at a considerable depth the seepage flow q can be estimated after Vedermikov's method as follows.

$$q = K (B + AH)$$

Shere B = width of the canal

H = Depth of the canal

A is a parameter which varies with $\frac{B}{H}$ for different side slopes of the canal the curve for which is available.

Since the pond water will be drained out though the canals the canal bottom is kept at a lower than that of the pond. Generally, the canal bottom level is kept 0.15 m lower than the bottom level of the pond. A mild slope of an average order of 1" in 100 ft. towards the water gate my be maintained. It will help in washing out the accumulated silt to some extent in low tide.

b) <u>Side slopes</u>

The soil of the lower Sunderbans deltas can be classified into five categories (i) clayey soil, (ii) Loamy soil (iii) Sandy loam (iv) Sandy soil (v) silty soil. But predominantly it is clayey soil (silt 38.9, clay 41.00 sand 20.1). The angle of repose of this type of soil is generally 1.5 : 1 to 1 : 1. A little flatter slope than this is maintained for the sides of the ponds so that it may not collapse due to the superimposed load of the dyke. Specially when the pond water is entirely drained out there is risk of collapsing of the pond slope. Hence adequate slope should be provided to withstand the danger of drawdown.

c) Berm

For facilitating easy netting of the ponds and also for increasing the stability of the base of the dykes the proper berm width should be provided at the base of the dyke. In absence of berm also the pond sides may collapse when the water will be drained out. 1.5m to 2.0m berm width is maintained in the brackishwater farm layouts in Henry's and Mahisani Islands.

d) The canal

**A tidal channel of uniform cross section as is often** excavated is found to be unstable. Because tidal discharge decreases with the increasing distance from the sea. So if a constant cross section is maintained the gradually decreasing velocity will lead to the siltation of the channel. Hence forvery long feeder channel in a big farm it may be necessary to evolve proper design criteria for such channel.

The longitudinal variation of cross sectional area of a tidal channel below mean tide level (MTL) at a distance may be worked out from continuity equation as follows:

$$A(x) = Ao.\ e^{-kx}$$

Where $K = \frac{W h_o}{V_o H_o}$

$W = \frac{2\pi}{T}$

$T$ = Tidal period
$h_o$ = Tidal amplitude (vertical)
$V_o$ = Tidal velocity amplitude
$H_o$ = Depth below MTL at the sea face

In non-tidal canals there exist a set of empirical relationships for evaluating cross-sectional parameters for a particular discharge. Such type of generalisation is, however, not available for tidal systems. But the peak tidal discharge during average spring tide and cross sectional areas below MTL are related more or less in the same fashion as that of non-tidal system and the general equation as mean of all relationship may be of the form:

$$A = 1.30 \times Qm^{0.963} \text{ in CGS system}$$

Where $A$ = Area in $ft^2$ below main tide level

and $Qm$ = Maximum tidal discharge in $ft^3/sec$ at spring tide condition.

These formulae will be helpful in designing tidal channels.

iv) Embankments

Marginal embankment

The main function of the marginal embankment is to protect the farm from being flooded by the tidal water. Since it faces direct thrust by the tide it is designed to be strong enough to withstand this thrust.

a) Height of the marginal embankment

Height of the marginal dyke should be such designed that it can most safely prevent the tide water from overtopping the dyke which may result in breach and ultimate collapse of the dyke. To ensure this a minimum free board of 1m should be provided above the maximum high flood level recorded in 10-15 years. The biggest tide occurs in Bay of Bengal in the month of September-October when the tide rises even to a hight of 3m above MSL. Since the average ground level of the islands of Sunderbans is 1.5m above MSL, the tidal height varies from 0.5 to 1.5m above the ground level. If this tide is associated with high wind the tidal rise is more. All these factors should be taken into account for designing the height of the embankment. But the height of the dyke cannot be raised to any extent because availability of earth is also a deciding factor in designing the height of the marginal embankment. To determine the height of the dyke and to design its crest level allowances will have to be made for wave upsurge along the slope, subsidence of the foundation layer and required free board. The wave run up calculated by the formulae

$$\mu = 8H \tan \alpha \cos \beta$$

$\mu$ = wave run up along slope

$H$ = Wave height

$\alpha$ = angle of the riverside slope

$\beta$ = angle of approach of the wave

b) Side slope of the dykes

Safe side slopes are required to be provided for different types of soils. If the slope is steep there is possibility of sliding down of earth when it is wet due to constant with tide water and the embankment is likely to fail. On the other hand if it is unnecessarily flatter the volume of earth required for construction of the dyke also will be greater which will reduce the effective water area of the farm.

The table furnished below shows the safe side slopes for different kind of soils. This can be taken as a thumb rule for designing the side slopes.

| Nature of soil | Upto 8 ft height | 8 ft. to 15 ft height |
|---|---|---|
| Ordinary earth, soft clay, dry sand | 1.5 : 1 | 2 : 1 |
| Loose earth, loose sandy loam | 2 : 1 | 3 : 1 |
| Wet sand | 2½ : 1 | 4 : 1 |

c) Crest width

The crest of the marginal embankment can be taken as the main link road of the farm and it should be sufficiently be wide so that the small vehicle can ply over it. For a big commercial farm the crest width of the peripherial dyké should be 3m or more for transportation of farm implements, fish stock, fish seed, manure etc.

The crest may be designed to have an outward slop so that rainwater falling on the crest is prevented from flowing into the pond and rapid silting-up of the pond can be checked. Availability of earth is also a guiding factor in determining the crest width.

The cross-section of the marginal dyke should not be weaker than the minimum cross section required for its structural stability. If the volume of earth available from pond excavation is more than the minimum volume of dyke then the dyke can be further strengthen by the deposition of excess earth. On the other hand ponds may be needed to be excavated more than the designed depth if the amount of excavated earth is not sufficient enough for constructing the dyke.

The ratio of the perimeter length of a rectangle to its area decreases as the area increases. Hence as the individual pond area will be bigger more volume of earth will be available for the construction of the dyke. But pond size cannot be increased to any extent because in that case cost due to lead in depositing the earth in peripherial dykes will also increase.

d) Key-trench

Burrowing animals like crab, eel, thalasima etc are the major menaces in Sunderbans areas. It makes tunnels underneath the ground joining upstreams and downstream side of the embankment and water retained in the pond flow out through this tunnel carrying stocked fish-seed. Black clay abundantly available in Sunderban islands 4' 0" - 5' 0" below the ground level is quite useful to resist the burrowing action by those animals. Key trench line is dug parallel to the toe of the embankment and it is filled with the puddle clay. The depth of the trench should reach the layer of the black soil. Highly impermeable in nature, this soil will also check the seepage of water, through the bottom of the dyke.

v) Subsidiary dyke

Besides the marginal dykes subsidiary dykes are also constructed in between the ponds. These dykes are made of smaller cross section because it will face very little hydrostatic pressure. Its cross section will be also designed on the basis of the volume of earth left after the construction of the marginal dykes is completed.

vi) Design of the sluice

Sluice is a most vital component of a brackishwater fish farm complex. Function of a sluice is not only to regulate the flow of water from the creek to the feeder canal but also to drain out water of the farm ponds as and when required. In a big brackishwater farm every individual pond should be fitted with independent sluices of designed dimension for taking water from the feeder canal and draining it out.

In addition to these small and secondary sluices main sluices of bigger dimensions are constructed on the main feeder canal for taking in water from the supplying creek or river. The number and size of the sluice will vary according to the total demand of water in the farm. Major sluices should be such designed that the rate of flow of water through the sluice per unit time is adequate enough to feed the farm with the required volume of water if the sluice is operated for the entire duration of the tide.

Since the discharge per unit width through the main sluice will be quite large and the possibility of under-scouring will be more it should be better constructed of concrete and masonry with cut-off wall of necessary depth. The important aspects of designing the sluice are as follows:

a) Design of vent area

In the case of ordinary irrigation sluices the vent area is designed mainly on the basis of the required discharge and available upstream water head. Since the water is discharged through the submerged hume pipe the same vent area is in function under the same hydrostatic pressure throughout the entire period of discharge. But in the case of open type sluices in brackishwater farm the effective area of vent itself changes with the change in tidal height and the velocity will also change with the change in tidal phases. Due to this constant change in tidal velocity and tidal height the water flow will be very complex in nature and some different method of computation should be adopted for designing the vent.

The tidal height with respect to time follows a simple harmonic motion or sine curve and though the time velocity curve is a curve of second degree in nature it can be considered very close to linear function within the short time interval of 3 to 4 hours during which the sluices is likely to be operated for intaking water. From these two observed curves the formula for the discharge of tide water has been established as follows :-

$$Q = K \left[ \frac{C't^2}{2} + C \, \frac{\sin \frac{\pi}{6}(t - t')}{\left(\frac{\pi}{6}\right)^2} - \frac{t \cos \frac{\pi}{6}(t-t')}{\left(\frac{\pi}{6}\right)} \right]$$

( Sengupta, 1979)

Where - Q = discharge volume

C' = level difference between the sluice floor level and the m.s.l.

t' = time required for the tide to reach m.s.l. from the floor level of the sluice

K = rate of change of velocity

C = A constant

t = time measured from the moment the tide rises to the floor level

On the basis of the above formula the vent width of the sluice may be such designed that the volume of water entering through the sluice during the desired operation period can replenish the entire farm. In the case of the fish farm on Henry's island total area of the pond is designed to be 65.17 hn and the average water depth in the pond is taken to be 0.7m. Thus the total volume of water demanded by the farm is calculated to be 456190 cm. Since a regular sluice gate will be top big to be managed conveniently for supplying this huge column of water in an operation period of three to four hours two main sluices of similar dimensions are provided and the design discharge through each sluice is half of the total volume i.e. 228000 cm approximately and by applying the earlier formula the vents of the sluice have been designed knowing all other tidal data.

b) Depth of the floor

Bottom level of the sluice should be such adjusted at the mouths of the feeder canal that in the month of March and April when the quality fish seed like *Peaneus monodon*, *Mugil persia*, *Lize tade* etc etc are in plenty in rivers and creeks water can be taken in through the sluice as soon as the level of water starts rising up. But the floor level of the sluice should be at a higher level than the LLWL (low low water level) of the main creek in the spring tide period so that the pond water can be easily drained out as and when required. Bottom level of the sluice should preferably be 0.15 cm below the bottom level of the feeder canal to facilitate the easy drainage of water.

c) Length and thickness of the floor

Standard practice in designing the drainage sluice with constant discharge is also followed in the case of designing length and thickness of the floor. Since in this case unlike the drainage sluice the discharge changes with time the thickness and the depth should be designed on the basis of the maximum discharge.

The other components of the sluice such as the cut-off abutments etc are designed as per the standard practice. Detailed drawing of the main sluice structure for the 500 acre farm on Henry's island/has been shown in the attached drawing.

/prepared by CIFRI

**vii)** Subsidiary sluices

Though the main sluices are designed to be of masonry structure the subsidiary sluices in individual ponds are preferred to be of lighter structure for the following reasons.

a) Generally the soil at deltaic regions contains a high percentage of silt and clay with high plasticity index and low liquid limit and it becomes very soft and slushy with the contact of water. Construction of permanent masonry structure over this type of unreliable soil will be costly.

b) There exists a perpetual threat of ghoges made by the burrowing animals beneath the under sluices and if there is a ghog formation tidal water will play through it. The ghog will gradually gain in size and ultimately it may result in collapsing the sluice. The repairing of ghog underneath the masonry sluice will be difficult and costly also. But the wooden sluice can be easily taken out and can be fixed again in position after ghog is repaired.

Type of sluice

The sluice whose top is open is preferred to the closed box type of sluice. The huge volume of silt which will be continuously deposited by the silt-laden water can easily be cleared from an open top sluice. In the case of a box sluice the dyke on the top of the sluice will have to be removed and the top plank should be taken out to clear the silt. This is an inconvenient and expensive operation. The silt deposition in the open sluice can be cleared very easily. The open sluice are provided with adjustable shutters so that by adjusting and fixing the shutters at different levels water can be taken in stage by stage as the water level increases in the main canal.

Foundation of the sluice

Since the silty clayey soil of the canal bottom will become invariably soft and inconsistent in contact with the water the sluice should not be placed directly over the soft soil. The soil at the base of the sluice should be made firm and stable by driving wooden piles made from locally available, plants, like geon, garan etc. Seasoned sal or suitable local wood can be selected for constructing the sluice. Before placing the sluice in position it would be coated with coal tar. A coating of coal tar will prevent the material from being spoiled rapidly by the weathering action and attack by the wood boring organisms like barnacles.

In both box type and open top sluices the bottom plank should be projected outside. The load of earth over this projected portion will prevent the wooden sluice from being floated up due to the buoyancy. The wooden planks of the sluice will be joined together by wooden battens of preferably (3" X 2") cross section. The battens will be fixed on the outer side of the wall. This wooden battens increase the friction between the earth and the plank and will prevent the sluice from sliding due to the water pressure. It will also help in preventing the tunnelling action between the earth and the wooden structure. Transverse wooden struts will be fitted with the walls so that the walls cannot be buckled down by the enormous pressure of the wet earth retained by its sides. The thickness of the plank should be 3/4" to 1".

C. Construction

After the farm is properly designed, the construction work will be taken up. The steps to be followed serially in carrying the construction work are as follows :

a) Layout of the pond and dyke

Before commencement of the earthwork the layout of the pond and embankments are given in the field. Outer and inner edges of the ponds sides are marked with pegs.

The centre line of the dyke should be marked by pegs and complete profile of the embankment should be set up with ropes and bamboo poles at regular intervals and at every change of section to guide the labourer to deposit earth as per profile.

b) Preparation of the seat of the dyke

Before taking up the construction work all big trees bushes and shrubs are mowed down and cleared up. But after clearing the jungles also the upper surface of the soil may contain lot of roots, stumps and other organic residues.

If these are allowed to remain in the soil it will decay in course of time and will cause piping in the soil and water will leak through it. Soil should be free of these harmful elements. Generally the upper layer of the soil of these deltas are soft and fluffy due to high salinity. Before going to deposit earth on the dyke the seat of the dyke should be prepared by removing loose soft soil to a depth of 6" or more according to the condition of local soil and degree of occurence of roots and shrubs etc in the soil. A major portion of the soft breathing-roots which is the prodominent characteristics of the mangrove forests will be removed by this process. If any hard tree stump which cannot be removed by cutting and is left in the soil it can be burnt down to ashes by applying kerosene or other fuel. Very hard stumps of Sundri tree (<u>Sunneratia apetata</u>) which are commonly found at a depth of 3 - 4 feet in Sunderbans Deltas will have to be burnt while excavating the pond.

After the seat is prepared the earth available from the pond excavation will be deposited for the construction of the dyke. The excavated earth from the upper layer should not be deposited because it will also contain roots and stumps.

c) <u>Compaction of the embankment</u>

Earth in embankments should be deposited in layers not exceeding 0' - 9" to 1' - 0" stretching right across the whole section. All clods should be broken and each layer should be rammed well by flat wooden rams to flatten all clods. Water should be sprinkled on every layer before the next layer is spread over it so that there is a good adhesion between the successive layers. The top surface of every layer should have a concavity having a slope inward and it will increase adhesion between two successive layers.

d) <u>Brick edging and drainage</u>

The crest of the embankment should have a gentle outward slope so that rain water falling on the crest of the dyke flows down the outer slope of the dyke. The edges of the crest will have brick edging which will prevent the crest earth from sliding down. There will be gaps in regular intervals in the brick edging on the outer edge. Drainage channels with brick linning will be constructed below these gaps along the outer slope of the dyke. The storm water falling in the crest will flow out through this linned drainage and thus rain erosion will be prevented to a great extent. The rapid filling up of the pond bed by the dyke washing can also thus be prevented.

e) <u>Grass turfing of the slope</u>

To check the rain cut and also sheet erosion by the wind the slope of the dykes should be turfed with grasses. In Sunderban deltas since the soil is very saline it is difficult to grow ordinary grass but some saline resistant grass grows on the sides of the river canals. This grass sods can be applied on the dyke slopes for turfing.

But since the outer slope of the marginal dykes faces thrust of the tidal wave it should preferably be strengthened by brick lining whenever it is required. The work of brick lining should be taken up after the deposited earth of the dyke is settled and stabilised.

f) Key-trench

The construction of the key trench may be taken up if the black puddle clay is available while excavating the pond. It will not be economic to carry black clay from some other place. The key trench will be excavated along the toe line of the dyke and subsequently it will be filled up by the black clay available from the pond excavation. The key trench will taper downwards. After filling the clay in the trench it should be rammed well so that the soil is well compacted to give a good resistance to the burrowing animals.

g) Silt trap

Siltation is an enormous problem in the estuaries of lower Sunderbans. Suspended silt load carried by the tidal water to the pond and impounded there are deposited in the pond bottom in the time interval between two successive spring tides. Thus the depth of the pond decreases rapidly causing a constant reduction of water-holding capacity of the pond and affecting the water management system. This menace can be fought to certain extent by building silt trap.

Silt traps are large water tanks encompassed by the earthen dykes and it is built in the mouth of the feeder canal. Silt laden water from the main river or creek are taken in this tank and are allowed to settle down at the bottom of the tank and silt-free water from the surface is allowed to enter the farm through the feeder canal.

But this system has got certain limitations and are not always practicable due to the following reasons.

i) For a big commercial fish farm a very big silt trap will have to be constructed to supply silt-free water to the farm. And the area of the silt trap is needed to be almost equal to the farm area. This will be a huge additional expenditure and besides that so much land may not be available to accommodated this silt trap.

ii) The silt deposited at the bottom of the silt trap will have to be cut and removed regularly and cost of removing this silt will be no less than the cost of desilting of the main farm.

## D. Maintenance and operation of the farm

Periodical maintenance of the farm should be done to keep the farm dykes and ponds in good shape. Desiltation of the pond bed and redressing of the dykes should be carried out either every year or once in two years just after the monsoon is over.

Where the water carries heavy amount of suspended silt the rapid siltation in the feeder canal and pond bottom may appreciably reduce the efficiency of the farm. One of the most effective method to fight out this problem is to scientificially plan the intake of water.

Regular observations have been conducted on the silt concentration in the tidal water in the estuary of lower Sunderban and it has been observed that the silt load concentration in the water varies with the change in tidal phase. It has been also observed that the upper surface of the water contains less silt than the bottom surface. By statistical analysis it is inferred that the variation of silt load in respect of tidal time follows a second degree polynominal (Sengupta and Roy, 1980, MS). The fitted regression for the silt load at surface and bottom in Kakdwip canal near the sluice mouth of the Kakdwip fish farm has been found to follow approximately the curves of following nature respectively :

$$Y = 5.55062 - 0.042688\ X + 0.000012\ X^2$$

$$Y = 5.096588 - .046404\ X + 0.100136\ X^2$$

Where Y is estimated silt concentration in g/litre and X is the tidal time in minutes from the start of tide.

From this two curves it is evident that the minimum silt load occurs approximately after three hours from the start of the tide. The tide reaches its peak after four hours. From this it is evident that silt ingress can be minimised if water is allowed to enter the farm around the peak hours of the tide instead of taking water from the imitiation of the tide which is the traditional practice in brackishwater farming. The exact timing and duration of taking water can be calculated from the earlier formula of discharge. Though the above equations are strictly applicable for a particular site a broad idea about siltation phenomena is available from it and appropriate equation can be established for other sites also to corelate the silt concentration with tidal time.

Heavy amount of silt will also be deposited due to the dyke washing. Ponds should be drained off and silt should be left exposed to the sun for drying. On being dried the silt will crack and form cakes which can be lifted conveniently.

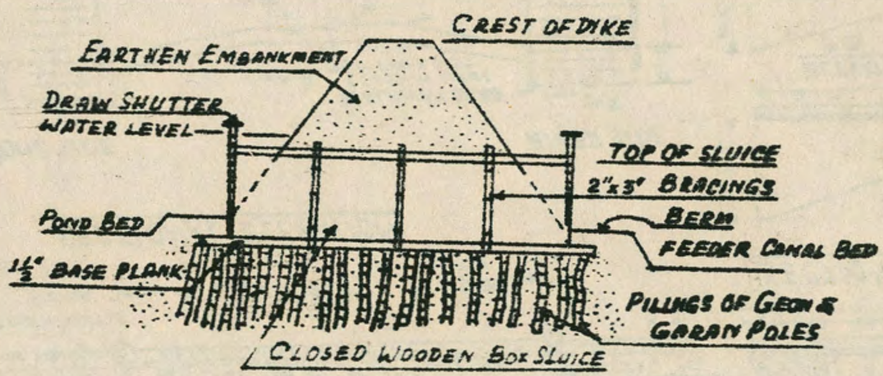
Slip may sometimes occurs due to the oversaturation of the soil near base of the dyke or embankment. The chance is more when the pond will be dewatered. When a slip has occured all slipped portion and loose slushy stuff must be removed and replaced by fresh dry material added layer by layer to proper slope.

If the water flowing through a leak is sluggish and clear it may be seepage water and there is not any immediate danger but a muddy water flowing with some force shows that the soil particles are being washed away and needs immediate attention. Correct location of the hole or the both sides of the embankment is essential which may not always be perpendicular to the embankment.

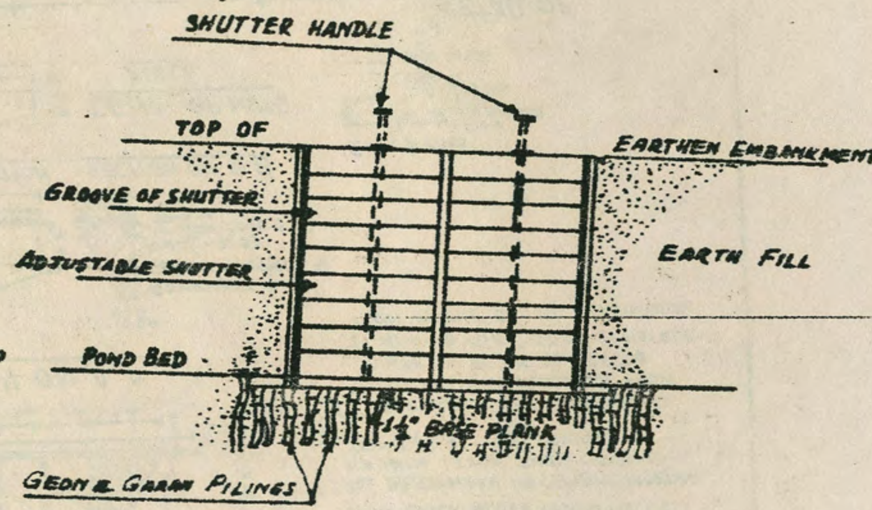
Instead of minor leakages sometimes there may be major breaches in the dykes. This may be very dangerous during the high tide of September and October when the wind velocity is high and tidal rise is also maximum.

In such exigencies two end of the breached portions should be protected to prevent further widening by a semicircular bundh constructed with bamboo mattresses and sandbags and water is bailed out from within. Then earth is dumped on the breached portion.

The subsidiary wooden sluices should preferably be painted with coaltar every year which will protect the sluice from weathering action or from the attack of barnacles.

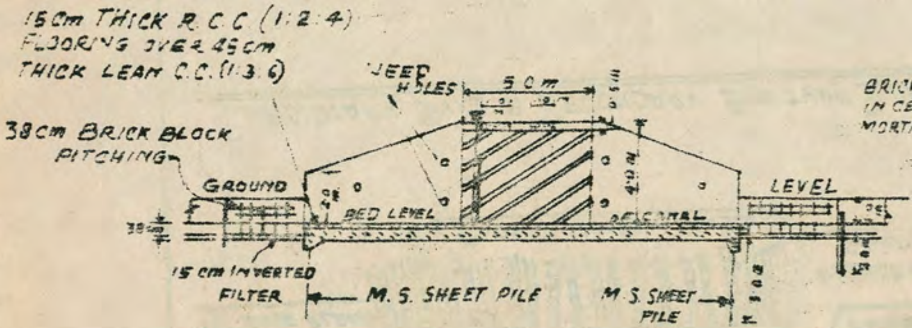



SUBSIDIARY DYKE & SECONDARY BOX TYPE SLUICE

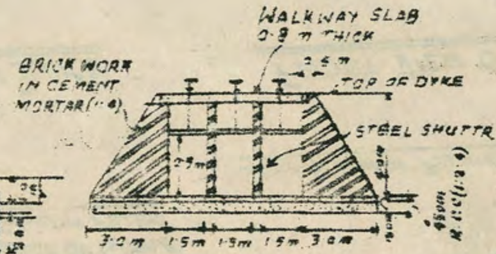



FRONT VIEW OF OPEN SLUICE

# DETAILS OF THE MAIN SLUICE STRUCTURE FOR THE PROPOSED BRACKISHWATER FISH FARM AT HENRY'S ISLAND



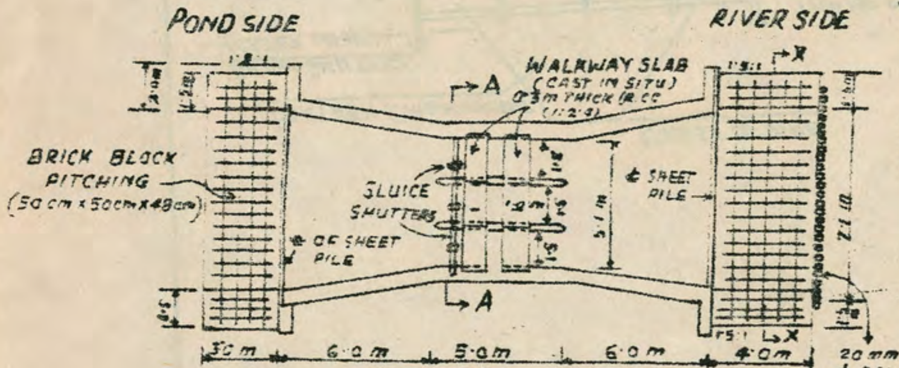

SECTIONAL ELEVATION



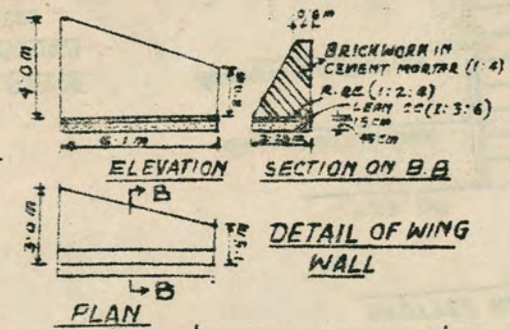

SECTION ON A.A.

**DESIGN CONSIDERATIONS:-**

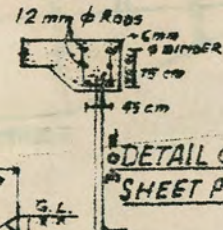
1) STANDING WATER HEAD IN POND 1.0 m
2) EXIT GRADIENT 1 IN 6
3) SILT FACTOR FOR VERY FINE SILT 0.33
4) DEPTH OF FEEDER CANAL 1.0 m
5) SIDE SLOPE OF THE INVERTED FILTER WITH BRICK BLOCK PITCHING 1.5:1
6) ALL BRICKWORK IN CEMENT MORTAR 1:4 WITH 13 mm THICK CEMENT SAND (1:4) PLASTERING.
7) CREST WIDTH OF THE MARGINAL DYKE HAS BEEN REDUCED FROM 10 m TO 5 m AT THE SLUICE TO MINIMISE THE COST OF CONSTRUCTION OF THE SLUICE STRUCTURE.



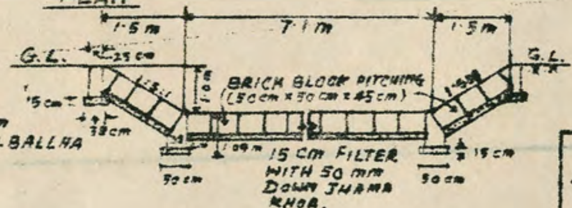

PLAN




DETAIL OF WING WALL




DETAIL OF SHEET PILE




SECTION ON X.X.

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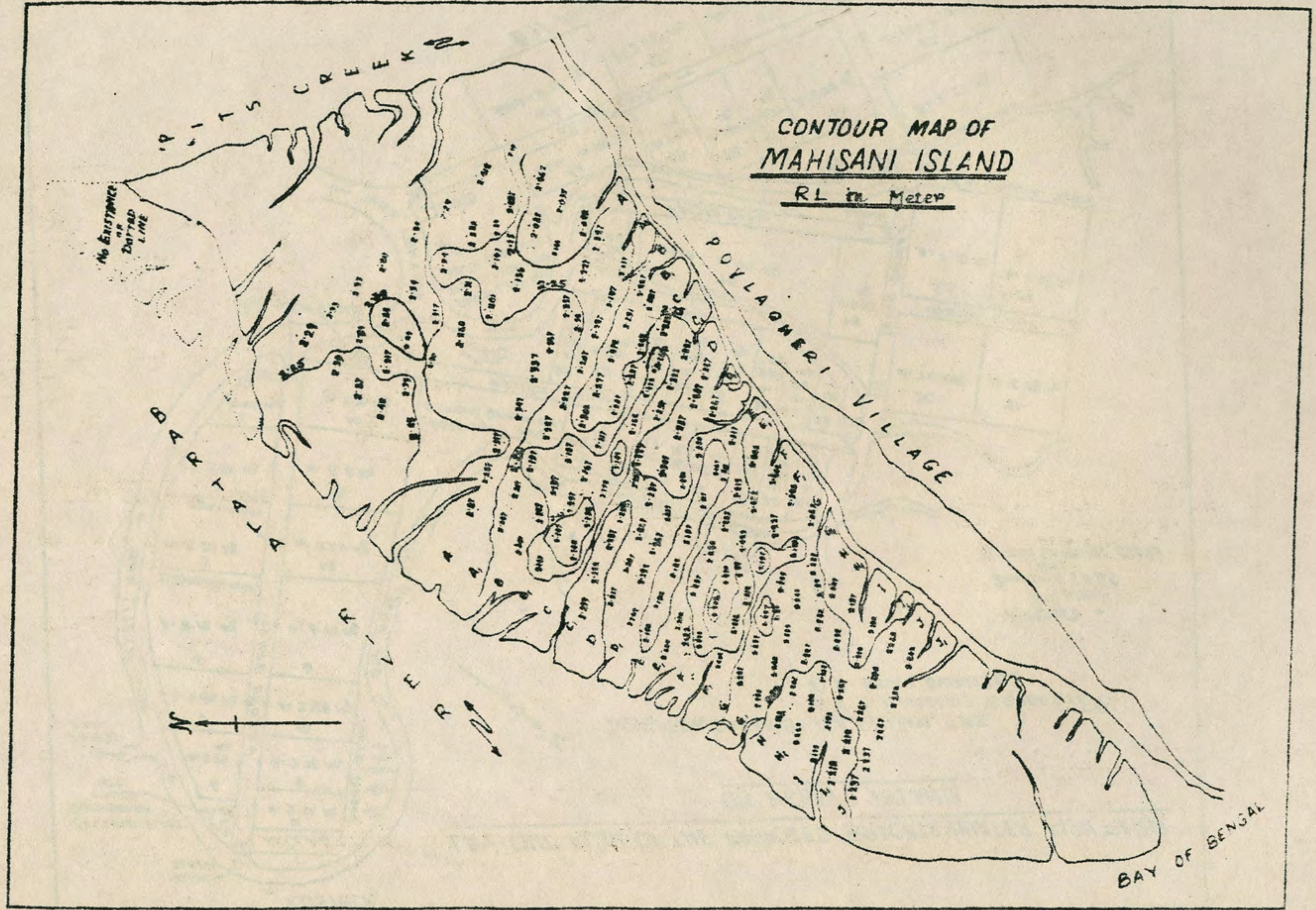
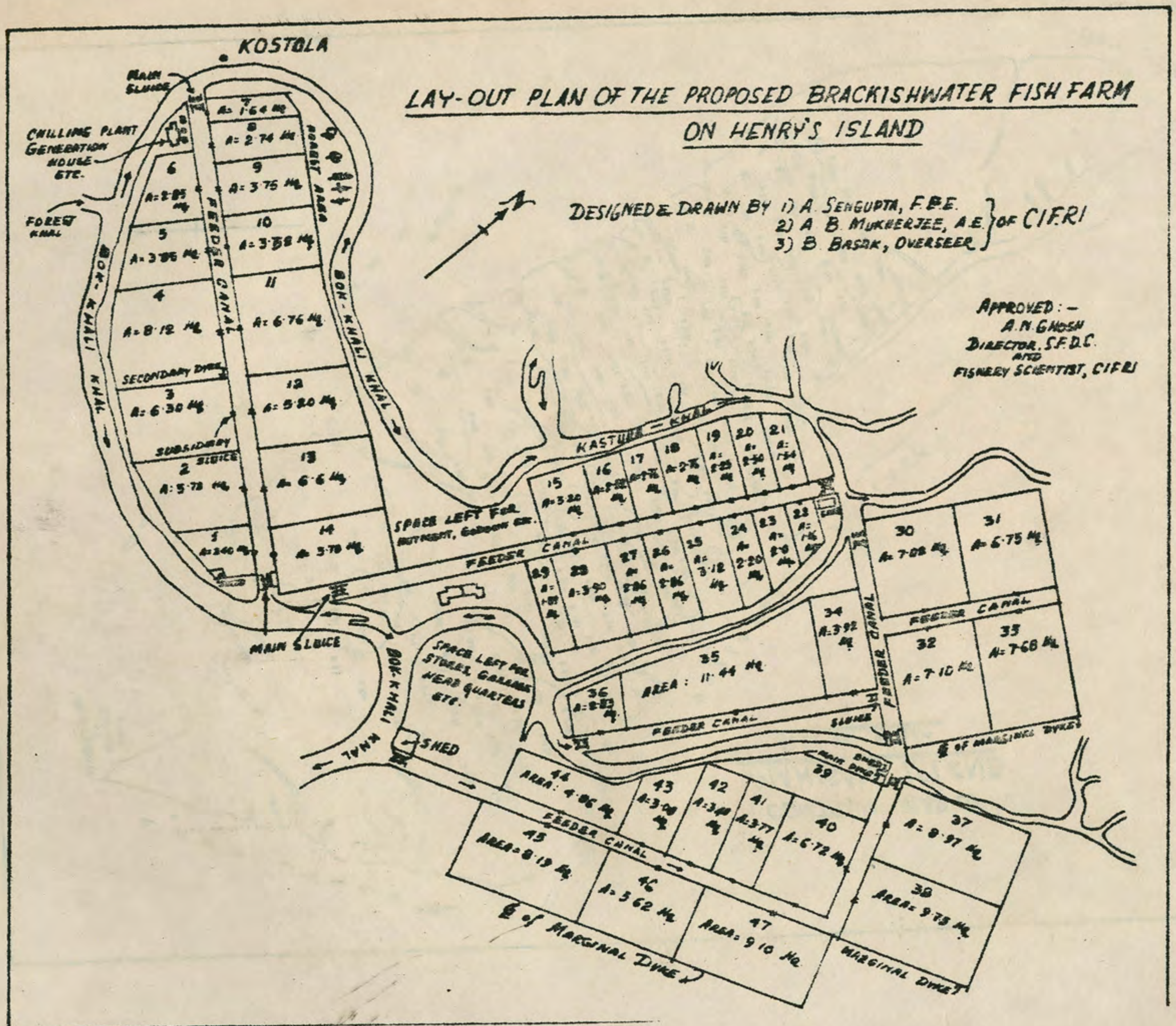


CONTOUR MAP OF
MAHISANI ISLAND
RL in Meter
PITS CREEK
POYLAGHERI VILLAGE
BARTALA RIVER
BAY OF BENGAL
NO EXISTANCE OF DOTTED LINE
N


LAY-OUT PLAN OF THE PROPOSED BRACKISHWATER FISH FARM
ON HENRY'S ISLAND
DESIGNED & DRAWN BY 1) A. SENGUPTA, F.B.E.
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FISHERY SCIENTIST, CIFRI
KOSTOLA
MAIN SLUICE
CHILLING PLANT GENERATION HOUSE ETC.
FOREST KHAL
BOK-KHALI KHAL
FEEDER CANAL
SECONDARY DYKE
SUBSIDIARY SLUICE
KASTURI-KHAL
SPACE LEFT FOR HUTMENT, GODOWN ETC.
SPACE LEFT FOR STORES, GARAGE, HEAD QUARTERS ETC.
SHED
AREA: 11·44 Ha
MARGINAL DYKE