CERTIFICATION

MOHAMMED, Sani A. Bakeko, a Postgraduate Diploma Student in the Department of Agricultural Engineering with Reg. No. PGD/AGRIC/60/98/99 has satisfactorily completed the requirements for the course and Project works for the award of Postgraduate Diploma (PGD) in Agricultural Engineering.

The work embodied in this project is original and has not been submitted in part or full for any other diploma or degree of this or any other University.

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DEDICATION

To Nigerian peasant farmers who despite less Government encouragement still feed the Nation.

DESIGN OF HYDRAULIC STRUCTURES FOR A SMALL- SCALE FADAMA STREAM DIVERSION IRRIGATION SCHEME AT ZUKUCHI-NIGER STATE

BY

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ABSTRACT

Small scale stream diversion irrigation scheme design is an integrated aspect involving data collection, collation, leveling, crop water requirement computation and design of a water control system comprising canals, water control structures, pipe outlets, drains, head-dyke and embankments.

Trapezoidal canal cross section having discharge capacity of $0.49m^3/s$, canal water control structure of the same discharge and pipe outlet of 9.39l/s are designed. The design of head dyke having crest discharge of $1.30m^3/s$ apron length of 2m, wing wall of 2m and embankment with top width of 2m is also presented. Also a drain of $1.66\ m^3/s$ was designed and methods of on farmland preparation are suggested.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Fadama is a Hausa word meaning low-lying area that is susceptible to seasonal flooding. In effect fadama are river flood plains or swamps. Water is often available in these flood plains/Fadama through the dry season either as flow in the river, ponds in the river channel or saturated sands close to the surface. In northern part of Nigeria this water has been used for many centuries for irrigation of small garden plots.

Traditional irrigation schemes built and operated by small holders farmers have existed since pre-colonial times for rice production. In addition, Shadouf (traditional method of irrigation) was practiced along river courses or with wells in various areas of the north, mainly for vegetables cultivation and wheat. Spontaneous development of traditional irrigation was at considerable pace without much government participation. In most cases these schemes are technically defective.

Importance of the contribution of these traditional schemes to the nation's food supply cannot be overstressed. There is increasing demand for its products from urban centers, possibly due to rapid growth of urban centers as a result of rural-urban drift. This situation motivated the government to provide technical assistance for improvement to the farming communities purposely to increase their output. The technical assistance includes improving agricultural practices, better control of the water flow and increases the area under irrigation.

For more details, the assistance are provided in either of the following forms:

(i) Provision of the water pumps to replace Shadouf for direct pumping from perennial source of water at surface (pond or stream) on credit basis.

(ii) Exploitation of shallow ground water aquifers of the fadama areas by constructing small diameter tube wells and using water pumps to lift water for irrigation, and

(iii) Improvement on the development of small-scale river diversion irrigation method.

This report concentrates on the design of river/stream diversion method of irrigation at Zukuchi scheme in Niger State. This river diversion method delivered water to the field through irrigation canals under the gravitational effect. It consists of a water control system comprising the following main features; head-dyke, canals, gates, embankments, pipe outlets and drains.

1.2 STATEMENT OF PROBLEM

The following are the major problems observed at the scheme that necessitated its improvement:

(a) ***Poor field water management***-uncontrolled flows of water and unlevelled field create problems that hinder uniform water application.

(b) ***Reduced potential cultivable area*** –because of unlevelled field, the water flows on the lower spots being unable to supply the edges.

(c) ***Restriction to specific crop variety***-since field water management is a problem; farmers are limited to specific variety of crop (rice) against high yielding varieties that requires more water and of high fertilizer response.

1.3 OBJECTIVES OF THE STUDY

(a) To improve the field water management

(b) To increase the potential cultivable area

(c) To improve the agricultural practices

1.4 IMPORTANCE OF THE STUDY

The development of the scheme shall ensure the followings:

(a) Effective field water flow control system

(b) Increased potential area of cultivation

(c) Facilitating the adoption of better agricultural production technologies.

CHAPTER TWO

2.0 LITERATURE REVIEW

The interest to develop irrigated agriculture is not limited to Nigeria, not even to the third world countries. Between 1950 and 1980, there was more or less a threefold increase in the total area or irrigated agriculture throughout the world (Cernia, 1985). If there was any increase in food production at all, particularly in the third world countries, such an increase has been closely linked with the expansion of irrigated land. However, the development of new high-yielding varieties as well as agricultural inputs cannot be ignored. India, Indonesia, Pakistan, Philippines, Sri-Lanka, Thailand are examples of areas where irrigated agriculture has thrived and quite successfully too (Dhawan, 1988; Chambers, 1988;)

The growth of irrigation contributed between 50% and 60% of the massive increase in agriculture output of the developing countries from 1960 to 1980 (Ladan, 1998). Interest in expanding irrigation is shown not only by host countries, international financial organizations too have made significant inputs to developing irrigated agriculture. For example, the World Bank recorded that between 1947 and 1985, $11 billion were given to foster irrigation and drainage schemes in developing countries. Another $7.5 billion was also given out as loans to finance area development projects, which on most occasions included significant irrigation project (Ladan, 1998). Of all the loans issued by the Asian Development Bank in the 1970s, 13% were closely related to irrigation project (Ladan, 1998).

Though these irrigation projects were considered as being successful schemes in their own right they were still faced with serious management related problems. This observation is correct because ' many large – scale irrigation project have not been sustainable in the sense that the net flow of benefits after the projects were completed did not exceed the net costs " (Ladan, 1998). Economic sustainability can be determined by assessing whether the economic rate of return is equal to, and if possible greater then the opportunity cost of capital (Cernia, 1987). Using this standard International bank for Rural Development (I B R D) discovered 1985 that many large-scale irrigation projects have generated "Disappointing operational results".

The short review of irrigation schemes performance is relevant to the study of Nigeria large irrigation schemes. The series of drought years that hit the sahelian zone, including northern Nigeria, in the early seventies, has induced governments in the afflicted area to broaden the drought – proof production base through in increased emphasis on irrigated agriculture. The national development plan of Nigeria (1975 to 1980) reflected this new preoccupation with protection against droughts (World Rank Report, 1979). As it happens, the crops that commonly grown under irrigation also the food stuffs that feature most prominently in Nigeria import bill, namely wheat, sugar and rice. The Nigeria Government placed emphasis on curbing import by increased domestic production of these commodities. This importance of irrigation lead to the creation of a separate federal ministry of water resources in 1975 and the creation of eleven River Basin Authorities (RBDA) covering the entire country.

While in the fifties and sixties, Government intervention in irrigation was limited to the construction and operation of small schemes (mostly well below 1000ha).

A series of ambitious and large-scale projects were stated in the early seventies, often without adequate preparation .The problems encountered by the large irrigation were summarized as follows (World Bank Report, 1979):

1. Very high development cost per ha.
2. Changes in design were required in several cases during or following the construction of the main irrigation infrastructure.
3. Problems related to faulty irrigation layout and on farm development (e.g. large levelling problem).
4. The need to mechanized farm operation on some project areas with sparse farm populations.
5. The high percentage of light texture and permeable soils reduce the scope for the cultivation of high value crops like rice and wheat in favour of less demanding crops that can be grown under rainfed condition such as sorghum, groundnuts and cowpeas.

The economical evaluation studies on these projects by World Bank in 1979 indicated low economic return. At this juncture the Federal Government of Nigeria based on this study was advised to consolidate on the developed irrigation project rather than embark on second phase of the existing projects or even new large-scale irrigation projects.

As from there on the Nigeria Government shifted its emphasis to small-scale irrigation development. According to preliminary estimates these small – scale projects have potential of 8,000 ha. in 1978.this is far from being exhausted and could be extended to reach two million ha ultimately. The potential use of fadama and swamp lands is not only determined by physical factors such as soil quality and water management but also by factors such as customary land titles and tenure, availability of labour and allocation of labour between rainfed and irrigation field crops. The system of land tenure, in particular the security of acquired and improved land is an important factor determining the degree of self – help farmers will offers. The amount of self – help that can be mobilized has a profound impact on project design, construction method, and above all, fiscal cost of projects (World Bank Report, 1979). This type of traditional small – scale irrigation development depends on readily available water resources in the form of rainfall, runoff and natural ground storage.

The Guinea savannah zone in which Niger State lies is characterize by isolated swamps fed by rainfall only, narrow riverine swamps and large alluvial fadamas flooded annually by rivers. The narrow river valleys are mostly small and interconnected and drain into the larger river systems. The type of water management required for the narrow riverine swamps entails some drainage, water retention, temporary storage and redistribution of the runoff over areas wider than those normally inundated by the stream during the wet season. The purpose of this work is to advance planting dates by early irrigation, and to provide supplementary irrigation during dry spells of the wet season. An additional benefit to be derived from the construction of small reservoir for storage of run off in the upper parts of the catchments is recharge of shallow ground water tables. Utilization of this ground water for dry season crops could be achieved by making use of residual soil moisture and capillary rise around the reservoir and by small-scale irrigation from shallow wells, further down stream, (Savvides, 1981).

These irrigation systems emphasize low – cost construction methods and simplicity of operation and maintenance. Construction method is based on appropriate technology using as much as possible locally available materials, which ensure proper feature maintenance (Word Bank Report, 1979). The cost of this small irrigation works depends very much on the designs, the quality of construction and on farm development work that can be left to farmers. Costs estimate given for small-scale gravity irrigation ranges from ₦ 1500 to ₦ 2,500 per ha (Abakaliki, Bida, 1980). With a reasonable amount of water control average yield of rice grown in these schemes ranges from 3 to 4 t / ha if other in puts such as improved seed and fertilizer are available (World Bank Report, 1979) also other crops such as maize, cassava and vegetables are grown in these schemes.

CHAPTER THREE

3.0 THE STUDY AREA

3.1 LOCATION AND GENERAL DESCRIPTION

The project area is located in Shiroro Local Government Area of Niger State. The scheme is located about 18km north east of Kuta on the Kuta to Gurmana road. Kuta is the headquarters of Shiroro Local Government Area, about 58km away from Minna, Capital of Niger State of Nigeria.

The site is a strip of land along both sides of Zukuchi stream (valley). The site has potential area of 20ha for irrigation but presently only 7ha could be cultivated for rice crop.

3.2 TOPOGRAPHY OF THE STUDY AREA

The land surface of the project area is relatively flat in most parts with undulation in some area. The elevation varies from 900.00m to998.00m above mean sea level.Seefig.7 for the topographical map.

3.3 CLIMATE OF THE STUDY AREA

The climate of the project area is characterized by distinct wet and dry season. The wet season generally lasts from April to October. The dry season, which for a period, is marked by harmattan conditions prevailing for several days lasts from October to March.

The vegetation of the area consists mainly of savannah. According to Keays classification indicated in the Agro-climatologically Atlas of Northern states of Nigeria, the project area belongs to the southern Guinea Zone type or transition woodland.

During the wet season and tempered heat, favourable conditions exist for a certain range of crops to be grown during 6 months between April to October. The dry season from October to April accompanied by high temperatures growing possibilities decreases considerable except for certain hot season crops. The monthly rainfall, mean monthly daily temperature and relative humidity are presented in appendix A

3.4 HYDROLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The scheme is fed by Zukuchi stream, which drains to river Kaduna. This stream is an intermittent stream, which flows during the wet season but dries up during the season of drought. The stream has catchments area of about 40ha from the position selected for head-dyke construction. The stream can only sustains supplementary irrigation during and towards the end of wet season (October to December).

The fadama site lie entirely on the crystalline basement complex of Nigeria (Geological map of Nigeria, 1974). Granites found around the project area seen in their characteristic light colour and coarse to medium grained sizes. The stream flow in this type of formation is related to the rains (amount and timing) and big floods may be expected when intensive rain occurs.

3.5 FADAMA FORMATION

The formation of fadama (or swamps) is a combination of water flowing in the stream and the developed seepages along the sides of the valley. Both water flowing and seepages result in rising the water table of the entire valley up to the soil surface and situation will remain as such, until both factors will cease to exist. The upper weathered formation develops sandy soil on top, causing high rate of infiltration. At certain depth this formation is impervious, the absorbed rain water does not move vertically but after saturating the upper permeable layers it moves laterally towards the natural gradient i.e. valleys.

Depending upon the storage capacity of the strata over the impermeable layer, the transmissivity of water through the swamps may last for a short or longer period.

3.4 SOILS OF THE STUDY AREA

The soils of the site are mostly medium textured and consist of high clay content thereby making infiltration rate very slow such soil is best suitable for rice growth though other crops such as sugarcane and vegetables can also be grown. Soil texture analysis report is attached as appendix B.

CHAPTER FOUR

4.0 METHODOLOGY AND PROCEDURE

4.1 MAIN FEATURES OF A WATER CONTROL SYSTEM

The concept of a water control system is to prevent the fadama to be flooded. The water should be controlled and directed to the field whenever it is required. Big floods should be taken away through a floodway (drain) and every field should have access in both the water supply and the drain system.

The prevention of water to flood the area is succeeded by constructing a head-dyke in a suitable site across the swamp. Two peripheral canals constructed along the edges (sides) of the swamp will supply water to the entire field through special outlets. A drain excavated in the middle of the swamp will take care of the peak flows and of the water draining from the paddies. The sketch of the layout system is included as appendix D, fig. 1

4.2 DESIGN OF CANALS

The main canals are located at the periphery of the fadama and on the higher elevation than the fields to be irrigated. Topography survey of the site was conducted to determine the canal location and alignment.

4.2.1 CANAL CAPACITY

The canals are designed to carry enough water to satisfy the crop water requirements, the losses due to deep percolation and evaporation within the canal, deep percolation in the paddies, water consumption by the weeds and management losses.

4.2.2 DESIGN CALCULATIONS;

DESIGN DATA

Major crop - rice

Area - 20 ha

Computed crop water requirement (CWR) during peak water requirement (rice) is 9.2mm/day (see appendix E).

Effective rooting depth (Varshney et al, 1982) – 0.6m.

Soil type of the field – clay loom .

Available water holding capacity of clay loam (FAO 24,1984) – 150 mm/m

Readily available soil water, that is fraction of total available soil water permitting unrestricted evatopotranspiration and/or crop growth (rice) = 0.40

Application efficiency (Ea) (FAO 24,1984)= 0.58

Depth of irrigation application (d) including application losses is calculate as follows (FAO 24, 1984)

$$d = \frac{(pSa).D}{Ea} \quad mm \text{ -} (1)$$

Where d = depth of irrigation application, mm.

p = fraction of available soil water permitting unrestricted evapotranspiration, fraction.

Sa = total available soil water mm/m soil depth.

D = rooting depth, m.

Ea = application efficiency, fraction

$$\therefore \quad d = \frac{0.40x150x0.60}{0.58} = 62mm$$

Frequency of irrigation (fi) is; $(fi) = \frac{(p.Sa)D}{ETc} \quad days --- (2)$

Where ETc = crop evatopotranspiration in mm.

$$\therefore \; fi = \frac{0.4x150x0.60}{9.2} = 3.9 \Rightarrow 4days$$

Volume of water (V) required for each irrigation of the 20 ha field calculated using this formula, (FAO 24, 1984)

$$V = q.t = \frac{10}{Ea}(p.Sa).D.A., m^3 ------------------(3)$$

Where; V = Volume of water. m^3

q = stream size, m^3/s

t = supply duration, seconds

A = acreage, ha

$$V = \frac{10}{0.58} \; x0.40x150x0.60x20$$

$= 12413.79m^3 - = 12414\ m^3$

The soil in filtration rate (Varshney &Gupta, 1982) for clay loam ranges from 6 to 8 mm/hr as such 7mm/hr is used.

Time of irrigation application (Afzal, 1978) :

$$Ti = \frac{di}{si} \quad hour ----(4)$$

Where Ti = time application in hour

di = depth of irrigation application in mm

si = soil intake rate, mm/h

$$Ti = \frac{62}{7} = 8.86hr$$

Considering the basin method of water application, FAO 24, (1984) suggests that the water should be applied within 40% of the time necessary for the required depth of water to enter the soil. As such the time of irrigation application then will be

8.86 x 0.4 = 3.54 hr

Required stream size (q) = $\frac{V}{Ti}$ m^3/s -------------------------(5)

$$q = \frac{12414}{3.54x3600} = 0.97m^3/s$$

Since the q will be supplied by the two peripheral canals then designed

$$q = \frac{0.97}{2} = 0.49m^3/s$$

Channel Cross Sectional Design:

Considering roughness of coefficient (n) for earth, and straight and uniform channel to be 0.03 (Vipond and Stanly, 1974),

Channel side slope (Z) = 1.5: 1 for clay loam and

Design bed slope (S) = 0.002,

The channel cross-section can be designed using the equation 6 for non-erodable uniform flow.

$$\frac{Qn}{S^{1/2}} = AR^{2/3} \text{ -------------------- (6)}$$

Where Q = the design stream size in m^3/s

n = roughness of coefficient

S = channel bed slope, fraction

A = channel cross sectional area, m^2

R = hydraulic radius, in m

For trapezoidal cross section

$$A = (b + zd)\ d \qquad m^2 \text{ ---(7)}$$

$$P = b + 2d\ \sqrt{z^2 + 1} \qquad m \text{ ---(8)}$$

$$R = \frac{A}{P} = \frac{(b + zd)d}{b + 2d\sqrt{z^2 + 1}} \qquad m \text{ ---(9)}$$

Where A as in equation 6

b = channel bottom width, m

d = channel water depth, m

Z = channel side slope,

p = wetted perimeter of the channel, m

R =Hydraulic radius, m

$$\text{Hence } AR^{2/3} = \frac{[(b + zd)d]^{5/3}}{[b + (2d\sqrt{z^2 + 1})]^{2/3}} \text{ ------------ (10)}$$

After a series of trial and error, the following values were designed;

Bottom width (b) = 0.45m

Depth of flow (d) =0.56m

Substituting these values into the equation (10)

$$\frac{[(0.45 + 1.5 \times 0.56)0.56]^{5/3}}{[0.45 + (2 \times 0.56 \times \sqrt{1.5^2 + 1})]^{2/3}} = 0.32$$

While $\frac{Qn}{s^{1/2}} = \frac{0.49 \times 0.03}{0.002^{1/2}} = 0.32$

Therefore,

$$\frac{Qn}{s^{1/2}} = AR^{2/3}$$

To provide allowance for freeboard (F) is determined using the formula in equation (11), (Vipond and Stanly 1974)

F=cy---(11)

Where F = the freeboard, m

c = a coefficient, 0.46 for canals up to $0.7\,m^3/s$

y = depth of water flow

$\therefore f = 0.46 \times 0.56 = 0.26m$

The channel depth (D) = d+f----------------------------(12)

Therefore, D = 0.56+0.26=0.82m

Channel top width (T) = b+2DZ, m-----------------------------(13)

Therefore T = 0.45+2 x 0.82 x1.5= 2.91m

4.2.3 CANAL WATER CONTROL STRUCTURE DESIGN

At the beginning of the canal, a water control structure is provided to prevent high flows and damages on the canal. A simple and contracted rectangular weir capacity is determined by use of the shutters. The weir capacity is determined by use of the equation (14) below (Afzal,1978)

$Q = 1.86\,(L\text{-}0.2H)H^{3/2}$---(14)

where Q = Flow rate, m^3/s

L = Length of weir crest, m

H = Head of water over the weir, m, = D of the channel

..erefore the length of weir crest can be determined from above equation (14) as

$$L = \left[\frac{Q}{1.86(H)^{3/2}}\right] + 0.2H \text{ ------------------------------ (15)}$$

The length of weir crest for the canal of 0.49m^3 /s and H of 0.82m will be

$$\therefore\ L = [\frac{0.49}{1.86(0.82)^{3/2}}] + 0.2 \times 0.82 = 0.52m$$

Refer to fig 3 for the water control structure sketch.

4.2.4 PIPE OUTLET DESIGN

Pipe outlets are installed in the canals at certain intervals in order to get water out of the canal to the field. The interval depends on the topography, nature of swamp and field boundaries. The pipe outlet is the simplest and cheapest and can operate with very small head. Selecting 7.62cm (3") diameter PVC pipe, the discharge flowing out freely can be determined using the equation (16) (Savvides, 1981).

$$Q = AC\sqrt{2gh} \text{ -- (16)}$$

Where Q = Discharge water, m^3/s

A = Cross sectional area of the pipe, m^2

g = Acceleration due to gravity equal to 9.81m/s^2

C = Coefficient of discharge (about 0.60)

H = pressure head over the centre of the pipe in m.

Therefore, the discharge (Q) in 7.62cm diameter pipe with estimated pressure head (h) of 0.6m is calculated as follows;

$$Q = \frac{\pi\ x\ 0.0762^2}{4}\ x\ 0.60\ x\sqrt{2x9.81x0.60}$$

$$= 9.39x10^{-3}\ m^3/s \ => 9.39\ l/s$$

4.3 HEAD DYKE DESIGN

Head dyke is a water control structure usually of a rectangular weir type structure usually of a rectangular weir type structure equipped with wooden shutters (planks) for regulating the water level behind the pool. It consists of crest, apron, cut-off and wings.

4.3.1 CREST DESIGN

A low crest level of a flux but a discharge per meter is proposed. The term afflux means the rise of water level at river up stream when obstruction (weir) is placed across the river. Effort was made to avoid too deep water over the crest, which may result in an increased height of gates, thickness of floor and cost of super structure above floor level. In view of this, the proposed height of water over the weir crest is 0.45m. The overall length of the weir can be determined using the given sharp crest weirs head-dyke formula in equation 17 (Varshney et al, 1982).

$$Q=1.84(L-0.1nH)\,H^{3/2} \text{---} (17)$$

Where Q=discharge of the stream flow, m^3/s

L=total clear water way, m

n= the number of end contractions

H=the head over the crest, m

Therefore

$$L=\left[\frac{Q}{1.84(H)^{3/2}}\right]+0.1nH \text{ ----------------------------------- } (18)$$

The stream flow discharge (Q) is determined based on run-off estimation of watershed of the stream calculated from topographical map (fig.7) and rainfall of the area as in appendix A, using equation (19)

Rational method of run-off estimation (Varshney et al, 1982)

$$Q = \frac{CIA}{36} \quad \text{--}(19)$$

Where Q= flood flow, m^3/s

C=dimensionless runoff coefficient

I= intensity of storm of design return period and duration equal to the time of concentration for the catchment concerned, cm/h

A= catchment area, ha.

The calculated data for determining the Q are as follows:

C= 0.36, A=40ha and I=3.25cm/h

$$\therefore \quad Q = \frac{0.36x3.25x40}{36} = 1.30m^3 / s,$$

Therefore length (L) of head-dyke is determined using the equation (18) considering Q of 1.30 m^3/s and H of 0.45m, assuming head-dyke of 2 bays and one pier. The calculated (L) value given below was obtained after series of trials and errors.

$$L = \left[\frac{1.30}{1.84(0.45)^{3/2}}\right] + 0.1x1x0.45$$

=2.385m => 2.40m

This indicates

2 bays of 1.2m each = 2.40m

1 pier at 0.50m =0.50m

Overall water way =2.90m

H=0.45 freeboard of 0.20 = 0.65m for construction. For further information see fig 4.

4.3.2 APRON AND CUT-OFF DESIGN

Apron is provided to protect the structure from erosion problems due to waterfall and the consequent damage on the structure. Furthermore, it gives stability to structure against over turning moments while cut-off protects the structure against underneath water piping and erosion and gives stability against upward pressure. Length of the apron is designed using the equation (20), (varshney et al 1982)

$$GE=\frac{H}{d}.\frac{1}{\pi\sqrt{\lambda}} \quad \text{--(20)}$$

Where GE = Exit gradient

H=maximum static head, m

d=downstream depth of cutoff, m

$$\therefore \quad \frac{1}{\pi\sqrt{\lambda}} = GE(d/H) \quad \text{--(21)}$$

Taking safe exit gradient (GE) = 1:7

Maximum static head (H) =0.45m

Depth of downstream cutoff (d)=0.30m

Using equation 21

$$\therefore \quad \frac{1}{\pi\sqrt{\lambda}} = \frac{1}{7} x \frac{0.3}{0.45} = 0.095$$

From Khosla's exit gradient curve (fig.8) α=21.05 for $\frac{1}{\pi\sqrt{\lambda}}$ of 0.095

Hence, the of apron floor (L) = αd---(22)

L=21.05x0.095=>2m

4.3.3 WING WALL AND EMBANKMENT

The purpose of providing a wing wall is to guide the flow of stream through the weir structure. Its length depends on the length of apron, which is 2m.

Embankment is provided to protect fadama area to be flooded and at the same time it forms a pool of water behind which create the head for water to flow in the canals designed in 4.2.1. The dimensions of the embankment designed are top width of 2m and side slope of 3:1. With this design of head-dyke is completed. For assessment of the stability of the designed head-dyke refer to appendix C, for analysis of forces acting on the head-dyke. Also for the designed head-dyke see fig 4.

4.3..4 DRAINAGE CANAL DESIGN

The purpose of the drain is to take care of the excess water during floods and take away drained or out flow from the paddies. The bed slope of the drain may follow the natural slope of the fadama or be designed including drain capacity such as:

1. Design peak flood, which is 1.30m^3/s
2. Drains from the paddies calculated using equation (19), C=0.40, I=3.24 and A=10ha

$$Q = \frac{0.40x3.24x10}{36} = 0.36m^3 / s$$

Therefore the drainage (Q) =1.30+0.36=1.66m^3/s

It was 10ha used in the above calculation based on the fact that 10ha close to the drain in the field must have drained away before the ones on the upper part will reach.

The channel cross section is designed using non-erodible manning formula as in equation (6). Taking side slope (Z) of 1.5:1, bed slope S=0.02, roughness coefficient (n) of 0.03, the following dimension are designed after a series of trial and error.

Bottom width (b)	=0.40m
Water depth (d)	=0.60m
Freeboard (f)	=0.23m
Top width (T)	=2.2m
Channel depth (D)	=0.88m

To test using the equation (6), i.e. $Qn/S^{1/2}=AR^{2/3}$

$$Qn/S^{1/2} = \frac{1.69x0.03}{0.02^{1/2}} = 0.35$$

$$AR^{2/3} = \frac{[(b+2d)d]^{5/3}}{[b+(2d\sqrt{z^2+1})]^{2/3}}$$

Substituting above value of (b) and (d) to above formula:

$$\frac{[(0.40+1.5x0.60)0.60]}{[0.40+(2x0.60x\sqrt{1.5^2+1})]^{2/3}} = 0.35$$

CHAPTER FIVE

5.0 COST ANALYSIS

5.1 COST OF INFRASTRUCTURE CONSTRUCTION

The summary of the cost for construction of the designed infrastructure in the fedama is presented in table 1 using in-house labour (based on current rate of savvides, 1981).

TABLE 1 LABOUR COST:

S/No	Item Description	Unit	Quantity	Unit Price ₦	Total Price ₦
1	Canal alignment	Man-day	20	200	4,000.00
2	Canal excavation	Man-day	40	200	8,000.00
3	Canal control structure	Man-day	5	200	1,000.00
4	Drain alignment	Man-day	10	200	2,000.00
5	Drain excavation	Man-day	40	200	8,000.00
6	Canal pipe outlet	Man-day	40	200	8,000.00
7	Head-dyke excavation	Man-day	10	200	2,000.00
8	Head-dyke Construction	Man-day	130	200	26,000.00
9	Embankment Compaction	Man-day	20	200	4,000.00
SUB TOTAL					**63,000.00**

ABLE 2 **MATERIAL COST**

Total volume of concrete = $9.302m^3$. concrete ratio = 1:2:4 that is cement, sand, and gravel.

S/No	Item Description	Unit	Quantity	Unit price ₦	Total cost ₦
1	Cement (Portland)	Bags (50kg)	55	650	35,750.00
2	Gravel	M^3	75	500	37,500.00
3	Sharp sand	M^3	40	240	9,600.00
4	Wood 2"x2"x12'	No	15	100	1,500.00
5	Plank1''x2''x12' soft	No	15	250	3,750.00
6	Plank1''x2''x12' hard	No	5	350	1,750.00
7	Nail 4''	Ib	10	40	400.00
8	Nail 3''	Ib	10	40	400.00
	SUB TOTAL				90,650.00
	GRAND TOTAL				**128,450.00**

5.2 ANALYSIS OF ANNUAL EXPECTED1 RETURN FROM 20 HA. FADAMA

5.2.1 **YIELD**: Shiawoya et al 1985 reported that farmers are able to raise yield from 1.5 to 2.8 t/ha. from improved fadamas.

: Expected yield (20 ha) = 2.8 X 20 = 56t

1999 ADP market survey, paddy rice, was ₦50, 000/ t = ₦ 2,800,000

therefore 56t will be 56x50,000= **₦ 2,800,000.00**

5.2.2 COST OF PRODUCTION (RICE) PER HA. (Source: from Kuta ADP zonal office 1999).

1. Land preparation including basin construction ...₦ 6,000.00
2. Seed 40kg @ ₦50/kg..₦2, 000.00
3. Planting 4 labourers @ ₦300..............................₦1, 200.00
4. Herbicide application/weeding...........................₦ 4, 000.00
5. Fertilizer 8 bags of NPK @1200.........................₦ 9,600.00
6. Fertilizer application 2 laborers @300..............₦ 600.00
7. Irrigation application 11 man-days @ 300...........₦ 3, 300.00
8. Harvesting 5 laborers @ 300..............................₦ 1, 500.00
9. Threshing 5 laborers @ 300...............................₦ 1, 500.00
10. Winnowing 4 laborers @ 300.............................₦ 1, 200.00
11. Bagging 48 bags @ ₦40......................................₦1,920.00
12. Labour for bagging 2 @ 300...............................₦600.00
13. Transportation (lump)..₦5000.00
14. Supervision lump..₦ 5000.00

TOTAL COST...₦43, 420.00

:.Total cost of production for 20 ha. = ₦868, 400.00

From above, the annual return from the fadama exceeds total cost of infrastructure and cost of production **(₦1,022,080.00)** as such it can be suggested that it is a viable project.

CHAPTER SIX

6. RESULTS AND DISCUSSIONS

6.1 OBSERVED PROBLEMS AT THE FADAMA

The field investigation carried out shows that the farmers are encountering the following problems at the fadama.

1. The planting time depends on the water conditions. When the flow is too little, it runs in the existing course of the stream or in the lower parts of the fadama. This makes impossible the planting of entire area at this stage. By the time that all the fadama is covered by water, the flow is increased considerably in short time and farmers are unable to plant the rest of the swamp due to high level of water. They have to wait until the water depth is reduced to the proper levels. However, as time goes on it may be too late to plant and if they proceed to plant, the water may be reduced considerably and insufficient to meet the demand at the growth stages.
2. Due to lack of water control, the benefits of fertilizer and herbicide application are not derived as most of the time they are often washed off by flood.
3. Poor crop performance was observed especially around the edges of the fadama where water could not reach and the crop suffers from water shortage.
4. As the water depth in the fadama varies considerably and no control of water, adoption of improved high yielding varieties that require certain control level of water becomes difficult. Farmers are therefore restricted to specific varieties that are low yielding.
5. Due to lack of control of water flow, the cultivation is restricted to the immediate narrow strips of fadamas along the stream thereby abandoning a reasonable size of potential cultivable area.

6.2 DESIGNED FEATURES

6.2.1 IRRIGATION CANALS

The scheme is designed with two peripheral canals. Each has discharge capacity of 0.49 m^3/s capable of irrigating 5ha paddy field (10ha for the 2 canals), within irrigation period of 3.54hours.The designed parameters and dimensions of the canal are as follows; manning coefficient (n) 0.03, channel bed slope (S) 0.002, side slope (Z) 1.5:1, total channel depth (D) 0.82m, bottom width (b) 0.45m and top width (T) 2.90m.

Canal water control structure comprising rectangular weir device and shutter, and pipe outlets were incorporated into the canals for regulating the flow in the canal and to deliver water to the field respectively.

6.2.2 HEAD DYKE

Designed head-dyke has two bays of 1.30m wide, capable of over-spilling 1.30m^3/s flood and impound the stream flow if the shutters are closed to a level of 0.45m high above its normal level. This impounded water level provides adequate head for water to flow into the canals to the field safely without erosion hazard.

Apron, cut-off, stilling basin, wings and embankments are designed accordingly to protect the head-dyke.

Drainage canal was also designed with discharge capacity of 1.69m^3/s to collect and dispose excess water from the paddy and overlie watershed.

6.3 SYSTEM OF OPERATION

The irrigation system designed can be operated with a rotational supply system to irrigate 10ha field per shift. Two shifts are required to complete irrigation of the entire project area for a period of 3.54 hours. Also, continuous supply of the system can be used to irrigate the field for a period of 7 hours. Frequency of irrigation is 4 days with 36mm net depth of water application. The field will be irrigated using basin application method.

The field is to be prepared by contouring the basin where necessary so that during irrigation upper reach basin overtop is to supply down one and the excess overflow to the drain.

6.4 SOLUTION TO THE OBSERVED FIELD PROBLEMS

If the designed irrigation scheme is developed, it will assist solving enumerated problems in section 6.1 as follows:

1. With a water control system, the farmers can control the water and direct it to the field whenever it is required. It will therefore enable him plant on schedule whether the stream flow is low or high.
2. The water control system in the fadama will enhance efficient fertilizer and herbicides application. At the time of the fertilizer and herbicide application, the water flow into the field can be controlled to facilitate absorption of the chemical into the ground before it is washed off by flood.
3. As each basin will be levelled, it will ensure uniform water distribution over the entire field without any low or high spot constituting irrigation problem.
4. With water control system in place, water supply is guaranteed in every part of the fadama. There will be no longer crop variety limitation, high yielding varieties that require much water can be grown without effect of water shortage.

5. Also cultivation cannot further be restricted to the narrow strip area along the stream as water can be directed to any part of the field. Therefore it will facilitate cultivation of all available potential areas.

CHAPTER SEVEN

7.0 CONCLUSION

This study has presented the development of an irrigation scheme to ensure that maximum benefit is derived from it. The existing situation of the scheme hampers remarkably the exploitation of the fadama for agricultural purposes by the farming communities of Zukuchi. Therefore the limited available fadama requires judicious use through appropriate technology if the inhabitants are to achieve their rice production goal by increasing their output per unit area. The appropriate technology consists of design and construction of a weir structure across the stream, canals and water control structures at the periphery of the fadama, the drain along the stream watercourse, and on farm field preparation purposely to direct and regulate the water flow over the fadama area. This will facilitate improved agricultural practices that will increase the output per unit area.

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APPENDIX A

CLIMATIC DATA

Table 3 MONTHLY RAINFALL FOR 1985-1998 (MM)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	-	-	-	30	127	132	262	205	331	24	-	-
1986	-	-	13.4	58.8	66.4	186.9	277.6	279	350.2	60.1	34.5	-
1987	-	-	12.5	13.5	62.5	217.5	151.5	188.7	245	84.5	-	-
1988	-	-	-	155.1	88.2	174.9	239.6	289.5	361.4	11.7	-	-
1989	-	-	2.5	91.2	189.8	152.6	152.5	289.6	118	80.5	-	-
1990	-	-	-	174.7	160.0	227.5	416.1	276.1	350.1	143.3	-	-
1991	-	-	5.6	22.2	300.3	146.1	450.3	238.1	158	37.7	-	-
1992	-	-	2.6	74.9	198.3	183.2	188	280.4	368.1	139.1	78	-
1993	-	-	21.9	27.2	118.3	164.5	377.7	257.5	334.5	72.8	-	-
1994	-	-	-	58.7	74.5	225.9	106.8	264.7	208.7	238.2	-	-
1995	-	-	-	2	107.7	132.1	192.0	443.8	178.2	147.6	0.8	-
1996	-	-	1.1	44.4	164.7	214	189.6	233.9	307.2	88.1	-	-
1997	-	-	41.6	63.3	191.85	190.1	308.7	271.1	473.2	180.7	0.5	-
1998	-	-	-	69.1	102.9	185.5	278.6	280.3	194.9	142.1	-	-

Source: Shiroro hydroelectric power station.

Table 4 MEAN MONTHLY DAILY TEMPERATURE IN ^{0}C FOR 1986-1998

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	29.41	32.64	32.86	33.52	31.52	28.71	27.31	27.53	27.68	29.74	29.74	27.18
1987	29.75	31.72	32.87	34.51	33.42	29.34	28.9	28.92	28.88	29.83	30.36	29.58
1988	28.6	31.24	33.92	32.71	30.36	28.69	28.07	26.36	27.36	29.25	30.14	29.48
7989	27.16	29.36	33.56	33.2	30.02	28.83	27.55	27.39	27.93	28.94	31.00	29.4
1990	30.47	30.39	33.18	32.52	30.1	29.63	28.03	27.68	28.53	30.12	30.83	30.29
1991	29.63	32.66	33.4	32.53	29.52	29.25	27.18	27.76	28.62	28.69	30.82	28.82
1992	27.15	31.46	32.98	32.42	31.32	29.72	28.31	27.1	27.1	29.00	29.25	28.24
1993	26.92	28.57	33.23	33.18	31.79	-	-	26.67	26.94	27.74	28.12	26.65
1994	25.33	26.96	29.6	29.54	28.39	27.15	26.53	25.8	25.82	26.21	26.09	24.02
1995	23.85	25.79	29.35	29.8	31.21	28.68	27.39	26.90	27.80	29.58	30.45	29.18
1996	27.34	29.67	31.99	32.84	29.61	27.78	26.71	27.01	26.81	27.41	26.93	28.56
1997	29.07	26.21	29.64	30.25	29.04	27.45	26.66	26.71	27.79	28.45	29.35	26.65
1998	25.06	28.13	30.40	33.39	30.08	25.87	27.72	28.38	28.24	28.46	29.04	29.90

Source: Shiroro Hydroelectric Power Station.

Table 5 MONTHLY DAILY RELATIVE HUMIDITY (%) FOR 1985-1998

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	40.8	36.8	37.6	47.8	60	80.7	81.5	81.7	85.6	75.2	33.9	33.9
1986	23.7	22.57	37.74	40.5	53.38	65.5	70.6	76.1	65.2	57.2	46.8	40.3
1987	75.4	43.6	78.8	69.3	76	65	65	71.9	66.6	54.1	34.2	31.2
1988	29.4	28.1	30.8	44.3	57	65.4	57	93.6	86.4	62.6	44.2	38.6
1989	33.2	34	43.9	52	72.5	73.3	76.5	83.5	78.4	66.9	42.5	40.6
1990	49.1	42.1	51.7	76.8	82.6	86.3	89.2	89.1	88.5	86.9	65.8	67.9
1991	70.8	91.3	92.1	92	87.3	86.8	90.7	91.4	88	85.3	56.8	60.8
1992	55.1	36.3	35	73	80.7	79.3	87	87.58	88.2	81	55.8	42
1993	34	41	59.3	65.1	75.6	82.4	80.5	86.3	80	26.1	64.3	36
1994	32.4	16.73	41.8	67.47	66.9	72.8	75.3	87.2	88.9	81.7	47.8	25.6
1995	23.3	19.6	36.2	51.5	55.4	70.4	85.2	89.7	88.8	84.1	58.0	49.7
1996	55.1	64.2	67.2	72.6	85.5	86.7	91.7	91.1	90.7	84.1	51.3	46.4
1997	47.9	52.0	58.5	76.4	85.1	90.4	93.1	93.8	92.0	90.8	75.0	50.5
1998	45.1	47.5	42.2	69.7	87.2	91.7	95.8	96.1	89.2	85.4	57.0	29.9

Source: Shiroro Hydroelectric Power Station.

TABLE 6

MONTHLY SUNSHINE HOURS FOR 1985-1998

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1985	7.1	7.2	6.3	6.4	7.2	7.2	5.6	6.6	5.5	7.7	8.7	5.9
1986	7.2	8.4	6.8	8.2	8.7	7.5	5.5	5.8	5.1	7.6	5.1	7.6
1987	8.3	7.6	7.0	7.2	7.9	6.7	5.2	3.5	4.7	8.0	9.5	8.9
1988	8.4	8.5	8.2	7.8	7.5	6.3	4.3	4.0	5.2	7.1	8.7	8.5
1989	8.3	8.2	8.4	8.9	8.8	7.3	5.1	3.9	5.3	8.3	9.4	8.9
1990	8.2	7.8	7.2	8.0	7.9	7.2	5.6	4.7	6.3	8.5	9.1	8.8
1991	6.9	8.6	6.7	8.3	6.9	7.3	4.8	4.6	6.0	7.6	8.4	8.9
1992	8.4	6.8	7.5	7.7	7.8	6.4	5.3	4.5	5.9	7.3	8.0	8.3
1993	5.5	8.4	7.1	7.3	8.2	6.5	6.1	4.3	6.6	6.5	8.6	8.0
1994	7.1	6.8	7.3	6.5	7.4	6.6	6.4	6.1	6.7	7.2	6.1	6.5
1995	8.8	9.0	8.2	6.4	7.8	6.5	5.9	5.2	6.1	6.3	9.0	8.8
1996	6.5	6.1	8.1	7.8	7.2	9.0	5.7	5.8	6.3	7.6	9.1	8.2
1997	6.8	7.2	6.2	7.9	7.5	7.2	5.9	4.4	5.4	7.9	8.9	8.7
1998	8.5	8.8	7.9	7.8	7.4	6.8	6.7	4.8	5.8	6.9	8.5	7.4

Source: Shiroro Hydroelectric Power Station

APPENDIX B

SOIL TEXTURE ANALYSIS

1.0 Materials used: Measuring cylinder, water, stirring rod, pistil, mortar, soil auger and polythene bags.

2.0 Procedure: Three 50gm samples of soil were taken at the field at various depth of 0 to 20cm, 20 to 40cm and 40 to 60cm respectively. Each sample was dried and grinded with pistil and mortar to powdery form. The samples were then poured into graduated measuring cylinders containing some water, stirred for some minutes and kept aside for 36 hours for settlement. After the 36 hours the sand particles are seen settled at bottom of the cylinder, followed by silt and then clay on top. The thickness of each soil particles settlement were measured and expressed in percentage.

Results:

Sample 1 (0 – 20 cm) $\%\ \text{sand} = \frac{3.12}{8} x100 = 39\%$

$\%\ \text{Silt}\ \frac{2}{8} x100 = 25\%$

$\%\ \text{Clay} = \frac{2.88}{8} X100 = 36\%$

Sample 11 (20 – 40 cm) $\%\ \text{Sand} = \frac{2}{7} X100 = 28.6\%$

$\%\ \text{Silt} = \frac{2}{7} X100 = 28.6\%$

$\%\ \text{Clay} = \frac{3}{7} X100 = 42.9\%$

Sample 111 (40 – 60 cm) $\%\ \text{Sand} = \frac{2.34}{9} X100 = 26\%$

$\%\ \text{Silt} = \frac{3.24}{9} X100 = 36\%$

$$\% \text{ Clay} = \frac{3.42}{9} X\,100 = 38\%$$

Using the United State Department of Agriculture (USDA) soil classification indicate the three samples belong to clay loam texture group, it is just % of particles that varies from layer to layer.

APPENDIX C

ASSESSMENT OF THE STABILITY OF THE HEAD DYKE

In general, the following conditions are checked to ensure the stability of the designed head dyke:

1. To avoid tension in the masonry at the base of the head dyke.
2. To safe guard the head dyke from overturning,
3. To prevent the sliding of masonry at the base of the head dyke and
4. To prevent crushing of masonry at the base of the head dyke.

The stability of any structure largely depends on its firm base, in this respect a minimum base width for the head dyke is designed to check the effect of the above conditions.

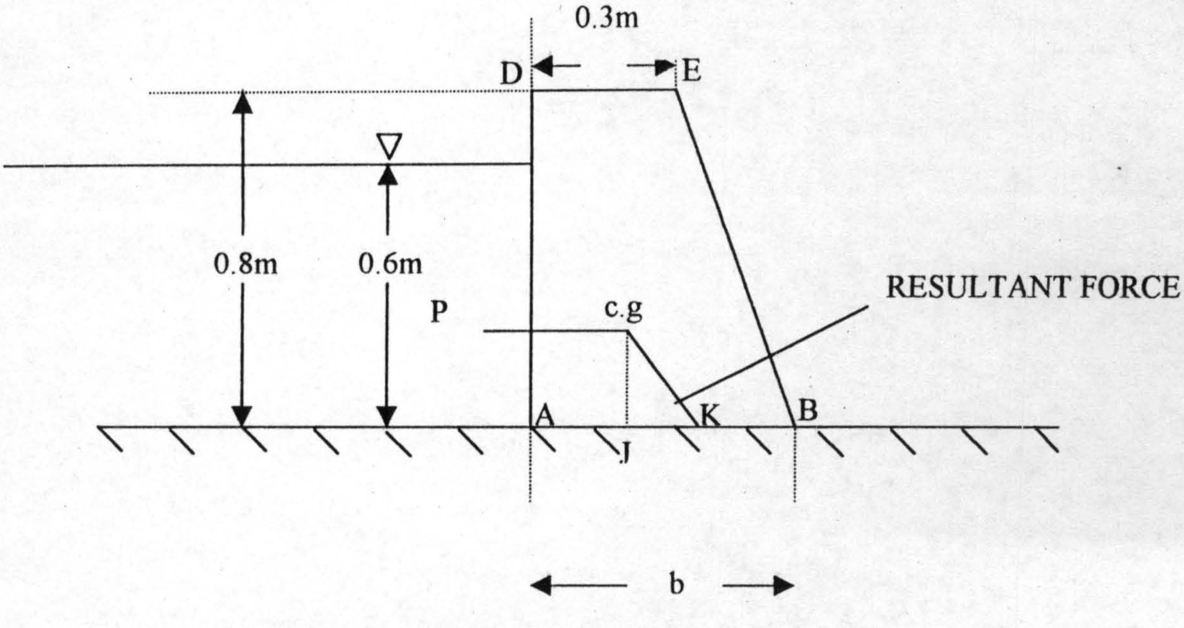

FIG. 8 A SECTION OF CREST SHOWING LINE OF FORCES

Considering above section of Head dyke crest

Height of crest, (H) = 0.8m

Height of water, (h) = 0.6m

Top width of crest (a) = 0.3m

Density of concrete $\rho = 22.6$ KN/m^3 assumed (Charles & James,1976)

Density of water $\rho = 9.81$ KN/m^3

Minimum bottom of crest (b) =?

Total water pressure on the head dyke per metre length (P):

$$P = \frac{wh^2}{2} = \frac{9.8 x 0.6^2}{2} = 1.77 KN$$

The weight of head dyke per metre length (W)

$$W = P.a.H. = 22.6 \times \frac{(0.3+b)}{2} X\ 0.8$$

$$= 9.04\,(0.3 + b)\ KN$$

To find the centre of gravity (C.G) of the head dyke section,

$$AJ = \frac{a^2 + ab + b^2}{3(a+b)} = \frac{0.3^2 + 0.3b + b^2}{3(0.3+b)}$$

Then X (JK), $X = \frac{P}{W} X \frac{h}{3}$

$$= \frac{1.77}{9.04(0.3+b)} X \frac{0.6}{3} = \frac{0.04}{(0.3+b)}$$

$$= \frac{0.21 + 0.3b + b^2}{3(0.3+b)}$$

Since Eccentricity of the resultant (e), $= d - \frac{b}{2}$

Then $e = \frac{0.21 + 0.3b + b^2}{3(0.3+b)} - \frac{b}{2}$

In order to avoid tension in the masonry at the base of head dyke, the eccentricity (e) supposed to be:

$$\frac{b}{6}\ or\ \frac{0.21 + 0.3b + b^2}{3(0.3+b)} - \frac{b}{2} = \frac{b}{6}$$

$$\therefore \frac{0.21 + 0.3b + b^2}{3(0.3+b)} = \frac{b}{6} + \frac{b}{2} = \frac{2b}{3}$$

$0.21 + 0.3b + b^2 = 2b(0.3 + b) = 0.65 + 2b^2$

or $b^2 + 0.3b + 0.21 = 0$

Solving for b using quadratic equation from above equation:

$$:.\ b = \frac{-0.3 + \sqrt{0.3^2 + 4 \times 0.21}}{2}$$

$$b = \frac{-0.3 + 0.93}{2} = 0.315$$

b =0.32m but 0.4m chosen.

P max = Maximum stress across the base at B.

$P\ max = \frac{2w}{b}$, $W = 9.04\ (0.3 + 0.4) = 6.3KN$

$$:.\ P\ max = \frac{2\ X\ 6.3}{0.4} = 31.5\ KN/\text{m}^2$$

The horizontal distances AJ, JK and d by substituting value b in their respective equations:

$$AJ = \frac{a^2 + ab + b^2}{3(a+b)} = \frac{0.3^2 + (0.3\ X\ 0.4) + 0.4^2}{3(0.3 + 0.4)}$$

AJ = 0.18m

$$JK\ (x) = \frac{0.04}{0.3 + b} = \frac{0.04}{6.3 + 0.4} = 0.057 \Rightarrow 0.06m$$

d = AJ + JK = 0.18 + 0.06 = 0.24m

The eccentricity of the resultant (e) = d - $\frac{b}{2}$, $0.24 - \frac{0.4}{2}$ = 0.04m.

VERIFICATION (according to Khurmi, 1976):

1 To avoid tension in the masonry of the head dyke at its base, the resultant force (K) must lie within the middle third of the base width. Since b is 0.4m where d is 0.24m, then the structure is safe from tension in the masonry at its base.

2. To avoid overturning of the structure, also since the position of the resultant (K) lies within A and B in figure then the structure is safe from overturning.

3. To prevent sliding of the structure, the maximum available force of friction (f max) should be at least 1.5 times the total weight to water pressure per metre length.

   F max = μw, where μ = coefficient of friction between the base of head dyke and the soil, w = weight of the structure. μ For wet clay surface is o

   as such $\frac{w}{p} = \frac{6.3}{1.77} = 3.5$

   The ratio 3.5 exceeds the 1.5, which indicates that the head dyke is safe from sliding.

4. To prevent crushing of masonry at the base of the structure the maximum stress (P max) should be less than the permissible stress in the masonry. P max is 31.5KN/m^2, while safe bearing compression for eccentric load on 1:2:4 plain concrete is (Charles & James, 1976)6.88MN/m^2 which is very far above P max.

APPEDIX D
Designed Drawings

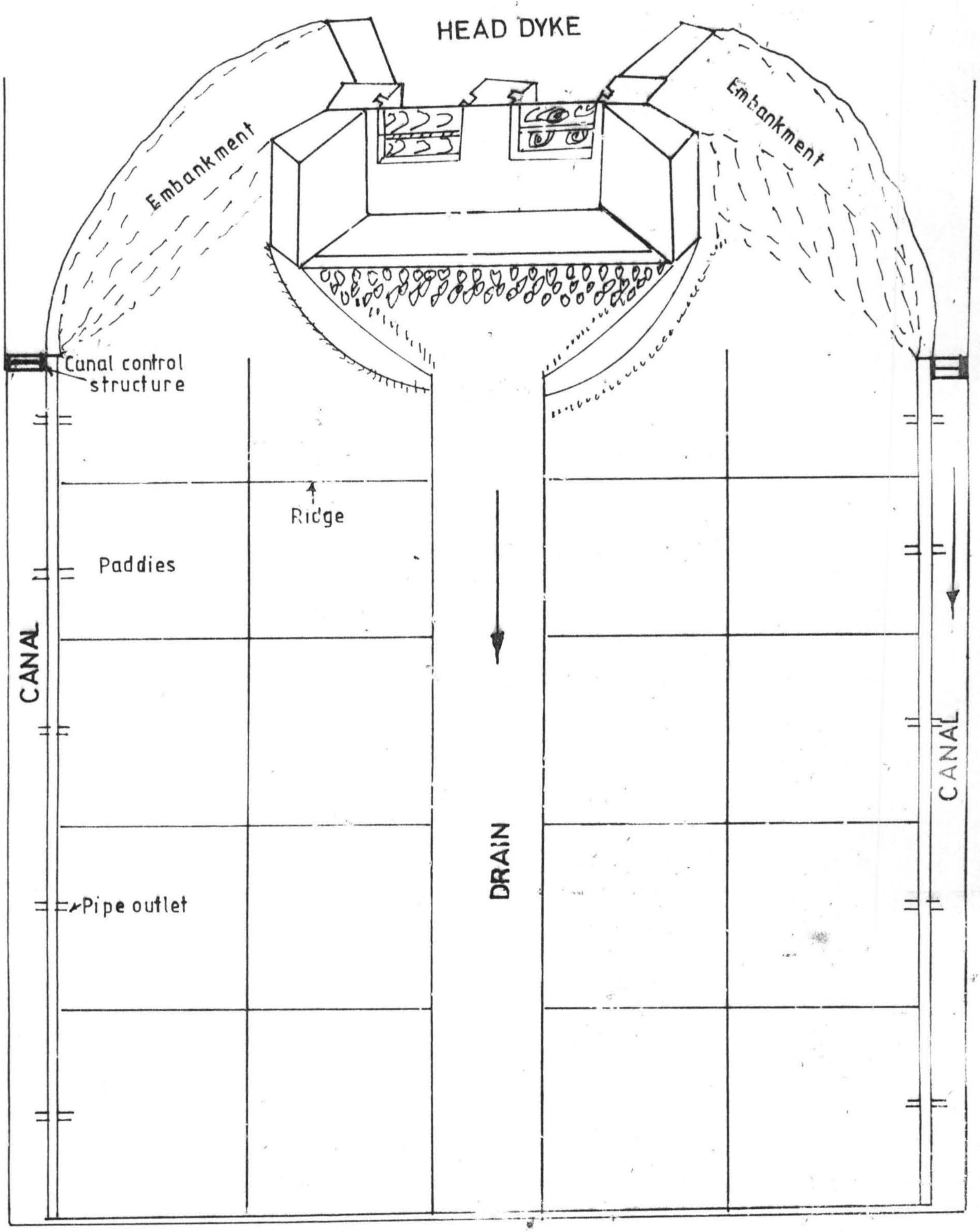

Fig.1 Sketch of a water control system layout

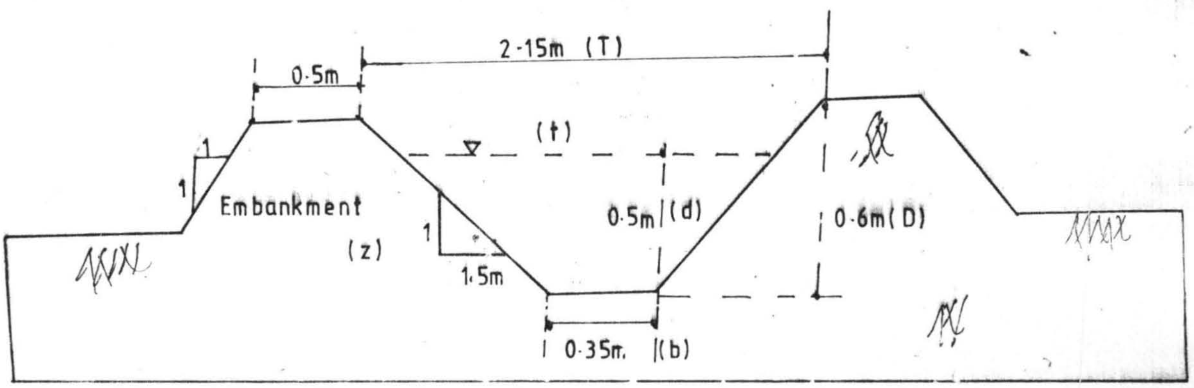

Fig. 2
TRAPEZOIDAL CROSS SECTION OF IRRIGATION CANAL

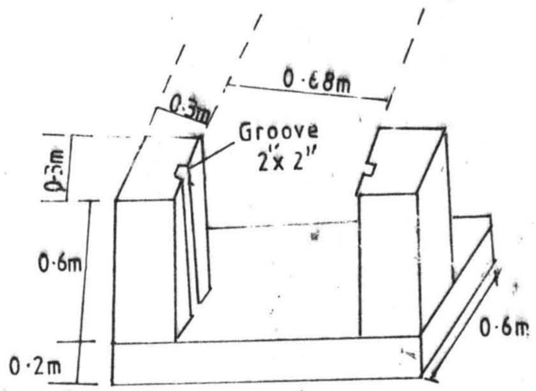

Fig. 3
CANAL WATER CONTROL STRUCTURE SKETCH.

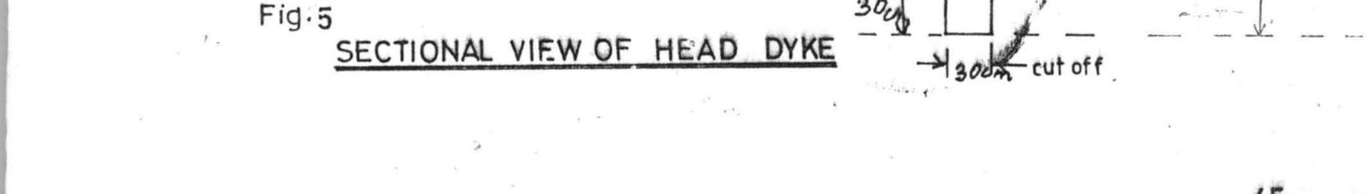

Fig. 5
SECTIONAL VIEW OF HEAD DYKE

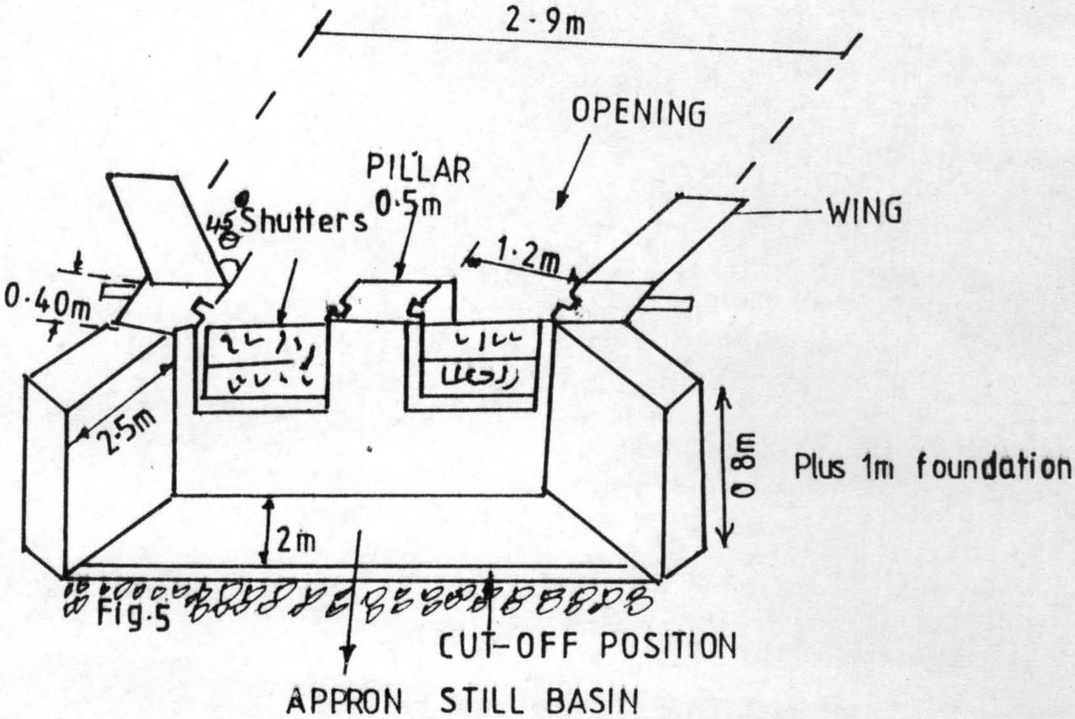

Fig. 4 BACK VIEW OF DESIGNED HEAD DYKE

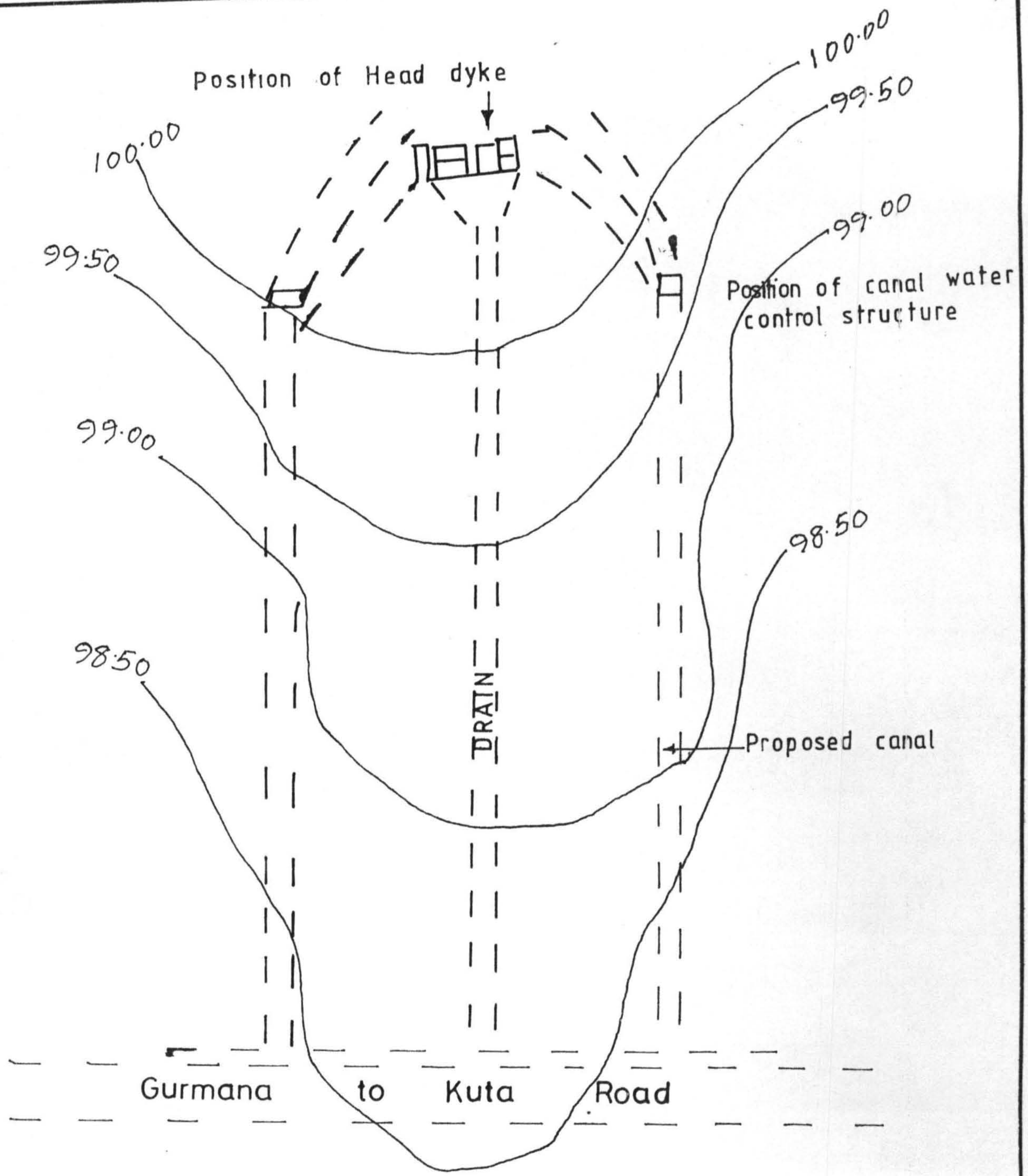

Fig 6 Surveyed Topo Map of the site

Scale 1cm to 60m

NB

Canal take off point level 100m

Crest level 100·50m

Foundation level 99·50m

PART OF TOPOGRAPHIC MAP OF NIGERIA 164 N.W.

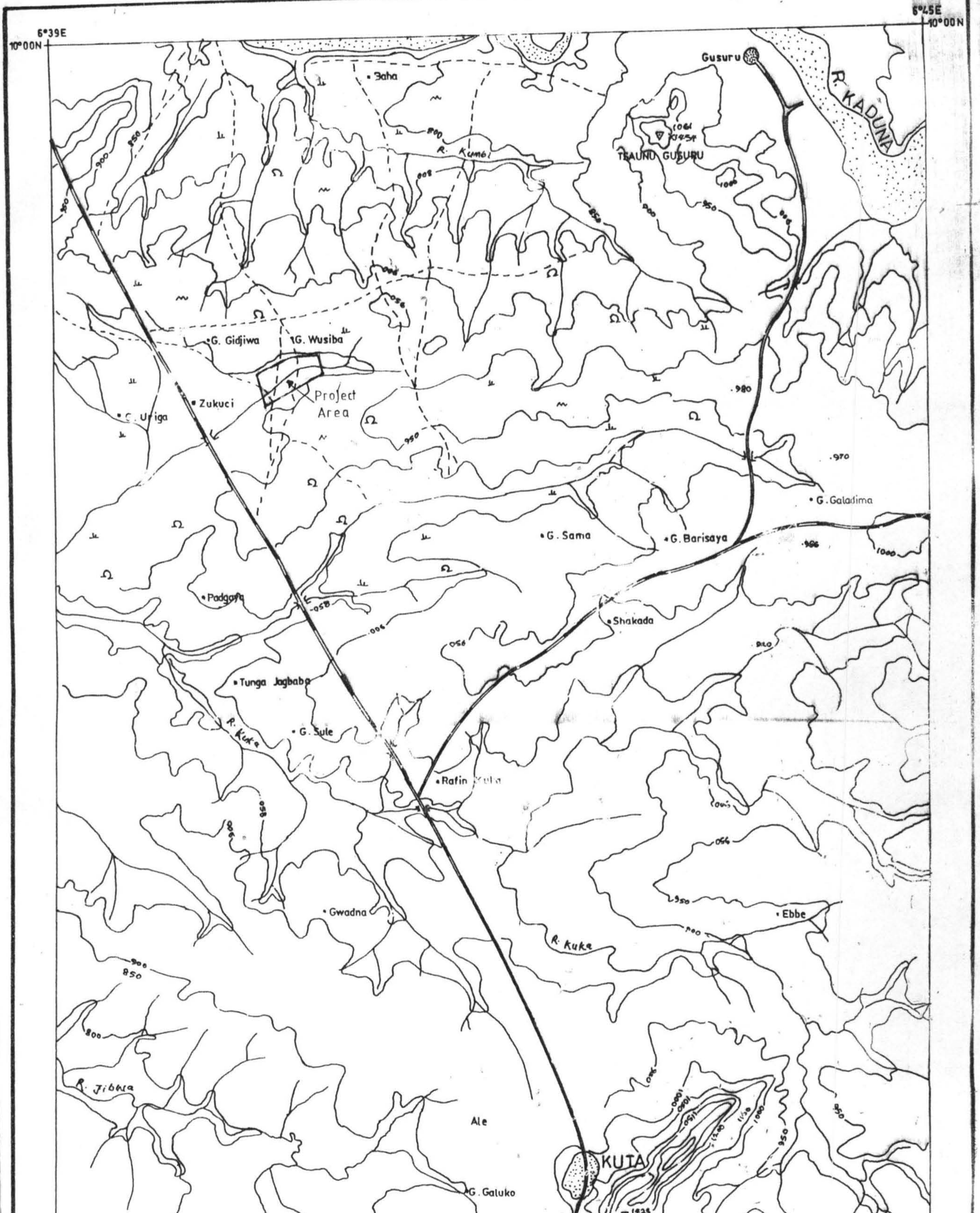

Fig. 7

SCALE:-1:50,000

SCALE:-1:50,000

Main Roads	
Secondary Roads	
Minor Roads	
Minor Paths	
Villages	Zukuci
Light Forest	
Savanna Orchard Bush	
Scrub	
Scattered Cultivation	
Plantation	
Contours (V.I 50 Ft.)	1050 950

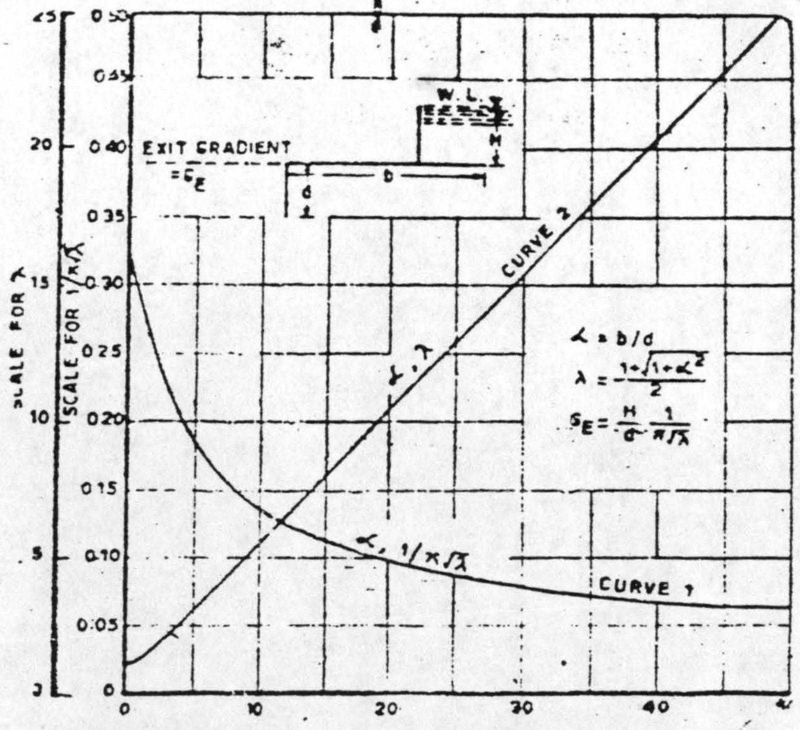

Fig. 9 Khosla's safe exit gradient curve

APPENDIX E

POTENTIAL EVAPOTRANSPIRATION COMPUTATION
BLANY MORIN NIGERIA (1984) METHOD:

$Etp=rf(0.45T+8)(520-R^{1.31})/100$

Where, Etp=potential evapotranspiration, mm/day

rf=ratio of maximum possible radiation to the annual maximum.

T=summation of mean daily temperature

(^0c) over a month divided by number of days in that mouth.

R=summation of the daily means of relative humidity over a month and divided by the number of days in that month.

The period of irrigation of the designed scheme is during the month of October to December, the maximum data within the period is use for the calculation :

rf= 0.10

T = 31°C

R= 43.0%

Therefore $Etp=0.10(0.45x31+8)(520-42.5^{1.31})/100$

$Etp=0.10(21.95)(382.0)=8.38mm/day$

Crop evapotranspiration (Etc) is then calculated by multiplying Etp by kc (crop coefficient), kc value for rice at maturity stage FAO(1984)

: . $Etc=8.43x1.10 =9.20mm/day$.