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UPPER SHIRE RIVER NAVIGATION CHANNEL
ANNEX B

KAMPSAX

KAMPMANN, KIERULFF & SAXI
CONSULTING ENGINEERS - COPEN

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TO GENERAL REPORT

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CONSULTING ENGINEERS - COPENHAGEN

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UPPER SHIRE RIVER NAVIGATION CHANNEL

1. INTRODUCTION

1.1 General.

The Delft Hydraulics Laboratory, Holland, was requested by Kampsax to assist in studying the possibility of an improvement of the navigability of the Upper Shire River from Lake Malawi through Lake Malombe as far down as to the existing barrage at Liwonde.

Kampsax submitted to the Delft Hydraulics Laboratory all information regarding hydraulics of the Lake Malawi and the Shire River then available. After a short study of this documentation, the necessary investigations in Malawi were started in the beginning of February, 1967. Two engineers of the Delft Hydraulics Laboratory stayed in Malawi for a period of two and eight weeks respectively. They took contact with the authorities in Malawi, more particularly the Water Development Department under the Ministry of Works and Supplies, and ESCOM and various ministries in Malawi.

Fortunately a very detailed study by Sir William Halcrow & Partners: "A Report on the Control and Development of Lake Nyasa and the Shire River (1954)" could be made available to the Delft Hydraulics Laboratory engineers. This study contained detailed soundings of the Upper Shire River from Lake Malawi down to the barrage at Liwonde, made during the years 1951-1954. The investigations in Malawi could, therefore, be restricted to control of existing detailed measurements of riverbed levels, supplemented by further investigations necessary for evaluating the navigability of the Upper Shire River.

On basis of available information from other sources and the investigations carried out in Malawi, the present report has been prepared.

1.2 Scope of the Study.

The study of an improvement to the navigability of the Upper Shire River has to provide data about the construction cost of dredging a navigation channel from Lake Malawi to Liwonde and about the cost of maintaining such a channel.

The size of the vessels, especially their draft, is an important criterion with regard to the determination of the cross section of the navigation channel. The size of the ships is governed by sailing conditions on Lake Malawi and also in the Upper Shire River. These questions are dealt with in ANNEX D "Lake and River Craft" to the General Report.

Of special importance for the navigability study is the question of water levels on Lake Malawi. A prognosis of the variations in water level had to be made in order to estimate the amount of dredging to be carried out. A study of water levels on Lake Malawi and of a future operation scheme for the barrage at Liwonde was under preparation by the ESCOM consultants, Messrs. Watermeyer, Legge, Piesold and Uhlmann, during the time of elaboration of the present report. The final findings of the ESCOM consultants as to a proposed operating rule for the Liwonde barrage with the purpose of maintaining a relative high lake water level are given in Appendix C of their: Tedzani Falls Hydro-Electric Scheme Project Report, October 1967.

It has been necessary to approach the ESCOM consultants along with the preparation of the present Lake and River Transportation report prior to the appearance of the above mentioned Project Report, and request them to make certain special investigations in order to arrive at a preliminary prognosis for the variation in the water level of Lake Malawi with corresponding probabilities of their occurrence. After the issue of the said Project Report with recommendation of an operating policy for the barrage, they have on Kampsax's request examined the resulting backwater effect in Shire River and worked out a final estimate of probabilities of various lake levels. The findings are further discussed in sections 3.3.3 and 3.3.4 of this report.

Finally, certain restrictions on size and weight of goods transported by the Malawi Railways from Beira harbour (Mozambique) to Malawi have to be considered when determining the size of dredgers to be used, as the dredgers are intended to be assembled in Malawi from sections manufactured abroad.

2. LAKE MALAWI AND SHIRE RIVER

2.1 General Features.

The Shire River (drwg. B 1) is fed by the water from Lake Malawi. Therefore the regime of the river is dependent on the hydrologic conditions of the lake.

The Shire River can conveniently be divided in three natural sections (drwg. B 2):

the Upper Shire River, from Lake Malawi, through Lake Malombe, via Liwonde to Matope. This river section is characterized by a gentle gradient,

the Middle Shire River from Matope to Hamilton Falls is characterized by cataracts and rapids. There is a difference in level of about 1250 ft (380 m) over a distance of only 50 miles (80 km),

the Lower Shire River from Hamilton Falls to the confluence with the Zambezi River has again a gentle gradient.

For the present navigability study, only the Upper Shire River is of importance, more particularly that part of the river which is located upstream of the existing barrage near Liwonde (drwg. B 3).

2.2 Lake Malawi.

Lake Malawi (area 11,430 square miles (29,600 km^2)) receives its water from rainfall on the surrounding plateaus (37,420 square miles (96,600 km^2)) and on the lake itself.

Drwg. B 4 represents the topography of Malawi, while drwg. B 5 represents the catchment areas of Lake Malawi and Shire River and drwg. B 6 the average annual rainfall in Malawi.

Most of the rain falls from November to April. During this rainy season the lake level is rising 3 to 4 ft (0.9 to 1.2 m). In the dry season, from April to November, the lake level is going down again due to the enormous evaporation on the lake.

Systematic records of the lake level available since 1896 (drwg. B 7) show the annual variation. Besides, long-term variations of about 15 ft (4.5 m) occur. From 1896 until 1915, the level has been declining to about 1,537.8 ft above Shire Valley Project Datum (S.V.P. Datum, which refers to mean sea level at Beira).

In 1915, the outlet of the lake (viz. the Shire River) was blocked by sandbanks caused by floods of its tributaries, especially the Nkasi River. The small flow of the Shire River at that time was not able to remove the sediments. The flow through the river ceased for about 20 years, during which time the lake level rose again.

In 1934 the Shire River was again opened. In 1937 the lake level reached a maximum of 1,556.4 ft above S.V.P. Datum. After 1937 until the present date (1967), the lake level has remained rather high, reaching even a new maximum level in 1964, viz. 1,557.4 ft above S.V.P. Datum.

2.3 Upper Shire River.

The discharge through the Upper Shire River is governed by the water level of Lake Malawi.

Drwg. B 8 represents the topography of the Upper Shire River region. This drawing also makes it possible to distinguish four characteristic sections of this part of the river:

- a section of about 10 miles (16 km) between Lake Malawi and Lake Malombe.
- Lake Malombe, length about 16 miles (25 km).
- a section of about 25 miles (40 km) between Lake Malombe and Liwonde.
- a section of about 30 miles (50 km) between Liwonde and Matope.

The first three sections are of importance for the present navigability study. These sections have various tributaries (drwg. B 9) of which the Nkasi River is the most important.

Drwg. B 10 gives the variations in the discharge through the Upper Shire River since 1935, i.e. since the reopening of the river.

Drwg. B 11 represents the present (1967) discharge rating curve near Liwonde. The recently constructed barrage at this place is shown on drwg. B 12.

2.4 Morphologic Data.

2.4.1 General.

From 1951 till 1954, an extensive study of the Shire River has been carried out by Sir William Halcrow and Partners. The results of this study have been given in their report: "A Report on the Control and Development of Lake Nyasa and the Shire River" (1954).

The measurements on the river carried out in the beginning of 1967 by the Delft Hydraulics Laboratory were necessary for the following reasons:

a. To study whether the complete soundings of Sir William Halcrow and Partners were accurate enough to describe the present situation. This question had to be investigated before the preliminary design of a navigation channel could be based on these soundings.

b. Additional morphologic information was required to establish reliable estimates of the quantities to be dredged initially - and the kind of soil to be dredged - as well as for the maintenance of the channel.

The results of the measurements have been summarized in the various drawings of this report. It should be mentioned that the soundings made by Sir William Halcrow still are found to be describing the present riverbed reasonably well. Therefore, these soundings have been reproduced in the present report (drwg. B 13 to B 26).

Drwgs. B 27 to B 33 represent a comparison of the riverbed configuration in 1951 to 1954 (Sir William Halcrow) and 1967 (Delft Hydraulics Laboratory).

Drwgs. B 34 to B 37 represent additional measurements on the distributions of the current velocities and of the grain size of the bed material.

All data about levels are related to S.V.P. Datum, while the locations along the river have been indicated by the mileage North (N) or South (S) from Fort Johnston.

2.4.2 Morphologic Character of River Bed.

By means of the available data, a reasonable knowledge of the morphologic conditions of the Upper Shire River could be obtained. In the following, the main aspects with regard to the dredging and maintenance of a navigation channel through this part of the river will be given.

Entrance to the River From Lake Malawi.

The entrance of the Shire River (drwg. B 14) at Lake Malawi is characterized by a bar. This rather shallow area contains a reasonably well defined channel. Naturally, the formation of the bar is influenced by water level variations of the lake and by wave-action along the coast in form of littoral drift. During the period of low lake levels (before 1925) and especially during the period in which the Shire River has been blocked, the bar has been part of the southern coast of Lake Malawi.

During the obstruction of the Shire River near the mouth of the Nkasi River, there may have been a temporary discharge over the Lake Malawi bar in southern as well as sometimes in northern direction. Evidence from bottom samples shows that a littoral drift of sand takes place from West to East. This is for instance shown by the difference between the present soundings and those from the Sir William Halcrow Report (cross-section 2, on drwg. B 27).

The present sandspit, north of the Namingundi river-mouth (drwg. B 14) seems to grow in an easterly direction.

Although the sand movement at the Lake Malawi bar, particularly at the channel through this bar at present (1967), is rather modest, some resiltation of a channel dredged through the bar is to be expected. However, fair estimates of the resiltation cannot be given, mainly due to the lack of meteorological data to enable an estimation of wave action on the southern part of Lake Malawi.

The future policy of controlling the lake level by means of the barrage near Liwonde now being based on maintaining of relatively high lake levels, very serious resiltation should, therefore, not be expected. The distance between the mentioned sandspit and the channel through the bar seems large enough to avoid difficulties from this sandspit during many years to come.

Besides, spoil from the channel to be dredged through the bar should at any rate be deposited at the eastern side of the channel.

River Section 5N - 4S.

This part of the Shire River in the vicinity of Fort Johnston is characterized by a relatively wide cross-profile. Consequently, the current velocities are small. The river is reasonably stable, although some bank erosion seems to take place at the right bank between 2S and 3S. The soundings from the Halcrow Report (drwgs. B 15 and B 16) are still reasonably well representing the bed level. Deviations from the actual bed level (drwgs. B 28 and B 33) occur only locally. The bed material (drwg. B 35) has almost the same characteristics as that of the bar at the entrance.

Under present lake level conditions the sediment transportation in the river is very small, except at local narrow cross-sections. This has been demonstrated from calculations of bed load transport on basis of the hydraulic measurements carried out. There will be no difficulties with regard to construction and maintenance of a navigation channel in this part of the river.

Outlet in Lake Malombe.

Downstream of 5S the Shire River enters Lake Malombe. There is a kind of delta formation at this location. The reduction of the current velocities towards Lake Malombe creates a certain segregation of the bed material: the mean grain size is considerably smaller than further upstream (drwg. B 35). The cross-sections made at this place (drwg. B 29) suggest some changes in the river since the Halcrow measurements were made (confer sections 16 and 18 of drwg. B 29). However, these changes may not be very significant.

Lake Malombe.

This lake, from 5S to 20S, has a remarkably flat bottom, shown by the contours on drwg. B 18 and the longitudinal profiles presented in drwg. B 30. The bottom of Lake Malombe consists of consolidated clay with a thin layer of silt on top.

River 20S to 25S.

From Lake Malombe the river flows in a southern direction. Drwgs. B 19 and B 20 represent the soundings made in this region. This section of the river does not show significant differences between the soundings from 1951/54 and those of 1967 (drwgs. B 31 and B 32). The cross-section of the river is relatively large and the current velocities therefore small, about 1 ft/sec. (drwg. B 34).

River 25S to 32S.

This part of the Shire River is significantly influenced by its most important tributary: the Nkasi River (drwg. B 21), and the sediments carried by this river. This is clearly demonstrated in the results of the tests on the bottom samples (drwg. B 36). The Nkasi River mouth is situated at about 28S and both northward and southward of this place, relatively coarse bed material is found in the Shire River.

Significant discharges through the Nkasi River seem very seldom to occur. However, in such cases, leading once to the said obstruction of the Shire River, large amounts of sand may enter the river.

There is a difference between the coarse bed material of the Shire River (up to 5 mm, drwg. B 36) and the relatively fine material found in the (dry) bed of the Nkasi River (about 1 mm, drwg. B 37). There are two possible explanations to this difference. The sand found at the present dry bed of the Nkasi River is not significant for the sand transported at occasionally very high discharge. In the Shire River a process of segregation seems to have taken place during the last decades: the relatively weak current will mainly transport the finer fractions of the bed material.

River 32S to Liwonde.

Downstream of the Nkasi, the Shire River obtains a slightly different character. Gradients, velocities, and consequently the sand transporting capacity, are greater in this region.

While upstream of the Nkasi-mouth, the Shire River can hardly be called active, downstream of this place the river shows some activity.

3. IMPROVEMENT OF THE NAVIGABILITY OF THE UPPER SHIRE RIVER

3.1 General.

The navigability of the Upper Shire River can be improved by dredging. The feasibility of the improvement, however, depends largely on the quantities to be dredged, both initially and for maintenance. This section deals with calculations regarding channel dimensions and of the quantities to be dredged. The channel dimensions will be determined (see 3.2 below) on basis of the size of the vessels that will be using the channel, and of the future water levels of Lake Malawi (see 3.3).

Paragraph 3.4 finally gives quantities for inital and maintenance dredging estimated by means of the data of the previous sections.

3.2 Channel Dimensions.

3.2.1 Size of Ships Navigating the Channel.

Channel dimensions depend on the size of vessels using the channel.

Table 1 gives information about the existing and the proposed new vessels that are supposed to navigate the new channel.

Due to the fairly long distance between Lake Malawi and Liwonde, a sufficiently high service speed is required. However, high speeds ask for large channel dimensions.

Existing And New Ships Navigating The New River Channel.

Note: The drafts given in this table are taken amidships. Draft aft may be larger. However, as a rule the increase seldom exceeds 2 ft.

Type of Ship	Length overall ft (m)	Length p.p. ft (m)	Breadth ft (m)	Draft ft (m)	Service speed Knots
a. Existing Ships:					
m.s. Ilala		160'-0" (48.77)	30'-6" (9.30)	7'-3" (2.21)	$10\frac{1}{2}$
m.s. Chauncey Maples		120'-0" (36.58)	20'-0" (6.10)	6'-6" (1.98)	abt. 9
m.s. Nkwasi		105'-0" (32.00)	27'-0" (8.23)	7'-6" (2.29)	8
m.s. Mpasa		100'-0" (30.48)	22'-0" (6.71)	7'-10" (2.39)	$7\frac{1}{2}$
m.s. Zomba m.s. Mlanje m.s. Dedza m.s. Dowa m.s. Chola	47'-0" (14.33)		11'-0" (3.35)	3'-0" (0.91)	8
m.s. Nsipa	39'-4" (11.99)		9'-6" (2.90)	3'-6" (1.07)	8
m.l. Ncheni	46'-2" (14.07)		11'-3" (3.43)	4'-0" (1.22)	$8\frac{1}{2}$
b. Future Ships:					
m.s. Nkwasi lengthened		134'-9" (41.07)	27'-0" (8.23)	7'-6" (2.29)	abt. 8
500 ts dw Cargo Ship		145'-0" (44.20)	32'-2" (9.80)	9'-0" (2.75)	abt. 10
500 ts dw Cattle Ship		145'-0" (44.20)	32'-2" (9.80)	8'-0" (2.44)	abt. 10
750 ts dw Cargo Ship		160'-9" (49.00)	32'-2" (9.80)	11'-3" (3.43)	abt. $10\frac{1}{2}$
250 ts dw Tanker		115'-0" (35.05)	20'-4" (6.20)	6'-8" (2.03)	abt. 9
Combined Passenger & Cargo Ship		98'-6" (30.00)	26'-3" (8.00)	7'-6" (2.29)	abt. $9\frac{1}{2}$

Navigation in the channel must be possible at any time, as the channel is only a small part of a much longer sailing route. Therefore, two-way traffic as well as traffic during night is necessary. However, the density of the traffic will be small.

Pilots will not be necessary on the channel, as the same vessels will use the route regularly.

Navigation at current velocities of about 2 ft/sec. must be possible. Moreover, possible wind effects on Lake Malawi and Lake Malombe must be taken into consideration.

3.2.2 Width of Channel.

The main channel dimension is the required width. For the present feasibility study a tentative estimation will be sufficient, leaving the final width to be further considered in the project stage. The required width is determined by three factors:

- the width of the lane for one ship
- the horizontal clearance between the two lanes
- the clearance between ship-lane and river bank.

There are various reasons for taking moderate values for these three factors. Although it has to be designed for two-way traffic, the channel will have a low traffic density. There is therefore no objection to a speed reduction for the vessels during passage. Moreover, the captains of the ships will be familiar with the route. Finally, the cross-section of the channel is part of a much wider river cross-section.

The following tentative dimensions have been chosen in relation to the width b of the ships:

Width of two traffic lanes	2 x 1.5b
Clearance between the two lanes	0.5b
Clearance between lane and river bank	2 x 0.5b
Total width	4.5b

This total width of 4.5 b has to be present at the bottom level of the ships. Locally, in bends, a larger width is required depending on the length and radius of the bend.

The bottom width of the channel depends of course also on the clearance under the keel.

3.2.3 Depth of Channel.

The required clearance varies along the channel.

The following factors govern the required clearance under the keel of the ships:

a) - sinkage due to squat
b) - influence of trimming
c) - irregularities in riverbed (dunes and ripples)
d) - effect of wind waves on the lakes (pitching and rolling)
e) - drop of water level due to the wind effects for the shallow Lake Malombe.

These factors are not of equal importance for the various parts of the channel. Table 2 gives an indication about the importance of the factors.

TABLE 2

Factors Governing The Required Clearance Under The Ship's Keel.

Channel Section	Clearance Factor				
	a	b	c	d	e
Lake Malawi	+	+	-	+	-
Shire 4.5N - 4.5S 23S - 28S	+	+	x	-	-
Lake Malombe	+	+	-	+	+
Shire 28S - 45S	+	+	+	-	-

+ = important; x = slightly important; - = not important

After detailed investigation of the various factors, a keel clearance between 3.5 and 5 ft (1.05 - 1.55 m) has been adopted, which in connection with the max. draft of the ships of 9 ft and the above-mentioned requirements with regard to the width has led to a proposal for the channel dimensions, as shown in drwg. B 38.

The bank slope (α) of the channel will depend on the conditions of the soil in the banks. As an average, a slope of 1:5 has been assumed for the estimate of the quantities to be dredged.

3.2.4 Alignment of Channel.

The proposed alignment of the channel is indicated on the sounding maps (drwgs. B 14 to B 26).

The following factors have been taken into consideration for this proposal:

- an alignment along the "thalweg" of the river reduces dredging cost.
- the radius of bends has in principle been chosen at more than ten times the length of the ship. In some cases this proportion

could not be obtained.

- one existing sharp river bend just upstream of Liwonde (drwg. B 25) will have to be cut off.
- straight sections of the channel are designed in such a way that beacons can be installed at the banks in order to guide navigation.
- channel bends have been designed with a constant radius for the convenience of navigation.

3.3 Lake Level Analysis and Prognoses.

3.3.1 General.

For the given bed levels of the Shire River and the two lakes, Malawi and Malombe, the required channel dimensions and the quantities to be dredged can only be determined on the basis of an adopted design water level.

A second factor which has to be considered regards the speed of the dredging operations: the cost of dredging will depend on the time available for completing the channel.

It has been supposed that navigation by ships of full draft, 9 ft, must be possible in the beginning of 1975, giving about 5 1/2 years to carry out the initial dredging.

3.3.2 Lake Level Variations.

The water level of Lake Malawi is determined by rainfall, run-off from catchment area, evaporation on Lake Malawi, and by discharge through the Shire River. Various investigators have studied the hydrology of the Lake (Kantack, 1948: Cochrane, 1956/57, and Pike, 1964). Table 3 gives an impression of the different factors of the

TABLE 3

Water Balance of Lake Malawi.

Factors of the water balance	Quantities in: ft acres x 10^6 (m^3 x 10^9)	Quantities in: Percentage
1. Supply of Water to Lake Malawi.		
a. rainfall on the lake	33 (40)	62 (62)
average annual rainfall on the lake $4\frac{1}{2}$ ft (1.37 m)		
area lake surface 11430 sq. miles (29,600 km^2)		
b. inflow rivers	20 (25)	38 (38)
average annual rainfall on the catchment area 3.85 ft (1.17 m) (drwg. B 6)		
catchment area 37420 sq. miles (96,900 km^2) (drwg. B 5)		
run-off percentage 22		
	53 (65)	100 (100)
2. Evaporation	47 (58)	88 a 89
average annual evaporation 6.4 ft (1.95 m)		
area lake surface 11430 sq. miles (29,600 km^2)		
3. Free water available for Shire River discharge	6 (7)	12 a 11

water balance. These data are collected from the publications of the three authors, and based on 40 years averages.

These figures show that only 11 to 12% of the total supply to the lake, i.e. rainfall on the lake and on the catchment area, viz. 8,000 to 9,000 cusecs (about 250 m^3/sec.) is available for river discharge.

Besides the annual variations in lake level, long-term lake level variations occur (drwg. B 7) due to long periods of heavy rainfall and/or evaporation.

Drwg. B 39 represents the recorded lake levels from 1916. Earlier figures have not been considered, as they are less accurate. It has been indicated in this drawing, how the lake level would have changed if no discharge had taken place through the Shire River also after 1935.

As a general tendency, this curve shows from 1930 to 1955/60 an almost linear increase, corresponding to an average annual discharge of about 10,000 cusecs (285 m^3/sec.), while the quantity of free water even seems to increase further during the last 5 to 10 years. Besides this general tendency, a more or less regular variation within ten year periods seems to exist.

There has been great discussions in literature about the possible correlation of these regularities with the annual number of sunspots. The numbers of sunspots reached maxima in 1917, 1927, 1937, 1948 and 1957, thus with a period of approximately 10 years.

A regularity in the lake level variation seems thus to exist, and evidence seems to show that also the year 1966 represented a relatively high lake level. Due to the small rainfall in the first part of 1967, the quantity of free water expected in 1967 will have a negative value. It is expected that the lake level will fall again during the next years.

The above considerations could lead to a statistical analysis of what may happen after a relative maximum (analysis of the period after 1917, 1927, 1937, 1948, 1957), and thus of what could occur after 1966.

The above mentioned five periods after a year with high lake levels have been indicated in drwg. B 40. In all five cases the water levels are those of no discharge through the Shire River.

3.3.3 Determination of Design Lake Levels.

The ESCOM Consultants, Messrs. Watermeyer, Legge, Piesold & Uhlmann, have for the Malawi Government carried out a study of the Tedzani Fall Hydro-electric Scheme, which has resulted in a proposed future operation scheme for the Liwonde barrage. Their report was submitted to the Government in October, 1967.

The ESCOM Consultants, as mentioned in section 1.2, were also approached by Kampsax with regard to future lake levels, future surface elevation levels in the river and the backwater effect of the barrage at Liwonde in relation to the present Lake and River Transportation survey. Preliminary information with regard hereto was received towards the end of 1967 and final proposals at the end of January, 1968. (See further page 27.)

The operation scheme for the Liwonde barrage will have to serve many interests. Hydropower, irrigation, flood protection and lake and river navigation have their special requirements with regard to the optimum lake levels. For the navigation of the Shire River and Lake Malombe, relatively high lake levels are attractive, as they will reduce the costs for dredging of the channel.

The conclusions and recommendations of the ESCOM Consultants, as it appears from their Project Report on the Tedzani Falls Hydro-electric Scheme, Appendix C, are the following:

i) The continuous available discharge, if the Barrage is operated as stated below, is 6,000 cusecs.

ii) The following Barrage operating policy is proposed:

   a) Release 6,000 cusecs from the Barrage provided the lake level at Fort Johnston is above SVP + 1548.5 ft and below SVP + 1553 ft.

   b) If the Lake is above SVP + 1553 ft make the maximum discharge possible.

   c) If the Lake falls below SVP + 1548.5 ft release 3,000 cusecs.

iii) This operating rule can be further improved by modifying the SVP + 1553 ft criterion appropriately to take account of the monthly fluctuations of free water. Various studies have been made in this regard and the effect on high lake levels has been found to be negligible. The calculations show, however, that the reliability of discharge is much improved.

According to the ESCOM Consultants, confer the above mentioned Appendix C to their Project Report, the following determining levels should be applied to the Lake Malawi:

Mean Water Level (MWL)	1553.0 ft
Lowest Low Water Level (LLW)	1548.5 ft
Highest High Water Level (HHW)	1558.5 ft

3.3.4 Determination of Design River Levels.

For the harbour site at Fort Johnston, five miles south of Lake Malawi bar in the Shire River, the same three water levels, as indicated above for Lake Malawi, do apply.

Further down the Shire River, and particularly at Liwonde, the water levels depend to a great extent on the operation procedure of the Liwonde barrage. In order to maintain the high mean water level at Lake Malawi of 1553 ft. it will be necessary to regulate the flow of the river, as recommended above, by means of the barrage at 6,000 cusecs. If the lake level is higher than 1553 ft. the barrage should be fully open. Should the lake level fall below 1548.5 ft. only 3,000 cusecs should be released.

The ESCOM Consultants have calculated the surface elevation in the river from the bar at Lake Malawi to Liwonde corresponding to lake levels of 1551, 1550, 1549 and 1548.5 ft. These surface elevations are given in table 4. With a lake level of 1548.5 ft. there is a drop of about 4 ft. from Lake Malawi to Liwonde. This corresponds to present normal flow of the river.

The per cent chance of the lake falling below level 1549.5 ft., found by interpolation of the figures in table 5, is given in table 6. It will be noted that there is a 13-16 per cent chance of the lake level falling below 1549.5 ft. during the months of October-November, so that this might happen once in every seventh year, which is considered a reasonable chance to take. It should be mentioned that a small reduction in cargo tonnage and service speed of the vessels would be possible during this rare occurrence. Moreover, the very regular yearly behaviour of the lake level makes it possible to estimate the low levels in November-December of a certain year sufficiently ahead. The lake falling below level 1550 ft. would happen about every fourth year, and the choice of this lake level is therefore considered a bit unsafe.

TABLE 4

Backwater Effect in Shire River Due to Liwonde Barrage for Various Lake Levels.

Section Reference Drwg. B 33	Chainage in Miles from Liwonde	Surface Elevation in River Corresponding to Assumed Lake Levels of:			
		1551 ft	1550 ft	1549 ft	1548.5 ft
(Mvera)					
31	22.4	1551.01	1550.05	1549.05	1548.55
32	20.4	1551.00	1550.03	1549.02	1548.52
33	16.8	1550.98	1549.99	1548.97	1548.46
34	16.7	1550.96	1549.97	1548.94	1548.43
35	16.5	1550.93	1549.92	1548.84	1548.29
36	16.0	1550.86	1549.81	1548.66	1548.02
37	15.5	1550.84	1549.76	1548.56	1547.89
38	14.0	1550.73	1549.60	1548.30	1547.53
39	13.5	1550.72	1549.59	1548.27	1547.48
40	10.7	1550.61	1549.42	1547.96	1547.01
41	2.3	1550.25	1548.86	1546.91	1544.76
42	2.2	1550.25	1548.86	1546.91	1544.76
43	1.7	1550.25	1548.86	1546.90	1544.73
(Liwonde) 44	0	1550.20	1548.81	1546.85	1544.62

The probabilities, i.e. the per cent chance of the lake falling below the assumed lake levels of table 4, are given in table 5.

TABLE 5

Per Cent Probabilities of Lake Level Falling Below Indicated Levels.

	Lake Levels			
Month	1551 ft.	1550 ft.	1549 ft.	1548.5 ft.
January	25	9	1	+
February	12	+	+	+
March	2	+	+	+
April	+	+	+	+
May	1	+	+	+
June	9	+	+	+
July	22	3	+	+
August	30	9	1	+
September	36	20	1	+
October	39	26	6	2
November	46	24	9	4
December	36	19	3	+

Note: + means a probability of less than 1 per cent.

These probabilities were derived by the ESCOM Consultants, using the release policy described in their above mentioned report to the Malawi Government of October, 1967.

TABLE 6

Per Cent Probabilities of Lake Level Falling Below 1549.5 ft.

Month	Lake Level 1549.5 ft.
January	4
February	+
March	+
April	+
May	+
June	+
July	1
August	4
September	7
October	13
November	16
December	10

Note: + means a probability of less than 1 per cent.

Lake level of 1549.5 ft. has therefore on basis of the above been chosen as the design lake level for the navigation channel of the Upper Shire River between Lake Malawi and Liwonde. The drop in surface elevation for different chainages as given in table 7, which is derived from table 4, will in this case only be 1.7 ft. between Lake Malawi and Liwonde, due to the backwater effect of the Liwonde barrage - and of the Shire River channel between Lake Malombe and Liwonde.

TABLE 7 (See also note page 27)

Backwater Effect in Shire River from Mvera to Liwonde Corresponding to Lake Level of 1549.5 ft.

Section Reference Drwg. B 33	Chainage in Miles from Liwonde	Surface Elevation for Lake Level 1549.5 ft.
(Mvera)		
31	22.4	1549.6
32	20.4	1549.5
33	16.8	1549.5
34	16.7	1549.5
35	16.5	1549.4
36	16.0	1549.2
37	15.5	1549.2
38	14.0	1549.0
39	13.5	1548.9
40	10.7	1548.7
41	2.3	1547.9
42	2.2	1547.9
43	1.7	1547.9
44	0	1547.8
(Liwonde)		

Cross sections for the navigation channel for a maximum draft of ships at 9 ft. at the different stretches of the Upper Shire River above Liwonde are given in section 3.2 above. These sections together with the surface elevation for different chainages from table 7 make it possible to determine the quantities to be dredged for the navigation channel.

At Liwonde the Lowest Low Water level (LLW) should according to table 7 be 1547.8 ft. The Highest High Water level (HHW) at Liwonde should according to literature regarding the unobstructed river channel flow be HHW at the lake: 1558.5 ft. less drop in water level between the lake and Liwonde: 5 ft. = 1553.5 ft. It is not possible to fix a mean water level at Liwonde, which would depend entirely on the operating policy of the barrage. The said extreme river levels at Liwonde have been used for the Liwonde harbour project and for determining the quantities to be dredged in this harbour.

3.4 Quantities to be Dredged.

Note: After finalizing the transportation project on the basis of the above information from ESCOM, detailed back-water levels in Shire river duly considering river cross sections after the execution of the navigation channel, have been received. It appears that the backwater level at Liwonde might have been raised by about 1 ft extra, while it at Lake Malombe would remain the same.

The dredging of quantities of the river channel could hereby be reduced a little. Such a reduction has not been considered due to the late arrival of the new information. It will be on the safe side not to reckon with the small reduction in dredging costs caused by the somewhat higher water levels in the lower part of the Upper Shire river.

The quantities to be dredged have been compiled on the basis of the channel dimensions proposed in paragraph 3.2. The quantities are given in drwg. B 41 for the chosen design of 1549.5 ft. lake level.

Two possible sites for the harbour terminal have been considered (refer drwg. B 8):

Plan A: Harbour at Liwonde.

Plan B: Harbour upstream of the Nkasi River mouth.

Plan B has been considered for two reasons. Firstly, the amount of initial dredging work per mile is relatively high downstream of the Nkasi River. Moreover, also the amount of maintenance dredging in the Shire River is likely to be higher downstream of this tributary.

The estimates of maintenance dredging have been based on computations of the bed material transport capacity of the Shire River.

For plan A the future yearly permanent maintenance dredging after 1975 has been estimated at 200,000 to 400,000 cu. yd.

For plan B the corresponding amount is 125,000 to 250,000 cu. yd. of maintenance dredging. The total amount of initial dredging work in the channel is for plan A: 3.4×10^6 cu. yd. and for plan B: 2.0×10^6 cu. yd. The annual amount of initial and maintenance dredging reckoned with in the Design and Building Programme in the General Report is for plan A: 1.1×10^6 cu. yd. and for plan B: 0.75×10^6 cu. yd., the said amounts comprising initial and maintenance dredging for the river channel as well as for the river harbours.

4. DREDGING OF THE NAVIGATION CHANNEL

4.1 General.

The cost of the dredging operations depends primarily on the annual quantities to be dredged, in order to permit navigation in the river for ships with drafts up to 9 ft (2.74 m) in 1975. These quantities are determined by channel dimensions, the present bottom configuration of the Upper Shire River and Lake Malombe, and the possible lake level for 1975. As explained in section 3.3.4 above the design lake level has been fixed at 1549.5 ft. Knowing the annual quantities to be dredged, the equipment and the organization necessary to carry out the dredging can be considered (see 4.2 and 4.3 below). The dredging cost based on capital investment and annual operation costs can then be estimated, see 4.4 below.

4.2 Dredging Equipment.

The dredging equipment will depend on the following:

choice of type of dredger
way of dumping the spoil
capacity and number of dredgers
required service vessels.

The type of dredger depends mainly on the characteristics of the soil to be dredged, i.e. initially dredged soil and soil dredged for maintenance.

Initially sand and gravel are to be removed in the river and on the bars, for which suction dredging can be applied. Clay, however, has to be dredged in Lake Malombe and partly also in the river. Cutter-head suction dredging is therefore required.

For maintenance of the navigation channel, sand, gravel, and silt will have to be removed, for which suction dredging with a dust-pan is suitable.

On basis of these considerations, a combination of dust-pan suction and cutter-head suction dredging is required. For the initial dredging, a cutter-head suction dredger will be required. For maintenance dredging, where thin layers of sand and silt have to be removed, a cutter-head suction dredger is less efficient, whereas a dust-pan dredger will be more suitable. A dredger with interchangeable heads - cutter-head and dust-pan, drwg. B 42 - should therefore be preferable.

Along the Shire River no special interests in the use of the dredged soil seem to exist. On an economical basis, the shortest soil transportation distance is therefore most desirable. An investigation of possible spoil deposit areas along the river shows that the material can be dumped at distances from the dredger not exceeding 500-800 ft (150-250 m), see drwg. B 43. The said distance should not be chosen too short due to the danger of spoil running back into the dredged channel. A floating pipeline for pumping ashore is most suitable under these circumstances.

At Liwonde the dredged materials from the harbour basin are supposed to be used in the reclamation of the harbour areas.

The required totally available dredging capacity is determined by the annual quantities to be dredged (see 3.4 above) and the annual number of effective working hours.

Experience and calculations of costs seem to indicate that about 3,500 working hours of dredging annually will be most economical. Therefore two shifts will have to be worked, each of eight hours, six days a week and 44 weeks a year. By working in two shifts, it is possible to do important repairs during nights.

Small repairs and other delays during daytime reduces of course also the operation time. Furthermore, it is assumed that two months a year are needed for a general inspection and overhaul of the equipment.

The necessary dredging capacity for the years 1969-1975 expressed in cu.yd. per working hour including maintenance dredging and dredging for Fort Johnston and Liwonde harbours, is for Plan A 310 cu.yd./hour and for Plan B 220 cu.yd./hour.

The number of dredgers is determined by two considerations:

a. In order to start the dredging quickly, say mid 1969, a dredger should be bought outside Malawi and transported to the lake. The only feasible way of transportation to the lake is the railroad from Beira, and the dredger will therefore have to be transported in sections. As limitations for the transport by rail from Beira to Balaka, the following dimensions have been given:

   wagon: max. length 46'6" (14.17 m)
   max. width 8'0" (2.44 m)
   max. weight 35 tons

   max. transport width 10'6" (3.20 m)

   max. transport height 9'3" (2.82 m)

   From Balaka to the river at Liwonde, the transportation can take place by means of low-loaders.

   A 50 t derrick will be provided both at Balaka and at Liwonde for unloading of heavy pieces.

From an economic point of view it is evident that standard dismountable dredgers should be used.

b. The equipment must be easy to repair and flexible in its use. Therefore, at least 2 equal dredgers should be used.

On basis of a survey of presently known dredgers and the above mentioned transport restrictions, the use of two dredgers is most probable both for plans A and B.

For a proper functioning of the dredging equipment, a few service vessels are necessary, viz.:

For the whole dredging scheme:

- one house boat
- one fuel barge for the supply of fuel, food, drinking water, spare parts, etc.

For each dredger:

- a repair barge
- a tug to transport barges and floating pipelines, but also to use for regularly taking of soundings before and after dredging
- a speed boat.

Further a field office boat will be necessary.

4.3 The Organization of the Dredging Operation.

Recommendations regarding a more detailed dredging organization will be given in the project study. However, in order to get an impression of the size of the dredging organization and the way the project has to be carried out, some considerations have been made.

The organization of the whole channel dredging project can be divided in two parts, viz. the supervision and the organization of the dredging operation proper.

The supervision is primarily responsible for the proper planning and control of the dredging operations. Their task will comprise collection of data, hereunder soil investigation, studying of the river behaviour, designing and supervising dredging schemes, preparation of navigation maps, etc.

Therefore the supervision needs specialized hydraulic engineers and other technical and administrative personnel. To carry out field activities, the supervision must have at their disposal a well equipped survey vessel.

For a proper execution of the dredging operations approximately 40-60 crew members and workmen are required to man the two dredgers, their service vessels, the soil dumps and the field office boat. This number includes some trainees. Roughly 25 per cent of the crew and the workmen need to be well experienced, 25 per cent should be skilled labourers and 50 per cent unskilled labourers.

At present people with experience in dredging work cannot be found in Malawi, neither for the supervision nor for the execution of dredging operations. A consultant will therefore be required to take care of the supervision during the beginning of the operation. Meanwhile an organization can be built up, possibly within the Malawi Government, which can take over the consultants' responsibility.

The initial dredging work should be carried out by a contractor. After finishing of the initial dredging work, the future maintenance dredging in the navigation channel has to be carried out by the Malawi Government after having obtained experience in dredging and supervision of dredging operation from consultant and contractor.

Appointment of Malawian counterparts for crew and workmen and use of dredging equipment suitable for the execution of maintenance dredging may help in the transfer of dredging operations from contractor to Government.

4.4 Cost of Dredging of The River Channel and River Harbours.

The cost of the total dredging scheme depends on three factors:

a. the cost of the initial dredging work
b. the cost of maintenance dredging which has partly to be carried out concurrently with the initial dredging
c. the cost of supervision.

Re.: a: With a design lake level of 1549.5 ft above S.V.P. Datum, the required expenditures for initial dredging of the River Channel and the River Harbours in the two cases, Plan A and Plan B (see 3.4 above) are indicated in table 8.

TABLE 8

Cost of Dredging for Plan A and Plan B.

	Plan A Harbour at Liwonde	Plan B Harbour upstream of Nkasi river-mouth
Dredging for the navigation Channel:	£ 600,000	£ 425,000
Dredging for Fort Johnston and Liwonde (Nkasi) Harbours	£ 160,000	£ 190,000
Total	£ 760,000	£ 615,000
Cost of dredging of one foot extra depth:		
The navigation Channel:	£ 230,000	£ 160,000
Fort Johnston and Liwonde (Nkasi) Harbours:	£ 20,000	£ 20,000
Total	£ 250,000	£ 180,000

The above calculations lead to a unit price per dredged cubic yard of about 3-1/2 sh for Plan A and about 4-1/4 sh for Plan B. Much too low

Re.: b. Siltation will occur from the moment when the dredging operations start, which means that concurrent with the initial dredging work, maintenance dredging in the navigation channel (and in the harbours) has to be carried out. The average annual cost hereof is estimated at about £ 60,000 for Plan A and £ 50,000 for Plan B. Adv maintenance

After the initial dredging work has been finished, the annual maintenance dredging, which is estimated at 370,000 cu. yd. for Plan A and 270,000 cu. yd. for Plan B, will be about twice as expensive per cu. yd. due to a less efficient use of the dredging equipment.

The total annual expenses of maintenance dredging after 1975 are thus estimated at £ 130,000 for Plan A and £ 115,000 for Plan B.

Re.: c. For the supervision an annual amount of £ 30,000 is estimated to be required to cover salaries, buildings, transport, measuring equipment, survey cost, etc.

The prices given in a, b and c above cannot be but approximate estimates. The actual prices depend largely on the refinement during the project stage. Moreover, the final prices to be paid to a contractor depend to a great extent on the interest the contractor manifests in tendering for the job.

5. TERMINAL HARBOUR AT NKASI AS ALTERNATIVE TO A HARBOUR AT LIWONDE

In section 3.4 and 4.4 above two alternatives with regard to the location of a terminal harbour in Shire River have been discussed: Plan A at Liwonde on the Eastern river bank North of the existing barrage, and Plan B about 15 miles further upstream on the Western river bank, just North of the mouth of the tributary Nkasi.

The quantity and thereby the cost of dredging channel and harbours included is about 20 per cent less for Plan B than it is for Plan A as it appears from table 8 above.

In case Plan B is adopted, the savings obtained would thus comprise lower cost of the initial dredging of the Shire River as well as less future annual cost of maintenance dredging in the channel after 1975.

These savings should be compared with the extra expenses involved in the building of a railtrack along the Western bank of Shire River connecting Nkasi with the Nacala Rail Link at Liwonde, an additional station at Nkasi and the necessary connections of Nkasi to the existing road net.

A comparison between Plan A and Plan B of capital costs and capitalized annual maintenance costs is given below under the assumption that the cost of construction of a harbour is the same for Liwonde and for Nkasi, except for dredging work, which due to the adopted higher unit price as a result of smaller quantities in Plan B will be somewhat higher for the harbour at Nkasi than for the harbour at Liwonde.

a. Savings.

		Initial dredging of the channel incl. simultaneous maintenance dredging for the period 1/7-69 to 1/1 1975	Annual maintenance dredging for the period after 1/1 1975
		£	£
Plan A.			
Harbour at Liwonde			
Initial dredging			
Channel and harbour	£760,000		
Maintenance 5-1/2 yrs.	330,000		
Supervision 5-1/2 yrs.	165,000	1,255,000	130,000
Plan B.			
Harbour at Nkasi			
Initial dredging			
Channel and harbour	£615,000		
Maintenance 5-1/2 yrs.	275,000		
Supervision 5-1/2 yrs.	165,000	1,055,000	115,000
Difference A - B		200,000	15,000

Total Savings:

Initial dredging of River channel	£200,000
Maintenance dredging of channel after 1/1-75 capitalized (5 per cent p.a.) = 15,000 x $\frac{100}{5}$ =	£300,000
Total savings	£500,000

b. Extra expenses.

Railway connection Nkasi - Liwonde (18 miles) incl. station at Nkasi	£ 900,000
Road connection from Nkasi to existing road system (14 miles)	£ 200,000
	£ 1,100,000
Maintenance of railway and roads 1.5 à 2.0 per cent p.a.	£ 20,000

Total extra expenses:

Construction of railway and roads	£ 1,100,000
Maintenance of railway and roads, capitalized (5 per cent p.a. = $20,000 \times \frac{100}{5} =$	£ 400,000
Total extra expenses	£ 1,500,000

It appears from the above that an additional investment of £1,000,000 is necessary in case the terminal harbour in Shire River is placed at Nkasi (Plan B) instead of at Liwonde (Plan A). Furthermore, other expenses, not considered above, such as running of the extra railway section, higher freight rates for moving of goods to Nkasi as a result of longer land transport, etc, also favour the choice of location of the harbour terminal at Liwonde.

But even other things being equal, there is no doubt that owing to its central location at the crossing point between the Shire River, the main road Zomba - Balaka and the new Nacala Rail Link, Liwonde is the natural place for establishing the terminal harbour for transfer of goods and passengers between ships, rail and road.

6. BRIDGE AT FORT JOHNSTON

It has been proposed to construct a high level bridge at Fort Johnston instead of the present car and passenger ferry connection. The bridge would cost about £400,000, which seems excessive compared to the cost of running the ferry arrangement. The mentioned sum could perhaps be utilized better in the construction of feeder roads on the Eastern side of the Upper Shire River opposite Fort Johnston and then maintain the ferry connection.

The construction of a low level bridge with a bascule span for the passage of lake and river vessels might be somewhat less costly; it would, however, have many disadvantages compared to a fixed high level bridge.

None of the two mentioned solutions seems satisfactory, and it is therefore until further proposed to keep the present ferry connection.

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1. F.E. Kanthack, "Report on the Measures to be taken to permanently stabilize the Water Level of Lake Nyasa", 1948.

2. Sir William Halcrow and Partners, "Control and Development of Lake Nyasa and the Shire River", September, 1954.

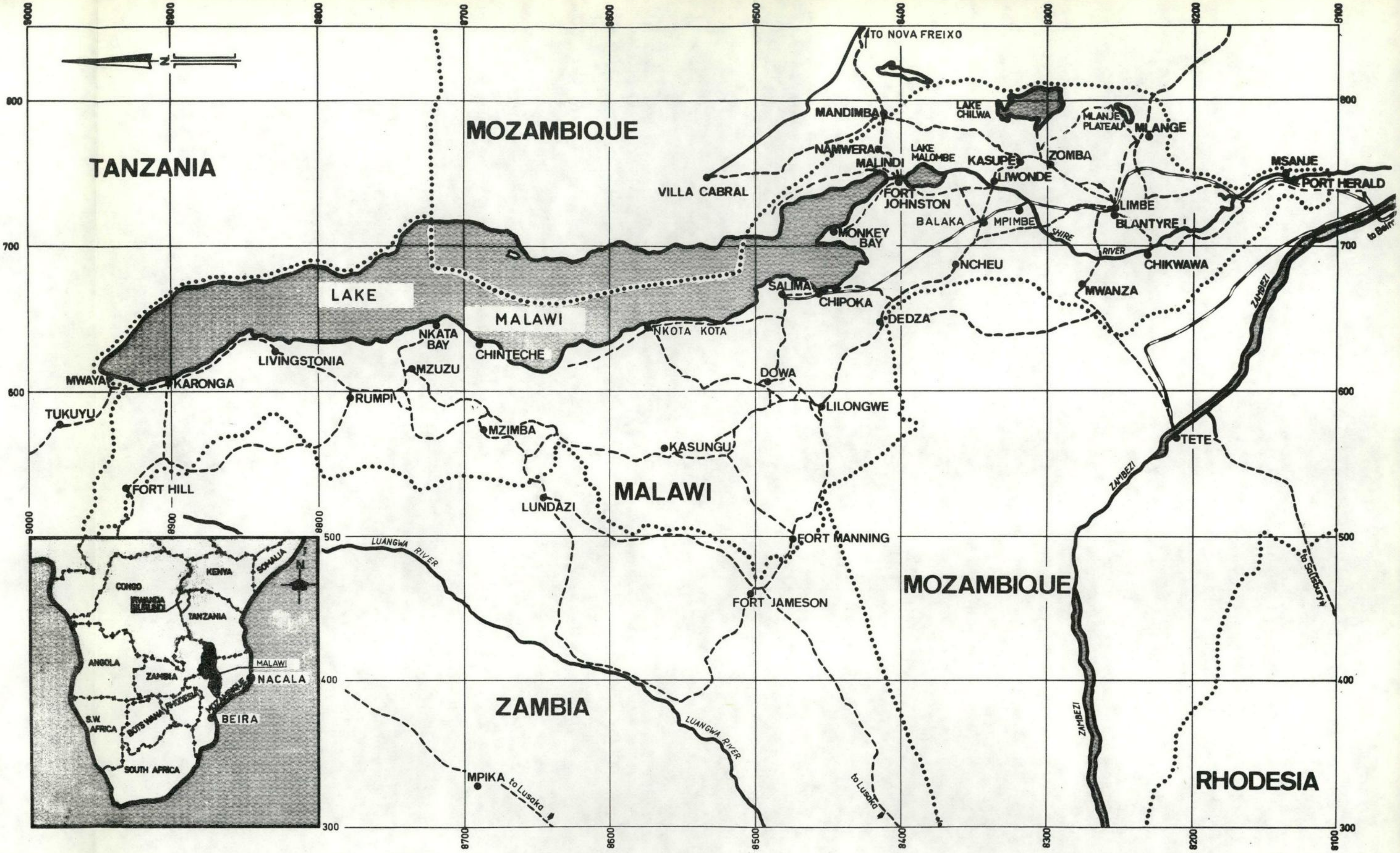
3. N.J. Cochrane, "Lake Nyasa and the Shire River", Proceeding of the Institution of Civil Engineers, December, 1957.

4. N.J. Cochrane, "Discussion on Lake Nyasa and the Shire River", Proceedings of the Institution of Civil Engineers, June, 1948.

5. F.E. Kanthack and Partners, "Nkula Falls Hydro-electric Scheme", November, 1959.

6. J.G. Pike, "The Hydrology of Lake Nyasa", Journal of the Institution of Water Engineers, No. 7, November, 1964.

7. Kennedy & Donkin, "Tedzani Falls Hydro-electric Scheme", Project Report, October, 1967.



NOTE: NUMBERED LINES INDICATE THE 1000 METRE UNIVERSAL TRANSVERSE MERCATOR GRID, CLARKE 1880 (MODIFIED) SPHEROÏD (THE LAST THREE DIGITS OF THE NUMBER ARE OMITTED)

0 50 100km

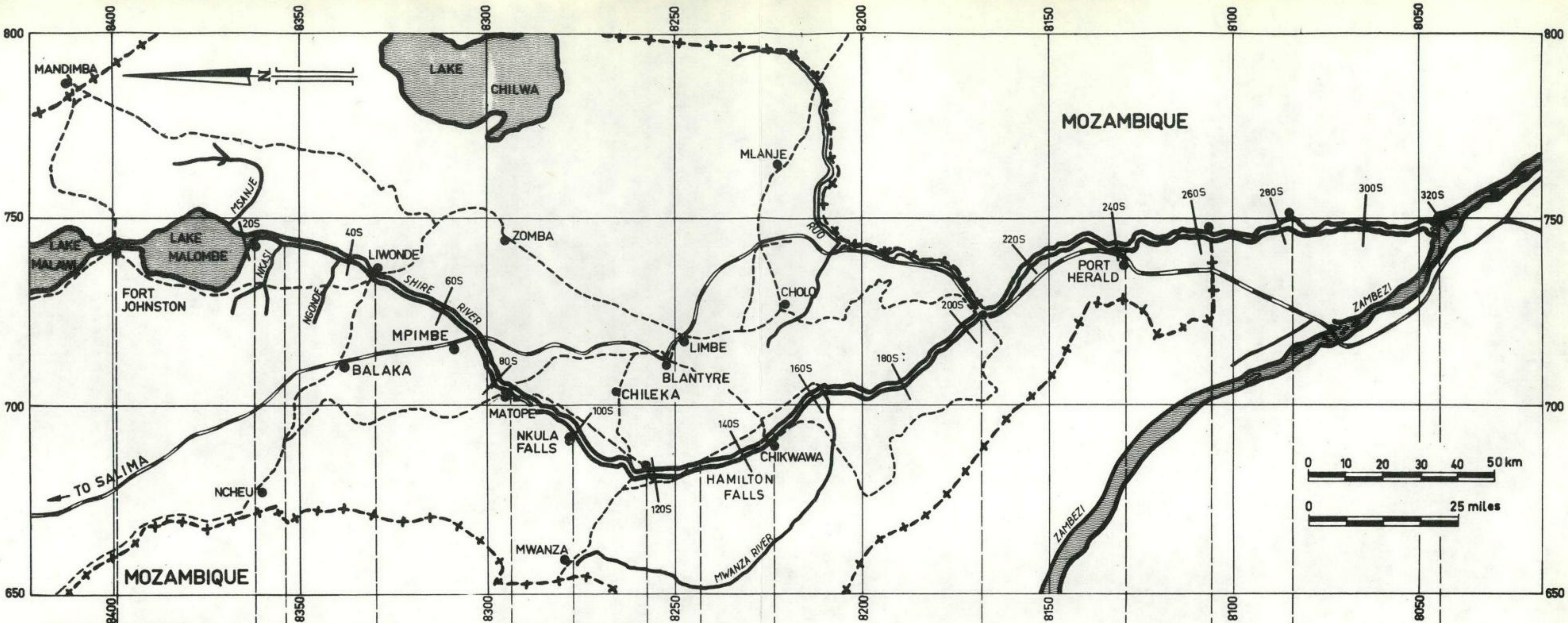
0 50 100miles

LEGEND:

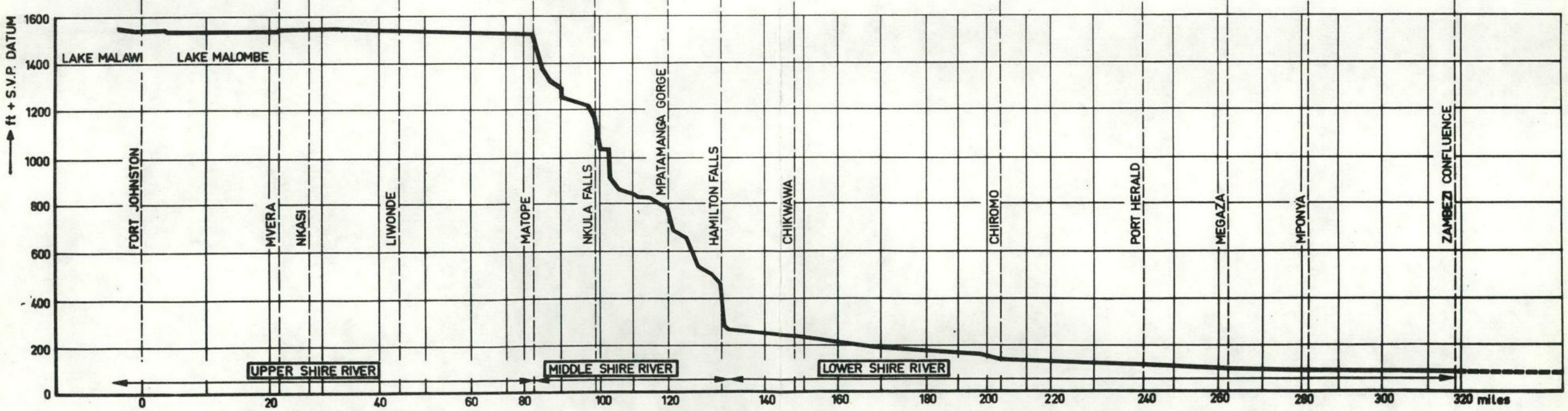
- RAILWAYS
- ROADS
- INTERNATIONAL FRONTIERS

SCALE: PLAN 1:2 500 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN
MAP OF MALAWI	APPROVED FEBR.1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	R. 420 S. N. 3297 NO. 81



PLAN SHIRE RIVER 1:1 250 000



LONGITUDINAL PROFILE SHIRE RIVER

NOTE :
1. LONGITUDINAL PROFILE TAKEN FROM HALCROW REPORT (1954)
2. ALL LEVELS RELATED TO SHIRE VALLEY PROJECT DATUM, S.V.P.D. WHICH REFERS TO MEAN SEALEVEL AT BEIRA
3. GRID-SYSTEM PLAN SEE DRWG. B 1
4. STATIONS ALONG THE RIVER INDICATE DISTANCES ALONG THE SHIRE RIVER MEASURED IN MILES FROM FORT JOHNSTON

LEGEND PLAN :

RAILWAYS
ROADS
INTERNATIONAL FRONTIERS
60 S MILEAGE FROM FORT JOHNSTON SOUTHWARDS

SCALE: PLAN 1:1 250 000

GOVERNMENT OF MALAWI

LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT

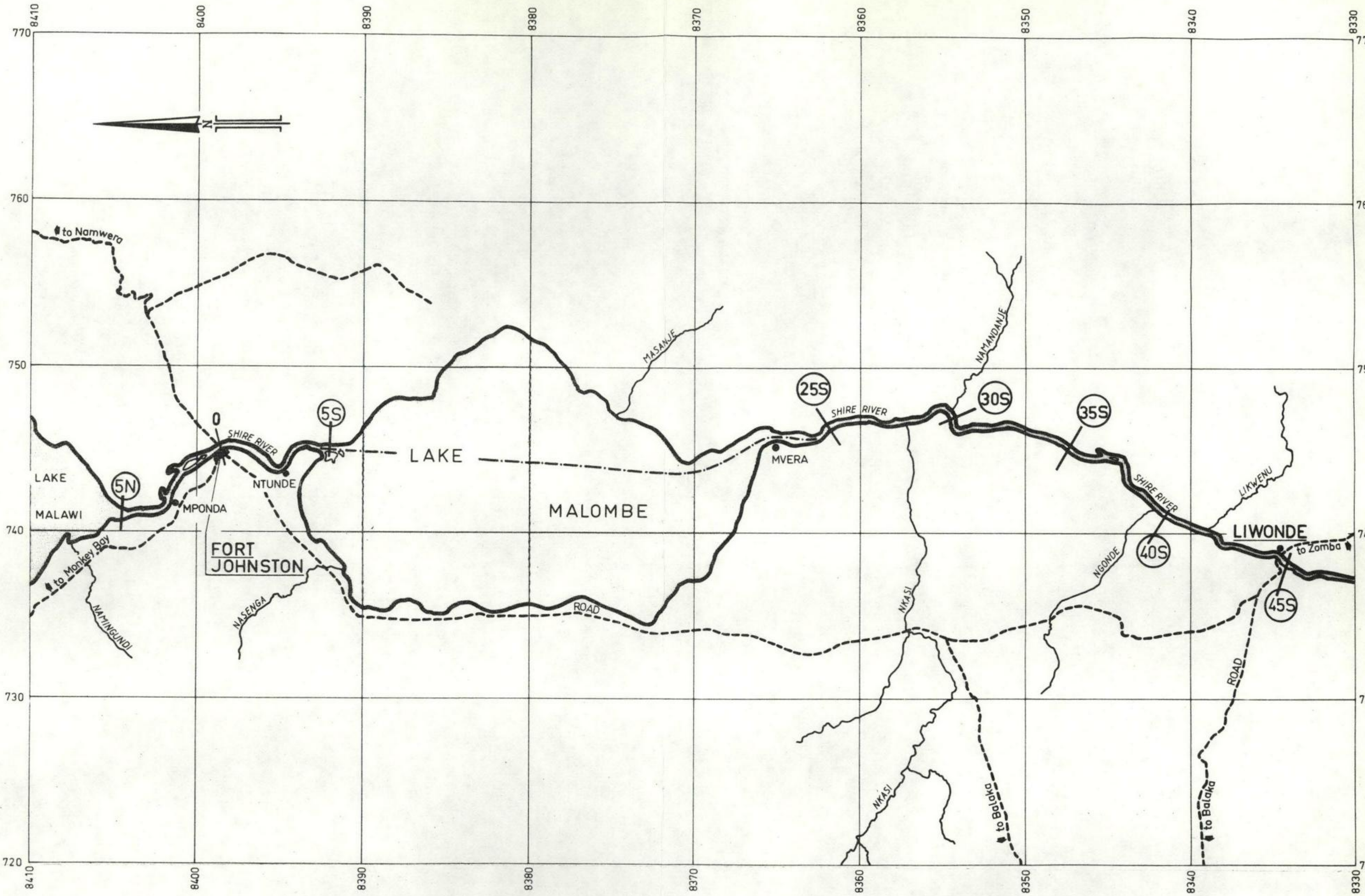
MAP AND LONGITUDINAL PROFILE SHIRE RIVER

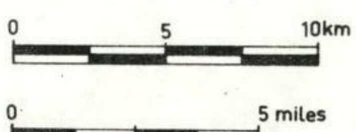
DESIGNED
DRAWN
APPROVED
FEBR. 1968

DELFT HYDRAULICS LABORATORY

KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN

R. 420
S. N. 3297
NO. B 2





NOTE: 1.-NUMBERED LINES INDICATE THE 1000 METRE UNIVERSAL TRANSVERSE MERCATOR GRID ZONE 36 CLARKE 1880 (MODIFIED) SPHEROID.
(The last three digits of the number are omitted)

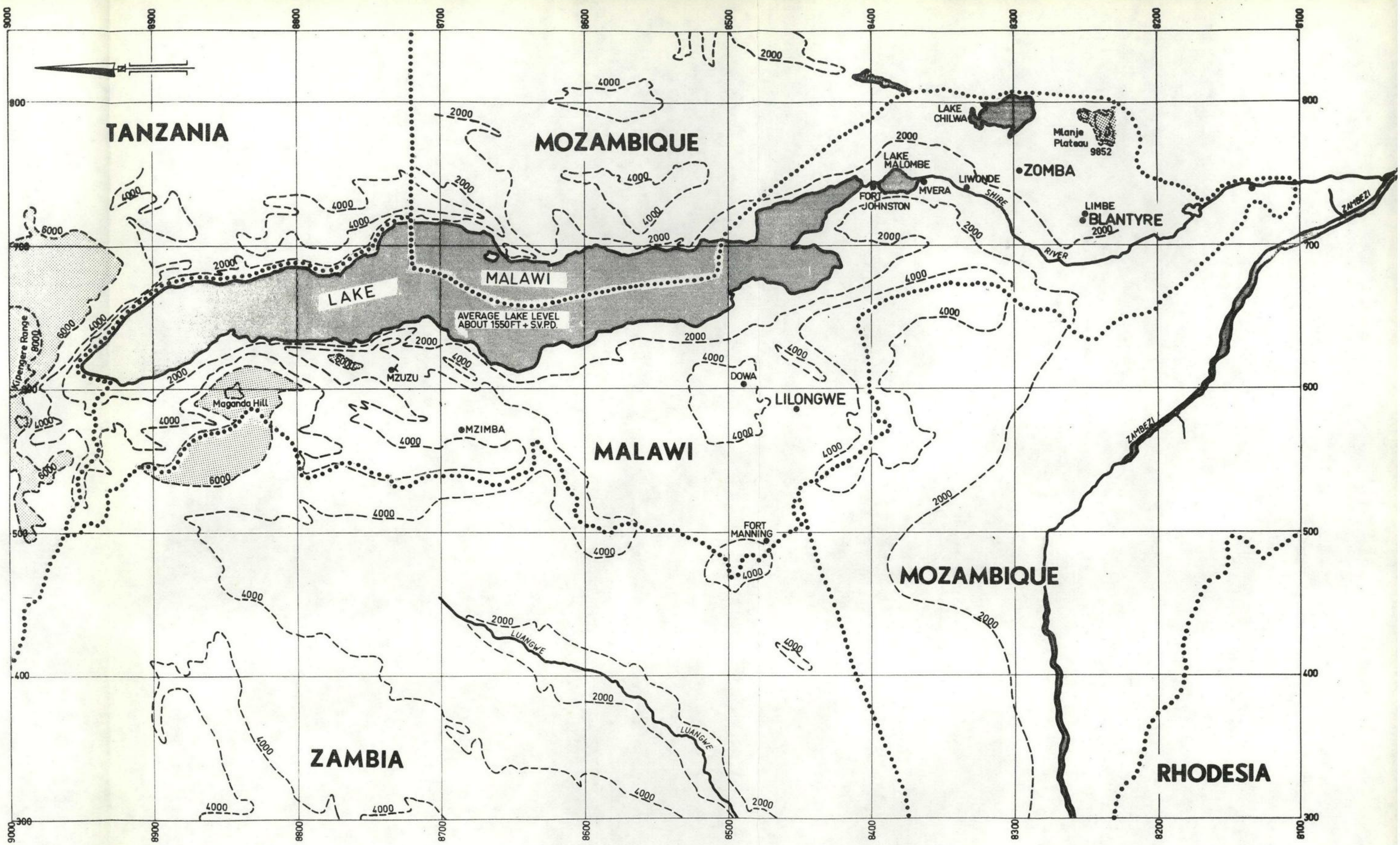
2.- STATIONS MENTIONED ALONG THE RIVER INDICATE DISTANCES ALONG THE CENTRE-LINE OF THE SHIRE RIVER MEASURED IN MILES FROM FORT JOHNSTON FERRY, RESPECTIVELY IN NORTHERN (N) AND SOUTHERN (S) DIRECTION.

5-N MILEAGE FROM FORT JOHNSTON NORTHWARDS

25 S MILEAGE FROM FORT JOHNSTON SOUTHWARDS

SCALE: 1 : 250 000

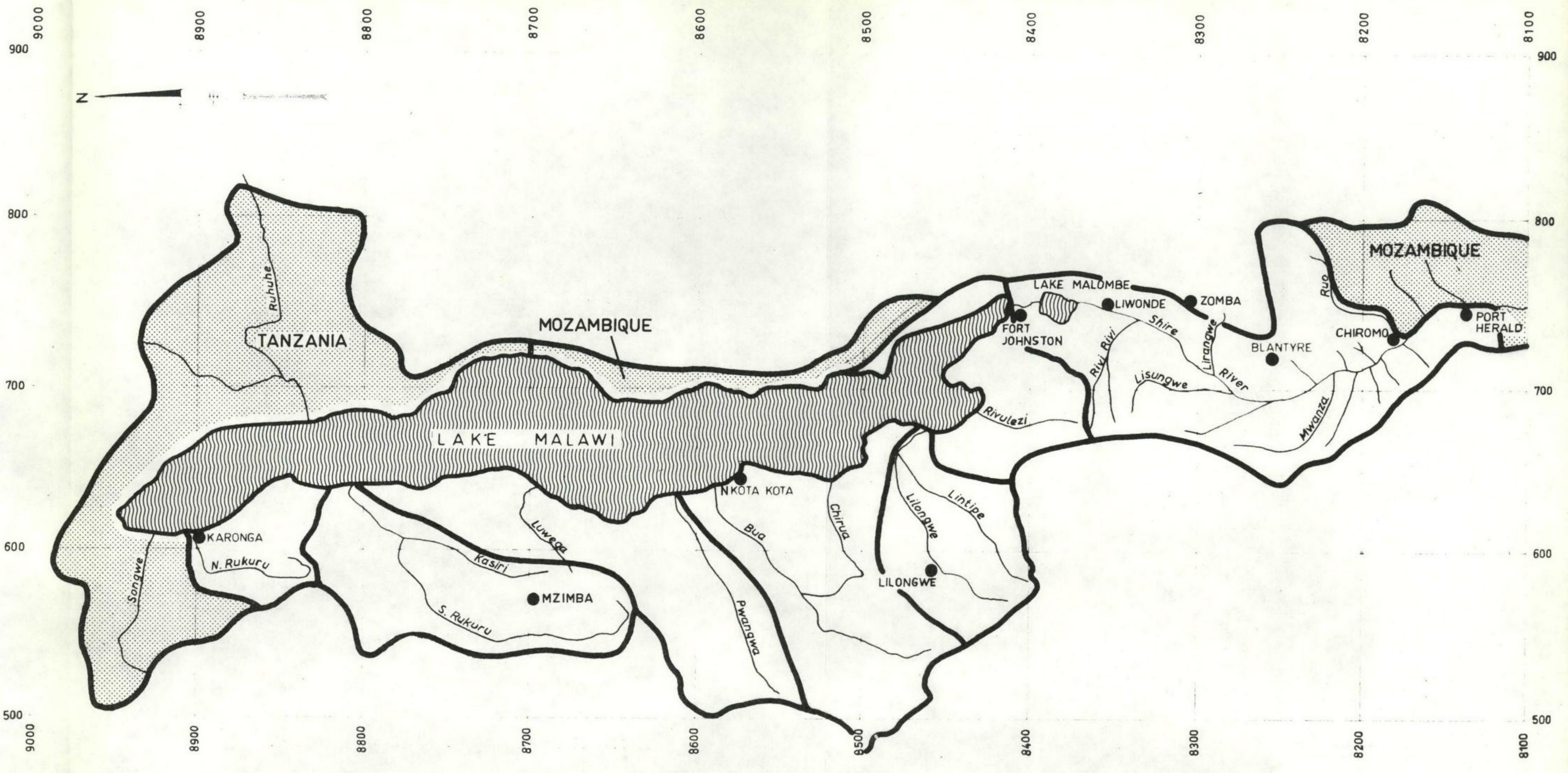
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
MAP OF PART OF UPPER SHIRE RIVER	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS · COPENHAGEN	S. N. 3297 NO. B 3



NOTE: 1 - GRIDSYSTEM SEE DRWG. B 1
2 - ALL LEVELS IN FT ABOVE SEALEVEL

SCALE: 1:2 500 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
TOPOGRAPHY OF MALAWI	APPROVED
	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297
	NO. B 4



0 100 miles

0 100km

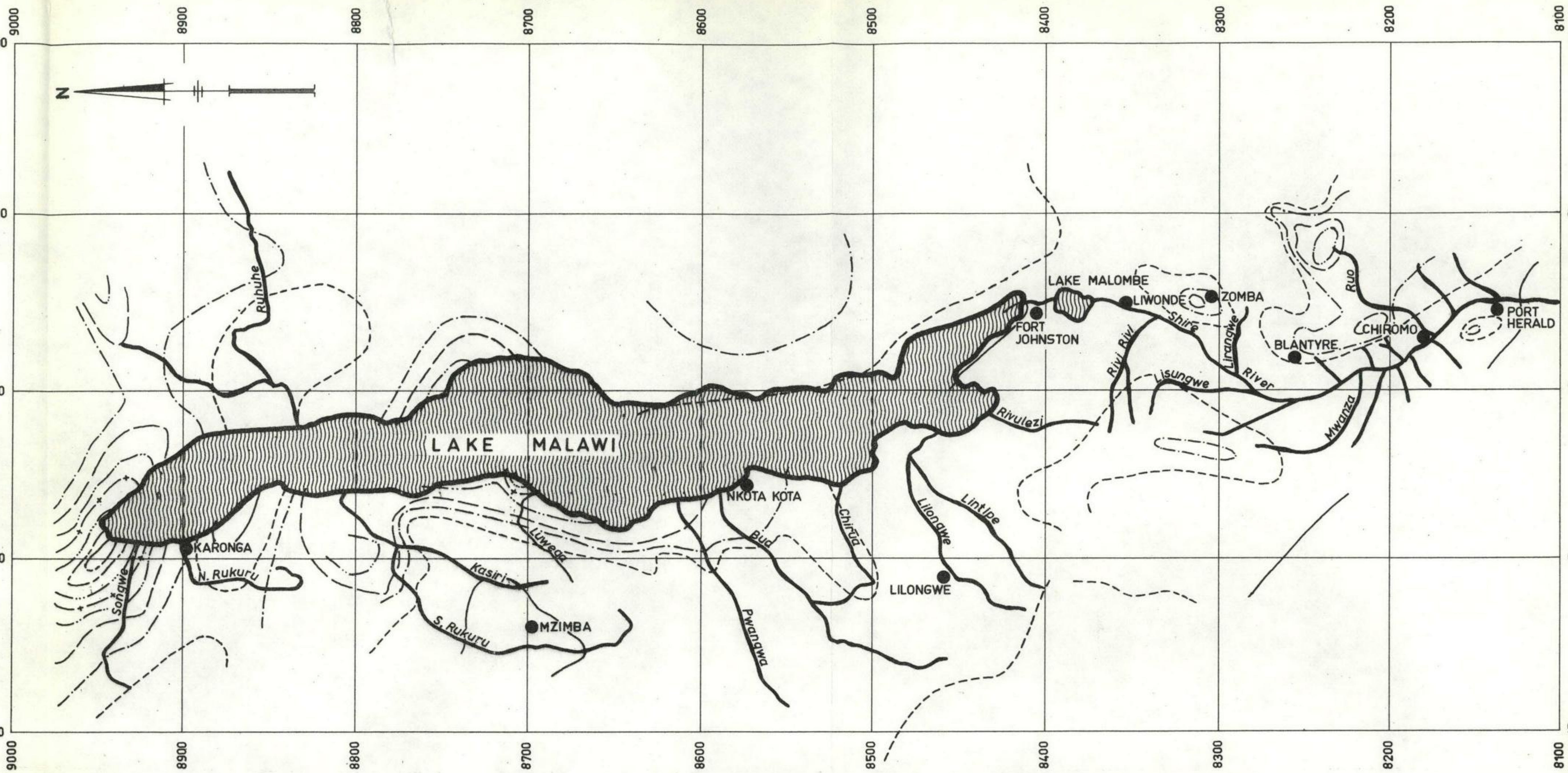
NOTE : 1 COPIED FROM HALCROW REPORT (1954)

2. GRIDSYSTEEM SEE **DRWG. B 1**

CATCHMENT AREAS, NOT SITUATED IN MALAWI

SCALE: 1:2 500 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT CATCHMENT AREAS LAKE MALAWI AND SHIRE RIVER	DESIGNED DRAWN APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	R. 420 S. N. 3297 NO. B 5



0 100 miles

0 100km

NOTE : 1. COPIED FROM HALCROW REPORT (1954)

2. GRIDSYSTEEM SEE DRWG. B 1

LEGEND

————	30 INCH/YEAR RAINFALL	—+—	80 INCH/YEAR RAINFALL
------	40 " " "	—··—	90 " " "
—·—·—	50 " " "	—-—	100 " " "
— —	60 " " "	—--—	110 " " "
—·-—	70 " " "		

SCALE: 1:2 500 000

GOVERNMENT OF MALAWI

LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT
AVERAGE ANNUAL RAINFALL MALAWI (ISOHYETAL MAP)

DESIGNED
DRAWN
APPROVED
FEBR. 1968

DELFT HYDRAULICS LABORATORY

KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN

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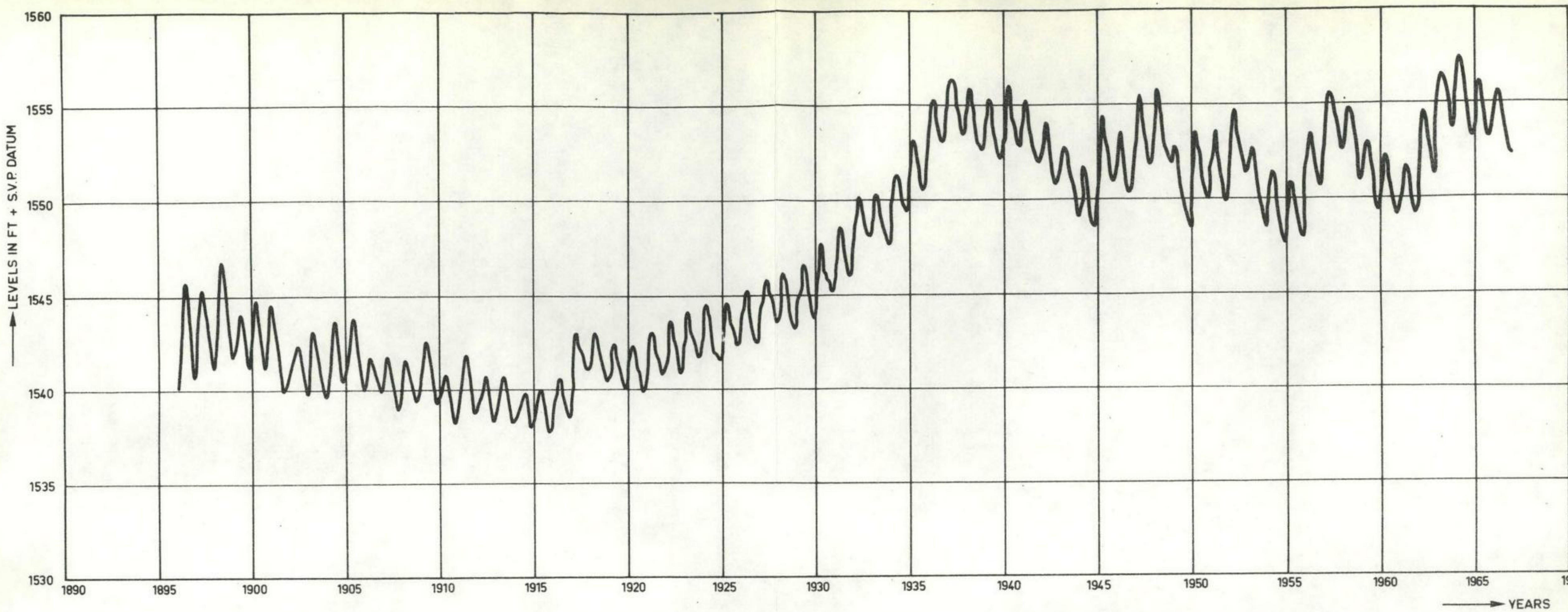
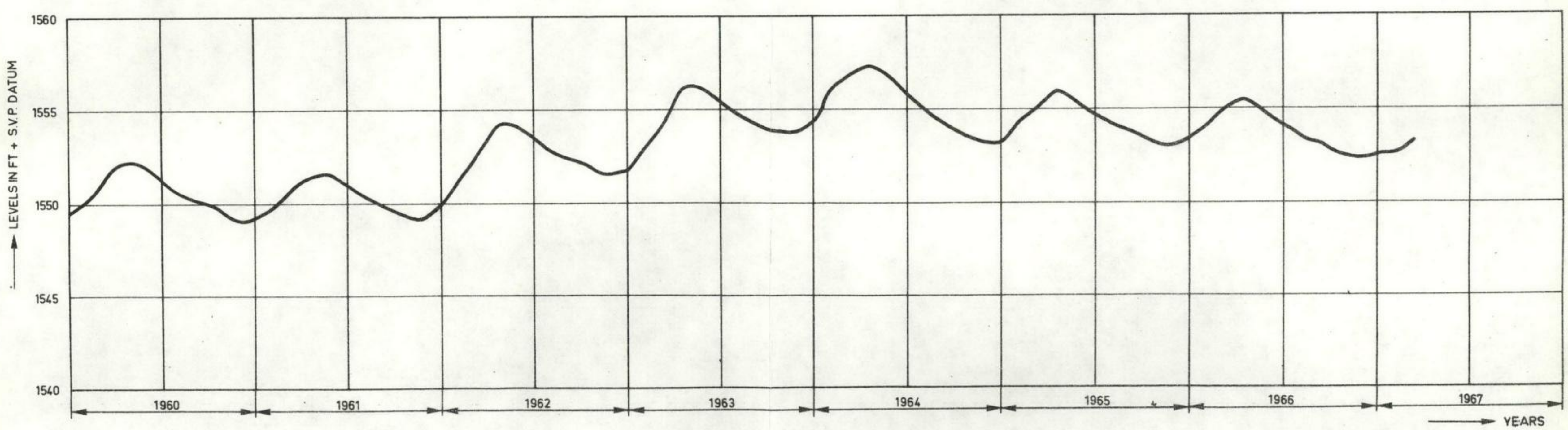
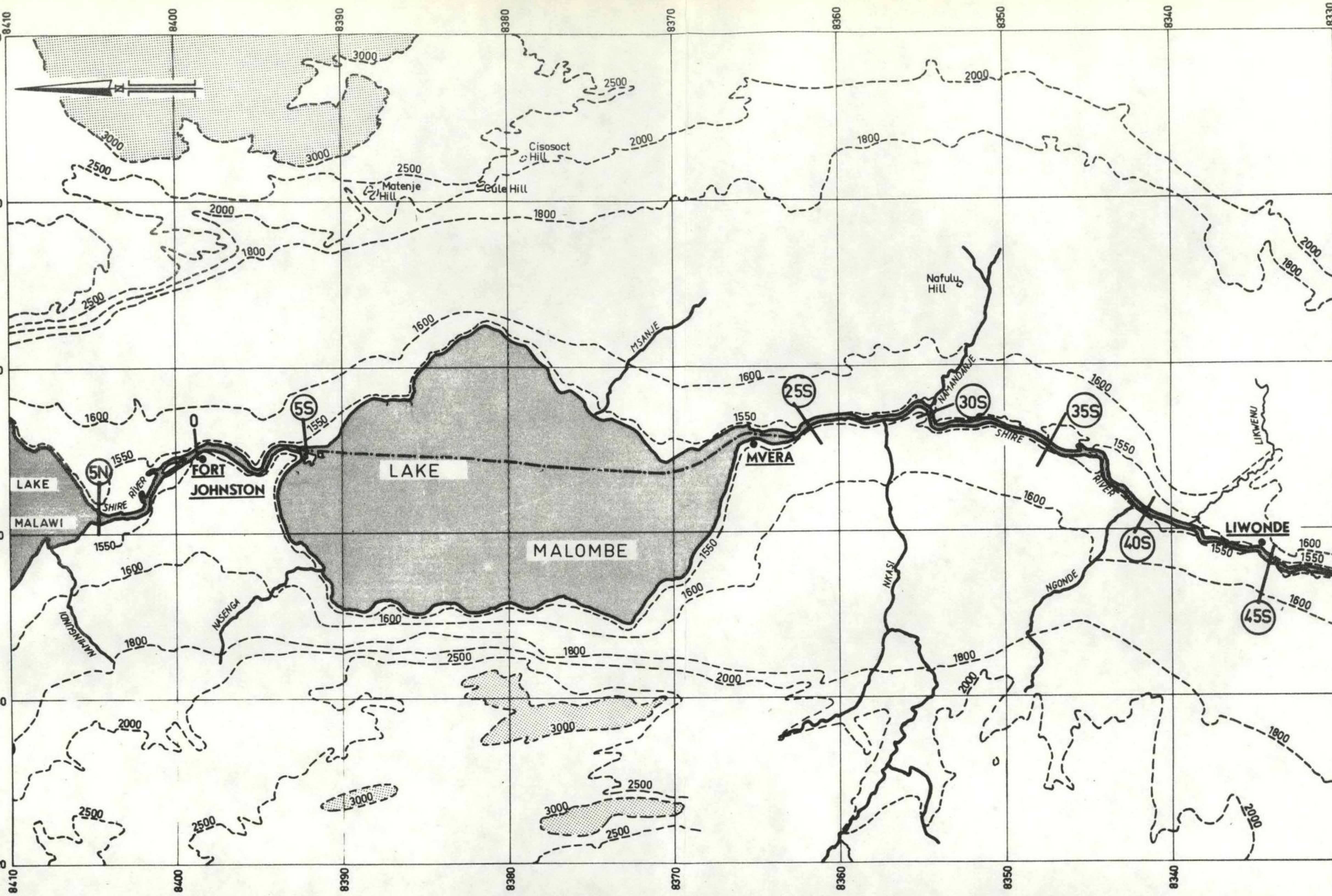
S. N. 3297
NO. B 6





NOTE: 1. LEVELS UP TO 1954 TAKEN FROM HALCROW REPORT (1954)
2. LEVELS FROM 1954 – 1967 OBTAINED FROM THE WATER DEVELOPMENT DEPARTMENT IN MALAWI

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
WATERLEVEL - RECORD LAKE MALAWI	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297 NO. B 7



NOTE: 1 - GRIDSYSTEM + RIVERSTATIONS SEE DRWG. B 3
2 - ALL LEVELS IN FT ABOVE SEALEVEL

0 5 10km

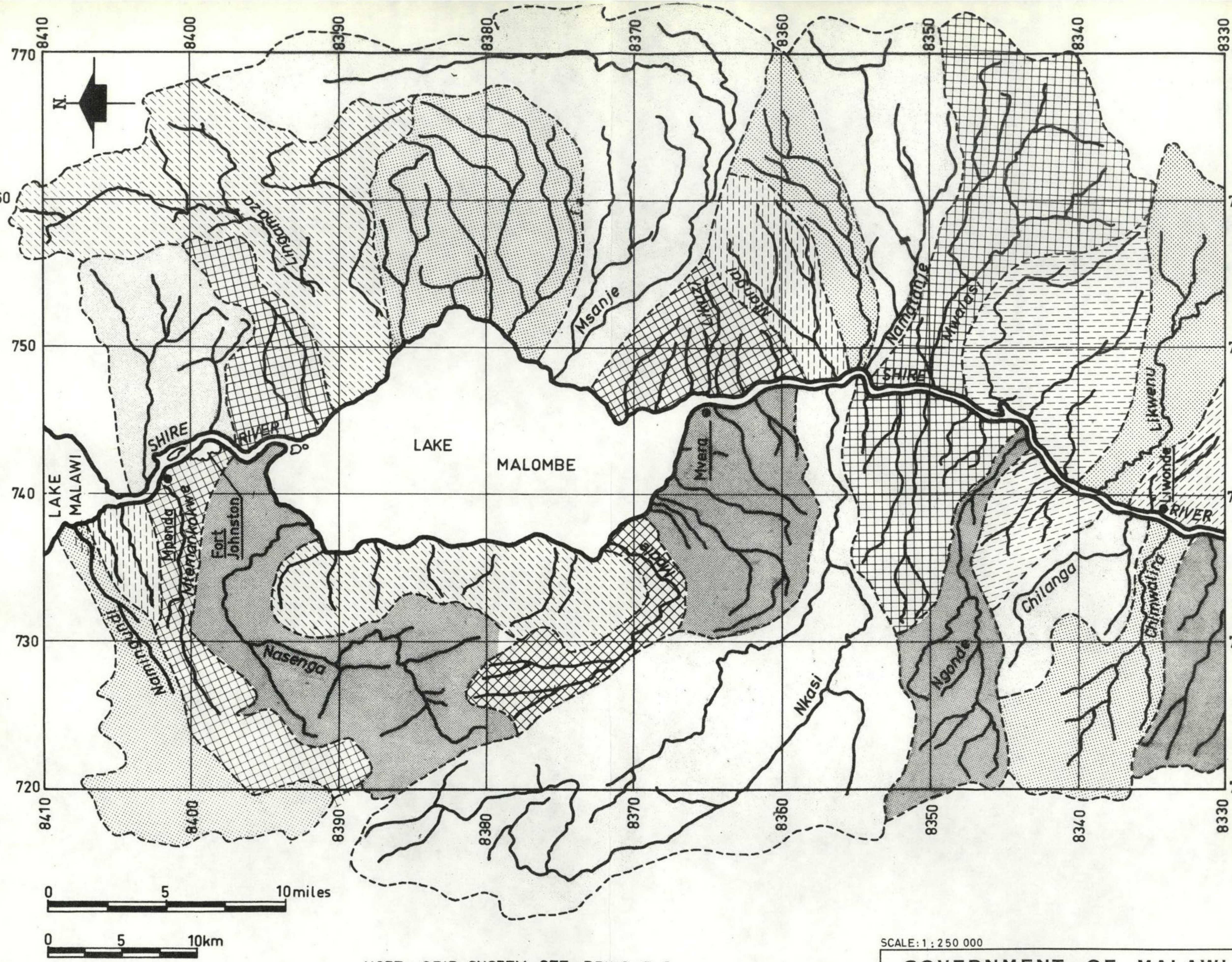
0 5miles

5 N MILEAGE FROM FORT JOHNSTON NORTHWARDS

25 S MILEAGE FROM FORT JOHNSTON SOUTHWARDS

SCALE: 1: 250 000

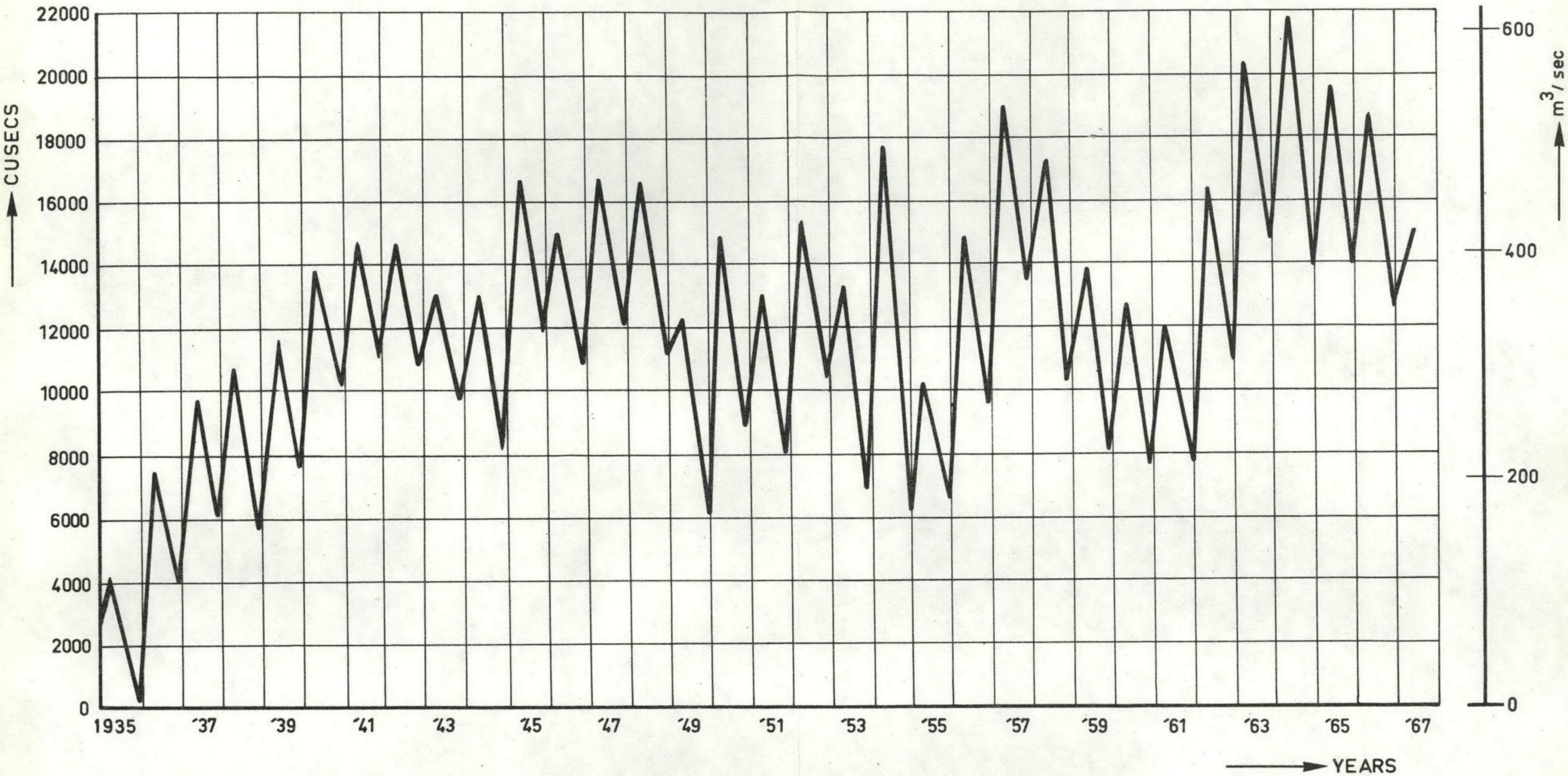
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT TOPOGRAPHY OF UPPER SHIRE RIVER REGION	DESIGNED DRAWN APPROVED FEBR.1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	R. 420 S. N. 3297 NO. B 8



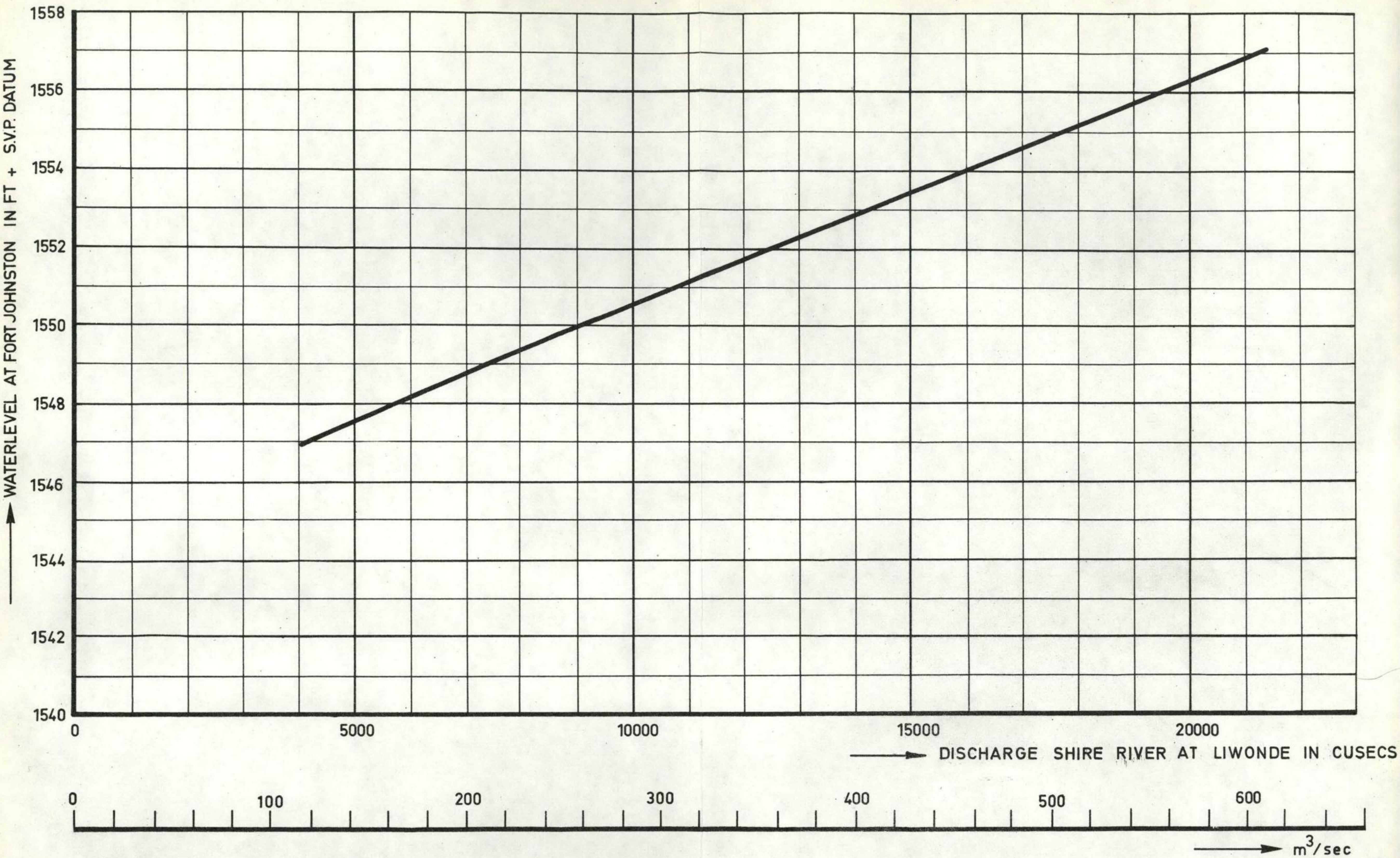
NOTE: GRID SYSTEM SEE DRWG. B 3

SCALE: 1 : 250 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
CATCHMENT AREAS OF THE TRIBUTARIES OF THE UPPER SHIRE RIVER	APPROVED
	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297
	NO. B 9

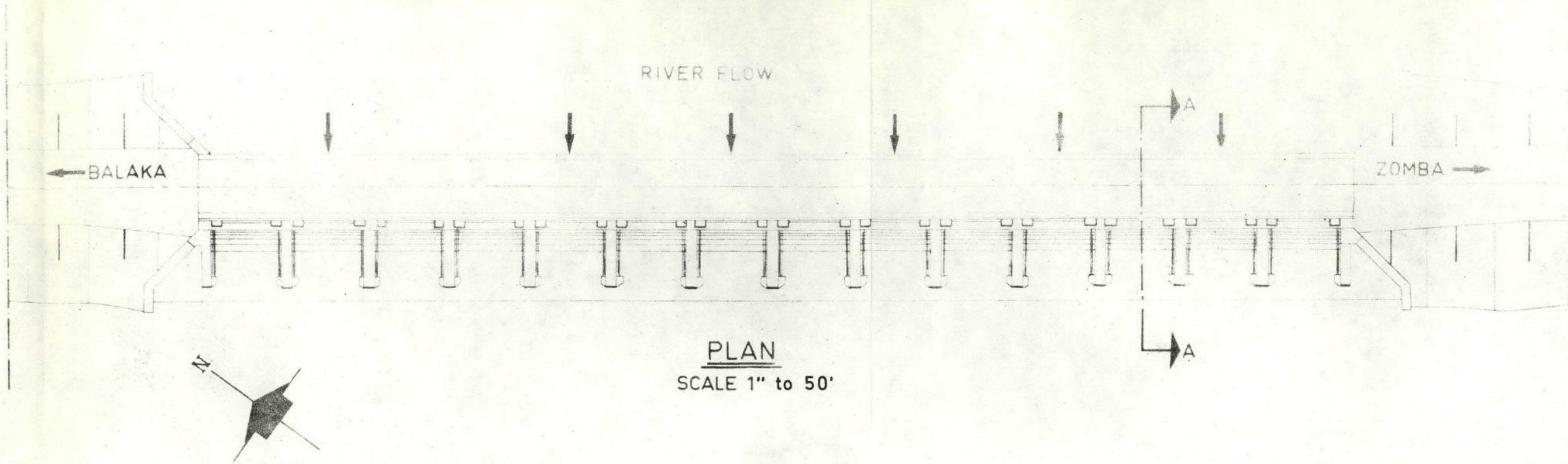


GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
DISCHARGE-RECORD UPPER SHIRE RIVER	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297 NO. B 10



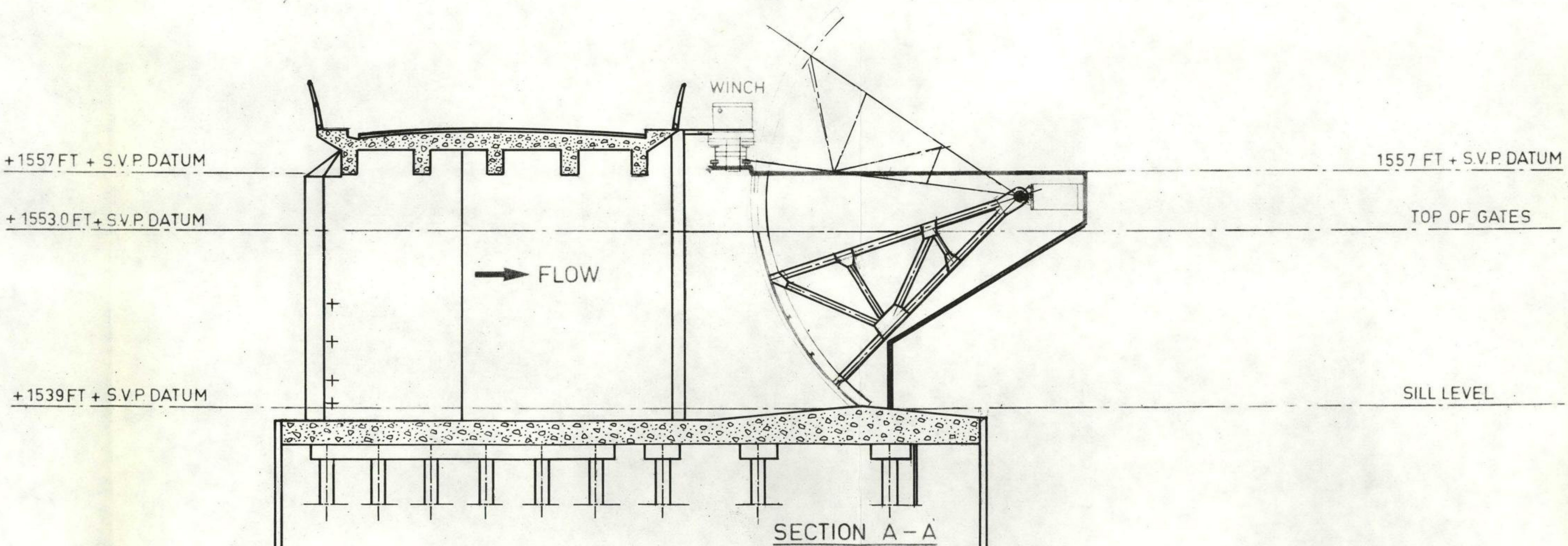
NOTE: DATA OBTAINED FROM THE WATER DEVELOPMENT DEPARTMENT IN MALAWI

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
DISCHARGE-RATINGCURVE FOR SHIRE RIVER AT LIWONDE (1967)	APPROVED FEBR.1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297
	NO. B 11



PLAN

SCALE 1" to 50'

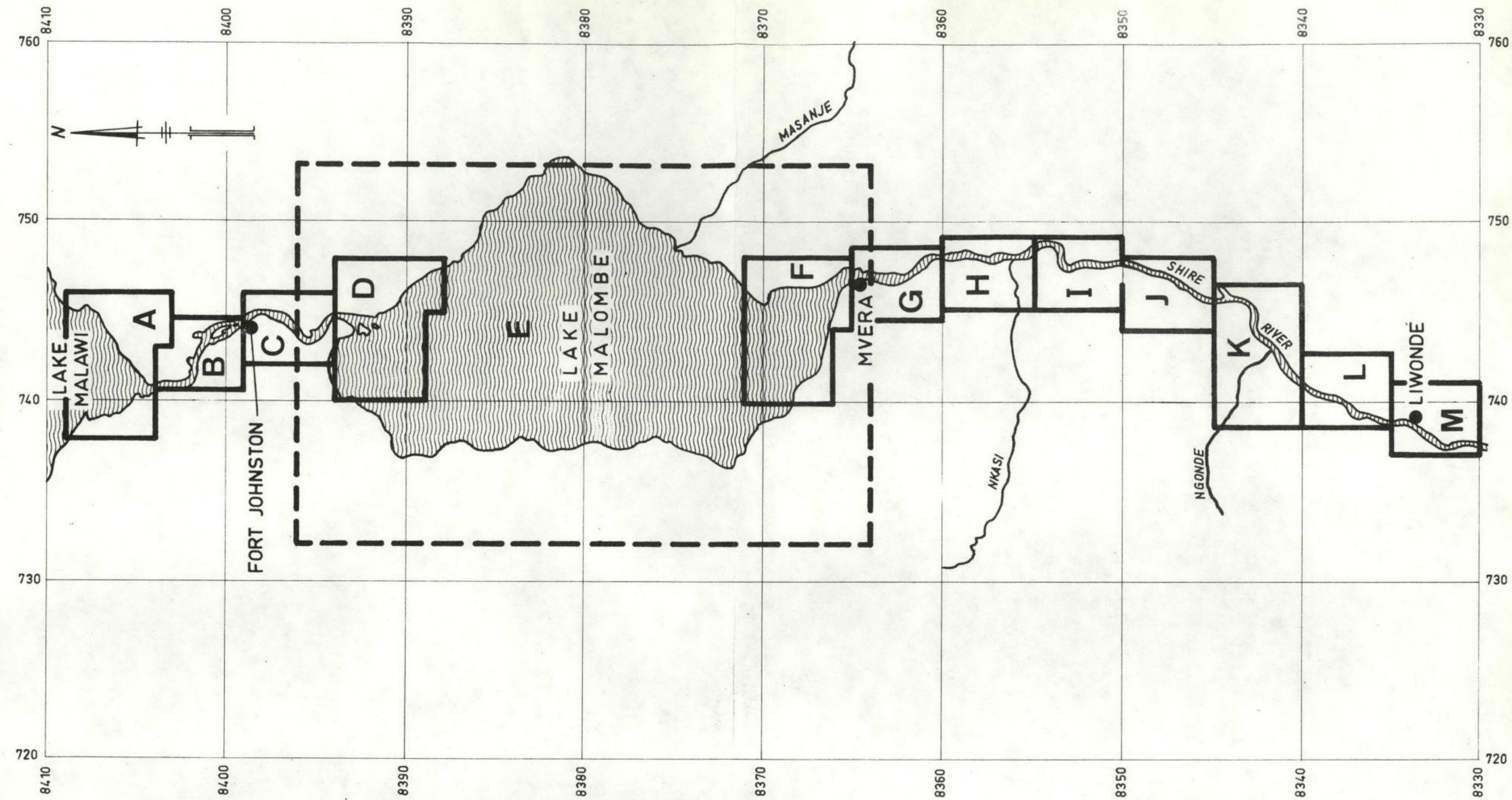


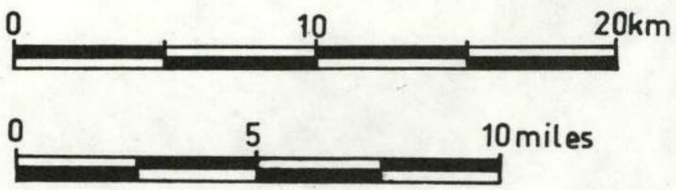
SECTION A-A

SCALE 1:96 (1/8" to 1')

NOTE: PLAN TAKEN FROM F.E KANTHACK AND PARTNERS PROJECT FOR LIWONDE BARRAGE

GOVERNMENT OF MALAWI	
NACALA RAIL LINK PROJECT LIWONDE BARRAGE	DESIGNED DRAWN APPROVED FEBR. 1968
KAMPSAX — KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3310 NO. B 12





NOTE :

- GRID SYSTEM , SEE DRWG. B 3
- CHARACTERS A - M INDICATE CODE SOUNDING CHARTS

SCALE: 1: 250 000

GOVERNMENT OF MALAWI

LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT

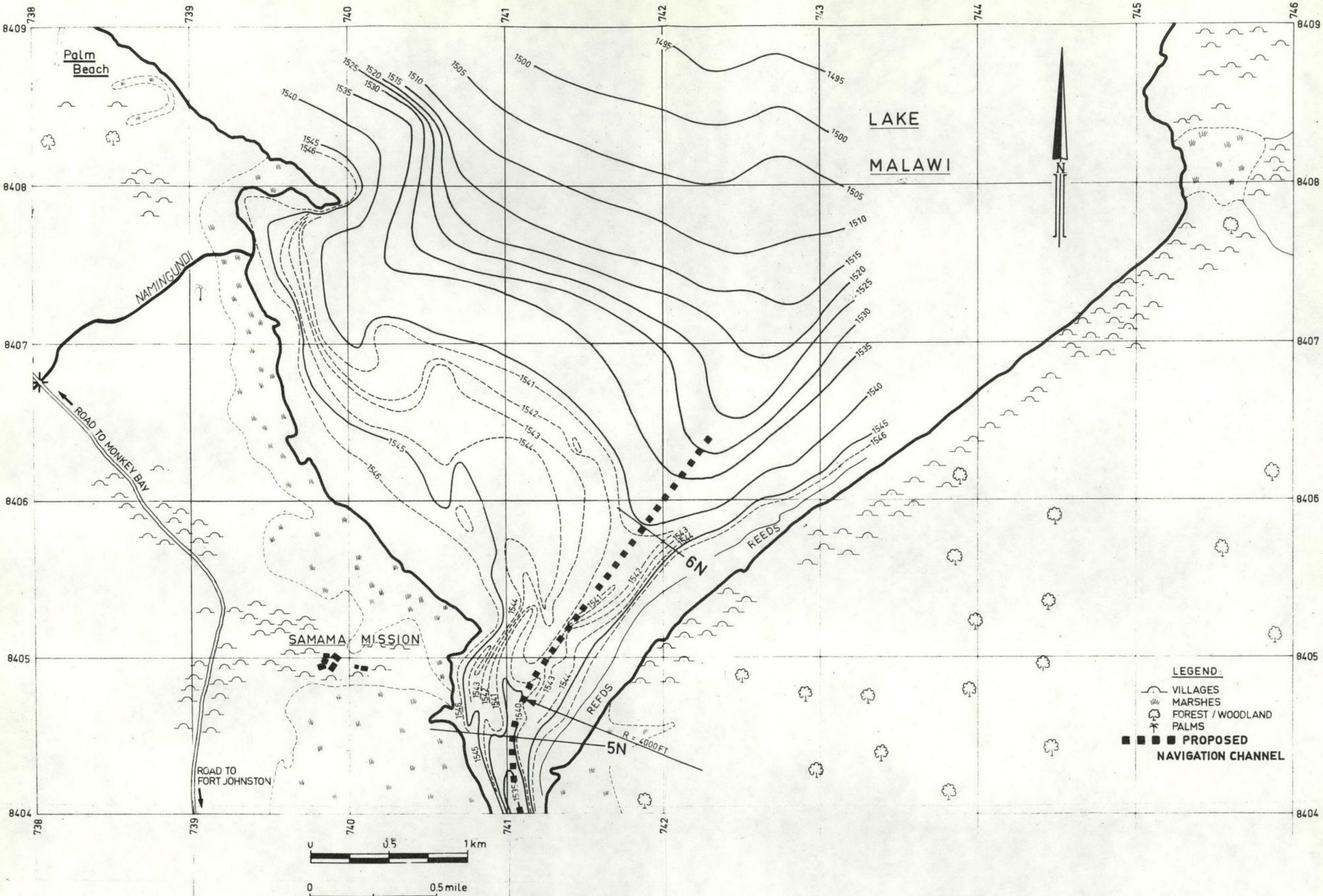
KEY-PLAN FOR SOUNDING CHARTS

DELFT HYDRAULICS LABORATORY

KAMPSAX KAMPMANN. KIERULFF & SAXILD A/S CONSULTING ENGINEERS . COPENHAGEN

DESIGNED
DRAWN
APPROVED
FEBR. 1968

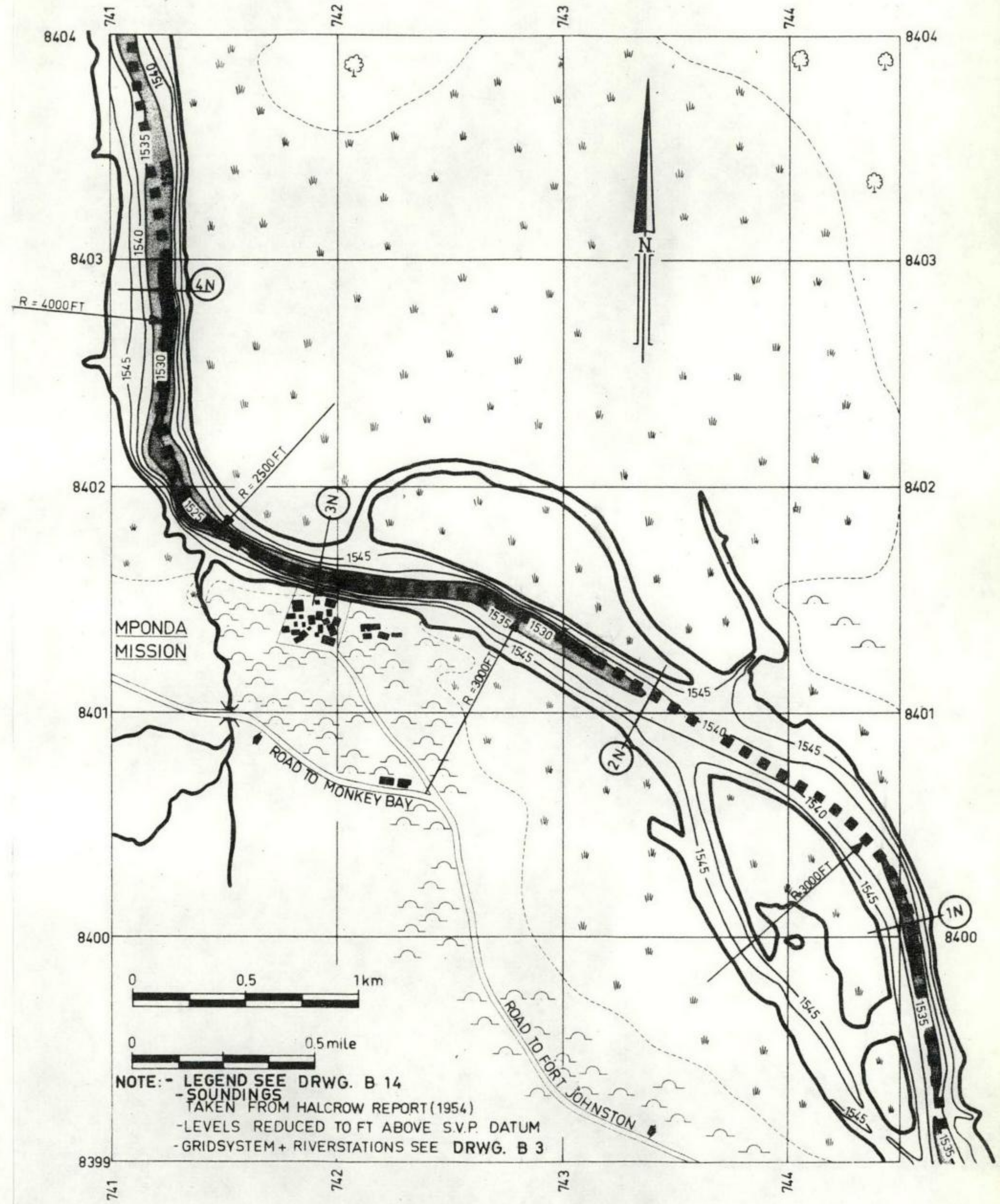
R. 420
S. N. 3297
NO. B 13



NOTE: – SOUNDINGS TAKEN FROM HALCROW REPORT (1954)
– LEVELS REDUCED TO FT ABOVE S.V.P. DATUM
– GRIDSYSTEM + RIVERSTATIONS SEE DRWG. B 3

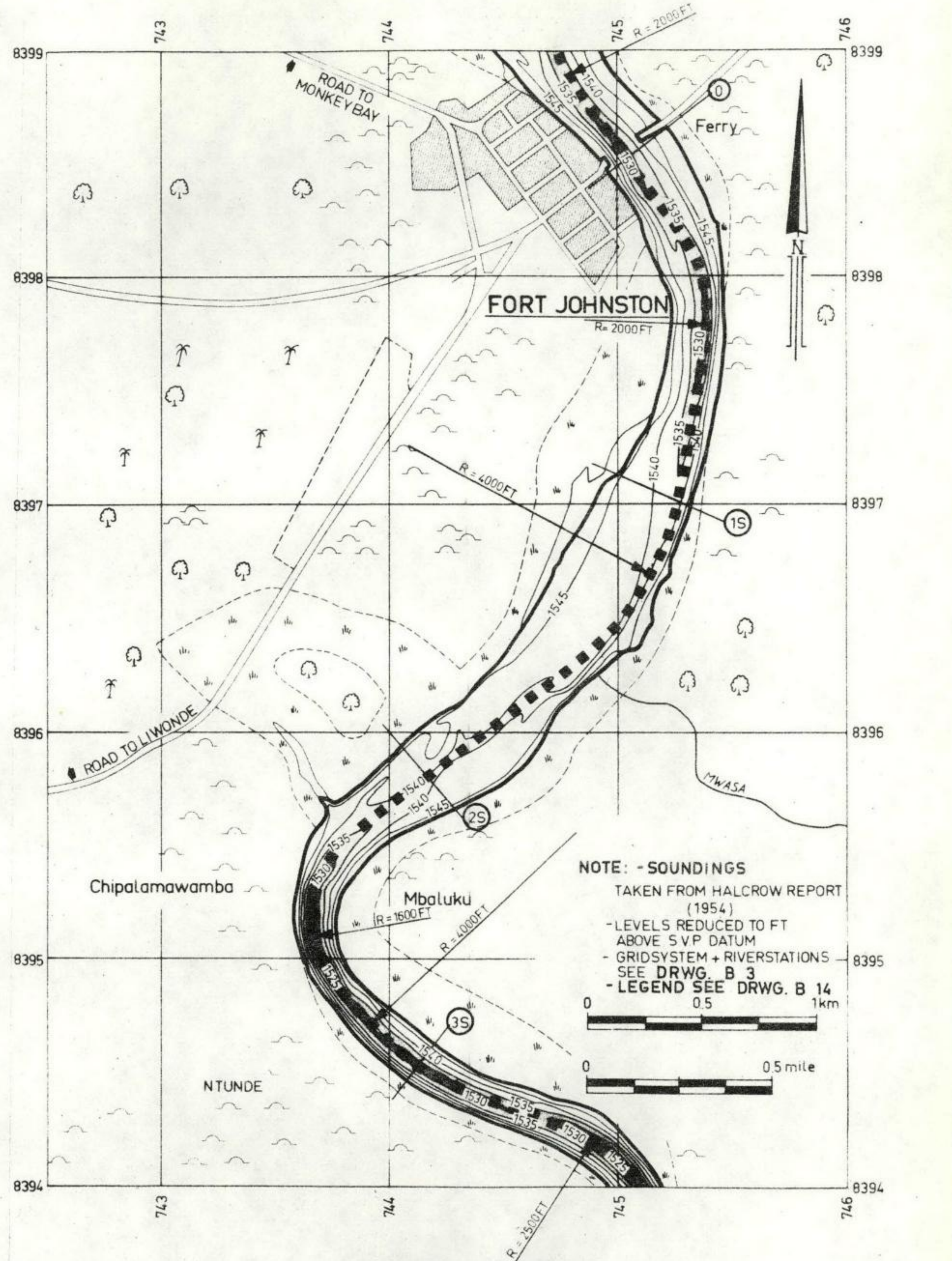
SCALE: 1: 25 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
SOUNDING CHART 7.0 N - 4.7 N (A)	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS · COPENHAGEN	S. N. 3297 NO. B 14



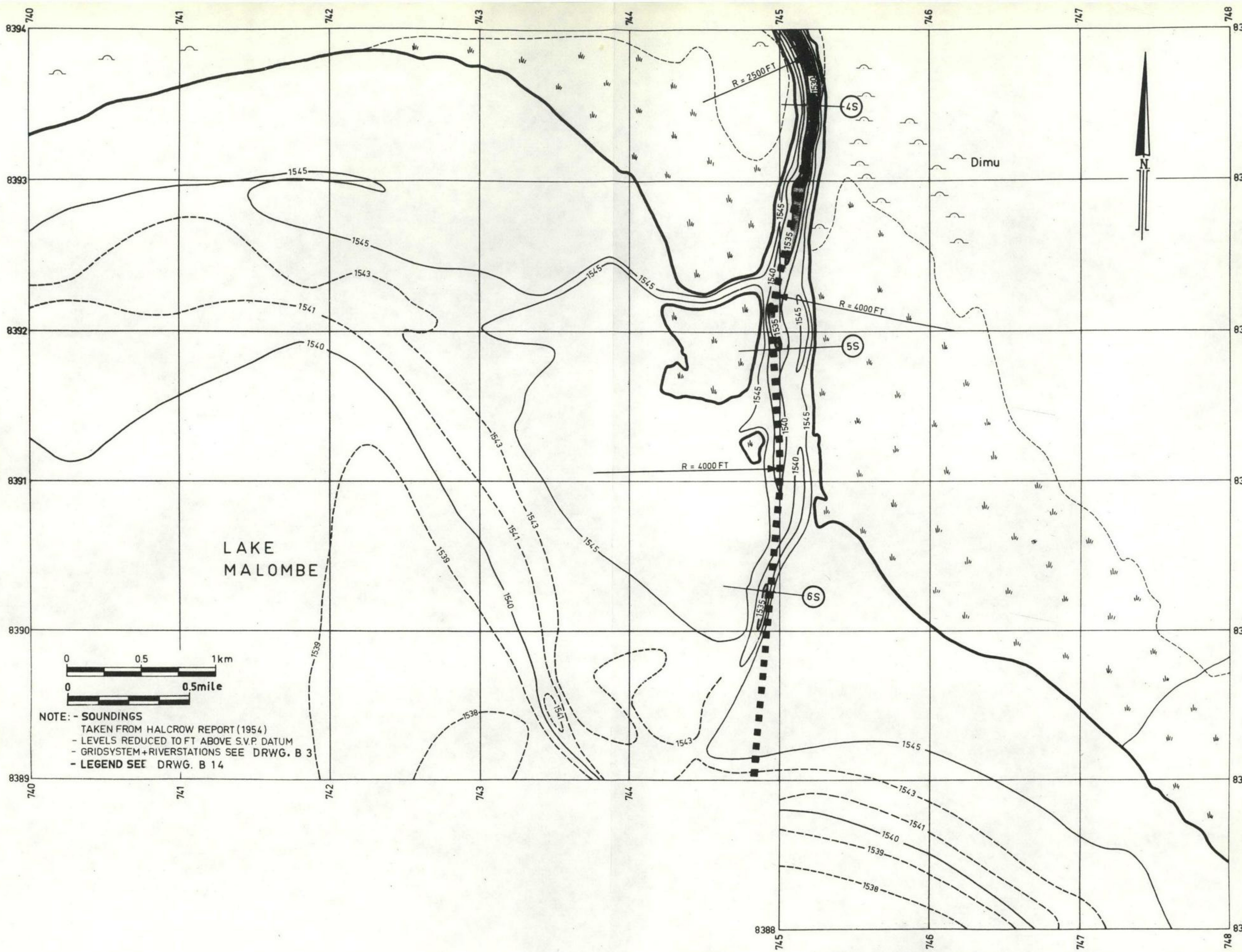
SCALE : 1 : 25 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
SOUNDING CHART 4.7 N - 0.3 N (B)	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297 NO. B 15



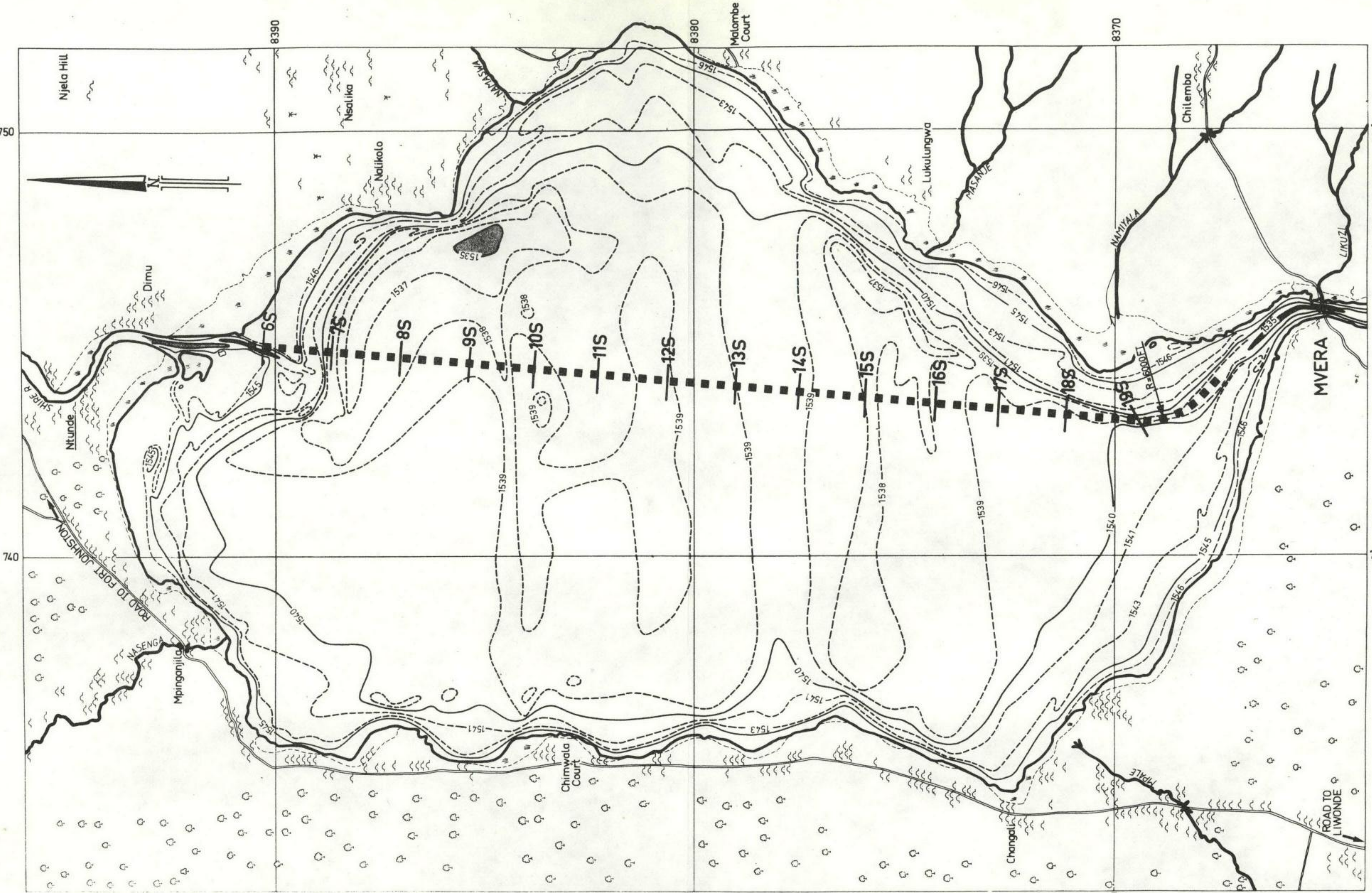
SCALE: 1: 25000

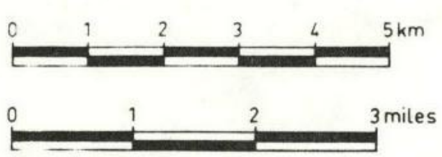
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT SOUNDING CHART 0.3 N - 3.7 S (C)	DESIGNED DRAWN APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	R. 420 S. N. 3297 NO. B 16



SCALE: 1:25 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
SOUNDING CHART 3.7 S - 6.8 S (D)	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297 NO. B 17

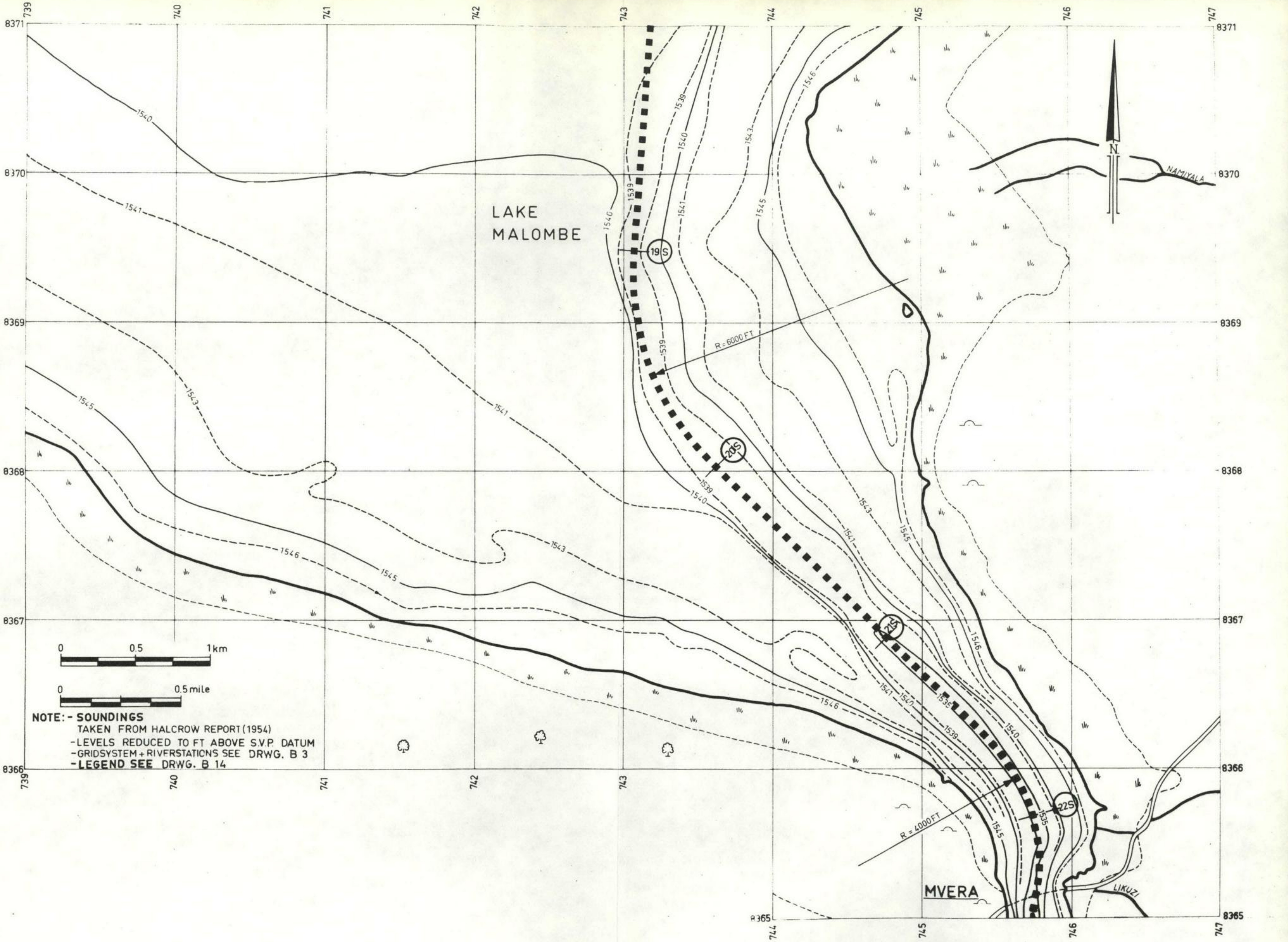




NOTE: - SOUNDINGS
TAKEN FROM HALCROW REPORT (1954).
- LEVELS REDUCED TO FT ABOVE S.V.P. DATUM
- GRIDSYSTEM + RIVERSTATIONS SEE DRWG. B 3
- LEGEND SEE DRWG. B 14

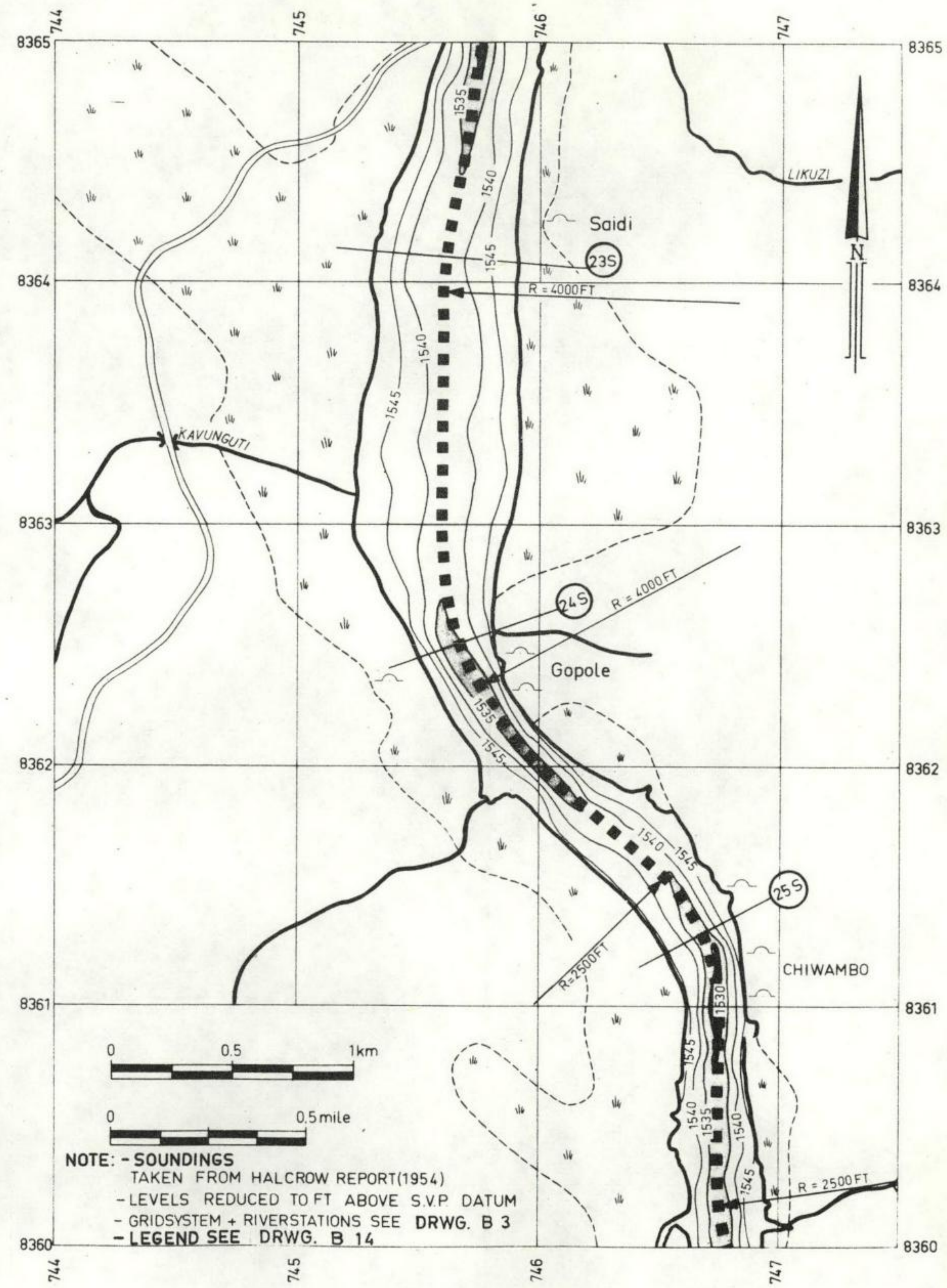
SCALE : 1 : 100 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
SOUNDING CHART LAKE MALOMBE (E)	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297 NO. B 18



SCALE: 1: 25 000

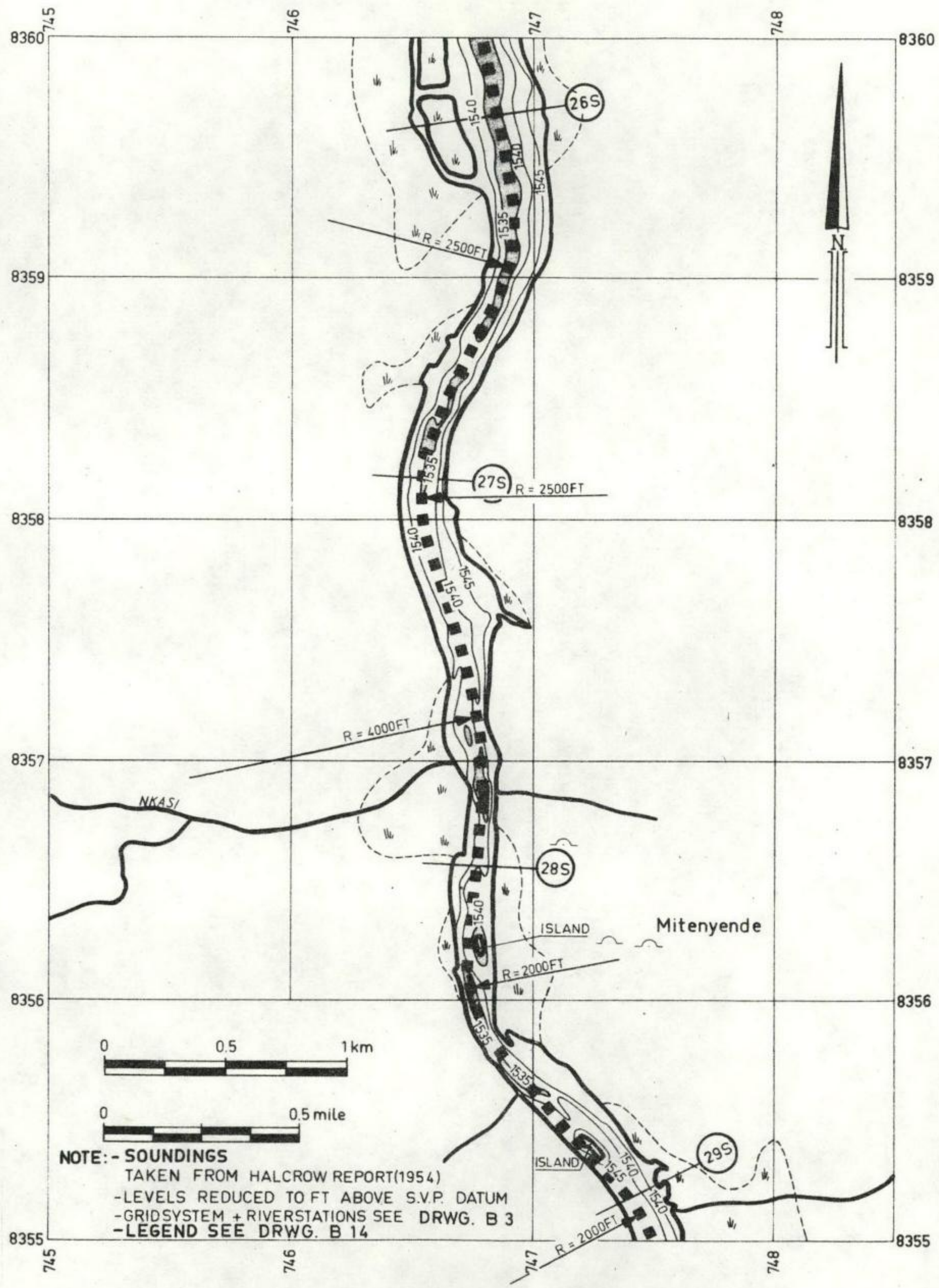
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
SOUNDING CHART 18.1 S - 22,4 S (F)	APPROVED
	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S	S. N. 3297
CONSULTING ENGINEERS · COPENHAGEN	NO. B 19



NOTE: - SOUNDINGS
TAKEN FROM HALCROW REPORT(1954)
- LEVELS REDUCED TO FT ABOVE S.V.P DATUM
- GRIDSYSTEM + RIVERSTATIONS SEE DRWG. B 3
- LEGEND SEE DRWG. B 14

SCALE : 1 : 25 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT SOUNDING CHART 22.4 S - 25.8 S (G)	DESIGNED DRAWN APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	R. 420 S. N. 3297 NO. B 20



SCALE : 1:25 000

GOVERNMENT OF MALAWI

LAKE MALAWI AND UPPER SHIRE
TRANSPORTATION PROJECT

SOUNDING CHART 25.8 S - 29.1 S (H)

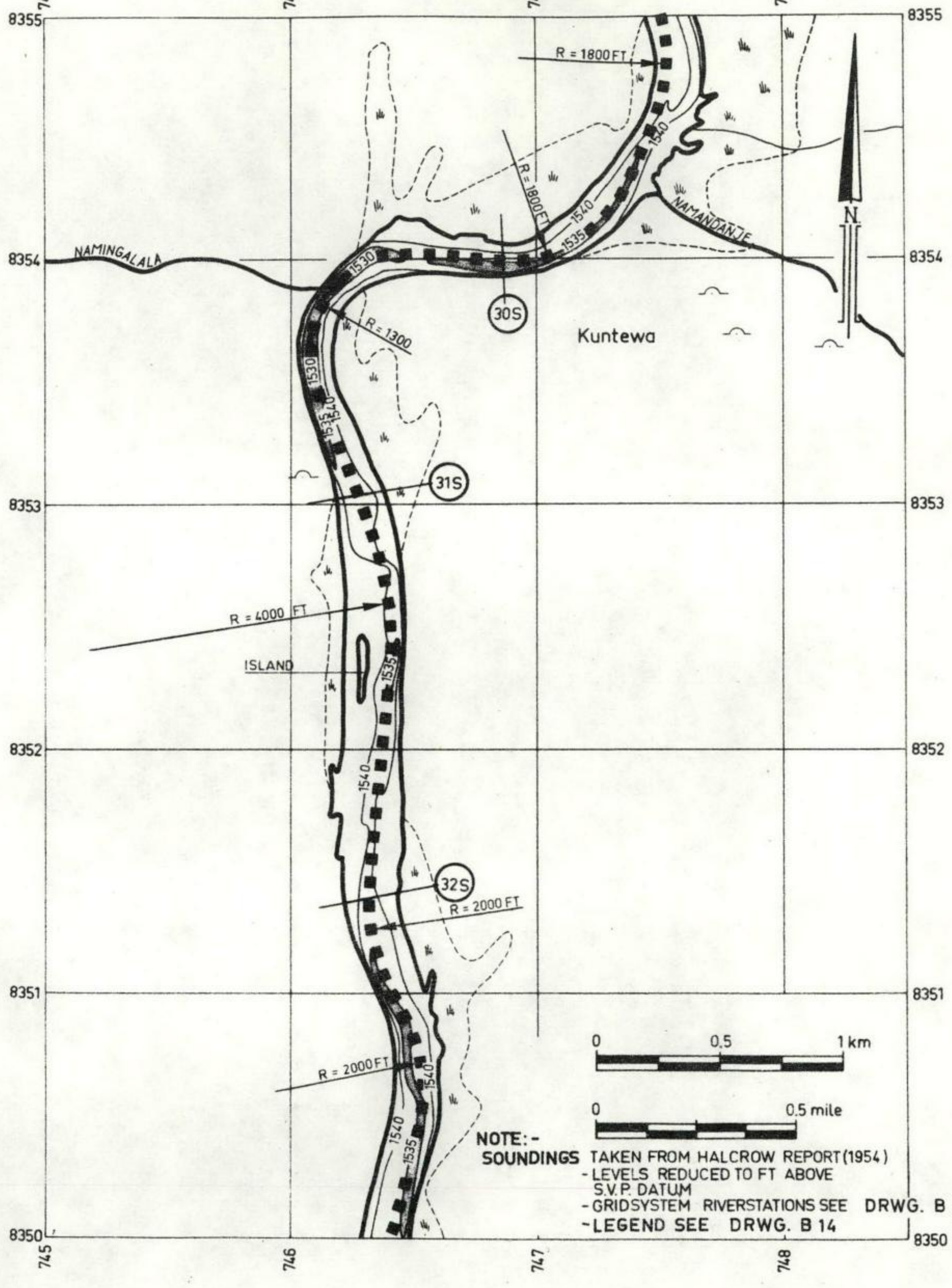
DESIGNED
DRAWN
APPROVED

FEBR. 1968

DELFT HYDRAULICS LABORATORY

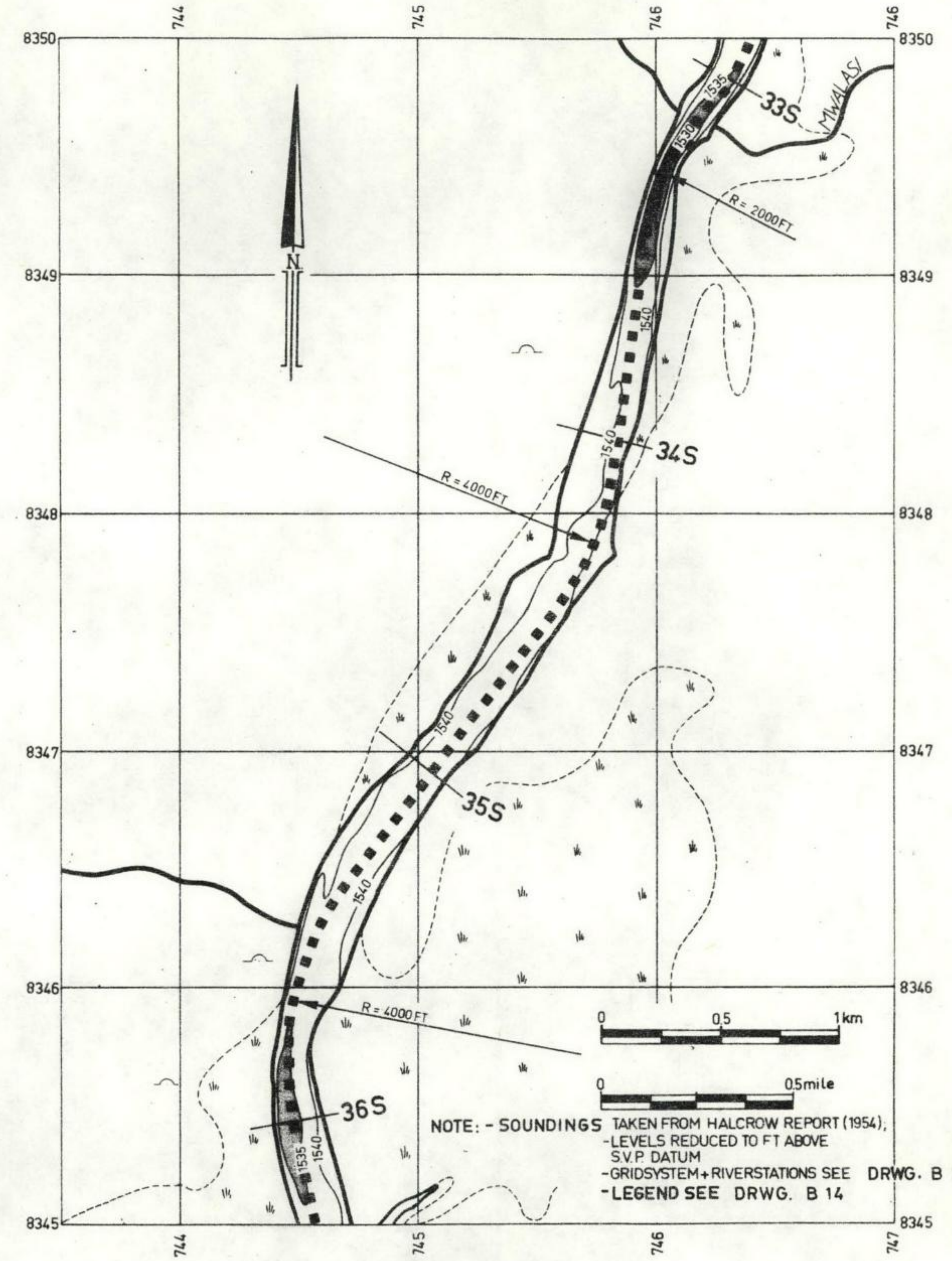
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S
CONSULTING ENGINEERS COPENHAGEN

R. 420
S. N. 3297
NO. B 21



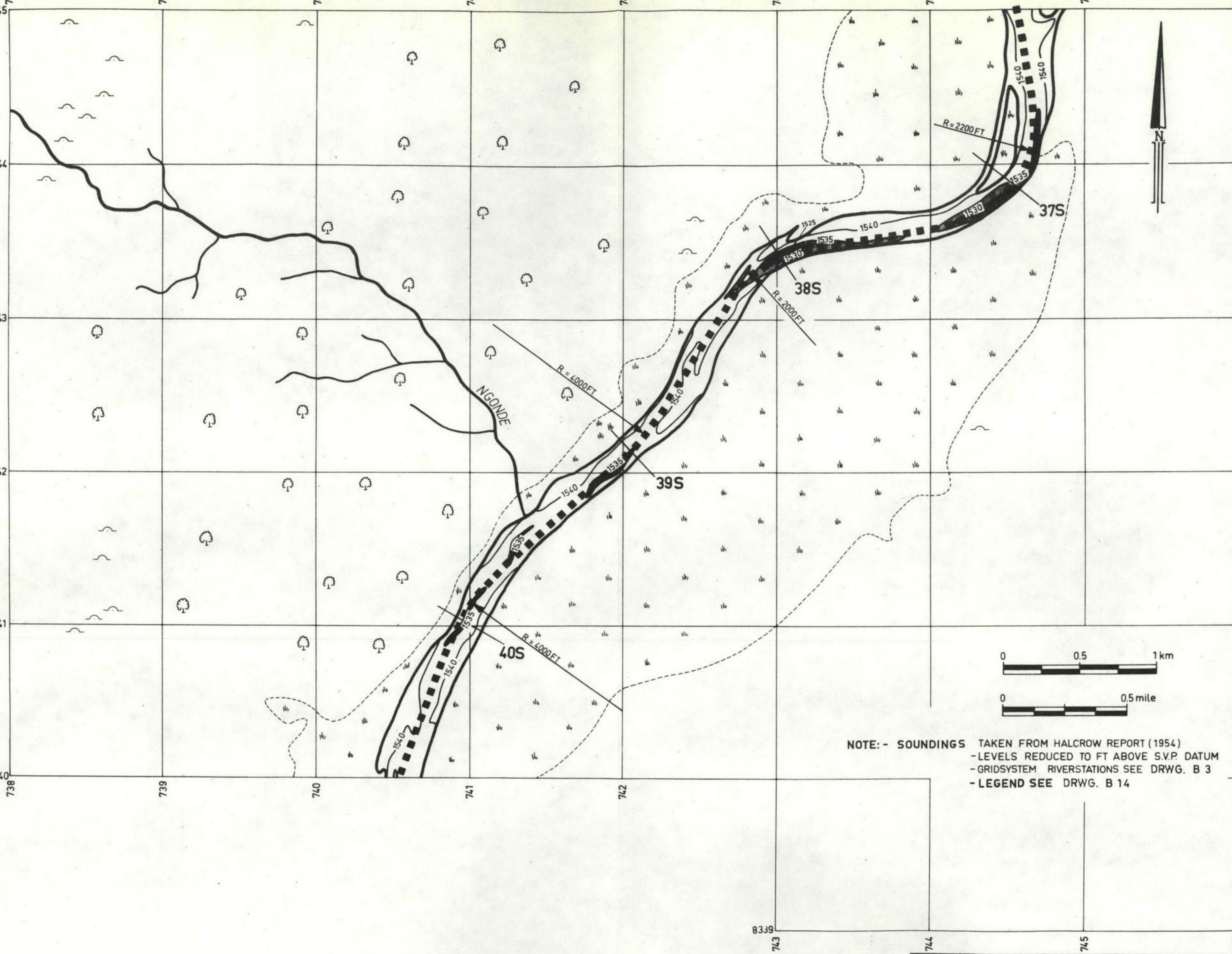
SCALE: 1 : 25 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
SOUNDING CHART 29.1 S - 32.9 S (I)	APPROVED
	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX — KAMPMANN, KIERULFF & SAXILD A/S — CONSULTING ENGINEERS COPENHAGEN	S. N. 3297
	NO. B 22



SCALE: 1:25 000

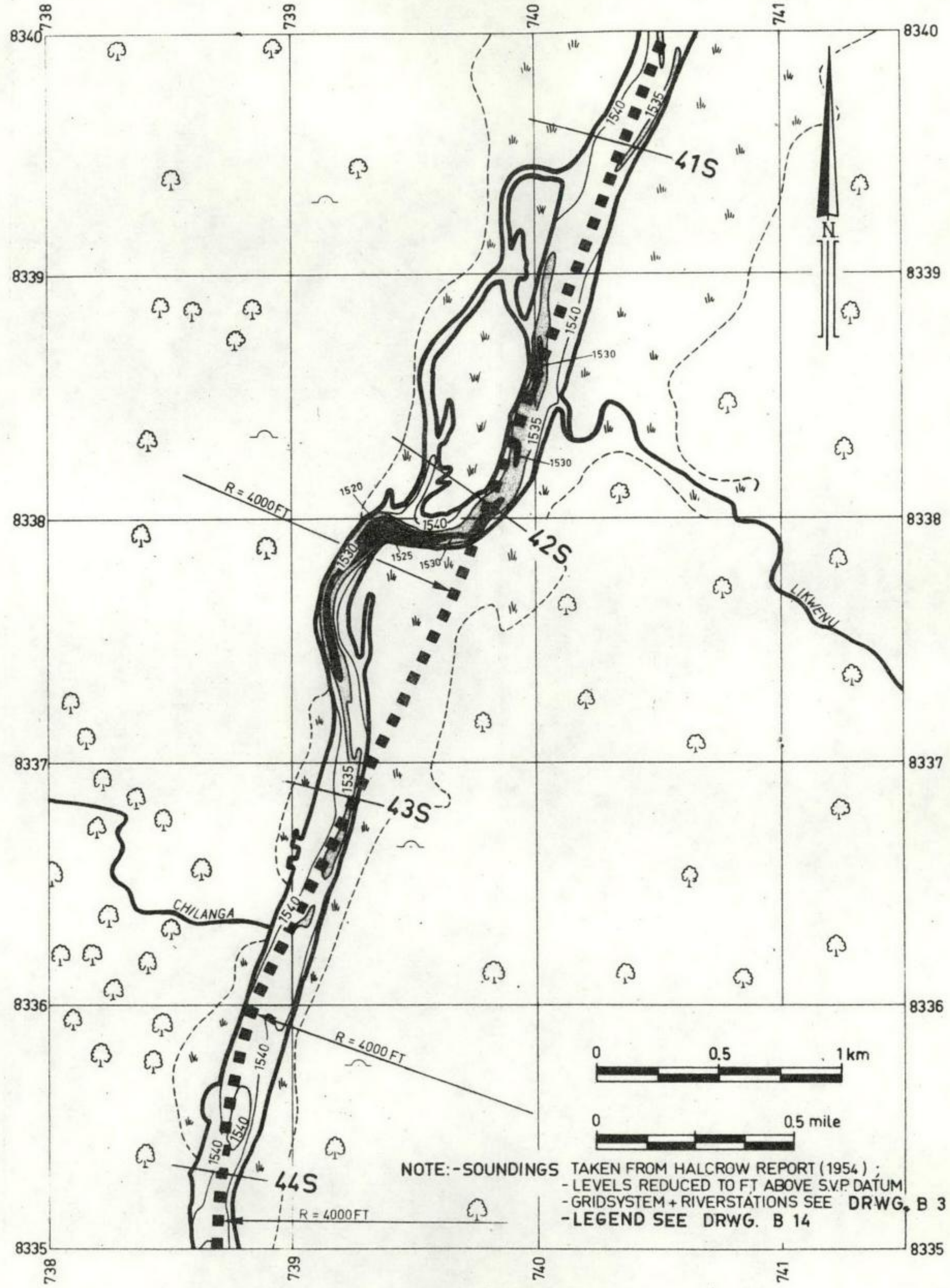
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
SOUNDING CHART 32.9 S - 36.3 S (J)	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX — KAMPMANN, KIERULFF & SAXILD A S, CONSULTING ENGINEERS, COPENHAGEN	S. N. 3297 NO. B 23



NOTE: - SOUNDINGS TAKEN FROM HALCROW REPORT (1954)
- LEVELS REDUCED TO FT ABOVE S.V.P. DATUM
- GRIDSYSTEM RIVERSTATIONS SEE DRWG. B 3
- LEGEND SEE DRWG. B 14

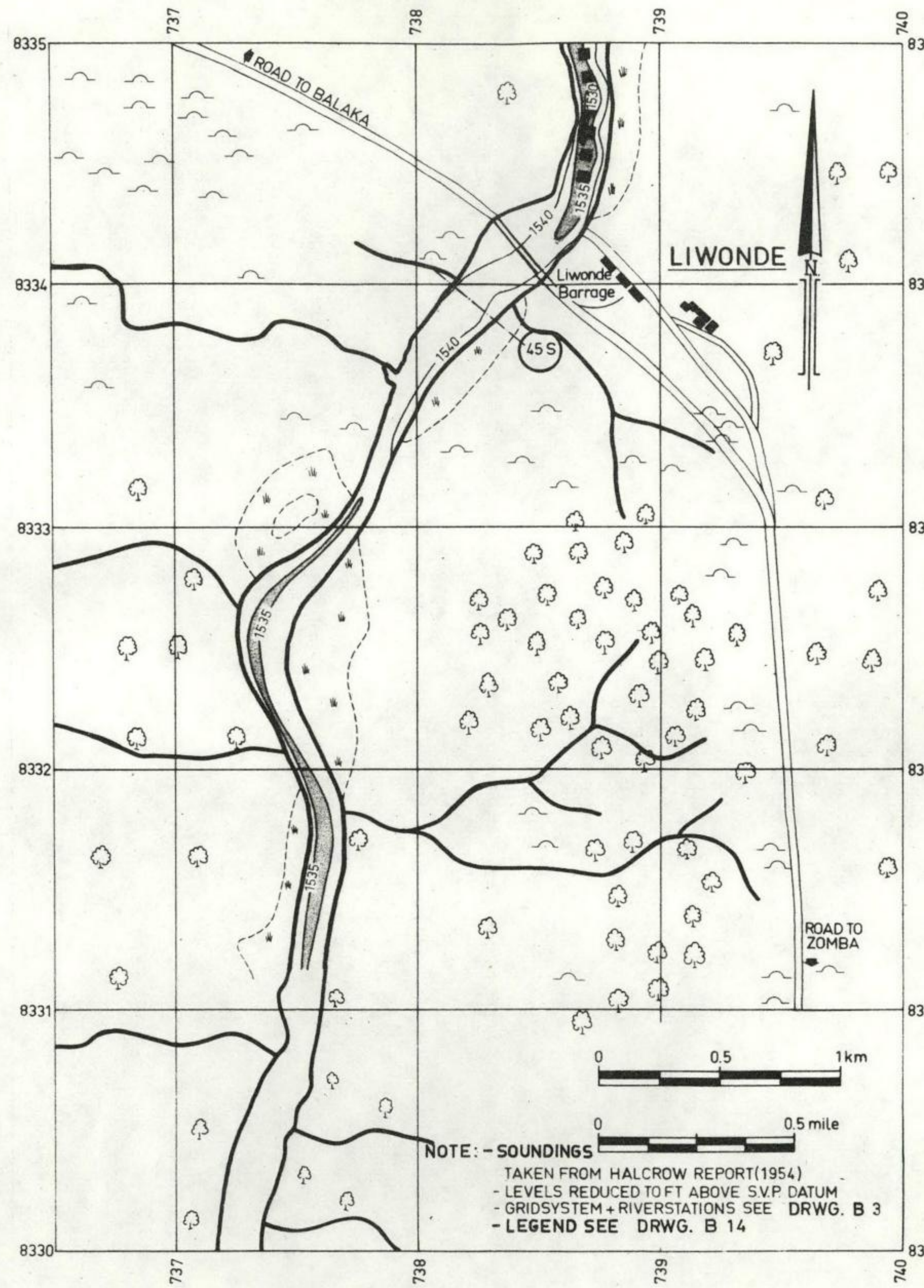
SCALE : 1 : 25 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
SOUNDING CHART 36.3 S - 40.7 S (K)	APPROVED
	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297
	NO. B 24



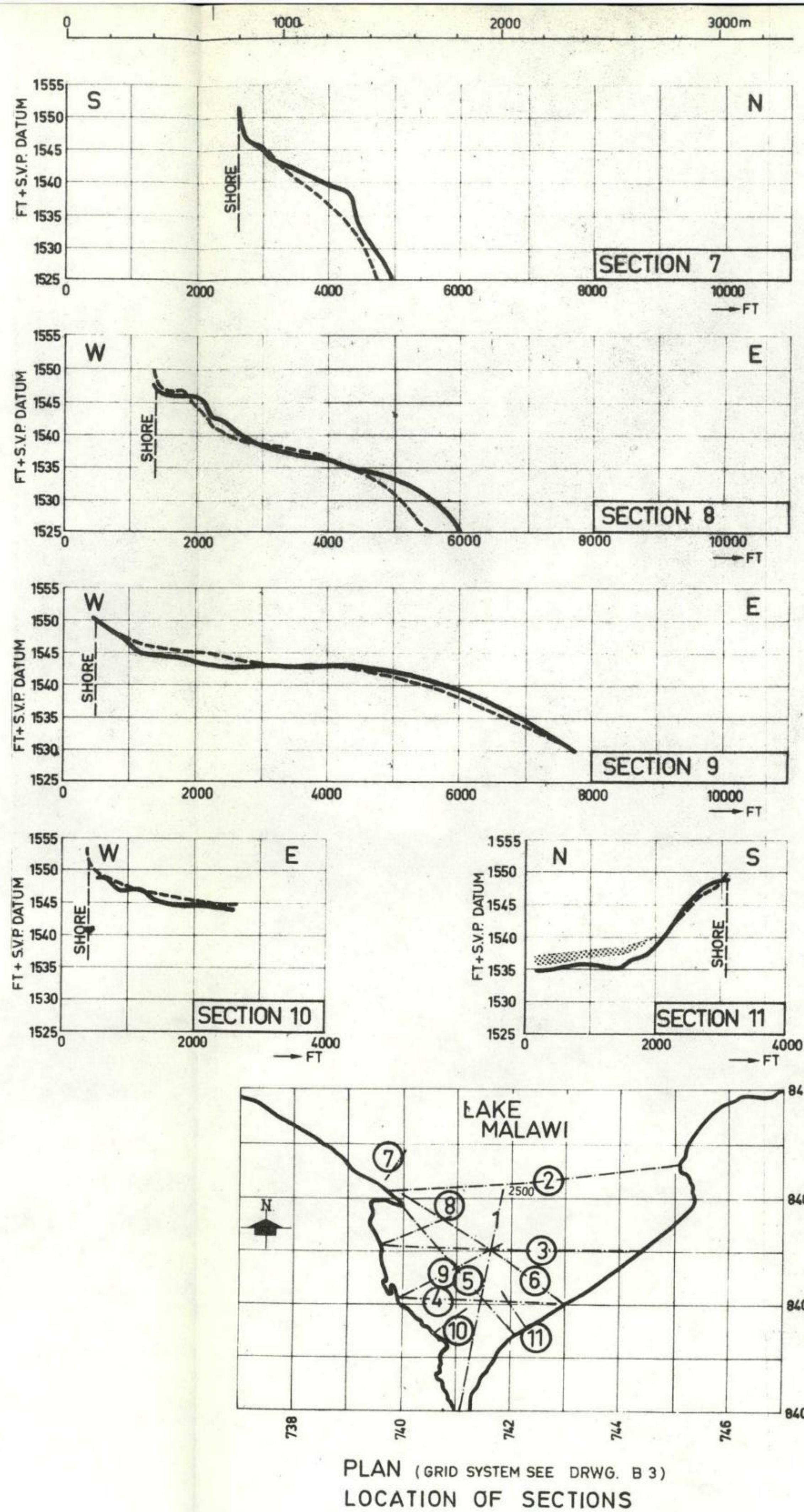
SCALE: 1: 25 000

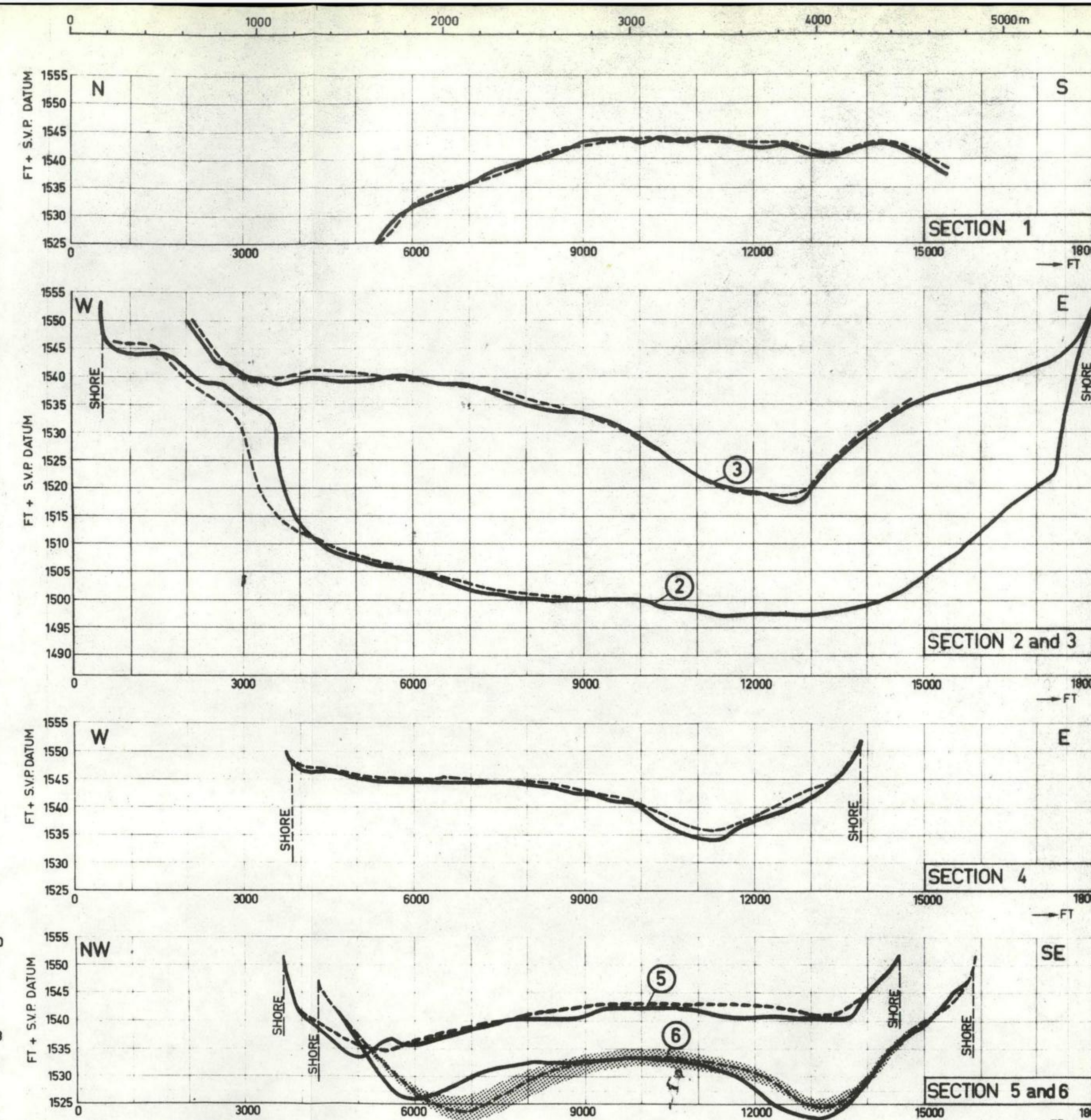
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
SOUNDING CHART 40.7 S - 44.2 S (L)	APPROVED
	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297
	NO. B 25



SCALE : 1 : 25 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN
SOUNDING CHART 44.2 S - 45.0 S (M)	APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297 NO. B 26





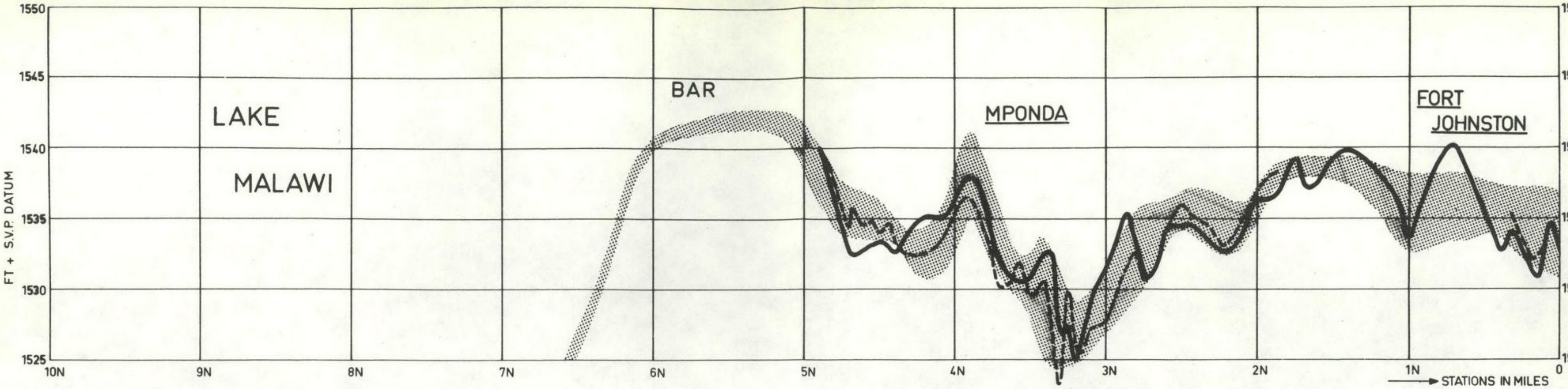
LEGEND:

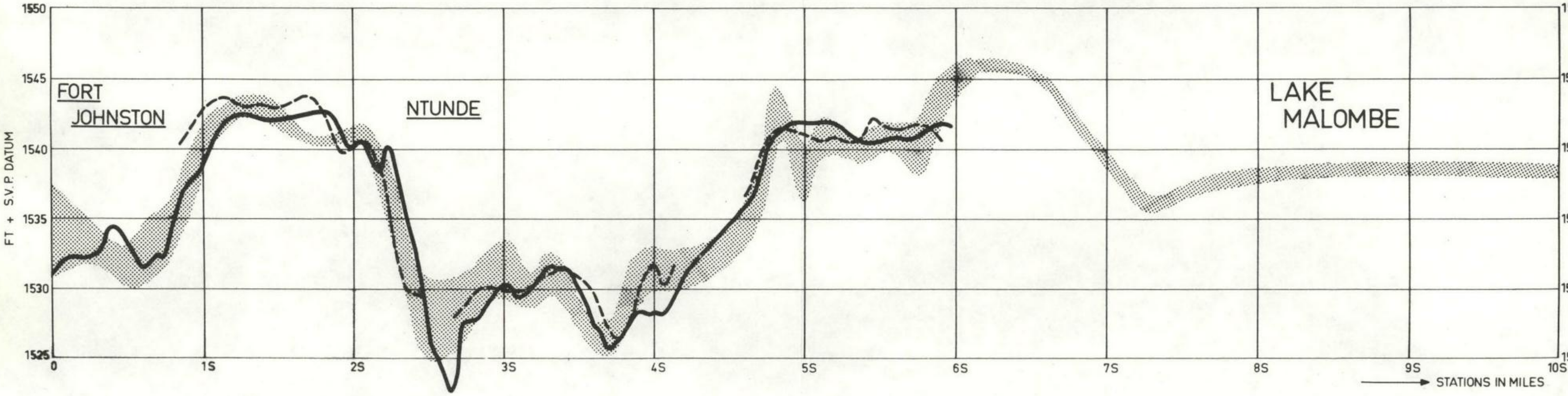
PROFILES MEASURED IN MARCH 1967

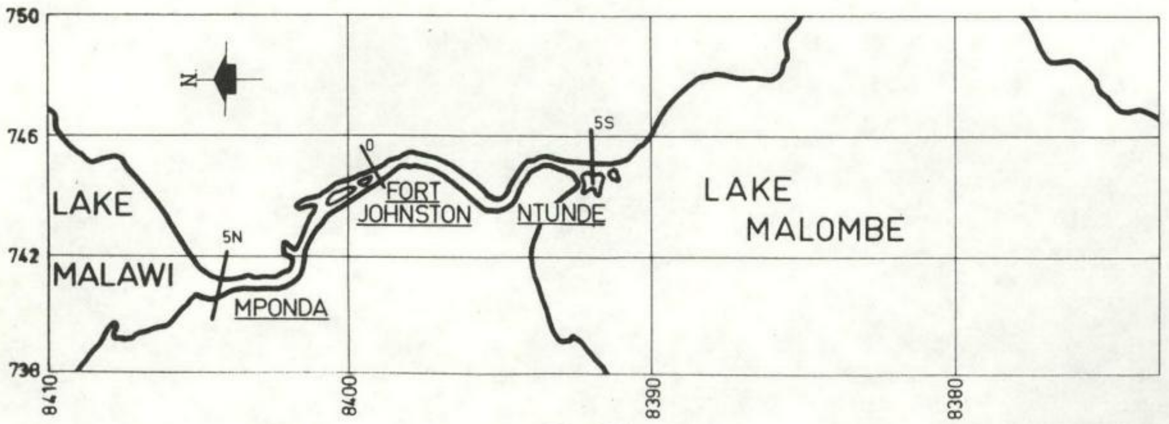
PROFILES TAKEN FROM HALCROW REPORT (1954)

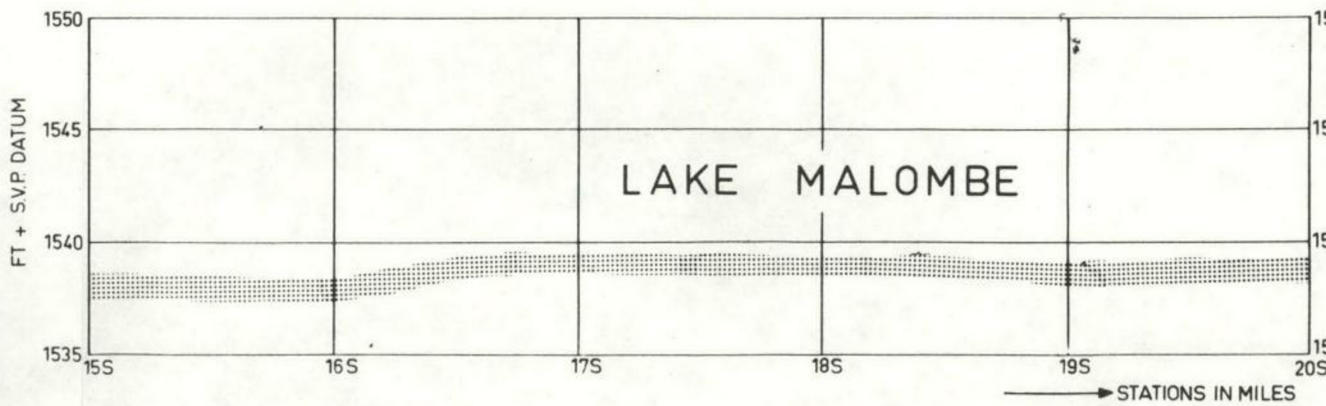
SCALE: PLAN 1:100 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
PROFILES LAKE MALAWI (MEASURED IN MARCH 1967)	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297 NO. B 27









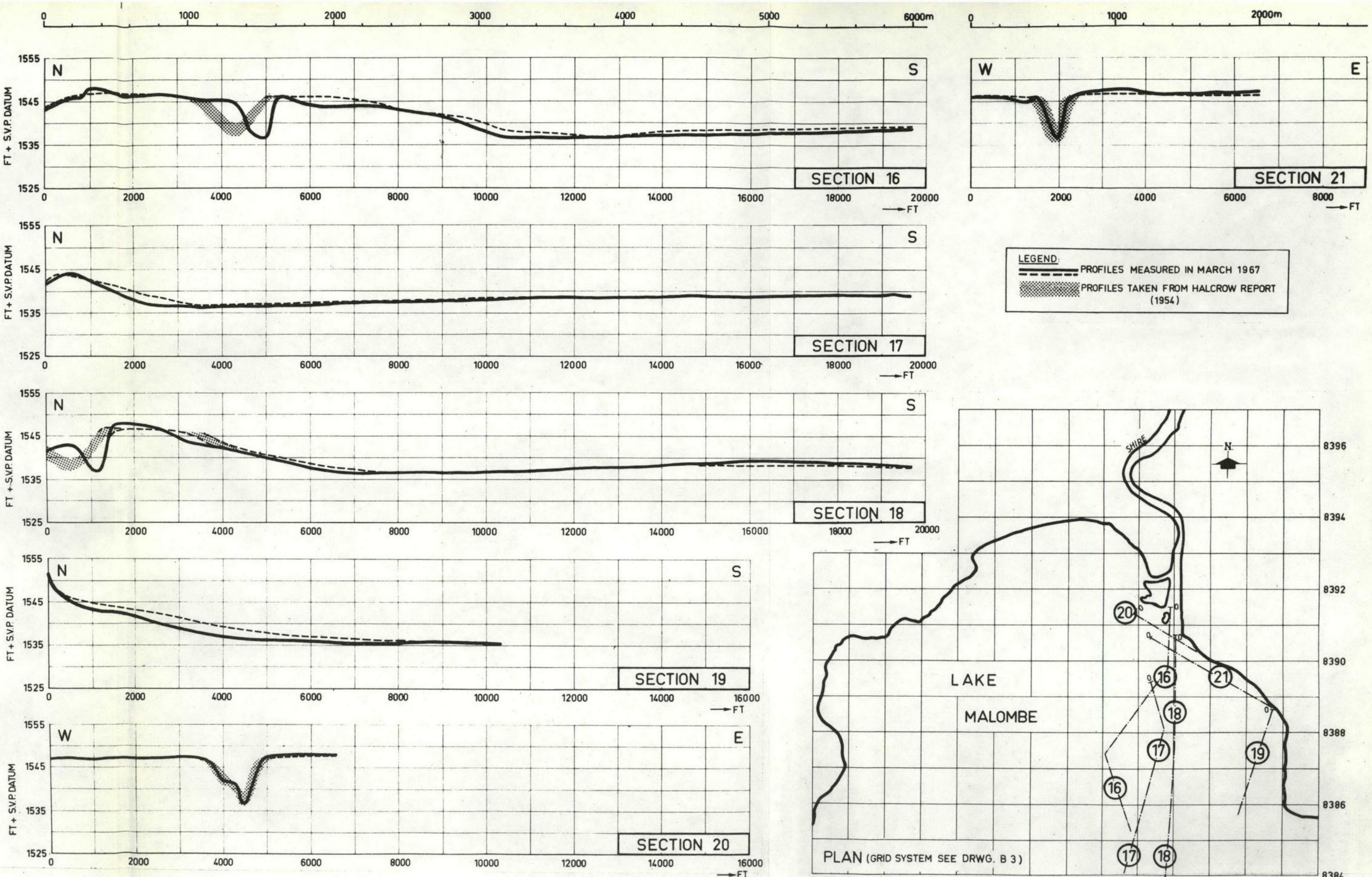
PLAN (GRID SYSTEM + RIVERSTATIONS SEE DRWG. B 3)

LEGEND

——— / - - - -	LONGITUDINAL PROFILES AS MEASURED TWICE APPROXIMATELY IN THE CENTRE-LINE OF THE RIVER (MARCH 1967)
(shaded)	LONGITUDINAL PROFILE AROUND THE CENTRE-LINE OF THE RIVER, TAKEN FROM HALCROW REPORT (1954)

SCALE : PLAN 1: 250 000

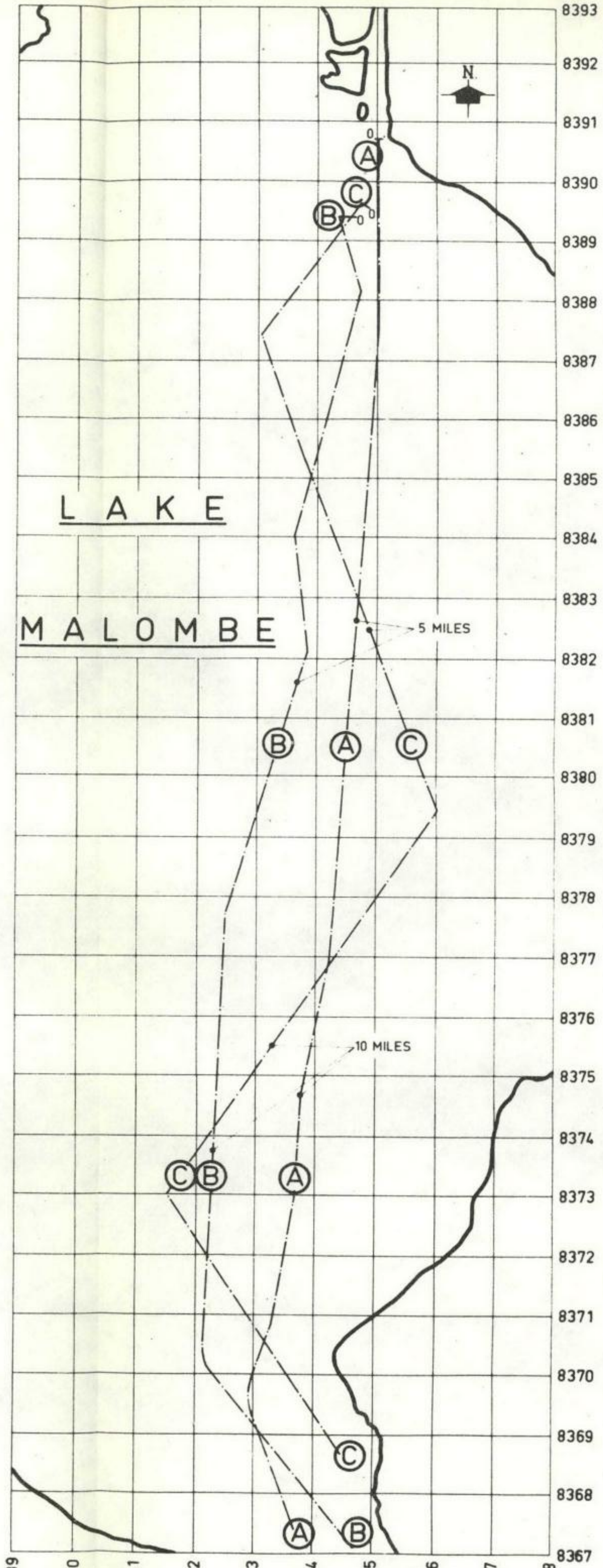
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN
LONGITUDINAL PROFILE SHIRE RIVER (5N-6S) (MEASURED IN MARCH 1967)	APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297 NO. B 28



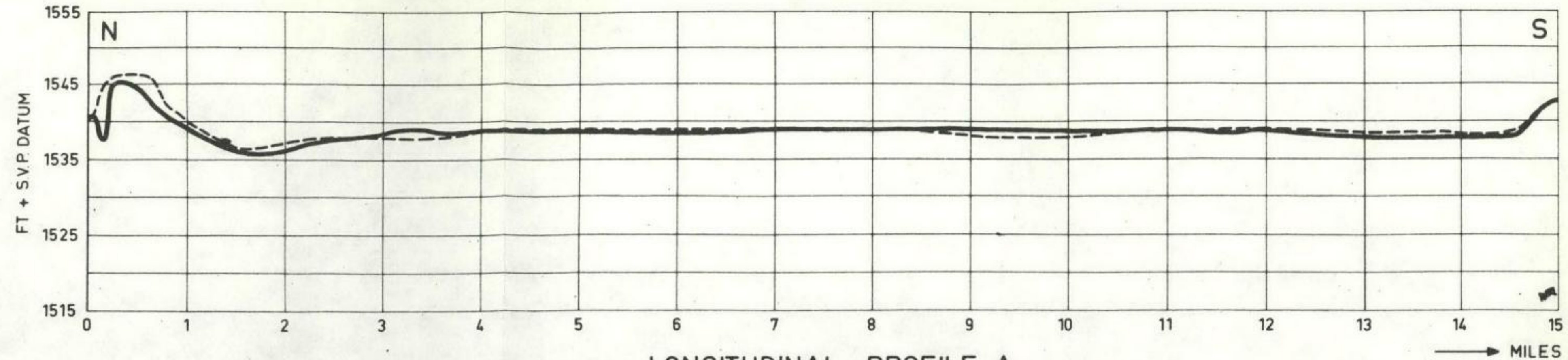
LOCATION OF SECTIONS

SCALE: PLAN 1:100 000

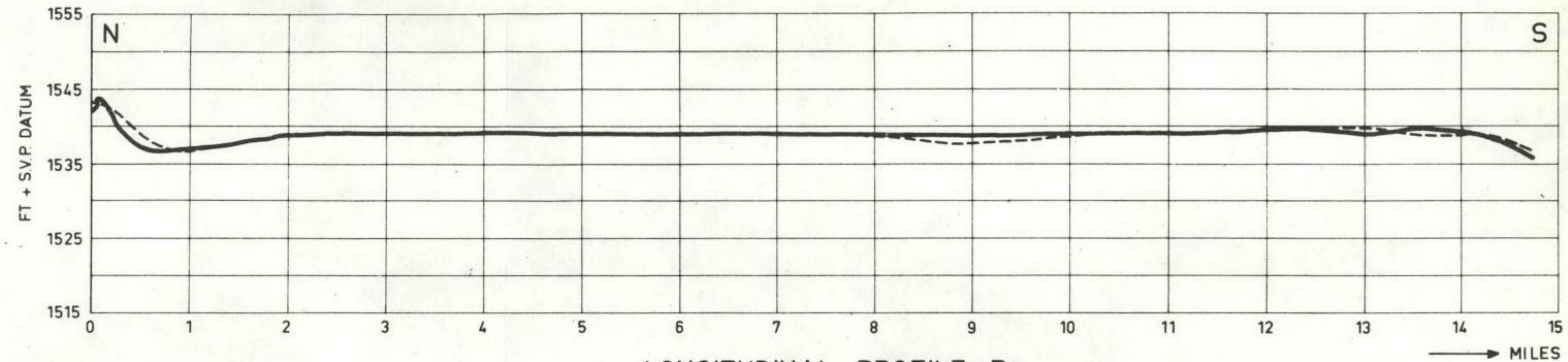
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
PROFILES LAKE MALOMBE- NORTH (MEASURED IN MARCH 1967)	APPROVED
	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297
	NO. B 29



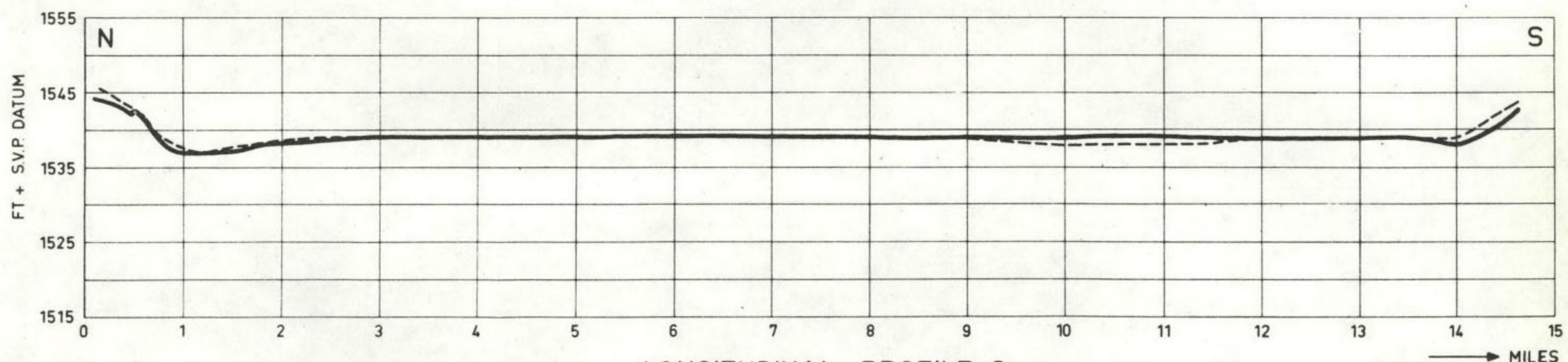
PLAN (GRID SYSTEM SEE DRWG. B 3)
LOCATION OF SECTIONS



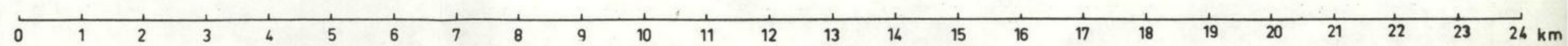
LONGITUDINAL PROFILE A



LONGITUDINAL PROFILE B



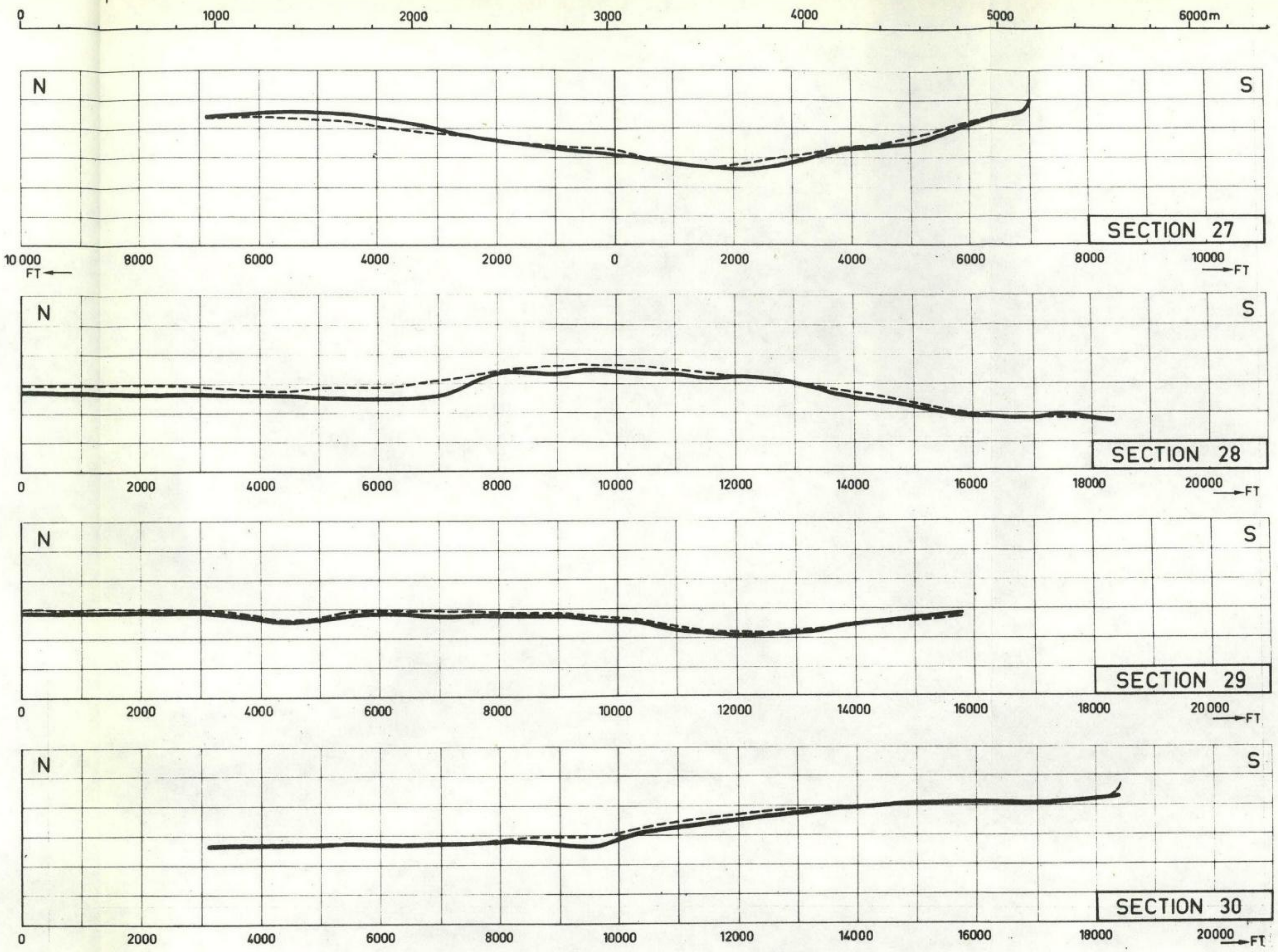
LONGITUDINAL PROFILE C

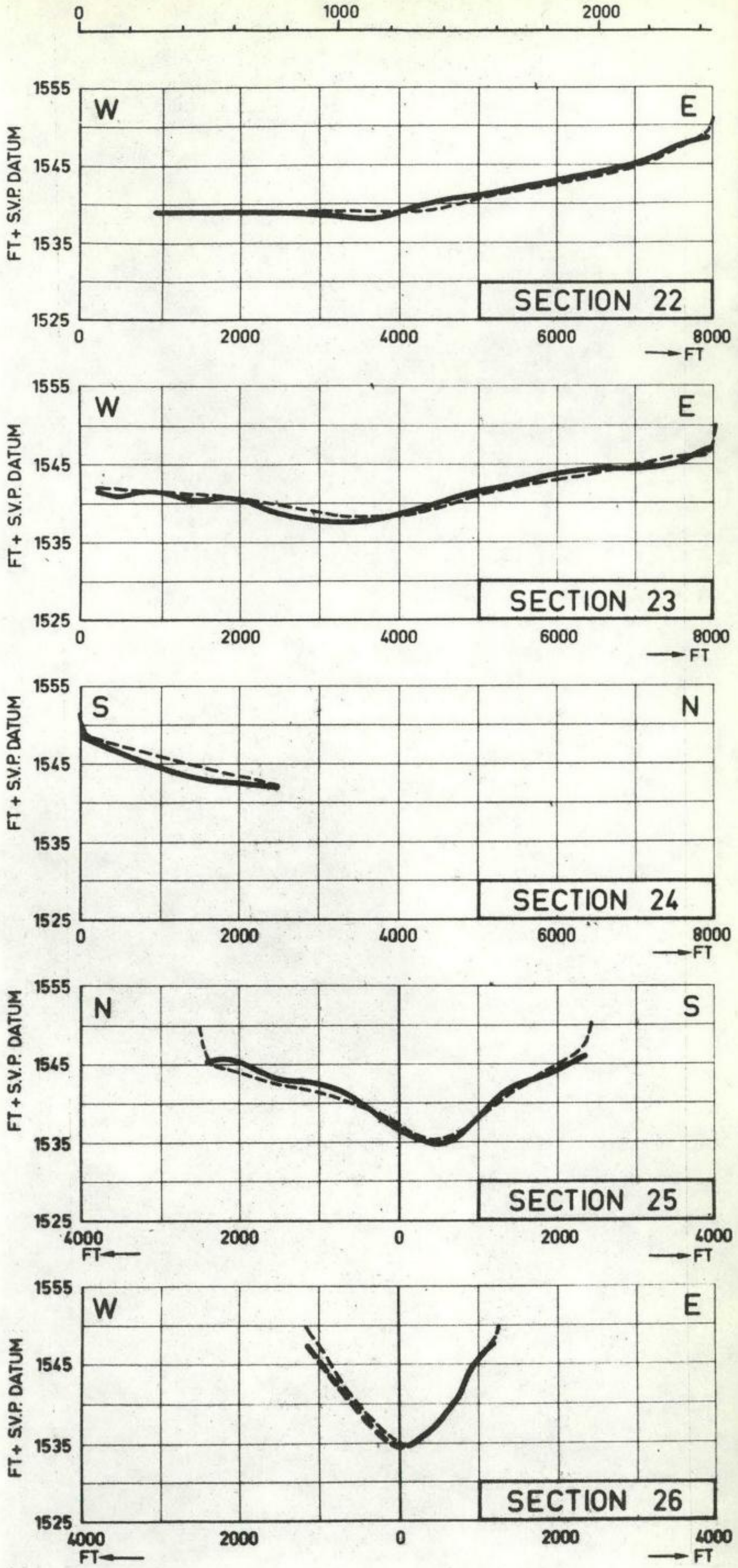


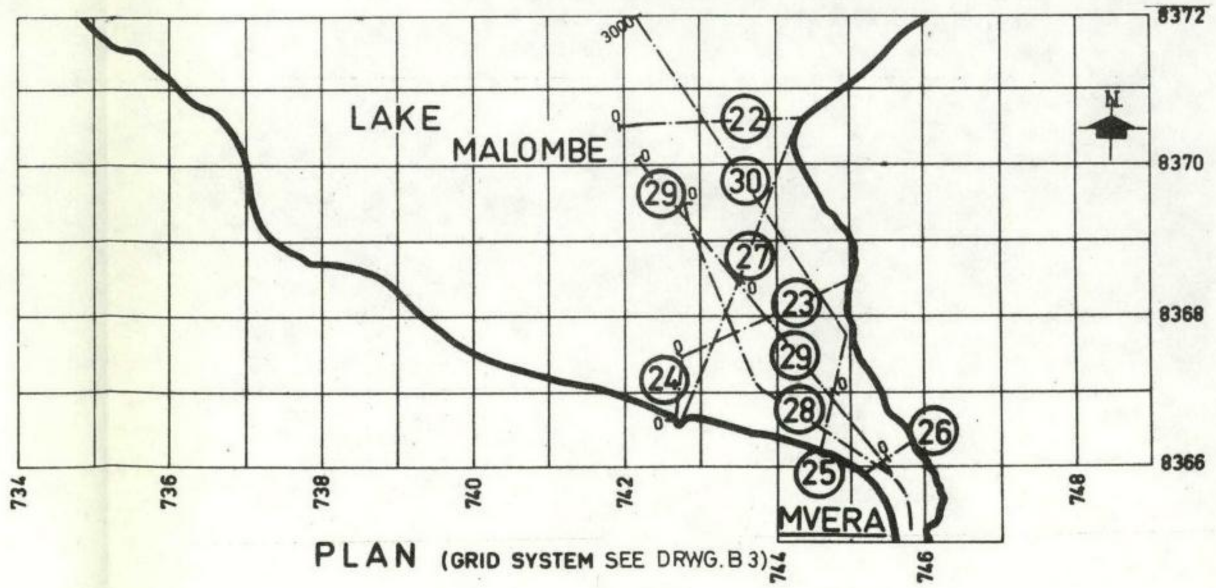
LEGEND:
- PROFILES MEASURED IN MARCH 1967 (solid line)
- PROFILES TAKEN FROM HALCROW REPORT (1954) (dashed line)

SCALE: PLAN 1:100 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
PROFILES LAKE MALOMBE (MEASURED IN MARCH 1967)	APPROVED
	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297
	NO. B 30







PLAN (GRID SYSTEM SEE DRWG. B 3)

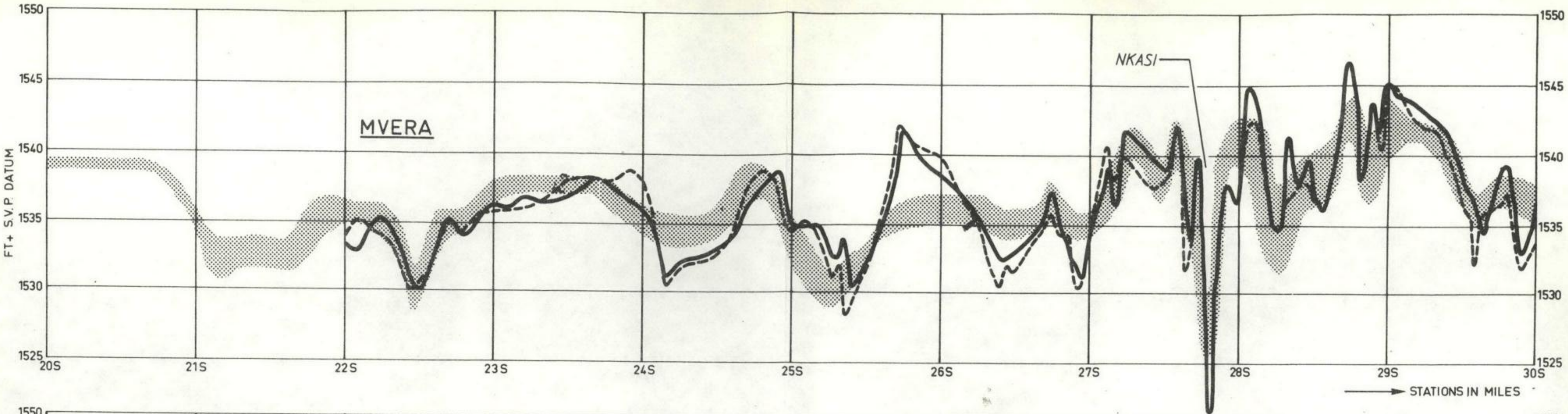
LOCATION OF SECTIONS

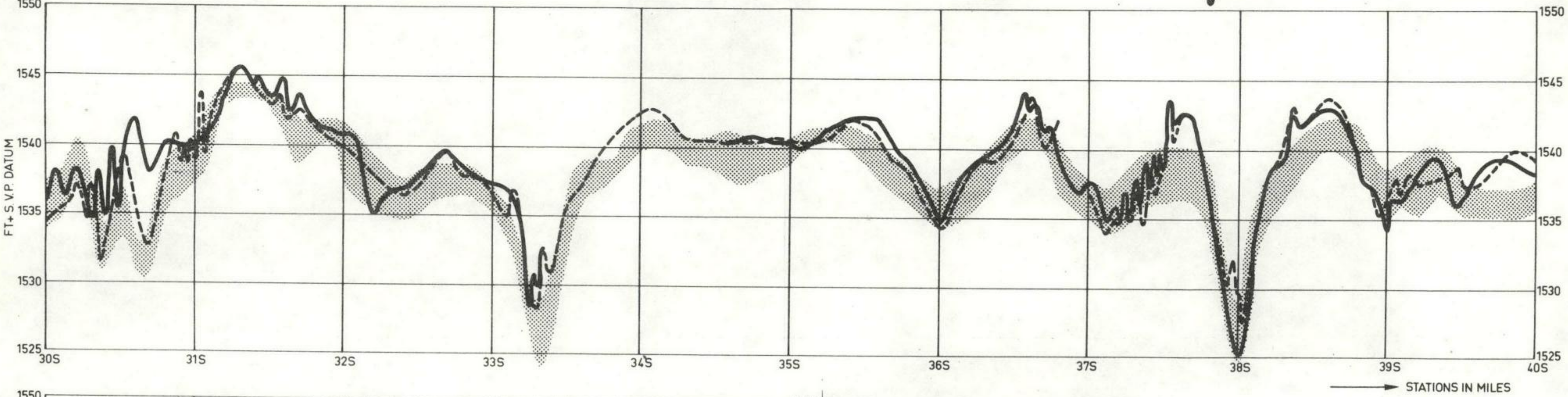
LEGEND:

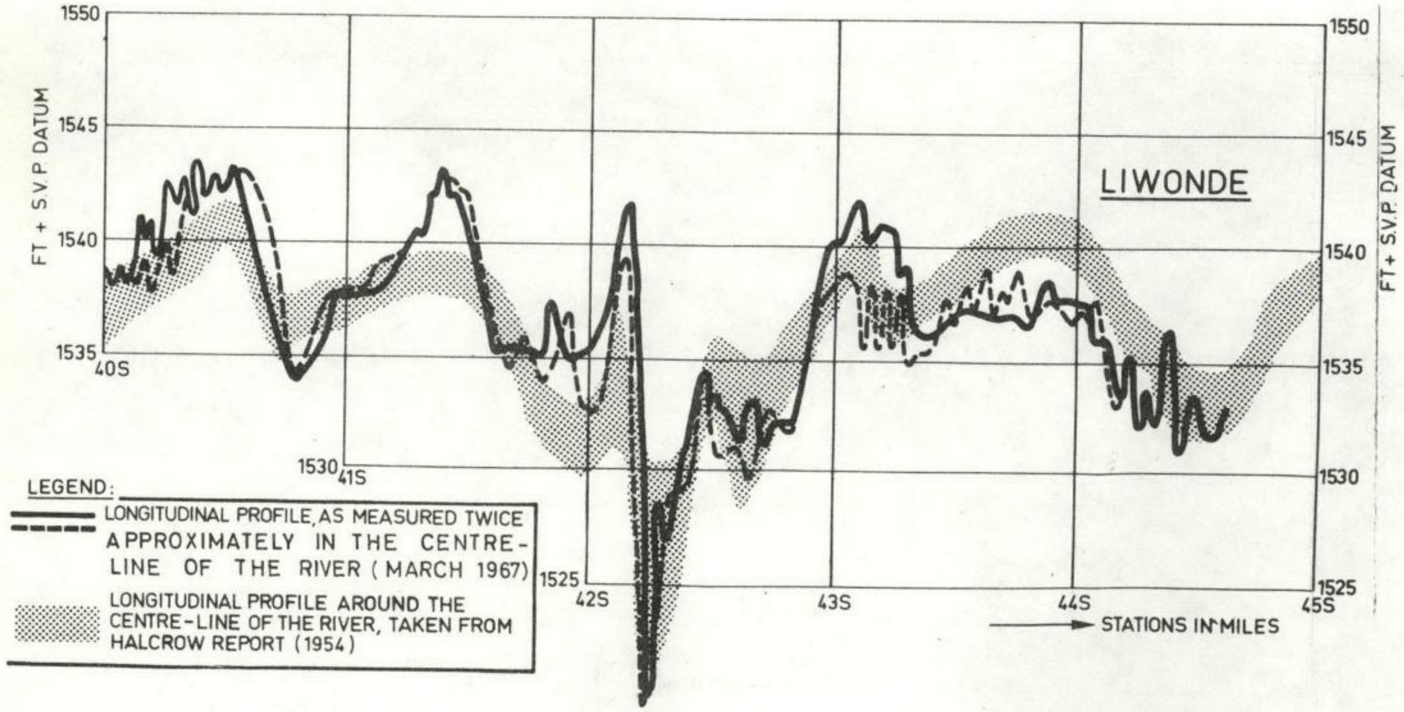
- PROFILES MEASURED IN MARCH 1967
- PROFILES TAKEN FROM HALCROW REPORT (1954)

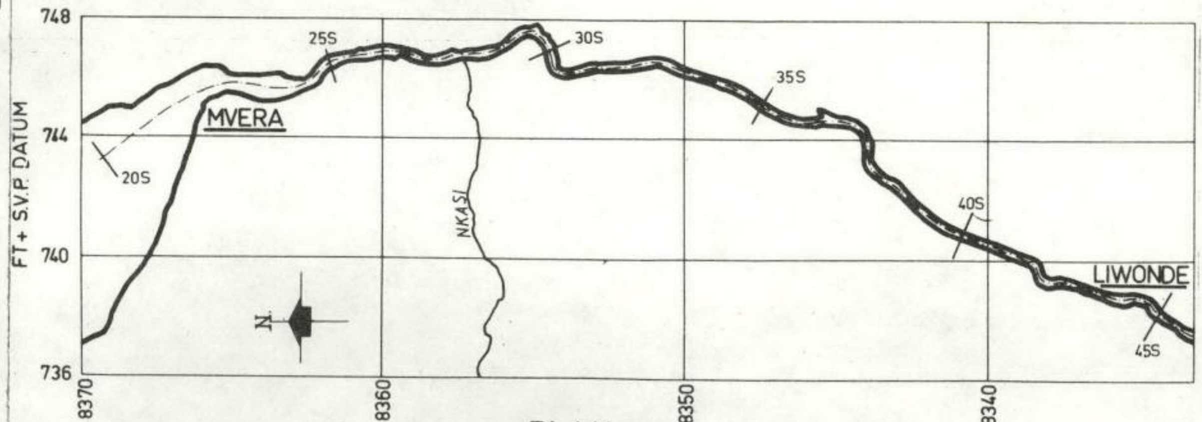
SCALE: PLAN 1:100 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
PROFILES LAKE MALOMBE – SOUTH (MEASURED IN MARCH 1967)	FEBR. 1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	R. 420 S. N. 3297 NO. B 31









PLAN (GRIDSYSTEM + RIVERSTATIONS SEE DRWG. B 3)

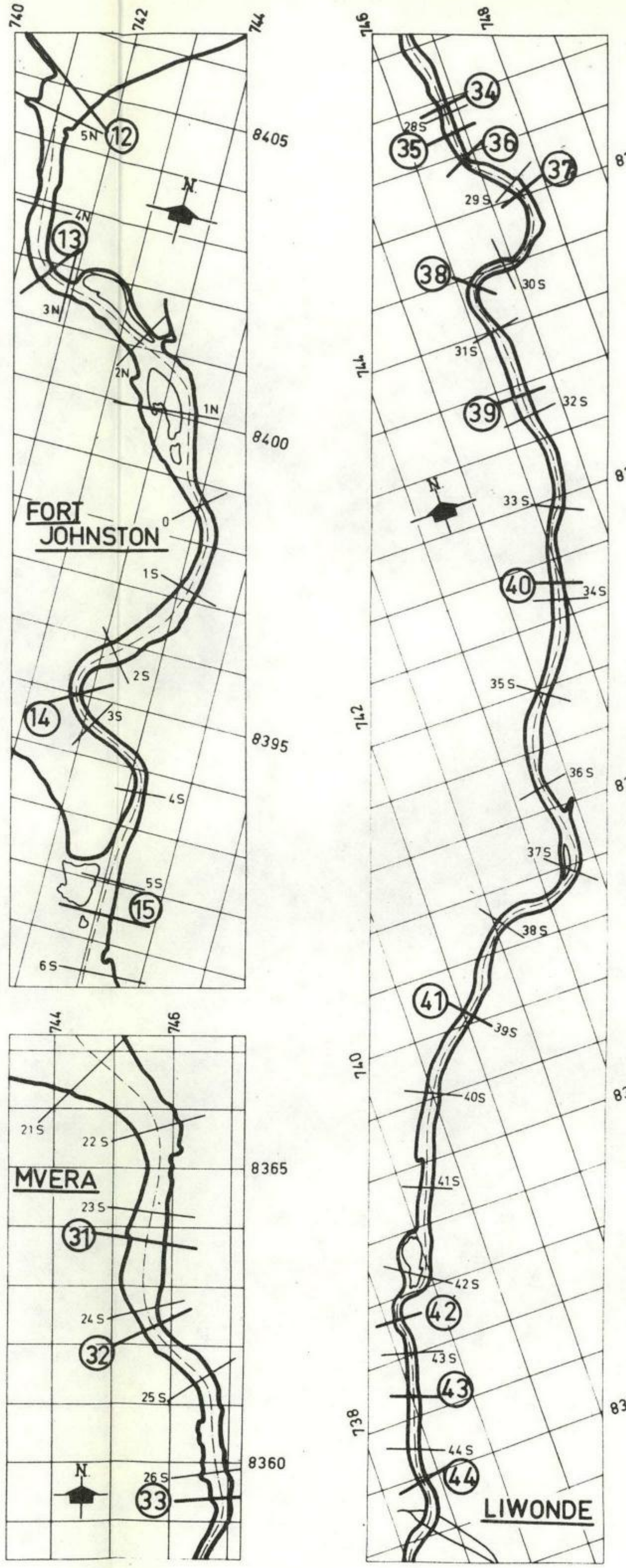
LEGEND:

LONGITUDINAL PROFILE, AS MEASURED TWICE APPROXIMATELY IN THE CENTRE-LINE OF THE RIVER (MARCH 1967)

LONGITUDINAL PROFILE AROUND THE CENTRE-LINE OF THE RIVER, TAKEN FROM HALCROW REPORT (1954)

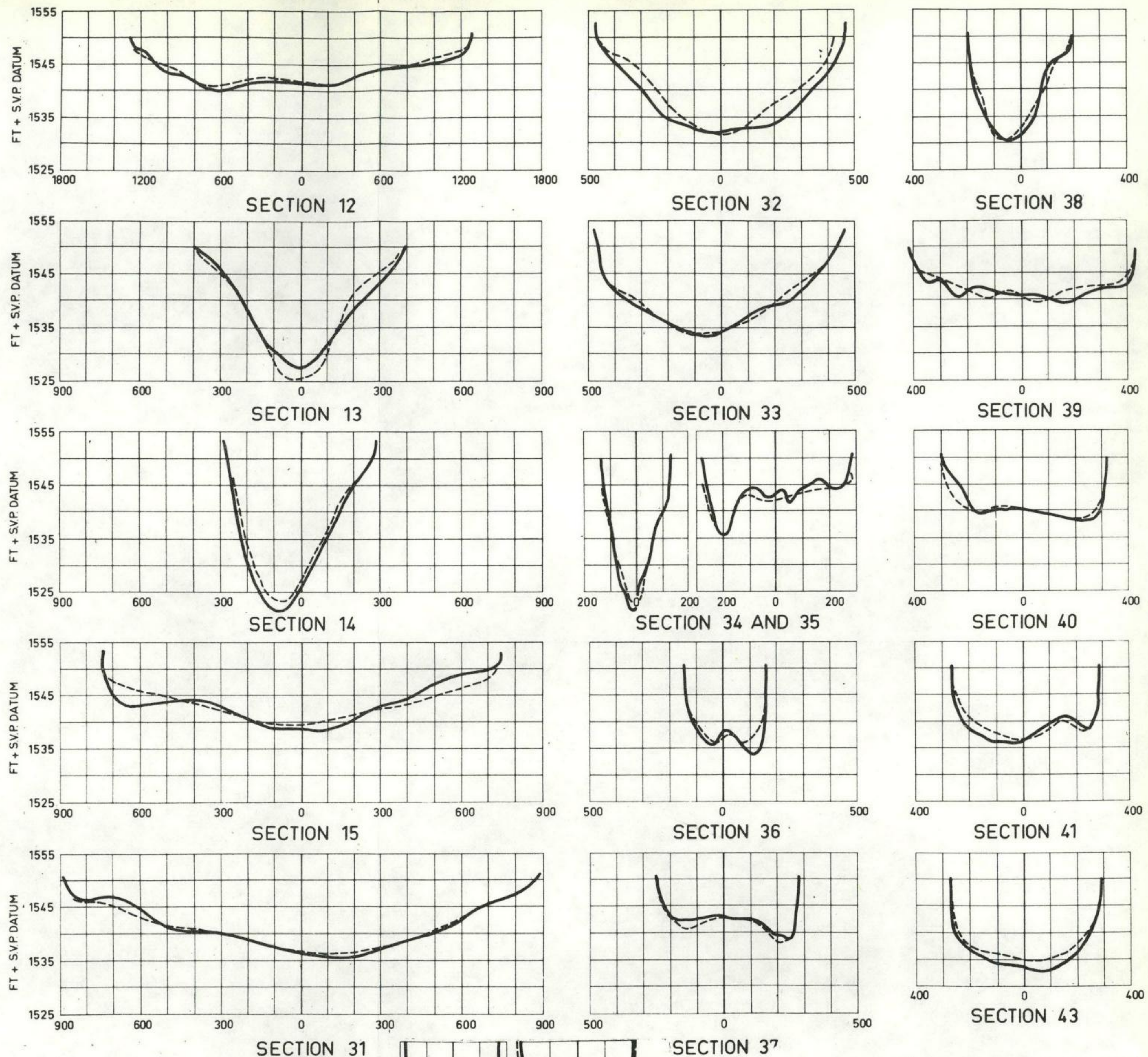
SCALE: PLAN 1:250 000

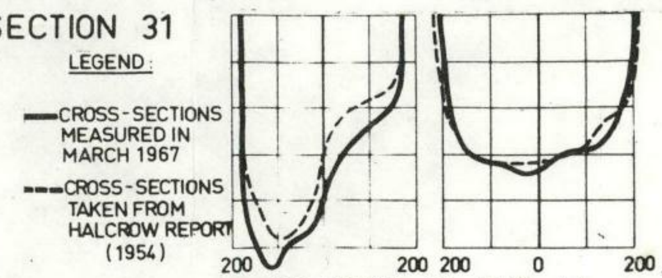
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT LONGITUDINAL PROFILE SHIRE RIVER (22S-45S) ~~(MEASURED IN MARCH 1967)~~	DESIGNED DRAWN APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297 NO. B 32



PLANS (GRIDSYSTEM + RIVERSTATIONS SEE DRWG. B 3)

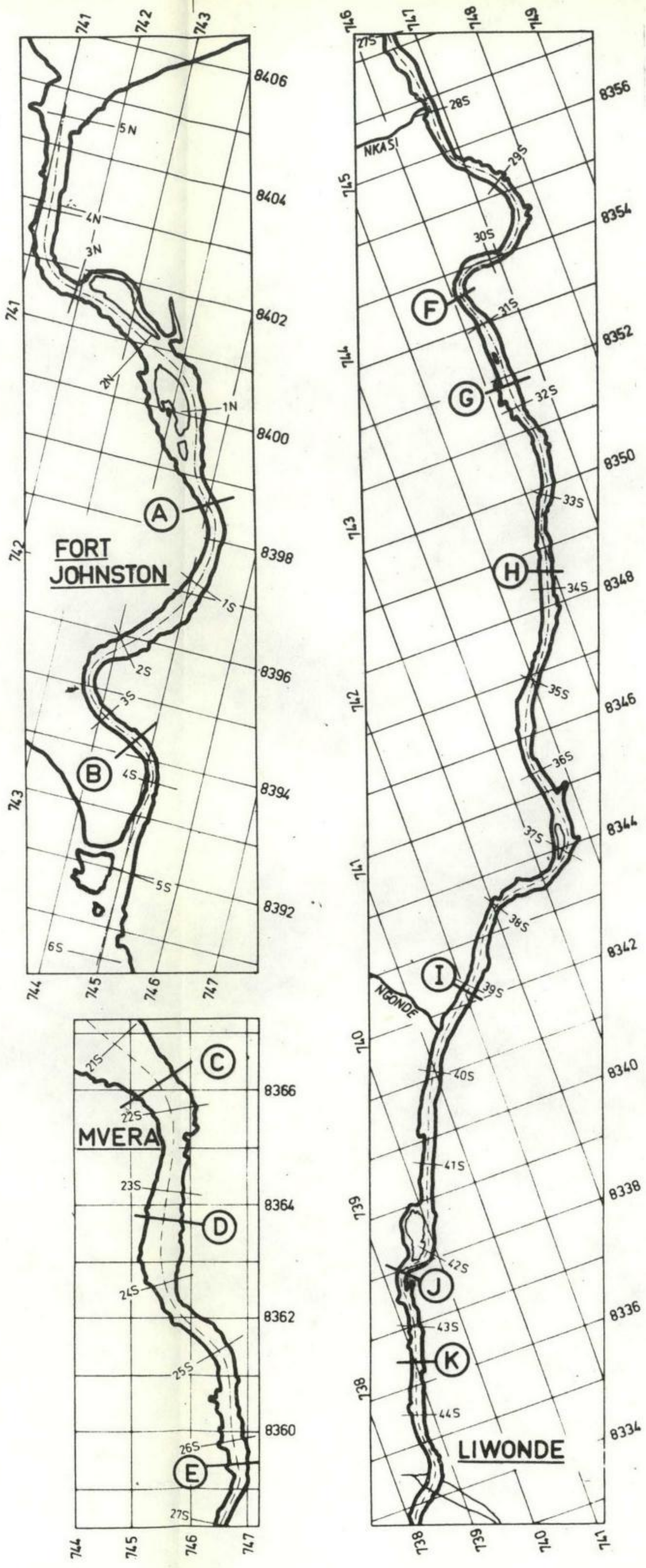
LOCATION OF SECTIONS



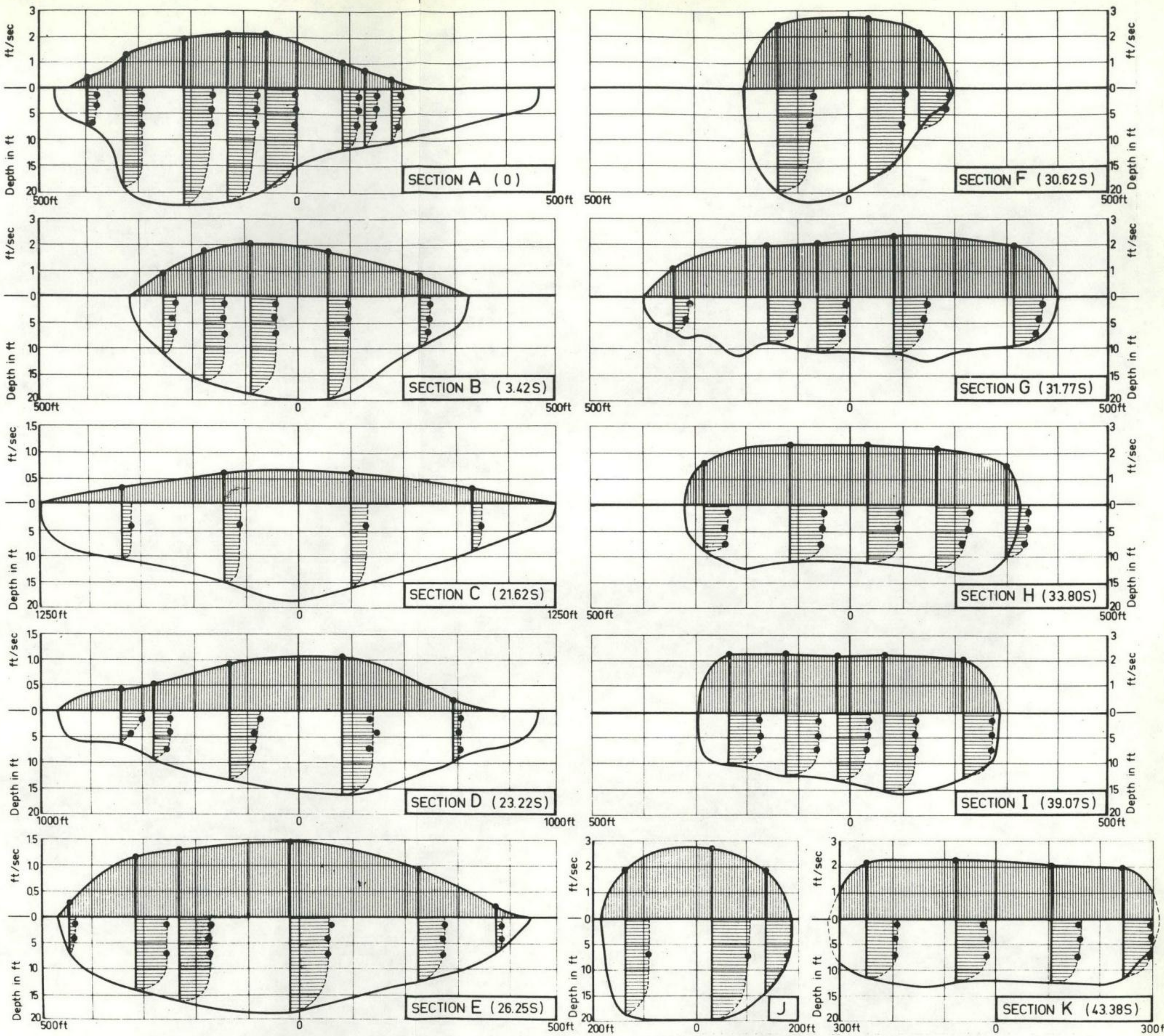


SCALE: PLANS 1:100 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN
CROSS-SECTIONS SHIRE RIVER (MEASURED IN MARCH 1967)	APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297 NO. B 33



PLANS, LOCATION OF SECTIONS



NOTE: 1. GRID SYSTEM PLAN + RIVERSTATIONS SEE DRWG. B 3
2. WATERLEVEL AT FORT JOHNSTON: 1552.75 FT + S.V.P. DATUM
WATERLEVEL AT LIWONDE: 1548.25 FT + S.V.P. DATUM
3. SCALE OF THE VELOCITIES IN THE VERTICAL DISTRIBUTIONS HALVED

SCALE: PLAN 1:100 000

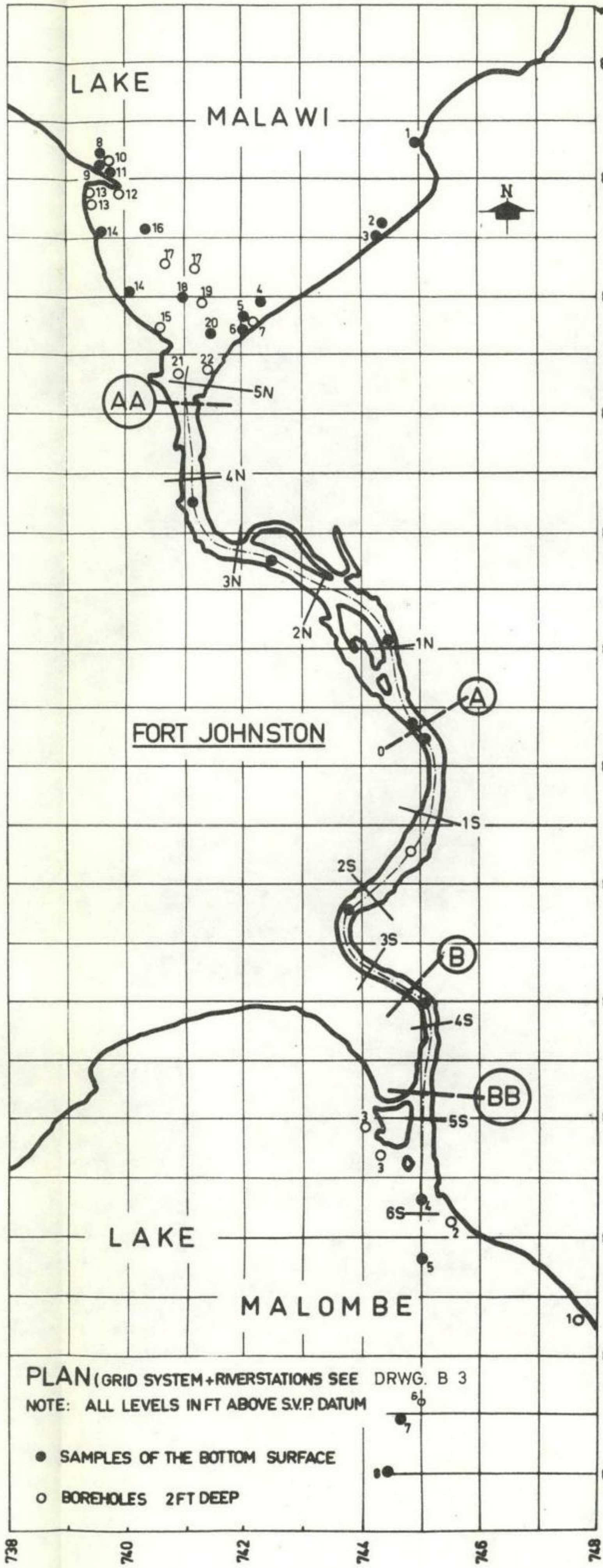
GOVERNMENT OF MALAWI

LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT
VELOCITY DISTRIBUTIONS
(MEASURED IN UPPER SHIRE RIVER IN MARCH 1967)

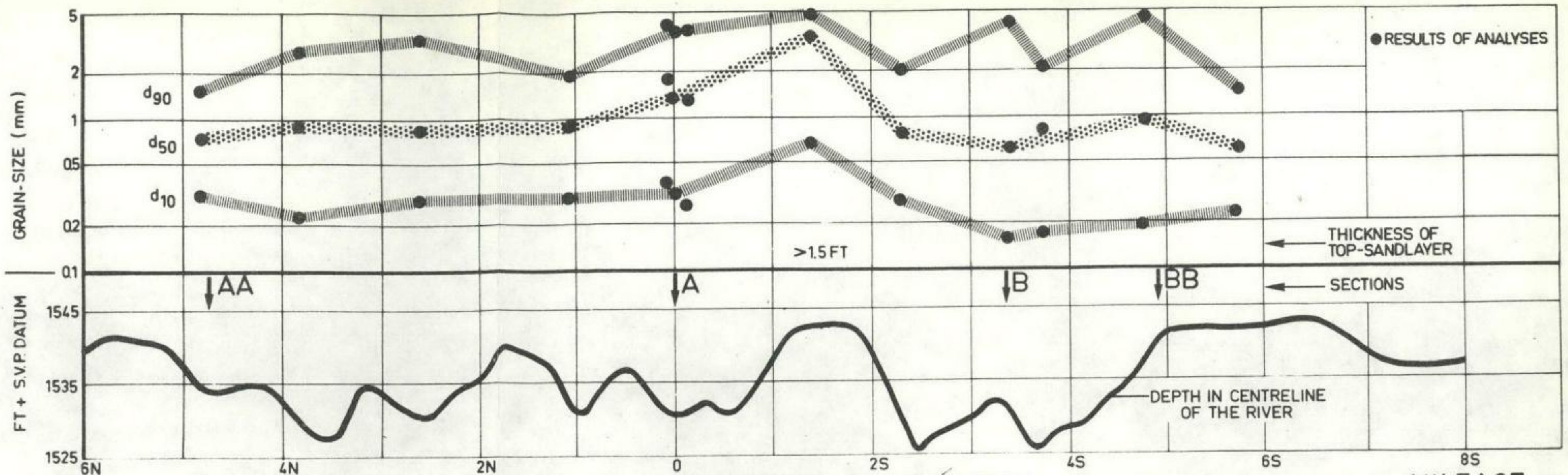
DESIGNED
DRAWN
APPROVED
FEBR. 1968

DELFT HYDRAULICS LABORATORY
R. 420

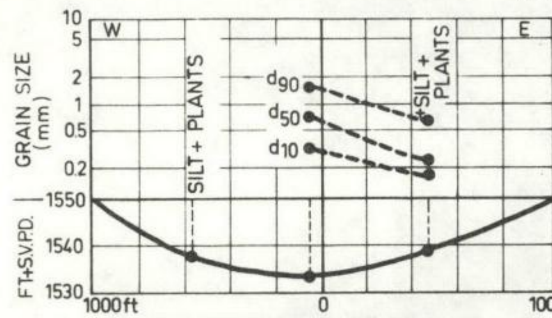
KAMPSAX — KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN
S. N. 3297
NO. B 34



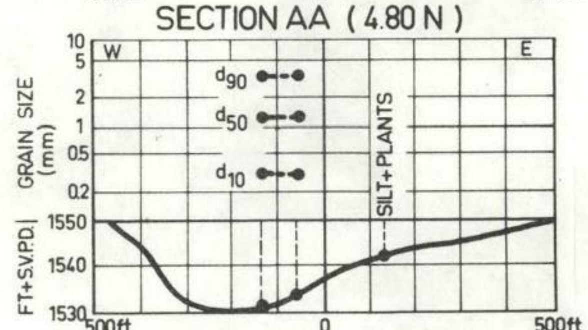
LOCATION OF SECTIONS



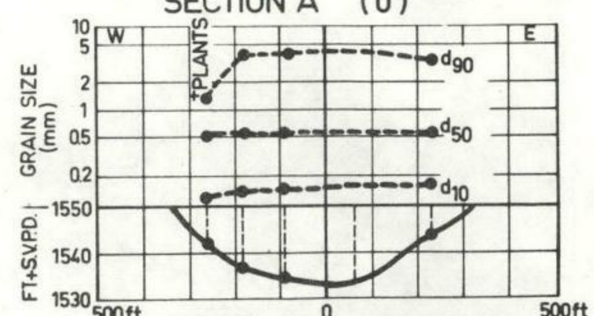
LONGITUDINAL GRAIN — SIZE DISTRIBUTION



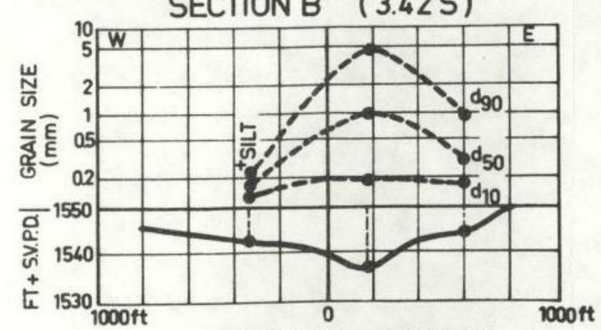
SECTION AA (4.80 N)



SECTION A (0)



SECTION B (3.42 S)



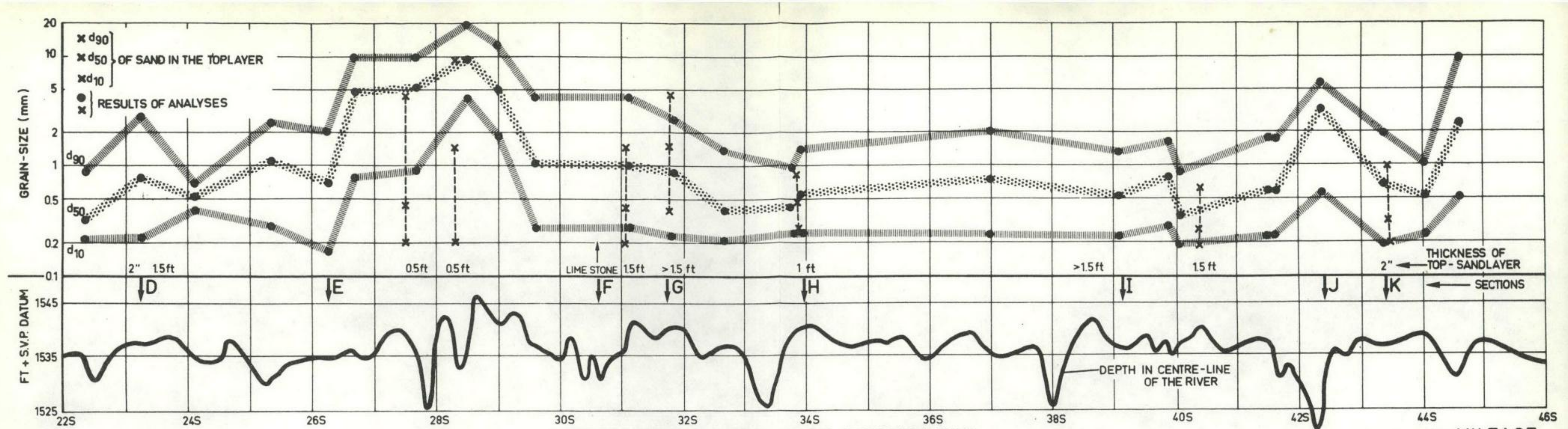
SECTION BB (4.77 S)

	Nr. Sample Borehole	GRAIN-SIZE IN mm's d_{10}	d_{50}	d_{90}	DISTANCE TO THE SHORE IN ft	REMARKS
LAKE MALAWI	1	0.22	0.34	0.75		
	2	0.45	1.10	2.40	500	
	3	0.10	0.22	0.35	10	
	4					FINE SAND AND PLANTS
	5					FINE SAND AND SILT
	6	0.09	0.12	0.18	300	
	7	0.14	0.18	0.21		TOP LAYER OF 0.5 ft
	8	0.12	0.25	0.58	500	+ SOME PLANTS
	9	0.11	0.24	2.00	50	
	10	0.15	0.30	0.60	400	FIRST LAYER OF 2"
	10	0.12	0.60	4.00	400	SECOND LAYER OF 0.5 ft
	10	0.09	0.27	1.30	400	THIRD LAYER OF 1ft
	11	0.28	0.57	2.20	100	
	12	0.58	1.50	3.90	30	LAYER OF MORE THAN 2 ft
	13				300	FINE SAND LAYER OF 2"; UNDERNEATH CLAY
	14					VERY FINE SAND, SILT AND CLAY
	15	0.21	0.65	1.35	100	TOP LAYER OF 2"- 4" SAND; UNDERN. SAND + SILT
	16	0.24	0.97	2.40		
	17	0.20	0.55	1.20		PLANTS; UNDERNEATH LAYERS OF 0.5 - 1ft
	18	0.33	0.70	1.60		PLANTS
	19	0.32	1.00	3.40		FIRST LAYER OF 2" + PLANTS ON TOP
	19	0.25	0.69	2.00		SECOND LAYER OF 1ft
	19	0.15	0.25	0.37		THIRD LAYER OF 1ft
	20					PLANTS
	21					FINE SAND AND SILT
	22	0.18	0.90	4.00	300	PLANTS ON TOP
LAKE MALOMBE NORTH	1	0.11	0.21	0.36	30	+ SILT
	2	0.08	0.14	0.31	200	TOP LAYER OF 0.5 - 1ft; UNDERNEATH CLAY
	3	0.09	0.23	0.90		NO SILT
	4	0.22	0.58	1.40		SOME PLANTS
	5	0.10	0.19	0.53		NO PLANTS
	6					SILTLAYER OF 2"; UNDERNEATH CLAY
	7					SILT AND CLAY
	8					SILT
	9					3 BOREHOLES IN THE MIDDLE OF LAKE MALOMBE FEW SILT, UNDERNEATH CONSOLIDATED CLAY

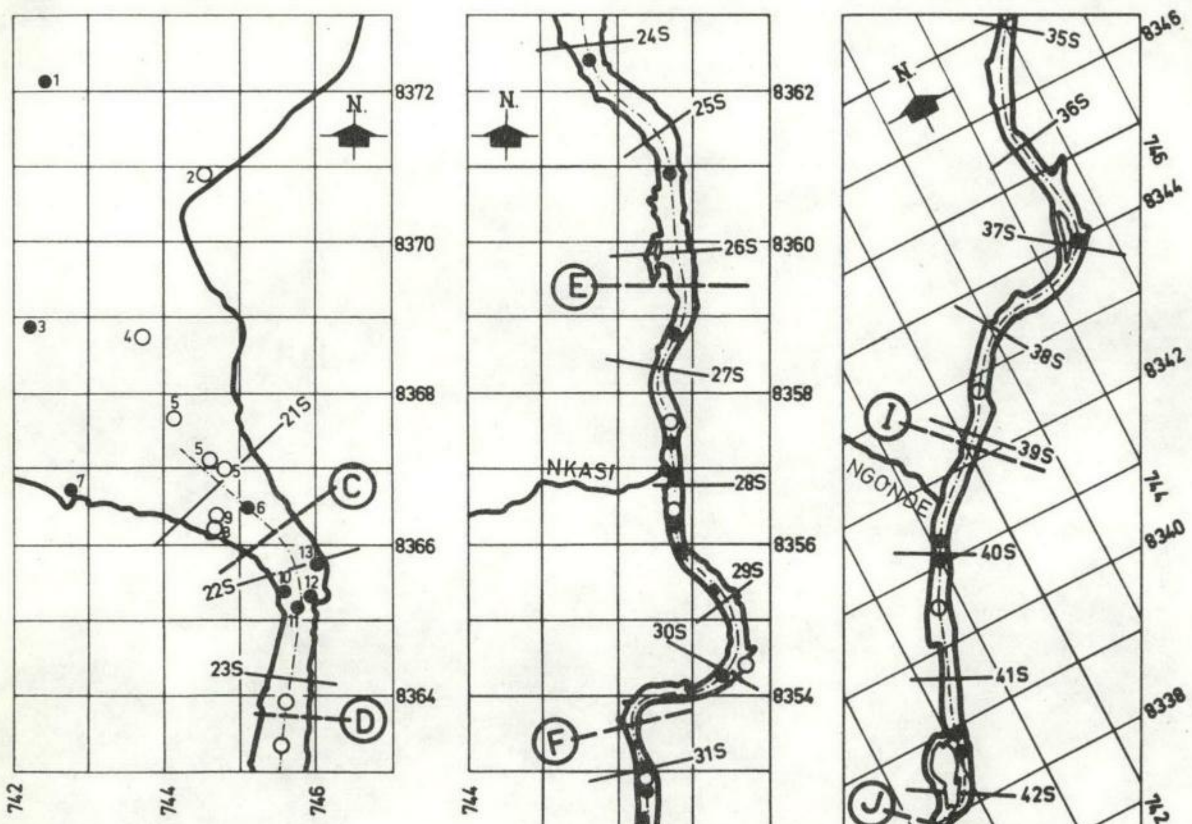
SCALE: PLAN 1:100 000

GOVERNMENT OF MALAWI

LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
GRAIN-SIZE DISTRIBUTION UPPER SHIRE RIVER-NORTH (SAMPLES AND BOREHOLES TAKEN IN MARCH 1967)	APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297
	NO. B 35



LONGITUDINAL GRAIN-SIZE DISTRIBUTION

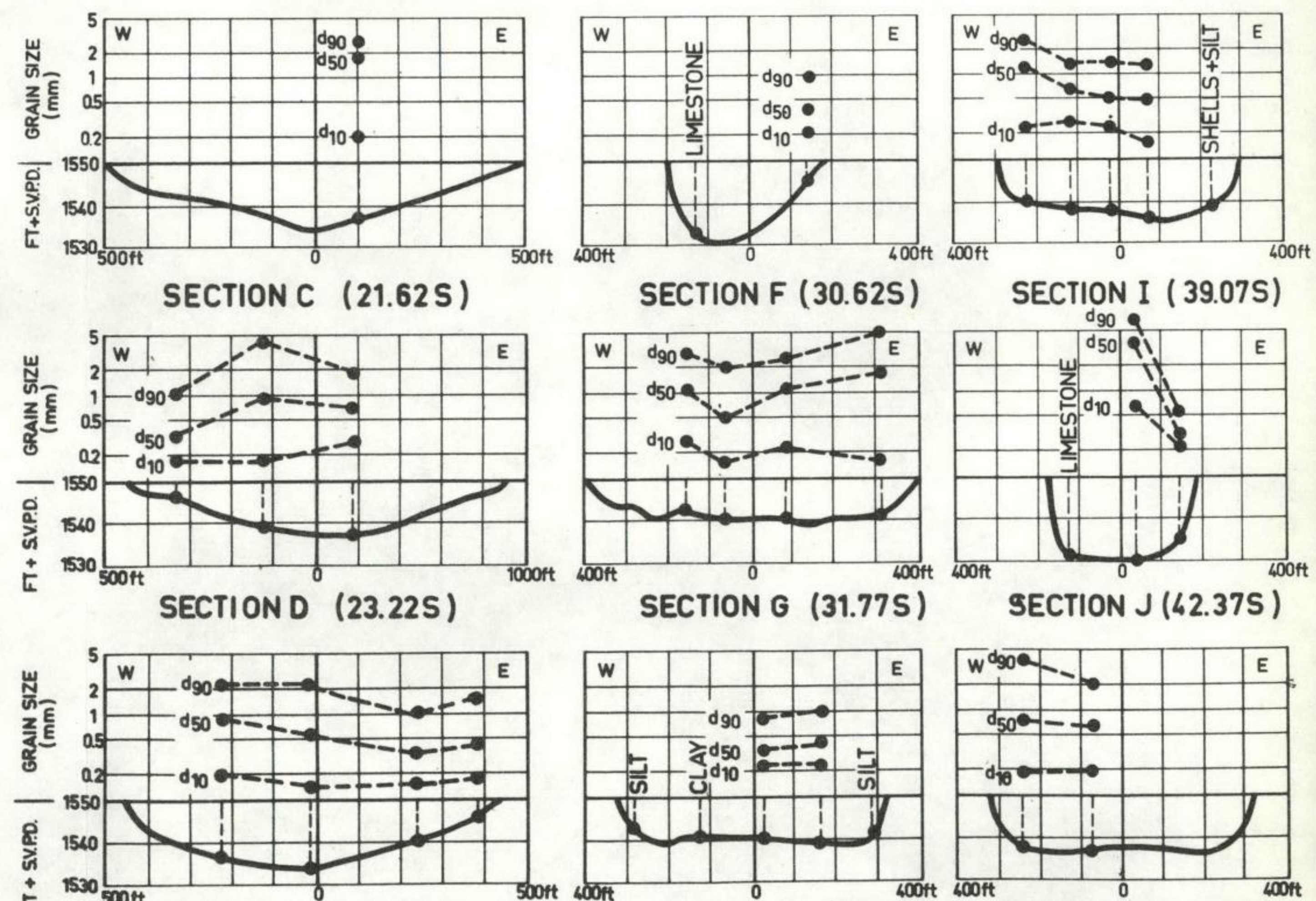


Nr SAMPLE BOREHOLE	PARTICLE-SIZE (mm) d_{10}	d_{50}	d_{90}	DISTANCE TO THE SHORE IN ft	REMARKS.
1					CLAY
2	0.17	0.29	1.10	100	FINE SAND, SILT AND PLANTS
3					SILT
4					CLAY
5					SILT LAYER OF 1", UNDERN. CLAY
6					FINE SAND
7	0.15	0.28	1.15	75	SAND UNDERN. SILT LAYER OF 1"
8	0.12	0.35	1.15	150	SAND, SILT AND ROOTS
9				600	FIRST LAYER OF 1ft SAND
					UNDERNEATH STIFF CLAY
C	0.22	1.75	2.40		SAND WITHOUT SILT
10				200	SILT
11	0.19	0.29	0.91		SAND
12					COARSER SAND THAN „11"
13					AS „12" + SILT AND SHELLS

PLAN (GRIDSYSTEM + RIVERSTATIONS SEE DRWG. B 3)
NOTE: ALL LEVELS IN FT ABOVE S.V.P. DATUM

● SAMPLES OF THE BOTTUM SURFACE
○ BOREHOLES 2FT DEEP

LOCATION OF SECTIONS



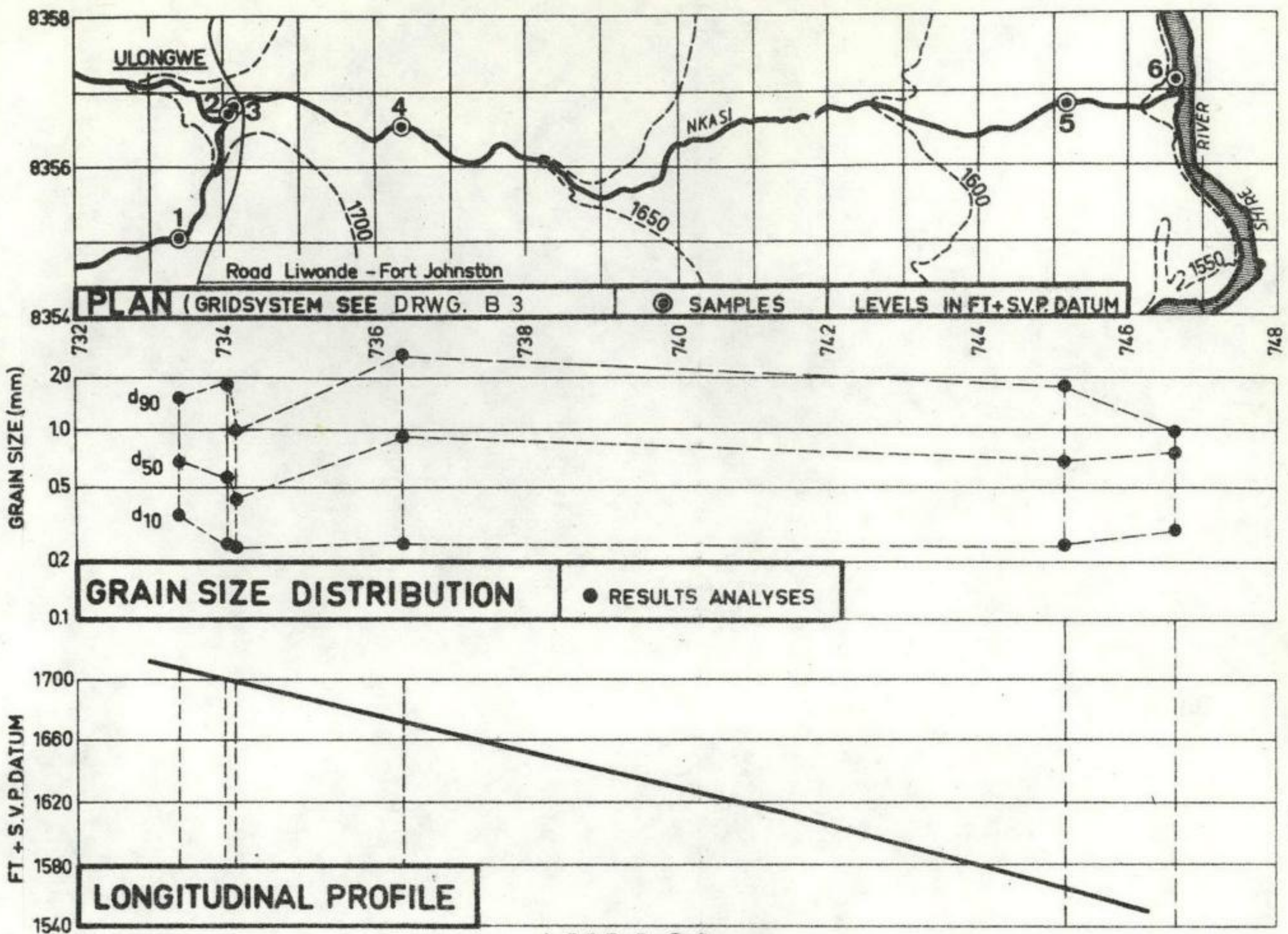
SECTION C (21.62S) SECTION F (30.62S) SECTION I (39.07S)

SECTION D (23.22S) SECTION G (31.77S) SECTION J (42.37S)

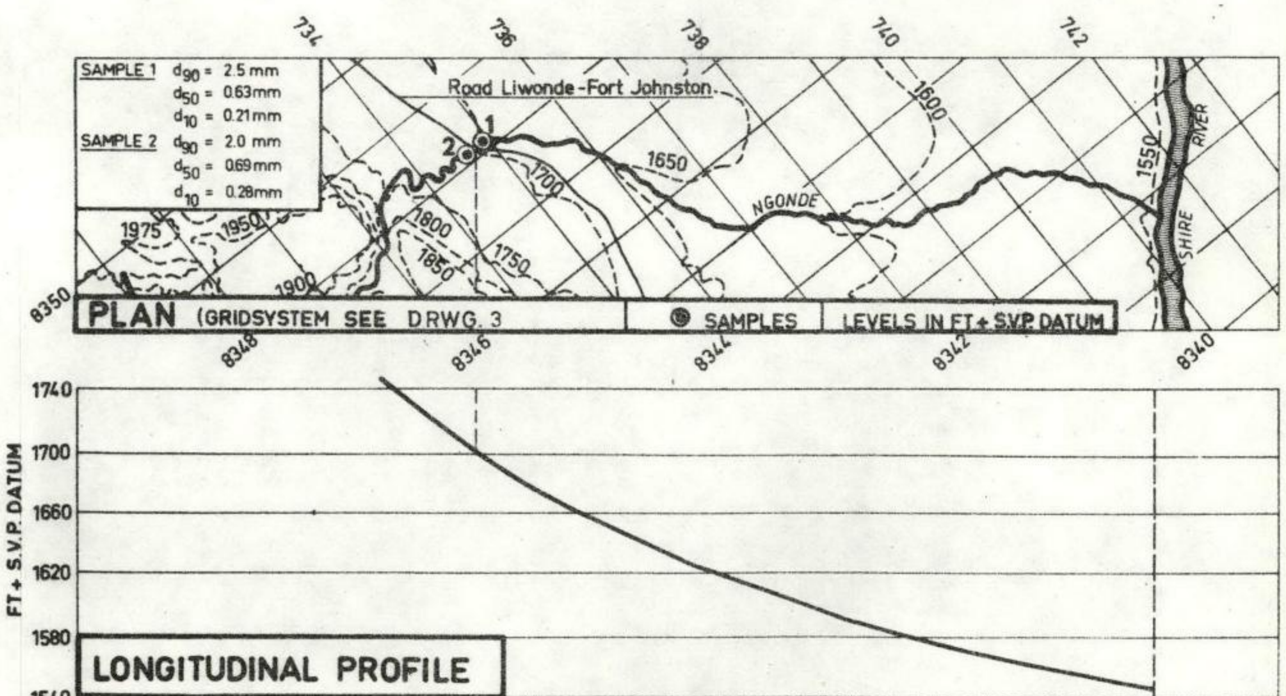
SECTION E (26.25S) SECTION H (33.80S) SECTION K (43.38S)

SCALE: PLAN 1:100 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED
	DRAWN
GRAIN-SIZE DISTRIBUTION UPPER SHIRE RIVER-SOUTH (SAMPLES AND BOREHOLES TAKEN IN MARCH 1967)	APPROVED
	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297
	NO. B 36



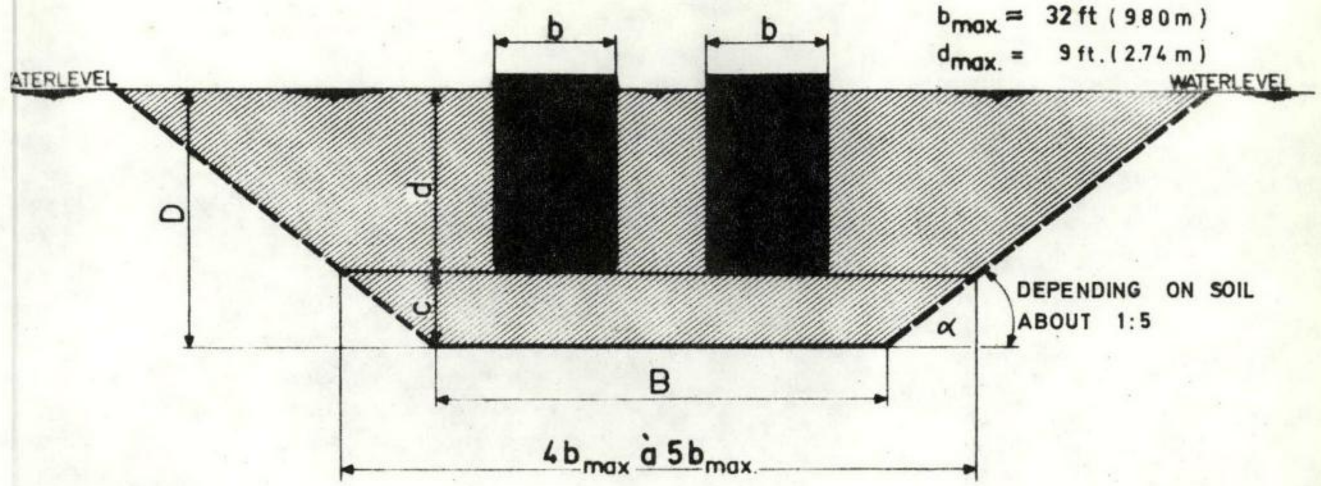
NKASI



NGONDE

SCALE : PLAN 1:100 000

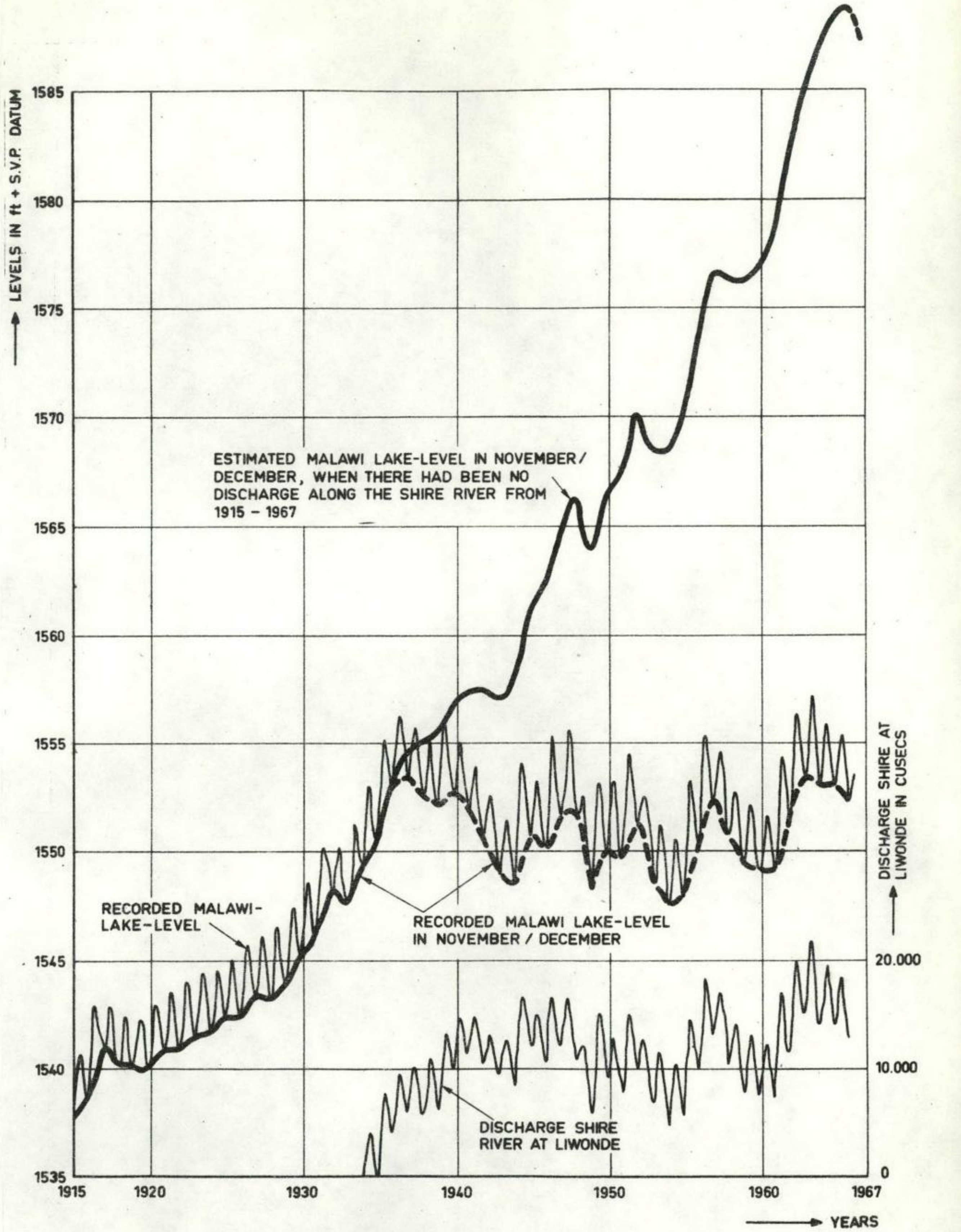
GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT GRAIN SIZE DISTRIBUTION NKASI AND NGONDE (MEASURED IN MARCH 1967)	DESIGNED DRAWN APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	R. 420 S. N. 3297 NO. B 37



	B in ft	c clearance in ft	D in ft
LAKE MALAWI	135	4	13
SHIRE 4.5N - 4.5S and 23S - 28S	110	3.5	12.5
LAKE MALOMBE	135	5	14
SHIRE 28S - 45S	110	4	13

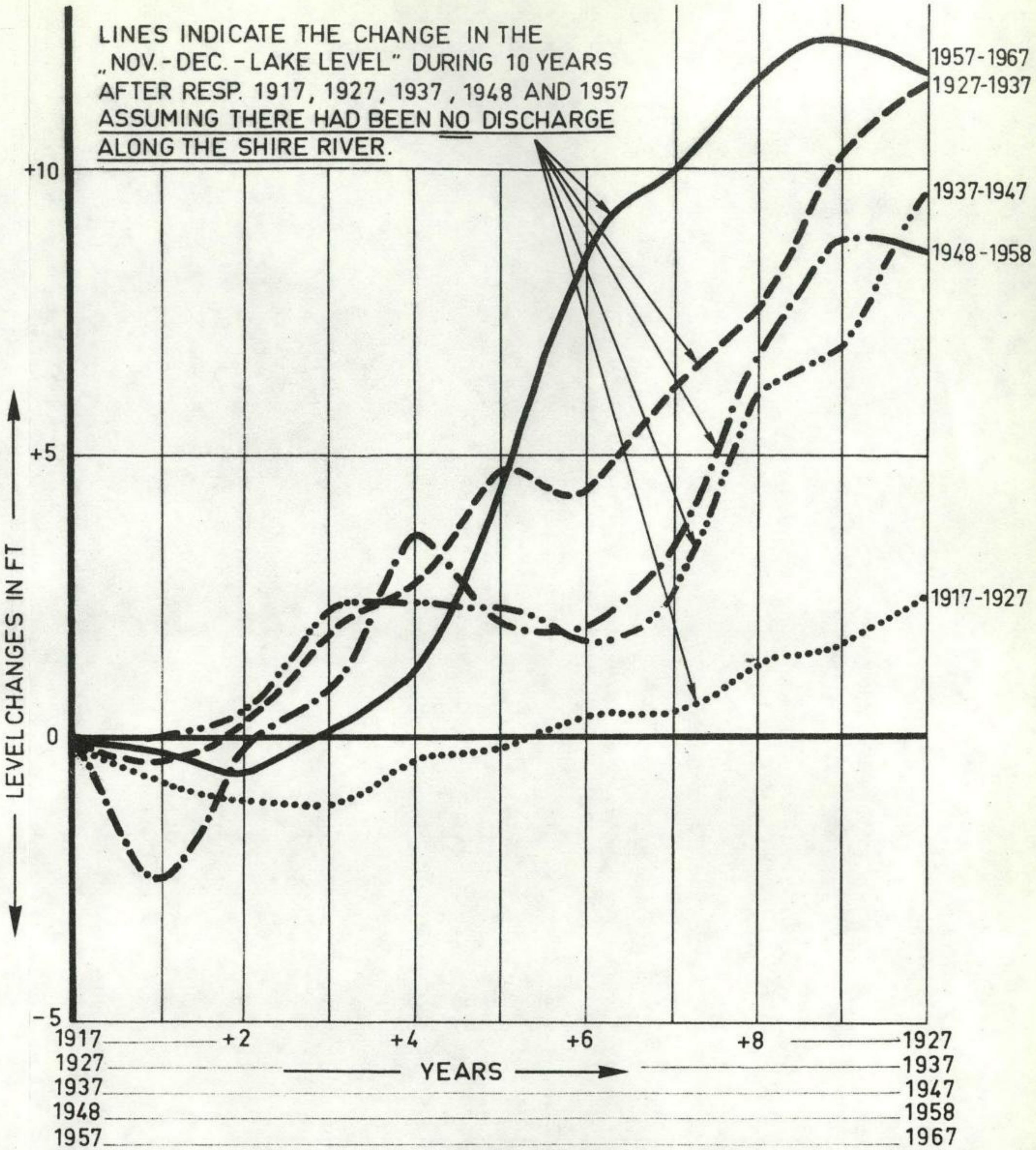
IN BENDS B HAS BEEN ENLARGED WITH 15 - 50 ft, DEPENDING ON LENGTH AND RADIUS OF THE BEND

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT PROPOSED CROSS-SECTION OF NAVIGATION CHANNEL	DESIGNED DRAWN APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	R 420 S.N. 3297 NO. B 38



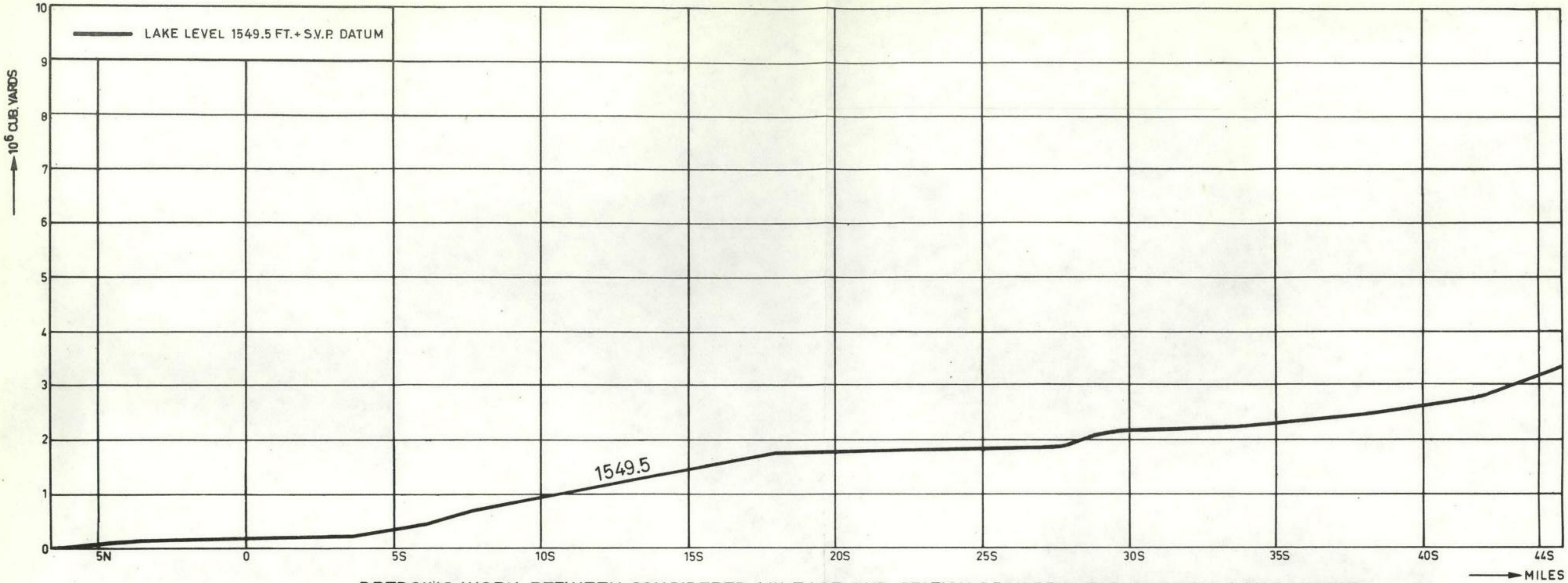
NOTE: RECORDED LAKE LEVELS AND DISCHARGES TAKEN FROM HALCROW REPORT (1954) AND FROM THE WATER DEVELOPMENT DEPARTMENT IN MALAWI

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
MALAWI LAKE LEVEL ANALYSIS	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297 NO. B 39

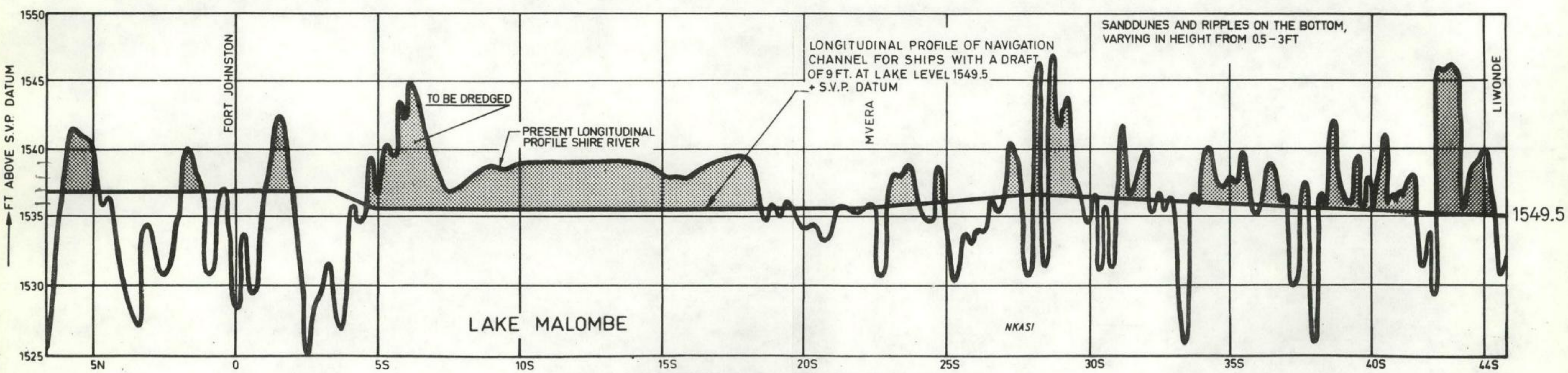


NOTE: CURVES ARE COPIED FROM DRWG. B 39

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT PROGNOSED LAKE LEVEL 1966-1976 (ASSUMING NO RIVER DISCHARGE)	DESIGNED DRAWN APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	S. N. 3297 NO. B 40



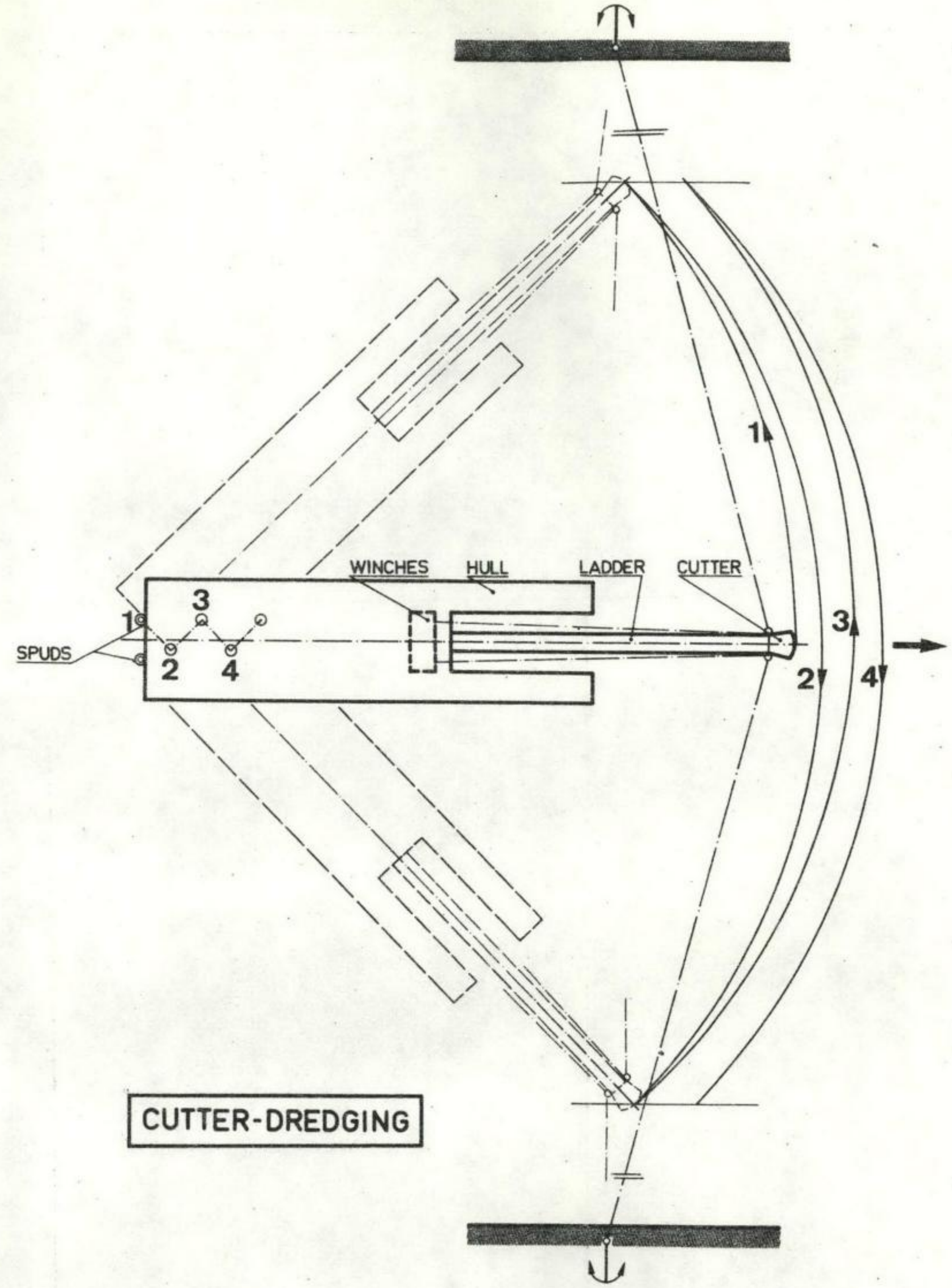
DREDGING WORK BETWEEN CONSIDERED MILEAGE AND STATION 6.5 NORTH FOR VARIOUS LAKE LEVELS



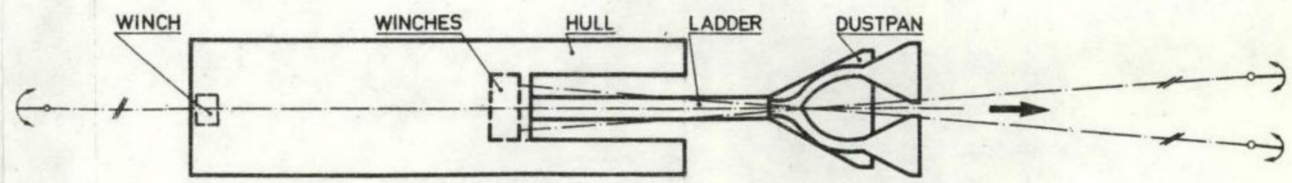
LONGITUDINAL BOTTOMPROFILES

NOTE: FOR SITUATION AND RIVERSTATIONS SEE DRWG. B 3

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT	DESIGNED DRAWN APPROVED
INITIAL DREDGING WORK (AS A FUNCTION OF MILEAGE AND THE LAKE LEVEL)	FEBR. 1968
DELFT HYDRAULICS LABORATORY	R. 420
KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	S. N. 3297 NO. B 41



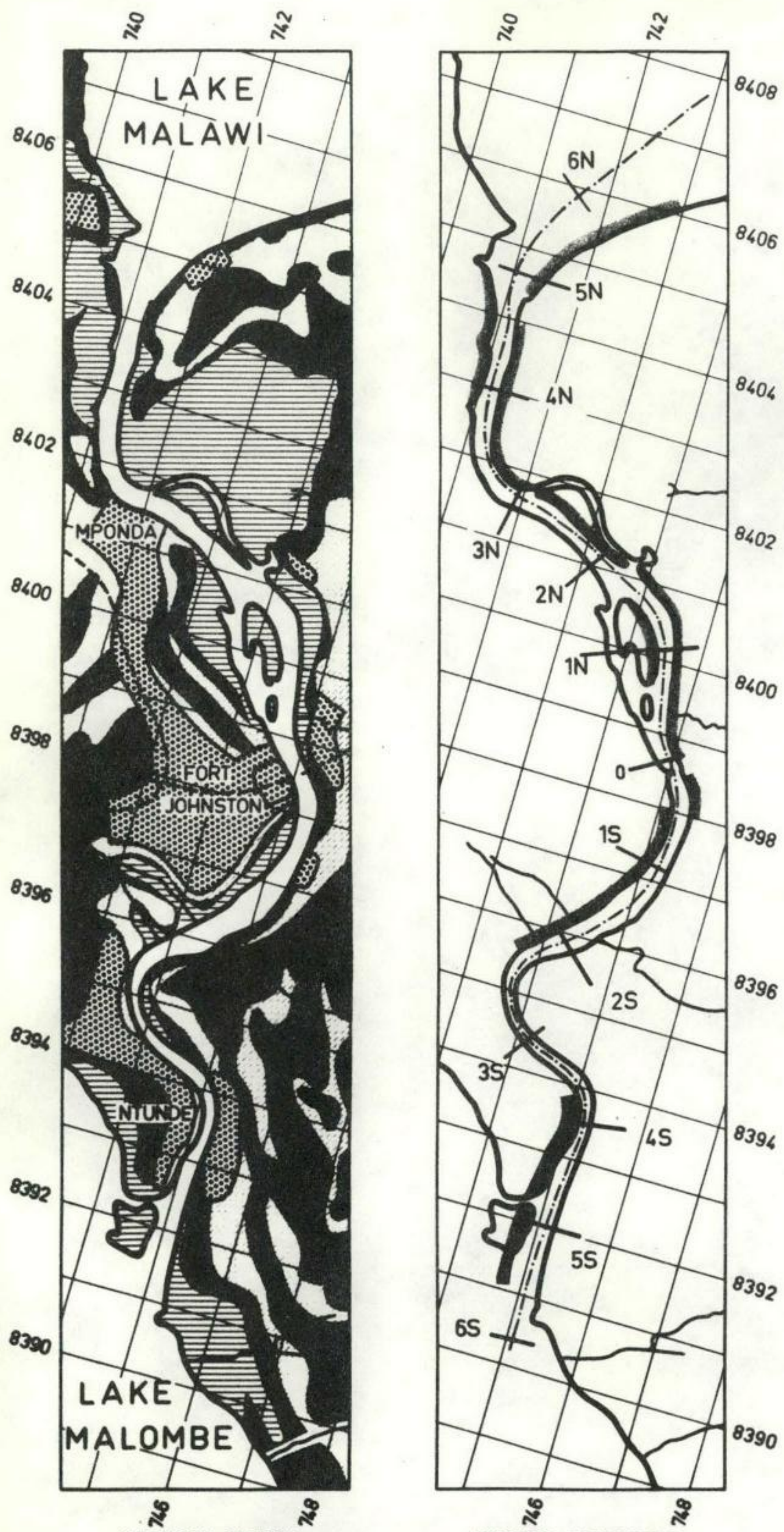
CUTTER-DREDGING



DUSTPAN-DREDGING

GOVERNMENT OF MALAWI

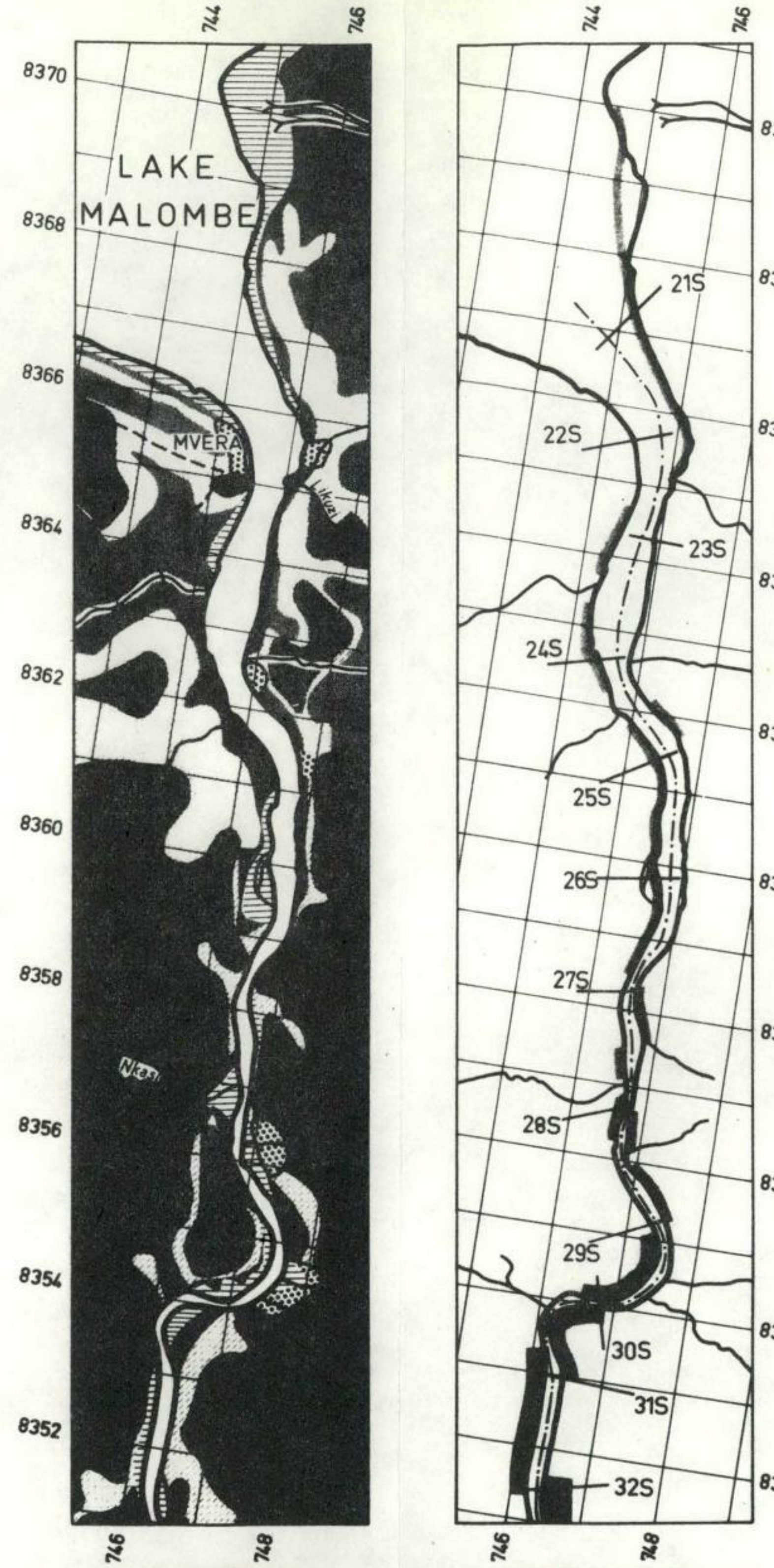
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT PRINCIPLE OF CUTTER-AND DUSTPAN - DREDGING	DESIGNED DRAWN APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS COPENHAGEN	R. 420 S. N. 3297 NO. B 42



SITUATION SKETCH (SEE LEGEND1)

POSSIBLE SPOILAREAS (SEE LEGEND 2)

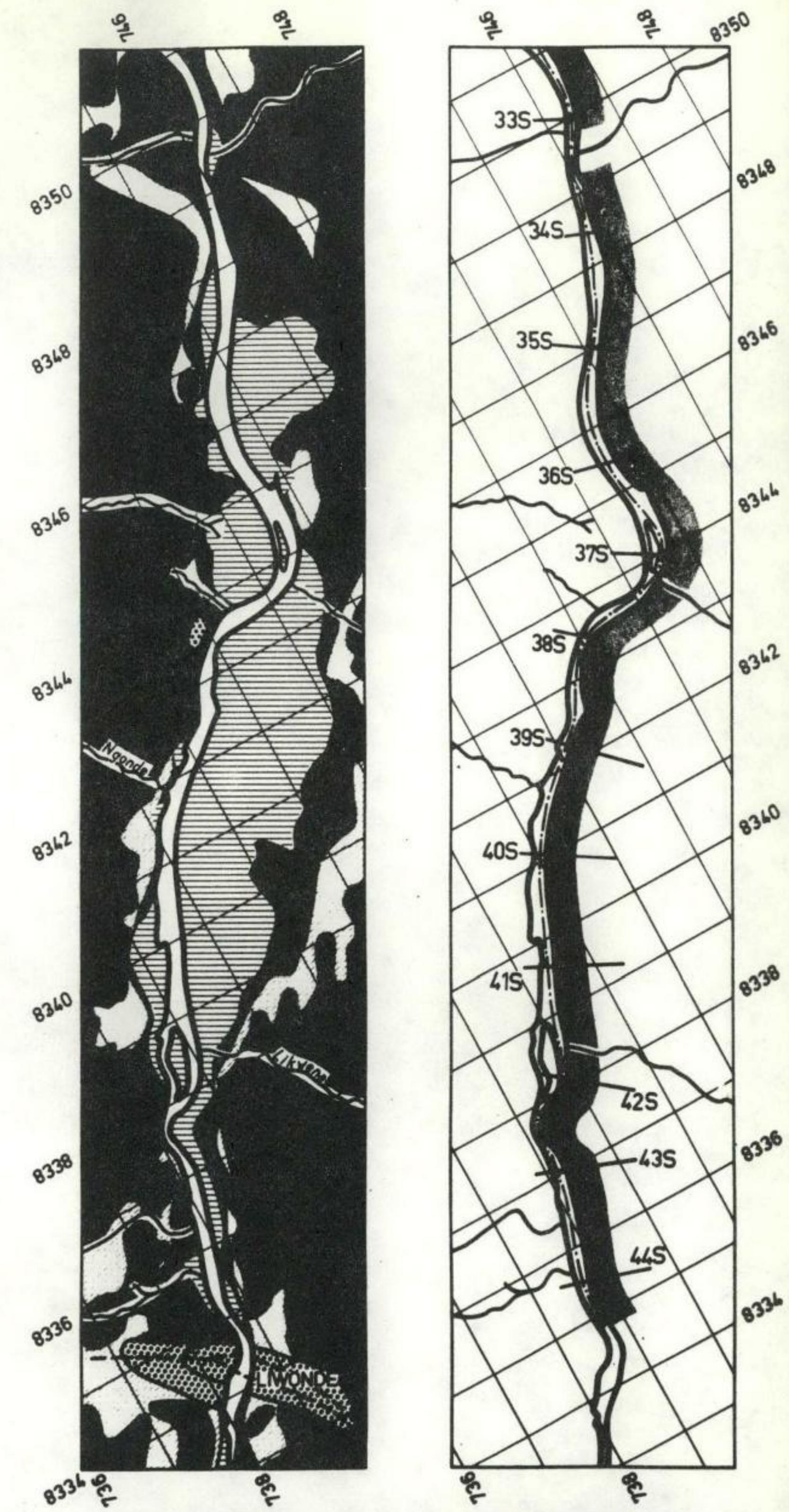
RIVERSECTION 6N - 6S



SITUATION SKETCH (SEE LEGEND1)

POSSIBLE SPOILAREAS (SEE LEGEND 2)

RIVERSECTION 20S - 32S



SITUATION SKETCH (SEE LEGEND1)

POSSIBLE SPOILAREAS (SEE LEGEND 2)

RIVERSECTION 32S - 45S

LEGEND 1

- POPULATED AREAS
- REEDS, MARSH
- GRASS LAND
- WOODLAND
- GRASS LAND WITH SCATTERED TREES

LEGEND 2

- POSSIBLE AREAS TO DUMP SPOIL-WIDTH OF THE AREAS GIVES A CERTAIN INDICATION OF THE AMOUNTS OF SPOIL TO BE DUMPED

0 1 2 3 MILES

0 1 2 3 4 5 km

NOTE:
- GRIDSYSTEM + RIVERSTATIONS SEE DRWG. B 3

SCALE: 1:100 000

GOVERNMENT OF MALAWI	
LAKE MALAWI AND UPPER SHIRE TRANSPORTATION PROJECT SPOIL DUMPING AREAS ALONG THE SHIRE RIVER	DESIGNED DRAWN APPROVED FEBR. 1968
DELFT HYDRAULICS LABORATORY KAMPSAX KAMPMANN, KIERULFF & SAXILD A/S CONSULTING ENGINEERS - COPENHAGEN	R. 420 S. N. 3297 NO. B 43