THE OKAVANGO DELTA

Report on the 1951 - 1953 Field Surveys

by

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PART III

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INTRODUCTION.

1. A description of the remarkable delta of the Okavango River would be lacking if it did not include the passage picturing the grandeur of the swamps, quoted by Captain A.G. Stigand, from Streitwolf's book - Der Caprivizipfel:

"...we reached the Taoge itself...which flowed briskly with its crystal clear water.... High leafy trees wooded the island banks and mirrored their hanging greenery in the water. Lotus lillies and water plants of all sorts covered the unruffled water surface. Countless water-fowl sat motionless in the pools and trees, among the deep green of which often showed forth the dazzling white of the heron. Duck, geese, "snake-neck" birds (cormorants) did not dare to disturb the silence of this secluded region. It is a beautiful world this swamp region! Practically uninhabited, except for a few Makua engaged in catching fish, shut off from the outer world and difficult of access, it has retained its virgin charm. Here dead silence reigns, only now and then broken by the distant snorting of a hippo ploughing its way through a river bed, or by the hoarse cry of a fish eagle circling majestically in the air above. Such is the swamp region of the Okavango. So far no white man has succeeded in crossing it...."

Many years have passed since this was written, but there has been little change; the grandeur and the seclusion of the swamps remain.

GENERAL.

2. The swamps of the Okavango are situated in the Batawana Native Reserve in the north-west of the Bechuanaland Protectorate; see Plate 1. This area, now usually called N'gamiland, is a vast flat country lying at an altitude of 3,000 feet above sea level and is part of the great sandy bush and scrub covered inland Kalahari plateau of Southern Africa. The climate is semi-arid, and average maximum temperatures range from 91.1°F in the hottest part of the year which is also the rain season (October to April) to 82.3°F in the dry winter months (May to September). Average minimum temperatures for the same periods respectively range from 63.1°F to 48.9°F. Average rainfall is about 19 inches.

3. N'gamiland is a remote area, difficult of access, backward in most respects and entirely undeveloped. Its chief centre is at Maun, and it is separated from the developed eastern portion of Bechuanaland by the Kalahari. Travel from railhead at Francistown involves a tedious journey of 306 miles through uninhabited country to the north of the Great
by an unmaintained 315 mile track from Maun to the Ma'abe depression, thence along the south side of the Linyanti and Zambezi rivers to Victoria Falls and Livingstone; but the route is seldom used as it becomes impassable during the rainy season.

THE OKAVANGO.

4. The hydrography of the Okavango river and the various branch channels connected with it will be treated in detail later. At this stage it is intended merely to present a general account of the remarkable and somewhat complicated swamp and river system of the Okavango after its entry into the Bechuanaland Protectorate.

5. The Okavango is a large perennial river. After the Zambezi it is the largest river in Southern Africa and provides an annual flow of a little more than a fifth of the total estimated run-off of the Union of South Africa. But the whole flow of this great river runs to waste within Bechuanaland as, after losing most of its water among the Ngamiland swamps and in Lake Ngami, the balance passes into a river called the Botletle (formerly the Zouga) which runs for a distance of 160 miles in a general east by south direction finally to enter the great Makarikari salt pans which lie a little north of the centre of Bechuanaland.

It may here be mentioned that it is customary in Bechuanaland for rivers and channels to be given new names as they pass from one area to another. In this report the name of a river will be retained throughout its course whenever this simplifies a description.

6. It was by following the Botletle river upstream that Livingstone, Oswell and Murray were led in 1849 to the discovery of Lake Ngami. The same route was followed by later travellers and it will be seen by referring to the map, Plate I, that the earlier travellers who followed the Botletle upstream along its right bank could easily have gained the impression, which was supported by local information, that the Botletle really came from Lake Ngami and that the Thamalakane was a tributary coming from the north. Although this conception was questioned by some of the later visitors to Ngamiland who observed water flowing into, and not from, Lake Ngami, the earlier reports are nevertheless still used as evidence of the former magnitude of Lake Ngami.

Reference has initially been made to what happens at the lower or tail end of the Okavango so that, with this knowledge in mind, it will be easier to devote remaining attention to the delta and swamps which are the main concern of this report.

7. The Okavango rises in the summer rainfall region of the Angola Highlands at an elevation of over 4,000 feet and flows in a general southerly direction into the lower inland Kalahari plateau as far as 18°S. It then deflects eastwards and becomes the border between Angola and South West Africa. A little farther downstream it is joined by the Kwito river which also rises in the Highlands and contributes a flow almost equal to that of
the Okavango at that point. After its junction with the Kwitu, the Okavango continues eastwards until it reaches Andara at 18° S, 21°30' E, on the north border of the Caprivi Strip which is a narrow corridor belt of country lying between Angola and Bechuanaland.

8. From Andara the river turns south-east, crosses the Caprivi Strip and, soon after passing the Popa Falls (about 12 ft. high), it enters Bechuanaland as a single broad river at Moembo. Here the valley of the Okavango widens to a width of 6 to 7 miles which is retained throughout the length of the valley which extends for a distance of about 90 miles in a south-east direction. In this valley the Okavango begins to break up into one or more channels which flood the valley as they meander peacefully to its lower end at approximately 18°50' S and 26°-25' E. Here the general slope of the country lessens; the well defined marginal banks of the valley swing out and merge with the surrounding land, and the river channels spread into a wide expanse of swamps forming the head of a large inland delta.

THE DELTA.

9. The delta of the Okavango is triangular in shape, and covers an overall area of approximately 6,500 square miles. As mentioned above, it starts at the lower end of the 90 mile valley. Thereafter it fans out to the east and to the south of a central axis lying along the same south-east direction as the main valley. The distance from the head of the delta to its base at Maun is 100 miles. The base of the delta lies in a north-east to south-west direction at right angles to the "axis" for a distance of about 140 miles.

10. In the vicinity of Ikwaga, near the lower end of the main valley, the Okavango divides into two major streams known as the Ngogha and the Taoge. The former is the larger branch and flows in an easterly direction into the delta, flooding the countryside. Later it sub-divides into a number of lesser channels that eventually discharge at the base of the delta. The left margin of the swamps of the Ngogha marks the northern limit of the delta.

11. The Taoge branch, after entering the head of the delta, flows southwards for the whole of its course along the western margin of the delta and ends as it reaches Lake Ngami at the extreme south-west corner of the delta. Unlike the Ngogha, the Taoge retains its winding course within the limits of a shallow and narrow valley almost throughout its length, and, although it floods in the upper regions of the delta, it does not split or divide into minor channels until it approaches Lake Ngami. There it breaks up into a number of waterways of rapidly diminishing section which fade away as they enter the sandy northern margin of Lake Ngami.

12. Normally, the Ngogha discharges water perennially at the base of the delta via its lower system of channels; but the Taoge, for reasons which will be explained later, seldom carries water in its lower reaches, and no water in a conceivable quantity has reached as far as Lake Ngami.
with papyrus right from its start and for some distance downstream, where it is joined by an open channel coming across the swamps from the Ngogha. From this point the Taoge becomes an open stream for a short distance as far as the upstream end of the main blockage.

17. When the Okavango comes down in flood, usually during March and April each year, the perennial swamps receive more water than they can hold, and, as the general water level rises, they discharge the excess water in a south-east direction towards the base of the delta.

18. Where there are no defined stream-beds, the rising floods slowly spread over any low-lying ground and advance along a series of shallow waterway channels and depressions called molapos. As the floods rise and more water enters the molapos they fill and overflow into other neighbouring channels and molapos leaving any intervening high ground as islands which often form a remarkable ground-pattern (see Figs. 175 and 176).

19. Most of the flood-channel systems in the lower part of the delta only receive water during the annual flood season. Consequently large volumes of water are needed each year in order to soak the dry sandy soils and fill the numerous channels and molapos, and to meet the losses by subsequent evaporation, seepage and transpiration. It is not surprising, therefore, that so little of the flow of the Okavango reaches the Boteti river. The movement of water in the swamps is slow, and floods at Mohombo usually arrive at Maun some five months later.

20. The delta may be regarded as being divided into three longitudinal parts. The northerly part or section includes the Ngogha and its lower system of channels. These are contained between the northern margin of the delta and a long wide strip of dry land known as Chief's Island which extends from a point near the head of the delta to the area adjoining the Thamalakane at the base of the delta. The second or central section extends down the middle of the delta and follows the south side of Chief's Island along an almost direct line to Maun. The third section includes the Taoge river which follows the western margin of the delta.

21. The Ngogha, through its lower system of channels, provides the only perennial source of water to the Thamalakane, but in the low-flow season the amount of water discharged is very little. Water from the central swamps reaches the end of the delta only during the annual flood season; a portion finds its way into the Thamalakane river and the rest is intercepted and conveyed via the Kunyere river to Lake Ngami.

FEATURES OF THE SWAMPS.

22. The swamps of the delta are not like the usual foetid swamps found in the tropics. The waters are almost crystal-clear everywhere although they appear to be quite black at places among the shallow marginal areas where the underlying soils are dark or covered with decaying vegetation. The swamps are difficult to travel in and even with the aid of air photographs it is easy to become lost.
It might be inferred from the brief description given that the swamps consist of vast masses of water of unpredictable behaviour and completely without control. This is not so. There is a surprising degree of regularity in the incidence of flood waters, which is not apparent to a casual visitor. Local inhabitants, however, are fully aware of the reliable behaviour of floods (excluding variations in volume) and they are generally able to adjust their agricultural activities to suit.

23. Apart from the three parts described above, the swamps may be divided into two zones stretching across the general direction of flow down the delta. The upper zone includes the "...ole of the perennial swamps and can be regarded as being stable to the extent that the only major change that normally occurs is a rise and fall of water level during and after floods. The second or lower zone, is that which receives the annual overflow from the perennial swamps, and extends to the base of the delta. As both the duration and volume of floods vary annually, there is a corresponding advance and recession of flow in this zone.

24. What happens at the points to which flood waters recede each year often has an important bearing on the behaviour of subsequent floods in the lower zone. Here reeds and other aquatic growths, which appear soon after the channels first receive flood water, either die or are cleared by burning when the waters recede and the channels dry out. But at the points where recession ceases sufficient water is available to maintain aquatic growth including papyrus. In years of poor flood the recession is greater, and in many places the previously floating mat of papyrus is allowed to sink to the ground. If the mat should then become firmly rooted to the ground, as it sometimes does, it thereafter presents a low but effective barrier to subsequent flow. The result of this can be far-reaching and is possibly one of the causes whereby the extent of floods at the base of the delta varies from point to point in different years. Another reasonable explanation for this variation is that hippos in their wanderings develop paths which can eventually function as effective drains to lead water from one channel to another.

THE MAKWEGANA OR SELINDA SPILLWAY.

25. This is a waterway connecting the Okavango with the Linyanti river which is tributary of the Zambezi. It leads away from the delta in an east to north-east direction, starting from the margin of the Ngogha swamps at the head of the delta where the left bank of the broad valley of the Okavango swings to the north-east. The existence of this connection with the Linyanti is often taken as evidence in support of the view that the Okavango was at one time a tributary of the Zambezi.

The ground level at the Linyanti end of the spillway was found during the 1925 Kalahari Reconnaissance Survey to be 3,098 feet above mean sea level and Jeffares found in 1937 that water level in the Ngogha at Gaenga Island was 3,176 feet. If a water gradient of 1 in 10,000 (see diagram Plate 17) is allowed for the fall of river above Gaenga, it means that the spillway entrance must be roughly 100 feet above the Linyanti over a distance of about 75 miles.
But, although there appears to be ample fall to the Linyanti, all available evidence indicates that the Makwegana acts as a spillway only during years of exceptional flood such as that in 1944. Air photographs taken at that time showed that the size of the channel in operation towards the Linyanti end was so small that no appreciable flow could have passed into the Linyanti. Action of the spillway is limited by the fact that the Okavango does not maintain a high flood level long enough to sustain the slow rate of advance of water along the spillway.

**Tsetse Fly.**

26. The approximate limits of the areas occupied by Tsetse fly are marked on the general map, Plate 3. It will be seen that, with the exception of country marginal to the delta on the south-east and the west, and the region of the perennial swamps, the whole of the delta is infested. Efforts are being made to eradicate the fly in certain areas, and also to prevent it from spreading across the south-east and middle-west margins of the delta.

It is evident that the possibilities of extensive development in the delta will depend to a large extent upon the successful outcome of measures to deal with the Tsetse menace. If the proposals referred to later in this report, which are designed to control the spread of flood water from the central swamp area, are carried out, it should be possible to reclaim large areas of economically important country.

**Habitation.**

27. Most of the indigenous population in Ngamiland live in villages located at intervals along the fly-free margins of the delta. Nearly all rely on raising cattle for a living; others are river people and engage in fishing.

Food, not always enough for requirements, is generally grown under dry-land conditions in depressions or old river beds, or on ground adjoining the main rivers where better soils are usually to be found. Agricultural practice is primitive, but the people, by reason of their knowledge of the incidence and behaviour of flood water, have evolved crude systems of irrigation in many places.

The people living along the lower permanently dry reaches of the Taoge river and in the areas adjoining Lake Ngami have to depend on dug wells for all domestic and stock requirements.

**Origin of the Delta.**

28. To end the general description of the delta, some indication of how this remarkable region came into being should be of interest. The following account by the late Dr. A.L. du Toit is taken from his report of the Kalahari Reconnaissance of 1925. Writing about the great Mababe depression and the Linyanti river which used to flow into it at its northern end via a branch channel called the Savuti, he says:-

"...A river such as this (the Linyanti) could not,
"of course, excavate well below the levels of the adjacent river systems, and it accordingly becomes necessary to invoke an actual SINKING OF THE CRUST OF THE EARTH in this region to explain the abnormal depth as well as position of this hollow. Once this has to be admitted the probable explanation of the Okavango delta is forthcoming, and further investigation on these lines brings out many facts favouring such an hypothesis. The gigantic series of fractures that affected the Tanganyika and Nyasa and regions, leading to the production of these great troughs known comprehensively as "The Great Rift Valley" of Central Africa, could quite possibly have in milder form extended further towards the south-west. The enormous fault-trough of the Loangwa Valley in Northern, and that of Wankie in Southern Rhodesia, have probably to be connected with the initial efforts of these tremendous earth movements, and it is not unlikely that a repetition of sinking in such or in adjacent belts of country took place in geologically recent times.

The great but very shallow hollow made by the drainage systems of this particular region trends most suggestively in a north-easterly direction, parallel to the important lines of trough-faulting in Rhodesia. It is, instructive to find the solid formation exposed on the opposed margins of this "depression", namely, at the Ngambwe and Mbandwe Falls on the Zambezi and Popa Falls on the Okavango, and again from Mambova to Kachikau and along the south-eastern shore of Ngami.

All these suggest an actual sagging of the crust over an area fully 100 miles broad at the most and with a length of at least 300, though apparently much greater, bounded partly by benzings, and partly by fractures;....

.....Granting a movement of this kind, it can then be deduced that prior thereto the big rivers flowed across the plain of Kalahari sand, each in a well defined single channel, the Okavango straight across to the Botletle and thence through the Makarikari to the Limpopo.....The "delta" not having yet come into existence, the Makarikari could well have been an immense lake, as is so generally assumed. With sinking of the crust athwart this drainage system, the flow of the rivers would have been intercepted and the Makarikari DEPRIVED OF ITS SUPPLY. Each of the three rivers would then have started to develop a delta.... branches would have been formed, to alter their position as sand was brought down from Angola and Barotseland, and spread out over the low ground, just as happens in present day deltas... bodies of open water would have remained down to a late period, whence the Mababe and Ngami hollows, these having so far escaped being completely silted up, perhaps mainly because they lay furthest from the "axis" of the delta which the Ngogha River appears to follow."
SURVEYS.

Extent of previous knowledge:

29. From the time when Livingstone discovered Lake Ngami in 1849 to the end of the last century, the only information available about the Okavango is that found in the writings of a number of travellers.

Captain A.G. Stigand who had been resident in Ngamiland for many years travelled extensively in the swamps and knew the delta better than any other person. In 1923 he published a general account of the swamps and produced a very good map of Ngamiland.

30. This was followed by the valuable "Report on the Kalahari Reconnaissance of 1925" by Dr. A.L. du Toit. This survey was arranged by the Union Government as the result of much public interest and a great controversy waged in the Press in South Africa concerning the views and claims propounded in 1918 by Professor Swartz who claimed, among other things, that by restoring the great lakes of the Kalahari, the combined evaporation therefrom would very soon permanently increase the rainfall over most of the Union of South Africa and the Bechuanaland Protectorate. The investigation was the first to be based on actual ground surveys, and checked levels were run from Livingstone to Maun, thus providing a basis for subsequent surveys. The report dealt with facts, figures and deductions relating principally to the base of the delta from the Mababe to Lake Ngami along the Thamalakane. The Okavango itself and the swamps of the delta were not investigated.

31. In 1937 Mr. J.L.S. Jeffares was engaged by the Bechuanaland Administration to undertake a limited survey in the swamps to ascertain what fall existed through the length of the delta, and to obtain data concerning the flow of the Okavango and some of the channels in the swamps. The report on the surveys was not published.

From 1937 to 1950 the Bechuanaland Administration was unable to finance any further investigation, and the present surveys were eventually made possible by a generous grant-in-aid under the Colonial Development and Welfare Act.

The extent and location of surveys undertaken in Ngamiland up to the end of 1953 are indicated on the Key map, Plate 2.

THE NEED FOR SURVEYS.

32. Although nothing was done for so long to add to information and data acquired up to 1937 the need for further information had always been recognised. Not only was it necessary to deal with some of the pressing local problems caused by lack of water away from the swamps for domestic, animal and agricultural needs, but it was also necessary to have information which could be used to lessen the number of ill-informed schemes that were advocated from time to time in the Press.
Visitors to Ngamiland are invariably impressed by the pleasant nature of the open grassed mopos and clear running streams which can be readily seen in the vicinity of Maun or by flight over the swamps. They can also see the large volume of water in the Okavango at Shakawe and at Mohembo. But, except for a very limited view of only part of the Lake Ngami area, a traveller going by road from Maun to Mohembo sees nothing of the delta.

33. The findings of the 1925 survey enabled the controversial proposals of Professor Swartz to be cleared up. It furnished information regarding the possibilities of irrigation in the Mababe and Ngami, which were important factors to be taken into account in deciding whether ground of that value should be given over to flooding in order to provide benefits in which Bechuanaland could have little or no share. Further, it presented and discussed in outline proposals for large-scale irrigation in the Kalahari at Rakops, and alternative schemes for development in Lake Ngami.

34. The present surveys and investigations have succeeded in providing much hitherto unknown basic information regarding ground and water levels to an extent sufficient to permit future development to be planned. In addition, detailed recommendations are made later in the report concerning a proposed plan of development covering certain projects that formed part of the following terms of reference of the surveys:

(i) to discover the nature, behaviour and flow of the Okavango River itself and of the main channels of its delta;

(ii) to ascertain the feasibility and cost of projects of a modest nature aimed at:

(a) increasing the flow of the Botlhole River,
(b) leading water from the Okavango system into the Mababe,
(c) reclaiming areas of swamps which could be used for cultivation;

(iii) to provide machinery of a special type for removing papyrus blockages on the important channels of the Okavango delta.

PLANS AND METHODS OF THE SURVEYS.

35. It was realised from the start that investigations would have to be based on measurements. It was apparent, also, that traverses would have to be check-levelled throughout, and that levels would have to be carried all the way from Maun to Mohembo, apart from any other traverses into the swamps or elsewhere. This was not an easy undertaking, especially as it would have to be completed, apart from any other work or investigations, in three dry-weather working seasons from April to October. The aim was only achieved by working right through the rainy season of 1953 under almost impossible conditions.
36. The total distance levelled during the surveys was 625 miles. As far as possible, levels were carried along important channels - the Taoge in particular - to determine their grades. To do this as effectively as possible the behaviour of the floods in the swamps had to be carefully studied so that field work could be undertaken at times when flood water had fully receded. To save time, surveys into the swamps were planned to relate work solely to the problem under investigation and to omit traverses which would afford general information only. For example, the need for a cross section into the swamps from the Taoge was combined with the need to investigate the feasibility of developing a waterway to Maun from an area selected for large-scale agricultural development.

37. During the first field season work was somewhat slow and difficult because available maps showed very little of the known and accessible areas, and were blank in respect of areas within the swamps. This lack of information involved much additional reconnaissance work. However, excellent air survey photographs became available during the following season and every aspect of work thereafter was made relatively easier.

38. The necessity of producing a map to accompany this report presented a real difficulty as the topographic air-survey maps being prepared by the Directorate of Colonial Surveys would not be on an appropriate scale, and could not in any case be ready for a year or so. Accordingly it has been necessary to limit the information shown on Plate 3 to the areas actually investigated.

It was unfortunate that the air survey photography in 1951 was not carried out at the desired time of the year. It would then have shown the actual courses taken by flood-water to the base of the delta and a "full" Late Ngami under the high flood of 1951. It would have been impossible to attempt to discover by ordinary ground-survey methods which channels or paths advancing flood-water would take.

AIR PHOTOGRAPH RECORDS.

39. When the matter of preparing plans of the traverses was being considered it was felt that the limited topographical detail which they would normally contain would convey little information and, as was found when attempts were made to use plans produced during previous surveys, they would be extremely difficult to follow in the field afterwards. The alternative procedure of plotting the traverses on contact prints of air photographs, thereby affording full and accurate topographical information, was, therefore, adopted. The important point of this procedure is that it will enable the traverse routes to be followed in the field without difficulty at any future time. The positions of all bench mark beacons have been accurately pin-hole pointed on photographs.

CONTROL.

40. Throughout the investigations the location of
position and control of traverse were fixed by Astronomical observations. Meridian and circummeridian altitudes of north and south stars at transit were used to determine Latitude; and altitudes of east and west stars for Time and Longitude. Greenwich time was obtained by wireless.

PART II.

HYDROGRAPHY:

41. Before submitting recommendations concerning any particular scheme or discussing the possibilities of development of either short or long-term projects, it is necessary to examine the hydrography of the various channels of the Okavango system.

THE OKAVANGO.

42. The charts on Plate 16 have been compiled from all available information. They show that the Okavango reaches its maximum flood with remarkable regularity towards the end of March or early April each year. Thereafter the drop in water level continues steadily, and lowest flow normally occurs in September to October, just before the beginning of the local rainy season.

43. The lowest flood recorded was in 1946 and the highest in 1944, which was, however, less than that of 1925 judging by evidence of levels taken at Maun that year (Kalahari Reconnaissance Report). The flood in 1947, following the low 1946 year, apparently reached a good peak after which there is a gap in the records; but the swamps received so little water in 1946 that Thamalakane at the other end of the delta became completely dry.

44. No river level records at Mohembo are given for 1948 as the Police Camp there was abandoned and re-established later at Shakawe, about 10 miles below Mohembo. A new series of records was started at Shakawe in 1949 and these are also shown on Plate 16. Unfortunately, it was not possible to correlate the gauge posts at Mohembo and Shakawe as the post at Mohembo was damaged in 1950 and was not replaced.

45. The flow of the Okavango had been the subject of speculation and guesswork for many years. In 1925 Dr. du Toit attempted calculation based on losses from seepage, evaporation and transpiration in the total area of swamps indicated on Stigand's maps, and he arrived at an estimate ranging between 16,000 and 21,000 cubic.
the 1937 survey. His gauging at Mohembo recorded flows
of 13,000 cusecs in July and 6,500 cusecs during low
flow in October. He repeated the measurements in the
same months at Begane in the Caprivi Strip and observed
similar flows: 13,200 and 6,700 cusecs. In
1950 Davies measured 6,500 cusecs in July at both
Mohembo and Shakawe.

46. The site selected for a permanent gauging station
at Shakawe is marked on the air photograph Fig. 169.
Figs. 1 and 2 show views of the imposing river at
Shakawe above and below the gauging station. A wire
cable has been laid across the river to mark the exact
gauging site and a permanent anchorage has been erected
on the sandy left bank of the river to facilitate future
gauging work.

It was not possible to get to Shakawe in 1951
and measurement of the high and sustained flood of that
year was missed. Current meter gaugings were taken
during high flood in April 1952 and 1953 when the flows
amounted to 12,386 and 15,843 cusecs respectively. Low
flows in October 1952 measured 4,572 cusecs.

47. The gauging site at Shakawe is not an ideal one
in some respects; very high floods would top the sandy
left bank, and at periods of normal flow the area beyond
the left bank within the valley of the river is flooded
among reeds and papyrus. Flow in this swamped section
has not been taken into account in the gaugings.
However, the site is the best that can be found within
the Protectorate and, as it is important that steps
should be taken to obtain accurate records of flow of the
Okavango, it is suggested that a water level recorder
should be installed at Shakawe.

Rating curves were plotted from the results of
the recent gaugings taken at Mohembo and at Shakawe and,
although adjustments will be required as further information
of flow at high flood stages becomes available, it has
been possible to convert existing records to give a fair
estimate of the annual discharge of the main channel of
the river. The figures are: 6,800,000 acre
feet at Mohembo and 6,200,000 acre feet at Shakawe.
The average of these figures is equivalent to a mean
annual flow of about 9,000 cusecs.

At the time that the photographs of Figs. 1
and 2 were taken the river at Shakawe was 425 feet wide
and 13 feet deep. The ground along the right bank of
the river is high, well wooded, and rock outcrops at
places.

48. After passing Shakawe the Okavango adheres to
the right hand margin of its valley for about 13 miles
and then meanders across to the opposite side where the
valley banks rise to 60 feet or more above the river.
The main channel keeps slightly to the right of the
valley centre for a time and then veers to the right bank
at Sepopa, 96 river miles below Shakawe. The corresponding
distance by road from Shakawe to Sepopa is 37 miles.
49. The Okavango, by that name, ends at a place called Ikwaga, 17 river miles downstream from Sepopa, where the Okavango divides into two main branches, the Ngogha and Taoge. There is no noticeable change along the Ngogha at the point of divide, but the beginning of the Taoge is hard to distinguish as it takes off at a sharp renentrant bend and the channel is completely blocked with papyrus.

50. Throughout its course along the wide 30 mile long valley, the Okavango (see Figs. 3, 7 and 8) flows majestically between dense papyrus margins rising 12 to 24 feet above water level. To a traveller the repeating scene of sky, water and papyrus becomes very monotonous. Along most of the river it is difficult to determine where the real banks of the channel lie as the depth to bottom at the edges of the papyrus is often almost as deep as in the channel itself.

The monotony of scene is occasionally relieved when an island or bank of mainland is reached — see Fig. 4. Because the high papyrus flanks restrict the view, it is not an easy matter to observe the nature, variation and extent of surrounding conditions, and occasional narrow open waterways leading off the main channels afford the only facilities for explorations.

GRADIENTS AND RIVER DEPTHS.

51. By running branch traverses and keeping as near river and swamps as circumstances allowed, efforts were made during the surveys, often under trying conditions, to obtain information to determine the grades of rivers. In addition the nature of the channels was examined by taking soundings along as much of the length of the main rivers as possible.

The diagram on Plate 17 shows that the water level gradient of the Okavango from Shakawe to Ikwaga in May 1952 was 1 in 20,500 or a little over 6 inches per mile. It also shows that, except at one point about 4 miles below Shakawe, the depth of water in May was nowhere less than 16 feet, and that in many reaches it increases to 15 and 20 feet.

A part of the diagram on Plate 17 has been based on the assumption that the gradient along the Ngogha is roughly 1 in 10,000 and it is interesting to note that this check remarkably with the water level determined at Agenga Island during the 1937 survey.

THE NGOGHA RIVER.

52. It was mentioned at paragraph 49 that the Ngogha is, to all appearances, a continuation of the Okavango where the latter divides into the Ngogha and Taoge in the vicinity of Ikwaga. From this point the Ngogha twists and winds its way in a broad arc across the width of the lower end of the main Okavango valley to a place called Seronga (Figs. 11 and 12) on the left bank of the valley.
After this the general river direction turns towards the south-east and the Ngogha continues its tortuous course into the delta in a region of perennial swamps. As on the Okavango, the Ngogha channel is bordered throughout its length with tall papyrus, and to a traveller the absence of visual landmarks combined with the repeated twists and winds of the river, have the peculiar effect of making the sun appear to wander aimlessly in the sky.

53. Contrary to expectations, the Ngogha is a strongly flowing stream. Its depth in most sections exceeds 19 feet and its width where it begins is about 85 feet, but this soon widens to about 120 feet which is maintained all the way to Seronga with only occasional narrowings. Surface velocity near the Taoge take-off was 2.65 feet per second in April 1952.

54. At a point 6 miles by river below Seronga an open channel leaves the Ngogha on its right bank. This channel, which has sometimes been mistaken for the Taoge, flows in a southerly direction away from the Ngogha valley and joins the Taoge. It will be referred to in more detail later. (paragraph 121).

55. The Ngogha was gauged by current meter upstream of the above mentioned take-off channel during high flow in April 1952; the discharge was found to be 7,660 cusecs. Another gauging was taken at the same place during low flow in October that year and the discharge had dropped to 3,550 cusecs. The greatest velocity measured were 3.21 feet per second in April and the rather surprising high figure of 2.39 feet per second in October.

56. The Ngogha, after entering the head of the delta in a general southerly direction, changes its course rather abruptly towards the east in the neighbourhood of Mombo which is the name given to the low-lying land masses cut by a number of flood channels at the upper end of Chief's Island. Chief's Island, which is about 60 miles long and 8 miles wide on the average, forms the backbone of the delta along an approximate south-east direction. It extends almost to the base of the delta and forms the southern margin of the wide swamp valley of the Ngogha.

57. Small channels lead out from the main channel of the Ngogha here and there to feed the vast surrounding swamps. The main river, however, maintains a fast flow but begins to lose width gradually. Fig. 15 shows a typical spill-out channel and Figs. 13, 14 and 16 picture the nature of the gradually tapering river. After about 12 miles downstream from Seronga there are very few islands along the Ngogha other than an occasional one such as Gaenga Island which was the farthest upstream point reached by the 1937 surveys. Fig. 17 is of interest as it relates to a seriously made suggestion that a box of matches is all that is needed to clear papyrus; it shows a wide area of papyrus that had recently received the burning treatment and it also shows that regrowth
had already started.

58. The Ngogha was examined along the whole of its open length of channel which extend for 104 miles from Ribwega to the top end of its blockage. Soundings were taken at regular intervals and the depths measured are shown in the diagram on Plate 17. Depths were found to be remarkably consistent, being seldom less than 12 feet, at a time (October) of low flow; they show that there are no sand-bar obstructions which are often thought to be a cause of swamping.

**THE NGOGHA BLOCKAGE.**

59. The approximate position of the top end of the Ngogha blockage in 1952 is shown on Plate 3 as being where the line of meridian 23° E. cuts the river. Downstream from this point the Ngogha is completely blocked by papyrus for many miles. The creation of the blockage has been attributed to a number of causes which will be discussed in detail later when the similar blockage on the Taoge river is described (paragraphs 122 and 123).

The nature of the blockage is shown in the photographs Figs. 19 and 20: it consists of an accumulating mass of tangled papyrus stalks and roots, and Fig. 18 shows some of these on the way to join the pile-up at the blockage. This is a continuing process and explains a reason for the gradual upstream creep of the blockage.

Trees, broken or abandoned native dug-out canoes (mokoros), and anything that floats down the river become lodged in the blockage. At the time of the visit, a boat without oars but in good condition was "rescued" from the tangle; it had been lost at Shakawe nine months previously. Attention is invited to the growth of the creeper water-grass (Echinochloa Pyramidalis) shown on the left in Fig. 20.

60. A gradual diminution of current was observed as the blockage was approached, and escaping flow from the main river channel into the surrounding papyrus was quite noticeable; nevertheless, despite the fact that the river was at low stage at that time, flow was entering the blockage with a surface velocity of 1.35 feet per second. A gauging taken immediately above the blockage showed that a flow of 263 cubic feet was entering it.

**OTHER CHANNELS OF THE NGOGHA SYSTEM.**

61. The map (Plate 3) shows a river called the Kwee, which is taken off from the Ngogha between Gaenga Island and the blockage. The entrance to the Kwee is overgrown and cannot be easily seen from the Ngogha. However, it gradually develops into an open stream. When viewed from the air, it can be mistaken for the Ngogha which is obscured by its complete blockage. Both rivers lie in the wide perennially swamped region between Chief's Island and the northern mainland margin of the delta.
After becoming an open channel, the Moanachira wanders a great deal and feeds into a number of large lagoons. Farther downstream it divides at the point of a large triangular shaped dry land mass which extends into the delta from the west of the Mababe river. Part of the Moanachira flow continues eastwards on the north side of the land mass but tapers rapidly as it passes into a channel called the Mochaba which changes name and becomes the Kudume. There it finally connects with the Mababe river near the south end of the great Mababe Depression.

62. The main flow of the Moanachira goes south and south-east to rejoin the Ngogha in the swamps below the Ngogha Blockage. Here the Ngogha loses its name and a new series of channels develop.

THE LOWER NGOGHA SYSTEM.

63. The new channels that emerge from the swamps of the reunited Moanachira-Ngogha are the Borokha and then, in order of position from north to south, the Mokhoheklo, the Gomoti and the Santantadiwa. The Borokha is the chief channel but is really the upper part of the Gomoti and ceases to be called the Borokha after a short distance.

The area in which these rivers advance as they approach the base of the delta is still bounded on the south by Chief's Island; on the north the limit is defined by the triangular area of dry land previously mentioned.

The country at the lower end of the system is remarkable; not only does it flatten out and reduce the grades of the channels as they approach and finally enter the Thamalakane drainage at the base of the delta, but it also begins to fall away in two opposite directions at a point known as the "Critical Point". The result of this is that discharge into the Thamalakane from the lower Ngogha system can flow either north-east towards the Mababe Depression or south-west to Maun.

Another change takes place in this area; the lower end of Chief's Island merges into the flat surrounding country and becomes indistinguishable. These peculiar features are undoubtedly the results of the warping which took place when the delta was formed.

THE MOKHOKHEL. 64. This river emerges on the north side of the Critical Point but very rarely attains a flow into the drainage leading to the Mababe. In its upper reaches it shares the water feeding the neighbouring river, the Gomoti. Owing to the blockage in the Gomoti, a greater flow than usual now appears to be diverted into the Mokhoheklo, see Fig. 100; but in 1952 and 1953, following the high flood of 1951, the farthest point reached by water was half a mile short of the road to the Mababe, see Figs. 102 and 104.

THE GOMOTI/............
THE GOMOTI.

65. On Stigand's evidence the Gomoti was a perennial river which regularly contributed the greatest flow of the various channels discharging into the Thamalakane. But this is not so today. In 1937 Jeffares followed the nearby Santantadibe river but made no reference to the hydrography of the Gomoti.

During the investigations of this report it was found that, although the Gomoti appeared to be flowing into the Thamalakane, the water was in fact part of the discharge from the lower end of the Santantadibe. Only a mile or two above its mouth the Gomoti channel was quite dry and that state continued for a distance of no less than 18 miles upstream from the Thamalakane. It is not possible to say how long these conditions have existed; but it was confirmed locally that the same section had been dry since at least 1948.

66. The drying up of the lower reaches of the Gomoti can only be attributed to the increasing growth of blockages farther upstream. It has been known for a long time that, in addition to papyrus, the Gomoti was being gradually invaded and choked by the growth of Ficus verruculosa known locally as the Gomoti Tree which is peculiarly limited to the Gomoti region. Figs. 98 and 99 show Ficus verruculosa growing in the Gomoti near the tail end of its water, and Fig. 97 shows how the papyrus has become rooted to earth across the channel, thereby creating another substantial obstruction to flow. The assumption that the Gomoti is blocked further upstream is fully borne out by air photographs.

The sandy nature of the dry Gomoti channel which is very well defined can be seen in Figs. 95 and 96. The whole 18 mile course investigated is clear of obstructions. Palm trees (native name Mokolaises) which seem to thrive and grow freely, form a regular feature of the Gomoti-Santantadibe region landscape, see Figs. 89 to 93.

LEVELS.

67. Traverses were run (a) to determine the river bed gradient along the Gomoti and its relation to water level in the neighbouring Santantadibe river, and (b) to examine the feasibility of controlling or diverting the Santantadibe so as to reclaim ground from the areas flooded by that river.

The route taken by the traverses is marked on the maps, Plates 2 and 3. The branch traverse from the Gomoti to the Santantadibe followed a distinct line of Mopane timbered ridge between the two river systems. Figs. 88 and 92 are views of the Santantadibe at the terminal point of the traverse.

The information obtained is given on Plate 4.

Points of interest are:

(1)/......
(1) there is a drop of nearly 8 feet from water level in the Santantadibe to the dry bed of a large molapo waterway only one and half miles away in which water from the Santantadibe was slowly advancing. A slight cut or lowering of the ground level at the divide where water was taking out from the Santantadibe would allow diversion of water for economic use in large areas connecting with the molapo;

(11) there is a fall of over 22 feet in a distance of 17 miles between the Santantadibe and the Gomoti; so that, if the Santantadibe were dammed with right abitment on Chief's Island and connection made with the high ground at the ridge surveyed, water now flowing in the Santantadibe would be forced to find its way into the Gomoti;

(111) there is a good gradient along the Gomoti in the reaches surveyed, and the channel is free from sandbar obstructions.

THE SANTANTADIBE.

68. Reference was made to the Santantadibe when describing the Gomoti because they are adjacent and are fed from the same source. The Santantadibe is the most southerly of the rivers of the lower Ngogha system; in its upper reaches its course is controlled by Chief's Island. Lower down, where Chief's Island ends, the Santantadibe proceeds towards the Thamalakane along a series of permanently swamped molapos. It enters the Thamalakane in a defined channel but some of its lower molapos flow in what appears to be an upstream direction to join the Gomoti just before that river enters the Thamalakane. Viewed from the Thamalakane, the Gomoti appears to be a flowing river and there is nothing to indicate that it is a dry river a little upstream. This may well be the reason why no report was ever made about the desiccation of the stream that used to supply the bulk of flow in the Thamalakane.

The nature of the Santantadibe swamps and the ground pattern formed by the molapos and intervening islands may be seen in the air photograph, Fig. 176.

69. Water in the Santantadibe and its swamps is perennial. Now that the Gomoti is dry in its lower reaches, the Santantadibe affords the only permanent source of supply to the Thamalakane which it enters approximately 15 miles above Maun. But the supply from the Santantadibe is very small, even during floods, and drops almost to nothing during the low flow season which occurs at the base of the delta from November to the following May. The Thamalakane at Maun was dry in May 1951, see Fig. 45. Conditions in the Santantadibe seem to have deteriorated considerably since 1937 when Jeffares measured a flow of 70 cusecs in October and 50
cusecs in the following February during the rainy season.

THE BORO SYSTEM AND CENTRAL SWAMP AREAS.

76. Adjacent to the Santantadibe on the south are the flood channels of the Boro. They are similar in pattern and arrangement to the Santantadibe swamps; see Fig. 175, but differ in one important respect, namely that they are not perennial and discharge into the Thamalakane only during the annual flood season—June to September. Peak discharge occurs during July and September. Peak discharge occurs during July and August, and in a good year water may continue to flow as late as October or longer. The annual drying up of the channels and molapos reduce the growth of weeds and other aquatic obstructions to flow; consequently there is little to hinder the advance of floods in the following year.

Although the Boro is usually dry in June and in November each year, it now supplies by far the greatest volume of the annual flow of the Thamalakane. The main channel, see Fig. 85, enters 8 miles above Maun and a little to the north of the Matlapaneng road bridge.

71. Jeffares measured the flow of the Boro in 1937 as being 330 cusecs and 77 cusecs in July and October respectively. Davies records a flow of 208 cusecs in August 1951. In early September 1951 it was 264 cusecs and in August 1952 it was not possible to gauge the Boro properly near its mouth because the channel had become almost completely overgrown with Eichhornia pyramidalis; but 80 cusecs were flowing in the remaining open channel, see Fig. 86.

A small overflow channel of the Boro called the "Little Boro" joins the Thamalakane just below Matlapaneng bridge. The discharge of this feeder in August 1951 was 17 cusecs and in the same month the following year it was 62 cusecs.

72. Another channel, the Shashi, brings water into the Thamalakane 3 miles south of Maun. It is fed by water which overflows to the south-west from the Boro where the latter approaches the "lip" or fault line near the base of the delta. Fig. 174 will help to explain the position. Further information concerning the Shashi is given at paragraphs 76 and 80 when levels are discussed. Normally the flow of the Shashi is not large; in July 1951 it was discharging 65 cusecs and in August 1952 the flow was 38 cusecs.

The last and most southerly of the flood channels connecting the swamps with the Thamalakane is the Gabaracha. It enters a little above the outlet to the Botletle, but it is not a normal source of supply and has not been known to flow for many years.

73. None of the discharges entering the Thamalakane is large, and now that flow from the Gomoti has been entirely lost, the need for a better and permanent supply of water at Maun is becoming a matter of serious concern.
In the circumstances it is evident that, unless something is done, the flow of the Thamalakane will be gradually reduced almost solely to that which it may receive from the Boro during annual floods.

CENTRAL AREA SWAMPS.

74. The source of the Boro is in the upper perennial flood region of the delta between the Ngogha and the Taoge. No definite stream or channel exists in that area although here and there an open run of water begins to develop, but none of them persists for long. Consequently, when the perennially swamped region overflows during floods, water in that area moves down the delta along a broad irregular front, filling molapo after molapo in succession.

A little below the Mombo region the advancing flood waters are gradually contained within a wide area bounded on one side by the southern margin of Chief's Island and on the other by a large area of dry land which extends to the base of the delta, dividing the central swamps from the middle and lower reaches of the Taoge.

75. Part of the central area floods pass straight down the delta in a south-east direction into the Boro. A little later, at a point about 12 miles north of Maun, the Boro reaches the slight "lip" along the fault line previously described (paragraph 72). Here flow is impeded until the water level, in a collection of large pools, is raised sufficiently to allow water to pass into the final series of channels and molapos connecting with the Thamalakane. Some of the water from the pools escapes to the south-west along the line of the lip before entering the Shashi flood-channel leading to the Thamalakane below Maun. See air photograph Fig. 174.

76. Another channel flowing almost parallel with the Boro and a little south of it also develops in the lower parts of the central area swamps. This channel is known as the Kwapa and it reaches the "lip" at the point where the Shashi passes through to the Thamalakane. The Shashi is, in fact, a continuation of the Kwapa, but it as flow from that river escapes towards the Matseebe-Kunyere system higher up.

THE MATSEEBE KUNYERE SYSTEM:

77. Only a portion of the annual flood flow from the upper central area swamps passes to the Boro and Kwapa, the rest, and by far the greater portion goes into the Matseebe which starts as a series of channels that lead into the dry land area flanking the central swamps on the south. These channels, while flowing towards the base of the delta, are gradually deflected southwards by the gentle warp of the country, and when they reach the lip of the fault lying parallel with the Thamalakane, they are abruptly deflected into the drainage of the Kunyere. See paragraph 13.

Besides/......
78. Besides the Matsebe and the Kunyere, the channels comprising the system near the base of the delta are: the Marope, the Naragha or upper reaches of the Kunyere and the Kudum. With exception of the Naragha, all the channels enter the Kunyere in much the same fashion as the Gomoti, Santantadibe and Boro, farther up the delta base enter the Thamalakane.

79. The drainage lines of the Lake River and the Kunyere gradually converge and eventually join at a place called Toten, 42 miles south-west from Mau. The annual floods from the Kunyere usually reach Toten late in June or early July and flow normally continues until the end of September in average flood seasons. The combined flows of the channels feeding into the Kunyere was gauged at Toten – see Fig. 82.

In early August of 1951 (the big flood year) the flow of the Kunyere was as much as 1,148 cusecs. Early in July 1952 it was only 103 cusecs and in September 1953 it was 281 cusecs. Jeffares measured as little as 36 cusecs at the end of September 1937, and du Toit estimated the maximum flow to be 800 cusecs in September 1925.

LEVELS.

80. The gradient available along the Shashi channel is important as it will be required to discharge a greatly increased flow if the proposals of this report to increase flow into the Thamalakane and Botletle is carried out.

The information given in plate L shows that the Shashi (ignoring the dip or hollow where it receives water coming from the Boro) has a fall of .45 feet in 16 miles. The bed is very winding but could be readily improved. The fact that the Shashi now delivers only a small volume of water during floods is purely the result of the limited flow it receives from the Boro and Kwapa.

Levels of the bed of the Naragha and Kunyere show that the grade continues eveny, without sandbar obstructions, all the way to Toten where the Kunyere ends as it joins the Lake River just above the entrance to Lake Ngami. There is a fall along the Kunyere of 28 feet in a distance of 41.5 miles.

CENTRAL AREA: FLOOD DIVERSION.

81. As the whole flow of the Kunyere derives from the swamps of the Central area, its discharge can be regarded as taking place at the expense of the Thamalakane. If, therefore, it were found possible to divert or stop flow passing into the Matsebe-Kudum-Marope-Kunyere system and keep that water within areas feeding to the Boro, Kwapa and Shashi, the result would be a greatly increased flow into the Thamalakane and the Botletle.

Careful study was given to this problem during the surveys and the findings of the investigations show that...
that the desired results can be attained without much
difficulty. A consequence, of course, would be the
drying up of the Kurnyere and an annual loss of unrestricted
flow into Lake Nyami. But, as will be pointed out
later, there is in fact much to be gained by accepting
this apparent loss.

82. Between the entrance to the Shashi and another
flood channel known as the Gabaracha, 8 miles to the south-
west of the Shashi, the intervening ground rises and falls
in a series of low ridges and depressions. This ground
is always dry and forms a divide between the Shashi and
other channels draining towards the Kurnyere. Each year
water advances to a point near the top end of the Gabaracha
but is prevented from entering it by a low narrow
ridge. It would be a simple matter to open the Gabaracha
and use it to take water to the Thamalakane but, if
its use for such purpose is shelved, the reclamation of
large areas of arable ground with nearby water under
control would be gained.

By excluding the Gabaracha from use, it was
possible to select high ground forming the right bank of
the Shashi as a suitable control point for levels to
determine whether and to what extent it would be possible
by building dams, dykes or levees (a) to cut off flow in
channels that drain towards the Kurnyere and (b) to divert
flow into areas which drain towards the Boro.

THE MATSEBE.

83. It was mentioned previously that the Matsebe
is the chief source of supply from the central area
swamps to the Kurnyere. It begins as a series of adjacent
channels and molapos some 45 miles into the delta from
the Shashi.

It is obvious that control aimed at preventing
water from entering the Matsebe and by-passing flow into
the central area waterways should be located as near the
entrance as possible. The general water level would not
be materially raised at the controls because of the very
wide adjacent waterway area of the central swamps which
extend for miles across to Chief's Island. To dam the
channels lower downstream would require structures to raise
the water level in each channel to a height sufficient to
make water spill past the source. This would be difficult
and would require a whole series of levees or banks to
prevent the dams from being outflanked by flow into the
numerous molapos leading from or connected with the channels.
Damming downstream would incidentally flood much good
arable molapo country which would be reclaimed by locating
the controls at channel source.

84. Three other matters were taken into account in
planning the investigation:—

(a) assuming the feasibility of controlling the head-
waters of the Matsebe channels, it would be necessary
to prevent escape of water from the central area by

channels/......
channels elsewhere such as the Marope lower down the delta,

(b) the western Alluvial of control across the Matsebe head-waters would have to be made on permanently dry land which would not be outflanked.

(c) it would be necessary to make sure that damming a large flow in the vicinity of swamps and waterways that drain into the Taoge would not result in diverting water in that direction away from the central area.

The doubt relating to (c) was resolved before proceeding with the rest of the investigations when the point of divide of the Taoge and central area swamp systems was located and connected by levels along a branch traverse from the main Maun-Mohembo traverse. A concrete bench mark - Beacon 11C - was fixed at this point which lies just below latitude 19° 30' south and about 12 miles above the most westerly channel entrance of the Matsebe - see air photograph Fig. 179.

Survey reconnaissance started from the right bank of the Shashi at bench-mark Beacon No. 1 where the teepee fly control fence crosses the channel. The object of the reconnaissance was to trace high ground leading towards the head-waters of the Matsebe, and to select dam sites across channels serving as overflow outlets leading away from areas draining towards the Boro.

Results were surprisingly successful. After selecting the obvious site for a control dam (C.D.1) at the teepee control camp at Chuchumberga, 4.68 miles from the Shashi, dry land was followed for a further 21.52 miles to a second dam site (C.D.2) where a distinct heavily timbered narrow ridge, rising 15 to 27 feet above surrounding ground, was found. See Figs. 132 and 133.

This outstanding feature continued thereafter in a general north-west direction right up to the eastern margin of the Matsebe headwaters, 45 miles from the Shashi. In the whole of the distance along the ridge from control dam No. 2 to the Matsebe, namely 17.25 miles, there are only two small gaps that require to be dammed, see sections C.D.3 and C.D.4 on Plate 6, also Figs. 126 to 128.

86. The entire length of the ridge examined provides an effective natural dyke and helps to solve what might otherwise have been a most difficult problem. Part of the wooded ridge near Beacon 11E can be seen in Fig. 178. If the four dams are built and a little low dyking is undertaken near the Shashi, it would only be necessary to close the gaps across the Matsebe headwaters in order to divert the whole of the flow of the Kunyere into the Thamalakane.

Unfortunately, advancing floods made it impossible to complete the survey across the Matsebe. But, from knowledge gained of the surrounding country it is considered that there should be no difficulty in selecting and surveying suitable places to locate the necessary/...
necessary controls. Such investigation can be effect-
ively undertaken in this area only when the annual floods
have fully receded, usually from November to January
each year. Normally the channels of the Matshebe head-
waters should be dry during those months, but the exact
state could easily be checked by air reconnaissance.
Local rains might cause some difficulty as was the case
during December 1952 when the position of the "divide
point" was being surveyed.

As the scheme for the surveys expired in
March 1954 it was not possible to wait until the follow-
ing December to complete the survey at the Matshebe head-
waters. But, as the unsurveyed gap is short and as the
scene of work can be readily approached even during rains
by travel along the dry land massa from the base of the
delta on the west of the Matshebe, it is hoped that the
Bechuanaland Administration can arrange to complete the
investigation at an early date.

The route of the survey from Beacon No. 1 to
Beacon No. 18 is shown by the full line on Plate 3; the
broken line suggests the probable best line for locating
controls across the Matshebe.

THE THAMALAKANE AND LAKE RIVER.

87. References have already been made to the
channels that convey water from the delta into the Thama-
lakane. The amount of flow from those sources varies
considerably during the year, and also from year to year.
The following is a summary of measured discharges of the
Thamalakane at Maun:

<table>
<thead>
<tr>
<th>Date</th>
<th>Flow in Cubecs</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14th September 1925</td>
<td>2,500</td>
<td>Du Toit: but 2,000 was later suggested as being correct. The river was carrying the highest flood on record.</td>
</tr>
<tr>
<td>29th July, 1937</td>
<td>500</td>
<td>Jeffares: River in flood.</td>
</tr>
<tr>
<td>5th October, 1937</td>
<td>119</td>
<td>Jeffares: After flood.</td>
</tr>
<tr>
<td>10th July 1950</td>
<td>265</td>
<td>Davies: River in flood.</td>
</tr>
<tr>
<td>May 1951</td>
<td>Nil</td>
<td>River dry</td>
</tr>
<tr>
<td>31st August, 1951</td>
<td>477</td>
<td>River in flood.</td>
</tr>
<tr>
<td>14th August, 1952</td>
<td>511</td>
<td>River in flood.</td>
</tr>
<tr>
<td>4th September, 1953</td>
<td>650</td>
<td>River in flood.</td>
</tr>
</tbody>
</table>

None of the gaugings can be regarded as being
accurate as the river is slow-flowing and the width of
open channel is usually governed by the extent of rush and reed growth. The discharge of the Shashi is not included in any of the above measurements. As most of the gaugings listed were taken during the flood seasons, there is a tendency to overlook the fact that the flow of the river drops almost to nothing during low flow. Figs. 68 and 69 show the river dry on 1st June, 1951, and the photographs of Figs. 70 and 71, which were taken four weeks later, show the great and pleasant change that occurs when good floods arrive.

88. Levelling along the Thamalakane was not undertaken during the surveys of this report because that work had already been done twice, first during the 1925 Reconnaissance and again in the 1937 surveys. Levels in the former survey were taken past the Botletle junction down the whole length of the Lake River to Lake Ngami, but the 1937 levels stopped a little way down the Lake River at the point where flow had ceased.

Two facts emerged from the 1937 levelling:
(a) that the grade of the Thamalakane is only 1 in 17,000 and (b) that the elevation at a controlling barrier just inside the entrance to the Botletle is 3057.1 feet. The significance of (b) will become apparent when Lake Ngami is discussed—paragraph 96.

89. After passing Mau, the Thamalakane continues to a point about 12 miles downstream where it divides; most of its flow passes eastwards into the Botletle river and the remainder flows slowly down the Ngabe or Lake River which follows the same general southwesterly direction as the Thamalakane as far as Lake Ngami. Flow down the Lake River is impeded by a series of silcrete rock-bar outcrops below the Botletle junction, see Fig. 77. As the gradient along the Lake River is small, it usually takes a long time for water to advance as far as Toten where it joins with the Kunyere a little to the northeast of Lake Ngami. It normally requires a good flood year for the Lake River to deliver water in any quantity at the Toten junction, as in 1925, 1944, and 1951. A small flow reached Toten in 1953, see Fig. 79.

The valley of the Lake River is wide, being seldom less than 1,200 to 1,500 feet with high ground on each side. Fig. 78 gives a picturesque view of the river at Gwekwa, and Fig. 57 is a view taken from the Lake River looking downstream to show the junction of the Lake and Kunyere rivers before the advent of floods.

LAKE NGAMI.

90. Lake Ngami has been the subject of much interest ever since it was first seen by Livingstone. Sewell and Murray on 1st August 1849. The descriptions given by Livingstone and Oswell were followed by other accounts in the writings of later visitors to Ngamiland.

Study of these records have led to various theories and conclusions relating to climatic changes, former extent of the Lake and the volume of flow of the
Lake Ngami is a flat elongated hollow lying in a north-east to south-west direction with an upward curling bay at its north-west extremity. It is narrow at the Toten end, wide at the south-west and narrow at the north-west bay. Its overall area is about 260 square miles, and its greatest length measured from the north-west to the south-west corner is approximately 34 miles.

The south-eastern margin is fairly straight and is flanked by high well-timbered ground in which various hard formations can be seen. Approaching the south-west the margin appears as a ridge which gradually descends to ground level at a flat rock exposure adjoining a deposit of gravels which mark a former lake shore.

The western margin is formed by a high well-defined timbered ridge extending north to south along a slightly curving line from the vicinity of the north-west bay to the flat rock exposure mentioned above. The ridge rises to a height of thirty feet above the ground at the edge of the lake area, but it gradually narrows and loses height until it reaches ground level opposite the end of the southern margin ridge at the same rock exposure mentioned above. The gap formed between the ridges is narrow and, although levels were not taken through the opening into the country beyond the Ngami area, an eye estimate indicates that, if the lake should ever fill to the rock level, a further rise of a few feet would cause water to spill into the low lying country beyond.

The northern perimeter of the lake is flat and very sandy and is well forested with camelthorn trees (Acacia giraffae). It follows the main road from Toten to Tsau for about 20 miles as far as Sehitwa, after which it trends westwards opposite the widest part of the lake area. Finally, after making abrupt turns, first to the north and then to the north-east marking the bay, it turns in a sharp curve and links with the western margin.

THE OPEN SPACES.

The open area of Lake Ngami begins about 3 miles downstream from the Kanyere-Lake River junction at Toten after the Lake River has passed through a heavily-timbered belt of camelthorn trees. Fig. 62 and Fig. 63 are views taken from almost the same place, showing some of the succession of cattle-watering wells at the entrance to the open lake area before and after inflow into the Lake. Except for encroachment by thorn bush along the south-eastern margin and in the extreme west, the whole of Lake Ngami is open and provides a vast area of good grazing. But it is grossly overstocked. Fig. 83 is typical of the deplorable state found at so many places along the snady margins of the lake and around the countless cattle/...
cattle posts established throughout the area.

Not far from Sehitwa, on the northern fringe of the area inundated in good flood years, there are numbers of large dead tree trunks which are not to be found anywhere else in the Lake area. There can be little doubt that they are the same trees seen and remarked upon by Livingstone — "A number of dead trees lie on this space." This tends to indicate that the level of the lake as seen by Livingstone was much the same as that in 1951.

The widest part of the open area lies to the south and south-west of Sehitwa. It is crossed by the main road from Sehitwa to Chanzi and there is hardly a bush to be seen for miles.

The deepest part of the Lake hollow is roughly midway between Sehitwa and Toten. To the south-west of Sehitwa the hollow widens and at the same time the ground begins to rise a little. To the west of Sehitwa the northern rim of the hollow is marked by a terrace of sand-covered surface limestone and the ground from there to the northern timbered margin is even and much flatter.

The bay at the north-west corner is the area (see air photograph Fig. 181) in which the Taoge river formerly discharged into the lake via a number of overflow channels entering through the surrounding heavily-sanded parklike country. The bay opens to the south and east into the general expanse of the lake area.

The physiography of the lake is not easy to describe, but the contours which have been drawn on the map, Plate 3, should assist the description given.

**SOILS.**

94. A reference to the nature of the soils in Lake Ngami is necessary in view of the possibilities of irrigation within the area. A number of soil samples were taken at positions marked on the key map, Plate 2. The analyses and descriptions of these samples (Nos. 19 to 31) are given in the list of soil samples in Annexure B.

Further description is best made by quoting from the Kalahari Reconnaissance Report of 1925:—

"...While the 'shores' are formed by porous, medium-grained greyish soils more calcareous on the south and more silicious on the north, the floor is occupied by a loamy or even a clayey soil, hard and often powdery in the dry season, but dark and tenacious when wet. Flooding brings about an extraordinarily rapid growth of vegetation which, on the drying up of the lake, leads to great areas of dead reeds. All authorities agree in their statements that over the floor, away from the margins, there is a good depth of loamy or clayey soil full of ash from the periodic burning out of the reeds. Indeed, there is so much vegetable matter in the soil that once the latter takes fire it is said to smoulder for
"months to depths of several feet below the surface, leaving a porous ashy mass over which it may be dangerous to walk. In the neighbourhood of Toten the pits which we dug showed a few inches of loamy soil, then anything up to eighteen inches of laminated material extremely light in weight and full of roots, stem-cases and ash, resting upon a drab clayey sand.

The chemical analyses ... show the upper loamy soil as being surprisingly high in potash, with adequate lime, still rather low in phosphoric acid though high in organic matter, but the subsoil is less well supplied with plant foods and is extremely low in phosphoric acid. As soils go in this part of Southern Africa, it is an example well above the average."

The phenomenon of underground burning of reeds has not been known to occur since the time referred to.

WATER IN THE LAKE.

95. A considerable amount of survey work was carried out in the Ngami region to obtain reliable information regarding the size, shape and capacity of the lake reservoir at various stages. Up to now it has been necessary to rely on hearsay and on the writings of travellers.

A point of particular concern was to find the full supply level of the lake assuming that sufficient water were available to fill it. This information is required, apart from mere interest, in order to see whether the proposal made in the 1925 Reconnaissance Report for using Lake Ngami as a storage reservoir for large-scale irrigation at Rakops (many miles away on the Botletle) would be feasible.

96. The surveys show that the level of the natural control at the rock bar in the Botletle entrance at elevation 3057.1 established during the 1937 survey (see paragraph 88) corresponds with the level of the ancient lake shore lines and the bed of the channel where water from the Taoge used to enter the lake - see details shown near Beacon No. 6 on Plate II at mileage 214.

Thus, it can be accepted that at R.L. 3058 the lake would spill into the Botletle. This agrees with the elevation near the rock exposure and gravel deposit found at the extreme south-west corner of the lake, see branch traverse Plate 12, mile 18. It also agrees with the elevation of the lake floor on the western margin at the foot of the western boundary ridge near mileage 14.72 of the branch traverse.

If the lake were filled to capacity, water would stand in the Lake River as far as the Botletle junction, and an arm would extend up the Kunyere for 7 miles from Toten.
The natural phenomenon of ponding back into the Lake River that occurs at the junction of the Kunyere and the Lake River when the Kunyere is in flood, has led to some curious assumptions. In paragraph 79 of the Kalahari Reconnaissance Report Du Toit says:

".....In normal years the Kunyere discharges its waters into Ngami, and in September, 1925 was damming back the Lake River for nearly a mile to the north-east. According to Stigand the presence of a bar close to Toten raised the level of the Kunyere on occasions sufficiently to enable its waters to pass along the Lake River into the Botetile, though such would not at first sight appear to be probable. It is striking, however, to find both Livingstone in 1849 and Anderson in 1853 commenting on the lack of any perceptible movement in the waters of the Lake River near Toten, which would indicate that the height within the lake itself was then sufficient to pond back the flows of the Kunyere and of the Thamalakane."

The present surveys along the bed of the Kunyere show that the bar close to Toten, mentioned by Stigand, does not exist. Furthermore, du Toit's deduction that ponding in the Lake River at Toten is an indication of the height of water within the lake is not correct for reasons that will now be explained.

58. In normal and even in good flood years (e.g., 1951 when the lake extended fully 20 miles) the surface of the lake does not consist of a single sheet of water until a certain level is reached. This may seem an extraordinary statement, completely at variance with statements by Livingstone and other travellers, and, in fact, by all who have ever seen the lake. Nevertheless, the evidence provided by the surveys shows that the lake really consists of two parts, as may be seen from the contours marked on the map, Plate 3.

The upper part, which starts about 6 miles below Toten, consists of an irregular-shaped shallow area of low-lying ground fed by overflow from the Lake River as it passes through the depression. The bed of the river is partly maintained through the area, but it becomes a well-defined channel again as it leaves the area. It then continues as a well-defined channel for a short distance until it finally enters the main and deeper hollow of the lake at a point very roughly midway from Toten to Sehitwa. All this is clearly shown in the air photograph Fig. 177.

The upper flood area lies mostly on the right of the Lake River and reaches as far as the main motor road from Toten to Sehitwa. It fills each year when there is enough water to pass on towards the main lake area.

Fig. 64 shows part of the upper flood area in 1951 and Figs 65 and 66 give an idea of the vast expanse of the main lake. No reeds had grown when the photographs were taken, and the whole area had been dry only a
few months previously.

99. Had the air survey in 1951 been carried out at the time requested, it would have provided a valuable record of the extent of water in Lake Ngami during a high flood year. However, the photographs showing the dry lake area are of value in disclosing the shape and nature of the lake floor. In Fig. 177 the single well-defined channel at the "waist line" connecting the two parts of the lake can be clearly seen.

It is quite probable that the place from which Livingstone, Oswell and Murray first viewed the lake was on the southern side of the single channel connecting the two parts of the lake where the ground on both banks, though flat, is slightly higher than that in the nearby areas. Describing the general shore lines of the lake, Oswell states:

"...Towards E. they continued slowly but gradually approaching each other, and contracted suddenly at the place where the wagon stood. What was an expanse of water eight miles across, is now, just below, but a moderately broad river (say two hundred yards.)."

100. A link for comparison of present and past lake areas is afforded by references to the depth of Lake Ngami made by Livingstone and later travellers. Even though such evidence is only a guide, it is sufficient to indicate that the extent of the lake in those days did not greatly exceed that of present times. The significant point is that nearly every one of the early visitors to Ngamiland remarked upon the shallowness of the lake. Chapman, who was at the lake in November 1853 says: "The depths I have since had an opportunity of testing and found it not to be more than six feet." He was there again in November 1856 and says: "...on the lake, which I was sorry to find, was becoming alarmingly shallow, not containing more than three and a half feet of water on the average."

Reports on the size of Lake Ngami should always take into account the time of year at which the lake is seen. Obviously, in any year the lake is at its largest during the flood season which usually extends from early July to the end of September. In 1951 the lake was dry in June, but it was full in August; and in June the following year it was dry again.

LEVELS.

101. The full supply level of water in Lake Ngami is 3058 feet, or possibly 3059 feet whereafter it would flow out into the Botetile river. The lowest point of the lake floor lies at 3027 feet, and the bed level of the Lake River at the Toten Junction is 3047.3 feet.

During the good floods of 1951 the water surface in the main portion of the lake rose to 3032 feet, giving a maximum depth of five feet, while that in the upper and separate portion of the lake stood at 3036 feet, i.e., four feet higher.
The 1951 flood reached Sehitwa, 20 miles from Toten, but had inflow been sufficient to raise the main lake level to that of the upper lake portion at 3036 feet, water would have advanced to the south-west beyond Sehitwa by another seven miles to a point a little short of Bodiben.

102. During the highest known flood, namely that of 1925, a rise above 3036 feet must have occurred because, in a letter to the STAR newspaper on 10th October, 1925, Mr. Matabele Wilson reported that water had actually reached Bodiben.

This information places the 1925 lake level at approximately 3043 feet as indicated by the contour on the map, Plate 3. It also places the north-east end of the lake at that time approximately a little over five miles from Toten which agrees with the position of open water found by du Toit (Plate II of the 1925 Kalahari Reconnaissance Report).

It has been necessary to make these deductions because there is obviously a discrepancy in the levels as given by du Toit who shows the open water in Lake Ngami as being at elevation 3057 feet, i.e., 17 feet higher.

Proof that the 1925 level of the lake could not have risen to the elevation given by du Toit comes from a statement by the late Mr. H. Riley of Maun that he selected the present site of the store at Sehitwa just after the 1925 flood so that it would be above reach of a similar future flood. The level of ground at the store is 3044.46 feet, which serves to confirm that the deduced maximum lake level of 3040 feet in 1925 must be reasonably correct.

As mentioned in paragraph 101 the river bed level at the junction of the Kunyere and Lake River is 3047.3 feet, which is more than seven feet above the deduced 3040 foot level of the lake surface in 1925, and disposes of the suggestion by du Toit (see paragraph 97) that ponding at the Kunyere junction in September 1925 was being caused by the height of water in the lake.

103. With the information now available it would not be out of place to suggest that the extent of the lake in 1925 was probably greater than that seen by Livingstone and his companions. There are two possible reasons for this suggestion: (a) the depth of the lake in 1925 would have reached thirteen feet, whereas Livingstone remarked on its shallowness, and (b) the ground where Livingstone's party stood to view the narrow channel just below them would have been covered with water, under the 1925 conditions, and the narrow channel, as such, would not have been evident. Furthermore, as the channel is narrow only when flowing either at or slightly above bank level, it is reasonable to assume that the lower portion of the lake had not reached elevation 3036 above which the lake would become a single sheet of water.
FLOW INTO LAKE NGAMI.

104. Most of the early travellers say that the chief source of supply to the Lake came from the Taoge river (referred to as the Teouge, Teouge, Teoge and Mokolane) at the north-west corner of the lake. Few actually saw the Taoge; Anderson in 1853 described it as a winding stream about 40 yards in width and deep in the flood season; du Toit says that, according to Stigand, it began to dry up about 1883 and ceased to flow seasonally after 1887. Apart from the extraordinary feature mentioned later in the last part of paragraph 105 there is no particular reason to doubt the generally accepted opinion that the Taoge formerly did contribute the bulk of flow into Lake Ngami. In the present day general dry state of the lower reaches of the Taoge, it is not an easy matter to trace the channels in which the main discharge was formerly carried to the lake. Flow appears to have entered at a number of places via a series of winding overflow-channels which cut their way through the heavily-sanded northern margin of the lake. Some of these channels can be seen in the air photograph Fig. 181.

105. The main channel of the Taoge comes from the north and approaches the lake area through a gap in a broad sand-belt ridge about six miles from Mochabeni which is near the north-west corner of the lake. This ridge trends in a north-to-south direction and joins with the high sand ridge that forms the western margin of the lake.

Shortly after passing through the sand belt, the Taoge begins to feed into the overflow channels as mentioned above. Some of these channels become quite well-defined, but they too divide here and there into minor channels as they approach the margin of the lake, whilst others do not approach the lake but taper and disappear towards the north-east.

Reference to the levels at mileage 211 Plate 11 shows the manner in which the principal overflow channel to the lake leaves the Taoge. At this point the Taoge is quite deep, but three miles further downstream (to the east of Mochabeni) the bed of the Taoge ends at ground level and can no longer be traced.

Besides the main Taoge channel, other well defined channels coming from the north, approach the lake in the Sehitwa area. Most of these connect with a number of ancient flood channels that come from the Taoge about 26 miles upstream in the area to the north and west of Tsau.

A remarkable feature about the lake near the Taoge mouth is that there is not a sign or vestige of a channel or old drainage line anywhere along the margin of the lake floor to indicate the entry of large volumes of water in the past, despite the fact that there is a thirty foot fall from the margin into the hollow of the lake.

106. The only existing source of water for Lake Ngami is the seasonal flow of the combined Kunyere and Lake River. The manner in which the flow is finally
carried into the lake by the Lake River has already been described (paragraph 98). This annual flow from the north-east was described by Livingstone and has apparently continued in the same manner for more than a hundred years.

Whereas water from the Taoge used to enter the lake at its highest point (full supply level) and thereafter find its way towards the hollow of the lake floor without leaving a trace of a drainage line, the Lake River, in marked contrast, not only enters at a much lower level but also continues into the lake along a well-defined waterway.

USE OF WATER IN LAKE NGAMI.

107. When there is water in Lake Ngami it serves no useful purpose other than that of watering stock. When the lake, or most of it, dries up between flood seasons, the local people have to rely on dug wells for their needs. No loss would be felt, therefore, if the flow of the Kunyere and Lake River were to be held and controlled and an amount sufficient for stock were allowed to pass into the lake area. On the other hand, the lake would be reclaimed and more land would become available for grazing, if other forms of development such as irrigation are not undertaken.

108. Before referring to the possibilities of irrigation within the lake, it would be relevant to comment on a scheme of far-reaching magnitude which was outlined in detail in the 1925 Reconnaissance Report. The scheme envisaged the lake as a vast storage basin to provide water for large-scale irrigation at Rakops, 120 river miles away on the Botetile river. The scheme was based on building a dam and regulator across the Lake River at a place called Haka where there is a rock barrier estimated by du Toit as lying at elevation 3063 feet. It was assumed that it would be possible to restore flow in the Taoge as this would be necessary to augment the flow of the Kunyere in order to provide enough water for the scheme. It was accepted that all water below level 3063 feet in the lake would become "dead" water and thus would not be available for use, so it was planned to raise the water level another ten feet to level 3073 by means of the regulator at Haka and thus provide 1,600,000 acre feet of effective storage. In the calculations the dead water was regarded as filling the lake to its maximum capacity, i.e., with a surface area of 250 square miles.

109. Apart from the unlikely prospect of developing a sufficiently prolonged flow from the Kunyere and the restored Taoge to raise the lake to level 3073 feet, there is a discrepancy in du Toit's estimated level of the rock barrier at Haka as there was in the case of the lake; see paragraph 102. But apart from this discrepancy, the scheme is unsound because it assumed that the level of the lake could be raised 10 feet above that of the dead water without increasing the surface area of 250 square miles. In any case the storage could not be raised to level 3073 as suggested without (a) spreading water over the whole of the country on the north and north-west margins of the lake, putting Sehitwa 29 feet under water and reaching back up the Taoge for 20 miles as far as
Mogopudis; (b) causing a spill past the south-west corner of the lake into the country beyond, and (c) flooding the whole of the Kunnyere and Naraga valley as far north as Marupe, 41 miles upstream from Toten.

IRRIGATION WITHIN THE LAKE.

110. Although the lake is a shallow depression with no drainage outlet, it is possible to irrigate large areas of potentially good soils provided precautions are taken to reserve some of the lower ground as a drainage basin.

The local natives grow crops under dry land conditions in the darker soils at many places along the northern margin of the lake, and, when rainfall is normal, they reap good crops. They also cultivate the lower ground along the south-eastern shore of the lake. The rapid growth of grass and reeds under rainfall and after flooding indicate that the soils should respond well to cultivation.

Although some of the lower-lying darker soils appear to be heavy, they drain well, judging by the rapid drying up of the lake after heavy flooding. A description of the soils of the lake was given at paragraph 94.

111. Two schemes for irrigating restricted areas of the lake are possible; one in the western region from the Taoge when its flow can be restored, and the other in the north-east with water from the Kunnyere which could be diverted and stored in the Lake River in a manner described later.

Assuming that the flow of the Taoge could be restored, there is no apparent means of providing storage anywhere along the river, and irrigation from the Taoge would therefore have to be planned on flood or basin methods during the winter months. It is not possible to suggest what quantity of water could be expected from the Taoge as information will be available only after the upstream blockages have been removed and improvements made to the main channel in the vicinity of Mogopudis and Makakum. Fig. 67A shows some of the 40,000 acres which invite irrigation from the Taoge if sufficient water for that purpose could be obtained.

If it should eventually transpire that a low flow of say two or three hundred cusecs could be provided as a result of clearing and developing the Taoge channel, the planning of irrigation would require some means for controlling and diverting excess flood water away from the lake in order to prevent flooding the lake hollow. This point was kept in mind during the surveys and it was found that diversion of any unwanted flood water could be conveniently and easily arranged just before the Taoge passes into the sand-belt gap mentioned in paragraph 105.

LAKE/......
LAKE RIVER STORAGE SCHEME.

112. It has been pointed out that water entering the lake from the north-east amounts to an annual waste, and a description has been given of the means by which the flow of the Kunyere could be diverted for better use into the Thamalakane and Botletle via Kwapa-Shashi-Boro system.

If the Kunyere diversion were carried out without certain ancillary works on the Lake River it is obvious that a greatly increased flow from the Thamalakane into the Botletle would also cause an increased flow down the Lake River and so back into Lake Ngami. It is necessary, therefore, to provide a control dam across the Lake River which would maintain the bulk of flow in the Botletle and allow just sufficient for downstream requirements to pass along the Lake River.

113. Such a dam has always been regarded as an essential part of any scheme aimed at increasing the flow of the Thamalakane into the Botletle, and accordingly, a suitable site near the Botletle, just above the Ghatassau Falls, was provisionally selected at an early stage of the surveys, see section on Plate 15. However, when it was found later that diversion of the Kunyere into the Thamalakane was practicable, it became necessary to seek a solution of the dual problem of (a) requiring the Thamalakane to discharge greatly increased quantities of water along its flat gradient during the flood season, and (b) restricting discharge towards the end of the following low-flow season as the effect of diminished flow at Maun has become a matter of serious concern owing to the loss of any increment from the now dry Comoti river.

114. The provision of an overflow dam or weir on the Botletle in addition to the dam on the Lake River offers an effective solution of the problem.

By setting the crest of the Botletle weir at elevation 3073 the two dams would create a river-valley reservoir or lake which would extend twenty miles up the Thamalakane from the Botletle junction and retain a depth of water at Maun equal to that attained during the floods of 1925. The extent of increased flood flow into the Thamalakane from the Kwapa-Shashi-Boro system by diversion of the Kunyere cannot be predicted with any accuracy, but the increase would not have to be carried along the flat grade of the Thamalakane as it would enter the lake raising its water level to conform with aflux at the weir on the Botletle. If the length of the overflow section of the weir were made six hundred feet, a flood of about 3,600 cusecs could be passed with an eighteen inch rise in water level. The level of the lake could not rise above 3076 without causing water to escape northwards past the critical point above the Comoti river mouth towards the Mababe Depression.

115. The most promising weir site found on the Botletle is at the wide silcrete rock barrier at the Maun-Rakops road crossing at Samadupi, 11 miles below the junction, see Plate 3 and Fig. 140A.
The level traverse from Maun to Samadupi (Plate 14) shows that the intervening ground on the left of the Thamalakane and on the left of the Botletle is well above the highest proposed lake level.

116. It is obvious that the extent of the proposed river valley lake could be greatly increased if the originally chosen dam site on the Lake River near the Botletle junction could be moved lower downstream so as to include as much as possible of the wide Lake River valley within the storage.

Surveys were taken along the ground on the right of the Lake River to determine the general elevation of the divide between the Lake River and the nearby Kunyere and Naragha valleys. It was somewhat surprising to find that the general elevation of the ground along the motor road approaching Toten from Maun is higher than the ground at Maun.

The result of the investigations that it is possible to use the whole of the Lake River valley from the Botletle junction to Toten for storage; and a suitable dam site on the Lake River was selected just above the Kunyere junction, see Figs. 80 and 81.

117. With dams at Toten and at Samadupi the total length of the river valley lake will be 7½ miles. There are many wide reaches along the valleys of the rivers concerned, but on a conservative basis it is estimated that no less than 85,000 acre feet of storage can be provided with an effective depth of 10 feet of water.

Although no reliable figures can be given of the maximum flow to be expected from the combined discharges of the Kunyere, Botletle and Lake rivers, du Toit estimated from Gaugings that during an exceptional year like 1925, the amount discharged could not have exceeded 4,000 cusecs as a maximum with an average of 2,000 cusecs at Maun.

Flows such as the above would provide more than enough to keep the Botletle flowing all the year. On the other hand, during a poor flood year, the combined discharges are not likely to yield less than 750 cusecs for six weeks at the height of the flood season (July, August), nor less than 350 cusecs for a month afterwards. It is most improbable, therefore, that the proposed reservoir would ever fail to be filled.

118. It would be possible to increase the storage capacity of the reservoir by another third or approximately 28,000 acre feet by providing removable or falling shutters on the Botletle weir to raise the water level of the lake by three feet to the level of the Critical Point at 3076 feet after the annual floods have passed. The final design of the weir should be made so that this could be done at some future date.

The capacity of the proposed Lake River reservoir is sufficient to provide for irrigating about 17,000 acres in the north-eastern areas of Lake Ngami.
where some 30,000 acres could be brought under command above the 3030 contour. The area below that level should be reserved for drainage disposal. Arrangements should be made at the Toten dam to deliver water into Lake Ngami for existing stock needs until irrigation development becomes a reality.

THE TAOGE RIVER.

119. Brief reference to this important branch of the Okavango has been made in the general description of the delta and elsewhere. Trending north to south along a winding course, the main channel of the Taoge hugs the western margin of the delta from its start at Ikwaga above the head of the delta, to its end at Lake Ngami. The direct distance between these points, measured on the map, is 114 miles, while the length of the course followed by the channel of the river is as much as 286 miles.

The value and importance of the Taoge has been recognised from the early days by the people living in Ngamiland. They had established the tribal centre at Tsau and around Lake Ngami long before the present centre of Maun was thought of. The value and importance of the Taoge remain, but the gradual dwindling of the flow of the river, which had begun long before Livingstone visited Ngamiland, has continued steadily ever since. Many, including Livingstone, have ascribed the diminution of flow to desiccation brought about by climatic changes, whereas the simple reason is that the river channel had become choked and blocked by the growth and spread of papyrus and other water-growing plants and grasses. This process continues today and there is no hope for any improvement or change for the better unless either a new and more direct channel is dredged or the blockages removed.

120. At its source the Taoge is complete blocked by papyrus whilst the Ngogha at that point is a fine open stream. The blocked Taoge continues downstream within a sea of papyrus occupying the full width of the submerged valley of the river. The width of the valley decreases as it approaches a short narrow strait between the high western mainland shore and a belt of low-lying ground within the swamps at a point 17 miles downstream from the beginning of the Taoge.

On the other side of the narrow gap the submerged valley widens rapidly and the sea of papyrus extends eastwards across the perennial swamps while the blocked channel keeps a course towards the western land margin. Apart from the imposing open lagoon at Ikwaga (see Fig. 21) there is nothing to be seen from the mainland shore in this region beyond a vast expanse of papyrus with occasional clumps of distant trees marking the position of some small islands.

121. Nine miles below the strait, the blockage in the channel of the Taoge ends at the point where it is joined by a well-defined open stream flowing in a southerly
direction across the perennial swamps from the Ngogha; see map Plate 3; also paragraph 54.

The open stream is shallow at its take off from the Ngogha but it soon increases in depth and grade as it crosses the swamps on its way to join the Taoge eleven miles away. There is nothing other than a sudden increase in river depth to 30 feet to mark the point where it actually enters the Taoge. Both the channel from the Ngogha and the Taoge after their junction are flanked on each side by tall papyrus in the same fashion as that found on the Okavango and Ngogha.

Some idea of the general nature of the Taoge and its submerged valley in the upper swamps may be gained by reference to the air photograph Fig. 170.

Four miles after the Taoge's confluence with the stream from the Ngogha, a side channel enters the river from a large expanse of open water known as Guma Lagoon, which adjoins the western land margin of the swamps. This impressive sheet of water is nowhere less than 10 feet deep, and abounds with hippo. See Figs. 24 and 25.

122. After passing Guma a noticeable change in the régime of the river behins to take place, and the photographs of Figs. 26, 27 and 28 were taken at intervals along a 6 mile reach of water where the photographs were taken is not less than 15 to 17 feet.

The first photograph shows a long reach of river where a wide encroachment of water grass (Echinochloa Pyramidalis) is spreading out into the channel from the right hand edge of papyrus and has reached almost halfway across the channel. Here the left hand margin is free from water grass. In Fig. 27, a little further downstream, E. Pyramidalis has encroached from both sides of the river, narrowing the open channel considerably; and in Fig. 28 a link across the river has almost been made. A root and stem of E. Pyramidalis is shown in Fig. 31.

123. It is obvious that, as soon as the encroachment of E. Pyramidalis forms a junction across the river, all floating debris which mostly consists of papyrus stalks and roots, will be held up and the creation of a blockage will have begun. Should a break-through occur, the accumulated debris will merely float down to the next similar barrier. If there is no break-through, the build-up will become firmly established at that point although there may still be a portion of open river on the downstream side. However, the shielding effect of the blockage will encourage the spread of the E. Pyramidalis downstream and it will not be long before the downstream open reaches are also completely blocked.

124. The photographs of Figs. 29 and 30 show the upstream end of the great Taoge blockage on the 28th April, 1952, at a point six and a half miles downstream from Guma Lagoon. When visited at the end of December 1951, the top end of the blockage was one and a half miles further downstream. It is of interest to note that the appearance of the end of the Taoge
country extending southwards parallel with the course of the Taoge below Danagha. One or two of these channels combine and join the Taoge further downstream. The others continue southwards and end as dry tapering watercourses.

The extent to which these channels function depends upon the volume of the annual floods; in good years a small discharge is usually carried to the Taoge along the Karangana and the Mathlabane to in the region south of Boaxankwe — see Plate 3.

THE MIDDLE REACHES OF THE TAOGE.

129. This is generally regarded as being the portion of river from Gomare to about 25 miles north of Taau bordered by numerous settlements. All the villages are located on the right bank side of the river because the area on the left of the river is infested with tsetse fly. The inhabitants make use of flood areas and numerous old river loops to grow their crops. They also employ primitive irrigation methods in many places by building low control dams across molapos and old river loops, where the general sandy nature of the soils is improved by humus and the products of reed burning.

130. Prior to 1938 the whole of the middle reaches of the Taoge was blocked with papyrus but, for reasons which will be explained later, the river is now clear as far north as Thebe.

Fig. 37 shows water emerging from under the papyrus mat at the end of the blockage at Thebe during the flood season. This flow drops steadily after the end of the flood season and, as recession normally takes place during the summer crop-grow months, the local natives follow the retreating water and plant in the moistened soil of the river bed, knowing that they can reap before the next winter floods are due.

DEVELOPMENT POTENTIAL IN THE MIDDLE REACHES.

131. During the course of the surveys it was found that there are many thousands of acres of potentially good arable ground adjoining the Taoge between Gomare and Nokaneng, and also on Tubu Island. This was brought to the notice of the Administration, whereupon a comprehensive examination of the region was undertaken by the Director of Agriculture.

The findings of the agricultural survey were favourable and proposals were made for starting a pilot scheme. It was realised, however, that there could be no subsequent large-scale follow up unless it were possible to provide economic means for transporting produce to Maun. For, apart from the high cost of using motor vehicles over long distances, the deplorably undeveloped state of roads in Ngamiland would make road transport well nigh impossible.
132. In view of this it was decided to investigate possibilities of developing a waterway from the Taoge to connect with any of the channels of the central area which would ultimately lead to the Boro system although it was realised that such a waterway could probably function only during flood seasons.

As time was limited, the investigation had to be undertaken by working through the rainy season of 1952. No information regarding levels in the interior of the delta was available, so it was decided to adopt the direct method of locating a line of canal to a grade of not less than 1 in 10,000, starting from a point on the Karangana which was found to have a connection with the Taoge near Thebe.

The chances of success were based on the hope that the various channels to the east of the Taoge which would have to be crossed would be found to carry water throughout the year, in which case a waterway crossing could be provided by merely building a dam with a spillway across the channel to control full supply level in the canal. Failing this, it would be necessary to deepen the beds of the channels to maintain a flow from the perennial swamps, which would require a lot of further investigation and aid materially to the costs of developing a waterway.

133. It was surprising to find that, apart from the Karangana and another channel 1½ miles to the east of the Taoge, all other drainage lines were dry in December 1952. It was planned to end the waterway canal at the last (and largest) of these flood channels at mile 23, whereafter, by following it upstream, connection could be made with channels conveying water in the direction of Maun.

In view of the conditions found, and as all the country traversed is infested with Tsetse fly, it is felt that the provision of a waterway in the areas examined would not be practical or economical.

THE TAUGE BLOCKAGE.

134. The formidable lower Taoge blockage which begins 6½ miles below Guma lagoon and ends just below Thebe, covers a total length of 97 river miles. This is apart from the 27 mile upper blockage from the start of the Taoge to the point where it is joined by the open stream coming from the Ngogha. The need for clearing the upper blockage can be postponed for future consideration as its removal would become important only if it should ever be found necessary to add to the flow coming from the Ngogha connection.

135. Nearly all the main blockage is caused by papyrus, but in some reaches - particularly in the region of Kakadau and Danagha - the papyrus is replaced by a thick floating grass mat with closely interwoven roots, rich in humus, and 18 to 24 inches in thickness. It is known locally by the native name "Tetemetsi".
Humans, animals and even sleighs drawn by oxen, can cross the river on this floating Tetemetea mat. There is often no sign of river or water where this type of obstruction occurs and, in appearance, there is little to distinguish the river from the adjoining ground other than a drop in ground level indicating the presence of the river banks.

The supporting capacity of the floating Tetemetea is remarkable, as may be gathered by reference to Fig. 51 which shows where a narrow cut across the Taoge had been made for investigation purposes near Daragha. All the people on the right of the photograph are being supported on the floating mat, and the top of a 10 foot levelling stave showing just above water level serves to indicate the depth of water below the mat. In Fig. 53 the floating mat is being rolled back to show the nature of the root system.

136. The extensive papyrus blockage differs from the Tetemetea obstruction in many respects. Wherever open ground extends to the blocked river channel, the tall papyrus stems can be seen standing well above ground level, and it is easy to follow the course of the river. At other places the river is flanked by reed swamps which obscure the channel, and in the upper perennial swamps the channel meanders within a wide expanse of papyrus and cannot be reached except with great difficulty. These conditions are well illustrated in Figs. 157, 153 and 152.

137. The nature of papyrus growing in the river may be seen by reference to Figs. 48, 49, 50 and 55. The stems, which are often as much as three inches in thickness, grow in groups from a ramified and closely intertwined floating root system about two to three feet thick, generally termed the "mat". The floating mat is usually well rooted to ground where water is shallow as at the sides and banks of streams; but in deeper water the mat connects to earth by means of occasional long single taproots. When cut and partially drained the average weight of a square yard of mat is half a ton.

It is generally possible to walk through floating papyrus and, by breaking down the stems, a firm pathway can be easily developed. Such paths are extensively used by local inhabitants as normal river crossings.

Mature papyrus stems usually grow to a height of about eight feet but in many areas they reach to twelve or even fourteen feet. If the stems are cut above mat level, regrowth to a height of three to four feet is very rapid - a matter of six weeks. Destruction of the upper papyrus growth, as by cutting, burning, or other method, does not affect the wet mat and does nothing to prevent regrowth.

Eradication of papyrus or tetemetea obstruction can be done effectively only by removing the floating mat or by burning at places where the river beds can be dried out by drainage or other means. The now
clear and dry lower reaches of the once perennial and obstructed Gomoti is an example of clearing by desiccation.

PREVIOUS EXTENT OF THE TAOGE BLOCKAGE.

138. In 1938 the Taoge was completely blocked as far down as a point 25 miles north of Tsau, or approximately 50 miles downstream of the present lower end of the blockage. Even during high flood years water seldom passed the end of the blockage where repeated water recession had permitted the mat to become firmly rooted to ground at many places.

Although nobody knew much about the river at that time, the Administration decided to embark upon an experimental effort to clear the channel by hand in order to observe and study the effects of clearing. The work was onerous, but as the depth of water in the lower end of the blockage was seldom found to exceed four or five feet, it was possible to continue with hand clearing far more than was anticipated.

As soon as the clearing had passed the area most affected by the rooted papyrus dams, further work was greatly aided by the drainage afforded by the cleared downstream channel. Later it was found that not only could better drainage be attained by digging canals to short cut some of the long river loops, but a saving of time and costs could also be made.

139. The success achieved by hand clearing was remarkable. By 1941 seventy miles of river had been cleared or by-passed when difficulties were created at Xasa by cross-country flooding from the Karangana channel three miles to the east. Then, as war had come and funds provided for clearing work were nearly spent, it was decided to end up by digging a small waterway to connect with the Karangana with the object of transferring flow into the cleared reaches of the Taoge. A part of the water was to bring water from the Karangana is shown in Fig. 39.

Two important results were achieved by the clearing work undertaken at that time. Firstly, water (mostly from the Karangana) again began to reach Tsau during each normal flood year, and in good floods it reaches as far south as Mogopudi and Makakun, only 25 miles from Lake Ngami. According to Stigand this was the limit reached during the high floods of 1930. Secondly, there has been no regrowth of papyrus along the whole of the length cleared more than 14 years ago. Fig. 38 shows the Taoge at Xasa at low flow in January during 1951; the whole river at this point was completely blocked in 1940.

140. Since the completion of the above mentioned clearing operations, a series of droughts were experienced, particularly during 1948 and 1949, with the result that the Taoge above Xasa dried up almost as far as Thebe. Local inhabitants took advantage of this to burn out the papyrus as it dried in order to make way for planting crops/......
crops in the river bed. By this indirect means fifteen more miles were added to the length previously cleared. But a point has now been reached, such that, even if another series of droughts should occur, little hope can be entertained of materially extending river clearing by employing hand-clearing methods.

RIVER CLEARING MACHINERY.

141. The importance of re-opening the Taoge and the effect it will have on development in Ngami land is referred to in Part III of this report. The brief description that follows relates only to the action taken in respect of part of the terms of reference of the surveys, namely, to provide machinery for use in clearing important overgrown river channels in the Okayango swamps.

142. As a preliminary, much time had to be spent in locating and examining the type, nature and extent of the blockage on the Taoge. Many of the blocked reaches of the river were difficult to get to.

After this, steps were taken to prepare a brief specification of design based on the following requirements.—

(a) the machine should be fully floating and be capable of carrying a full load of papyrus and mat preparatory to disposal;

(b) the machine should be capable of cutting and disposing of 650 tons of papyrus mat per working day;

(c) the width of a single cleared cut should be not less than twenty-four feet so as to provide a reasonable initial waterway for river discharge and to allow the cleared channel to be put to use and be maintained against regrowth of tetemete grass. A lesser width would require more cuts to clear a channel of increasing waterway width towards the upper reaches of the river;

(d) the use of power to keep the machine against the face of the blockage when in working position should be entirely avoided. Power drive should only be used for operating cutting and disposal mechanisms;

(e) it should be possible to transport all parts or units in three or five ton lorries over long distances and bad roads.

143. A plan of operation had also to be considered. On first thoughts it might appear that clearing should obviously start from the upper end of the blockage where the current should assist in keeping the machine against the work. However, there are two reasons why such a plan should be avoided: firstly, the
machine would soon become locked in by all loose material floating down behind it; secondly, as work progressed, long river journeys against strong currents would be necessary to return from work to island camps or supply bases.

But there is also an objection against starting from the bottom end of the blockage for, during low flow periods, the drainage afforded by the downstream cleared channel would make it difficult, if not impossible, to keep the machine afloat.

The procedure actually adopted was to select a starting point three miles below Gomare at a place called Thale, some distance above the bottom end of the blockage where it was found by observation that an adequate depth of water would be available throughout the year as a result of the damming effect of the untouched downstream obstruction. An advantage of the site at Thale is that it is only half a mile from a road. It was proposed that the few miles of downstream undisturbed blockage could eventually be cleared by working from the upstream end.

144. It was not an easy matter to find time from surveys to prepare design and detailed working drawings of the machinery and to interview and to seek quotations from manufacturers as far afield as Johannesburg and Durban. Orders for manufacture were placed in 1952 and delivery was expected in November that year, but delay followed, and the plant was not received at railhead, 474 miles away, until February 9th, 1953. Despite adverse weather, the major task of transporting the machinery and plant over bad roads and tracks was successfully completed in four weeks. Figs. 145 to 147 are of interest in this connection. The total haulage involved was 66,011 ton miles.

Launching, fitting, welding and erecting the machinery was another major task which could only be done in stages because work had to be left for periods to continue with time-governed survey work and distant river gauging.

145. Figs. 155 and 156 give an idea of the clearing machine after it had been erected. It was designed in accordance with the requirements mentioned in paragraph 142 and could lift a six ton load of cut material on to a platform from which it could be discharged at a height of ten feet above water so as to clear the top of adjoining uncut papyrus.

The front part of the machine consists of a fixed inclined platform, curved at its lower end. The curved end, or shoe, lies four feet beneath water level and enters under the papyrus mat when the machine is in working position. The whole machine is kept hard up against the face of the blockage during operation by pull exerted by two hand-operated winches on wire rope connected to anchors fixed in the blockage ahead.

a moveable/.....
A moveable power-operated "carrier" fitted with horizontal and vertical cutters can be moved up or down on the inclined platform. The top of the carrier has a cover-shield which is set four feet above the platform to provide space for the cut material. The framework of the carrier divides it into three bays, each eight feet wide, and the front edges of the dividing frames are fitted with vertical cutters. The leading edge of the carrier shield is fitted with horizontal cutters extending the full width of the machine.

A flap measuring four feet by eight feet is fitted in each of the three sections of the carrier. The flap is hinged at points under the carrier shield four feet back from the leading edge, and is held under and parallel with the top shield when in an "open" or not in use position. The flap is operated by power through quadrant gears, and in operation it swings through an arc of 90 degrees into the "closed" position.

When the machine is ready to operate, i.e., when it has been winched forward and the curved shoe or toe has entered under the papyrus mat, the carrier is lowered with the flaps in the open position and the cutters are set in motion. As the papyrus is entered the cutters slice the mat into eight feet wide blocks which pass into the carrier. Downward movement of the carrier is continued until the horizontal cutters meet the front edge of the underwater shoe of the main platform.

On completion of the cut the cutters are thrown out of action and the flap is brought to its closed position, thereby sweeping the floating cut material to the bottom of the straight surface of the main platform. Then, with the flap locked in the closed position, the whole carrier is raised and the cut material is carried up to the top of the platform from which it is automatically dumped on to the rear "disposal" platform, completing the cycle of operation.

While the cut papyrus is being raised the machine is winched forward into position for the next cut and, while the carrier is being lowered, the waste from the preceding cut is disposed of. The design of the machine allows an average four foot length of cut to be made during each cycle of operation.

The counterweight tank seen at the back of the machine in Fig. 158 was added as a safety measure after the first designs were made; it also helps to reduce the horse-power needed for operating the machine.

TRAILS.

During the preliminary trials of the machine it was found that the cast iron quadrant gears for operating the flaps would have to be strengthened by replacement in steel, and that the underwater curved tow of the main platform needed modification.
It took time and a special visit to Johannesburg to arrange for the work to be done, and the end of the last field working season had arrived before it was possible to continue with trials after repairing damages caused during transit and re-fitting.

Figs. 159 to 164 show the machine in action, and Figs. 165 to 167 show some of the cut papyrus deposited on the disposal platform.

148. Unfortunately, after the trials had been in progress for a short while and the techniques of operation and management were being mastered, the cable linkages which operate the horizontal cutters broke. It was not possible to effect repairs in the field, nor was there time to re-design the parts and await their delivery.

Important final survey links had still to be completed and, as barely four months remained to cover this and permit return to Mafeking to plot the results of three years' field work and prepare estimates of the cost of carrying out the recommendation of this report, it regrettably became necessary to shelve further work on the clearing machinery.

THE TAOGE BELOW XAXA.

149. River flow in the Taoge south of the blockage varies greatly. In poor flood years water rarely reaches Tsau. In January, 1951, after two bad flood years, there was little or no flow at Xaxa—see Fig. 38. Heavy floods occurred later that year and, as stated in paragraph 139, water passed Tsau and reached Mogopudi.

There are two places a few miles upstream from Tsau where the river, when in flood, spills out and enters a number of depressions. In former times some of these led into flood areas which eventually drained towards Lake Ngami.

150. From Tsau the Taoge continues in a single channel until it reaches the vicinity of Mogopudi and Makakun where it enters a series of shallow hollows. At Makakun the channel of the Taoge becomes more defined after passing a point where water could easily escape towards the southwest and thence along a series of ancient flood channels to the west of Lake Ngami. None of these channels was followed or investigated during the surveys. To prevent losses in the Mogopudi and Makakun region it would only be necessary to build embankments, for about a mile and a half, in all.

151. The reason why flood flow in the Taoge seldom goes beyond the Mogopudi-Makakun area is that, by the time the water reaches that region, flow at and above Xaxa begins to recede and soon drops below the amount required to balance seepage and other losses. It will not be possible to maintain a continuous low flow in the Taoge as far as Lake Ngami until the river blockages

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are removed and connection is made with the vast storage in the perennial swamps.

It would be desirable to have some means for controlling flood flow in the Taoge after the blockages are cleared, but it is not apparent how this could be effectively done in the upper swamp areas other than by perhaps retaining part of the upper blockage until results lower down can be properly observed. So far as flood control near Lake Ngami is concerned, it would be a simple matter to dispose of unwanted flood water by providing diversion where the river enters the sand-belt mentioned in paragraph 105.

152. At present there are many places where the capacity of the channel of the Taoge would be insufficient to carry heavy flood discharges, and much flooding can occur within the valley of the river and in the adjoining flats where the valley is not sufficiently defined.

Evidence that the Taoge has not flowed beyond Makakun for many years is afforded by the well established thorn trees found in the river bed, as may be seen in Fig. 45, 47 and in air photograph, Fig. 189.

153. Measurement of flow in the Taoge was made a few miles below Xasa during the high floods of 1951 (July) when the discharge was 302 cusecs. It was estimated that the maximum flow the channel would take at that point without overflowing would be about 450 cusecs.

Information recorded in 1940 during the hand-clearing operations indicated that there is a loss of 1½ to 2 cusecs per mile along the Taoge; and rough measurements taken during 1951 indicated the same. On this basis the flow at Xasa would have to be maintained at a minimum ranging from 200 to 270 cusecs to enable water to reach as far as Lake Ngami during the low flow season each year.

Flow at the road bridge at Tsau was 90 cusecs in early August 1951, but it increased to 145 cusecs during the first week of September.

154. As nothing was known about the grade of the Taoge from Tsau to Lake Ngami, and it was important to know which of the numerous winding channels in the lower reaches was the actual Taoge, it was necessary to extend the surveys and follow the river closely whilst levelling.

It may be seen by reference to the information given in Plate 11 that the gradients along the dry river bed in the lower reaches are fairly consistent and are sufficient to carry water to the lake. A small dam would be required across the main channel near Beacon 7 at mile 211 to divert all flow into the spillway channel leading to the Lake. If flow in the main channel were allowed to pass this point, it would only be lost by dispersion and tapering flow, see paragraph 105.
THE KUDUMANE RIVER AND THE MABABE DEPRESSION.

155. Another part of the terms of reference of the survey was to investigate the possibilities of leading water from the Mochaba river in the north-east corner of the delta to the lower portion of the Mababe Depression for irrigation.

Reason for assuming that this might be possible was that the levels taken during the 1925 Kalahari Reconnaissance indicated that there is a considerable fall (some 44 feet) between the bed of the Kudumane river upstream from its junction with the Mababe river and the lowest part of the floor of the Mababe Depression.

The Kudumane (see Plate 3) is the name of the lower portion of the Mochaba river which is fed by water from the Ngogha-Mosachira system as described in paragraph 61. A little before the point where the Mochaba takes a sharp bend and becomes the Kudumane, the course of the river is deflected north-eastwards by a low ridge. At the bend the river (now the Kudumane) turns to the south-east to find an outlet in the Mababe river around the bottom end of the long north-to-south Magwikwe sand ridge which runs parallel with the western margin of the Mababe Depression.

156. After preliminary reconnaissance it was considered that the most promising place for diversion was at the point of the Mochaba-Kudumane bend. In order to obtain as much command as possible in the Mababe, levels were run from the bend on a low grade of 1 in 20,000 in an easterly direction towards the sand ridge. To some extent the choice of line was taken so as to make use of a rather well defined though flat waterway running in the required direction.

The route traversed from the Mochaba to the ridge and thence to the Mababe is shown in Plate 3. The levels are plotted in Plate 15 and show the nature of the obstacle presented by the Magwikwe sand ridge. The maximum height of the ridge above ground level on the west side was 27 feet and the greatest width at the base was 3,500 feet. There was no apparent sign of reduction in height or width of the ridge towards the south.

The line of levels from the eastern side of the ridge was not taken along a prospective canal route which would have entered the Mababe much further to the north; the aim was to ascertain the fall available into the Mababe at a point where much more irrigable ground could be commanded than that for which water was likely to be available.

157. Although these preliminary surveys show that it would be possible to irrigate large areas in the Mababe by water from the Mochaba if a cut is made through the sand ridge, it would first be necessary to make sure that sufficient water would always be available at the point of diversion. At present this is not
the case. Considerable development along the Mochaba and Moanchira is required before conditions favourable to the planning of diversion to the Mababe can be established.

Flood water normally reaches as far as a point about 15 miles upstream from the Mochaba-Kudumane bend but, when good floods occur, as in 1951, water finds its way down the Kudumane to its junction with the Mababe river. The floods of the following year were not as high as those of 1951, but water was found to be slowly passing along the Kudumane in August 1952, see Figs. 166 and 167.

Vegetation bordering the Mochaba and Kudumane consists of dense thorn trees, and tsetse fly infestation in those areas is intense. Between the Kudumane and the sand ridge and on towards the Mababe the thorn trees are replaced with general Mopani forest and Mopani scrub.

PART III

DEVELOPMENT.

GENERAL.

158. Almost invariably — and no doubt correctly — the reply made to any suggestion or specific recommendation concerning the possibilities of developing the resources of the Okavango is that nothing could be usefully considered until reliable knowledge regarding the flow of the Okavango and its main channels, and levels within the delta, could be ascertained. A deadlock is generally reached when this argument is followed by another suggesting that, as Ngamiland is so far away from railhead, there could be little justification in spending considerable sum of money on experiment or intensive investigation by pilot schemes to determine and prove the potential of economic development, unless it were known that a railway outlet would be likely to follow.

159. The surveys that have now been undertaken with the generous assistance afforded under the Colonial Development and Welfare Act, provide much hitherto unknown essential basic information regarding river flow and levels in the Okavango delta. The information obtained is sufficient to enable the broad outline of large-scale development to be considered, and to allow the preparation of certain ad hoc schemes to meet immediate requirements. A point about the works recommended in the report is that they will fit in with and can become part of subsequent large scale development.

Although/......
160. Although further gaugings at intermediate and at peak stages are desirable in order to prepare a reliable discharge curve for the Okavango river at Mokembo or Shakawe, existing records covering a number of years and the gaugings undertaken so far, show that much more water is available than can possibly be used for some time to come. It was mentioned previously that the mean annual discharge of the Okavango is about six and a half million acre feet, equivalent to a fifth of the total estimated run-off in the Union of South Africa.

In the light of this information, consideration of initial development rests not so much on what flow is available at the top end of the delta but on what is or could be made available towards the lower end of the delta where water is needed.

161. Although Ngamiland is an isolated and backward area, it nevertheless has a place in the future economy and development of the Protectorate.

The question of a railway outlet within easy reach of Ngamiland will be referred to later. It may be stated here that the works recommended as result of the surveys are needed for specific purposes and do not depend upon the existence of a railway. It is suggested that the works should be undertaken as part of a development plan which would determine the potential of future economic expansion and have considerable influence on future policy of railway development.

162. There is an instinctive tendency to regard ultimate development of the resources of the Okavango as one in which the whole of the delta should be reclaimed, thus making hundreds of thousands of acres of presumably good alluvial soils available for development.

Reclamation on this scale would entail harnessing the flow of the Okavango and regulating discharge along certain major waterways or canals; the Taage to serve the western areas and Lake Ngami; a channel down the central area leading to the Botlele south of Maun; the Ngogha–Gomoti, and the Makwegana Spillway. This objective could be achieved only by creating a vast storage reservoir in the 90 mile valley of the Okavango above the delta by building a dam not less than seven and a half miles long or, alternatively, by diverting unwanted flood flow towards the Chobe via the Makwegana.

But diversion would fail to provide the large storage needed in order to maintain discharge requirements during the low flow periods when the demand for water for irrigation would be greatest. However, apart from many other difficulties, the cost of development on these lines would be economically prohibitive and, as yet, there is insufficient evidence of the existence of vast areas of good alluvial soils within the delta.
FACTORS AFFECTING DEVELOPMENT.

163. Several factors have to be taken into account in planning initial development in Ngamiland. Any scheme should be based not only on results and information following a particular investigation but also on matters connected with the social, political, administrative and economic aspects of the plan.

The whole of the delta lies in the Batawana Native Reserve, and the Batawana people consider that all the water as well as the land in the delta belongs exclusively to themselves. They are quick to resist any plan or action which might in any way threaten to alter their accustomed use of water. This resistive attitude was experienced on numerous occasions during the surveys as when it became necessary to erect small dams to make travel possible in many places. The people living near some of the rivers or channels claim rights to conserve or divert water as and when they please, and they appear to do so without regard to the needs or rights of others living farther downstream. Many breaches were found to have been cut in the low banks of the Taoge along the sections that had been cleared and banked during 1940.

Taken as a whole the natives of Ngamiland are backward to a degree and take no interest in the idea of development. The total African population in Ngamiland, according to the 1947 census, amounts to only 41,700, and includes a number of different tribes. There are 13,000 Beyei and only about 8,000 Batawana. The river people, the Mampukushu, number about 5,000. The main local industry is stock breeding, and the total cattle population is about 110,000.

164. It is clear that development in Ngamiland cannot be based on settlement by Europeans, and it is equally clear that little or no progress can be achieved with the present limited and disinterested African population. It followed, therefore, that development should be planned with the aim of increasing the population by inducing settlement by newcomer Africans from outside the Batawana Reserve, after allowing for the fullest possible needs and aspirations of the local inhabitants.

165. This raises the rather difficult question of land tenure. Obviously neither the local African nor those from outside are likely to take any interest in development unless planning can be made to include a definite inducement element as well as arrangements offering security of land tenure.

As there is no ownership of land under the present communal tribal system it will be hardly possible to ensure the success of development unless steps are taken to expropriate all land within a potential area of development and reapportion it after meeting any justifiable claims for compensation. Local inhabitants should be given priority and every chance of supporting the scheme, whereafter it should be carried out.
SOCIAL AND ECONOMIC INDUCEMENTS.

166. It is suggested that the best prospect of successful development lies in the field of co-operative effort in which prospective settlers, after probationary training, should be allowed security of tenure and a share in benefits and profits.

Expansion of development would become a simple matter of initial plans and experiments were based on the principle of development by units in which the best number and size of holdings, layout, grouping of houses, cropping, rotations, cultural practice, management and other factors could all be determined and proved in actual practice.

It would be important to ensure that prospective settlers should not be allowed to regard themselves as mere paid labourers during probation and training. This could be achieved during the initial stages of development which, perforce, would have to be financed, operated and controlled by Government, by making payments to working tenants in the form of advances or subsidies which would be recoverable to the extent of proceeds realised as development progresses.

Though radically at variance with normal fiscal policy, another inducement which could do much to encourage individual interest would be to devote the major part, if not the whole, of the annual hut tax payable by new settlers to a fund that could eventually be used to meet interest on loans that may be required from time to time for economic improvements. This cannot be said to occasion a loss in general revenue because without the increased population to be brought about by development, there would be no revenue to lose.

AGRICULTURE.

167. Closely linked with the political and administrative aspects is the agricultural or practical side of development. Prospects of future economic development, utilising the resources of the Okavango, will depend to a great extent on the results of initial agricultural investigations. Until recently little has been done to improve the backward state of agriculture in Ngamiland by technical advice and demonstration, and the need for instruction in the elementary use of water for irrigation is great. No plan which envisages the construction of engineering works in the delta would be complete unless it included measures for undertaking agricultural investigations to enable full benefit of such works to be obtained.

168. It is proposed, therefore, that provision for agricultural investigations should form part of an initial five year plan of development in Ngamiland. Other items to be included in the plan are works which are recommended as result of the surveys. Not less than a five year period would be required to complete the agricultural investigations which would have to start/.....
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start from scratch and proceed on carefully planned lines as previously suggested. A lot more is required than a mere half-acre experimental plot to indicate what crops could be grown under conditions existing in the delta.

169. In order to be able to prepare clear-cut co-ordinated plans for future economic development and settlement, reliable information must be obtained at the start concerning such matters as the best size and arrangement of settlement holdings, outlay and working costs, management and overhead costs, and income to be expected. It is considered that experiment should be applied to unit blocks of land not less than some 250 to 300 acres and that the size of family holdings should be about 10 acres. The aim should be to make each unit a self-supporting profitable undertaking.

170. Details of crop varieties best suited to climate, local terrain and soils should be known at the end of five years. Clearly, it will only pay to grow produce of high market value. It is thought that rice, wheat, ground nuts, tobacco, lucerne and beans should all do well; vines (for sultanas), citrus and, in particular the date palm, should do equally well.

171. The delta covers a large area and there are marked differences in agricultural conditions in the lower north-eastern, lower southern and mid-western regions. The differences make it necessary to undertake investigations in at least three centres. For instance, the heavy soils in Lake Ngami must be tested for crops which will eventually be grown under irrigation. At many places along the Tsege the marginal flood plains present rather difficult conditions for, although flat, the ground in those areas is very broken and cut by a chain of uneven depressions, and efforts to prepare ground for irrigation will result in bringing the surface large areas of almost pure sand. Again, successful agricultural development in most of the lower north-eastern areas as well as in any "reclaimed" ground, will require close study to decide upon the best methods of applying irrigation to an intricate system of both broad and narrow irregular-shaped shallow depressions.

SOILS.

172. Soil samples were taken at numerous places during the surveys. All samples were numbered and their locations in the field are marked on the key map, Plate 2. Analyses of the samples are given in Annexure B.

While there are many places where the soils may be regarded as being good in quality and structure, nearly all the soils are sandy and deficient in essential plant nutrients and must be classed as being rather poor. Humus content is generally confined to a top layer seldom more than six to eight inches deep, and the under-
lying subsoil almost invariably consists of fine sand with traces of clay. Isolated lenses of dark clay subsoil occur here and there. Normally this rather poor class of soil is not expected in any alluvial deltaic plain, but the Okavango differs from most rivers in that it carries little or no silt, even during flood.

173. The following note on the soils in the Gomare–Tubu Island region was made by the Director of Agriculture:

"... The soils, as elsewhere inside and outside the delta, are of Kalahari origin but have developed a heavier texture under conditions which existed there.

Soil types range from brown sandy loams to dark brown and dark grey clay-loams, from twelve to over sixty inches in depth overlying light-coloured sand of varying texture.

... Black organic soils are found in the reed covered swamps. The relatively high water table throughout the area adds to the value of the soils which remain moist throughout the low flood water season.

It is of interest to note that the major soil type of the successful Vaal-Hartz irrigation scheme consists of reddish-brown fine sand and is classified as not higher than third grade irrigable land because of low fertility and poor water holding capacity.

... 10,000 to 20,000 acres of arable land are estimated to be available for crop production in this area."

FIVE YEAR PLAN AND COSTS.

174. It is recommended that there should be a five year plan to include the following:

(i) Water Control and Conservation
(ii) River Clearing
(iii) Agriculture.

Detailed estimates of each of these main subheads have been submitted to the Bechuanaland Protectorate Administration. The proposals and estimates relating to Agriculture were prepared in consultation with the Agricultural Department.

If it should be decided to proceed with a plan of development in Ngamiland, it is suggested that the responsibility for and the control and operation of the scheme should be vested in a specially constituted Board or Authority with powers to act and to be directly responsible/.......

The need for agricultural investigation in connection with the scheme has been discussed. Apart from this, it is clearly more economic and advantageous to undertake the work at a time when plant, equipment and transport required for other works could be shared, and when engineering staff would be available to advise and help with irrigation problems.

The total cost of agricultural operations during five years is estimated at £76,000 of which £17,000 is required for capital expenditure and about £59,000 for recurrent and working charges.

WATER CONTROL AND CONSERVATION.

The works recommended under this part of the scheme include the building of dykes and dams to control and divert flood flow from the central area swamp regions into the Tamalakanke and Botete rivers to increase the flow therein and, in addition, the construction of a dam and a weir on the Lake and Botete rivers respectively to provide a storage reservoir of 85,000 acre feet capacity. Details of these proposals and some of the results to be expected have been described in Part II of this report.

It is estimated that costs will amount to approximately £238,000. Of this total £68,000 is needed for technical staff and supervision, and £63,000 for working charges. Capital expenditure amounting to £38,000 is required for housing, purchase of plant, tools, equipment, transport vehicles, construction materials and means for maintaining machinery and equipment. Expenditure on capital equipment is somewhat high but it must, however, be pointed out that, if the works were being carried out in a readily accessible area, the charges could be reduced considerably. As it is, the provisions made for transporting materials and equipment from railhead (involving a four hundred mile single journey on the average) and for working in the difficult interior swamp areas, have been reduced to a minimum.

It would be impossible to rely on local transport contractors. It is estimated that the charges for using hired transport at local contract rates to deliver cement requirements alone would cost £9,000 more than the whole capital provision made for transport vehicles together with their operating costs.

The unit cost of the 85,000 acre feet river reservoir will be as low as thirty shillings per acre foot, and compares most favourably with the pre-war average cost of £6 per acre foot in the Union of South Africa.

An analysis of costs of results to be achieved by the proposed measures for controlling the flow of the Matsese and Kunyere waters is not easy. Besides

greatly/.....
greatly increasing the volume of flow on the Thamalakane and Botletle, large acreages of good arable molapo ground will be reclaimed. It is difficult to form a reliable estimate of the total reclaimed area but it is not likely to be less than 100,000 acres, in which case the cost per acre would not exceed £1.

178. Another important result of reclaiming the flood areas of the Matsobe and Kunyere systems is that it should be possible to recast effectively the plans and efforts now being made to control and eradicate the tsetse fly menace along the Marope-Naragha-Kunyere front. By drying up the numerous attractive molapos of the Matsobe system the game will be forced to move towards the upper swamp areas. The existing protective fencing could then be moved and re-erected along the controlling line of the dams and dykes. Finally, a plan for gradual settlement along the dry-land side of the fencing could be evolved as there would be plenty of good arable molapo land available as well as water under control at all dams. It may be mentioned that the question of starting settlements along the Naragha and Kunyere valleys has been considered from time to time as a means of preventing the spread of tsetse fly, but nothing has been done as it has not been possible to control the variable and uncertain incidence of flood water to safeguard the growing of crops. See paragraphs 23 and 24.

RIVER CLEARING

180. Apart from the Taoge, it is considered that the problem of clearing the numerous blockages in the channels of the delta, including the main Ngogha blockage, should be left for future consideration. Restoration of the flow of the Taoge is without doubt the greatest immediate need in Ngamiland. Not only will the clearing of the river provide great benefit for humans and stimulate the livestock industry, but it will also (a) return for good use land which becomes inundated by over flow from the river in the blocked reaches, and (b) allow water to flow to Lake Ngami where it could be used for irrigation.

181. The clearing work carried out during 1938 to 1941, and details of the work undertaken during the surveys on the design, construction and trials of papyrus clearing machinery have been described in Part II. In light of this detailed information that is now available, it would be a reasonably simple matter to effect modifications to the existing machinery to improve its performance and to design a lighter and more effective machine.

Two-thirds of the 97 miles of blockage lie in the perennial swamps. The quantity of papyrus that will have to be removed to provide a sufficient waterway is estimated to be not less than 2,350,000 tons. To do this would require three years continuous work with
four machines, each handling not less than 170,000 tons per year.

The total estimated cost of clearing the Taorge blockage is £75,000. On the basis of the abovementioned output, the cost would be ninepence per ton.

COMMUNICATIONS.

182. There can be no doubt that economic large-scale development in Ngamiland depends upon having a railway outlet. To develop a good class road across the Kalahari to existing railhead would be extremely expensive because of the prevailing heavy sand mantle and because of the entire absence of suitable road-making materials. Apart from this, long distances and the high costs of fuels and deplorable lack of facilities for machine maintenance would make the employment of motor transport an uneconomic proposition.

187. Some years ago surveys were made for a railway across Bechuanaland to connect the line south of Livingstone with the rail terminus at Gobabis in South West Africa to gain access to the west coast port of Walvis Bay. Nothing came of the proposals.

But there have been many changes since that time, and the day will come when the need for a west coast outlet will become a live issue again. It is not unreasonable to suggest that great changes may be expected in Ngamiland, and particularly in the adjoining Cobe crown land areas and the eastern Caprivi Strip by the prospect of obtaining cheap power for pumping purposes from the great Kariba hydro-electric project in Southern Rhodesia. Furthermore, it might well be desirable to have a west coast port for export of surplus coal from Wankie as the Northern Rhodesia industries will undoubtedly switch to cheap electric power.

184. There have been recent announcements in the press outlining private enterprise proposals to form a Company that would be open to public subscription to build a railway line across Bechuanaland to the north of the delta. It would be unfortunate if the proposal should receive the support of Government as an alternative to possibilities of other routes of more direct benefit to the country.

WATERWAYS.

185. Even if it were possible to count upon the prospect of a rail outlet to serve Ngamiland, there still remains the necessity for dealing with the communication problem within the delta. This was pointed out when the possibility of exploiting the potential of economic agricultural development in the Gomare-Tubu Island region was discussed. Paragraphs 131 to 133.
Fortunately, a great stride towards improvement of communications will be made by clearing the Taoge River. It would then be possible to operate inexpensive waterway transport all the way from beyond Mogembo to Lake Ngami, and this would open the way for considering practical plans of development along the whole western front of the delta.

The prospect of intensive development in the Lake Ngami area is a factor of sufficient importance to require that any railway serving Ngamiland should be brought to Lake Ngami, and this would enhance the economic value of the Taoge waterway a hundredfold.

186. Another waterway of economic importance is that which would be provided if the recommendations for constructing the Thamalakane-Bothletle-Lake River reservoir are accepted. In the absence of a railway this waterway could provide a cheap means of transport between Lake Ngami and Maun and avoid the extremely bad road conditions along the forty-two mile journey between Maun and Totten.

If irrigation in Lake Ngami should become a reality, it would be essential to build permanent all-weather roads throughout the area. Large quantities of stone would be required for this and for other works ancillary to development, but no stone is to be found anywhere in the region. The nearest source of material is at the large rock outcrops near the junction of the Lake and Botletle rivers, and is thus ideally situated for transport by waterway.

THE MAKWEGANA SPILLWAY AND THE MABABE.

187. Although not part of the terms of reference of the surveys it is felt that, before ending this report, attention should be called to the possible use of the resources of the Okavango in the development of the great irrigation potential of the Mababe Depression where not less than 300,000 acres of good soils are available for development.

The Mababe lies in crown lands adjoining Ngamiland to the north-east. It is generally regarded as an area which could be developed by taking water from the Chobe (or Linyanti) river which formerly used to flow into the northern end of the depression along the now dry Savuti channel. Except for the first few miles where it leads away from the Linyanti, the Savuti has a good gradient all the way to the Mababe.

A reconnaissance undertaken in 1944 indicated that the resources of the Linyanti would not be sufficient for large-scale development in the Mababe. But the limitation could be overcome if some of the resources of the Okavango could be added.

It/.....
It was pointed out in paragraph 25 that there is a good overall fall from the Okavango to the Linyanti along the course of the Makwengana Spillway. Although little water now escapes along the spillway, it may well be possible to alter conditions by deepening the channel. If this were found to be feasible it is felt that it should also be possible to provide a waterway to connect the lower end of the Makwengana with the nearby Savuti so as to bypass the Linyanti. This diversion need not interfere with the possibilities of taking water from the Linyanti.

Because of the asset afforded by the great economic potential of the Mababe, it is recommended that these matters should be the subject of further examination by survey when circumstances permit.

ACKNOWLEDGEMENTS

The writer here wishes to express his thanks and appreciation for the generous assistance received from the following:—

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**Remark:**

**WATER LEVELS AND FLOW DISCHARGES**

**CAUMAUX V**

**NATIONAL WATERWAYS SURVEY**

**ANNEXURE A**
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Remarks:
- Flow in narrow open channel, measured at 1.25 ft.6.