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THE INTRODUCTION OF RAINWATER CATCHMENT TANKS AND MICRO-IRRIGATION TO BOTSWANA

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PREFACE

"In the field or the backyard – grow more vegetables". So runs a poster issued for the Freedom From Hunger Campaign. Yes, but how is a peasant farmer to do it if his rainfall is not right for vegetables like tomatoes, cabbages and beans, and if he lives in a place where there is no source of water to bring on the seedlings and carry them over the periods of drought?

Every one of the millions of gardeners in England, for example, knows that he cannot do without his watering can or his hose for his kitchen garden. Every backyard used to have its rainwater barrel filled from the roof and could not do without it. Even now, many people still have these "catchment tanks", and the monthly journal "Do It Yourself" recently had an article telling its readers how to make a concrete catchment tank for themselves.

If we in England need to water our kitchen gardens, and have catchment tanks to do it with (while complaining that it never stops raining), what about the peasant farmers in those semi-arid developing countries where the rainfall is even less favourable in its distribution, although it may be quite adequate for field crops?

Sometimes these peasant village communities have springs, or wells, or are close to streams or lakes, so that they can get water to irrigate. They are the lucky ones. There are huge regions in the developing countries where there is adequate rainfall for agriculture and sufficient for drinking, but not enough for irrigation, even on the scale of a backyard kitchen garden. In Africa, for example, there are four great belts where these conditions are found. There is the mid-African Savanna belt just south of the Sahara, running right across the continent. There is the East African Savanna region and the savanna region in the south western part of Africa with Botswana in the middle. Fourthly, there is the North African belt, inland from the coast, where these conditions apply in several parts.

How are the people in these areas to get the water they need if they are to do what the Freedom From Hunger Campaign's poster tells them to do, each in his own backyard? Unless he can dig a well, or has his own spring, right in the backyard itself (which indeed is a rare possibility) or unless the government lays out a piped water supply with a tap in each backyard (which is almost as rare in the places we are thinking of) there is only one way to do it – exactly the same way we all used to do it in England and other countries, the way many of us still do it – by catching rain when and where it falls, putting it into a storage tank, and dipping into it with a watering can whenever the backyard vegetable plot needs it. That is, by having a catchment tank.

Just as people in countries such as England are learning to make their own catchment tanks, so can the country-folk in the developing countries. There is no reason at all why the "do-it-yourself" method should be the privilege of the most advanced and richest communities of the world. If a prosperous citizen in England can get himself a cheap catchment tank by doing the manual labour himself, so that all he has to pay for is the materials, why shouldn't a villager be able to do the same? – especially when the seasonal nature of his fieldwork means that he has plenty of time to do the work?

These ideas had emerged from the "Land and Water Use Survey" in Kordofan Province, in the Republic of the Sudan, between 1962 and 1966, mounted by F.A.O., an agency of the United Nations Special Fund, and executed under contract by Doxiadis Associates. Several types of "do-it-yourself" catchment tanks had been evolved, combining local materials with small quantities of imported plastic and cement, and constructed by local labour. Primarily they were intended for drinking water, but in the latter part of the Survey their application for supplementary "micro-irrigation" of backyard kitchen gardens in peasant villages began to be considered. The Kordofan Survey had come to its end before practical application to vegetable-growing could be tested.

At this point in time (1966), discussion took place in London between the I.T.D.G. and Mr Michael Ionides, who had been the Project Manager of the Kordofan Survey for Doxiadis Associates. It was decided to take the idea a step further forward at the Bamangwato Development Association's farm at Radisele in Botswana. These trials covered the adaptation of catchment tank design and construction to suit local conditions, and a series of horticultural trials to get practical assessments of the benefit in terms of fresh vegetable produce.

The results were encouraging, and the first part of the present Report describes them. Resources were not enough to enable the horticultural trials to be subjected to rigorous scientific, statistical control. But the essential feature of the Radisele climate is that vegetables such as tomatoes and cabbages cannot be grown at all on the natural rain, so that the effect of supplying water for supplementary micro-irrigation is to produce yield where, without it, there is zero yield. Consequently, the benefit would be convincingly demonstrable and appreciable to the eye, even without any measurements at all.

Having thus established, in a very practical way, that rainwater catchment tanks could do the trick and enable the peasant to grow vegetables in his own backyard, the next question came automatically into the picture. How to show him how to do it?

There is no "Do It Yourself" magazine in Botswana. Neither F.A.O. nor any other United Nations agency has yet got around to producing one. It still remains the prerogative of the rich and prosperous peoples to have journals showing them how to get something for nothing by putting their own manual labour into it instead of paying someone else to do it. Nor is it only the poor who do it. Millionaires can be seen fixing up their catchment tanks and dipping their watering cans in.

But not yet for the peasant, though I.T.D.G. is on the trail. The plan formed was to see whether the rural schools could be used, as a channel for showing people how to do it. A number of school masters could be brought to Radisele for a short training course. They would be given the materials and tools for a couple of tanks and backyard kitchen gardens at each of their schools, and they would then pass on their training to the children by showing them how to construct their school tanks and how to use them for growing vegetables.

A "work-plan" for this Project was formulated in late 1966 by I.T.D.G. with the collaboration of Mr Michael Ionides (and indebtedness to Doxiadis Associates of Athens). Early in 1967 Oxfam agreed to finance the project, with a Voluntary Service Overseas assistant. Supervision at Radisele was in charge of Mr Vernon Gibberd, agriculturalist, and Mr Paul Moody was appointed to the V.S.O. post. The Project began in August, 1967, and ended in August, 1968. By that time, the team from the Reading University Department of Agricultural Economics was at work in Botswana, under the direction of Dr Douglas Thornton, in other, but allied, missions, and became familiar with the Project.

In October, 1968, when the project was completed and Mr Paul Moody had returned to England, it was decided that a full Report should be made, covering the initial work at Radisele and the Oxfam school-garden Project. The main body of the Report was written by Mr Paul Moody. The final version incorporates additions and amendments arising from comments and joint discussion with Mr Michael Ionides, the Reading University Team, led by Dr Thornton, and the I.T.D.G. staff, led by Mrs Julia Porter.

ACKNOWLEDGEMENTS

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I.T.D.G. also thank the Departments of Government in Botswana, and the Organisations and individuals, both there and in the U.K., who contributed so much to the Project and its evaluation.

Those who played a leading part include:

Mr. Michael G. Ionides, of Doxiadis Associates, whose original work on the design of Water Catchment Tanks using polythene as the main material made the idea of low-cost water conservation a practical possibility;

Mr. Garth ap Rees, the U.N.D.P. Resident Representative in Botswana;
The Ministry of Labour, Education and Social Service, the Department of Agriculture, the Education Committee of the Central District Council, Bamangwato Administration, and the Bamangwato Development Association;

Mr. Vernon Gibberd, formerly Agricultural Adviser to the Bamangwato Development Association, who conducted the original trials in Botswana and who supervised the Pilot Project;

Voluntary Service Overseas, who supplied a volunteer, and Rowen Engineering who sponsored the volunteer;

Mr. Paul R. Moody, the volunteer who was responsible for the day to day workings of the Pilot Project and who spent much time on the writing of this Report;

Dr. Douglas S. Thornton and Mr. Martin Upton of the Department of Agricultural Economics, University of Reading, who, with Mr. Ionides, gave considerable help and guidance in the writing of this Report.

I.T.D.G. Ltd.,
LONDON,
SEPTEMBER, 1969.

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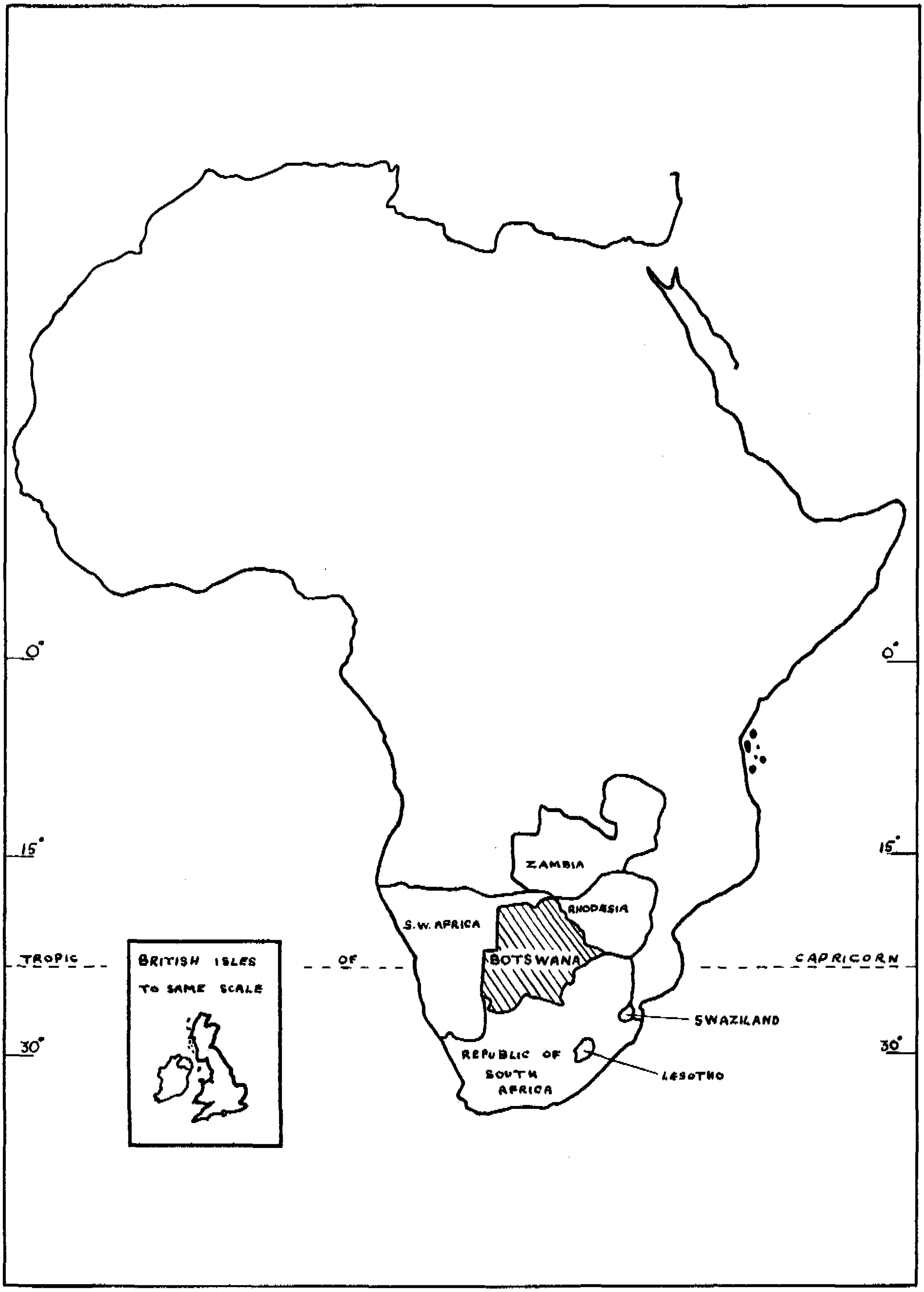


FIG. 1. Botswana – its Continental Setting.

I. INTRODUCTION

A. THE COUNTRY OF BOTSWANA

1. General

576 000 km² = 16 x Nederland

Botswana is a vast country of 225,000 square miles with a low rainfall and a long dry season. Much of the country is a relatively featureless, gently undulating, sand-covered plain with low scrub vegetation. Nearly 75% of the total population of 540,000 (in 1964)* live in the east of the country, that is to the east of the sandy plain, in the more developed region which is traversed by the railway from South Africa to Rhodesia. (See Figs 1 to 3)

Botswana is not economically self sufficient: its economy is centred on livestock and arable agriculture, but the export of meat is insufficient to provide the foreign exchange necessary to pay for essential imports, and the country relies heavily on development grants from other countries. Recently, exploratory work has been started to evaluate the mineral potential of Botswana, but as yet this does not contribute noticeably to the economy. It is hoped that within the next ten years the production of minerals will make a sizeable contribution to the economy.

2. Physiography

The land surface of Botswana is a slightly basin-shaped plain, lying mainly between 3,000 and 4,000 feet above sea level. About 85% of the country is covered by geologically recent wind-blown or fluviate sands of the Kalahari system.† (See Fig 2)

3. Vegetation

Reference to Fig 3 shows that the vegetation over most of the country is very sparse, being desert grasses and shrubs. However, in a few areas the desert grasses give way to more dense forms of vegetation. This sparseness is due both to the type of soil (predominantly sandy) and the low rainfall (see Fig 4).

4. Rainfall

From Fig 4 it can be seen that at Mahalapye the rainy season is short, and this is typical of the whole country. Emphasis is placed by the people on ploughing and planting sorghum during and immediately after the rains, and on the tending of cattle during the long dry season. However, the total amount of rainfall from one year to the next is very variable, and this can create large problems of food shortage. Also the rainfall may be of considerable quantity but also torrential and is therefore quickly lost in flash floods, thus benefiting the people very little.

Futher, evaporation is great (see Fig 4) and therefore a considerable part of the total rainfall is lost in this way.

All of these put a premium on water storage and control for existing crops and livestock, for drinking water and for supplementary cropping (including horticulture).

5. Temperatures

As may well be expected of a country partly situated within the tropics, the air temperatures in Botswana are high, as the diagram of mean temperatures at Mahalapye shows. (See Fig 5). The temperatures indicated in that diagram are fairly typical of the country as a whole, although local variations will always occur.

* "The Development of the Bechuanaland Economy"–Report of the Ministry of Overseas Development Ecomomic Survey Mission (November 1965)

† "Land Resources of Eastern Bechuanaland." M. G. Bawden and A.R.Stobbs (Directorate of Overseas Surveys)

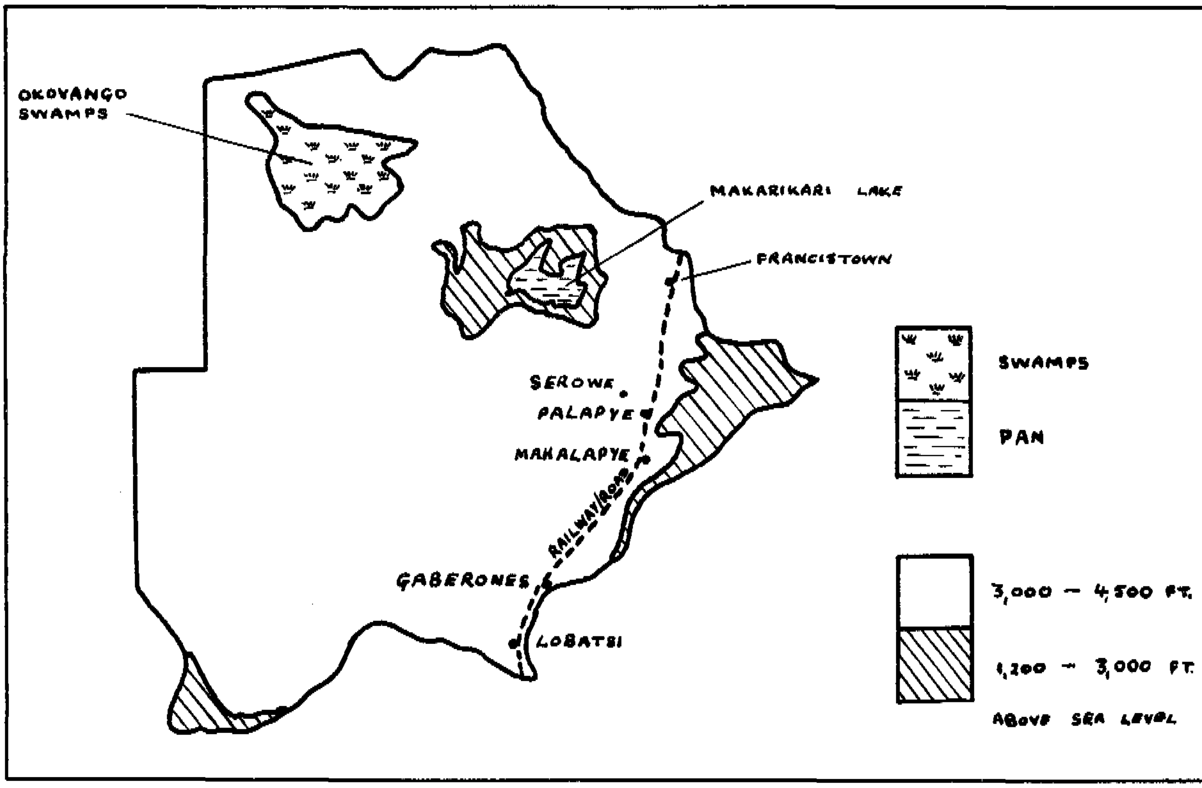


FIG. 2. Botswana – Relief.

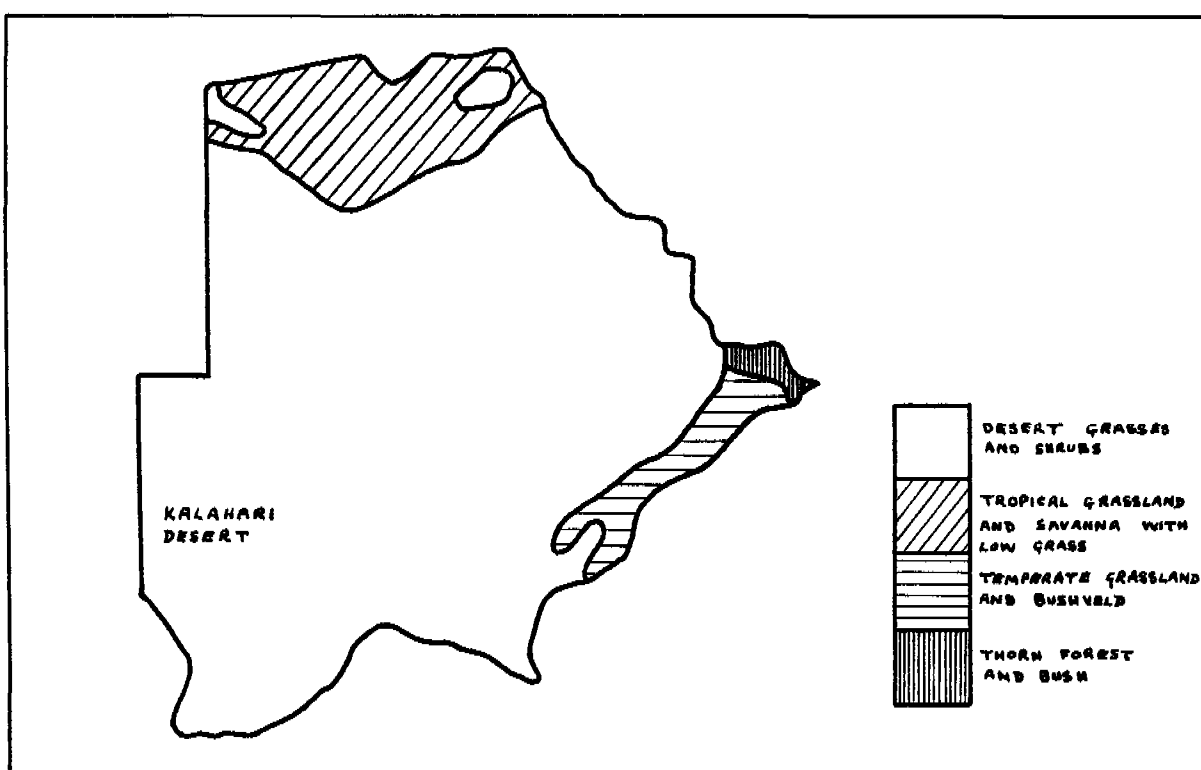


FIG. 3. Botswana – Vegetation.

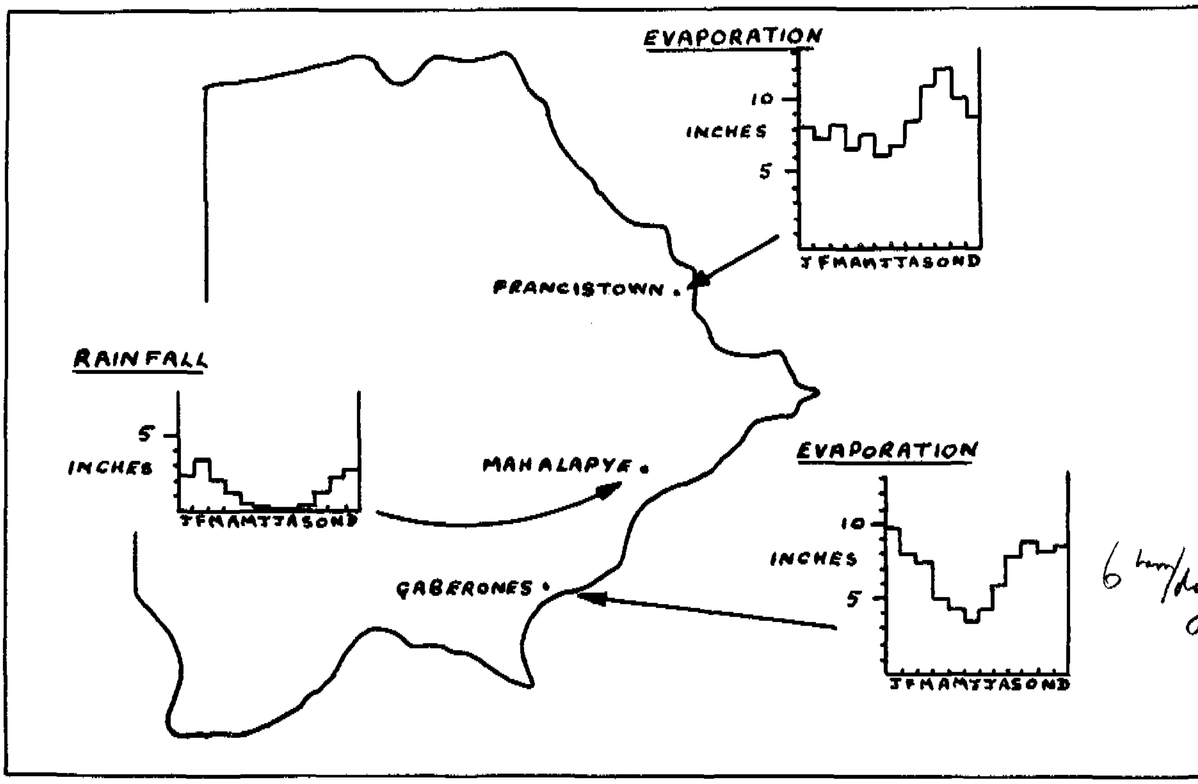


FIG. 4. Botswana – Mean Rainfall and Evaporation

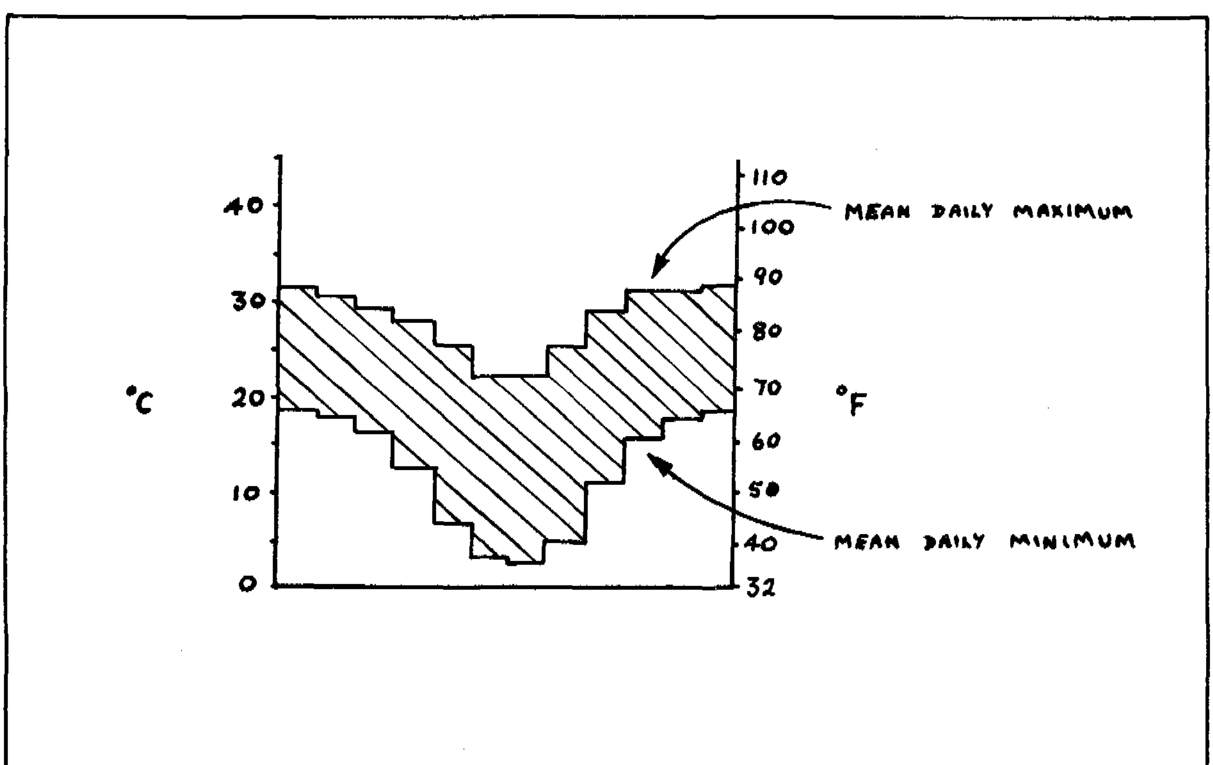


FIG. 5. Mean Air Temperatures at Mahalapye.

B. HISTORICAL RECORD RELEVANT TO THIS REPORT

During the years 1960 to 1966, Botswana as a whole was in a state of drought. Rainfall at Mahalapye during those years averaged 14 inches per annum. However, all of the rain fell in insignificant showers too late to be of any use agriculturally. Evaporation averaged 90 inches per annum. One report puts cattle losses during the year ending September, 1965, at 300,000. There was widespread malnutrition and famine and considerable general hardship.

Famine relief contributions received from all major sources from 1959 to early 1966 amounted to about £95,000. However, it is not possible to give exact figures for contributions to Botswana but these figures give a good indication of just how the country suffered.

The famine relief scheme during the drought years provided a basic but balanced diet. With the resumption of a regular rainfall pattern (or so it seemed) in 1966/67, making it possible to increase the national herd and to resume arable agriculture, the relief scheme ceased. However, during the year 1967/68, to which this Report refers, rainfall was small and late, resulting in few crops being planted. Relief restarted in early 1968 when it was realised that those crops that were planted would not only be very poor but also inadequate.

The normal pattern of farming, i.e. with adequate rain at the best time, does not in any case provide a balanced diet. In other countries this is compensated for by the widespread practice of working small irrigated gardens for producing a certain amount of fruit and vegetables throughout the year. In Botswana, however, due to the lack of cheap water this is impossible.

The following figures give some indication of the rainfall situation:

(i) Rainfall for 1967/68 Season at Radisele

Total Rainfall	10.7 inches
Length of Rainy Season	88 days
First significant Rain	15th February, 1968
Details of the numbers of days with rain:	
Less than 0.16 inches	11 days
0.16 to 0.32 inches	11 days
0.32 to 0.47 inches	2 days
0.47 to 0.63 inches	2 days
Over 0.63 inches	4 days
Total number of days with rain	30 days

(ii) Longest Drought Ever Recorded

The longest drought recorded since records were first made in 1961 was of 61 days duration. The average duration of drought is 22 days. (These are of course the numbers of consecutive days without rain during the rainy season).

C. TRADITIONAL WAYS OF OBTAINING AND USING WATER IN BOTSWANA

1. Surface Water.

(a) Springs

These exist only in hill areas and are therefore rare. (Botswana is a predominantly flat country). The springs that do exist are used extensively. However, many have salty water, which can be used for nothing except washing clothes. Cattle will drink water from such springs and food can be cooked with such water, but only when other sources have failed. Those springs with good water are rarely used for watering cattle – the cattle have to be taken up-hill often through rocks, or else the water has to be borne down by cart..

The traditions of the country virtually prohibit piping of water from springs. Many cases exist where springs could be tapped and the water piped to the villages below. However, there have been cases where springs were piped and they immediately dried up. (e.g. At Moeng College a spring was dammed on a large scale and pipes put down to the school ½ mile below. The spring ran dry within six months for no apparent reason). Because of instances such as this the people are wary of allowing water from springs to be piped. This traditional belief cannot be overcome until a sufficiently good explanation is shown to the people that the drying up of the springs is in no way caused by the piping thereof.

(b) Pans

These are shallow natural depressions in land, filling with water in rain. They are mud-filled and usually have very coarse grasses growing in them. Few, if any, are fenced off; certainly no grazing control is practised in the immediate vicinity of any of them. The land around them rapidly becomes bare and grassless, with innumerable cattle tracks leading to them, from as far away as four miles in some cases. In an aerial view the impression is given of a wheel, with the pan being the hub and the cattle tracks the spokes.

Being mud-filled (cattle trample and dung in them) they retain water for long periods but have a high loss due to evaporation. The majority of pans are small, they are usually circular with a diameter of between 10 and 60 yards. A few are the size of lakes; e.g. Lecheng (= 'lake'), which is near Palapye and is up to a mile wide. The water in them is used almost solely by cattle and goats. Stock are either brought to them specifically for watering or else naturally tend to graze around them. This aggravates the overgrazing problem all the time. Occasionally the water is used by the local people for cooking, though rarely for washing clothes as the water is invariably too dirty. A surprising fact is that the people of Botswana seem to suffer no ill effects through drinking the water so obviously laden with bacteria—yet if the water was drunk by a European, illness would undoubtedly occur. Pans are the most widely used supply for watering cattle (discounting private boreholes). They are the most reliable source of naturally-lying water.

(c) River Beds

Most rivers in Botswana only run in heavy rain, and for a short period after rain. They are filled with well washed sand and gravel—often to a great depth. (10 feet is not uncommon in the Mahalapshwe). The sand retains a large quantity of water and the traditional method of obtaining such water is to dig a hollow in the sand and let it fill with water seeping in from the sand. The hollow becomes progressively deeper as the season goes on. Variations on this include a 40 gallon oil drum, perforated and with the top and bottom plates removed, driven down into the sand, which is then scooped out. Water seeps in through the perforations and is drawn out by bucket or pump. Concrete sumps are also used to obtain water in this way. (Mahalapye's piped water supply comes from two of these concrete sumps; they are 20 feet wide and the water is is drawn out be centrifugal pumps on the river bank). Water is removed from the hollows and sumps either by bucket (and then carried in the bucket) or else it is poured into a donkey-drawn bowzer. The quality of the water is usually good—in fact the sand has a definite filtering effect upon the water. However, there is rarely any control over stock, so water in the hollows is soon spoiled. This source of water cannot be relied on for more than a year without recharge (Mahalapye's piped supply was rationed in early 1968—the last rain being in April 1967 and the next exactly a year later). The water would of course last far longer if the vast number of holes were covered to prevent evaporation.

(d) Dams

The word 'dam' in Tswana refers to any way in which water is held naturally or artificially. So a catchment tank can be a dam, as well as what we know as a dam—a barrier in a flow of water.

There are a number of true dams in Botswana (the most well known being at Gaberones and Palapye). The reservoir behind the dam at Gaberones is of considerable size—in one place it is two miles wide. It supplies water to all of the Gaberones area throughout the year; water rationing does occur however, indicating scarcity of water in the reservoir at the end of the dry season With the vast surface area of the reservoir evaporation is of course considerable. Fishing and sailing take place on the dam, but bilharzia is present, rendering it dangerous for swimming. (See Plate 1). In Palapye a small stream is dammed. This stream only runs during and immediately after rain, but the wall retains sufficient water for the town for most of the year.

Generally a 'dam' in Tswana refers to a wall of earth built to catch run-off water. A large number of these dams were built be Ipelegeng labour (a food-for-work programme famine relief scheme in 1966-67.) Some were poorly sited but the majority were well situated to catch a large volume of run-off water. They are usually semi-circular or horseshoe-shaped, with the wall made from the soil excavated from the centre. They are shallow, though some between six and seven feet deep just after rain can be seen.

As with pans little or no grazing control is practised and the same problems recur here: bareness of the surrounding area and dirty water. As cattle are the major users of dams, the beds are well trampled mud, giving excellent water retention properties. Loss of water by evaporation and by seepage through the walls is very great (theoretically over 100% of the water stored). All dams except the larger ones, dry up within three to nine months of the last filling rain.

(e) Tanks and Catchment Tanks (both open and covered)

Both of these are rarely used by the native population, except in certain cases where tanks have been supplied by government (e.g. at some schools) or by other sources (i.e. the Pilot Project).

Tanks are expensive to buy and only the richer people can afford them; also there is always the fact to consider that 99% of the population live in thatched huts, which cannot easily have a gutter attached and so a tank cannot be filled. The European Community's houses in all areas invariably have corrugated iron water tanks filled from the roofs, the water being used for watering gardens. All schools, government buildings, stores, etc. that are suitably built, have water tanks. Generally, corrugated iron tanks have a capacity of between 1000 and 6000 gallons. The water held in this way way is clean and the method of storage is becoming increasingly popular. Catchment tanks, as this report will show, are a very recent innovation. None have been built other than those at Radisele, at eleven schools in the Project, and by the Community Development Department training courses at Mochudi, Serowe and Tsabong.

2. Ground Water

(a) Wells

The word 'well' ('Sedibeng' in Tswana) refers to two kinds: the first is that which we know as a well—a shaft in the ground into which water seeps, and is drawn out by a bucket. A number of these exist throughout Botswana, but as with some springs, many have salty water—presumably caused by the rocks through which the water flows while underground. The other type to which the word refers is a hollow scooped out in the ground and into which water seeps (see Plate 2). The action is the same as in river beds but in this case the hollow need only be on lower lying ground—or where the water table is near the surface.

Both types of well have clean water—the latter only if it is well protected from stock. They are reliable supplies much used in Botswana.

(b) Boreholes

Many boreholes exist, primarily in towns, but they are widespread wherever a community with a water supply problem is present. They are costly to drill and very

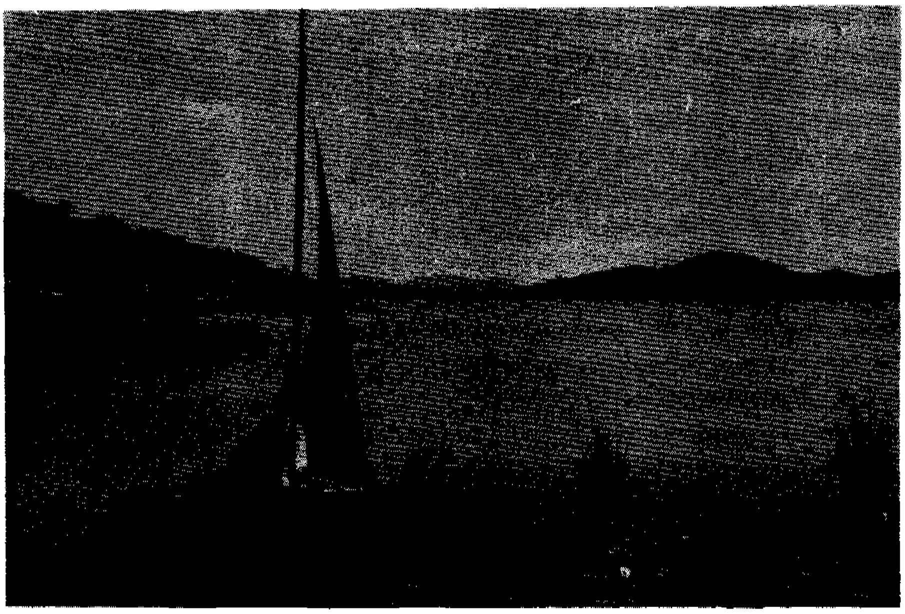


PLATE 1. The Reservoir at Gaberones Dam.

PLATE 2. One traditional type of Well – a hollow scooped out in the ground into which the water seeps.

often many trial drillings have to take place before a successful shaft is made. Boreholes and the ancillary equipment, such as pumps and reservoirs, are above the means of all except communities as a whole, the Government, large farms and establishments such as Bamangwato Development Association. The water from boreholes is clean, though occasionally salty. Volume of supply varies very greatly, being anything between 100 and 2000 gallons or more per hour, dependent entirely on the siting of the shaft. 0.5 — 10 m³/hour

3. **Uses of Water in Botswana**

(a) Cattle Watering

This is the largest use of water. Botswana is a cattle country and cattle mean money and and money means food for the population. As long as the cattle thrive then there can be little fear of famine.

(b) Drinking

Batswana can apparently make do with drinking water which is far from clean.

(c) Cooking

(d) Washing—Personal and Clothes

Batswana prefer clean water for washing themselves and their clothes.

(e) Irrigation

Until recently (i.e. in the last ten years) no irrigation on anything but the smallest scale was practised. However, with the advent of boreholes, superior agricultural and mechanical techniques, some richer farmers can now irrigate. (In the Tuli Block farms, run by white South Africans and Europeans etc., irrigation of all crops is widespread. However, for these non-Batswana farmers, capital is not a problem and also in many cases they have access to markets which are not readily available to farmers in other parts of the country. Most of the irrigated farms are adjacent to the River Limpopo or its tributaries which are running rivers in some degree for the most part of the year. Irrigation in these cases is an integral part of the farm.)

It is impossible to state how irrigation could be spread simply and cheaply, but with more conservation of water it is hoped that micro- and macro-irrigation will become in time a fully contributory factor to the economy of Botswana.

D. REASONS FOR WATER SHORTAGE IN BOTSWANA

1. Limited Supply

The lack of rain is, of course, the prime reason: nothing can be done about this, except in perfecting methods of conserving what rain does fall. In every single year, rain does fall even though it may be in insignificant showers spread over the eight months from September to April. Even these showers are enough to replenish catchment tanks and, more often, pans.

Evaporation of surface water supplies further aggravates the shortage.

2. Increasing Demand

With the spread of arable lands, water sources become further away from homes. 95% of the population travel between their lands (cultivated arable areas) and towns—going to the lands to plough and harvest for part of the year and in the remaining part of the year they are working in towns or villages. With this semi-nomadic way of life any one family must have two sources of water—one for the lands and one for the villages and towns. Normally villages have their traditional supply of water not too far away (the villages have grown up where there is water available most of the time). At the lands, however, water may be very far away—up to six miles.

An increasing population means that more crops and livestock are necessary to maintain the present level of living standards; and a striving for better living standards means that even more crops and livestock are necessary to make possible the purchasing of non-essential living commodities.

Such increases in crop and animal production are reliant more upon increased rural water supplies than any other factor.

II. THE POSSIBILITIES OF WATER CATCHMENT TANKS IN BOTSWANA

A. BACKGROUND AND DESCRIPTION OF WATER CATCHMENT TANKS

A system of conserving rainfall in excavated pits was developed in the Kordofan Province of the Sudan, by Doxiadis Associates under a United Nations Special Fund Project, during the years 1960–66. The system is labour-intensive using unskilled labour throughout, materials used are almost totally available naturally and locally, and a bare minimum of imported materials is necessary.

Results in the Sudan indicated that the system could be admirably suited to Botswana–the only difference being in the use of the water, once held. In the Sudan the catchment tanks were designed specifically for holding drinking water for villages, whereas in Botswana the tanks were made for use in irrigation.

A "Catchment Tank" is simply a tank or cistern, in the ground, with a "catchment apron" alongside, which catches the rainfall so that it runs into the tank, where it is kept in store until it is needed. It is an ancient way of obtaining dry-weather water wherever there is no better or cheaper way.*

The Catchment Tank Design which was evolved in the Sudan and which was introduced to Botswana is described in detail in the article already quoted from by M. G. Ionides, and given in full in Appendix I.

However, to outline very briefly the main points of the design, the tank is an excavated pit which is lined with polythene sheeting or a rubber membrane to make it watertight; an area of gently sloping ground is used as the catchment area, in order to provide the necessary run-off of rain to fill the tank; and a cover is put over the tank to prevent evaporation of the water during storage.

Obviously a number of practical difficulties arise in the construction, and to overcome some of these, which include the availability of much unskilled labour and the non-availability of skilled labour, a system of sausages of concrete in polythene tubes has been developed to provide a concrete revetment which requires no shuttering or reinforcement of the traditional kinds.

The most important point about the tanks is that in an area where there is rainfall, albeit a very low amount, a supply of water which will be available throughout the year is quite possible – provided, of course, that consumption is regulated to a low enough rate so as not to exhaust the supply in the first few months.

B. POSSIBLE APPLICATIONS FOR BOTSWANA

1. The Problems

As was shown in Part I (INTRODUCTION) one of the great problems of Botswana is malnutrition, which can be directly related to the shortage of water. Even in 'good' years there is not such a bountiful supply of water that a reasonable supply of vegetables are grown to provide a balanced diet: indeed, vegetables hardly figure at all in the diet of the rural population.

If the means of providing an all-the-year-round water supply were found, then it would be possible to grow better crops, especially of a nutritionally-rich vegetable kind, in order

* M. Ionides "Rainwater Catchment Tanks" · I.T.D.G. Bulletin No. I (See Appendix I).

that the people might benefit from an improved diet and the associated benefits of good health and resistance to disease, etc.

2. How Catchment Tanks Can Solve the Problems

From what has been said already, it is evident that catchment tanks are a very likely means of solving the water shortage, and hence malnutritional, problems of Botswana.

As well as the general concept of water catchment tanks solving the water shortage problems, there are other points inherent in their design, which make them far more suitable to Botswana's situation than, for example, a very large scheme involving a big dam and canals or pipelines hundreds of miles long. They are:

(i) The greatest possible use can be made of the skills of local people.
(ii) The least possible use need be made of professional or skilled persons. From this it can be seen that the sooner the indigenous people are shown *how* to make the tanks and ancillaries the better it is for future work.
(iii) The maximum use of natural and locally available materials can be made. There must be only a minimum use of materials which are bought for cash – important especially when a transaction involving foreign exchange is envisaged.
(iv) The minimum use of imported items must be made. These involve a degree of upkeep usually beyond the financial means of local people in a developing country, and a higher degree of knowledge for their function than is within the capabilities of the people.

Although the present Report is concerned with the use of water from catchment tanks to raise vegetables by intensive micro-irrigation, the supply of drinking water for man and beast is also a potential application for catchment tanks. On a farm where animals are used for ploughing and where a herd is kept, there are three distinct points of water consumption. For some purposes, water must of necessity be available inside the household, and unless there is a well situated at the household itself, or a water supply by pipe, then all the water has to be carried there – unless the rainwater can be saved and stored. The animals that pull the plough must drink, and if they have to be walked off to a dam or a borehole, that is time and energy lost – but catchment tanks can be placed literally anywhere, to suit the needs. The grazing herds are different, because they can drink at a dam or a borehole and then go off to the pastures, and their circuit of travel is "all in the day's work".

III. THE TRIALS AT RADISELE

A. INTRODUCTION

In view of the general feeling, expressed in the previous section, that water catchment tanks would be of great benefit to Botswana some preliminary trials were held at the Bamangwato Development Association at Radisele. The trials were intended as the first check as to whether there were any fundamental reasons as to why the tanks should not be suitable, although no such reasons were envisaged.

The research into tanks and micro-irrigation* in Botswana began in September 1966. Mr Vernon Gibberd, then Agricultural Adviser to the Bamangwato Development Association, built two mud/polythene tanks purely as trials to determine how suitable the design was when applied to Botswana. Both tanks gave good indications as to a suitable method of construction for Botswana.

The water from these tanks was used on a small intensive garden adjacent to the tanks. No commercial proposition was envisaged in the garden (though returns paid for seed, etc.) because it was constructed purely to determine (i) how much water is necessary to keep plants in condition and to give as good a fruit as possible with the available water quantity and (ii) the value of water related to growing nutritious crops in (relatively) small quantities.

The nature of the research was at the start necessarily trial and error—nothing of this kind had been done before in Botswana or elsewhere. The trials were viewed as pilot research work. Because of this there were a number of failures in crops due to too little water being applied. Later on a good proportion of crops planted attained excellent results both as regards yields and consumption of water.

B. THE TANKS AT RADISELE

1. Siting of the Tanks

Few problems occur in the siting of tanks. The main factor which must be borne in mind is the quantity of water flowing from the catchment area into the tanks. It must be sufficient to fill it with minimum rainfall, yet should a heavy rainfall occur then there should be an outlet for surplus water, and some degree of protection against large volumes of water flowing over the site and conceivably causing damage. Rain water flows in traditional paths and although a knowledge of the immediate area is helpful it is not essential. It is quite possible to determine on site in which direction the water flows and roughly how much flows. There are no perennial streams in Botswana, though 'streams' do run during and immediately after rain, forming channels along which the greater volume of water flows.

The best site for a tank is near or in a road or track. One feature of roads in Botswana is that in rain they are all rivers. They are well worn, hard surfaced and bare, giving tremendous run-off with little water being absorbed. Land is so plentiful that roads can be diverted round the site very easily—few people object so long as the reason for the diversion is fully explained to them. The original road can then be 'dammed' by putting a bank of soil across it to guide water from the road into the tank. (See Fig. 6).

In the preliminary trials carried out at Radisele by V. Gibberd, one tank was sited less than 40 feet from a track. The catchment area for this tank was estimated to be in excess

* Micro-irrigation: a term used to describe irrigation on a very small scale—sometimes the water is applied with a watering can or similar vessel.

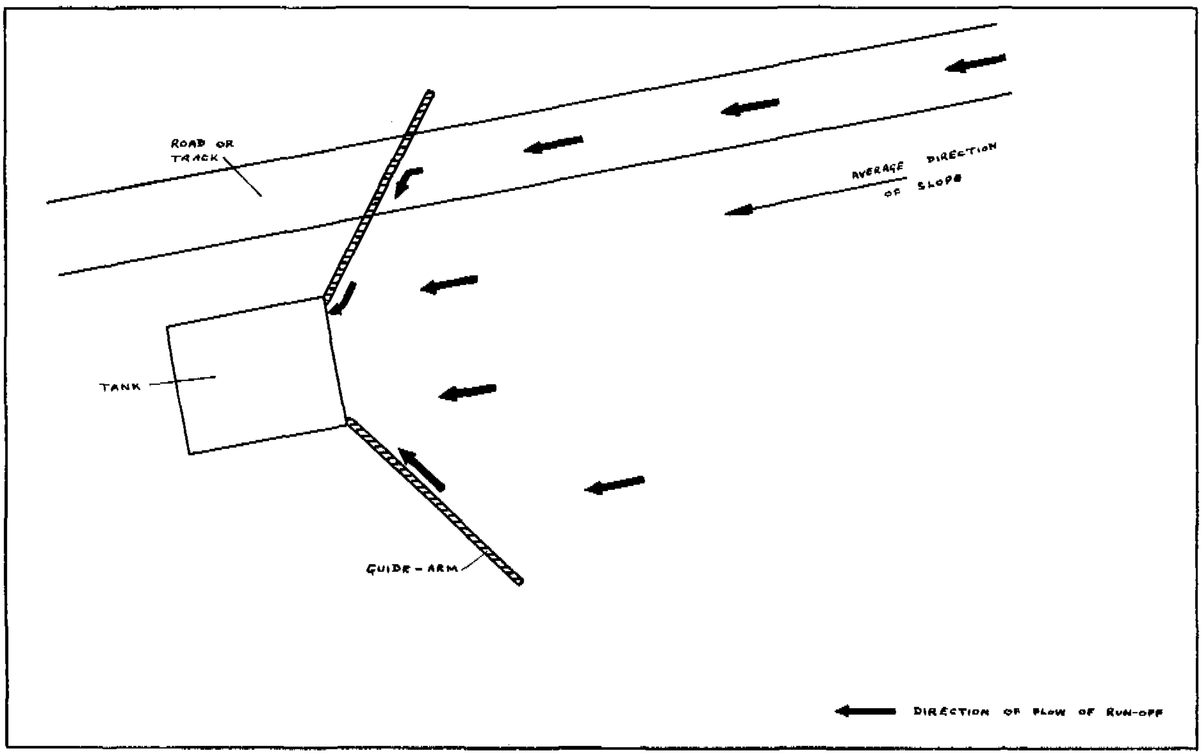


FIG. 6. Schematic illustration of a Roadside Site for a Catchment Tank.

of 2 square miles with the majority of the run-off water flowing along the track. This volume of water was enough to fill the tank many times over (in the design an overflow is provided). The entire run-off from the 2 square miles could if necessary be harnessed for use.

2. The First Tank at Radisele

The first tank built was of 8000 gallons capacity (See Appendix 2 for V. Gibberd's Report of 1.12.68). It was not built to full specifications of the semi-proved Sudanese design as these had not been received and it was necessary to start construction as soon as possible. This tank had three alternate layers of mud and polythene with insecticide mixed into the first layer of mud (i.e. the layer directly in contact with the sides of the excavation). Excavation itself was done by hired labour. The size of the tank was approximately 16 ft. by 12 ft. with sloping sides and a depth of 6 feet.

A revetment of reinforced concrete sausages protected the inner linings. The inflow side fell in during filling, because in this trial tank there was no extra protection given to counteract the tremendous force of the inflowing water, (approximately 2,000 gallons/min.) 150 l/sec
Also the full specification allows for a further layer of mud and polythene with a spacer revetment of sand sausages between layers 3 and 5. (The concept of the sausages will become apparent when construction of the tanks to full specification is described below). 550 m³/h

The tank was covered by black polythene on wire netting supported by a pole framework on concrete sausage pillars.

Once the reason for the collapse of the inflow side had become apparent and the water which was retained had been used or soaked away, the lining was replaced and rocks were placed on the floor of the tank to break the fall of the water. However, in spite of these precautions and changes the tank was still unsatisfactory and was losing water at an impracticable rate.

3. The Second Tank at Radisele

The second tank at Radisele (to full specification) was built purely to finalize the design of tank to be used in the Pilot Project*

This tank utilized for its water collection, the overflow of the first tank (See Fig. 7). It was directly below the first, in the line of flow of water. Dimensions of the tank differed from the first only slightly—the length was 20 feet, width 16 feet and the depth 6½ feet. The inflow side was slightly rounded against the great force of water likely to flow over the edge.

The excavation as before was carried out by V. Gibberd and a certain amount of paid labour, with help from volunteers from the community at B.D.A. The soil was virtually stone free. Once the excavation was roughly complete, the sides were sloped and smoothed, leaving a finish that would hold mud easily, with no sharp projections. The slope was roughly 6½ feet in 1 ft. (in fact later trials indicated that this slope was too great for easy and successful construction). Mud and sand were collected and piled near the site so that no time would be lost through carrying material from some distance to the tank. At this stage it was essential to prove that the methods employed in construction were transferable to the proposed schools' Project. It was also essential to prove that the tanks held water satisfactorily, in order to prove to the sources of finance that such a project would be of some benefit.

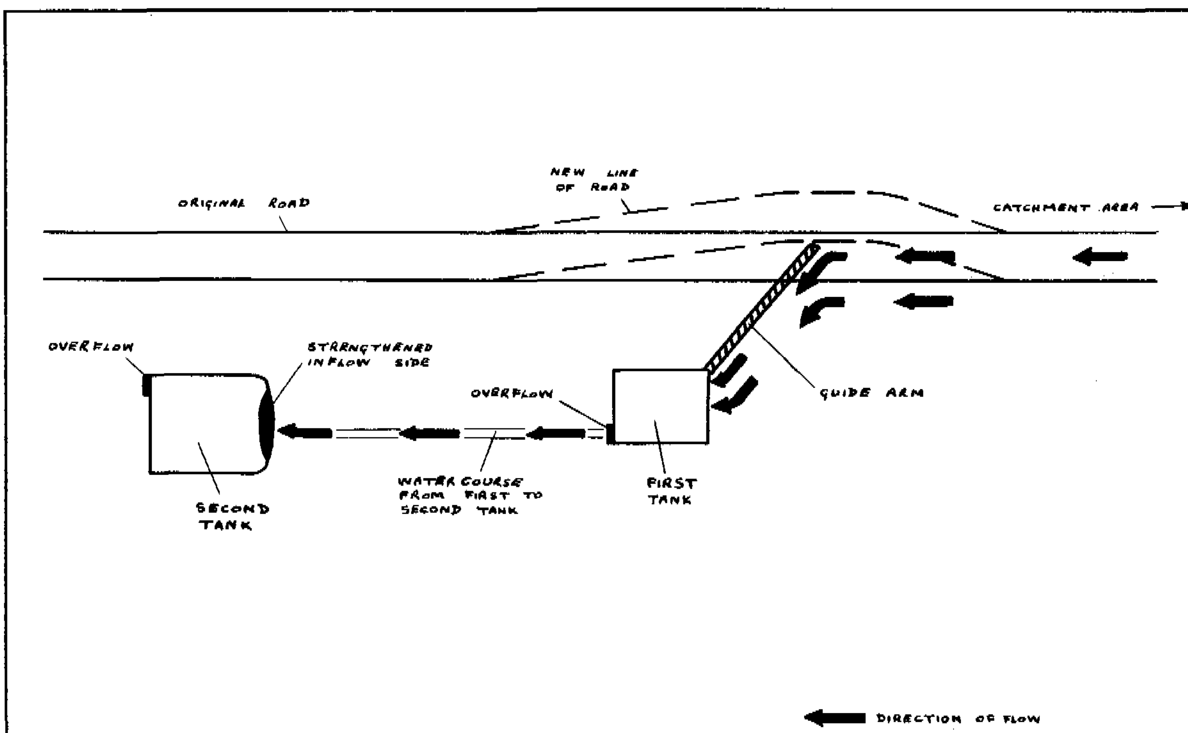


FIG. 7. Diagrammatic layout of the first two Trial Tanks at Radisele.

* An outline description of the types of tank based on the design of mud/polythene/sausages, can be found in Bulletin No. 1 of the Intermediate Technology Development Group, which is reproduced here in Appendix I. Full details were covered in the reports, submitted by Doxiadis Associates to the Food and Agriculture Organization, on the results of the Land and Water Use Survey in Kordofan Province of the Republic of the Sudan. This survey (1962–66) was financed jointly by the United Nations Special Fund and the Sudan Government.

4. The Construction of the Tanks in General

The following is a detailed description of the construction of the second tank at Radisele, a construction which was common to all the mud/polythene lined tanks made during the Pilot Project.

(a) The sausage concept

Before describing the construction in general it is necessary to outline the concrete sausages that form an essential part of the design.

Basically, the concrete sausages consisted of a sand/cement mix inside a polythene tube which was used as a building block to construct pillars in the middle of the tank to support the roof, or as a revetment to the sloping sides of the tank. (See Plate 3 where the sausages are clearly visible in the foreground).

The method of making the sausages was as follows: thin polythene tubing (made of polythene of 1½/1000 inch thickness) was cut into lengths and tied at one end. The tube was then filled with a *dry* sand/cement mix in the ratio of 14 parts of sand to one part of cement. (The normal ratio for mortar used for brickwork is 3 to 1, so it can be seen that a great saving on cement was made). The other end of the tube was then tied – the most satisfactory length of sausage was found to be about 18 inches, with a thickness of about three inches.

A stockpile of such sausages was made so that they could be used when needed and without delay. The work of filling the sausages was done solely by an old man, the work being light but monotonous; his wage was ¼c (about three tenths of a penny) per sausage completed.

Immediately before use the sausages were perforated with a number of small holes in a line along the length, they were then laid with the perforations downward in ½ inch of water in a tray and left for five minutes. In this time the water seeped up into the sand/cement mixture by capillary action, thoroughly moistening the mix, but not saturating it.

The sausages were then laid in place, in exactly the same way as bricks, but with no mortar. Instead they were tamped down using a flat board to bind them together. As the mix was in an enclosed space it could not dry out quickly (a point more especially important in a hot country) and so the cement was able to cure fully, creating maximum strength, which would not be possible if the mix had dried out in a few days. (Cement takes over four weeks to attain its full strength during which time it should not dry out). This is why a much smaller proportion of cement was permissible than in ordinary brickwork mortar, where the cement dries out after a few days.

In order to further bind the sausages together, 9 inch lengths of Gauge 8 wires were pushed through the sausages as reinforcing 'pins', to secure one row of sausages to the next.

At certain points within the construction of the tanks it was not necessary that the sausages should eventually harden, indeed a permanently 'soft' effect was desirable (just where these points were will become apparent below) and so sausages that contained sand only were made. In this case, of course, it was not necessary to perforate the sausages and lay them in water as there was no cement to be moistened.

(b) The general construction

Having detailed the idea of the sausages, the overall construction of the tanks may now be described. (See Fig. 8 and Plates 3 and 4).

Once the pit had been dug and trimmed to shape, two alternate layers of mud and polythene (the thickness of the polythene was 1½/1000 inch) were laid, with the first layer of mud containing DDT as a termite and insect repellent. This layer of mud not only acted as a protection for the first layer of polythene but also as a bond between the polythene and the walls of the pit. The mud was generally less than ½ inch thick.

A layer of sand sausages (i.e. those with no cement) was then used to line the tank, using mud as a mortar: it is essential that this mud in the lining should be kept in a

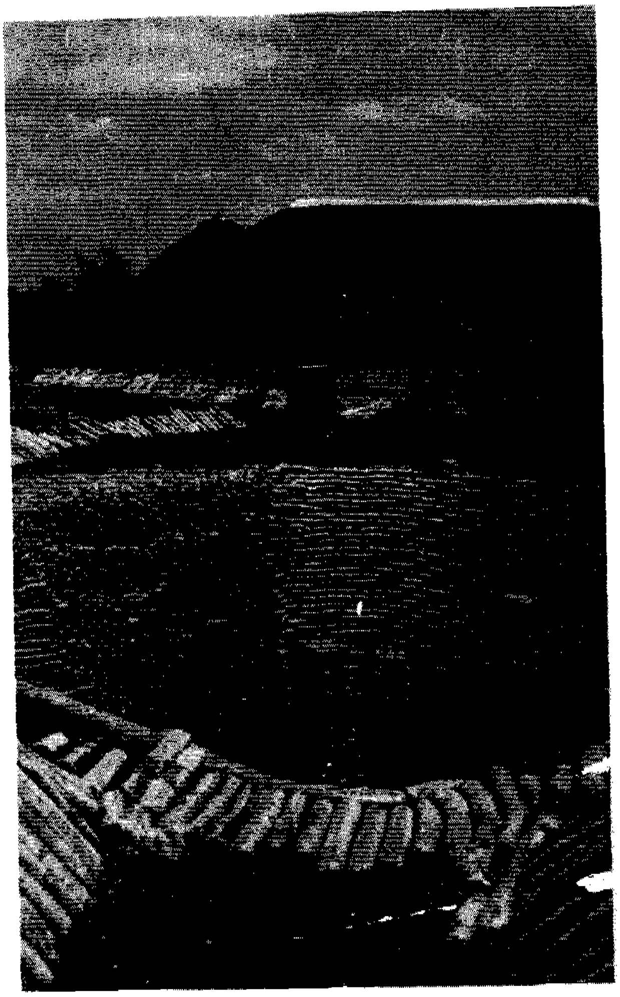


PLATE 3. The Second Tank at Radisele. In the foreground can be seen the concrete sausages, the partially built pillars to support the roof can be seen in the tank, while the canal leading from the first tank can be seen in the background.

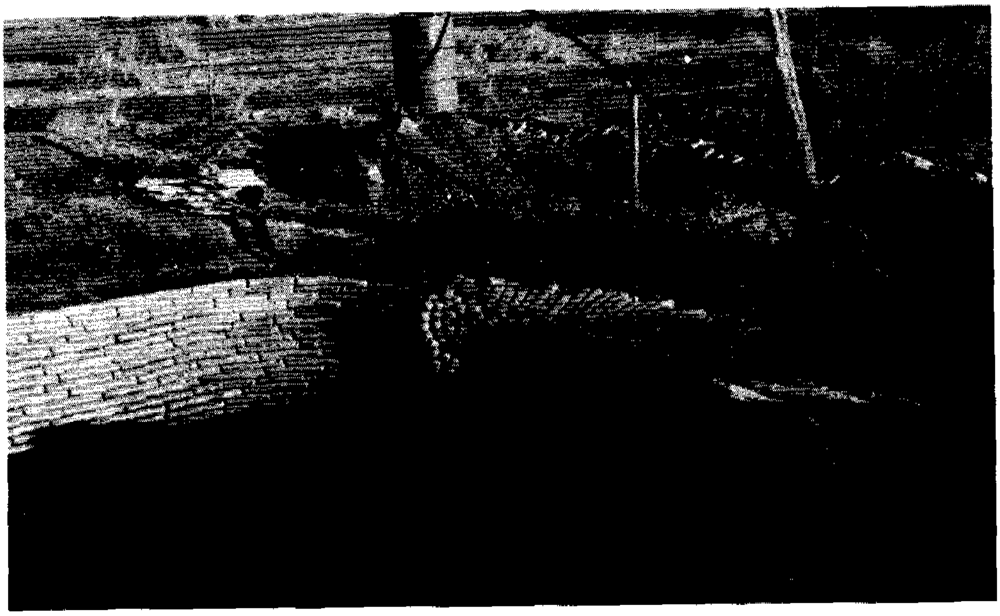


PLATE 4. The Second Tank at Radisele. The extra construction at the inflow can be clearly seen, while on the right can be seen a hand operated pump for the extraction of the water.

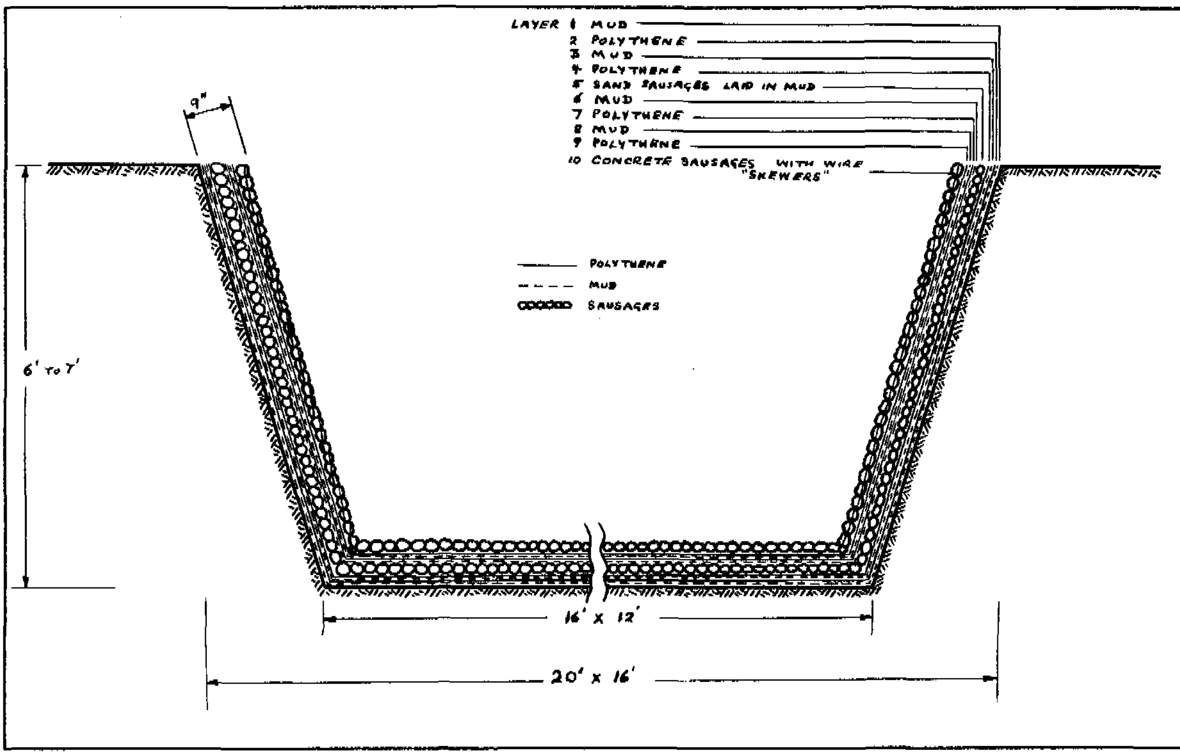


FIG. 8. Cross-section of a Mud/Polythene Tank.

moist condition all the time. This layer of sand sausages acted as a spacer layer to give body and a cushioning effect for the further layers of mud and polythene. The floor of the tank was first lined with the sand sausages, and then the walls of the tank were built up from the floor, each sheet of polythene bound to the next by an overlap of between 6″ and 1′.

The next layer after the sand sausages was polythene, this sticking to the mud around the sausages. A further layer each of mud and polythene completed the mud and polythene part of the lining.

The final layer was made of the concrete sausages that have already been described. These sausages formed the hard wearing finish and were laid first on the floor of the tank and then up the sides, using the wires to give reinforcement to the walls—the wires were pushed down into the sausages every three layers.

On the side where the water would flow into the tank, further work was necessary. This was because on the inflow side of a catchment tank the flow of water produces a considerable force which has the effect of tearing the lining away from the side of the pit and washing it down into the tank, so rendering the tank useless. The inflow can be as much as 2,000 gallons per minute in heavy rain: a 10,000 gallon tank at Radisele has been known to fill within five minutes.

In constructing the second trial tank at Radisele, the lesson learnt from the first tank was remembered, and a solid wall of concrete sausages, reinforced with wire, was constructed on the inflow side to counteract the force of the water as it flowed in.

The sausages were laid with their lengths parallel to the flow of the water, and with the ends forming a slight slope so that the fall of the water was broken gradually (see Plate 4). This meant that by the time that the water had reached the floor of the tank much of its energy had been dissipated. Further, baffles about a foot away from the edge of the tank were made so as to slow the flow of water before it actually entered the tank.

Finally, the two tanks at Radisele were connected by a canal, so that the overflow from the first tank could form the inflow to the second tank. This was simply a water course fashioned in the soil, which when compacted did not absorb much water, and the sides were faced with concrete sausages to prevent minor erosion. (See Plate 3).

A point about the use of polythene, which does deteriorate and crack if exposed to the atmosphere, and particularly sunlight, is that all the polythene which must be permanently watertight (i.e. the main linings) is covered; the only polythene which remains exposed is that forming the skins of the concrete sausages, and once the concrete has cured then it does not matter if the polythene is damaged – it is only needed as a watertight form of shuttering for the first few weeks.

It should be noted that more plates showing the methods of construction of these tanks are given further on in this Report. Also, the reader may be confused by the differences between the design of the tanks and those described by M. G. Ionides in Appendix I: it should be noted that the tanks made in Sudan (Appendix I) were for drinking water only – and thus sand filters were desirable – whereas the tanks in Botswana were made to store water for irrigation, and not human, use.

5. Other Tanks Built at Radisele

Other tanks built as trials at Radisele were: –

(i) 20,000 gallon P.V.C. single membraned lined catchment tank. This tank replaced the first mud/polythene tank which even after repair and modification did not hold water satisfactorily. The excavation was enlarged and lined with this P.V.C. liner (See Plate 5).

(ii) 4,500 gallon drinking water tank with artificial catchment area. This tank was of the mud/polythene – multiple beehive type, a scaled down version of those constructed in the Sudan. This type used sand as a filter for the water. A similar design 100,000 gallon tank was built during August and September 1968.

(iii) 15,000 gallon Butyl (synthetic rubber) single membrane lined catchment tank. This type of liner although easier to install is considerably more costly – far beyond the resources of the general population. However, even though the price delivered at Radisele was 15/- per sq. yd. it would be possible for a syndicate to buy and build such a tank. From Fig. 9 it can be seen that this liner which is pre-fabricated to the shape of the tank is simply layed in the pit, and stones are used to secure the edges.

(iv) 3,000 gallon circular family drinking water tank with a fabricated butyl single-membrane liner. This tank was the only real failure in the series of trials; rodents became trapped behind the liner (i.e. between the liner and the sides of the hole) during construction and ate so many large holes in the liner that it was not practical to mend them all. (The hole was later used for a trial ensilage of sorghum for feeding to B.D.A. Ranch stock). The hole will be used for the original purpose but will be lined with the proven mud/polythene combination.

(v) A nil-lining tank – i.e. one with no lining at all. This was dug purely to demonstrate that a lining is necessary if water is to be retained for any appreciable length of time. It was demonstrated that unless a hole is lined with some type of waterproof membrane water loss will be at a rate in excess of 100 gallons per 24 hours. The hole was later lined with a flat sheet of butyl, when it was seen that further rain was unlikely and the available quantity of water would be insufficient for the period of time in which there is no rain. The hole was lined with no preparation whatsoever – the sheet was simply placed neatly in the hole and anchored around the top edges with heavy stones.

Research into a number of different linings was carried out to determine which is most suitable to Botswana. Suitability must take into account: –

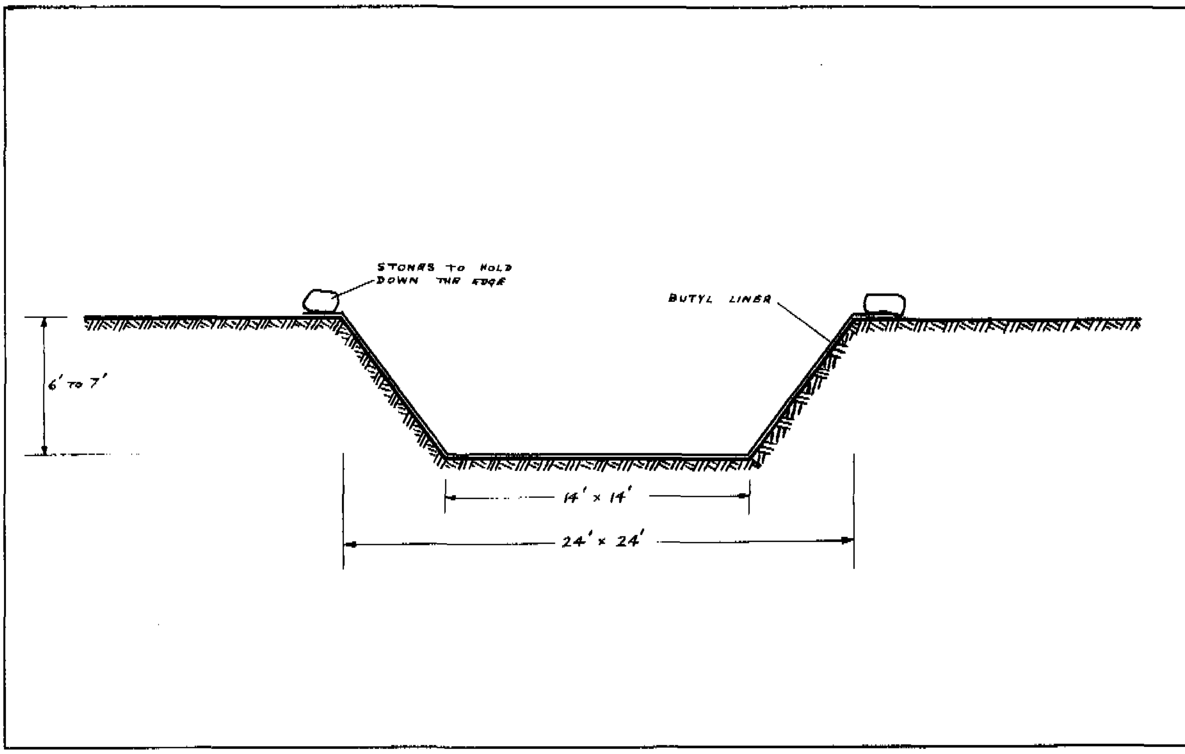


FIG. 9. Cross-section of a Butyl lined Tank.

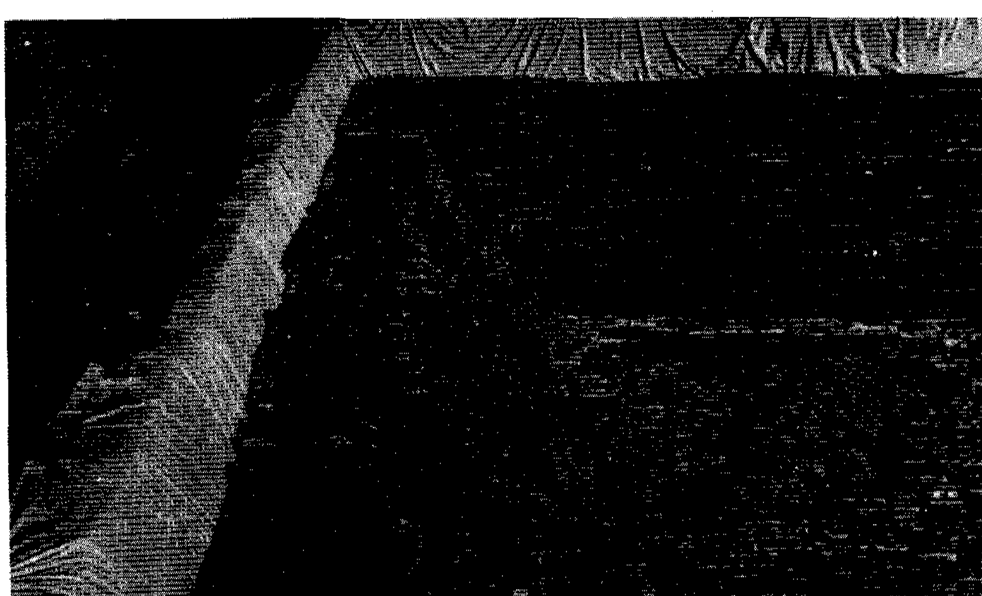


PLATE 5. The P.V.C. Single Membrane Lined Tank at Radisele. The P.V.C. lining and the additional construction at the inflow can be seen.

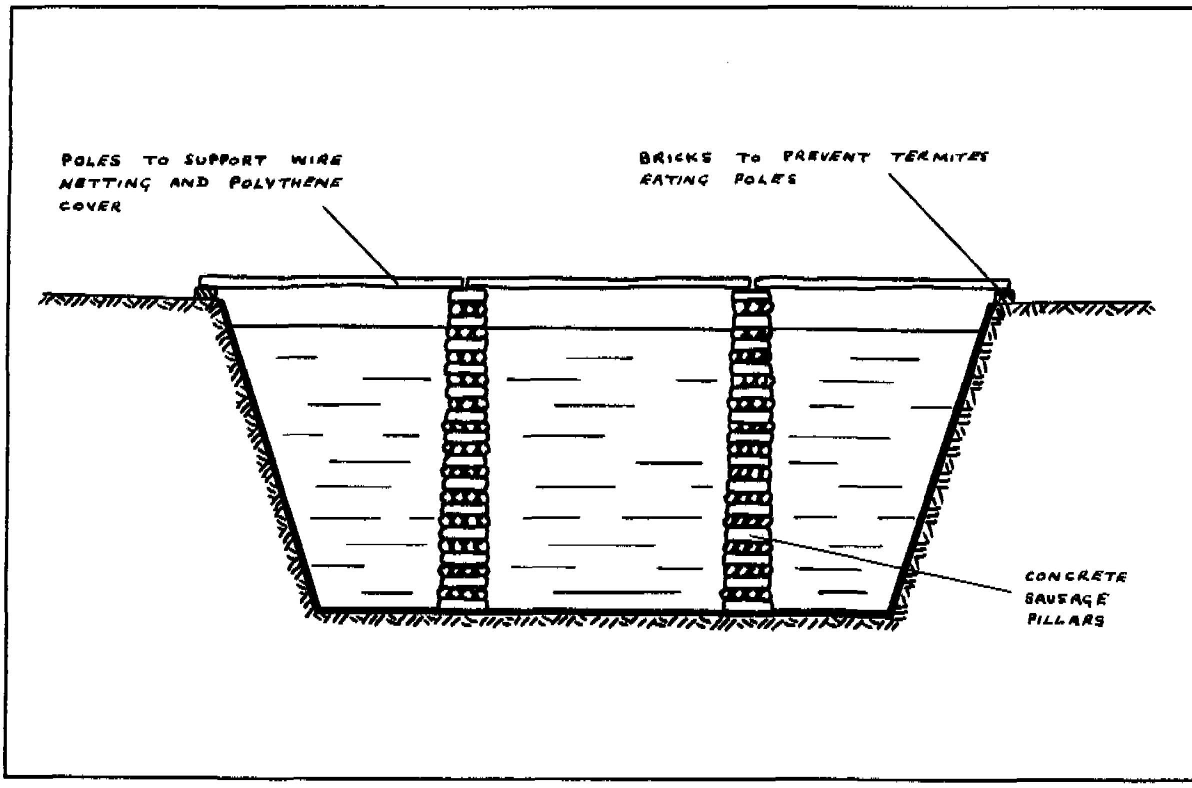


FIG. 10. Cross-section of a Tank showing the use of Concrete Sausage Pillars to support the Cover.

(i) Cost – would an average African family be able to afford the initial outlay?
(ii) Skill in construction – could the average African do it?
(iii) Is the lining satisfactory?
(iv) How long will it last?

Research was concentrated in the latter part of the period on the mud/polythene tanks using natural catchments wherever possible.

6. Covering of the Trial Tanks

A number of ways were used to prevent evaporation from the tanks; most of them fullfilled this purpose but due to a number of other factors (cost, simplicity, etc) they were not all completely satisfactory.

(i) A total covering of the 15,000 gallon butyl lined tank was achieved by a flat sheet of butyl laid over the surface of the water, overlapping the edges of the tank by about 18". The overlapping area was weighted down by rocks. This gave a 'total' seal to the tank so that evaporation was nil but it could not be used in a large extension programme with a number of tanks. The cost of the sheet used (24' × 24') was £33 and this method was used only on the one tank. It could never be considered as a way of preventing evaporation from a large number of tanks.

(ii) The 20,000 gallon P.V.C. tank was covered by black polythene on wire netting supported by wood poles on concrete sausage pillars in the tank (see Fig. 10, also Plate 6 for the incomplete pillars). This cover was entirely satisfactory except for two things:
(a) the black polythene was 'sucked' up by wind and in the flapping soon tore apart from the securing string.
(b) the pillars in the tank reduced the volume considerably. They were 18" square and 7 ft. high – a volume of 15 cu. ft or about 90 gallons per pillar; there were 6 pillars in the tank so 540 gallons at least were lost.

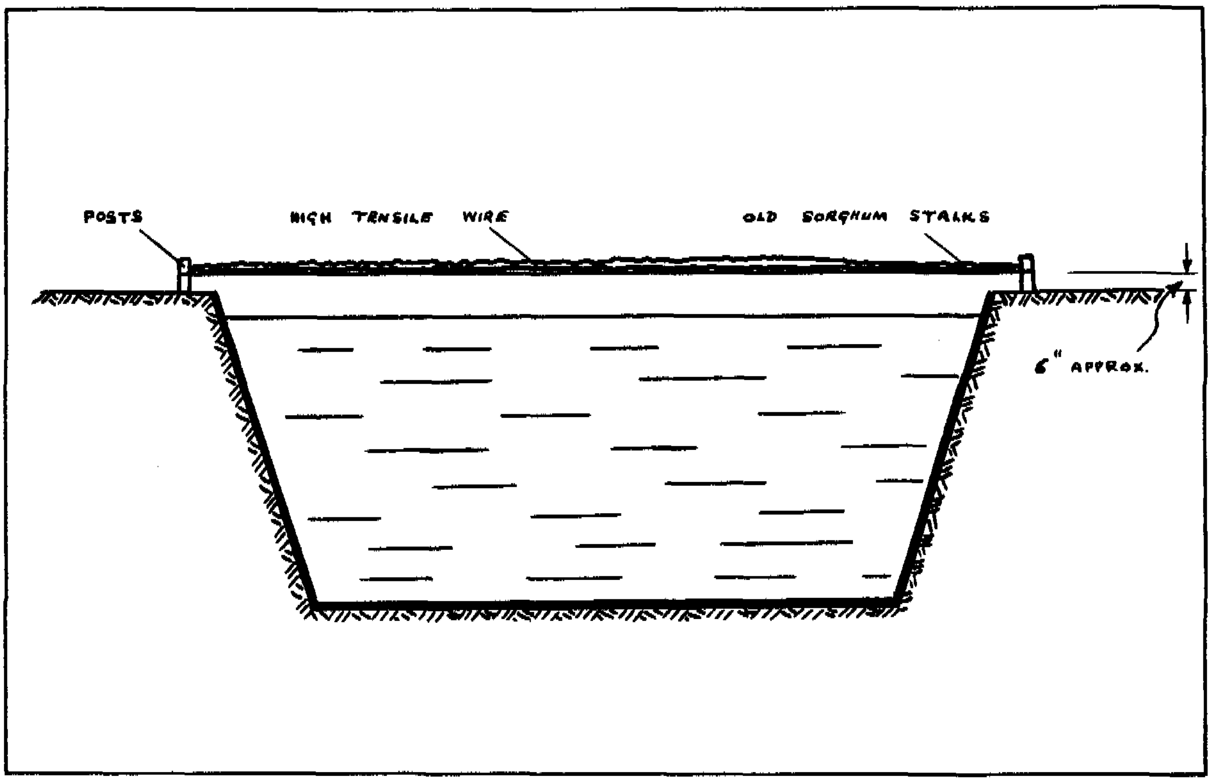


FIG. 11. Cross-section of a Tank showing the use of High Tensile Wires to support the Cover.

(iii) The mud-polythene tank at Radisele was covered with sorghum stalks on wire netting supported by high tensile wire across the tank. (See Fig. 11). The wires were anchored on stout short piles around the edge of the tank. This gave an almost complete cover, but smaller pieces of stalk fell into the water, causing the pump to block. Also some of the stalk blew away in not-so-strong winds. A more successful use of the sorghum stalk was achieved by making 'mats' of it – individual stalks tied together with string. The mats were pulled across the wire netting and tied down. Covering a tank in this way ensures that no volume is lost to pillars in the tank. It is a cheap method and one that uses mostly locally available material. (Sorghum stalk is free and plentiful after harvest). The wire used, although expensive, is not used in great quantities. The quality of 'seal' is adequate and the removal of water (by bucket or pump) is no problem – one corner of the cover is folded back.

7. Costs of the Catchment Tanks

The cost of the materials used for the three different kinds of lining are estimated in the table below. It must of course be remembered that these are figures that applied at Radisele during 1967/68.

Cost of materials for:

Mud/polythene tank (10,000 gallons)	R25	(polythene tubing, polythene sheeting, gauge 8 wire, DDT and cement)
0.012 inch P.V.C. tank (20,000 gallons)	R85	(P.V.C. lining)
0.03 inch Butyl tank (15,000 gallons)	R200	(Butyl liner)

(Before the devaluation of the £ sterling in November, 1967, 1 Rand = 10/- sterling; Since November, 1967, 1 Rand = 11/8 sterling)

Allowing for the difference in capacity of the three types of tank, it can be seen that the capital cost per unit volume of water of the P.V.C. tank is over 1½ times that of the mud-polythene tank, while the Butyl tank is over 5 times as costly; although this is not an accurate comparison as the tanks are of different capacity, and the smaller the tank the greater the ratio of surface area of lining to volume of water. Thus the mud-polythene tank is even cheaper in comparison to the other linings than these figures suggest.

In some instances it may be desirable to convert these capital costs into annual costs of depreciation for comparison with other sources of water. Such analysis requires sensible estimates of the life of the various types of lining, and these no one knows. M. Upton has included catchment tanks in his economic appraisal of irrigation in Botswana* where he concludes that catchment tank water is the most expensive per unit volume of water. Such conclusions are typical of many facets of life – the small-scale item costs more per unit volume than the large-scale item. However, to be offset against the greater cost of water from catchment tanks is the fact that they can be built almost anywhere – ie. where the water is going to be used – whereas one large supply of water is used by people living in an area of several square miles of surrounding land, causing most of them to carry their water considerable distances. Such availability will make all the difference between, for example, a family having or not having a vegetable garden for its own use, as vegetables must be irrigated in Botswana.

In considering the above list of costs for the various types of catchment tank the question arises as to whether the cheapest is necessarily the best – that although the Butyl liner is much more expensive it may last so much longer that it is worth the extra initial capital outlay. Such an argument might apply all the more to the P.V.C. lining, which is less than twice the cost of the mud/polythene lining. In fact, although the Butyl liner is the toughest, and the single membrane P.V.C. liner is much stronger than a sheet of polythene, the mud/polythene lining appears to be technically the best lining.

The reason is that it is made up of several layers – two layers of mud/polythene sandwiches (each of two layers of polythene) are separated by the sand sausages, and the cement sausages provide the final protection. Thus even if a termite makes its way right through all four layers of polythene, the resultant flow of water will carry some of the mud into the hole and seal it, whereas if a small hole is made in the P.V.C. or butyl lining, no such sealing will take place.

It might be argued that the butyl liner is termite-proof (whereas experience at Radisele certainly showed that the P.V.C. lining is not), but in this case the cost is prohibitive for the kind of country and people being considered the butyl liner is not so superior to make its greater cost feasible.

**Irrigation in Botswana.* M. Upton. Development Study No. 5, Department of Agricultural Economics, University of Reading, May 1969.

C. THE MICRO-IRRIGATION EXPERIMENTS AT RADISELE

1. Introduction

As already stated, these experiments began in September, 1968. Once the tanks were completed, the gardens were almost entirely irrigated with water from them, the farthest of which was 150 feet away. However, for a short period (about three weeks) during early 1968 water from a borehole was used because all tanks had been emptied due to the fact that two tanks had failed to hold water and those that were able to had not filled due to lack of rain between September 1967 and February 1968. It was considered best to continue the production of, and experiments with, the crops and sacrifice the ideal that the gardens should be watered solely from catchment tanks, rather than risk losing the entire production to drought.

The research into vegetable growing at Radisele was in no way a statistically controlled experiment. However a number of ideals were adhered to:

(i) As little water as possible should be used, but at the same time no loss of yield should result through droughting of crops.

(ii) The water applied must be applied in a way which could be adapted to use on school, private or community gardens in Botswana.

(iii) Extraction from the tanks must be of simple design, adaptable in part or whole to schools, villages, etc. which have a garden or which may be starting one in the future.

(iv) All materials used should if possible be cheap, locally and naturally available. Because of this the greatest possible use was made of organic manures such as kraal manure (stock are enclosed at night), rotting crop residues etc., even dead carcases of animals. Organic manures are almost universally available in unlimited quantities and nearly always are free, whereas chemical fertilizers have to be imported and are always costly. However, a certain amount of chemical fertilizer *was* used to demonstrate just how little is needed to produce an excellent crop.

(v) Although no statistically significant results would be obtained it was essential that complete records of water consumption of each crop be kept in detail.

The garden layout was based purely on ease of work, ease of irrigation and the most economical use of available space.

Cultivations carried out utilized a number of different methods of water retention, fertilizing etc. The main thing adhered to was the necessity to prevent evaporation directly from the soil. Ideas were gained from the Valley Trust in Natal, South Africa and from V. Gibberd's experience with his own private vegetable garden.

2. Treatments

The treatments given below refer to the way in which the soil was cultivated. Four series of experiments were conducted and the details of the treaments for each series are as follows:

SERIES I. Plot size 7′ × 15′

In this series there were two kinds of mulches and two methods of sub-soil cultivation. Four plots were used to compare the four possible combinations of mulch and sub-soil cultivation.

Mulches

Plots 1 and 2: Entire plot surface covered with a mulch of gravel on perforated 0.0015″ thick transparent polythene. Cost – ¼c per sq. ft.

Plots 3 and 4: Mulched with organic matter in winter only.

Sub-soil cultivation

Plots 1 and 3: 50% of the subsoil replaced by thrashing waste (unrotted) to a depth of 42″. This was not very well done – some top soil became 'lost' in the process leaving exposed subsoil for planting.

Plots 2 and 4: Subsoil loosened to 24″. Kraal (farmyard) manure worked into top soil.

SERIES II. Plot size 2' X 25'

The plots were separated by 2 ft paths of sand on perforated polythene, which would minimize evaporation from the soil but allow rain to pass into the soil. (See Fig. 12).

Treatment 1: Depth of between 12″ and 24″ of soil replaced by top soil from elsewhere. Entire plot surface covered with a mulch of sand on perforated 0.0015″ thick transparent polythene.

Treatment 2: 50% subsoil carefully replaced by thrashing waste (unrotted) to a depth of 48″.

Treatment 3: Conventional treatment only – soil loosened to 24″ where possible.

Treatment 4: Additional rainfall and run-off acceptance area under paths between plots, consisting of 12″ depth of sand. The top-soil displaced by this treatment was put in place of the second 12″ of soil in the plot. This second 12″ was discarded.

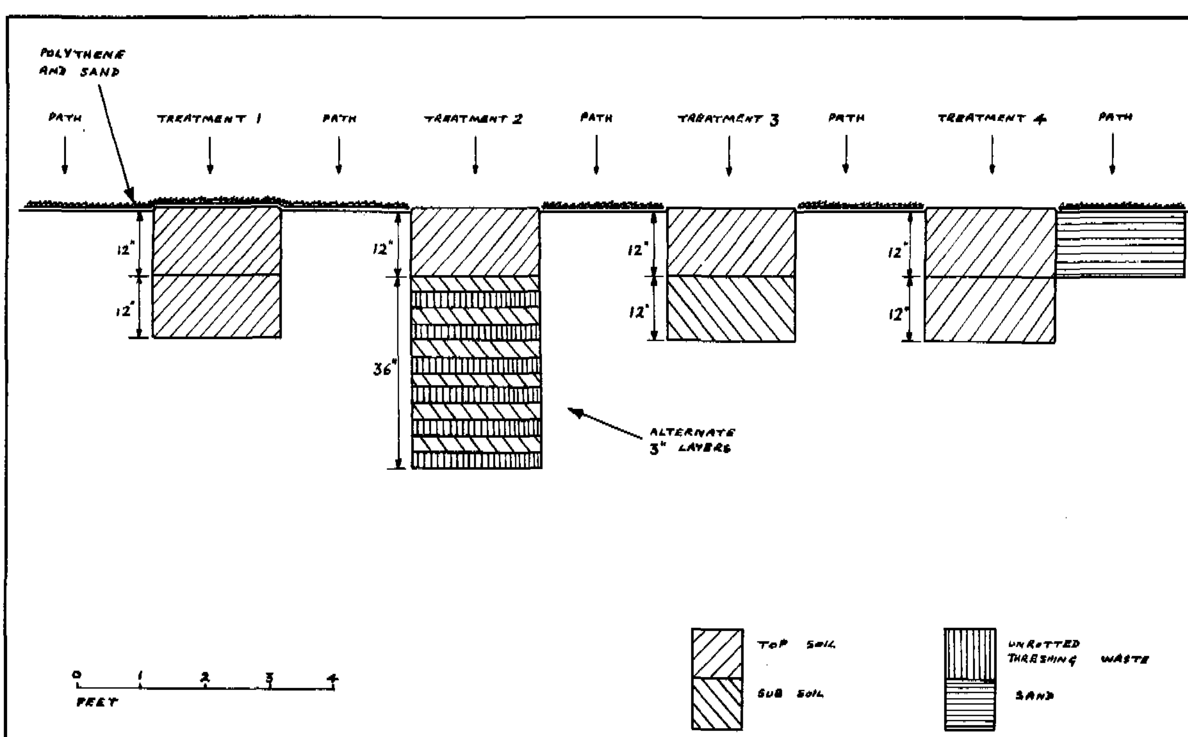


FIG. 12. Soil profile of Series II cultivation treatment at Radisele.

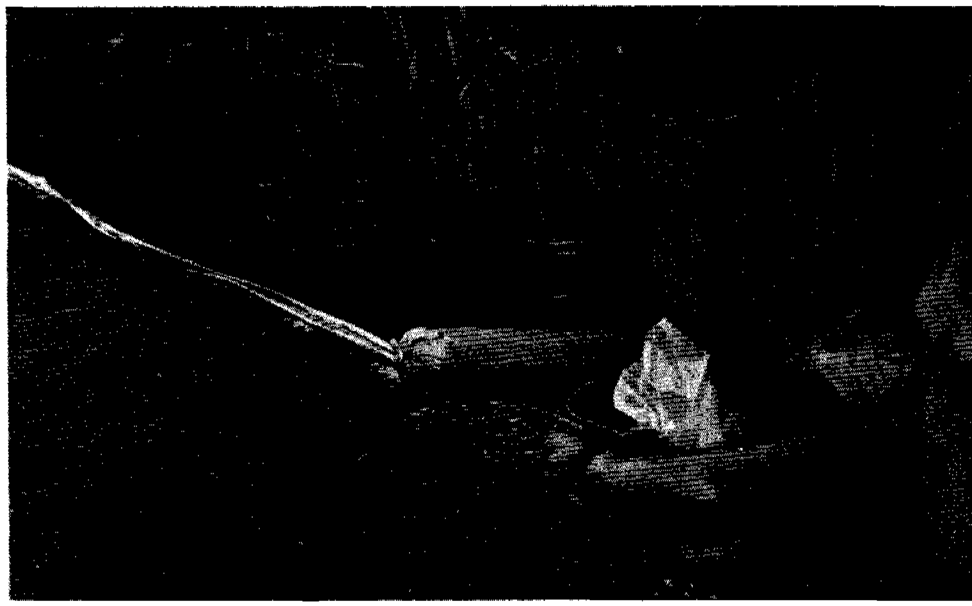


PLATE 6. Series III Ring Cultivation Treatment showing plants in bottomless pots standing in gravel-filled trench, at Radisele.

PLATE 7. Series IV Cultivation Treatment showing polythene catchment strips between cultivated strips, at Radisele.

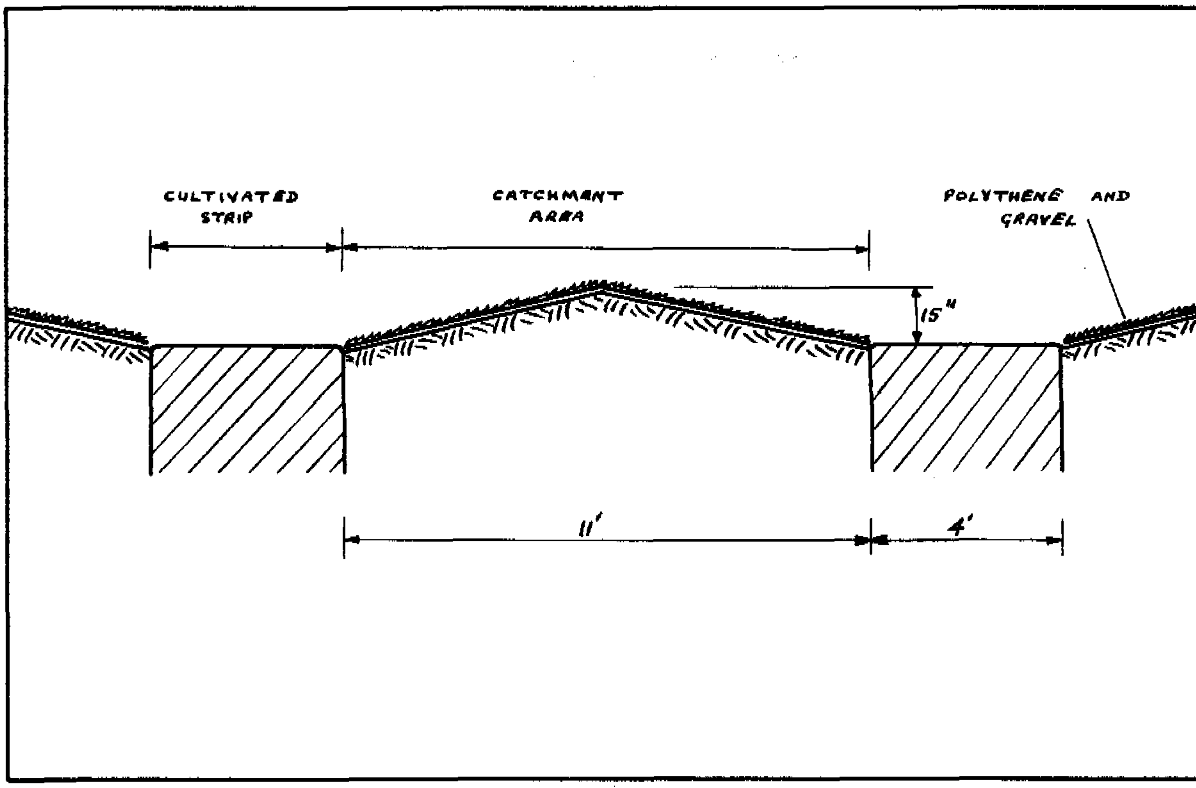


FIG. 13. Cross-section of Series IV Cultivation Treatment at Radisele.

PLATE 8. Operating the "Shadouf" at Radisele to lift water from the tank. The method of supporting the tank cover on high tensile wires can be seen. (This photograph was taken during the Teachers' Course described later).

SERIES III. Ring Culture

Plants put in bottomless pots of 1/3 cu. ft. volume filled with 2: 1: 1 of kraal manure: loam: pan mud. Pots placed on sand and gravel filled trenches lined with polythene sheeting to prevent drainage of water. Trench size: 15″ wide, 15″ deep. Water applied to trench to keep sand moist, 4 applications of 'Welgro' (a proprietory soluble balanced tomato food/fertilizer) into pots during growing period.

SERIES IV

Double rows of crops planted on 4′ wide strip of plain veld type soil subsoiled to 18″ along the main contour. 5′ 6″ wide ramped catchment strip on either side covered with 1½/1,000″ thick polythene protected with stone. Eucalyptus seedlings were also planted along rows and whole strip mulched with sunflower thrashing residue. (See Fig. 13 and Plate 8)

In addition to describing these four basic series of soil treatments mention should be made of the other treatments given or omitted (e.g. fertilizer, pest control). These may conveniently be summarized as follows:–

(i) Fertilizer: all tomatoes, peas, and cabbage received a light basic dressing of Nitrogen and Phosphorus. Cabbage was dressed with Urea. The costs of this are included in the Results given in the table under direct costs of treatment.

(ii) Disease prevention: none. Tomatoes in Series I were affected by blight during much of the season, some peas died off prematurely under series I and II with a fungal infection.

(iii) Pest Control: a light application of Rogor CE and 85% Sevin on cabbage only achieved partial control of a stem-weevil and aphis. Heavier and further applications had to be avoided due to the need for safe eating of the produce. The costs of this are included in the Results given on opposite page.

(v) All normal surface cultivations were carried out; windbreaks of 6′ 6″ high corn stalk were erected to windward of all gardens.

3. **Irrigation at Radisele**

Irrigation water was applied mostly as necessary. All of the Series II, 1967–68 tomatoes received no irrigation water during the last 120 growing days, during which they received 8.4″ of rain. Series II irrigations were applied at 0.75″ per irrigation, while Series I at 1.00″ to 1.25″ per irrigation.

All watering of the plots was through ¾″ black polythene piping with perforations at 2 ft. intervals. The pipes were laid down the centres of the plots with the plants being spaced as equally as possible to each side. In this way it was possible to ensure that all the plants received the same quantity of water.

Water was fed to these ¾″ pipes from 1½″ black polythene piping connected to 45 gallon oil drums raised 6 ft. above the plots and filled directly from the various tanks. The flow down the piping was by gravity – hence the oil drums being 6 ft. above the plots.

A number of methods were tried to determine the best way of extracting the water from the catchment tanks using as little costly equipment (e.g. motorized pumps) as possible.

The methods employed were:

(i) Semi-rotary, hand operated pump. This was a fairly cheap item and often unsatisfactory. Its pumping capacity in good conditions was excellent (about 45 gallons in 5 minutes–which is perfectly adequate for the purpose). However, the basic design of semi-rotary pumps is such that the pump is quite intolerant of solids (grass, leaves, soil, etc.) in the water, and water in catchment tanks is rarely free from such trash. This type of pump seizes hard at the least sign of sand or grass and it is a half hour job to take the pump to pieces to clean it.

(ii) Diaphragm pump. This also was a costly piece of equipment, but it worked very well for some months – until the diaphram (a circular piece of rubber-backed canvas) perished and a new one seemed unobtainable. One was made from the inner tube of an old tyre,

Results of the Micro-Irrigation Experiments at Radisele

Crop	*Treatment*	*Inches of irrigation water*	*Yield per square yard*	*Direct cost per square yard excluding water*	*Gross output per square yard*	*Gross margin per square yard*	*Gross margin per 1,000 galls. irrigation water*
		inches	*lbs.*	*cents*	*cents*	*cents*	*Rands*
Tomatoes							
French Khaki	I.1	nil	6.1	5	43	38	infinite
1967	I.2	nil	13.8	5	87	82	infinite
	I.3	6	10.7	5	86	81	28.8
	I.4	6	16.3	5	113	108	38.4
	II.1	17.5	7.1	13	56	43	5.2
	II.2	17.5	4.2	11	34	23	2.8
	II.3	17.5	12.5	11	105	94	11.5
	II.4	17.5	9.1	6	77	71	8.7
French Khaki	II.av.	2.3	0.9	2	9	7	6.5
1968	III.av.	7.3	8.3	12	83	71	20.8
Peas							
Greenfeast	I.1	5	0.36	4	5	1	0.4*
1967	I.2	5	0.44	5	7	2	0.8
	I.3	5	0.43	4	6	2	0.8
	I.4	5	0.49	4	7	3	1.3
Greenfeast 1968	II.av.	7.8	1.6	3.5	24	20.5	5.6
Stratagem 1968	II.av.	7.8	1.4	3.5	21	17.5	4.8
Cabbage							
Drumhead	I.1	20	6.0	17	19	2	0.2*
1967	I.2	20	5.2	18	19	1	0.1*
	I.3	20	3.3	18	14	−4	−0.4
	I.4	20	3.5	17	14	−3	−0.3
Dwarf Beans							
Canadian Wonder	I.1	nil	0.5	5	5	nil	
1967	I.2	nil	1.4	5	14	9	infinite
	I.3	6	1.1	5	11	6	2.1
	I.4	6	2.1	5	21	16	5.7
Green Maize							
Mostert	I.av.	5.7	2.2**	3	9.3	6.3	2.4
1968	IV.av.	2	2.9**	9	7.4	−1.6	−1.7
Kalahari Topcross 1968	IV.av.	2	1.6**	9	3.9	−5.1	−5.4
Lettuce							
Webb's Wonderful	II.av.	4.7	5.3	3.5	26.5	23	10.5
1968	II.av.	1.8	2.4	2	12.0	10	11.9

Losses are indicated by a negative (minus) sign.

* If irrigation water is costed at 63 cents per 1,000 gallons, these results were losses, in addition to the other losses shown.

** In the case of Green Maize (Mealies), the yield is quoted in cobs/sq.yd. and not lb./sq.yd.

but because of its lack of strength it needed replacing frequently. (This type of pump, once the problem of the diaphram is overcome, seems to be the answer to the extraction of water from catchment tanks. Operation is easy, maintenance is minimal, water with solids in it can be pumped with little trouble and the output is quite adequate, but it is slow and gives little pressure.)

(iii) "Shadouf". This was the final and cheapest method employed for raising the water from the tanks to the oil drums and was based on the shadouf. The traditional shadouf, as has been used for centuries in Egypt, consists of a pivoted pole with a bucket attached to one end and a counterbalance weight to the other. The operator then stands either in the source of water, or very nearly so. Because of the design of the catchment tanks, this original system needed modification and the arrangement employed was as shown in Fig. 14. The arm to which the bucket is attached is pivoted at 'P' and the operator holds the end marked 'O'. It is then a simple job for him to lower the bucket into the tank, lift it full of water and swing it round over the oil drum, where an assistant empties it into the drum.

This system was started at one tank purely as a trial. However, as the system was seen to be very good it was decided to advise the schools to use the system in the forthcoming Pilot Project, and also this system was installed on all four irrigation catchment tanks at Radisele.

The main point with all the watering systems was to keep them as simple as possible. The pumps were used when they were working but the greater part of the watering was done using the "shadoufs".

4. Results of the Micro-Irrigation Experiments

In considering the results of the micro-irrigation experiments it must be remembered that they were being carried out to demonstrate that the quantities of water available from a catchment tank are sufficient to give a reasonable and worthwhile crop of vegetables from a family kitchen garden. This was because it was envisaged that catchment tanks could be used for irrigating vegetable plots where there would be no other source of water available for irrigation (or if the water was available, the cost of it in terms of time and effort in transporting it from the source would be too great to make the growing of vegetables at all attractive). Vegetables were chosen rather than other crops as they lend themselves to small-scale cultivation and they are nutritionally rich compared with most other crops.

The experiments were successful because vegetables were grown on the quantities of water available from a catchment tank (together with rainfall which they would receive anyway), whereas they would not have grown without irrigation. The yields (in lbs/sq.yd.) that were obtained with the various crops and cultivation treatments are listed in the Table of Results. It can be seen that in all cases a crop was produced.

In fact the quantities of vegetables produced at Radisele were too great for immediate consumption on the farm (with more than one tank and a series of trials more vegetables than one family would normally grow were produced) and so the produce was sold. The prices obtained reflected the quality as well as the quantity of the vegetables. Thus a comparison of the yields in lb/sq.yd. and gross output/ sq.yd. in the Table does not give a constant price for each type of vegetable.

However, before commenting further on the Table of Results, it should be noted that with regard to vegetable production in Botswana there are two geographical areas to be considered. It has been said already that vegetables do not feature very predominantly in the Batswanan diet, but vegetables are available in those towns on or near the railway or where there is an expatriate population. Elsewhere, though, vegetables are rare. This latter case is the more predominant. Such variations in availability lead to two different economic situations with regard to vegetables and catchment tanks.

(i) *the areas where there are virtually no vegetables.*

In these areas the man who wants to eat vegetables must grow his own – there is no other source available. To grow them he needs water, and although he can get water to his house (otherwise he could not live there) the water source will generally be some distance away – perhaps one or two miles away – and so carrying water for anything other than drinking, cooking and washing is out of the question.

To grow vegetables he therefore needs his own water supply. As an individual his concern is whether he can afford the capital cost of his water supply – whether he has the necessary money in his pocket. He does not think in terms of economic life, depreciation and bank loans – although he will want to know whether his water source will last only one year, or for two or three or more years. In the kind of situation we are considering here, the cheapest (in terms of capital cost) water supply is a catchment tank – and this will give him sufficient water for a small kitchen garden. In addition to the cost of the tank, he will have to pay for his seeds and other ancillaries to grow his vegetables year by year, and his only concern is whether he has the money to supply himself and his family with vegetables which they will not have from any other source. There is no question of his vegetables making a profit or loss as there is no market price to compare his costs with.

(ii) *the areas where there is an established vegetable market.*

Here the situation is rather different. In this case even the man who only intends to grow vegetables for his own use will want to know whether he is making a profit or loss, by comparing his costs in growing vegetables with the amount he would have to spend in the market to have the same quantity and quality of vegetables (unless he is so anxious to have home-grown produce that money does not enter into his thinking). It is in this situation where the economic analysis of the Table of Results has a place.

It will be seen in that Table, that the final column gives the gross margin per 1,000 gallons of irrigation water. This figure does not take account of the cost of water. Immediately the question arises as to how to cost the water. If the life of a mud/polythene tank is taken as five years (Upton in his report, op. cit., took it as ten years), and it cannot be overstressed that both these figures are little more than guesses for no one knows how long these tanks will last, the capital cost (R25) of the materials can be depreciated over that time. Charging an interest rate of 8%* the annual cost of water from a mud/polythene tank is 63 cents per 1,000 gallons – assuming the tank only fills once during the year. Assuming that this is a correct estimate of the cost of irrigation water, subtracting it from the gross margin per 1000 gallons of irrigation water (in the final column of the table) will give the profit (neglecting labour and other indirect costs) to be had in growing these vegetables. It can be seen that at a water charge of 63 cents/1000 gallons not all the vegetables were profitable, whereas others were very profitable indeed.

From the figures given in the Table, and costing water at 63 cents/1000 gallons, the following facts can be deduced. In the case of French Khaki tomatoes, 1967, treatment I.3, the total direct costs (i.e. the cost of seeds, fertilizer, insecticide, polythene sheeting for mulches, etc) including water were 6.8 cents/sq.yd and the output was 86 cents/sq.yd, making the profit (or gross margin) to be 79.2 cents/sq.yd., i.e. the profit is over eleven times the investment. It must be stressed that this is assuming that labour charges are nil. Alternatively, it can be shown that in the case of French Khaki tomatoes, 1967, treatment I.4, the total investment (direct) costs of using 1,000 gallons of water were R2.41, including water costs. Such an investment gave a return or output of R40.20, i.e. a profit (gross margin) of R37.79, or a profit which was over 15 times the investment. Of course, the two figures are at the top end of the range, but even the modest results of the Canadian Wonder Dwarf Beans, 1967, treatment I.3, had an investment cost of 6.8 cents/sq.yd. including water costs, and a return of 11 cents/sq.yd., which is a return of 162% on the investment.

* Interest rate of 8% pa – the rate charged by the National Development Bank on agricultural loans, and used by Upton in his calculations.

As these figures were arrived at by taking into account current market prices, it can be said that not only do these figures give an indication of the profits to be made by setting up a business based on micro-irrigation and catchment tanks, but they also show which vegtables it would be cheaper for the family grower to buy in the market rather than grow himself.

Clearly, however, these figures must be regarded with very great caution and only used to demonstrate the principles involved in assessing the economics of micro-irrigation in areas where there is an established vegetable market, as they are based on small samples which were not controlled in a strictly scientific manner and the true life of the catchment tank is not known. It is worth, however, making a few further comments on the Table of Results.

First, it should be noted that the "Treatment" number in the Table refers to the series and treatment as detailed in the section above, entitled "Treatments". From the Table, it can be seen that for certain crops these techniques of micro-irrigation can yield very high margins per unit of land. The gross margin per square yard of over R1 for Series I.4 tomatoes may be compared with a maximum gross margin from irrigated field crops of under R100 per acre, or only 2 cents per square yard (see Upton's Report).

Similarly, for certain crops these techniques yield very high returns per unit of water applied. This is a very important advantage in a country like Botswana where water is scarce and therefore valuable. The gross margin per 1,000 gallons for some tomato and pea plots is over 100 times the gross margin per 1,000 gallons from field scale irrigation.

It should be noted that no information was collected on labour use. Where vegetable growing is treated as a supplementary enterprise it may be safe to ignore the labour cost. However, in order to justify the adoption of micro-irrigation as a full-time occupation it would be necessary to measure the labour requirements of this very intensive vegetable growing and to estimate the area which one man or one family could manage. It would then be possible to assess the potential income which would be earned. In considering the possibilities of micro-irrigation forming the basis of a full-time occupation, the question arises as to whether an ordinary farmer could manage crops grown by such techniques, more particularly in the case of 'fancy' techniques, where great precision is required if the crop is not to be an economic loss. The success of many of the schools' gardens described below suggest that if the more traditional forms of cultivation are used useful crops can be grown, although the very high returns possible with more complex cultivations are perhaps not attained.

It can be seen from the Table that green maize and cabbages made a loss in nearly every case (assuming that water costs 63 cents/1000 gallons) and they are perhaps unsuited to micro-irrigation techniques *for those areas where an existing market necessitates an economic appraisal.* Further, the margin in the case of some of the peas in 1967 was rather small, whereas the results in 1968 were more encouraging. In all other cases very high returns to land and water were obtained, which are unlikely ever to be matched by ordinary irrigation. There is therefore a very strong case for further trials to be carried out in order to determine:

(a) which crops give the most promising returns.
(b) which techniques of cultivation and treatment are most effective.
(c) the labour costs of growing vegetables under these conditions.

With regard to the role of catchment tanks in development work generally, there is a need for cost/benefit analyses to establish how they might be integrated with dams and boreholes and other 'traditional' water supply systems when water development over a large area is considered; such work will include investigations into the optimum size of the tanks, the social implications of possibly larger tanks being shared by two or more farmers, the self-help aspects of catchment tank building as opposed to the essentially mechanised construction of dams and boreholes. Such analysis cannot of course, be done in a vacuum but must be related to actual conditions in a developing country.

Important as the financial analysis is, it should be remembered that the prime object of the Radisele trials was to establish that catchment tanks and micro-irrigation are a feasible answer to growing vegetables in the kitchen garden in those areas where no other source of vegetables exists. For these areas, it was felt that catchment tanks and micro-irrigation were a very likely answer to the need of a cheap system of producing all the kinds of vegetables tried at Radisele, particularly bearing in mind that generally in such areas of Botswana voluntary labour is available to build the tanks, thus developing a useful rural craft and system of self-help.

5. Tree Planting at Radisele

About 25 young guava trees and 50 eucalyptus trees (Spp. Camaldulensis and Citriodora) were planted at Radisele. The former give a fruit high in vitamin C, they are quick maturing, fairly drought-tolerant and ideal for inclusion in a project such as this. The Eucalyptus trees are also quick-maturing giving straight, strong poles, mostly used in building. At present uniformly round, straight poles are only available from South Africa or Rhodesia and it is envisaged that the planting of large numbers of eucalyptus seedlings will make importing less necessary.

The guava trees were planted in an area of about 500 sq. yds. of land 'upstream' of the inflow of the 'first' tank. This area was levelled so that the flow of water over it would be as slow as possible; the ground was covered with a mulch of perforated polythene and gravel—

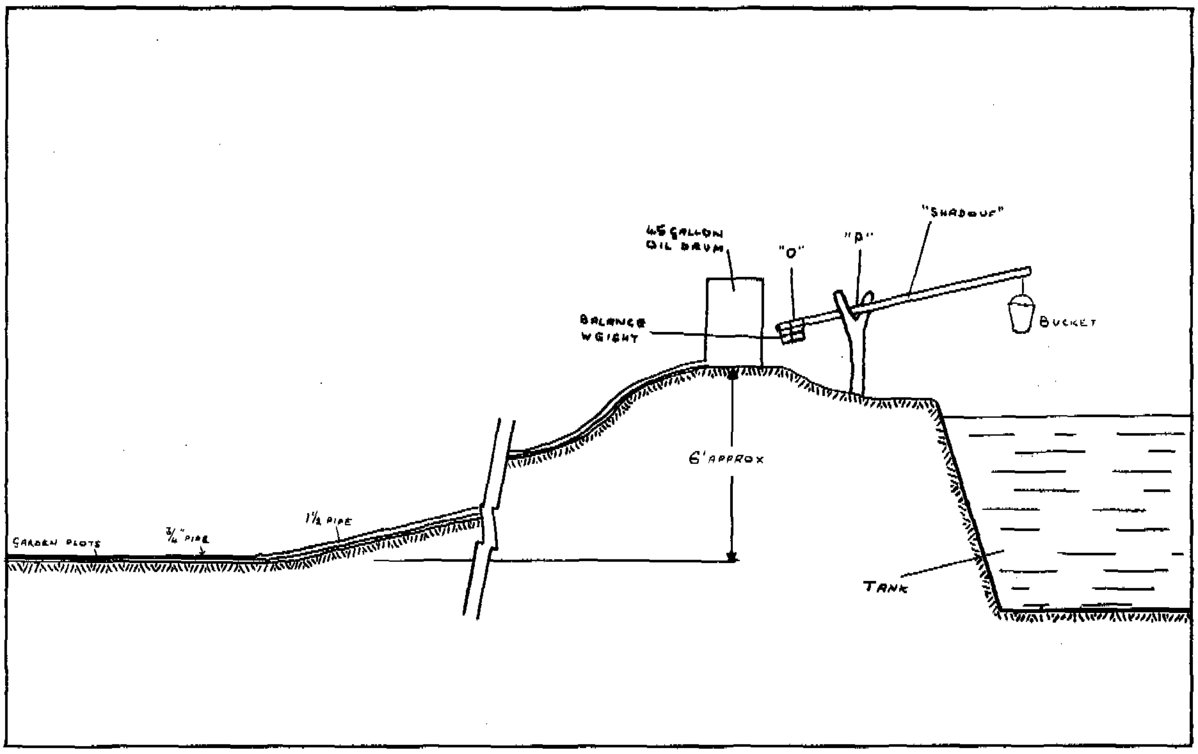


FIG. 14. Layout of "Shadouf" system of irrigation at Radisele.

* Futher notes on the Research and Development Work carried out at Radisele from September 1966 to November 1968 are given in Appendix 2.

this meant that some of the water would soak into the ground as it flowed over the area, but evaporation losses from the soil during the dry season would be minimal. In order that the trees should not be drowned, a small wall of earth was built up around each tree (see plates 7 and 8).

One trouble experienced was damage to trees by termites. In spite of large and frequent doses of DDT three of four trees died because the trunks were eaten through at ground level by termites (white ants). Dieldrin was used later and proved effective. Apart from those few trees killed the remainder grew extremely well and would be expected to produce fruit in 1969.

The eucalyptus trees were planted in cultivated strips along the average contour, utilizing run off from catchment banks on each side of the cultivated strip. The cultivated strip (3 ft. wide) was subsoiled as deep as possible – about 18″ – and poor soil from elsewhere used to build up the catchment banks. The catchment area was completely covered with clear polythene sheeting protected with gravel to prevent damage by wind and sun.

IV. THE PILOT PROJECT

A. BACKGROUND

With very encouraging results from the minor trials at Radisele, V. Gibberd decided that such trials that had already been carried out by him could be admirably transferred to a general usage in Botswana with benefit to the country as a whole wherever used. At the time, a school feeding programme as part of the famine relief scheme was being carried out. This provided an adequate but basically unbalanced diet, furthermore it was likely to be discontinued once the rainfall pattern had reverted to normal.

The easiest way of tackling an extension project such as gardening and water conservation was thought to be through primary schools—there are only seven secondary schools in the country, and the gain would be small compared with that in primary schools. The greater part of the transmission of knowledge from person to person in Botswana is carried on in primary schools. It is also the children who really require a balanced, nutritious diet (a diet which includes vegetables and fruit) for they are the future generations and the imparters of knowledge on the widest scale. With a combination of the school feeding programme and some way of giving the children fresh fruit and vegetables the problem of nutrition could begin to be tackled.

With this in mind, proposals were drawn up by V. Gibberd in consultation with the Education Department, Local Education Authority and Community Development Department. Basically, the proposals (which together with the financial estimates are given in full in Appendix 3) were to set up a Pilot Project which would be:

(i) to hold a course at B.D.A. Radisele to train ten primary school teachers in the construction of a water catchment tank and in the laying out of a vegetable garden to be irrigated from the tank.

(ii) to organise and direct these teachers in the construction of tanks and gardens at their schools.

Oxfam were approached in March 1967 and asked to support the proposed project with a grant of £2,800—this they did. The Oxfam Field Director for Southern Africa, at the time Mr. M. Carruthers, had given £100 from his discretionary fund to cover the out-of-pocket expenses incurred by V. Gibberd during the early stages of the research. Oxfam further backed this up with a grant of £200.

Permission to start the project was received on 14th July 1967—both from Oxfam and from the interested parties in Botswana, namely the Central District Council and the Local Education Authority.

B. THE TEACHERS' COURSE

1. Introduction

(a) Qualifications for attendance.

Between 14th July and 20th August, 1967, all schools within a 60 mile radius of Radisele were informed of the proposed course for teachers, and asked to send in applications and nominations for teachers to be on the course.

The smaller, more remote schools were the first to reply although the postal service to these outlying areas is extremely poor (in most cases, mail only goes in once a week). The most common occurrence was for head-teachers to simply delegate 'someone' to attend the course; little thought was given to whether or not that person would be suitable for such a course, or suitable to demonstrate to children. In future courses, should they be held, it would be an essential part of the programme (although adding cost) that each interested teacher be at least seen before he is finally accepted for the course. In this way only suitable applicants would be accepted. Essential qualifications would appear to be:

(i) An ability to apply the knowledge gained on a course.
(ii) An ability to apply the knowledge gained and the knowledge they already have to future projects.
(iii) An ability to work fairly hard for a short time in a self-help project.
(iv) An ability to put across to fellow teachers, children, villagers etc. the reasons why such a course is needed in the first place, also what the course is aiming to do.
(v) An ability to recognise the need for some sort of supplementary food. In this case only the simplest form of nutrition need be shown to the teacher.

(b) Preparations for the Course

Before the course started the greater part of the hole which would be lined by the teachers was dug out. This was done by paid labour, leaving only the final smoothing of the sloping sides and floor to be completed on the course. Time was expected to be short on the course so the major amount of work such as collecting sand and mud and digging was done beforehand. Accommodation for the teachers was already available—rondavels, normally used by Young Farmers on a Training Scheme organised at B.D.A., were vacant at the time. A load of firewood was brought for use by the teachers who were expected to cook and care for themselves.

(c) Attendance

The proposals and estimates allowed for ten local teachers and five observers to take part in the construction of one water-catchment tank at Radisele, and the setting out of a garden system integral with that tank—the system to be almost identical with that proposed for use in the schools. In fact eighteen teachers came and one observer—a headmaster designate of a large mission school at Madinare, about 100 miles away. One applicant to be an observer, from the Kalahari, was unable to arrange transport from there; another misunderstood a telephone message.

(d) Teachers' Finance

All teachers attending the course were paid their travelling expenses for the return journey (average 11/- each) and a maintenance allowance of 10/- per day. This allowance had to be slightly reduced at the end, by common consent, as the estimates, although allowing for a longer course, allowed for only half the number of teachers and observers.

2. Course Content

The course was held from 21st August to 1st September, 1967, during which time one complete mud-polythene catchment tank was built. The first day was spent in finishing off the surface of the excavation, i.e. removing projecting stones from the walls, sloping the sides and clearing the area for ease of working; and making sausages. The first day also included a short lecture on what we hoped would be done during the course and the reason for such a course being held.

The remainder of the first week was taken up in the actual lining of the hole. As this was only the third tank of its kind to be constructed in the country a certain amount of trial and error was still involved. However, it can be said that a considerable amount was learnt—not only by those on the course, but also by their instructors—V. Gibberd and P. Moody.

Tremendous enthusiasm for the work was shown by the majority of the teachers throughout the course. Only a few were inclined to sit around and let others do all the work. But it must be remembered that the teachers were completely unused to any type of manual

PLATE 9. Guava Tree Plantation at Radisele. The plantation is in the course of construction.

PLATE 10. Guava Tree Plantation at Radisele during the rains. The Tank is off the bottom left of the picture.

work, and that the work they did was both very dirty and strenuous – points which make the fact that a considerable amount was achieved even more remarkable.

It was found that too many hands in and around the tank slowed rather than hastened the construction; so, rather than let some remain idle and watching others work, parties of 3 or 4 were shown the other tanks on trial at Radisele; they were also shown the experimental garden.

The teachers showed a great aptitude for picking up knowledge – having been shown a fairly complicated and maybe technical process just once, they were able to continue it without supervision. This made the task of instruction easier, for it saved the necessity of repeating something four or five times – the teachers transmitted it amongst themselves. This they did in their own language and therefore it was all the more easy for them to understand than the instructors attempts at explanation in a foreign language.

The last four days of the course were used:

(i) To make the garden. This was constructed on exactly the same lines as the experimental garden already existing at Radisele; it was also on the same lines as those the schools were to be advised to have.
(ii) To tidy up the site around the tank ("a good-looking and tidy site is always the best").
(iii) To cover the tank. This was done in perhaps the cheapest way; wire netting across the tank, suspended on high tensile wires and then covered with mats of sorghum stalks. The mats were simply the stalks tied together with thin string. It is interesting to note that the roof of this tank is the one that lasted best – those on the other tanks all deteriorated rapidly.
(iv) To construct the guide arms, guide trenches, silt traps and overflow for controlling the water going into and out of the tank.
(v) To make some form of unit for removing water from the tank. The teachers were all shown the various pumps in use or out of use at the time, but for the tank they had constructed a 'shadouf' was made. It was made from a forked branch which had until then been growing within ten feet of the tank and a pole which had been used in the covering of one of the other tanks.

About three hours were given up on the last day solely to going over notes on the construction and techniques of the tanks and gardens. It was also explained to the teachers how the Project would progress after the course. The notes were then duplicated, each person receiving a copy, and in some cases two or three.

Throughout the course emphasis had been placed on a number of important points:

(i) The Project was being sponsored by people in Great Britain (contributors to Oxfam, who sponsored the Project). Therefore, the best use possible should be made of that money.
(ii) Locally available, natural materials should be used wherever possible (this in keeping with the whole concept established). To give an example of how this is put into practise: it is not necessary to use a pair of expensive pliers or wire-cutters to cut the reinforcing skewers to go in the concrete sausage revetment. All that is needed is a pair of hard stones, one of which has a slight raised edge on it. The wire can then be 'cut' by beating it between the stones to weaken it, and then by bending by hand. This method, although it may seem slower, was shown to the teachers who, it was noticed, later adapted it by using old plough shares, small pieces of railway line and odd bits of scrap metal that appeared as if from nowhere (see plate 9). In fact cutting wire in this way not only saves time and money but saves tempers as well – judging by the general run of pliers and wire-cutters on sale.

3. Schools chosen to continue in the Project

Preference was given to those schools which had applied early for a place on the course (see map, Fig. 15)

PLATE 11. Cutting wire with a hammer and a length of railway rail.

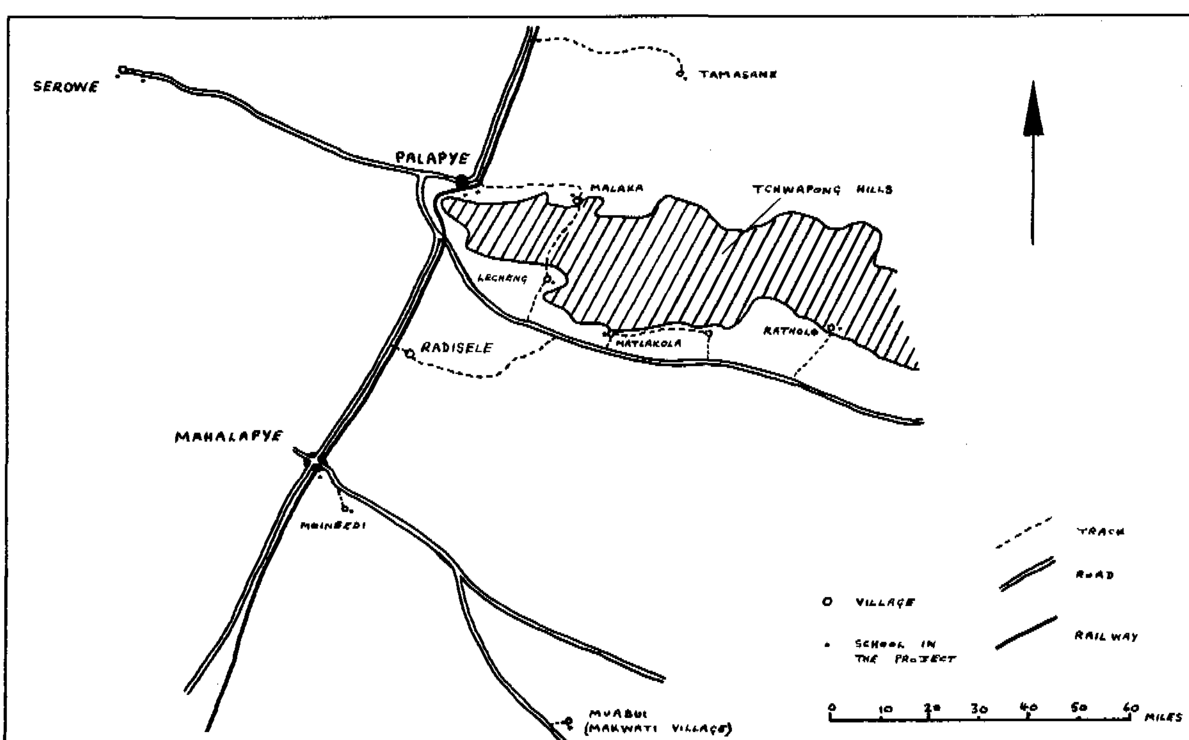


FIG. 15. Map showing the location of the Schools in the Pilot Project.

Those chosen were (listed not by order of application but in order of the case histories given below):

Malaka	35	miles (from Radisele)
Matlakola	30	,,
Lecheng	30	,,
Moineedi	30	,,
Muabui	60	,,
Palapye Central	25	,,
Ratholo	46	,,
Mahalapye Schools (shared)	28	,,
Newtown, Serowe	60	,,
Tamasane	40	,,

Sebeso School, Palapye, although not actually chosen decided after discussion amongst its Board and with Central School (with whom they would have shared a tank) that it would pay for its own tank, garden and equipment. This school is very well endowed and as provision had only been made for ten tanks for ten schools this was obviously the course to follow. Materials were bought through the Project and the school received exactly the same attention as other non-paying schools.

Simon Ratshosa School, Serowe, was very keen to be in the Project. However, the nature of the ground for two miles round the school (solid rock) and the provision for only ten tanks meant that they were unable to have a mud/polythene tank, but they were promised the first butyl liner. They did in fact start excavation immediately, struck rock, moved the site and restarted. The teacher who had attended the course then went to Malawi to learn how to teach blind people. Needless to say the school was provided with tools and was visited as the other schools, but plans for the school were shelved until later.

C. INDIVIDUAL CASE HISTORIES OF WORK AT THE SCHOOLS

1. Introduction

Instead of having to buy new excavation tools (the estimates had allowed for this) it was discovered that due to the end of active food-for-work schemes (1966/67 was a good rain year) there were tremendous quantities of tools lying at depots in Serowe and Palapye. In fact at one time more than 500 wheelbarrows were neatly stacked against a shed in Palapye, while inside the shed were an uncountable number of picks, shovels, mattocks, axes, etc. Rather than let these remain unused (a vast sum must have been paid out initially to buy them and the case must have been duplicated many times over) it was found that it was possible to borrow whatever was needed, thereby enabling money that would have been spent on new equipment to be used elswhere in the Project.

All tools needed for the schools were collected from the depots three days after the course ended and within the next fourteen days each school was supplied with one wheelbarrow, four shovels, four picks and two spades. On the same journey the sites for the school tanks were either approved or chosen. The teachers involved had given quite a lot of thought to the sites and their own knowledge of the local water run-off was of course considerably greater than the Project Managers', and therefore the teacher's advice was generally acted on. In only two cases was it obviously necessary to alter the site.

Although accuracy in measurement of the excavation area was of only secondary importance a tape measure was used to get as near right angled corners as possible – the people involved could have done the measurement very well by pacing or even by using a 12" school ruler.

The schools then went on to excavate the pits: the digging was done most often by the children and teachers. Two villages in which there were schools in the Project were addressed at a kgotla (meeting) to explain to the inhabitants and parents the fundementals of the tanks and the purpose of the Project and the tanks. The meetings were also a means of trying to enlist some help (unpaid if possible) in the excavation.

Once schools had completed excavation they notified the Project Manager at Radisele who then checked the excavations. 90% were satisfactory and the others needed only a little finishing and attention to minor details. On this journey the schools were supplied with polythene, wire, DDT, string, cement, etc. Most schools had already begun to collect sand and mud and bring it to the site.

The way in which sand and mud were collected was usually for each pupil to bring a bowlfull each morning. Although the school feeding programme supplied food it did not supply eating utensils; so each child was already carrying a bowl to school and sand is available everywhere, mostly in the tracks and roads. Mud in some cases was difficult to obtain but details of this will be covered in the individual case histories.

Throughout the Project, work on the tanks and gardens was done mostly during recreation periods—usually afternoons on Mondays and Fridays; some varied this to doing half an hour every day either before or after lunch. In either case the amount of time necessary to complete the work presented few problems. Most schools finished work at 12.30 p.m., however, in some cases there were too few classrooms or too few teachers, so two 'shifts' were worked, one in the morning for half the children and one in the afternoon for the other half.

In the individual case histories which are given below, no particular order of the schools has been followed—the order is merely based on convenience so as to cover all the points.

2. Malaka School

This was by far the most remote school. It was well away from any regular road and served only by a very rough track. It was nevertheless one of the really successful schools, entirely due, it was felt, to the fact that the teacher was fully qualified. Very few teachers indeed have any qualifications—only two teachers in the Project had been to training college.

Malaka village is fifteen miles from Palapye, lying at the bottom of a range of steep sided and fairly high hills (an off-shoot of the Tchwapong range which stretches for nearly eighty miles from the railway and road at Palapye to the Limpopo and border of South Africa). The village although very remote has a good supply of water throughout the year, from a low lying but narrow flood plain. Water is obtained by scooping a hollow in the sandy soil. There are also springs up in the hills, about two miles away. Because of the remoteness and inaccessibility and lack of transport, the villagers were thinking of moving elsewhere. However, a co-operative store was likely to open up in the village so the situation may have eased a little since 1968.

The site of the tank was approved on 12th September, 1967. It was about 200 yards from the school on one low corner of the football and netball field (bare earth). (See Fig. 16). This gave an excellent catchment for the tank. Had it not been there an artificial catchment using flat stones would probably have had to be made because the soil in the area is very sandy, giving poor run-off.

A kgotla was addressed on the first visit—the visit when tools were delivered—but no help was given to the school throughout the work. However, the digging was very easy, and it seemed, not at all hard for the children. This possibly is the reason why the school was not only the first to finish the excavation but also the first to finish the lining and garden. Another reason is the fact that the teacher realised how important such a Project could be.

The lining of the tank was finished on 23rd October 1967—just over a month from when tools were issued to the school. The lining was done very well, not only was the construction good but the area was left looking tidy—a great help when outside observers see such a Project as this. Mud for the lining was available only 50 yards away in the hollows in the flood plain. Sand, as usual in Botswana, was there in any quantity. Water, too, came

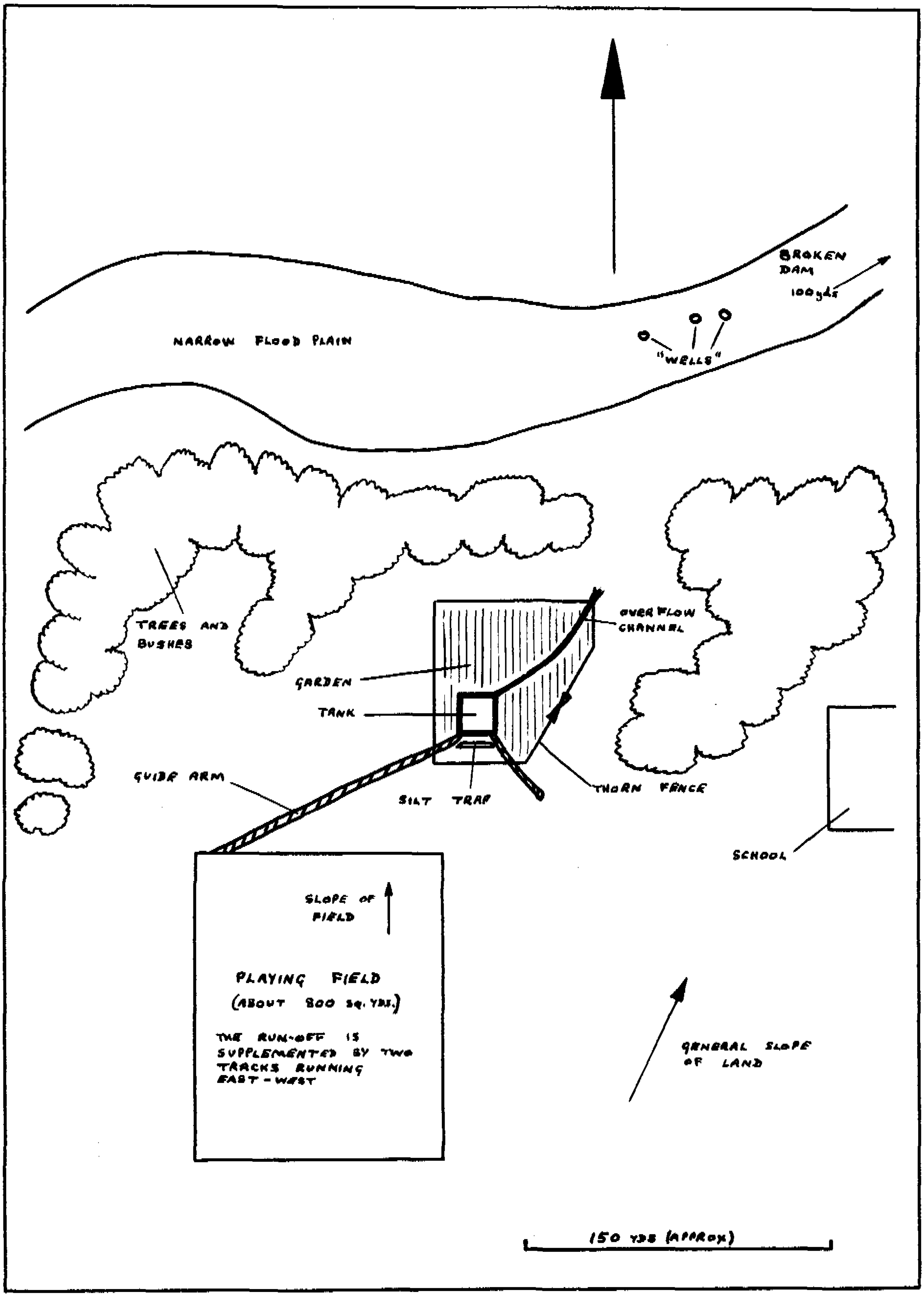


FIG. 16. Detailed layout of the Site at Malaka School.

PLATE 12. Partly completed Tank at Malaka School. The buttresses on the inflow side are visible; and on the left of the Tank the sand only sausages can just be seen behind the polythene and the concrete sausages.

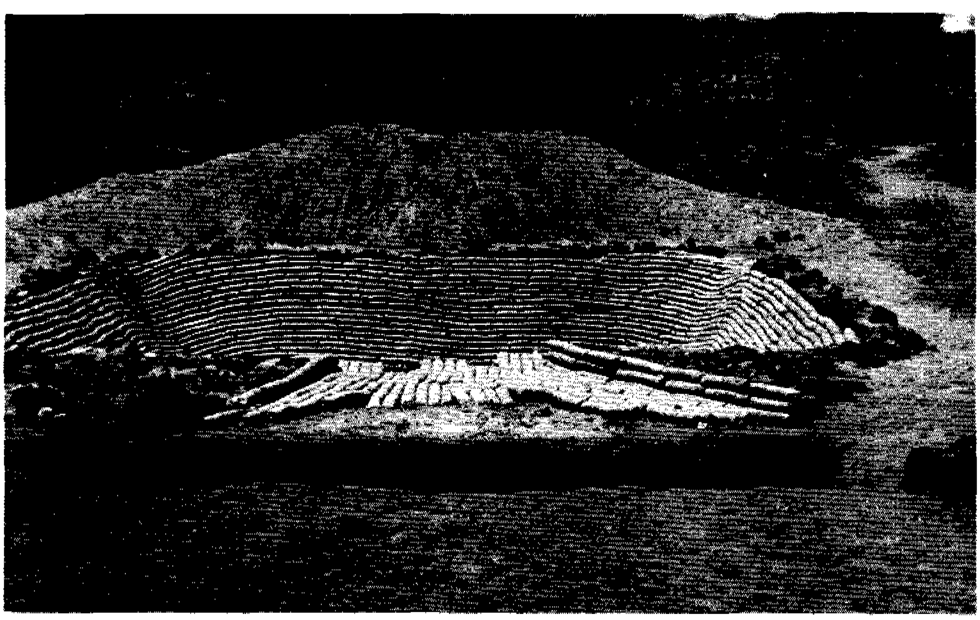


PLATE 13. Completed Tank at Malaka School. The trench in the foreground is a silt trap, on the far right-hand side of the tank a break in the surrounding stones marks the overflow, while beyond the pile of spoil is the flood plain, in which is situated the Garden.

from the flood plain – drums were filled at the wells and rolled up to the site (See Plates 10 and 11).

Vegetables grown in the garden were those grown at all the schools and at Radisele; mainly cabbage, green beans (runner beans), spinach, carrots and tomatoes. Other vegetables were grown with seed bought by the school – onions, mealies (maize), beetroot and peas. Seed was issued to all schools but some of the teachers, such as at Malaka, liked to try other crops with seed bought in the stores.

3. Matlakola School

This school was by far the most technically interesting case in the Project. However, it was not without a number of problems.

The site was approved on 14th September 1967. The area around the school was very rocky and would have caused a number of difficulties in excavation. There were a number of old, disused shallow wells (cf. Hollows) about 300 yards below the school and it was one of these that was chosen as the site for a circular-shaped tank. Although no circular tank had been built it was to prove perfectly satisfactory insomuch as volume achieved and ease of construction were concerned (See Plates 12 and 13). However, the lining was not well done and the tank did not hold water for the length of time really necessary – many sand water courses provided sufficient water to fill the tank.

At this village a meeting was held on the first visit to try and enlist some help from the inhabitants for the work on the tank and garden. Although there was agreement from the people they did not in fact give any help to begin with. In this case help was not needed so much in the excavation for this was fairly easy, (the wells had long since half-filled with silt). Help was needed, though, in collecting mud and water. The nearest mud source was two miles away; water also was a long way away (about 3 miles) being from a spring up in the hills. As no help from parents and villagers was forthcoming the children had to collect the mud and water in tins. Unfortunately, these materials were needed just at the warmest time of the year. The parents became more and more irritated by the fact that their children were having to carry mud and water so far, and because of that the work slowed up considerably.

The lining of the tank was finished during December 1967 and when the new term started in January, work on the garden side of the project began also. A meeting was arranged with the villagers so that V. Gibberd could try again to get their help with the hard work of preparing the garden and diverting some water from the water-courses into the tank. This meeting did not materialize because the previous day had seen some rainfall and everyone had gone to the lands in order to get some ploughing done. Another date for the meeting was arranged.

This second meeting was well attended and everyone put their complaints. The parents were reminded that they had originally promised to help but had never done so and it was for this reason that their children had to do all the work. Another promise of help was given by the villagers and with wheel barrows and tools loaned by the Project they cleaned up the garden and made guide arms for the tank.

Work on the gardening started in July 1968 – much later than was hoped – because for no reason at all the teacher who had attended the training course and then constructed the tank was transferred to a school ten miles away. No matter how much the Local Education Authority was pressed it was not possible to obtain a reversal of the transfer. However, the idea of the garden was explained to the new teacher and as most of the work had already been done he agreed to continue the work.

Two other shallow wells, both of which were adjacent to the tank, were chosen to be the garden. They were cleaned up (the stones and grass were removed) and the soil enriched with kraal manure, and mud from some old huts nearby served to increase the volume of soil. At the beginning of August 1968 two or three small beds in the garden had been planted with spinach and tomatoes and judging by the amount of water left in the tank the school should have had some vegetables.

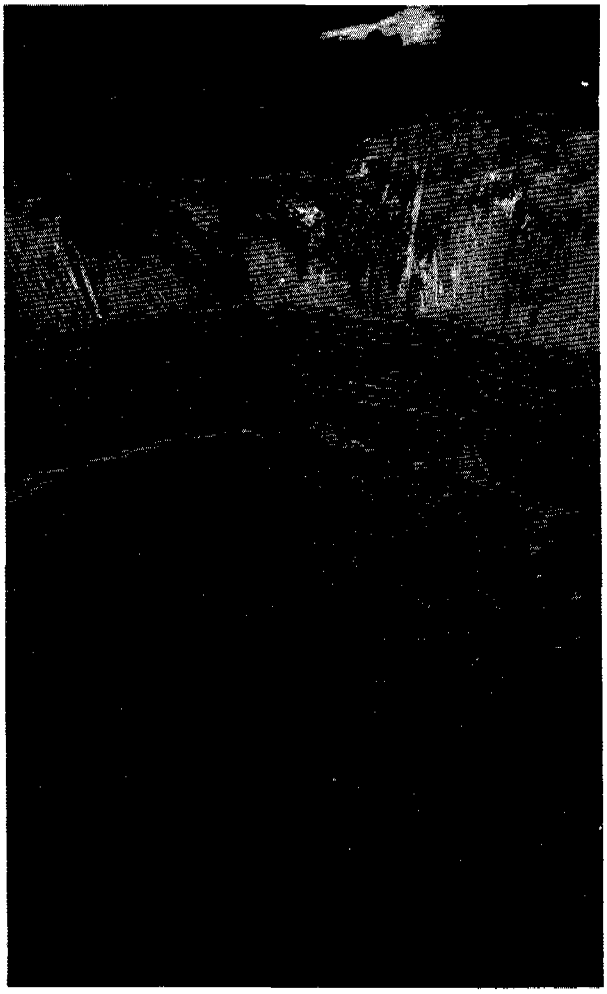


PLATE 14. Partly completed Tank at Matlakola School. The sloping side of the Tank in the background has been covered with the initial layers of polythene and the layer of sand sausages has been partially completed.

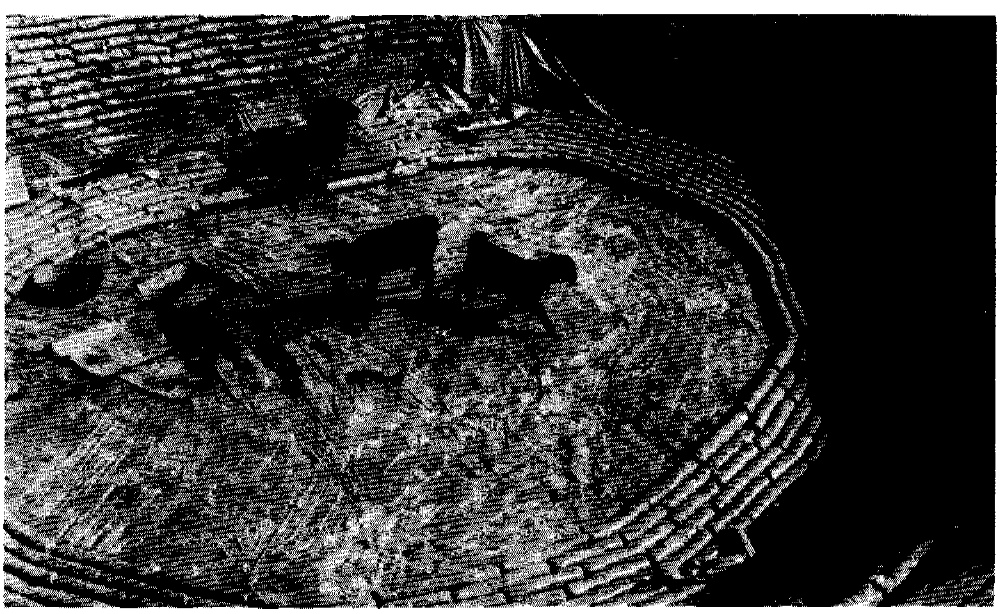


PLATE 15. Partly completed Tank at Matlakola School. Goats often caused considerable damage by both eating the polythene and piercing it with their sharp hooves.

Future plans for this school include the addition of a butyl lined tank – this would require only minimal labour in the excavation and would ensure a year round supply of water for the garden. Vegetables have been eaten from the garden and it seems that in spite of transferring the teacher this school will go on to produce good crops of vegetables.

4. Lecheng School

This school was the only one which was reluctantly regarded as a failure. The site, approved on 16th September 1967, was about 100 yards below the school, the whole area being fairly flat but a slope existed above and below the tank site – giving adequate run-off possibilities and escape for the water once the tank had filled. The soil is very soft and the digging was therefore completed fairly quickly. The soil is in fact alluvial with a lot of sand in it (See Plate 14).

This school had to be accepted into the Project because it was the first one to apply for a place on the course, and although the teacher was not one of the best on the course he was very keen for his school to have a tank and garden. The fact that the teacher was not one of the best showed up when construction of the tank began; although it had been impressed on the teachers that a buttress on the inflow side of the tank was essential, Lecheng did not make one. Other errors were made in the lining of the tank and some time after it had been completed parts of it fell in. Whether this was due to poor instruction on the course is not known, but nevertheless all teachers had notes on construction and there was no real excuse for inadequacies in the lining. Perhaps one reason for the failure was that the school had a number of other self-help projects on at the time – classrooms, mostly – and this probably diverted attention from the tank. It is not thought that the school was not interested in helping itself, for the very fact that they were building their own classrooms indicates to the contrary.

The school had not dug a hole for a butyl lined tank so it seems unlikely that anything further can be done with the school for the time being. However, it is on the direct route to other schools so should there be any change in the situation it is a simple matter to give any help and advice.

5. Moineedi School

This school, like Malaka, was very successful. Although the teacher was a very quiet person the end result of both tank and garden at the school was extremely successful.

The site was certainly one of the best of those chosen by either the teacher or the Project Manager. It was about 200 yards away from the school at the junction of a number of tracks and adjacent to a muddy donga (eroded gully) (See Fig. 17 and Plates 15 and 16). The tracks all ran down a slope towards the tank and so the position assured a plentiful supply of water during rain. Sand, of course, was ever present. The soil was hard and slightly rocky but excavation and construction were completed by soon after the beginning of the second term of the Project – January 1968. This fact is all the more commendable because the school is only a small one (60 pupils) and the children were all small in size and strength – a factor which means that hard manual work is done rather more slowly than it would otherwise be with stronger children. There were two teachers, one of whom attended the course at Radisele and did most of the work on the tank and garden at the school. The other teacher refused to give any help or encouragement, stating that he was there not to get his hands dirty but to teach academically. This sort of thing only occurred once and was therefore no great problem. However, it must be borne in mind that such a case could be duplicated some number of times over and could be the let down of any extension project where the people work to help themselves as a community.

The construction was done very well and the tank lost virtually no water between April 1968 and August 1968. This latter fact is difficult to verify because no checks were kept on the depth of water in any of the school tanks and any losses would have been by seepage or by water being removed from the tank for purposes other than gardening at the

PLATE 16. Marking out the site at Lecheng School.

PLATE 17. Children filling the sausages at Moineedi School. A simple hopper has been set up to increase the speed of work, which is being done by both boys and girls.

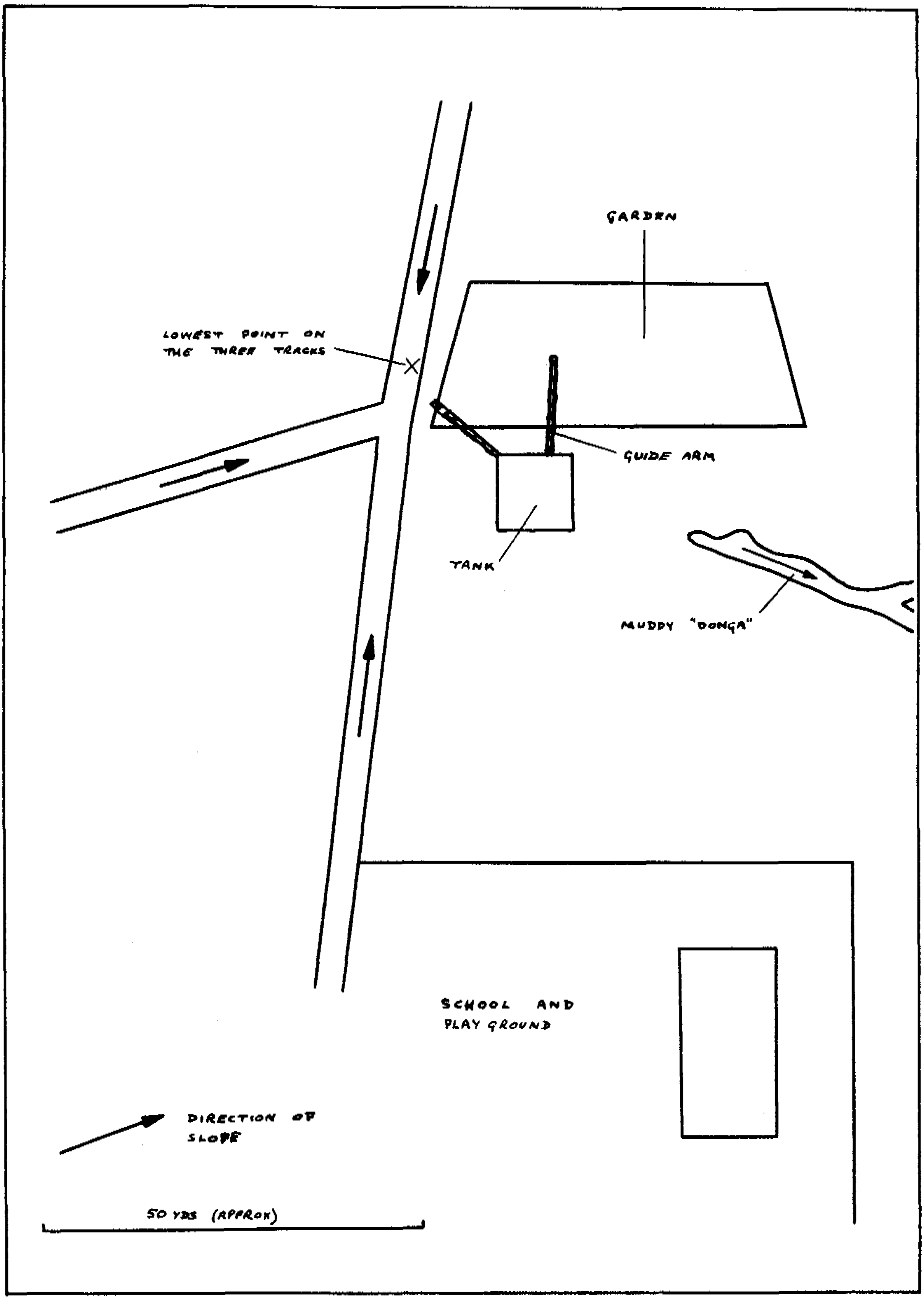


FIG. 17. Detailed layout of the Site at Moineedi School.

school. In a project of this kind—i.e. one involving collection and storage of water—it is wise to take precautions that water is only used for the purpose for which it was collected and that it is not misused, for example for stock watering or human use.

The garden was by far the best of all the schools' gardens. The school received jointly with Tamasane, the prize for the best garden at July 1968. When this was awarded (it was simply a football and spare bladder) a number of things were taken into account; neatness, amount of cultivation, quantity of vegetables growing, quantity of vegetables harvested and general use of available materials (a high use of manure without being advised to use it by the Project ranked important in the awarding of the prize.) A vast amount of vegetables were grown between January and August 1968 and the children all stated that they like eating them very much—something that is very important to consider; if they did not, and *some* of course do not, then more problems occur. Vegetables grown in this school's garden were the usual ones grown with seed issued by the Project (cabbage, beans, carrots, tomatoes and spinach) and also those grown with seed bought in local stores by the school itself (such as lettuce, beetroot, potatoes and onions). The school in fact managed to grow potatoes whereas in the experimental garden at Radisele this could not be done even with the use of 'exotic' chemical fertilizers: the reason for the school being able to do so is not evident but perhaps the soil is particularly suitable for potatoes.

Work on the hole for the Butyl lined tank started on about 12th July, 1968. The site, adjacent to the mud/polythene tank, was marked out on that date and the excavation was started by the children and teacher. It was hoped that as soon as the easiest (top 4 ft.) had been done by the school itself, then villagers would come in and complete the digging which would become increasingly difficult as the depth increased. An amount had been allowed for in the Oxfam grant to pay for men to work on excavating for tanks.

6. Muabui School

This school was the furthest away from Radisele of all the schools. It is 35 miles east of Mahalapye, 60 miles from Radisele. Although not a particularly successful school the teacher was very keen. By August 1968 no tank that would hold water had been constructed, though a mud/polythene tank had been made but was destroyed by goats (due to the lack of a sufficiently good fence around the site) and by water breaking down the inflow side of the tank—it had no buttresses to protect it from the force of the water. However, the site was directly adjacent to a well so a successful garden was started, and the children have had vegetables from it.

The site was about a mile from the school next to a well in the centre of a large pan. Water seems to be available throughout the year from this well. What had promised to be an ideal site for the tank (mud, sand and water present) and for the garden (fairly good soil around the pan) turned out not to be so because 4 ft. below the soil surface very hard limestone was encountered. Although it would have been possible to dig down through this rock until the required depth had been reached the children were all small so the excavation was increased in length to obtain equal volume for reduced depth. (See Plates 17 and 18) Unfortunately, during the lining of the hole goats forced their way through the thorn fence into the enclosure and destroyed part of the completed wall. The site was therefore totally enclosed by a wire netting fence, after which no trouble was experienced with goats.

The garden in mid-July had ten small vegetable beds 3 ft. wide and 10 ft. long in which beetroot, cabbage, spinach and onions were growing well and giving most of the children a little fresh vegetable twice a week.

7. Palapye Central School

This is one of three or four schools in Palapye, and one of two there to be participating in the Project. Palapye itself is extremely sandy and for this reason there is little or no run-off. The site was only a few yards from the school adjacent to a disused, but fenced garden and 50 yards from a periodic borehole reservoir belonging to the tribe.

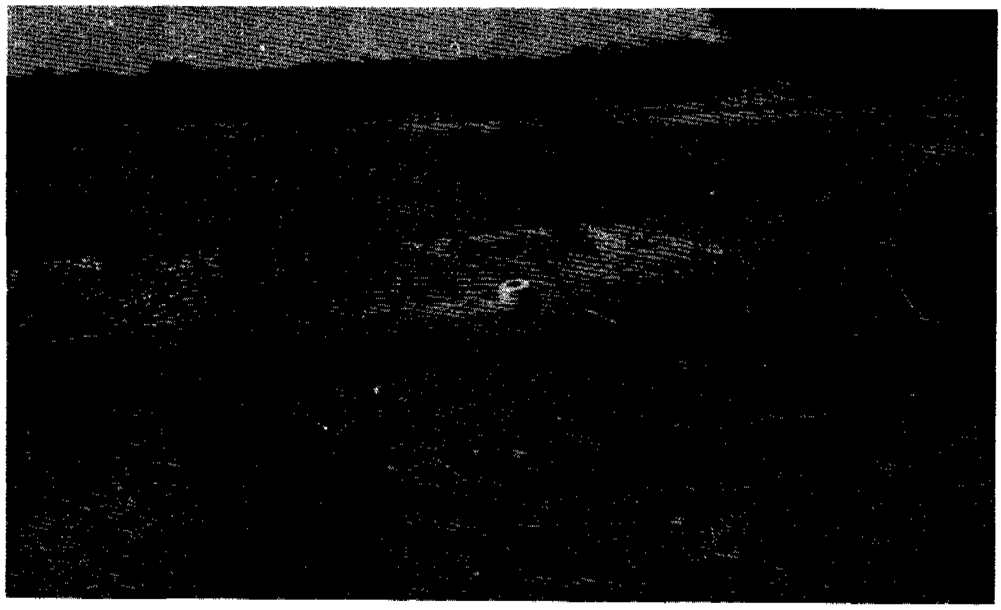


PLATE 18. Almost completed Tank at Moineedi School. In the background the mud-filled donga (a gully eroded by water) can just be seen.

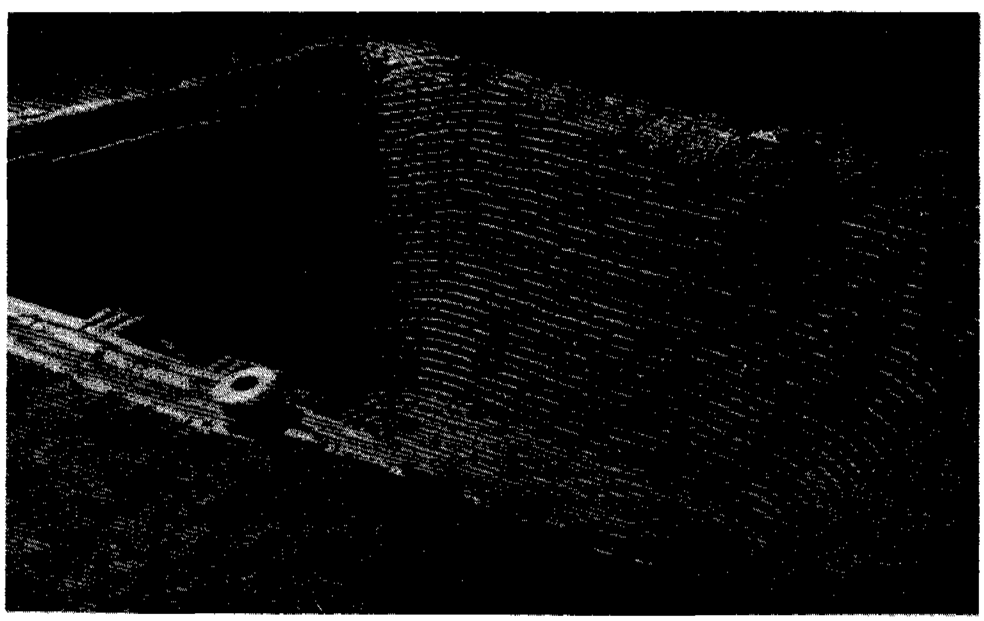


PLATE 19. Almost completed Tank at Moineedi School. The sand sausage spacer layer can just be seen in the centre top of the picture, while the polythene/mud lining and the concrete sausages are clearly visible to the right of the picture. In the foreground can be seen a roll of polythene tubing which is cut to the required length to make the sausages.

PLATE 20. Excavation in progress at Muabui School.

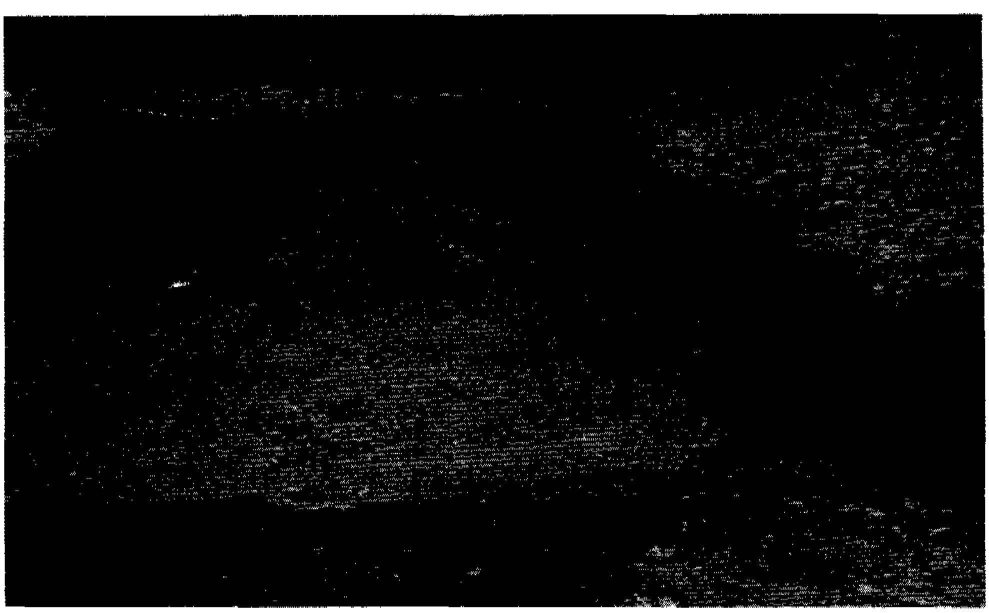


PLATE 21. Excavation complete except for sloping the sides at Muabui School.

Because of the lack of natural run-off a prepared catchment area was made around the tank (See Fig 18 and Plates 19 and 20). The soil from the excavation was banked around the tank, rammed down firm and then covered with flat stones from a dry river bed about 1½ miles away. The spaces between the stones were filled with thick mud which baked dry in the sun – the surface then allowed very little water to be lost by seepage into the soil. Mud for the lining, between the flat stones and for adding to the soil in the garden was obtained from the river bed, in fact from just behind Palapye Dam.

Although work progressed very slowly to begin with, the tank was completed early in 1968. The construction was very neat and well done. In this case no buttresses were necessary as the force of water from the catchment would never be as great coming from all four sides as from just one direction. A very large garden (50 yds. X 20 yds) was taking shape by July, 1968. They had some very good seedlings coming up and good prospects of some fine crops.

The teacher who attended the training course was a quiet person and soon after starting work on the tank and garden at the school, he seemed to fade into the background. However, the Head-Teacher took his place although he had not attended the course, and being a very keen and energetic person with a certain amount of gardening knowledge, he was able to carry on where the other teacher had left off.

8. Ratholo School

This school was certainly the unluckiest. No sooner had the catchment tank been completed than a very heavy, short, sharp, and entirely local, shower of rain caused an Ipelegeng Dam* nearby to overflow; this thoroughly destroyed the completed tank. However, this was not really a loss, although nothing could be salvaged, because water was not in short supply and there was already a very well fenced and partly cultivated garden. With a catchment tank not immediately necessary – water was available from the dam – the garden was soon established (early December 1967) and produced good quantities of vegetables.

The dam, however, would not hold water for a whole year, so a catchment tank of some kind seemed essential in the longer term – excavations for a Butyl lined tank began in June. The site was further away from the dam than the original mud-polythene tank so no trouble could be expected from the overflow from the dam. The cause of destruction of the first tank could in fact have hardly been foreseen, but it is from experiences such as this that much can be gained for future projects of the same kind.

The garden size was about 170 square yards in June, 1968 with an excellent pole fence around it. (The poles being hammered into the ground as close together as possible, then tied with bark from trees, or string if available). The teacher incidentally was a very keen gardener which undoubtedly helped to make the garden such a good one.

9. Mahalapye Schools

In this case one tank and garden was to be shared between St. Patrick's School (400 children and the smallest in the town) and Tamoucha School (a larger one). All three of the schools in Mahalapye were represented on the course and of the three two sent teachers who were keen and suitable for the follow up Project after the course. One of them, from St. Patrick's, was the only sucessful one in the end.

The site for the garden and catchment tank was chosen to be on the opposite side of the Mahalapshwe River from the school. This was because the school (in fact on the southern side of the river at that point) was situated on a granite outcrop. The other side of the river was less rocky with a more alluvial type of soil, meaning easier digging as well as better soil for the garden.

It had been planned that Tamoucha school and St. Patrick's would co-operate and share a tank, but this broke down very early on because the schools were rather far apart and liaison proved difficult. It seems that at the time each thought the others were doing too little of the work. So it was St. Patrick's School which remained the sole school in Mahalapye to be in the Project.

* Ipelegeng Dam: a dam built by food-for-work programme labour (see under Section I C 1(d) 'Dams').

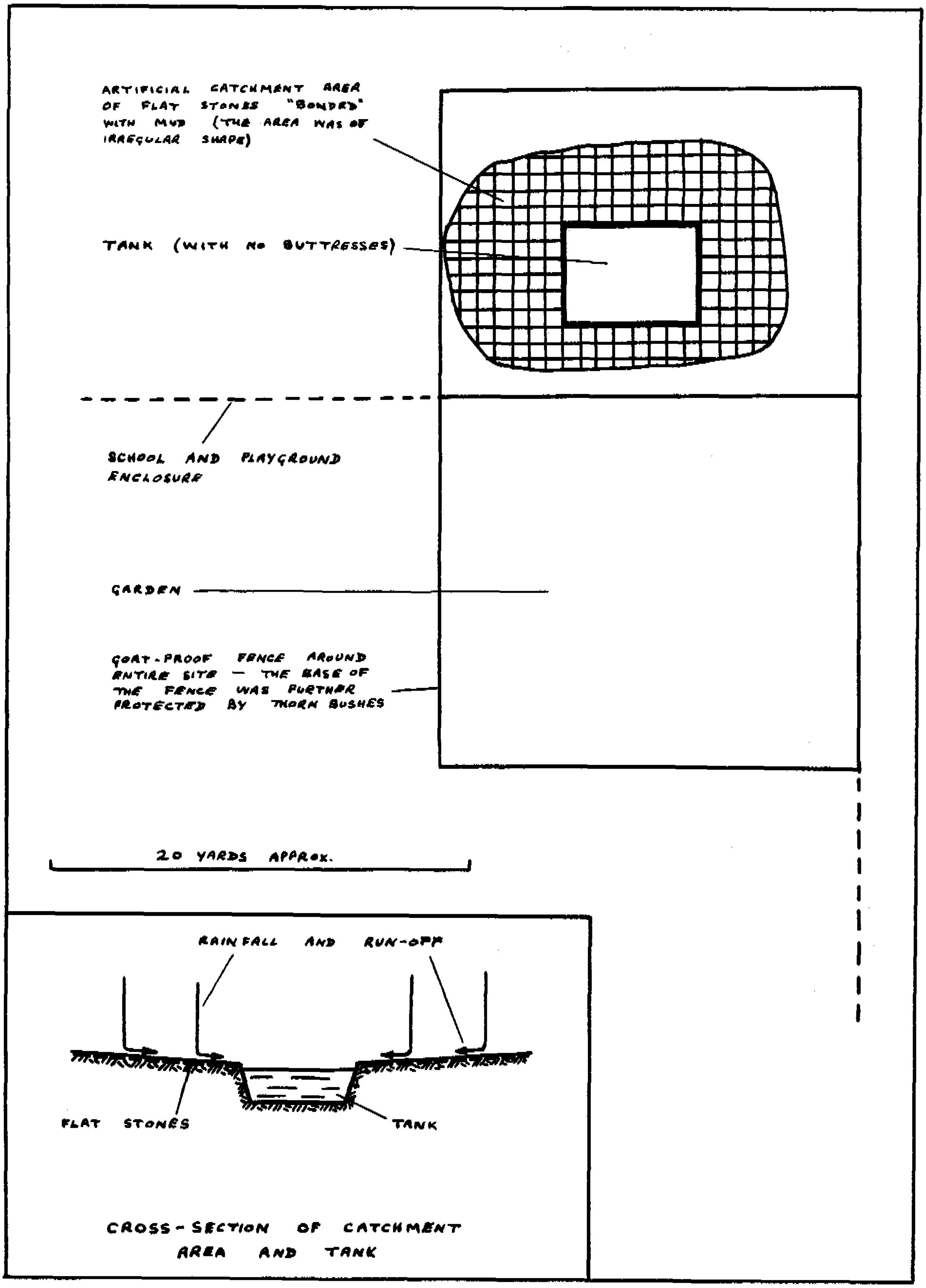


FIG. 18. Detailed layout of the Site at Palapye Central School.

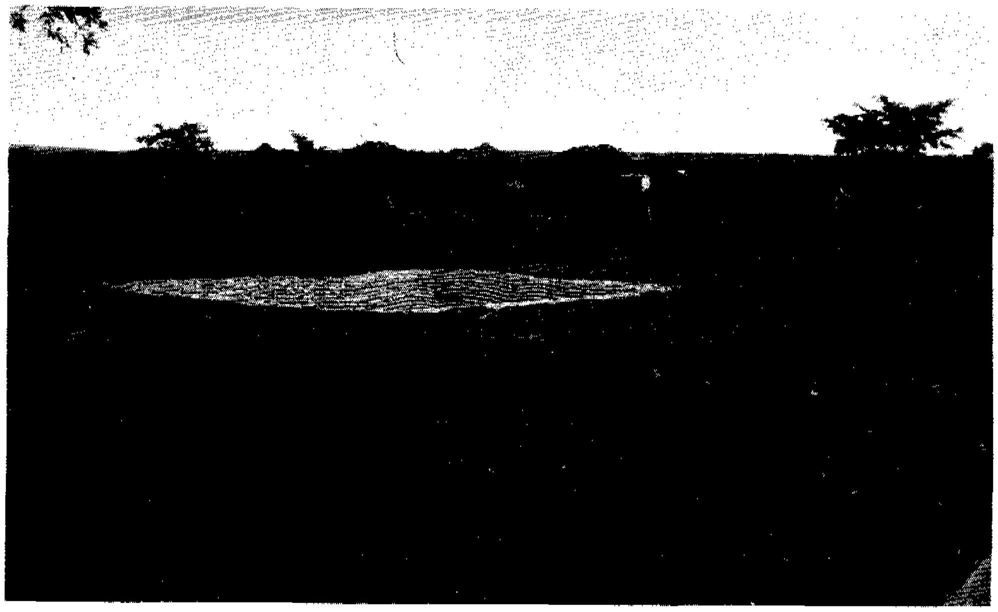


PLATE 22. Overall view of completed Tank, and catchment area in preparation at Palapye Central School.

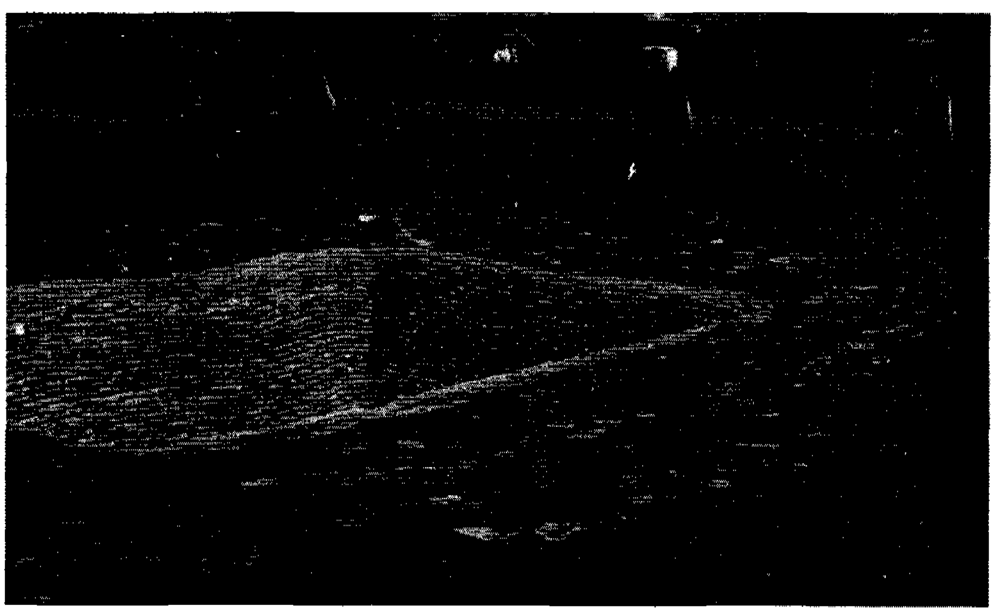


PLATE 23. Detail of Tank and catchment area with flat stones, at Palapye Central School.

The tank was made during November 1967. Unfortunately this was another school which failed to put buttresses on the inflow side, with the result that the tank was destroyed beyond repair by a short sharp local shower.

The garden was directly adjacent to a big wide sand river and beneath the sand there was a plentiful source of perennial water, so the catchment tank loss was not a disaster as the garden could still carry on. The area of the garden was fenced off originally as a Women's Guild Garden; it never really functioned as such and the authorities made it over to St. Patrick's. The fence was made almost entirely goat proof by building a 'dry' brick wall around the base of the netting of the fence. The bricks were throw-outs from a nearby brickfield. Although goats still caused occasional trouble by forcing their way through the fence, it was not serious. It does not seem as if any vegetables were pilfered from the garden—this is fairly remarkable because that is the sort of thing that one would expect to go with civilization. (Mahalapye town is rather large and cosmopolitan).

By July 1968, there were seven large beds of spinach which looked very healthy, two beds of carrots, some of which had already been eaten, two beds of cabbage and a large number of seedlings to follow on, three beds of tomatoes which were bitten by frost but regrew, and two beds of lettuce seedlings. The size of the beds varied between 6 ft. and 10 ft. long and 2 ft. and 4 ft. wide. Up to July most of the children in the school had had a small meal of vegetables at least once a week for three or four weeks. The children who had been regularly and actively involved in the garden and tank had more.

10. Newtown School, Serowe

There were eight primary schools in Serowe, and of these four were represented on the training course. Unfortunately only one of these schools did in fact continue in the Project.

Newtown School is four miles away from the other schools and therefore, it was out of the question for it to share with the others. The other schools were all in the centre of the town which is a very rocky place indeed and no tank could have been built at any of the schools without great difficulty. There is no rock-free area until one is a mile outside the town, so it would have been possible for the three schools in the centre of the town to share a tank while Newtown had its own, but they were reluctant to share. It was Newtown therefore that carried on in the Project. (Simon Ratshosa School, Serowe, did in fact start a tank but as has been reported the teacher involved left to go to a training school for teachers of blind people in Malawi).

The teacher at Newtown really had the wrong outlook on the self-help type of work involved in making the tank and garden. He was a driver rather than a leader and looked upon the work as a means of punishing pupils; even then the work went on so slowly that the tank was nowhere complete by June 1968. Hopes for a mud-polythene tank were shelved while the school went on to enlarge the hole, already partly dug, for a Butyl liner. This was done during July 1968 and the result was very satisfactory.

The site was next to the school in an area which was virtually bare of all vegetation (it was overgrazed in fact) except for some 4 ft. to 6 ft. thorn bushes. Run-off from the ground was adequate. The school dug the hole for the mud-polythene to a depth of 3 to 4 ft. but they encountered a large amount of rock. The site was moved a few yards and excavation resumed unhindered.

The garden in July 1968 had not been started to any extent—even though water was available in quantity from a tribal borehole about 100 yds. away from the school. A number of tomato seedlings were growing in a nursery bed, but nothing else.

11. Tamasane School

This school had, in July 1968, the most impressive garden in the whole project (See Plates 21, 22 and 23). Originally the garden was a very small area enclosed with a stockade of mopane branches (a type of small tree) stuck in the ground. It was extended twice and became well over four times the size of the small school garden it was before.

All this garden was cultivated by August 1968 and most of it planted. It produced a tremendous amount of vegetables and up to mid-July had been producing enough carrots, spinach and beans to give each child (about 100 attend the school) a meal of vegetables up to twice a week.

The school had already earned the praise of the Education Officer on one of his visits for the state of their garden and the work done on it. In fact the quality of the garden was matched by the catchment tank. This was made before what rain there was fell, with the result that the tank did fill, enabling gardening to progress quickly. Very little water was lost by seepage from the tank and with a butyl lined tank this school could be the first to have a very large garden watered from tanks—completely independent of any other source of water—as had been planned for all the schools.

12. Sebeso School, Palapye

This school was originally going to share a tank and garden with Central School but later decided not to do so. They were a well endowed school with presumably a good bank balance—and they decided to purchase materials for their tank and garden. Visits to this school were made in the same way as other schools.

Unlike most of Palapye, this school was on firm ground—a heavy loam, much nearer the river—with the result that there was a good run-off. A conventional type of catchment tank was made. The work did progress, but rather slowly—other activities within the school took pride of place (sports, concerts, etc). The tank strangely enough was one of the first to be completed, and it may be because of this initial burst of work that the school lost interest; the work slowed down and it was well into July 1968 before any work was done on the garden. The tank lost very little water between filling in November 1967 and August 1968, indicating a well constructed one. Both garden and tank were fenced off well—in fact a professional fencer was hired by the school to do this work. The gate into the enclosure had a padlock—something most unusual in Botswana and an excellent deterrent against misuse of water and pilfering of the vegetables.

By July 1968, the garden had produced nothing; cultivation was being done but again very slowly. However, in spite of this a number of healthy looking tomato seedlings were nearly ready for transplanting and a number of beds were nearly ready for receiving them. The area of the garden was 360 square yards—meaning plenty of space would be available for expansion of the garden under cultivation.

D. SCHOOL CATCHMENT TANKS

The case histories of the schools cover most of the relevant points about the schools' tanks, but a number of points applicable to all have not yet been mentioned.

1. Buttresses

All schools except for Palapye Central should have had buttresses for protection of the inflow side. It is not clear whether or not the failure of some schools to incorporate buttresses is attributable to insufficient emphasis being placed upon the need for buttresses by the Project Manager or else failure on the part of the schools. In any future project a combination of more emphasis on the points of importance and more follow up visits ought to solve problems of this kind.

2. Linings

Lining of all tanks was fairly well done—but it is difficult to define a good lining in any case. There are no standards to go by other than those gained at Radisele, all that can be said about the general work on the linings is that most were done in such a way as to retain water well.

PLATE 24.   Detail of construction at Tamasane School.

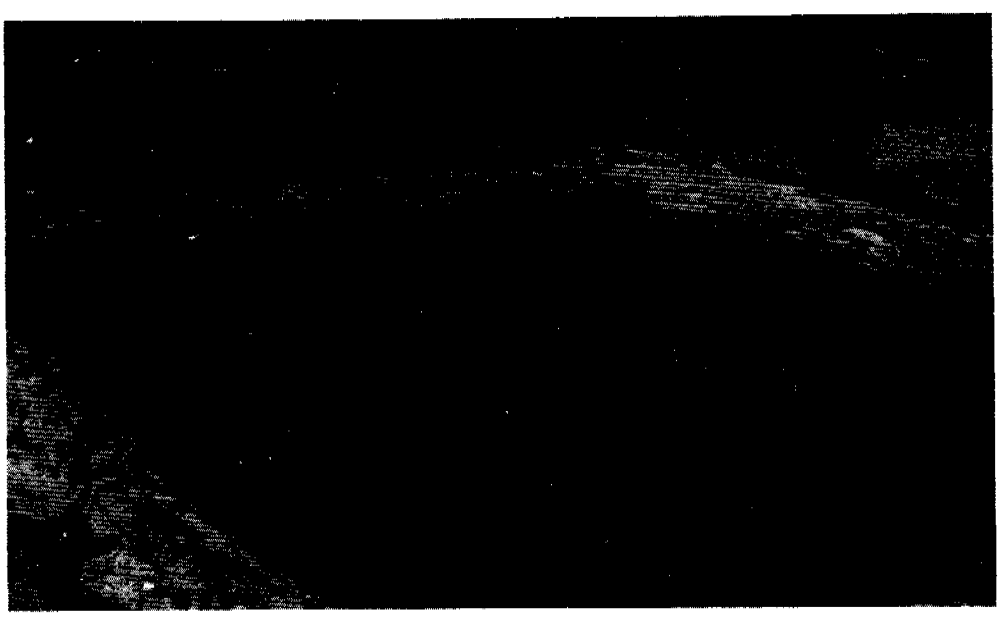


PLATE 25.   Completed Tank and surrounding fence at Tamasane School.

PLATE 26. Children and Garden at Tamasane School.

3. Covers for School Tanks

As a result of the trials done at Radisele the schools were advised to use a system that was thought to last for quite a long time: high tensile wire across the width and length of the tanks at 5 ft. intervals, anchored on poles in the ground around the outside of the tank, supporting wire netting. The final cover on top of the netting could be either grass, corn-stalk, cardboard, thick foliage—in fact anything that would prevent evaporation. By July 1968, all surviving tanks had been covered, or were in the process of being covered.

4. Extraction of Water from the Tanks

Most schools asked for pumps to remove the water, but those pumps that had been in use at one time or another at Radisele had been found to be very unsatisfactory and unsuitable for general distribution to the schools. As no fully reliable pump had at that time been found, schools used either buckets or shadoufs to take water from the tanks. Both bucket and shadouf were found to be satisfactory for the relatively small quantities of water necessary for the gardens at that stage. With the extension of the Project and increase in size of existing gardens a pump of some kind seems essential in order to be able to handle the greater volume of water entailed. Such a pump would have to be reliable, simple to maintain, simple in operation (a child of 7 must operate it), portable, and above all cheap.

5. Use of Butyl Lined Tanks in Schools

Due to the late arrival from U.K. of the butyl liners, only two had been distributed by August 1968—to Newtown and Ratholo. It can be assumed that had the liners been at Radisele in early September 1967 as had been hoped, then each of the eleven schools would have had a fully operational tank (and therefore garden) by December 1967. The mud-polythene tanks would have been built later on after the butyl tanks and after the rains—thereby saving some mud-polythene tanks from being destroyed.

The ease with which a butyl lined tank can be made assures a quick collection of water. The longest single operation in constructing such a tank is in the excavation, but this is easier than for a mud-polythene tank because the sides are sloped very gradually (see Figs. 8 and 9) enabling a wheelbarrow to be pulled from the floor to the surface, and a simpler excavation generally.

6. Sausage Making

The work of making sausages is very easy and light, but monotonous—eminentally suitable to being done by old people and small children. In the cases of the schools, sausages were made almost entirely by the girls in the schools. It was noticed that some became very quick at filling the tubes but uniformity was not a strong point. In fact uniformity is not essential, but it helps considerably in the handling of the sausages from the surface down into the hole.

Goats were a tremendous hindrance around the sausage making area—it seems that as well as thriving on paper and jute sacks they also find polythene extremely appetising and easy to digest. In future projects the whole site for garden and tank must be adequately fenced before any work starts. This would ensure that no damage at all is done by goats—whether to the garden, tank or while sausages are being made.

E. SCHOOL GARDENS

As with the School Catchment Tanks, a number of general points should be added to the detailed case histories.

1. Cultivation

The form of cultivation was left almost entirely to the teachers. They did have, however, notes on those types of bed which were tried out and used at Radisele. Generally 'conventional' cultivations only were done—i.e. the top 1 ft. of soil loosened and turned. It was found that this cultivation gave better yields than other more 'exotic' cultivations such as deep digging, polythene/sand mulched surface, etc. This must indicate that the soil could bear fairly concentrated cropping for at least 18 months. Whether or not it could bear it for longer periods will be seen in future experiments and further results from the schools.

2. Seeds

The only seeds issued as part of the material supplied by the Project to the schools were those of vegetables that are of high nutritional value. Most schools also bought seeds of their own choice from local shops, thereby trying out nearly every available type.

Seeds issued by Project	*Type*	*Seeds bought by Schools*
Cabbage	Drumhead	Lettuce
Carrots		Onions
Runner Beans		Potatoes
Dwarf Beans	Canadian Wonder	Maize (mealies)
Tomatoes	French Kaki and Moneymaker	Beetroot
Spinach		
Peas	Greenfeast, Strategem	

3. Watering of Gardens

All watering of the gardens was done by the children with directions from the teachers. Micro-irrigation was used throughout—a tin filled directly from the bucket or the 'shadouf' and the water poured carefully around each plant. In the case of nursery beds where plants were very close together, the bed was flooded to ensure an even distribution of water.

4. Results

Results from the school gardens were not kept, but it is quite certain that had they been kept (weight, yields, water consumed, fertilizer used, etc) then the results would quite probably have been far better than those achieved in the experimental garden at Radisele which was under semi-strict control.

5. Consumption of Vegetables

By July 1968 most schools were producing enough vegetables for many children to have a meal supplemented by a vegetable twice a week. Every primary school had a midday meal of World Food Programme mealie meal, cooked by women from the village in which the school was situated. It was with this meal usually that the vegetables were eaten. As far as could be seen very few of the children disliked eating vegetables, and it is thought that this was purely a matter of getting used to a new type of food: although vegetables were not a new food stuff to the country, a number of naturally occurring plants were eaten by Batswanas in the same way as Europeans eat vegetables.

6. Fruit trees

In addition to the seeds, each school was supplied with two guava trees and shown how to plant them in the way which was found best at Radisele. Generally only one of the trees at each school grew well. One or other of the trees (and in two cases both) were eaten by goats: it was found that the reason for either failure of a tank or garden could be traced almost always to goats. It could be said, indeed by many people has been said, that goats are the cause of most damage and nuisance in Botswana. In spite of apparently very good barricades of poles around the fruit trees, goats managed by continuous worrying to force their way through to the trees. This could have been prevented by 'posting a guard' over the trees, which were fairly expensive, thus ensuring that no goats broke through and that the barricade was always as goat-proof as possible, but the goats were incredibly determined to reach any foliage visible to them—there being little enough natural vegetation anyway.

The guavas ought to fruit in 1969, however those that had the foliage eaten by goats may take a long time to recover—if in fact they ever do recover. Some trees were inevitably hit by frost but generally recovered very quickly once warmer weather arrived. Incidentally, frost in Botswana is only local and never severe; many schools protected plants and fruit trees by covering them with dense foliage on sticks.

Wherever possible the guavas were planted next to a down pipe from a gutter on the school roof. This assured adequate water, whenever there was rain in small or large amounts then the trees would be watered. In the case of a school with a thatched roof this was not possible, thatched roofs give little collectable run-off, so the trees had to be planted in the garden and watered from the catchment tank.

The high vitamin content of fruit meant that they were an almost essential part of any gardening programme, but the success of growing them really depended on the school's ability to exclude goats and on the availability of water—the latter, of course, it is hoped was solved.

F. OVERALL ACHIEVEMENTS AND COSTS OF THE PILOT PROJECTS

1. Work Completed by July, 1968

The following lists give a brief review of the position of the work in the schools at July, 1968.

Of the eleven schools (including Sebeso School, Palapye) in the Project, five had built very good mud/polythene tanks, one had built a good butyl tank, another had built a moderately good mud/polythene tank, and one had built what apparently was a good tank, but it was unfortunately destroyed due to an Ipelegeng Dam suddenly overflowing. The other three schools had their tanks destroyed, because amongst other reasons, they did not build buttresses on the inflow side.

So far as the school gardens were concerned, six schools were known to be producing vegetables by July 1968 and a further four schools are assumed to have produced vegetables since then.

The details are as follows:

(i) *Schools with tanks satisfactorily constructed by July, 1968*

Malaka	completed	October 1967
Moineedi	,,	January 1968
Palapye Central	,,	February 1968
Tamasane	,,	November 1967
Sebeso, Palapye	,,	October 1967
Newtown, Serowe (Butyl tank)	,,	July 1968
Matlakola (lining not very watertight)	,,	December, 1967.

Ratholo—tank destroyed by overflowing Ipelegeng Dam.

(ii) *Schools with gardens producing vegetables at July, 1968*

Malaka
Moineedi
Muabui
Ratholo
Mahalapye (St. Patrick's)
Tamasane

(iii) *Schools assumed to have produced vegetables since July, 1968*

Matlakola
Palapye Central
Newtown, Serowe
Sebeso, Palapye.

2. Quantities and Costs of Materials for the School Tanks and Gardens.

The following table shows the quantities and costs of materials supplied by the Project for the school tanks and gardens. Of a total of twelve tanks, eleven were installed in the schools and one was constructed during the teachers' training course. All the tanks were of 10,000 gallons capacity.

	Quantity	*Cost*
Ten mud/polythene tanks:		
Polythene sheeting	4,800 sq. yds.	R 100
"Layflat" polythene tubing	456 lbs.	R 160
Cement	4½ tons.	R 90
Wire	900 lbs.	R 55
Insecticide	70 lbs.	R 21
Two Butyl tanks:		
Butyl liners (12,000 gallons)	2	R 400
Gardens:		
Seed (including 18 Guava trees)		R 22
TOTAL COST OF MATERIALS:		R 848

Again it should be noted that these are the costs that applied at Radisele in 1967/68.

V. CONCLUSIONS

This report has set out to describe simply and methodically the trials so far carried out in Botswana with water catchment tanks, first at the Radisele Farm of the Bamangwato Development Association, and later at a scatter of twelve schools. Originally designed for not dissimilar physical conditions in Kordofan Province, Sudan, they were modified to suit local conditions in Botswana.

The catchment tank, which may provide water for human and animal drinking or for small-scale irrigation, appears to have important potential in Botswana, where rainfall is seasonally concentrated yet not negligible, is highly variable from year to year yet seldom fails in any locality. The catchment tank's virtue is that, in a suitable location, it concentrates and conserves good quality rainwater gathered from a large catchment area.

Although expensive in terms of cost per gallon stored it may provide water in areas where other methods of water provision are out of the question, thus rendering habitable some tracts of land which would otherwise be empty, or suitable only for nomadic occupation. In such a case, the catchment tank must be regarded as one of a group of investment items which, once having been combined, provide benefits in excess of costs as a whole, and thus constitute an economic project.

Also there is reason to believe that there may be some areas of Botswana where the physiography is such that quite complex combinations of water-conservation and exploitation might be suitable (including small and medium dams, and boreholes as well as catchment tanks) in patterns designed so as to raise living standards substantially.

The Report also describes in detail the use of water stored in catchment tanks for small-scale irrigation. A variety of lifting devices were tried for removing the water from the tank when required, but a modified shadouf was the most promising.

High yields of a number of different vegetables were obtained and the establishment of trees proved feasible. Supplies of fresh vegetables (once the taste for them has developed) may make a substantial addition to local diet, with perhaps a marked improvement in human health—a benefit which is difficult to measure but nonetheless may be important. It was with this objective in mind that the project was mounted; the possibility of using rainwater catchment tanks to grow vegetables for market needs to be considered though it is outside the scope of this project.

High costs are involved in irrigated farming on this small scale, if expensive polythene/gravel mulches are to be used to reduce soil-water losses; these entail *cash* costs for the farmer. Even so, it may be well worth diverting capital to this purpose.

The Report stresses that much careful experimentation in alternative irrigation methods and cultural techniques is required. It is too early yet to judge whether investment in small scale irrigation will become popular either for producing vegetables for home consumption or for the market. It is perhaps enough to say, as a general conclusion, that a start has been made with an important inquiry with far reaching implications throughout the developing world. The interest inspired amongst the local people may in time lead to significant efforts toward development by a method which is specifically adapted to local conditions and which relies on the skill and industry of the local people themselves.

APPENDICES

APPENDIX 1

Rainwater Catchment Tanks
By Michael Ionides. (Consultant Engineer)

A practical illustration of Intermediate Technology in action developed by Doxiadis Ionides Associates Ltd. of Ripley, Surrey (U.K.) in collaboration with Doxiadis Associates International of Athens. The initial application of this research and development work was in the Sudan in connection with the Land and Water Use Survey in Kordofan Province, through the United Nations Development Programme, via the Food and Agriculture Organization.

A 'Catchment Tank' is simply a tank or cistern, in the ground with a 'catchment apron' alongside, which catches the rainfall and runs it into the tank, where it is kept in store until it is needed.

It is an ancient way of obtaining dry-weather water wherever there is no better or cheaper way. It is going to come back into its own again, for two clear reasons:

The first reason is – need. There are great tracts of semi-arid territory where population growth is pressing on the water-supplies for drinking and where a truly adequate solution demands very large numbers of catchment tanks to get water just where it is wanted, i.e. at the farm and at the household.

The second reason is–opportunity. Within the last couple of decades, modern science has produced revolutionary new materials, in the form of cheap impervious membranes of plastic or artificial rubber. These materials provide a completely new and essential basis for solutions by Intermediate Technology. They open the way for a massive attack on a problem which is becoming more and more acute as the years go by.

The photographs and sketch illustrate one particular type of catchment tank, which is designed to give 'best quality' filtered water. It holds about 20,000 gallons and the water in store is completely protected.

In photograph A, the excavation has been completed and an impervious lining is being laid. In B and C workmen are constructing a kind of honeycomb structure. The open mouth of each cell is covered over with a dome, so as to form a load-bearing roof over the whole tank. Sand is then backfilled, covering over the domes with a depth of a foot or so on top. After this backfilling, the entire structure is underground and out of harms way, except for the well-shaft, shown in D.

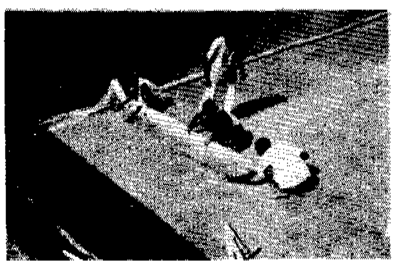
The sketch shows how it works. When rain falls, the water runs off the sloping catchment apron. It ponds up over the sand filter, which is supported on the domed roof. Then it soaks through the sand, trickling down into the cavities under the domes, inside the honeycomb of circular cells. To get water out, a bucket is lowered into the well's shaft. Or, in a more advanced stage, a hand-pump can be incorporated. The well-shaft is surrounded by a sand filter bed, so the water is filtered on its way into the tank, and also on its way out.

The impervious lining can be made in various ways and of various materials, according to local conditions and other relevant factors.

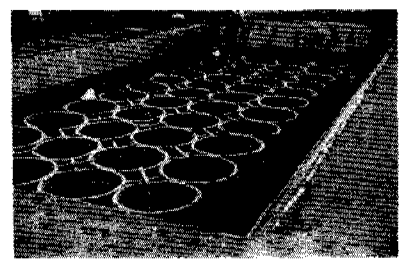
The cells and domes are built by a newly-developed process for forming concrete which is specially suitable for the essential 'do-it-yourself' requirement.

The technique consists of a very simple sequence of repetitive operations which can be quickly taught to country people without any craft training. It requires an absolute minimum of tools and plant. The structure shown in the photographs is a reinforced concrete shell formation. But no formwork is needed. The domes are built without any supports, by adding ring after ring in a decreasing radius. The only tools needed are a spade, a funnel, a carving knife and a little wooden mallet. Whereas ordinary concrete work has to be kept watered and wet, day-after-day until it is cured, the type used in this technique requires no attention at all after it is laid, because all the fresh concrete is enclosed inside a very fine-gauge (and cheap) plastic skin, like sausages. The water in the fresh concrete cannot be lost by evaporation and curing proceeds with uniform moisture, automatically.

This method of construction is truly a 'technology' because it is (to follow the dictionary) 'the result of the scientific study of the practical art', indeed the ancient art, of catching rainwater and storing it. It is a marriage of the very latest and most advanced of industrial products, with the best of local skills and local materials. The method is 'intermediate' because it can be taught to, and mastered by, a man whose skill is 'intermediate', not even requiring a craft training.



A



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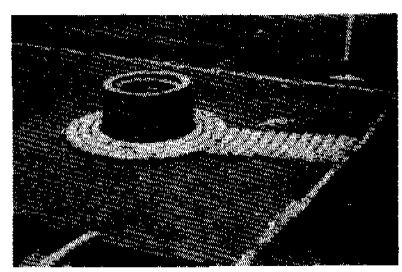
C



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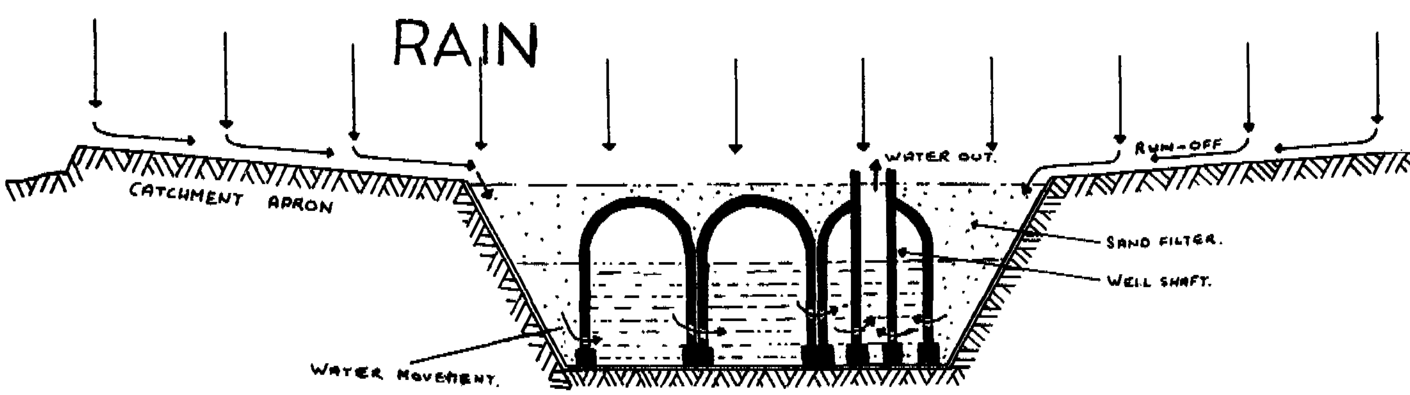

Since it can be so easily taught, the number of people capable of doing it can be multiplied quickly, through short-course training which can be done (for example) at existing agricultural schools; or by special open-air establishments set up for the purpose; or in the field itself by extension workers; and finally in the case of the smaller units, through village schools.

The number of people able to do it can be easily multipied, the technique can be spread throughout the rural community and become an 'industry' in its own right.

On this basis, it is quite possible to see the solution to the drinking water problem realized, by a progressive process of direct investment of the surplus, seasonal under-employed labour of the people themselves plus the local investment of a current cash surplus to buy the materials, which, inescapably, have to be bought from the outside. By such a mass attack, the job can be done. No other way is in sight for a comparable solution. A very large proportion of the developing countries find proper drinking water the essential key to any significant upgrading of agricultural productivity.

The illustrations show only one type of catchment tank out of many variations of size, design and materials. Indeed it is of the essence of the method that the standardizations are specifically related to local needs, purposes, skills and terrain. These can be commonly studied and defined on the basis of substantial-sized geographical regions. Preliminary studies are necessary to guide the choice from the available armoury of types.

Although these catchment tanks have been described here in terms of drinking water, there are many semi-arid places where the combination of soil and climate make it quite practical to use a tank for hand-watering in the household garden, so that fresh vegetables can be added to the diet.

APPENDIX 2

Summary of Research and Development Work at Radisele September, 1966 – November, 1968

1. Introduction

Dry as Botswana appears to be, every year there is rain. The driest year of the last seven years of 'drought' at Radisele had a total rainfall of 8½ inches, which is nearly 200,000 gallons on every acre. It is therefore better to identify the problem as being– not of insufficient rain (about which nothing can be done)–but of:

(a) storage of water, because classical dam sites are rare;
(b) showers often being of short duration, giving no time for rain to penetrate to the main rooting zone of crops;
(c) the rainfall intensity often being so great and the soils 'sealing' so quickly that much rain is lost in the arable areas by run-off;
(d) high rate of evaporation, making shallow reservoirs inefficient and causing soil to dry out fully between most showers.

Consequently we have been concerned with improving the efficiency with which crops use rainfall rather than with the more conventional concept of water conservation; hence the title.

The Report is divided into the following sections:

(a) Experimental work on long term water storage using hafirs;
(b) development and extension work arising from this;
(c) experimental work on supplementary irrigation of field crops from small dams;
(d) experimental work on growth of perennial crops, using run-off concentration and flood spreading techniques;
(e) intensive horticulture using water stored in hafirs.

2. Experimental Work on Hafirs

A hafir is excavated storage—a hole in the ground—that fills with water running off the surrounding land or from a specially prepared catchment. It can, therefore, be sited almost anywhere that has a reasonable depth of soil and can be of any size, bringing such a project into the reach of any able bodied person with a pick and shovel. Many such hafirs have, indeed, been made by people at their lands and even in villages, and, where the soil is reasonably impervious, they often hold water for many weeks into the dry season, which will usually be enough to last a family until the season's work on the lands is over. However, to enable permanent settlement at lands, the year-round production of small fruit and vegetable crops or any other activity that a small and relatively expensive water supply can support, these hafirs need to be lined and covered in all but the most favoured areas where seepage is of no consequence. The Radisele experimental progamme has tested a number of linings, covers and designs. A detailed report on them follows:

Type 1
- (a) Size: 8,000 gal.; 6′ deep.
- (b) Lining – three alternate layers of mud and polythene with termite-repellent layer of insecticide in first layer and protective revetment of reinforced concrete sausages.
- (c) Cover – black polythene on wire netting on light pole framework supported on reinforced concrete-sausage pillars built in tank.
- (d) Catchment – run-off from adjacent road (@ 2,000 g.p.m. in heavy rain).
- (e) Performance – failure, due to collapse of side when filling and excess seepage. It was the first to be built and was not built to full specification of the Sudan prototypes, because this had not been received at the time. For full specification, see Type 2. The cover was also unsuitable due to cost, vulnerability to wind and the volume lost to the bulky supporting pillars. Has been scrapped and turned into Type 3.

Type 2
- (a) Size – 10,000 gal. 6½′ deep.
- (b) Lining – as Type 1 but with an additional layer of polythene and mud, and a layer of sand-sausages in mud between layers 2 and 3. Sides less steep – 70 degrees. Wall heavily strengthened on inflow side.
- (c) Cover – sorghum stalks laid loosely on wire netting supported on plain wire strained across the tank.
- (d) Catchment – as Type 1.
- (e) Performance – successful, has filled four times and has very low seepage losses. Cover still not perfect; stalks blow away in high winds and detritus falling into the water causes the formation of a surface film that inhibits the spread of malariol (a diesoline based larvicidal oil for the control of mosquitoes).
- (f) Cost per sq. yd. of lining – 43c.
- (g) Cost per sq. yd. of cover – 24c.
- (h) Application – very labour intensive but with low material cost; lining may also have a life of not more than 10 years. Therefore, most suited to people with limited capital who are unemployed for much of the year. No skills are required and much of the work can be done by women and children.

Type 3
- (a) Size – 24,000 gal.; 7′ deep.
- (b) Lining – sheet of .012″ thick PVC prefabricated in factory to fit hole. Sand and sand-saugages lining bottom half of hole to protect sheet from stony subsoil. No insecticide used; revetment of cement sausages to protect sheet.
- (c) Cover – as Type 1.
- (d) Catchment – as Type 1.

(e) Performance – unsuccessful so far: under cover of the revetment, mice and termites attacked the PVC causing so many leaks that it leaked at a rate of 100 g.p.h. The revetment has been removed and holes patched; there are still more leaks and the firm supplying the lining has ignored requests for further patching material. We hope still to get it into commission.
(f) Cost per sq. yd. of lining – 70c.
(g) Cost per sq. yd. of cover – 43c.
(h) Application (if it can be brought into effective service) – is much simpler and requires much less labour than Type 2, but the ease with which it can be punctured (and impossibility of repairing it until all the water has been lost) makes it unsuitable for widespread introduction at present.

Type 4 (a) Size – 18,000 gal.; 6′ deep.
(b) Lining – a flat sheet of .030″ thick butyl sheeting put into a hole with 45 degree sides and soil spread over the stoney parts of the subsoil to protect the lining from puncture. No revetment, no insecticide.
(c) Cover – single sheet of butyl sheeting spread over the surface of the water.
(d) Catchment – as Type 1.
(e) Performance – perfect. Seepage and evaporation losses nil.
(f) Cost of lining – Rl.50 per sq. yd.
(g) Cost of cover – Rl.50 per sq. yd.
(h) Application – this is the simplest and most expensive lining tested; it is imported from the U.K. so that it is best ordered in large quatities (this price is based on a £1,000 order) so that it is beyond the reach of individuals, but could have a wide use in commercial and institutional organizations. Because the sides slope so gently, water can not be extracted by bucket; a pump of some sort or an Archimedes screw would be essential. South African butyl sheeting is available but is more than twice as expensive as that imported from U.K.

Type 5 (a) Size – 15,000 gal.; 8′ deep.
Exactly the same as Type 4 but with 80 degree sides and a cover of floating slabs of polystyrene. Because of the steep sides, there is wastage of the sheeting at the corners, thus increasing the cost of the lining, but making extraction and covering easier. The polystyrene covering cost 60c. per sq. yd. and was repeatedly damaged by wind. Application – the wastage in the corners could be eliminated by fabrication to fit the excavation and an alternative cover could be used, it would then be slightly more cost–effective than Type 4.

Type 6 (a) Size – 4,500 gal. approximately; 6′ deep; circular (all others are rectangular).
(b) Lining – as Type 2. Inside the hafir, 7 pots are built of reinforced cement sausages only (i.e. they permit the free passage of water) with domed tops which support a 1′ thick layer of sand that acts as a filter bed. Sand is also filled into the interstitial spaces between the pots (which are cylindrical and contiguous) and a sheet of perforated polythene is placed just below the surface of the sand filter bed to prevent evaporation of contents of tank from the sand surface.
(c) Cover – incorporated in sand filter bed.
(d) Catchment – black, heavy duty polythene sheet spread on the soil that has been dug from the excavation and smoothed back to give a 10 degree slope on all sides of the tank.
(e) Performance – successful; has filled twice so far. Very little seepage

and evaporation losses; the water was tested for potability by the Veterinary Research Laboratories after being stored for three months and found to be free of all pathogenic organisms – i.e. fit for drinking without boiling.

(f) Cost of lining – 43c. per sq. yd. N.B. – Cost of pots is R2.50 each (hold 500 gal.)

(g) Cost of cover – 2½c. per sq. yd.

(h) Application – as for Type 2. If the tank is costed over 5 years, the drinking water provided will cost approximately 7c per drum of 45 gal. – water delivery services where available usually charge at least 25c. per drum in villages.

Type 7 (a) Size – 3,000 gal. 6½′ deep; circular.

(b) Lining – prototype of a butyl liner that could be mass produced. A fabricated liner from the same material as the Type 4 to fit a cylindrical hole; required backing with sand sausages in lower part because of stony subsoil and had a cement sausage revetment to support the vertical sides.

(c) Cover – butyl sheet cut to fit mouth of hole.

(d) Catchment – as Type 1.

(e) Performance – mice got behind the revetment while the tank was still empty and severely punctured the liner. Repairs could only be effected after complete removal of the revetment, almost nothing of which was salvaged for re-use.

(f) Cost of lining – R3.60 per sq. yd.

(g) Cost of cover – R3.50 per sq. yd.

(h) Application – a heavily galvanised tank let into the ground would be better, cheaper and simpler. It is quite unsuited to Botswana.

Type 8 This one is still under construction and will be basically a mud-lined hafir. The sub-soil will be treated with both insecticide and herbicide. This will then be followed by a 4″ thich application of stiff well worked mud, kept moist and prevented from cracking by a single thickness of thin polythene sheeting and the whole lining will then be protected by a revetment of cement sausages. Cost of lining should be 25c. per sq. yd.

Type 9 This one is also still under construction and will test the effectiveness of an application of bitumen of varying thicknesses. The sub-soil is first treated with insecticide and herbicide; the soil surface is then made quite smooth if necessary by smearing with mud and the bitumen (a cutback–Shelmac RC2) is applied. A protective cement sausage revetment is applied to protect the lining from erosion.

No control hafir (one with no lining at all) was made because of the rapid loss of water through the punctured linings–making the point that a lining was necessary here quite adequately.

3. Development and Extension Work on Lined Hafirs

The successful, low-material cost Type 2 has been chosen for the follow up programme.

(a) Practical Instruction Courses

(i) August, 1967 – 11-day course for 19 Primary school teachers; one 10,000 gallon type 2 hafir constructed and covered with rough matting made of sorghum stalks supported on wire strained across; elements of low irrigation-requirement gardening also included. This course was the beginning of a separate project financed by OXFAM for the introduction of this type of hafir and gardening methods into Primary schools in the district on a pilot scale, with a view to its providing the basis for a continuation of the School Feeding Programme after outside help is withdrawn in 1971.

(ii) October, 1967 – 10-day course for Agricultural Demonstrators. A small Type 2 hafir was contructed. They also helped with the installation of a Type 3 and a Type 4.

(iii) March, 1968 – some staff members of the Friends Rural Service Centre, Bulawayo, Rhodesia, were instructed in the construction of a Type 2 hafir and a 10,000 gallon tank was subsequently completed. However, latest reports are that this has been severely damaged during the first filling (November, 1968). The cause of this is not at present known, but may reflect the large amount of mud that had to be used in the first layer of the lining, because of the extremely irregular surface left after the excavation was done–the ground was very rocky. Other developments at the F.R.S.C., Bulawayo, include the construction of a Type 3 using heavy grade polythene, and an outside project shortly to be undertaken at the Remand Home, probably using a Type 2.

(iv) August, 1968 – 12-day course for 16 Community Development Assistants. They began the lining of a large (130,000 gal.) Type 2 and Type 6 combined and the construction of the pots to support the filter bed. They also had general instruction in and demonstrations of other methods of rainfall utilisation improvement that are mentioned in this Report. This particular tank is designed as a combined drinking water tank (enough for say 10 families or if used for a farm training scheme, enough for 40 trainees for a dry season) and irrigation water tank sufficient for a ¼ acre garden, such as a village women's group or a farm training scheme might have. The drinking water end will have its own prepared catchment to ensure maximum purity of the water. It will be smeared in the same way as a threshing floor and possibly also treated with bitumen or a cement slurry.

(v) November, 1968 – Course arranged by the Community Development Department as follow-up of the August course held here, at a school in Mochudi, Botswana. There was a mixed attendance of men and women chosen from village leaders and Community Development Department staff, and a Type 2 hafir was made.

(vi) Proposed courses – one to be held in Serowe and the other in Tsabong before the end of the year, similar to (v). The Tsabong course will be of particular significance because this will be the first occasion for constructing such hafirs in the Kalahari Desert.

(b) Further Development

The large Hafir mentioned under (iv) has now to be completed, although the farm training scheme that it was to serve is not now to be started. Thereafter, this work will be transferred to Swaneng Hill School and will concentrate on cheapening and simplifying the various linings that are or have been tested here. It is also likely that a Batswana will be trained up in this work so that he can concentrate on the Extension side, which seems likely to grow very rapidly. It is also possible that lined hafirs may be installed at Primary schools on a national scale, if any general school gardening programme is adopted by the Ministry of Education. There is also the possibility that very large-scale hafirs, probably of Type 4, could be used in areas where grazing is good but where there are no reliable surface or underground water supplies.

4. Supplementary Irrigation of Field Crops from Small Dams

This concept applies mainly to the arable areas of Eastern Botswana, where the bare, overgrazed veld and the hard soils give rise to much run-off, sufficient to cause big washaways in ploughed land, and also to fill small dams in a short time. Because of the lack of good dam sites, such dams must of necessity be largely excavated and will also have a very high floor-area-and-surface-area to volume ratio. Consequently, they will store water relatively inefficiently (but very cheaply, especially if they are made by hand) and for maximum effectiveness, this water must be used as quickly as the crop to be irrigated can use it. Therefore, it is only irrigation to *supplement* the natural rainfall that can be given, yet, in a season with several rainy spells, such a dam might be filled and emptied several times, thus providing generous amounts of irrigation and making two crops possible. Two such dams have been made, each of approximately 10 acre-feet capacity, and both have since filled to about one third of this capacity on the first gentle rains of this season.

Dam No. 1 – Built during 1968 using entirely mechanical aids with the exception of a nominal amount of work with an ox-drawn dam scoop in connection with a teaching programme. The aids used were simple enough for operators to be easily trained on the job and were chosen for their ready availability to those who could afford mechanised farming. They were – a Massey-Ferguson 35 tractor (by far the commonest tractor in Botswana): a light-duty sub-soiler for loosening soil prior to excavation with a half-cubic-yard mounted soil scoop. The capital cost of the whole unit would be about R2,200 which, judging from the large numbers of such tractors that are about in Botswana (being grossly under-used), should be well within the reach of wealthier members of the community. Work on this dam is now nearly finished and the full cost is unlikely to exceed R450 (use of tractor and equipment being charged at regular commercial rates). Since perhaps half of this would represent indirect (overhead) costs, the actual cash expenditure that a private tractor owner would have to meet on such a job would almost certainly not be more than R250.

Dam No. 2 – Built during 1968, using largely hand labour—with a view to contrasting the two schemes. Since a tractor can loosen soil far more easily than it can move it, and hand labour can move soil far more easily than it can loosen it—especially when the soil is dry, as it always is in the dam-building season, a tractor and sub-soiler was used periodically to loosen soil in the basin, prior to the labourers moving it to the wall with shovels and wheelbarrows. The tractor was also used for wall consolidation, and a little touching up of the rather ragged wall left by the labourers.

Costs on this one have been higher, Approximately R460 on labour and R100 on tractor work. The former represents about 1,000 man-days, so that a syndicate of perhaps five families could, if determined enough, embark on such a project for themselves. Consequently, the labour cost would fall away, leaving them about R20 each for tractor hire. Since they would be able to irrigate at least one acre each, this represents very cheap irrigation.

Application – as implied above—i.e. individual tractor owners could put their equipment to good and economic use during the winter making such small dams. Groups of farmers could also do likewise, making use of hand tools that they can borrow freely from Government. Department of Agriculture tractors could also be effectively used in this way (instead of being parked in neat rows in Mahalapye) especially if equipped with slightly larger earthmoving equipment. Irrigation from these dams could be by an Archimedes screw and flooding. Alternatively, there are small portable overhead irrigation sets that can be bought quite cheaply (see *Tools for Progress**), or, if there were a number of such dams in a small area, a tractor could be equipped with a PTO-driven centrifugal pump and provide a mobile irrigation unit, charging so much per acre/inch. This would have the added advantage of again using the tractor more fully since, if it is dry enough for irrigation to be done, it will be too dry to plough or plant according to conventional practice.

5. Flood-spreading and Run-off Concentration for Perennial Crops

The intention here is to store water in situ, but in the subsoil where it will not be lost by evaporation from the surface. It obviously cannot be practised in areas subject to

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waterlogging and, unless artificial catchments are provided, it can only be done where there is appreciable run-off. For the water to penetrate deeply into the sub-soil, run-off water must be delayed on the surface long enough and in sufficient quantities to ensure that something like three times as much water as is derived from rain directly received by the crop goes into the ground. Normal rains rarely penetrate much more than 18″ in dry years. Infiltration is also encouraged by the use of mulches, which also retard surface evaporation. A few small trials have been initiated so far:

(a) Flood-Spreading

Two small orchards of guavas were planted in early 1968 with a gravel-polythene mulch in one and a mulch of flat 'crazy-paving' type stones in the other. Both areas are innundated by about 2″ of water when rain is heavy enough to generate much run-off (4 times this year) (1968) and this usually persists for about an hour after the heavy rain has stopped. The guavas have survived the winter and are now putting on new growth, having only received one irrigation of 15 gallons each in October, 1968. In one orchard, cape gooseberries were established in May, and have given fruit though without receiving any irrigation at all.

(b) Run-Off Concentration

Early in 1968, a quarter-acre plot of Eucalyptus meliodora and E. camaldulensis was planted. The trees were spaced at 8 feet on strips laid out along the mean contour (general slope about ½%), 12 feet apart. The spaces between the strips were made up into low ridges, covered with thin polythene and small stones. Three strips were planted with annual crops, in addition to the trees. and from one strip, planted with maize, sufficient was produced and sold to cover the cost of the polythene sheeting used. The trees grew continuously except for the very cold spell during the winter, and are now, 9 months after planting, some of them more than 6′ tall. However, this method is too costly and elaborate for widespread introduction, but it is the forerunner of a simpler system that is now being developed for use with annual as well as perennial crops. This system is being laid down on some lands recently cleared from bush in very overgrazed areas with a 1% slope. In it, there are to be, alternately, cultivated and smoothed uncultivated strips along the mean contour. The strips will be between 4′ and 6′ wide. The cultivated strips will therefore, receive additional water from the adjacent smooth, bare uncultivated strips and, if mulch and fertilizer are used, substantial yield increases should be obtained. Work still has to be done, though, not only to prove this, but also to determine the optimum widths of the strips, and what measures should be taken to protect the system from erosion in the event of a long spell of repeated heavy rains.

(c) Application

This is still in a very early stage of development, but it certainly seems possible to consider the establishment of trees on this system on a large scale—e.g. village timber lots to make up for the rapidly dwindling supplies of good building timber from the bush, and firewood in the bigger villages. Fruit production may also be possible, and if annual crops respond well enough to this, the whole scheme of dryland arable farming may be revolutionised.

6. Intensive Horticulture

A series of micro-irrigation trials, using water from the experimental lined hafirs, on different vegetables grown under different conditions has been carried on for nearly two years to determine what cultural methods, if any, give a better yield from a given amount of water. The results of this have been written up separately—"Micro-Irrigation Experiments at Radisele", September, 1968—but can be summarised here:

(a) Treatments

(i) 50% sub-soil to 4 feet replaced by unrotted organic matter—mainly threshing waste.

(ii) Surface of bed covered with a mulch of perforated polythene sheet protected by gravel or sand.
(iii) 2-feet wide and 1-foot deep strips of sand put between the beds to enable more water to go into the sub-soil at times of heavy rain.
(iv) Soil prepared in the conventional way—deep digging and incorporating kraal manure.

(b) Vegetables Grown

Peas, dwarf beans, cabbage, lettuce, green maize and tomatoes.

(c) Results

Treatment (i) has fairly consistently given the best returns, but excellent lettuce yields were derived from treatment (iii), after the good autumn rains of 1968, and cabbage has responded well to treatment (ii). In terms of production per 100 gallons of water applied, tomatoes and lettuce (18 and 60 lb. respectively) have done best. Green maize has far too high a water requirement (and too low a cash and nutritional value) to be worth growing on this system – 7 cobs per 100 gallons of water. Cabbage and peas at 6 lb. per 100 gallons are also promising.

(d) Application

Using treatments like these and irrigating very sparingly, substantial production can be obtained from very limited water supplies. It would be of most use to family vegetable growing; it involves too much labour to have much commercial application, unless prices are very high. However, it is likely that a commercial vegetable production unit, using some of these techniques may soon be brought into operation at the Serowe Farmers' Brigade, when valuable commercial experience will be gained. This method would also be relevant to a school gardening programme.

7. Summary

Botswana receives enough rain to support an active water conservation programme. Shortage of capital and high rural and urban unemployment combined with the lack of rivers and good dam sites, make it necessary to think out a new approach to such a programme. A number of methods that improve the efficiency with which this rain is used, are being tried at Radisele—a few are ready for wider scale introduction, but most require a few more years of experiment and development—and almost all of them combine features of low capital cost and high labour requirement.

In conclusion, it can be said that when we can say we should dam the roads (to divert the water that runs down them during rain into a lined hafir) and regard our bare, overgrazed veld as an asset (for its high run-off potential that ensures small dams and hafirs will fill only on one good rain), then we have arrived!

Radisele V. GIBBERD
1st December, 1968.

APPENDIX 3

PROPOSAL FOR A PILOT PROJECT: "CATCHMENT TANKS AND MICRO–IRRIGATION GARDENING FOR BOTSWANA PRIMARY SCHOOLS."

BAMANGWATO DEVELOPMENT ASSOCIATION
in association with
THE INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP

History

A system of conserving rainfall in excavated pits, in a dry area of the Sudan using only a few cheap purchased materials in addition to the locally available sand clay and grass has been developed by Doxiadis Associates as a United Nations Special Fund Project over the last five years. Preliminary results were sufficiently good for the project to be extended to several villages.

The writer visited the Project's experimental yard in June 1966.

Development in Botswana

During the last six months, one such tank has been constructed at Radisele, as a local initiative and based on the Sudanese designs. In January this year an experimental garden designed primarily to test the effect of a gravel-polythene soil-moisture trap on irrigation needs of a vegetable crop has been started. Further tanks will be completed during the next few months, using slightly different designs in an attempt to improve water-retaining qualities. All this is being done at the Radisele headquarters of the B.D.A. and in close consultation with Mr. Ionides of Doxiadis-Ionides Associates, and the I.T.D.G. whose Secretary recently visited the project.

Relevance to Botswana's Needs

The recent five-year drought in Botswana has been a world concern and a large-scale famine relief programme has been mounted to provide a basic but balanced diet for destitutes and school children. With the resumption of a rainfall pattern that makes arable agriculture again possible for the average farmer, this programme is likely to be discontinued.

However, even the normal pattern of farming fails to provide a *balanced* diet for the population throughout the year and, whereas in other countries this is compensated for by the widespread practice of working small hand-irrigated gardens to produce fruit and vegetables throughout the year, lack of cheap water makes such gardening impossible in Botswana. Most water is derived from deep boreholes, widely scattered and with little spare capacity. At the same time, even in a drought year, there is enough rain in heavy showers to give a large run-off from all except the most sandy uncultivated land. If some of this was stored in these catchment tanks and used with the sort of experimental irrigation techniques at present on trial at Radisele, permanent horticulture would become a possibility. In sandy areas such as the Kalahari artificial catchments could be made with smeared mud, augmented with roof run-off.

The type of construction used in making these tanks, furthermore, is very labour intensive yet requires no skilled artisans and only minimal purchased materials. It therefore has a wide potential application—not only in schools to provide children with some 'protective foods' and as a demonstration, but also in every village and 'lands' home. And its design can be modified to provide a clean supply of drinking water.

Proposal

Provided that:—

(i) the Local Education Authority agrees;

(ii) the Botswana Ministry of Education agrees; and

(iii) at least one prototype of each of the proposed designs can be constructed and demonstrated to be reasonably watertight before the end of May, it is proposed to implement the following pilot project.

1. Operational Plan

Form a temporary field training school at the B.D.A. headquarters at Radisele. Ten teachers (men or women) will attend for a fortnight's practical training course from, provisionally Monday 21st August 1967, and then be provided with materials for building two tanks in each of their schools. They will be chosen from schools within a 50 mile radius of Radisele and will be paid their expenses. On returning to their schools for the next term, they will teach the pupils how to construct the tanks and lay out the garden with assistance from the Project Manager who will make regular visits and ensure that all tools and materials are supplied. The Project would last two years during which time the Project Manager would make regular visits and reports and be freely available to give advice and assistance.

2. Management

The Governing Council of the B.D.A. will be the responsible agency for the project and will appoint their agricultural consultant, Mr. V. Gibberd, as Project Manager. He will be responsible for liaison with the education authorities, I.T.D.G. in London Doxiadis-Ionides Associates, for obtaining all the necessary purchased supplies and employing such casual labour as may be necessary on the training course. The I.T.D.G. will collaborate with Doxiadis-Ionides Associates, in providing technical data and obtaining supplies of such imported materials as may be required, and with the body granting the money for the project's finance.

3. Estimates

These will be finalised in consultation with London and later attached. They will include provision for the following

a. Salary of trained Batswana Instructor (£6 a month)
b. Casual labour to assist with excavation of tanks (3/- per cu yd)
c. Casual labour to assist at the training course (£1 a week)
d. Dynamite and a licensed operator 410/- per day, in case rock is encountered at any of the selected schools
e. Administrative expenses–post, phone, stationery etc.
f. Travelling expenses of about 2d a mile for the return trip to Radisele from their schools and a subsistance allowance of 10/- a day for each teacher attending the course.
g. Travelling allowance, by car, to allow for up to 16 visits to each school during the 2 years of the project.
h. Butyl, polythene, wire, cement and insecticides for 11 Polythene & 11 butyl tanks (i.e. one of each for each participating school and the training course).
i. Transport of clay, sand, poles and grass for training course.
j. Excavating tools for training course and for loan to the participating schools (ownership of tools to be transferred to Local Education Authority?)
k. Tools, seeds, polythene for each school garden.
l. Photographs, for reports back and use as visual aids in Botswana if project successful.
m. Fencing materials for schools.
n. No provision is made for the Project Manager's salary as this is already assured, but a technical assistant would be essential. If this were a volunteer seconded when needed from another government department, then no further expense would be entailed. It is hoped that the Ministry of Education would endeavour to have one released for say, the three months during and immediately following the training course.
o. A provisional item to provide for travelling and subsistance for up to 5 additional persons coming from other parts of Botswana to observe the course and to act as 'nuclei' for any further development that may be engendered by the project's success. Such persons might be Education Officers, Relief and Rehabilitation Officers or voluntary workers from projects similar to B.D.A.

4. Outline Designs

Tank capacity–about 9,000 gal; size–20 sq. ft. top, sloping sides, 7′ deep. Two such tanks should be sufficient for 1/25 acre garden.

Linings: (i) Prefabricated butyl liner with sandcrete revetment cast in polony-shaped polythene membranes secured to each other with skewers of gauge 8 wire;

(ii) quadruple mud-polythene sandwich with a layer of sand-sausage spacers (i.e. as revetment above but no cement) between layers 2 & 3, with sandcrete revetment as above. Insecticide sprayed on sides and floor of pit before lining to deter termites.

Roof: thatched or netting-polythene-gravel on sandcrete pillars.

Garden: prepared in normal way, then soil covered with first perforated polythene, then 2" of gravel; holes made through this for planting.

Polythene used; 1½/1,000" thick max. Sandcrete 1:15 sand of any quality, but not containing earth or organic matter.

Vernon Gibberd

Botswana, 13.2.67

ESTIMATES FOR THE PILOT PROJECT – "CATCHMENT TANKS FOR BOTSWANA PRIMARY SCHOOLS"

	£	s.	d.
Personnel:			
Project Manager–salary assured from elsewhere.			
Technical Assistant–volunteer seconded from other government dept. for three months			
Foreman–trained Batswana, £6 per month, 12 months	72	–	–
Casual Labour–assuming half the excavation of each of the 22 pits requires hired labour @ 3/- per cu. yd.	88	–	–
Casual Labour to assist at training course: 4 for 2 weeks @ 18/- a week	7	4	–
Licensed explosives operator @ 10/- a day say ten days	5	–	–
	£172	4	–
Administration:			
Post, phone, stationery, duplicating etc.	30	–	–
Travelling expenses for Project Manager & assistant, assume average distance of schools from Radisele to be 40 miles. Advisable make one pre-course visit, monthly visits after the course for 6 months, thereafter bi-monthly. Total mileage; 40 x 2 x 10 schools x (1 + 6 + 8) visits = 12,000 miles @ 1/3 a mile	750	–	–
	£780	–	–
Teachers' Allowances			
Travelling to and from course @ 2c a mile; average distance: 40 miles. Total mileage 40 x 2 x 10 teachers	8	–	–
Subsistance @ 10/- a day, for 14 days	70	–	–
	£78	–	–

Material for pits: 11 pits of each type, 16′ sq. top, 14′ sq. bottom, 7′ deep.			
polythene sheeting, 31,000 sq. ft. @ .328 cents/Sq. ft.	48	14	7
tubings, 290 lbs. @ 46 cents/lb	66	14	–
cement, 198 pockets @ 66 cents	65	6	10
wire, 7 rolls of gauge 8 @ 52/- a roll	18	4	–
insecticide, say	2	15	–
butyl liners, 11 @ say £90 each	990	–	–
polythene tubing, 181 lbs @ 46 cents/lb	41	12	7
cement, 198 pockets @ 66 cents	65	6	10
wire, 7 rolls gauge 8 @ 52/- a roll	18	4	–
insecticide, say	2	15	–
contingencies allow 10%	131	3	1
	£1,450	12	11
Tools			
for school garden (4 trowels, spades, mattocks; 2 rakes & forks)	125	–	–
for excavation (4 picks, 4 shovels each school)	70	–	–
	£195	–	–
Other Materials			
photography: colour and black & white	6	–	–
netting fence–60 yds per school	36	–	–
seeds, allow £4 per school for 2 years	40	–	–
polythene for school gardens: 10 x 1/25 acre	29	10	5
transport of clay, sand and poles for training course	2	10	–
	£113	–	5
Grand Total	£2,788	17	4

N.B. The price of butyl liners, duty and transport paid is a guess at £90. Error here could affect total greatly. Mileage for follow up visits may be excessive: it may prove possible to see two or more schools in one trip; as visits will mostly be made in my Landrover which has an element of subsidy in its running costs, already, it could be charged at 6d a mile (saving £450) instead of the standard rate for a lwb Landrover.

Provisional item

Transport (@ £5 ea.)and subsistance (@ £7) for an additional 5 people to come to the training course to observe methods	£60	–	–
Additional item omitted above: dynamite etc.	10	–	–

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