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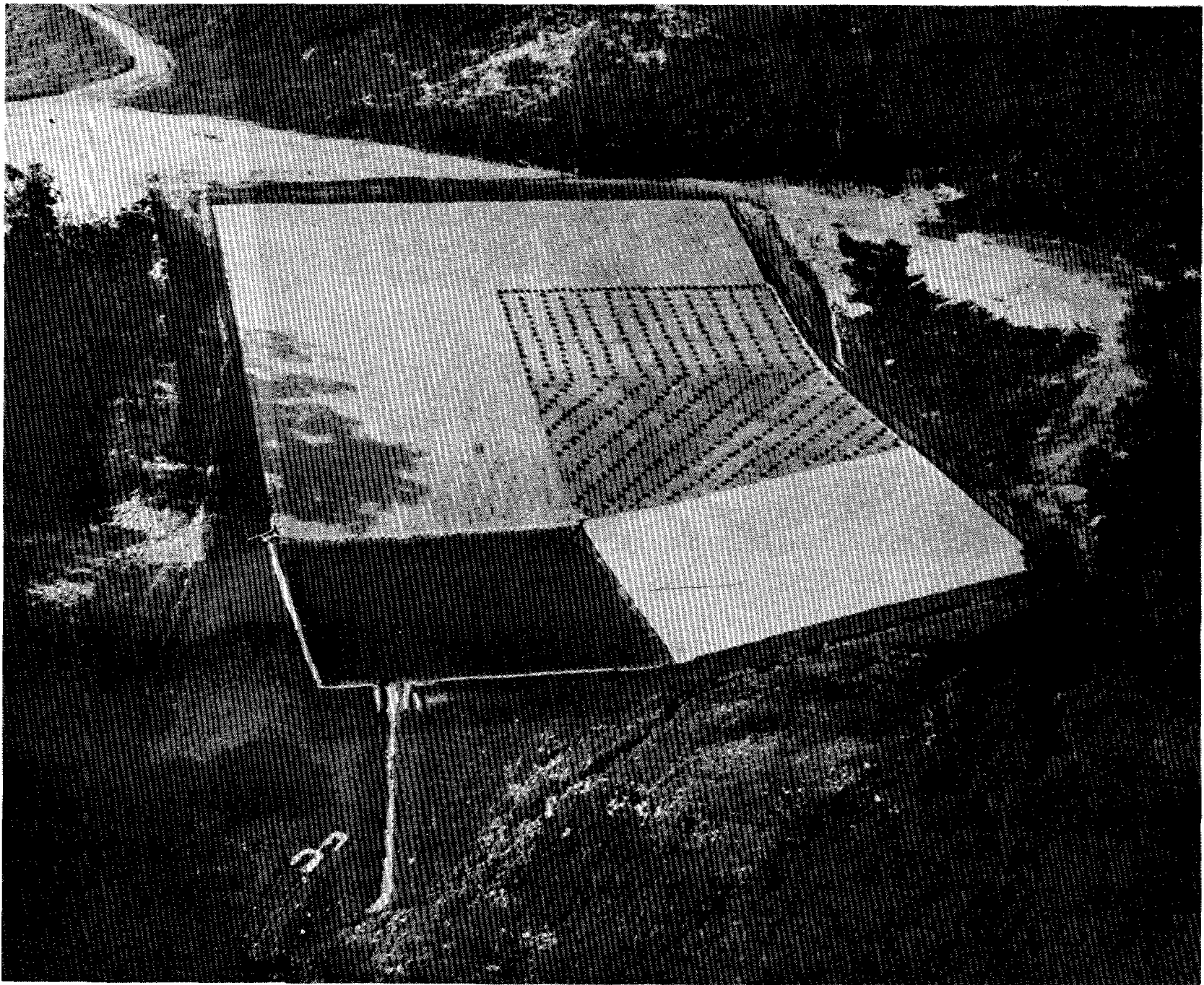
RAINWATER CATCHMENT PROJECT JAMAICA

November 1973

Water Resources Division
Ministry of Mining and
Natural Resources
Government of Jamaica

Inter-Technology Services Ltd.
Parnell House
25 Wilton Road
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CATCHMENT STORAGE AT WK.10 UNIT, OCTOBER 1973.

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CONTENTS

	<u>Page</u>
SUMMARY AND CONCLUSIONS	1
I. INTRODUCTION	
a. Origin of the Project	3
b. Duration of project	4
c. Geological Survey Department, Jamaica ...	4
d. Co-operation with Alcan	5
e. Programme	5
f. Acknowledgements	8
II. BACKGROUND	
a. Data collection	9
b. Jamaica	10
c. Upland Limestone Areas	16
d. Responsibility for Water Supplies ...	21
e. The Water Supply Situation in the Upland Areas of St. Ann, Manchester and St. Elizabeth	22
III. EXPERIMENTAL RAINWATER CATCHMENT UNIT	
a. Outline	25
b. Choice of Site	26
c. Design Considerations	28
d. Design Assumptions for the Unit	32
e. Design of the Unit	33
f. Construction of the Unit	39
g. Costs	41
IV. CATCHMENT TRIALS	
a. Introduction	46
b. Bitumen Spray Tests	47
c. Trial Catchment Surfaces	49
d. Costs of Trial Catchment Surfaces ...	55

e. Costs of Concrete Catchments	59
f. Conclusions	62
V. STORAGE TANKS FOR INDIVIDUAL HOUSEHOLDERS	
a. Introduction	63
b. Design Considerations	64
c. Design of the 10,000-gallon PVC-lined Galvanised Steel Tank at Cross Keys..	67
d. Installation of Rainwater Catchment System at Cross Keys	68
e. Analysis of Costs of 10,000 gallon Tanks	69
f. Cisterns in Rural Areas	71
VI. SURVEY OF PARISH WATER SUPPLIES	
a. Introduction	77
b. Summary of Results	78
c. Recommendations	81
BIBLIOGRAPHY	83
DRAWING - Sand Filter Tank at West Kirkvine ...	93
APPENDICES	
1. Terms of reference for a Water Engineer for service with the Geological Survey Department, Jamaica.	
2. Programme.	
3. Sources of information.	
4. Design and construction of the WK 10 Unit.	
5. Construction costs for the WK 10 Unit.	
6. Construction details and costs for the 10,000 gallon tank.	
7. Quotation for traditional 10,000 gallon tank	
8. Report on the rural water supplies of St. Ann, Manchester and St. Elizabeth.	
9. Suppliers of construction materials in Jamaica.	

MAPS

Jamaica - General

Jamaica - Regional Position.

Population Distribution

Proposed Urban Structure

Topography

Geology

Climate

Limestone Areas above 1000 ft. altitude

Population densities and distribution by Parish

Jamaica - Surface drainage

Groundwater

Piped Water Supply

Jamaica - Location of WK 10 unit and 10,000 gallon capacity storage unit at Cross Keys.

Note - A further Appendix entitled "Review of Materials" will be issued as a separate document

SUMMARY AND CONCLUSIONS

This report deals with the work undertaken between June 1971 and July 1973 by the Rainwater Catchment Project in Jamaica.

A rainwater catchment unit with a storage capacity of 660,000 imperial gallons and an artificial catchment area of approximately $1\frac{1}{2}$ acres has been constructed in Manchester and it is estimated that this unit will be able to provide a supply in excess of 65,000 gallons per day throughout a year of average rainfall. The unit has been operational since March 1973 and cost approximately $\$30,000^*$ to design and build. The unit has demonstrated the feasibility of using flexible and semi-rigid membranes, which are cheaper than either reinforced concrete or steel in this type of construction, and has provided information on the cost and durability of the materials used. Units such as this should be considered as sources of water for the rural populations of Jamaica.

A 10,000 gallon capacity water storage tank has been built at Cross Keys, Manchester and the cost and simplicity of construction show that it is an excellent method of providing water storage for an individual household.

Two cheap underground cisterns have also been built which reduce evaporation losses from stored water and provide good quality water. These cisterns may have a use for domestic water supplies in remote areas and for stock water throughout the rural areas of Jamaica.

A survey of the Rural Water Supplies of St. Ann, Manchester and St. Elizabeth has been completed, showing that 67 communities in St. Ann, 68 communities in Manchester and 50 communities in St. Elizabeth are currently using their public rainwater catchment tanks. In most of these communities the only water supply is that of rainwater catchment and the

* Unless otherwise mentioned all prices and rates quoted in this Report are in Jamaican Dollars.

public tanks together with the privately owned tanks of individual householders must supply the communities with their water needs. In general the maintenance of the public tanks is not good and only 5 tanks in St. Ann, 8 tanks in Manchester and none in St. Elizabeth have both a cover to the tank and a simple system of chlorinating the water. This project recommends that all public tanks should be provided with a cover and a chlorinator and that all the public installations are brought to a reasonable state of repair as soon as possible. In addition it is recommended that every encouragement should be given to individual householders to build their own tanks and that programmes to develop a more responsible attitude by the public towards the rainwater catchment supplies should be instituted.

In the course of the Project many publications have been studied on the use of materials other than concrete and steel to make both water storages and catchment areas. Section 2b, the Bibliography and Appendix 10 of this report provide a list and brief assessment of the materials and techniques examined by the Project.

I. INTRODUCTION

a. Origin of the Project.

Detailed groundwater studies in certain of the limestone regions of Jamaica had by 1968 established that there were considerable problems attached to the provision of domestic water on the higher parts of the White Limestone plateaux. At about the same time a number of minor schemes for the supply of re-lifted water were costed and it became apparent that the unit cost of water supplied in this manner would be very high indeed. The Water Resources Division of the Geological Survey Department working with the UNDP Project * was responsible for identifying water sources for all sectors of the economy. Its attention was therefore directed to investigating possible alternatives to groundwater supplies in the high White Limestone areas. The idea of building large catchments and storage facilities using cheap materials was developed and a Project outline prepared. There was at this time no possibility of diverting a member of the staff of the Geological Survey to this study and after consultations with the Economics Division of the Ministry of Finance and with Mr. D. S. Ferguson, Water Development Adviser of the Overseas Development Administration of the United Kingdom (ODA), a request for technical assistance was formulated in October 1969 for the consideration of ODA. In April 1970 Mr. P.H. Stern Assistant Water Development Adviser of ODA visited Jamaica to evaluate the request and on his recommendation ODA agreed to provide assistance.

ODA appointed Intermediate Technology Services Limited to provide a water engineer in Jamaica and to supervise his work. The terms of reference for the Project were agreed between ODA and ITS and these were accepted by the Government of Jamaica. The original terms of reference appear in

* The Development and Management of Water Resources (1970-73)

Appendix 1. ITS recruited a civil engineer, Mr. David Maddocks, in February 1971 and he took up his appointment on June 1st 1971.

b. Duration of Project.

In accordance with the terms of reference Mr. Maddocks spent one month in Great Britain visiting several organisations concerned with aspects of rainwater catchment and storage. He arrived in Jamaica on the 30th June 1971 to begin the Jamaican operations of the Project. In April 1973 ODA agreed to a two month extension of the Project. The Project ended its work in Jamaica at the end of July 1973.

c. Geological Survey Department, Jamaica.

The Geological Survey Department was named in the agreement between ODA and ITS as the collaborating agency in the Project. The work of the Project has therefore been based in this Department. The Department was established in 1949 as a Branch of the Lands Department and became a Department of the Ministry of Finance in its own right in 1951. Its basic function was originally defined as the detailed geological mapping and prospecting of the island and the preparation of geological maps and descriptive bulletins, including the investigation of mineral resources. Since then, the increasing sophistication of the economy has generated a requirement for other services, such as engineering geology, seismic investigations, raw materials surveys, e.g. for clay and aggregates, and water resources evaluations.

In 1965, with the help of the UNDP and FAO, a Groundwater Investigation Project was initiated with a primary emphasis on groundwater for irrigation purposes. This led, in 1968, to the establishment of a Water Resources Division of the Department, with responsibility for the investigation of both ground and surface water. The extension of the original Groundwater Project was followed in 1970 by a new UNDP Project devoted to the Development and Management of Water Resources. This added water resources planning and management to the original functions. In April 1972 the Geological

Survey Department became one of the government organisations to constitute the new Ministry of Mining and Natural Resources. In April 1973 the Water Resources Division of the old Geological Survey Department was established in its own right as a Division of the Ministry of Mining and Natural Resources. The remaining Divisions of the old Geological Survey Department were amalgamated with the Department of Mines to form the Mines and Geology Division of the Ministry. The UNDP Project on the Development and Management of Water Resources completed its work in Jamaica at the end of July 1973.

d. Co-operation with Alcan.

In 1970 informal contact revealed that Alcan Jamaica Limited were interested in co-operating with the Geological Survey Department in research into the feasibility of rain-water catchment and storage. Alcan saw their involvement as a part of their on-going Restoration Research Programme which they hope will end with the establishment of farming communities in areas where bauxite mining has been completed. Discussions were held with officers of the Company's Property Administration Division and it was agreed that if ODA assistance were provided then an experimental programme would proceed in collaboration with Alcan. The company offered to make available a worked-out bauxite pit as the site for an experimental rainwater catchment unit and to provide the plant and operators required to carry out the necessary earth moving operations.

e. Programme.

The Project has followed four main lines of investigation.

(1) An investigation into the feasibility of providing large scale rainwater catchment units which will serve as supplies of domestic water for the rural populations. Most of these populations already have rainwater catchment units of 100,000 gallons capacity. The Project investigated methods of providing much larger units using construction methods which are technically satisfactory but are considerably

cheaper than either reinforced concrete or steel, the two materials that have been used up to this time.

The investigation started by identifying the areas where these units would be required. Once this had been done it was possible to identify the type of site conditions that would be met when building a unit. Information was collected and assimilated on materials that were available to waterproof both catchment and storage surfaces. A site for a large scale unit was selected in Manchester and a preliminary design and costing exercise was carried out. As a result of this exercise it was decided to build a unit with a storage capacity in the region of $\frac{1}{2}$ million gallons which would require a catchment area of over $1\frac{1}{4}$ acres. The design and construction of the experimental unit was carried out with the full co-operation of Alcan Jamaica Limited. The starting date for the construction of this experimental unit was set for December 1972/January 1973. A series of field trials were carried out to test five different methods of catchment construction. As a result of these trials three methods of catchment construction were chosen for the experimental unit. The final design of the experimental unit was completed, working drawings were produced and construction was begun on January 2nd 1973. The unit was completed early in March 1973 and has been operational since that date. The tank was filled during the April-May rains. The overflow facilities were tested by releasing all this water and the tank was then refilled. Although the unit has been built in an area where domestic water supplies will be required the water was not being used at the time of writing.

(2) An investigation to determine a cheap and simple method of constructing a water storage tank suitable for use by an individual householder.

Many homes in Jamaica have rainwater catchment tanks which utilise the roof of the house as catchment. In areas which have a large number of private tanks there is a reduced demand on the public rainwater catchment tank so that the existing supplies are adequate for the present population.

The Project investigated methods of constructing a 10,000 gallon capacity tank which could be built by unskilled labour under a trained supervisor. It was decided that a metal tank shell, lined with a PVC bag, was the most likely solution to the problem. Two tank shells, one galvanised steel, the other aluminium, were bought by the Project and the former has been erected at the Cross Keys Health Centre, Manchester where it is now in service.

In addition, two underground tanks have been built using polyethylene sheet as the impermeable membrane. If it is to have a reasonable life expectation polyethylene must be buried. The polyethylene in the first of these tanks is covered by a series of domed structures that support a one foot thick layer of sand which filters the water entering the tank. The materials used are cheap and the tank is easy to build. This type of tank should provide water for domestic use. In the second tank the polyethylene is covered by a protective layer of sand and the tank is filled with rock. This type of tank reduces the loss of stored water by evaporation.

These two cisterns are more suited to remote areas or to cases where an artificial catchment has to be constructed. They might be particularly effective in use with an aggregate covered polyethylene catchment.

(3) A survey of the existing public rainwater catchment supplies in the parishes of St. Ann, Manchester and St. Elizabeth.

These three parishes were selected as those most likely to have to continue their dependence on rainwater catchment supplies. It became apparent early in the Project that the basic data on these supplies was not available and that without this data an accurate assessment of the water supply situation in the rural areas could not be made. Information was gathered from the Parish Councils who are responsible for these supplies and then visits were made to each tank. The positions of the tanks were plotted on maps and these were confirmed by studying the aerial photos of the areas flown in 1971 by NASA. All this information has been collected together in a systematic manner and now provides a reasonably accurate background to the rural water supply situation.

(4) The collection and assessment of information relating to rainwater catchment and storage.

Throughout the Project correspondence has been carried on to collect as much information as possible on techniques of rainwater catchment and storage. The bulk of the research has been done in the United States and Australia and there are a substantial number of publications on the subject. A Project bibliography has been prepared. It has not been possible to assess all the publications but a review of many of the methods and materials and their suitability to Jamaican conditions has been prepared. In addition recommendations and advice have been received from several manufacturers.

A chronological list of the work done by the Project appears as Appendix 2.

f. Acknowledgements.

Acknowledgements are due to Messrs. R. I. Mason, H. W. Milner, and A. L. Walters of the Ministry of Finance, Jamaica, whose interest and encouragement was largely instrumental in establishing the agreement with the Overseas Development Administration that led to the execution of the Project. Thanks are also due to Mr. E. S. Capstick, Dr. B. Davidson and Mr. E. Tatham of Alcan Jamaica Limited who made available the resources of the Agricultural and Property Division, and particularly to Mr. Gladstone Morgan of the same Division who worked untiringly on both the design and execution phases of the prototype catchment unit. Messrs. Ardill and Brindley of Aluminium Products of Jamaica co-operated in connection with the design and fabrication of a prototype domestic tank. Mr. Rainford and Mrs. Goodleigh of the Jamaica Livestock Association co-operated in supplying the Project with a galvanised steel grain bin from the United States for use as a prototype domestic water storage tank.

With regard to the supply of offshore materials, thanks are due to the Department of Supply, Jamaica, who expedited clearance and to Alcan Booth Limited who transported the reservoir liner to Jamaica. Messrs. Goodyear Jamaica Limited kindly donated a large number of reject tyres used for

anchoring purposes on the catchment. Mr. Handy, PWD Superintendent at Mandeville offered ready co-operation in connection with the construction of the first experimental domestic tank at Cross Keys.

Miss B. Adolphus of the Town Planning Department provided copies of maps from the National Atlas of Jamaica and a National Physical Plan for Jamaica. These publications, produced in 1971 by the Town Planning Department under a United Nations Special Fund Project of Assistance in Physical Development Planning, have been used extensively to provide the background information for this report.

Mr. S. Martin, Superintendent of Roads and Works for the Parish of St. Ann, has had long experience of building rainwater catchment units for the rural water supplies and made his knowledge available to the Project. The Assistant Superintendents for Water Supplies in the Parishes of St. Ann, Manchester and St. Elizabeth, Messrs. Perkins, Harris and Sanderson respectively, provided the information on which the survey of the existing public rural water supplies was based.

The preparation of the maps and diagrams for this report was carried out in the Drawing Office of the Water Resources Division.

Thanks are due to Mrs. Lewis who typed the original draft of this report and to Mrs. Roberts who assisted her.

II. BACKGROUND

a. Data Collection.

During the first month of the Project, the Project Engineer visited organisations in the U.K. to gather information on techniques and materials available for rainwater catchment and storage. These investigations were continued during his tour in Jamaica, when contact was made with a

large number of organisations and authorities in the UK, USA, Australia and other parts of the world. Details of all these sources of information are given in Appendix 3.

b. Jamaica.

Geography.

Jamaica is centrally located within the Caribbean region being situated between latitude $17\frac{1}{2}^{\circ}$ and $18\frac{1}{2}^{\circ}$ North and longitude $76\frac{1}{2}^{\circ}$ and $78\frac{1}{2}^{\circ}$ West.

It is 146 miles long and has a maximum width of 51 miles giving it a land area of approximately 4,400 square miles. Maps showing Jamaica and its regional position will be found at the end of this report.

Topography.

Almost half of Jamaica is over 1,000 feet above sea level. The three main types of land forms of the island are:

- 1) The interior mountain ranges;
- 2) The dissected limestone plateaux and hills;
- 3) The coastal plains and interior valleys.

This Project has been concerned with the areas of dissected limestone plateaux and hills. These areas flank the higher interior ranges on all sides and occupy more than half the island. These plateaux have been karstified to varying degrees. Karst landscape is particularly evident in the north central part of Jamaica and reaches its most pronounced stage in the Cockpit Country. There, the innumerable conical hills and enclosed circular depressions, up to 300-400 feet deep with steep, sharp and irregular sides, make the area largely inaccessible and unusable. Elsewhere, on the limestone plateaux, karst is somewhat less developed and takes the form of rolling hills, ridges, shallow sinkholes and open knob and valley country.

Geology.

The geological structure and processes of Jamaica have created its richly varied complex of landforms, wide range of

soils, significant mineral deposits (notably bauxite) and have partially determined the nature and extent of water resources. The presence of many geological faults means that certain areas are vulnerable to earthquakes.

Geologically the dominant theme of central and western Jamaica is limestone. Nearly two thirds of the surface of Jamaica are of limestone, interrupted by the metamorphic and igneous inliers with interior basins and the southern coastal plains covered by alluvium overlying the limestone. Eastern Jamaica has a more complex geology of metamorphic and igneous rocks.

The oldest known fossil bearing rocks are Cretaceous in age. They were originally deposited on the seafloor as mud. Deposition was interrupted from time to time by intense volcanic activity, resulting in vast quantities of volcanic ash being interlain between the shales and limestone. Towards the end of the Cretaceous period, the deeply buried Cretaceous rocks were invaded by large igneous intrusions of granite.

At the end of the Cretaceous times, the entire area was flooded and uplifted and most or possibly all of the island rose above sea level. Later, much of the island gradually submerged again and rather impure Yellow Limestone was laid down. As subsidence continued and the sea became deeper the very pure White Limestone was deposited.

After sedimentation of the White Limestone, extensive uplift accompanied by folding and faulting affected the entire island. Most of the faults now dissecting the White Limestone plateaux originated at this time. Activity was particularly intense at the eastern end of the island where the Blue Mountains were elevated to over 7,000 feet.

Following this uplift, most of the White Limestone areas underwent karstification. The White Limestone dissolved resulting in the distinctive karst topography. The numerous faults and joints in the highly soluble White Limestone provide lines of drainage to the downward percolating water. These lines become enlarged by solution and eventually develop into the numerous sinkholes, caves and underground rivers that characterise the limestone areas of Jamaica.

Climate.

Jamaica has a tropical climate with temperatures which are warm and equable throughout the year. The 77.1 in. average annual rainfall is relatively high but a wide range of micro climates is created by the mountainous character of the island.

The prevailing north east winds of the area are modified in three major respects: because of the high Blue Mountains in the east of the island, the trades swing round St. Thomas to strike the Kingston area from an east or east-south-east direction; alternating sea breezes (onshore during the day) and land breezes (offshore during the night) occur daily and occasional cold fronts known as 'northers' reach Jamaica from the American mainland during the winter season.

Temperatures at the lower elevations are warm with small seasonal daily ranges. The average daily temperature in the coastal areas ranges from about 75°F in the cool season to about 83°F in some localities in the warm season. The temperature often rises to about 91°F during the afternoons of the warm season and falls to about 67°F in the early mornings during the cool season. Temperatures have a slightly wider range further inland because of the greater distance from the moderating influence of the sea. Temperatures are 10°F to 20°F cooler in the highlands. Daily temperature variation is about 15°F.

There are two periods of higher-than-average rainfall in Jamaica. The period of lesser rainfall maximum is in May-June when the sun is overhead and convectional storms are common. The greater maximum occurs in September-October when there are again many convectional storms plus the heavy rains brought by the occasional hurricanes which tend to occur in this season. The major dry period is from January to March.

Jamaica experiences irregularity of rainfall and droughts have been fairly frequent. The most recent and one of the worst droughts was in 1967-1968.

Relative humidity is fairly high being in general about 85% at 7 a.m; and 72% at 3 p.m. Variations occur between specific points owing to differences in altitude and position.

In coastal areas the daily sea breezes are of greater climatic influence than the seasonal variations.

Hurricanes are a perennial threat to Jamaica. Between 1886 and 1967 19 tropical storms hit Jamaica directly and 98 (of which 48 were of hurricane force) had centres within 150 miles of the island. About one third of these storms caused flooding and damage. The hurricane season is from July to November with the greatest possibility of occurrence in August, September and October. The destructive forces of hurricanes are extremely high winds (75 to 200 miles per hour) intense rains and high waves. Jamaica has not experienced a direct hit from a hurricane since 1951.

Vegetation and Land Use.

The following table shows a classification of land in Jamaica, by vegetation and use:

	<u>Per Cent</u>
Agricultural, including pastures	-- 46.4
Forest -- -- -- -- -- --	24.1
Other woodland -- -- -- -- --	19.8
Natural range and grassland -- --	3.8
Urban -- -- -- -- -- --	3.6
Swamp -- -- -- -- -- --	1.8
Mined -- -- -- -- -- --	0.4
Barren -- -- -- -- -- --	0.1
	<u>100.0</u>

The three principal types of agricultural use are plantation crops grown mostly for export, mixed farming of food crops for domestic consumption, and pasture for beef and dairy cattle.

Export crops grown on plantations include sugar cane, bananas and citrus. Export crops which are usually inter-cropped on small plots of land scattered throughout several areas in the island include pimento, coffee and cocoa. Coconuts are grown as a plantation crop but are virtually all used in Jamaica.

Mixed farming areas occupy most of the central uplands of Jamaica as well as some other suitable areas. Mixed farming refers to cultivation of a great variety of food crops, including yams, sweet potatoes, irish potatoes, corn, pumpkin, peas, cassava, and other vegetables, tree crops such as ackees, avocados, mangoes, guavas and pawpaws as well as small fields of sugar cane and bananas.

Forests are defined as those areas with trees whose crowns cover more than 20% of the area and are not used primarily for purposes other than forestry. Few large areas of virgin forest exist in Jamaica and the 24% land area classified as forest includes areas of ruinate or second growth trees.

The other woodlands are areas with less than 20% tree coverage or areas of shrubs and stunted trees not primarily used for agricultural or other non-forestry purposes. Mangrove swamps are included in this classification. Some of these woodlands are utilised for cattle pasture but not on an intensive basis.

Although only a small percentage of the land is currently being mined the bauxite companies have become major landowners based on Government policy that the land had to be purchased before mining could take place. Much of the land owned by the bauxite companies has remained in agricultural use.

Three major developments are seen in Land Use up to 1990. A policy of upgrading natural pastures and grassland to improved pasture, where this is feasible, is recommended although by 1990 it is not expected that more than about 50% of the land will be under agricultural use including these improved pastures. Since there is a finite limit to the available land emphasis will be on raising productivity per acre rather than expansion of acreage. Urban development will proceed to cater for the increasing demands of housing, tourism and industry and it is expected that by 1990 5.3% of the land will be so used. This expansion will allow only a minimum intrusion on to good agricultural land. All existing forest lands will be retained in protective or productive forest and forest plantations will be developed to meet projected demand for softwood. It is recommended that all swamp

lands are retained in their natural conditions and it is expected that the total mining operation will continue to use the same land as at present. Most of these changes will be brought about by the appropriate development of the areas now described as Natural Range and Grassland and Other Woodland.

Population.

The 1970 Census carried out by the Department of Statistics determined the population of Jamaica to be approximately 1,900,000. Approximately 30% of this population is concentrated in the Kingston and St. Andrew area. The annual rate of growth of population between 1960 and 1970 was 1.46% per annum. Jamaica now has a relatively dense and in rural areas, highly dispersed distribution of population except for those areas of little or no agricultural value.

The outstanding feature of Jamaica's settlement pattern is the dominance of Kingston. In addition there are some 1,150 towns and villages dispersed throughout the country.

It is projected that the population of Jamaica will be approximately 2,700,000 in 1990.

About 1,025 of the population centres are small villages which are primarily retail and service centres with a limited number of shops and a few public facilities such as a postal agency and primary school. These villages are usually within walking distance of the farm households they serve, but the villages contain few houses because the farmers tend to live on their farm holdings. Because of the high density of the rural population the remaining 126 towns are often of greater functional importance than their own population size would indicate.

In 1971 the Physical Planning Unit of the Ministry of Finance and Planning proposed a programme of urban development based on concentrating development in a number of selected urban centres. It is felt that in addition to its own development such an urban system can be both a stimulus and focus of rural development and will play a role in the integrated rural development on a regional basis. The need for more water in the rural areas to improve the standard of

life is recognised as a necessary part of the effort to raise agricultural productivity but it is also recognised that because of the limited resources of Jamaica it will only be possible to develop piped water supplies in selected areas where the majority of people can benefit. The selection of urban centres to be developed was carried out after a comprehensive analysis of development factors. It has been recommended that three types of urban centre are established: the largest of these is the Regional Urban Centre of which there are five in the island excluding Kingston, Sub-Regional Urban Centres of which it is proposed there be 19 and 87 District Towns. All of these centres should contain basic infrastructure consisting of at least a post office, electricity supply, telephone and telegraph service, paved road accessibility and piped water.

c. Upland Limestone Areas.

Location.

A study of the maps of geology and contours reveals that a large majority of the White Limestone plateaux over 1,000 ft. above sea level falls within the three Parishes of St. Ann, Manchester and St. Elizabeth. This Project has concentrated its attention on these three Parishes as they represent the largest areas and the greatest number of people currently dependent on rainwater catchment supplies.

Geology and Topography.

The geology and topography of these areas is typical of the White Limestone areas described in Section b. The White Limestone in St. Ann, especially in the western half of the Parish, displays a pronounced Karst landscape. In general the topography of St. Ann is more rugged than that of the other two Parishes, with deeper and more enclosed depressions and steeper slopes. This can be appreciated most easily by comparing the mined out pits of the Kaiser Bauxite Company at their Tobolski mine in St. Ann with the mined out pits of Alcan Jamaica Limited at their West Kirkvine mine in Manchester.

The former are in general considerably deeper and have much steeper sides. in southern Manchester and southern St. Elizabeth the karst is much less developed and takes the form of the rolling hills described in Section b.

Rainfall.

Based on average annual rainfall all the Parish of St. Ann enjoys over 50" of rain per year except for a narrow coastal strip extending westwards from Runaway Bay. The western half of the Parish and the coastal strip extending back in the north east to Bamboo and Clarendon has an average annual rainfall between 50 and 70 in. The south eastern corner and an area to the south of Bamboo has a higher average annual rainfall of between 100 and 150 in.

The northern half of Manchester has an average annual rainfall of between 70 and 100 in., while most of the southern half and the area around Mandeville extending north east to Kendal and Mizpah has an average annual rainfall of between 50 and 70 in. In the east of the Parish an area extending westwards from Porus to Old England enjoys a higher rainfall which is between 100 and 150 in. The south west corner of the Parish from Rose Hill south to Plowden Hill and the sea has the lowest average annual rainfall of below 50 in.

The northern half of St. Elizabeth has an average annual rainfall of between 70 and 100 in. and a small area around Quick Step on the southern edge of the Cockpit Country enjoys an even higher rainfall. The coastal strip eastwards from Black River to Alligator Pond has the least rainfall and this area of under 50 in. average annual rainfall includes Southfield on the south west side of the Santa Cruz Mountains. The remainder of the Parish including the southern half of the Santa Cruz Mountains enjoys an average annual rainfall of between 50 and 70 in.

As noted in Section b. Jamaica experiences irregularity of rainfall and there is a wide variation in the annual rainfall figures that make up the average annual rainfall. Rainfall records for Mandeville from 1931 to 1971 show that the highest annual rainfall of 149.72 in. occurred in 1933 and the lowest

annual rainfall of 43.48 in. occurred in 1965. The average rainfall over the same period in Mandeville was 79.01 in.

More important from the rainfall catchment point of view is the occurrence of relative droughts and extended periods of low rainfall that are common especially in the period December-April. At this time demand on storage is at its greatest and even if storage proves sufficient for this period there is a great dependence on the May-June wet season to replenish the supply. Further strain on storage is normally felt during July and August and it is only the second wet season in September-October that can be relied on to replenish the storage.

Population.

In 1970 the Census showed that each of the Parishes of St. Ann, Manchester and St. Elizabeth contained approximately $6\frac{1}{2}\%$ of the total island population. The average population density in these three Parishes was 250-350 persons per square mile in St. Ann and St. Elizabeth with 350-450 persons per square mile in Manchester. These average population densities compare with 2,000 - 3,000 persons per square mile in Kingston and St. Andrew but are otherwise typical of the rural areas.

The maps of Population Distribution and Population Centres (at the end of this report) show that in Manchester there is a reasonably uniform distribution of population throughout the Parish with concentration of population at Mandeville, Porus and Christiana.

In St. Elizabeth the population is situated mainly in the north and north west and the south and south east, the central portion of the Parish being dominated by the Black River and its marshes. Thus, the bulk of the population lives in the high limestone areas.

In St. Ann the population is distributed along the lines of communication with major concentrations on the coast at St. Ann's Bay and Ocho Rios on the limestone plateaux at Brown's Town. Thus there are areas of central, south and south west St. Ann that are inaccessible by road and do not support any appreciable population.

The percentage of the total island population living in the three Parishes has been decreasing with each census since 1943 as it has in every other Parish except St. James, St. Catherine and Kingston and St. Andrew. In 1943 the Parishes of St. Ann, Manchester and St. Elizabeth each held approximately 8% of the total island population. Because of total population growth, however, the population of the three Parishes is now approximately 370,000 whereas in 1943 it was only 300,000.

The population trend figure for 1990 for Manchester is 149,600 with a target population of 141,600 representing 5.3% of the total island population of 1990. It is not expected that Manchester will participate greatly in the recommended growth of tourism and the bauxite and alumina industry have a relatively static degree of employment.

The population trend figure for 1990 for St. Elizabeth is 149,600 with a target figure of 133,600 representing 5% of the total island population. The same criteria for these figures exist as in Manchester. However, these figures published in 1971 do not take into account the construction of an oil refinery complex at Luana Point in St. Elizabeth announced in June 1973. Associated with the refinery is the possibility of the construction of an aluminium smelter and these two factors will change the target populations for both Parishes. However, the effect of this construction on the rural population is unlikely to be so great.

The population trend figure for 1990 for St. Ann is 141,600 and the target figure is 176,300 representing 6.6% of the total population. The larger target figure demonstrates the recommendation to increase the rate of growth in the northern Parishes mainly as a result of meeting the requirements of an expanded tourist industry.

More important, however, is the projection that the rural population growth will remain static for the next twenty years and that the population increase will take place almost wholly in the urban areas.

The Physical Planning Unit of the Ministry of Finance and Planning has proposed that in Manchester, Mandeville is developed as one of the Regional Urban Centres. Christiana and

Spaldings would become Sub-Regional Urban Centres and Mile Gully, Newport, Porus, Pratville and Williamsfield would be District Towns.

In St. Ann it is proposed that St. Ann's Bay or Ocho Rios becomes the Regional Urban Centre with Moneague, and Brown's Town as Sub-Regional Centres. Alexandria, Bamboo, Cave Valley, Claremont, Discovery Bay, Runaway Bay and Watt Town would become District Towns.

In St. Elizabeth, Black River, Santa Cruz and Alligator Pond are proposed as Sub-Regional Centres with Balaclava, Elderslie, Junction and Bull Savanna, Lacovia, Maggotty, Malvern, Middle Quarters, Newell, Newmarket, Southfield, and Treasure Beach as District Towns.

Water Resources.

The map of Surface Water Drainage shows that there is a total absence of surface rivers in the high limestone areas of St. Ann, Manchester and St. Elizabeth. Most of the rain falling on the permeable White Limestone is directly absorbed and passes into an intricate system of underground drainage. Only during periods of high intensity precipitation is run off developed and even this is quickly absorbed. The result is that these karstified areas have mostly underground waterflow.

Plentiful groundwater generally occupies the large areas of permeable limestone and the alluvial plains in the north and south central parts of the island, although because of the depth below ground level at which the water occurs well capacity can vary greatly. Water depth becomes a major factor in development costs, especially in the White Limestone uplands where the water table can extend as far down as 2,000 feet below ground level. The groundwater level at Mandeville is at 1,000 feet below the surface and it is particularly difficult to locate water bearing zones at so great a depth. One of the deepest production wells now being operated in Jamaica by the NWA is the Minard well where the lift to ground level is approximately 600 feet. This well supplies Brown's Town in St. Ann.

Generally, groundwater potential is much greater and pumping lifts are less in the limestone aquifers at lower elevations. This has led to a number of water supply systems using extensive pipelines and re-lift pumps to carry water from wells at a low elevation to distribution networks at a much higher elevation. Such a system provides Mandeville (elevation 2,000 feet.) with a water supply from Porus (elevation 500 feet). An expansion of the Mandeville supply is planned to bring water from the western side of the Manchester uplands in a similar fashion to the Porus scheme.

Bearing in mind the reservation of the depth at which groundwater occurs most of St. Ann and St. Elizabeth are classed as areas of plentiful groundwater. The southern strip of St. Ann, bordering on the area of impermeable volcanic rock where there is no groundwater, is classed as having very limited groundwater. Similarly an area of the Santa Cruz Mountains running south east from Malvern is classed as having very limited groundwater. Most of the Manchester uplands are classed as having limited groundwater.

d. Responsibility for Water Supplies.

Present water supply development in Jamaica is under three administrative authorities. The Water Commission is responsible for development and distribution of water to serve the Kingston Metropolitan Area. The Commission is planning to bring water from St. Catherine, Portland and St. Thomas to supply the increasing demands. The National Water Authority is responsible for water development and distribution for all major schemes outside Kingston. The Parish Councils provide some water distribution in the form of minor systems for small towns and rural areas. These systems include incarcerated springs and rainwater catchment tanks. In 1970 some of the Parish Councils operated a loan scheme to assist individual householders with the construction of private water storage tanks. A similar scheme was operated by the Ministry of Rural Land Development through its various Land Authorities. In 1972 the Ministry of Rural Land Development was re-absorbed into the Ministry of Agriculture.

Recommended National Physical Development Goals include the provision of efficient utility and communication services to urban and village areas identified as economic growth points, and to specific economic development areas, in a rational manner so that the public cost is not unnecessarily high. It is recognised that the effective management and distribution of public water supplies will be especially important.

e. The Water Supply Situation in the Upland Areas of St. Ann, Manchester and St. Elizabeth.

Many of the population centres in the three Parishes depend on rainwater catchment tanks for their public water supply. This Project has conducted a survey of this existing network of Public tanks and a detailed report appears in Section VI of this report. Where piped water supplies are now available in the rural areas the responsibility for the development, commissioning and operation of the larger water sources lies with the National Water Authority (NWA) while the distribution networks from these sources are the responsibility of the Parish Councils. The Parish Councils also operate a number of smaller supplies having responsibility for all aspects of them. A review of the existing situation in each Parish is given below.

St. Ann.

The coastal strip including Discovery Bay, Runaway Bay, St. Ann's Bay and Ocho Rios all have piped water supplies. This area with its tourist centres is one of a number of areas where studies are being carried out to increase the water supply. The NWA has recently drilled a well in the Discovery Bay area. A number of communities in the hills leading up to the limestone plateau behind the coastal strip have small piped systems based on wells and the numerous springs of the area. On the limestone plateau only Browns Town, Claremont and Moneague have piped systems based on wells. The Browns Town supply comes from the Minard well, at 600 feet the deepest well that NWA is now operating. The large rainwater catchment tank in Browns Town

is now used as a storage reservoir in this scheme. The Claremont supply has recently been commissioned and will be extended to supply communities in the immediate vicinity of Claremont. This system is being wholly administered by the NWA. The Moneague supply is run by the Parish Council and is based on a well with its own distribution reservoir. The system supplies Moneague and one or two closely associated communities. The Parish Council also operates small piped distribution schemes at Cave Valley, Pedro River and Borobridge, all three areas being near the border of the White Limestone and the Central Inlier.

The NWA is planning to develop and extend the Browns Town supply. A study is about to be undertaken to examine the possibility of supplying Bamboo. The sources under appraisal will be the possibility of a deep well in the Bamboo area or a pump relift scheme from a source at lower altitude towards the north coast.

There are no plans at this stage for developing piped supplies to Watt Town and Alexandria, both communities suggested as District Towns in the National Plan. Watt Town and Alexandria are both in the Kaiser Bauxite Co. Ltd. mining area and this company is already operating its own wells in the Browns Town area. Alcan Jamaica Ltd. are now preparing to start their mining operation in central St. Ann and have drilled a successful production well at Alderton.

Manchester.

Two major piped supply schemes exist in Manchester and both sources are operated by the NWA. The Parish Councils are responsible for the distribution networks. Mandeville is supplied by a relift pump scheme based on wells at Porus. The communities through which this pipeline passes are also supplied with piped water. The scheme makes use of the large rainwater catchment tanks at Battersea and Perth, both districts of Mandeville, for emergency storage purposes. The second major system is based on a river take off at Christiana, the water being pumped to two rainwater catchment tanks at Spaldings for distribution and treatment. The distribution network for this

supply is over-extended and the communities at the farthest extremes of the scheme such as Mizpah, Walderston, Lichfield, Bombay and Clones receive only an intermittent supply of water, if any. There are also piped distribution schemes operated by the Parish Council at Troy and at the foot of Spur Tree Hill from wells at Pepper in St. Elizabeth.

The NWA has commissioned a study of the Christiana area in an effort to find a new source of water and to improve the existing scheme. Plans have been announced to provide a second relift pumping scheme for Mandeville based on wells at the foot of Spur Tree Hill near the St. Elizabeth border. Three towns which have been proposed as District Towns are currently without piped water. However, Newport should receive water from the expanded Mandeville supply and Mile Gully would be in the area to be served by an improved and enlarged supply from Christiana. The NWA is planning to drill an exploratory well at Warwick in southern Manchester and although the geological conditions are not hopeful if a source is found and developed Pratville would receive piped water. In the north west some communities may receive water from the Balaclava supply now being undertaken by the NWA and similarly some communities in the south west may benefit from the development of the source at New Forest in St. Elizabeth.

St. Elizabeth.

Two systems with NWA-operated sources exist in southern St. Elizabeth. A well at New Forest is the source of the distribution network to the Junction and Bull Savanna area. Wells at Dalintober and Luana are the sources for the system that supplies Black River and its immediate surroundings. A distribution reservoir for the system is situated at Dalintober. The Parish Council operates several wells on the Pedro Plains to supply the Treasure Beach and Newell area. The Parish Council also operates systems delivering piped water to Santa Cruz, Lacovia, Middle Quarters, Siloah, Elderslie and Ginger Hill.

The NWA has commissioned a well at Beacon to improve the Pedro Plains system. A well has been drilled near Balaclava

and a piped system will shortly be installed in this area. Improvements and expansion of the Junction and Bull Savanna systems are also to be undertaken and Alligator Pond will receive water from this scheme. A well has been developed at Hounslow and a system which will include Southfield, Munro and Malvern is to be constructed. The NWA will be studying the Newmarket area with a view to developing a piped water supply for the area. Maggoty, on the Black River, has been recommended as a District Town and the alumina plant of Revere Bauxite Company is only a mile from the town.

The process of extraction of alumina from bauxite requires large amounts of water and in all three Parishes there are alumina plants that use water from privately developed wells.

The National Plan recommended improved co-ordination among the various authorities dealing with water supply in order to achieve maximum efficiency in the provision of water. The government recently announced that the NWA would be giving greater assistance to the Parish Councils on matters concerning water supply.

III. EXPERIMENTAL RAINWATER CATCHMENT UNIT.

a. Outline.

In the latter part of 1971 it was decided that a large-scale experimental rainwater catchment unit should be built on land donated by Alcan Jamaica Ltd. in their West Kirkvine mining area in Manchester. Alcan also agreed to provide the heavy machinery for any earthmoving operations that would be required for the construction of the unit. The work came under the general direction of the Alcan Land Committee and the supervision of this project for Alcan was undertaken by the

Superintendent of Research in the Agricultural Division, Mr. Gladstone Morgan. Assistance was received from many individuals from all of the Alcan Divisions.

After a year of planning and preliminary research the experimental unit was constructed during the first two months of 1973. It has been in operation since March 1973 and its performance is being monitored.

b. Choice of Site.

Bauxite occurs in the depressions in the White Limestone caused by karstification. Before mining a survey is carried out using a small borehole rig to determine the thickness of bauxite overlaying the White Limestone throughout the orebody. Chemical tests are also carried out on the bauxite to determine the composition of the ore and to determine if it is suitable for processing to alumina. In some cases bauxite from different orebodies will be mixed together before being processed for alumina. All bauxite in Jamaica is mined by the open cast method and a variety of excavators is used to remove the bauxite back to the White Limestone surfaces. This can result in the creation of pits up to 100 feet deep with sheer sides comprising White Limestone cliffs. In many cases this White Limestone is relatively soft and because of the fractured nature of its upper surface it can be reshaped by a D8 bulldozer, if necessary using its ripper. Before mining begins the productive top soil is removed and stockpiled and once the mining operation has been completed D8 bulldozers reshape the pits to achieve, as nearly as possible, a topography that is suitable for agricultural use. The topsoil is then spread over the reclaimed area and planted with grass or suitable agricultural crops.

It was hoped that the mined out pits might be used as water storage areas with a minimum requirement of reshaping or that the earthworks required for a rainwater catchment unit could be incorporated in the reclamation process.

This Project has concerned itself with methods of water-proofing based on inexpensive flexible membranes, all of which depend on their sub-surfaces for structural strength and all of which are relatively easily punctured. It was recognised early

on that these materials, when used with the unsophisticated methods of construction of earthworks envisaged, could not support large heads of water nor were they suitable for direct use on the broken limestone surfaces left after mining. In addition the mined out pits are confined to relatively small areas of the White Limestone plateaux and this Project was more concerned with developing a method of construction that could be used, with minor variations, anywhere on the plateaux.

The Project has received information from manufacturers on methods of grouting and waterproofing fractured rock surfaces but these treatments are generally very expensive. However, it is felt that the interested parties should pursue these methods bearing in mind that the greatly increased volumes of storage that might be created by these methods would offset a higher cost of construction. Such large volumes of water storage would have to be supplied from large areas of natural catchment or from wells. The scale and scope of these investigations was felt to be outside the terms of reference of the present Project.

Within a mining area, however, there is almost always a site which is suitable for a membrane lined catchment unit. This Project decided, after studying the relevant literature listed in the Bibliography, that a suitable site for a rain-water catchment unit should have:-

- i. sufficient soil or easily excavated rock to provide for a reservoir that would not exceed 20' in depth;
- ii. catchment slopes that were preferably gentle and which would require a minimum of reshaping;
- iii. provision for an overflow that would deal with all the overflow from the reservoir without overtopping the lining of the reservoir.

A photograph* of the WK10 orebody in the Alcan mine at West Kirkvine, Manchester, shows the state of the site when

* Photograph No. 1, in the photograph section at the end of this report.

it was selected in September 1971. The orebody had only been partially mined before mining was stopped because the ore was not suitable for processing. Gentle bauxite-covered slopes lead down from the road in the top right hand corner to a shallow triangular shaped pit. Below this pit a second deeper excavation can be seen. The triangular pit was selected as the site of the reservoir and it was hoped that the catchment would be provided by the gentle slopes. The lower pit would be used to absorb the overflow from the reservoir. The site was surveyed in November 1971 and a plan prepared. When the preliminary reservoir design was carried out by the Alcan Engineering Division in March 1972 it became apparent that the tree covered area above the triangular pit would have to be used as a catchment area too. This area was cleared in November 1972 and a final survey of the site resulted in the plan on which the final design was based.

Orebody WK 10 is at a high point of the West Kirkvine mine. Much of the land to the south of this orebody will be flooded by the red mud lake which collects the effluent from the alumina processing works. To the north the mine slopes down to the present site of the bauxite stockpile. The reservoir at WK 10 can thus be used to supply water by gravity feed to any farmers who settle in these reclaimed areas. Where a rainwater catchment unit is proposed as a supply to an existing community the selection of a site for the unit will be complicated by the need for a satisfactory distribution system.

c. Design Considerations.

A feature of the design of rainwater catchment units using inexpensive flexible membranes is that the designer has a variety of solutions for any given site. Before the final design is prepared he will have to have made the decisions that govern the shape of the unit and the materials he is going to use. Some of these problems are now discussed.

All the literature consulted (See Bibliography) has stated that the use of flexible membranes to form reservoirs and catchments makes the cost of the water produced prohibitively expensive for irrigation use. Only in exceptional

circumstances, where for example, small quantities of water may be used over short periods to start a high value crop that could not otherwise be grown, can rainwater catchment be considered economically feasible as a supply of irrigation water. Generally, rainwater catchment units can only be justified where the water is for domestic or stock use in areas which have no alternative water sources. The most popularly used flexible membranes for sealing reservoirs and catchments are the plastic membranes polyethylene and PVC, the synthetic rubber membranes butyl or ethylene propylene diene monomer (EPDM) and various membranes using bitumen or bitumen products. All the membranes are subject to mechanical damage and only the synthetic rubbers can be left exposed to the effects of sunlight without rapid deterioration. The manufacturers of the membranes other than the synthetic rubbers recommend therefore that their products are buried under about one foot of fine grained material to protect them from both damage and sunlight. However, if a reservoir is to be completely covered, usually justified in terms of health and safety because the expense is not justified in terms of saving evaporation losses, then any membrane can be used uncovered below it. This has led to the suggestions of polyethylene or PVC lined reservoirs with floating butyl rubber covers. The designer is always looking for ways to use the cheaper membranes which are, in ascending order of cost, polyethylene, PVC, and butyl. The bitumen spray treatments are also cheap if the right bitumen products are locally available. If it is decided to completely cover the reservoir then special arrangements must be made to allow the water to enter the reservoir from the catchments. Similar arrangements must be made if a reservoir with a buried lining is to be left uncovered to ensure that the incoming water does not scour the material placed on the liner.

If it can be guaranteed that a reservoir liner will always be covered by water then polyethylene and PVC can be used without being buried except for that part of the liner which will be above and around the water surface. If the fluctuation of water level is within well defined limits the same applies except that the liner must be buried over that

portion that may be exposed. These considerations generally only apply to reservoirs that are being supplied with water from wells or river take offs. The fluctuation of water level in the reservoir of a rainwater catchment unit will usually be very great and there is always the possibility that it will be completely dry.

Two main factors affect the choice of catchment material. It has been shown that water running off an exposed bitumen surface is discoloured by the oxidation products of the bitumen. It has not been shown that this water is in any way harmful to human beings but in the Jamaican context such water would not be satisfactory for a domestic supply. It is however perfectly acceptable for stock water and the relatively low cost of building a bitumen catchment is an added factor in favour of this type of treatment. The second factor is the slope of the catchment surface. The bitumens and gravel covered polyethylene will be badly scoured if the slope and length of the catchments is sufficient to produce a high velocity run off.

The flexibility of the mebranes means that the shape of the reservoir and catchment areas is almost arbitrary. The governing factors are rather in the supply of the reservoir lining material where, if the whole liner is prefabricated, a regular shape may be preferred. In most cases, even if the liner is to be jointed on site, there are many advantages in having a regular shape. The catchment areas should avoid concentrating the flow of run off except into areas specially designed and reinforced for such a flow and should try to keep run off distances as short as possible. The simplest inlet to the reservoir is to flow straight off the catchment and down the side of the reservoir and this can be done on any or all of the sides of the reservoir, other factors allowing. Alternatively flow from the catchments can be concentrated into specially designed headworks and conducted to the reservoir by pipes. This allows for a complete separation of reservoir and catchment but may require greater land space.

The designer must also make some decisions regarding the life span of the unit he is designing. As far as the reservoir is concerned if the liner is installed following the manufacturer's instructions then it should only be subject to

accidental or malicious mechanical damage. All of the membranes themselves are easily repaired but more serious damage can be done to the sub-surface especially from undetected leaks over a period of time. Thus there is a case for burying any sort of liner to minimise the chances of mechanical damage. Manufacturers are generally not willing to guarantee the life of their product but the evidence is that all buried membranes of polyethylene, PVC and bitumen have long lives, in excess of 15 years. An exposed butyl rubber lining may be assumed to have a similar life. When used as a catchment surface bitumen steadily deteriorates and requires a new surface coat at regular intervals. One manufacturer of PVC claims that it is most economical to lay a thin sheet of PVC as an exposed catchment and replace it when it deteriorates. The relatively low cost of PVC is used as justification for this view.

In all that has been written above it is clear that the designer is making not only technical decisions but ones of economy. If the information is available and there is sufficient time then several schemes should be prepared for the same unit and each scheme should be both technically and economically assessed over a long term to decide which is the best solution.

In the design of the earthworks the usual engineering practice of balancing cut and fill should be followed and it may be possible to minimise the work involved in building the reservoir by a combination of embankment and excavation.

The successful design of a rainwater catchment unit depends on the quality of the rainfall records for the area and a reasonable forecast of the demand for water. In Jamaica there are rainfall records for all areas of the island extending over at least a 30-year period for most places. A study of the consumption of water in any one of the limestone plateaux communities now solely dependent on rainwater catchment should provide the basis of a reasonably accurate forecast of demand.

d. Design Assumptions for the Unit.

The experimental rainwater catchment unit at WK 10 was regarded primarily as an exercise to show the feasibility of building large scale rainwater catchment units. It was also built to provide basic cost data for this type of work and to familiarise those concerned in its construction with the techniques of membrane lining. It is not claimed that the WK 10 unit is the cheapest unit that could have been built on that site but the design assumptions listed below were reached on a logical basis and led to the successful construction of an experimental unit.

In December 1971 a preliminary design exercise was carried out to ascertain the approximate cost of providing domestic and irrigation water by rainwater catchment supplies. It was estimated that a 1 million^{gallon}/capacity reservoir with a 1.75 acre artificial catchment would provide a minimum 6,000 gallons per day throughout the year at a cost of 55 cents per 1,000 gallons based on a 25 year life and minimum maintenance costs. The same reservoir using a catchment of $\frac{3}{4}$ acre could provide in an average year 328,000 gallons per month between mid November and mid March for irrigation as well as a small supply of water for domestic use. Assuming an irrigation figure of 80,000 gallons per acre per month this is sufficient to irrigate only 4 acres during the dry season and with the same assumptions as before the cost would be 82 cents per 1,000 gallons. It was therefore decided that the rainwater catchment unit only had a role as a supply of domestic or stock water and that the WK 10 experimental unit should be designed as a source of domestic water to satisfy a constant daily demand throughout the year.

At this stage it was estimated that the cost of a butyl rubber liner for the reservoir would be approximately \$6,000 and it was estimated that the cost of a floating butyl rubber cover would be the same. It was therefore decided that the reservoir should be built without a cover and that at a later stage experiments in reducing evaporation loss by using floating styrofoam rafts might be pursued if the costs were favourable. The design of the catchment area therefore allowed for evaporation loss from the reservoir. It was assumed that the simplest

and therefore cheapest method of conducting the water from the catchments into the reservoir was to bring the catchment surface right up to the reservoir lining and to allow the water to flow directly into the reservoir. It was decided to design the unit so that a constant demand for water could be met throughout the two driest consecutive years in the last 40 years of records. Thus for those two years the unit would collect all the water falling and be of sufficient size to regulate the water supply to satisfy a steady demand for that water. This meant that the water level in the reservoir would fluctuate widely. Thus the combination of the direct inflow from the catchment down the sides of the reservoir and the fluctuating water level ruled out the possibility of using a buried liner for the reservoir.

Several factors combined in the decision to use butyl rubber as the liner for the reservoir. It was felt that the sub-soil preparation of the reservoir earthworks might not result in a completely smooth surface of compacted bauxite. In addition it was known that both labour and supervision were not skilled in the laying of a liner. Finally a long life was required from the exposed lining so butyl rubber, the toughest of the plastic and rubber membranes was chosen.

The preliminary design exercise for the 1 million gallon reservoir had included an estimate of \$40,000 for the total construction cost. In January 1972 at a meeting between Alcan and the Geological Survey Department a review of resources available for the construction of the experimental unit led to a decision to build a smaller unit of approximately $\frac{1}{2}$ million gallon capacity.

e. Design of the Unit.

In march 1972 a preliminary design for the earthworks of the reservoir was carried out by the Alcan Engineering Division and a reservoir whose crest dimensions were 124 feet x 119 feet with side slopes of 1 to 2 and a total depth of 16 feet was decided on. The reservoir was provided with a 3 in. supply pipe and a 4 in. washout pipe which both led from the floor of the reservoir under the northern embankment to deliver

water below the reservoir site. Overflow from the reservoir was dealt with by a 2 ft. deep spillway cut through the top of the northern embankment and leading down to the lower pit in orebody WK 10. This resulted in a maximum depth of water in the reservoir of 14 ft. and a total reservoir capacity of 660,000 imperial gallons.

Early in 1972 it was decided that several different catchment surfaces should be incorporated in the experimental unit and a budget of \$30,000 was proposed for the construction of the unit at WK 10.

In May 1972 the Project Engineer visited Great Britain to finalise arrangements for the supply of the reservoir liner. The supplier, Butyl Products of Billericay, Essex, recommended that a single rectangular sheet of butyl rubber be used to line the reservoir and that the corners of the liner be folded under itself until a good fit was achieved. By adopting this method field jointing was avoided and a working tolerance was provided for the earthworks. After consultations it was agreed that the liner should be fabricated from a material which is a blend between butyl and EPDM rubber. This material is the same price as butyl rubber but the presence of the EPDM increases the weathering properties of the material, particularly its ozone resistance. The liner was ordered in June and arrived in Jamaica in November.

During the middle of 1972 a series of experiments and trials were carried out on five different catchment surfaces. These trials are described in Section IV. In September 1972 after a preliminary assessment of the trials it was decided that three catchment surfaces be laid down at the experimental unit. These were aluminium sheet, aluminium foil and polyethylene covered with limestone chips. Materials for the catchments were ordered in September and had all been assembled by the end of November.

The final calculation of the catchment requirements for the reservoir ~~was~~ carried out in November. Rainfall records from stations surrounding the WK 10 site were collected and examined. These stations were Kendal, Mandeville Public

Works Department, Williamsfield and Grove Place. It was decided to use the figures from the Kendal station which is about $1\frac{1}{2}$ miles from the WK 10 site, at a similar altitude and surrounded by similar topography. The records obtained from the Meteorological office were complete from 1930 to 1966 except for three periods in 1951, 1957 and 1964. The Water Resources Division have developed a computer analysis of rainfall records which by comparing the rainfall records of nearby stations can supply an estimate of the rainfall at any given station. The complete records for the Kendal station arrived at by this analysis appear in Appendix 4. The two driest consecutive years were chosen by inspection to be 1946 and 1947. Original records exist for both these years and for 1937 which was chosen as a year which had a rainfall pattern most closely resembling that of the average for the 1931 - 1971 period.

No long term records of evaporation exist in Jamaica and only a number of meteorological stations throughout the island have any data on evaporation. Some work has been done on estimating evaporation where information is available on temperature, humidity and wind speed at given altitudes. There is evidence to suggest that the annual variation of evaporation is not very great and it was felt that for the purposes of the WK 10 design it would be satisfactory to use figures obtained during 1972 from an American Class A Evaporation Pan at the weather station run by the Alcan Agricultural Division at its Mandeville Head Office. These figures reflect the nationally recognised pattern of highest evaporation between May and July and the lowest evaporation between October and February. It was assumed that the figures from the Class A pan could be used without adjustment for the evaporation from the larger surface area of the reservoir.

A standard mass curve type of analysis was used to determine what size of catchment was needed to serve the 660,000 gallon reservoir. It was assumed that there would be 100% run off from the catchment areas and secondly that evaporation losses would only take place from the surface of the stored water. In December 1972 this monthly loss was based on the surface area of the reservoir when full. It is

now recognised that this is an extremely conservative estimate and the typical calculation for the catchment area that appears in Appendix 4 has assumed a monthly evaporation loss from the surface area of the reservoir when half full.

The December 1972 analysis on which the catchment areas for the WK 10 unit were based showed that a total catchment of 1.77 acres was required. This catchment would result in a steady supply of approximately 130,000 gallons per month. The calculation was re-worked using the 1937 rainfall figures and it was found that the WK 10 unit would be able to supply 195,000 gallons per month in an average year.

The catchment surface area of the WK 10 reservoir itself is approximately $\frac{1}{8}$ of an acre and it was decided therefore to adopt a design requiring 1.5 acres of artificial catchment.

At this stage of the design the final topographical survey of the WK 10 site was completed and it then became necessary to select the best arrangement of reservoir and catchment area. The choice of catchment areas was conditioned by the materials that had been chosen for the catchment surfaces. The Project Engineer, who was solely responsible for these design decisions and calculations, decided to re-orientate the position of the reservoir from that in the preliminary design to minimise the work required to achieve plane surfaces on the catchment areas. It was decided that, if possible, catchment surfaces should remain plane to minimise problems of laying the membranes, all of which being rectangular rolls of one form or another would require special treatment if laid on other than plane surfaces. It was also apparent that only to the west of the site were the slopes suitable for the polyethylene and limestone chip type of catchment and that only the aluminium type of catchments could be used on the slope to the south of the reservoir.

It was decided therefore to adopt a catchment design based on two plane areas of differing slopes. It was recognised that where these two slopes met there would be a concentration of run-off which ruled out the use of the polyethylene and limestone chip catchment in this area. It was also appreciated that, of the aluminium materials, only the foil had the flexibility to deal with a change of slope without having to resort

to special sheets. Thus, once the decision was made to adopt two plane surfaces for the catchment areas the materials chose their own location. It was decided to line the whole of the western catchment area with polyethylene and limestone chips. The area covered in this way was regarded as only 70% efficient and the total area of catchment was increased from 1.5 acres accordingly. The final design called for a catchment area, which would be considered 100% efficient, of 1.62 acres, the actual area covered being nearly $1\frac{3}{4}$ acres. This was largely due to a reluctance to stop the aluminium catchments below the crest of the slope forming the southern and south western catchment areas. Thus the WK 10 unit as designed has substantially more catchment area than a balanced design based on the two driest years calls for. However, this should mean that a slightly higher rate of demand can be satisfied than has been predicted and that catchment efficiencies of less than 100% have been amply catered for.

Two other features of the design should be noted. The design of the catchments concentrates all the run off from the south western catchment areas at the south west corner of the reservoir. It was felt that it was undesirable to allow all this water to flow directly down the liner in one concentrated area so a concrete headworks to funnel the water into a pipe capable of handling the storm run off was designed. This pipe discharges on to the liner in an area in which a concrete slab has been built under the liner to absorb the energy of the falling water. It was also recognised that this type of arrangement would demonstrate how water from a catchment surface could be conveyed to a reservoir by a pipeline.

In order to protect the polyethylene and limestone chip catchment from any cross flow of water from the aluminium foil surface a ditch and mound were designed to separate the two catchment areas.

Both the spillway across the northern embankment of the reservoir and the pipe from the south western catchment area are designed to be able to handle a storm run off equivalent to a rain of 6 in. per hour.

A series of drawings and calculations was then carried out to determine the extent of the earthworks involved. The bulk of the work was in cutting and filling of the southern catchment area particularly on its eastern side, and in the formation of the northern embankment of the reservoir. Calculations showed that about 12 ft. would have to be cut from the upper section and a similar quantity would be required to fill the lower section of the southern catchment. Very little work was required on the western catchment. It was calculated that 5,000 cu. yds. of bauxite material would be required to complete the reservoir embankments and that a further 3,750 cu. yds. would be required to blanket the catchment areas.

The top width of the reservoir embankments was made 15 ft to enable the earth-moving contractor to construct the whole of the embankment using his standard heavy machinery. In addition it was pointed out to the contractor that if he experienced difficulty in ripping and cutting the limestone on the southern catchment then either Alcan would use their standard blasting equipment to assist in breaking up the surface or the slope of the southern catchment above the point where the southern and western slopes meet could be made steeper so long as the transition between the upper and lower slope of the southern catchment was gradual.

The remaining drawings of the details of the construction of the unit were completed while the earthworks were in progress (See Appendix 4). It had been noted in the catchment trials that weights made of polypropylene bags filled with fine grained material placed on top of the aluminium sheet and foil deteriorated and within 6 months had broken. In addition surface weights are aesthetically unpleasant. It was decided therefore to anchor the aluminium sheet to the ground by screwing it to aluminium sheet sections buried in the bauxite blanket. The spacing at approximately 24 ft. centres of these anchorage pieces was decided on after observing the distribution of weights on the trial catchment area of aluminium sheet. The placing of these anchorage pieces was designed to avoid any of the lap joints on the sheets. It was not possible to avoid using surface weights on the aluminium foil and it

was decided to use rejected rubber car tyres. Goodyear Jamaica Ltd. supplied the project with approximately 800 tyres that are regularly destroyed during testing procedures at their factory. Used car tyres, while not weighing as much as filled polypropylene sacks, are equally satisfactory. The limestone rip rap on a 2 ft. wide shelf around the top of the reservoir serves to prevent the limestone chips being washed off the polyethylene, to weight down the lowest edge of the aluminium sheet and to break up the flow of the run-off water as it enters the reservoir. Recommendations from the publication Water for Irrigation (see Bibliography) were followed in the design of the spillway and the concrete energy absorber.

The complete WK 10 catchment area was surrounded by a drainage ditch to collect storm run-off from surrounding areas and prevent it entering the storage reservoir.

A work schedule for all operations following the earthworks was drawn up at the beginning of January. All separate items of work were identified and the job requirements listed. A bar chart was then compiled but since the number of men available to work on the project was not known this chart only showed the best sequence of operations to complete the job. The chart was kept up to date during the work and provides a record of the progress of the job. The chart is reproduced in Appendix 4.

f. Construction of the unit.

In December 1972 the Management of Alcan's mining operations decided to let out a contract for the earthworks of the WK 10 unit. At a meeting between Mr. Richard Myers of Wilbros, a firm of earth moving and construction contractors, Mr. George Brown, Alcan's Mining Superintendent and the Project Engineer, the drawings for the earthworks were presented and the requirements for the job were discussed. The sites from which it was proposed to haul any bauxite required for constructing the reservoir or blanketing the catchment areas were also visited. At the suggestion of the Project Engineer it was agreed that as much bauxite as possible should be taken from the WK 10 pit itself below the site of the reservoir. The second bauxite

source involved a haul of a mile. As a result of this meeting Wilbros submitted a tender for the job amounting to \$30,000. This tender was renegotiated by Mr. Brown and Mr. Myers and a contract signed for the rental, operation and supervision of the machines required for the job. A minimum number of hours was guaranteed for each machine that was brought to the site. A copy of the agreement is included in Appendix 4, which also contains a detailed description of the construction, a summary of which follows here.

Work began on January 2nd 1973. The Project Engineer acted as Resident Engineer, referring necessary problems to Alcan's Mining Department who were in overall charge of the earthmoving contract. The Alcan Property Department provided a surveyor for the survey control of the construction. Alcan employed a timekeeper for the contract.

After forming the floor of the reservoir, the two galvanised steel pipes (3 in. for delivery and 4 in. for wash-out) were laid in their correct positions, the reservoir sides and embankments were formed, all fill being placed in layers, spread and compacted. Preparation of the perimeter catchment surfaces involved a considerable amount of earthmoving.

The earthworks contract was completed on the 26th of January, when a labour force (average 15 men) drawn from the Alcan Agricultural Division, started work on lining the reservoir. The supervision of this work was shared between Alcan and the Project Engineer. The work consisted of hand-excavating the liner anchorage trenches, and the spillway across the northern embankment, excavating for the energy dissipator and pouring the concrete for this structure, and preparing the reservoir surface to receive the liner.

The liner was provided as a single rectangular sheet of Butyl Rubber, 140 ft. x 145 ft., weighing approximately 2 tons. The sheet arrived folded into a strip, rolled up round

a hollow tube, and crated. With the help of a Caterpillar 955 tractor the roll was lifted by a bar passed through the hollow tube, and unrolled along the eastern edge of the reservoir. The sheet was then unfolded gradually until it covered the whole of the reservoir surface.

The four corners of the liner were tidied up by pleating the liner under itself, holes for the outlet pipes were cut and sealed, minor tears in the sheet were repaired with patches and adhesive, and the reservoir was completed by back-filling the anchorage trenches with bauxite. The overflow liner, a 13ft. 6 in. wide strip of Butyl Rubber 100 ft. long was placed in the spill-way and jointed to the reservoir liner with a jointing strip and adhesive.

On completion of the reservoir, work was concentrated on laying aluminium sheet on the southern catchment area. The sheets, which are 0.015 in. thick are joined by self-tapping alloy screws, the spacing of the screws being based on the results on the trial catchments (described in Section IV). Just over 1,000 aluminium sheets, 12 ft. 5 in. x 3 ft. 3 in. were laid using approximately 1,100 man-hours.

Two other materials were laid on the other catchment surfaces, aluminium foil and polyethylene covered with a 1-in. layer of limestone chips.

g. Costs

The total cost of constructing the WK 10 Unit amounted to \$ 30,195-48. A breakdown of this is given in Appendix 5. This total does not include any sum for supervision or for the preliminary survey of the site and the design of the Unit. Some tentative figures for these services are given below.

	\$
(i) Survey of site and production of plan	400.00
(ii) Design of unit, production of working drawings and site visits during construction	1,500.00
(iii) Foreman to act as Inspector during the earthworks contract and to direct site operations during the lining of the reservoir and catchments	1,500.00
	<u>\$ 3,400.00</u>

Where applicable the rates of pay have been indicated so that adjustments may be made for new or different rates.

It should be remembered that the design for the WK 10 unit called for 1.62 acres of catchment to serve a 660,000 gallon capacity reservoir. As explained in Section IIIe this figure is unduly high owing to probably excessive estimates of evaporation losses from the reservoir and conservative choices of catchment areas. The calculation in Appendix 4 shows that for maximum efficiency in the two driest years on record a catchment of 1.12 acres only is required. This considerably smaller catchment would represent a large saving in capital cost. However, if the lower estimates of evaporation losses are correct the WK 10 unit will be able to meet a higher demand than that

predicted by the original analysis. The relation between the catchment and storage is, however, no longer the most efficient to deal with the driest years.

Cost figures for the construction of the various parts of the WK 10 unit remain absolutely valid and may be used as a guide for any future construction. The only cost figure that will be affected by this change in design assumptions is the cost per 1,000 gallons but this figure is in any event an extremely tenuous figure, being dependent on a number of assumptions that have at this stage to be made without any justifying evidence.

The cost of the complete unit has been analysed to give estimates of the cost of construction of each part of the unit. These estimates are for materials and labour directly associated with each part of the construction and do not include the cost of items peculiar to the unit as a whole. The items included in each estimate are set out below so that by comparing these estimates with Appendix 5 it is possible to see which items were considered as applying to the whole unit.

Cost of construction of Reservoir

£

Earthworks

Wilbros	5,039.56
Cat 955	72.00
Survey control	840.00
Timekeeper	32.80

5,984.36

Materials

Galvanised 3" and 4" pipes with fittings	703.00
Butyl rubber liners	3,514.16
Shipping and transport	430.06
Concrete for energy absorbers	35.00
Tools	50.00

4,732.22

(Contd.../)

Labour

Manual labour	308.00	
Mason	32.00	
Tractor and Trailer	88.00	
	<hr/>	
		428.00
		<hr/>
		£11,144.58

Cost of 660,000 imp. gallons storage = £11,200.00

Construction cost £17.00 per 1,000 gallons of storage

Cost of Catchment Preparation

Earthworks

Wilbros	8,611.44	
Survey control	560.00	
Timekeeper	52.20	
Alcan grader	7.00	
	<hr/>	
		£9,230.64

Approximate area of lined catchments is 8,700 sq.yds.

Catchment preparation costs £1.06 per sq.yd. of lined catchment

N.B. The area that it was necessary to clear to achieve the 8,700 sq.yds. of lined catchment was approximately 11,500 sq.yds. It should also be remembered that approximately half of this area was fractured limestone and that approximately a quarter of this area involved an average cut of 6 ft., the deepest cut being 12 ft.

Cost of laying aluminium sheet catchment

Materials

Sheet	4,043.12	
Anchorage pieces	373.23	
Screws	252.00	
Icepicks	10.00	
Safety glasses	18.00	
4" shovels	20.00	
Tools	100.00	
Prefix	33.00	
	<hr/>	
		4,849.35

Labour

Manual labour	274.00	
Tractor and trailer	20.00	
	<hr/>	
		294.00
		<hr/>
		£5,143.35

Approximate area of aluminium sheet catchment = 4,400 sq.yds.

Cost of aluminium sheet catchment = \$1.17 per sq.yd.

Cost of laying Polyethylene covered with limestone aggregate catchment.

Materials

Polyethylene sheet	328.37	
Limestone aggregate	360.00	
Tools	25.00	
Prefix	14.00	
	<hr/>	727.37

Labour

Manual labour	116.00	
Tractor and trailer	64.00	
	<hr/>	180.00
		<hr/>
		\$ 907.37

Approximate area of polyethylene catchment = 1,800 sq.yds.

Cost of polyethylene and limestone aggregate catchment = \$0.50 per sq.yd.

Cost of laying aluminium foil catchment

Materials

Aluminium foil	1,082.90	
Black plastic cement	220.00	
Transport of tyres	160.00	
Safety glasses	18.00	
Tools	27.00	
Prefix	18.00	
	<hr/>	1,525.90

Labour

Manual labour	168.75	
Tractor and trailer	4.00	
	<hr/>	172.75
		<hr/>
		\$1,698.65

Approximate area of aluminium foil catchment = 2,400 sq.yds.

Cost of aluminium foil catchment = \$0.71 per sq.yd.

Cost of installing 10" diameter pipe and concrete headworks

Materials

10" diameter pipe	329.00	
Concrete	34.00	
	<hr/>	363.00

Labour

Manual labour	19.50	
Mason	16.00	
	<hr/>	35.50
		<hr/>
		\$ 398.50

IV. CATCHMENT TRIALS

a. Introduction.

In October 1971 it was decided to build a number of experimental catchments each using a different water-proofing technique. The purpose of the trials was:

- 1) to gain experience in preparing typical surfaces to receive catchment membranes;
- 2) to gain experience of the different water proofing materials and the techniques of laying them;
- 3) to obtain information on the cost of construction of each type of catchment so that an estimate could be made of the cost of construction of a full scale catchment suitable for the WK 10 unit;
- 4) to test the durability and run off characteristics of the catchments under the conditions prevailing in the upland limestone areas.

In February 1972 a site was chosen for the trial catchments near to the WK 10 orebody in the Alcan Mining area at West Kirkvine, Manchester. This site displayed the two most typical surfaces to be encountered in the area, namely one area of relatively gently sloping bauxite overlying limestone which was covered in grass and a more steeply sloping area of fractured limestone with a thick cover of trees and other vegetation.

In October 1971 a review of the available literature on waterproofing techniques for artificial catchments was carried out. Where possible information on probable costs was included. The techniques were in two basic classes, (a) the 'plastic' membranes that are prefabricated and only require site jointing to form an impervious surface and, (b) the bitumen and chemical treatments and the sheet metals where the impervious surface is fabricated completely at the site. The review also brought out the fact that all these thin membranes are subject to accidental or malicious damage and that the exposed bitumen surfaces oxidised over a period of time and caused discolouration of the water running off the surface.

In October 1971 after the review of catchment materials had been studied it was decided to experiment with catchments of polyethylene covered by a protective layer of limestone

aggregate, lime stabilised bauxite, and two bitumen treatments, one with a reinforcing membrane, the other without. In July 1972 following a suggestion of Mr. R. F. Anderson of Alcan, aluminium sheet and aluminium foil were also added to the list of trial catchments.

In February 1972 a programme for the trial catchments was drawn up. It was recognised that before the bitumen catchments could be laid some experiments would have to be carried out to determine the behaviour of various bitumen products when sprayed on to bauxite surfaces. These bitumen spray tests were carried out in May and June 1972.

b. Bitumen Spray Tests.

All the methods of constructing bitumen catchments depend on the bitumen penetrating the soil surface and stabilising the soil by binding its particles together. This stabilised layer forms a base to which an impervious layer of bitumen may be bonded. These methods are best used on sandy soils that do not shrink and swell. Bauxite is not an expanding clay but approximately 35% of bauxite consists of clay size grains. This contributes to making compacted bauxite practically impervious and also puts it in the class of soils which Esso state cannot be satisfactorily treated with bitumen.

All the methods of bitumen catchment construction use a cutback bitumen to achieve the initial penetration. Both medium and rapid cure cutbacks are available in Jamaica but it is safer to heat the medium cure cutback which is customarily used.

The tests carried out at Alcan's Agricultural yard at Shooters Hill in May and June 1972 were to determine the extent to which cutback bitumens would penetrate compacted bauxite, and to establish if it was necessary to heat the bitumen and if prewetting/^{the bauxite} increased penetration. It was also hoped to establish an application rate.

Three boxes, 1 yard square, were filled with bauxite which was compacted to a bulk density of 107 lb/cu.ft. The moisture content of the soil was determined to be 0.296 giving

a dry density of 83 lb/cu.ft. This is slightly lower than bauxite compacted at its optimum moisture content but is near enough to compactions that might be achieved in the field. MCl bitumen was sprayed on to box 1 at its normal temperature of 36°C using a hand operated bitumen spray. The bitumen was heated to 65°C before spraying on to box 2, and box 3 was watered before the hot bitumen was sprayed on to it. Bitumen was sprayed on to each box until it began to collect on the surface, when spraying was stopped. The boxes were covered and left for a week after which each box was opened and the bauxite sectioned vertically. There was no measurable penetration of the bitumen in any of the boxes, confirming that bauxite is not a suitable material for bitumen treatment.

However many road bases in Jamaica are made of rolled marl, a soft chalky limestone available in pits all over the upland limestone areas. These roads are prepared by spraying first with a medium cure cutback and then a wearing surface of straight run bitumen with aggregate rolled into it is used.

The bitumen tests were therefore repeated on two boxes of marl, with a bulk density of 111 lb/cu.ft. The medium cure bitumen was sprayed on to the marl in box 1 at 105°C and the same bitumen was sprayed on to the marl in box 2 after it had been moistened with water. Again the bitumen was sprayed until it began to collect on the surface of the marl. On examination it was found that the bitumen applied to the dry marl had penetrated the top 1 to 1½ in. although it did not appear that the bitumen had any great binding effect on the marl particles. The bitumen failed to penetrate the marl that had been moistened before application. It was estimated that about three quarters of a gallon of bitumen was absorbed by the square yard of marl before ponding of the bitumen occurred on the surface.

Colas is an emulsion of bitumen that can be applied without heating so it was sprayed on to dry marl and marl that had been moistened. In neither case did the emulsion penetrate the surface of the marl.

As a result of these tests it was realised that any bitumen catchments would have to be laid on a blanket of marl.

Marl is commonly available and is as easily handled as bauxite so that the two materials can be used equally easily.

c. Trial Catchment Surfaces.

In April 1972 the site selected for the trial catchments was cleared of all vegetation by Caterpillar D8 tractors following their standard reclamation procedure for wooded areas. The site was split into two halves by an existing access road, and one half was fractured limestone with a maximum slope of approximately 12° , while the other half consisted of a thin layer of bauxite overlying the limestone. It was decided to prepare two 100ft x 40ft wide blankets of compacted marl approximately 6in deep and to clear a third 100ft x 40ft wide strip on top of the limestone. Both marl blankets were to have small ponds roughly constructed at their lower ends. On the other side of the road where the slope was a reasonably uniform 8° it was proposed to create three areas blanketed with 6in of bauxite, one measuring 200ft x 40ft and the other two being 100ft x 40ft. A pond was also to be built at the lower end of the 200ft x 40ft area. The longest area was to be used as the subsurface of a polyethylene and limestone aggregate catchment while the other two areas would serve as bases for an aluminium foil catchment and a lime stabilised bauxite catchment. The two marl areas would be the base for bitumen catchments, the steeper one being a straightforward application of two coats of bitumen, the other one incorporating a glass fibre reinforcing membrane. It was hoped to lay the aluminium sheet directly on the limestone surface that had been cleared and smoothed.

The corners of the areas requiring blanketing were marked out but otherwise it was left to the machine operator under the supervision of Mr. Gladstone Morgan to achieve plane surfaces of uniform slope. Caterpillar D8 tractors did the initial preparation and then Caterpillar 631 B Scrapers dropped loads of bauxite and marl in the appropriate areas. These loads were levelled off and compacted by a Caterpillar 824 tractor. Some marl was spread and compacted on the area to be lined by polyethylene but it was realised that the surface achieved was

not sufficiently smooth and it was covered with bauxite. A grader was used to provide a final smooth surface but was rejected in favour of the 824. The bauxite blankets produced for the polyethylene catchment and the aluminium foil catchment were completely satisfactory as left by these machines.

However, the two marl surfaces were not very smooth. A large part of this failure to produce a really smooth surface was due to the use of coarsely graded marl. However, a roller was brought to the site and managed to produce a reasonably smooth surface from the material available. The roller was also used to build up the lower corners of these two areas to counteract the slight cross fall that had been built into these areas. If bitumen catchments are to be used on a large scale then the standard procedure of producing a marl road should be followed in the creation of the marl blanket. This involves the repeated rolling and watering of the marl and the use of finely graded marl in the top surface. A perfectly smooth surface can be achieved by this procedure.

The area of limestone cleared for the aluminium sheet was obviously not a suitable base on which to lay a thin membrane. It was irregular and its fractured nature would not provide a continuous support under a membrane. This area was therefore blanketed with bauxite.

The ponds at the bottom of the bitumen and polyethylene catchments were built by the D8's which formed the embankments from loose limestone rubble and bauxite. Very little compaction of the embankments was achieved. However, none of the ponds exceeded 6ft. in depth and were envisaged as only temporary structures. The inside surfaces of the ponds were trimmed up by hand labour and a thin blanket of soil was spread over all the inner faces. An anchorage trench was dug around the top of the pond embankments and all three ponds were lined with a sheet of black polyethylene 0.010 in. thick. All the pond liners required a site joint running through the pond. The manufacturer of the polyethylene sheet does not recommend that the liners be jointed thus unless the liner is to be immediately buried. In the case of the two ponds on the bitumen catchments they almost immediately filled with water and the

liners proved to be watertight. The liner to the pond on the polyethylene catchment was left exposed to the sun for some weeks before it began to fill with water and the joint by this time leaked badly. This liner, which only ever had a few inches of water in the bottom, was cut out and stolen about a month after the trial catchments were completed. Work described in Section V has been carried out on two of these ponds to show that cheap water storage units can be built using polyethylene and can be designed to reduce evaporation loss, provide filtration of the stored water and to prevent malicious damage.

The five trial catchment surfaces which were laid in August 1972 are reviewed below but only the construction of the bitumen catchments is described in detail since the construction of the other catchments has already been covered in Section IIIf and Appendix 4.

Polyethylene covered with limestone aggregate.

On this small catchment no jointing of sheets was necessary and the aggregate was spread by hand, running loaded wheelbarrows over the sheet. This catchment has performed well during the year of its existence. Occasional checks are required to ensure that no area of polyethylene has been exposed by movement of the aggregate. There is no evidence that dust is collecting in the aggregate thereby reducing further the efficiency of this catchment.

Aluminium foil.

An area of 50ft x 30ft was covered with aluminium foil. The major drawback is the narrow width of sheet (31½ in.). On this catchment polypropylene bags filled with bauxite or limestone fines were used as weights. After 6 months exposure the bags began to disintegrate. The catchment performs well with good run off characteristics but after 9 months in service one of the seams opened up. The seams are easily repaired once the dust and debris has been removed from the joint. Any angular object under the foil will tear it when pressure is applied. It is easy to patch the foil using the black plastic cement and another piece of foil.

Aluminium sheet.

Two areas of sheet were laid down. In August a 50ft x 30ft area of aluminium sheet was laid. Two thicknesses of sheet were used, namely 0.010 and 0.015 in. It proved extremely difficult to handle and lay the thinner material and it was abandoned as unsuitable. The 0.015in thick sheets were 10 ft long and 3ft 4in wide with a 1 in. upstand on each long edge. Two sheets were laid side by side and the upstands were cut diagonally and crimped back at approximately 1 foot intervals. Difficulty was experienced in getting the sheet to lie flat on the ground and where one sheet lapped over another the upper sheet bowed upwards across its width. The catchment, especially the lap joints, was weighted down with polypropylene bags filled with bauxite or limestone fines. It was not felt that this was a very satisfactory system and in September a second 50ft x 30ft area of aluminium sheet was laid below the aluminium foil catchment. The sheets were of the same thickness but had raised trough sections running down the long sides. The edge sections on adjacent sheets clipped over one another and were secured together with self tapping sheet metal screws with neoprene washers. This is very similar to the type of construction used on aluminium roofing. This catchment was also weighted down with polypropylene bags but because each lap joint was screwed together it was found that less weights were necessary than on the alternative system. 8 months after the construction of the first catchment the polypropylene bags had deteriorated and the wind got under the catchment and tore out several sheets. The 50ft x 30ft area of sheet, as used at WK 10, is in excellent condition although the polypropylene bags have deteriorated.

Bitumen methods.

There are several different methods of sealing the stabilised soil layer created by spraying with a cutback bitumen. Esso, on soils of low clay content, do not apply a seal coat, Myers recommends the use of a bitumen emulsion such as Flintkote developed for the roofing industry, and the Asphalt Institute recommends the use of a straight run bitumen preferably catalytically blown, but if not of the lowest penetration grade

available. Catalytically blown bitumen is not available in Jamaica and Flintkote and other bitumen emulsions are not supplied in bulk. Straight run bitumens are available, the 60/70 penetration grade being the most commonly used. 10/20 grade is also available but because of its higher softening point it is rarely used in spray applications. It was decided to use the 60/70 grade as the seal coat for both catchments. The cutback bitumen and straight run bitumen were both applied from a distributor by a hand lance.

Double bitumen coat.

The first coat of MCl cutback bitumen heated to 140°F was applied to the surface until the bitumen began to pond on the surface. The application rate was approximately 0.6 gallons/square yard. Four days later the seal coat of 60/70 bitumen heated to 300°F was sprayed on to the base coat at a rate of 0.9 gallons/square yard. This application rate was slightly too high and gave rise to some bitumen running down the catchment slope. The application of the bitumens was extremely simple and quickly accomplished.

Double coat bitumen with a layer of fibre glass.

A tack coat of MCl cutback bitumen heated to 140°F was sprayed on to the catchment surface at a rate of approximately half a gallon/square yard. Starting at the bottom of the catchment slope 5 ft wide strips of M700 chopped strand fibre glass sheeting weighing 102/s. ft. were spread across the catchment slope. The fibre glass sheet was then saturated by a further application of hot MCl cutback bitumen at a rate of approximately half a gallon/square yard. Each fibre glass sheet overlapped the sheet below it and the bitumen held the sheets together. Where wrinkles developed in the sheet the wrinkle was cut, smoothed down and a patch of fibre glass sheet placed over it and impregnated with hot MCl cutback bitumen. Four days later a seal coat of 60/70 bitumen heated to 300°F was sprayed over the catchment. Approximately half a gallon/square yard of 60/70 bitumen was used. When the seal coat was applied the cutback bitumen of the base coat was still wet to the touch.

Again the procedure of laying the catchment surface was simple and quickly completed.

Both bitumen catchments suffered from rain damage during construction. Almost directly after the cutback bitumen was applied to the two catchments there was a rainstorm of 1 in. in 2 hours. Some of the cutback bitumen was washed down the fibre glass sheet into the pond but the sheet remained well impregnated with bitumen and apparently undamaged. On the other catchment the water running off the catchment cut several gullies into the marl and washed down some of the cutback bitumen into the pond. The gullies were filled in with marl and cutback bitumen applied by hand to the damaged areas.

The same thing happened directly after the spraying of the seal coat. However, the rain seemed to have little or no effect on the fibre glass reinforced catchment but it did get under a part of the seal coat on the other catchment.

The liner to the pond serving the fibre glass reinforced catchment was replaced because the original liner had become covered with bitumen running off the catchment. However, after a short period of service it was apparent that the run off from the bitumen catchments was discoloured. For this reason no further interest was shown in the bitumen catchments in relation to the WK 10 unit. However, both catchments have performed well for the year they have been in operation. The fibre glass reinforcing made this type of catchment the most expensive of the trial catchments but the unreinforced bitumen catchment was the second cheapest trial catchment. The rough marl surface on which this catchment was laid will hasten its deterioration and it is evidently oxidising. All bitumen catchments are essentially shorter term installations which require a regular resurfacing. However the simplicity and speed of construction of this type of catchment may recommend itself to units that might be built for stock purposes only.

The application of two coats of bitumen to a marl surface is a standard procedure used on many roads in Jamaica. The Asphalt Institute has suggested that discolouration of run off can be reduced by spreading sand or pea sized gravel on to

the freshly sprayed seal coat and lightly rolling it into the surface. This makes this method of construction directly analogous to the standard road construction technique. In March 1973 a white bitumen based paint, Decoralt, was applied to the fibre glass reinforced catchment to try and reduce oxidation of the bitumen and discolouration of the run off water. This application is however relatively expensive.

Lime stabilised bauxite.

The lime stabilisation of a soil can reduce its plasticity, increase its shear strength and bearing capacity and provide a material which is much less susceptible to the reduction in strength normally associated with increases in moisture content. Before lime stabilisation can be attempted a series of laboratory trials must be undertaken to determine whether lime stabilisation is worthwhile and, if it is, the application rates of lime and optimum moisture contents at which compaction should take place. The P.W.D. Materials Laboratory in Kingston started this series of tests but due to various other pressures the tests were never completed. In the meantime it was realised that the method required a relatively high number of machines to achieve the stabilised layer. It was also realised that unless all cracking was stopped by the stabilisation of the soil there would eventually be erosion of the surface by the run off water. The evidence is that lime stabilised soils remain susceptible to hair line cracking which it is felt would soon be developed by erosion. If, therefore, it is necessary to put a protective coat of bitumen on the lime stabilised layer the whole object of the exercise is lost. It was therefore decided not to pursue this type of treatment.

d. Costs of Trial Catchment Surfaces.

Records of machine hours, materials and labour were kept throughout the construction of the trial catchment surfaces. An analysis of these records showed that:-

₯

1. Cost of clearing bush and rough grading ready to receive blanketing materials. 0.08 per square yard of total area cleared.
2. Cost of blanket material, mining, transport, spreading and compacting (not including the use of a roller) 1.05 per square yard of area blanketed.
3. Cost of blanket material, mining, transport, spreading and compacting including the use of a roller 1.10 per square yard of area blanketed.
4. Polyethylene and limestone aggregate.

Polyethylene	0.22	
Limestone aggregate	0.20	
Prefix (herbicide)	<u>0.02</u>	0.44
Labour to prepare anchorage trenches	0.01	
Labour to lay and cover polyethylene	<u>0.05</u>	<u>0.06</u>
		₯ 0.50

Cost to lay polyethylene and limestone aggregate catchment = ₯0.50 per square yard of effective catchment.
5. Aluminium foil.

Aluminium foil	0.50	
Black plastic cement	0.06	
Prefix	0.02	
Weights	<u>0.11</u>	0.69
Labour to prepare anchorage trenches	0.06	
Labour to lay and joint foil	<u>0.04</u>	<u>0.10</u>
		₯ 0.79

Cost to lay aluminium foil catchment = ₯0.79 per square yard of effective catchment.

6. Aluminium sheet.

Aluminium sheet	0.84	
Aluminium edge pieces	0.14	
Screws	0.03	
Prefix	0.02	
Weights	0.04	
		<u>1.07</u>
Labour to prepare anchorage trenches	0.04	
Labour to lay and joint sheets	0.01	
		<u>0.05</u>
		₹ 1.12
Cost to lay aluminium sheet catchment	=	₹ 1.12 per square yard of effective catchment.

7. Bitumen reinforced with fibre glass sheeting.

Cutback bitumen	0.14	
Fibre glass sheet	0.86	
60/70 bitumen	0.07	
Prefix	0.02	
Decoralt	0.15	
		<u>1.24</u>
Labour to prepare anchorage trenches	0.04	
Labour to lay fibre glass sheet	0.01	
Hire of distributor to spray bitumen	0.51	
Labour to apply Decoralt	0.01	
		<u>0.57</u>
Cost of laying bitumen reinforced with fibre glass sheet catchment at experimental site	=	₹1.81 per square yard of effective catchment.

N.B. The distributor which visited the site twice to spray the base coats on the first visit and the seal coat on the second visit was hired on a daily basis for ₹150.00 per day.

The quantity of bitumen sprayed on each occasion was only a small part of the total capacity of the distributor. It has been calculated that if the same rates of application are used on a larger catchment and the distributor uses its total capacity then the cost of application by the distributor would be reduced to \$0.12 per square yard of effective catchment.

This means that a better estimate for a large scale catchment of this type would be:-

Estimated cost of large scale reinforced bitumen catchment	=	\$1.42 per square yard of effective catchment.
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The major cost item of this method is the fibre glass sheet which was imported by a local agent from the United States. Myers reports a cost of US\$0.75* for this type of catchment built at Phoenix, Arizona in 1970. Similar types of catchment can be built using different reinforcing materials such as woven polypropylene sheet or Phillips Petromat fabric and these may prove cheaper.

Reinforced bitumen membranes are at their most effective when the surface to be covered is cracked or small movements are expected. They are also recommended as pond liners.

8. Bitumen.		\$
Outback bitumen	0.08	
60/70 bitumen	0.12	
Prefix	0.02	
	<hr/>	0.22
Labour to prepare anchorage trenches	0.01	
Hire of distributor to spray bitumen	0.49	
	<hr/>	0.50
		<hr/>
		\$ 0.72

* Approximately \$ Jamaican 0.62 in 1970.

Cost of laying bitumen catchment at
experimental site = \$0.72 per square yard of
effective catchment.

As explained under the reinforced bitumen catchment, an estimate was made of the cost of spraying the bitumen if the distributor was used most efficiently. In this case the hire of the distributor would be reduced to \$0.11 giving rise to the following estimate:-

Estimated cost of large
scale bitumen catchment = \$0.34 per square yard of
effective catchment.

The costs for earthworks and the non-bitumen membranes proved to be good estimates for the WK10 unit. Costs quoted in Section III show that catchment preparation costs were very similar. This indicates that the much more difficult work involved at WK 10 offset any advantages that might have been expected from the larger scale of the operation. In addition there was virtually no hauling of bauxite at the WK 10 site and no charge was made for the bauxite mined other than a sum for the purchase of the land.

The polyethylene and limestone aggregate catchment cost the same at both sites and the fall to \$0.71 per square yard of aluminium foil at the WK 10 site can in part be attributed to the use of used rubber tyres as weights. The increase in cost to \$1.17 per square yard for the aluminium sheet at the WK 10 site is due to the system of buried aluminium anchorage pieces used there. This operation was time consuming because of the hardness of the compacted bauxite.

e. Cost of Concrete Catchments.

This project has found it very difficult to establish the cost of constructing a concrete catchment. Apart from the well recognised variables of the remoteness of the site and of the slope of the site there is also the question of what constitutes a concrete catchment.

Mr. Martin, Superintendent of Roads and Works, in the Parish of St. Ann, has explained that the method of building concrete catchments has been through several phases. In the

first instance attempts were made to level off the whole of the catchment area and then a 3 in. slab of concrete would be cast. Sometimes the catchment area was split into a number of small rectangular bays which were cast with expansion joints between them. The slabs were generally not reinforced although some experiments were carried out using chicken wire to reinforce the slab. However, even when all these precautions were taken, the slabs still cracked, although in a more controlled fashion. As is the custom with most concrete work in all but the largest engineering enterprises in Jamaica the concrete slabs were always rendered. Because maintenance was still required on slabs with reinforcement and expansion joints it was felt that both these items were an unnecessary expense and the method most commonly used today is as follows. The hillside is cleared and cleaned but only the worst depressions are filled and only the loose projecting rocks are removed. A 3 in. layer of lean concrete of a 1:5:10 mix is then applied over the whole surface with no construction or expansion joints. It has been noted that the higher the ratio of cement in a mix the more readily do cracks develop. This is the reason for using the lean mix. Reinforcement is not used. The concrete is laid over all the projecting rocks and a concrete block wall is built around the edge of the catchment to form a gutter on the lower parts of the catchment to conduct the run off water to the tank. When the slab has been completed it is rendered. In this way catchments have been built on extremely steep hillsides.

Three cost figures have been obtained from three different sources.

A figure of \$3.00 per square yard has been quoted by a member of the Mandeville P.W.D. as the expected average cost of constructing a concrete catchment area for a tank. It is not certain if this includes all the preparation of the ground surface or is the estimated cost of laying a 3 in. slab of concrete on a prepared surface. The P.W.D. pays its contractors approximately \$18.00 per cubic yard of 1:3:6 concrete supplied and placed under normal conditions. The figure of \$3.00 therefore appears on the low side.

The St. Ann Parish Council has just completed payment of \$25,274.00 for a 100,000 gallon closed steel storage tank with a half acre concrete catchment. The cost of fabricating the tank on site in the latter part of 1972 was \$12,000. Assuming the preparation of the compacted marl base for the tank and the pipe connecting the tank and catchment cost just over \$1,000, it is estimated that the cost of the half acre ^{concrete} catchment was approximately \$13,000. This works out to a cost of \$5.37 per square yard of catchment.

When the Project was constructing the trial catchments at West Kirkvine in August 1972 a local contractor was shown an area of the hillside that had been cleared of trees, presenting a surface of rough and broken limestone, and was asked to give a quotation for constructing a concrete catchment of 50ft. x 30ft similar in size to the aluminium sheet catchment that was laid on the same surface. The estimate was for an "Average 4 in. thick slab of 1:3:6 concrete on a well compacted marl sub base over gently sloping ground. The slab is reinforced with 130 JRC mesh and with expansion joints. The surface is finished with a steel trowel and provision has been made for swaling to falls." The reinforcement is a 6in. x 6 in. square mesh of $\frac{1}{8}$ in. diameter bar.

The total estimate was for \$1,519.50, the job being estimated on the normal construction industry rates and assuming that the site was within a 5 mile radius of Mandeville. This works out to a cost of \$9.10 per square yard but it is for a catchment which is reinforced and has expansion joints.

The Project Engineer feels that the figure \$5.37 per square yard is probably the most realistic of the three figures obtained.

Similar cost figures for the trial catchment surfaces are;

Polyethylene and limestone aggregate	\$1.63
Aluminium foil	1.92
Aluminium sheet	2.25
"Best" reinforced bitumen	2.60
"Best" double bitumen	1.52

Very similar figures were obtained for the three surfaces at the W.K.10 unit.

f. Conclusions

On relatively gentle slopes where polyethylene and limestone aggregate catchments can be used it is apparent that considerable savings in cost can be made over concrete catchments. So far there has been no sign of deterioration of the black polyethylene and it appears as though the thin layer of limestone aggregate gives it sufficient protection from the sunlight. The Polyethylene has the advantage of being a flexible sheet and should not require any maintenance. It should be remembered that this type of catchment is not 100% "efficient" and some increase in price should be made when comparing it with catchments of 100% efficiency.

The aluminium foil is only suited to smaller catchments where it can be under constant inspection but it is very much cheaper than concrete and easier to lay.

The aluminium sheet still has to be proven in a very strong wind and some of the edge and lap anchorage details could be improved. It provides excellent run off and if it remains stable in all conditions it promises to be a very durable catchment.

Both bitumen catchments require regular resurfacing as the seal coat oxidises and the low initial cost of the double bitumen catchment must be seen in the light of regular maintenance expenditure. Neither bitumen catchment is ideal for the supply of domestic water.

Concrete catchments have definite advantages of virtually no limit to the slope on which they may be constructed and little or no risk of malicious or accidental damage so long as they are kept in good repair. It appears, however, that they crack quite frequently and require regular maintenance in the same way as the bitumen catchments.

It should finally be mentioned that the cost of laying a sheet of ^{butyl}EPDM blend material on a surface prepared as for the polyethylene and limestone aggregate would cost approximately \$3.18 per square yard. This is considerably cheaper than the \$5.37 per square yard for concrete although no allowance has been made for holding down the butyl rubber sheet.

Mr. C. E. Staff has repeatedly stated that in his opinion the use of an exposed P.V.C. membrane, given a life of four years before it has to be replaced, can be economically justified because of the low cost of P.V.C.

It would appear that all the membrane materials used are cheaper than concrete but all have limitations to their use. In the right circumstances, considerable savings will be made by using these alternatives to concrete.

V. STORAGE TANKS FOR INDIVIDUAL HOUSEHOLDERS

a. Introduction

In most communities in the upland limestone areas there are homes that have their own rainwater catchment tanks. The roof of the home is invariably used as the catchment area for the tank, the water being led to the tank through galvanised gutters and pipes. This system of private water supply has been in existence since the communities started and the older tanks are usually constructed of masonry with the waterproof lining provided by a cement and marl rendering. More recently tanks have been built of concrete blocks reinforced with steel bars with the same waterproof rendering. The tanks are built as low into the ground as possible to provide additional strength for the tank walls and to make it easier to conduct the run off water from the roofs to the tanks. The excavation for the tank, in ground that nearly always contains some white limestone, is a major part of the construction of the tank and is normally the responsibility of the householder. Once the excavation has been completed a local mason is usually employed to build the tank. The excavation is made as deep as possible and is usually stopped by the limestone becoming too difficult to remove. It is then left to the mason to achieve the depth of tank required by building up suitably reinforced walls above ground level. The most popular size for the tank is

10 x 10 x 10 feet giving a capacity of approximately 6,000 gallons. Most of the tanks in the rural areas are uncovered except perhaps for a layer of wire mesh to keep out debris. Few of these tanks have concrete covers but a number have roofs of galvanised steel sheets. Water is normally removed from the tanks by a bucket but in the higher income areas hand pumps or small electric pumps may be used to draw the water from the tank to an overhead distribution tank. In high income areas such as Mandeville many homes incorporate a water tank into the basement of the house. Water is led from the roof to the tank by rain pipes and the tank is usually under the floor of the house.

It is immediately noticeable that the problem of water supply in communities that have a high proportion of private tanks is less acute than those communities where a majority rely on a public rainwater tank. In periods of drought a far greater control is exercised on private sources than on public ones and it is invariably the distribution of water from private tanks to other less fortunate members of a community that assists communities through long periods of drought. Most people, given the financial resources, will have their own tanks built.

This Project was concerned to develop a cheap storage tank that is easily built and that might become a standard model that could be built throughout the upland limestone areas. The tank is covered.

b. Design Considerations.

It was decided to investigate the performance of a 10,000 gallon capacity tank under typical rainfall conditions for the upland limestone areas. Using the same rainfall figures as those used for the design of the WK 10 unit and making no allowance for evaporation losses, because the tank was to be covered, it was found that in the two consecutive driest years a catchment of just over 1,000 square feet would enable a steady monthly demand of approximately 2,400 gallons to be met. This reduces to approximately 78 gallons/day which gives an eight person family nearly 10 gallons/head/day. In an average year the same unit would yield approximately 3,200 gallons/month which can be reduced to approximately 100 gallons/day. Although 1,000

square feet is probably more catchment area than is available from most house roofs in the rural areas it was decided to pursue the design of a 10,000 gallon tank on the assumption that additional artificial catchment to the roof could be constructed.

It was immediately realised that the existing method of building these small tanks has much to recommend it, not the least is that it is a well tried design and that the cost is relatively low. Only three alternatives were given consideration. Prefabricated tanks of welded steel, and prefabricated sectional tanks of pressed steel (Braithwaite) and reinforced plastics (Hydroglas); all proved to be above the price range considered practical for the Project. An interesting design for a reinforced plaster reservoir developed by the Ministry of Water Development in Rhodesia and South Africa was studied but the limit on wall height to approximately 6 ft. and the wall thickness of only $3\frac{1}{2}$ in. suggested that this tank was not suitable for an area which is regularly subjected to earth tremors. The tank is reportedly very cheap but would still require a mason's skill to construct it.

The most attractive alternative was a metal grain storage bin which could be made waterproof by lining it with a plastic or rubber membrane. The structural strength is provided by the walls of the grain bin which support the waterproof liner. British fabricators of butyl rubber market a standard open tank consisting of a sectional metal tank and a prefabricated liner to fit inside the erected tank. However, a paper, published by Messrs. A. R. Dedrick and C. W. Lauritzen of the U.S. Agricultural Research Service in Logan, Utah (see Bibliography) describing a galvanised steel grain silo that had been lined with a PVC liner to successfully make a 35,000 gallon capacity water storage tank, seemed to offer the best alternative. Because the tank is covered there is no restriction on the use of the cheaper plastic materials, polyethylene and PVC as the waterproof liner.

Polyethylene, the cheapest membrane, is however very difficult to seam and form into a waterproof sack, whereas

this is an easy procedure with PVC. It was decided therefore that a 14 foot diameter tank approximately 11 feet high should be developed. Enquiries on costs for PVC liners for such a tank brought a quotation from the United States of US\$325.00 F.O.B. for a liner 0.020 in. thick and US\$400.00 for a liner 0.030 in. thick. The manufacturer stated that the liners should have a life of 10 years. A British fabricator, Stephens Plastics, quoted a price of £38.50 F.O.B. for a 0.020 in. thick PVC liner, although they recommended the use of a reinforced butyl rubber liner costing £81.00. Although it was recognised that the 0.020 in. thick PVC liner barely satisfied the requirements, the quotation from Stephens Plastics was accepted and four of their liners were imported.

The Jamaica Livestock Association holds the agency for the importation of galvanised steel feed silos manufactured by Read Steel Products of Birmingham, Alabama, and an increasing number of these silos are being used on chicken farms throughout the island. Following discussions with the J.L.A. and the sales representative of Read, an order was placed for a standard 14 foot diameter farm grain bin. The bin was supplied complete with roof and fittings and dome headed bolts were supplied for use in bolting together the wall sections. The tank arrived in Jamaica at the end of January 1973.

In June 1972 Alcan Products of Jamaica were approached to see if they could manufacture a 14 ft. diameter, 11 ft. high aluminium tank with a roof, suitable for use with a waterproof lining as a 10,000 gallon water storage tank. The tank was designed by Mr. J. Brindley and used 4 rings of 16 gauge aluminium bolted together with half round headed cadmium plated bolts to form the body of the tank. The roof was formed from four pieces of 22 gauge aluminium curved so as to form a barrel vault roof. Gutters were provided on the roof and pipes led the water from the roof to the tank. The ends of the barrel vault roof were blocked in with sheets of aluminium. A final order for this tank was placed with Alprojam in November 1972. The tank sections were fabricated and hand drilled before erection at the Alprojam works. The tank was completed in

December 1972. In March 1973 the tank was marked and dissembled in such a way that it would be easily reassembled. The tank is, at the time of writing, stored in the Water Resources Division yard awaiting transport to the Bluefields Property of the Jamaica Agricultural Society in St. Ann where it is to be erected as a water tank to serve two small farm buildings recently erected on that property.

c. Design of the 10,000 gallon PVC-lined Galvanised Steel Tank at Cross Keys.

In March 1973 the Ministry of Mining and Natural Resources decided to erect one of the experimental 10,000 gallon tanks on the site of a Government building in southern Manchester. The Project proposed the Health Centre at Cross Keys, as being a suitable site and the Ministry accepted this.

The Health Centre at Cross Keys serves a large area of south west Manchester. It is open daily and a nurse and assistant nurse are on duty. It is also the base for a Public Health nurse and regular clinics and doctors consultations are held there. The Centre has all the modern sanitary conveniences but it is supplied with water from the Cross Keys Public rainwater catchment tank. The nurse's home, which adjoins the Centre, is also connected to this supply. The Centre is therefore a major consumer of water in Cross Keys. The Centre has a roof area of approximately 1,800 square feet which is not used as a catchment. It was felt that, apart from the desirability of a Health Centre having its own water supply, if a tank was erected at the Centre some of the demand on the public supply would be reduced.

On April 19th, 1973 the Project Engineer visited the Health Centre and surveyed the Centre and the land surrounding it. A plan, including contours, was drawn up and a site for the water storage tank was selected. It was realised that in order for the tank to be of use to the Centre a complete water system would have to be installed including the guttering for the roof, an overhead distribution tank, a pump to fill the distribution tank and pipes to carry the water between the

tanks and back into the Health Centre. The Project Engineer assumed responsibility for all these aspects.

Rainfall figures from Stones Hope, 2 miles north of Cross Keys and at a similar altitude were studied and the catchment area for the tank calculated on the basis of the two consecutive driest years which were 1946 and 1947. It was assumed that only 95% of the rainfall would be conducted to the tank, allowing for splash losses. Following the standard calculation it was estimated that a catchment of 1,115 square feet was required. The Centre has a two level, gabled roof, and by placing guttering on both sides of the smaller high level roof and on one side of the lower roof a catchment area of approximately 1,275 square feet is utilised. In an average year it is estimated that this unit will yield approximately 3,500 gallons per month. In the driest year the yield was estimated as 2,300 gallons per month. Notwithstanding the fact that these figures indicate a daily usage of 100 gallons, it was decided to erect a standard welded steel overhead tank of 400 gallons capacity, supported on an 11 ft. high tubular steel frame. The site chosen for this tank was on the highest ground in the Centre which runs beside the road. It was also conveniently situated for leading the water back into the pipe from the public rainwater catchment tank which serves the Centre. It was proposed to use a small electric pump to lift water from the storage tank to the overhead tank and to reduce friction losses a buried PVC pipe was used. It was proposed to erect the storage tank at ground level on a 9 in. thick reinforced concrete base. Thus it was possible to install two outlet pipes for the water in the base of the tank. See the Drawings for the layout and construction details of the installation at Cross Keys.

d. Installation of Rainwater Catchment Supply System at Cross Keys

Once the design was completed the Project contacted the P.W.D. in Mandeville and explained the job to the Superintendent, Mr. Handy. He contacted the Works Supervisor in Newport, Mr. Marks and a local contractor, Mr. Martins, was given the job of erecting the tanks. The Project Engineer contracted the West

Indies College, Mandeville, to supply and install the guttering and rainpipes and Mr. Lindsay visited the site to determine the size of guttering required. Mr. D. Crum Ewing of Hood Daniel Well Company Ltd., Mandeville, gave advice on the pump and piping to be used and his company was contracted to supply and install the plumbing. The overhead tank and stand was fabricated and delivered to site by Mr. A. Francis of Mandeville.

Construction details for this work and detailed costs are given in Appendix 6. The total cost amounted to \$2,229.80.

e. Analysis of Costs of 10,000 gallon Tanks.

Three types of tank have been considered for the individual household installations. The costs for the galvanised steel tank are shown in Appendix 6.

The aluminium tank supplied by Aluminium Products of Jamaica cost \$780.00 in December 1972. However, Alprojam agreed to bear the overheads for the construction of this tank and these were estimated at \$272.00 making a total cost of \$1,052.00 for the aluminium tank. On a production order of several hundred tanks this figure might be lowered. However, the 16 gauge aluminium sheets are more prone to damage during transport than their galvanised steel equivalents and the barrel vault roof proposed for the aluminium tank is not as effective as the roof of the galvanised steel tank. There is unlikely to be much difference in the cost of erection of the two metal tanks.

The galvanised steel tank was imported from the United States in January 1973 and the cost delivered to the Project was \$800.00.

An attempt was made to find out the cost of building a 10,000 gallon tank using the traditional methods. Two contractors in Mandeville were contacted and asked for quotations. Copies of these quotations are shown in Appendix 7 with the specifications supplied by the contractors in September 1972. One contractor stated that they were not interested in this type of work but could recommend contractors to carry out the work. For this and other reasons the names of the contractors

are not shown in this report. The lower quotation was for \$1,924.10, made up of \$311.00 for excavation, \$989.10 for the tank and inlet and outlet pipes, and \$373.00 for the roof with appropriate additions for the contractors overheads. Both contractors proposed to use a reinforced concrete base of 6 in. thickness but laid on a compacted marl base. Thus, the cost of the block tank and concrete roof once the excavations are completed is approximately \$1,560.00 including overheads. This compares with a cost of \$1,341.76 for the erection of the base, tank and roof of the galvanised steel tank at Cross Keys. Thus the saving by using the PVC lined steel tank is not dramatic. However, the steel tank has certain advantages. Once the base has been built the erection of the tank is simple and relatively straightforward and could be carried out by unskilled labourers with a minimum of training. It also requires very little equipment to erect, the basic necessities being two or three ladders and the scaffolding. The tank being prefabricated and easily transported would lend itself to any large scale scheme which envisaged a central storage depot.

It should be remembered that the tank built at Cross Keys incorporates all the ideal aspects of a water storage tank and as such represented the highest cost of such a system. The U.S. Agricultural Research Service reports that a number of these types of tanks have been built not using a concrete base but on bases of well compacted soil. In Jamaica, compacted marl, if suitably protected from erosion outside the walls of the tank, would probably form an admirable base. The liner would have to be 0.030 in. thick PVC or even of reinforced butyl rubber 0.030 in. thick but the increase in cost of the liner would still represent a saving when set against the cost of building a reinforced concrete base. Similarly, if the tank was erected in a deep excavation, bottom outlet pipes would not be used and a single suction pipe entering the tank from the top with a foot valve at its bottom end would be used.

Previous schemes to assist people to build their own tanks have all been based on money loans, leaving the individual to collect the necessary materials and skilled labourers to build the tanks. The prefabricated galvanised steel tank and

its waterproof liner would be ideal for a scheme that envisaged the householder preparing the excavation and base and the loan authority providing the materials for the tank.

The 0.020in.thick PVC liner used in the Cross Keys tank has proved satisfactory. However this material is comparatively easily damaged and in the event of a large number of these tanks being erected by unskilled labour or by a trained team consideration should be given to the advantages of using a reinforced rubber liner. This material is heavier but would withstand greater punishment during construction than the PVC liner. In 1972 the cost of a reinforced butyl rubber liner was £81.00 FOB Great Britain compared to £38.50 for the 0.020 in thick PVC liner from the same supplier.

f. Cisterns in Rural Areas.

In Section IVc brief mention was made of the polyethylene ponds built to collect water from some of the trial catchments in Alcan's West Kirkvine mining area. Polyethylene is by far the cheapest of the prefabricated lining materials but it must be buried if it is to be used successfully as a long term lining. In March 1973 the Project undertook to rebuild two of the polyethylene ponds at the site of the trial catchments to demonstrate that polyethylene can be used successfully and that other simple construction methods can be used to reduce evaporation losses from water storage cisterns and to filter the water that is being stored.

Two methods of construction were followed. The pond at the bottom of the fibre glass reinforced catchment was rebuilt to form a rock filled tank as described by C. Brent Cluff in his paper "Plastic catchments for economic harvesting of rainfall" (see Bibliography). Then the pond at the bottom of the polyethylene and limestone aggregate catchment was relined with polyethylene and in the central portion ten beehive structures were built which supported a 1 foot thick sand filter and provided cavities for the storage of the filtered water. This method of construction has been developed by the Intermediate Technology Development Group Ltd. in the Sudan, Botswana and Swaziland.

Rock filled tank.

As described in Section IVc the pond at the bottom of the reinforced bitumen catchment had been roughly formed by D8's and then hand trimmed and blanketed with a thin layer of soil. A rectangular sheet of polyethylene had been used to line the pond and was anchored around the edge of the excavation. By March 1973 this liner had been torn in a number of places by stones and other debris thrown into the pond. The pond was pumped dry and the liner cleaned and repaired. A 1 ft. thick layer of sand was then placed over the bottom of the pond (16 ft. x 11 ft.) Used tyres were then laid side by side until they completely covered the sloping side walls of the tank. The voids in the centre of the tyres and between them were then filled up with sand until the sloping sides of the tank were covered by a 6 in. thick layer of tyres and sand. Limestone rocks, gathered from the hills surrounding the experimental area, were then laid on top of the sand layer until the whole of the surface area of the tank was covered by a 1 ft. thick layer of limestone rocks. The remainder of the pond was then filled by throwing limestone rocks into it, a small open shaft about 2 ft. in diameter was left at one side of the tank. The area of the bottom and side slopes of the pond that was covered was approximately 750 sq.ft. Approximately 100 tyres were laid on the sloping sides and approximately 16 cu.yds. of sand was required to form the sand blanket. It is estimated that a volume of approximately 60 cu. yds. was then filled with limestone rock. The capacity of the tank before lining with sand and rocks was approximately 13,500 gallons and assuming that little or no water is stored in the sand layer and accepting Cluff's estimate of a reduction of volume of 50% by the rock the tank is capable of storing 5,250 gallons. The limestone rock used in the tank is heavily pitted and the estimate of a 50% reduction in volume may be conservative. It could be checked by pumping the full tank dry and measuring the quantity drawn off. The cost of the 0.010 in. thick polyethylene, river sand and the transport of tyres was approximately (\$33 + \$75 + \$20 respectively) \$128. Cluff reports that the rock filled tank reduces evaporation loss to 25% of that on an open tank and that the water from such a tank would be suitable for domestic and stock use. In Jamaica such

a tank with a polyethylene and limestone aggregate catchment would be a most useful source of stock water in remote pastures especially if linked to a cattle trough with a float valve. Material costs are low and it is assumed that the farmer would be able to form the pond and collect all the necessary rock at a minimum cost to himself although it is a labour intensive job. The sand used at the experimental site came from the river at May Pen so that although sand is not always locally available it can be transported to most areas. Sand was preferred as the fine material because it is insoluble whereas it was felt that the locally available limestone fines and bauxite would migrate more readily and would discolour the water.

Tank incorporating a sand filter.

In March 1973 the pond at the bottom of the polyethylene and limestone aggregate catchment was reconstructed. The remains of the stolen liner were removed and the erosion damage on the inlet face of the pond was repaired. The pond was reshaped until the bottom area measured 21 ft. x 9 ft. and the side slopes were approximately 1 in 1.5. The depth of the pond was 6ft. It was recognised that this shape was not ideal for the type of construction envisaged where the side slopes should be as near vertical as possible to minimise the quantity of filter material required to surround the beehive structures. However it was not possible to alter the shape of the pond so drastically and the Project was most interested in demonstrating the construction techniques which could still be used effectively. A cross section of this tank is shown in the Drawing on p.93.

The pond was lined with a sheet of 0.010 in. thick black polyethylene measuring approximately 50 ft. x 40 ft. made up from two pieces of the standard 25 ft. wide roll. The liner was anchored around three edges of the pond and secured under the catchment liner on the inlet face. Ten domed structures were then constructed to cover the floor of the pond. Each of these structures resembles an old fashioned beehive and was a hollow cylinder of 3 ft. 6 in. internal diameter and 3 ft. high. A domed roof sealed the top of the cylinder leaving the whole structure approximately 5 ft. high. One of the ten beehives also incorporated a central shaft of 1 ft. 6 in. diameter which passed

through the roof and served finally as the well shaft of the tank. Each of the beehives was built up from a standard flexible block, manufactured at the site. These were made by cutting a 4 ft. length of 6 in. lay-flat clear polyethylene tubing 0.002 in. thick. One end of the tube was knotted and then a 3 ft. length of the tube was filled with a dry mixture of sand and cement in the proportions 10 parts of sand to 1 part of cement. The tube was then closed by knotting the top end. Before laying in position in the tank the tube was perforated down one side with approximately 12 small holes using a piece of 8 gauge wire to make the holes. The tube was then laid with the holes down in about 2 in. of water and the mixture inside the tube became moistened by the water drawn in through the holes. It was found that the soaking of the tubes is a critical factor in this construction because tubes which are not sufficiently dampened when laid do not cure and harden and on several occasions early in the job caused the collapse of the structure. The soaking of each tube takes only a few minutes and can be speeded up by puncturing a second side of the tube and turning it over in the water. The makers of the tubes soon come to know the appearance of the soaked tube required for successful use.

The tubes are then laid to form the cylindrical bases of the beehives. The first two layers of tubes were laid around a truck tyre of the appropriate diameter to ensure a reasonably circular structure. The tyre was then removed. The tubes when laid, compact down into a three inch high and three and a half inches wide tube with the cross section of a round cornered rectangle. 4 tubes were used on each ring of the bottom cylinder of the structure. Each ring of tubes was secured to the rings below by pushing 9 in. lengths of No. 8 gauge galvanised wire down through them. About four such pins were used on each tube. Each ring was laid so that the ends of the tubes were overlapped and were thus staggered as the structure gained in height. The tubes began to harden in 24 hours. Once all ten cylinders had been brought up to 3 ft. in height some sand was backfilled around them. This sand also covered the joint on the polyethylene liner and the weight of the sand pressed the jointing materials together forming an effective and watertight joint. This weighting down of the joint should be carried out as soon as possible. The domed roofs to the cylinders were then constructed by reducing the diameter of each ring added to the

structure. The top rings of the cylinders were reinforced with more wire pins to resist the pressures put on this part of the structure by the dome. It was found that to make a successful dome pins were required at approximately nine inch spacing in each ring.

When the domes were completed on all ten beehives the tank was backfilled with sand to the base of the domes. The purpose of the beehive structures is to support a 1 ft. thick layer of sand which filters all the water entering the tank and to provide a void space in which the filtered water can be stored. Where the sides of the tanks are almost vertical little sand is required to fill up the additional spaces around the beehives. Because of the relatively shallow slope of the sides of the tank at the experimental site it was decided to incorporate a 2 ft. thick layer of limestone rocks to save on the cost of sand and to provide additional water storage space. The top and sides of this layer of rock were covered with a piece of 0.010 in. thick black polythene which was perforated with small holes to allow the water to pass through but to prevent the filter layer of sand from migrating downwards. The domes were also covered with polyethylene sheet to ensure that water would have to travel down to the cylindrical sections of the beehives before it could enter the storage volumes. The sides of the tank where the rock layer was to be used were lined with used tyres and sand to protect the polyethylene liner from the rock. Once the rock and polyethylene cover had been laid the final 1 ft. thick layer of sand was spread on top of the tank.

It is estimated that the following materials were required to make the ten beehive structures:

3,200 feet of 0.002 in thick clear 6 in lay flat polyethylene tube at 90 ft/lb. weighing approximately 36 lb. at 40c/lb.	14.40
Sand and cement to fill tubes is approximately 6 cu.yds. i.e. 5½ cu. yds. sand @ \$4.60/cu.yd. and 15 bags of cement @ \$1.10 per bag	41.80
150 lb. No. 8 gauge galvanised wire	19.29
Total	<u>\$75.49</u>

Some allowance should be made for wastage due to the polyethylene bursting or splitting and the consequent loss of the sand cement mixture.

Assuming that the sides of the tank had been nearly vertical with a slope of 3 in 1 and that only sand was used as the filter material a further 40 cu.yds. of sand would have been required. The polyethylene used in lining the tank and covering the domes would have amounted to approximately 1,900 square feet of 0.010 in. thick black polyethylene.

Thus:

Cost of 40 cu.yds. of sand	184.00
Cost of one roll of 0.010 in. thick polyethylene imported 1972 (2,500 sq.ft.)	<u>41.00</u>
	₹225.00

Thus it is estimated that a sand filter tank 6 ft. deep with side slopes of 3 in 1 and top dimensions of 24 ft. x 13 ft. would have a material cost of ₹300.00. The tank has a minimum storage capacity of 2,500 gallons assuming no water stored in the sand is available for draw off. The original volume of the open tank is approximately 5,500 gallons. The water stored in the tank is filtered and cannot suffer from evaporation. If the well shaft is covered the water is completely protected from contamination.

The labour content of this method is high but this type of tank with a polyethylene and limestone aggregate catchment could be used to provide high quality water for domestic use in the ^{remote} rural areas. The material costs are low and it is assumed that the tank would be constructed on a self help basis.

VI. SURVEY OF PARISH WATER SUPPLIES

a. Introduction.

By July 1972 information collected by the Project had shown that no single organisation had a complete knowledge of the water supply situation in the rural areas or the necessary data to be able to present an accurate assessment of the situation. This Project, in the time that has been available to it between its other activities, has attempted to collect the basic data and present it in a way that should assist any future planning in these areas. This Project concentrated its survey on the public rainwater catchment tank system but as a result of this work and of the information gathered into this report it is now possible to give a general review of the water supply situation in each of the three Parishes covered by the survey, namely St. Ann, Manchester and St. Elizabeth.

During the period from July to September 1972 Mr. C. Broomfield carried out a field survey of the network of existing public rainwater catchment tanks. The aim of the survey was to locate each tank, identify its position on a map and gather sufficient information to completely describe the tank and its performance as a water supply. This preliminary survey was based on information collected from the Assistant Superintendents responsible for the Parish water supplies in each Parish.

In November 1972 the Project Engineer carried out a preliminary analysis of the data collected. It was apparent that before a final report could be written further field work would be required to check certain discrepancies and absence of data in the preliminary survey. To aid in the location of the tanks the Project Engineer examined the aerial photographs flown by NASA in 1971 as well as the Land Valuation Series Maps (1951-1955) covering the three Parishes. A new series of Land Valuation maps is currently being drawn and printed by the Survey Department and the sites of all the public tanks will in due course appear on them. As a result of this examination the sites of additional tanks were noted.

In April 1973 the Project Engineer tried to complete the field work for the survey. In three weeks 122 tanks were visited throughout the three Parishes. An analysis of all the data was carried out and a start was made on the presentation of the data.

In July 1973 Mr. H. Duval collected the missing data which enabled the survey to be completed in its present form.

The full report of the Water Supply Situation in the Parishes of St. Ann, Manchester and St. Elizabeth appears in Appendix 8.

b. Summary of Results.

St. Ann.

Total number of tanks listed	75	
Tanks now used as part of a pumped water supply	3	
Tanks not now used for domestic water supply	5	
Tanks in use with rainwater catchment units	<u> </u>	67
Tanks in use with rainwater catchment units but having a capacity of less than 50,000 gallons	10	
Closed steel tanks of 100,000 gallons capacity	4	
Tanks with reinforced concrete covers:		
a. 50,000 gallon capacity and above	22	
b. less than 50,000 gallon capacity	1	
Tanks with sheet metal covers:		
a. 50,000 gallon capacity and above	11	
b. less than 50,000 gallon capacity	1	
Total number of covered tanks	<u> </u>	39
Number of tanks without covers:		
a. 50,000 gallon capacity and above	20	
b. less than 50,000 gallon capacity	8	
Total number of tanks without covers	<u> </u>	28
Rainwater catchment units with chlorinators	6	

Rainwater catchment units without chlorinators:		
a. 50,000 gallon capacity and above	51	
b. less than 50,000 gallon capacity	10	
Number of units without chlorinators	<u> </u>	61
 Rainwater catchment units with covers and chlorinators	 5	
 Catchments:		
Concrete	66	
Roof	1	
 Number of 1,500 gallon steel tanks distributed throughout the Parish and regularly filled by the Parish Council	 <u>20</u>	

Manchester.

Total number of tanks listed	82	
Tanks now used as part of a pumped supply scheme	4	
Tanks not now used for domestic water supply	10	
Tanks in use with rainwater catchment units	<u> </u>	68
Tanks in use with rainwater catchment units but having a capacity of less than 50,000 gallons	8	
Closed Steel tanks	0	
Tanks with reinforced concrete covers:		
a. 50,000 gallons capacity and above	26	
b. less than 50,000 gallons capacity	0	
There are no sheet metal covers to any of the tanks on the rainwater catchment units in Manchester		
Total number of covered tanks		26
Number of tanks without covers:		
a. 50,000 gallons capacity and above	34	
b. less than 50,000 gallons capacity	8	
Total number of tanks without covers	<u> </u>	42
Rainwater catchment units with chlorinators:		
a. 50,000 gallons capacity and above	17	
b. less than 50,000 gallons capacity	1	
Rainwater catchment units without chlorinators:		
a. 50,000 gallons capacity and above	43	
b. less than 50,000 gallons capacity	7	
Number of units without chlorinators	<u> </u>	50
Number of tanks with covers and chlorinators	9	

Catchments:	
Concrete	63
Galvanised steel sheet	2
Roofs	3

Number of 1,500 gallon steel tanks distributed throughout the Parish and regularly filled by the Parish Council	54
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St. Elizabeth

Total number of tanks listed	54	
Tanks now used as part of a pumped water supply scheme	0	
Tanks not now used for domestic water supply	4	
Tanks in use with rainwater catchment units	<u>4</u>	50
Tanks in use with rainwater catchment units but having a capacity of less than 50,000 gallons	2	
Closed steel tanks 100,000 gallons capacity	1	
Tanks with reinforced concrete covers:		
a. 50,000 gallons capacity and above	25	
b. less than 50,000 gallons capacity	1	
Tanks with sheet metal covers:		
a. 50,000 gallons capacity and above	4	
b. less than 50,000 gallons capacity	<u>1</u>	
Total number of covered tanks		32
Number of tanks without covers:		
a. 50,000 gallons capacity and above	18	
b. less than 50,000 gallons capacity	<u>0</u>	
Total number of tanks without covers		18
Rainwater catchment units with chlorinators	3	
Rainwater catchment units without chlorinators:		
a. 50,000 gallons capacity and above	45	
b. less than 50,000 gallons capacity	<u>2</u>	
Total number of units without chlorinators		47
Rainwater catchment units with covers and chlorinators	0	
Catchments:		
Concrete	50	
Number of 1,500 gallon steel tanks distributed throughout the Parish and regularly filled by the Parish Council	60	

c. Recommendations.

The survey has shown that in the three Parishes many communities, excepting only the major population centres, depend to a large extent for their water supply on the public rainwater catchment tanks. The public tanks, in conjunction with private tanks and the 1,500 gallon capacity steel tanks filled regularly by the Parish Council, are the primary sources of water for the rural areas. In times of drought recourse may be made to springs or rivers at some distance from the community.

The public rainwater catchment tank should not be viewed in isolation as a supply of water. The survey showed that it is the relation between the public and private tanks that determines the success of the water supply. Few of the public tanks are large enough to sustain the demand of a community through a prolonged drought. However in many communities there are sufficient private tanks to relieve the demand on the public tank, which in some cases becomes a reserve for the periods of drought. In prolonged droughts it is interesting to note that the last of the local water supplies to run out is always the private tanks. This is an indication of the far greater control that can be exercised over a private source than over a public one.

The public rainwater catchment tanks vary considerably in their state of maintenance and therefore in the service they provide. The three fundamental elements of a good supply are a clean catchment, a covered tank and a chlorinator on the outlet pipe. The figures show that each Parish has very few tanks with all these elements. The performance of a tank is often a reflection of the personality of the tank keeper. If the tank is provided with a pipe house which can be locked and with valves so that water can be locked off from the pipe then a conscientious tank keeper can control the rate at which water is drawn off from the tank. This becomes crucial during prolonged droughts. However many tanks are without these simple features and it is impossible for anyone to exercise control over the consumption of water.

The rural population in general has very little sense of responsibility towards its public water supplies. The only regulator on demand is the time and distance involved in carrying

water from the public tank to the point of consumption. Those tank keepers that are able to enforce the twice daily periods when water can be taken from the tank are liable to be abused in time of drought and the installations may be broken into. Damage to standpipes is not uncommon and most tank keepers can instance cases of wastage.

It has been brought home to this Project that in the rural areas there can be little hope of self help under the prevailing conditions and attitudes. Repeatedly during the survey requests were made that work on cleaning the catchments or tanks should be given out and paid for. In the absence of the promise of payment catchments remain overgrown and cracked and tanks which could easily be cleaned remain fouled. The improvement in the quantity or quality of water provided is not sufficient in itself to provide an incentive for the work to be done. This Project is not qualified to explain this attitude but reports it as a well observed phenomenon.

Recognising that the public tanks are an important part of the rural water supply and will remain so for some time to come this Project recommends that immediate improvements in quality, primarily, but also in quantity be made by:-

1. Instituting a programme whereby all uncovered tanks are covered and all tanks are provided with drip feed chlorinators as quickly as possible.
2. A vigorous programme of repair followed by an improved system of maintenance, instituted as soon as possible.
3. A scheme to induce the building of as many private tanks as possible in the rural areas, to be started as soon as possible.
4. A programme of education aimed at all sections of the community to develop a more responsible attitude towards rural water supplies.

The background and development of these points is to be found in the Report on the Rural Water Supplies in Appendix 8. This Project recognises that these recommendations depend for their success on the expenditure of public funds but the sums involved are relatively small and would convert an existing system of dubious merit into a viable and safe water supply system. Suggestions are made in Appendix 8 as to how the cost of those improvements may be kept to a minimum.

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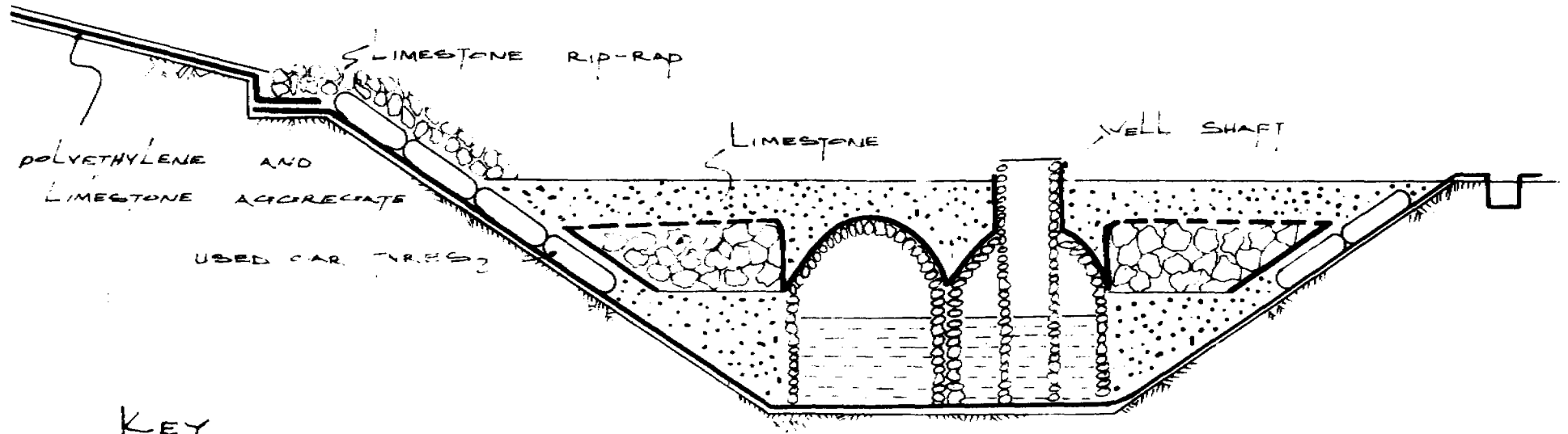
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77. Practical Hydraulics for the Public Works Engineer
From "Public Works Magazine" Sept. Oct. Nov. 1968

See Also: 15, 19, 39, 52, 65.

Additional Publications received by the Project but not directly relating to the work of this Project

78. A Survey of Watershed Yield
H. D. Ayers
Report No. 63, Water Research Laboratory
University of New South Wales 1962
79. Improved Techniques for Estimating Run off with
Brief Records.
F. C. Bell
Report No. 91, Water Research Laboratory
University of New South Wales 1966
80. Lag Time of Natural Catchments
Arthur J. Askew
Report No. 107, Water Research Laboratory
University of New South Wales 1968
81. Mitigation of Siltation in Farm Water Storages
R. C. Hattersley, R. C. Nelson
Report No. 114, Water Research Laboratory
University of New South Wales 1969
82. Effects of Land Management on Quantity and
Quality of Available Water
A Review by W. C. Boughton
Report No. 120, Water Research Laboratory
Australian Resources Council Research
Project 68/2
University of New South Wales 1972
83. Hydraulic Investigation of Critical Gradients for
Approaches to Farm Water Storages.
R. C. Hattersley, K. C. Yong
Report No. 127, Water Research Laboratory
University of New South Wales 1972

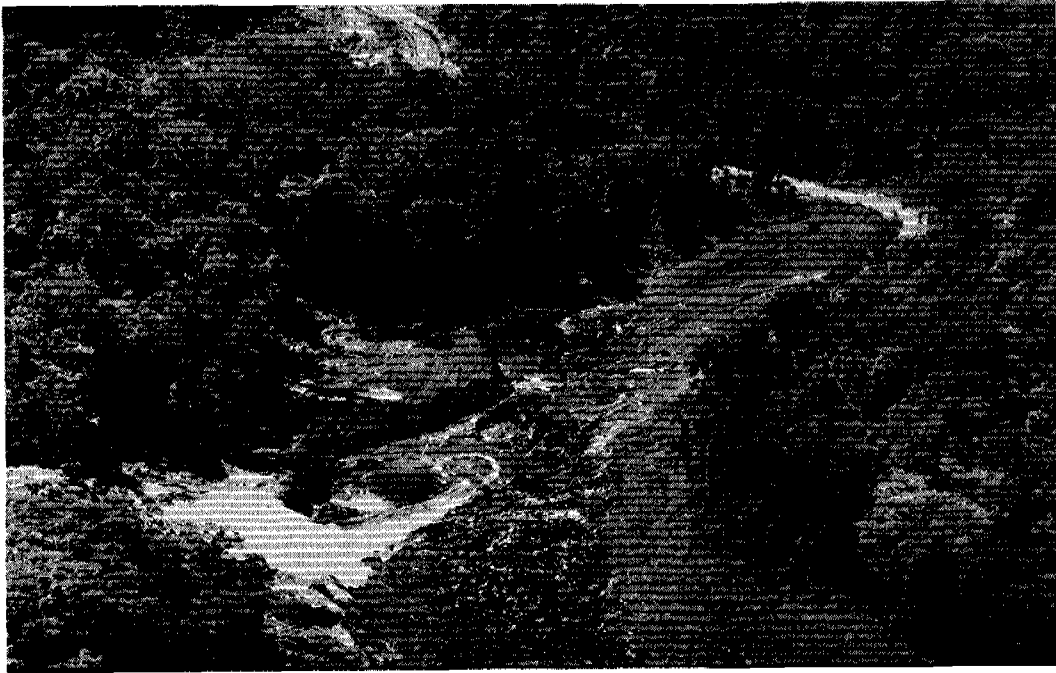
SAND FILTER TANK AT SITE OF TRIAL CATCHMENTS AT WEST KIRKLYNE - MANCHESTER



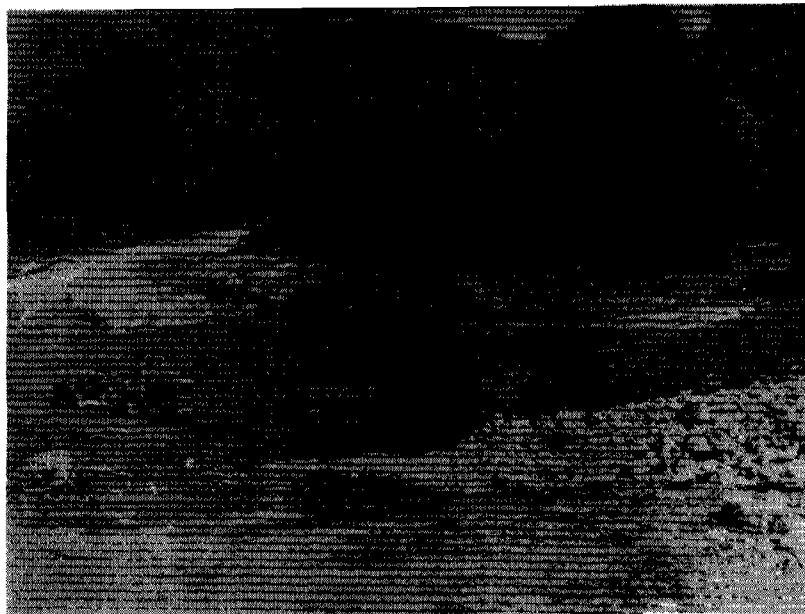
KEY

- 3/4" THICK BLACK POLYETHYLENE SHEET
- [Stippled pattern] SAND
- [Horizontal line pattern] WATER

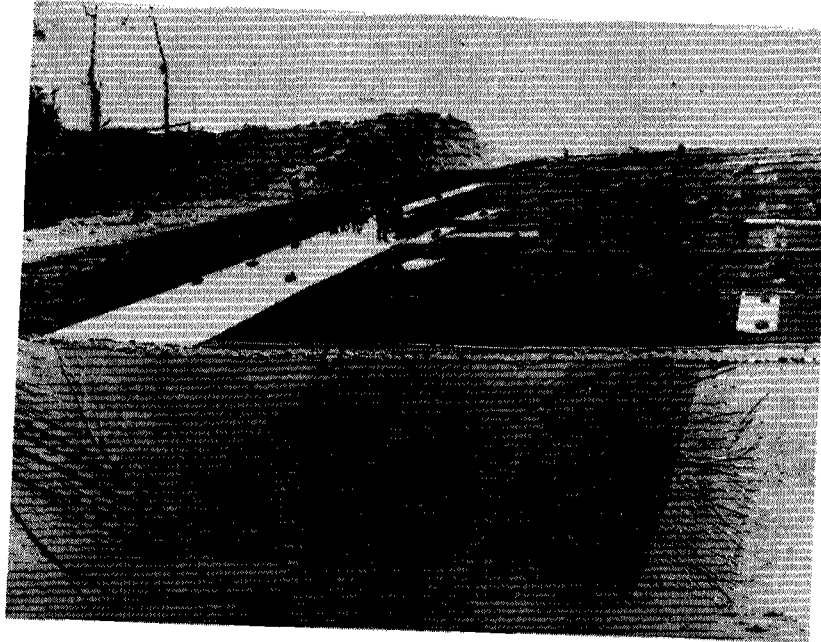
SCALE : 1/4" = 1'



1. *Site of WK.10 Unit, September 1971*



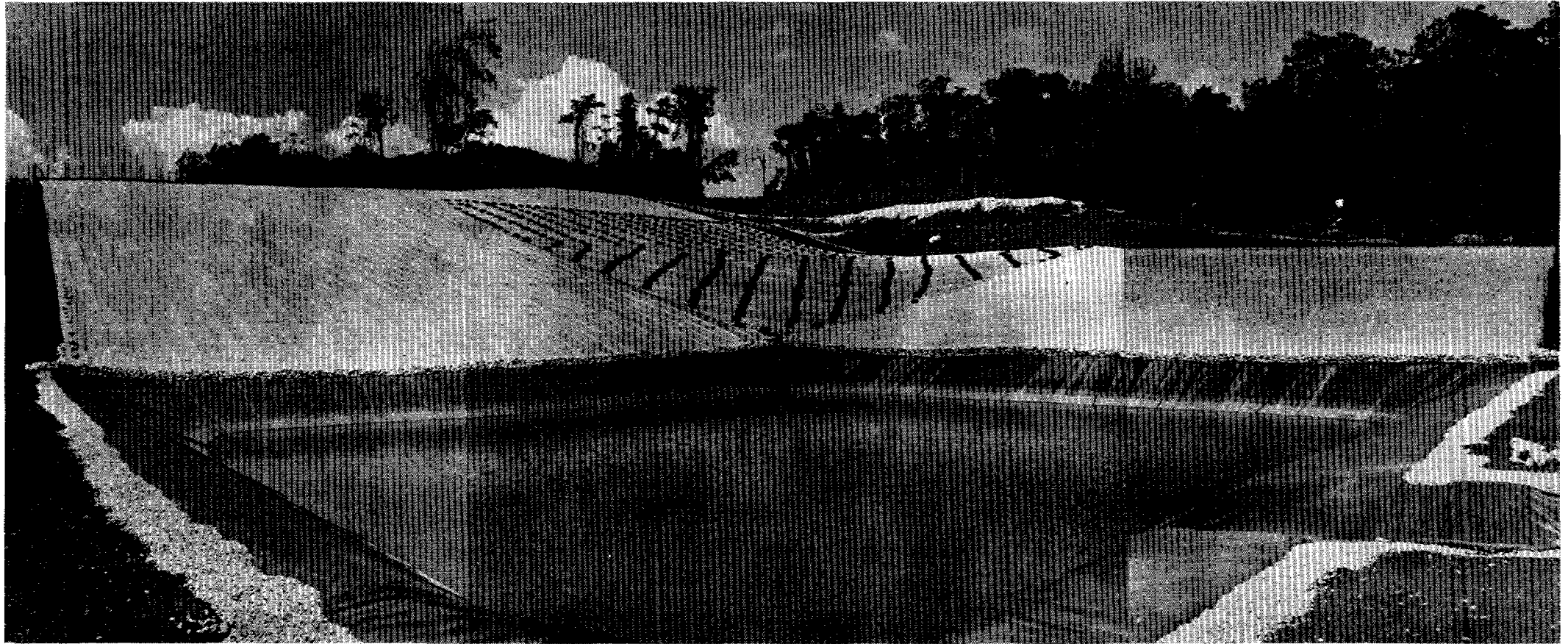
2. *Grading the bauxite blanket on the WK.10 catchment aprons, January 1973.*



3. *Laying aluminium sheet on the catchment apron, March 1973.*



4. *Sealing a joint in the black polyethylene sheet. Note limestone aggregate covering in background.*



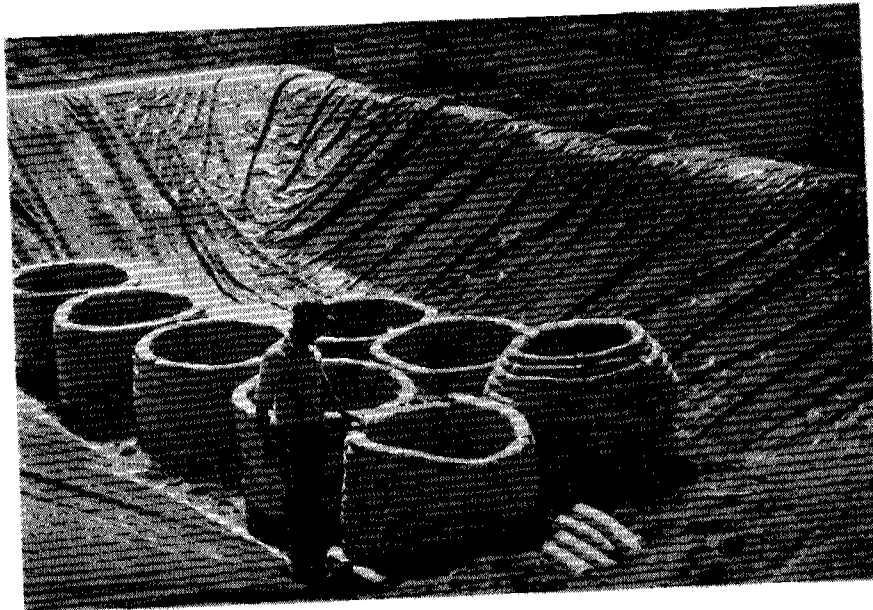
5. Completed WK.10 unit, July 1973.



6. *Trial Catchment programme; bitumen reinforced with fibre glass.*



7. *Trial Catchment programme; polyethylene with limestone aggregate.*



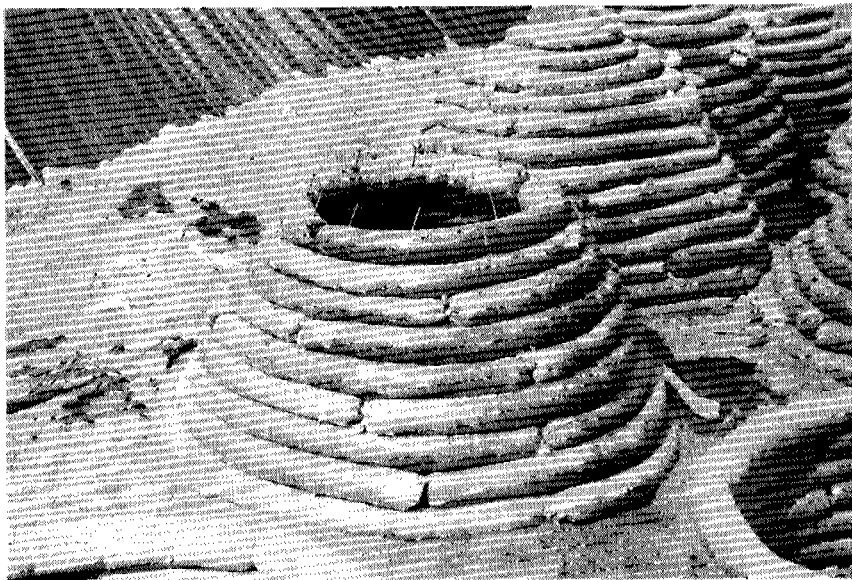
8. *Sand filter tank, trial catchment area; construction of beehives.*



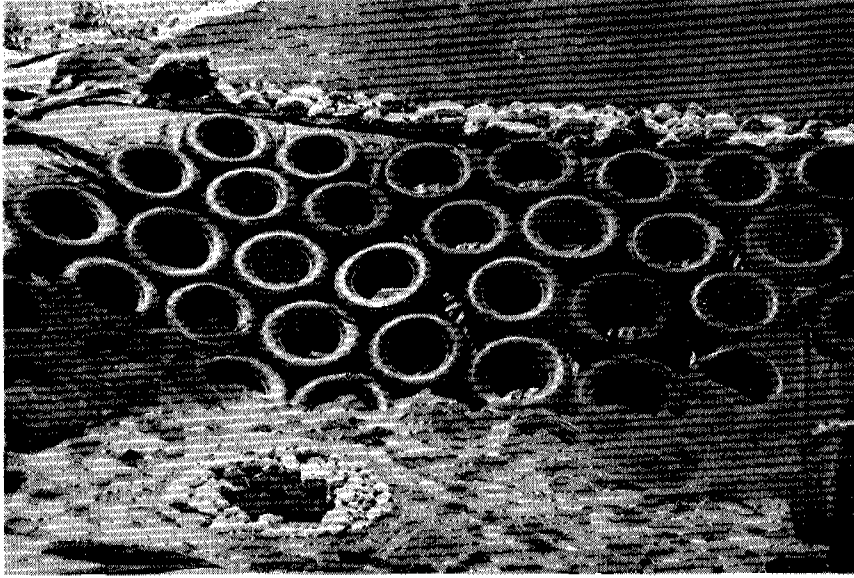
9. *Sand filter tank; building domes. Note sand fill.*



Sand filter tank, beehive with well shaft.



11. Sand filter tank; detail of dome structure.



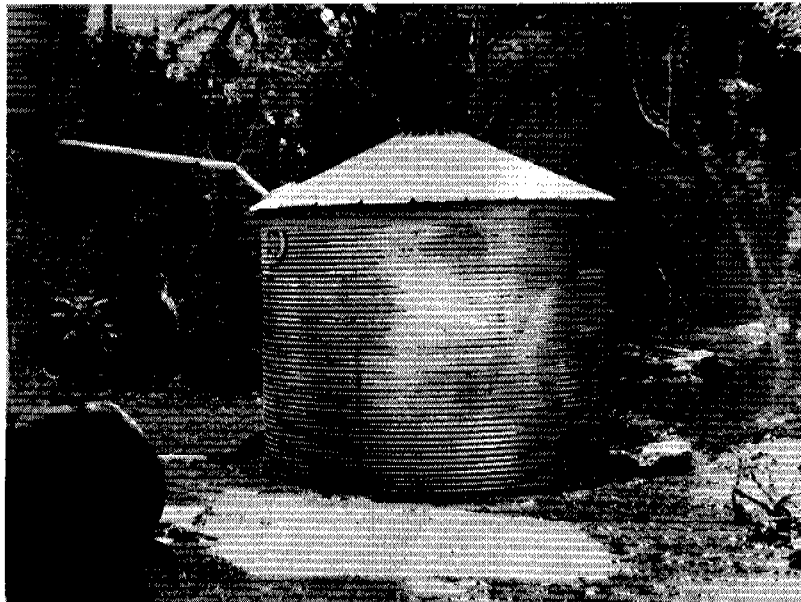
12. *Rock-filled tank; inlet face covered with tyres, sand layer in bed.*



13. *Rock-filled tank; placing first layer of rock.*



14. Cross Keys public rainwater catchment tank; cracks in concrete joints marked by weed growth.



15. Completed 10,000 gallon PVC-lined tank at Cross Keys.

APPENDIX 1

TERMS OF REFERENCE FOR A WATER ENGINEER FOR SERVICE WITH THE GEOLOGICAL SURVEY DEPARTMENT, JAMAICA

1. Introduction

This project is geographically confined to those parts of Jamaica where the rural communities already rely on rain-water catchment and storage. The object is to see how modern materials and techniques can be applied so as to improve these indigenous systems.

Existing methods of constructing both catchment aprons and storage units in concrete would be extremely expensive when applied to attachments of several acres and a minimum cost method of sealing limestone areas on this scale is required. Consideration will also be given to small-scale self-help possibilities for individual family units.

Waterproof materials which will be considered and tested according to their merits will include all types of commercial impervious membranes, emulsions derived from oil or coal, water repellent dressing; in general any industrial product which appears to have promise. As regards possibilities for treating stored rainwater of improved quality, consideration will be given to all available materials, plant, apparatus or techniques which appear to be appropriate to the scale of circumstances which are concerned.

2. The Water Engineer (Mr. Maddocks) will:-

- i. Visit all the relevant industrial concerns in the United Kingdom collecting brochures, samples, unit prices, technical data sheets etc., and compile an inventory and directory from the results, to be available for reference in Jamaica and at the office of the Intermediate Technology Development Group;
- ii. Then visit Jamaica to identify and delineate the relevant geographical areas of the limestone upland on existing survey maps, where the cost of lifting water from available sources at lower elevations is not likely to be economically feasible;
- iii. Make an inventory of the communities and their population in the areas so identified;
- iv. Consider the relevance of the various materials and techniques collected initially in the United Kingdom and evaluate the cheapest and most practical methods for providing water.
- v. Make an economic investigation comparing the cost of supply from the catchments with that of pumped supplies in a number of typical cases.

vi. Liaise with any work which is being done by Alcan or any other agency in Jamaica concerned with similar problems.

vii. Choose a suitable location for a prototype pilot installation.

viii. The Engineer will then visit the selected short list of industrial concerned in the United Kingdom and discuss with their technical staff how their particular materials can best be applied to the construction of the specified pilot prototype already decided upon.

ix. Design a pilot scheme and, in collaboration with the Government of Jamaica, supervise its construction.

x. Test and operate the pilot scheme, making necessary arrangements for collecting and compiling performance data.

APPENDIX 2

PROGRAMME

1971

July

Meeting of interested parties to discuss Project. Represented were:- Geological Survey Department, U.N. Water Resources Project, National Water Authority (N.W.A.), Water Commission, Jamaica Agricultural Society (J.A.S.), Alcan, Kaiser.

Meeting with Mr. Walters, Under Secretary, Ministry of Finance to explain the government's views on the Project.

Visit to St. Ann, St. Elizabeth and Manchester to see at first hand the areas with which the Project will be concerned, including a visit to the Kaiser Mining Area at Tobdski, St. Ann, and the Alcan Mining Area at Kirkvine, Manchester.

Map drawn to define White Limestone areas over 100 ft altitude.

August

Inventory of the population centres in the White Limestone areas compiled.

Meeting with Mr. R. Mason, Under Secretary, Ministry of Finance, to approve the Terms of Reference and the budget for the Project.

Meeting with Mr. Stewart, Assistant Under Secretary, Ministry of Local Government, to explain the aims of the Project and to secure the co-operation of the Parish Councils.

Circular sent to the Parish Councils and Land Authorities to explain the aims of the Project.

Meeting with Mr. C. J. Morrison, Co-ordinator of the Ministry of Rural Land Development, to discuss the Project.

Beginning of correspondence to collect information on rainwater catchment and storage.

Visit to southern Manchester to examine rural water supply situation.

Visit to Manchester and St. Ann to meet the Parish Council Secretaries, Land Authority Executive Officers and Medical Officers of Health.

Visit to Bluefields property of J.A.S. to advise on possibilities of rainwater catchment and storage.

September Information on waterproofing techniques collected
October and assimilated.

Preliminary review of waterproofing methods and costs.

Meeting with Alcan. Site of experimental reservoir selected at orebody WK 10 in the West Kirkvine mine, Manchester. Decision to construct trial catchments.

Project Bibliography started.

Preliminary investigation of rainfall records for the WK 10 unit.

November Review and discussion of Project with the Director, Geological Survey Department and the Manager, U.N. Water Resources Project.

Visit to St. Ann to select a second site for a pilot rainwater catchment unit.

Preliminary design and preparation of a cost estimate for a 1 million gallon reservoir and $2\frac{1}{2}$ acre catchment at WK 10.

December First survey of WK 10 site carried out and plan drawn.

Cost estimate of \$40,000 for 1 million gallon unit presented.

1972

January Decision to build experimental unit of approximately $\frac{1}{2}$ million gallon capacity with $1\frac{1}{4}$ acres of catchment at WK 10 in December 72/ January 1973.

February Programme for construction of experimental catchments agreed. Site for experimental catchments chosen near to WK 10.

Decision to use more than one catchment construction method on the WK 10 unit.

March Change in Government.

April Geological Survey Department became a part of the
May Ministry of Mining and Natural Resources.

Experimental area at West Kirkvine cleared.

Project Engineer visited England to consult suppliers of butyl rubber liner and to report to ITS.

- Tests on bitumen spray methods at Shooters Hill, Manchester.
- Investigation of cost of a PVC lined metal water storage tank.
- Study of aerial photos to locate possible sites for second pilot rainwater catchment unit.
- Visit to Bluefields property of J.A.S. to advise on construction of a 10,000 gallon storage tank.
- June P.W.D. began testing of lime stabilised bauxite.
- Completion of bitumen spray tests and decision to apply bitumen only to marl surfaces.
- Choice of 1/32" thick butyl rubber - EPDM blend material for liner of WK 10 reservoir. The liner to be supplied as a single sheet.
- July Machine preparation of experimental catchment areas and ponds.
- Preliminary survey of existing Public rainwater catchment tanks started.
- Decision to use aluminium sheet and aluminium foil in catchment trials.
- August Trial catchment surfaces laid at experimental site.
- Display at Denbigh Agricultural Show.
- September Meeting to programme construction of WK 10 unit. Catchment materials selected.
- Materials for WK 10 unit ordered.
- Preliminary survey of Public rainwater catchment units completed.
- Second aluminium sheet catchment laid at experimental site.
- Meeting with Mr. G. Thomas, Farms Jamaica Ltd. (Alpart) to discuss an experimental programme of rainwater catchment and storage.
- October Costs of catchment constructions presented.
- Orders placed for one galvanised steel and one aluminium storage tank of 10,000 gallon capacity.
- November 1:12,500 Land Valuation Series Maps (1951-1955) examined to confirm sites of Public rainwater catchment tanks in St. Ann, Manchester and St. Elizabeth.

Preliminary review of literature on waterproofing catchments and reservoirs.

Catchment area of WK 10 unit cleared of trees.

December NASA aerial photos (1971) examined to locate Public rainwater catchment tanks at St. Ann, Manchester and St. Elizabeth.

Final design of WK 10 unit carried out.

Working drawings for WK 10 unit produced.

Contract for earthworks of WK 10 unit negotiated.

York Castle, St. Ann, recommended for further investigation to determine its suitability as the site for a second pilot rainwater catchment unit.

1973

January Earthworks at WK 10 unit started.

February Reservoir liners laid.

Catchment surfaces laid.

March WK 10 unit completed.

Rock filled tank and sand filter tank built at experimental site.

Preliminary cost analysis of WK 10 unit.

April Geological Survey Department and the Department of Mines reformed into the Water Resources Division and the Mines and Geology Division of the Ministry of Mining and Natural Resources.

Final survey of Public rainwater catchment tanks in St. Ann, Manchester and St. Elizabeth.

Mr. P. H. Stern, representing ITS, visited Jamaica.

Cross Keys Health Centre, Manchester, selected as the site of the 10,000 gallon, PVC lined, water storage tank.

May Design and organisation of labour and materials for the construction of a 10,000 gallon water storage tank at Cross Keys Health Centre.

Visit of Prime Minister to the WK 10 unit during a tour of the Alcan tenant farmers operation.

Start of construction at Cross Keys.

June Completion of the 10,000 gallon water storage tank
 at Cross Keys Health Centre, Manchester.

 Completion of final survey of Public rainwater catch-
 ment tanks in St. Ann, Manchester and St. Elizabeth.

 Compilation of Final Report.

July End of Project.

APPENDIX 3

SOURCES OF INFORMATION

A. DATA COLLECTION IN U.K.

The Project engineer joined ITS on the 1st June, 1971 and in accordance with the terms of reference of the Project visited a number of organisations in the U.K. to gather information on techniques and materials available for rainwater catchment and storage. The Project Engineer flew to Jamaica on June 30th, 1971.

The organisations visited were:

- a. Ministry of Agriculture, Fisheries and Food, Land Drainage, Water Supply and Machinery Division.
Chief Engineer: Mr. C. N. Prickett.

The Division is concerned with giving advice to farmers on the construction of farm reservoirs. The bulletin "Water for Irrigation" (see Bibliography) deals with all aspects of the design and construction of earth reservoirs limiting itself to those reservoirs less than 15 ft. deep. In Great Britain many of the reservoirs are built in impermeable soils and the water stored in the reservoir comes from a pumped supply or a river take-off. The Ministry has had experience of lining reservoirs with butyl rubber, prefabricated bitumen sheets, polyethylene and P.V.C.

- b. British Petroleum.
Mr. D. A. B. Llewelyn.

Mr. Llewelyn is involved with the development of a simple solar still to provide pure water in areas of very low rainfall. B.P. have abandoned their experiments with bitumen spraying of the desert in the Middle East to conserve water for plants. B.P. have an interest in chain alcohols which reduce evaporation losses from reservoirs. B.P. are also following experiments conducted in Arizona of spraying silicon onto earth surfaces to waterproof them.

- c. Laporte Industries.
Products Development Manager: Mr. C. O. Gossett.

Laporte Industries produce Betonite. Mr. Gossett discussed the use of Bentonite to waterproof soils.

Thomas Ness Ltd.
Marketing Development Manager: Mr. J. M. Swinstead.

Thomas Ness manufacture roofing compounds and water repellent dressings suitable for use on smooth surfaces such as brick or concrete. These compounds are coal tar based and it has been shown that they contain carcinogens in small

quantities. They are not suitable for use in the storage or collection of drinking water.

Thomas Ness have the franchise for selling mortar-plas, a polyethylene-bitumen sandwich used in the roofing industry. It is expensive and does not appear to have possibilities in the rainwater catchment fields.

- e. British Visqueen Ltd.
Export Sales Manager: Mr. D. J. Pye.

British Visqueen have experience of lining reservoirs in several parts of the world. Polyethylene must be buried if it is to have a reasonable life span. It is the cheapest of the plastic films currently available.

- f. Butyl Products.
Sales Manager: Mr. M. A. Grayburn.

Butyl Products fabricate large sheets of butyl rubber suitable for lining reservoirs, grain silos, water tanks and other similar products from rolls of butyl rubber supplied by Storey's of Lancaster. Although it is the most expensive of the plastic or rubber membranes butyl rubber can be left exposed to the sunlight without serious deterioration.

- g. Trylon Ltd.
Mr. R. D. Sawtell.

Trylon produce polyester resins. Polyester resins are generally used in conjunction with glass fibre sheeting but are relatively expensive. They do not appear to be suitable for large scale applications.

- h. Shell.
Agricultural Extension Projects: Mr. J. Groome.

Shell have a company marketing fuel, lubricants and bitumen products in Jamaica. Shell Composites at Slough produce bitumen products suitable for roofing etc.

- i. Road Research Laboratories.
Mr. B. F. Burglass.

Discussions centred on the lime stabilisation of lateritic soils and the suitability of this technique for forming catchments.

B. DATA COLLECTION IN JAMAICA.

This section is divided into two halves. The first gives a list of commercial companies who provided information on their products as indicated under the subject headings. The second half gives a list of the institutions who provided information on the subjects as indicated. When searching for information on a particular technique both halves should

be consulted. The bibliography also includes publications which contain important information and which are not mentioned in this section.

I. Commercial Companies.

(i) Plastic or Rubber Membranes suitable for Rainwater Catchment and Storage.

- a. Synthetic rubber materials, reinforced or unreinforced. Butyl rubber, ethylene propylene diene monomer (EPDM) and blends of the two materials.
Butyl Products, Billericay, Essex, England.
Globe Linings Inc. California, USA.
Groupe Esmery Caron, Paris, France.
Staff Industries Inc., New Jersey, USA.
Stephens (Plastics) Limited, Corsham, Wiltshire, England.
Uniroyal Inc. Indiana, USA. (Agents: The Fire Safety Co. Limited, Kingston, Jamaica).
Wisdom Rubber Industries, Honolulu, Hawaii.
- b. Polyvinyl-chloride (PVC)
Groupe Esmery Caron, Paris, France.
Staff Industries Inc., New Jersey, USA.
Stephens (Plastics) Limited, Corsham, Wiltshire, England.
- c. Polythene.
British Visqueen Ltd., Stevenage, Herts., England.
Dow Chemical Company, Midland, Michigan, USA.
Metal Box Company of Jamaica, Kingston, Jamaica.
Sinclair-Koppers Company, Durethene Division, Pennsylvania, USA.
Staff Industries Inc., New Jersey, USA.
Stephens (Plastics) Limited, Corsham, Wiltshire, England.
- d. Chlorinated polyethylene.
Staff Industries Inc., New Jersey, USA.

(ii) Bitumen Materials Suitable for Rainwater Catchment and Storage.

- a. Liquid bitumens which may have to be heated before application.
Straight run bitumen (asphalt cement), cutback bitumens, bitumen emulsions.
The Asphalt Paving Company, Kingston, Jamaica.
Esso Research and Engineering Co., New Jersey, USA.
Flintkote Emulsions (Shell), (Agent: Clare Bitumens, Kingston, Jamaica.)
Perma roof, U.S.A.
Shell Company (West Indies) Ltd., Kingston, Jamaica.
- b. Asphaltic Concrete (hot mix consisting of dense, graded stone, sand aggregates, filler and bitumen).

The Asphalt Paving Co.Ltd., Kingston, Jamaica.
Shell Co. (West Indies) Ltd., Kingston, Jamaica.

c. Reinforced Bitumen Membranes.
Phillips Petroleum Company, Oklahoma, USA.

d. Prefabricated Bitumous Sheets.
Globe Linings Inc., California, USA.

(iii) Materials for Protecting Rubber and Bitumen Surfaces
from Sunlight and Oxidation.

Globe Linings Inc., California, USA.
Shell Company (West Indies) Ltd., Kingston, Jamaica.

(iv) Metal Sheets suitable for Rainwater Catchment.

Aluminium.
Aluminium Products of Jamaica. (Alprojam), Kingston,
Jamaica.

(v) Other Membrane Material suggested for Waterproofing
Water Storages.

- a. Bitumen sealants applied to water filled storage to
reduce seepage.
The Larutan Corporation, California, USA.
Shell Construction Service, London, England.
- b. Chemical Treatment of Soils.
Laporte Industries Ltd., Grimsby, Lincolnshire, England.
- c. Gunitite.
Cementation Ground Engineering, London, England.
- d. Epoxy Resins.
Craig Plastics, Nottingham, England.

(vi) Water Storage Tanks.

Prefabricated Waterproof Tanks.

- a. Steel.
Braithwaite and Company, Surrey, England.
- b. Synthetic Rubber.
Butyl Products, Billericay, Essex, England.
Firestone Coated Fabrics Company, Arkansa, USA.
Stephens (Plastics) Limited, Corsham, Wiltshire,
England.
Uniroyal Inc., Indiana, USA.

- c. Reinforced Plastics.
BTR Reinforced Plastics Ltd., Uxbridge, England.
Prefabricated Tanks that require a waterproof lining.
- a. Steel.
Read Steel Products, Birmingham, Alabama.
Titan Tanks Ltd., Billingshurst, Sussex.
- b. Aluminium.
Aluminium Products of Jamaica, Kingston, Jamaica.
Howard Harvestone Products Ltd., Harleston, Norfolk,
England.

(vii) Reservoir Covers.

- a. Floating Synthetic Rubber.
Globe Linings Inc., California, USA.
- b. Aluminium.
Alcan, London, England.

(viii) Treatment of Rural Water Supplies.

- a. Gas chlorinators.
Hood-Daniel Well Co. Ltd., Mandeville, Jamaica.
- b. Chemicals.
Fospur International, Birmingham, England.

II. Institutions.

- a. U.S. Department of Agriculture.
Agricultural Research Service
Soil and Water Conservation Research Division.
Utah State University, Logan, Utah, USA.

Water Storage: Buried Polythene or PVC.

Synthetic rubber, Chlorinated polythene and polyester coated fabric, Reservoir liners combining a PVC bottom with synthetic rubber sides, Closed fabricated synthetic rubber tanks. Galvanised steel tanks with plastic liners, Asphalt and asphalt-fibre glass.

Rainwater Catchment: PVC, Polyethylene and gravel, Synthetic rubber, Polyester coated fabric, Sprayable butyl and polypropylene, Asphalt-fibre glass, Galvanised steel.

Rain Traps: of steel or of synthetic rubber.

Evaporation Control: Foamed butyl rubber.

- b. U.S. Department of Agriculture,
Agricultural Research Service,
U.S. Water Conservation Laboratory,
Phoenix, Arizona, U.S.A.

Water Storage: Asphalt-fibre glass membranes.

Rainwater catchment: Bitumen, Protective coatings for bitumen membranes, Asphalt-fibre glass, Creation of hydrophobic (water repellent) soils using sodium methyl silanolate, Increasing runoff from soil surfaces using sodium salts (carbonate and chloride). Cleared smooth soil surface, Aluminium foil bonded to a smooth soil surface with asphalt.

Evaporation Control: Foamed wax blocks

- c. U.S. Department of Agriculture
Agricultural Research Service
Water Conservation Research Division
Fort Collins, Colorado and Laramie, Wyoming, U.S.A.

Water Storage: Steel bins with plastic liners, Closed synthetic rubber storage bags, Polyethylene, Bentonite blankets,

Rainwater Catchment: Steel catchments, Bitumen roofing catchments, Polyethylene covered with gravel, Synthetic rubber, Bitumen catchments.

- d. U.S. Department of Agriculture
Soil Conservation Service.

Water Storage: Compacted soil, Waterproof earth blankets, Bentonite blankets, Treatment of suitable soils with sodium polyphosphates or sodium chloride, Synthetic rubber, PVC and polyethylene.

- e. Water Resources Research Centre
University of Arizona
Tucson, Arizona, U.S.A.

Water Storage: Polyethylene liner with synthetic rubber cover supported on aluminium tubing, Polyethylene lined-rock filled tanks, Concrete coated Polyethylene.

Rainwater Catchment: Polyethylene covered with gravel, Concrete coated polyethylene, Butyl coated polypropylene, Compacted earth (CE) and Compacted earth sodium treated (CEST) catchments, Asphalt plastic asphalt chip-coated (APAC) catchments using either polyethylene or polypropylene as the plastic layer.

Evaporation Control: Monolayers of long chain alcohols, Styrofoam rafts coated with sprayable butyl rubber, Floating concrete rafts, Coupled expanded-polystyrene asphalt chip-coated (CEPAC) rafts.

- f. U.S. Department of the Interior
Bureau of Reclamation
Engineering and Research Centre
Denver, Colorado, U.S.A.

Water Storage: Properties and use of polyethylene, chlorinated polyethylene and PVC, Properties and use of synthetic rubber materials, i.e. butyl and EPDM, unreinforced and reinforced, Properties and use of asphaltic concrete, Properties of buried sprayed bitumen membranes, Underwater subsurface injected bitumen sealants, Waterborne bitumen sealants.

Rainwater Catchment: Chemical stabilisation of soils using petrochemicals, i.e. liquid vinyl polymer, acrylic copolymer, elastomeric emulsion, epoxized-silicone, petroleum resins, bitumen primers, cutback bitumen.

- g. The Asphalt Institute
College Park
Maryland, U.S.A.

Water Storage: Asphalt concrete, Buried sprayed bitumen membranes, Prefabricated bitumen panels.

Rainwater Catchment: Properties and use of sprayable bitumen, Protective reflective coatings for bitumen membranes.

- h. Water Research Laboratory
University of New South Wales
Manly Vale, New South Wales, Australia.

Water Storage: Properties and uses of polyethylene and PVC, Bentonite, Sodium-tri-polyphosphate, Bitumen, Explosives.

- i. Irrigation and Water Supply Commission
Brisbane, Australia.

Rainwater Catchment: Soil compaction and grading (Roaded catchments), Galvanised steel sheets, Fibre glass reinforced sprayed bitumen, Prefabricated bitumen-fibre glass-PVC panels.

Evaporation Control: Mono-molecular layers.

- j. Department of Civil Engineering
University of Western Australia
Nedlands, Western Australia, Australia.

Rainwater Catchment: Soil compaction and grading (Roaded catchments), Technical and Economic evaluation of Surface treatments for increasing run-off from Small Rural Communities.

- k. State Rivers and Water Supply Commission of Victoria,
Armadale, Victoria, Australia.

Evaporation Control: Polystyrene foam sheets, Woven Polyethylene laminated with a polyethylene sheet, Woven Polyethylene mesh, Foam polyethylene mesh used with cetyl alcohol, Strips of polyethylene sheet.

- l. Water Research Foundation of Australia
New South Wales,
Australia.

Water Storage: Compacted soil, Properties of soils.

Evaporation Control: Monomolecular surface films.

- m. Water Research Association
Marlow, Bucks., England.

Evaporation Control: Polystyrene foam balls, monomolecular layers.

- n. Intermediate Technology Development Group Limited,
London, England.

Water Storage: Bitumen reinforced with woven polypropylene
Polyethylene-mud-sand and cement revetment, polyethylene
lined tanks incorporating a sand filter.

APPENDIX 4 - DESIGN AND CONSTRUCTION
OF THE WK 10 UNIT

- A. Monthly rainfall records for Kendal.
- B. Catchment area calculations.
- C. Earthworks progress chart.
- D. Earthworks contract.
- E. Construction details

A. MONTHLY RAINFALL RECORDS FOR KENDAL

	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941
JAN	2.69	0.45	2.14	4.53	1.30	5.71	1.20	0.83	0.86	3.52	3.86
FEB	3.98	0.90	0.45	9.28	7.61	1.80	2.75	1.85	2.90	1.44	10.91
MAR	1.11	0.57	2.55	5.04	1.34	3.10	4.99	3.42	3.59	2.42	1.51
APR	8.63	14.61	0.73	6.71	5.58	11.51	3.81	11.19	1.25	1.40	6.61
MAY	9.39	11.99	6.89	9.01	7.83	38.80	10.68	3.09	4.58	11.68	7.28
JUNE	13.41	17.55	10.97	3.78	2.37	20.99	5.14	4.93	5.82	1.97	2.28
JULY	14.48	6.33	14.71	4.39	3.48	6.90	4.64	4.89	1.87	4.45	3.57
AUG	5.70	5.75	16.82	12.45	9.69	5.40	7.45	8.14	4.05	5.11	3.94
SEPT	8.88	4.93	15.99	5.33	15.65	4.07	4.68	11.02	5.40	6.67	2.88
OCT	11.73	16.78	31.39	10.41	11.90	7.81	9.38	5.35	8.67	9.31	6.10
NOV	9.98	18.71	0.80	3.66	2.63	5.24	7.96	3.01	20.98	2.66	3.06
DEC	1.61	0.86	0.80	2.36	1.32	1.54	1.81	1.76	2.69	3.30	2.70
TOT	91.59	99.43	104.24	76.95	70.70	112.87	64.49	59.48	62.72	53.93	54.70

	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952
JAN	4.25	2.46	1.24	0.21	1.19	2.13	3.16	0.12	1.92	0.60	0.67
FEB	1.14	1.11	0.25	0.35	2.20	2.91	0.36	0.28	2.06	1.29	3.19
MAR	7.64	3.92	1.55	0.29	2.20	1.12	0.19	4.28	1.58	3.94	3.13
APR	6.26	10.70	7.94	6.76	5.56	1.83	7.93	0.97	7.31	6.22	12.31
MAY	10.70	13.00	12.37	12.76	1.79	6.77	11.72	13.73	7.76	12.31	6.60
JUNE	13.62	3.28	8.50	3.89	1.48	1.51	12.58	7.62	4.81	5.57	4.69
JULY	4.15	1.98	13.05	1.78	2.38	3.38	3.50	7.53	5.01	6.15	10.12
AUG	18.97	5.13	11.74	10.00	5.50	10.23	5.22	4.36	11.69	11.96	6.46
SEPT	7.25	3.86	11.90	15.28	7.44	11.87	17.40	7.94	11.39	3.90	7.90
OCT	13.11	14.00	24.79	7.48	8.24	10.81	10.52	9.76	24.65	10.68	4.77
NOV	1.56	10.11	2.60	10.52	3.97	2.08	2.25	4.92	3.03	6.80	2.35
DEC	4.17	0.14	0.0	2.84	5.10	1.97	1.44	1.94	4.57	3.36	1.20
TOT	92.82	69.69	95.93	72.16	47.05	56.61	76.27	63.45	85.78	72.78	63.39

	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
JAN	2.68	2.75	1.49	0.80	1.57	6.07	1.45	2.03	0.0	0.0	1.30
FEB	1.68	6.38	2.13	1.03	9.56	2.10	1.89	2.71	1.86	3.77	2.85
MAR	4.15	3.69	6.20	5.61	5.60	1.37	1.72	5.91	3.73	5.60	4.95
APR	1.58	5.46	8.40	3.24	6.39	2.06	5.52	9.07	5.20	6.30	2.25
MAY	17.53	4.14	5.84	6.98	5.80	14.20	10.46	4.78	6.53	3.85	12.25
JUNE	6.47	4.66	9.01	5.29	4.69	16.80	0.58	16.10	5.17	4.67	4.10
JULY	5.63	2.88	4.53	4.40	3.71	4.35	4.68	4.84	6.57	2.85	2.10
AUG	2.23	7.69	6.47	6.00	3.47	6.03	5.67	4.89	3.48	6.22	6.45
SEPT	10.31	9.54	7.60	5.50	11.01	3.58	7.58	7.13	8.20	9.18	7.97
OCT	5.83	8.22	7.86	8.06	6.79	12.25	10.14	14.45	6.45	8.52	7.03
NOV	3.45	7.28	0.94	4.72	3.36	5.25	8.70	4.16	5.13	3.78	4.92
DEC	1.75	0.65	2.90	3.72	5.81	2.39	4.16	0.36	3.13	1.35	5.30
TOT	63.30	63.34	63.37	55.35	67.76	76.45	62.55	76.43	55.45	56.09	60.47

	1964	1965	1966	1967	1968	1969	1970	1971	AVERAGES
JAN	3.01	1.08	2.97	1.18	2.68	4.44	6.23	3.74	2.21
FEB	0.96	0.0	0.38	1.83	3.14	1.04	1.81	2.54	2.60
MAR	0.95	2.12	1.86	6.40	3.42	1.26	1.59	5.85	3.21
APR	6.45	2.40	5.02	3.07	2.12	12.67	2.53	6.51	5.90
MAY	4.41	9.53	6.77	1.96	2.50	18.34	13.64	6.39	9.43
JUNE	5.36	2.97	25.77	7.25	8.78	17.65	5.54	1.48	7.54
JULY	3.98	2.21	3.66	4.23	4.96	3.86	9.29	2.07	5.11
AUG	5.26	3.87	0.91	1.56	8.13	8.88	7.85	8.50	7.06
SEPT	6.68	8.28	9.30	6.92	8.64	6.54	6.96	5.75	8.25
OCT	16.41	3.90	8.65	7.01	13.44	8.22	11.52	11.92	10.84
NOV	3.56	6.55	4.70	3.97	4.12	2.97	4.93	4.08	5.25
DEC	5.34	1.40	1.87	2.60	2.77	3.92	2.79	2.58	2.49
TOT	62.37	44.31	71.86	47.98	64.70	89.79	74.68	61.41	69.89

B. CATCHMENT AREA CALCULATIONS

Rainwater Catchment Unit WK 10

To determine the catchment area required for a storage of 29.2 acre ins.

Assumptions:

1. The monthly rainfall figures for the two driest consecutive years in the period 1931 - 1971 will be used. These years were 1946 - 1947.
2. The unit is designed to collect all the rain falling in these two years and to satisfy a steady demand for that water throughout the two years.
3. Evaporation is assumed to take place from the open water surface of the storage only and this is assumed to be always 10% of the total catchment area. Monthly evaporation figures are those recorded by the Alcan Agricultural Division at its Mandeville station from the American Class A Evaporation Pan during 1972.
4. It is assumed that the catchment is impervious and that because the run off distances are relatively small 100% of the rain falling on the catchment is collected.
5. The effective volume of the reservoir is approximately 660,000 imperial gallons which is taken as being 29.2 acre ins.
6. A standard mass curve type of analysis will be used to determine the catchment area required.

Analysis of rainfall catchment for the years 1946-1947

Month	Rainfall ins.	Free water evaporation ins.	Water available ins.	Cumulative water available ins.	Cumulative Demand ins.	Excess or deficiency to meet demand ins.
1946 Jan	1.19	4.90	0.70	0.70	3.74	- 3.04
Feb	2.20	5.23	1.68	2.38	7.48	- 5.10
Mar	2.20	5.86	1.61	3.99	11.22	- 7.23
Apr	5.56	7.35	4.82	8.81	14.96	- 6.15
May	1.79	6.54	1.14	9.95	18.70	- 8.75
June	1.48	6.12	0.87	10.82	22.44	- 11.62
July	2.38	6.94	1.69	12.51	26.18	- 13.67
Aug	5.50	6.54	4.85	17.36	29.92	- 12.56
Sept	7.44	5.79	6.86	24.22	33.66	- 9.44
Oct	8.24	5.15	7.72	31.94	37.40	- 5.46
Nov	3.97	5.13	3.46	35.40	41.14	- 5.74
Dec	5.10	4.00	4.70	40.10	44.88	- 4.78
1947 Jan	2.13	4.90	1.64	41.74	48.62	- 6.88
Feb	2.91	5.23	2.39	44.13	52.36	- 8.23
Mar	1.12	5.86	0.53	44.66	56.10	- 11.44
Apr	1.83	7.35	1.09	45.75	59.84	- 14.09
May	6.77	6.54	6.12	51.87	63.58	- 11.71
June	1.51	6.12	0.90	52.77	67.32	- 14.55
July	3.38	6.94	2.69	55.46	71.06	- 15.60
Aug	10.23	6.54	9.58	65.04	74.80	- 9.76
Sept	11.87	5.79	11.29	76.33	78.54	- 2.21
Oct	10.81	5.15	10.29	86.62	82.28	+ 4.34
Nov	2.08	5.13	1.57	88.19	86.02	+ 2.17
Dec	1.97	4.00	1.57	89.76	89.76	

Example: Jan 1946. Water available = Rainfall - 10% evaporation =
1.19 - 0.49 = 0.70 ins.

Storage required to satisfy
uniform demand = 15.60 + 4.34 = 19.94 ins.
But storage available = 29.2 acre ins.
Catchment required = $\frac{29.2}{19.94}$ acres = 1.46 acres

But the reservoir itself has a catchment area of 119' x 124'
= .34 acres.
An artificial catchment of 1.46 - 0.34 = 1.12 acres is required.

The steady monthly demand that can be satisfied is therefore
 $3.74 \times 1.46 \times 22,610 = 124,000$ imperial gallons

Therefore in a dry year a 660,000 gallon reservoir served by a 100% efficiency catchment area of $1\frac{1}{8}$ acres can deliver 124,000 gallons per month (approximately 4,000 gallons a day)

Area of catchment = 1.46 acres

Surface area of water in reservoir when there is 7' of water in it
 $= 88' \times 83' = 0.168$ acres

Evaporation takes place from 11.5% of the total catchment area.

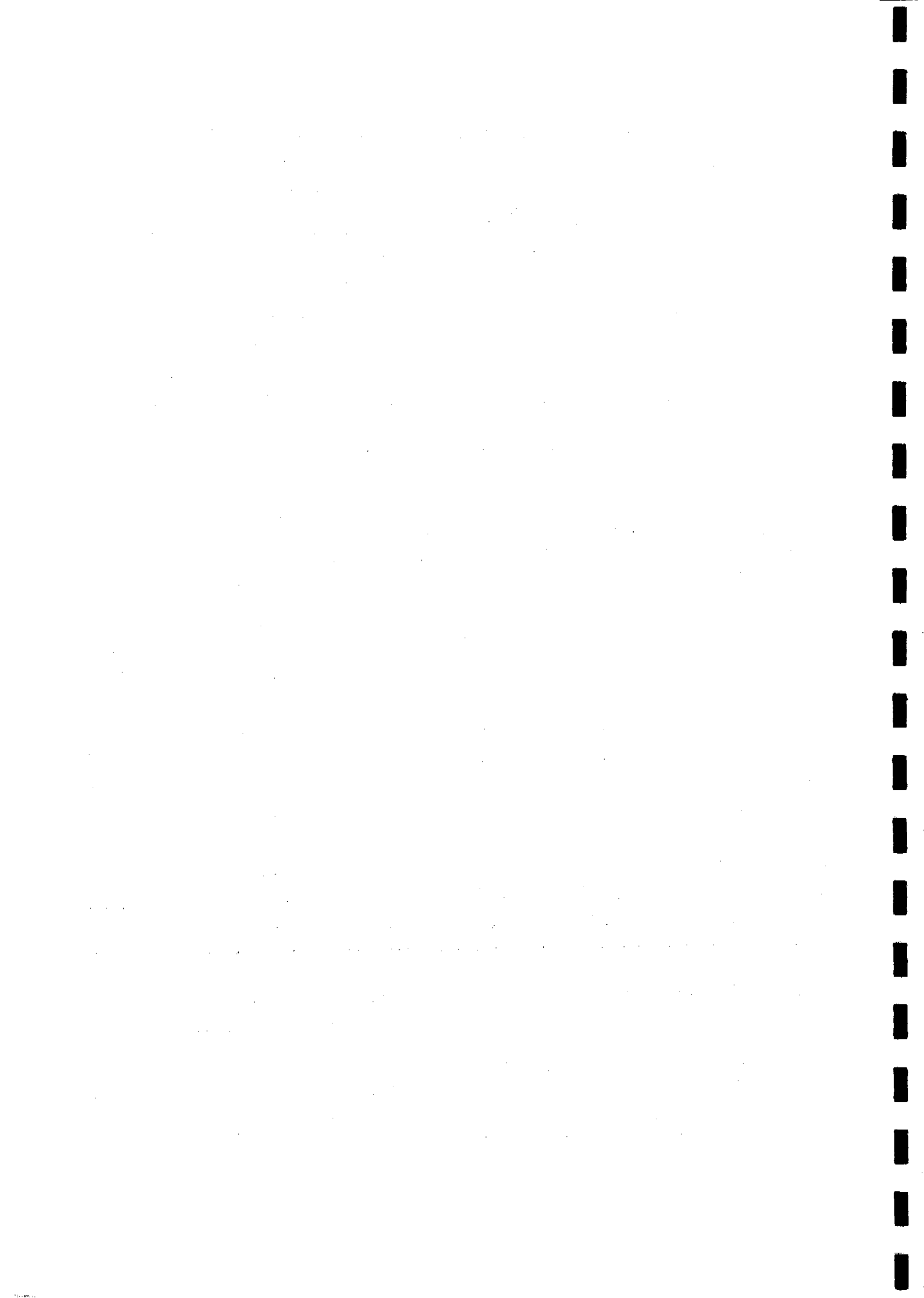
Analysis of rainfall catchment for the year 1937

Month	Rainfall	Free water evaporation	Water available	Cumulative water available	Cumulative Demand	Excess or deficiency to meet demand
	ins.	ins.	ins.	ins.	ins.	ins.
Jan	1.20	4.90	0.71	0.71	4.79	- 4.08
Feb	2.75	5.23	2.23	2.94	9.58	- 6.64
Mar	4.99	5.86	4.40	7.34	14.37	- 7.03
Apr	3.81	7.35	3.07	10.41	19.16	- <u>8.75</u>
May	10.68	6.54	10.03	20.44	23.95	- 3.51
June	5.14	6.12	4.53	24.97	28.74	- 3.77
July	4.64	6.94	3.95	28.92	33.53	- 4.61
Aug	7.45	6.54	6.80	35.72	38.32	- 2.60
Sept	4.68	5.79	4.10	39.82	43.11	- 3.29
Oct	9.38	5.15	8.86	48.68	47.90	+ 0.78
Nov	7.96	5.13	7.45	56.13	52.69	+ <u>3.44</u>
Dec	1.81	4.00	1.41	57.54	57.48	

If the catchment area is 1.46 acres a storage of $(8.75 + 3.44)$
 $1.46 \times 22,610 = 402,500$ gallons is required to ensure that the steady demand is met

But the storage is 660,000 gallons so that a demand of 4.79×1.46
 $\times 22,610 = 158,000$ gallons per month can be met

In an average year the WK 10 unit would be able to provide 158,000 gallons per month (approximately 5,000 gallons per day.)



D. EARTHWORKS CONTRACT

Contractors: Wilbros Limited
45 Dunrobin Avenue
Kingston 10.

Item No.	Quantity	Description	Unit Price
		<u>Required for:</u> Reclamation Experimental Catchment/Reservoir(WK 10) This order is to cover the cost of rental for the following units:	
1	2	Cat. 631B Tractor Scrapers for a minimum total of 140 hours @ J\$32.00/hr. (inclusive of Operator)	J\$4,480
2	2	Cat. D.8 Tractors for a minimum total of 100 hours @ J\$22.00/hr. (inclusive of Operator)	J\$2,200
3	1	Cat. 824 Tractor for a minimum of 50 hours @ J\$22.00/hr. (inclusive of Operator)	J\$1,100
4	1	WABCO 777 Motor Grader for a minimum of 50 hours @ J\$14.00/hr (inclusive of Operator)	J\$ 700
5	1	Vibratory Roller @ J\$6.00/hr (inclusive of Operator) for a minimum of 50 hrs.	J\$ 300
6	1	Front End Loader @ J\$34.00/hr (inclusive of Operator) for a minimum of 70 hours (If needed on the Job)	J\$2,380

Operations will be based on a (10) ten hour day.

Supervision must be provided by the Contractor on a daily basis

Ten percent (10%) of the total equipment charge will be paid to the Contractor for supervision.

Work will be carried out on a seven day (7) week basis.

There is no charge to Alcan for transportation of equipment.

Final Payment will be on actual machine hours worked.

There must be a daily agreement between Alcan's Mr. G. A. Barnett and the Contractor's representative on the number of machine hours worked.

Records must be kept of daily machine hours worked.

Work must be done in accordance with Alcan's survey specifications.

All equipment repairs are the responsibility of the Contractor.

Alcan will supply fuel and lubricants.

The Contractor must pay "Bauxite Rates" to his Operators.

The Contractor must equip his operators with Safety Equipment to Alcan's standard.

The Contractor must obtain passes for his Operators from Alcan's Personnel Department before the work commences and is responsible for their return at the completion of the Contract.

Work to commence 2/1/73.

E. CONSTRUCTION DETAILS

WK 10 Unit

Work began on January 2nd 1973. Although nominally Alcan's Mining Department was in charge of the earthmoving contract the Project Engineer acted as Resident Engineer referring necessary problems to Mr. Brown and Mr. Barnett of the Mining Department. The contractor had one Supervisor, Mr. Peter Rogers, on site throughout the contract. All the survey control for the construction of the unit was provided by Mr. D. Neita, a surveyor from the Alcan Property Department. The topographical surveys of the WK 10 site were carried out using a plane table with a combined tachometer and alidade. This system of survey was used throughout the contract with the final check on the reservoir being by engineers level and tape. It is in the nature of a job using heavy earthmoving equipment that survey guides are frequently destroyed and need replacing. It is not practical to have a surveyor standing by on such a job all the time and it is felt that it would be better for the responsibility for survey control to rest with the contractor. In the case of Wilbros the supervisor could have carried out the function of surveyor and with suitable increase to the supervision fee this would probably have been a more satisfactory arrangement. Alcan employed a timekeeper who was on site throughout the contract and who agreed with the Wilbros supervisor the hours worked by each machine each day.

The first machines on site were the Caterpillar D8 tractors fitted with heavy duty rippers. Their first job was to clear the floor of the reservoir of loose bauxitic material that had been washed down from the catchment slopes. Undisturbed bauxite was revealed and then bauxite fill was compacted back where needed to bring the floor of the reservoir to its design level. Very little fill was required. The bulk of the work for the D8 tractors then became the cutting of the upper section of the southern catchment area and the fill of the lower section. While the D8's concentrated on this work the two galvanised steel pipes for the 3 in. delivery and 4 in. washout were laid in their correct positions in the bottom of the reservoir and extended until they cleared the northern toe of the proposed northern embankment. The pipes were in 20 ft. sections and each section had a 2 ft. square seepage collar of sheet steel welded on to it. The heads of the pipes, where the reservoir liner would be secured to the pipes, were set in concrete. The heads of the pipes consisted of flanges of the appropriate diameter with the securing bolts for the top plates welded into them. The faces of the flanges were machined flat. Once the outlet pipes had been laid the contractor started to build up the eastern and northern embankments to the reservoir. The bauxite was taken from the lower part of the WK 10 pit and was mined by a D8 tractor push loading Caterpillar 631B Scraper. The scrapers dropped their loads where required and the Caterpillar 824 Tractor (an articulated vehicle with four rubber tyred wheels and a blade) spread and compacted the load in thin layers. The following scraper passed over this layer still carrying its load before repeating the same process. In this way adequate compaction of the embankments was achieved.

The southern face of the reservoir was built up with bauxite before the southern catchment was completed. In this way it was possible to keep to a minimum loose limestone that was pushed into the reservoir area. The whole of the top of the southern catchment area had to be ripped before the limestone was sufficiently broken for the D8's to push it with their blades. Although this was a time consuming operation the limestone remained soft enough to be dealt with by the rippers alone. In this way the 12 ft. depth of cut was achieved. More material was cut than was required for fill and this material was used to form a road and a turning space on the south west side of the site. The scrapers alone were able to prepare the western catchment by stripping the top soil. Once the catchment slopes had been formed the scrapers began to spread bauxite on the catchment surfaces. On the 1 in 3.75 slope of the southern catchment the scrapers could only spread their loads while travelling down the slope. The 824 spread the bauxite to achieve an 8 in. layer of compacted bauxite. The 824 towed a grid roller to aid in the compaction. The grid roller had been brought on site to replace a small and ineffectual vibratory roller that had repeated mechanical problems and could only operate on level surfaces. The method of construction of the reservoir embankments was to build up the embankments with the toe of the inside slopes in the correct position. Bauxite naturally stands at approximately a 1 in 1.5 slope and so when the embankment had reached its full height a D8 tractor back bladed the inside slope down to the designed 1 in 2 slope. This operation should be carried out under strict survey control to ensure that the machine does not overcut the slope. The material dragged to the bottom of the reservoir was then pushed out of the reservoir at the south east corner by either the 824 or the D8. Final compaction of the inside faces of the reservoir was achieved by the 824 and the grid roller. The 824 could reverse push the roller up the 1 in 2 slope from the bottom of the reservoir. It could also allow the grid roller to begin to roll down the slope from the top but only so far that the 824 could still get wheel grip to pull it clear again. A similar procedure to that outlined above was used on the outside slopes of the embankment. Because of the longer slopes compaction up and down the slope was achieved by using only the D8 tracking up and down.

The continuous working from January 2nd was interrupted by heavy rain on January 19th. The rain caused considerable erosion of the bauxite blanket on the lower catchment areas particularly where flow was concentrated down the meeting of the southern and western catchment slopes. There was heavy erosion of the southern and western inlet faces of the reservoir particularly in the south west corner. All the silt, up to 1 ft. 6 in. deep in the south west corner, was collected in the bottom of the reservoir as well as approximately 2 ft. of water. Light rain on a compacted bauxite slope makes the surface extremely slippery and treacherous and in trying to get the 824 off the catchment area at the beginning of the rain the operator lost traction and the weight of the grid roller pulled the machine down the length of the slope to come to rest beside the reservoir. It is felt that no matter what precautions are taken there is always the possibility of flood damage of this type once the reservoir has been completed. The cost of providing temporary drainage would not, in most cases, be justified.

The bung in the 4 in. pipe was pulled and most of the water and slurry drained out of the reservoir. No work was done to repair the damage until January 25th. The 824 then pushed dry bauxite material into the reservoir where a D8 mixed the dry material and mud together and began to push it out of the south east corner of the reservoir. For a period the two D8's worked together one pushing the other out until most of the loose material had been removed. A WABCO 777 Motor Grader then finally graded the catchment areas after the 824 and a scraper had spread and compacted bauxite in the damaged areas. The grader was able to travel across the 1 in 3.75 slope of the southern catchment with the blade extended downhill of the machine to provide greater stability. The 824 and grid roller were able to repair most of the damage to the inlet faces of the reservoir. Finally a D8 ripped anchorage trenches for the rubber liner around the western, northern and eastern sides of the reservoir. The grader ripped a number of shallow trenches across the face of the southern catchment to assist in digging the trenches for the aluminium anchorage pieces. A D8 cut a drainage channel all around the catchment area. This channel was to collect storm run off from the surrounding areas and to conduct it away from the WK 10 catchments and reservoir. The earthworks contract was accepted as completed satisfactorily on the 26th January.

It can be seen from the Earthworks Progress Chart (at C, this Appendix) that of the machines brought on to site the scrapers and the roller were used for less than the minimum hours contracted for. However the D8's worked 226 hours as opposed to the 100 hours estimated and the 824 worked 89 hours instead of the 50 estimated. The grading of the completed catchment areas was extremely simple and is reflected by the fact that the grader spent only 11½ hours working. The Front End Loader was not required for loading bauxite because it proved possible to push load the scrapers with the D8's, explaining in part why the D8's worked so many hours. Except for two or three scraper loads of bauxite, which were taken from the farther pit after the WK 10 pit had become waterlogged, all the bauxite used on the site was mined from the lower section of the WK 10 pit. This reduced considerably the time spent on hauling bauxite. In contrast nearly half of the catchment area was prepared from limestone rock requiring the breaking up and moving of approximately 5,000 cu yds of limestone in places 12 ft. deep.

By studying the daily diary of work and the progress chart it has been estimated that the following time was spent on catchment and reservoir construction.

<u>Machine</u>	<u>% time on catchment</u>	<u>% time on reservoir</u>	<u>Total hours worked</u>
D8	75	25	226
631B	60	40	119
824	40	60	89
Roller	25	75	26
Grader	100		12

Although a depression already existed and was utilised as the site of the reservoir for the WK 10 unit this is not seen as a great saving on contract time or cost. Different machinery would have been required had the construction of the reservoir required an excavation of 16 ft. in bauxite but the excavated material might have been used on the catchment areas. Each site will make different demands but at WK 10 a large percentage of the time was devoted to working on the limestone on the southern catchment and a substantial embankment was built as the northern wall of the reservoir. Situations at other sites might well balance out these factors. The one peculiar asset of the WK 10 unit was that nearly all the bauxite required for the unit was found at the site of the unit. This is unlikely always to be the case.

The labour force started work on the site on the 26th January. The work was completed on March 5th and throughout this period the labour force worked six days a week. Although the number of men working varied from day to day an average of about 15 men worked each week day with less on Saturdays. The men were drawn from the pool of agricultural labourers that are employed on a daily basis by the Alcan Agricultural Division. None of these men had experience of a construction project of this type. For most of the time a headman also worked with the gang.

The supervision of the work was shared by the Project Engineer and Mr. Gladstone Morgan. One or other of these supervisors was on site throughout the work. If a second unit were to be built the site supervision should be carried out by a competent foreman, with occasional site visits from the engineer in charge.

The work concentrated on preparing the reservoir to receive the butyl rubber lining so that further flood damage to the reservoir could be avoided. This work consisted of digging the liner anchorage trenches round the four sides of the reservoir, digging the spillway across the northern embankment, digging and pouring the concrete energy absorber and preparing the reservoir surface to receive the liner. The liner anchorage trenches on the south and west sides were the first to be dug, in part to provide protection against any further rain. The 2 ft. wide shelves to support the rip rap on the south and west sides of the reservoir were then dug. Work was started on digging the concrete energy absorber but on 30th January a second heavy rain storm caused some erosion of the lower catchment areas and the southern inlet face of the reservoir. A quantity of silt was again washed into the south west corner of the reservoir and 6 in. of water covered the reservoir floor. The liner anchorage trench on the south side was filled with silt. The following day work was concentrated on clearing the liner anchorage trenches and completing the excavation for the energy absorber. The concrete was poured to form the 6 in. slab on the same day. Work then concentrated on removing all the water from the floor of the reservoir. In the absence of a satisfactory sludge pump this was done by hand with buckets being passed up and down a line of men. The reservoir surfaces as left by Wilbros were well compacted but contained a number of small limestone rocks protruding through the surface. All of these rocks were removed by hand as well as the more irregular lumps of hard bauxite. On the 2nd February a Caterpillar 955 tractor (a medium size, tracked vehicle with a front bucket) was hired from a local

contractor and cleared out all the silt from the reservoir. Some of the silt had to be shovelled into the 955's bucket before it could be removed. The 955 then dropped several loads of bauxite on the southern inlet face where it was spread and compacted as well as was possible to repair the erosion damage. A final inspection was made of the reservoir surfaces before it was decided that the liner could be laid. One hundred jute sacks were each filled with approximately 50 lbs. of bauxite and their mouths tied with wire. These weights were then spread around the four sides of the reservoir ready to act as temporary weights on the liner. The bolts on the two outlet pipes in the floor of the reservoir were bound with cloth to prevent them from damaging the liner.

The liner was provided as a single rectangular sheet 140 ft. x 145 ft. The liner had been concertina folded across the 140 ft. width into a 7 ft. wide by 145 ft. long strip. The strip had then been rolled up around a hollow tube so that the resulting roll fitted into a wooden packing case approximately 7 x 4 x 4 ft. The weight of the roll was approximately 2 tons. The crate was transported to the WK 10 site on a trailer and was unpacked on the 2nd February. A lifting bar was passed through the central core of the roll and steel lifting ropes were slung from the ends of the lifting bar to the outer teeth of the 955's bucket. A wooden spreader bar with notched ends was then placed above the roll between the lifting cables to keep them from rubbing against the rubber as it was transported. The 955 then lifted the roll and travelled with it to the eastern side of the reservoir. A side-man walked with the machine to steady the roll. The liner was unrolled along the eastern side of the reservoir by the 955. The lower of the 145 ft. long edges was then anchored down with the weights. 17 men then spread out across the width of the liner and lifting several of the folds of the liner began to drag the remaining folds of the liner down the eastern face of the reservoir. Once the liner began to pull out, the weight of the material assisted in this operation. Once the liner had reached the bottom of the reservoir the folded section carried down that far was pulled out to extend almost to the middle of the reservoir. More men were concentrated on the southern and northern slopes of the reservoir to prevent the liner from pulling itself down into the bottom of the reservoir. The laying crew then walked over the liner already pulled out, selected a line on which to pull and pulled down more of the liner from the eastern side. This pleat was then moved across the floor of the reservoir. This operation was repeated until only a single sheet of butyl rubber lay down the eastern face and across the floor of the reservoir with sufficient liner accumulated at the foot of the western reservoir slope for it to be pulled up to the anchorage trench at the top of that slope. Throughout the operation as the liner reached its final position the weights were placed in the anchorage trenches to secure it there. The lining was completed by dragging the liner up the western slope and securing it in the anchorage trenches with the weights. The complete operation of pulling out the liner from the eastern side of the reservoir took less than 2 hours. The liner was designed to have some slack in it and before the anchorage trenches were backfilled the larger part of this slack was moved on to the side slopes of the reservoir to relieve the tension on the liner in these areas. The four corners of the liner were then tidied up by pleating the excess liner under itself. The holes for the outlet pipes were then cut through the

liner and the binding removed from the bolts. Holes were then cut to allow the bolts to pass through the liner and using a rubber gasket above and below the liner the top plates were bolted into position. A rubber compound was spread around the gaskets and bolts to ensure a watertight connection. The 3 in. outlet pipe has a 6 in. upstand with a metal filter cap and the 4 in. washout pipe has a hinged lid on it. This lid was attached to a galvanised steel wire which was carried to the side of the reservoir so that when required the flap can be pulled open. About four small tears were found in the liner, all of them being above water level. These tears were easily repaired using the adhesive, uncured butyl rubber strip and a patch of butyl rubber as recommended and supplied by the fabricator. The reservoir was completed by backfilling the anchorage trenches with bauxite and compacting it. Limestone rocks collected from the areas surrounding the WK 10 site were placed on the 2 ft. wide shelf on the southern side of the reservoir. The overflow liner, a 13 ft. 6 in. wide strip of butyl rubber 100 ft. long was jointed to the reservoir liner using the adhesive and uncured butyl rubber as recommended by the fabricator. The joint was easily made although some difficulty was experienced in stripping the protective polythene backing from the uncured butyl rubber. This operation is probably best carried out in the cooler temperature of early morning. On this evidence field jointing is not difficult but requires some skill and patience. As with all materials jointed in this manner a long joint between two sheets requires the careful positioning of the two sheets for a successful joint to be made.

An analysis of the labour and machinery used at the WK 10 site was carried out and it is estimated that approximately 1,200 man hours were involved in laying the outlet pipes, preparing the reservoir to receive the liner including the construction of the concrete energy absorber, laying the liners for both the reservoir and spillway and collecting and placing the limestone rip rap on the reservoir and spillway. A tractor and trailer was required for approximately 50 hours and the Cat 955 worked for 6 hours.

Once the reservoir had been completed work was concentrated on laying the aluminium sheet on the southern catchment area. The trenches ripped by the grader were cleared using specially cut down 4 in. wide spades. The bauxite blanket was very hard and the trenches had to be deepened by pick before they could be cleared to the required dimensions. It was a simple operation to lay the aluminium anchorage section in the trench and backfill it. Care had to be taken to ensure that the top surface of the aluminium section remained flush with the bauxite surface. It is impossible to cut a square edged trench in such hard and friable material and it was necessary to push material back under the top surface of the aluminium section to ensure that this surface was firm and would not move away from the screws being screwed into it from the sheets above. It is also impossible to dig a straight trench with a vertical side over a long distance. As far as the anchorage sections were concerned this did not matter as it was possible to feel and see where the section was as the catchment sheets were being laid. However it did cause problems on the side

anchorage trenches. Drawing 104 * shows the ideal arrangement of the aluminium anchorage section. However when the catchment sheet extends over the anchorage trench the aluminium anchorage piece has no support behind its vertical side. Once the anchorage piece has been screwed to the catchment sheet and the anchorage piece is backfilled there is a tendency for the anchorage piece to be forced under the catchment sheet. This results in the catchment sheet being slightly buckled and lifting off the ground surface. This problem has been encountered and the anchorage pieces were dug out, what material that could be was forced behind them and then they were carefully backfilled. So far the problem is not serious but anything that causes the catchment sheet to lift off the ground is a potential source of trouble. This phenomenon generally causes the end joints between sheets to open and provides a channel for wind to get under the sheets. In any future installations of this type an alternative edge anchorage detail may be worthwhile.

The catchment sheets were laid from east to west so that the lap is open on the eastern side of each ridge joint. Had there been any evidence that the prevailing wind was in this direction it would have been preferable to lay the sheets from west to east so that the open side was in the lee of the prevailing wind. However there was no such evidence for the WK 10 site.

The sheets which are 0.015 in. thick are joined by self tapping alloy screws fitted with neoprene washers. Each sheet is 12 ft. 5 in. long and 3 ft. 3 in. from the centre of the edge ridges. Based on the experience of the trial catchment using these same materials three screws were evenly spaced across the width of each sheet on the lap joint. Three screws were also used along the length of the ridge of each sheet. Holes were made for the screws through all the sheets to be joined (maximum of three layers on the ridge at a lap joint). The sheet is very soft and any lateral movement of the tool being used to make the holes causes the holes to be elongated. The use of a hand drill and bit was rejected early on in favour of an ice pick. The holes could be made more quickly with the ice pick and it was reasonably easy to push it in and pull it out in the same line. It was found that a stop on the pick which only allowed about 1 in. of the pick to be pushed through the sheet resulted in the most satisfactory hole.

Since the catchment has been completed it has been observed that occasionally wind will get under the sheets and cause a ripple to cross the catchment. It is just possible to see the ripple cross the catchment but it is more easily heard. It has also been found that a number of screws have loosened themselves. Neither of these phenomena have been observed on the very much smaller trial catchment. It is felt that the loose screws were the result of overlarge holes and all these screws have been replaced. It was also felt that the whole catchment would benefit

* Drawings 100 to 106 are held at the Water Resources Division of the Ministry of Mining and Natural Resources, Kingston.

by the use of more screws especially on the ridge joints and these have now been added. Alprojam have informed us that on standard roofing they recommend that screws are placed at 2 - 3ft. centres along the ridges.

It remains to be seen whether the 24 ft. spacing of the aluminium anchorage pieces under the catchment is adequate to resist very high winds. In July 1973 there are no indications that the spacing is inadequate. However during construction it was observed that if wind gets under an area of sheet which lifts then the screws in the thin aluminium sheet are torn out with little resistance. Improved anchorage details nearly all require more expensive fixings and at some point it must be considered whether it is preferable to spend money now to minimise the chance of damage in high winds or to make what provisions one can now and accept that later there may be a repair cost.

All the men who worked on the aluminium sheet were provided with dark glasses to give some protection from the glare of the sun.

The catchment surface as left by the earthworks contractor was in general satisfactory for the laying of the aluminium sheet. However several men worked ahead of the crew laying the aluminium sheet preparing the bauxite surface. This involved removing any sharp projections and filling any rills and gullies formed during the rain storms. It also involved spraying the surface with a herbicide, Prefix, to prevent the growth of any plants under the catchment. Sufficient care to ensure that the catchment slope was maintained right to the edge of the reservoir was not taken with the result that there was a transition between the catchment slope and the reservoir side slope over the liner anchorage trench on the southern side. This had to be accommodated by bending the lowest sheets in the catchment and while technically the only drawback is that the ridge joints between the bent sheets are opened out the effect is not aesthetically pleasing. In very heavy rains it is reported that some run off is lost through these openings but the water must still find its way into the reservoir because the openings are over the reservoir liner. In any future installations this detail should not be overlooked and time should be spent to ensure that the design is followed.

A programme of monthly inspections has been instituted to monitor all the aspects of the aluminium sheet catchment noted above as well as the performance of the other catchments and reservoir.

Just over 1,000 aluminium sheets were laid and it is estimated that all the work of digging and burying the flashings and then laying the sheets took approximately 1,100 man hours. A tractor and trailer was required for approximately 10 hours.

Before either the aluminium foil or the polyethylene covered with limestone chips could be laid the 10 in. pipe and the concrete headworks had to be installed. The ditch and mound that separate the foil and the polyethylene catchments were dug and the excavation for the concrete headworks completed. The 10 in. diameter steel pipe was fabricated in Mandeville by Mr. A. Francis

who also fabricated the outlet pipes for the reservoir. It was delivered by truck to the WK 10 site and lifted into position. The formwork for the concrete headworks was erected around the pipe and the concrete poured on 9th February. The headworks were rendered so that the foil and polyethylene could be laid across a smooth surface. It is estimated that this installation required 78 man hours in addition to the 32 hours which the mason worked.

On the 14th and 15th February more rain fell at the WK 10 site and about 6 in. of water was collected in the reservoir. A small amount of silt collected in the south west corner. On the 16th February work began on laying the black polyethylene sheet. The catchment area was surrounded by well rounded berms and all the loose material on the catchment was swept off. All the sharp stones and pieces of bauxite were removed and the hollows filled in with bauxite. The area to be covered with polyethylene was then sprayed with Prefix to prevent growth of plants below the catchment. The 25 ft. wide rolls of polyethylene came in 100 ft. long rolls. The material was 0.010 in. thick. The polyethylene was laid out on the catchment surface and temporarily weighted down with the rubber tyres supplied by Goodyear for the aluminium foil catchment. Where necessary the sheets of polyethylene were joined together using the mastic tape and pipewrap tape recommended and supplied by the manufacturer. It was found that the best way to distribute the $\frac{1}{2}$ - $\frac{3}{4}$ in. limestone aggregate over the polyethylene was to drop a load of aggregate from a tractor with a tipping trailer on to the top edge of the polyethylene sheet. This could be accomplished without the tractor or trailer driving on the polyethylene. The piles of aggregate were then shovelled over the 25 ft. width of the polyethylene so that a layer of aggregate about 1 in. thick completely covered the polyethylene. The polyethylene was strong enough not to be punctured by men walking directly on it or on top of the aggregate. The occasional accidental tear was repaired using the pipewrap tape. As the aggregate covered the polyethylene the rubber tyres were removed.

The lowest sheet of polyethylene extended down on to the 2 ft wide shelf of the reservoir. It was then anchored there with rip rap of limestone blocks collected from the area surrounding the WK 10 unit. This rip rap supported the limestone chips and prevented them from being washed down the catchment. Each succeeding sheet of polyethylene up the slope overlapped the lower sheet by 6 in. The polyethylene was carried over the berms to be buried on the western and northern sides and to provide a lining to the drainage ditch on the southern side. The top 20 ft. width of the polyethylene catchment was lined with 0.006 in. thick black polyethylene supplied in 5 ft. widths by Metal Box Jamaica Limited. In the confined space at the top of the catchment the aggregate was spread using wheelbarrows in place of the tractor and trailer. The operation was simple and was quickly carried out. It is estimated that to cover an area of approximately 1,800 sq. yds. 464 man hours were required with 32 hours use of a tractor and trailer.

On the 19th February a grader spent half an hour on the south west catchment area to repair the damage done by the rain. On the 21st February a start was made on laying the aluminium foil catchment area. Work was started at the headworks of the

10 in. diameter pipe and the foil was laid in strips perpendicular to the line where the two catchment slopes met. The foil was stuck to the concrete headworks using a black plastic cement developed for roofing work. Each successive strip of aluminium foil overlapped the lower strip by 3 in. The men laying the foil were given 3 in. guides and the wooden spatulas for spreading the black plastic compound were just under 3 in. wide. Each strip was laid, then its top edge would be coated with a band of black cement and the next strip rolled out and pushed down to form the joint. As work progressed a continual check was made on all the joints in the aluminium foil and where required more cement was applied. Until the cement begins to dry out it is necessary to keep on checking the joints to ensure that they are not lifting. As the work proceeded the used rubber tyres were spread on top of the foil to prevent it lifting. These tyres had sections cut out of the lower wall of the tyre to allow any water collecting inside the tyre to drain out. It is extremely important to keep the weights well up behind the laying crew and to weight down each new strip as it is laid. On the northern edge of the foil catchment the foil was run through the drainage ditch and over the berm on top of the polyethylene. It was secured by burying it under the limestone chips. On the eastern side the foil was stuck to the top of the aluminium anchorage piece and a piece of split $\frac{1}{2}$ in. in diameter PVC hose was clamped over the edge to further secure the foil. Similar catchment preparation was carried out as for the polyethylene catchment and the area was sprayed with Prefix to prevent plant growth beneath the catchment. It was found that any small object left under the foil tended to tear the foil if it was walked on. Drawing 105 shows the arrangement of the aluminium strips adopted to cover the catchment area. On free edges the foil was carried over the edge berm and buried. The aluminium foil comes in a roll 200 ft. long by $31\frac{1}{2}$ in. wide and is only 0.08 mm thick (0.003 in.). It is heavily embossed. The men working on the aluminium foil were provided with dark glasses to provide some protection from the glare of the sun. It is estimated that to lay 2,400 square yards of foil (approximately 49 rolls of foil) 675 man hours were required and a tractor and trailer were required for 2 hours to transport the foil and cement to the WK 10 site.

In June 1973 the wind got under one of the joints in the aluminium foil catchment and lifted an area measuring approximately 50 ft. x 15 ft. The tyres offered little resistance to a section of the membrane of this size. As soon as this was discovered the foil, which had lifted as a flap, was replaced and the section was repaired using new pieces of aluminium foil where necessary.

Apart from this occasion the foil catchment has appeared stable but it has been observed on the trial catchment area that the joints between the sheets are prone to lifting. The tyres weighting down the foil do not bind the foil to the underlying soil and are only effective as long as no wind can get under the sheet. From these short term observations it would appear that the black plastic cement has a relatively short life as an effective sealant between the aluminium foil sheets.

In July 1973 Alcan were considering the possibility of replacing the whole of the foil catchment area with aluminium sheet, using an aluminium gutter or a narrow strip of butyl rubber along the line where the southern and western catchment slopes meet.

The valves were fitted to the 3 in. and 4 in. pipes on the 1st March and the unit became operational on the 5th March when the valves were locked off. All the work on the catchment areas was completed on 3rd March. Thereafter it was left to one or two men to complete the reservoir spillway and to place the additional screws in the aluminium sheet. A grader was used to trim up the drainage channel surrounding the catchments and a D8 and an 824 tidied up the areas immediately surrounding the unit. Two men erected a fence consisting of 6 ft. high fence posts at 6 ft. intervals with 5 strands of barbed wire and 4 ft. of hog wire around the whole of the unit. A metal gate allows access at the west side of the unit and to the northern embankment of the reservoir. Grass is to be planted on the outer slopes of the northern and eastern reservoir embankments to reduce erosion and it is hoped that grass planted on areas surrounding the WK 10 unit will reduce storm water run off.

Some aspects of the construction of the WK 10 unit are shown in the Photographs section of this report.

APPENDIX 5

CONSTRUCTION COSTS FOR THE WK 10 UNIT

<u>Item</u>	<u>£</u>
1. 5 acres of land @ £100 per acre	500.00
2. Earthworks. Shaping of catchment areas and reservoir, lining catchment areas with bauxite and cutting protective drainage ditch around site, including supervision	13,651.00
3. Survey control	1,400.00
4. Timekeepers pay @ £5.00/day	85.00
5. Galvanised 3" and 4" pipes 120' long fitted with seepage collars and including lock off valves	703.00
6. Cleaning out of reservoir and transport of butyl rubber liner on site 2nd February 1973 by Cat. 955	72.00
7. Concrete for energy absorber (approx. 5 cu.yds.)	35.00
8. Butyl rubber liner for reservoir and spillway jointing materials and repair kit 8.8.72 FOB London £1,757.08	3,514.16
9. Shipping, wharfeage and transport to Shooters Hill, Manchester, of the liner	430.06
10. 10" diameter pipe 27' long. Supply, fabrication and delivery	329.00
11. Concrete for headworks to 10" diameter pipe (approx. 5 cu.yds.)	34.00
12. Aluminium sheet. 1005 sheets 12'5" x 3'3" 0.015" thick @ £4.47 including 10% discount per sheet	4,043.12
13. Aluminium anchorage pieces 286 pieces 10' long including 10% discount	373.23
14. Alloy screws. 10,000	252.00
15. Aluminium foil. 0.08 mm. thick. 49 rolls 200' x 31½" @ £26.00 per roll, including 15% discount	1,082.90

16.	Black plastic cement. 1050 lbs.	220.00
17.	Transport of 600 used tyres to WK lo site from Jamaica	160.00
18.	Polyethylene sheet. 6 rolls 200' x 25' 0.010" thick supplied from England with jointing materials.	292.29
19.	Polyethylene sheet. 2 rolls 260' x 5' 0.006" thick supplied by Metal Box Co. Jamaica Limited	36.08
20.	Limestone aggregate. 90 cu. yds.	360.00
21.	Daily labour. Approximately 450 man days, @ \$2.00 per day.	950.00
22.	Masons pay @ \$4.00 per day	48.00
23.	Tractor and trailer @ \$2.00 per hour	106.00
24.	Grader. $\frac{1}{2}$ hour 19.2.73	7.00
25.	100 jute sacks	10.00
26.	Prefix. 22 lbs. (applied at 12 lb/acre)	66.00
27.	12 pairs of safety glasses	36.00
28.	$\frac{1}{4}$ " galvanised steel rope 50' long	14.40
29.	Tools	162.69
30.	Sundry materials	5.00
31.	Site hut. Materials and labour ³	82.00
32.	Watchman. Special Constable from 29.1.73 to 10.3.73 for 16 hours/day @ 90¢ per hour	597.60
33.	Fencing. Materials and labour	438.24
34.	Landscaping 824, D8 and Grader	100.00
		<hr/> <u>\$30,195.48</u>

APPENDIX 6 - CONSTRUCTION DETAILS AND
COSTS FOR THE 10,000 GALLON TANK

Constructed at Cross Keys Health Centre, Manchester

The galvanised steel grain bin delivered by Read aims to be air and rat tight when erected. The brackets supplied for fixing the roof to the top ring of the tank did not therefore allow any room for the PVC liner and its two anchorage pipes to pass over the top edge of the ring. The brackets were redesigned by the Project Engineer and were fabricated to drawings supplied by Mr. V. Chin of Kingston. It did not prove possible to get these brackets galvanised before they were required but they were given two coats of zinc chromate, red oxide metal primer. The top ring of the tank had to be redrilled to receive the fixings for the new brackets and two holes were cut near to the top edge to accommodate a PVC overflow pipe.

Work began on excavating the foundation for the tank on May 28th. White limestone was encountered in one corner of the excavation but the remaining area was undisturbed bauxite. The base was made 18 ft. diameter to provide a 2 ft. working space around the steel tank. The reinforced concrete base was poured on June 4th and four holding down bolts as well as the two outlet pipes were cast into the base. On June 6th the bottom 16 gauge ring of the galvanised steel tank was erected and bolted down. A 2 in. screed tapering down to the outlet pipes was laid inside the ring to provide a smooth base for the PVC liner. The following day the remaining 3 rings of 18 gauge galvanised steel were erected to complete the walls of the tank. Two aluminium step ladders and a 14 ft. length of aluminium ladder were used in this operation. On the 12th June the bolts to secure the roof brackets to the top ring of the tank wall were fixed. Plastic pipe wrap tape was then placed over the domed bolt heads on the inside of the tank. The first liner anchorage pipe, a 7/16 in. I.D. garden hose split down one side, was then fixed around the top edge of the tank wall being tied at intervals with fine gauge wire, and the liner was lowered into the tank. Two men wearing soft soled shoes opened out the liner and spread it over the base of the tank. The holes for the outlet pipes were cut and the top plates bolted down with two rubber gaskets to make a watertight joint. The walls of the PVC liner were then raised up the side of the tank and held temporarily by three men at equal intervals around the tank. A fourth man then fixed the second of the plastic anchorage pipes over the PVC liner to secure it at the top edge of the tank. Once the liner was installed the bottom of the tank was covered with a layer of jute sacks and a further layer of opened out cardboard boxes. A scaffold platform was then erected inside the tank to give a working platform of 2 ft. below the top of the tank walls. All the scaffold poles were 10 ft. long or less so that they could be easily removed once the roof was completed. While the scaffolding was being erected the liner on the outside of the tank was pushed over the bolts for securing the roof brackets and then the roof brackets were bolted on. The following day the roof was erected on the tank. Read suggest

that the centre ring is supported a measured distance above the base of the tank before the roof sections are bolted on. It was found that only by bolting up roof sections symmetrically placed around the tank could the sections be made to fit. The following day a small tear in the liner which had been made while lowering the liner into the tank was repaired using an adhesive supplied by Stephens Plastics and a patch of PVC. The tear is about 4 in. from the top of the tank and should remain above the top water level. The rest of the liner was inspected for damage and then the scaffold was taken down and removed through the hatches in the roof. The sacks and cardboard were removed and the inside of the tank cleaned up. A 14 ft. ladder, whose feet had been wrapped in several layers of sacks, was then lowered into the hatch and the men in the tank climbed out through the central hatch.

The excavation of approximately 17 cu. yds. was completed in 5 man days. 6 men mixed and poured the concrete for the base in one day. 3 men erected the bottom ring in approximately 2 hours and care was taken to ensure that this ring was a good 14 ft. diameter circle. A mason and his mate mixed and laid the screed in half a day. 3 men with occasional help from the Project Engineer erected the three remaining rings of the tank walls in one day. In one day 3 men with the Project Engineer installed the tank liner, erected the scaffold inside the tank and bolted on the roof brackets. The same four men took one day to complete the bolting up of the roof, and a further half a day to remove everything from inside the tank and leave it ready to collect water. Thus the tank was erected in $4\frac{1}{2}$ working days by a crew of four men.

The West Indies College fabricates its own Cornish guttering and pipes from galvanised steel sheets in approximately 6 ft. lengths. The guttering is soldered together on site and nailed to the weather board and rafters of the roof. The gutters on the higher roof were specified as $6\frac{1}{2}$ in. Cornish gutters and that on the lower roof as 8 in. Cornish gutters. All the pipes connecting the gutters and the storage tank were 4 in. diameter. All the necessary drops and bends were precut and soldered on site. Two men jointed and fixed 90 ft. of guttering and approximately 40 ft. of pipe in three days.

Two galvanised steel outlet pipes were built into the base of the storage tank. A 2 in. diameter washout pipe leads towards the soakaway of the septic tank serving the Centre and is plugged. The $1\frac{1}{2}$ in. diameter outlet pipe has a 3 in. upstand inside the tank fitted with a metal filter. A small electrically powered self priming pump was installed inside the Centre. Approximately 80 ft. of 1 in. diameter PVC pipe was installed as the suction line to the pump. The pipe has a lock off valve at the tank and immediately behind this a non-return valve. The lock off will enable servicing to be carried out on the pipeline without losing water from the tank and the non-return valve keeps the suction line flooded. The lift from the storage tank to pump is approximately 5 ft. A 1 in. diameter buried PVC pipe 60 ft. long delivers water to the base of the overhead tank where the water is pumped up a 1 in. diameter galvanised steel pipe to the top of the overhead tank. A 1 in. diameter galvanised steel pipe

runs from the bottom of the tank to ground level where a further 45 ft. of 1 in. diameter PVC pipe leads the water back into the existing supply line from the public rainwater catchment tank. A T-junction was used to join the two pipes and both supply lines are fitted with lock off valves at this point. The PVC pipe was supplied in 20 ft. lengths and jointed on site with PVC sleeves and adhesive. The trenches were dug for the pipes and the plumber and his mate installed all the pipes and the pump in one day.

Costs of installation at Cross Keys Health Centre, Manchester.

10,000 gallon capacity PVC lined galvanised steel storage tank.

	£
1. Clear site	10.00
2. Excavate base 17 cu.yds. @ £1.60 per cu.yd. in 70% bauxite 30% limestone	27.20
3. 540 square feet of BRC 121 fabric reinforcement	72.60
4. Labour to cut and place reinforcement and chairs	13.80
5. To make and place spacing blocks for reinforcement	4.80
6. One 1½" diameter galvanised steel outlet pipe 20' long	20.00
7. One 2" diameter galvanised steel washout pipe 10' long	20.00
8. To fix outlet pipes in base	2.00
9. Supply and place 9 cu.yds. 1:3:6 concrete	162.00
10. Supply and place rendering to tank base	15.00
11. Supply galvanised steel grain bin complete with roof, fittings and fasteners.	800.00
12. Supply one PVC liner (£38.50 FOB + 15% freight and handling charge)	88.56
13. Liner anchorage pipes. 50' of 7/16" diameter garden hose (£3.00) and 50' of ½" diameter PVC pipe (£17.50)	20.50
14. Labour to erect tank and liner	80.00
15. 10' length 2" diameter PVC pipe for overflow	2.50
16. Transport of tank, liner and reinforcement to Manchester	40.00
	<hr/> <hr/>
To supply and erect a 10,000 gallon water storage tank	1,378.96

₹

Overhead storage tank.

1.	Excavate base 1 cu.yd. in bauxite	1.60
2.	Supply to site 4' x 4' x 4' x $\frac{1}{8}$ " thick welded steel tank with drain plug and $\frac{3}{4}$ " diameter inlet and outlet fittings and painted with two coats zinc chromate red oxide paint	130.00
3.	Supply to site 11' high stand to support overhead tank made of 3" diameter steel tube painted as item 2.	100.00
4.	Erect tank stand and tank	10.00
5.	Reinforcement to base 25 sq. ft. BRC 121 fabric	3.36
6.	Supply and place 1 cu. yd. 1:3:6 concrete	18.00

To supply and erect a 400 gallon capacity tank on an 11' high stand 262.96

To install pump and plumbing.

1.	To dig and backfill 175' of pipe trench not exceeding 8" deep in bauxite	10.00
2.	To supply one Barnes Minute Master Portable self priming pump	72.00
3.	To supply approximately 185' 1" diameter PVC pipe and approximately 26' 1" diameter galvanised steel pipe with bends and connections	66.25
4.	To supply two lock off valves and one non-return valve	42.70
5.	To supply switch and make the electrical connection for the pump	15.50
6.	Labour to install pump and pipes including travelling	50.00
7.	To re plaster wall where pipes enter the Centre	2.00

To install pump and plumbing 258.45

Guttering and piping to roof.

£

To supply and fix approximately 50' of 6½" wide Cornish guttering, 42' of 8" wide Cornish guttering and 40' of 4" diameter pipe with all necessary drops and bends. Guttering to roof	210.00
To relocate power supply to Centre and provide new bracket	10.00
To cart away spoil and clear up site	25.00
Installation of water supply at Cross Keys Health Centre, Manchester	<u>£2,145.37</u>

Development costs.

1. Tools	5.03
2. 72 No. roof brackets of ½" mild steel plate	38.40
3. Brazing roof brackets	10.00
4. To supply paint and paint brackets	5.00
5. To redrill bracket holes in top tank ring and cut overflow holes	5.00
6. Plated nuts and bolts to secure brackets	7.50
7. Hire for 1 month of scaffolding	13.50
	<u> </u>
Development costs	£84.43

APPENDIX 7

QUOTATION FOR TRADITIONAL 10,000 GALLON TANK

Estimate submitted by local contractors
for the construction of a 10,000 gallon
capacity covered water storage tank.

10,000 Gallons Water Tank

Earthwork.

6'0" of excavation and approximately
50% rock. - 311.00

Tank.

8" block wall with all cavities filled
reinforced at 8" centres vertically with
 $\frac{1}{2}$ " diameter bars and $\frac{3}{8}$ " diameter bars
horizontally at 24" centres, base to be
6" reinforced concrete laid in 6" hard-
core and $\frac{1}{2}$ " diameter bars at approx.
9" centres both ways. Internal wall and
base to be rendered and finished with a
steel float. Provisional for Cat ladder
and inlet and outlet pipe - 989.10

6" reinforced concrete cover with $\frac{1}{2}$ " diameter
bars at approx. 6" centres both ways 373.00
To add contractors overhead 15% - 251.00

TOTAL - \$1,924.10

To construct ground tank internal dimensions 12 ft. long
x 10 ft. wide x 12 ft. deep, approximately 4 ft. out of ground,
of 8" cc. blocks reinforced with $\frac{1}{2}$ " diameter bars, at 8" vertically
and $\frac{1}{2}$ " diameter bars at 2 ft. horizontally, and with 1:2:4 cc.
stiffeners at corners reinforced with 4 - $\frac{1}{2}$ " diameter bars and $\frac{1}{4}$ "
diameter stirrups at 12" centres, and with 2 belt beam courses of
1:2:4 cc. reinforcement with 4 - $\frac{1}{2}$ " bars and $\frac{1}{4}$ " diameter stirrups
at 12" centres, all sitting on 6" slab on well compacted hard fill
and reinforced with $\frac{1}{2}$ " and $\frac{3}{8}$ " diameter bars, and having all internal
surfaces rendered in 1-3 water proof mortar,

Amounting to \$2,307.97

To cover top of tank with W.P.P. frame of 2 x 10 bearers
2 x 6 purlins and 2 x 4 plate with galvanised iron roofing, and
with wire mesh vermin guard over openings and painted in 2 coats
oil paint

Amounting to \$ 382.24

The above estimate assumed that excavation will be earth and loose stones. Should solid formation of rock be encountered, an extra price of \$5.00 per cu. yd. will be applicable to measured quantities. The above estimate also assumes current J.I.C. Rates, and a 5 mile radius, and location within a 5 mile radius of Mandeville. No provisions for liability insurance have been included.

APPENDIX 8 - REPORT ON THE RURAL WATER SUPPLIES OF
ST. ANN, MANCHESTER AND ST. ELIZABETH

- a. Summary and Recommendations.
- b. Method of survey.
- c. General rural water supply situation.
- d. Administration of rural water supplies.
- e. Payment for rural water supplies.
- f. Chlorination of rural water supplies.
- g. Construction and improvements of Public rainwater catchment tanks.
- h. Promotion of rural water supplies.

a. Summary and Recommendations.

A summary of all the water supplies in the Parishes of St. Ann, Manchester and St. Elizabeth has been made based on information collected by this Project as described in this report.

It is recommended that the Parish Councils should each have complete documentation of all the water supplies in their Parish. This Project has identified the locations of all the public rainwater catchment tanks in the Parishes and has collected basic data for each tank. The Parish Councils should complete this work as soon as possible to contribute to a more efficient administration of the supplies in each Parish.

The survey of the public rainwater catchment units has shown that 67 communities in St. Ann, 68 communities in Manchester and 50 communities in St. Elizabeth are now being supplied with water from public rainwater catchment tanks. The general level of maintenance of these units is not good and it is recommended that a programme is instituted as soon as possible to repair these units and to improve the system of maintenance. It is also recommended that immediate improvements may be made by covering all the tanks that are now open and providing each tank with a simple drip feed chlorinator. In St. Ann 28 units require covers and 61 require the provision of chlorinators. In Manchester 42 units require covers and 50 require chlorinators. In St. Elizabeth 18 units require covers and 47 units require chlorinators.

This Project feels that the present situation justifies the full time employment of one man provided with adequate transport in each Parish to be responsible for the public tanks only.

Once the programme of repair and maintenance of the public tanks has been completed this Project recommends that a programme of education of the rural population is undertaken aimed at creating a greater responsibility towards the rural water supplies. It is suggested that this may best be achieved by greater local participation in the administration of the supplies and that in lieu of payment for water local populations should be made responsible for the upkeep of their own public tanks.

It is also recommended that loan schemes be instituted to encourage individual householders in the areas to build their own rainwater catchment tanks. The result of such a programme would be a better supply of water for more individuals and less strain on the public supplies.

The financial implication of the recommendation to cover the tanks and provide chlorinators is the expenditure of approximately \$220,000 (assuming a cost per roof of \$2,500 and per chlorinator of \$50.) This figure might be reduced if the programme was well co-ordinated and approached as a continuous operation or if research provides a cheaper cover. Suggestions on reducing the cost of the covers are given in this report.

These recommendations also require an increased expenditure of public funds on rural water supplies and on increase of manpower to administer these supplies.

This report has not taken into account the planned expansion of piped water supplies in the rural areas. However the plans now under consideration will only directly affect the south east St. Elizabeth area. It is the view of the Project however that in the past the public rainwater catchment units have been abandoned with undue haste when piped supplies have been installed and that essentially the whole of the existing network of public rainwater catchment tanks should be refurbished.

b. Method of survey.

i. Public rainwater catchment tanks.

The Assistant Superintendents for Water Supplies in each Parish provided the Project with all the data in their possession concerning the public rainwater catchment tanks. A field survey was then conducted based on this information. Each tank was visited and its location recorded on a map. The maps of Jamaica currently in use based on the 1:50,000 map were drawn and published in 1958. This sometimes made the exact location of a tank on the ground difficult to transfer on to the maps. The dimensions of the tank were then measured using a steel tape. The internal dimensions were measured wherever possible but in some cases estimates, based on external measurements, were made. The data concerning the structure of the tank and catchment was then recorded. In most cases the information on the demand for water and the districts served by the tank was provided by the tank keepers. In the absence of the tank keepers, local residents provided the information. Anyone who has had experience of this type of questionnaire

in the rural areas will immediately recognise the failings of this method. However in the absence of any other information this data has been recorded but should be treated accordingly. Cross checks were carried out wherever possible and the observations of the Project's staff were used to verify the data. It was encouraging to find substantial agreement over data wherever these cross checks could be carried out.

After this preliminary survey had been completed the Land Valuation Series of Maps 1:12,500 scale (based on aerial photographs flown during the period 1951 - 1955) were examined to confirm the locations of tanks. The Land Valuation Series of Maps is now being redrawn from aerial photos flown in 1968. During the period of the Project the sheets covering the Parishes of St. Ann, Manchester and St. Elizabeth had not been completed. When completed these 1:12,500 scale maps should show every public tank as well as the private tanks in all of the island. To assist further in the exact location of tanks visited during the preliminary survey the Project Engineer examined the aerial photos for the three Parishes flown during the NASA survey of Jamaica in 1971. Except in cases of heavy shadow, especially in the cockpit type topography, and of cloud cover the public tanks are easily identified on these photographs. As a result of this examination a number of extra tanks were added to the original lists supplied by the Parish Councils. By July 1973 all the public tanks had been visited and data collected.

In June 1973 a map for each Parish was prepared showing the sites of all the public tanks and giving an indication of the size of the tanks and of the nature of use of the unit. In addition the data for each tank was recorded on a single sheet and a file of data sheets built up for each Parish.

The dimensions and capacities of the tanks are the results of direct measurement and give an accurate picture of the units. However these dimensions should be checked before any designs for roofs are prepared.

The information on the number of people depending on the tanks for water is an estimate based on information received from the local people. The figure is an indication of the number of people in the locality who own their own tanks.

Similarly the information on when the tank goes dry is based on what was reported to the Project by the local people. This evidence is not sound enough to stand much analysis but it should be noted that many units never go dry. Thus it appears that in some communities the combination of the public and private tanks with rationing during periods of drought is sufficient to satisfy the minimum needs of the existing population. The National Plan states that this population is unlikely to grow during the period 1970-1990 so that it may be concluded that some communities now possess water supplies sufficient to satisfy their minimum requirements until 1990.

- ii. 1,500 gallon capacity steel tanks distributed throughout the Parish and filled regularly by the Parish Councils.

During the course of the survey note was made of the steel

tanks distributed throughout the Parishes. In July 1973 the Assistant Superintendents for Water Supplies in the three Parishes provided lists of the locations of these tanks. The Project has not had time to locate each of these tanks and add them to the maps but this should be done as soon as possible.

iii Piped supplies.

During the course of the Project data has been acquired relating to the piped water supplies in each of the Parishes. In July 1973 the Chief Engineer of the N.W.A. and the Assistant Superintendents for Water Supplies in the three Parishes provided the information on the piped supplies included below.

c. General rural water supply situation in each Parish.

The water supplies in each of the three Parishes can be broken down into five categories:

- i. Major piped schemes confined to large population centres and not of immediate benefit to the rural areas.
- ii. Minor piped schemes generally confined to small areas and based on shallow wells and springs.
- iii. Public rainwater catchment tanks.
- iv. 1,500 gallon capacity steel tanks filled regularly by the Parish Council.
- v. Private tanks or oil drums using roof catchments.

Apart from the small number of rural communities supplied from minor piped schemes the remainder of the rural areas depend on a combination of items iii, iv and v. In periods of extended drought the Parish Council may, with the permission of the Ministry of Local Government, hire additional water trucks to carry water into areas of need. The situation in each Parish is outlined below.

St. Ann.

This Project has not concerned itself with the coastal strip from Discovery Bay to Ocho Rios. This is an area of tourist development and is scheduled for the development of the existing major water supplies. There are numerous springs in the hills behind the coastal strip leading up to the road joining Browns Town in the west to Bamboo in the east. Three minor piped schemes exist in this area serving Sturge Town, Chester and Lime Hall. The first two systems are based on springs. The Lime Hall system is based on a spring at New Ground from which water is pumped to the covered rainwater catchment tank at Lime Hall for storage and distribution. The area also includes a number of rainwater catchment tanks.

The Parish has three major piped schemes serving the upland areas. The Brown's Town supply is based on a 600 ft. deep well at

Minard. A submersible pump lifts water from the well to fill the open rainwater catchment tank in Browns Town, which is now used as a storage and distribution reservoir for this scheme. The N.W.A. have just completed the laying of pipes and the commissioning of a well at Claremont. The Parish Council operates the piped supply at Moneague based on a well at Moneague with its own service reservoir. The Parish Council hopes to extend this supply to Clackham in the near future. The benefit to the rural areas from these supplies is limited to those areas in the immediate vicinity of Browns Town, Claremont and Moneague.

The Parish Council operates minor piped supplies at Pedro River, Macknie, Cave Valley, Norwood and Cascade. The Pedro River supply is based on a spring at Fort George and there is provision to top up the Bensonton public rainwater catchment tank from the same spring. The Macknie supply is based on a spring at Douglas Castle which is used to fill two closed steel storage tanks of 5,000 and 6,000 gallons capacity. The Cave Valley system is based on a shallow well and local residents claim it is not very reliable. There is also a small covered public rainwater catchment tank in Cave Valley. The Norwood supply has not been in operation for the last few years ostensibly because of the lack of a pump. The Cascade supply is based on a spring which serves a 50,000 gallon capacity closed concrete tank. The supply includes a filter and coagulating station. The Parish Council plans to have gas chlorinators operational on all these systems.

Full details of the network of public rainwater catchment tanks throughout the Parish are given in the map and data sheets accompanying this report. 75 tanks are listed. The tanks at Browns Town, Lime Hall and Golden Grove are now regularly filled by pumped supplies and are no longer operating as rainwater catchment tanks. The tanks at Top Buxton and Moneague have been made redundant by other other supplies while the small tanks at Davis Town and St. Johns are not used for drinking water because of pollution. The tank at Tobolski is no longer used because the population has moved away as a result of the bauxite mining. This leaves 67 communities being served by rainwater catchment supplies. Of these 67, 10 have tanks of less than 50,000 gallons capacity. The tanks at Retirement (near Lawrence Park), Culloden, Upper Rosetta, Old Road, Philadelphia and Pilot are all less than 20,000 gallons and while they evidently serve some purpose they can hardly be regarded as important public supplies. The Parish has also acquired four old property tanks and catchments which are now used as public supplies. They are the tanks at Armadale, Inverness, Lower Buxton and York Castle. The Parish Council has recently built four new rainwater catchment units each of which has a 100,000 gallon closed steel storage tank. The Superintendent informed the Project that it has been cheaper to build steel tanks fabricated on site than to build reinforced concrete tanks. These four tanks are at John Reid, Caledonia, Grants Bailey and Top Buxton. The latter replaces the old tank as the water supply for Top Buxton. 23 of the remaining tanks were either built with reinforced concrete covers or have had them added. More recently the Parish Council has been covering open tanks using aluminium sheets supported on a steel frame. 12 tanks are now covered in this way. Only six tanks have any provision for chlorinating the water leaving the tank. They are the tanks at Compound, Lawrence

Park, Farm, Calderwood, Claremont and Walkers Wood. The remaining tanks may be treated by throwing a handful of chlorine powder into the tank at irregular intervals but this method is not effective. All the tanks are served by concrete catchments except the tank at Beechamville which collects the rain falling on the local church roof.

Of the 67 rainwater catchment units, 20 units of over 50,000 gallons capacity and 8 of less than 50,000 gallons capacity are not covered. 51 units of over 50,000 gallons capacity and a further 10 of less than 50,000 gallons capacity have no provision for regular chlorination. Only the tanks at Compound, Lawrence Park, Farm, Calderwood and Walkers Wood are both covered and have chlorinators.

The Parish Council has twenty 1,500 gallon capacity steel tanks distributed throughout the Parish which are regularly filled with water. The Parish Council operates two sprinklers of its own and the P.W.D. assists in this work with 1 or 2 of its sprinklers. Each sprinkler has a capacity when loaded of 1,750 gallons and can pump the water from itself into the roadside tanks. The Council aims to fill each tank twice a week.

Manchester.

Manchester has two major piped supply schemes. Water for the Mandeville supply is pumped from Porus to distribution reservoirs at Perth and Battersea where the rainwater catchment tanks are also used as storage and distribution reservoirs. The pipeline from Porus passes through Broadleaf and near to Heartease. Broadleaf has a piped water supply and the rainwater catchment tank at Heartease is kept topped up with water from the Porus supply. The Christiana supply is a river take off and the water is pumped for storage and distribution to the old rainwater catchment tanks at Sedburgh. Both these major supplies are chlorinated.

The Parish Council has minor piped supplies based on springs at Spice Grove and Nottingham. This scheme serves the area from Spice Grove down to Pepper. There is also a supply in the Troy district which has a small steel storage reservoir at Cowick Park.

82 public rainwater catchment tanks have been listed for Manchester. The tanks at Perth, Battersea, Sedburgh and Heartease are now regularly filled by pumped supplies although all of them except Sedburgh still use their catchments to collect additional water. 10 tanks are no longer used as sources of domestic water. The tanks at Clones, Robins Hall, Devon, Chudleigh, Walderston and Mizpah, are all in areas served by the Christiana supply and are now badly polluted. The tank at Broadleaf has been superseded by the piped supply from the wells at Porus. Windsor Forest and Cocoa Walk are both old property tanks and are heavily polluted and in a bad state of repair. The sheet steel catchment of the Shooters Hill tank has been taken down and the water in the tank is polluted. This leaves 68 communities being served by rainwater catchment supplies and eight of these tanks are under 50,000 gallons capacity. The tank at Shirehampton has a capacity of only 12,500 gallons and cannot be considered as an important public

supply. The Parish has acquired eleven old property tanks which are now used as Public supplies. They are the tanks at Wickwar, Shirehampton, Ballynure, Hearitree, Rose Hill, Newfield, Woodlands, Lancaster, Lewisfield, Windsor Forest, Farm and Park Hall. There are no closed steel tanks with any of the units in Manchester. 26 tanks were built with reinforced concrete covers or have had them added. None of the rainwater catchment tanks in Manchester has a sheet metal roof. (One of the tanks at Sedburgh does have a galvanised steel sheet roof). Eighteen tanks have the equipment to chlorinate the water as it leaves the tank. They are the tanks at Mayfield, Maidstone, Good Intent, Downs, Lincoln, Craig Head, Berkshire, Rest Store, Lichfield, Cross Keys, Resource, Lancaster, Old England, Ellen Street, Warwick, Bellefield, Pusey Hill and Victoria Town. Of these only Lancaster has a capacity of less than 50,000 gallons. The tanks at Berkshire and Ebenezer are served by catchments of galvanised steel sheet which are supported clear of the ground on a wooden framework. (The tanks at Perth, Battersea, and Sedburgh also have areas of catchment which are made of corrugated galvanised steel sheet). The remaining 63 tanks are all served by concrete catchments.

Of the 68 rainwater catchment units, 34 of over 50,000 gallons capacity and 8 of less than 50,000 gallons capacity are not covered. 43 units of over 50,000 gallons capacity and 7 units of less than 50,000 gallons capacity have no provision for regular chlorination.

Nine tanks in the Parish are covered and provided with a chlorinator. They are the tanks at Mayfield, Maidstone, Lincoln, Craig Head, Rest Store, Lichfield, Cross Keys, Ellen Street and Warwick.

The Parish Council has 54 1,500 gallon capacity steel tanks distributed throughout the Parish which are regularly filled. This work is carried out by 3 P.W.D. sprinklers which aim to fill each tank every other day. Reports received by the Project suggest that the 3 sprinklers cannot achieve this regularity.

In July 1973 many areas of the Parish were suffering from a drought. The Parish Council had been authorised by the Ministry of Local Government to hire private trucks to carry water into the areas of need. 9 trucks were employed on this work which usually amounts to filling oil drums left by householders at the side of the road. In some cases the water is pumped into the Public tanks.

St. Elizabeth.

The Parish has two major piped supply schemes. Wells at New Forest supply the Junction and Bull Savanna area. A well and 100,000 gallon closed steel distribution reservoir at Dalintober provides one part of the Black River supply while a well at Luana with distribution reservoirs of 175,000 gallons capacity provides the other.

Minor piped supply schemes are operated in Santa Cruz, Pepper, Lacovia, Middle Quarters, Siloah, Elderslie, Ginger Hill, Brompton and in the Pedro Plains. The Santa Cruz supply is based

on a well in Santa Cruz. A spring at Georges Valley to the north east of Santa Cruz and a well at Newton to the north west of Santa Cruz which has a 25,000 gallons capacity closed steel storage tank also provide piped supplies in the Santa Cruz area. A well at Pepper supplies piped water for the immediate district. The Lacovia supply is based on a well at Burnt Savanna. Middle Quarters is supplied by a pipeline leading from the Y.S. River. The Siloah supply is based on a spring at Aberdeen and the Elderslie supply comes from the Node Wood spring. A 50,000 gallons capacity closed steel tank serves the Elderslie supply. Ginger Hill is supplied from an entombed spring. The Brompton area is served by a pipeline from the Hannah spring which is near Cotterwood. The Pedro Plain scheme is based on wells at Parottee and Hounslow. A 100,000 gallon capacity, covered, reinforced concrete reservoir serves as storage for the Parottee Well. The well at Hounslow supplies four covered reinforced concrete reservoirs. At Claremont Park the reservoir is 100,000 gallons capacity, at Newcombe Valley and Parottee the reservoirs are 50,000 gallons capacity and at Little Park the reservoir is 30,000 gallons capacity.

54 public rainwater catchment tanks are listed in St. Elizabeth. None of these tanks has been used for storage in a pumped supply scheme. Four tanks at Leeds, Union, Junction and Lititz are no longer used to supply domestic water. The smaller of the two tanks at Leeds is reportedly leaking and is no longer used. The water in the tank at Union is badly polluted and is used only for washing and watering animals. The tanks at Junction and Lititz have been made redundant by the New Forest piped supply and both tanks have been allowed to fall into disrepair and the water in both is badly polluted. This leaves 50 communities being served by rainwater catchment supplies. 2 of these tanks are under 50,000 gallons capacity but both the tanks are covered and obviously provide a service to their communities. All the tanks now in use as rainwater catchment units in St. Elizabeth were built as public supplies. The tank at Springfield is a 100,000 gallon closed steel tank and is the only one in the Parish. 25 tanks of over 50,000 gallons capacity and 1 tank of less than 50,000 gallon capacity were built with reinforced concrete roofs or have had them added. The tank at Whitehall has an aluminium sheet roof supported on a steel frame and the tanks at Spring Vale, Bartons, and Phoenix Park have roofs of galvanised steel sheet. The tank at Hodges Land, which is less than 50,000 gallons capacity has a galvanised steel sheet roof supported on a timber frame. Only 3 tanks in the Parish have any provision for regular chlorination of the water leaving the tank and they are Newmarket, Ballards Valley and Nain. All the tanks in St. Elizabeth are supplied by concrete catchments.

Of the 50 rainwater catchment units, 18 units of over 50,000 gallons capacity are not covered. 45 units of over 50,000 gallons capacity and 2 units of less than 50,000 gallons capacity have no provision for regular chlorination.

There are no tanks in St. Elizabeth which have both a cover and a chlorinator.

The Parish Council has sixty 1,500 gallon capacity steel tanks distributed throughout the Parish and filled regularly. The

tanks are filled by three Parish Council sprinklers and up to four sprinklers operated by the P.W.D. It is reported that some of these tanks in the Pedro Plains are filled as many as three times a day during periods of drought.

d. Administration of Rural Water Supplies

In general the administration of major piped supplies is split between the N.W.A. and the Parish Councils. The N.W.A. is responsible for the source of water and the Parish Council remains responsible for the distribution system. The minor piped supplies and all other public supplies in the rural areas are the responsibility of the Parish Council.

St. Ann.

The Superintendent of Roads and Works reported that he has an adequate provision for staff to administer the Parish Water supplies. The N.W.A. is operating the Claremont supply and is responsible for the Minard well which serves the Browns Town supply but all other rural water supplies are administered by the Parish Council.

In 1973 budgetary provision was made for \$30,000 to be spent on the public rainwater catchment tank system.

Each public rainwater catchment tank has a paid tank keeper and he is expected to keep the unit clean, to report any damage to the unit to the Parish Council and to regulate the supply of water. It is also his responsibility to inform the Parish Council if the tank goes dry.

In the event of trucking of water to drought stricken areas permission to spend fixed amounts of money must first be obtained from the Ministry of Local Government.

Manchester.

The Parish Council in Manchester is responsible for the distribution of water in both the Mandeville and Christiana supply areas. In addition it is responsible for all other rural water supplies in the Parish. The Assistant Superintendent responsible for Water Supplies has one Works Overseer and these two men are responsible for all aspects of the Parish water supplies. They estimate that at least 50% of their time is spent on dealing with problems connected with the Mandeville and Christiana supplies.

Each of the public tanks has a paid tank keeper and his duties are similar to those described in the St. Ann section. Repairs that are needed are reported to the Parish Council and estimates are then prepared to cover the cost of the work. These estimates are then presented for funding either by the Parish Council or the Ministry of Local Government.

In 1973 Manchester Parish Council had a budget of \$7,000 for repairs and maintenance of public tanks and a budget of \$10,000 to be spent during drought periods on private trucking of water.

Any additional sums to be spent on private trucking will require the sanction of the Ministry of Local Government.

St. Elizabeth.

In St. Elizabeth the N.W.A. is administering the Dalentober arm of the Black River supply and is also responsible for the well at New Forest. All the remaining water supply systems in the Parish are administered by the Parish Council. The Assistant Superintendent responsible for Water Supplies has two Works Overseers and one Parish plumber to assist him.

Each of the public tanks has a paid tank keeper and his duties are similar to those of the tank keepers in the other Parishes.

In 1973 the St. Elizabeth Parish Council had a budget of \$6,500 for the maintenance and repair of public tanks and a budget of \$5,000 for the trucking of water. By July 1973 \$30,000 has been spent on trucking water and these additional sums have been sanctioned by the Ministry of Local Government. In 1973 a special budget of \$17,000 was included for work on the tanks in the south east area of St. Elizabeth.

In addition to the administration of existing supplies the Parish Councils have plans to develop further rural water supplies.

In St. Ann there are plans to entomb a spring at McDowell with the possibility of supplying the York Castle area. Interest was also expressed in the possibility of using water from the river caves at Noisy Water. It has already been mentioned that the Moneague supply is to be extended to Clackham.

In Manchester there are plans to build a public rainwater catchment tank at Evergreen. It is thought that a closed steel tank will be used with a concrete catchment.

In St. Elizabeth a well at the Junior Secondary School in Maggoty is producing 100 gallons per minute and may be developed as a supply for Maggoty. Interest is being shown in developing another source for Santa Cruz. A public rainwater catchment tank is just being completed at Bailey Ground near Lancewood. It is reported that the unit consists of a covered, reinforced concrete tank fed by a concrete catchment.

The administration of the rural water supplies would be made considerably more orderly if adequate records of the existing supplies were kept. This Project is not aware that any of the Parishes has maps and data that provide a comprehensive coverage of the supplies. A map should exist for each Parish identifying the areas served by major piped supplies, the communities served by minor piped supplies and the sites of the public rainwater catchment tanks and of the roadside 1,500 gallon tanks. In addition to this overall map there should be detailed maps showing all the relevant details of the major and minor piped supplies. These should include all the details of the source, all the details of the pumps and all the details of the distribution systems including

the positions and size of pipelines and the location of all valves, standpipes, meters, etc. This Project has made a start to locating the public rainwater catchment tanks and recording all the available data about them. The data sheets are not 100% complete and it is hoped that the Parish Councils will check all the data so far recorded and complete each sheet. It should be a relatively easy task to locate on the Project maps the positions of the 1,500 gallon steel roadside tanks.

When all the basic data has been collected it should be kept in one place as a permanent record. Only copies of the information should be allowed to leave the permanent keeping place. These records cannot be regarded as an end in themselves and must be continually updated to remain a record of the existing situation. Only in this way can anyone have an accurate idea of the water supply situation throughout a Parish.

e. Payment for Rural Water Supplies.

All water that is delivered to a standpipe in Jamaica may be consumed free of charge.

Where piped connections are made into homes a flat water rate is generally levied.

Some of the major piped supplies include meters for individual households. It is believed that Mandeville levies a water rate based on the recorded consumption of water. The St. Elizabeth Parish Council has installed meters on the Black River supply but in July 1973 was still continuing to levy a flat water rate irrespective of the recorded consumption.

f. Chlorination of Rural Water Supplies.

In general the major piped supply schemes provide chlorinated water. The Assistant Superintendent responsible for Water Supplies in St. Ann claims that nearly all the piped supplies in St. Ann have been fitted with gas chlorinators. A gas chlorinator is installed on one of the stand-by reservoirs at Battersea and a drip feed chlorinator is installed on the stand-by reservoir at Perth both of which are used in the Mandeville supply. Water leaving the storage tanks of the Christiana Supply at Sedburgh is chlorinated by the drip feed method. This Project has no knowledge of the provision of chlorinators on the piped supplies in St. Elizabeth although it is assumed that all but the smallest schemes will be chlorinated.

The drip feed chlorinators fitted to the Public rainwater catchment tanks are extremely simple. A covered plastic tank the size of a small dustbin is filled with a solution of chlorine. A plastic pipe leads down to the jet that is installed in the outlet pipe of the public tank. The water passing down the outlet pipe from the public tank sucks sufficient of the chlorine solution from

the jet to adequately chlorinate the water. The plastic tank containing the chlorine solution is usually supported on a wooden platform level with the top of the public tank, to provide sufficient head, and is surrounded by a slatted wooden cage that can be locked to prevent pilfering. The tank keeper is provided with a supply of chlorine powder or pills to make up the chlorine solution.

Even though the equipment is so simple, once the jet has been installed, only 6 tanks in St. Ann, 18 in Manchester and 3 in St. Elizabeth are provided with the equipment. It is not obvious that all these are being used. It has been pointed out that chlorine powder and pills when stored over a long period lose their effectiveness but in a reasonably organised system this should present no problems.

Many of the tank keepers report that chlorine pills or powder are thrown directly into the tank when either the Health Inspector or officials of the Parish Council visit the tanks. As far as can be ascertained this is only done at infrequent intervals for each tank. The residual and lasting effect of chlorine applied in this way is negligible.

The Assistant Superintendent responsible for Water Supplies in St. Ann reports that he is planning to assign a man to the task of installing chlorinators on all the public tanks. The Manchester and St. Elizabeth Parish Councils do not have any money to buy the equipment for the chlorinators.

g. Construction and improvements of public rainwater catchment tanks

Mr. Brian Grover in his paper "Harvesting Precipitation for Community Water Supplies " (P61 and 62) (See Bibliography) points out that a covered water supply minimises the already low risk of serious pollution of a rainwater catchment supply. In Jamaica uncovered tanks have been observed to be polluted principally by frogs but also by weed, algae, dead animals and general debris thrown there by the local populace. It is now generally recognised that small tanks of the public rainwater catchment variety must be covered. A cover is likely to bring a greater improvement in the quality of water delivered at the standpipe than a chlorinator on an open tank.

In recent years only the Parishes of St. Ann and St. Elizabeth have been building new public rainwater catchment tanks. In St. Ann it has been decided that the necessity for a cover on the tank makes the building of a reinforced concrete tank, with all the formwork that entails, too costly. The four most recent tanks to be built in St. Ann all have 100,000 gallon capacity closed steel storage tanks fabricated on site. In the latter part of 1972 the tank at Caledonia was built for approximately \$12,000. The tank has a welded steel sheet floor and was erected on a flat surface prepared by filling and compacting the hollows and levelling the high points. A reinforced concrete base was not used. Three of the four steel tanks are served by catchments on very steep hillsides. Mr. Stanley Martin, Superintendent of Roads and Works for

the Parish Council of St. Ann, who has had a great deal of experience in building these public rainwater catchment tanks, explained the method of building the catchments. In the past attempts were made to level the catchment areas and some of the catchments were cast in bays with expansion joints between the bays. It was found that while this system controlled the cracking, there were still a number of cracks which required repair and maintenance. Some experiments were carried out using chicken wire mesh reinforcement but cracking still occurred. It was decided that cracking was more directly related to the quantity of cement in the concrete mix, which is a well recognised phenomenon. The method of building catchments now used is to do a minimum of clearing of the ground surface, only filling the worst depressions with compacted marl and removing those rocks easily removed. A 2 - 3 in. thick layer of 1:5:10 concrete is then spread on the ground surface and over any protruding rocks. The catchment, when completed is rendered with a marl and cement mixture. A low concrete block wall usually surrounds the catchment, forming in the lower parts a gutter to conduct the water into the tank. The unit at Caledonia cost approximately \$26,300 to complete. If the cost of fabricating the tank and preparing its base is taken as \$13,000 then the cost of catchment preparation is approximately \$13,000. Where possible, and if it does not require too much work, the catchment is levelled to assist the workmen, as at the John Reid tank.

In St. Elizabeth a covered reinforced concrete tank was built in 1970 at Ivor Cottage with a concrete catchment. The tank leaked when first filled with water but it has now been repaired. A second similar tank is now being completed at Bailey Ground. A figure of \$19,000 has been given as the cost of building this unit but it seems that this figure is more likely the cost of building the tank alone.

Recently only St. Ann has been concerned with covering existing open tanks. Sheet metal roofs supported on a steel framework have been favoured as the cheapest method. Mr. Martin quoted a figure of \$1.00 per square foot for a sheet metal roof. A tank of 45 ft. diameter at its top has a plan area of approximately 1,750 square feet which would require covering.

In St. Elizabeth estimates have been submitted for covering some of the open tanks and it is reported that each roof was estimated to cost \$3,000. Two types of steel supporting structures have been seen by this Project. One is based on radial members of standard universal beams of substantial cross section supporting lighter circumferential members. The second is based on welded space frame members supporting lighter circumferential members.

This Project has erected a galvanised steel grain bin with a galvanised steel roof supplied by Read Steel Products of Alabama, U.S.A. This company manufactures as a standard item a 48 ft. diameter grain bin with a galvanised steel roof. The galvanised roof sheets provide part of the strength of the roof and are supported on light space frame members connected together with circumferential members. Part of the roof structure required to relieve the stresses on the grain bin walls might not be required if this type of roof were erected on a public tank. The costs

of this ready made item should be investigated before any estimates for a locally fabricated roof are accepted.

This Project feels that the floating type of cover described by Mr. C. B. Cluff, of the University of Arizona, and using expanded polystyrene rafts 1 in. thick and coated with a sand dusted bitumen layer should be cheap and easy to build on straight sided tanks. It is doubtful, however, if a raft of this type would support the weight of an animal or a child.

Butyl rubber sheets with eyes manufactured into the sheet and suitable drainage provision, could be supported quite simply above a tank using steel wire ropes.

On the smaller rectangular tanks the problem of support is much simpler and vaulted roofs of aluminium sheet without a supporting structure may prove practical. Several tanks in St. Elizabeth were built with wooden roofs and the tank at Hodges Land has a wooden supporting structure. All the wooden roofs have collapsed and have not been replaced. The enclosed and humid atmosphere on the top of a water tank is a most unsuitable one for the successful use of timber.

Whatever method is adopted an economy of numbers may be achieved if a sufficient number of tanks of the same dimension are to be covered. A "one off" tank cover will prove to be a relatively expensive item.

It should be remembered that in any future piped water developments in the rural areas the existing public tanks, where suitably placed, may be used as storage and distribution reservoirs for the piped schemes. The roofs, that it is proposed to install on the tanks, can thus be regarded in many cases as long term investments.

In general with the development of piped water supplies, as great a use as possible should be made of the existing public tanks. The tank at Heartease in Manchester is an example of a public tank kept filled by a piped supply so that in the event of the piped supply failing the water stored in the tank can be used in the system. The communities at the ends of the Christiana supply would have benefitted enormously if the piped supply had been led to one of the existing public tanks with the inflow controlled by a float valve. It is an unfortunate feature of the rural water supplies that the pumps serving some areas are frequently breaking down. The pumps at the Minard well serving Browns Town in St. Ann and at New Forest serving the Junction-Bull Savanna area of St. Elizabeth both come in this category. Under these circumstances the more storage units that can be built into the supply scheme the better it will be.

h. Promotion of rural water supplies.

The water supply situation in the rural areas would be very much worse were it not for the large number of homes that have their own private rainwater catchment tanks. It is probably true

to say that all those who can afford to will build their own catchmen tanks rather than rely on the public tank. Most private tanks are of approximately 6,000 gallons capacity and the owners can exercise a degree of control over their own supply that is not possible with the public tank. In most communities it is the larger private tanks that are the last supplies of water in times of drought.

This Project is only aware of one scheme run by the Parish Council of St. Ann that offers loans to encourage people to build their own tanks. It is estimated that under this scheme approximately 20 tanks are built each year. The Land Authorities used to run a similar scheme to assist farmers to build water tanks but it is not known if this scheme is being pursued under the reorganised Land Authorities.

One of the reasons people are anxious to own their own tanks is that it gives them an independence from the public tanks which are often abused as water supplies. The general impression retained by this Project after visiting all the tanks in the three Parishes is of the very low standard of maintenance on most of the units. It is very difficult to generalise and it must be said that some units provide an excellent service. However it is obvious that there is not sufficient money to carry out all the repairs necessary to return all the units to good working order. In addition the people who depend on these tanks for their water supply complain of the lack of response from the Authorities responsible for the rainwater catchment units. It is the opinion of this Project that this is in some part due to insufficient manpower and transport in the bodies administering these water supplies.

All the Parishes are supposed to operate a system whereby water can be obtained from the public tanks twice daily, once during a two hour period in the morning and once again during a two hour period in the evening. Where this system is operated the tank keeper can do something to control the consumption of water. In some cases during prolonged droughts some tank keepers can impose a limit of one four gallon measure per person. In this way the public system supplies can be used to maximum benefit. However for this system to operate it is essential that the tank keeper can lock off the water on the standpipe and in addition that no one else can turn it back on. On well maintained units it is often only necessary to lock the pipehouse to ensure that no water is drawn off outside the stipulated hours. However in many cases there is no pipehouse or they have been broken into and in many other cases anyone can turn the lock off valves from the tank on or off. Once a unit falls into disrepair it is very difficult for a tank keeper to maintain any form of authority and the behaviour of the general public towards its water supply deteriorates.

It is felt that only when a determined effort is made to repair and maintain the rainwater catchment units can a programme of education of the rural population in the use of their water supplies expect to meet with any success. In his paper "Rural Water Supplies in Developing Countries" (See Bibliography) David Donaldson has pointed out a number of features common to all successful rural

water programmes. One of these is that payment for the water used at a rate that covered at least the operation and maintenance of the system is required and that a local organisation for operating, maintaining and collecting rates should be set up in each community. While it is argued in Jamaica that the rural population cannot afford realistic water rates it is probable that only by this type of direct involvement can the rural population be persuaded of the value of its water supplies. Ideally the communities who depend on the public tanks for their water supply should also be responsible for the upkeep of the tanks. A first step in this direction might be to provide materials which can be used in a self help programme.

APPENDIX 9

SUPPLIERS OF CONSTRUCTION MATERIALS IN JAMAICA

Aluminium sheet 0.015" thick	}	Aluminium Products of Jamaica. Kingston.
Aluminium foil 200' x 31½" rolls		
Aluminium storage tank 14' diameter 11' high. 16 gauge corrugated		
Bitumen. MCI cutback. 60/70 penetration		Esso, Kingston.
Bitumen Distributor. 2000 gallon capacity		Lyews Construction Ltd Kingston.
Black Plastic Compound (Joining aluminium foil sheets)		Hole in the Wall, Kingston.
B.R.C. Fabric		Specialist Construct- ion Ltd. Kingston.
Decoralt White (reflective paint)		Shell Co. (W.I.) Ltd. Kingston.
Earthmoving equipment		Wilbros, Kingston.
Fibre Glass		N. Andrade. Kingston.
Galvanising		Carib Pipe, Spanish Town, Stewart, 1 Ocean View Avenue. Kingston.
Limestone Aggregate		Townend and Godfrey Bros. Ltd. Mandeville.
Polyethylene		Metal Box Co. of Jamaica, Kingston.
Prefix (Herbicide)		Shell Co. (W.I.) Ltd. Kingston.
Pumps, plumbing and gas chlorinators		Hood Daniel Well Co. Ltd. Mandeville.
Sand and cement		Townend & Godfrey Bros.Ltd. Mandeville.
Scaffolding		Templars Scaffolding Ltd., Kingston.
Steel Silo with roof. 16 and 18 gauge prefabricated sheets. 10,000 gall. cap.		Jamaica Livestock Assoc. Ltd. Kingston
Welded Pipework & brackets		A. Francis, Mandeville
Welded steel water storage tanks and stands. 400 gallons capacity		A. Francis, Mandeville Lankesters, May Pen.
Welded Steel shell storage tank 10,000 gallon capacity		Hood Daniel Well Co. Ltd. Mandeville.
Used Rubber Tyres		Goodyear Jamaica Ltd. Kingston.