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IMPERIAL ETHIOPIAN GOVERMENT
UNITED NATIONS SPECIAL FUND PROJECT

REPORT ON

SURVEY OF THE AWASH RIVER BASIN

GENERAL REPORT

UNITED NATIONS SPECIAL FUND
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

REPORT ON

SURVEY OF THE AWASH RIVER BASIN

Volume I

GENERAL REPORT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

UNITED NATIONS SPECIAL FUND ROME 1965

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GLOSSARY

UNITS OF MEASURE

METRIC SYSTEM SYMBOLS

μ	= 10^{-3}mm	micron	
mm	= 10^{-3}m	millimetre	
cm	= 10^{-2}m	centimetre	
m		metre	
Km	= 1,000m	kilometre	
cm2	=	square centimetre	
m2		square metre	
ha	= 10,000m2	hectare	
km2	= 100 ha	square kilometre	
l		litre	
m3	= 1,000 l	cubic metre	
hm3	= 1,000,000 m3	cubic hectometre	
g		gramme	
kg	= 1,000g	kilogramme	
q	= 100kg	quintal	
t	= 1,000kg	metric ton	

s; sec		second
min		minute
h, hr		hour
d		day
°C		degree centigrade
cal		small calorie
mA		miliampere
kV		kilovolt
kVA		kilovolt-ampere
kW		kilowatt
GWh	= 1,000,000 kWh	gigawatthour

ETHIOPIAN MEASURES

one gasha = 40 ha

one massa = 1/40 ha = 250 m2

one kunna of sorghum, noog = 3.0 kg
barley = 4.0 kg
beans = 5.5 kg
wheat, maize, lentils, linseed 6.0 kg
peas, guaya, teff or any other product = 5.0 kg

one dawula = 20 kunna

one Ethiopian Dollar (E$) - 0.40 US Dollar

PREFACE

The Report on the Survey of the Awash River Basin comprises the following volumes:

Volume	I	General Report
Volume	II	Soils and Agronomy
Volume	III	Climatology and Hydrology
Volume	IV	Water Storage and Power Development
Volume	V	Irrigation and Water Planning

These volumes are all issued on the authority of the Special Fund of the United Nations and the Food and Agriculture Organisation.

Volume I is a comprehensive Report covering concisely all aspects of the Survey, and setting out the conclusions reached and the recommendations made. It is wholly prepared by FAO. It embraces and is based on the contents of the other volumes.

The other volumes were all drafted by the Sub-Contractors, S.O.G.R.E.A.H. of Grenoble, France, who carried out the main work of the Project. They have subsequently been edited by FAO. Each of these volumes in its more specialised field provides and analyses the relevant data, discusses the results, and sets out the conclusions to which they point. The discussions in one volume of course in various respects have reference to and depend upon the discussions in other volumes.

The scope of Volume I, as will be seen from the Table of Contents, covers the following:

Chapter	I	Introduction and Historical Account
Chapter	II	Summary of Main Conclusions and Recommendations
Chapter	III	Description of the Awash Basin
Chapter	IV	Outlines of Existing Land Use
Chapter	V	Soil Survey and Land Classification
Chapter	VI	Prospective Land Use under Development
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Chapter	X	Development of Irrigation
Chapter	XI	Estimates of Costs and Economic Appraisals
Chapter	XII	Additional Remarks

It will be realised that Volume I covers the whole work of the Survey, and by itself provides a comprehensive and co-ordinated statement of what it has achieved. The other volumes are essentially technical volumes, to which reference may be made for more detailed information on any particular aspect of the work.

CHAPTER I - INTRODUCTION AND HISTORICAL ACCOUNT

1. Purpose and Scope of the Project

The Awash River is the only large stream in Ethiopia which flows towards the east and north. These which flow towards the west and north-west, including the Baro, the Blue Nile, and the Setit, have larger annual flows, but their courses in Ethiopia lie largely in deep valleys and canyons, which are much less accessible, and thus do not present immediate possibilities of developing extensive areas of irrigation, commensurate with their flows. The Awash basin, in contrast, is in many parts relatively open. It has, over much of its extent, rainfalls which are limited in amount, and are confined to one part of the year. Its lands include considerable areas of fertile soils, which at present are used only to a very limited extent. Many of the people living within its limits at present have a quite low standard of livelihood. The needs for development are obvious, and potentialities clearly exist. It is not surprising, therefore, that for a number of years considerable interest has been shown in the possibilities of developing both irrigation and hydro-electric power. In 1960 the Imperial Ethiopian Government asked for the help of the United Nations Special Fund in appraising the resources of the basin in land and water, and their potential development for these purposes. The Food and Agriculture Organisation was designated as Executing Agency. The Plan of Operation was signed by the three parties on February 7, 1961, and authorisation to begin operations was given on February 21, 1961.

The Awash Basin in relation to the rest of Ethiopia is shown on Fig. 1 - General Map.

2. Terms of Reference

The Project was specified to include the following:

(i) Survey of water resources, based on hydrological and meteorological observations.

(ii) Studies of possibilities of water control by storage and otherwise, and preparation of a water management plan, taking into account the requirements of irrigation and hydro-electric power.

(iii) Soil surveys and land classification according to suitability for irrigation:

- (a) On reconnaissance standard over about 500,000 ha of agricultural land and about 200,000 ha of grazing land.
- (b) On semi-detailed standard over selected areas totalling some 100,000 ha and on detailed standard over areas totalling some 20,000 ha, for pilot schemes.

(iv) Geological and engineering studies of potential dam sites, with outline designs and estimates.

(v) Survey of erosion and sedimentation.

(vi) Agronomic studies of land use, present and future.

(vii) Aerial photography over some 30,000 km^2, and contour mapping, particularly of potential reservoir areas.

(viii) Training of Ethiopian counterpart staff.

Neither economic nor sociological investigations were included in the original Terms of Reference. However, preliminary economic appraisals of potential developments were ultimately made, and are briefly described in this Report.

The Plan of Operation, and the subsequent amendments thereof, are attached as Appendix No. 1 to this Volume.

3. Arrangements for Execution

The Plan of Operation specified that the project should be executed by sub-contract. The following contracts were let:

(i) On February 23, 1961 to Hunting Surveys Ltd., London, for the aerial photography required.

(ii) On July 13, 1961 to SOGREAH (Societé Grenobloise d'Etudes et d'Applications Hydrauliques), Grenoble, for the provision of specialist staff and the execution of the main work of the survey.

(iii) On September 13, 1962 to Ing. Giovanni Rodio S.A. Milano for test borings on the sites of prospective dams.

The Project Manager, Mr. M. Reklewski, was appointed on August 10, 1961 and arrived at Adis Abeba, his duty station, on August 13. 1961. The following staff from FAO served as Administrative Officers:

Mr. Ch. de Beck Lambly	December 3, 1961 - June 30, 1963
Mr. K. Danillowicz	July 1, 1963 - June 30, 1964
Mr. G. Abolafio	July 1, 1964 - December 31, 1964

Field Operations for aerial surveys were supervised by Mr. H. Williams, chief of Hunting Surveys office in Nairobi. Processing and preparation of mosaics were done in Hunting Survey's office in Great Britain.

The main part of the general work of the survey was done by SOGREAH in the field and at their headquarters in Grenoble, under the direction of Mr. P.M. Lafont, Water Planning and Irrigation Engineer. The names and services of the specialists provided by SOGREAH are shown on page 5.

The interpretation of the results of the test borings made by G. Rodio S.A. was the responsibility of specialists of SOGREAH.

In September-December 1964, Special Fund sent two consultants to ascertain in close collaboration with the Project Manager the economic feasibility of the development schemes recommended as the result of the technical studies. These were:

Dr. L.G. Allbaugh
Mr. R.M. Arbuckle

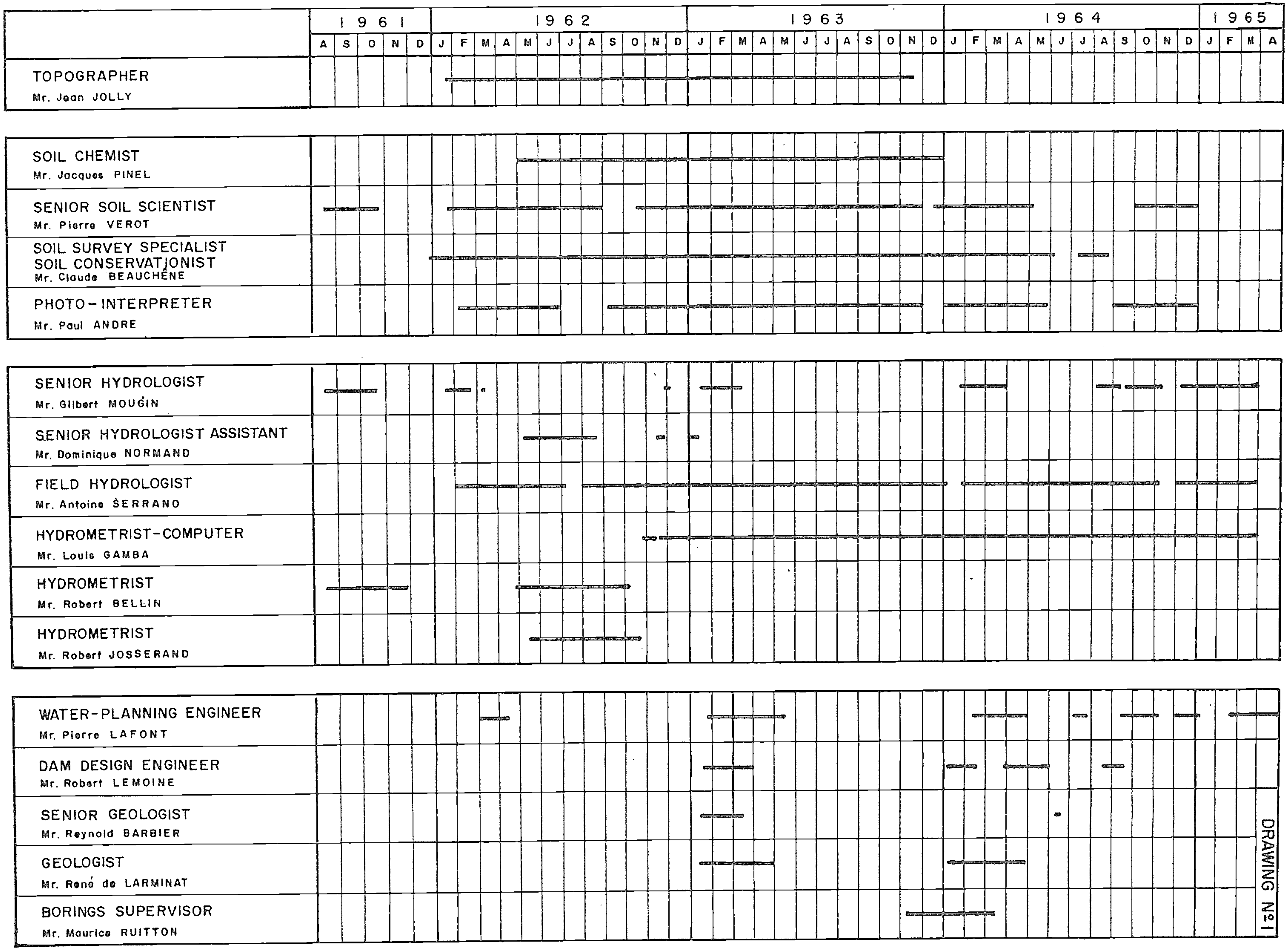
Government Counterpart staff, provided through the Awash Valley Authority, were under the control of the Co-Managers, as follows :

H.E. Dr. Haile Georghis	August 1961 - April 1962
Ato Getachew Wolde Emmanuel	April 1962 - December 1964

Other counterpart staff included:

4 Soils and agricultural technicians.
5 Hydrological technicians.
1 Surveyor and 3 assistant surveyors.
1 Draftsman.
12 Assistant hydrometrists and computers.
109 Observers for hydrological and meteorological stations.
8 Clerical staff.
1 Mechanic and 14 Drivers.
6 Watchmen.

TIME TABLE OF EXPERTS ASSIGNMENTS



4. Modification of Plan of Operation

After preliminary reconnaissances in August and September 1961, and subsequent discussions between Government, FAO, and Special Fund, it was agreed that to cover increases required in aerial photography and in the number of river gauging stations, the provision of access tracks to remote sites, the making of exploratory borings, to investigate foundation conditions at potential dam sites, etc., the contribution of the Special Fund should be increased by US $ 90,000, and that of Government by US $ 50,000. The necessary amendment to the Plan of Operation was signed in September 1962.

Subsequently it was agreed that prospective savings on counterpart staff could be used to meet increased expenditure on the running and maintenance of vehicles, and certain other local costs.

5. Summary of Field Work. The following facts and figures indicate the nature and scope of the work done in the field:

(i) Access and Communications. 240 Km. of tracks and 2 bridges were built, and 2 ferry boats installed. 5 airstrips were prepared and 2 existing strips were repaired. 4 radio telephone sets were installed.

(ii) Installations. Headquarters for the project, with store and workshop was arranged. 2 field bases with offices and living quarters were set up, and 6 field shelters. A soil and water laboratory was installed at the Forestry Institute of the Haile Selassie I University. 30 river gauging stations, 8 meteorological stations, and 95 raingauges were installed and put into use.

(iii) Transport. 1,760,000 Km. in all were run by 19 vehicles under the project, at an average cost of US $ 0.07 per Km. 272 hours were flown by hired aircraft, planes and helicopters.

(iv) Aerial Photography. This was completed in two periods, in May and November 1961. Mosaics were made available by May 1962.

(v) Soil Survey. When modification of the Plan of Operation was under discussion in March 1962, it was agreed that in place of the 20,000 ha of detailed soil survey specified therein, an additional 50,000 ha should be surveyed on semi-detailed standard, to bring the total to 150,000 ha. Field work on soils was completed by July 1963, and two interim reports, on the areas suitable for irrigation in the Middle Valley and in the Lower Plains, were submitted in September 1963.

(vi) Hydrology and Climatology. About 2,500 flow measurements were made, about 2,200 water samples were tested for silt content. The great part of the hydrometric and climatological network was made operational in the course of 1962. Regular observations were made during 1962/63 and 1963/64 hydrological cycles and lasted till October 31st 1964. A programme for continuation of recording was prepared and submitted to Awash Valley Authority.

(vii) Appraisal of river hydraulics in the Delta area. Because of very high cost of establishing gauging stations in the deltaic section of the river and as detailed topographical works would have been needed for any meaningful hydrological studies in these regions, it was decided - in March 1962 - to exclude the unstable river section from the programme of systematic flow measurements. At the same time it was decided to proceed to an expert appraisal of river's behaviour in the Delta area. The appraisal was carried out in March 1963 and the relevant report submitted to the Government in September 1963.

(viii) Test Borings. These were made at the prospective sites for Kesem and Tendaho Dams between November 1963 and March 1964, in accordance with the recommendations of the geologist.

(ix) Health Conditions. These, with special regard to bilharziasis, were investigated in 1964 by specialists from W.H.O. and by Dr. Aklilu-Lemma, parasitologist in the Haile Selassie I University.

Field operations ended on October 31, 1964, and the Project Manager left Ethiopia on December 15, 1964 to take part with the sub-contractors in the preparation of the Final Report at Grenoble and F.A.O. headquarters in Rome.

6. Follow-up Project.

In April 1964, the Government approached Special Fund about a possible follow-up project, for the preparation of irrigation layouts and dam designs in the Awash Basin. Government also asked for an appraisal of the economic feasibility of schemes proposed as a result of the survey. To this the Special Fund agreed, and the appraisal was made in September-December 1964; it should be noted that for this incomplete figures of estimated costs had to be used, which later in some cases had to be revised. The formal request for a follow-up project was submitted by Government to Special Fund in November 1964.

Subsequently it was agreed between the Government and the Special Fund, that the reinforcement of the Authority responsible for development of the Awash River Basin was necessary before the initiation of a second phase of surveys. In 1965 an Interim Project aimed at Assistance in the strengthening of the Awash Valley Authority was approved.

7. Training and Fellowships.

Although no specific provisions for fellowships had been made in the Plan of Operation, it was found possible, with the help of SOGREAH, to arrange for 6 scholarships of 6 months each, under the bilateral cooperation scheme of the French Government. 6 technicians, 3 in soils and 3 in hydrology, received training at Grenoble.

An important part of the Project was in-service training for Government counterpart staff, in soil survey, and laboratory work, hydrology and climatology, topographical survey and photo-interpretation. It was not in all cases possible to recruit suitable qualified trainees in sufficient numbers.

8. Final Report.

The Final Report as now presented by F.A.O. consists of the following volumes:

Volume I	General Report
Volume II	Soils and Agronomy
Volume III	Hydrology and Climatology
Volume IV	Water Storage and Power Development
Volume V	Irrigation and Water Planning.

9. Acknowledgements.

Grateful acknowledgement is made of the help and cooperation received from many branches and officials of the Government and other authorities, as well as from firms and private individuals. In particular, collaboration from the following Departments and Institutes was appreciated:

Ministry of Agriculture, particularly the Statistic Department, Animal Husbandry Department (Mission Vétérinaire Française), and Research Department.
Ministry of Public Works and Communications, particularly Water Resources Department.
Imperial Highways Authority
Imperial Ethiopian Mapping and Geography Institute
Ethiopian Electric Light and Power Authority
Central Statistical Office
Haile Selassie I University (Forestry Institute)
Institut Pasteur d'Ethiopie
Civil Aviation Department (National Meteorological Department)
Ethiopian Airlines
Chemin de Fer Franco-Ethiopien
Provincial Governors and officers, Police etc.

10. Place Names.

The spelling of place names used in this Report follows wherever possible that introduced recently by the Imperial Institute of Mapping and Geography. This in some cases may differ from the spelling hitherto commonly used, but no difficulties should arise, because the differences are not large.

CHAPTER II - SUMMARY OF MAIN CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Description.

See Figs Nos. 1, 2, 5, 6, 8, 14, and Chapter III. The Awash Basin, in area some 70,000 km^2, lies between the latitudes of 8° N and 12° N, on the southern and eastern sides of the central plateau of Ethiopia. The greater part of the Basin lies geologically within the Great Rift Valley. In elevation the Basin ranges from 3,000 m to 250 m above sea level. Its lower parts open out to the North and East, towards the Red Sea, but the river does not reach the sea, ending in the large depression of Lake Abe, where its remaining waters are lost by evaporation and seepage.

The Basin may conveniently be described as consisting of the following parts :

The Upper Basin from the headwaters down to Koka dam.
The Upper Valley, from the Koka dam to Metehara.
The Middle Valley, from Metehara to Tendaho.
The Lower Plains, from Tendaho to Lake Abe.

The Basin includes the capital of Ethiopia, Adis Abeba, with a population of about 450,000, and several other towns, all relatively much smaller. On the plateau and in the Upper Valley the people are mostly Christian; outside the towns they are largely agricultural, with a proportion engaged in commerce and, recently, in industry. The rest of the Basin, including all the lower lands, is relatively thinly populated, mostly by Moslem tribes, largely nomadic and pastoralists.

There pass through or across the Basin, the railway between Adis Abeba and the port of Djibouti and, further north, the main road from Adis Abeba to the port of Aseb and Asmera. A new main road from Adis Abeba to Aseb is projected, and this would probably be aligned down the right bank of the Awash, at least beyond Awash station on the railway; if so, it would pass near to potential areas of irrigation in the Basin, and would greatly facilitate their development. (See Figs 1 and 5).

2. Existing Land Use.

On the plateau lands and in the Upper Valley, large tracks of lands of good quality are already cultivated with rain-grown crops. In the Upper Valley are also some areas under irrigation, notably the plantation of 6,000 ha at Wenji, growing sugarcane. In the Middle Valley are irrigated areas totalling some 1500 ha, and in the Lower Plains, cotton plantations totalling some 4,500 ha at Dubti and Dit Bahri are under irrigation, with several thousand ha in Asayita delta used to grow crops after natural flooding. (See also Figs 14).

3. Resources of Land.

The Upper Valley offers relatively little additional land for development, beyond that now cultivated. Elsewhere in the Basin, as the result of reconnaissance soil survey over some 2 million ha, followed by a semi-detailed soil survey on selected area totalling some 502,000 ha, the lands were classified according to their suitability for irrigation, in the following classes :

Class I	Good irrigable land.
Class II	Moderately good irrigable land.
Class III	Marginal irrigable land.
Class IV	Land unsuitable for irrigation, except under special conditions.
Class V	Land of which the suitability for irrigation is undetermined.
Class VI	Land permanently unsuitable for irrigation.

See Fig. No. 6.

Of the 502,000 ha covered by the semi-detailed survey, the classification was as follows :

Land Classification

Class	Middle Valley (ha)	Lower Plains (ha)	Totals (ha)	%
I	-	-	-	-
II	56,600	30,000	86,600	17
III	58,000	39,000	97,000	19
IV	40,100	33,000	73,100	15
V	9,900	15,000	24,900	5
VI	97,400	123,000	220,400	44
	262,000	240,000	502,000	100

Thus there are 183,600 ha of lands in Classes II and III; in addition, some lands mainly in the Lower Plains placed in Class IV because of liability to flooding are also worthy of development, if effective control of the flooding is provided. It is safe to say that some 200,000 ha of suitable land can be made available for irrigation. (See Figs 7 and 8 - in folder).

4. Resources of Water.

i) Climate. See Chapter VII.

(a) Rainfall. This is shown on Map No. 11 in the folder. Typical normal annual totals are as follows :

		Millimetres
Upper Basin -	above Koka Dam	1000
Middle Valley -	Koka to Hertale	850
Middle Valley -	Hertale to Tendaho	610
Lower Plains --	Tendaho to Lake Abe	215

There are two rainy seasons in the year, the lesser rains from March to May, and the main rains from July to September, which provide nearly 90% of the total annual run-off in the streams. The rainfall minimum in the two seasons, in June, is more pronounced in the drier northern part of the Basin. From October to February, hardly any rain falls.

Rainfalls vary widely from year to year in total amount; in general they may range from 50% to 150% of the mean figure. Individual rainstorms are usually fairly brief, and do not cover very large areas.

(b) Temperatures. Some ranges of temperatures which may occur are indicated by the following figures, observed during 1962-64 :

	°Centigrade	
	Maxima	Minima
Adis Abeba	28	6
Koka	34	7
Metehara	39	7
Gewani	42	8
Tendaho	46	6

Temperatures vary with the season, and also with altitude and aridity. In certain parts of the Basin, sheltered from South West winds, "Foehn" effects may raise the temperature locally.

(c) Winds. During the dry season from October to February, the prevailing winds are "anticyclone" winds, mainly from the North East. At other times of t the year, winds are variable in direction and strength, but in general the upper rain-bearing air currents come from the South West.

ii) Hydrology. See Chapter VII and Map No. 13.

Except for a few fairly long records, such as that for the gauge at Awash railway station, observations of river flows are available only for 1962-64. It has been possible to extend the period for some stations by correlation with longer records of rainfalls. In this way have been prepared estimates of flows at various points in the Basin, for a "normal" year. These estimates must however be taken as tentative and approximate, and subject to adjustment in the future, as more data of actual observations become available.

Flows from the Upper Valley are already regulated by the operation of Koka Reservoir (Lake Gelilea), so far primarily in order to generate hydro-electric power most effectively. Only since this reservoir came into operation in 1961 has the flow of the Awash become permanent throughout the year; previously it dried up in its lower course in the dry season. Subject to this regulation at Koka, the following are the resulting present estimated annual total flows at various points :

	hm^3
Inflow to Lake Gelilea	1895
less losses from reservoir (evaporation and leakage)	695
Outflow from Lake Gelilea	1200
Flow at Awash Station	2460
Flow at Hertale	2840
Flow at Dubti	3490

Some maximum rates of flood flows with probabilities of occurrence estimated to be less than once in 1000 years are expected to be as follows :

River	m^3/s
Awash at Koka	1050
Awash at Awash Station	1050
Awash at Melka Warar	1150
Awash at Hertale	850
Awash at Tendaho	1000
Kesem at Awora Melka	1400
Kebena	1300

Degradation by erosion is estimated to occur as follows :

	$Tons/km^2/year$
Steep eastern slopes of high plateau	1200
Gentler southern slopes of high plateau	850
Middle Valley - Koka to Gewani	150
Arid lowlands downstream of Gewani	850
North-western slopes of Chercher Mountains	400

Deposition of sediment occurs :

(a) In natural swamps and flooded areas
(b) In all storage reservoirs; ultimately, perhaps after centuries, any reservoir will silt up.

5. Prospective Land Use under Development. See Chapter VI and Figs 7 and 8 (in folder).

i) Areas. The areas suitable for development (land in Class II and III) are :

(a) In the Middle Valley 114,600 ha
(b) In the Lower Plains 69,000 ha

In the Middle Valley, on the whole, the lands are more suitable in type and somewhat better in quality. But the amounts of water available, even with control and storage, might not suffice for the irrigation of all the suitable lands in the Upper and Middle Valleys. In the Lower Plains, in contrast, more water could be made available than would be required for the irrigation of all the suitable lands.

ii) Costs and Returns. Because the development of irrigated agriculture is expensive, it must bring sufficiently high returns. This calls for cropping patterns as intensive as the prevailing conditions will allow, with, where possible, a suitable proportion of high-value crops.

iii) Crops. Agronomically, conditions in the Awash Basin are suitable for growing a wide range of crops, including fibres (and particularly cotton), oil seeds, pulses, cereals, sugar cane, vegetables, and fruits of many different sorts. Selection is likely to depend more on economic factors than on agronomic conditions. Animal husbandry should be combined with agriculture, and this will involve the inclusion of legumes and other forage crops in the rotations, both to feed the animals and as green manure to maintain the fertility of the land. Dairying is also to be encouraged.

iv) Rotations. These should not be finally determined without extensive and systematic experimentation. Meantime, for the assessment of possibilities, and for the preparation of suggestions for staged development, two tentative crop patterns have been assumed, as shown in Fig. No. 9 and 10.

(a) For lands in the Middle Valley intensity 1.75-2.0 crops a year
(b) For lands in the Lower Plains intensity 1.0 - 1.5 " " "

For both the period is four years; the main cash crop is cotton, on about 40% of the gross area.

v) Perennial Crops. Crops of this type, such as citrus and other tree fruits, bananas, etc. are not included in the typical rotations assumed, but may be grown on areas allotted for this purpose. It is suggested that :

(a) Doum palms now growing naturally may be replaced by date palms.
(b) Useful timber trees, e.g. eucalyptus and poplars, may be grown along the river, in replacement of existing woodlands of poor quality, or on other areas now flooded.

vi) Grazing. It may, or may not, be economically feasible to improve grazing lands by simple methods of irrigation. However this may be, the establishment of additional watering points for animals to drink at, and the control of flooding on grazing lands, will be beneficial.

vii) Water Requirements for Irrigation. These have been estimated to be as follows, on the assumed rotations :

	Cubic meters per hectare of commanded area												
Months	J	F	M	A	M	J	J	A	S	O	N	D	Year
Middle Valley	1645	1585	1195	1220	1940	2135	1140	770	1365	1020	955	1770	16,740
Lower Plains	845	875	880	705	285	1075	1935	1615	2075	2010	1590	1455	15,345

viii) Quality of Water. In quality, the waters of the Awash River are quite suitable for irrigation. But water from the saline springs and wells, or from lakes fed by saline springs, should not be used.

6. Water Control. See Chapter VIII and Fig. 14.

Because of the extremely wide range of variations in natural flows of the main river and its tributaries between the dry season and the season of rains, excess flows in the latter season cannot be used for irrigation, and in large measure must be wasted and lost, while in contrast, in the dry season there is serious shortage of water. Water control therefore aims at storing the excess flows in the flood season, until they can be used to supplement the natural flows in the dry season. This is to be done by storage reservoirs. The use of these will incidentally also reduce the peak rates of flood run-off, and thus reduce the extent to which lands alongside the river are exposed to the risk of being flooded. In addition to storage reservoirs, possibilities exist of increasing the supplies of water in the Upper Awash, by the diversion to Koka Reservoir of part of the flows of the Meki River in the adjoining catchment of Lake Ziway. The main criteria in selecting sites for storage reservoirs are :

(a) The prime purpose of storage is the supply and regulation of water for irrigation, with the generation of power as an important but secondary purpose :
(b) Storage of water should submerge cultivated lands as little as possible:
(c) Reservoirs should be reasonably near to the lands irrigable from them.

The projects for the supply and control of water on the Awash, existing or now proposed, may be summarized as follows :

i) Koka Reservoir - in use since 1961. Net available capacity 1,660 hm^3, Height of concrete dam 42 m. Primary purpose is the generation of power. Maximum rate of outflow through turbines 3.6 hm^3/day. Normal annual outflow about 1200 hm^3. Losses by evaporation about 315 hm^3/year, and by percolation about 380 hm^3/year. The last is serious, and calls for investigation to find a remedy. (See Fig. 14).

ii) Meki River Diversion. Proposed, if found feasible, to supply some 200 hm^3 annually via the Dubeta River into Lake Gelilea. This, if used only for irrigation, might suffice for about 40,000 ha. Further technical and economic investigation is necessary, including the effects of diversion on the catchment of the Lake Ziway. (See Fig. 15).

iii) Compensation Reservoir. If the Meki Diversion is not feasible, the outflows from Lake Gelilea, suited to power production, can be regulated so as to suit the requirements of irrigation, month by month, by a compensation reservoir, of capacity tentatively estimated at 50 hm^3. A site near Awash Station may be suitable to provide this, by a dam some 40 m in height. Investigations of this and other sites will be required.

If it can be arranged, after construction of hydro power plants on other rivers, that the releases of water from Lake Gelilea can be adjusted to suit irrigation requirements more nearly, it may not be necessary to construct a compensation reservoir. (See Fig. 14).

iv) Kesem Reservoir. Proposed to have a gross capacity of 370 hm^3, with a depth of water of 69 m. This would provide a usable amount sufficient to irrigate some 22,000 ha, and to generate about 52 GWh of power annually. Loss of water by evaporation would be about 35 hm^3 per year. Some test drilling of the foundation was done, and it appears that the site is suitable for a rockfill dam. Grouting to reduce losses by percolation would be necessary. (See Fig. 14)

v) Tendaho Reservoir. Proposed to have a gross capacity of 970 hm^3 with a depth of water of 32 m. This would provide a usable amount of water sufficient to irrigate some 70,000 ha, and to generate about 91 GWh of power annually. Loss of water by evaporation would be heavy, about 294 hm^3 annually. Some test drilling of the foundation was done, and it appears that here also a rockfill dam would be a suitable type. Grouting to reduce percolation losses would be necessary. (See Fig. 14)

vi) Power Stations. At Koka Dam, Awash I power station generates about 110 GWh annually. Further downstream, Awash II and Awash III stations are now under construction; they also will use the flows released from Lake Gelilea, and are expected to generate together some 364 GWh each year. Still further down, but still in the Upper Valley, Awash IV, of capacity similar to that of Awash II or Awash III, is in prospect. The ultimate possibilities of power generation may total some 950 GWh annually. (See Fig.14

7. Priorities in Planning Water Use. Se Chapter IX.

It is apparent that with the degree of control now provided by Koka Reservoir, the amounts of water available in an average year are enough to irrigate about 67,000 ha. in the whole Valley. Observations and investigations made so far indicate that, given sufficient additional water control by schemes now proposed, the amounts of water available in the conditions of a year like 1962-63 (taken as approximating to an average year) would suffice for some 200,000 ha. Because hydrological data so far are limited and incomplete, and taking into account the results of soil surveys and engineering investigations, it appears wise to reckon on a smaller figure. For the purposes of the present Report, the target is adopted of 163,250 ha., to include areas already under irrigation. Investigations of the implications of various combinations of schemes of water control, and of areas of irrigation possible with them in the different parts of the Valley, have brought out the following points:

i) The Middle Valley. This, with a better climate and better soils than the Lower Plains, is more suited to the development of intensive agriculture on commercial-type farms; yields per ha will be higher and benefits greater than elsewhere. No technical argument arises against development here. However, as will be shown later, development in certain parts, such as Kesem, will be relatively costly.

ii) In the Lower Plains, soils and climate are somewhat less favourable, and as a result, the range of types of crop patterns is less wide. In its present condition, much of the area is subject to flooding, and the numerous channels of the river are unstable. For these reasons, the expansion of systematic irrigation beyond a total of about 20,000 ha cannot be recommended until Tendaho Dam is built. Although the present development of systematic irrigation has been achieved largely by commercial estates, there is scope for, and demand for, smaller family-type farms. Prospective cultivators in sufficient numbers appear to be available. Communications to Aseb and to the high plateau are reasonable.

Taking into account all considerations, technical, economic, and social, it is proposed that development should proceed in all parts of the Valley, and notably in the Middle Valley and the Lower Plains, in three successive stages, as discussed in Chapter IX, and as there set out in Table 27, which for convenience is reproduced here.

TABLE 27 - PRESENT AND PROPOSED STAGES OF DEVELOPMENT

Stage	Water Control	Target Areas of Development			hectares
		Upper Valley	Middle Valley	Lower Plains	Totals
Present	Koka Reservoir only	6,650	1,550	16,100	24,300
First	Koka Reservoir only	12,000	19,500	31,900	63,400
Second	Koka Reservoir + Meki Diversion Scheme (or Compensation Reservoir) + Tendaho Reservoir.	12,000	50,850	51,300	114,150
Third	As second stage + Kesem Reservoir	12,000	84,950	66,300	163,250

See also Fig. 19.

It will be seen that Stage I, up to a total of some 63,000 ha, can be achieved with the water control now provided by Koka Reservoir. Stage II will involve the construction of either the Meki Diversion Scheme or the Compensation Reservoir, and of Tendaho Dam; it will then be possible to extend irrigation to a total of some 114,150 ha, of which about 51,000 ha would be in the Middle Valley and about the same amount in the Lower Plains. Stage III would involve the construction of the Kesem Dam; it would then be possible to extend the total to about 163,250 ha.

To ensure the orderly and effective progress of this development, the whole of it from the start should be carried through in accordance with a "master plan" which, flexible in application and in design of details, should ensure that nothing done in the earlier stages will be inconsistent with the most effective development of the later stages. This plan should be adjusted as soon as the necessary further surveys and investigations can be made.

8. The Development of Irrigation. See Chapter X.

In order to make the most advantageous use of the available water, the development of new areas should be planned to use the best available and most accessible lands, and on them to ensure the optimum combination of economy, effectiveness, and reliability in watering and in cultivation. Gravity irrigation is preferable wherever possible, though pumping may be more suitable in certain areas. In general, unlined canals are proposed, except where evidence indicates that percolation losses would be too heavy. Standardized layouts are proposed for canalisation and field plots. Drainage systems are proposed, expected to be sufficient to ensure that no area remains submerged by storms for more than 24 hours more often than once in two years. Where necessary, protection against flooding from the river or tributaries is to be given by dykes.

Particulars of the various individual schemes proposed to be included in the different stages of the programme are given in Chapter X. The areas of schemes, stage by stage, are summarized in Table 28 which, for convenience of reference, is repeated in page 14 of this Chapter. (See Fig. 19).

9. Estimates of Capital Costs. See Chapter XI.

The figures there given come under two main categories; (a) those for works of control and supply of water; and (b) those for works of irrigation development. The particulars are given in Chapter XI in Tables 29 to 32. These show clearly what classes of works are included in the estimates, and what are not. It should be noted that all estimates of capital costs include margins for contingencies, and for the costs of designing and supervision of construction. The figures for the main items may be summarized as follows :

TABLE 28 - PROPOSED DEVELOPMENT OF IRRIGATION BY PROJECTS AND STAGES

Projects	Present Area	First Stage		Second Stage		Third Stage	
		Additional	Total	Additional	Total	Additional	Total
UPPER VALLEY							
Wonji, Genet and others	6,600	0	6,600	0	6,600	0	6,600
Nuri, Eva	50	5,350	5,400	0	5,400	0	5,400
Total Upper Valley	6,650	5,350	12,000	0	12,000	0	12,000
MIDDLE VALLEY							
Abadir - Metehara	850	9,650	10,500	0	10,500	0	10,500
Kesem - Kebena	650	1,350	2,000	0	2,000	15,550	17,550
Melki Sedi	0	6,000	6,000	2,550	8,550	0	8,550
Amibara - Angelele	50	950	1,000	15,650	16,650	0	16,650
Bolhamo	0	0	0	2,500	2,500	6,400	8,900
Maro Gala	0	0	0	10,650	10,650	12,150	22,800
Total Middle Valley	1,550	17,950	19,500	31,350	50,850	34,100	84,950
LOWER PLAINS							
Dubti	4,000	5,050	9,050*	0	9,050	0	9,050
Small riverside areas	0	0	0	0	0	3,700	3,700
Dit Bahri	500	10,450	10,950*	5,400	16,350	0	16,350
Asayita Delta etc.	11,600	300	11,900	14,000	25,900	0	25,900
Old Awash	0	0	0	0	0	11,300	11,300
Total Lower Plains	16,100	15,800	31,900	19,400	51,300	15,000	66,300
GRAND TOTALS	24,300	39,100	63,400	50,750	114,150	49,100	163,250

* Total of 20,000 ha covers water rights granted to Tendaho Plantations Share Co. and outgrowers.

(a) Works for Control and Supply of Water

Item	Attributable to Irrigation E $	Attributable to Power E $	Totals	Remarks
Meki River Diversion	10,527,000	-	10,527,000	Very tentative and subject to revision.
Compensation Dam (alternative to Meki Div.) (1)	(10,000,000)	?	(10,000,000)	No estimate yet possible.
Kesem Dam	29,932,000	6,322,000	36,254,000	
Tendaho Dam	22,233,000	12,806,000	35,039,000	
Total	62,692,000	19,128,000	81,820,000	
Protection and River Training works in the Lower Plains	5,400,000		5,400,000	

(b) Works for Irrigation, Drainage and Flood Protection

Scheme	Hectares	Cost E $	E $/ha	Remarks
Middle Valley				
Abadir-Metehara	(10,500)	17,000,000	1702	Extrapolated figure
Kesem-Kebena	17,550	32,240,000	1837	
Melka-Sedi	8,550	15,382,000	1799	
Amibara-Angelele	16,650	30,376,000	1824	
Bolhamo	8,900	18,784,000	2110	
Maro-Gala	22,800	29,908,000	1312	
	84,950	143,690,000	1702	
Lower Plains				
Dit Bahri	16,350	28,272,000	1729	
Dubti	9,050	14,161,000	1564	6500 ha by gravity Rem. by pumping
Asayita Delta	25,900	30,185,000	1165	By pumping
Old Awash	11,300	12,951,000	1146	By pumping
Small Areas	3,700	4,310,000	1165	By pumping
	66,300	89,879,000	1356	

It is not yet possible to give estimates of the total investment regardless whether from public or private sources, required in each of the three proposed stages of development. But very tentatively, the following figures may indicate their order of magnitude exclusive of roads, farmsteads and farm machinery.

	Millions of E $
Stage I	66
Stage II	116
Stage III	105
Total for additional 139,000 ha as per table 28	287

(1) See para 7 above.

10. Economic Appraisals. See Chapter XI.

These appraisals were made by two consultants appointed by Special Fund, and their conclusions, based on interim data available at the time of their appraisal, may be briefly summarized as follows :

i) The proposed further development of irrigation, assumed to be some 150,000 ha additional to that now in hand, could have a benefit/cost ratio of 1.95:1, at an interest rate of 6%.

ii) In addition some 115 million Kwh of electric power could be generated, at 1/4 to 1/3 of the cost from the best alternative source.

iii) Control of floods would increase net incomes by about E.$. 100,000 annually.

iv) The gross value of the annual agriculture product of the project will be about E$ 181 million, with an increase of about E$ 60 millions over the present annual net gain.

v) The investment required both for initial investment and associated costs was expected to be in the order of E$ 430 million. Using the cost figures of the finally revised estimates, the total investment required for the overall project remains at the same magnitude, although some differencies appear in the estimates for the individual project areas.

vi) The projects are expected to provide 10,000 - 15,000 family farms, and employment for 25,000 - 30,000 workers.

vii) The survey and the economic appraisals are preliminary. Further detail soil and other surveys, and pre-investment studies and investigations will be necessary. Even so, it is believed that appraisals now made give a reasonably approximate assessments of the costs of developing the agricultural economy of the Awash Basin, that the estimates of costs are sufficient and that the estimates of annual yields are conservative. This conclusion is supported by comparison of interim and revised overall costs per hectare.

ix) While the Government of Ethiopia favours development of irrigation by large scale mechanised enterprises, socially there is a case for allotment of a proportion of the lands made available to small farmers, trained in irrigation by experience on the larger schemes.

x) Economically the Awash basin is well situated, between Adis Abeba and the Red Sea ports, with good communications to be still further improved by the new main road to Aseb down the right bank of the river.

xi) In the circumstances of the basin, a short term "crash" programme would not be appropriate. Programmes of carefully planned and selected projects, economically sound, spread over 10 to 25 years are what are wanted.

These conclusions and suggestions of the economic appraisal can be endorsed. Points to be noted, however, include the following :

(a) To achieve satisfactorily high rates of benefit-cost ratio, it is important to include in the cropping plan of each project a reasonable proportion of high-value crops, according to local conditions, in each case.

(b) In considering how schemes of irrigated agriculture should be operated, the implications of different methods and arrangements have to be taken into account. The financial benefit of commercial farms in most cases will exceed those of family farms. But the social advantages of the latter may be outweigh their financial inferiority.

(c) The revenues from developing high yielding areas at an early stage, may be used to create a "revolving fund" available for the subsequent development of less profitable areas. But care is necessary to avoid "skimming the cream".

B. RECOMMENDATIONS

11. The paragraphs which follow set out the Main Recommendations now made as a result of the Survey.

12. Hydrology

The recording and interpretation of data from weather stations, and of flows, water levels, and sediment loads at river gauging stations, should be continued without interruption, and extended to new stations wherever required. See page 65.

13. River Control and Training

Studies should be made of methods of reducing losses in swamps and flooded areas, and of stabilizing river channels in the Lower Plains, and early action should be taken accordingly. In particular, efforts should be made to prevent obstruction of the river channels in the Delta of the Awash, which might lead to the diversion of much or all of the flow from the areas under cultivation. The closing off of the head of the Isa branch of the river, and the cutting-off of the "neck" of the meander at that point, is recommended as a provisional measure, to be executed, however, under expert supervision. See pages 73 and 95.

14. Soil Surveys

Detailed soil surveys should be made for every irrigation project proposed, preferably on a continuing program, and certainly in each individual case before the final layout of canalisation and drainage is prepared. See pages 104 and 109.

15. Agronomic Studies

Experimental Stations for applied agricultural research should be set up in the Middle Valley and the Lower Plains. The work in these stations should cover all types of farm crops, vegetables, fruit trees and date palms, and timber plantations. Types of crops, cultural methods, prospective yields, and prices and marketing problems should all be studied. See page 50.

16. Cropping Patterns and Rotations

Because the development of irrigated agriculture is relatively expensive, it should bring returns sufficient to justify its cost. Cropping patterns should be investigated and selected with this consideration in mind. In general it implies a pattern as intensive as is compatible with the conditions, including double cropping where feasible. But before conclusions are reached, all factors should be considered, including soils, climate, cultivators, management both technical and economic, yields and prices, communications and markets etc. In order to combine animal husbandry with agriculture, legumes and other green crops should be grown, to provide fedder as well as green manure. This will also make possible the development of dairying.

Rotations should not be finally determined without extensive and systematic research. Perennial crops, including citrus and fruit trees, dates, timber plantations, etc. may be grown outside the rotation areas. See pages 50 - 55.

17. Regulation of High-value Crops

This factor calls for special consideration in the study of cropping patterns. The extent to which crops of high value (e.g. sugar-cane, fruits, vegetables) can be included in cropping patters significantly affects their benefit-cost ratios. But the scope for marketing such crops, whether within or outside of Ethiopia, is limited. Therefore their inclusion should be carefully controlled, both in extent and in location, in the national interest. For example, a suitable proportion of such crops in the pattern may justify development in an area of marginal quality. The question of whether regulations, or even special legislation, are required, calls for particular study. See pages 52 and 111.

18. Fertilisers

Trials of the effects of fertilizers were not specifically scheduled under the Project, but these effects should be fully taken into account in planning future agricultural research, in assessing the yields and revenues to be expected, and the economic feasibilities of the various items of development in agriculture and irrigation now in prospect. See page 57.

19. Irrigation Practices and Water Requirements

The methods of irrigation and field layouts now used should be critically examined with a view to developing improved practices. The extent of the need for and the cost of land levelling should be further studied. The water requirements of the various crops, in the various possible conditions of climate and soils, should be tested. See pages 56 and 98.

20. Irrigation Design and Layout

To make the best use of available water, the development of new areas should be planned so as to use the best and most accessible lands, and on them to ensure the optimum combination of economy, effectiveness, and reliability, in watering and in cultivation. Irrigation by gravity-flow should be used wherever possible; however in certain areas and conditions irrigation supplied by pumps will be preferable. Standardised designs and layouts for canalisation and water distribution should be evolved and applied. Adequate drainage should be provided and, where necessary, protection for lands exposed to flooding from the river or its tributaries should be given by means of dykes. See pages 98 and 99.

21. Water Control by Storage Reservoirs.

Detailed studies of technical and economic feasibility should be made for the various schemes of water control proposed. In the first place the Meki Diversion Scheme should be studied, including its effects on the Lake Ziway catchment, and on all aspects of control at Koka Reservoir, including power development, losses by evaporation, losses by percolation etc. At the same time, the scheme for Tendaho Storage Reservoir should be further investigated. If the Meki Diversion Scheme is not in all respects feasible and desirable, the possibility of constructing instead a Compensation Reservoir on the Awash River upstream of Awash Station, to adjust the flows resulting from control for power production so as to suit the requirements of irrigation, should be investigated. Later, the scheme for the Kesem Storage Reservoir should be further investigated. In all cases, every relevant aspect of the conditions should be thoroughly studied, particularly the question of foundations, by thorough geological examinations, including drilled borings and test pits as necessary. See pages 74 - 92.

22. Power.

The potentialities of generating power, at all points from the Upper Valley down to Tendaho, should be further investigated, and their technical and economic feasibilities assessed. The use and marketing of power should also be studied, including its allocation for pump irrigation where required and feasible, and its sale for other purposes, with the costs, charges, revenues, and economic assessments involved. See pages 80, 86 and 92.

23. Methods of Operating Irrigation Schemes

While the Government of Ethiopia in general favours the development of large mechanised agricultural enterprises, there is a case for the allotment of a proportion of the lands made available, to small farmers, trained in irrigation by experience on the larger schemes. The technical, economic, and other aspects of the various possible alternative arrangements should be studied. It is vitally necessary to ensure that every scheme will operate under an effective organisation of the direction of all the activities involved, technical, economic, and social. See pages 109 and 112.

24. Economic and Social Considerations and Priorities

While the preliminary estimates and economic appraisals made under the Project indicate clearly favourable prospects for development, further and more detailed soil and other surveys, pre-investment studies, and economic appraisals should be made, for all potential schemes now recommended, as soon as possible, and in any case before any item of development is finally planned for execution. The results of these further studies and appraisals will make possible adequate comparisons of the relative priorities of the various alternatives. See pages 93 and 109.

25. Phases and Programs of Development

On present information, it is recommended that development in all parts of the Basin should proceed steadily and simultaneously, in three successive phases, as set out in Table 27, which is reproduced on page 15. Priorities are important and should be carefully considered. A short-term program would not be appropriate; a program covering from 10 to 25 years, of carefully planned and selected schemes, economically sound, is what is required. The revenues from high-yielding areas developed at an early stage may be used later to finance the development of less profitable areas, by the use of a "revolving fund". But care must be taken not to "skim the cream" from the most promising areas first, without making suitable allocations of the resulting revenues. See pages 110 and 112.

26. Master Plan

To ensure orderly, effective, and economical progress in development, it should from the start be carried through in accordance with a "Master Plan" which, embracing the three phases mentioned above, should be laid down as soon as the further investigations of all kinds, recommended above, have made sufficient progress. This "Master Plan" should be flexible in application, and in design of details; it should be periodically reviewed and whenever necessary revised, in the light of further knowledge and experience. See pages 96 and 112.

27. Reclamation of Swamps

In conjunction with the studies of irrigation problems, the reclamation of swamps, for either grazing or agriculture, should be investigated, particularly the swamps in the Lower Plains and in the upper valley of the Borkena River. See page 114.

28. Improvement of Grazing Lands and Range Pastures

Investigations should be made of the extent to which surplus water can be spread on grazing lands and range pastures, with assessments of economic feasibility. The provision of drinking water supplies and watering points in all such lands, by all practicable means, should be similarly studied. In particular, the sinking of test wells in the Aleydegi Plain is recommended. See page 114.

29. Watershed Management

All problems of soil conservation in the upper parts of the Basin should be fully investigated, with a view to the application of adequate measures of control. Re-forestation should be actively promoted on sloping lands, particularly in the catchments of reservoirs for water control, with a view to reducing sediment loads brought down, and thus increasing the effective lives of these reservoirs. See pages 67, 114, and 115.

30. Health Studies

In view of the incidence of bilharziasis in the Awash Basin, particular care should be given to the studies of health problems and precautions against diseases, especially in the areas where the development of irrigation is proposed. See page 98.

31. Awash Valley Authority

To plan, direct, and control the manifold activities involved in the development of the Basin of the Awash the Imperial Government has set up the Awash Valley Authority. This, however, does not yet possess powers or resources, staffs or finances, commensurate with the magnitude and variety of the tasks with which it will have to deal, as summarised above. It is of urgent importance that immediate action be taken, by legislation, by staffing, by equipping, and by budgetary allocation, to remedy this situation. Otherwise, it is not possible to see how the potential benefits of the developments recommended in this Report, can be realised. The Authority may suitably be made responsible for carrying out all the varied surveys, studies, and appraisals recommended; for preparing on them as a basis the "Master Plan" to be approved by the Imperial Government; for directing and supervising the implementation of this Plan, and in part at least, its actual execution; and finally for supervising the operation of schemes of development, to ensure their technical and economic effectiveness in the exploitation of lands and water, which are national assets. See page 113.

CHAPTER III - DESCRIPTION OF THE AWASH BASIN

1. Location and Extent of the Basin.

The situation of the Awash Basin in relation to the rest of Ethiopia is seen on Maps. Nos. 1 and 2. On some maps of Ethiopia, all the area lying between the catchment of the Webi Shebeli river to the south, the catchment of the Blue Nile to the west, the inland depressions of the Dankali desert to the north, and the border of French Somaliland to the east, is designated as the basin of the Awash, extending to some 120,000 km^2. Following the first reconnaissance flights, and examination of physiography, it was apparent that large parts of this area cannot be drained by the Awash. Large tracts of land near the border of French Somaliland are isolated by volcanic hills lying to the east of the Great Rift Valley, and numerous stream courses on the north-western slopes of the Chercher Mountains do not reach the Awash, but terminate in local depressions amongst the hills, where their waters evaporate. These indications were supported later by photo-interpretation, and although exact limits for the basin could not be rigidly defined on the maps, the survey was confined to the areas which certainly are effectively drained by the Awash river and its various tributaries, estimated to be about 70,000 km^2.

2. The River.

The highest sources of the Awash lie in a mountain range lying near the southern edge of the "High Plateau" of Ethiopia, some 150 km. west of the capital, Adis Abeba, at an altitude of about 3,000 m. above sea level. After flowing to the south-east for about 250 km., the river enters the Great Rift Valley, which it follows for the rest of its course, to where it ends in Lake Abe on the border with French Somaliland, at an altitude of about 250 m. The total length of the river is about 1,200 km. A longitudinal profile of its course is given in Fig. 3.

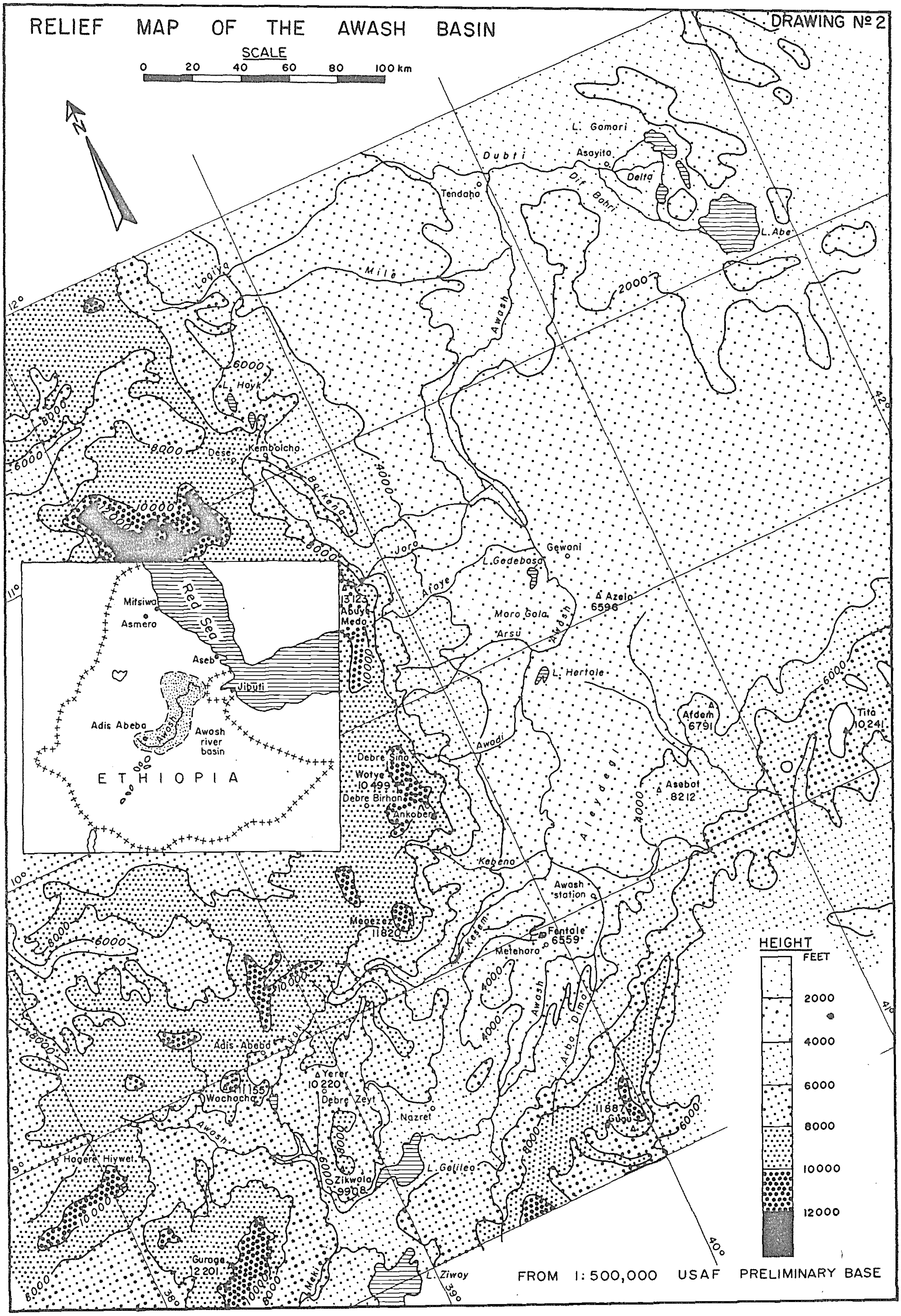
The Awash is the principal river of the Ethiopian section of the Great Rift Valley. Where it enters the Rift, at an altitude of some 1,500 m., it flows close to the watershed between its own basin and the internal basins of the Plateau of Lakes; indeed it is possible here to identify as a former Awash tributary a stream which now flows into Lake Ziway, the first lake of the series.

Pursuing its course to the east, the river runs across a series of geological faults associated with a sharp bend in the general direction of the Rift Valley, and then turns northwards, between the great faults which delineate its eastern and western sides.

For the purposes of the survey, the Basin may be described under the following sections:

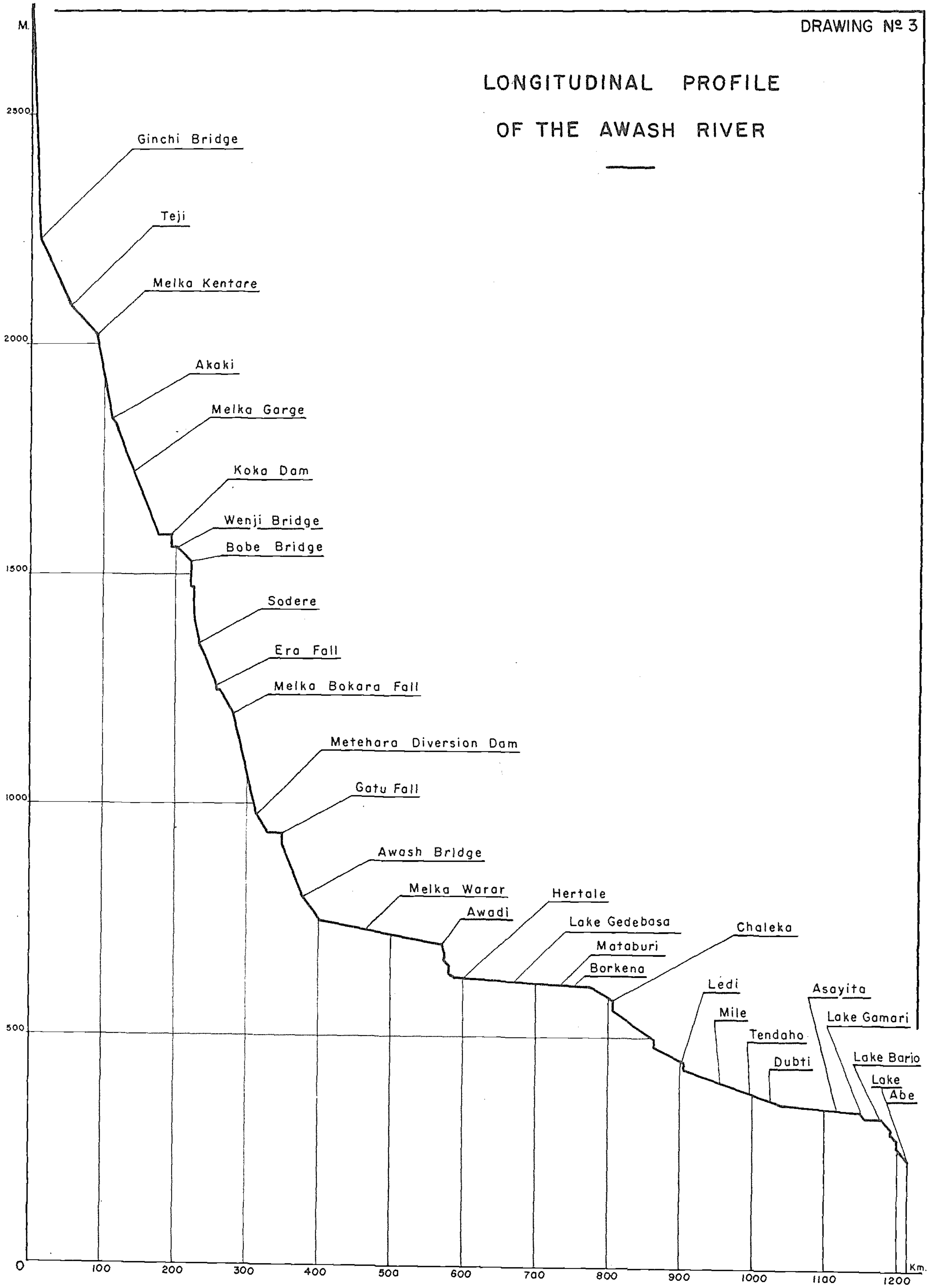
(i) Upper Valley comprising its course south-east and east down to the point where it turns northwards along the line of the Rift. In this section its average slope exceeds 6°/oo, and there are many waterfalls, some of which have been used for hydro-electric power. The length is about 300 km.

(ii) Middle Valley comprising the course northwards to a point downstream of the confluence of the Mile River, near Tendaho. In this section the general slope is less than 1°/oo; there are numerous rapids where the river crosses bars of igneous rocks, between which occur reaches of flood plain and swamp in places. The altitudes in the Middle Valley range from 1,000 m. at Metehara to about 500 m. at the rapids upstream the confluence of the Mile. The length of this section is about 650 km.


RELIEF MAP OF THE AWASH BASIN
DRAWING Nº 2
SCALE
0 20 40 60 80 100 km
N
L. Gomori
Dubti
Asayita
Delta
Dif Bahri
Tendaho
L. Abe
Logiya
Mile
Awash
2000
12°
6000
L. Hayk
8000
Dese
Kembolcho
Borkena
4000
10000
12000
Joro
Gewoni
L. Gedebosa
Afaye
Azelo 6596
Moro Gola
Arsu
L. Hertale
11°
13 123
Abuye Medo
Red Sea
Mitsiwa
Asmera
Aseb
Jibuti
Adis Abeba
Awash
Awash river basin
ETHIOPIA
Afdem 6791
Tita 10 241
Debre Sina
Wotye 10 499
Debre Birhan
Ankober
Asebot 8212
Aleydegi
Kebeno
10°
Awash station
Megezez 11820
Kesem
Fentale 6559
Metehoro
HEIGHT
FEET
2000
4000
6000
8000
10000
12000
Adis Abeba
Akaki
Yerer 10 220
11 155
Wochocha
Debre Zeyt
Nazret
Arba Dimo
11 887
Gugu
Hagere Hiywet
9°
L. Galilea
Zikwala 9908
Gurage 12 201
L. Ziway
Moke
38°
39°
40°
41°
42°
FROM 1:500,000 USAF PRELIMINARY BASE

DRAWING Nº 3

LONGITUDINAL PROFILE OF THE AWASH RIVER



(iii) Lower Plains. A short distance south of Tendaho occur a series of faults aligned generally north-west to south-east, which have caused the river to turn south-east wards across the alluvial plains. Its slope in this section is only about $0.3^{o}/oo$; its course is meandering, deltaic, and unstable; extensive areas are flooded, and changes of course often occur. Several lakes exist, of which the largest is Lake Abe, which receives the remaining flows. The length of this part of the course, to the entrance of Lake Abe, is about 250 km.

3. Physical Features

The section of the Great Rift Valley which comprises the Middle Valley and the Lower Plains resembles a wide open "V" facing the Red Sea. The arms of the "V" are on one side the eastern edge of the Ethiopian High Plateau, and on the other the northern edge of the Galla Plateau, marked by high peaks such as Abuya Meda, Wotye Meghezez, Yerer, Zikwala, Gurage, Gugu, and others. From both plateaux, the lands fall in series of steps, in many places high cliffs, on the lines of extensive faults. The basaltic rocks of the High Plateau have been deeply cut by numerous rivers, forming canyons. Along the main faults, more recent volcanic activity has covered waterborne deposits with new volcanic formations which, in turn, have again been eroded to form extensive cones and fans of debris below the slopes and cliffs. Numerous volcanic cones, distributed along the main faults, bear witness to this activity. Extensive areas have been covered with lavas, pumices, and tuffs.

In the lower parts of the Rift Valley, other recent volcanic activities have resulted in a number of hills, more or less isolated, of which some are perfectly shaped cones and others are heavily eroded. Their distribution, associated with the secondary faults, is generally west-east, i.e. more or less at right angles to the main faults. The resulting bars of volcanic formations have been cut through by the river, to form rapids, while in the hollows between them the river has deposited sediments. Large alluvial plains in the Middle Valley probably originated in this way. Further down, below Dabita Ale mountain, in another trough not yet completely filled up, are the extensive swamps of Gewani. Still further north the alluvial valley becomes narrow, less than 4 km. wide, and continues for about 100 km as a narrow marsh covered with trees and vegetation.

Near Tendaho village, the river has cut a gorge through a volcanic range, probably associated with a series of faults parallel with the main faults, i.e. north-south. Beyond this gorge begin the Lower Plains, which in this part were probably once covered by large lakes, which dried up after the river had cut for itself a final outlet through another recent volcanic range in the region of Asayita, towards its final outlet to lake Abe.

The most outstanding physical features of the basin are steep cliffs and slopes in a succession of steps from the heights of the plateaux to the plains, and the recent volcanic activities, still evidenced by a geyser and several mud-volcanoes in the Lower Plains. The alluvial soils likely to be suitable for irrigation are confined to separated regions; in respect of soils, as well as climate and hydrology, development can be considered in clearly defined units. The alluvial plains are reasonably large; in contrast to other Ethiopian rivers, they are not confined narrow strips along the course of the river, but extend to considerable widths, up to 20 km. or even more. Further, the trough of the river in general is only moderately deep, so that irrigation of the plains involves only relatively low diversion dams and feeder canals of moderate length to convey water to the irrigable areas. The Awash basin appears to be one of the few in Ethiopia where conditions are favourable for the development of irrigated agriculture at reasonable cost.

4. Hydrology Factors

On the maps and sketches made by early explorers, the Awash, in the middle and lower parts of its course, is described as an intermittent river. Carrying large flows in the rainy season, it used to dry up in the low season; this was due not only to the irregular incidence of rainfall, but also to the heavy losses caused by spill and evaporation in flood plains, swamps and lakes, and by seepage in permeable ground and, perhaps, faults.

Since the construction of the reservoir and hydro-electric station at Koka in the Upper Basin, the flows at that point have been largely controlled. On the average, the power plant can discharge about 40 m^3/sec. As a result, further downstream the areas flooded are reduced, and the losses by evaporation correspondingly diminished. It is thought that the large swamps of Gewani and Buri in the Middle Valley are steadily shrinking, or at least are flooded for shorter periods. It may also be, though it seems less probable, that the extent of flooding in the Lower Plains and particularly in the Delta is somewhat reduced. However this may be, it is clear that the Koka reservoir has significantly modified the hydrological regime of the river at that point. But this does not affect the flows of the tributaries which join further downstream. These, particularly the torrential left bank tributaries of the Middle Valley, are still liable to flood extensive areas, and refill lakes and swamps. The resulting losses are large, and call for special measures to reduce the waste. The low-lying alluvial lands are still exposed to inundation; flooding which occurred on the Lower Plains in August 1964 would have resulted in heavy damages had these lands been then fully developed for irrigation.

Further, as already mentioned, flood flows in the Lower Plains cause shifting of the course of the river; to prevent this, river training appears necessary. This may be difficult to achieve successfully, unless the flood flows from the tributaries are controlled by storage reservoirs, either on the tributaries themselves, or on the main river below their confluence with it.

Another natural factor of importance is the heavy erosion which occurs on the highlands in the upper reaches of the main river and the tributaries. According to the nature of the ground, this may be either sheet erosion, or rill and gully erosion, which latter may develop into its most spectacular form of deep ravines and canyons. Almost all the main tributaries of the Awash, particularly those descending from the eastern edge of the High Plateau, cross lands which are subject to severe erosion; their total area is estimated at over 20% of the total catchment. As the inevitable consequence of this erosion, the flood flows of the Awash carry heavy loads of sediment, which of course are deposited wherever the velocities of the flows are checked, in artificial reservoirs no less than in swamps and lakes. The implications of this factor are taken into account in the discussions of later chapters, particularly Chapters VI to IX.

On the High Plateau, ground water appears to be generally available, probably due to the occurrence of basaltic traps, and the generally horizontal formations of the geological beds. In the upper reaches of streams, there are many springs, rivulets flow throughout the year, and many shallow wells are found. Deep tube wells now being sunk on the gently sloping lands in the Upper Basin in most cases strike underground aquifers providing supplies which, though not abundant, seem sufficient for the domestic requirements of men and beasts.

5. Traditional Climatic Zones.

One of the major factors determining climatic conditions in the Awash Basin, as elsewhere in Ethiopia, is altitude. Ethiopian tradition identifies four major natural zones according to altitude, climate, and to some extent, natural vegetation.

These are described below.

(i) DEGA. This is the name given to tropical highlands above 2,500 m., with a cool and wet climate. Extensively cultivated, this zone was heavily deforested, and now carries very few trees, except a few remnants of former forests, and planted eucalyptus. A variety of crops are grown, including barley, wheat, flax, horsebeans and chickpeas, but the soils show signs of deficiencies in calcium and nitrogen. 7% of the Awash catchment lies in this zone.

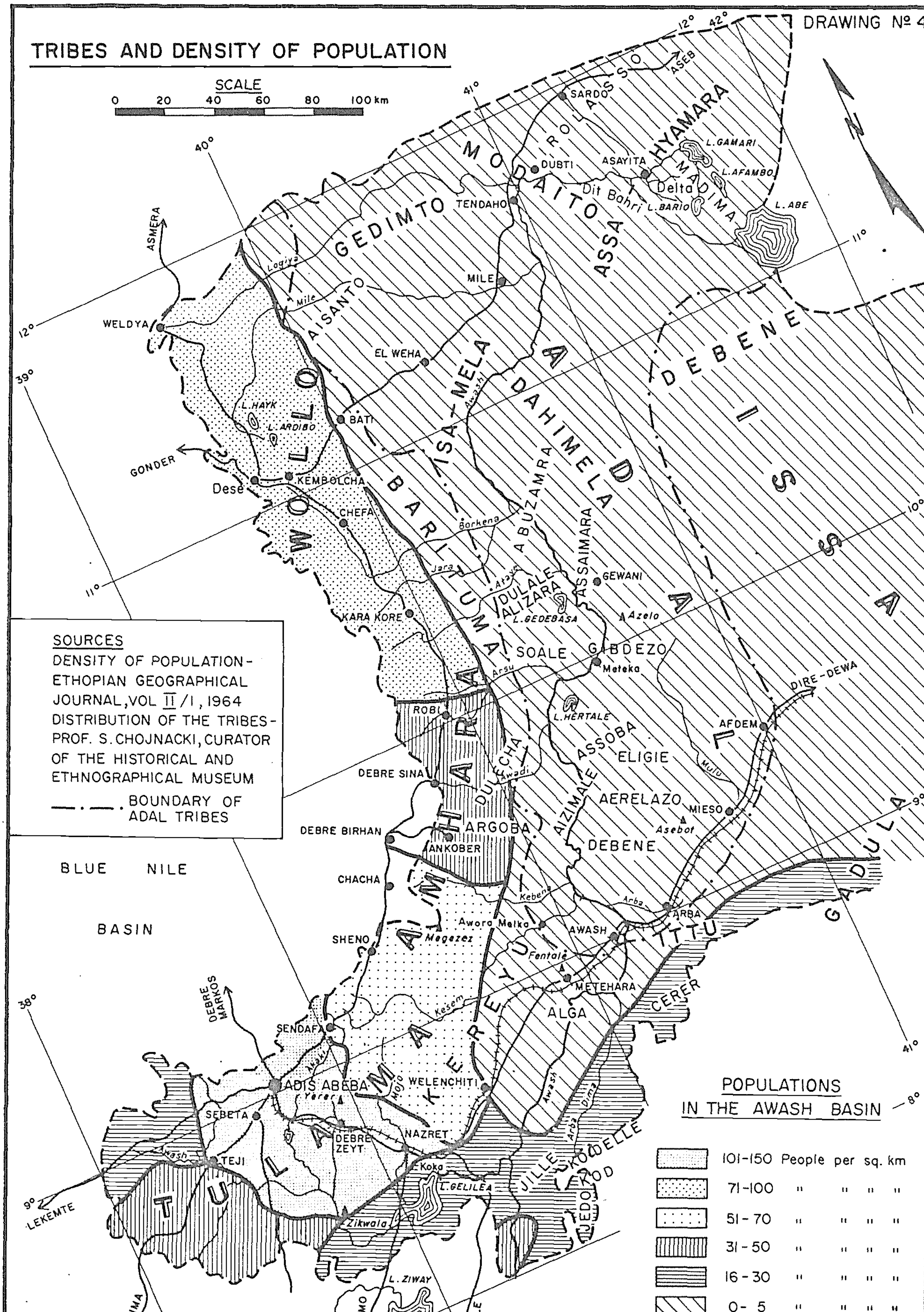
(ii) WOINA DEGA. This name is given to the tropical to sub-tropical plateaux at altitudes from 2,500 m. down to 1,800 m. The natural conditions in this zone are well suited to rain-grown agriculture. In the Awash Basin, this zone is at present the richest agriculturally, growing a wide range of crops, and producing surpluses for sale on local and export markets. 13% of the Awash catchment lies in this zone.

(iii) KOLLA. This covers the agricultural lands lying between 1,800 m. and 1,500 m. in altitude. There are significant differences in rainfalls between the deep mountainous valleys which receive abundant rains, and the more open lands on gentler slopes at similar altitudes. It is therefore convenient to divide the KOLLA into humid and dry tracts. In the humid valleys two crops each year can be raised on the very fertile black soils. In the dry tracts the agricultural settlement is less dense, and the rainfalls suffice for one crop only. Both food and cash crops are grown. 22% of the Awash basin lies in the KOLLA, of which 6% is in the humid valleys.

(iv) BEREHA. This name is given to semi-arid and sub-desert lowlands at altitudes below 1,500 m. It includes extensive grasslands and steppes, large tracts of rocky and hilly lands, and also alluvial plains with good deep soils, of which some are saline in varying degrees. Because the rainfall is too scanty, agriculture is not possible without irrigation. One of the particular objects of the Awash Basin survey was to assess the possibilities of developing the low lands. 58% of the Awash basin lies in this zone.

6. Population

The ethnic divisions and densities of population in the various parts of the Awash Basin are shown on Map No. 4. In general terms, the highlands are called Christian lands by the Muslim peoples who live at lower altitudes. They are settled by Amhara and Galla people who follow the Christian faith. The Upper Basin of the Awash is the borderland between these two most important ethnical groups. South-east of Adis Abeba the rural populations seem to be mainly of Galla origin, while those south-west of the city are from Guragi tribes. The Amhara people have settled mostly in the cities and towns. The industrial development of the Adis Abeba region has attracted many immigrants from the regions of Jima and Arusi to the S.W., and Tigre to the North. In the western highlands as far north as Debre Sina, Amhara people form the largest element in the population. Further north, the highlands and the mountainous valleys seem to be settled mostly by Gallas, and in the region of Dese by Wollo people. These descriptions can only be very approximate, since in fact there is considerable mingling of people of different ethnic origins.



DRAWING № 4
TRIBES AND DENSITY OF POPULATION
SCALE
0 20 40 60 80 100 km
SOURCES
DENSITY OF POPULATION - ETHOPIAN GEOGRAPHICAL JOURNAL, VOL II/1, 1964
DISTRIBUTION OF THE TRIBES - PROF. S. CHOJNACKI, CURATOR OF THE HISTORICAL AND ETHNOGRAPHICAL MUSEUM
BOUNDARY OF ADAL TRIBES
POPULATIONS IN THE AWASH BASIN
101-150 People per sq. km
71-100
51-70
31-50
16-30
0-5
BLUE NILE BASIN
ASMERA
WELDYA
GONDER
Dese
KEMBOLCHA
BATI
L. HAYK
L. ARDIBO
CHEFA
KARA KORE
ROBI
DEBRE SINA
DEBRE BIRHAN
ANKOBER
CHACHA
SHENO
SENDAFA
DEBRE MARKOS
ADIS ABEBA
SEBETA
TEJI
LEKEMTE
JIMA
DEBRE ZEYT
NAZRET
WELENCHITI
Koka
L. GELILEA
Zikwala
L. ZIWAY
SIDAMO
ASELE
Aworo Melka
Megezez
AWASH
METEHARA
Fentale
ARBA
MIESO
Asebot
AFDEM
DIRE-DEWA
Meteka
L. HERTALE
GEWANI
Azelo
L. GEDEBASA
EL WEHA
MILE
TENDAHO
DUBTI
SARDO
ASAYITA
ASEB
L. GAMARI
L. AFAMBO
L. BARIO
Delta
Dit Bahri
L. ABE
N
WOLLO
GEDIMTO
AISANTO
MODAITO
ROLASSO
HYAMARA
MADIMA
ASSA
ADAL
ISA
DEBENE
ISA-MELA
DAHIMELA
BARI
TUMA
ABUZAMRA
ASSAIMARA
DULALE
ALIZARA
SOALE
GIBDEZO
DULCHA
ASSOBA
ELIGIE
AIZIMALE
AERELAZO
DEBENE
ARGOBA
AMHARA
ITTU
GADULA
CERER
ALGA
KEREYU
TULAMA
JILLE
KOTTELLE
JEDO KOD
Awash
Mile
Logiya
Borkena
Jara
Ataye
Arsu
Awadi
Kesem
Kebena
Arba
Mulu
Mojo
Yerer
Dima

On the right bank in the southern part of the valley, Arusi people form a large element among both cultivators and shepherds; on the highlands population densities are fairly high, and some signs of overpopulation are evident. East of the Nazret region, the sedentary Galla cultivators are replaced by Galla pastoralists of the Kereyu tribes. These are the first of the nomads to be encountered in the lowlands of the Awash; beyond them are the Danakil, and further east, the Isa tribes. The Danakil, or Adal in the Amharic language, call themselves Afar; they occupy the largest part of the potential areas of irrigation development, and therefore they merit a short account of their way of life, the more so since they are still relatively little known to the ethnologists.

These nomadic peoples, of Semitic origin, are amongst the less developed tribes in Ethiopia. Their household utensils are primitive; pottery is almost unknown, and wicker baskets lined with clay and soot are used for milking and storage. Goatskins serve for churning butter and carrying water. Iron is used only for making spearheads and swords; iron tools are unknown. Houses are dome-shaped huts made of matting spread over bent sticks. Fires are little used, and most food is eaten uncooked. All work at home and with the animals is done by women, while the men, formerly only fighters, spend their time scouting for water and pastures. Their status as warriors is enhanced by the possession of rifles, for which they will pay high prices.

The social pattern and customary law of the Danakil are not yet well known, but in general the basic social unit appears to be a small group of kinsfolk living together. In the Middle Valley no one indigenous authority is generally recognised, except perhaps some kind of tribal leaders' council. In the Lower Plains, the successor of the former Sultan of the Aussa is regarded as the spiritual leader. In both areas, the authority of the central Government appears to be unchallenged.

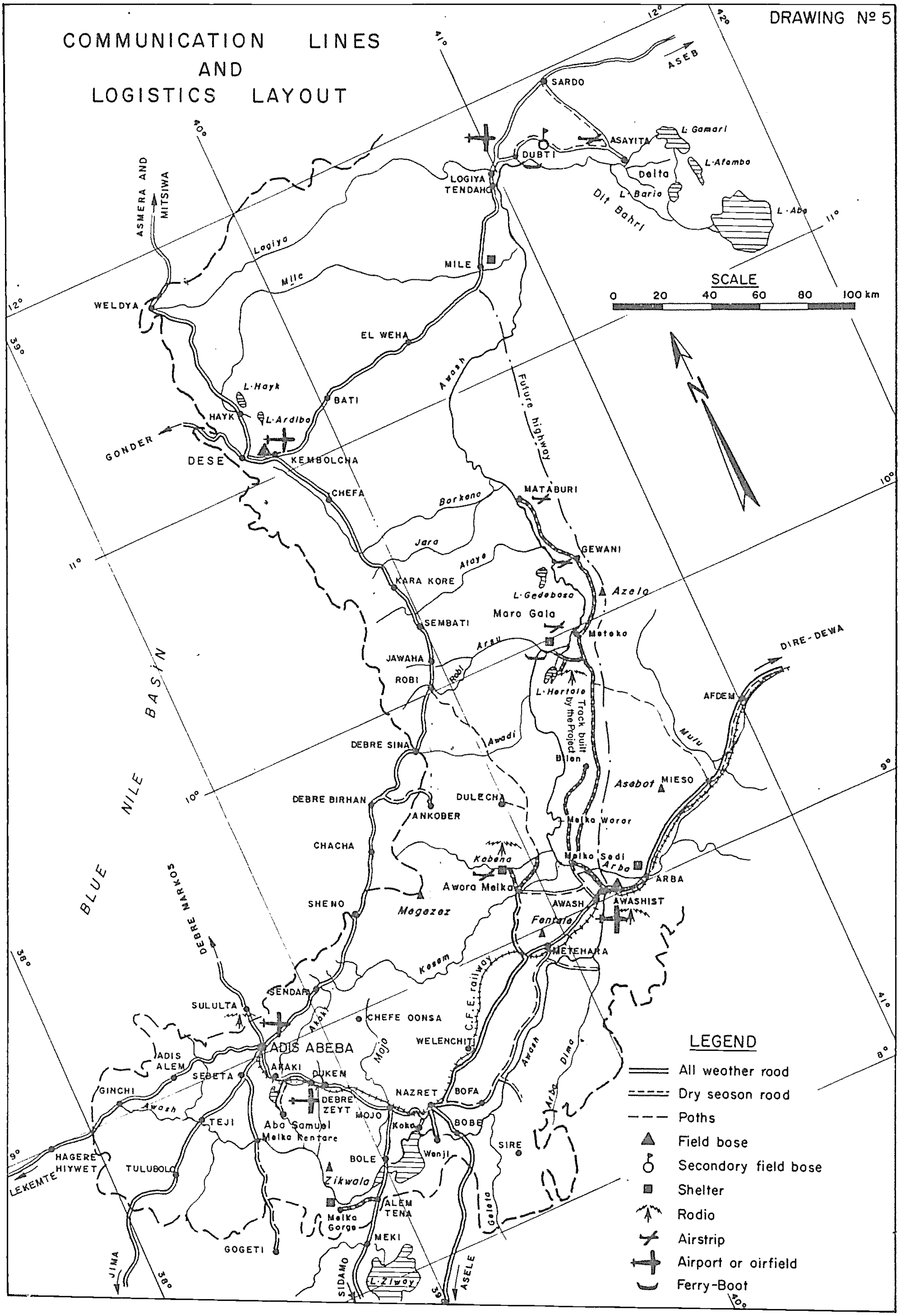
Strong feelings often arise between tribal groups, usually over grazing and water rights. Bloody battles between the Danakil and the Issa or the Kereyu are not uncommon.

In contrast with these primitive peoples of the lowlands, the agriculturists of Amhara or Galla origin, settled on the high plateau, are highly civilised people with a social organisation fairly well developed round the parish church and the local administration. Agricultural techniques are relatively advanced, in spite of the use of somewhat primitive implements. The Ethiopian peasant is hard-working and sturdy, and it is these people of the plateau, possibly from the over-populated areas in Tigre province, who offer one of the main fields for recruitment of settlers for the prospective areas of irrigation development. In contrast, the prospects of recruitment from the lowland tribes would appear to be limited, at least in the near future, particularly in view of the low densities of population and absence of land hunger. However, the introduction and settlement in lowland regions of "stranger" peoples of tribal origin and faith very different from the local nomads will raise social and economic problems, which will not be easily solved without much careful thinking in advance, and wise and patient administration.

The absolute and relative figures of population in the Upper Valley are hardly relevant to the present survey, since there is little scope there for further development. Elsewhere in the Awash Basin, only approximate estimates of the nomadic populations are as yet possible. It is thought that they may total anything from 50,000 to 100,000 people, of which perhaps some 25,000 to 30,000 are in the Lower Plains with Asayita delta as their centre, and the rest are in the Middle Valley.

7. Lines of communication

Principal lines of communication linking the capital to the sea ports run across the Awash Basin (see Map No. 5). With the new highway to be constructed shortly and which will follow approximately the right bank of the river, the main development areas will be provided with good communications both with Adis Abeba and the Red Sea ports.


DRAWING Nº 5
COMMUNICATION LINES AND LOGISTICS LAYOUT
SCALE
0 20 40 60 80 100 km
N
LEGEND
All weather road
Dry season road
Paths
Field base
Secondary field base
Shelter
Radio
Airstrip
Airport or airfield
Ferry-Boat
ASEB
SARDO
ASAYITA
L. Gamari
L. Afambo
DUBTI
LOGIYA
TENDAHO
Delta
L. Bario
Dit Bahri
L. Abe
ASMERA AND MITSIWA
WELDYA
Logiya
Mile
MILE
EL WEHA
BATI
L. Hayk
HAYK
L. Ardibo
GONDER
DESE
KEMBOLCHA
CHEFA
Awash
Future highway
MATABURI
Borkena
Jara
Ataye
KARA KORE
GEWANI
L. Gedebosa
Azelo
SEMBATI
Maro Gala
Meteka
JAWAHA
ROBI
Robi
L. Hertale
Track built by the Project
AFDEM
DIRE-DEWA
Mulu
DEBRE SINA
Awadi
Bilen
Asebot
MIESO
BLUE NILE BASIN
DEBRE BIRHAN
ANKOBER
DULECHA
Melka Woror
CHACHA
Kobena
Melka Sedi
Arba
Awora Melka
ARBA
AWASH
AWASHIST
SHENO
Megezez
Fentale
METEHARA
DEBRE MARKOS
Kesem
C.F.E. railway
SENDAFA
SULULTA
CHEFE DONSA
Akaki
ADIS ABEBA
Mojo
WELENCHITI
ADIS ALEM
ARAKI
DUKEN
SEBETA
GINCHI
DEBRE ZEYT
NAZRET
BOFA
Awash
Dima
Arba
TEJI
Aba Samuel
Melka Kentare
MOJO
Koka
BOBE
Wenji
SIRE
HAGERE HIYWET
LEKEMTE
TULUBOLO
BOLE
Zikwala
ALEM TENA
Melka Gorge
Gelela
GOGETI
MEKI
JIMA
SIDAMO
L. Ziway
ASELE

CHAPTER IV - OUTLINES OF EXISTING LAND USE

1. Patterns of Vegetation

A general map of land use was prepared on the basis of aerial photographs and then carefully checked during numerous field trips both by car and aircraft. The classification of natural vegetation adopted for this map follows as closely as possible that recommended by the Scientific Council for Africa South of the Sahara, and proposed for Ethiopia by Huffnagel in his book "Agriculture of Ethiopia". Table No. 1 shows the areas of the main types of land use in the Awash River Basin.

The large proportion of cropland, which may appear high when compared with the figures usually given for the country as a whole, is due to the fact that lands under long duration fallows, as well as actually cropped lands, are classified under this heading.

The delineation between different types of vegetation is not easy on small scale maps and its accuracy is necessarily approximate, particularly since the various types are in some cases closely intermingled and it is not uncommon to find a small patch of wooded savanna or open forest in the midst of a sub-desert steppe. Also the distinction between "shrub savanna" and"tree and shrub steppe" is unclear and is based mainly on the density of vegetation associated with the various types of soils. The common feature of all the lands covered by the natural vegetation, regardless of how thin and poor it might be, is that they are all used by the nomads as grazing lands wherever watering points are available at a reasonable distance one from another.

On the waste lands a very scanty vegetation may be just sufficient for nomadic herds when crossing the desert on treks between better grazing lands. But neither desert nor bad lands can permanently support even the most sparse settlement and its beasts.

2. Agriculture - General

There are pronounced differences between agriculture on the flat or gently rolling lands of the plateau, and that on the steep mountainous slopes. The former does not require skill and labour-consuming efforts for terrace building, contour bunding and other soil conservation measures: animal-drawn implements can easily be used for ploughing and cultivation. Also the yields on the level or gently rolling lands are believed to be appreciably higher than on sloping grounds, as the soils there are generally deeper. But there is no marked difference in the types of soils, and the cropping pattern depends more on the climatic conditions than on the configuration of the ground and the quality of the soils.

3. Crops.

The chief agricultural crops in the Awash catchment area are food or subsistence crops and very few industrial or cash crops are currently grown.

i) Cereals

Teff (Eragrostis Abyssinica) is one of the most important cereals grown in the surveyed area. It provides a staple food and is economically attractive because its price on the local markets is noticeably higher than that of other cereals. This is why the Ethiopian peasant gives his teff special treatment, plants it on his best land, carefully prepares the seed bed and weeds the crop. Yields may be over 10 quintals per hectare, and on the black soils in the Borkena Valley yields at over 20 q/ha have been recorded.

TABLE 1 - LAND USE IN THE AWASH RIVER BASIN

	AREA (km^2)			Percentage of the total area		
CROPLAND	18,850			26.9		
- Agricultural land on level or slightly undulating ground		11,700	11,700		16.7	16.7
- Agricultural land on sloping ground		6,850	6,850		9.8	9.8
- Irrigated agricultural land		300	300		0.4	0.4
LAND WITH NATURAL VEGETATION	43,250			61.8		
- Short grass savanna		3,900	3,900		5.6	5.6
- Woodland and bush		18,700			26.7	
: Dense forest (Mountain and riparian)			1,000			1.4
: Woodland and savanna			8,300			11.9
: Open woodland and bush			4,750			6.8
: Shrub savanna			4,650			6.6
- Tree and shrub steppe and subdesert steppe		19,900			28.4	
: Tree and shrub steppe			6,150			8.8
: Tree and shrub steppe with occasional trees			1,650			2.3
: Subdesert steppe			12,100			17.3
- Marshes		750	750		1.1	1.1
WASTE LAND	7,500			10.7		
- Desert		3,000	3,000		4.3	4.3
- Sand dunes		100	100		0.1	0.1
- Badlands		4,400	4,400		6.3	6.3
LAKES	400	400	400	0.6	0.6	0.6
	70,000 km^2			100%		

Barley comes next to Teff as the most important crop in the Awash River Basin. It is sturdy enough to be planted at high altitudes, up to 3000 m and more, and although it is not exactly brewery barley, it serves nevertheless to make a local beer "Tala." The yields may be as high as 15 q/ha.

Wheat grows at altitudes intermediary between those of Teff and Barley. The district of Debre Zeyt, which has a suitable altitude and climate is a big producer of Wheat, the yield ranging between 11 and 13 q/ha. The majority of industries which are engaged in the processing of wheat flour and its products are located in this neighbourhood.

Maize is grown in the Awash basin both as a rainfed and as an irrigated crop at lower altitudes, well below 2,100 metres. It is grown on a large scale in the Nazret plain, the Borkena valley and Asayita delta, as well as on a smaller scale on the rolling terrains of Bofa, Bati, Dese and the upper Mile. The yield ranges from 8-9 q/ha. Maize is used for making local beverage, and also eaten cooked or roasted.

Sorghum is grown very widely as a rainfed or irrigated crop throughout the agricultural regions of the Woina Dega, Kolla and Bereha, up to the altitudes of 2,500 metres. The best sorghum, however, is grown on lands of altitude around 1,800 metres. The Robi - Chefa - Kembolcha area, the rolling lands of Bati, upper Mile, Welenchiti, Asebot-Mieso, and the Asayita delta are well known for the production of sorghum, the yield being usually between 8 & 10 q/ha.

ii) Pulses are widely grown in the surveyed areas, sometimes as catch crops. Horsebeans and Guaya (vicia Sp) can withstand the highest altitudes; broad beans and chickpeas are often consumed green as vegetables; peas and lentils are grown on lower altitudes.

iii) Oilseeds harvested in the Awash basin are often grown for food. Edible oil is obtained from the following :

Noog called Niger in India (Guixotia Abyssinica Can.) is the most important oil crop, grown at altitudes between 1,800 and 2,500 metres, generally on poor wet soils. The average yield is very low, ranging from 4 to 5 q/ha. It has an oil content of more than 40% when properly pressed. Noog is grown in the Debre Zeyt, Teji and Sire areas of the Awash basin.

Sesame is an oil crop which is grown on a small scale in the Awash basin with irrigation, especially in the Bereha lowlands.

Linseed is grown at the higher altitudes of the Dega region as an oil crop, but not as a fibre crop. Linseed is mostly used for therapeutical purposes, for linseed oil meal or cake.

iv) Only a few Industrial Crops may be grown at altitudes where rainfed agriculture is still feasible. There are various spices currently used as local condiments, some of them being exportable, e.g. red pepper and onions. Fibre crops are ensete (Ensete Eduli), and cotton grown as a perennial shrub, but as the latter yields only 80-100 kg/ha of lint cotton, it is used mostly for home weaving. Under irrigation numerous gardens produce vegetables, fruits and sugar cane for home consumption, while marketable products come from large and medium scale irrigated farms, located at the lower altitudes (e.g. Wenji, Metehara, Awora-Melka, Dubti).

4. Agriculture in the highlands

Tillage is usually done with the local plough drawn by two bullocks or with the hoe by hand digging. Hand digging is practised where the land is too steep to use animal drawn ploughs or where holdings are too small.

When a careful preparation of land is needed, deep ploughing is also done by a hoe-like tool which has a handle with two points at the end, and a pair of conical-shaped sleeves attached to the points. This is mostly used to break virgin soils and is followed by ordinary ploughing, especially for ensete and eucalyptus planting.

Weeding and hoeing are done by hand, harvesting by sickle, threshing either by hand or by trampling with animals. Storage presents difficulties and losses from rodents and insects are estimated at 20%. Mud plastered wicker work store bins suspended off the ground, earthen jars or animal skins are mostly used to store small grains.

Irrigation is a necessity below 1500 m , whereas in the highlands only fruits and vegetables need artificial watering. In some rare cases, irrigation is practised to raise two crops yearly.

Soil burning - "denshering" - is popular with the Dega farmers on the high altitudes. Rotations adapted to the soil and climate conditions are generally practised. The rotations provide for fallowing which may be of various durations. Along with the short duration fallows of one or two years, the land may be left idle and grazed only for many years until the soil is believed to be regenerated.

Terracing, contour bunding and general soil conservation practices are widely developed only on the steep slopes, and in certain regions, e.g. in the northern parts of the river basin, appear to be highly efficient. Construction and maintenance work is carefully carried out, but the drainage facilities often appear insufficient. The agriculturists till not only the artificially levelled land, but any flat or even sloping plain land available, regardless of how inaccessible it may be. Thus, in many cases a handful of farms or even completely isolated fields are cultivated on table-shaped summits surrounded by ravines several hundred metres deep. Obviously such isolated farming is merely subsistence agriculture and it will always be backward. It is extremely difficult, indeed, to modernize and improve farming practices of the peasants living in such isolation. Even the administration of the country is seriously hampered by lack of access roads.

5. Agriculture in the lowlands

Irrigated agriculture has been developed mostly at altitudes below about 1000 m . Several modern irrigation schemes are operational in the lowlands. As well as a very modern and thriving sugar cane plantation at Wenji (which is located at more than 1500 m), the plantations at Metehara and Awora Melka bear witness to the potentialities of the Middle Valley. Several new projects have recently been started with good prospects that they will be developed in the near future. However, this development, although encouraging in its spontaneity, is characterized by a haphazard approach, and before it becomes too advanced, it is essential to plan for the best overall use of land and limited water resources.

In the Lower Plains Dubti, Dit Bahri, and Barga are developing into big cotton production centres. Besides the large scale concessionary plantation, there are increasing numbers family-size agricultural undertakings in the delta area of Asayita. Agriculture in this region is an old venture, probably several centuries old, developed by the once autonomous sultanate. Although probably some 10 to 15,000 ha are cultivated in the Asayita region, the farming practices are fairly primitive and the irrigation methods consist only of natural flooding; when the floods recede, the land is planted. In fact, water supply to the agriculturists in the delta area depends only on the hazards of floods from several branches of the Awash river, floods which are irregular and uncontrolled.

6. Land tenure and farming units

Figures collected from several sample surveys and from direct inquiries suggest that from 50 to 70% of the agricultural lands are farmed by tenants, on various forms of agreement with the landlords. Holdings are generally small on the better lands located in the valleys and at lower altitudes, the average area being between 0.8 and 2.0 ha. They are larger, up to 6-8 ha, at higher altitudes and on poorer lands. Yields are generally low and well reflect the rather obsolete farming methods. The value of agricultural implements used on the farms is estimated at about 9 E$ per holding. Agricultural revenues are also low, ranging from 130 to 250 E$ per holding, which works out a per capita revenue of 35 to 60 E$, as against an average Gross National Product at about 100 E$ (US$ 40).

Livestock population on the holdings is fairly important: Most peasants keep about 6 head of cattle, and a few goats and sheep. The animals graze mostly on the fallowing lands, but there is evidence of communal grazing lands in the mountains. Near the escarpment, it is said, peasants may use some of the adjacent slopes and ravines, where their livestock sometimes meet that of the nomadic pastoralists.

7. Livestock breeding

Livestock breeding is the main occupation of the lowlanders, where the climatic conditions, particularly the scarcity of rainfall, are too severe for agriculture. On the gentle slopes of the southern portion of the river basin there is no clear-cut boundary between the settler and the nomadic populations. Pastoralists are found in the vicinity of Lake Gelilea and in the open woodlands in the upper parts of the Great Rift Valley. But, rainfall being sufficient, and the temperature at the altitudes between 1500 and 1000 m still relatively cool, farming may also be found in that region. A noticeable extension of cultivated lands towards the lowlands as far down as Metehara has been observed in recent years. Glades are cleared in the open forest, woody savanna and the bush, and new farms start on the land which till now was merely grazed by the nomadic herds. This recent trend is probably related to the steady growth of settled population and may be regarded as the first symptoms of demographic pressure in this part of the country.

In contrast, on the eastern escarpment of the central plateau, where the slopes are very steep, agriculture stops abruptly at the limit of the higher rainfalls, and the pastoralists may graze their herds at the foot of the very hills on which the farmers are tilling their land.

8. Ranching methods

Livestock breeding on these more or less waterless lowlands is limited to the tracts within 20 to 25 km from watering points. These are principally permanent water courses, which are rather scarce, and several lakes apparently fed either by hot springs or by underground infiltrations from the Awash river. There are very few wells and water holes, but artificial ponds which store rainwater for a couple of weeks may be occasionally found where natural conditions are suitable.

TABLE 2. GRAZING POSSIBILITIES OF THE GRASSLANDS

Grassland corresponding to the sample No.	Grazing days per ha per animal in respect of		Daily intake of green grasses required to satisfy nutritive needs of one animal	
	Energy value U.F.	Digestible protein	Energy (kg/day)	Protein (kg/day)
1	145	75	21.0	40.0
2	120	75	24.0	37.0
3	40	20	17.5	33.0
4	45	45	18.5	20.0
5	85	30	20.0	60.0
6	100	110	18.0	16.5
7	45	70	14.5	10.0

The grazing rules and the wandering routes of the nomads are not well known, nevertheless it is believed that their treks may cover yearly as much as 200 km in each direction. The migration routes on the higher altitudes and on the gentler slopes of the southern valley are, however, shorter, and it would appear that in this region the pastoralists and their animals move only within a radius of 60 km.

A special case seems to be that of the Madima, the partially settled tribe living around the Asayita delta. There, it would appear, the herds are semi-sedentary, linked with the agricultural nucleus of the delta. Nevertheless, during exceptionally wet seasons, like that of 1964, the nomads wander far off to take advantage of abundant grasses.

9. Value of grasslands

As previously seen, more than 61% of the total river basin, i.e. about 43,000 km^2, are covered with natural vegetation, the lower undergrowth of which may provide pastures. But only 3,900 km^2, located mainly in the Middle Valley, are classified as fair to good grassland. Laboratory analysis proved that among these grasslands there are some relatively rich pastures which may support a fairly dense livestock population, e.g. one head of cattle per 4 hectares, and others much poorer where no less than 9 hectares are required to feed one beast. (See Table 2). In general, and this is a common feature with the natural pastures of Africa, the availability of digestible proteins is the governing factor.

Grasses growing on the wide tracts described under the heading of "wooded savanna" seem to be of (similar) reasonable quality; those growing on the "shrub savanna" and the steppes are less abundant and probably of lower nutritive value. It is believed realistic to admit that, taking into consideration the scarcity of watering facilities, the grazing lands in the Awash basin may support on the average one head of cattle on 15 to 20 hectares. The higher of these figures would appear to correspond to the present load on the pastures as, it is believed, the number of cattle grazing on in the Middle Valley and Lower Plains may be around 200,000 animals. It should be noted, that this number might probably be increased if more evenly distributed watering facilities were available. Also the livestock population may be substantially increased if along with improvement of drinking water supply, supplementary fodder resources from irrigated pastures are made available.

10. Living standards of nomadic tribes

No systematic investigation was carried out to assess the revenue of the pastoralists. In general it would appear that they are living outside the market economy and that their living standards are rather low. Their monetary revenue comes mainly from the selling of hides, and pays for purchases of clothing and a few cereals. Animals are very seldom sold. Milk and milk products are consumed by the shepherds and their families.

11. Production from the land

The foregoing brief discussion of problems related to land use and living standards in the Awash river basin leads to the conclusion that revenues from the land are low both in the high lands and the lowlands.

Extension of agricultural production is governed by the climatic conditions. The variety of crops grown on the highlands is limited by the altitude and practically no exportable and only few cash crops may be grown on a large scale, unless under irrigation and at lower altitudes. The contribution of livestock breeding in the Awash Valley to the national economy is almost non existent at present. Therefore, the development of agriculture and animal husbandry in the surveyed area appears likely to be primarily dependent on the development of land and water in the middle and lower reaches of the basin.

CHAPTER V - SOIL SURVEY AND LAND CLASSIFICATION

1. Soil Survey - General

The soil survey was carried out to achieve an inventory of development possibilities in the lowlands and, with relation to land use studies, to ascertain the production potentialities in the highlands. Fig. 6 shows the areas surveyed.

It was carried out in three successive phases :

A. General reconnaissance of the lands of the whole river basin. The results of this were mapped on a general map to the scale of 1:1,000,000 included in Vol. 2.

B. Reconnaissance soil survey of the lowlands to select potentiality irrigable areas on maps to the scale of 1:250,000 included in Vol. 2.

C. Semi-detailed soil survey within the limits of potentiality irrigable areas to ascertain the irrigation suitability classification. The soil and irrigation suitability classification was mapped on the scale of 1:100,000. See Maps Nos 7 and 8.

The comprehensive report on the soil survey and the attached relevant maps are presented in Volume 2. Only a very brief summary is given below.

2. General Reconnaissance of Soils

In order to ascertain general information on the soils in the river basin, a general reconnaissance of lands carried out covering the whole catchment area. Table No. 3 gives the percentage results classified by soil groups.

It will be seen from the table that large tracts of the river basin are not cultivable. In the highlands mostly Vertisols and relatively small areas of Regosols are used for agriculture. There are no alluvial soils in the highlands, and only limited areas of alluvial soils are cultivated under irrigation in the Middle Valley and in the Delta area.

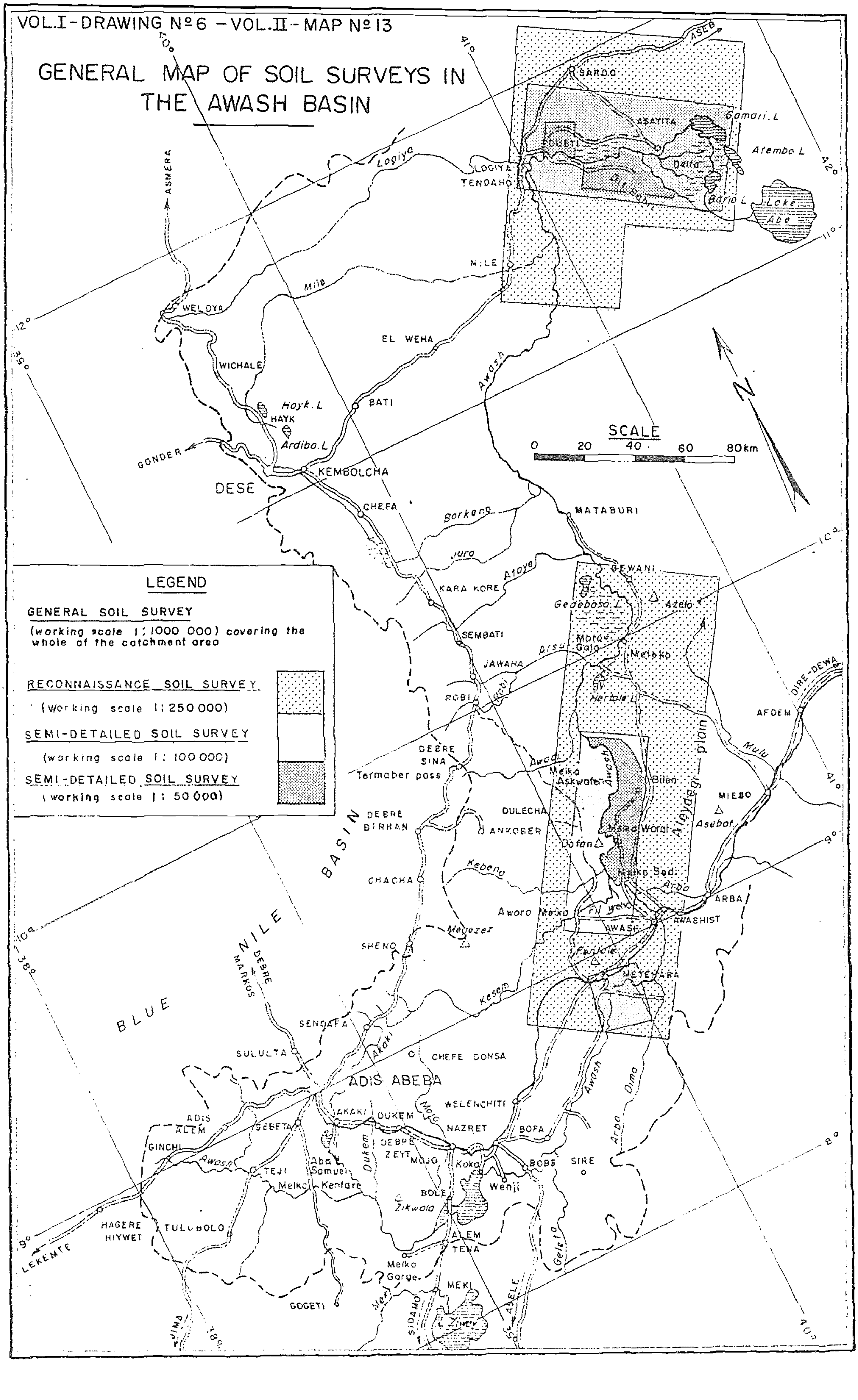

VOL.I-DRAWING Nº6 -VOL.II-MAP Nº13
GENERAL MAP OF SOIL SURVEYS IN THE AWASH BASIN
LEGEND
GENERAL SOIL SURVEY
(working scale 1:1000 000) covering the whole of the catchment area
RECONNAISSANCE SOIL SURVEY
(working scale 1:250 000)
SEMI-DETAILED SOIL SURVEY
(working scale 1:100 000)
SEMI-DETAILED SOIL SURVEY
(working scale 1:50 000)
SCALE
0 20 40 60 80km
N
ASEB
BARDO
ASAYITA
Gamari. L
Afambo. L
Dubti
Lake Abe
LOGIYA
TENDAHO
Logiya
MILE
Mile
WELDYA
ASMERA
EL WEHA
WICHALE
Hayk. L
HAYK
Ardibo. L
BATI
GONDER
KEMBOLCHA
DESE
Awash
MATABURI
CHEFA
Borkena
Jara
Ataye
GEWANI
Gedebosa. L
Azelo
KARA KORE
SEMBATI
Melka
JAWAHA
ROBI
Robi
Hertale. L
AFDEM
DIRE-DEWA
Mulu
DEBRE SINA
Termaber pass
Melka Askwafen
Bilen
MIESO
DULECHA
Asebot
DEBRE BIRHAN
ANKOBER
Melka Worar
Dofan
Melka Sedi
Arba
ARBA
BASIN
CHACHA
Kebena
Aworo Melka
AWASH
AWASHIST
SHENO
Megezez
Fentale
METEHARA
NILE
DEBRE MARKOS
BLUE
Kesem
SENDAFA
SULULTA
Akaki
CHEFE DONSA
ADIS ABEBA
ADIS ALEM
GINCHI
SEBETA
AKAKI
DUKEM
WELENCHITI
NAZRET
BOFA
Oma
Arba
Awash
TEJI
Aba Samuel
Dukem
DEBRE ZEYT
MOJO
Koka
BOBE
SIRE
Melka Kenfare
Wenji
BOLE
Zikwala
HAGERE HIYWET
TULU BOLO
LEKEMTE
ALEM
TENA
Melka Gorge
Gelela
GOGETI
Meki
MEKI
SIDAMO
ASELE
JIMA
Ziway

TABLE 3 - GENERAL SOIL RECONNAISSANCE

Soil group	% of area
Alluvial soils (young soils on alluvial deposits)	2.4
Vertisols (black or brown soils containing swelling clay)	15.2
Vertisols associated with Lithosols	19.1
Semi arid brown soils	12.6
Saline and saline-alkali soils including Regosols	6.4
Hydromorphic soils (developed under water)	3.0
Regosols (eroded soils in arid regions)	15.9
Lithosols (with stony and rocky surface)	25.4
	100%

Perusal of the general reconnaissance soil survey map shows that there are three main areas where irrigable soils may be identified: two of them are located in the Middle Valley and consist of a succession of plains stretching from Metehara to Angelele and of isolated plains in the vicinity of the central Gewani swamps. The third lies in the Lower Plains stretching downstream from Tendaho. Reconnaissance in these areas was carried out during the second phase of soil survey. (See map 6).

3. Reconnaissance Soil Survey in the Potential Development areas in the Lowlands.

This was done to select potentially irrigable areas for more detailed surveying. It included the examination of soil formation conditions, classification by the various soil groups and subgroups, and topographical aspects. The reconaissance soil survey covered about 2,000,000 hectares both in the Middle Valley and in the Lower Plains and it showed that :

i) Skeletal soils take up about half of the surveyed area.

ii) Old alluvial and colluvial areas are comparatively extensive in both regions. They cover an area twice the size of the recent alluvial area.

iii) Alluvial soils cover a bigger area in the Middle valley than in the Lower Plains.

iv) Vertisols come next, again covering a bigger area in the Middle valley than in the Lower Plains.

v) Appreciable quantities of hydromorphic soils are observed along the Awash in the Middle Valley.

vi) A comparatively large area is taken up by marshlands in the Lower Plains.

vii) Predominant among soils on old alluvia and colluvia are semi-arid brown soils, vertisols and regosols in the Middle Valley and mainly saline and semi-arid brown soils in the Lower Plains.

Recent alluvial land most suitable for irrigation is thus limited in extent compared to with that of the old alluvial areas.

The reconnaissance soil survey was followed by an initial classification in respect to irrigation suitability. These land classes are in terms of present suitability for development under irrigation, as follows :

Class A : land suitable for development under irrigation.

Class B : arable land non-irrigable in its present state except under certain special conditions.

Class C : non-arable, non-irrigable land, i.e., rock, very stony ground, dunes, swamps, very saline land and "badlands".

Table No. 4 gives the summary on land suitability for irrigation.

Table 4 - RECONNAISSANCE SOIL SURVEY-SUITABILITY FOR IRRIGATION

	Middle Valley		Lower Plains		Total area	
	ha	%	ha	%	ha	%
Class A	125,000	10.9	75,000	6.6	200,000	17.5
Class B	601,000	52.7	125,000	10.9	726,000	63.6
Class C	20,000	1.8	195,000	17.1	215,000	18.9
Total alluvial and colluvial area	746,000	65.4	395,000	34.6	1,141,000	100.0
Lithosols	375,000	46.0	441,000	54.0	816,000	100.0
Total mapped area	1,121,000		836,000		1,957,000	

4. Semi-Detailed Soil Survey - Selection.

On the basis of the reconnaissance soil survey and of the preliminary land classification, it was found that the Middle Valley and Lower Plains of the Awash basin contain fairly large areas of recent alluvium which could be irrigated under gravity. Irrigation could also be extended to some of the older alluvia and colluvia not so saline as to require excessive leaching water applications. The following areas were selected for subsequent semi-detailed soil survey :

i) In the Middle Valley

The Metehara, Melka Sedi, Amibara, Kesem-Kebena and Bolhamo irrigation area, cover an overall gross area of about 100,000 hectares. These are mainly Class A land.

Decisive elements considered in making this choice were land quality, irrigability under gravity, and access into and from the area concerned. Thus, for instance, the large Aleydegi plain, where soils on old alluvia and colluvia may be considered partly as suitable for irrigation, was excluded from further investigations, because it lies about 70 m higher than the river and would require uneconomic pumping.

ii) In the Lower Plains

The choice was more difficult for this region because of its poor accessibility and vulnerability to flooding by the Awash at high water. Furthermore, an appreciable amount of this land is so saline as to require the application of above-average quantities of water for its development. Alkalinity in the low-lying parts of the area ("bottom-lands") is also rather a problem. Some of these various adverse features affect each of the areas selected.

The Dubti area was selected among others because of its recently introduced cotton growing activities.

The Dit Bahri area offers a larger expanse of level land which would appear to lend itself well to irrigation under gravity.

Finally, crops are already being raised in the Asayita delta as the floods recede and the presence of farmers there and the possibility of extending irrigation to the north of this area were considered to warrant its selection for a semi-detailed soil survey.

5. Semi-Detailed Soil Survey -

i) Soil Classification within Class A Land - Soil Types and Areas

This was carried out on sketch maps drawn from 1:40,000 aerial photographs, eventually reduced to the scale of 1:50,000. The final mapping was done to a scale of 1:100,000.

The purpose of the survey was to enable soil series and phases (where applicable) to be defined and the corresponding units to be mapped with the accuracy required to give at least a clear definition of patches of land of 25-30 hectares. About one profile for every 200 or 300 hectares of land was analysed in the Middle Valley, and one for every 300 hectares in the Lower Plains, except in the Dubti area where one profile was analysed for every 150 hectares, because of the occurrence of closely intermingled saline soils.

Besides the analysis, soil samples were tested in respect of salinity hazards for base exchange capacity, available moisture, infiltration rates and structural stability. Several samples were subject to X-ray examination in order to determine the nature of clay components in the soils.

Table No. 5 gives a summary of the distribution of soils as identified by the semi-detailed survey. (See page 41).

TABLE 5 - SUMMARY DISTRIBUTION OF SOILS ON THE SEMI-DETAILED SOIL SURVEY

	Soil Groups	Middle Valley Area (ha)	%	(Total)	Lower Plains Area (ha)	%	Total (ha)	%
i.	Soils on recent alluvia	86,440	33.0		95,700	39.9	182,140	36.4
	Alluvial soils	43,530	16.6		52,000	21.7	95,530	19.1
	Vertisols	37,810	14.4		16,000	6.7	53,810	10.8
	Hydromorphic soils	2,250	0.9		6,000	2.5	8,250	1.7
	Hydromorphic soils on alkaline materials	2,850	1.1		900	0.3	3,750	0.7
	Organic soils	–	–		20,800	8.7	20,800	4.1
ii.	Soils on old alluvia and colluvia	98,890	38.0		76,000	31.7	174,890	34.8
	Vertisols	25,800	9.9		–	–	25,800	5.1
	Semi-arid brown soils	40,570	15.5		–	–	40,570	8.1
	Regosols	24,420	9.3				24,420	4.9
	Sandy regosols on dunes	–	–		7,300	3.0	7,300	1.4
	Regosols and saline soils	1,300	0.5			–	1,300	0.2
	Saline soils	4,550	1.9		34,000	14.2	38,550	7.7
	Saline alkali soils	2,250	0.9		34,700	14.5	36,950	7.4
iii.	Lithosols and skeletal soils	76,670	29.0		68,300	28.4	144,970	28.8
	TOTAL	262,000	100.0		240,000	100.0	502,000	100.0

The soils on recent alluvia are deep to very deep, those overlying the old alluvia and colluvia reasonably deep, but sometimes their depth is limited by gravel beds and calcareous crusts in the Middle Valley, or by saline marls and old stony alluvium in the Lower Plains.

There is no apparent difference in the soil texture between the two considered regions Middle Valley and Lower Plains : the clay content is medium to moderately high. Fine textures are found mainly in the depressions. The lime content of the Middle Valley soils is low, particularly in the alluvial soils, whereas in the Lower Plains soils are more calcareous.

The organic matter content varies considerably in the two surveyed regions. Almost 60% of samples tested show organic matter content less than 1% for the Lower Plains, against 7% only of samples from the Middle Valley. However, the Middle Valley soils are not particularly rich in organic matter; about 65% of samples tested show its content ranging from 1 to 2%.

Infiltration rates vary between 1 and 2 cm/h in the alluvial soils, and are less than 1 cm/h in Vertisols. Natural drainage conditions are in general better in the Middle Valley than in the Lower Plains. A common feature of most of the surveyed soils is a rather low rate of available moisture. In 85% of samples tested, the available moisture rates ranged from 6 to 13% which is fairly low.

Saline and saline-alkali soils are found mostly in the Lower Plains, where they amount to more than 28% of the surveyed areas and are located mainly on the old alluvia and colluvia. In the Middle Valley saline soils occur in patches mostly in relation to hot and saline springs. The results of the leaching tests carried out on certain medium saline soils in the Lower Plains appear to suggest that a modest proportion could be improved by leaching.

The fertility of the soils belonging to the groups listed as recent alluvial and Vertisols is satisfactory, although phosphorus content is not very high. Nitrogen rates are adequate, except in the alluvial soils at Dubti and Dit Bahri and in the Vertisols on the left bank in the Lower Plains.

ii) Land Classification for Irrigation

On the basis of the semi-detailed soil maps the classification of land according to its suitability for irrigation was carried out. Some of the principal soil characteristics defining the land suitability for irrigation have already been reviewed in the foregoing discussion. Other features had also to be taken into consideration.

Certain areas in the irrigable plains are subject to prolonged flooding, e.g. substantial portions of the alluvial soils in the Lower Plains. In the Middle Valley, the extent of temporary flooding has recently been limited by the control exercised by the Koka Dam; it thus now offers a relatively minor problem. But runoffs from surrounding rocky hills cause temporary floodings of the Vertisols in the valley bottoms, and on the colluvial and alluvial soils at the foot of these hills. This is the case in the Metehara area and in a portion of Melka Sedi.

In connection with flooding and runoff, local erosion is often observed in the Middle Valley, mainly on the hillsides. Generally there are no definable slopes but soils over the old deposits, shaped in cones of alluvia and colluvia from the torrential tributaries may have a slope of up to 2 or 3%.

Vertisols and hydromorphic soils affected by temporary flooding develop a network of deep channels and surface holes due to the excessive desiccation of swelling clay. ("gilgai" effect).

These features have been additionally taken into consideration when processing land classifications. The criteria used correspond to the international standards as proposed in the U.S. Bureau of Reclamation Manual. Soil classes are defined as follows :

Class I - Good irrigable land

Class II - Moderately good irrigable land

Class III- Marginal irrigable land

Class IV - Not irrigable, except under special conditions.

Class V - Undetermined suitability for irrigation

Class VI - Permanently non-irrigable land

Table No. 6 gives the summary on land classification for irrigation purposes; and appended 1:100,000 scale maps No. 7 and 8 show the distribution and location of land classes.

TABLE 6 - SEMI-DETAILED SOIL SURVEY - LAND CLASSIFICATION FOR IRRIGATION

	Metehara		Rest of Middle Valley		Lower Plains		Total area	
	ha	%	ha	%	ha	%	ha	%
Class II am 1/	-	-	24,700	7.0	-	-	24,700	7.-
Class II	4,200	1.2	27,700	7.7	30,000	8.4	61,900	17.3
Class III	7,300	2.0	50,700	14.2	39,000	10.9	97,000	27.1
Class IV	11,100	3.1	29,000	8.1	33,000	9.3	73,100	20.5
Class V	5,600	1.6	4.300	1.2	15,000	4.2	24,900	7.0
Class VI without lithosols and skeletal soils	2,500	0.7	18,300	5.1	54,700	15.3	75,500	21.1
TOTAL ALLUVIAL AND COLLUVIAL	30,700	8.6	154,700	43.3	171,700	48.1	357,100	100.0
Lithosols and skeletal soils	7,300		69,300		68,300		144,900	
TOTAL MAPPED AREA	38,000		224,000		240,000		502,000	

1/ Good irrigable land which cannot be classified as Class I only because of low moisture availability.

None of the land in the areas considered is found to be up to the standards of Class I. Soils along the right bank of the Awash in the Middle Valley might have been included in this class, but their water-holding capacity is so low that they would require frequent applications of small quantities of water. Although they cannot be included in Class I, they nevertheless still represent the best soils in Class II, and have been given the map reference II am. They appear to be potentially the most productive in the entire valley, with reasonably low farming costs. With irrigation methods adapted to the low available water in the soil and suitable crops for the local climate, they should be able to produce high yields.

In the Class II range, about 17.3% of alluvial and colluvial lands were surveyed in the Awash river lowlands. The factors limiting the development of this land may be in the Middle Valley :

i) On the left bank :

Mainly slight salinity and microrelief problems, or temporary flooding.

ii) On the right bank :

Drainage problems due to the presence of fine-textured soils or vertisols, temporary flooding, microrelief, and possibly also salinity (near Debu).

Drainage is also the limiting factor in the fine-textured vertisols of Metehara area.

Short duration flooding, moderate drainage, high Na/T ratio, high value of pH and low organic matter content are to be reckoned with in the Class II alluvial areas located in the Lower Plains.

Class II land in the Middle Valley is potentially more productive than in the Lower Plains, because it is less alkaline, contains more organic matter, and is affected by few or no salinity problems.

In the Class III lands were included the deep Vertisols and hydromorphic soils at the Kesem-Awash confluence and in the Angelele area as well as medium salinity soils occurring in patches in Kesem-Kebena plain, because of certain drainage problems, microrelief and of need for a stricter salinity control.

The risk of flooding and the existence of basalt gravel beds in the soils are the limiting factors in the Class III lands in the alluvial and colluvial areas of Metehara.

In the Lower Plains Class III land occupies the low-lying areas most often affected by flooding, which contain slightly saline, fine to moderately fine-textured soils in the deeper horizon. In Asayita and Dit Bahri the water table may rise fairly rapidly and increase the salinity of the soil.

Class IV land is more difficult to develop under irrigation and it will require special treatment. Thus, in the Middle Valley it occurs at higher elevations, not readily commanded from the river, or when located in the alluvial areas, lacks adequate drainage and is subject to severe flooding. Where land is too saline or too alkaline to be economically leached. or too shallow, like in Metehara region, it is included in Class IV.

Most of the Class IV land in the Lower Plain is flooded whenever the Awash is in spate and features numerous channels and depressions. Some of this land may be reclaimed if efficient flood control is achieved, but its development will call for considerable levelling and establishment of a fairly close drainage system. Certain areas of Class IV in the Lower Plains will be more difficult to reclaim because of their salinity and alkalinity, e.g. bottom lands in the Dit Bahri area.

Lands affected with excessive salinity and/or alkalinity, too shallow, or with a serious levelling problem were included in Class V.

Class VI lands are considered as permanently unfit for irrigation, and they account for 21.1% of the surveyed alluvial and colluvial area.

6. Conclusions

By way of conclusion it may be pointed out that the soil survey operations revealed a considerable scope for the development of irrigated agriculture: more than 180,000 ha of suitable lands are identified as Class II and III. Moreover some portions of floodible Class IV land in the Lower Plains may also be developed provided that efficient flood control is achieved by adequate damming. Storage reservoirs will be also essential to increase the water resources, as those currently available are insufficient for the development of all irrigable lands. The estimates of water resources indispensable for this purpose will have to be made in relation to the potential crop pattern which can be reasonably suggested for the development areas on lands identified as in Class II^{am}, II, III and to some extent in Class IV.

CHAPTER VI - PROSPECTIVE LAND USE UNDER DEVELOPMENT

1. General considerations

Scrutiny of the soil maps, as well as those of irrigation suitability, will indicate that large tracts of good soils are located in the Middle Awash Valley. Moreover, certain lands located on both river banks upstream of Metehara may also prove to be of similar good quality. These were not selected for the semi-detailed soil survey, because in the early stages of the Project operations it was already realized that the currently available water supply in the upper reaches of the Middle Valley would certainly not be sufficient for all the irrigable lands available in this region.

In the Lower Plains the situation is different, as here, in order to use the water contributed by the large tributaries draining the lower part of the catchment area, notably the Borkena and Mile rivers, relatively poorer soils had to be selected. The fact that commercial development in the region had already started, along with the existence of indigenous agriculture in the Asayita delta, had also to be taken into consideration.

Thus, the agricultural value of the two development regions would appear to be unequal and therefore the prospective patterns of land utilization will be different for the Middle Valley and the Lower Plains. The range of the crops which can be grown in both regions being probably similar the main problem is to select an adequate intensity of cropping pattern for the respective regions.

2. Management

If high expenditure is called for the development of irrigated agriculture, it should bring high returns. This demands a cropping pattern as intensive as is compatible with the natural conditions; whenever possible, double cropping. Normally natural climatic conditions are no impediment for the development of double cropping; serious difficulties may however arise from the management point of view.

In the first place there is a need for assessment of agronomical implications, such as selection of most suitable growing period, the necessity for maintenance and/or improvement of soil fertility, and the development of appropriate irrigation practices. Assessment of these, as well as selection of types and rates of application of most suitable fertilizers, is related to extensive experimental and applied research work which will have to be carried out in the development areas. However, experimentation being a long and difficult process, it will be impracticable to postpone the actual development until such time as all the results of experimentation are known.

It is essential, too, that the knowledge acquired from experimental work be applied on the farms without delay. Efficient extension services will be indispensable to guide and help the farmers in their task of developing intensive irrigated agriculture. The difficulties inherent in the operation and management of irrigated settlement schemes, in spite of an effective and highly organized extension service, are well known and should not be underestimated. On the other hand, it is the general experience that capital-intensive commercial farms, usually staffed by well qualified technicians, are better adapted to deal with delicate development problems in the areas as yet uncultivated.

In fact, it would appear that less risk is involved in starting double cropping, highly intensive irrigation projects on commercial type farms. Natural conditions for the development of intensive irrigation farming would appear more favourable in the Middle Valley rather than in the Lower Plains. The operational difficulties of an intensive irrigation project may be more easily overcome on the commercial than on the family farms. Inasmuch as high productivity on agricultural investment is regarded as the development target, it would appear that commercial farms will have to be given priority, at least provisionally, in the Middle Valley. Since less extensive irrigation seems more suitable for the settlement schemes, the promotion of family size farming would appear advisable in the Lower Plains.

3. Crops

Most types of crops grown under irrigation would seem suitable for the Awash valley. Generally speaking, the selection of crops and rotations will be subject to economic rather than agronomic conditions.

i) Fibre crops will probably be given preference in view of the shortage of supply and the steadily growing market for home fibres. Cotton is already successfully grown in the area, but careful experimentation is needed in order to select most suitable varieties and the appropriate growing season. In fact, varieties currently planted have a relatively long vegetation cycle and the interval between the picking and planting time for a second crop in the same year is rather short.

Kenaf (Hibiscus Canabinus) is also a fibre crop which finds a ready market and may probably be grown with success.

In view of great demand for coarse fibre needed in the bag manufacturing industry, sisal may be introduced in the irrigation cropping pattern. This plant, however, being successfully grown without irrigation, irrigated sisal plantation should be allowed only where it will not impede the development of more economic crops.

ii) Oil seeds for industrial processing will probably have a large share in the crop plans of irrigated farms, as vegetable fats are in high demand on world markets. Ground nuts would appear of special interest provided that the most suitable varieties are determined and developed. Soya beans, sunflower, safflower and small grain oilseeds will have to be tested, but prospects for their innblusion in the crop plans appear reasonable. Sesame and castor beans are grown on a small scale and with low yields; again research into suitable varieties is essential.

iii) Pulses are an important export product of Ethiopia and further development of the market seems possible. Therefore lentils, peas and particularly haricot beans, which have a short vegetation period, may be successfully involved in the rotation as catch crops.

iv) Cereals will probably be of little interest to the large scale irrigated farms, as food is in ample supply in Ethiopia and export possibilities - for the time being - are rather slim.

Maize and sorghum however will certainly be grown by the settler on the delta and already sizeable areas are planted with these cereals in the Asayita delta. There will be need of experimental work in order to introduce short vegetation period and more productive, perhaps hybrid, varieties.

Development of vegetables, fruit and sugar cane production is related to the establishment of plants and to the home and foreign market situation. The areas under these crops while initially limited, have reasonable prospects of subsequently increasing.

4. Other Factors

i) Regulation of High Value Crops

As the above are high value crops and their inclusion in the crop pattern weighs considerably in maximisation of benefits it may appear advisable that regulations covering the growing of such type of crops be enacted. While a good development policy may consist in giving all the investors the opportunity to have a fair share in the benefits of high value crops, inclusion of high value crops may provide encouragement and justification for development in the areas where more investment will be needed.

ii) Animal Husbandry and Forage Crops

Integration of animal husbandry in the irrigated farming pattern should be given particular attention. This may provide a helpful means to the promotion of living standards of the pastoralists and prove to be a realistic and efficient approach to the settlement policy with respect to the nomadic populations.

Implementation of rational forage crops is essential for agronomical reasons in order to maintain the fertility status of the soils and build up their organic matter content, which anyhow is only moderate in the irrigable plains. It will not be easy to achieve unless forage is consumed on the farms, the pastoralists being usually reluctant to purchase fodder for their livestock. In fact there is little chance that the nomads will be willing to purchase hay or silage produced on the irrigable farms. It would appear more realistic, therefore, that the farmers endeavour to start buying cattle when the dry season is advanced, and nomadic stock has to be kept close to the watering points in the river or in the canals. The purchased cattle may then be intensively fed on the irrigated pastures with the help of harvested fodder. Not only irrigated forage crops, but also other sources of animal food will be available in the irrigated farms, such as by-products of processing plants. Thus all stages of the fattening business may be carried on in the irrigated areas. Market for meat cattle may be easily found as Ethiopia is at present striving to export its meat and several related projects are already operational (e.g. the Shashemene abattoirs).

iii) Dairying

Progressive development of dairying may also be contemplated since many dairy products are currently imported to Ethiopia, and their consumption is bound to increase with the growing living standards.

iv) Green Manuring

Until the proportion of animal husbandry in the irrigated agriculture business is large enough to allow irrigated forage crops to be sufficiently extended to take care of the maintenance of fertility status and organic matter rates, green manuring should be strongly recommended. Species like sweet clover (Melilotus sp.) or Sesbania which are excellent green manures and, at the same time, provide reasonably good grazing lands may be considered as double purpose (green manure and fodder) crops and their introduction appears advisable. At any rate inclusion of soil improving crops in the rotational system should be vigorously promoted, and fallowing practices strongly discouraged. An appropriate water rates policy may prove very useful in this respect.

5. Rotations

Selection of the rotational pattern and respective proportions of different crops cannot be suggested without extensive and systematic experimentation. Nor can the starting date of the agricultural cycle yet be determined because of the lack of adequate agronomical information. The examples of rather intensive rotations given on Charts Nos. 9 and 10 herewith should be regarded merely as suggestions for experimental work.

They include a cash crop, fibre crops or oilseeds, every year and pulses and/or cereals as alternative catch crops; legumes, like pulses or ground nuts occur often, and forage crops or irrigated pastures are introduced in the rotation in order to maintain soil fertility. It is emphasized however that suggested types of rotations cannot be implemented without an extensive and systematic use of fertilizers. The selection of types of fertilizers, methods and rates of application, etc, will depend on the result of field trials.

The rotational pattern for the Middle Valley differs from that suggested for the Lower Plains mainly in the cropping intensity. The former ranges from a cropping intensity of 1.75:1 to 2:1. The latter, because of the less favourable natural conditions and of larger proportion of less mechanized family size farms, provide for 1 to 1.5crops yearly. The proportion of cotton in the rotations is high, generally about 40% of the land would be earmarked for this crop.

Perennial crops, like orchards, citrus and banana plantation, sugar cane, sisal, etc. are not shown on the rotation charts included. Usually they stay in the field for more than four years, which is the period of the longest suggested rotations. Obviously, care must be given to maintain a high fertility status of the soils either by periodic green manuring or by inter-row cultivation of legumes.

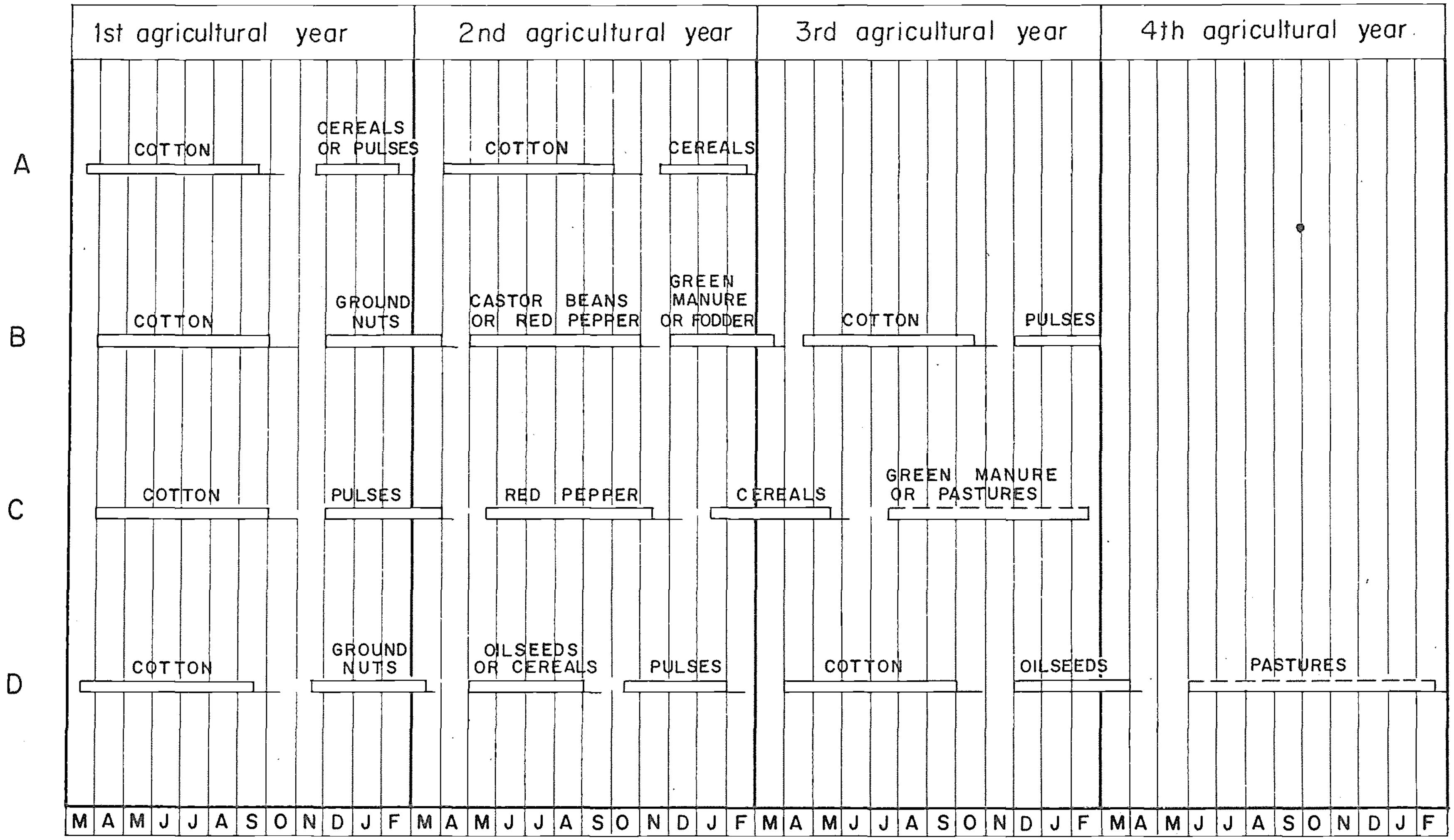
6. Arboriculture

Several hot springs of appreciable discharge are located in the Middle Valley and some of them result in marshy areas with a brackish or slightly saline water table. A thick growth of wild palms may be observed on the outskirts of such marshes. It is very probable that highly productive date palm trees (Phoenix dactylifera), which are known for their tolerance to saline water, may replace the unproductive ones. The same experiment should be made on the Lower Plains, where date palm trees of a poor variety are grown on the spoil heaps along the channel banks in the Asayita delta area. Only relatively small expenditure and a simple layout will be required to start the planting of date palm trees which may contribute considerably to the welfare of the local people.

A riparian forest grows on marshy areas on both banks of the Awash river, which will be difficult to reclaim for irrigation purposes. The largest such riparian forest is located in a long narrow strip downstream of the Gewani swamps. The existing vegetation consists of valueless trees and shrubs which may be advantageously replaced by productive varieties. Eucalyptus and poplars are reputed quick growing and useful species for the production of paper pulp and for the packing industry respectively, and both grow well with a high groundwater level.

Other species may be selected and suggested by the forestry specialists. In any case experiments in introducing productive trees in the marshy areas which will not be put under irrigation appear to be highly advisable at an early date.

SUGGESTED CROP ROTATION SCHEMES
MIDDLE VALLEY

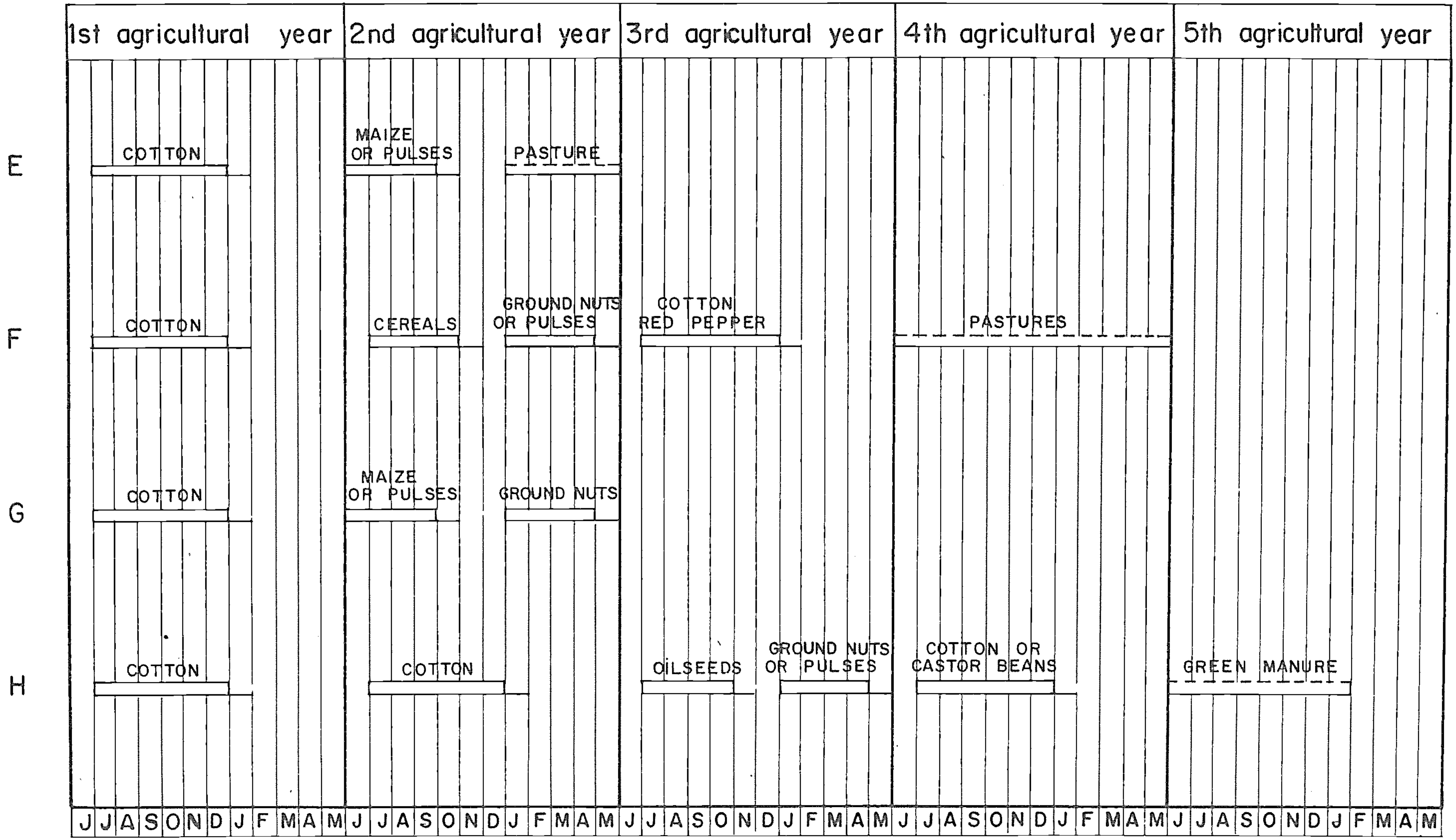


For the water requirement computations, the agricultural year has been positioned as shown on the above calendar

Normal irrigation — Land occupation — Slight irrigation

VOL.I-DRAWING Nº 9
VOL.II-FIG.8

SUGGESTED CROP ROTATION SCHEMES
LOWER PLAINS



For the water requirement computations, the agricultural year has been positioned as shown on the above calendar

Normal irrigation — Land occupation — Slight irrigation

VOL I - DRAWING Nº 10
VOL.II - FIG.9

7. Improvement of grazing lands

Simultaneously with the development of irrigated agriculture, action should be initiated for the improvement of grazing lands. Before a long range programme of basic improvement of the pastures is devised, through introduction of new species and regeneration of existing productive grasses, it will be necessary to prevent local overgrazing and establish new watering points. A programme of sinking shallow wells in the beds of intermittent water courses is suggested in an Appendix to Volume II. The building of reservoirs and ponds to collect runoff during the rainy season, and of small dams on seasonal watercourses, may considerably improve the productiveness of the pastures. Farmers and irrigation authorities may perhaps help the nomads to initiate the establishment of new watering points, and occasionally use their heavy equipment for construction of the reservoirs.

Spreading flood waters from intermittent streams over range pastures topographically best suited to flooding is another way of increasing the productiveness of some grasslands. Very simple structures consisting of small barrages across intermittent streams and a network of drainage ditches will help to spread flood waters at little cost. Again, the heavy equipment from irrigated farms may be advantageously used for such works.

The establishment of irrigation systems in the Middle Valley and the Lower Plains of the Awash basin will, by consuming the water at present draining into them, contribute substantially to a partial reclamation of the marshlands such as those at Gewani, Boyale, Dit Bahri, and in the Asayita Delta.

The pastures on the reclaimed marshes may be fairly productive as the full scale control of flows makes it possible to regulate the amount of water entering the marshlands. Thus, water levels can be regulated and desirable rates of moisture maintained in the soils all through the year.

8. Irrigation Water Requirements and Water Quality

As usual in preliminary surveys, no adequate data on the consumptive use of irrigation water in the main development area were available. The estimates of water requirements had therefore to be made on the basis of formulae abstracted from climatological data : Turc's formula was given preference. Evapotranspiration data obtained were subsequently applied to the suggested crop pattern and the final figures of water requirements were computed in relation to the potentially commanded area. Allowance was made for an irrigation efficiency coefficient of 70% in the Middle Valley areas and of 60% for the areas located in the Lower Plains.

For purpose of estimation, it has been assumed that the suggested crop patterns will comprise the rotation discussed in the section of this chapter in equal proportions, so that the final water requirements for the crop pattern may be considered as an arithmetic mean of the specific water requirements for each suggested rotation.

The following table No. 7 shows the average monthly and yearly figures of computed water quantities needed in the development areas of the Awash Valley.

TABLE 7 - IRRIGATION WATER REQUIREMENTS

Cubic meters per hectare of commanded area

Months	J	F	M	A	M	J	J	A	S	O	N	D	Year
Middle Valley	1645	1585	1195	1220	1940	2135	1140	770	1365	1020	955	1770	16,740
Lower Plains	845	875	880	705	285	1075	1935	1615	2075	2010	1590	1455	15,345

It will be noted that, in spite of significantly higher potential evapotranspiration rate in the Lower Plains than in the Middle Valley, water requirements computed for the latter are greater. This is due to the much more intensive cropping pattern applicable to the Middle Valley, 1.75 to 2 crops a year, as against the less intensive cropping pattern of 1 to 1.5 crops yearly suggested for the Lower Plains.

Also the nominal specific rate of flow was computed for the peak monthly water requirements for the considered cropping pattern, on the assumption that the effective time of water application during the peak month will be 18 hours a day. It was found to be very similar in both development areas, and for all practical purposes a figure of 1.1 litre per second per hectare of commanded area was accepted.

The water quality of the Awash River and its tributaries, springs and lakes has been checked for salinity and sodium content. It has been found that, in general, river water is suitable for unrestricted use on all soils, unless of very low permeability. Surface water in the lakes fed by the rivers in the Middle Valley and Lower Plains is only slightly sodic and, with moderate leaching of the cropped lands may be used for irrigation purposes. Reservoir stored water in these areas will probably be of similar quality. The use of spring and underground water, as well as that from the lakes fed by the saline springs cannot be recommended for irrigation.

9. Fertilizers

The Project as scheduled in the Plan of Operation did not include specifically trials of the effects of fertilizers. It is clearly necessary however, that these should be fully taken into account in planning future agricultural research, and in assessing the yields and revenues to be expected, on which economic benefits will depend, and economic appraisals will be made.

CHAPTER VII - CLIMATOLOGY AND HYDROLOGY

1. Arrangements

With the purpose of correlating actually measured flows at a number of points on the main river and its tributaries, with the rainfalls observed on the respective catchment areas, a network of rainfall and river gauging stations was established. Observations from 120 rain gauges, out of which 95 were installed by the Project team, were used to compute rainfall maps. Seven climatological stations recorded data on temperature, relative humidity, solar radiation, insolation, evaporation, wind velocity and direction. Thirty river gauging stations were established, out of which three had cable ways and eight had light cable ways, 24 gauging stations were equipped with automatic water level recorders. Systematic measurements of sediment load were also carried out at each gauging station.

The hydrometric and climatological network was installed in the course of 1962. Observations and measurements lasted for three rainy seasons. The purpose of the first season's measurements was mainly to adjust the stations and to complete the installations in the light of in-service experience. Results from two other seasons' measurements were processed and, a series of normal values, usable for the Project, were estimated both in respect of the climatological and the hydrological data. On the basis of these normal values, a hydrological balance for the Awash River Basin was drafted. For budgetary reasons, the systematic hydrometric survey did not include the deltaic region downstream from Dubti. The relevant component of the hydrological balance is therefore a tentative estimate.

The results of climatological and hydrological studies are fully discussed in Vol.III of this Report. Only a brief summary of the principal findings is given below.

2. Climatology

i) Rainfall

Rainfall conditions in Ethiopia are governed by seasonal movements of the Inter-Tropical Front. These movements are mainly due to the cyclic variation of the sun's position, and are modified by somewhat irregular behaviour of the Egyptian high. One characteristic feature of rainfall conditions in Ethiopia is the relative constancy of their seasonal timing, which they derive from the movements of the Inter-Tropical Front.

The very pronounced overall relief features of the Awash basin (which is part of the Great African Rift extending from Lake Nyasa to the Dead Sea) impart a westerly direction to the moist air stream supplying the major rainfall to the basin. During a well-established rainy season, this air stream comes in from the south-west and proceeds north-eastward down the Awash Valley, gradually exhausting its potential rainfall on the way. The marked changes in the relief of the Awash basin and the exposures of the valley hillsides decisively affect the rainfall experienced during a normal year. The effect of these major factors is the same throughout a given region, in which rainfall during the year is found to vary linearly with altitude. The gradient of this relationship typifies the region.

The month-by-month distribution of rainfall during a normal year can be used to give a picture of rainfall conditions. By expressing the rainfall for each month in relation to annual rainfall, it was found that the proportional rainfall distribution over the various months of the year is practically the same at several gauging stations. This justifies the subdivision of the Awash basin into a number of different climate areas, each with its characteristic month-by-month rainfall distribution. (See Map No. 11).

A characteristic feature of rainfall conditions in the Awash basin is that there are two rainy seasons in the year, one a period of minor rains from March to May, with the other - the main rainy season - beginning in July and lasting till September. The secondary rainfall minimum, in June, is more pronounced in the arid northern part of the basin. It is hardly appreciable in the upper basin in the south, where the rains are practically continuous from March to September.

<u>The following are a few significant normal rainfall figures</u> :

Upper Basin upstream from Koka dam	1,000 mm
Middle Valley between Koka and Hertale	850 mm
Lower Valley between Hertale and Dubti	610 mm
Lower Reaches between Dubti and Lake Abe	215 mm

The average normal annual rainfall figure for the whole of the Awash basin thus works out at about 710 mm.

During the seven-month period from March to September including both rainy seasons, the Upper Awash basin receives over 90% of its total annual rainfall, while the Middle Valley and Lower Plains only receive about 85% of their respective annual amount. Rainfall during the dry season is thus proportionately more appreciable in the arid zone than in the humid sub-tropical part of the basin.

Raimfall in the basin almost always occurs in distinct individual heavy downpours affecting areas a few ten square kilometres in extent. These downpours often start as comparatively moderate showers which then gradually increase in intensity. At its climax, the downpour suddenly ceases. In the arid zone, the day's rainfall - and frequently also the month's - occurs as a single downpour not lasting for more than four or five hours. Hillsides with a humid sub-tropical climate may receive repeated showers during the same day - three at most at the same place - the total duration of which may be anything up to 12 or 15 hours, though with none of them individually lasting more than eight or nine hours.

The very irregular discontinuous rainfall distribution in the form of local downpours shows the effect of relief features on rainfall conditions in the Awash basin; this results in irregular daily inflows from the tributaries of the Awash during the rainy season.

As a general rule, the daily intensity of rainfall is not particularly high in the Awash basin; the highest, recorded, 140 mm in a day, occurred in the Lake Abe region, and its probability is estimated as about once in 500 years. An even lower probability can be assumed for a rainfall of 120-130 mm/day in the high valleys; though this figure was actually recorded, this was at the beginning of the rainy season so that it should be viewed with some caution. The computation shows that during a well-estimated rain rainy season, rainfall amounts of 120 mm/day in the wettest part of the basin would on an average only be experienced once a hundred years. In the most abundantly supplied part of the Awash basin, above an altitude of 1,400 m, daily rainfall values in fact more frequently fluctuate between only 30 mm and 40 mm.

Data from the two fully recorded rainfall cycles, 1962/63 and 1963/64, can be compared with the estimated normal value. The former season with values about 12% above normal in the Upper Basin, was about 8% below normal for the remainder. The latter, while showing slightly sub-normal values for the Upper Basin, is substantially above normal (25%) in the Lower Basin. In the subsequent studies of dam reservoirs and water-planning, the hydrological cycle November 1962/October 1963 has been used as a basis.

ii) Air Temperature

Data on the maxima and minima temperature for any longer period were not available in the meteorological records. The duration of observations taken on the Project's meteorological stations for two or three years is too short for the records to be representative. The figures quoted herewith are merely examples of variation of temperatures which may be observed and should not be extrapolated.

TABLE 8 - SOME TEMPERATURES OBSERVED IN 1962-64

MINIMA AND MAXIMA CENTIGRADE

Stations	Maxima	Minima
Adis Abeba	28.5	6.0
Koka	34.5	7.0
Chefa	35.0	5.0
Robi	36.5	5.5
Metehara	39.5	7.0
Awora Melka	39.5	5.5
Gewani	41.8	8.1
Tendaho	45.6	6.0

The temperature only very exceptionally falls to 0° C on the highest peaks above the Awash Valley. These peaks only very seldom receive precipitation in solid form (usually hail) which invariably melts very quickly on the ground. Flows in the Awash basin are thus exclusively due to rainfall.

Normal annual air temperature variations are inversely related to altitude. With the rainfall conditions, this feature sharpens the distinction between individual climate levels or "stages" in the Awash basin. Within a given climate stage in the basin, annual air temperature varies mainly with altitude.

As a secondary consideration, the high hills met by the prevailing south-westerly winds cause a very distinct "Foehn" effect in certain limited areas of the basin. In the areas sheltered from south-westerly winds by the high hills surrounding the Awash basin, annual temperature are appreciably higher than in other basin regions at a similar altitude. Consequently, the "Foehn" effect is shown up by reduced rainfall in the sheltered areas, which, therefore, have a more arid climate than other more open areas at the same altitude.

The following are a few significant normal annual air temperature figures for the basin :

TABLE 9 - AWASH BASIN - AVERAGE ANNUAL TEMPERATURES

Regions exposed to prevailing south-westerly winds	T^oC	Areas sheltered from south westerly winds ("Foehn" effect)	T^oC
High tableland (plateaux), average altitude 10,000 ft.	13.5	No "Foehn" effect, as there are no high hills above this region	
Upper Awash Basin, around 5,500 ft. altitude, between Debre Zeyt and Koka.	19.5	Upper Awash Valley and the secondary rift north of Debre Sina, averaging about 5,500 ft. in altitude	21.0
Upper Valley around 4,000 ft. altitude, between Koka and Awash Station.	23.5	Chercher piedmont area towards Dire Dewa, average altitude 4,000 ft.	23.9
Middle Awash Valley, around 3,000 ft. altitude, between Awash Station and Awora Melka	26.2	No "Foehn" effect, as no high hills dominate this region	
Lower reaches of the Awash, around 1,500 ft. altitude, near Tendaho	29.0		

By considering monthly to annual air temperature ratios, temperature conditions were defined in comparable terms for various points in the basin. Associated with rainfall conditions, temperature conditions typify regional climates, and show up the appreciable difference between them.

As a general rule, monthly air temperatures are at a minimum in December and January, then gradually rising to a maximum value at a time of the year depending on the aridity of the local climate in each region. Thus, in the most arid regions of the Awash basin (Middle Valley and Lower Plains) peak monthly temperatures (15% to 20% above annual average) invariably occur in June, between the two rainy seasons. In the less arid regions, the highest monthly temperatures occur during the two months of the "secondary" rainy season from March to May; they are only about 10% above the annual mean.

Monthly air temperatures decrease sharply with the onset of the main rainy season and reach a secondary minimum throughout the basin near the end of the rains.

iii) Evaporation

(a) The results of evaporation measurements with a tank sunk into the ground at a few points in the Awash Basin have enabled normal evaporation rates to be estimated from the surface of a small and very shallow free surface of water.

Normal annual evaporation rates measured in this way were found to depend closely on altitude, thus confirming the important effect of altitude in the division of the Awash Basin into several distinct climate regions.

TABLE 10 - NORMAL ANNUAL EVAPORATION MEASURED BY SUNKEN TANK (m)

Altitude (m)	Maximum, at a point distant from any existing major evaporating surface	Minimum, at an existing major evaporation surface	Ratio minimum to maximum evaporation (%)
2,500	1.60	0.60	38
1,500	2.85	2.25	79
900	3.60	3.25	90
500	3.90	3.65	94

(b) Normal evaporation rates from an extensive and fairly deep reservoir were deduced from the corresponding evaporation rates determined with a sunken tank, by the application of various correction factors. (See Vol.III).

The following are a few normal annual evaporation rates for a large deep reservoir :

TABLE 10[a] - NORMAL ANNUAL EVAPORATION FROM A LARGE DEEP RESERVOIR (m)

Altitude (m)	Maximum, at a point distant from any existing major avaporating surface	Minimum, at an existing major evaporation surface	Ratio minimum to maximum evaporation (%)
2,500	1.30	0.40	31
1,500	2.40	1.85	77
900	3.00	2.70	90
500	3.30	3.05	93

3. Regional climates in the Awash Basin

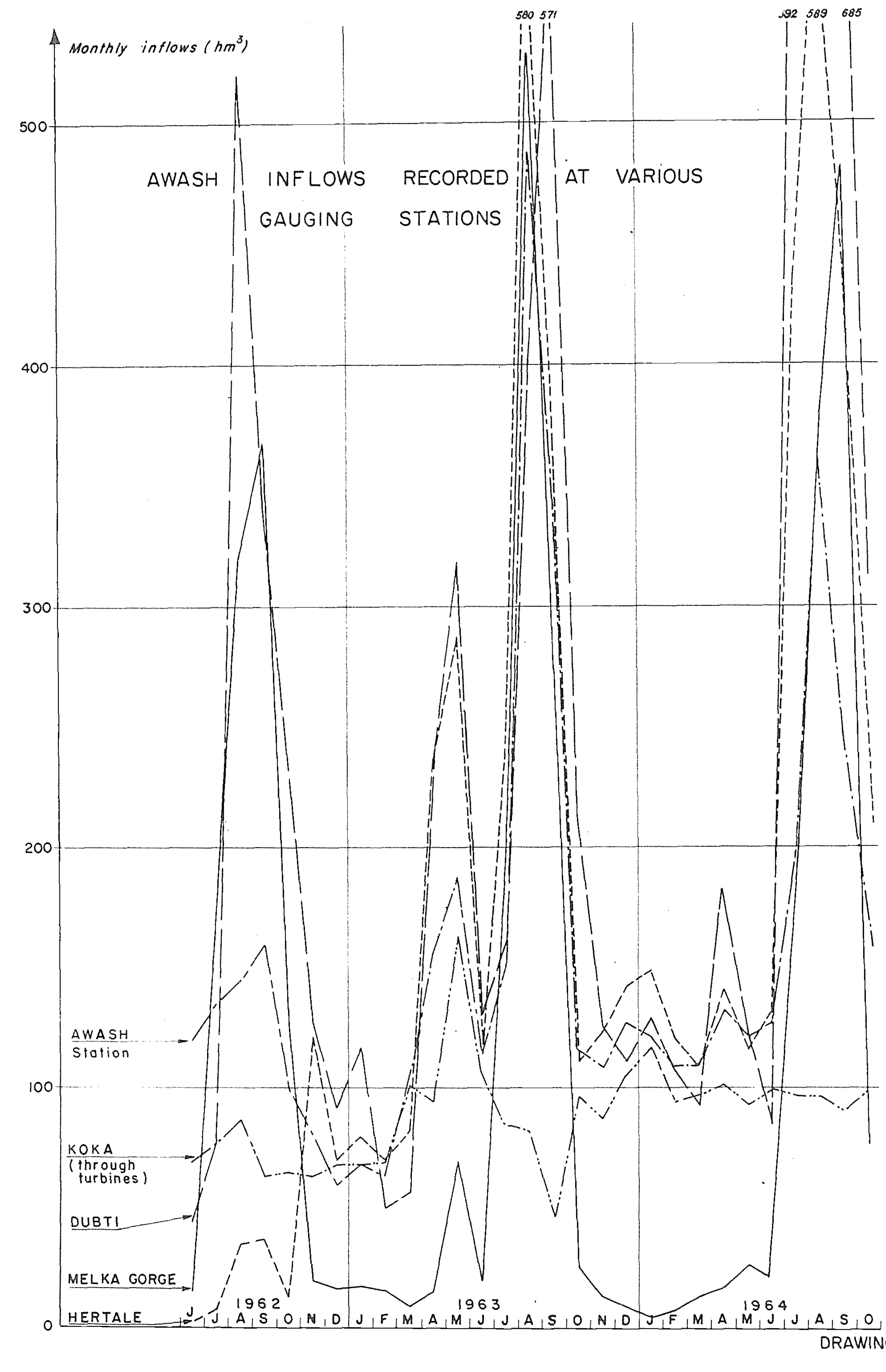
The local climate mainly depends on altitude. Analysis of the main climatic factors (rainfall, air temperature and evaporation) has confirmed the general outlines of the climate subdivision traditionally accepted in Ethiopia.

As this traditional classification is entirely based on altitude, however, it makes no allowance for the by no means inconsiderable regional variations from the general climate, caused by the very marked relief changes in the Awash Basin. In typifying a definite region in the basin, therefore, it is necessary to allow not only for altitude but also for orographic effects, and especially for the exposure of the valley hillsides to the prevailing south-westerly winds.

The traditionally accepted Ethiopian classification for climate regions in the Awash Basin is set out in detail in the following table 11.

TABLE 11 - CLIMATIC ZONES

Ethiopian Classification	General type climate area	Altitude range	Rainfall and temperature features
BEREHA sub-desert	Arid	below 600-700 m	Temperature gradient - $-0.34^{\circ}C/100$ m
BEREHA semi-arid	Semi-arid	between 600-700 m and 1100-1200 m	a) Temperature gradient - $-0.84^{\circ}C/100$ Rainfall as for an arid region throughout b) temperature gradients subjects to change by "Foehn"
KOLLA dry or humid	Sub-tropical	between 1100-1200 m and 1700-1800 m	Hillside exposure governs climate dryness or humidity. Possible "Foehn" effect. No "Foehn" effect. Changing temperature gradient
WOINA DEGA	Sub-tropical humid	between 1700-1800 m and 2400-2500 m	Temperature gradient without "Foehn". -0.445 $-0.445^{\circ}C/100$ m Possible "Foehn" effect.
DEGA	Sub-tropical-humid and cold	above 2400-2500 m	No "Foehn" effect. Temperature gradient probably not varying appreciably about $-0.445^{\circ}C/100$ m



DRAWING Nº 12

4. Hydrology - General.

The hydrology of the Awash Basin, as at present known, is fully discussed in Volume III. In the present chapter is given a brief outline of the main relevant figures, with comments, in order to provide to the reader a general picture of the water resources available, and thus enable him to appreciate the validity and significance of the proposals for development discussed in later chapters.

From the data observed at the various river gauging stations for the hydrological years 1962/63 and 1963/64, annual flow balances for these years were computed. The results were then studied with reference to the relevant records of rainfall at stations in the Basin, some of which covered considerable periods of years; the maximum reliable period being the record of rainfall at Adis Abeba from 1946 to 1964. After statistical analysis of all available climatological data, appropriate correlations were established. Using these, it was found possible to estimate reasonable figures for the "normal" total annual flows at various points. Information is as yet insufficient to break down these into "normal" monthly flows. However, Fig. No. 12, showing flows at various points observed in 1962-1964, gives some indication of the very wide variations which occur in the flows at different times of the year. Already, however, the flows from the Upper Valley are regulated and modified by the action of the Koka reservoir, the effects of which can be traced right down the course of the river to the Lower Plains, though gradually diminishing in absolute and in relative magnitude. It will be realised that records of measured flows in, at most, 3 years, and rainfall records at stations which are few in number compared with the vast extent, some 70,000 km^2, of the whole Basin, are not sufficient to provide more than a tentative and approximate estimate of "normal" flows. Further, it is the extreme conditions, and notably the extremely low conditions, which may occur, that cause the real difficulties. Systematic and comprehensive observations of both river flows and rainfalls, over a good number of years, will be necessary to make possible really satisfactory assessments of flows, losses, and so on. It is important that these observations at all requisite stations, by reliable observers under trained supervision, should be continued without any break or interruption. Additional stations should be equipped and put into use as required. Further, the analysis of observations, by skilled staff, year after year, must be continued regularly, if essential data of flows are to be available as the basis for sound planning of development.

5. Analysis of Normal Annual Flows

The estimated amounts of inflows, losses, and outflows, in a normal year, for various reaches of the river, are shown on Map No. 13. In what follows, the same figures are set out in tabular form, with the object of giving a reasonably representative picture of the hydrology of the Basin as a whole.

TABLE 12 - ANALYSIS OF ANNUAL RUNOFF IN "NORMAL" YEAR

i)	Upper basin - to Koka Dam. Catchment 11.250 km^2	hm^3	hm^3
	Inflow to reservoir	1,750	
	add rainfall on the reservoir	145	
		1,895	
	less evaporation estimated at		315
	less losses by percolation		380
			695
	Passed through turbines to river dowstream of dam		1,200
ii)	Upper Valley : Koka dam to Awash Station. Catchment 7,320 km^2		
	Inflow from catchment	1,400	
	add Awash flow from (i)	1,200	
		2,600	
	less water used and evaporation losses		125
	less percolation losses		15
			140
	Flow at Awash Station		2,460
iii)	Middle Valley: Awash Station to Hertale. Catchment 15,310 km^2		
	Inflow from catchment	1,595	
	add springs	10	
	add Awash flow from (ii)	2,460	
		4,065	
	less losses by spill, evaporation, percolation and use		1,225
	flow at Hertale		2,840
iv)	Middle valley: Hertale to Dubti. Catchment 29,990 km^2		
	Inflow from catchment	1,915	
	add springs	70	
	add Awash flow from (iii)	2,840	
		4,825	
	less losses by spill, evaporation, percolation and use		1,335
	Flow at Dubti		3,490
v)	Lower Plains : Dubti to Lake Abe. Catchment 7,250 km^2		
	Data are not yet available for a proper estimate of the flow balance. But a tentative breakdown of the future normal balance (without Tendaho dam or further development) may be approximately as follows :		
	Inflow from catchment	10	
	add Awash inflow from (iv)	3,490	
		3,500	
	losses in swamps, flood plain and lakes, used for irrigation		1,440
	Evaporation from Lake Abe		2,060
			3,500

6. Comments on Hydrological Factors.

i) The losses by percolation from Lake Gelilea, estimated to be about 380 hm³, are a serious diminution of the available flow. In the interests both of irrigation and of power, every effort should be made to find out the causes, and to apply remedial measures so far as possible. If the diversion of water from the River Meki is possible (as discussed in Chapter VIII), this will result in higher levels of water in the Lake. If, as appears probable, the rate of percolation loss is related to the water level, this would mean that part of the water diverted from the Meki, at considerable trouble and expense, would merely go to increase the losses. Every effort should be made to avoid this. It appears that part of the amount lost, up to perhaps one quarter, may come back to the river between Koka and Wenji, as "return flow". But even so, it will be most desirable to reduce the losses by percolation from the Lake.

ii) As already mentioned in paragraph 4 above, Koka Reservoir already exercises a marked regulating effect on the flows of the Awash downstream of the dam. This is illustrated by the following figures, recorded at Awash Station, 150 km further down.

	1953-58	1960-64
	no reservoir	reservoir in use
	m^3/s	m^3/s
Absolute minimum flow	0.1	20-24
Minimum flow - 1st decile	0.2	23-30
Maximum flow - 9th decile	380	200-250
Absolute Maximum	1000	325

iii) Upper Valley - Koka to Awash Station

In this region the factor of run-off is appreciably higher than in the Upper Basin above Koka, due in some measure to the steep hillsides and the considerable rainfalls in the Chercher area. The river here flows in a valley relatively free of silt, with outcrops of porous formations and/or faults which encourage leakage.

iv) Middle Valley - Awash Station to Hertale

Vegetation in this region is sparser than in the region from Koka to Awash Station, and has less effect in modifying inflows. There are indications that the soils have a somewhat lower capacity for water retention. Losses in the flood plains and marshes downstream from Melka Sedi are considerable.

v) Middle Valley - Hertale to Dubti

The hydrological conditions of this reach are similar to those of the reach upstream of it, though with even heavier losses by spill etc;, and a lower capacity for water retention. Substantial inflows come from springs, notably in the region of Gewani, and to a lesser extent downstream. Large losses by percolation do not appear likely to occur, since in this reach sedimentation is considerable.

vi) Lower Plains - Dubti to Lake Abe.

In this region, because of the complex nature of the natural channels of the river, and the variability of its flows from one year to another, measurement of discharges was not attempted during the Survey. Below Dubti, no appreciable run-off from local rainfall reaches the river, except very occasional and intermittent flows from wadis into Lake Abe, which are unlikely ever to contribute more than perhaps 10 hm^3 to the annual flow. The levels in Lake Abe will rise and fall according to the balance between the inflows reaching it, and the evaporation losses corresponding to the levels at any time; approximately, the levels may range from about 245 to 253 m above sea level.

7. Flood Characteristics.

Flood spates in the Awash and its major tributaries may occur in frequent succession, according to the incidence of rainfalls. The fact that individual rain storms are limited both in duration and in extent has a moderating effect on the resulting flood peaks. During spates, the spilling of water on to the considerable area of flood plains below Awash Station also moderates the peaks in the Middle Valley and the Lower Plains. From physical evidence of past very high floods at various points in the Awash Valley, combined with the observations of flows made in 1962-1964, it has been found possible to estimate the peak rates which have actually occurred in the past. Statistical analysis indicates that the probability of such flood rates must be considerably less than once in 1000 years.

Already, of course, the existence of the Koka reservoir modifies all flood peaks. It has been possible to re-calculate the maximum flood rates to be expected, allowing for this. These are shown in Table 13.

It is both prudent and reasonable to allow for an exceptional maximum flood discharge when designing any hydraulic development project. In the present case, the figure for each site along the Awash down-river from Koka should be between the limits given by the morphological flood discharge and its reduced value. For river sites not affected by the Koka dam, the maximum flood should be assumed equal to the morphological flood.

Proposed maximum flood discharge assumptions for various points in the basin are tabulated above the recurrence frequency of all these floods is well in excess of 1,000 years.

8. Erosion and Sediment Load

i) Field Erosion

Problems related to erosion in the cultivated lands are discussed in Vol. II. It has been found that slope, run-off evacuation and marked dryness of ground during long periods are the main factors of erosion in the farmland. It is accelerated by lack of protective vegetation cover, deforestation, over-grazing on the harvested fields and inadequate tilling at the end of the dry period. Unprotected fields are severely ravaged by rills and gullies during the heavy showers at the beginning of the rainy season. Besides, on the relatively gentle slopes no control measures, such as terracing, bunding or contour ploughing are applied, as frequently happens on steeper slopes.

Suggestions for erosion control methods indicate the need for improvement of cultivation practices, drainage, reduction of velocity in the flow in gullies and, first of all, the necessity for planting protective bands of trees across the slope.

TABLE 13 - ESTIMATED MAXIMUM FLOOD DISCHARGE DATA FOR VARIOUS POINTS ALONG THE AWASH

(Average probability - onoe in 1.000 years)

Position in hydrographic network	Before Koka Dam			Koka Dam in Service			
	Basin area from source (km^2)	Morphological flood		Basin area downstream from Koka (km^2)	Maximum flood reduced by influence of Koka		Maximum flood discharge proposed for spillways (m^3/s)
		(1/s/km^2)	(m^3/s)		(1/s/km^2)	(m^3/s)	
Rivers not affected by Lake Gelilea (Koka Reservoir)							
MEKI to MEKI Village	2,430	124	300				300
KESEM to AWORA MELKA	3,135	450	1,400				1,400
KEBENA Gauging Station	1,245	1.040	1,300				1,300
AWASH to KOKA Dam	11,250	92	1,050				1,050
Rivers affected by Lake Gelilea							
AWASH to METEHARA	15,450	72	1,100	4,200	210	880	1,000
AWASH to AWASH Station	18,570	60	1,100	7,300	130	970	1,050
AWASH to MELKA SEDI	20,750	55	1,150	9,500	110	1,030	1,100
AWASH to MELKA WARAR	26,150	44	1,150	14,900	70	1,050	1,150
AWASH to HERTALE	33,880	26	900	22,650	36	800	850
AWASH to TENDAHO	59,500	18	1,070	48,280	21	1,000	1,000
AWASH to DUBTI	63,870	17	1,100	52,650	19	1,000	1,000

However, erosion being a national problem, the measures suggested should fit into the national programme for erosion control.

Implementation of such a programme implies :

- the establishment of a national organization for water and soil conservation;
- the subdivision of the country into regions, each covering one big watershed;
- the training and placement of technical staff specializing in educating farmers on cultivation practices and capable of directing operations for the control of waterways;
- appropriate legislation effectively enacted.

ii) Specific Degradation of a Whole Watershed

It appeared useful to complete studies of field erosion by studying the final effect of erosion in a whole watershed, in the form of sediment transportation by rivers.

This reflects the capacity of a watershed, considered as a whole, for losing or retaining eroded materials.

On the basis of sediment load measurements at the gauging stations, it was possible to determine the concept of "specific degradation", i.e. ratio between the net exportation of sediments to the area of individual sub-basins.

The following Table No. 14 shows the normal values of "specific degradation" :

TABLE 14 - AWASH BASIN SEDIMENT LOAD AND SPECIFIC DEGRADATION

Rainfall	Catchment area		Normal Sediment load	
stations	Limits	Area (km^2)	(10^6 tons)	Specific Degradation ($t/km^2/year$)
Gefersa Hagere Hiywet	Awash at Melka Kentare	4,440	3.752	845
Adis Abeba				
Akaki	Akaki at Akaki Village	982	0.295	300
Debre Zeyt	Mojo at Mojo Village	1,205	2.110	1.750
Siltu	Awash between Melka Kentare and Melka Gorge	3,283	2.948	900
Koka	Awash at Melka Gorge	7,723	6.700	870
Nazret	Meki at Meki Village	2,432	0.365	150
Wenjii				

TABLE 14 - SEDIMENT LOAD AND SPECIFIC DEGRADATION (Cont'd)

Rainfall stations	Catchment area: Limits	Catchment area: Area (km^2)	Normal sediment load: (10^6 tons)	Normal sediment load: Specific degradation t/km^2/year
Sire	Geleta (Gauging station)	745	0.210	280
Gelemso	Awash between Koka and Metehara	4,240	0.870	205
Awash-Station	Awash between Metehara and Awash - Station	3,050	1.250	400
	Awash between Koka and Awash Station	7,290	2.120	290
Sheno	Upper Kesem (Gauging Station)	40	0.052	1,300
Megezes	Kesem at Awora Melka		3.570	1,140
Ankober	Kebena (Gauging Station)	1,245	1.520	1,220
Chacha Debre Birhan	Awash between Awash St Station and Hertale	15,339	3.070	200
Sela Dingay	Awash between Koka and Hertale	22,629	5.190	230
Debre Sina	Jawaha (Gauging Station)	565	1.960	3,480
Chefa	Jara (Gauging Station)	193	0.054	280
Kembolcha	Borkena (Swamps Inlet)	388	0.570	1,460
Dese	Borkena (Swamp Outlet)	1,735	0	0
Hayk	Mile (Gauging Station)	4,350	3.660	840
Weldya Wichale	Awash between Hertale and Dubti	29,988	27.600	920
Bati	Awash at Dubti	52,617	32.790	620

Data collected were processed in relation to physical relief and rainfall factors; on the basis of this analysis, the Awash basin has been subdivided, from the specific degradation point of view, into five main regions :

Regions	Normal Specific Degradation
Eastern slopes of the Central Plateau	about 1,200 ^{t}/km^2/year
Southern gentle slopes of the Central Plateau	about 850 ^{t}/km^2/year
Arid Lowlands downstream of Gewani Swamps	about 850-900 ^{t}/year
North Western slopes of Chercher Moutains	about 400 ^{t}/km^2/year
Middle Valley between Koka Dam and Gewani Swamps	about 150 ^{t}/km^2/year

The main factors of the specific degradation are physical relief and especially lack of vegetation cover; climatic factors, in particular rainfall intensity, appear to be of secondary importance. This may be seen when comparing the most heavily eroded, extensively cultivated Mojo basin with the adjacent southern slopes of the Plateau, bearing more abundant natural vegetation. The same is true of the well-covered sloping hillsides of Chercher mountains where specific degradation is much lower than in other mountainous regions with similar rainfall.

iii) Sediment Load in the Rivers

Soil particles worn away from agricultural lands are conveyed by the flow of streams and rivers. Before they deposit in lakes, storage reservoirs or swamps, the sediment load of the rivers is usually responsible for the instability of river beds.

An attempt has been made to delineate the main deposition areas in the Awash basin. Water discharged from the Koka power plant is almost clear; the sediment load conveyed from the upper reaches of Awash River is therefore deposited in the Gelilea Lake. Fortunately the bulk of Koka catchment area is subject to relatively slight erosion.

The catchment area of the Middle Valley includes the severely eroded eastern slopes of the High Plateau, but in general the specific degradation of this area is the lowest in the Awash basin. Extensive swamps and floodable areas act as effective silt-traps; they appear to be rather more efficient in the Middle Valley, upstream of Hertale gauging station, than downstream of this point. A possible explanation is the relatively well developed hydrographic network of natural channels in the large Gewani swamps. Flow velocity in these channels is high enough to convey out of the swampy area large part of sediment load, which do not deposit in the area. Besides a considerable part of the sediments conveyed by the torrential tributaries, which usually do not reach the main river, is probably deposited on the alluvial plains, especially on the left bank. This explains the relatively low sediment load measured at the Hertale gauging station.

Also, in the extensive swamps stretching from Gewani to the confluence with the Borkena river depositing of sediments is probably active. However, the sediment load increases considerably in the river during its course through the severely eroded region downstream of Gewani swamps. This is certainly in relation with extensive tracts of vegetationless "badlands" located close to the riverbed on both banks.

The Lower Plains are natural deposition areas. This results in the very flat ground slope which communicates an extreme instability to the riverbed and its numerous shifting meanders. There is little hope of stabilising the riverbed in the Lower Plains unless floods are brought under effective control. The observations of the 1964 floods, however, may suggest that the removal of fallen trees and débris which often obstruct the riverbed, may to some degree provisionally reduce the extent of the inundations, prevent the building up of new channels, and the diverting into these new channels of a substantial part of the flow.

CHAPTER VIII - WATER CONTROL FOR IRRIGATION AND POWER

1. Need for Development of Water Resources

Hydrological survey has shown that the flow of the Awash River itself is fairly regular at its entrance into the Middle Valley, whereas the regime of the tributaries is subject to wide variations in the rainy and dry season. The correlation of data from the old staff gauge in the gorge near Awash Station with the records of the hydrometric stations installed in 1962 in the same gorge reveals that, under its natural regime, the Awash River used nearly to dry up with the flow as low as 200 l/s. Since the construction of Koka dam, the lowest rates of flow recorded at Awash Station have seldom fallen below 30 m^3/s. Accordingly, peak floods, formerly reaching 700 m^3/s, are now much reduced; maximum floods of 300 m^3/s are only recorded when flooding occurs in such major tributaries as the Arba Dima.

The Koka Dam has therefore considerably evened out the Awash flow, and an intermittent river converted into a permanent one. This experience shows the considerable effects that may be expected from subsequent flow regulation projects. But the tributaries continue to dry up during the dry seasons and the floods occurring during the rainy seasons may account for as much as 95% of the total annual flow. This water is lost for any economic use. Moreover, the regulating effect of Koka dam gradually diminishes downstream, where large inflows from tributaries contribute to swell the seasonal floods of the river. Additional dams will therefore be needed to store the flood waters and to ensure that the best possible use can be made of existing and potential water resources.

The possibilities for and the feasibility of water resources development in the Awash basin, and ways and means for improving irrigation water supply and subsidiary hydro-power production are fully discussed in Vol. IV of this Report. Besides new facilities for storage, consideration has also been given to the idea of increasing water supplies in the Awash Basin by providing additional flows from adjacent river basins.

Finally the prospects of adapting the present Awash flow, so far regulated only for hydro-power needs, so that it may assist irrigation requirements, are given attention.

2. Storage Dams - General

(i) Criteria for selection

Dam site investigations were conducted on the main river and the tributaries. While a number of potential dam sites are discussed in Volume IV of this Report, only the more promising sites which were subject to more detailed studies will be mentioned in this Chapter. (See Map 14).

In the selection of potential dam sites for further investigation the following main criteria have been applied:

- The principal purpose of new storage dams will be the supply of irrigation water and flood protection with power production as a subsidiary function;
- Stored water should not submerge good cultivated lands;
- Dams should be located close to potentially irrigable areas.

In relation to these criteria several potential dam sites identified under the Project's operations have been discarded. Some possible dam sites in the gorges of the Middle Valley appear more suitable for power production than for irrigation purposes. A dam site on the Awadi River would have too small a storage capacity. One on the Borkena River would result in drowning excellent cultivated lands. Those on the lower Awash at the confluence with Ledi or on the Mile River, are too far from the potential irrigable areas.

Some of these, and perhaps other dam sites identified by the Project's team can perhaps be developed in the future when high returns from irrigated agricultural will warrant sufficient repayment rates, but their construction can hardly be justified in the present stage of the country's economic development.

(ii) <u>Scope of technical investigations for selected dam sites</u>

Three potential storage dam sites have been selected for more detailed investigations. They are located on the left bank tributaries Kesem and Kebena, and on the Awash itself at Tendaho.

In order to calculate storage capacity, contour maps of the reservoir areas were drawn to a scale of 1:20,000. Detailed surveys of the dam sites were subsequently carried out to the scale of 1:1,000 and served for geological and civil engineering investigations.

The very special features of the geological structure of the Awash basin called for a particularly careful geological survey. This was carried out not only for the foundation studies, but also in respect of possible leakage problems. After a thorough surface survey, relevant programmes of test borings for the purpose of deep reconnaissance and permeability assessments were prepared and executed at the Kesem and Tendaho dam sites.

Hydraulic and civil engineering investigations, necessary to establish the relevant water balance, included analyses of inflows, both natural and those resulting from irrigation development upstream, reservoir evaporation, irrigation water requirements and potential hydro-power output. The hydrological year 1962/63 has been taken as the reference year, because its hydrological conditions have been found to be close to those in a "normal" year.

A set of preliminary design documents and costings were prepared and are appended to Volume IV.

3. <u>Kesem Dam</u>

(i) <u>Topography and Capacity</u>

Kesem storage dam site is in a gorge cut by the Kesen river, a large left bank tributary, to a depth of about 70 m, and about 200 m wide at the mouth. Its location is shown on Map 14. The following table gives the main characteristics of the potential reservoir.

TABLE 15 - KESEM DAM CAPACITIES

Water Depth (m)	Surface of the reservoir (ha)	Storage capacity (hm^3)
55	1400	190
64	1850	270
69	2300	370
74	2850	500

(ii) Geology

The gorge is cut in volcanic outflows which consist of alternations of hard rocks, mostly andesite and basalt, and soft layers of volcanic tuffs and ashes. As regards foundations, the alluvial layer in the riverbed is only 5 m thick, and the conditions for constructing a rock-fill dam are reasonably good. High permeabilities have been found in some sections of the abutments and therefore a substantial grouting curtain will be needed, fortunately of limited extent.

No particular risks of leakage from the reservoir along its boundaries were apparent, provided that water storage is kept at a level corresponding to a dam height not exceeding 70 m. Above this level secondary dykes would have to be constructed at one point on the boundary of the reservoir. The recommended water depth at the dam site is therefore 69 m, which will provide a storage capacity of about 370 hm^3.

The geologist concludes that a rockfill dam would appear to suit best the geological structure of the dam site. A concrete dam may also be constructed provided that the alluvium in the river bed is cleared down to the bedrock.

(iii) Hydrology and Water Balance

The total normal inflow in the storage reservoir, as computed by the statistical rainfall and runoff studies, is estimated at about 600 hm^3, out of which about 90 percent are discharged during the rainy months of July, August and September. The selected capacity of the reservoir is therefore insufficient to ensure full annual regulation and a part of the high flow during the rainy season will have to be discharged.

The total silt load contained in the flow corresponds to a mean annual inflow into the reservoir of about 3,000,000 m^3 of sediment. Almost all of this is carried during the period of heavy floods, and it may be possible to route the flood-waters through the dewatering conduit and carry some of the sediment out of the reservoir. However, this will be at most a small proportion of the silt load, and the life time of the storage dam, which may be estimated at about 100 years if all the sediment load was deposited in the reservoir, may only slightly be increased.

The probabilities of peak floods have been estimated as follows:

A flood of at least 840 m^3/s may probably occur once in 10 years

A flood of at least 1100 m^3/s may probably occur once in 50 years

A flood of at least 1180 m^3/s may probably occur once in 100 years

A flood of 1400 m^3/s is considered as the maximum possible

The spillway may be designed for a maximum discharge of 1500 m^3/s. However, except in emergency, the rate of spilling should not exceed 500 m^3/s, because of the risk of flooding in the irrigable area.

Net losses by evaporation from the water surface are estimated, following the findings of the meteorological survey, at about 20,000 m^3/ha per annum, which works out to a total annual loss of about 35.5 hm^3 for the average surface of the reservoir (1770 ha).

(iv) Water Use and Management

Estimates of irrigation water requirements suggest that a minimum storage capacity of 300 hm^3 in the reservoir will help to irrigate about 22,500 ha of land, approximately 5,000 ha more than is available in the Ksem-Kebena Plain. This irrigation water can also be used for power generation as the tail race head still commands the irrigation areas by gravity.

Water planning studies have shown that a supply of irrigation water to a slightly smaller area of 22,000 ha would allow a monthly hydro-power production of about 3,5 GWh. In order to achieve this minimum firm power production, the power plant would discharge over 4 months more water than can be taken up in irrigation; the total annual excess outflow would be about 16 hm^3.

This excess outflow has been provided for in the following water management schedule for the dam, which provides for a continuous intensive irrigation of 22,000 ha and for a power plant output of 3.5 GWh per month, (Table 17) overleaf.

(v) Civil engineering

The following alternatives were considered: a concrete hollow dam or a rockfill one, the latter is cheaper and was given preference.

For construction purposes a diversion gallery 400 m long will have to be built on the left bank. The gallery with discharge capacity of about 500 m^3/s will eventually be used as an outlet conduit. The power plant will be installed also on the left bank at the foot of the dam. The spillway, equipped with two sector gates, is located on the right bank.

A grout curtain, needed to prevent leakage, will be injected into both banks. Its total surface is estimated at 100,000 m^2.

Table 16 shows the principal characteristics of the scheme.

TABLE 16 - REGULATION OF KESEM RESERVOIR (Irrigation 22,000 ha)

Months (1962-63)	O	N	D	J	F	M	A	M	J	J	A	S
Storage contents at the beginning of the month (Vi(hm3)	367	350	325.5	285.5	248.5	212	183.5	162	124.5	78	166	367
Water consumption R (hm3) (Irrigation+Power+Evaporation)--inflow	17	24.5	40	37	36.5	28.5	21.5	37.5	46.5	-88	-304.5	-36
Spilling Sp(hm3)	-	-	-	-	-	-	-	-	-	-	103.5	36
Mean head of water H (m)	68.6	67.6	65.9	63.8	61.7	59.6	57.8	55.5	51.5	53.2	63.2	69.0
Power productivity P(GWh)	3.51	3.53	5.71	5.10	4.80	3.51	3.47	5.24	5.38	3.55	3.51	4.60

TABLE 17 - KESEM DAM - PRINCIPAL CHARACTERISTICS

PERFORMANCE	Irrigation possibilities	22,000 ha
	Firm power productivity per annum	42.5 GWh
	Damping of floods to a limit of	500 m^3/s
DAM AND POWER PLANT	Height of crest above river level	74 m
	Length at the crest	220 m
	Width at the crest	10 m
	Volume of rockfill dam	900,000 m^3
	Spillway capacity	1,500 m^3/s
	Freeboard above exceptional maximum water level	2 m
	Installed power	12,000 KW
	T.W.L. above river	69 m
RESERVOIR	Normal maximum capacity	370 hm^3
	Corresponding surface	2,300 ha
	Total inflow of silt per annum	3 hm^3
	Net evaporation from the reservoir per annum	35 hm^3

4. Kebena Dam

Kebena River, an important tributary of the Awash, runs across the alluvial plain parallel to the Kesem at a distance of about 15 km.

It commands the same development area as the Kesem river, and no other areas to which Kebena water may be more easily conveyed have been identified. Thus damming of the Kebena would only be justified if the cost were significantly less than that of the Kesem dam. Topographical examination and surface survey of the geological structure of the site showed at an early stage that construction costs of the dam would be relatively higher than those expected for the Kesem dam.

It was therefore decided not to implement the programme of test borings suggested by the geologist. The view that the Kebena dam will be relatively expensive has been confirmed by subsequent hydraulic and civil engineering studies, as may be seen in the section dealing with estimates in Chapter XI.

The principal characteristics of a potential concrete gravity dam on the Kebena River are shown in Table 18.

TABLE 18 - KEBENA DAM - PRINCIPAL CHARACTERISTICS

PERFORMANCE	Irrigation possibilities	5,000 ha
	Firm power productivity per annum	12 GWh
DAM AND POWER PLANT	Height above river level	65 m
	Length on the crest	125 m
	Volume of concrete dam	135,000 m^3
	Spillway capacity	1,200 m^3/s
	Installed power	3,800 KW
RESERVOIR	Normal maximum capacity	50 hm^3
	Corresponding surface	220 ha
	Evaporation from the reservoir per annum	4,5 hm^3
	Total inflow of silt per annum	1,0 hm^3

5. Tendaho Dam

(i) Topography and Capacity

The dam site is located in a narrow section of the river between two volcanic hills, which rise about 50 m above the river bed; the cross-section widens gradually upwards from about 200 m at the base of the hills. A saddle on the left bank hill, through which runs the highway to Aseb, is only 30 m above the river level.

The reservoir area appears to be long and rather narrow, with a gentle side slope in its upstream part. An extensive part of the lake would therefore be covered by a shallow sheet of water if its surface were not limited.

The storage capacity and surface area of the potential reservoir in relation to the height of the dam are given in Table 19.

TABLE 19 - TENDAHO DAM - ALTERNATIVE CAPACITIES

Water depth (m)	Surface of the reservoir (km^2)	Storage capacity (hm^3)
26	63.5	376
28	81	516
30	104	716
32	131.5	970
34	about 165	about 1300
36	about 210	about 1800

The figures on the two bottom lines have been extrapolated.

(ii) Geology

The volcanic hills on both sides of the river consist of alternating basaltic outflows and layers of slag and volcanic ashes mixed with dusty material of uncertain origin and with soft tuff. There is a general conformity of the formations on both hills, although the thickness of layers varies noticeably. Permeabilities found in the abutment areas are reasonably low and a small grout curtain will be needed only for the more pervious formations.

Test borings in the river bed did not reveal any volcanic rocks and a thick layer of sedimentary formations was identified. It is not clear whether the volcanic formations of the hills overlie a large sedimentary plain, or whether the Awash river has filled up a deep valley with alluvia. The sediments consist mainly of clayey loams and fine sands with occasional beds of conglomerates. No evidence of water table was found in this terrain. The sediments are fairly impervious and there is small chance of seepage from the reservoir bottom.

The reservoir sides, however, showed high local permeabilities associated with a system of faults on the right bank. Fortunately the pervious area seems limited to the vicinity of the faults. Similar faults are identified on the left bank, mainly in the saddle area. Although no test borings were drilled in this area, the probability is high that leakage is serious also in this area. Thus grout screens will be needed on both banks. The exact extent of them may be ascertained only by further test borings.

The geologist supports the feasibility of a rockfill dam, but rules out a concrete one and recommends a series of supplementary test borings for the purpose of determining the scope of operations to prevent leakage.

(iii) Hydrology and Water Balanoe

The period of hydrometrio measurements inoluded, for Lower Plains, a year with heavy floods and inundations. During this year, 1964, the total flow at the Dubti hydrometrio station was found to be about 3700 hm^3, as against a flow of less than 2500 hm^3 in the previous year 1962/63, and as the oorresponding rainfall was oonsidered to be slightly less than normal, it was deoided to adopt the 1962/63 year as the standard for water management of the reservoir. Beoause of the shortness of the observation period this solution was believed to give margin of safety than any attempt to oompute the theoretioal flow of a normal year.

The total silt load brought into the reservoir area was estimated at an average of 29,000,000 t, or at a volume of about 20 hm^3 per annum. If all the sediments were deposited in the reservoir, it would be filled up in about 50 years. In faot, the sediments oonsist mostly of fine to very fine partioles whioh do not deposit readily, and there is a fair probability that some part of the sediment load may be oarried out of the reservoir during the period of high flows. The oonstruotion of silt traps on the Awash and Mile rivers may help to extend the life time of the reservoir.

Evaporation is fairly high in the Lower Plains and an annual loss of about 30,000 m^3/ha of water surfaoe should be reokoned with. The following table gives the estimates of evaporation losses in relation to the mean head of water and oorresponding mean reservoir area.

TABLE 20 - TENDAHO DAM - EVAPORATION LOSSES

Mean depth of water (m)	Mean surfaoe of reservoir (km^2)	Annual loss by evaporation (hm^3)
26	63.5	189
28	81	214
30	104	310
32	131.5	392
34	164	491
36	210	625

With a high evaporation rate there might be risk of exoessive water salinization in the reservoir. Analysis revealed that the total soluble salt oontent in the samples taken at the Dubti hydrometrio station was around 0.35 g/l. Subsequently it was oomputed that for the suggested water operation plan the mean annual salt oontent in the disoharged water will probably not rise above a range between 0.40 to 0.42 g/l, so that its water quality for irrigation purposes will not be affeoted.

The probability and frequenoy of peak floods is disoussed in Vol. III, and to ensure that these oan in all oases be safely dealt with, the disoharge oapaoity of the spillway should be 1000 m^3/s. But in order to avoid flooding in the Lower Plains, it is desirable that the total disoharge should not exoeed 300 m^3/s. Thus the reservoir oapaoity must be large enough to so damp out the floods, that all disoharge above 300 m^3/s may be temporarily stored. It has been oalculated that a very high and long lasting flood whioh ooourred in 1964 might have been stored in a reservoir designed for a normal maximum oapaoity of 970 hm^3, with a freeboard allowanoe of 3 m.

TABLE 21 – REGULATION OF TENDAHO RESERVOIR

Months (1962-63)	N	D	J	F	M	A	M	J	J	A	S	O
Vi(hm3)	970	871	759	675.5	549	418.5	455	517	373.5	376.5	609	955.5
E (hm3)	26	23.5	21	20.5	21	19	23	24	14.5	18.5	30.5	32.5
B (hm3)	105.5	96.5	56	58	58.5	47	19	71.5	128.5	107.5	138	133.5
R (hm3)	25.5	35.5	66	68	76.5	86	100	71.5	44	47	10	5.5
C (hm3)	99	112	83.5	126.5	130.5	-36.5	-62	143.5	-3	-232.5	-346.5	-30
H (m)	30.45	29.65	28.95	27.95	26.35	25.75	26.50	25.70	24.50	26.10	29.05	30.05
P (GWh)	8.87	8.70	7.85	7.82	7.90	7.61	7.01	8.17	9.40	8.97	9.55	9.47

Vi – Storage capacity at the beginning of the month
E – Net evaporation from mean monthly surface of the lake
B – Irrigation water requirement for 66.500 ha
R – Supplementary discharge for power production and water spreading
C – Water consumption – less inflow
H – Mean head of Water
P – Potential power output

(iv) Water Use and Management

A water management plan for the reservoir is fully discussed in Vol. IV. Noticeable modifications of inflow rates into the reservoir are bound to occur as a result of irrigation development and relevant flow regulation in the upstream areas. Three assumptions, each corresponding to a specific case of possible development in the Middle Valley, were successively analyzed and water management plans established for each of these. For the second case, the assumption was made that no complementary water resources will be developed in the Basin, e.g. from Meki River, but that the flow of the main river is modulated in accordance to the expected irrigation requirements of about 50,000 ha.

As the Tendaho dam is likely to be operational at this intermediary stage of development, main features of the relevant water management schedule are given in Table 21. The maximum normal water depth at the dam site, i.e. 32 m, has been taken into consideration in both regulation and power production requirements. The total area of irrigable lands commanded by the dam and available for development without reclamation is estimated, in accordance with soil-survey findings and irrigation layout, at 66,300 ha. Supply of irrigation water for this area of land is provided for in each alternative water management schedule. Significant variations, however, result in power production potential, as this is bound to decrease with higher water consumption in upper reaches.

The lowest potential power output figures found in the three water management plans have been selected for dimensioning the power plant (21,000 KW) and estimates for the firm potential power output (91 GWh per annum). The latter includes power earmarked for pumping irrigation water (22 GWh) on an area amounting to approximately 45,000 ha. (See Map 18).

(v) Civil engineering

The dam consists of two parts: a rockfill dam across the river and a concrete structure on the left bank.

Power plant offtakes and dewatering gate are installed on the concrete section of the dam. The spillway, equipped with two sector gates, is established on the left bank.

The area of grout curtain needed to prevent leakage is estimated at about 80,000 m^2.

Table 22 shows the principal features of the dam.

TABLE 22 - TENDAHO DAM - PRINCIPAL CHARACTERISTICS

PERFORMANCE	Irrigated areas	66,500 ha
	Total annual potential power output	91 GWh
	Power earmarked for pumping of irrigation water	22 GWh
	Damping of floods to a limit of	300 m^3/s
DAM AND POWER PLANT	Height above river bed	35 m
	Length at the crest	280 m
	Width of the crest	7 m
	Volume of rockfill dam	300,000 m^3
	Spillway capacity	1,000 m^3/s
	Freeboard above normal maximum water level	3 m
	Installed power plant	21,000 KW
RESERVOIR	T.W.L. above river	32 m
	Normal maximum capacity	970 hm^3
	Corresponding surface	131.5 km^2
	Total inflow of sediments per annum	20 hm^3
	Evaporation from the reservoir per annum	274 hm^3

6. Meki Diversion Scheme

(i) Topography

The idea of supplementing the Awash water resources by diverting a part of the flow from adjacent basins has been mentioned in the reports of various previous reconnaissance missions. With the establishment of the Koka dam and power plants, the possibility of constructing a relatively short canal to lead the waters of Lake Ziway into Lake Gelilea with a minimum difference of elevation of about 45 m, appeared sufficiently attractive to justify preliminary investigations. These were initiated by the Project team, although not included in the plan of operations.

A series of interconnected marshy depressions was located between a small Awash right bank tributary, the Dubeta, amd the Meki River which flows into Lake Ziway from the North West. Preliminary observations revealed that the depressions probably mark the alignment of an old channel connecting the two rivers. (See Map 15).

Subsequent topographic operations have shown that for some distance the ground slopes towards the Meki river, which may be due to an orogenic movement. The canal would have to be about 18 km long, and would cross elevated ground before reaching the Dubeta river. Consequently, relatively substantial excavation would be necessary; a short section of the canal would be about 22 m deep.

On the other hand the slope of the Dubeta is significantly steeper than that of the Meki, so that control of current velocity in the canal would be needed.

(ii) Hydrology and Water Control

From observations made at a hydrometric station installed in 1963 specially for this purpose, the total flow of the Meki river from November 1963 to October 1964 inclusive was found to be 230 hm^3. 95 percent of the recorded flow occurred in 5 months of the year.

It appeared reasonable to contemplate eventually the diversion of some 200 hm^3 annually into Lake Gelilea above Koka Dam, achieved by stages over several years. Such an amount would raise the water level in Lake Gelilea by about 1.0 m, which appears safe with present freeboard at Koka Dam of 2.5 m above Top Water Level. In point of fact at the highest water level yet attained in the Lake, the freeboard was 3.0 m.

Additional amounts so stored in the Lake could be used either to increase the flow passed through the turbines for power, or specifically for irrigation.

In the former case, the production of power plants dependent on the Koka Dam would increase by about 15 percent, i.e. by 16 GWh at the existing station (Awash I), and by 74 GWh when the two stations now under construction (Awash II and Awash III) come into operation, provided the leakage from the reservoir continues in the same proportion as at present. The supplementary flows would make possible the irrigation of some 10,000 ha additional in the Middle Valley.

In the latter case, the supplementary water would all be released from Koka Reservoir during the months of low flow. This, it is estimated, would make possible the irrigation of some 40,000 ha of additional land. Some increase in the output of firm power could be expected, but its amount cannot yet be estimated.

(iii) Civil engineering

Civil engineering works would involve mainly the excavation of the initial canal which is expected to take progressively its final section and stable slope by erosion. In order to prevent too active a regressive erosion, however, a series of sills will be needed in the channel of the Dubeta rivers.

The off-take structure may be provided with two roller gates and the Meki river dammed with a submersible weir formed of gabions.

The total volume of excavation is tentatively estimated at 7,200,000 m.

The project seems attractive, but no detailed engineering studies should be initiated until a few important problems are first elucidated.

(iv) Further investigations required

The catchment area of Meki river is about 2,400 km^2 and accounts for 1/3 of the total catchment area to Ziway Lake, which usually discharges its water into the brackish lake of Hora-Abyita. Diversion of a part or all of the Meki flow will result in lowering of the Ziway Lake water level and, consequently, in a reduction of its discharge. A hydrological survey of the Plateau of Lakes will be needed in order to appreciate the effects of diversion of the Meki flow on the hydrological balance of the Lakes.

The permeability of terrain across which the diversion canal is to run must be carefully investigated. The surface soils consist of very light volcanic ashes and extensive gully erosion has occurred. It is possible however that the alluvial layers deposited in the old river bed are deep enough to ensure reasonably low permeabilities in the future channel. A series of test borings will be needed to ascertain the permeability of deep layers.

Although the capacity of the Lake Gelilea is sufficient to store the additional volume of water, with the level of the lake rising by about 1m, there remains the need for a thorough study of the possible effect of higher water levels in the reservoir on the present considerable leakage losses. This is discussed below.

7. Management of Available Water Resources

In relation to the possible improvement of water management in the Koka reservoir, two major problems should be considered:

- Siltation control
- Water loss prevention

(i) Siltation control

An efficient control of the rate of siltation is of paramount importance because of the reduction of reservoir capacity following deposition of sediments at the bottom of the lake. Long before the reservoir is completely silted up, the reduction of its capacity will result in a progressive reduction of power productibility and the supply of water for irrigation.

Data recorded at the Project's hydrometric station suggest that the total volume of sediment load brought into the reservoir is about 6 hm^3 per annum. As this volume amounts to about 0.33 percent of the capacity, it suggests that the reservoir would be completely filled with sediments in about 300 years. It should be pointed out, however, that this estimate is based on only a very short period of observations. The forecast of the life-time of the reservoir must be confirmed by systematic surveys by depth sounder, which will help to establish the reservoir capacity, up to date, to locate the main areas of deposition, and to check the progress of sediment deposit.

To a limited degree siltation control may be improved by diverting a part of the sediment-laden inflows into the marshy fringe areas of the reservoir. These marshes may be progressively reclaimed by isolating them from the main body of the reservoir by dykes and warping with sediment-laden water.

(ii) Water loss prevention

Since the Koka dam went into effective service, it has been obvious that the water losses in Lake Gelilea are higher than expected. This is due to somewhat higher evaporation rates than initially reckoned with, and, apparently, to considerable seepage from the reservoir. The cumulative annual water loss would appear, on the basis of 3 years' observations by Project hydrologists, to be as high as 700 hm^3, equivalent to a continuous rate or flow of almost 22 m^3/s. Evaporation losses are estimated at about 320 hm^3, the balance is probably due to leakage.

Unfortunately, effective measures to reduce evaporation cannot yet be assured, the development of suitable methods being still at the experimental stage. Evaporation is more active in the shallower fringes of the water body, where water is warmer, than in the deeper section. Moreover, vegetation usually grows in the shallow water, and its transpiration adds to the evaporation losses from the open water surface. The suggestion to reclaim the marshy fringes of the lake, referred to above would appear, at the moment, about the only possible measure to reduce the evaporation losses.

Seepage losses, computed as balance between total inflows and outflows (turbine flow + evaporation loss), may be estimated at an equivalent of a continuous discharge of about 12 m^3/s. Such a flow might have produced about 35 GWh/year of electricity at the Koka plant; this figure illustrates the magnitude of the problem, which is still far from being sufficiently elucidated. As the areas where losses of water occur are very scattered, direct measurement of the total leakage is not easy. It is believed that seepage occurs mainly through the bottom of the reservoir. A closer study of leakage areas should be given a top priority as it may reveal a possible means of reducing, at least partially, the loss of water.

8. Compensation Dam

The discharge from Koka dam is regulated according to the needs of power production. Apart from daily and weekly variations of the discharge, no apparent law governing the monthly outflows could be detected, but it may be assumed that, with increasing power demand, the volume of water discharged will become less irregular from one month to another. Such uniform regulation does not agree with irrigation requirements, which vary considerably at different seasons of the year. In the table below a critical period of 5 months of particularly low flow is analyzed.

TABLE 23 - ANALYSIS OF AWASH FLOW IN LOWER PERIOD

Description		1962 Nov.	1962 Dec.	1963 Jan.	1963 Feb.	1963 Mar.
1. Observed River Flow at Awash Station	hm^3	80.0	59.5	68.0	63.0	104.0
2. Requirements for Nura-Era and Metehara areas (15,000ha)	hm^3	15.5	25.0	23.5	23.8	18.5
3. Balance of flow available	hm^3	64.5	34.5	44.5	40.0	85.5
4. Net rate of use in m^3 per ha (assuming 20% return flow)		765	1415	1315	1270	955
5. Hectares irrigable (3) ÷ (4)		84,000	24,500	34,000	31,500	89,500

The wide variations in the remaining monthly flows and the irrigable areas are obvious.

Compensation for these variations may be achieved by establishing a reservoir in which surplus water in the wet months may be stored to supplement the flow in the dry ones. The effective storage capacities required in order to ensure such compensation during the critical period referred above are listed in Table 24 in relation to the areas in the Middle Valley below Awash Station which might have been irrigated with each given capacity.

TABLE 24

COMPENSATION RESERVOIR - CAPACITIES AND AREAS IRRIGABLE

Area (ha)	Capacity (hm^3)
24,500	0
25,000	0.5
30,000	8.0
35,000	21.5
40,000	41.5
45,000	59.5
50,000	82.5
55,000	103.5

The decision to provide such a reservoir and the selection of the capacity to be given to it will depend to a great extent on the general plan of development. With the available water supply substantial areas of land may already be irrigated. Future economic development may justify priority implementation of the Meki or Kesem projects, as each of them would increase the available resources of water. Finally, a steady increase in power consumption, together with the harnessing of other rivers for power production, may allow the water management plan for Koka Dam to be so modified that the monthly flow at the entry into the Middle Valley will never fall below 70 to 80 hm^3. This flow would provide sufficient water to irrigate about 50,000 ha in this region, i.e. the greater part of the lands to which Awash water can be economically applied. An appropriate agreement with EELPA (Ethiopian Electric Light and Power Authority) to guarantee an adequate discharge at the Koka Dam may obviate the need for a monthly compensation dam.

In case such an agreement cannot be reached, a possible site for a dam has been tentatively located in the deep gorges cut in the basaltic formation near Awash Station. Only a very rough topographical reconnaissance was made and this revealed that a 40 m high dam constructed near the railway bridge may probably store about 50 hm^3, which is believed to be the maximum capacity to be contemplated for the reservoir. More detailed studies and geological investigations will be needed before this project can be appraised.

9. Hydro-Power Potential of the Upper Basin

Three falls and several rapids between Awash III power plant now under construction and Awash Station, have been inspected by the Project team. The cumulative head at these falls and rapids is estimated to be about 158 m. It would appear possible to construct a series of power plants using the flow regulated by the Koka dam. The following gives a rough estimate of the total power potential available in the Upper Valley of Awash River.

TABLE 25 - UPPER VALLEY - ESTIMATED POWER POTENTIAL

Power site	Average head (m)	Annual Productivity (GWh)
Koka plant (Awash I) - in service	36	110
Awash II and III - under construction	119	360
Awash IV - at design stage	58	180
Three downstream sites - first priority	50	150
Rapids - second priority	50	150
Totals	313	950

CHAPTER IX - PRIORITIES IN PLANNING WATER USE

1. Areas possible

It is apparent that the amounts of water available with the present degree of water control, i.e. that provided by the Koka Reservoir, are sufficient for the irrigation of some 66,000-67,000 ha in the whole Valley. The hydrological studies made so far indicate that had sufficient additional water control been achieved by a suitable selection of the projects discussed in chapter VIII, with programmes of water management strictly adapted to irrigation requirements, in the conditions of the year 1962/63, the irrigation of some 200,000 ha might have been possible. It is believed that the conditions of 1962/63 approximated to those of an average year. But in view of the very limited period for which records of flows are available, at present it appears wise to assume a smaller figure for the total area irrigable in the Basin. Further, on the basis of soil survey and preliminary engineering investigations a total of 163,250 ha is adopted as the target, to include those lands of good quality to which water can most easily be conveyed, as well as all the areas nor irrigated.

2. Areas possible with various combinations of water control schemes.

Numerous computations were made by SOGREAH to determine the maximum area irrigable in the Upper Middle Valleys, and the Lower Plains, respectively, with various combinations of schemes of water control. The results are shown in Table 26. For ease of comparison of the various alternatives there are set out in two groups, those without Tendaho Dam and those with it. In some cases, the figures of area are determined by considerations of soils and accessibility to irrigation and not merely by amounts of water likely to be available: these are made clear by notes attached to the Table. Rates of costs per ha of area are based on the estimates of capital costs given in chapter XI ; they cover the costs of schemes of water control only.

The main points revealed by study of the Table may be summarized as follows :

i) In respect both of areas irrigable, and of cost per ha, one of the most advantageous projects of water control is the Meki Diversion Scheme, provided it is technically and economically feasible, which is still uncertain. It appears highly desirable to initiate as soon as possible the further investigations required to determine this. (See Figs. 14 and 15)

ii) If the Meki Diversion Scheme is feasible, the decision as to whether its benefit in water should be used primarily for power (P) or primarily for irrigation (I) is a matter for Government to decide, on comparison of the respective economic and social advantages of these two alternatives. For the further purposes of this Report, it has been assumed that the decision is in favour of irrigation.

iii) If the Meki Diversion Scheme proves not to be feasible, the Compensation Reservoir will provide a useful, but much less beneficial, alternative.

iv) Tendaho Dam is essential to make possible the maximum development of the Lower Plains, at reasonable rates of cost.

v) Kesem Dam can contribute to the increase of area in the Lower Plains, and alone will make possible the irrigation of certain areas in the Kesem-Kebena area of the Middle Valley which are not accessible to irrigation from the Awash itself. The cost per ha. of development irrigated from Kesem Dam will be relatively higher than with other schemes of water control.

TABLE 26 - MAXIMUM AREAS WHICH COULD HAVE BEEN IRRIGATED IN 1962/63 WITH VARIOUS SCHEMES FOR WATER CONTROL

Schemes of Water Control	Maximum Areas Hectares				Average Unit Capital Cost E$/ha	Remarks
	Upper and Middle Valley	Lower Plains	Whole Awash Valley	Increase on (1)		
A. Without Tendaho Dam						
(1) Koka Dam only as at present	46,050	20,000**	66,050	-		Alternative - UMV 54,250, LP 12,750, Total 67,000 ha
(2) Koka + Comp^n Dam	56,300	20,000**	76,300	10,250	875	" UMV 70,200, LP 7,700, Total 77,900 ha
(3) Koka + Meki (P)	56,200	20,000**	76,200	10,150	1,040	" UMV 65,500, LP 11,750, Total 77,250 ha
(4) Koka + Meki (I)	81,400*	27,400	108,800	42,750	245	
(5) Koka + Kesem	71,250	20,000**	91,250	25,200	1,190	Alternative - UMV 80,150, LP 12,150, Total 92,300 ha
(6) Koka + Comp^n + Meki (P)	67,150	20,000**	87,150	21,100	920	" UMV 81,400, LP 7,400, Total 88,800 ha
(7) Koka + Comp^n + Meki (I)	81,400*	41,500	122,900	56,850	340	
(8) Koka + Comp^n + Kesem	81,500	20,000**	101,500	34,450	1,095	Alternative - UMV 93,850, LP 9,100, Total 102,950 ha
(9) Koka +Kesem + Meki (P)	81,500	20,000**	101,500	35,450	1,140	" UMV 89,300, LP 13,100, Total 102,400 ha
(10) Koka + Kesem + Meki (I)	96,950*	40,000	136,950	70,900	570	
(11) Koka + Comp^n + Kesem + Meki (MP)	92,400	20,000**	112,400	46,350	1,065	Alternative - UMV 96,950, LP 16,000, Total 112,950 ha
(12) Koka + Comp^n + Kesem + Meki (I)	96,950*	60,900	157,850	91,800	540	
B. With Tendaho Dam						
(13) Koka + Tend	54,250	66,300*	120,550*	54,500	410	
(14) Koka + Comp^n + Tend	70,200	66,300*	136,500*	70,450	450	
(15) Koka + Meki (P) + Tend	65,500	66,300*	131,800*	65,750	500	
(16) Koka + Meki (I) + Tend	81,400*	66,300*	147,700*	81,650	400	
(17) Koka + Kesem + Tend	80,150	66,300*	146,450*	80,450	650	
(18) Koka + Comp^n + Meki (P) + Tend	81,400*	66,300*	147,700*	81,650	510	
(19) Koka + Comp^n + Kesem + Tend	93,850	66,300*	160,150*	94,100	650	
(20) Koka + Meki (P) + Kesem + Tend	89,300	66,300*	155,600*	89,550	700	
(21) Koka + Meki (I) + Kesem + Tend	96,950*	66,300*	163,250*	97,200	645	
(22) Koka + Comp^n + Meki (P) + Tend	96,950*	66,300*	163,250*	97,200	740	

* Maximum limited by extend of land found suitable in respect of quality of soils and commandibility for irrigation.

** Area in Lower Plains assumed at 20,000 ha, being full amount of water right now granted. If this area is less, area in Upper and Middle Valley can be increased - See Remarks column.

Legend - Koka = Koka Reservoir as now existing.
Comp^n Dam - Compensation Res^r of about 50 hm3 capacity to reconcile water use for hydropower.
Meki (P) = Meki Diversion Scheme Priority for hydropower.
Meki (I) = " " " " " irrigation only.
Kesem = Kesem Res^r with a capacity of 350 hm3.
Tend = Tendaho Res^r with a capacity of 960 hm3.

It should be noted that only Tendaho and Kesem Dams were investigated by the Survey in sufficient detail to establish provisionally their feasibility. The Meki Diversion Project and the Compensation Dam were the subject of preliminary reconnaissance and examination only.

3. Factors affecting Relative Priorities of Irrigation Development.

The chief problem affecting the timing and magnitude of the various future stages of irrigation development is whether the Middle Valley should have priority over the Lower Plains, or vice versa, or whether both should be developed at the same time.

The Middle Valley has a better climate, being at a greater altitude and better soils and appears to be more suited to the development of intensive irrigated agriculture or commercial type farms. Yields will be higher, and agricultural benefits greater. The abstraction of irrigation water here has the advantage of decreasing the flows further downstream, and thus of diminishing the amounts spilt into swamps and flood areas with consequent loss.

Communications, though needing improvement, are not bad; many of the irrigable areas are not unduly far from the railway. No reason appears so far to indicate difficulties in finding sufficient cultivations for development in the Middle Valley.

In the Lower Plains the soils are definitely less fertile, and the climate is less favourable; as a result, the potential crop patterns are appreciably less intensive, and the yields to be expected are somewhat less. A very important factor is the instability of the river channels in this region, which are liable to change their section or even their course completely, or break out in new branch channels; many areas are subject to serious damage by flooding. However, these dangers and difficulties can be obviated by the water control to be provided by the Tendaho Dam; it can be said that the construction of this Dam is a pre-requisite to considerable development of irrigation in the Lower Plains, certainly beyond the 20,000 ha of commercial farming and "outgrowers" for which water rights have already been granted and the 10,000 - 15,000 ha of "flood" cultivation in the Asayita delta by smallholders. No reason has appeared so far to indicate difficulties in finding cultivators for development here, any more than in the Middle Valley. Communications with the rest of Ethiopia and other countries are provided by the Adis Abeba-Dese-Aseb road; another main road from Adis Abeba to Aseb is to be built shortly. Socially and politically, development in the Lower Plains appears to be highly desirable, and offers in the long run the prospect of establishing family size farms, which should be supported by sound services for agricultural extension and credit.

On grounds purely of technical and economic benefit to Ethiopia as a whole, the balance of advantage appears definitely to lie with the early development of areas in the Upper and Middle Valley to the maximum possible without Kesem Dam (which, necessary for full ultimate development in these regions, involves relatively high expenditure and may be contemplated at a later stage). But the extent and timing of such development in the Upper and Middle Valley cannot be definitely planned until it can be determined whether the Meki Diversion Scheme in some form or other is possible, or whether only the compensation reservoir must be assumed and if so, where and of what capacity. The need for surveys and investigations to determine these questions will operate to defer to some extent the rate of development in the Upper and Middle Valley.

In the Lower Plains, Government is already committed to water rights for about 20,000 ha at Dubti and Dit Bahri, plus existing small-holders cultivation in the Asayita area, say some 11,000 ha. These developments are at present subject to the risks of flooding, instability of channels, etc. To some extent it might be possible to control these by local river training works etc. But the efficacy of such works could never be certain and their cost would be considerable. Further, the construction of the Tendaho Dam would control these risks much more effectively. It would also make possible the ultimate extension of irrigation to a total of at least 66,300 ha and possibly 70,000 ha in the Lower Plains. Clearly, then, on technical and economic grounds alone the construction of Tendaho Dam at a fairly early stage of development would be fully justified.

The construction of Kesem Dam can be deferred until it becomes apparent that it is essential for the full ultimate development of irrigation.

4. Stages of Development Proposed

Taking into account all the considerations discussed above, three successive stages of development are proposed, on the general lines set out in Table 27.

TABLE 27 - PRESENT AND PROPOSED STAGES OF DEVELOPMENT

Stage	Water Control	Target Areas of Development			hectares
		Upper Valley	Middle Valley	Lower Plains	Totals
Present	Koka Reservoir only	6,650	1,550	16,100	24,300
First	Koka Reservoir only	12,000	19,500	31,900	63,400
Second	Koka Reservoir, + Meki Diversion Scheme (or compensation Reservoir) + Tendaho Reservoir	12,000	50,850	51,300	114,150
Third	As second stage + Kesem Reservoir	12,000	84,950	66,300	163,250

Technical considerations affecting the implementation of development in these stages, including particulars of individual areas and schemes, and the works and costs involved, are discussed in chapter X - Development of Irrigation.

5. Master Plan

Once the necessary further surveys and investigations have resolved the present remaining uncertainties affecting water control and irrigation development, it will be possible to prepare a "Master Plan", at least in its main outlines, for the whole Awash Valley, in such a form as to fit into the national development plan for Ethiopia, and make the optimum possible contribution to the country's economy. In this of course, the financing of development will have to be taken into account, with a realistic schedule of investment.

Within the framework of the master plan, the timing of the successive stages can be flexible, to be suited to circumstances.

CHAPTER X - DEVELOPMENT OF IRRIGATION

1. Present Development.

As yet relatively little use has been made of the water resources in the Awash Basin for irrigation. In the Upper Valley, the 6,000 hectares plantation at Wenji for sugar cane has been very successful from all aspects. Other schemes of modest size include those at Genet* and Nura-Era. In the Middle Valley, 850 hectares at Abadi-Metehara, and 650 hectares at Kesem-Kebena, with a small area at Melka Warar, are developed. In the Lower Plains the Tendaho Plantation Share Co. has developed 4,000 ha at Dubti, and 500 ha at Dit Bahri; in addition some 11,600 ha in the Asayita and old Awash areas are under cultivation by small holders with crude means and only moderate yields: in the Lower Plains the main cash crop is cotton. The total present area under irrigation from the Awash is about 24,300 ha. Under the present relatively liberal regulations for the use of land and water, much of this development has so far proceeded with little planning and preparation and technical or administrative coordination. The Awash Valley Authority was recently set up as a controlling body, responsible for planning the hydraulic and agricultural development of the basin as a follow-up to the investigations of the present Survey. Until this planning materializes in action, it is to be expected that for several years at least, development will continue on the lines followed so far.

2. Principles affecting the Extension of Agricultural Development.

It is clearly very desirable that the development of all new areas should benefit from the latest technical means and knowledge, so as to ensure the best combination of economy, effectiveness and reliability. Only the lands of suitable quality (in this case Class II and III), and those most easily provided with water and cultivated, should be considered for development.

i) Methods of Supply. In general, supply schemes operating by gravity are recommended; these involve canal headworks with, or without, a diversion weir or barrage across the river. Pumping is recommended in some cases, for instance for the modernization of the irrigation in the Asayita delta; with small units drawing water from existing channels, and supplying each from 150 to 200 ha of land. Large pumping units are advisable in cases where gravity irrigation would involve long and costly feeder canals, e.g. the cases of the Bolhamo area in the Middle Valley and the Old Awash area in the Lower Plains.

ii) Canalisation. To reduce costs, in most cases earth canals are proposed, as the ground through which they will pass appears to be sufficiently impervious. A fairly high average velocity of flow (0.75 m/s) is proposed, to reduce as much as possible the risks of sedimentation, and as a precaution against bilharziasis. Structures on canals should provide for the best available techniques of water control and distribution, in order to simplify operation and reduce losses.

In the layout of canal systems, each area has been divided into units of, at most, 40 ha (= 1 gasa) each. It is proposed that these should where possible be rectangular, with standard dimensions of 400 m x 1000 m which are suitable for either furrow or strip irrigation where slopes are gentle. Figure No. 16 (in the folder) shows a typical layout with small pumping unit, as proposed for the Asayita delta.

* TEFSETE GENET in the TIBILA PLAIN

iii) Drainage. Systems of drains are proposed, to ensure the collection and disposal of natural runoff and surplus irrigation water within the irrigable areas. The specific rate of 2.5 litres/sec/ha is proposed, which should ensure that no area of land remains submerged for more than 24 hours, more often that once in 2 years. Runoffs from catchment lying above irrigable areas should be passed through them to discharge freely downstream.

iv) Flood Protection. Where necessary, dykes should be provided to protect irrigable areas from flooding by spill from rivers and streams, or to divert flows of natural runoff.
The application of these principles to individual schemes is described in Vol.V.

3. Individual Irrigation Schemes - Upper Valley.

The chief development possible here will be the extension of the Nura-Era scheme to an ultimate area of 5400 ha. No more irrigation development in this region would appear advisable, unless the Meki river diversion for irrigation project is implemented. The Upper Valley is a marginal region for rainfed agriculture, and further development of irrigation here should only be authorized after water is provided for arid and semi-arid regions.

4. Individual Irrigation Schemes - Middle Valley.

Schemes on the principles outlined above have been evolved for five areas in the Middle Valley, with preliminary estimates of cost to make possible tentative economic appraisals. They are shown in schematic form on Map No. 17 (in the folder). Notes on these five schemes follow :

i) Kesem-Kebena. When the Kesem dam is built, this area, ultimately of about 17,550 ha could be irrigated from headworks at the present water intake at Awora Melka, supplying a canal system fanning out towards the Awash. These subsidiary areas would require dykes to protect them against flooding from these rivers, joining up with the system of dykes along the Awash.

ii) Melka Sedi. The area here some 8,550 ha, could draw water from the Awash by a weir and headworks on the right bank at the outlet of the gorge below Awash Station. These works would raise the water level at low stage by some 3 m , and would supply a main canal aligned along the foot of the hills above the Aleydegi plain. Because the banks of the Awash here have built themselves up by spill, a branch canal along the higher ground beside the river will be necessary. Dykes will be needed to give protection from flooding by the Kesem and Kebena rivers, and if necessary from the raised water level resulting from a diversion work at Melka Warrar see iii) below).

iii) Amibara-Angele. This area, ultimately some 16,650 ha, lies on the right bank immediately downstream (ii). It could be supplied either

a) by an extension of the Melka Sedi canal system.
b) by a barrage with gates on the rock hill at Melka Warrar, below Mount Dofan.

Investigation indicates that the latter would be the more economical solution, and it would still avoid undesirable interference with the drainage of areas upstream. Here, as in (ii), a branch canal along the raised ground beside the Awash would be necessary. Extensive dykes would be needed to protect the lower parts of this area against flooding.

iv) Bolhamo. This area of 8,900 ha, on the left bank opposite Amibara is delineated by an amphitheatre of the hills through which no permanent river runs. Water for this area will have to come from the Awash at the Melka Warar barrage, via the Amibara riverside canal, to a pipe on the bridge across the Awash.

v) Maro-Gala. This area lies further north than (i) to (iv), along the western edge of the Gewani swamp. Its ultimate area is some 23,000 ha, and it is compact in shape. It could readily be supplied with water from a headworks on the Awash at the lower end of the gorge bear Mount Dabita Ale. Four fifths of the area could be irrigated by gravity, and the rest, on its upstream side, by pumping. Arrangements for drainage and protection against flooding could probably be simple and relatively inexpensive.

vi) Comments. Because these schemes in the Middle Valley can almost entirely be supplied with water by gravity, they are in general fairly inexpensive. The Melka Sedi and Amibara areas further are favourably located, and therefore merit priority development. The Bolhamo and Kesem Kebena areas have lower priorities, the former because of its higher initial and operating costs, and the latter because of its dependance on the large and somewhat expensive Kesem Dam.
Metehara-Abadir areas covering some 10,500 ha in the Middle Valley have been surveyed in detail by Israeli and Dutch experts. No schematic irrigation layout was prepared for this region by the Project team in view of the expectation that the Metehara project would be developed on a concession basis.

5. Individual Irrigation Schemes - Lower Plains.

As already indicated the Lower Plains are deltaic, with a complex and unstable network of channels. Every year during the high water period the rivers overflow and the lands are flooded. This, it is true, results in beneficial deposits of sediment, but it also conduces to modifications of the branch channels, and even to the formation of new channels, with consequent changes in the pattern of irrigable lands. Something of this sort probably happened in the northern part of the Asayita delta, as a result of which a considerable area of arable land had to be abandoned. The Boyale branch is now gradually forming a new channel for itself.

Apart from uncertainties due to flooding and unstable river channels, irrigated crops in the Lower Plains are affected because adequate supplies in the river are only available during the relatively short period of high flows. The primary purpose of building a dam at Tendaho is to regulate the flows in the Awash so as to be able to satisfy the irrigation requirements of the maximum possible area of land and at any time of the year. This dam, however, will also control the flood peaks, and thus remove the main factors causing instability of the channels. This will also result in the partial reclamation of extensive marshes, which may become grazing lands. The retention in the reservoir of much of the sediment load of the Awash will affect the regime of the channels downstream which are likely to be eroded. However it should be possible to counter this by suitable works for river training and stabilisation, and by the use of flow distributors at channel bifurcations, e.g. at the heads of the Bogale and Issa branches. Such water spreading should improve the grazing on lands between the irrigable areas, to replace those taken into the latter.

The layouts of Individual Schemes are shown in schematic form on Map No. 18. (see folder). Notes on them are as follows :

i) Dubti. This area, now under development by the Tendaho Plantations Share Co. under a concession for 6,000 ha, has a canal system fed partly by gravity intake, and partly by pumps. The area could be extended to some 9,050 acres, and could also supply water to private cultivations outside, as far as the Boyale branch and swamp.

ii) Dit Bahri. The development of this has just begun, also by the T.P.S. Co, under a concession for 6,000 ha. No diversion weir across the river appears necessary, but the headworks, in view of its vulnerability and importance, should be suitably protected.

iii) Minor riverside areas between Dubti and Dit Bahri will have to be irrigated by small pumping units.

iv) Asayita delta Here lands are cultivated by small holders as the floods recede, in somewhat primitive fashion, with short-term crops. The area comprises a whole network of meandering natural channels. To make the best use of the area these should be realigned and intermediate channels should be opened. But this cannot well achieve the best possible results until the Tendaho reservoir controls the flows, and reduces flooding and instability. It will then be possible to use small pumping units drawing from the network of channels, and supplying tertiary irrigation units of say 150 to 200 ha, thus providing an adaptable means of modernising cultivation and improving yields in this area. The ultimate area is forecast at some 26,000 ha .

v) Old Awash Area. This is surrounded by a former channel of the Awash, from which it was still being irrigated a few decades ago. The restoration of this area to effective agriculture will involve the diversion of water supplies to fill this old channel, or better, the excavation of a new canal along the same route. A single pumping station of some 900 kW at its head is proposed to boost the water level in the system, which in present conditions seems likely to be inadequate. The ultimate area may be about 11,300 ha .

vi) Comments. Power for all pumping required is expected to be available from the Tendaho Dam. It is clear that development of the Lower Plains can only be done on a relatively limited scale, until this Dam is constructed. After its construction, reclamation of marshes may add not only grazing lands, but perhaps even irrigable lands, which being at present flooding have been either classified as Class IV land or not surveyed.

6. Stages of Development. Table 28 and Map 19 show summary particulars of the development of the various individual projects or groups of projects, in the various parts of the Basin, as now existing and as suggested for the three stages of Development discussed in Chapter IX para 4.

The First Stage, possible with the degree of water control already provided by the Koka Reservoir, would increase the total area to over 63,000 ha, more than 2½ times its present figure. This may be expected to take a number of years, which will give time for the necessary further investigations required (see para 7 below), and their results considered. In the Lower Plains, before the promoters of irrigation can fully achieve their present nominal entitlement, much less expand further, it will be essential to construct the Tendaho Dam: the decision to build it should therefore be taken in the First Stage.

Before the Second Stage begins, it will be very desirable, and should have been possible, to prepare the master plan for the ultimate development of the whole Basin. The implementation of the stage will call for further water control to make more water available for use in the Middle Valley; this will preferably be the

TABLE 28 - PROPOSED DEVELOPMENT OF IRRIGATION BY PROJECTS AND STAGES

Projects	Present Area	First Stage		Second Stage		Third Stage	
		Additional	Total	Additional	Total	Additional	Total
UPPER VALLEY							
Wonji, Genet and others	6,600	0	6,600	0	6,600	0	6,600
Nuri, Eva	50	5,350	5,400	0	5,400	0	5,400
Total Upper Valley	6,650	5,350	12,000	0	12,000	0	12,000
MIDDLE VALLEY							
Abadir - Metehara	850	9,650	10,500	0	10,500	0	10,500
Kesem - Kebena	650	1,350	2,000	0	2,000	15,550	17,550
Melki Sedi	0	6,000	6,000	2,550	8,550	0	8,550
Amibara - Augelele	50	950	1,000	15,650	16,650	0	16,650
Bolhamo	0	0	0	2,500	2,500	6,400	8,900
Maro Gala	0	0	0	10,650	10,650	12,150	22,800
Total Middle Valley	1,550	17,950	19,500	31,350	50,850	34,100	84,950
LOWER PLAINS							
Dubti	4,000	5,050	9,050*	0	9,050	0	9,050
Small riverside areas	0	0	0	0	0	3,700	3,700
Dit Bahri	500	10,450	10,950*	5,400	16,350	0	16,350
Asayita Delta etc.	11,600	300	11,900	14,000	25,900	0	25,900
Old Awash	0	0	0	0	0	11,300	11,300
Total Lower Plains	16,100	15,800	31,900	19,400	51,300	15,000	66,300
GRAND TOTALS	24,300	39,100	63,400	50,750	114,150	49,100	163,250

* Total of 20,000 ha covers water rights granted to Tendaho Plantations Share Co. and outgrowers.

Meki Diversion Scheme, if found feasible, or alternatively a compensation reservoir on the Awash below Koka Reservoir and the power sites further downstream. Unless the Meki Diversion is possible, no further irrigation development is recommended in the Upper Valley; this is a marginal area for rain-watered agriculture and further agriculture development would involve the cleaning of extensive areas of woodlands, and also would tend to reduce the power potential of the Awash flows.

The third Stage would achieve the full development of irrigation in the Awash Basin, up to a total of some 163,000 ha . For this, further water control would be needed in the construction of the Kesem Dam.

The costs of development, both of water control works and of irrigation schemes, are estimated and discussed in Chapter XI.

7. Comments on Suggested Developments. The layouts and designs suggested for the various projects in the three stages of development outlined above are entirely preliminary. Knowledge of the topography of the areas to be developed is not yet sufficient for the preparation of more definite layouts. In the Middle Valley, areas for development are well defined by natural features, such as foothills etc., and they occur in more or less separate units of moderate size. In the Lower Plains, on the other hand, natural boundaries are less well defined. Land classification, following the soil survey, provided the first criteria for delineating tentative schemes of irrigation development. Except in small areas, little is known of the topography of this area, and the Map No. 18 should be regarded as providing merely a schematic concept of a possible layout.

It is clear that before a comprehensive plan for the development of irrigated agriculture can be prepared, further extensive surveys and engineering studies must be undertaken. This is primarily the responsibility of Government, or at least of a Government sponsored authority. Detailed layouts and designs for the execution of individual projects may be prepared either by Government authority, or by concessionaries or owners of the lands, as may be found most appropriate in each particular case.

The development of irrigable lands in the Middle Valley appears to be technically relatively simple. Even where areas are adjacent, separate layouts for irrigation can be prepared without difficulty, provided due allowance is made for the needs of other areas, e.g. for feeder canals, drainage, etc. In the Lower Plains in contrast, development should be regarded as technically more difficult; it will be desirable to outline a comprehensive scheme for the whole region before attempting to prepare definite layouts for individual projects. The technical studies involved will be more complexe and will need more time than those for the Middle Valley.

CHAPTER XI - ESTIMATES OF COSTS AND ECONOMIC APPRAISALS

1. Estimates of Costs

Estimates have been prepared of the costs involved in the development of the principal projects discussed in this report. The basis on which these estimates have been framed are set out Vol. IV and V.

Since the engineering investigations made so far have been of a preliminary nature and detailed designs have not yet been made, the costing is necessarily approximate. In projects where no geological or soil mechanics investigations were carried out, it has been assumed that no particular foundation problems will be encountered. For the Kebena dam, it was assumed that similar precautions to those foreseen on the Kesem dam site would be necessary. For the Meki River Diversion, the assumption was made that the permeability and erodibility of the bed of the diversion canal will be sufficiently low to make lining unecessary.

No provision was made for changes in the basic rates of cost of materials, plant and equipment, labour, taxes, customs, etc. Machinery prices were taken at those prevailing in the world market at the end of 1964. Data of unit prices for civil engineering works as quoted by contractors in Ethiopia were systematically collected and kept up to date during the field operations of the Project.

Irrigation schemes cost-estimates include all engineering and land preparing works which are a responsibility of either the Public Authority or Government, or the landwners or farmers. Investment in the field distribution systems, i.e. farm canals and drainage ditches, and in land levelling, is usually the responsibility of landwners or farmers; this amounts to about 1/3 of the total estimated investment cost.

The allotment to individual projects of the cost of shared civil engineering works such as protection dykes or large drainage canals is often a difficult operation. A tentative allotment has been made for Middle Valley development areas, with resulting uneven distribution of this burden. Other cost allotment patterns might also be applied. For Lower Plains development areas, the engineering works common to all sub-areas are to be allotted to all irrigable land and evenly distributed.

The cost of roads and power transmission lines is not included in the irrigation development estimates. Expenditure for road building is to be added for purposes of economic analysis. The costs of transmission lines and that part of dam costs attributable to the generation of energy may be omitted if the power price for pumping includes delivery cost.

Annual charges must also be computed for economic analysis.

Since neither the date and period of constructing the works, nor the method by which they would be financed, nor the rate of interest is known, no allowance is included for interest on capital during the period of construction.

To the totals of costed major items, which include general expenses, there has been added 30% which should cover the cost of design, supervision of work, and an allowance for engineering contingencies.

TABLE 29 - ESTIMATED COSTS OF STORAGE DAMS

	Kasem dam	Tendaho dam
Height of TWL above low river	69 m	32 m
Capacity of reservoir	370 hm^3	970 hm^3
	E$	E$
ATTRIBUTABLE TO IRRIGATION		
1. Civil engineering	22,066,000	15,435,000
2. Mechanical equipment	959,000	467,000
3. Road relocation.......................	-	1,200,000
	23,025,000	17,102,000
Contingencies, design and supervision 30%.	6,907,500	5,130,600
	29,932,500	22,232,600*
ATTRIBUTABLE TO POWER		
1. Civil engineering	1,584,000	4,747,000
2. Electromechanical equipment	3,279,000	5,104,000
	4,863,000	9,851,000
Contingencies, design and supervision 30%.	1,458,900	2,955,300
	6,321,900	12,806,300
GRAND TOTAL	36,254,400	35,038,900

* Protective and river training works downstream of Tendaho dam to be affected to the whole development area are estimated at E$ 5,400,000

TABLE 30 - TENTATIVE FORECAST OF COST OF KEBENA DAM

	E$
1. Civil engineering	16,200,000
2. Electro andor mechanical equipment	2,237,000
	18,437,000
Contingencies, design and supervision 30% ...	5,533,000
	23,970,000

TABLE 31 - ESTIMATE OF COSTS OF DIVERSION OF MEKI RIVER

	E$
1. Civil engineering	7,896,400
2. Electro andor mechanical equipment	201,600
	8,098,000
Contingencies, design and supervision 30% ...	2,429,000
	10,527,000

TABLE 32 - IRRIGATION DEVELOPMENT - PARTICULARS OF WORKS AND ESTIMATES OF COST

Items	Middle			Valley				Lower			Plains (1)			
	Abadir-Metehara	Kesem Kebena	Melka Sedi	Amibara-Angelele	Bolhamo	Maro-Gala	Totals (2)	Dit Bahri	Asayta Delta	Old Awash	Gravity	Pumping	Small Areas	Totals
Areas - hectares	10,500	17,550	8,550	16,650	8,900	22,800	84,950	16,350	25,900	11,300	6,500	2 550	3 700	66 300
PARTICULARS OF WORKS														
Main and Secondary Canals - Km		85	45	57	54	100	341	74	94	43	-	-	-	-
Main and Secondary Drains - Km		61	119	119	39	65	284	56	62	45	-	-	-	-
Protection Dykes - Km		35	69	69	29	33	216	15	-	-	-	-	-	-
Excavation - Thous m3		1,850	4,300	4,300	2,350	1,650	10,150	2,150	1,800	750	-	-	-	-
ESTIMATES OF COST														
Headworks or Pumping Stations - Thous. E$	no estimates made	1,400	618	1,686	1,305	1,700	6,709	380	4,592	1,520	-	-	-	-
Canal Systems, Main secondary and tertiary " "		8,256	5,579	10,104	6,583	9,879	40,401	8,885	4,432	3,638	-	-	-	-
Field Channels " "		2,035	992	1,931	1,032	2,644	8,634	1,896	3,004	1,311	-	-	-	-
Protection Dykes " "		5,610	1,349	3,330	1,923	2,171	14,383	1,023	0	0	-	-	-	-
Land Clearing " "		2,071	702	1,080	698	912	5,463	2,220	2,386	668	-	-	-	-
Land Levelling " "		5,428	2,592	5,235	2,908	5,700	21,863	7,344	8,805	2,825	-	-	-	-
Totals		24,800	11,832	23,366	14,449	23,006	97,453	21,748	23,219	9,962	-	-	-	-
Design, supervision and counting 30% " "		7,440	3,550	7,010	4,335	6,902	29,237	6,524	6,966	2,989	-	-	-	-
GRAND TOTALS " "		32,240	15,382	30,376	18,784	29,908	126,690	28,272	30,185	12,951	(3) 11,239	(4) 2,922	(5) 4,310	89,879
COST PER HECTARE E$		1,837	1,799	1,824	2,110	1,312	1,702	1,729	1,165	1,146	(3) 1,729	(4) 1,146	(5) 1,165	1,356

Notes : (1) Figures do not include cost of river training and protection works (see table 29)
(2) Estimates of volume of works and of cost are releted to the Middle Valley without Abadir Metahare (84,950 - 10,500 = 74,450 ha)
(3) Cost per hectare assumed to be E$ 1,729 as for Dit Bahri
(4) " " " " " " E$ 1,146 " " Old Awash
(5) " " " " " " E$ 1,165 " " Asayita Delta

At June 1965, 2.5 E$ were equivalent to 1.0 US$.

2. <u>Economic Appraisal.</u>

An appraisal of the economic feasibility of the various developments proposed by the Survey was made by two consultants appointed by Special Fund, Dr. L.G.Allbaugh, Economic Production Economist, and Mr. R.M. Arbuckle, Agronomist. An abridged version of their report, submitted to Special Fund in January 1965, is attached to this volume as Appendix No. 3. Their main economic conclusion on the projects proposed may be summarized as follows :

(i) Assuming the additional area to be developed for irrigation on the Awash as 150,000 ha, the overall benefit/cost ratio would be about 1.95:1, at 6% interest:

(ii) In addition, some 115 million kilowatt-hours of electric power could be produced annually, at 1/4 to 1/3 of the cost from the best alternative source:

(iii) Control of floods would increase net incomes by about E$ 100,000 annually:

(iv) The gross value of the annual agricultural product of the whole project is expected to be E$ 181 million with an annual net gain over present production of about E$ 60 million:

(v) The investment (1) required for these results is expected to be:-

	E$ Million
Initial - Dams, irrigation works, roads etc.	250.6
Associated Costs by farmers (including E$ 62 millions for land levelling and quaternary canals).	179.7
Total	430.3

(vi) The projects are expected to provide some 10,000 to 15,000 family farms, and employment for some 25,000 to 30,000 workers:

(vii) Secondary benefits, not as yet estimated, will arise from services, transport, and processing industries:

(viii) The data of the survey, and the economic evaluations made in this appraisal, are entirely preliminary, and further detailed soil surveys and pre-investment studies and investigations are necessary. Nevertheless, it is believed that the findings of the economic report give a reasonably accurate assessment of the possibilities of developing the agricultural economy of the Awash region, that the estimates of costs are sufficiently liberal, and that the estimates of yields used are conservative:

(ix) While the Government of Ethiopia favours development of irrigated lands by large scale mechanised enterprises, under skilled management, from a social point of view it also appears desirable to allot a proportion of the available lands to small farmers, already trained and experienced in the practice of irrigation on the larger schemes:

(1) See comments in para. 3 below

(x) Economically, the Awash Basin is well situated, between Adis Abeba the capital, and the port of Aseb. The projected road on the right bank of the river to connect Nazret with Tendaho would facilitate the transport of agricultural products, or manufactured goods, in either direction as appropriate:

(xi) Before present haphazard agricultural development proceeds too far, it is desirable to prepare a master plan of development. For this purpose, the Awash Valley Authority should be strengthened financially and technically, to enable this autonomous body to carry out effectively all parts of its highly important task:

(xii) For the full development of the Valley, it is important to make full use of its water resources, for power, to be used for irrigation pumping, for industrial development, and for domestic use:

(xiii) Priorities are important. In Ethiopia there is no urgent food shortage and no population pressure on the land, and no great pressure for land settlement. The major problems are those of long-term economic development to increase production. Short-term "Crash" programmes are not appropriate, and programmes for 10 to 25 years, of carefully planned and selected projects, economically sound, are what is wanted.

3. Comments on the Economic Feasibility Report.

(i) Estimates of Cost. The estimates of cost used for the benefit/cost analyses of the Report were provided by the Sub-contractors to the Survey at a relatively early stage of the final engineering studies. Inevitably, they differ in various respects from the final estimated costs, given in paragraph 1 of this chapter. The changes made in arriving at the latter result from better knowledge of the climatological and hydrological conditions, which revealed the need for supplementary works for drainage and for protection against flooding, in the areas to be developed. However, comparison of corresponding figures shows that had the final revised estimates been used for the benefit/cost analyses, the general picture of economic feasibility of the project as a whole would not have changed significantly. This is illustrated by the figures in Table 33.

TABLE 33 - COMPARISON OF INVESTMENT REQUIRED PER HECTARE

Region	Investment required per hectare of gross area (including water control works and roads)	
	As used in Economic Feasibility Report	As derived from final estimates of cost, given in Tables 29, 30 and 32.
	E $	E $
Total Middle Valley	2,420	2,368
Total Lower Plains	1,699	1,773
Over Whole Project	2,084	2,090

The figures in both columns have been calculated in the same way, so as to be fairly comparable, The economic consultant remarks that "on the basis of the actual costs of irrigation systems already constructed, the investment estimates are liberal".

(ii) Incidence of High-value Crops. The figures of benefit/cost ratio in the economic appraisal are considerably influenced by the extent to which crops of relatively high value are included in the various cropping plans assumed. The scope for introducing high-value crops such as sugar cane, fruits, and vegetables, is restricted, first because the home market for such products is limited, and the possibilities of export are at present small. Further with increased production, the prices to the grower would tend to fall. In contrast, general crops, such as fibre crops, oil seeds, pulses, etc. are in steadily growing demand in Ethiopia, and their future prices seem less subject to unforeseen fluctuations. Table 34, derived from the economic appraisals made, compares the benefit/cost ratios for the two types of cropping plan, applied to various parts of the potential developments in the Awash Basin.

TABLE 34 - BENEFIT/COST RATIOS FOR GENERAL AND HIGH-VALUE CROPS

Development	Gross Area Hectares	Benefit/Cost		Ratios	
		General Crops Only		High value Crops incl.	
		Rate of Interest		Rate of Interest	
		6%	4%	6%	4%
Kesem-Kebena	17,550	0.7:1	0.9:1	1.24:1	1.58:1
Melka Sedi	8,550	2.7:1	3.4:1	2.73:1	3.39:1
Angelele	4,750	1.4:1	1.7:1	1.41:1	1.75:1
Middle Awash (no dams)*	42,000	2.4:1	3.2:1	5.50:1	6.93:1
Middle Awash (Total)*	80,000	1.4:1	1.9:1	2.38:1	2.97:1
Lower Awash	70,000	1.3:1	1.6:1	1.28:1	1.56:1
Total Awash Project*	150,000	1.3:1	1.7:1	1.95:1	2.42:1

* These areas include 5,600 ha plantation of sugar cane at Metehara.

In Table 34, crops of high value are assumed to be grown on about 1/7 of the gross areas to be developed in the Middle Valley. The figures show the advantages of growing these. If the full development of Awash Basin land and water resources is considered desirable from a national viewpoint. their inclusion in a relatively higher share provides the needed justification for development of the marginal areas. The Table also demonstrate, however, that even on general crops only, the Awash development as a whole will be economically profitable.

4. Incidence of Settlement.

Another problem affecting economic appraisals is the difference in the benefits to be expected from large-scale commercial schemes, as compared with those from family farms. Settlement is always relatively costly. The difficulties inherent in the operation of irrigation schemes with numerous small-holders will be increased by the fact that as yet irrigated agriculture is practised only on restricted areas in Ethiopia. Prospective settlers will in most cases be inexperienced, and will have to be taught almost everything about the art of irrigating. For this reason, in appraising the benefits of family farms, lower yields have been assumed, and longer time lags before full production is attained. As a result, returns from family farming are less than those from commercial farming, and the inclusion in a project of a high proportion of family farms will lower its overall benefit/cost ratio. For example, in the development of the Lower Plains, the benefit/cost ratio of 1.3 at 6% interest, given in Table 34 above, would have been 1.6 if the allotted to settlement had been taken as only 14,000 ha, instead of 50,000 ha as actually assumed.

5. Planning of Development.

Priorities of development cannot be determined solely on grounds of intrinsic physical and economic feasibility. Considerations of national economy, and social and political factors, also have to be taken into account. For example, the promotion of settlement schemes may be important for the long-term economic and social development of the country, even if the development of commercial schemes instead would initially produce larger revenues and more foreign currency.

The complex nature of the problems involved in determining priorities in the Awash Basin calls for very careful planning and coordination of development policy. For example, the revenues from high-yielding areas developed at an early stage may perhaps be used later to finance the devslopment of less profitable areas; in this way, a kind of "revolving fund" may be formed, which may help to complete the development of the Basin as a whole.

A danger to be guarded against is that of "skimming the cream" from the most promising areas first, without suitable allocation of the resulting revenues. This would make the returns on later developments appear to be relatively even less attractive. An appropriate policy of differential rates of water charges may offer a convenient and effective means of adjusting, as between the various types of projects, the otherwise uneven burden of investment costs. In fixing rates, it will be necessary to cover the costs of providing services and infra-structure, e.g. dams, headworks, and main canals, and to provide revenue for continued development, all with due regard to the benefits obtainable in each particular case.

6. Master Plan.

If the Imperial Government wishes to develop to the full the potential resources of the Awash Valley in the most effective and beneficial manner possible, two things are particularly essential. In the first place, it will be necessary to prepare a "Master Plan" of development, in contrast to the somewhat haphazard methods of development which have been applied hitherto. This plan will ensure that each item of development is designed so as to fit in properly with others in the co-ordinated whole, giving the most efficient use of the resources involved and the funds invested, which are national assets of the country as a whole. Further, it will make sure that the development of any item in the earlier stages will not in any way cause difficulties in the subsequent development of other items at later stages.

7. Awash Valley Authority.

In the second place, it will be equally necessary to ensure the effective implementation of the Master Plan, and the subsequent operation of the various schemes of development, in accordance with the stipulated conditions, so as to produce the benefits expected, for Ethiopia as a whole, and for the people engaged in these schemes in particular. With these objects in view, the Imperial Government has set up the Awash Valley Authority. But the Authority does not yet possess powers and resources, in staff, in equipment, in funds, in organisation, and in control, commensurate with the great magnitude of the tasks and responsibilities which it is called upon to face. It is of urgent importance that action to this end be taken as soon as may be possible. Otherwise, it is not possible to see how the potential benefits in prospect can be fully realised.

It is recommended that the Authority may suitably be made responsible for carrying out the varied surveys, studies, and appraisals, proposed in this Report; for preparing on them as a basis the Master Plan, to be approved by the Imperial Government; for supervising the implementation of this Plan and, in part at least, its actual execution, and finally for supervising the operation of the various schemes of development, to ensure their technical and economic effectiveness. The planning of the organisation of the Authority is itself a matter of great importance.

CHAPTER XII - ADDITIONAL REMARKS

This report deals mainly with the development possibilities in the lowlands of the Middle and Lower reaches of the basin and is concerned particularly with the land and water potential for irrigation.

However several important actions which should be undertaken with the aim of improving the agricultural and livestock production in the Basin are not overlooked.

1. In the lowlands

There is considerable scope for stepping up the standard of livestock production by improving grazing lands and providing supplementary watering points.

Measures recommended by water planning provide for the reclamation of several swamps and marshes. In the first place extensive swamps in the deltaic region may be partially reclaimed after the Tendaho dam is constructed. The water management plan for the Tendaho dam and irrigated areas provides for water to be spread on the reclaimed grazing lands. Detailed plans for watering of the pasture lands cannot be drafted before the series of recommended studies in the Lower Plains can produce the necessary basic information.

Extensive grazing lands in the Awash Valley lack necessary drinking water resources. A tentative scheme for underground water investigation in the Aleydegi plain was prepared under the project, and its implementation is strongly recommended.

2. In the high plateau

Although most of the arable lands are already under cultivation an appreciable potential for agricultural development, however, exists also in the upper reaches of the basin. One of the most attractive projects appears to be that of the reclamation of Borkena Swamps. About 10,000 ha of marshland could be cultivated after the swamp is drained. On the basis of observations made on the cultivated land on the shores of the swamp, it is believed that the reclaimed soils would be fertile. Suitable climatic conditions with a fairly high and well distributed rainfall, good communications and easy access should enable prosperous agriculture to be established in this area.

According to a preliminary survey a reduction of the water level in the swamp may be achieved by deepening the river bed at the outlet for a length of about 400 meters.

There is also wide scope for improvement of agricultural production in the upper reaches of the basin. It can be achieved by improvement of existing farming practices, modernizing of implements, use of fertilizers of improved seeds, and also by applying appropriate soil conservation measures. A programme of such measures should be drafted on a national level its implementation calling for appropriate legal and administrative measures.

Soil conservation measures are closely related with those which should be taken in order to arrest the deforestation of the basin. The lifetime of hydraulic structures, both for hydropower production and for irrigation, depends on action being taken to reduce land degradation in the basin. The necessity for replanting tree species, in particular in the vicinity of the capital city calls for immediate consideration.

Reforestation, soil conservation, swamp reclamation, improvement of farming practices on cultivated lands, underground water investigations and improvements on grazing lands, are activities which will increase the economic effects of irrigated agriculture development in the Awash River Basin.

Improvement of farming practices may be the greatest factor on raising the living standards of the great majority of the population. This, however, will be difficult to achieve unless experienced and well equipped extension services encourage and help the peasants in the transition from traditional subsistence agriculture to the modern, market-oriented farming.

There is little doubt also that enacting of appropriate agrarian legislation providing for greater security and larger share in benefits for the tenant farmers will be an important incentive for improvement of land and farming practices.

APPENDIX I

PLAN OF OPERATION

UNITED NATIONS SPECIAL FUND PROJECT IN ETHIOPIA

SURVEY OF THE AWASH RIVER BASIN

Special Fund Allocation:	US$ 930,100
Government Counterpart Contribution (equivalent of):	US$ 327,000*
Duration:	3 years
Executing Agency:	The Food and Agriculture Organization of the United Nations
Cooperating Government Agency:	Awash Valley Authority

For the purpose of the survey of the Awash River Basin to be undertaken by the Food and Agriculture Organization of the United Nations acting as Executing Agency for the United Nations Special Fund, this Plan of Operation shall be the Plan of Operation referred to in Article I, paragraph 2, of the Agreement signed on 13 July 1960 by the Government of Ethiopia and the United Nations Special Fund.

I. PURPOSE AND DESCRIPTION OF THE PROJECT

A. The Purpose of the Project

1. To obtain data on the water potential of the Awash River and its tributaries for irrigation and hydropower, and to establish the suitability of soils within the area commanded by the river and its tributaries for irrigation farming. Such basic information is required for the judicious utilization of land and water resources of the basin and for safeguarding national interests when granting water rights to water users.

B. Background

2. In recent years great interest has been shown by private companies, foreign as well as Ethiopian, and by the Government itself, in large scale irrigation farming and power schemes in the Awash River Basin.

3. As the amount of water available in the Awash for irrigation purposes is limited, the Government is anxious to establish, at the earliest possible date, the full development potential of the river before granting water and land rights.

4. At the same time the Government also wants to know the extent and location of soils within the basin suited for irrigation farming.

5. Coordination between utilization of water for the generation of power and for irrigation purposes is also an important requirement for which a good knowledge of hydrological and soils conditions is indispensable.

* Government contribution towards local facilities (in cash) are not included in this figure.

6. The Awash River originates in the highlands south and west of Addis Abeba at an elevation of about 2,500 meters. For a distance of approximately 800 kms the river flows in an easterly and north-easterly direction to end in a chain of lakes situated on the desert lowlands of Dankalia. The main Awash is joined along its course by several tributaries, all of which experience high floods during the rainy season and critically low flow during the rest of the year. The Awash is characterized by several water-falls, especially in its upper and middle course. Previous reconnaissance surveys have shown that there are potential power sites and new irrigable areas on several sections of the river valley. On one of those sites, situated at Koka, the Government has recently completed a storage dam and hydroelectric power station. Some irrigated agriculture already exists in the Upper Awash, which will be affected by the Koka Dam and reservoir. The dam impounds a reservoir of about 260 square kms of surface area and has an estimated storage capacity of 1,600,000,000 cubic meters. The total generator installation is of 43,200 kilowatt.

7. The present irrigated areas in the valley consist both of estate plantation devoted mainly to sugar cane, rice, cotton, groundnuts and fruit crops, and small peasant cultivation, mainly in the lower reaches devoted to growing a variety of crops, mainly cereals.

C. The Project

8. The project consists of:

(1) The survey of the water resources of the Awash river and its main tributaries, including studies of possible improvement of the water-regime by flood storage. Survey of the water potential will include:

a) the establishment of a network of river gauging stations;

b) carrying out of observations at these stations during the entire duration of the project;

c) strenthening of the meteorological network and correlation of meteorological data with hydrological data.

(2) Preparation of a water management plan based on the results of the hydrological study mentioned in item 1. This water management plan has to be worked out by taking account of the water requirements for irrigation, the operational requirements and economics of hydroelectric power plants. The utilization of groundwater as a supplementary source of supply should be taken into account to the extent to which data are made available by the Government.

(3) Soil Survey. This part of the project consists of a reconnaissance survey of the potentially irrigable areas commanded by the main river and its tributaries. The total area to be investigated first by a reconnaissance type of survey is estimated to be about 500,000 hectares. This first survey will eliminate areas not suited for irrigation farming and will then be a continued as a semi-detailed survey to cover an area which is estimated to be about 100,000 hectares. A detailed soil survey of pilot areas of about 20,000 hectares will be carried out in the final stages of the soil survey. As a result of this survey land classification maps will be prepared which will include not only irrigable soils, but also areas suitable as pasture land. A reconnaissance soil survey of the potential grassland areas, some 200,000 hectares, is also included in the project.

(4) The study of the dam sites suitable for storage as well as for generation of power. This investigation will include engineering studies as well as geological investigations for dam foundations and reservoir conditions. It will also include preliminary type of design and preliminary cost estimates for dams and power stations. More detailed investigations are envisaged for one or two selected sites.

(5) Sedimentation studies in the headwaters area. Sedimentation studies will cover the basin of the Upper Awash upstream the Koka dam and will be conducted in cooperation with the Government Forestry Service which is already making studies of the upper watershed. The main objective of this sediment and erosion survey is to establish the lifetime of the reservoir under prevailing conditions and establish the possibilities of a reduction of the silt and bed load in the river by introducing improved conditions in the watershed.

(6) Land use studies will consist partly in studies of the land use problems of the upper reaches, but will also extend over the lower Awash Basin. Here they will deal mainly with land use on irrigated land and with water requirements.

(7) Aerial photography and mapping: this will include the preparation of aerial photography covering the part of the Awash basin which has not yet been photographed. Contour mapping will cover mainly potential reservoir areas. The total area to be photographed is about 30,000 sq. km. A key map showing the area is attached to the Plan of Operations in Annex III.

(8) Training of Ethiopian personnel and utilization of Ethiopian personnel in the program to the maximum extent possible consistent with their abilities, are major objectives of the Programme.

II. WORK PLAN

A. Participation of the Executing Agency

9. Personnel Services - Total man-months: 367

(i) Water development planning engineer (project manager)

(ii) Hydrological Survey
1 Hydrologist
2 Hydrometrists
1 Computer

(iii) Water Management Planning
1 Waterplanning Engineer

(iv) Soil Survey
1 Senior Soil Scientist
1 Soil Survey Specialist
1 Soil Survey Photo Interpr.
1 Soil Chemist

(v) Power Damsites, Reservoir Studies
1 Power Dam Design Engineer
1 Engineering Geologist

(vi) Erosion Studies in Headwaters
1 Soil Conserv. Specialist
1 Sediment Hydrologist

(vii) Land Use Studies
1 Land Use Studies Expert

(viii) Administrative Officer

(ix) Short-term consultants

(x) Subcontractor personnel, giving supporting services on water management plans, designs, computing and costing.

10. Aerial Photography

Aerial photography of about 30,000 sq. kms. on 1/20,000 scale.

Contour maps of potential reservoirs 800-1000 sq. kms. 1/10,000 or 1/20,000 scale.

11. Equipment and Supplies

Hydrometric equipment
Topographic equipment
Field and laboratory equipment for soil survey
Transport vehicles - 4 wheel drive: 15
Boats for sediment measurements etc.
Preparation and printing of report.

11.a. Miscellaneous

Secretarial assistance
Travel within the country
Cable and postage charges.

12. United Nations Special Fund Contribution (in cash):

The Special Fund participation in the project shall be in the amount of the equivalent of US$ 930,100. Of this amount, the equivalent of US$ 6,000 is for preliminary investigations, US$ 79,400 is for agency costs (pro-rated), and US$ 60,000 is for personnel services supplied by the Executing Agency through direct employment. The balance of US$ 784,700 shall be deposited by the Special Fund on the basis of the Plan of Expenditure, Appendix I, in United Nations Special Fund accounts to be opened as required by the project, as follows:

Equivalent of US$ 425.010 on signature of the Plan of Operation
" " " 215,877 on or before 1 January 1962
" " " 143,813 on or before 1 January 1963

Total US$ 784,700

13. Subcontracts

The Executing Agency shall carry out the survey through subcontracts with consulting firms acceptable to the Government. The aerial photography shall be entrusted by the Executing Agency either to the same consulting firm or to a firm specialized in such work, acceptable to the Government. The subcontractor(s) may be requested by the Executing Agency to supply part of the equipment needed for the project; in this case he will prepare detailed lists which will need prior written approval by the Executing Agency before placing purchase orders. The sub-contractor will assume the same obligations as the Executing Agency under article 8, paragraph 8.

14. The Government shall issue entry visas to the personnel of sub-contractors employed on the project and shall grant duty-free import of equipment and material required for the execution of the survey. The Government shall also grant re-export of such equipment after completion of the contracts. The above facilities shall be granted by the Government to the sub-contractors on certification of the Executing Agency.

15. (a) The Government shall exempt from any taxes, duties. fees or levies which may be imposed on the sub-contractors, or their personnel in respect of:

(i) the salaries or wages earned by such personnel in the execution of the project with the exception of locally employed personnel;

(ii) any profits earned by the subcontractors in the execution of the project;

(iii) any equipment, materials and supplies, brought into the country by the sub-contractors for the completion of this Plan of Operation or which, after having been brought into the country may be subsequently withdrawn therefrom.

(b) Any property, brought by the firm or organization or its personnel for their personal use or consumption may be subsequently withdrawn therefrom after departure of such personnel.

B. Contribution of the Government

Counterpart participation

16. Technical personnel - Total man-months: 408

Hydrometrists
Meteorologists
Engineers
Technicians
Draftsmen
Soil Surveyors or soil survey assistants
Soil Laboratory technicians
Assistant Geologist
Soil Conservationist

17. Administrative Personnel

1 Administrative Assistant
1 Accountant Clerk
2 Labour Supervisors
1 Stock Keeper
1 Typist Secretary

18. Service Personnel

14 Gauge Observers
15 Drivers and boat operators
1 Fitter
Labour for Survey Teams,
building temporary roads, sheds.

19. Equipment and Supplies

(i) Construction of river gauging stations

(ii) 2 sets loose contact prints and 1 set photo mosaics for the area for which aerial photography is already available - 1:20,000 scale for the aerial survey by Huntings and 1:50,000 for the area in the part of the Awash basin bordering the Blue Nile.

(iii) Miscellaneous materials: small tools, local supplies and stationery.

20. Services

(i) Offices, rooms for field laboratory, storage space for equipment and materials, laboratory facilities for soil and water analysis at a suitable location(s).

(ii) Field accomodation for Ethiopian personnel and labour.

(iii) Operation and Maintenance of vehicles and boats (including insurance) and equipment.

(iv) Transportation, within Ethiopian territory, of Ethiopian personnel.

(v) Transportation, insurance, handling and storage of project equipment and materials within Ethiopian territory.

21. Government Counterpart Participation

(i) The above-mentioned Government counterpart participation in the project shall be in cash in the amount of the equivalent of US$ 327,000 and shall be deposited by the Government in the United Nations Special Fund Account (Account Number U-35) at the State Bank of Ethiopia and will be made available as follows:

Equivalent of US$ 118,000 on signature of the Plan of Operation
" " " 107,000 on or before 1 January 1962
" " " 102,000 on or before 1 January 1963

(ii) The Government, when they furnish a contribution in kind, whenever feasible, concerning the abovementioned personnel, equipment, supplies and services, shall be refunded in cash from the abovementioned account.

22. Government contribution towards local facilities (in cash)

(i) In accordance with Article V, paragraph 1 (a to d), of the Agreement between the Special Fund and the Government, the Government will contribute the equivalent of US$ 82,650 towards local facilities.

(ii) This amount represents 15% of the total cost to the Executing Agency of foreign personnel, including sub-contractor's personnel.

(iii) The amount mentioned above shall be deposited by the Government into the United Nations Special Fund account U-35 at the State Bank of Ethiopia, and will be made available as follows:

Equivalent of US$	28,200	on signature of Plan of Operation
" " "	32,750	on or before 1 January 1962
" " "	21,700	on or before 1 January 1963
Total US$	82,650	

(iv) The above payments shall be made on or before the dates specified above as a pre-requisite to operations. Payments made by the Government in Ethiopian dollars shall be made at the most favourable legal rate of exchange.

C. Organization

23. Overall responsibility for the organization and execution of the project rests with the Executing Agency who shall plan and direct operations.

24. The Government Agency responsible for Government participation in the project shall be the Awash Valley Authority, who shall also ensure coordination of the work of the various Government organisations participating in the project.

25. The Executing Agency shall appoint a Project Manager acceptable to the Government. Under the general supervision of the Executing Agency, the Project Manager shall be responsible for the detailed planning, administration and execution of the project, as well as for the supervision of the work of the subcontractor(s).

26. The Government shall appoint a Co-Manager acceptable to the Executing Agency, who will cooperate with the Project Manager in the execution of the project. He will be responsible for setting up preliminary arrangements agreed for the project and for the administration matters related to the project personnel furnished by the Government for the execution of the project. He shall be fully informed of all matters relating to the execution of the project.

27. The project shall be entrusted by the Executing Agency to subcontractor(s). However, the responsibility for the execution of all parts of the project will rest with the Executing Agency.

28. Under the supervision of and in close cooperation with the Executing Agency, the subcontractor(s) shall prepare detailed work plans, carry out surveys, establish and operate river gauging and meteorological stations, prepare reports, maps and charts. The project report shall be submitted to the Special Fund and the Government by the Executing Agency.

29. Headquarters for the project shall be at Addis Abeba.

D. Sequence of Operations

30. The Executing Agency shall commence operation of the Project upon written authorization to do so from the Managing Director of the United Nations Special Fund.

31. Immediately after signature of the Plan of Operation by the Government, the Executing Agency and the Special Fund, the Executing Agency shall appoint the Project Manager and shall enter into negotiations with sub-contractor(s) for participation in the project. Upon conclusion of these negotiations, the Executing Agency shall sign a contract with the sub-contractor(s), Prior to the signature of the contract, the Executing Agency shall send the draft text of the contract to the Government for information.

32. At the same time, the Government shall appoint the Co-Manager.

33. Upon arrival of the Project Manager the Government shall supply him with two complete sets of loose contact prints and one set of mosaics mentioned in paragraph 19 (ii).

34. A general plan of survey operations shall be drawn up by the sub-contractor(s) under supervision of and in cooperation with the Project Manager and in consultation with the Co-Manager not later than six weeks from the signing of the contract with the sub-contractor(s). For this purpose the Project Manager, the team members concerned, and the Co-Manager, should undertake reconnaissance flights over the river basin. Areas suited for development shall then be selected by the project team for more detailed investigations. In this plan staffing, equipment, transport, labour requirements of the various groups (hydrography, irrigation, engineering, topography, soils, geology and agronomy) shall be given in sufficient detail to ensure timely supply of materials, equipment, transport and lodging.

35. The subcontractor(s) shall prepare at the earliest possible date a detailed list of equipment, materials, etc. required for the project. The list of foreign equipment and material shall be sent to the Headquarters of the Executing Agency for review and approval. Orders for the above equipment shall be placed by the sub-contractor(s) or the Executing Agency as agreed upon between them and set out in the contract.

36. The various parts of the survey have to be carried out in a coordinated way. The hydrological survey should start immediately upon arrival of the subcontractor team in order to obtain a sufficiently long period of observations. The river gauging stations should be established during the first 4 months of the project. Gauge observations and flow measurements should be continued until the end of the project. Watershed management planning should be done in the third year of the project when sufficient hydrological data are available.

37. Soil survey should start at the beginning of the first year and should be completed in a two-year period. This will make it possible to assess the extent and distribution of irrigable land and facilitate the working out of a water management plan as far as irrigation water is concerned.

38. Power damsite and reservoir studies should start in the second year when sufficient preliminary information on water discharges on the various sections of the main river and its tributaries will become available.

39. Erosion studies in the headwaters should be carried out during the first two years.

40. Land use studies should start at the second part of the first year and be linked with the soil survey and the water planning. They should be carried through in the second and third year.

41. The local authorities shall be kept informed in time through Government about the movement of the teams and their requirements in accommodation, guides, local transport and materials.

III. BUDGET

42. In accordance with Article 1, para 3 of the Agreement between the United Nations Special Fund and the Government of Ethiopia, the total sum to be made available by the Special Fund through the Executing Agency to assist in the execution of this project in US$ 844,700.

43. In addition to the above, the United Nations Special Fund shall make available an amount of US$ 85,400 to the Executing Agency to defray the Agency costs. This includes US$ 6,000 for preliminary investigations.

44. The total cost of the project to be borne by the Government is estimated at (equivalent of) US$ 327,000 as being the counterpart contribution and the equivalent of US$ 82,650 as a cash contribution towards local operating costs of the project as mentioned in Appendix II. These amounts are to be deposited in the United Nations Special Fund account in the State Bank of Ethiopia in accordance with paragraphs 21 (i) and 22 (iii).

45. Unless otherwise agreed at any time by the Government, the Executing Agency and the United Nations Special Fund, these sums shall be disbursed under the main objects of expenditure in amounts and at times as scheduled in the Budget and Plan of Expenditure. The Budget and Plan of Expenditure are set out in Annex I and II attached.

46. All funds drawn on the accounts referred to in Articles 12, 21 and 22 hereof shall be by joint authorization of the two co-managers.

IV. REPORTS

47. Progress Reports

The Executing Agency will submit to the Managing Director of the United Nations Special Fund and to the Government the following reports on the project:

(i) an inception Report to be supplied three months from the date of receipt of authorization from the Managing Director to commence operations.

(ii) an end-of-year Report to reach the Managing Director by not later than 1 March each year covering the period from 1 July to 31 December of the previous calendar year;

(iii) A mid-year Report to reach the Managing Director by 1 September each year covering the work up to 30 June of that year.

(iv) Reports will include achievements of the period under review as well as the work plan for the next 6 months period.

48. Final Report

The Executing Agency will submit to the Managing Director of the United Nations Special Fund and to the Government, after conclusion of the project, a Final Report.

49. Financial Reports

The Executing Agency will submit financial reports to the Managing Director in a manner and at times to be agreed upon between the Managing Director and the Executing Agency.

The Government shall submit to the Executing Agency and the Executing Agency shall submit to the Government financial statements in a manner and at times to be agreed upon between the Executing Agency and the Government.

50. Audit Reports

The Executing Agency shall submit to the Managing Director audited annual statements of accounts. Accounts for a completed project will be submitted, as soon as practicable after the completion of a project, together with the External Auditor's Report Thereon.

V. CONCLUSIONS

51. Two months before completion of the project, a report will be submitted by the Government through the Executing Agency to the United Nations Special Fund on the benefits derived from the project and the activities planned by the Government to further the purpose of the project.

52. The technical material obtained during the course of the project will be handed over by the Executing Agency to the Government of Ethiopia for appropriate utilization as agreed with the United Nations Special Fund.

Agreed on behalf of the parties, by the Undersigned:

Date February 7 1961	Date February 7 1961	date February 7 1961
Imperial Ethiopian Government	United Nations Special Fund	Food and Agriculture Organization of the United Nations
by Signature	by Signature	by Signature
Yilma Deressa, Minister of Finance	Paul G. Hoffman Managing Director	Robert Watson Country Representative

Explanatory Note to Amendment No. 1

PLAN OF OPERATION

UNITED NATIONS SPECIAL FUND PROJECT IN ETHIOPIA

SURVEY OF THE AWASH RIVER BASIN

The experience gained in the past six months of project operation has indicated that the working conditions necessitate adjustment in the existing budget allocation, as well as allotment of additional funds both by the Special Fund and the Government to meet the technical requirements for successful implementation of the project in accordance with the established objectives in the Plan of Operation.

Details for the additional funds required are as follows:

1. The difficult access to the Survey area and particularly to the river gauging stations. This difficulty necessitates a larger number of vehicles against the number originally requested and a larger quantity of spare parts due to heavier wear on the vehicles.

2. The increase in the number of river gauging stations required for technical reasons.

3. The extremely high construction cost of these stations; and

4. The need for exploratory drilling at some of the potential damsites.

The Government has agreed to increase their contribution by the equivalent of US$ 50,000 and adjust their budgetary allocation as follows:

Survey Personnel	reduced by US$ 7,000
Equipment	increased by US$ 53,000
Service	increased by US$ 4,000

The Government considers that the reduction in man-month services of technical personnel is possible due to the shorter period of field work in soil science and less employment time of engineers, and also the actual wages paid to the local employees are less than originally budgeted.

As regards equipment and services the Government has agreed to increase their share of contributions by US$ 57,000 towards the additional requirement of funds for the additional work mentioned above.

The Government agreed to award the above mentioned additional funds subject to the Special Fund's approval to an additional allocation of funds of US$ 90,000 towards the following items:

Hydrometric and other technical equipment	US$ 18,000
Transport vehicles	16,000
Spares for vehicles	24,000
Test drilling equipment or drilling contract	32,000
	US$ 90,000

Necessary modifications in the Plan of Operation, including the Plans of Expenditure, are made as per the attached Amendment No. 1 to be signed by the three parties concerned. The Plan of Expenditure in Amendment No. 1 supersede the revised Plan of Expenditure for the Special Fund Allocation signed by the Executing Agency, the Special Fund and the Government on 28 February, 12 March and 13 March 1962, respectively, and the Plan of Expenditure for the Government Counterpart Contribution attached to the original Plan of Operation. Various items of expenditure included in the Government's Counterpart Contribution have been reclassified in connexion with the amendment of the Plan of Operation.

.mendment No. 1

PLAN OF OPERATION

UNITED NATIONS SPECIAL FUND PROJECT IN ETHIOPIA

SURVEY OF THE AWASH RIVER BASIN

In pursuance of the Plan of Operation signed on 7 February 1961, by the Food and Agriculture Organization as the Executing Agency, the U.N. Special Fund and the Government of Ethiopia;

Whereas it is found from experience of the first reconnaissance survey of the project that certain additional work has to be undertaken for successful completion of the project in accordance with the objectives of the project provided in the Plan of Operation;

And whereas it is considered necessary to make certain budgetary adjustments by increasing the existing allocated funds, provided both by the Government and by the Special Fund, modifications in the Plan of Operation and in the Plan of Expenditure in the said Plan of Operation are made as follows:

Page 1 - Heading

Read

Special Fund Allocation	US$ 1,020,100
Government Counterpart Contribution (equivalent of)	US$ 377,000

Page 2 - C. Project - Paragraph 8

Sub-paragraph (b) amended as follows:

"carrying out of observations at these stations during the entire duration of the project; flow measurements should cover three flood seasons and include sediment measurements on all major stations".

Page 3 - Paragraph 8

Add the following sentence at the end of the sub-paragraph (4):

"These studies will include exploratory drilling to be carried out through sub-contract".

Page 3 - Paragraph 8 - the following sentence is added at the end of sub-paragraph (5):

"Sediment measurements will also be conducted at all major gauging stations on the main river and most important tributaries".

Page 3 - Paragraph 8, sub-paragraph (7) is amended in the fourth line to read:

"area of 39,000 sq. kms." instead of: "30,000 sq. kms."

Page 4 - Paragraph 10 - Aerial Photography is amended as follows:

"Aerial photography of about 39,000 sq. kms. on 1:40,000 scale".

"Contour maps of potential reservoirs 800-1000 sq. kms. 1:10,000 or 1:20,000 scale (scale to be decided at a later stage)".

Page 4 - Add a new paragraph 10(a) as follows:

10(a) Exploratory Drilling

"Exploratory drilling at two damsites (contract)".

Page 4 - Paragraph 11 - Equipment and Supplies, is amended as follows:

Hydrometric equipment;
Topographic equipment;
Field and laboratory equipment for soil survey;
20 transport vehicles (4 wheel drive) and spare parts including winches;
Supply or hire of aircraft;
Preparation and printing of reports and maps.

Page 4 - Paragraph 13 - Subcontracts add the following in the second sentence (second line) after photography..... ....

"and the exploratory drilling".

Page 5 - Paragraph 16 read 350 instead of 408, against "Total man-months".

Page 5 - Paragraph 18 - Service Personnel, is amended as follows:

14 Gauge observers
20 Drivers
1 Fitter
Labour for survey teams, building of temporary roads, sheds.

Page 5 - Paragraph 19 - Equipment and Supplies is amended as follows:

(i) Construction of 20 automatic river gauging stations and 6 plain gauging stations including cableways and shelters;

(ii) construction of meteorological stations;

(iii) 2 sets loose contact prints and 1 set photo mosaics for the area for which aerial photography is already available - 1:40,000 scale for the aerial survey by Huntings and 1:50,000 for the area in the part of the Awash basin bordering the Blue Nile;

(iv) Miscellaneous materials: small tools, local supplies and stationery;

(v) Hire of bulldozers, graders, oil, lubricants for these machines and contingencies.

Page 6 - Paragraph 20 - Services. Add the following as an additional item (vi)

"(vi) Hire of insurable aircraft for reconnaissance flights".

Page 6 - Paragraph 21 (i) in the third line read:

"US$ 377,000" instead of: "US$ 327,000".

and

at the end of sub-paragraph 21 (i) add:

"Equivalent of US$ 50,000 on or before 1st January 1964".

Page 9 - Section III - Budget

Paragraph 42 In the fourth line read:

"US$ 934,700" instead of: "US$ 844,700".

Paragraph 44 In the second line read:

"US$ 377,000" instead of: "US$ 327,000".

Appendices

Appendices I, II and III are amended to reflect the changes as indicated above and are attached.

This agreement amending the original Plan of Operation seen and agreed:

For the Imperial Ethiopian Government

Mulatu Debebe

Assistant Minister
Awash Valley Authority

Date: 12 September 1962

For the United Nations Special Fund

Edgar Marland

Assistant TAB Resident Representative
and Assistant Director of Special Fund
Programmes in Ethiopia

Date: 12 September 1962

For the Food and Agriculture Organization
of the United Nations

Oris V. Wells

Assistant Director-General
(Program and Budget)

Date: 3 September 1962

APPENDIX I

UNITED NATIONS SPECIAL FUND PROJECT

ETHIOPIA: SURVEY OF THE AWASH RIVER BASIN

Revised Plan of Expenditure

United Nations Special Fund Allocation

	Period Man-Mos.	Total Project Costs $	Estimated Cash Disbursement 1961 $	1962 $	1963 $	1964 $
1. Personal Services						
(i) Water Development Planning Engineer (P.M.)	36	70,200	10,800	20,950	22,000	16,450
(ii) Administrative Officer	36	38,200	1,700	13,810	12,690	10,000
(iii) Consultants	4	8,000	-	6,000	2,000	-
	76	116,400	12,500	40,760	36,690	26,450
2. Equipment and Supplies						
20 Transport vehicles including spare parts and winches		85,000				
Hydrometric equipment / Field and laboratory equipment		104,000	23,300	185,700	5,000	10,000
Supply or hire of aircraft		15,000				
Printing of reports and maps		20,000				
		224,000	23,300	185,700	5,000	10,000
3. Sub-Contracts						
Personal Services		437,000	39,700	180,000	147,300	70,000
Aerial photography and contour mapping		97,600	10,000	87,600	-	-
Exploratory Drilling		32,000	-	32,000	-	-
		566,600	49,700	299,600	147,300	70,000

	Period Man-Mos.	Total Project Costs $	Estimated Cash Disbursements 1961 $	1962 $	1963 $	1964 $
4. Miscellaneous						
Cable and postal expenses		6,000	-	2,000	2,000	2,000
Secretarial Assistance		12,050	-	4,000	4,000	4,050
Contingencies		9,650	100	2,000	3,000	4,550
		27,700	100	8,000	9,000	10,600
Total Gross Project Cost		934,700	85,600	534,060	197,990	117,050
5. Executing Agency Costs		79,400	40,000	24,000	15,400	-
6. Cost of Preliminary Investigations		6,000	6,000	-	-	-
Special Fund Allocation 1/		1,020,100	131,600	558,060	213,390	117.050

1/ The Special Fund Allocation includes the equivalent amount of US$ 82,650 to be paid by the Government towards local operating costs of the project. This amount represents 15% of the expert costs including cost of foreign personnel of sub-contractors. This amount is payable by the Government in instalments as shown in Section II, paragraph 22 of the Plan of Operation signed on 7 February 1961.

APPENDIX II

UNITED NATIONS SPECIAL FUND PROJECT

ETHIOPIA: SURVEY OF THE AWASH RIVER BASIN

Revised Plan of Expenditure

Government's Counterpart Contribution in Cash and Estimated Cost

	Period Man-Mos.	Total Project Costs $	Estimated Cash Disbursements 1961 $	1962 $	1963 $	1964 $
1. Professional Staff						
(i) Hydrometrists)						
(ii) Meteorologist)						
(iii) Engineers and Technicians)						
(iv) Soil Surveyors)						
(v) Soil Laboratory Technician)	350	79,000	5,800	30,000	33,200	10,000
(vi) Assistant Geologist)						
(vii) Soil Conservationist)						
(viii) Draftsmen)						
(ix) Administrative Assistant	36					
	386	79,000	5,800	30,000	33,000	10,000
2. Clerical Drafting and Laboratory Non-Professional Staff and Labourers						
Accounts clerk)						
Typist)						
Labour Supervisors)						
Stock-Keeper)	756	68,000)				
Drivers and Mechanics)		)				
Gauge Observers)		)	1,400	46,000	45,600	30,000
Labour survey operations, road building and hire of bulldozers	1,000	55,000)				
	1,756	123,000	1,400	46,000	45,600	30,000

	Period Man-Mos.	Total Cost $	1961 $	1962 $	1963 $	1964 $
			Estimated Cash Disbursements			
3. **Equipment and Supplies**						
Miscellaneous tools equipment, etc.		17,000)				
Meteorological equipment		3,000)				
Operation and Maintenance of vehicles		54,000)	5,500	30,000	26,500	12,000
		74,000	5,500	30,000	26,500	12,000
4. **Sub-Contractors**						
Construction of gauges		55,000)				
Hire of aircraft		20,000)	10,000	60,000	7,000	3,000
Aerial photography		5,000)				
		80,000	10,000	60,000	7,000	3,000
5. **Miscellaneous**						
Offices, laboratory facilities, store rooms		5,000	-	2,000	2,000	1,000
Field accommodation		6,000	-	2,500	2,000	1,500
Transportation and storage of equipment		10,000	-	6,000	2,000	2,000
		21,000	-	10,500	6,000	4,500
Total estimated cost of counterpart contribution in cash expressed in US dollar equivalent		377,000	22,700	176,500	118,300	59,500

UNITED NATIONS SPECIAL FUND PROJECT

ETHIOPIA: SURVEY OF THE AWASH RIVER BASIN

Total Government Contribution

	Total	Equivalent in US$ 1961	1962	1963	1964
Counterpart contribution in cash 1/ (Appendix II)	377,000	118,000	107,000	102,000	50,000
Payment in cash for local operating costs 2/ (Appendix I - see footnote)	82,650	28,200	32,750	21,700	-
	459,650	146,200	139,750	123,700	50,000

1/ These amounts have been calculated at the prevailing United Nations operating rate of exchange of one US dollar = 2.484 Ethiopian Dollars

2/ These amounts are payable in local currency at the United Nations operating rate of exchange (which is based on the most favourable legal exchange available to the Special Fund), which at the present time is one US dollar = 2.484 Ethiopian Dollars.

APPENDIX II

TOPOGRAPHY AND MAPPING

1. General Maps

Stretching from the 8th to the 12th degree of north latitude and between the 38th and 42nd degree of eastern longitude, the Awash River Basin occupies the eastern part of central Ethiopia. In spite of its strategic situation and relative accessibility, the region was little explored until recent years, and no detailed maps and topographical information other than those covering the whole country, were available to the Project, when it began its work.

The basic maps belong to the series of world aeronautic charts drafted following the world aerial survey of 1944, edited by the Aeronautical Chart Service at the scale of 1:1,000,000 and subsequently revised. The 1954 edition was used for Project purposes, as well as the enlargement of this on a scale of 1:500,000, published by the British War Office in 1947.

The contour lines are drawn at intervals of 1,000 feet on the basis of barometric measurements made at several control points. The accuracy of these maps is relative.

More recent and more accurate 1:500,000 scale maps compiled by the USAF in 1954 and which exist only in draft form, were also used by the Project.

The Upper reaches of the Awash basin were air-surveyed for the purpose of the Blue Nile River Basin Survey in 1956 at the theoretical scale of 1:50,000. Contact prints of the relevant photographs were made available by the Government. The Middle Valley and the Lower Plain were covered by aerial photographs at a scale of 1:40,000, made by Messrs. Hunting Surveys Ltd., under a contract with the Project. Air photographs at the scale of 1:20,000 for limited areas were available from the Imperial Highways Authority.

No general triangulation data were available during the Project's field operation, as the levelling data from the Geodesic survey of the Blue Nile River Basin were published only in 1964.

Thus aerial photographs contact prints and uncontrolled mosaics served as a basis for the work of the Project in topography, engineering, and land survey.

2. Topographical Work

Topographical work for the Project was undertaken with the object of facilitating the carrying out of surveys in other fields namely, agrology, pedology, hydrology, dam studies and irrigation works. No overall topographical survey was made, but merely specific surveys for particular needs.

For lack of reference points, particularly as regards altitudes, many of these surveys could neither be collated from the standpoint of altimetry, nor controlled in planimetry. The work done included mapping, surveying, photogrammetry and levelling.

i) Mapping

Since there were no recent maps on scales suitable for the Project it was necessary to compile maps with the help of aerial photographs. These were made on the following scales:

(a) 1:250,000 This planimetric map covered the entire Awash watershed (70,000 km^2) and showed its natural boundaries.

The distance covered being 450 km, from north to south, the distortion of distances was significant. The map was compiled by interpretation of aerial photographs, using east of the 40th meridian a cover made specially for the Project, and west of the 40th meridian the mosaics of the Imperial Highways Authority (in preference to those of the Water Resources Department which did not fit into the geodetic grid).

Two areas in the western and northwestern part of the Basin not covered by these mosaics, were corrected by means of a template, with the help of the Institute of Mapping and Geography.

This compilation, although somewhat heterogeneous and not completely controlled (it involved some distortion in the reading of distances and areas) was used as a basis for studies of land use, erosion and hydrology.

This map, reduced to a scale of 1:1,000,000 was used for the final report.

(b) 1:100,000 These planimetric maps were obtained by reducing the base maps obtained directly from mosaics on the following scales:

1:42,000 for the Lower Plains
1:41,000 for the Middle Valley

They covered about 12,000 km^2 in each of these two regions. For inclusion in the report they were reduced to a scale of 1:250,000.

(c) 1:50,000 Three planimetric maps on this scale covered areas of which more detailed studies were made, namely:

Dubti (200 km^2)
Dit Bahri (500 km^2)

The first of these was corrected by means of a template.

These maps were included in various notes and interim reports distributed during the execution of the Project.

ii) Special Surveys

Regular surveys were made of the sites of the major dams at Kesem and Tendaho, on a scale of 1:1,000 and for the Kebena at 1:2,000. The sub-contractors using photogrammetry plotted out topography of the reservoir basins of these dams.

The corresponding maps were drawn on the scale of 1:20,000; the total area thus covered came to approximately 200 km^2.

iii) Land Levelling and Miscellaneous Work

(a) For the preliminary layouts of irrigation canals from the sites of the future water diversion works, and to define areas which they would command, level surveys were made in the following area of the Middle Valley:

Melka Sedi - Amibara - Angelele, Kesem-Kebema, Bolhano, Maro Gala. Previously a crois-section levelled in the plain of Aleydegi had shown that gravity irrigation from the Awash was practically impossible. The levelling totalled about 150 km.

(b) Other levelling operations were carried out between the lakes of Ziway and Gelilea, and more detailed operations between the Meki river, an affluent to Lake Ziway, and the Dubeta river, an affluent of the Awash.

The purpose of this work was to determine the feasibility of diversion of the Meki river into Lake Gelilea.

(c) Preliminary topographical reconnaissance gave a rough idea of where a dam could be sited in the gorge near Awash Station, to form a compensation reservoir, for regulation of the plows released from the hydroelectric plant at Koka Dam.

(d) Similarly the bed of the upper Borkena, downstream of the marshes, was surveyed quickly to determine the feasibility of draining the marshes by lowering the rocky sill.

(e) At the request of the Ethiopian Government a track 165 km long was laid out between Awashist and Gewani.

It should be pointed out, that the spelling of geographical names in this report and on the appended maps may sometimes differ from the spelling currently used in Ethiopia. The Imperial Ethiopian Mapping and Geography Institute provided, at the request of the Project, a nearly complete list of geographical names with the newly introduced spelling.

APPENDIX III

FEASIBILITY REPORT ON DEVELOPMENT OF IRRIGATED AGRICULTURE AND HYDROELECTRIC POWER IN THE AWASH RIVER BASIN, ETHIOPIA

By L.G. Allbaugh and R.M. Arbuckle

Introduction

A survey of the resources of the Awash River Basin has been carried out over the past three years by the United Nations Special Fund with the Food and Agriculture Organization as Executing Agent. The French Firm of SOGREAH (Société Grenobloise d'Etudes d'Applications Hydrauliques) in contract with FAO provided the personnel for the study in conjunction with technicians and counterpart trainees from the Imperial Government of Ethiopia. The survey covered aerial photography, topography, soil classification and analysis, present land use, river hydrology, meteorology, dam sites, water storage facilities and irrigation engineering.

The survey indicated that the Awash River Basin had definite development potentialities and UNSF/FAO decided that a preliminary economic feasibility study was desirable. Two Consultants, Dr. L.G. Allbaugh, Economic Production Economist, and Mr. R.M. Arbuckle, Agronomist, were appointed in September 1964 to undertake this study and to present their findings to the Special Fund in January 1965. The experts proceeded to Ethiopia and in collaboration with Mr. M. Reklewski, Project Manager of the Awash River Basin Survey, assembled the available economic and agronomic data to enable them to produce the following Report. Terms of reference of the above experts are appended.

Appreciation is recorded by the Experts of the valuable and kind assistance rendered by Ministers and Officers of the Imperial Government of Ethiopia and by the farmers and other pioneers throughout the Awash Valley.

Summary

Preliminary estimates for the Total Awash Project of 150,000 hectares indicate that the annual net gains are almost double the annual costs, with a benefit-cost ratic of 1.95 to 1.00 at 6 per cent interest for the irrigation phase of the project. In addition, the power phase will produce 115 million kwhr for one-fourth to one-third of its cost if obtained from the best alternative source, at an annual saving of about E.$ 8 million. The flood control phase will also increase net incomes by an estimated average of E.$. 100,000 annually.

The irrigated cultivated land in the project area will be increased 14 times; the annual gross product value 27 times; and the annual net gains 50 times. The irrigable area will be more than double the maximum irrigable area of 63,000 hectares without dams. After completion, the project is expected to produce E.$ 181 million gross value agricultural products annually, with an annual net gain over present production of E.$ 6.7 million. The importance of these figures is significant when compared with a national budget of E.$. 306 million, total exports of E.$. 220 million and total imports of E.$. 276 million in 1963. These income figures are also significant when compared with the Total Estimated Initial Investments of E.$. 250.6 million for dams, irrogation works and roads, and the Total Associated Costs (Investments) of E.$. 179.7 million of farmers, making a G.and Total Investemt of E.$. 430.3 million. However, the project is expected to provide employment to 25-30,000 persons and farms for 10-15,000 farm families.

Secondary benefits were not computed but there will be important additions to the regional and national economy through increased income to thousands of workers and farmers, either presently under-employed or with meagre incomes.

In this type of development programme, the concomitant servicing (private and governmental), transportation and processing industries must develop, and will provide a further impetus to the economy of the area and the nation.

While the Awash Basin Survey data and these evaluations are entirely preliminary and further detailed soil and pre-investment studies are necessary, it is believed that the findings of this report provide a reasonably accurate assessment of the possibilities in developing the agricultural economy of this important region of Ethiopia. On the basis of actual costs of irrigation systems already constructed, the investment estimates are liberal. On the other hand, conservative estimates of crop yields and prices have been used. Total production has been kept within estimated market demands. A brief summary of the general economy of the country will help in understanding the findings of this report.

Ethiopia has 22 million people with an average annual per capita income of about E.$. 95 (US$ 38). This low income is reflected in their housing, clothing and education, but not in nutrition. Of this population, 90 per cent are engaged in agriculture, generally at a subsistence level. They cultivate only 8 per cent of the 120 million hectare total land area. Agriculture produces three-fours of the Gross National Product and 90 per cent of the foreign currency trade. Coffee, oilseeds, pulses and livestock products are the major exports. The largest area of cultivated land is devoted to cereals and pulses, mainly grown on the rain-fed mountain plateaus.

Although there is a trend towards industrialization, agricultural products must provide most of the raw materials for industry, as well as the foreign exchange required to purchase the necessary machinery and equipment. But most of the public credits obtained by the Imperial Ethiopian Government recently have been devoted to improvement of the infrastructure, highways and telecommunications, with only 23 per cent for the augmentation of production directly. This is resulting in a serious debt servicing problem which will require either increased exports, decreased imports or both.

Within a decade the development of 6,600 hectares of land along the Awash River has made the country self-sufficient in sugar and reduced the foreign currency drain by E.$. 6 million annually. There are other commodities to which this pattern of development might be applied, i.e. cotton to replace a large share of the E.$. 40 million annual imports of cotton textiles. Likewise, sisal and kenaf can be grown to replace the E.$. 2 million of gunnybags imported annually. Similar products include fresh and canned fruits and vegetables, butter, cheese, soap and other oil-based products.

On the basic of these facts and with the knowledge that selected areas in the Awash Valley have suitable climates, soils and water for growing a wide variety of crops under irrigation, the agronomist developed crop plans which would yield the highest net returns to the farmer and add most to the national economy by reducing food and fibre imports and/or increasing exports to earn additional foreign exchange. This is in sharp contrast to the millions of acres of Awash Valley grazing land, thinly populated by nomadic tribes who are dependent on seasonal rains to provide water and pasture for their cattle, sheep, goats and camels. However, some agricultural development totalling 10,500 hectares has already started in the project area under Government auspices and by private emterprise.

The Imperial Government of Ethiopia favours development of irrigated lands by large scale mechanized farming enterprises, particularly by concessionaries who invest capital and provide technical knowledge, experience and management skills to produce crops for industry and export. For rapid development of virgin lands such enterprises will produce most income. From a social point of view it seems desirable to have a proportion of the available land allotted to small farmers already trained in irrigation practices on the large holdings, backed by an effective extension service to supervise the use of credits and to provide technical assistance.

Such a policy would allow the indigenous population to play an important role in the development of their own lands and resources, and to contribute significantly in the growing national economy.

From an economic point of view, the Awash River Basin is strategically situated, having its axis running from the capital towards the Red Sea. A road, now projected on the right bank of the river, connecting Nazareth with Tendaho, would provide marketing outlets for agricultural produce or manufactured goods, either to the capital, Adis Abeba, or to the port of Assab.

Before current haphazard agricultural development becomes too far advanced, it is desirable to set up a master development plan, based on the findings of the UNSF/FAO Survey of the Awash River Valley and on further investigations. For this purpose the Awash River Valley Authority ought to be strengthened, both financially and technically, so that this autonomous body will be in a position to carry out its task of administering and supervising the development of natural resources under its jurisdiction. Expertise is necessary to devise and levy water rates, to establish a competent technical and operational service able to deal with the complex problems of water apportionment and its controlled distribution; and to plan and supervise the construction of an efficient and co-ordinated irrigation system as well as its maintenance and operation after completion.

For the full development of the Valley, fuller use of it water resources for hydro power is important. With 88 per cent of the electric power in the nation produced by public utilities and the remainder generated by thermal power units in industrial plants for their own use, hydro power production is primarily a governmental function. At present 40 per cent of the 176 million kwhr produced in Ethiopia is generated by the waters of the Awash. An this is less than one third of its hydro power possibilities. To date, all of this power is used in Adis Abeba and contiguous area, with none available to the Middle and Lower Awash areas. Consequently, the production of 115 million kwhr from the power stations in the two proposed dams can assist greatly in the development of the region. About one fifth of this power would be utilized for irrigation pumping. The remainder can play an important role in industry location and development and improved living levels of the people.

Since regional development involves a complex of problems, priorities and procedures must be determined, both in the region and in the larger governmental administratives areas. The urgency of the problems usually help in deciding upon the priorities, means and procedures for their solution. In Ethiopia there is no urgent food shortage; no population pressure on the land; and no great social pressure for land reform and land settlement schemes. The major problem is to select long time economic development projects which will place greater emphasis on direct production activities. Consequently, a "Crash Programme" of 5 to 10 years seems out of place. This suggestion is further confirmed by the shortage of well-trained administrative and technical personnel for the jobs required. Thus, a longer time 10 to 25 year programme employing long time planning and careful selection of projects on an economic basis would seem more applicable.

While the preliminary analysis of the Total Awash Project indicates that it is economically sound, there are wide differences between selected project areas and these must be carefully analyzed and compared. This study suggests that the Middle Awash Project can make the largest economic contribution within the region to assist with the national debt servicing problem and to develop agriculturally based industry. While the Lower Awash Project might contribute to the national economy to a lesser degree, there are local social and political problems which require solution and might justify its being carried out concurrently with the more favourable economic projects of the Middle Awash.

A decision as to the relative importance of projects which have larger economic benefits when compared with projects having larger social benefits requires careful consideration by the Government at high levels. An there are other problems requiring major policy decisions and, in some cases, legislation. Water rates or water charges is such a problem in Ethiopia, requiring a solution at both the policy and legislative levels. After legislation is enacted the problem remains as to the b basis of levying such water charges, whether by volume of water, by type of crop or by area. Other problems involve the determination of the total funds to be collected, the method of collection and the final use to be made of such funds.

An important policy involves the land use pattern in irrigated areas in order to obtain the highest net gains for farmers and for the national economy with the limited water resources available. Should water charges on the lower investment cost areas be used to assist in the development of the higher cost areas.

Each of these and other problems require well-trained and dedicated administrative and technical personnel - competent to analyze, plan, organize and implement the programme to be carried out. The selection and training of such personnel has top priority. Upon them rests the responsibility for the success of each project to be undertaken. But with competent responsibility these must be given authority and the necessary funds, or the means to acquire them; funds with which to implement the programme. The Awash Valley Authority is limited in each of these areas. No capital funds have been provided to construct irrigation works, even small diversion dams. No source of revenue has been devised other than a very limited category in the National Budget for river gauge readings and general administration, and a recent hastily-devised water use charge for certain users.

If the Awash Valley Authority is to function as the charter intended, there is need for some high level consideration by the Board of Director or even the Council of Ministers, of the problems facing the organization. Unless these matters are settled soon the "piecemeal" development of former years will continue and limit the land and water to the choice areas only and for such crops as the farmer may choose. This procedure is not apt to be in the best long run interests of the nation as a whole.

General Economy

Ethiopia has 120 million hectares of land area and 22 million people, 90 per cent of whom are engaged in agriculture. Agriculture produces three fourths of the Gross National Product and 90 per cent of the foreign currency trade. Yet, the National Budget allocates directly to the Ministry of Agriculture less than 2 per cent of its total budget (see Appendix III, Table 1). Agriculture, in general, is on a subsidence level. The per capita income per annum of E.$. 95 (US$ 38 1/ is the lowest of all countries for which country estimates have been made by the United States Department of Agriculture. Nevertheless because of its climate, reasonably fertile soils and predominance of rural population, nutrition and health conditions are by no means the lowest in the world.

1/ One US dollar = 2.50 Ethiopian dollars.

Under the leadership of His Imperial Majesty, Haile Selassie, Ethiopia is determined to modernize its economy, through increased trade with the outside world and by greater industrial development within the country. With mineral resources yet unexplored and undeveloped, Ethiopia must depend primarily upon the raw materials of agriculture for its industries and for obtaining the necessary foreign exchange to purchase machinery and equipment for industrialization. Gold ore production has averaged only E.$. 2.5 million during the past nine years. Recent discoveries of potash near the Red Sea lend encouragement to another source of foreign exchange.

The trend towards industrialization is indicated by the increase in fixed assets of manufacturing. Since 1955 these assets have been doubled, mostly in the larger enterprises of E.$. 5 million and over. Textile and electric power production have tripled since 1955. Employment and gross value of manufactured products have doubled since 1958. Annual capital expenditure in manufacturing has tripled since 1958, half of this total being in the textile industry. While the base for these rapid increases is rather small, they do reflect an early stage in industrial development, and the trends are indicative of confidence and willingness of local and foreign capitalists to invest in the future of the country.

The low income per capita and its concomitant living levels are reflected in housing, cloting and education, as revealed by recent census data for the capital Adis Abeba. Of the 460,000 population, 33 per cent are listed as literate. Average size of a household is 3.5 persons with one to three as most common. Of the households, 95 per cent have piped water supplies, while 10 per cent are dependent on a stream or other source. Forty per cent of the households are without electricity. About 70 per cent of the living quarters are rented. Only 5 per cent of the houses have stone walls, metal or concrete roofs, and foundations, while 10 per cent have Chica (mud and wood) walls and thatched roofs but no foundations. The remaining 85 per cent are made of chica with metal roofs but almost equally divided as to "with" or "without" foundations. In rural districts, illiteracy is greater, and streams and ponds are the only source of water, in many cases at considerable distance from the houses. Electricity is available only in the larger towns and municipalities. Few stone or brick houses are found outside the large towns and most houses are made of chica with thatched roofs.

While statistics are not available, there is little or no evidence of serious malnutrition. With a high proportion of the population engaged in agriculture, food shortage is unlikely. The large expanse of fertile soils, under loose ownership and a favourable climate, makes food production a possibility for those willing to expend a minimum of effort.

The clothing situation is reflected by a per capita consumption of cotton annually of less than one kilogram, as compared with two to three kilograms in many low-income countries and a world average of four to five kilograms. Yet, the variable night and day temperature throughout Ethiopia, in the mountains and in the deserts, warrants more clothing than the latitude might suggest. Lack of sufficient clothing and shoes is evident in town and country. The lack of shoes is in sharp contrast with the estimated 25 million head of cattle, more than one per capita of the population, and with the export of hides and skins to the value of E.$. 15 million annually.

Of 120 million hectares of land, 40 per cent is in pasture, 25 per cent forest and 25 per cent waste land according to rough estimates of the Ministry of Agriculture. Less than 10 per cent of the total area is in crop land (9.4 million hectares) of which two thirds is sown to cereals. Half of the cereal hectarage is devoted to "teff" (Eragrostis abyssinica) the seed of which is used by Ethiopians for the preparation of their staple unleavened bread or "enjera". Industrial crops occupy 1.25 million hectares, one half being in oil seeds. Pulses and vegetable crops (ratio 2:1) make up another 1.06 million hectares. Coffee plantations cover 43,000 hectares and produce the largest gross income of any crop. Coffee is the most important export, providing more than E.$. 100 million of foreign exchange annually (see Appendix III, Table 2). In fact, Ethiopia might be characterized as having a "cereal-cattle-coffee" economy which provides food, wealth status and a source of foreign funds (see Appendix III, Table 3). With tremendous resources of land and livestock, abundant wild life and a varied climate, hunger can only result from lack of initiative.

Under the aegis of the Emperor, Ethiopia is awakening to the possibilities of modernizing its economy. Better contact between the various sections of the nation and with the outside world is under way through increased expenditures for roads, transport (air and highway) and telecommunications.

Until 1958, Ethiopia had a long history of exporting annually more goods than were imported. Except for 1952, the total export of goods and services exceeded the total imports, thus providing a very favourable balance of trade during the decade 1948-57.

In the recent trend towards industrialization, the Imperial Government has obtained public loans and credits totalling E.$. 314.4 million 1/ of which 23 per cent only were earmarked for projects which would increase production directly. The remaining 77 per cent were concerned with indirect improvement, i.e. for infrastructure. Of the infrastructure allocation 98 per cent were for improving transport and communication facilities which should help directly in the production sectors of the economy, especially in agriculture with its relatively low value, bulky products. This is particularly true in a mountainous country like Ethiopia, with great distances between population centres, limited railroads and long tortuous roads from the capital and the main agricultural production areas to the sea ports. Both import and export commodities, as well as internal trade have been burdened with high transport charges.

In the short run, the wide gap in the ratio of loans for direct production and infrastructure projects may limit certain types of product for export and consequently may hinder Ethiopia from meeting her short-run obligations. Although such a gap is normal in an emerging economy, the need for developing and increasing production of all types of export commodities while reducing imports of agricultural and food products which can be produced economically within the country cannot be over-emphasized.

Since 1953, the nation's total burden of debt servicing has increased from 1.8 per cent to 14.4 per cent of the gross receipts on current account in 1962. 1/ To assist in meeting this debt servicing ability in a new industrializing nation, the agricultural sector requires greater intensification and diversification in its over-all production and increased emphasis on the higher gross value crops.

To improve the debt service situation, such crops as can be produced economically should be grown which will reduce the imports of similar raw products and processed goods manufactured from them, e.g. cotton and cotton textiles, fruits and vegetables, cereals, pulses, flour, butter, cheese, soap, tobacco, paper and cardboard.

1/ Ethiopian Economic Review, No. 8, April 1964.

During the past five years these commodities required over E.$. 54 million in foreign exchange annually and no single group averaged less than E.$. 1.3 annually. Raw cotton and cotton goods have accounted for about E.$. 40 million of imports annually since 1949 (see Appendix III, Table 5). In that year these two items amounted to almost one half of total imports but declined to 37 per cent for 1950-54, 23 per cent for 1955-61, and 15 per cent for the past two years. This decline in percentage has resulted primarily from larger increases in imports, such as industrial and agricultural machines, vehicles, etc. but actual imports of cotton and cotton goods have fallen by only 20 per cent in the period referred to. Prior to 1958 sugar imports used up considerable foreign exchange but in the last two years, Ethiopia has been able to export small surpluses of refined sugar.

Beside reducing imports, another means of solving the debt service problem is by increasing production of those crops, or their processed products, which will earn foreign exchange by their export on world markets. The proceeds can be used to service the debt and/or to purchase machinery, processing equipment and other items in an industrialization programme. In addition, a proportion of this increased production may be used internally to improve living levels which will provide incentive for all types of workers and producers.

To illustrate these economic possibilities, it is interesting to note that prior to 1962, sugar was not produced in Ethiopia. By laying out the Wonjii Sugar Estates on the Awash River and the formation of the "H.V.A. Ethiopia" company with its factories at Wonji and at Shoa, some 60,000 tons of refined sugar are now produced annually which satisfies the current internal demand and leaves a small surplus for export. For the period 1948-54, sugar imports averaged E.$. 5,400,000 annually. By 1963, a decade later, sugar imports had dwindled to E.$. 64,000 1/ and net exports of sugar on world markets provided E.$. 3,800,000 of foreign exchange, but such exports are liable to vary greatly because of violently fluctuating world sugar prices.

Inside the country, the per capita consumption of sugar has doubled in the past ten years. Thus, the E.$. 9.2 million improvement in Ethiopia's sugar trade balance has been made possible by an important change in land use; the utilization of available resources - fertile land and plentiful labour; and the importation of capital, management and technical skills, each of which is increasingly obtained from local sources.

Cotton is another crop which might repeat the sugar story in its effect on reducing foreign exchange drain. Due to mill requirements for varying types and grades of raw cotton, and the time required for developing land and training farmers to produce new crops, the period required for replacing cotton and cotton textile imports will be longer. The natural resources of the Awash Valley can play an important role in the cotton economy. Importation of management, technical skills and capital have already started. (See Appendix IV).

Since 1960 cotton production from newly irrigated lands in the Awash River Basin has increased from 400 metric tons of seed cotton from 560 hectares to 6,550 metric tons from 7,100 hectares in 1963. The crop for 1964 is estimated at 8,800 metric tons from 10,000 hectares. Preliminary production goals for 1967 are reported as 30,000 metric tons of seed cotton from 28,000 hectares (see Appendix III, Table 4). Even this production of 30,000 metric tons of seed cotton, equivalent to approximately 10,000 metric tons raw (lint) cotton, would not meet the annual con-

1/ Ethiopian Statistical Abstract, 1964, p. 77, Table 66.

sumption requirements of 12,824 metric tons for the local textile mills. Their estimated capacity in 1963 was 18,000 metric tons of raw cotton, or 180 per cent of the production goals set for 1967 by current cotton producers. Attempts at large scale commercial production on irrigated lands in other regions of Ethiopia such as Eritrea, have not succeeded or expanded. The only other production of major importance is an estimated 4,000 metric tons of seed cotton (1,330 metric tons raw) produced by small farmers on rainfed lands. Of this production about one half (700 metric tons raw) finds its way to the textile mills while the remainder is used in the cottage industry.

In two recent studies by FAO cotton experts in Ethiopia, demand for raw cotton by 1967 has been estimated at between 18,000 and 24,000 metric tons. Even the latter figure with population expansion would provide only one kilogramme of cotton per person annually. The experts have estimated that the per capita consumption will double during the next decade, requiring approximately 35,000 metric tons of raw cotton for an increased number of textile mills. Even the long term targets the present producers of irrigated cotton in the Awash Valley indicate only 15,000 to 20,000 metric tons of raw cotton, or 45,000 to 60,000 metric tons of seed cotton annually (see Appendix III, Table 4).

From 1960 to 1963 the total annual consumption of cotton and cotton textiles on a raw cotton (lint) equivalent basis has varied from 14,217 to 16,462 metric tons with an average of 15,780 metric tons annually, according to recent revised estimates (see Appendix III, Table 5). For the previous five years, the average annual consumption was 20 per cent less. About one half of the current consumption, on a raw cotton equivalent basis, consists of imported cotton textiles valued at E.$. 34.7 million compared with E.$. 37.3 million in 1954 to 1957, when imported textiles represented about three fourths of milled cotton consumption. These figures show a reduction of E.$. 2.6 million in foreign exchange, although the total consumption of cotton and cotton textiles increased in recent years (see Appendix III, Table 5).

Selected portions of the Awash River Valley have suitable climate, soils and irrigation water available for production of fruits and vegetables, especially high value crops such as citrus, bananas, papaya, grapes, etc. Because of the proximity of the Valley to the capital, and to the developing seaport of Assab, both internal and external market outlets will be available for these semi-perishable products. Fruits and veget ble imports have averaged E.$. 1.9 million annually for the past two two years. Yet, with ideal climatic conditions and the irrigation water resources in the Awash Valley, together with the cooler plateau areas having adequate rainfall, Ethiopia should be able to produce any type of fruit and vegetable desired by local demand throughout the year, and have sufficient for export either as fresh or canned products.

Imports of gunny bags have averaged E.$. 1.1 million for the past six years and reached a peak of E.$. 2.1 million in 1963. Considering that coffee is one of the main exports and sugar production is a newly emerged industry, there is a basis for a national fibre industry. It is expected that increased agricultural production of cotton, pulses, oilseeds, sugar, etc. will lead also to further demands for fibre crops suitable for production of sacks and similar containers. One proposed development plan by private enterprise in the Awash Valley includes sisal on irrigated land to assist meeting local demand. Kenaf has also been included in proposed rotations for other irrigated lands, but care must be exercised since this crop acts as a host for insects harmful to cotton production.

Oilseeds can also be produced under irrigation in the Awash Valley with satisfactory estimated net returns. In addition to increasing exports, now valued at E.$. 15 million annually, further production in concentrated areas might provide the necessary impetus to develop an oil processing industry. Soap imports have averaged E.$. 3.5 million annually for the past four years, reaching a high of E.$. 4.8 million in 1963, three fourths of which was for common soap. This high import suggests a ready market being available for oil processing and soap manufacturing industry. Cotton seed is being exported due to lack of a processing plant. It is estimated that a minimum of 25,000 metric tons of oil seeds are necessary annually to justify the operation of an oil mill. Other oil seeds under consideration for large scale production include castor and groundnuts. Sesame is also a possibility but the evaluation of net returns did not warrant inclusion in proposed rotations, although with better varieties and lower production costs, sesame may well be worthy of consideration. Castor, groundnuts and sesame are presently exported in fairly large quantities.

Legumes, other than ground nuts, might be grown for improved land use, more intensive labour use and to provide additional cash income. These would include haricot beans, horse beans, lentils and chick peas. Exports of these four commodities have averaged E.$. 16 million annually over the past four years, which indicates that oversea market outlets have already been established. Haricot beans have been included as a possible rotation on irrigated land, as quality white beans produce a relative high return compared with the other pulses.

Much of the 150,000 hectares of irrigable land is now utilized as grazing areas by nomadic herdsmen for cattle, sheep and goats, but the net return per hectare for the national economy is very low. Fodder crops can be raised on irrigated land with consequent increases in quantity and quality of meat and hides. Provision for ponds or wells in adjoining plains, together with disease control and modernization of production will enable the livestock industry, already one of the largest in Africa, to expand greatly over the next two decades.

While larger yields per hectare of cereal crops can be grown under irrigation, there are considerable areas on the high plateaus which are peculiarly suited to cereal production because of elevation, climate and soil. About two thirds of the 9.4 million hectares in cultivation in Ethiopia are devoted to cereals, but with low average yields estimated at 800 to 900 kilogrammes per hectares of wheat barley and maize. Yields can be increased on these lands by planting improved varieties, using lime and fertilizers and by better cultural methods. Consequently, it is believed that the limited water resources of the Awash Valley should be reserved for higher gross value crops adapted to the conditions obtaining in the valley. Limited areas of cereals could be grown for home consumption, livestock, or eventually for export if demand warranted such production.

To summarize the foregoing, Ethiopia, and the Awash River Basin in particular, is fortunate in having excellent and varied climates, extensive areas of fertile soils, and a plentiful supply of labour. With capital investment, management and technical skills, including judicious application of available water, production can be greatly increased to improve nutrition, raise living levels and even provide surpluses to assist in meeting the world gap in food, fibre and vegetable oil. Production from the Awash Valley can broaden the base of both agriculture and its related industries, thus making available additional foreign currency, paying the way to a more rapid industrialization and a balanced economy.

The Awash River Basin Economy

The Awash River whose headwaters rise near the capital, Adis Abeba, flows south and then northeastwards towards the Red Sea, but on reaching the Danakil Plains the river bends to the east, divides into three main branches, and ends in a series of lakes (see Appendix I). This internal river basin forms a strategic axis between the Read Sea ports and the capital. Its climate is varied, the land fertile, grazing extensive, but water resources limited. The basin includes

7,000,000 hectares or 70,000 square kilometers, which is about 6 per cent of Ethiopia's land area. Except for the portion above Nazareth, the valley is sparsely populated. Roving nomads seek seasonal grazing and water for their herds. It is estimated that there are 240,000 cattle, and 60,000 head of sheep, goats and camels between Awash Station and Lake Abbe.

A few farmers raise rainfed subsistence crops in scattered areas between Nazareth and Awash Station, and most of these farmers or their descendants will continue to do so, even after portions of the valley are developed for irrigation. It is thought that existing production in these areas will be affected little by new irrigation projects. However, these projects will utilize more fully the semi-desert grazing savannah lands now of extremely low gross productivity. With forage production on irrigated land, it is expected to increase over-all meat production even though the total grazing area is somewhat reduced by new cropping areas. In this preliminary study, no attempt has been made to assess present production, except on areas now actually irrigated.

Until 1952, only the upper reaches of the Valley around the capital produced cash crops for the nearby market. They were rain fed crops or crops on lands pre-irrigated by summer floods. Prior to the above date, only two organizations had pioneered the lands further downstream, Montañari Estate (Awora Melka) located northwest of Awash Station on the Kebena River (a tributary), and the Metehara Plantation on the Awash River west of Awash station. These estates made use of irrigation water to produce bananas, citrus, papaya, grapes, vegetables, cotton, rice, sugar, oilseeds etc., but transportation facilities to markets were inadequate. Just over a decade ago, planned irrigated areas below the present Koka Dam totalled less than 1,200 hectares. The Wonji Sugar Estates obtained a concession on Awash River near Nazareth for 5,000 hectares (later increased to 6,600 hectares) on which to produce sugar cane by irrigation.

In 1958 Mitchell Cotts Company obtained a concession for growing cotton on 18,000 hectares along the Awash River; 12,000 hectares were selected in the Lower Awash between Tendaho and Asayita; the location of the remaining 6,000 hectares was to be decided upon later. This year, 1964, Mitchell Cotts have a total of 7,100 hectares under irrigation in the Lower Awash with active plans to complete a 12,000 hectare development by 1967. Reconnaissance has been made to start developing the third tract of 6,000 hectares near Melka Sedi in the Middle Awash. The agricultural company formed by Mitchell Cotts in the Lower Awash, known as the Tendaho Plantation Share Corporation, is also assisting local irrigation farmers by providing seeds, spray materials, ginning facilities and technical supervision over 4,000 hectares of cotton on small farms in the Asayita area. (See Appendix III, Table 6).

These developments, along with the preliminary results of the UNSF/FAO Awash River Basin Survey, have encouraged other enterprises to plan future schemes, and to start pilot projects with the following targets: Abadir - 500 hectares; Nura Era - 5,400 hectares; Haile Selassie Welfare Trust - 1,500 hectares; and Tebila - 200 hectares (see Appendix IV). Before this somewhat hap-hazard development becomes too far advanced, it is essential to plan for the best over-all use of land and limited water resources, and it is suggested that every technical and administrative assistance should be given to the Awash Valley Authority, the autonomous Government body charged with the task of developing one of Ethiopia's main agricultural assets.

<u>Present Land Use</u>

As mentioned previously, some development is already taking place in the Awash River basin (see Appendix IV), mostly on a fairly large scale. A few rain fed plots of maize, cotton and teff are raised by railway employees near Melka Jilo, Metehara and Awash Station, but yields are low and sporadic. The whole region is sparsely populated and there has been no attempt at settled agriculture. Some years ago Metehara Plantation tried to encourage land settlement but only 40 families were induced to remain, cultivating some 20 hectares. Workers on the plantations are almost entirely from other regions, often coming as seasonal labour only. They do not take roots and avoid contact with the local pastoralists. Vast tracts of land are utilized by a relatively small number of nomadic graziers who move according to the availability of grass and water.

Only in the Lower Plains, around Asayita, has there been an attempt to utilize the waters of the Awash for irrigation, and settlement by the Muslim population there has been in evidence for centuries. Irrigation is mainly by inundation of flood water and crops are planted as the water recedes. Because of the silting deltaic channels, certain land formerly commanded by flood waters is no longer cultivable. Livestock in this region is an integral part of the farming pattern and are grazed on the flood areas not in cultivation and also on stubbles after harvest. Ploughing is done by bullocks culled from grazing herds.

The recent establishment of the concessionary Tendaho Plantation Share Company has encouraged new settlers from the highlands at the edge of the Rift Valley. In the past, there seems to have been a migratory type of farmer who would come down from the hills, plant a cotton crop, and after harvesting would return to his highland home. This type of farmer now tends to remain in the lowlands, and there appears to be some integration of races taking place around the Asayita district.

Development of Irrigated Agriculture

It is estimated that when the targets set up by concessionaires and related schemes are achieved some 46,000 hectares, gross area, will be operational (exclusive of Wonjii Sugar Estates). The present water supply regulated by Koka Dam plus tributaries of the Awash River will be sufficient to irrigate 63,000 hectares. Thus, without further works or contribution only 17,000 hectares beyond existing goals can be brought into cultivation. Another eight to ten years may elapse before the various schemes are fully operational, but if development of irrigated agriculture in the Awash Basin is not to be hampered by lack of water, action must be initiated now to increase the water resources in order to keep pace with future agricultural planning.

Several schemes to increase water resources can be contemplated and some of them have been investigated in some detail by the UNSF/FAO Survey.

1. Tendaho Dam

A reservoir dam might be created on the Lower Awash near the village of Tendaho. This would be a multi-purpose project for irrigation, flood protection and power production. Irrigation water would supply an additional 49,000 hectares and provide necessary flood control to an area of 70,000 hectares downstream of the dam.

A power plant could be included in the project with a production capability of about 80 million kwhr, some of which might be used for pump irrigation. If Tendaho Dam is erected, 12 Kms of the Adis Abeba-Assab road will need to be relocated.

2. Kesem Dam

A potential dam site has been investigated on the Kesem River, a left bank tributary of the Awash. Water storage by construction of this dam would permit irrigation of a supplementary 18,000 hectares. Power production capability is estimated at 35 million kwhr.

3. Meki River Diversion

The Meki River is located about 100 km. south of Adis Abeba and presently flows into Lake Ziway. Aerial photography suggests that at one time the Meki was a tributary of the Awash River. It would be feasible to excavate a canal along the old river bed and thus divert water into Koka Reservoir. An additional 15,000 hectares could be irrigated and production capability of all power plants dependent on Koka Dam would be increased by at least 10 per cent.

4. Awash Station Compensation Dam

With diversion of Meki River, the discharge flow from Koka could be regulated more precisely to irrigation requirements downstream with the further construction of a Compensation dam in a gorge near Awash Station. This would allow another 5,000 hectares to be irrigated.

The impact of the above projects for the development of the Awash River Basin can be summarized as follows :

TABLE A

IRRIGABLE AND FLOOD CONTROL AREAS AND POWER PRODUCTION AFTER STRUCTURAL DEVELOPMENT

Project	Additional Areas Irrigable (ha)	Total Areas Irrigable (ha)	Flood Protection	Power Production Capability (Mill. kwhr)
Current water resources - with Koka Dam		63,000		110 +
Tendaho Reservoir Dam	49,000	112,000	70,000	80
Kesem Reservoir Dam	18,000	130,000		35
Awash Station Compensation Dam	5,000	135,000		
Meki River Diversion	15,000	150,000		12 ++

\+ Production of Koka I power plant only

++ Increase in production of Koka power plant only.

Sequence of development will be discussed elsewhere, but it is necessary first to consider the economic aspects of these various irrigation, power production and flood control proposals, - investments required, estimates of costs and benefits, and their economic justification.

Benefit-Cost Analysis

The benefit-cost analysis of the irrigation phase of these projects is based upon (1) the physical feasibility analyses and estimate of hydrologists, geologists, soil and water chemists, dam engineers, irrigation engineers, soil surveyors and agronomists; (2) the cost estimates of engineers; (3) the production cost and yield estimates of agronomists; and (4) the estimates of future market needs and product prices by production and marketing economists. The benefit-cost analysis of the hydroelectric and flood control phases are also a part of the over-all study but will be treated later under separate headings. Only that part of the dams and necessary road relocation chargeable to irrigation will be included in this first phase of the benefit-cost analysis. (See Appendix III, Table 25).

Since more than 10,000 hectares of the proposed project area are already under irrigation, it is felt that this experience and acquired information on land preparation, crop production, crop yields and costs of production has provided a more accurate basis for estimates than usually occurs.

Based on the preliminary feasibility studies of the UNSF/FAO Survey team it has been determined that the quantity and quality of water that can be made available downstream from the Wonji Sugar Estates is sufficient to irrigate 150,000 hectares of land in the Awash Valley, provided certain suggested reservoir storage facilities are constructed. It is estimated that 80,000 hectares of land suitable for irrigation lie in the Middle Awash (Wonji to Gewani Swamps) and 70,000 hectares in the Lower Awash (downstream of Tendaho).

The agronomist has selected crops (see Appendix III, Tables 7 to 18 inclusive) whose soil, water and temperature requirements conform to the Valley's climatic conditions and the land and water resources available. Selection was influenced by gross and net values, crops being chosen to provide the highest net return to the farmer and to add most to the national economy by reducing food and fibre imports and/or increasing exports to earn additional foreign exchange. (See Appendix III, Table 19 to 24).

Priority has been given to cotton production in order to stimulate industry based on local agricultural products. Emphasis has also been placed on oilseeds and pulses as oversea markets have already been established for those commodities and soils, climate and growing periods are favourable. Some cereals will be required for an increased local population as well as other staple foodstuffs. Pasture and forage crops have been included, not only for soil improvement but as a means of integrating livestock production with irrigated agriculture. Returns in this connection have been calculated on the basis of liveweight gains, but there are possibilities for additional production of milk, butter and cheese. High value crops such as sugar cane, kenaf, sisal, citrus, bananas and vegetables were decided upon for limited areas, in accordance with estimated demand and for some exports. These high value crops have a considerable influence on the estimated benefit cost ratios. (See Appendix III, Tables 19, 20, 23).

Crop plans were designed with a view to obtaining the most favourable gains in different farm systems. High cropping intensities and high value crops were allocated to the sophisticated concessionaire type of agricultural enterprise, while simpler rotations were applied to the small farms (settlement farms). (See Appendix III, Tables 22 and 23).

While the Imperial Government favours initial development primarily by large scale commercial farming, there is also a desire on its part to promote establishment of small co-operative farms and settlement schemes. On the deltaic plains of the Lower Awash, a number of small farms under irrigation have been operating for centuries and an extension of this type of farming on an organized basis seems to be desirable in suitable areas throughout the Valley.

Estimates of yields (see Appendix III, Table 19) for the various crops were obtained from all available sources and statistics were analysed and extrapolated to provide reasonably accurate figures of crop production on large mechanized farms and on small farms. Similarly, production costs were obtained from existing operators and in cases where no costs were obtainable, e.g. bananas, citrus and vegetables, 60 per cent of the gross value was taken as cost of production. Government departments, banks, farmers, commercial enterprises and agricultural officers were consulted to obtain accurate commodity prices. From these estimated gross values and production costs, net gains were calculated for each crop. (See Appendix III, Table 19). Crop plans using certain rotations were then evolved, at the same time showing total production and net gains per hectare. (See Appendix III, Table 20).

By applying combinations of these crop plans to specific areas it has been possible to estimate total production for each area and when full development is achieved, for a net area of 135,000 hectares. (See Appendix III, Table 23).

In making the economic appraisal of the irrigation phase of the project, the value of land has not been included as a project cost, since most of it is desert grazing land at present. Instead, the value of production from the presently cultivated land has been deducted from the total production benefits derived from the project. The remaining costs and benefits have been summarized in economic terms, according to recognized procedures. 1/

In accordance with this procedure, the initial investment estimates for all required dams and diversion dams as well as the necessary headworks, canals, drainage ditches, land clearing and land levelling for 117,950 hectares of land have been made by the UNSF/FAO Survey team, and used as a basis for the over-all project estimates of 150,000 hectares. (See Appendix III, Tables 25, 27).

Comparison of these Survey team cost estimates for irrigation works and land preparation with the cost of work done by a half dozen concessionaires or large farmers in the project area indicates that they are reasonable. To the cost estimates of the survey team, the cost of E.$. 1.2 million for road relocation for 12 kilometers of highway affected by the Tendaho Dam has been added to the cost of that dam. 2/ Similarly, the cost of external highways to the project areas and additional internal roads totalling E.$. 5.5 million have been included. (See Appendix III, Table 26).

Since the Survey team did not make a soil survey and cost estimate for all of the proposed project area, extrapolation for the additional 3,700 hectares in

1/ "Benefit Cost Evaluations as applied to AID-financed Water and Related Land Use Projects, Supplement No. 1 to Feasibility Studies, Economic and Technical Soundness, Analysis, Capital Projects" prepared by the Agency for International Development, Department of State, Office of Engineering, U.S.A.

2/ Estimated by a representative of De Leuw Cather of Canada and confirmed by the Imperial Highway Authority.

the Lower Awash and 28,350 hectares in the Middle Awash were made. (See Appendix III, Tables 25 and 27). Estimates of the average investment per gross hectare by the Survey team for nearby and/or similar land areas were used in making these extrapolations, i.e. E.$. 1,205 per gross hectare in the Lower Awash and E.$. 1,732 (per hectare) in the Middle Awash. (See Appendix V for a more detailed explanation). Both the surveyed areas and the extrapolated areas were traversed and available information analyzed by one or more of the review panel - most of the areas by all three members.

Based on the Survey team estimates of E.$. 84.1 million for a diversion canal, a compensation dam and two major dams with accompanying dikes, etc., the extrapolated figure of E.$. 223.0 million for headworks and structures, canals, ditches, diversion dams, land clearing and levelling and farm canals and drainage ditches, and including the E.$. 5.5 million for additional roads, the total estimated investment for these irrigation related works is E.$. 312.5 million. This investment, which amounts to E.$. 2,084 per gross hectare (E.$. 2,315 per net or crop hectare) for the 150,000 hectares for which water supplies are estimated to be available, is a responsibility of both the public or government and the landowners or farmers. The initial investments, totalling E.$. 250.6 million for the major items, such as dams, canals, ditches, land clearing, diversion dams, roads, bridges and culverts are primarily a public responsibility. The investments of E.$. 62.0 million in land levelling, farm canals and farm drainage ditches in the distribution system are usually a responsibility of the landowners or farmers and are included in the "associated costs", along with the cost of houses for farmers and labourers, warehouses, office buildings for supervising and administrative personnel, totalling E.$. 55.3 million, as well as machinery and farm power investment of E.$. 62.4 million. This brings the estimates of "associated costs" investment to E.$. 179.7 million, and the "Grand Total Investment" to E.$. 430.3 million.

On the basis of these investments, annual costs of maintenance and operation of dams, canals, headworks and replacement of pumps have been computed at 2 per cent annually for a cost of E.$. 5.0 million. Amortization of investment costs over a 50-year period have been computed at both 6 per cent (0.06344) and 4 per cent (0.04655) for comparative purposes. The rate of 6 per cent, which was used at the suggestion of the Ethiopian Development Bank representative as a fair rate for this kind of project in Ethiopia, shows an annual charge of E.$. 15.9 million. The rate of 4 per cent was used as a possible rate for some international bank financing and gives an annual charge of E.$. 11.7 million. This latter rate might be especially applicable to the investment funds required for the two major dams. In this project an additional annual charge of E.$. 1.0 million or E.$. 16.50 per gross hectare of land operated by small farmers has been included for extension workers (or farm credit supervisors) to assist in the supervision of the development of small farms. Normally extension service costs are a part of the regular governmental functions and are included in the budget of the Minister of Agriculture. However, the more intensive supervision envisioned for this project requires additional personnel and separate financing.

The Associated Annual Costs of E.$. 14.0 million, to be paid by landowners includes a 2 per cent charge for maintenance and operation, distribution and drainage ditches, plus computed amortization charges for 50 years at 6 per cent (0.06344) and 4 per cent (0.04655) for the associated costs of land levelling, and distribution and drainage ditch investments. Amortization charges for 20 years on E.$. 55.3 million invested in farm and labourer houses, warehouses and office buildings for both small farm settlements and large farm developments at 6 per cent, (0.08718) and an interest charge only of 6 per cent on E.$. 62.4 million for farm machinery and equipment has been computed. Since depreciation charges on farm machinery and equipment have been included in the cost of producing the crops, no amortization charge has been made for this item. Pumping charges have been included where applicable in the Middle and Lower Awash areas. In the Lower Awash, pumping charges of E.$. 0.03 per kwhr for an estimated 20 million kwhr were made. According to EELPA 1/ officials, this would be the applicable rate for large industrial users. (E.$. 0.05 less 40 per cent discount or E.$. 0.03 per kwhr). In the Middle Awash, the estimated 15,000 hectares of land requiring pumping were computed at E.$. 40 per hectare or about E.$. 0.11 per kwhr, which is consistent with diesel-electric power costs. Construction of the Kesem dam and hydroelectric power unit would reduce this pumping charge to about one-third the present figure.

With the Annual Investment Costs of E.$. 21.9 million and Associated Annual Costs of E.$. 14.0 million including annual amortization, maintenance and operation and special charges determined, estimates of the Primary Benefits which will come to landowners were made. This required an estimate of present production as well as the future production of the completed project. In this instance estimates of the production of 10,500 hectares of land already under irrigation, the gross crop value and farm production costs indicated a "net yield at present" of E.$. 1.7 million. Since "Present Associated Investments" of E.$. 7 million have been made already by the farmers, annual amortization at 6 per cent (0.06344) is an additional current charge of E.$. 0.4 million which would reduce the present net yield to E.$. 1.3 million.

Estimates of the production, gross crop value, farm input costs and net gain of a completed project in full production several years hence is a difficult task. But the procedure for this was discussed in detail earlier and reference made to data in Appendix III, Tables 19 to 24. However, these data require further analysis and refinement to make them more useful in the economic feasibility study. Orchards, fruits, sugar, sisal, bananas and other products which require considerable time to get into full production must be discounted for the time lag (1 to 7 years have been used in these estimates). Even general crops which will be produced by beginner farmers or former nomads require time to reach full production. In this instance it has been estimated that it will take 10 years for small farmers to reach full production; thus, a 5-year time lag has been used. For large farmers a 2-year has been used - except in the Lower Awash where only a 1-year lag has been calculated because one-third of the land area for large farms is already under cultivation. Within a 3-year period it is estimated that two-thirds of the large farm area will be in full production. Consequently, even this 1-year lag for large farms may not be required in the Lower Awash. Nevertheless this realistic allowance for time lag in the development of the project has reduced the estimated "Gain in Net Annual Production" from E.$. 69.9 million to E.$. 56.9 million or about 19 per cent.

From the computed "Total Adjusted Gains" of E.$. 56.9 million obtained from crop production but reduced on account of time lag, the "Total Annual Associated Costs (TAAC)" of E.$. 14.0 million are deducted, leaving the "Net Annual Primary Benefits" of E.$. 42.9 million. A comparison of these "Net Annual Primary Benefits" with the "Annual Costs" of E.$. 21.9 million shows a Benefit Cost Ratio of 1.95 to 1.00 at 6 per cent, which is indicative of the relative profitability of the project. The benefit-Cost Ratio at 4 per cent interest is 2.42 to 1.00.

In summary, the preliminary data and analysis indicate that the annual net gains for agricultural production are almost double the annual costs for the irrigation phase of the Total Awash Project. After completion, the project is

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1/ Ethiopian Electric Light and Power Authority expected to produce E.$. 181 million gross agricultural products annually, with an annual net gain over present production of about E.$. 60 million.

Secondary benefits were not computed but there will be important additions to the regional and national economy through increased income to thousands of workers and farmers, either presently under-employed or with meagre incomes. In this type of development programme, the concomitant servicing (private and governmental), transportation and processing industries must develop and will provide a further impetus to the economy of the area and the nation.

In order to show how the Primary Benefit-Cost Ratio was determined, the procedure and data for the Total Awash Project are presented in brief form in Table E below. The detailed data for the Total Awash Project and for separate segments or areas are presented in Appendix III, Tables 32 to 40. On each of the area tables, the Benefit-Cost Ratio which is most likely to obtain if the whole Awash Valley Project is carried out, with proper over-all government planning and supervision, has been underlined. This preliminary analysis, which shows each area as being economically feasible, is predicated upon the idea that the Government will accept its responsibility to develop policies to encourage proper land and water use for the whole Awash Valley.

TABLE B - BENEFIT - COST ANALYSIS, TOTAL AWASH PROJECT

In E.$. millions

1. TOTAL PROJECT AREA - 150,000 has; Net - 135,000 has

2.	ESTIMATED INITIAL INVESTMENTS:	E.$ million	E.$ million
	Dams, dikes, diversion canals	84.1	
	Head Works, Canals, Ditches Diversion Dams, Land Clearing	161.0	
	Roads, Bridges, Culverts	5.5	
	TOTAL ESTIMATED INITIAL INVESTMENT		250.6
	ASSOCIATED COSTS:		
	Land Levelling, farm Canals and Ditches	62.0	
	Farm houses, Warehouses Buildings	55.3	
	Farm Machinery, Power	62.4	
	TOTAL ASSOCIATED COSTS		179.7
	Present Associated Investments, 10,500 ha. E.$ 7.0 million		
	GRAND TOTAL INVESTMENT		430.3
3.	ANNUAL COSTS:	Rate 6	Rate 4
	M-O & R* of Dams, Canals, Structures: 2% of E.$ 250.6 millions	5.0	5.0
	Amortization of Investment Costs: E.$ 250.6 million, 50 years,		
	at 6%: x 0.06344	15.9	
	at 4%: x 0.04655		11,7
	Recurrent Expenses, Extension Service	1.0	1.0
	TOTAL ANNUAL COSTS	21.9	17.7

*M-O & R: Maintenance and Operation of dams, Canals, and Structures and Replacement of Pumps.

4.	ASSOCIATED ANNUAL COSTS		
	Landowners		
	M-O: Maintenance and Operation of Distribution System and Drainage Ditches: 2% of E.$ 17.9 million	.4	.4
	Pumping Charges	1.2	1.2
	Amortization of Associated Costs: E.$ 62.0 million, 50 years,		
	at 6%: x 0.6344	3.9	
	at 4%: x 0.04655		2.9
	E.$ 55.3 million, 20 years at 6%: x 0.08718	4.8	4.8
	E.$ 62.4 x 0.06 interest only	3.7	3.7
	TOTAL ASSOCIATED ANNUAL COSTS	14.0	13.0

TABLE B: p.2 BENEFIT - COST ANALYSIS, TOTAL AWASH PROJECT
In E.$ millions

5. PRIMARY BENEFITS TO LANDOWNERS:

Production at present	E.$ mill.	
Gross Agricultural yield	6.7	
Less farm input costs	5.0	
Less Amort. 50 yrs. Present Investment	.4	
Net yield at present		1.3
Estimated Production after completion		
Gross at full development	181.5	
Less farm input costs	110.3	
GAIN IN NET ANNUAL PRODUCTION		69.9
Reduced Gain on account of Lag: Short-cut method at 6% (For details see Appendix II, Table 32, pages 3 and 4).		
Total Adjusted Gain - With Lag		56.9
Less Total Associated Annual Costs (Item 4)		14.0
NET ANNUAL PRIMARY BENEFITS - WITH LAG		42.9

6. BENEFIT-COST RATIOS:

	Rate 6%	Rate 4%
Annual Benefit - With Lag	42.9	42.9
Annual Costs (Item 3)	21.9	17.7
Ratio: With Lag	1.95 to 1.00	2.42 to 1.00

7. SECONDARY BENEFITS - None computed and none used above.

8. INVESTMENT PER HECTARE: in E.$. only

	Gross Area	Net Area
Irrigation works, dams and roads	E.$ 2,084	E.$ 2,315

In order to determine priorities for land development in the Awash River Valley, benefit-cost analyses of a few selected areas were made. (See Appendix III, Tables 32 to 40). A brief comparison of the benefit-cost ratios for these areas is given below in Table C.

TABLE C - COMPARISON OF BENEFIT-COST RATIOS BY AREAS IN AWASH RIVER PROJECT

	Hectares	Rate 6 with Lag	Rate 4 with Lag
Total Awash Project Area	150,000	1.95 to 1.00	2.42 to 1.00
Lower Awash Area	70,000	1.28 to 1.00	1.56 to 1.00
Middle Awash, Total	80,000	2.38 to 1,00	2.97 to 1.00
Middle Awash, no Dams	42,000	5.50 to 1.00	6.93 to 1.00
Kesem-Kebena Area	17,550	1.24 to 1.00	1.58 to 1.00
Melka-Sedi Area	8,550	2.73 to 1.00	3.39 to 1.00
Angelele Area	4,750	1.41 to 1.00	1.75 to 1.00

While there are wide differences in the benefit-cost ratios between the various areas, each one shows a favourable ratio. However, if the Kesem-Kebena area were to be devoted to general crops only, the benefit-cost ratio would drop to 0.68 to 1.00. In contrast, the Melka-Sedi and Angelele areas, when devoted only to general crops, show favourable benefit-cost ratios of 2.73 to 1.00 and 1.41 to 1.00 respectively. Of course the inclusion of some high value crops in each area increases their benefit-cost ratio markedly. (See Appendix III, Table 39). But negotiations are already under way for cotton production by a concessionaire and concomitant farm settlement programme which will utilize almost all of the Melka-Sedi area. Consequently, computations for high value crops in that area are academic and for comparative purposes only.

In the case of Kesem-Kebena, however, 200 hectares of orchard and bananas are already in production on the Aworka Melka plantation along the Kesem River. A larger hectarage (1,000 hectares) of these crops are included in the cropping plans, since additional water supplies can be assured. The inclusion of 500 hectares of citrus and 500 hectares of bananas is a proportionate share (one fifth) of these crops allocated to the Middle Awash area. Their inclusion provides a favourable benefit-cost ratio of 1.24 to 1.00 at 6 per cent interest, in spite of the large investment per hectare resulting from the necessary dam construction, and a small water storage capacity. From a national viewpoint the inclusion of a proportionate share of the high value crops in the Kesem-Kebena area provides the needed justification for a project which will provide 22 per cent of the land area in Middle Awash Project and about 12 per cent for the Total Awash Project. It will also provide additional hydro-electric power to the nearby area, thus making a multiple use of the limited water resources which will otherwise be wasted. The available power will also assist in the development of secondary freezing, storage and processing industries which will utilize the agricultural products.

Where soils are quite similar and climate and water are equally suitable for a wide variety of crops, it becomes a problem of how to assign the cropping plans to each area. In some instances transportation facilities or market outlets assist in the decision. But it should be recognized that the benefit-cost ratio will vary as the acreages of the more labour intensive, high value crops such as sugar cane, bananas, citrus, etc. are shifted from one area to another. For this reason the data for these Special or High Value Crops (HVC) which are included in Crop Plans 9, 10, 11 and 12 have been listed as a group at the top of Table 23, Appendix III. Thus, they are available for assignment to any area where soil, water, climate, market outlet, transportation and concessionaire or producer interest indicate that they might be grown economically. They are now included in the Total Project and both Middle Awash estimates. Desired hectarages of any of these special crops can be substituted for a similar hectarage of general crops in any area of the project, with a resulting improvement in the benefit-cost ratio for that area. Such was done for very logical reasons in the Kesem-Kebena area as shown in Table 36, Appendix III and as explained above. It has been done also for the Melka-Sedi area for comparative purposes only, unless the Government and the concessionaire for this land change their present agreement and plans.

In the case of sugar production, however, negotiations are already under way for the full quota to be assigned to the Metehara Plantation above Awash Station, because of railroad facilities and preliminary plans already made. Consequently, the production of sugar would not be available for any other area until the national demand for sugar more than doubled. Similar problems would arise as the hectarages of any special crop gave a production considerably in excess of local, national and/or export demand.

In order to show the effect of these high value crops in certain areas when compared with general crops, benefit-cost ratios have been computed for specified areas in the Middle Awash and presented in Table 39, Appendix III. From this table it is noted that a proportionate share of these high value crops such as sugar cane, citrus fruits and bananas were not included in the suggested cropping plans for the Lower Awash, especially when compared with the more suitable soils of the Middle Awash for these crops. If, however, limited areas in the Lower Awash are found for such high value crops, including vegetables, etc., a shift in hectarage may be made, with a resulting increase in the benefit-cost ratio for the area and a lowered transportation charge for any exportable commodity.

In order to provide more productive agricultural land for the nation and nearby hydro-electric power for the Middle Awash area through the utilization of a larger share of the area's limited water and irrigable land resources, the Government might consider giving preference to farmers who would develop the additional 800-1,000 hectares or more of land in bananas, citrus fruit and vegetables in the Kesem-Kebena area.

The Government must also decide whether to let the irrigation development of the Valley occur primarily in the areas of high benefit-cost ratios, such as the "Middle Awash - no Dams" area of 42,000 hectares and thus limit the Middle Valley development and total national production, or take the longer run viewpoint of developing as much as the total water resources of the Awash River would permit, est estimated at 80,000 hectares for the Middle Awash, with engineering structures. the latter policy is adopted, then shifts in cropping plans to utilize fully and economically all the land and water resources would appear to be justified.

Similarly, the Government must develop policies relative to water rates or water charges for use in agricultural production. To what extent should water charges be used to finance investment amortization and/or administration and supervision of the irrigation project? Should water charges be used as a means of obtaining funds from the land with crops giving higher net returns to assist in financing and making more viable the present or prospective lower return areas? Should water charges be made on a hectarage basis, as now planned, or upon the quantity of water used? More water is required per hectare of bananas or sugar cane than for beans, groundnuts or cotton. Should there be a minimum water charge to encourage the production of higher value crops and fuller production of all crops? Or should there be a ceiling water rate to encourage production of high value heavy water-using crops? Due to the concentration of rainfall in March-April and June to September, water rates might be reduced during this period to make fuller utilization of seasonal surplus water.

These and many other avenues for obtaining funds to assist in financing the project must be carefully studied and reviewed by appropriate experts. An early consideration of these and other problems require the attention of the Government, and especially of the General Manager and Board of Directors of the Awash Valley Authority. Their recommendations should then lead to approval and necessary legislation.

Project Financing

After determining that a project is economically feasible, a host of new problems arise relative to financing. What phases of the project should be financed by government or government-backed loans? What investments should be financed by the farmers and through what source of funds? What length of loan and what interest rates might be expected for each type of loan? There are wide differences in these matters according to lending agencies, length of loan, source of funds and the purpose for which the funds are used. The matter of past credit performance is also an important factor.

Since it is now a common practice for governments to consult with a finance expert who knows the various sources of funds for different types of loans, the panel gave little consideration to this matter. In order to point up the effect of shorter term loans than are provided for in the computation of the benefit-cost ratios, the Lower Awash Project was computed on a 25-year, 6 per cent loan amortization basis. (See Appendix III, Table 40). According to these calculations involving E.$ 91,753,500 for dams, dikes, major canals, ditches and pumps on a 25-year, 6 per cent (0.07823) amortization plan, but leaving all other costs at the same rates as previously, the benefit-cost ratio is 1.10 to 1.00.

DEVELOPMENT OF HYDROELECTRIC POWER AND FLOOD CONTROL

Water power is the most important source of electric energy in Ethiopia, with hydroelectric plants furnishing 60 percent of the 176 million kwhr produced in 1963. But preliminary studies have indicated that 45 billion kwhr can be supplied annually from the 16 major watersheds of the nation. In Ethiopia the production of electricity in primarily a function of the Public Utilities, being supplemented (12 percent of total production) by small industry-owned thermal plants which supply the needs of their own industry. Utilization of the water power of the Awash River began in 1960, upon the completion of Koka Power Dam (Koka I) with an installed capacity of 54,000 kw (KVA), the largest power plant in Ethiopia to date. In 1963 this plant produced 81 million kwhr which was 40 percent of the nation's total (including Eritrea). It is the primary source of electricity in the capital and contiguous area, supplemented by a local thermal station. But 40 percent of the homes in Addis Abeba are still without electricity, and power service to present consumers is inadequate.

Because of the high cost of thermal power in Ethiopia (E.$ 0.09 to E.$ 0.15 per kwhr), hydroelectric power can make an important contribution to industrial development and improved living levels. In this connection Ethiopian Electric Light and Power Authority (EELPA) has firm plans for developing certain water power resources, doubling the current electric power generation to 355 million kwhr by 1967. This means an annual increase of about 22 percent, which approximates the growth rate of the past decade.

To meet the demand in the capital area further use will be made of the Awash River by construction of Koka II (already in progress), Koka III and possibly Koka IV at selected sites downstream from Koka I. Water power development of the Blue Nile River is also under way with the construction of the Tis Abbai System, which will have an initial output of 15 million kwhr and a completion output of 57 million kwhr. Preliminary plans for Fincha Dam on a tributary of the Blue Nile with a capacity of about 80 million kw are also under consideration.

Approximately 21 million kwhr or one-third of the 66 million kwhr of the nation's thermal power is generated in industrial plants, usually due to a lack of any other source. Owing to long distance shipping and high overland transportation costs for fuel, primarily fuel oil, thermal power plants are high cost producers, 3 to 10 times the cost of hydropower.

Because of the rapidly growing consumer demand along with plans for industrial development in the areas to the east and north of the capital, the EELPA expressed an interest in any possible source of electric power which was economic. The construction of dams which could supply hydroelectric energy from the lower reaches of the Awash River or its tributaries should receive favourable consideration. Electricity generated at the Tendaho Dam site could be used locally, and the surplus made available either to Assab on the sea coast or to Kembolcha-Dese-Bati area, where industrial development is expected to take place. The power generated at the Kesem Dam would eventually be used in the expected development of the Middle Awash area. In the meantime, a connection with the transmission line from Addis Abeba to Dire Dawa and Harrar would help to meet the increasing demands in those areas.

In the over-all plans for Ethiopia, hydroelectric power from one of its great natural resources is expected to play an important role in industrial development and improved living levels. It will greatly affect industry location and land settlement schemes.

ECONOMIC FEASIBILITY OF THE HYDROELECTRIC POWER PROJECTS

A preliminary estimate of the economic feasibility of a hydroelectric power project in Ethiopia was suggested by a representative of the EELPA organization. In brief it is obtained by the following formula:

> "If Power Investment Cost is less than E.$ 0.24 per kwhr produced annually, the project is competitive with other hydroelectric sources of power in the country".

On this basis the Tendaho Dam power project with a total investment cost of E.$ 17.2 million and a production of 80 million kwhr would show an investment per kwhr of E.$ 0.215, or below the above limit of E.$ 0.24 per kwhr.

On a similar basis the Kesem Dam power project shows a cost of E.$ 0.231 per kwhr based on E.$ 8.1 million investment and an annual production of 35 million kwhr. This is also below the limit of E.$ 0.24 per kwhr set forth above. If a sub-station costing E.$ 500,000 and transmission line for E.$ 800,000 are included, the investment increases to E.$ 0.269 per kwhr, but such items are usually considered a part of the cost of the distribution system.

A more detailed description and benefit cost analysis of each of the two power projects are presented below.

LOWER AWASH (TENDAHO) HYDROELECTRIC POWER PROJECT

The project includes a separate concrete power subsection of an earth and rock fill dam built primarily to store water for irrigation and flood control. The powerhouse will be located at the toe of this concrete section. A sub-station will provide 20 million kwhr of electricity annually for pumping irrigation water and a limited amount for local use. This will require an 80 kw transmission line of 60 kv capacity and necessary transformers for the Asayita area. A step-up sub-station and a 160 to 250 kw transmission line of 132 kv capacity on steeel towers will provide an additional 60 million kwhr to either of two markets - Assab on the seacoast or the Kembolcha-Dese (Dessie) area. Both are in need of power for development but 200-240 kilometers of high voltage transmission lines and sub-stations will need to be built.

The cost of the dam itself is estimated at E.$ 25.4 million, while mechanical and electric power equipment totals E.$ 13.6 million. The relocation of 12 km. of roads will add another E.$ 1.2 million for a total cost of E.$ 40.2 million. The share of the cost of dam and other items charged to irrigation, flood control and power is shown in Table D below.

TABLE D

COST ALLOCATION OF TENDAHO DAM

	Civil Engineering	Mechanical and/or Electrical Equip.	Road Relocation	Total
Irrigation	18.9	1.0	1.2	21.1
Exceptional flood control	1.9	-	-	1.9
Power	4.6	12.6	-	17.2
	25.4	13.6	1.2	40.2

Of the total cost of the dam, E.$ 4.6 million has been allocated to power, to which is added E.$ 12.6 million for mechanical and electrical equipment, making a total of E.$ 17.2 million allocated to power. The powerhouse will have a rated capacity of 19,000 kw. Irrigation release will be adequate to maintain a firm capacity of 13,000 kw. Estimated useable power delivered is 80 million kwhr per year.

The cost of a transmission line to Asayita plus necessary transformers at pumping stations is estimated by EELPA to cost E.$ 1.0 million but this is chargeable to the distribution system and would be more than covered by the E.$ 0.03 per kwhr rate paid for electric power for pumping in the Lower Awash area. Similarly, the cost of sub-stations and transmission lines to Assab or Kembolcha-Dese area would be charged to distribution costs in the selected area.

TABLE E

BENEFIT-COST ANALYSIS OF HYDROELECTRIC POWER - TENDAHO DAM

Estimated Initial Investment (including contingencies):	Life		
Dam allocated to power, powerhouse + intake conduit	50 yrs	E.$ 4,600,000	
Turbines and generators	35 yrs	9,600,000	
Other electro-mechanic equipment (transformers, switchgear, control panels, cranes, etc.).	25 yrs	3,000,000	
Total Initial Investment		E.$17,200,000	
Annual Costs:		Rate 6	Rate 4
Maintenance and operation (includes allocated amount for dam operation): 2 percent of initial investment		E.$ 344,000	E.$. 344,000
Replacement of turbines and generators after 35 years at 6 percent, E.$ 9,600,000 x 0.06344		79,200	79,200
Replacement of other electro-mechanical equipment after 25 years at 6 percent, E.$ 3,000,000 x 0.2330 x 0.06344		44,300	44,300
Amortization of investment costs: 50 yrs at 6%: E.$ 17,200,000 x 0.06344		1,091,200	
50 yrs at 4%: E.$ 17,200,000 x 0.04655			800,700
Total Annual Cost:		E.$ 1,558,700	E.$ 1,268,200
Total power delivery - 80,000,000 kwhr cost per kwhr at load centre		E.$ 0.0195	E.$ 0.0158
Cost by best alternative source: Diesel-electric system		0.0900 to	0.1500

At this cost of less than E.$ 0.02 per kwhr, it is economical for the power company to provide transmission and transformers and deliver power from this source to regular customers at the current price of E.$ 0.10 per kwhr and to large industrial users at E.$ 0.03 per kwhr (the current rate). Since there is no alternative source of power in the area except diesel electric equipment, which is estimated to cost E.$ 0.09 to E.$ 0.15 per kwhr, it can assist greatly in developing and meeting all types of demand for power in this and nearby areas.

KESEM DAM HYDROELECTRIC POWER PROJECT

This project includes a powerhouse at the toe of a dam built to store water for irrigation, a step-up sub-station and a 25 kw transmission line with steel towers terminating at a connecting high line from Addis Abeba to Awash Station. Of the total cost of the dam (E.$ 31.1 million), none has been allocated to power. The power costs include the electro-mechanical equipment totalling E.$ 6.0 million plus E.$ 2.1 million for powerhouse and intake conduit. The powerhouse will have a rated capacity of 9,000 kw. Power will be transmitted at 60 kv. Estimated useable power delivered is 35 million kwhr per year.

The share of the cost of the dam and other items charged to irrigation and power for the Kesem Dam project is shown in Table E below.

TABLE F

COST ALLOCATION OF KESEM DAM

	Civil Engineering	Mechanical and/or Electrical Equip.	Total
		Millions of E.$	
Irrigation	29.0	2.1	31.1
Power	2.1	6.0	8.1
	31.1	8.1	39.2

At this cost it would be economical for large industrial power users to purchase their power from this source, as it would be much cheaper than the alternative source, diesel-electric system. As other sources of hydroelectric power are developed in other areas, this power could be used in the nearby Awash Station and Dire Dawa areas.

As indicated in Table G below, the construction of a sub-station and high voltage transmission lines to connect with the Addis Abeba-Dire Dawa high line near Awash Station (25 km. distant) will cost an estimated E.$ 1.3 million. But this cost is considered a part of the distribution system and would not affect the benefit-cost ratio for the dam.

TABLE G

BENEFIT-COST ANALYSIS, HYDROELECTRIC POWER,

KESEM DAM

Estimated Initial Investment: (Including contingencies)	Life	
Power and intake conduit	50 yrs	E.$ 2,100,000
Turbines and generators	35 yrs	3,500,000
Other electro-mechanical equipment	25 yrs	2,500,000
Total initial investment:		E.$ 8,100,000

Annual Costs:	Rate 6	Rate 4
Maintenance and operation (includes allocated amount for dam operation): 2 percent of E.$ 8,100,000	E.$ 162,000	E.$ 162,000
Replacement of turbines, generators, 35 years at 6 percent: E.$ 3,500,000 x 0.1301 x 0.06344	28,900	28,900
Replacement of sub-station equipment, 25 years at 6 percent: E.$ 2,500,000 x 0.2330 x 0.06344	37,000	37,000
Amortization of investment costs: E.$ 8,100,000, 50 yrs at 6 percent: x 0.06344 at 4 percent: x 0.04655	513,864	377,055
Total Annual Cost:	E.$ 741,764	E.$ 604,955
Total power delivery - 35,000,000 kwhr		
Cost per kwhr at dam site:	E.$ 0.021	E.$ 0.017
Cost per kwhr with sub-station and transmission lines costing E.$ 1.3 million included:	E.$ 0.024	E.$ 0.021
Cost per kwhr with best alternative Source: Diesel-electric system	E.$ 0.090 to	E.$ 0.100

FLOOD CONTROL

The Awash River has a few major left bank tributaries arising in the mountains to the north. Of these the Mile (Mille) River is the largest. It is this river which will make the water storage for irrigation possible - but it is also the river which causes the major flood damage by the Awash River below Tendaho. In August-September 1964, flood waters from the Mile River caused extensive damage to irrigation works and crops in the Dubti, Dit-Bahri and Asayita areas. The cost of replacing and repairing irrigation canals and structures by one farm with 5,500 hectares of cultivated land was E.$ 145,000. In addition, 500 hectares of prepared cotton land could not be planted this year with an estimated reduction in net returns of E.$ 175,000. A reduction in net return on an additional 2,000 hectares of E.$ 150,000 is due to poor stands and late plantings. In addition to this estimated loss of E.$ 470,000, the indicated production of small farmers is reduced by 1,000 to 2,000 M.T. of seed cotton with a reduced gross value of up to E.$ 1 million and reduced net income of E.$ 100,000 to E.$ 200,000. Thus, the total estimated loss during this single year amounted to an estimated E.$ 500,000 to E.$ 700,000, or about one-third of the E.$ 1.9 million cost of the dam allocated to flood control.

Since this type of flood is estimated to be a one-in-ten year type, there is ample justification for an allocation of E.$ 1.9 million of the dam cost for flood control.

FARM SYSTEMS AND SETTLEMENT

In developing agriculture in the Awash River Basin, consideration will have to be given to the possible farm systems which can be used to achieve an increase in the economy. Will development be undertaken by Government directly, concessionaires, individual farmers or co-operative small holders? One difficulty arises from the fact that the Awash Basin contains few people and these are mostly nomadic, who do not yet display an interest in cultivation and a settled existence. Only in the Lower Awash around Asayita, is irrigated farming carried on by family units. In general, the Ethiopian farmer is a hill man and shuns the hot plains and valleys; such areas are left for the nomads and their livestock.

This lack of population would suggest that development should start with concessionaires on large scale farms assisted by Government to become established in the Valley. A labour force would be attracted, as in the case of Wonji Sugar Estates, which would gradually become acquainted with the practices of modern, mechanized irrigation farming and thus form the nucleus of future settlement schemes. In laying out concessional projects, consideration should be given to leaving parcels or blocks of land free so that at a later date, indigenous farmers can be given the opportunity to participate in development programmes. These blocks could be used now for grazing in a system of integrated livestock production with irrigated farming. Some of the crop plans have been designed to include production of forage and pasture with the object of fattening livestock raised on natural pastures and scrub land.

The Imperial Ethiopian Government seems to favour the principle of concessionaire farming and quoted below is an extract from the Second Five Year Plan (1962-1967):

"Commercial Farms

28. Although significant development of the peasant sector has been foreseen, it will not be possible to realize the production targets in peasant agriculture exclusively. Important production targets will have to be realized on the big modern commercial farms. This sector will have to produce large quantities of raw material for the domestic industry such as cotton and other fibres, vegetables, fat cattle for the meat packing and canning industry, etc. as well as to increase production and

improve the quality of products intended for export. The commercial farms will have to produce better quality seeds and breeding cattle for the development of peasant agriculture. They will have to ensure the rational use of investment funds for the cultivation of wasteland in developing new regions, such as the Awash Valley, Wabi Shebelli Valley, etc.

29. There may be several types of such farms according to ownership: co-operative farms, farms owned by Ethiopian citizens or companies, farms organized by foreign concerns on the basis of concessions granted, mixed companies, public farms and others. The development of various types of farms will be encouraged, organized or supported by the Government.

30. The Government will help and stimulate, by all convenient, economic and other measures, the establishment and development of big private commercial farms. The existing land tenure system should not be allowed to interfere with the organization of large modern farms. Those who are interested will be granted Government land on a long-term lease at a low rent with the provision that they are obliged to start production at the latest within three years after obtaining the land and to cultivate all the granted land at the latest within five years in the manner agreed upon. Land obtained in this manner must not be sub-leased. The person who organizes a commercial farm on his own land should be exempted from taxes for five years. Special privileges may be granted to those who plant at least 40 percent of the land with cotton each year or who produce other fibres, particularly if they have to make larger investments per hectare in order to reclaim the land for production. Measures have to be taken so that the banks grant supervised credits at favourable terms for the promotion of commercial farms.

31. Special attention will be devoted to the establishment of public and co-operative large-scale farms. The largest part of the production targets assigned to the large commercial farms, particularly in this beginning phase, should be carried out by the public and co-operative farms. The very existence of these farms will be of extreme importance both for the introduction of more advanced farming methods on the peasant holdings in the surrounding areas, and for inducing the entrepreneurs to invest their capital in the large scale farm projects.

32. The following basic principles should guide the organization and operation of the public and co-operative farms:

(1) The farms will have to be built up as business organizations which will fully respect the rules of rational and economically sound business management. The workers should be paid according to the performance of their work. The organization of work and the methods of remuneration should be such as to develop an interest in the employees to increase labour productivity, utilize more efficiently the technical means, protect the property of the farm, etc.

(2) A possible degree of up-to-date mechanization has to be introduced on the farms; especially operations which ensure qualitative and timely agro-techniques should be mechanized. Yet, owing to the shortage of available capital on one hand, and ample resources of labour on the other, the labour-intensive methods of production should be given priority whenever they prove economically justified.

(3) Special attention has to be devoted to the working out of procedures which will most facilitate the procurement of land for farm establishments. It appears that in the practice of the Government, taking up land on a long-term concession offers the best possibility for a speedy development of large-scale co-operative and public farms. These policies should be favoured, particularly as payments for the concessions are very small at present, and at the same time this legal status of the occupancy of land would be very suitable to the business character of the farms.

(4) In view of the need to provide for new settlements as well as for resettlements of the population on agricultural land, the programme has to be so worked out that it will meet the demand for labour which will increase in proportion to the establishment and expansion of large scale co-operative farms. The experience already gained has shown that there exists a high degree of mobility of labour that is always ready to move to places wherever the opportunities for a gainful employment are opened to them."

Throughout this appraisal report, reference has been made to concessionaire or large scale farms and small (settlement) farms. For rapid development of virgin lands, there is no doubt that the large commercial enterprises initially will produce the most income, but from a social point of view it seems highly desirable to have a proportion of the available land allotted to small farmers backed by a sound extension service to supervise the use of credits and technical assistance either from Government or from established concessionaires. The Tendaho Plantation Share Company assists small farmers (outgrowers) in the Lower Awash in the production of cotton by providing certain services such as land levelling, ditching, ploughing and spraying at cost rates. Ginning facilities are made available by the Company, which buys the cotton at contract prices. The Imperial Government encourages the principles of community development, and settlement in the Awash Valley of groups of small farmers would be an ideal region to put these principles into practice. The Awash Valley Authority is now working on a pilot scheme for the settlement of 50 farmers in Lower Awash, but similar projects should be considered in other areas. In this economic assessment, due allowance has been made for the inclusion of small farmers to take part in the development programme.

Because of existing settlement by irrigation farmers and the current influx of new farmers (some of them recently nomads) attracted by the developing local cotton economy, five sevenths (5/7) of the irrigable hectarage have been allocated to small farms in the Lower Awash computations. Owing to the sparse population in the Middle Awash, calculations have been based on only one fifth (1/5) settlement by small farmers.

While Ethiopia as a whole has land tenure problems, it is considered that because of the under population in the Awash Valley, settlement in the first place by large scale commercial farm enterprises, the usual landlord-tenant difficulties will not arise. The tribal nomads enjoy certain grazing rights by occupation, but provided they have access to water, their way of life can continue undisturbed. Assistance might be given them by providing watering points on the river, or from canal extensions, ponds or wells.

A new road is under study which would link Nazareth, Awash Station and Gewani with Tendaho on the right bank of the Awash River. This road would open up the Valley and provide a desirable marketing outlet for agricultural produce. It may also have considerable influence on the sparse indigenous population who might gradually enter the economy of the Valley and adopt the habits of modern society.

AWASH VALLEY AUTHORITY

The Awash Valley Authority was set up by Charter as an autonomous body under the Imperial Ethiopian Government. It has the task of developing and administering the land and water resources throughout the Valley, but there is a conflict of interest in regard to water as the Ethiopian Electric Light and Power Authority utilizes the Awash River for hydroelectric energy and draws the entire revenue from sales of electricity.

The Awash Valley Authority is dependent on a meagre Treasury budget and has insufficient finances to build up a competent technical staff with which to implement large scale development. Until the Authority provides services, e.g. provision of dams, headworks and canals, it is difficult to set up water charges from which to derive sufficient revenue for continuing development. Recently, nominal water rates have been negotiated with the concessionaires now operating and using irrigation water from the Awash River, but fixed initial periods have been agreed when no charges will be made, in order to allow the farm enterprises to become established. Thus the Authority still lacks necessary current funds; even future revenues will be inadequate to finance dams and irrigation layouts as envisaged in this feasibility study. Thus, it will be incumbent upon the Imperial Ethiopian Government to assist the Authority not only in its primary investments, possibly with financial aid from international sources, but also provide additional funds for administrative and technical personnel during the first decade of development.

In addition to lack of funds, the Awash Valley Authority is short of the required professional personnel to carry out its functions. Expertise is necessary to devise and levy adequate water rates, to establish a competent technical and operational service able to deal with the complex problems of water apportioning and its controlled distribution; to plan and supervise the construction of an efficient and co-ordinated irrigation system and its maintenance and operation after completion.

In order to carry out its responsibilities, the Authority must also provide market analyses, domestic and foreign, of commodities which will give farmers the highest net returns and add most to the national economy. To supplement this, the extension service programme should be expanded to assist the farmers, not only with their fertilizer and soil management problems, seed selection and cropping practices, but also with their credit and marketing problems.

Additional financial assistance to the Awash Valley Authority should be dependent on sufficient professional experts being made available, preferably with administrative authority, to help fulfil the functions which this autonomous body was set up to do.

PRIORITIES OF DEVELOPMENT

While it is the responsibility of the Imperial Ethiopian Government to decide upon the order and rate of development, the following and other points are important in determining the priorities of various projects. Each point is relevant to each phase of the over-all project - irrigation, hydroelectric power, and flood control Their co-ordination will provide the basis for a more logical final judgement.

1. What are the major problems, which each phase of the project and each area project will help to solve? Economic? Social?

2. Which problems are most urgent and how long will it take to solve them?

3. Are the problems primarily social or economic? Local? Regional? National?

4. What is the financial (including credit) situation of the Government? Farmers?

5. What are the relative returns on these proposed investments when compared with alternative investment possibilities? To the Government? To the farmer? In the short-run and the long-run?

6. Will the Total Awash Project add more to the long-run productive capacity of the nation than alternative projects? Which of the Area projects in the Awash Valley will add most to the productive capacity of the region and the nation?

7. Among various areas, which projects will produce the greatest gross value of crops and show the largest return? To the farmer? To the national economy?

8. Which project will produce the greatest social gains? Affect the largest number of people?

9. In which area can development be started most easily and give greatest results? At the least cost? Give the highest returns per dollar invested?

The answers to these and other questions will assist in arriving at decisions relative to priorities among the various areas of this total project and between this project and other alternative uses of government funds, credit and personnel. Although there are many ways to develop the Awash Valley, they may be generalized under the following three approaches:

1. Allow the agricultural development to continue on a piecemeal basis without any over-all plan for future land or water use.

2. Make a major "Crash Programme" to develop the whole project in a very short period of time, perhaps 5 to 10 years.

3. Develop a 10 to 25 years over-all plan but carry it out in stages to utilize the land and water which will give the quickest and highest net returns - without damage to the land and with due regard to any social problem of the area.

Until recently, the first "piecemeal" approach has characterized the method of development followed in the Awash Valley. The building of Koka Dam and the signing of agreements with Wonji Sugar Estates and the Tendaho Plantation Share Corporation put an end to this "no-planning" stage. However, the development of the remaining land in the valley has continued on a piecemeal basis without regard to water rights, water usage or future water needs. Recent agricultural developments have pointed up the desirability and the necessity of an over-all plan for the use of the limited water resources of the Awash Valley in order to obtain the largest long-run economic and social benefits for the region. It was for this reason that the Awash Valley Authority was set up and the Awash Basin Survey conducted.

The second approach, involving a "Crash Programme", to develop the whole region through a 5 to 10 year programme, lacks reality. The basic factors of urgency which would require this approach are lacking. First, there is no great food problem facing the nation. Second, there is no great population pressure upon the land. Third, there is no great social pressure by the people for land reform and land settlement schemes. However, the major problem is one of long time economic development projects which will place greater emphasis upon productive projects. Such projects would assist in meeting the balance of trade and debt servicing problems of the nation in the decades ahead.

While a crash programme might worsen the financial situation temporarily the real obstacle is the lack of sufficient, trained and experienced personnel to plan, supervise and execute such a programme.

The third approach to development would seem to be the most logical, from both an economic and social viewpoint, for the Awash Valley. In this approach, the various areas of the Valley must be analyzed and compared. If the most urgent major problem toward which this project is directed is economic, i.e. helping to solve the debt servicing problem, then the major criteria for priority in the selection of the individual area projects should be the economic yardstick, i.e. the benefit-cost ratios. These ratios may be modified by some shift in cropping plans, but the over-all long run plan of agricultural production and crop rotations must be kept in mind.

The Government may be cognizant of urgent political and social problems in specific areas which will modify the purely economic approach. A balance between the two approaches may be most effective. The economic approach may fit one segment of the Valley, the Middle Awash for instance, while more emphasis will need to be given to the social approach in another segment, such as the Lower Awash.

The data compiled in this report indicates that the Middle Awash area will make the greatest contribution to the national economy and thus should be given top priority. Of this segment, the area above Awash Station and the Melka-Sedi project show the highest benefit-cost ratios. In these areas the extra cost of making irrigation water available, through small diversion dams, is lowest. The costs of the irrigation system land clearing and land levelling are also the least. Here, the market outlets are best and the transportation costs lowest.

Data on the Amibara project were not computed but irrigation investment costs and project location would probably give it second priority on an economic basis. Bolhamo, Angelele and Kesem-Kebena would follow in that order. Additional data is needed before the Maro-Gallo area can be classified. Although the shifting of high value crops to any of these areas could change the benefit-cost ratio, the location, topography, soils and total market outlet for these crops become limiting factors.

In the Lower Awash, the large dam, dikes and pumps necessary for full development, and the unsuitability of the soils for many of the highest value crops, caused the benefit-cost ratio (although favourable) to be much lower than the Middle Awash. But here the social and political problems are much more important. With this in mind, the Government may consider them sufficiently important to proceed with this project concurrently with the first high priority projects in the Middle Awash. This is especially true since the dam and dike construction will delay starting the farming operations an additional year or two beyond that of the less costly projects upstream.

But the highest priority should be given to the development of a small but competent administrative and technical staff:

1. To develop a long-time land and water use plan for the Awash Valley.

2. To assist farmers and government agencies in carrying out the plan by providing guidance: in small farm irrigation systems, fitting crop plans to soils, water requirements of various crops, cropping practices and market outlook for major crops.

3. To develop a system of water use charges and other means of financing the administrative, technical and supervisory personnel required for the maintenance and operation of the irrigation distribution system.

4. Relating each new agricultural development to the long-time land and water use plan for the Valley.

In summary, this analysis of the preliminary Awash Basin Survey indicates that the Total Awash Project is economically sound and can make important contributions towards the solution of economic and social problems, regionally and nationally. The Middle Awash Project can make the largest economic contribution within the region to assist the national debt servicing problem and to develop industry based on agricultural production; government policy should give priority in this area to the individual projects and crops which can best serve the national economy. While the Lower Awash Project might contribute towards the nation economy to a lesser degree, there are local social and political problems which may be solved by its early development.

EXTRACT FROM APPENDIX III

TABLE 39

COMPARISON OF BENEFIT-COST RATIOS, SPECIFIED AREAS BY

CROPPING PROGRAMMES AT DIFFERENT INTEREST RATES

Areas and Hectares in Crops		General Crops or HVC under Negotiation		Specified Areas in High Value Crops	
		In Ratio to 1.0		In Ratio to 1.0	
		Rate 6	Rate 4	Rate 6	Rate 4
1. Lower Awash	63,000 ha.				
(1) LF* - 18,000 ha; SF* - 45,000 ha.		1.3	1.6		
(2) LF - 50,500 hal SF - 12,500 ha.		1.6	2.0		
2. Melka-Sedi	7,700 ha.	2.7	3.4	6.5(a)	8.2(a)
3. Angelele	4,300 ha.	1.4	1.8	3.5(b)	4.2(b)
4. Kesem-Kebena	15.800 ha.	0.7	0.9	1.2(c)	1.6(c)
5. Middle Awash (No Dams)	38,000 ha.	2.4(e)	3.2(e)	5.5(d)	7.0(d)
6. Total Middle Awash (With Dams)	72,000 ha.	1.4(e)	1.9(e)	2.4(d)	3.0(d)
7. Total Awash	135,000 ha.				
(1) LF - 65,800 ha; SF - 56,500 ha; HVC* - 12,700 ha.				2.0(d)	2.4(d)
(2) LF - 97,800 ha; SF - 25,000 ha; HVC - 12,700 ha.				2.1(d)	2.7(d)
(3) LF - 70,900 ha; SF - 56,500 ha; HVC - 7,600 ha.				1.3(e)	1.7(e)
(4) LF - 102,400 ha; SF - 25,000 ha; HVC - 7,600 ha.				1.5(e)	1.9(eO

Note I:

(a) HVC: Citrus - 500 ha; Bananas - 500 ha; Sisal - 1,000 ha.
LF: 4,700 ha; SF: 1,000 ha.
(b) HVC: Citrus - 300 ha; Bananas - 300 ha; Sisal - 500 ha. LF - 2,300 ha
SF - 900 ha.
(c) HVC: Citrus - 500 ha; Bananas - 500 ha. LF: 11,600 ha. SF: 3,200 ha.
(d) HVC: Citrus - 2,500 ha; Bananas - 2,500 ha; Sisal - 2,000 ha;
Sugar cane - 5,600 ha; Vegetables - 100 ha.
(e) HVC: Sugar cane - 5,600 ha; Sisal - 2,000 ha.

TABLE 39 (Cont'd)

Note II:

Area No. 1. Lower Awash (General Crops)
Area No. 2. Melka Sedi (General Crops): LF - 6,000 ha; SF - 1,700 ha.
Area No. 3. Angelele (General Crops): LF - 3,400 ha; SF - 900 ha.
Area No. 4. Kesem-Kebeba (General Crops): LF - 12,600 ha; SF - 3,200 ha.
Area No. 5. Middle Awash, No Dams (General Crops): LF - 20,600 ha; SF - 4,700 ha
Area No. 6. " " With Dams (General Crops): LF - 53,000 ha; SF - 11,400 ha.
Area No. 7(3) and 7(4) include only sugar cane and sisal on Metahara.

Ratios which are included in Table C are underlined.

* LF - Large Farms; SF - Small Farms; (General Crops): HVC - High Value Crops

BIBLIOGRAPHY

GENERAL

C. Conti Rossini	Etiopia~~x~~i genti d'Etiopia
Franchetti	Nella Dancalia
Nesbitt	Desert and forest
W. Thesiger	The Awash River and the Aussa Sultanate
Cecchi	Da Zeila
Borelli	Voyage dans les Gallas du Sud et le pays de Sydama
Mapping and Geography Institute	Awash River Basin geographical names

GEOLOGY

G. Dainelli	Geologia dell'Africa Orientale
G. Stefanini	Saggio di una carta geologica dell'Eritrea, della Somalia e dell'Etiopia, alla scala di 1:2,000,000
P.A. Mohr	Report on a geological excursion through southern Ethiopia
P.A. Mohr	The geology of Ethiopia
H.A. Quinn	The mineral industry of Ethiopia in 1962, with notes on some mineral deposits and special projects.

SOILS AND VEGETATION

U.S. Department of Agriculture	Soil classification - 7th approximation
Murphy	The fertility status of some soils in Ethiopia
SOGREAH	Soils in the Dubti, Dit Bahri and Melka Sedi areas - Three interim reports
Pichi, Sermolli	Una carta geobotanica dell'africa Orientale
J.M. Rattray	Tapis graminéens d'Afrique
C.C.T.A.	Phytogéographie

CLIMATE, HYDROLOGY

F. Fournier	Climat et érosion
M. Visentini	Notizie idrografiche sull'Africa Orientale
E.N. Meneely	USOM Ethiopia - Hydrology

AGRICULTURE

H.P. Huffnagel	Agriculture in Ethiopia
G.W. Uhlenbrock	Background information on cotton in Ethiopia, with respect to the Project 1955-1959 EC
D. and I. Lalevich	Agricultural development possibilities of the Awash River Valley
H.V.A. - Ethiopia	Some facts about the Wonji and Shoa sugar estates
W.R.D. - Israel	Metahara Project - Master plan for the development and management of the estate

HYDRAULIC AND AGRICULTURAL DEVELOPMENT

M. Bruni	Progetto italiano per l'impianto di Coca sul fiume Auasc in Ethiopia
K.B. Amundsen	Koka kraftanlegg
D. Jovanovic	Report for hydroelectric possibilities along the Awash Valley
Reparations Office	Koka dam
EELPA	Electricity in Ethiopia
EELPA	Awash hydroelectric Project
SOGREAH	Expert appraisal of river hydraulics phenomena as they affect the delta area.
SOGREAH	Sur les possibilités de développement hydraulique et agricole dans la vallée moyenne de l'aouache (Ethiopie)
L.G. Allbaugh, R.M. Arbuckle	Feasibility report on development of irrigated agriculture and hydroelectric power of the Awash River Basin (Ethiopia)

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