UNDP / FAO / ETH 72 / 006

Informal Technical Report No. 24

DEVELOPMENT OF THE AWASH VALLEY – PHASE III

ETHIOPIA

EARTH RESOURCES TECHNOLOGY SATELLITE I USES, AND ADDITIONAL GROUNDWATER STUDIES IN THE AWASH VALLEY.

Report prepared by

D.T.CURREY, Hydrogeologist Consultant.

On Behalf of:
The State Rivers and Water Supply Commission
Victoria, Australia.

for the Executing Agency:
FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

APRIL 1974

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PART I - INTRODUCTION

The Earth Resources Technology Satellite 1 (ERTS 1) information is now available. Certain features have been described and an example of interpretation demonstrated from a colour enhanced image of Maro Gala in the Awash Valley. The ERTS B programme submitted by AVA to NASA is set out and the Imagery is expected to be available in 1975.

Water well drilling has been completed in the second phase of the Alledeghi study and five production wells have been completed. The hydraulic gradient of the groundwater and the bores are described and illustrated.

Readings from piezometers installed in the Lower Plains have been recorded and a continuous chart drawn. The regional groundwater resource, approximately 30 m below natural surface is separated from groundwater mounds under the irrigation areas by impermeable sediments. These subsurface conditions are illustrated.

The groundwater potential of an area west of Mt. Fantale is discussed. It is understood that drilling will be commenced shortly by the Ministry of Mines.

The foundation materials at the Tendaho Damsite are volcanic and sedimentary beds of varying strengths. A general discussion on these materials is included.

ACKNOWLEDGEMENTS

Ato Samuel Mehari, Senior Hydrologist, AVA was enthusiastic in the interpretation of the ERTS Imagery and readily acquired the background necessary to order the imagery from the Sioux Falls Centre.

DISCLAIMER

This technical report is one of a series of reports prepared during the course of the UNDP/FAO project identified on the title page. The conclusions and recommendations given in the report are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project.

ABSTRACT

Amongst the objectives of the UNDP/FAO/ETH 72/006 is the rendering of assistance in the investigation and development of groundwater on the Alledeghi Plain and in the investigation and planning of new schemes for development.

A description is given of the uses of the EARTH Resources Technology Satellite I Imagery in the investigation and recording of the irrigation areas in the Awash Valley.

Bore results from completed bores on the Alledeghi Plain, the Lower Plain and at Tendaho Damsite are recorded.

The groundwater potential of an area west of MT. FANTALE is discussed.

References:

Geomorphic, Geological and Groundwater Studies in the Awash Valley, by D.T. CURREY, May 1972, UNDP/SF/ETH 25 I.T.R. No. 4.

Additional Geomorphic, Geological and Groundwater Studies in the Awash Valley, May 1973, UNDP/FAO/ETH 72/006 I.T.R. No. 14.

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PART II - THE EARTH RESOURCES TECHNOLOGY SATELLITE 1

Introduction

In July 1972 the North American Space Agency launched a satellite, the Earth Resources Technology Satellite 1 with a nearly-circular, nearly polar orbit. The satellite will pass over the earth with the same ground illumination conditions at a given latitude at a given time of the year.

The satellite is unmanned and at an altitude of 900 km. A scanner on board images a 100 nautical mile strip of the earth in four parts of the spectrum. The scanner information is stored on a tape recorder and this information is later relayed to earth. Due to the wear on the tape heads the imagery coverage of Ethiopia ceased in March 1974.

The images are received in the form of 70 mm black and white transparencies, scale 1:3,369,000, which can be enlarged to the regular 9" x 9" black and white prints, scale 1:1,000,000. Analysis of the imagery products is completed by using the multispectral photography techniques, conventional photo-interpretation and image enhancement by using false colours.

Imagery of Ethiopia can be utilized by AVA to study the development taking place in the Awash Valley and to predict the crop yields of the various irrigation projects by using repetitive images which record the same area every 18 days. The most suitable soils for irrigation along the river can be recognized and mapped from the images.

1. Multispectral Images

The visible spectrum ranges from 380 to 700 nanometers (1000μ). The infra red range extends from 700 nm. At 1000 nm the infra red radiation received from the earth is 100% reflected and at 10 000 nm, it is 100% emitted radiation.

The aim of multispectral imagery is to separate the various wave lengths reflected by different features on the earth's surface. The sensors on the ERTS 1 register 4 wavelengths:

Spectral Band No.	4	wavelength nm 500 to 600	Blue-Green
	5	600 to 700	Red
	6	700 to 800	Infra Red
	7	800 to 1100	Infra Red

Each of the four wavelengths can be printed separately or in any combination. A colour print can be produced by adding all the images together with the correct filters.

False colour techniques can also be employed to enhance various natural features. This can be achieved by discarding one of the bands and changing the filters. It is not unusual to represent green vegetation as a red colour so that greater contrast is achieved with the adjoining non-vegetated areas.

2. Imagery of Ethiopia

A request was made to the EROS Data Centre, Sioux Falls, South Dakota, USA in June 1973 for printout data of the ERTS 1 Imagery covering portion of Ethiopia. The information requested was the area between N7° and N13° and E37° and E42°, with less than 30% cloud cover (see Fig. 1).

The printout information was received attached with a sheet titled "Code for Computer Printout for Remote Sensing Data" from the EROS Data Centre at Sioux Falls, S.D. The code gives meaning to the accession information such as code number, date of imagery, cloud cover, and latitude and longitude of each imagery frame (chip). The cost of each frame is US$2.50 or for each set of frames US$10. -

Similar requests should be made out to:

Miss Fredricka A. Simon
Chief, User Services
United States Department of the Interior
Geological Survey
EROS Data Center
Sioux Falls, South Dakota 57198.

3. Imagery of Awash Valley

Five separate frames cover the length of the Awash River. The separate frames, 100 nautical miles x 100 nautical miles, contain details of:

(a) Addis Ababa to L. Galila
(b) L. Galila to Amibara
(c) Amibara to Maro Gala
(d) Maro Gala to Dubti; and
(e) Dubti to Lake Abe

Each frame overlaps all adjoining frames by 10%. During each track every 18 days the centre of the field of the scanner may shift due to the orbit angle so that with successive passes there are a number of centres which cause a loss and an addition of different localities at the edges of the frame.

A table showing the coverage of each of the five areas including index number, date taken, cloud cover and the centre of the image will indicate the repetitive cover. In irrigation areas the growing season can be viewed as in time lapse photography due to the successive records of the same area.

An introductory interpretation of selected frames from each of the five areas will be given to indicate some of the uses which may be made of the ERTS 1 images (see Fig. 2). The vegetation will be described as well as the geology, and land forms such as the most apparent soil types and erosion features.

(a) Addis Ababa to Lake Galila (See Table 1)

This frame was repeated a number of times during the ERTS 1 programme. The table shows that there are seven frames with less than 30% cloud cover as well as the dates on which the imagery was recorded.

TABLE 1

ADDIS ABABA TO LAKE GALILA IMAGERY

Index Number	Date Recorded	Cloud Cover %	CENTRE					
			Latitude (N)			Longitude		
10480714	9.09.72	20	8°	38'	10"	38°	21'	03"
113807152	8.12.72	30	8°	29'	36"	38°	16'	26"
115607150	26.12.72	10	8°	49'	27"	38°	22'	04"
117407145	13.01.73	10	8°	38'	05"	38°	23'	19"
119207151	31.01.73	0	8°	46'	04"	38°	19'	57"
122807153	8.03.73	10	8°	50'	02"	38°	12'	46"
124607154	26.03.73	20	8°	49'	40"	38°	09'	41"

The frame, Index Number 119207151, taken on 31.1.73 was selected as an example due to the absence of cloud. A false colour composite print, scale 1:1,000,000 was produced by using spectral bands 4, 5 and 7. Band 6 was discarded so that greater contrast would result between the various features on the land surface. False colour was used for the same reason, the green vegetation which is depicted as red may confuse the inexperienced at first.

Two distinct shades of red can be identified. The deeper red depicts the eucalypt plantations due to the reflections of the infra red wavelength and the lighter red indicates the corn crops, because of the difference in the infra red reflection factor to the eucalypt. Addis Ababa city shows as a dull blue surrounded by the bright red of the eucalypt plantations.

The geology of the area is highlighted by the large volcano containing crater lakes. Fault lines, and new volcanic vents, also with crater lakes, are clearly defined. The black soil zones, which are the products from the breakdown of the newer basalt materials, contrast with the older soils depicted as yellow. Erosion gullies are evident on the large volcanic cones, and along the edges of the central plateau. The lakes vary from black to blue in Lake Galila, the blue represents suspended sediment in the water.

Seasonal changes in the vegetation pattern would be demonstrated by comparing the seven frames listed in the table.

(b) <u>Lake Galila to Amibara</u> (See Table 2)

There is 10% overlap on the edges of the frames covering Lake Galila to Amibara with the Addis Ababa to Lake Galila frame. Similarly there is also a 10% overlap with the Amibara to Maro Gala.

The table shows that there are five frames of the Lake Galila to Amibara area with less than 30% cloud cover.

TABLE 2

LAKE GALILA TO AMIBARA IMAGERY

Index Number	Date Recorded	Cloud Cover %	CENTRE					
			Latitude (N)			Longitude		
111907093	19.11.72	30	8^{o}	34'	53"	39^{o}	41'	46"
113707093	7.12.73	10	8^{o}	29'	09"	39^{o}	41'	14"
115507092	25.12.73	10	8^{o}	43'	50"	39^{o}	48'	10"
11737091	12.01.73	10	8^{o}	35'	21"	39^{o}	49'	48"
119107092	30.01.73	0	8^{o}	45'	56"	39^{o}	47'	03"

The frame, Index No. 119107092, taken on 30.1.73 was the selected example due to the absence of cloud cover. Three of the bands, 4, 5, and 7 were used to produce a colour enhanced composite print scale 1:1,000,000. In all cases false colour has been used.

The end of January coincides with both the latter part of the cotton picking season and also the maturity growth stage of the sugar-cane. Cotton planting starts in June, it is then irrigated from July to January and picking starts in December and continues to March.

The mature cotton plantation in the Amibara irrigation farm can be recognized. A patch work on the Wonji and Metahara sugar plantations represents ploughed paddocks and mature sugar-cane stands.

Lake Galila and the Newer volcanic cones on the west edge of the frame is a repetition of the Addis Ababa-Lake Galila frame. The fault scarps are represented with the outwash plains in front. Deep valley erosion occurs at the headwaters of the Kesem and Kebena Rivers and in the south-east an alluvial fan spreads out from the two rivers towards the Awash River. The alluvial soils adjacent to the Awash River show as the darker olive shades due to infra red absorption by the moisture content of the soil. These lands contain the most suitable soils for irrigation.

The repetitive series would show by changes in colour intensities the various growth stages of the cotton and sugar-cane. The colour intensities could be compared with yields so that future comparisons with the Skylab or ERTS 2 imagery can be made. It should then be possible to estimate yields from the imagery during the early growing stages of the various crops.

(c) Amibara to Maro Gala (See Table 3)

The frame covering the area from Amibara to the north of Maro Gala was repeated during a number of ERTS 1 tracks. The table shows that there are four frames with less than 30% cloud cover.

TABLE 3

AMIBARA TO MARO GALA IMAGERY

Index Number	Date Recorded	Cloud Cover %	CENTRE					
			Latitude (N)			Longitude		
111907091	19.11.72	20	10°	1'	32"	40°	1'	58"
11550790	25.12.72	10	10°	10'	15"	40°	8'	57"
117307084	12.01.73	10	10°	2'	0"	40°	10'	21"
11910790	30.01.73	0	12°	11'	40"	40°	7'	54"

The frame, Index Number 11910790, taken on 30th January, 1973, was selected as it is cloud free. A false colour enhanced print, scale 1:1,000,000, was produced from bands 4, 5 and 7, and also an area showing Maro Gala to a scale of 1:250,000. This colour enhanced enlargement has been used to demonstrate the use of the imagery and the accuracy of interpretation.

Interpretation

The various wavelengths are used to record various features. As an example, water absorbs the infra red wavelengths where vegetation reflects the infra red. When this is recorded on a tape or film and a print made with colour enhancement with a bias towards a red colour, the water will show black and the vegetation varying shades of red (see Plate 1).

A plan has been drawn depicting the zone boundaries of the various colours showing on the plate and the zones have been interpreted as depicting the vegetation and geology of the Maro Gala area (see Figure 2).

The large blue area in the centre of the colour print is Lake Gedebasa. The lake has a blue tinge which indicates a sediment content but there is one area which is black indicating water which is sediment free. There are a number of smaller lakes scattered around the area.

The red colour indicates vegetation, the dull more dense reds depict forest trees and the lighter, open grasslands. The reds fade towards yellow depicting that the grasses are drying out in the yellow areas. Very bright reds coincide with the hot springs of the area on the south-eastern edge of the flood plain. The flood plain and the lake clay areas if not containing vegetation, brown in colour. Adjoining these soils are near-white zones which are the gravel plains covered by soils with high salt contents.

A stream system discharging on to the Awash River flood plain to the north of Lake Gedebasa has formed a fan shown as brown. This area may be worth consideration for development when the feasibility study for the Maro Gala area is carried out. Adjacent to the fan there is a zone which could be interpreted as shallow alluvium covering the gravel deposits. There are a number of other areas which have been interpreted as shallow soils covering either gravel or rock and these have been depicted on the plan with large dots. The acid lavas have a green brown shade with faulting evident as lines across the eastern portion of the area.

The most prominent feature is a volcano named Azelo to the east of the lake, east of the volcano there is a lava field made up of basalt flows depicted as black on the image.

(d) Maro Gala to Dubti (See Table 4)

The frame covering the area between Maro Gala to Dubti was repeated during the ERTS 1 programme and the table shows that there are six frames with less than 30% cloud cover.

TABLE 4

MARO GALA TO DUBTI IMAGERY

Index Number	Date Recorded	Cloud Cover %	CENTRE					
			Latitude (N)			Longitude		
110107083	1.11.72	0	11°	26'	55"	40°	24'	11"
111907084	19.11.72	20	11°	27'	40"	40°	22'	11"
113707084	7.12.72	20	11°	23'	4"	40°	21'	41"
115507083	25.12.73	10	11°	37'	15"	40°	29'	48"
117307082	12.01.73	10	11°	28'	53"	40°	30'	50"
119107083	30.01.73	0	11°	38'	39"	40°	28'	50"

This frame was repeated on six successive passes every 18 days from 1.11.72 to 30.1.73. The area includes the Tendaho damsite and the reservoir area, also the Mille River catchment. To date a request has not been made to the EROS Date Centre for Imagery from this set but to complete the Awash River Valley-Coverage No. 119107083 will be ordered.

(e) Dubti to Lake Abe (See Table 5)

The frame covering the area between Dubti and Lake Abe was repeated during the ERTS 1 programme. The table shows that there are nine frames with less than 30% cloud coverage.

Index Nº 11910790, 30.1.1973
MARO GALA, colour enhanced
ERTS Image band 4, 5, 7.

TABLE 5

DUBTI TO LAKE ABE IMAGERY

Index Number	Date Recorded	Cloud Cover %	CENTRE					
			Latitude (N)			Longitude		
111007020	2.8.72	10	11°	35'	12"	41°	54'	59"
108207022	13.10.72	0	11°	34'	0"	41°	54'	46"
110007024	31.10.72	0	11°	27'	48"	41°	52'	08"
111807030	18.11.72	0	11°	29'	36"	41°	49'	26"
113607030	6.12.72	10	11°	22'	02"	41°	46'	59"
11540702	24.12.72	0	11°	34'	51"	41°	54'	19"
119007025	29.01.73	10	11°	41'	55"	41°	55'	33"
122607031	6.03.73	0	11°	41'	44"	41°	44'	41"
124407032	24.03.73	0	11°	38'	41"	41°	43'	18"

The frame, Index Number 11007020, taken on 2.8.72 and Index Number 111807030, taken on 18.11.72 were selected for the study. False colour enhanced prints were produced at a scale of 1:1,000,000 from 4, 5 and 7.

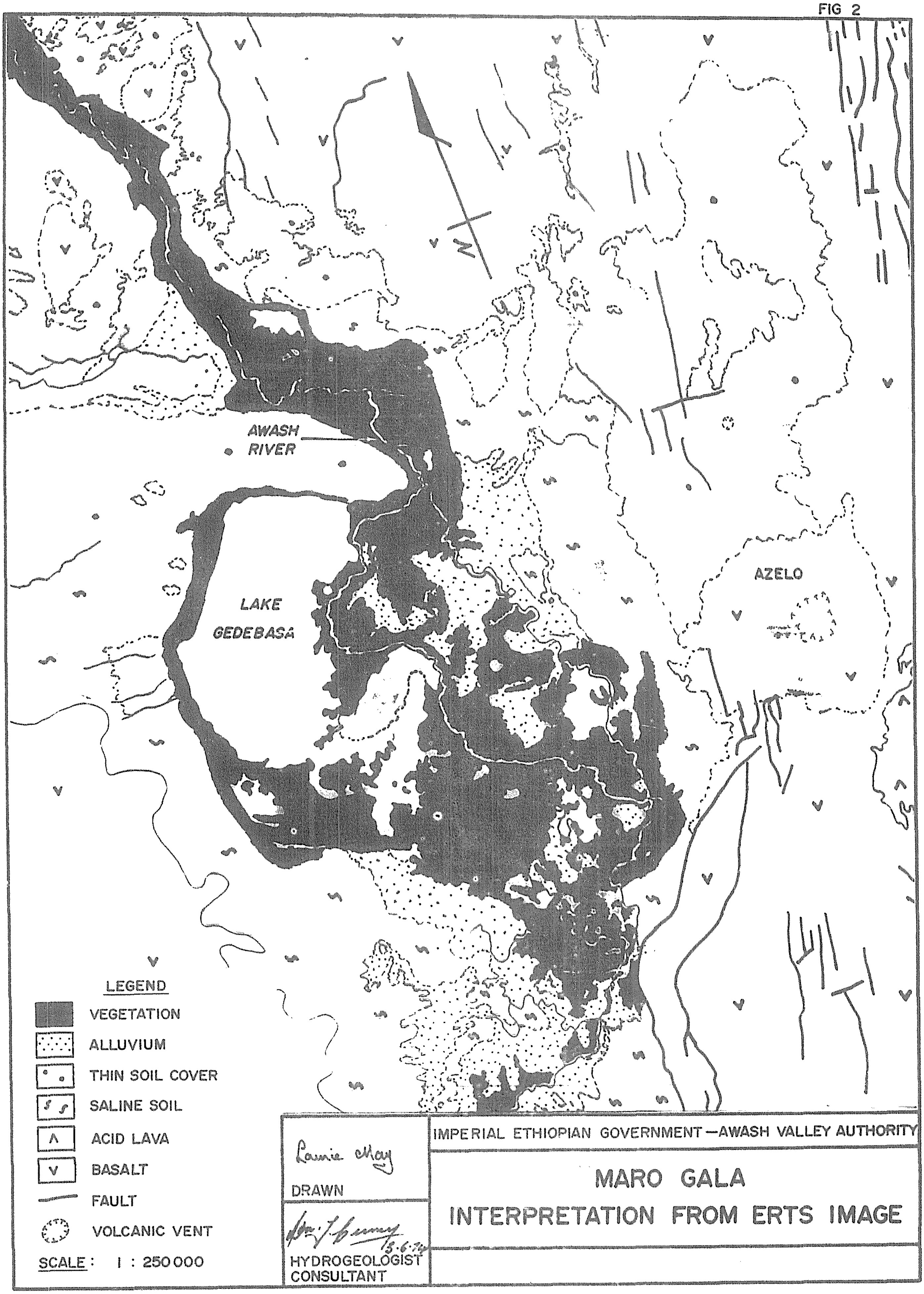
A comparison of the images indicate the extent of ploughing in the lower plains delta area, 2.8.73 and the crop growth up to 18th November, 1972, especially in the Tendaho and Dit Bahri plantations.

The crop comparisons can be made between Assayita to the lakes along the Awash River. A complete crop yield inventory from colour density comparisons is possible from successive frames. This can be used for future crop yield estimates for the ERTS 2 data when it becomes available

Features which are evident on a colour enhanced print of the image taken on the 18.11.72 are: (image not included)

(i) The vegetation of the irrigated lands of Tendaho and Dit Bahri and the delta which are depicted in red on a colour enhanced print, as are the Reed beds around the three lakes. A pink colour which is evident in the red indicates natural pasture growth and a brown colour indicates either bare ground, ploughed fields or swamp land.

FIG 2


AWASH RIVER
LAKE GEDEBASA
AZELO
LEGEND
VEGETATION
ALLUVIUM
THIN SOIL COVER
SALINE SOIL
ACID LAVA
BASALT
FAULT
VOLCANIC VENT
SCALE : 1 : 250000
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MARO GALA
INTERPRETATION FROM ERTS IMAGE

(ii) The white areas which are evident on the print are the deserts and thin red lines in the desert are inferred as vegetation growing along the discharges from springs.

(iii) The major fault trends are shown as dark lines, and black areas with distinctive vents are obviously volcanoes.

(iv) The water colours of the lakes should be black but the various shades of blue in the print indicate there is sediment in the water.

4. Skylab

The skylab mission recorded a number of areas in Africa by camera during the 1973-1974. There was no coverage of the Awash Valley area by the Skylab S-190A and S-190B passes. The photographs taken by hand held cameras are not programmed into the computer data base and cannot be retrieved by geographic coordinates. The Skylab III information will be available by March 1974. It is hoped that some of the photographs taken during this phase will include areas of interest to AVA.

The later phases of the mission includes extensive filming of many areas of Africa. It is expected that EROS will receive voluminous data over Africa, but it may be some time after the Skylab astronauts return to Earth before the film is received at the EROS Date Centre.

5. ERTS B. AVA Programme

A summary proposal form was submitted to NASA in December 1972 outlining the AVA programme for inclusion in the ERTS B programme; the imagery is expected to be available in 1976. The programme set out the description of the investigation and objectives. A detailed account of the proposal is given below:-

A. Scientific/Technical Description of the Investigation

To map the resources of the Awash Valley in particular the suitable irrigation areas, the groundwater basins, the thermal regions, and the mineral resources associated with volcanic regions. To indicate the major geological structures of the country and to define the most suitable access routes to the various resources.

B. Background

A number of agricultural areas have been defined along the Awash River and its tributaries, also a number of bores have indicated the potential groundwater resources within the catchment. A recent thermal energy survey was encouraging in locating potential resources especially along the edges of the East African Rift. A deposit of sulphur is being mined in the area and it is possible that there are additional areas in other volcanic areas. Although access is available to some of the areas it is most difficult in the more remote regions.

C. Objectives

The purpose of the investigation is to locate arable lands along the river frontages in the Awash Valley catchment, to plan the orderly development of the Valley and its water resources and to identify the groundwater basins within the Valley. The groundwater resources need further studies to define the capacity of the resource and its availability in the various areas.

The distribution and extent of the sulphur deposits in the volcanic regions could be of particular interest as a possible export item.

The area to be studied is the entire Awash River catchment, 120 000 km^2. The ERTS 2 remote sensing techniques will yield valuable information of the earth resources which would enable a broader study of the various regions.

The proposed application will aid the regional planning which is in progress. The methods can be justified as there are many remote regions yet to be visited.

D. Approach

Direct imagery interpretation will be used and checked in the field by either inspection and/or drilling. The suitability of multispectral projection will be examined to determine the combinations most useful for the investigation. The anticipated results of the inspection will be the production of comprehensive resource maps covering the Awash River Valley catchment in Ethiopia. The map should delineate target areas for future study.

E. Investigations Data Handling Plan

Positive prints at 1:1,000,000 will be produced from the band negatives and all will be stored at AVA H.Q. in Addis Ababa. Any enlargements of portions of the transparencies will be ordered after an initial examination.

F. Data Requirements

The longitudes and latitudes of the test area are:

Longitude	38°	42°	38°	42°
Latitude	7°N	7°N	12°N	12°N

The area can be defined as high relief, mountain, plateau and deep-gorge country with steep escarpments terminating at the edge of the deserts. The vegetation in the high relief country is sparse to dense and in the desert regions sparse.

Clear conditions expected in the area are summer 35%, rainy season 30%. Data is required at the end of the summer - July and during the rainy season - September.

Conclusions

Sufficient imagery coverage exists to compile a geological and geomorphic-soil association map of the Awash Basin. Repetitive images of irrigated crops can be used to prepare a crop yield - colour density comparison table so that future crop yields recorded by the ERTS 2 imagery can be predicted in advance.

Groundwater springs can be plotted and used for the groundwater study of the Awash catchment.

Records of land clearing and land development along the Awash River can be recorded from the imagery. The satellite information can be used as a surveillance tool relieving many man hours from random checking.

Recommendations

Obtain the repetitive frames for both the Middle and the Lower Plains, shown in the appropriate tables from EROS Data Centre.

Request information on the Awash Valley coverage by the Skylab from the EROS Data Centre. Order the appropriate records from the data centre.

Compile a chart with crop yields compared with the colour intensity for future crop yield predictions.

Compile a plan showing land development along the Awash River from the information recorded on the ERTS 1 imagery.

In 1975 the ERTS 2 information could be available. When the imagery is in hand use it in conjunction with the yield chart for crop predictions and update the Awash Valley developed areas plan. It would be useful to prepare a plan from the existing imagery record and compare them with the later information.

PART III - GROUNDWATER

PART III - 1

ALLEDEGHI PLAIN

Introduction

Additional information of the 1973 boring programme which has been completed, includes the description and logs of Bore Nos. 4, 5, 6B and 8, the hydraulic gradient and screen depths (see Table 8). A list of the bores along the Alledeghi Plain is also included (see Tables 6 and 7).

The logs for Bore Nos. 1, 2 and 3 are included in the Informal Technical (see index) Report No. 4, UNDP/SF/ETH.25, May 1972, and the log for Bore No. 7 is included in ITR., No. 14, UNDP/FAO/ETH. 1972/006, May 1973. Note that the R.L. for Bore No. 4 is incorrect in the ITR No. 14 as it should read R.L. 814.2. Latum for the levels is the Mille-Tendaho Running Distance elevations (Blue Nile Datum).

1. Bore Sites

The completed bores along the Alledeghi Plain constructed by AVA and Dr. Ing. Trapp & Co. are set out in Table 7 (also see Fig. 3).

A number of the bores were in progress after completion of ITR No. 14 (see p. ii). The additional information is set out below.

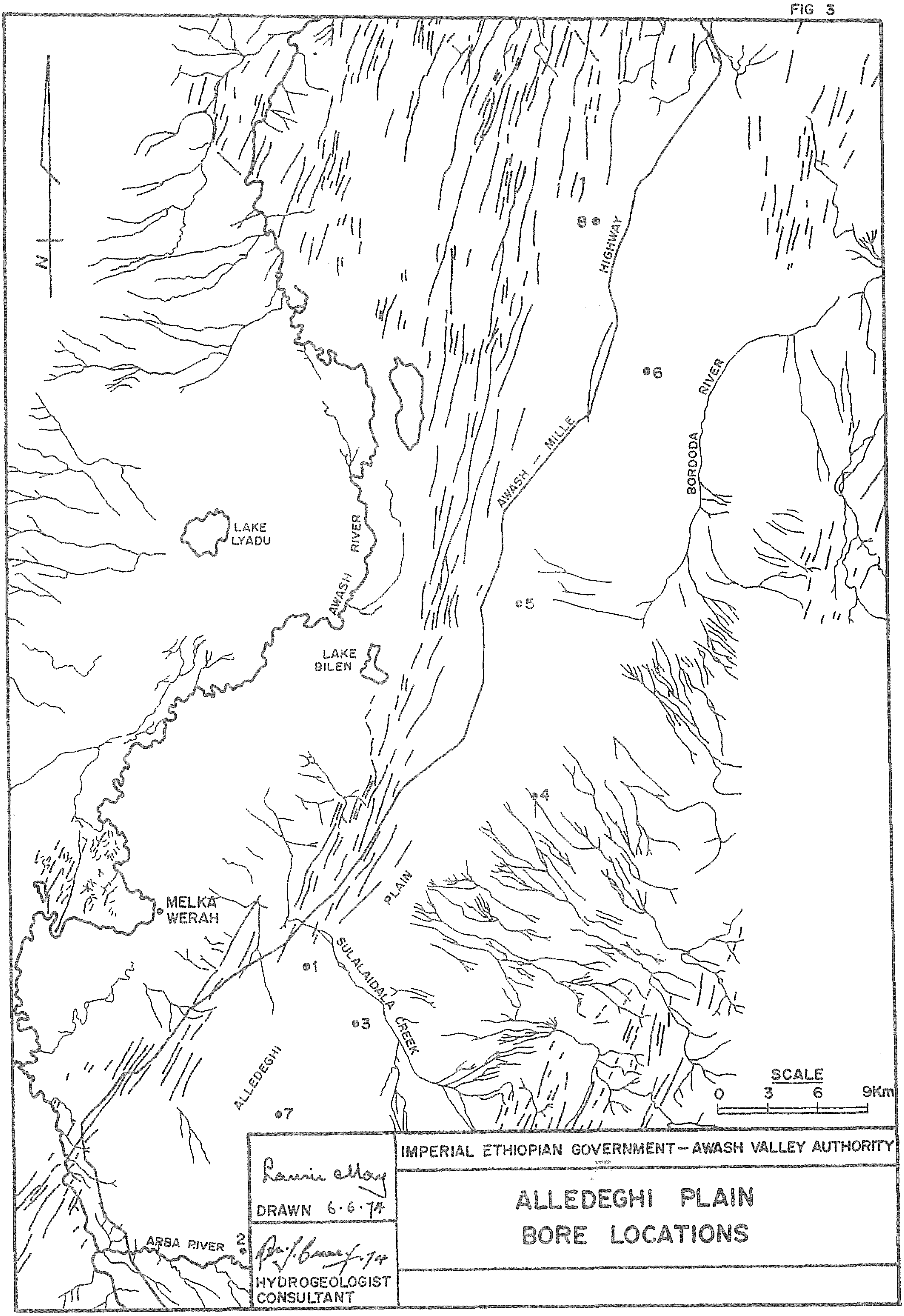
A. Bore No. 5 (see Log)

Bore No. 5 was drilled to 112 m and was reported to be dry. There are three sand beds below the hydraulic water gradient (see Fig. 4) so that it would be expected that these beds would contain water. An explanation could be that as there is a decomposed tuff (clay) bed above each sand bed, with the drilling technique employed, this material has blocked the pores of the sand beds for some distance behind the walls.

A slurry filled this bore hole to 50 m below natural surface at the end of drilling. It is suspected that the circulation water was mixed with the clay material, being penetrated to form the slurry. The hydraulic head of this coloumn could "grout" the sand beds thus preventing water from entering the well.

It is also suspected that aquifers in Bore No. 2 were blocked by the drilling slurry.

FIG 3



IMPERIAL ETHIOPIAN GOVERNMENT - AWASH VALLEY AUTHORITY

DRAWN 6·6·74

HYDROGEOLOGIST CONSULTANT

ALLEDEGHI PLAIN BORE LOCATIONS

The well was abandoned and suggestions that it be relocated 4 km to the east would be advisable only after attempts had been made to swab the sand aquifers by water jetting or chemical treatment to check that the sand beds do not contain water.

B. Bore No. 6B (see Bore Log)

Three sand aquifers occur in Bore No. 6B 68-69 m, 76-80 m and 85-89 m. Two three-meter screens were placed opposite the two lower aquifers (see Table 8).

The static water level 59 m, was lowered to 79 m and then recovered to 72 m after a flow of sediment free water. It remained at 72 m after 6 hours of the 12-hour pumping test at 5 l/sec. A pumping test of at least 20 l/sec. is necessary to determine the potential of this well. The pumping tests on other wells during this phase of the investigation were similarly inadequate.

The screens were installed in Bore No. 6B after the initial Bore No. 6A collapsed, when water was struck at 85 m the lower aquifer. This lends further weight to the possibility that the aquifers in Bore No. 5 are blocked, as it is evident that the two upper-aquifers in Bore 6A were blocked during the drilling operation.

C. Bore No. 7

See ITR No. 14, UNDP/FAO/Eth. 72/006

D. Bore No. 8 (see Bore Log)

Bore No. 8 was drilled to 67 m in alternating clay beds and lava flows to 28 m and then in lava to 67 m. The bore was abandoned 20 m above the hydraulic gradient (see Fig. 4) due to the "hard ground". Water should be available by deepening the bore.

If groundwater supplies are needed for this area in the future a drilling site could be selected some 6 km to the east of Bore No. 8. At the new location the bore would encounter only a few thin lava beds, and would be below the hydraulic gradient 50 m below natural surface.

2. Hydraulic Gradient (see Fig. 4)

There is good correlation between the static water levels in each bore along the 60 km length of the Alledeghi Plains. The gradient between Bore No. 7 and the Awash River, in the gorge section upstream from Melka Sedi, towards Awash, again indicates that river water replenishes the Alledeghi Plains water resource.

The hydraulic gradient indicated by the static water levels is 0.4 m/km between Bore No. 7 and Bore No. 6. The gradient can be used to predict the depth necessary to bore for water at future well locations.

3. Drilling Conditions

The drilling has shown that generally there are few lava flows towards the centre of the plain. Thick lava sections exist in the vicinity of the highway.

Future sites should therefore be selected towards the center of the plain, if convenient to location of water needs. The easterly extent of the resource has yet to be established downslope from Bore No. 2 which was dry.

Conclusions

The ground water resource of the Alledeghi Plains is as extensive as previously reported. It far exceeds the planned needs of the immediate future.

The eastern boundary of the resource has yet to be established but it would not be imprudent to expect it to extend to the toe of the Asebot Mountain Range.

The hydraulic surface is at a shallower depth 60 m in the north, whereas it is 90 m at the southern end of the plain. Drilling towards the centre of the plain encountered mostly alluvial deposits with a few thin lava beds.

Recommendations

Attempts should be made to bring Bore No. 5 into production by jet water swabbing, surging or checmical treatment before a decision is made to relocate the bore to the east. Bore No. 8 could either be deepened another 25 m or else relocated 6 km to the east. In either case water should be encountered.

At all times the drilling operation should be checked to ascertain that aquifers are not blocked by drilling mud or drill tailings.

Bore No. 4

Ato Fittiwy G. Yohannes-AVA site representative reported that:-

0-3	Dark brown clay	Struck water 86-50
3-6	Red brown silty clay	Static
6-9	Red brown clay with basalt chips	
9-13	Trachy basalt	
13-15	Red clay	
15-33	Clay and gravel	
33-56	Red silty clay and pebbles	
56-57	Red ferruginous clay	
57-64	Yellow clay with pebbles	
64-68	Red brown clay	
68-72	Coarse sand with clay content	
72-75	Scoria and clay	
75-80	Clayey sand	
80-86	Fine sand, some pebbles	
86-100	Pebbles and fine sand to coarse sand, water	

Bore No. 5

Ato Fittiwy G. Yohannes - AVA site representative reported that:-

0-1	Red brown clay
1-2	Basalt
2-55	Rhyolite and welded tuff
55-72	Tuff
72-82	Sand with gravel
82-86	Tuff
86-97	Sand
97-103	Tuff
103-112	Sand

Bore 6B

Mr. K. Matsumoto - AVA site representative reported that:-

0-1	Dark brown clay	water struck 69 m
1-3	Red brown clay	static level 59 m
3-13	Clay with basalt pieces	
13-16	Basalt	
16-18	Tuff	
18-21	Red brown clay	
21-28	Clayey sand	
28-30	Tuff	
30-34	Sand and gravel, clayey	
34-36	Sandy clay	
36-37	Basalt	
37-42	Sandy clay	
42-43	Basalt	
43-44	Grey clay	
44-66	Red brown and brown clay	
66-70	Interbedded sand and lava	
70-73	Sand and clay layers	
73-75	Basalt	
75-80	Gravel and sand	
80-81	Clay	
81-84	Rhyolite	
84-89	Sand	
89-93	Clay	

Bore No. 8

Ato Fittiwy G. Yohannes - AVA site representative reported that:-

0-3	Dark brown clay
3-6	Red brown clay
6-9	Tuff
9-13	Basalt
13-15	Red brown clay
15-22	Rhyolite
22-24	Sand
24-28	Red brown clay
28-67	Rhyolite

TABLE 6

ALLEDEGHI PLAIN BORES

Awash Valley Authority Bores						
Bore No.	Depth Meters	Reduced Level	Water		Position Highway Distance	Comments
			Struck	Standing		
1	101.5	802.3	737.3	742.0	42km 2km East	T42°, TDS 620 mg/l
2	145.0	830.0	-	-	14km 8km East	Dry
3	101.0	812.9	729.9	737.0	14km 7km S.E.	T39.5°C TDS 590 mg/l
4	101.0	814.2	723.7	729.2	57km 6km East	
5	112.0	796.5	-	-	68km 2km East	Dry
6A	90.0	779.9	710.9	719.9	86km 3km East	
6B	93.0	779.9	707.9	719.9	86km 3km East	T40.5°C TDS 510mg/l
7	100.0	829.4	740.4	742.4	30km 8km East	
8	69.0	802.9	-	-	95km 2km East	Dry

TABLE 7

Dr. Ing. Trapp & Co. Production Bores (10 l/sec.)

Highway Distance (km)	Depth (m)	Remarks
13	30	Arba River bed, TDS 485 mg/li
114	35	TDS 775 mg/li 44°C
125	14	TDS 875 mg/li
135	15	
147	35	
153	52	
270	18	River gravel-bed of Ledd, River
280	12	River gravel-bed of Gheraru River
296	12	

Screens and Aquifers

The depth and interval which screens have been inserted and the depth of the aquifers below natural surface are:

TABLE 8

Bore No.	Screen		Sand and/or gravel		Water Bearing	Remarks
	From	To	From	To		
1			30.50	32.50	Dry	Above Hydraulic gradient
			57.00	59.00	Wet	
	69	75	60.00	74.50	Water	
	83	87	90.50	101.00	Water	Rhyolite with tuff beds
	91	96				
2					Dry	Numerous sand and gravel beds
3			15.00	23.00	Dry	Above Hydraulic gradient
			37.00	48.00	Dry	" "
			62.00	63.00	Dry	" "
	83	88	81.50	93.00	Water	Including basalt and tuff beds
4			68.00	72.00	Dry	Above Hydraulic gradient
	88	94	80.00	100.00	Water	
5			72.00	82.00	Dry	Below the Hydraulic gradient
			86.00	97.00	Dry	Aquifers could have been blocked by drilling mud
			103.00	112.00	Dry	

TABLE 8 (Cont'd.)

Bore No.	Screen		Sand and/or gravel		Water Bearing	Remarks
	From	To	From	To		
6B			21.00	28.00	Dry	Above Hydraulic gradient
			30.00	34.00	Dry	
			66.00	78.00	Water	
	76	79	78.00	80.00	Water	
	85	88	84.00	89.00	Water	
7			12.00	18.00	Dry	Above Hydraulic gradient
			38.00	41.00	Dry	" "
			43.00	47.00	Dry	" "
			63.00	65.00	Dry	" "
			68.00	73.00	Dry	" "
			80.00	81.00	Dry	" "
	93	97	86.00	100.00	Water	
8			22.00	24.00	Dry	Above Hydraulic gradient

PART III - 2

LOWER PLAINS

Introduction

The Lower Plains drilling for piezometer installation was completed by November 1973. The aim of the programme is to measure the water table below ground surface and water table fluctuations in the future.

Information of the depth drilled has been confirmed by logging the samples, but information on the confined nature of the groundwater is awaited from Sir Alexander Gibb, London. The logs of the 23 bores are attached.

The piezometers have been read three times, in November 1973, January 1974 and February 1974 (see Table 9).

1. Groundwater

There appears to be three separate water tables in the Lower Plains. These are the resultant of the:

(i) Regional Groundwater Resource
(ii) River Water Seepages
(iii) Irrigation Water

A. Regional Groundwater Resource

The regional groundwater resource can be located beneath the plains at different depths dependent on the location. At Dubti to Dit Bahri the resource is approximately 30 m below natural surface but as the land surface slopes towards the lakes the depth to the water table is less. The gradient is flat, R.L. 340 except in the delta area where it falls 2 m in 20 km (see Fig. 5).

It will be noted that Bore No. 19 does not fit this pattern, and the water level is falling. It is suspected that this piezometer is blocked.

It is also suspected that the regional groundwater is confined by impermeable beds and that the groundwater is under pressure below the plains. However, this information and the water quality information should be contained in the Sir Alexander Gibbs report expected in April 1974.

(ii) River Water Seepages

It is suspected that the top of impermeable beds confining the regional groundwater forms the base for water mounds to build up from river seepages and from irrigation water applications.

The high readings in Bore Nos. 6 and 7, each side of the river opposite the Tendaho Plantation, indicates a mound formation along and below the river. This type of mound is to be expected along river courses and usually piezometer fluctuations are governed by the rise and fall of the river level.

(iii) Irrigation Water

In both Tendaho Plantation and Dit Bahri water mounds have resulted from the deep percolation of irrigation water (see Plans 4 and 5). The contour construction is taken as depth below natural surface, thus altering the sloping plain surface to an horizontal plane. This type of construction highlights groundwater mounds as the complication of the topography is erased

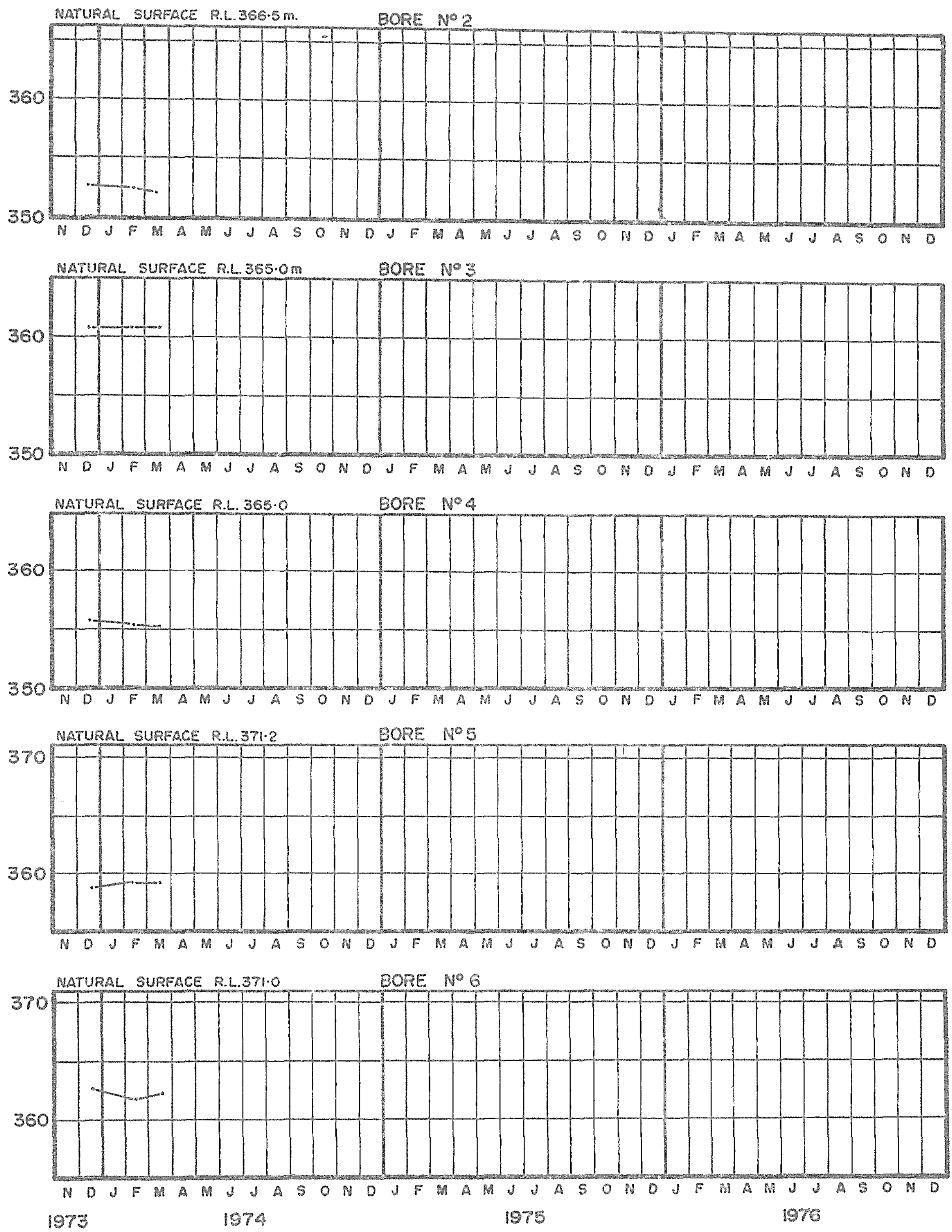
At Tendaho the groundwater is from 4.4 m to 13.6 m below natural surface. The shallowest coincides with a set of point bars representing an old river course of the Awash River situated at the lower end of the plantation. Additional piezometers in this course could well establish that the shallowest perched water in the mound coincides with this feature.

The water quality of this groundwater should be good, similar to the river seepage water. Township supplies could be drawn from the sand and gravel beds which occur in these sediments. Bore Nos. 2, 3, 5 and 6 show the best possibilities as sand or gravel beds have been intersected. The groundwater in the mound would be under the influence of the atmosphere except where confined by clay lenses.

The Dit Bahri mound would be expected to be under the whole plantation, but due to the lack of information it is confined to the western area. Again the shallowest groundwater would be expected in the Former Awash River course which crosses the plantation.

2. Piezometer Records (see Fig. 7)

The record of the piezometer readings have been plotted on a chart for Tendaho. The chart has been constructed to show the elevation of the water table for each month from November 1972



IMPERIAL ETHIOPIAN GOVERNMENT — AWASH VALLEY AUTHORITY

LOWER PLAINS GROUNDWATER
PIEZOMETER RECORD. TENDAHO.

DRAWN

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to 1980. The rise in meters per year of the groundwater mounds in the irrigation district can thus be monitored and drainage construction carried out to offset any damaging effects by a near surface groundwater.

3. Lower Delta Groundwater

Irrigation towards the lakes becomes more dangerous because of the possibility of the shallow depth of the impermeable base on which irrigation water will begin to build up. This dangerous situation could be showing up already at Bore No. 17, between SAHILLE and KASTALE. There may be a coincidence of the Awash River seepage water and irrigation water resulting in the high reading of 2.80 m. A later fluctuation to 4.05 may be due to the river water levels.

4. Sediments

The sediments of the Lower Plains are mainly silts and clays. Only one of the deep bores, 100 m Bore No. D penetrated to the base of the sequence. There could be three sedimentary sequences, these are:

(i) Lake sediments
(ii) Infilled valley sediments
(iii) Present river flood plain

The lake sediments are silts and clays with an occasional sand bed and shell horizon. The regional groundwater could be confined in these sediments. A wide valley, (see Fig. 5) may have been eroded in these sediments and then infilled. Tendaho plantation is situated on this suggested feature. Sand and gravel beds occur with silts and clays in this section. The river flood plain can be recognized by the abandoned river courses, fans and swamps. The better quality water may occur in the sediments of these two alluvial features.

Conclusions

There are three water tables in the lower plains:

(i) The regional water table with a flat gradient 30 m below the plain at Dubti and exposed as the lake surfaces to the north-east. It is expected that this resource will be the poorest quality and that the groundwater is confined;

(ii) the river seepage water mound following the course of the river; and

(iii) the irrigation deep seepage water mounds occurring below the irrigation areas. The river and irrigation mound would form on top of the confining layer of the regional groundwater resource.

Suitable water supplies could be obtained from the groundwater mound areas as sand and gravel beds occur in the sedimentary section below the irrigation areas.

The groundwater below the irrigation areas is rising yearly and should be monitored.

<u>Recommendation</u>

Establish additional piezometers in the main irrigated areas. Site the piezometers by using the geomorphology plan of the area, concentrating on the former river courses.

Construct piezometer record charts to monitor the groundwater fluctuations in the irrigation areas.

LOWER PLAINS

Piezometers

TABLE 9

Bore No.	R.L.	Depth Meters	Water Struck R.L. m	Standing R.L.	Date	Temp. C
1	373.5	28.85		344.65	18.11.73	47*
2	366.5	13.60	356.5	352.9	18.11.73	35
3	365.0	4.40		360.6	18.11.73	31*
4	365.0	9.60		356.1	18.11.73	35*
5	371.2	12.40	350.0	358.8	18.11.73	36
6	371.0	8.40		362.6	18.11.73	32*
7	382.9	18.40		364.5	19.11.73	39*
A	377.1	22.00		355.1	18.11.73	36*
B	377.1	22.40		354.7	19.11.73	39*
9	359.0	-		-	Destroyed	
10	354.6	23.80		330.8	19.11.73	
11	357.4	9.30		348.1	19.11.73	35*
12	353.3	30.75		322.5	19.11.73	
13	347.3	8.50	335.3 & 338	338.8	18.11.73	38
14	342.0	18.00		324.0	18.11.73	
15	345.1	18.00		327.1	18.11.73	
16	344.0	-		-	Destroyed	31
17	349.2	2.80	343.0	346.4	18.11.73	
18	344.9	-	339.9	-	Not Read	
19	342.0	-		-	Not Read	
C	341.0	28.20		312.8	18.11.73	36*
21	345.0	15.40		329.6	18.11.73	
D	352.5	11.90	319.5	340.6	18.11.73	34

* Flushing water used.

Piezometer Readings - Lower Plains

No.	Date			Remarks
	18-19.11.73	16-18.1.74	19-21.2.74	
1	28.85	24.95	24.40	
2	13.60	14.00	14.30	
3	4.40	4.30	4.40	
4	9.60	9.70	9.80	
5	12.40	12.00	12.00	
6	8.40	8.55	8.50	
7	18.40	18.25	18.10	
9	-	-	-	Destroyed
10	23.80	-	-	Destroyed
11	9.30	9.10	-	Destroyed
12	30.75	-	-	Bent pipe
13	8.50	8.60	-	Flooded
14	18.00	-	-	Flooded
15	18.00	20.00	-	Flooded
16	-	-	-	Destroyed
17	2.80	2.60	4.05	
18	-	4.35	4.20	Flooded
19	-	12.70	14.75	Flooded
21	15.40	14.77	-	Flooded
A	22.00	-	-	Destroyed
B	22.40	22.50		
C	28.20	29.75	29.65	
D	11.90	12.90	12.80	

LOWER PLAIN

Groundwater Bores

Bore No. 1

1-2	Brown clayey silt
2-14	Brown and grey clayey silt
14-25	Brown silty find sand
25-28	Grey clayey silt
28-34	Grey silty clay
34-50	Grey clayey silt

Bore No. 2

0-2	Grey fine sand
2-18	Grey silty clay and silt
18-27	Brown fine sand and silt
27-36	Brown fine sand
36-38	Grey clayey silt
38-40	Brown sand
40-50	Grey clayey silt and clay

Water Samples
6.60 and 9.60

Bore No. 3

1-2	Grey clayey silt
2-5	Grey silty clay
5-8	Brown sand
8-21	Brown silt and fine sand
21-48	Grey clayey silt
48-50	Grey silt and fine sand

Bore No. 4

1-13	Grey silt
13-17	Grey clayey silt
17-22	Grey silty clay
22-42	Grey clay silt and clay

Bore No. 5

1-21	Grey clayey silt and clay	
21-27	Brown sand and fine gravel	
27-32	Gravel	Water Samples
32-34	Grey clay and silt	4.40 and 14.42
34-38	Brown sand	
38-50	Grey clayey silt	

Bore No. 6

1-5	Grey and brown silt
5-16	Brown sand
16-22	Brown clayey silt
22-39	Brown and grey silt and fine sand
39-50	Grey clayey silt

Bore No. 7

1-8	Brown sand
8-15	Grey clay silt
15-17	Grey clay
17-40	Grey clay silt

Bore No. 9

1-26	Grey clayey silt
26-31	Grey silty clay
31-50	Grey clayey silt

Bore No. 10

1-12	Grey and brown clayey silt
12-19	Brown fine sand
19-47	Grey clayey silt

Bore No. 11

0-1	Grey silt
1-2	Brown clay
2-13	Grey clayey silt
13-22	Brown fine sand
22-50	Grey clayey silt

Bore No. 12

1-14	Brown and grey clayey silt
14-25	Brown fine sand and silt
25-30	Grey clayey silt

Bore No. 13

0-1	Grey silt and fine sand
1-9	Grey clayey silt
9-15.3	Brown silt and gravel-water
15.3-20	Grey clayey silt and clay

Bore No. 14

0-1	Lt. grey clayey silt
1-19	Grey clay
19-20	Grey clayey silt

Bore No. 15

0-1	Grey silty clay
1-11	Brown clayey silt and clay
11-12	Grey clayey silt and shell
12-13	Grey clay
13-20	Grey clayey silt and clay

Bore No. 16

0-0.2	Grey clay
0.2-2	Grey silty clay
2-8	Grey clay silt and clay
8-9	Grey fine sand
9-15	Grey clayey silt
15-17	Grey silt and fine sand
17-29	Grey clayey silt

Bore No. 17

1-14	Grey clayey silt (water at 14)
14-17	Grey clay and silt
17-19	Grey clayey silt

Bore No. 18

0-7	Dark grey clay
7-9	Grey clayey silt and clay
9-10	Grey clayey silt
10-18	Grey clay and silt

Bore No. 19

0-2	Grey clayey silt
2-17	Grey clay
17-20	Grey clayey silt

Bore No. 21

0-13	Grey silty clay
13-14	Grey silt
14-20	Grey clayey silt

Bore No. A

1-35	Grey clayey silt
35-38	Grey silty clay
38-100	Grey clayey silt

Bore No. B

1-2	Grey clay
2-20	Grey clayey silt
20-22	Black sand
22-24	Grey clay silt
24-25	Grey and black fine sand
25-35	Grey clayey silt and fine sand
35-40	Grey clayey silt

Bore No. C

0-3	Grey clay
3-9	Grey silty clay
9-17	Grey clayey silt and clay
17-22	Grey clayey silt
22-27	Dark grey clay
27-28	Grey silty clay
28-42	Grey clayey silt
42-47	Dark grey clay
47-50	Grey clayey silt
50-52	Grey clay
52-54	Grey clayey silt
54-60	Grey clay
60-80	Grey clayey silt

Bore No. D

0-12	Grey clayey silt
12-28	Grey clayey silt and clay
28-38	Grey clayey silt
38-44	Grey sand
44-63	Grey clay and magnesite (tuff)
63-66	Red and brown sand
66-74	Grey clay
74-79	Light brown sand
79-94.50	Brown and grey clay sand and silt (volcanic products)
94.50-98	Dark grey clay and sand (tuff ?)
98-100	Black basalt fragments

PART III - 3

MT. FANTALE (WEST)

Introduction

Fantale is a volcano considered to be active. It is in a faulted zone with broken ground to the east and a wide black soil plain to the west. In front and to the south of Fantale there are recent scoria and lava fields which have been extruded from parasitic cones and through fractures. The faults which extend south from the western cliff shore line of Lake Beseka.

The area from the highway to the Kessem River cstchment in the north and from Fantale to a fault escarpment to the west is a wide gently depressed black soil plain. Surface waters are of an intermittent order and cannot be relied upon for stocking purposes. Because of this, and the fertility of the soil, it has been suggested that groundwater could be beneficial to the local population of the area.

1. Groundwater

The groundwater possibilities of the area are good. The lake to the south has formed from the faults in the area, tapping the regional groundwater resource, which flows under pressure up the fault plane to the surface.

Three distinct isolated volcanoes in the plain are in line with a fault escarpment at the northern end of the plain.

Boring in the vicinity of the three volcanoes may be successful in obtaining groundwater stock supplies.

2. Groundwater Investigation

A groundwater investigation bore is to be drilled on the plain during March-April by the I.E.G. Ministry of Mines. Discussions have taken into account the AVA needs and the suggestion arose that if useful groundwater supplies were located negotiations could be held between the Ministry and AVA for the purchase of the casing so that it could remain in the well.

Conclusions

Possible groundwater resources west of Fantale are indicated by the lake to the south which is fed by spring water issuing from a fault system.

Recommendations

Follow up bore results from I.E.G. Ministry of Mines.

PART IV

Tendaho Damsite

Introduction

The foundation investigation drilling programme at Tendaho has been completed. A report complete with bore results, bore logs and information for design criteria can be expected from Sir Alexander Gibb in May 1974.

Core samples were inspected and a descriptive log made of the bores. Details of core losses and the precise engineering log which is necessary for accuracy and completeness was deemed not necessary as this would only be a duplication of the investigation already completed by the Contractor.

The aim of the inspection was to become familiar with the overall geological structure at the site and to determine significant features which may present difficulties to the design.

One such feature does not exist below the river alluvium. This feature was discussed by S.O.G.R.E.A.H. Vol. IV, 1965, and commented on by Currey, I.T.R. No. 4, May 1972. The section below the river alluvium was reported by S.O.G.R.E.A.H. to be older river alluvium. This was queried by Currey who suggested that the sediments were older than the river formation and may even under lie the volcanics of the abutments.

1. Drilling Investigation (see logs)

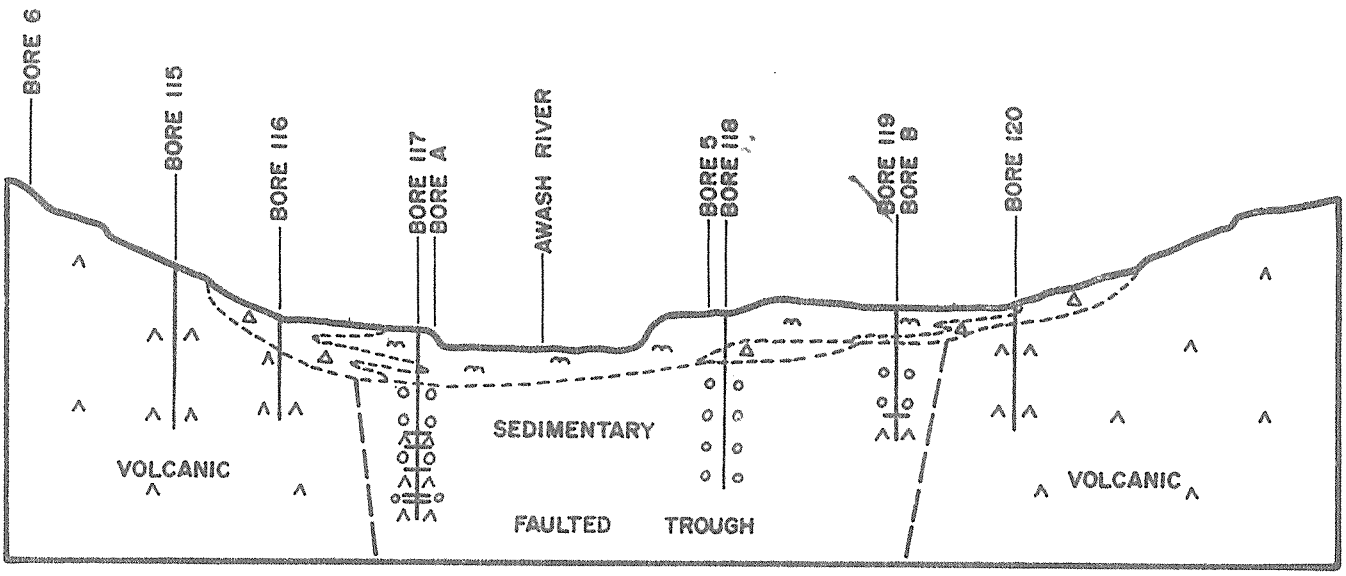
The bores on the alluvial flat at the site have dileneated the boundaries of a sedimentary sequence below the river alluvium. The boundaries between the volcanics and the sedimentary material on both sides of the valley is sharp, e.g. between Bore Nos. 117-116, 40 m apart (see Fig. 8).

The materials recovered during the drilling programme were:

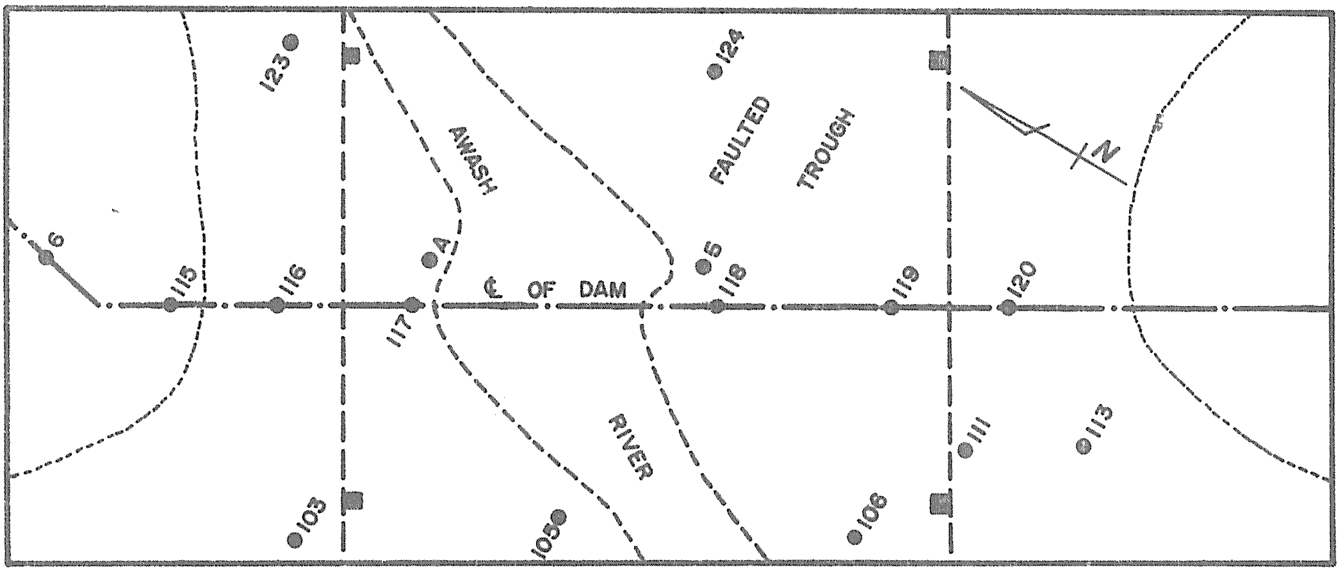
(i) Alluvium

The alluvium is approximately 14 m thick, consisting of clay, silt, sand and gravel with occasional interbedded with scree deposits.

FIG 8



DAMSITE CENTRELINE, CENTRE OF VALLEY, GRABEN.



LOCALITY PLAN, BORES, FAULTED TROUGH.

LEGEND

- ⌒ ALLUVIUM
- Δ HILLWASH
- ○ ○ GRAVEL OUTWASH PLAIN
- Λ VOLCANIC LAVA

HORIZONTAL SCALE 0 20 40 60 80 100m

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IMPERIAL ETHIOPIAN GOVERNMENT—AWASH VALLEY AUTHORITY

TENDAHO DAMSITE

CENTRELINE BORES

(ii) Sedimentary Beds

Bore No. 118 penetrated the deepest section of the sedimentary beds, 50 m below natural surface and, was terminated without proving the full depth of the sequence. The sediments consist of beds of varying thickness, to 3 m, of cemented conglomerate, consolidated friable sandstone and mudstone.

In Bore No. 117 the conglomerates were interbedded with a rhyolite flow before entering the volcanic sequence. The contact between the top of the rhyolite and the conglomerate is 25° and the dip of the sediments 7°, indicating that the flow was eroded before the conglomerate was deposited. The volcanic sequence contained 1 m of conglomerate between 40 m and 50 m.

(iii) Volcanics

The volcanic materials are bedded. Flows of basalt, rhyolite, scoria, tuff and a mixture of scoria and tuff (slag). Hard rock is interbedded. The soft tuff or slag is mostly impermeable. The volcanic rocks form the abutments at the damsite.

2. Structure

The suggestion by S.O.G.R.E.A.H. that the sedimentary materials below the alluvium at the damsite is older Awash River alluvium is again disputed. It is contended that the sediments are older than the alluvium and that the sequence occupies a down-faulted trough (graben). This structure determined the subsequent course of the river.

The reasons for this suggestion are that:

(i) The materials are consolidated appearing much older than the Lower Plains sediments. These sediments differ in compaction, colour, and composition to the materials in the Lower Plains already proven to 100 m by the groundwater investigation bores.

(ii) The interbedded nature of the basal conglomerates with the lavas.

(iii) The sharp boundaries on each side of the valley between the sediments and the volcanics.

(iv) The evidence of breccia in Bore No. 123 along the suggested graben lineation on the left flood plain.

(v) The absence of the sediments below the abutments (as deep as the bores have determined).

(vi) The existence of similar sediments interbedded with the lavas upstream from the Middle Valley.

The sediments may have covered the area before the trough faulting and have subsequently been eroded away. The sediments in the trough would have been protected from erosion, probably being covered with alluvium at an early stage.

3. Design

The design of the embankment should allow for differential consolidation for settlement. The bank will be on volcanic foundations on both edges of the flood plain, but an abrupt change to less fully consolidated sediments will form the central foundation below the highest section of the bank.

An additional hazard could occur if this structure is a graben for this would indicate that both abutments have moved away from each other. The possibility is that this area is technically active.

Conclusions

Sediments consisting of cemented conglomerate, friable sand-stone, and mudstone occupy a graben which is below the alluvium at the Tendaho damsite.

Recommendations

Consolidation tests on the volcanic materials and the deep sedimentary beds should be carried out to determine the differences in consolidation so that bank settlement figures can be predicted.

The seismic study being conducted at the moment should produce sufficient data to determine possible seismicity at the site. These records should be regarded as important in the design due to the possibility of a graben structure in the central valley section.

Tendaho Damsite Foundation

BORES

Bore 101 (Approximate R.L. 575)

0.47- 1.00	Brown Clay
1.00- 1.47	Grey silt and scree
1.47- 3.82	Grey clay silt and sand
3.82- 5.00	Dark grey silt
5.00- 8.25	Brown silty gravel
8.25- 9.30	Brown and grey silty gravel
9.30-13.40	Dark grey sandy gravel and silt
-	-
23.00-26.71	Grey consolidated friable siltstone and mudstone

Bore 103 (Approximate R.L. 578)

0.00- 2.50	Brown sandy clay
2.50- 3.50	Dark grey sand and silt (wet)
3.50- 6.00	Brown sandy clay
6.00- 7.00	Tuff basalt and gravel
7.00- 9.47	Versicular basalt and tuff mixture, then tuff
9.47-14.51	Basalt and tuff (grey clay)
14.51-18.99	Grey tuff 1 m
	Basalt 10 cm
	Tuff 7 m
	Basalt 20 cm
	Tuff
	Hard basalt to 17.50
	Scoria 10 cm
	Baked clay 20 cm
	Red scoria and basalt to 18.99
18.99-21.00	Basalt and scoria (broken)
21.00-23.03	Hard fresh basalt and versicular basalt

Bore 104 (Approximate R.L. 584)

0.00- 0.80	Black and grey clay
0.80- 1.00	Brown clay
1.00- 1.90	Scree
1.90- 4.50	Light grey clay
4.50- 5.10	Brown silt
5.10- 5.75	Grey clay and scree
5.75- 6.40	Grey silty clay
6.40- 6.70	Gravel (2")
6.70- 7.10	Red brown clay and sand (water)
7.10- 7.40	Red brown silt and clay
7.40- 9.20	Gravel to (5")
9.20-10.60	Gravel and cemented conglomerate
10.60-11.05	Brown sand and gravel
11.05-12.50	Light brown silty clay
12.50-13.00	Dark grey sand, clayey
13.00-14.20	Grey sand and gravel
14.20-14.70	Brown sand
14.70-15.30	Light brown clay
15.30-16.90	Brown sand and gravel (16.5 cemented)
16.90-18.50	Brown clay
18.50-23.70	Grey clay
23.70-24.77	Clay and scree
24.77-25.00	Grey clay

Bore 105 (Approximate R.L. 577)

1.00-2.50	Grey silt
2.50-3.70	Grey silty sand (water)
3.70-5.20	Grey silty clay
5.20-6.20	Sand
6.20-10.44	? Siltstone and conglomerate (cemented)
10.44-12.50	Conglomerate (cemented)
12.50-13.49	Friable siltstone and mudstone, conglomerate (cemented) 1 m
13.49-20.02	?
20.02-22.54	Cemented conglomerated and sandstone
22.54-35.00	Friable micaceous sandstone and mudstone

Bore 106 (Approximate R.L. 577)

0.00- 0.50	Grey silt
0.50- 1.50	Grey silty clay
1.50- 3.80	Brown sandy gravel (2")
3.80- 5.80	Grey sand and boulders
5.80- 6.50	Brown silty clay (water)
6.50- 7.40	Brown sand and gravel (2")
7.40- 7.80	Brown clayey sand
7.80- 9.45	Brown silty clay

Bore 107 (Approximate R.L. 612)

0.00- 0.50	Grey clayey silt
0.50- 1.90	Gravel and silt
1.90- 3.00	Silt
3.00- 3.50	Dark grey silty sand
3.50- 4.00	Grey clayey silt
4.00- 4.50	Sandy gravel
4.50- 4.95	Light brown silty clay
4.95- 5.25	Grey silty sand (water)
5.25- 6.20	Dark grey silty clay
6.20-28.00	Grey friable mudstone and siltstone
28.00-34.12	Hard fresh rhyolite with clay seams
34.12-34.22	Baked clay
34.22-35.00	Basalt, scoria, tuff mixture

Bore 108 (Approximate R.L. 595)

11.88-20.10	Dark grey silt and sandy gravel (water)
20.10-28.00	Hard fresh rhyolite

Bore 110 (Approximate R.L. 595)

0.00- 1.00	Sandy clay
1.00- 2.00	Grey silt
2.00- 3.50	Dark grey sandy clay
3.50- 7.04	Hard fresh rhyolite, clay filled joints
7.04-10.32	Broken versicular rhyolite
10.32-17.81	Hard fresh rhyolite, few clay filled joints
17.81-20.10	Baked earth
20.10-22.85	Hard fresh rhyolite
22.85-25.30	Hard fresh and versicular baked rhyolite
25.30-30.69	Broken versicular basalt and scoria-tuff mixture (impervious)
30.69-32.00	Hard fresh rhyolite
32.00-35.60	Scoria and tuff-tuff mixture (impervious)
35.60-43.00	Broken scoria (permeable)
43.00-46.85	Hard fresh rhyolite and broken scoria
46.85-52.37	Hard fresh rhyolite

Bore 112 (Approximate R.L. 580)

3.00-12.20	Hard fresh rhyolite few ironstained joints
12.20-12.45	Baked Earth
12.45-19.22	Scoria-tuff mixture
19.22-22.20	Basalt and rhyolite, 2 cm clay seam dip 75^{o}
22.20-24.40	Hard fresh rhyolite
24.40-26.00	Broken scoria-clay mixture
26.00-33.00	Hard fresh rhyolite
33.00-33.70	Baked earth and scoria
33.70-35.60	Hard fresh rhyolite broken
35.60-37.49	Hard fresh rhyolite
37.49-40.57	Scoria (porous), 2 x 1 m rhyolite beds
40.57-59.60	Hard fresh rhyolite (one section broken weathered)

Bore 113 (Approximate R.L. 580)

3.05- 5.19	Weathered basalt and clay
5.19- 7.75	Hard rhyolite, clay seams broken
7.75-10.20	Scoria-tuff mixture (impermeable)
10.20-34.20	Hard fresh rhyolite. Few clay seams
34.20-37.50	Red scoria-tuff mixture (some porous)
37.50-39.97	Hard fresh rhyolite

Bore 114 (Approximate R.L. 597)

6.50-10.00	Weathered basalt and tuff
10.00-12.80	Scoria-tuff mixture (impermeable)
12.80-15.00	Hard fresh rhyolite, clay seams
15.00-15.20	Baked red earth, versicular rhyolite
15.20-36.05	Scoria-tuff mixture and rhyolite flows
36.05-41.00	Hard fresh rhyolite, clay joints. Scoria-tuff mix at base

Bore 115 (Approximate R.L. 587)

0.00- 2.93	Brown clayey silt
2.93- 3.00	Broken basalt
3.00- 4.00	Black scoriaceous basalt
4.00- 6.00	Basalt with clay filled joints
6.00- 8.00	Broken basalt
8.00-15.00	Hard fresh basalt, versicular and broken, clay seams
15.00-19.35	Versicular basalt, scoria-tuff mix. clay joints
19.35-22.50	Hard fresh basalt, three broken areas
22.50-30.50	Hard fresh basalt, ironstained joints
30.50-35.15	Red and grey scoria and versicular basalt, 45° contact, porous
35.15-38.00	Hard fresh basalt, clay filled joints
38.00-45.00	Hard fresh basalt
45.00-55.00	Basalt and clay beds

Bore 116 (Approximate R.L. 577)

0.00- 1.00	Grey sandy clay
1.00- 4.00	Grey sand
4.00-10.00	Grey sand and clayey silt
10.00-15.70	Hard fresh rhyolite, ironstained joints
15.70-18.00	Scoria-tuff mix (impermeable)
18.00-23.00	Hard fresh rhyolite
23.00-29.00	Scoria-tuff mix, and hard fresh rhyolite beds
29.00-31.00	Hard fresh rhyolite
31.00-35.00	Scoria-tuff mix. (impermeable)

Bore 117 (Approximate R.L. 572)

0.50- 1.50	Grey silty clay
1.20- 2.00	Brown sand
2.00- 2.50	Scree
2.50- 3.00	Gravel
3.00- 4.00	Scree and gravel
4.00- 5.00	Grey sandy clay
5.00-10.00	Grey clayey silt with boulders
10.00-12.80	Grey clay and cemented sandstone
12.80-14.00	Gravel, last in mudstone and siltstone
14.00-18.90	Sandstone and mudstone friable, consolidated
18.90-21.49	Mudstone, sandstone, cemented conglomerate
21.49-24.59	Cemented conglomerate
24.59-30.50	Sandstone and mudstone, Dip. 7°
30.50-32.00	Cemented conglomerate
32.00-35.40	Rhyolite and conglomerate beds. Contact Dip 25°
35.40-37.00	Mudstone and sandstone
37.00-40.50	Hard fresh rhyolite
40.50-50.50	Rhyolite-tuff-breccia, 1 basalt flow, 1 conglomerate boulder

Bore 117A

0.00- 1.00	Brown clay
1.00- 2.00	Clay and scree
2.00- 3.30	Dark grey clayey silt
3.30- 3.70	Grey silty sand
3.70- 3.80	Dark grey sand
3.80- 4.20	Grey silty sand, water 4.20
4.20- 4.50	Brown clayey silt
4.50- 4.80	Dark grey sand
4.80- 5.00	Grey clay, silt and gravel
5.00- 5.40	Grey clay
5.40- 6.27	Grey silt and clay
6.27-10.80	Gravel, 3", and sand
10.80-12.90	Grey silt
12.90-13.80	Sand and gravel
13.80-14.30	Dark grey silty gravel
14.30-15.55	Grey silt

Bore 118 (Approximate R.L. 581)

0.00- 1.20	Light brown clay
1.20- 1.50	Brown clayey sand
1.50- 1.60	Brown sandy clay
1.60- 2.75	Dark grey sand and clay
2.75- 4.00	Grey fine sand
4.00- 5.00	Brown silty sand
5.00- 5.10	Gravel, 3"
5.10- 7.00	Grey gravel, 1"
7.00- 7.33	Dark grey clay
7.33- 8.30	Grey sandy gravel
8.30-14.20	Cemented conglomerate, sandstone, 2 m of gravel-silt and clay to 14.00
14.20-16.46	Grey clay
16.46-25.32	Siltstone and mudstone. Compacted friable
25.32-29.80	Siltstone and mudstone and sandstone
29.80-50.04	Siltstone and mudstone and sandstone and 10 cm cla

Bore 119 (Approximate R.L. 579)

0.00- 2.00	Dark grey silty clay
2.00- 4.00	Grey sand
4.00- 6.00	Grey silty sand
6.00- 8.00	Grey sandy gravel
8.00-10.00	Brown sandy clay
10.00-15.20	?
15.20-24.40	Siltstone and mudstone friable
24.40-29.70	Rhyolite and cemented conglomerate
29.70-35.50	Scoria-tuff mix (impermeable)

Bore 121 (Approximate R.L. 618)

5.40-14.00	Cemented conglomerate, 10 cm sandstone at 6 m
14.00-15.00	Sandstone and conglomerate
15.00-18.17	Siltstone and mudstone
18.17-18.60	Mudstone
18.60-20.70	Sandstone and cemented conglomerate, Dip. 3^{o}
20.70-27.00	Sandstone

Bore 122 (Approximate R.L. 618)

0.00- 1.50	Light grey clay silt and grey clayey sand
1.50- 3.00	Dark grey clayey sand
3.00- 4.00	Dark grey silty sand
4.00- 7.30	Dark grey sandy gravel 2"
7.30- 8.70	Grey sandy silt
8.70-10.00	Grey clayey silt
10.00-12.07	Grey silt, clay, and sand
12.07-12.86	Grey clay silt
12.86-13.00	Boulders and scree
13.00-18.35	Sandstone and conglomerate beds with siltstone and mudstone
18.35-21.10	Siltstone and mudstone
21.10-23.15	Siltstone and hard sandstone
23.15-26.20	Conglomerate, sandstone and mudstone
26.20-27.50	Conglomerate
27.50-31.00	Siltstone and mudstone
31.00-35.33	Conglomerate

Bore 123 (Approximate R.L. 570)

0.00- 1.30	Boulders and scree
1.30- 2.10	Dark grey sand
2.10- 2.90	Boulders
2.90- 3.25	Grey silty clay
3.25- 3.60	Grey clay
3.60- 4.75	Grey sand and scree (water)
4.75- 5.25	Grey silty clay
5.25- 6.80	Basalt scree and clay
6.80- 7.00	Red brown clayey sand
7.00- 7.70	Red brown clay and scree
7.70- 8.15	Red brown sandy clay
8.15- 8.20	Red brown sand
8.20- 9.50	Consolidated breccia
9.50-11.90	Hard fresh basalt two soft seams
11.90-13.00	Scoria-tuff mix (impermeable)
13.00-17.00	Hard fresh basalt clay filled joints (bottom of flow)
17.00-18.75	Scoria-tuff mix (impermeable)
18.75-24.00	Hard fresh basalt - two flows - clay and versicular basalt
24.00-24.50	Weathered bottom of flow
24.50-34.65	Rhyolite and scoria-tuff mix (impermeable)

Bore 124 (Approximate R.L. 579)

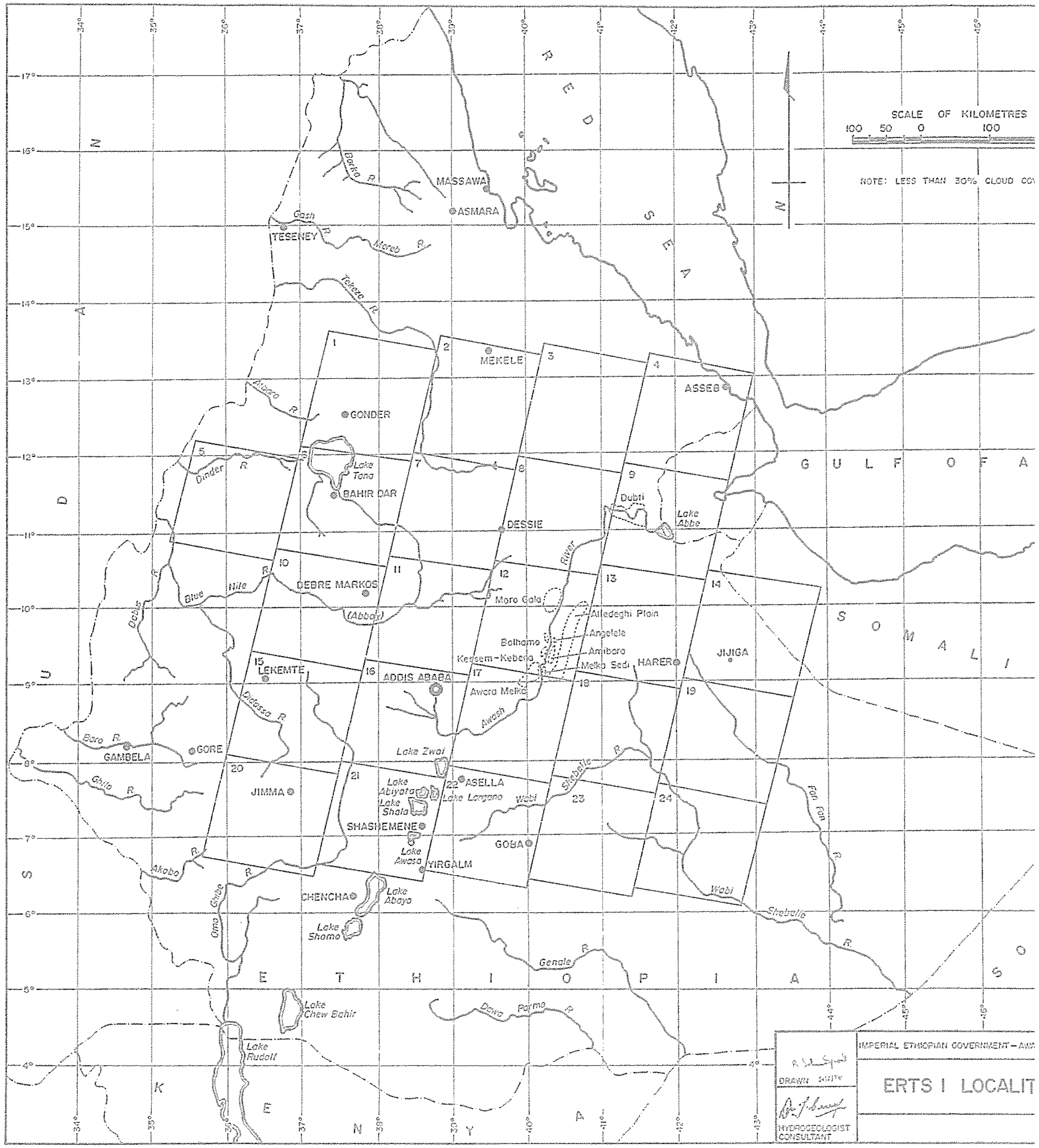
0.00- 1.00	Dark grey silty sand
1.00- 3.50	Dark grey sand
3.50- 4.00	Sand and gravel
4.00- 6.00	Brown sand
6.00- 6.40	Light grey clay
6.40-15.50	Cemented conglomerate
15.50-35.00	Siltstone and mudstone (friable)

Bore 125 (Approximate R.L. 575)

0.00- 2.00	Dark grey sand
2.00- 2.10	Brown clay
2.10- 4.27	?
4.27- 6.00	Hard fresh basalt - scoria (permeable)
6.00- 6.50	Baked earth
6.50-11.85	?
11.85-16.75	Hard fresh rhyolite, scoria beds, 4 cm
16.75-19.90	Hard fresh rhyolite, clay filled joints, 70° and horizontal

Bore 126

3.05- 9.48	Hard fresh basalt
9.48-19.85	Broken basalt, versicular, clay seams
19.85-31.00	Hard fresh rhyolite
31.00-32.50	Baked clay
32.50-59.80	Hard fresh rhyolite
59.80-60.00	Broken scoria


SCALE OF KILOMETRES
100 50 0 100
NOTE: LESS THAN 30% CLOUD CO
N
RED SEA
GULF OF A
SOMALI
ETHIOPIA
SUDAN
KENYA
MASSAWA
ASMARA
TESENEY
Gash R
Mareb R
Barka R
Tekeze R
Atbara R
MEKELE
GONDER
ASSEB
Lake Tana
BAHIR DAR
Dinder R
DESSIE
Dubti
Lake Abbe
DEBRE MARKOS
Blue Nile R
(Abbai)
Dabus R
Moro Gola
Alledeghi Plain
Angelele
Bolhamo
Amibara
Kessem-Kebena
Melka Sedi
HARER
JIJIGA
LEKEMTE
ADDIS ABABA
Awara Melka
Awash
River
Didessa R
Baro R
GAMBELA
GORE
Ghiba R
JIMMA
Lake Zwai
ASELLA
Lake Abiyata
Lake Shala
Lake Langano
SHASHEMENE
Lake Awasa
YIRGALM
GOBA
Wabi Shebelle R
Fafan R
Akobo R
Omo Ghibe R
CHENCHA
Lake Abaya
Lake Shomo
Genale R
Dawa Parma R
Lake Chew Bahir
Lake Rudolf
IMPERIAL ETHIOPIAN GOVERNMENT – AWA
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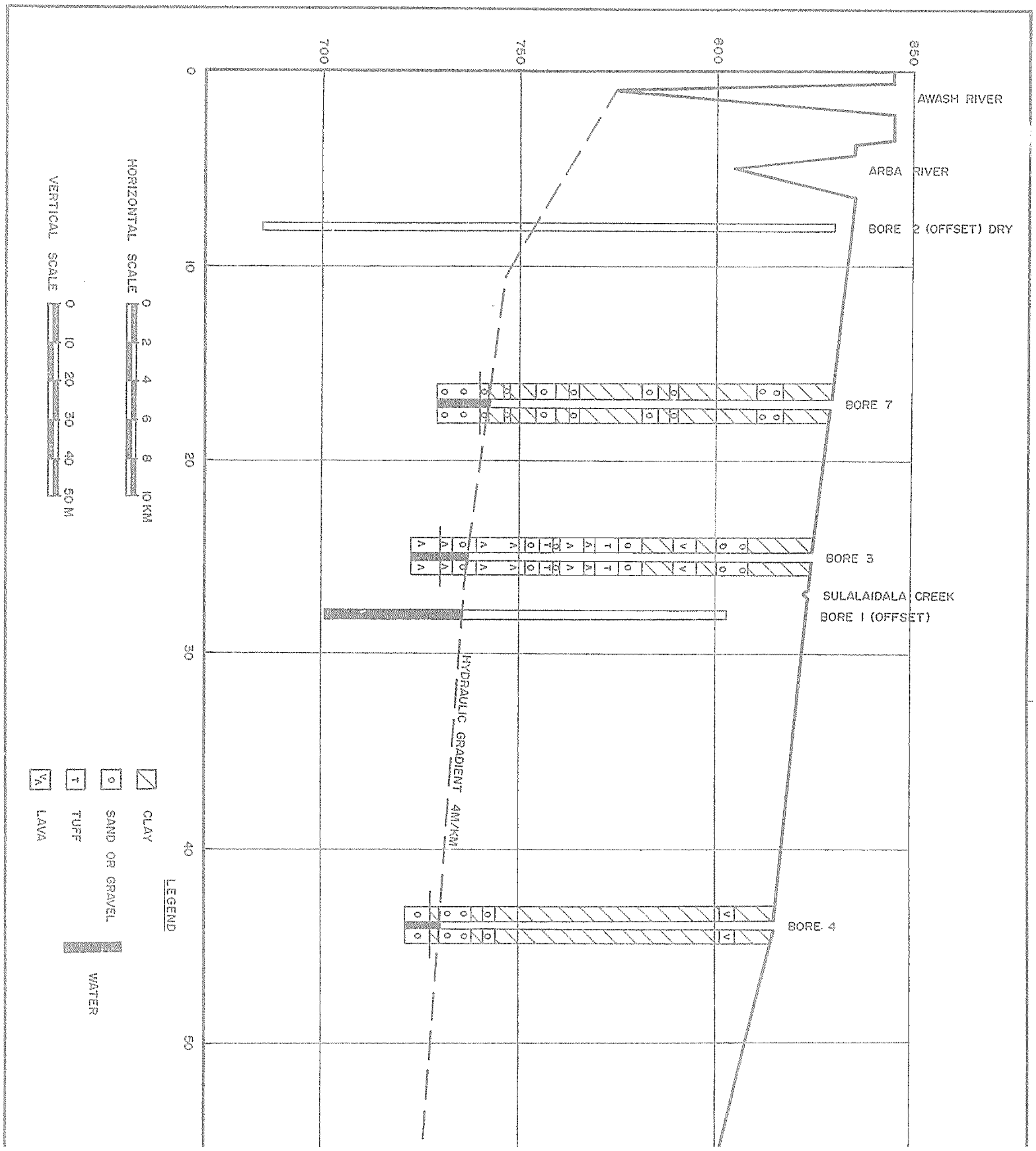
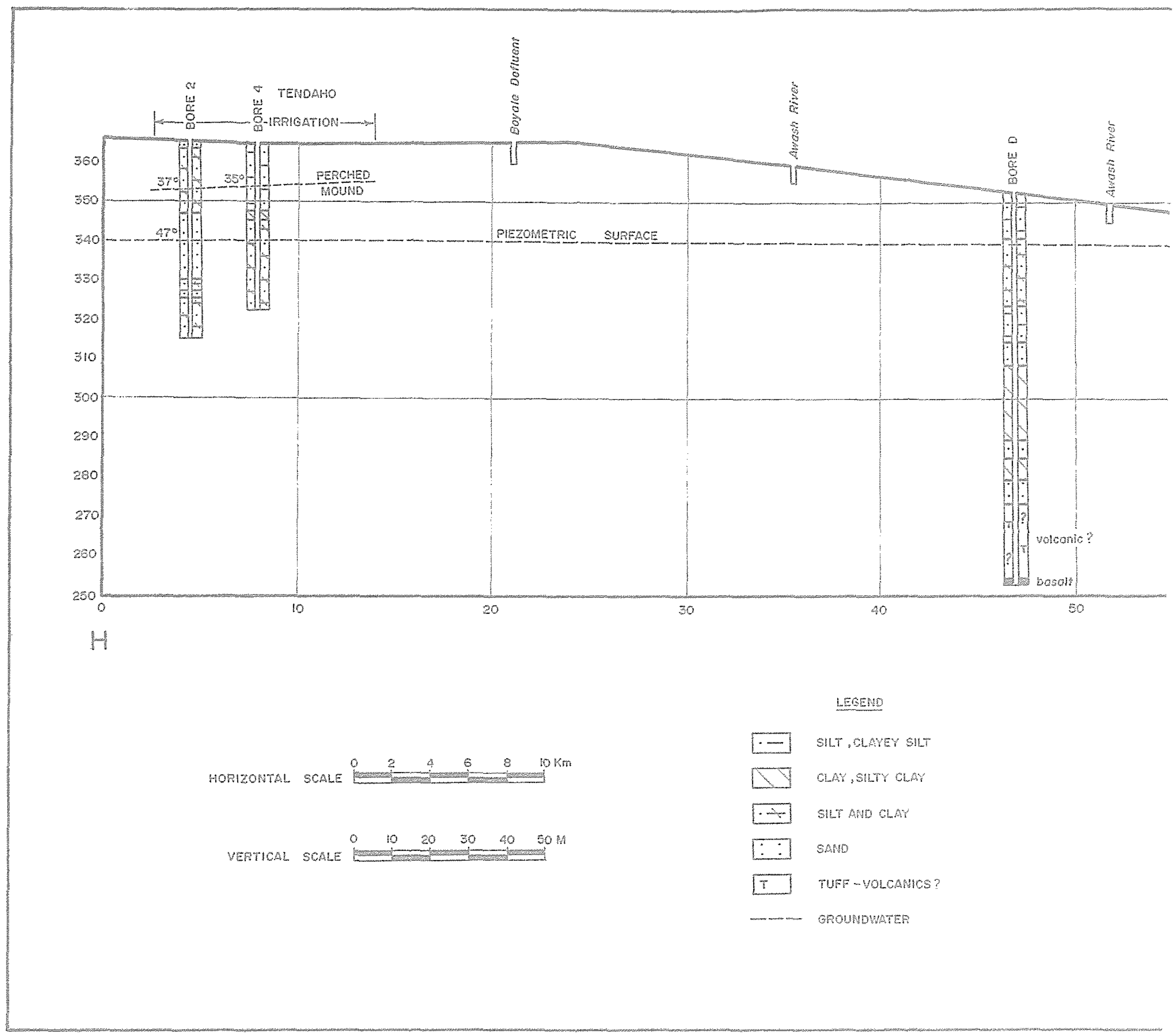
DRAWN
HYDROGEOLOGIST CONSULTANT



AWASH RIVER
ARBA RIVER
BORE 2 (OFFSET) DRY
BORE 7
BORE 3
SULALAIDALA CREEK
BORE I (OFFSET)
BORE 4
HYDRAULIC GRADIENT 4M/KM
700
750
800
850
0
10
20
30
40
50
HORIZONTAL SCALE
0 2 4 6 8 10 KM
VERTICAL SCALE
0 10 20 30 40 50 M
LEGEND
CLAY
SAND OR GRAVEL
TUFF
LAVA
WATER


TENDAHO
IRRIGATION
BORE 2
BORE 4
37°
35°
47°
PERCHED MOUND
Boyale Defluent
Awash River
BORE D
Awash River
PIEZOMETRIC SURFACE
volcanic ?
basalt
360
350
340
330
320
310
300
290
280
270
260
250
0
10
20
30
40
50
H
HORIZONTAL SCALE
0 2 4 6 8 10 Km
VERTICAL SCALE
0 10 20 30 40 50 M
LEGEND
SILT, CLAYEY SILT
CLAY, SILTY CLAY
SILT AND CLAY
SAND
TUFF - VOLCANICS ?
GROUNDWATER

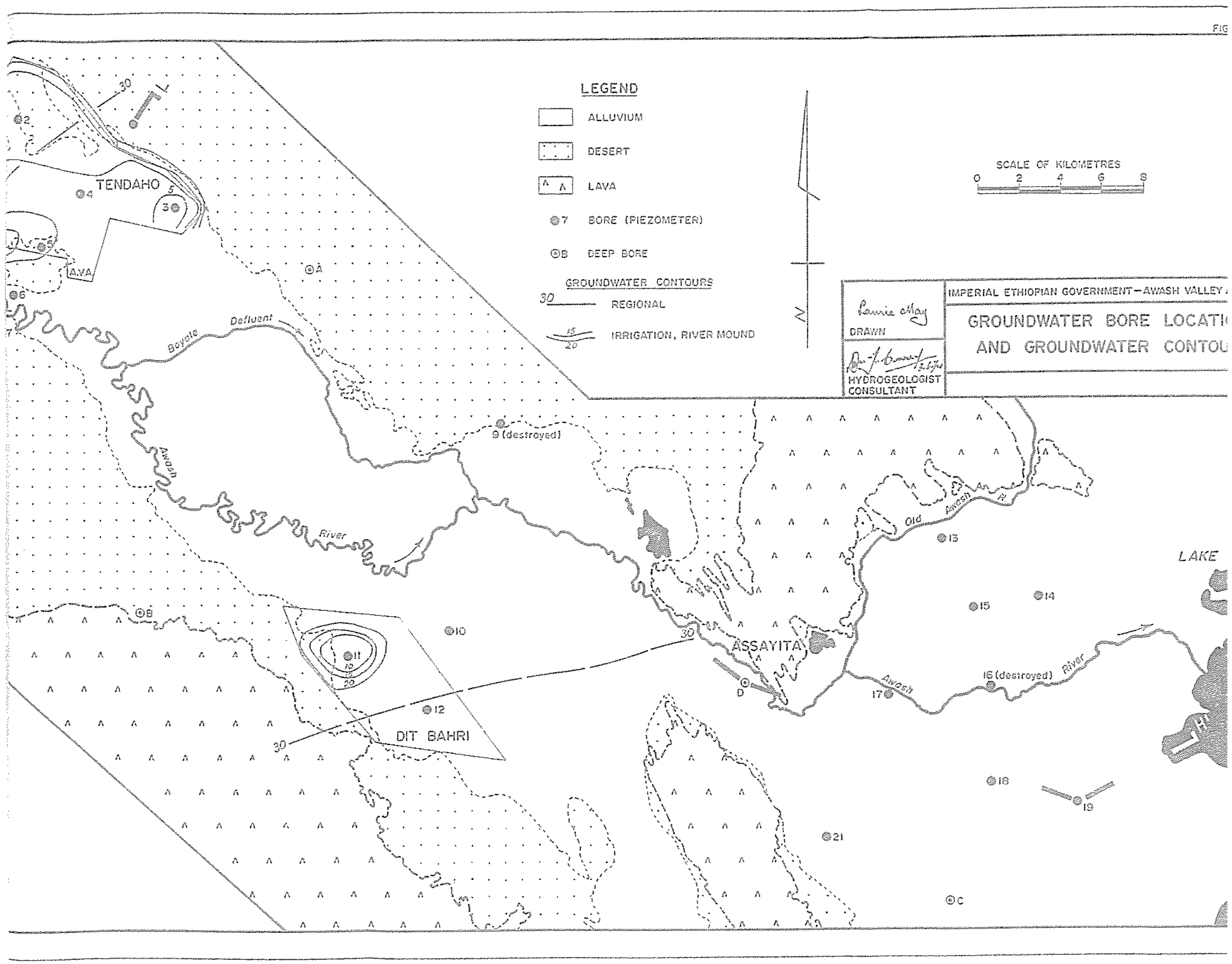


FIG
LEGEND
ALLUVIUM
DESERT
LAVA
7 BORE (PIEZOMETER)
B DEEP BORE
GROUNDWATER CONTOURS
30 REGIONAL
15 20 IRRIGATION, RIVER MOUND
N
SCALE OF KILOMETRES
0 2 4 6 8
IMPERIAL ETHIOPIAN GOVERNMENT—AWASH VALLEY
GROUNDWATER BORE LOCATI
AND GROUNDWATER CONTOU
DRAWN
HYDROGEOLOGIST
CONSULTANT
TENDAHO
AVA
Boyale Defluent
Awash River
9 (destroyed)
Old Awash R.
LAKE
ASSAYITA
DIT BAHRI
16 (destroyed)
Awash River