LAND AND WATER RESOURCES OF THE BLUE NILE BASIN

ETHIOPIA

APPENDIX IV - Land Classification

Prepared for the Department of State
Agency for International Development

By the United States Department of the Interior
Bureau of Reclamation
1964

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BLUE NILE BASIN

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APPENDIX IV - Land Classification

United States

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ABBREVIATIONS, CONVERSION FACTORS, AND ETHIOPIAN MONETARY AND CALENDAR EQUIVALENTS

Abbreviations:

EELPA = Ethiopian Electric Light and Power Authority
IEG = Imperial Ethiopian Government

Conversion Factors: Metric-English Systems

1 meter (m.) = 39.37 inches = 3.2808 feet
1 kilometer (km.) = 0.6214 mile = 3,280.8 feet
1 square meter (sq. m.) = 1.196 square yards = 10.764 square feet
1 hectare (ha.) = 10,000 square meters = 2.471 acres = 1/100 square kilometer
1 hectoliter = 0.1 cubic meter = 2.838 bushels; 26.417 gallons
1 square kilometer (sq. km.) = 0.3861 square mile = 100 hectares = 247.1 acres
1 cubic meter (cu. m. or m^3) = 1,000 liters = 1.308 cubic yards = 35.31 cubic feet
1 cubic meter = 0.000,810,7 acre-foot
1 acre-foot = 1,233 cubic meters
1 kilogram (kg.) = 2.204 pounds
1 kilogram per hectare (kg/ha) = 0.8926 pound per acre
1 metric ton = 2,204 pounds = weight of 1 cubic meter of water
1 kilogram per square centimeter (kg./sq. cm.) = 14.22 pounds per square inch = 32.8 feet of water
1 cubic meter per second (m^3/s.) = 35.31 cubic feet per second (c. f. s.)
1 English horsepower = 550 foot-pounds per second
1 metric horsepower = 75 kilogram-meters per second
1 metric horsepower = 0.9863 English horsepower = 735.45 watts
1 cubic meter of water per second under 1 meter head = 9.81 kilowatts at 100 percent efficiency
1 million cubic meters of water under 1 meter head = 2,730 kilowatt-hours at 100 percent efficiency

Temperature Conversion:

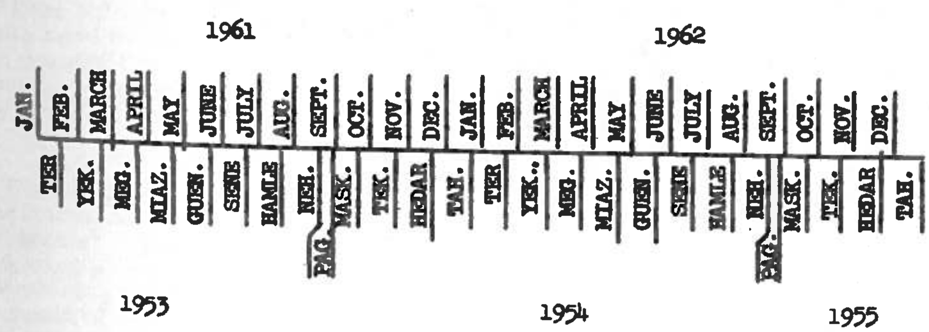
Centigrade: $C. = \frac{5}{9}(F^\circ - 32)$ Fahrenheit: $F. = \frac{9}{5}C^\circ + 32$

Ethiopian-United States Monetary Values: Rate of exchange used in this report
1 United States dollar (US$1.00) = 2.50 Ethiopian dollars (Eth$2.50)

Ethiopian Calendar (30-day months, except Pagume):

Maskaram	= Sept. 11 - Oct. 10	Miazia	= April 9 - May 8
Tekemt	= Oct. 11 - Nov. 9	Guenbot	= May 9 - June 7
Hedar	= Nov. 10 - Dec. 9	Sene	= June 8 - July 7
Tahessas	= Dec. 10 - Jan. 8	Hamle	= July 8 - Aug. 6
Ter	= Jan. 9 - Feb. 7	Nehasse	= Aug. 7 - Sept. 5
Yekatit	= Feb. 8 - March 9	Pagume	= Sept. 6 - Sept. 10
Megabit	= March 10 - April 8		

UNITED STATES OR GREGORIAN CALENDAR



ETHIOPIAN CALENDAR

TRANSLITERATION

Certain inconsistencies in the spelling of names may be noted on maps and drawings and in the text. Because of the difficulty in transliterating Arabic, Amharic, Galla, and Italian into exact English equivalents, some variation of spellings and even in names occurs in the basic maps and drawings. It will be noted, however, that the phonetic pronunciation of names is similar regardless of spelling, except in the rare situation where an entirely different English name is used because of long established convention. An example of the latter is the name for the principal river, Blue Nile, which in Amharic is known as Abbay (Abbai). Addis Ababa is often referred to as Addis Abeba. Other examples are as follows:

Tvol	Tul
Lekkemt	Nekemti
Acachi	Akaki
Jima	Jimma, Gima
Langano	Langana
Shashamane	Shashamana
Shewa	Shoa
Welaka	Votaka

In western and northwestern Ethiopia, local usage of Arabic words for streams and mountains is usually retained. For example, "Jebel" denotes mountain and "Khor" identifies a watercourse. In addition, the English name or abbreviation sometimes precedes the Arabic term, as with "Mt. Jebel Kir."

Local usage sometimes requires different names along different lengths of the same river. For example, the Guder River is known as Tacur, Bello, and Guder.

Wherever possible, a consistent spelling has been used for identical places in this report.

BLUE NILE BASIN

GENERAL LAND CLASSIFICATION INFORMATION

INTRODUCTION

The land classification work described in this appendix was part of the investigations made for irrigation development in the Blue Nile Basin of Ethiopia by the U. S. Bureau of Reclamation. The work was accomplished during the period 1959-1962. Mr. Howard J. Ferris, Supervisory Soil Scientist, was in charge of the land classification investigations. Mr. Ferris was killed in a helicopter crash in 1961, and the land classification was completed by his assistant, Mr. Robert G. Thrailkill, Supervisory Soil Scientist. Throughout the land classification studies, Ato Zaudi Telehune and other subprofessional assistants were assigned to the classification work by the Ethiopian Government. The able assistance of these Ethiopian technicians was greatly appreciated and contributed material assistance in the classification program.

The methods used in the land classification were quite similar throughout the area of investigation; therefore, much of the general information is not repeated for each individual area, but is presented in the following pages ahead of the information relating to each project area.

LAND CLASSIFICATION

General Information

The Blue Nile River Basin in Ethiopia comprises an area of about 203, 900 square kilometers with widely diverse physical characteristics. No basic soil survey data are available, and only very few soil borings have been made prior to this investigation in the Blue Nile Basin. Road facilities are very poor throughout most of the area. Because of the need to furnish land quality data quickly to an investigation team studying irrigation possibilities in an area where essentially no information existed, subreconnaissance procedures of investigation were adopted for the land classification. The accuracy of this technique is fairly low, but is believed to be generally in the range of 60-65 percent.

The most important purpose of the classification was to delineate the lands which are considered satisfactory for irrigation development. The classification designated lands as "arable" which are believed to be suitable for irrigation. Lands not suitable for irrigation are considered as "nonarable." The fundamental considerations involved in determining whether or not lands are arable includes the production capacity of the lands, the costs of crop production, and the land development costs associated with the soils, topography, and drainage factors.

The soils factor, with its many physical characteristics, is the basic resource evaluated in estimating productivity and suitability for irrigation. To be suitable, the soil should have a reasonably high available water-holding capacity, a satisfactory infiltration rate to permit adding water to the soil reservoir as needed, good tilth to permit deep root penetration and ample aeration for crop production, adequate drainage to avoid the accumulation of excess water on the surface or within the root zone, freedom from excessive salinity, alkalinity or acidity, and have an adequate supply of plant nutrients. The desired soil conditions can be correlated with such physical characteristics as color, texture, structure, depth, density, pore size distribution, and other factors.

The topographic factor is related to costs of land development, productivity, and cost of irrigation. It is usually evaluated by an appraisal of the slope, the character of surface relief, and the position. The type of tree cover also is considered to be a topographic feature. In this classification, correctable topographic deficiencies such as the amount of tree cover or needed land leveling have been disregarded in appraising the relative suitability of each tract of land for irrigation except for exclusion of very rough lands. Thus, lands considered suitable for irrigation development may require clearing and leveling but the development can be accomplished by a reasonable investment. Noncorrectable deficiencies such as slope have contributed most in determining the suitability of the topography for irrigation. This factor is of particular significance in the selection of the irrigation method, in planning the cropping systems, and in evaluating the needs for erosion control. The position factor was also considered. Any isolated or excessively high tract that could not be readily reached by gravity diversions was considered nonarable. However, there were insufficient data to delete all of the high areas.

Figure IV-1 - Helicopters afforded the only suitable means of transportation for land classification teams in much of Ethiopia. Soil samples were analyzed at the Imperial Ethiopian College of Agriculture and Mechanic Arts.

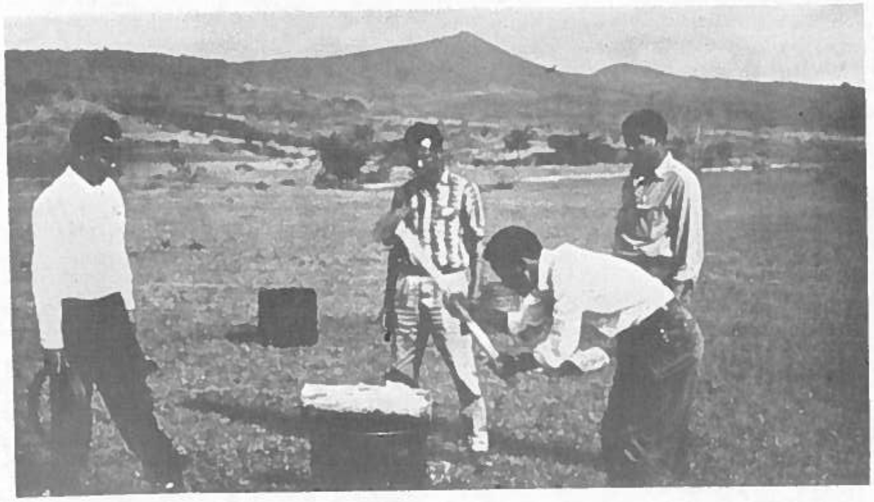


Figure IV-2 - Ethiopian land classification crew prepares for infiltration rate measurement by sinking test cylinder in ground.

The drainage factor is important, but was largely ignored in this classification because of the lack of time. A drainage study requires numerous deep borings, many field observations of present water table conditions, and in-place permeability tests. The latosol soils are generally well drained, and the grumusol soils generally have restricted internal drainage. Further study is needed to determine how this deficiency will affect crop yield, crop distribution, and irrigation suitability on these soils. Additional surface drainage facilities are needed on some lands. This can generally be achieved with a reasonable cost so it has not been considered in appraising the suitability of lands for irrigation, except on those lands which are obviously in too low a position to be drained.

Land Classes

Class 1--Arable. This class was used on a number of project areas, but not on all. These are the lands which are highly suited for irrigation. Such lands, when irrigated, should produce the highest net profit, have the highest yields, and should be adapted to the widest range of crops. These lands have good internal drainage, high water-holding capacities, and are free from harmful accumulations of salt. The topography is generally smooth and has a low gradient. Such lands are often covered with a dense bamboo forest in the Blue Nile Basin, but they are potentially excellent for irrigation. They represent only 7.2 percent of the irrigable area.

Class 2--Arable. These lands are not as good as Class 1, but are still very well adapted to irrigation. Within the Blue Nile Basin most of the Class 2 lands have latosol soils, are covered with an open forest, and have a slope of 3-5 percent. Although these lands are adaptable to about the same crops as Class 1 lands, they are more difficult to manage, will require more irrigation water control structures, and will yield less than the Class 1 lands. Irrigation methods may differ from Class 1 lands because of the generally steeper slope. These lands represent 24.6 percent of the total irrigable area.

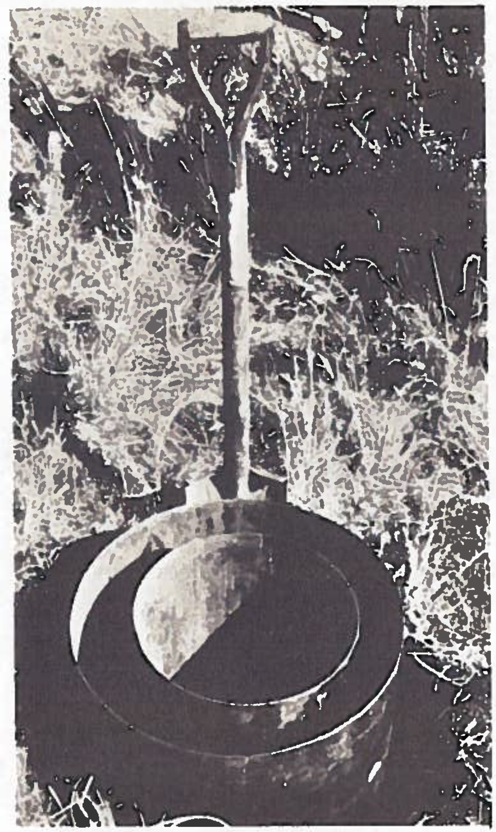


Figure IV-3 - Infiltration rate test cylinders are used to determine rate at which soil will accept irrigation water.

Class 3--Arable. Lands included in this class are least desirable for irrigation, but can be expected to produce satisfactorily if properly managed. Within the Blue Nile Basin, the largest percentage of Class 3 lands have grumusol soils with fairly smooth topography. A small percentage, but a substantial area, are steep lands (5 to 12 percent). The latter type lands generally have latosol soils, but will require good management to prevent excessive erosion. There is a greater risk in farming Class 3 lands than the better classes, and it may require larger farms to produce a satisfactory living standard.

Class 6--Nonarable. Lands included in this class are unsuitable for sustained irrigation. Most of the lands designated as Class 6 in this subreconnaissance classification are too steep or too rough for irrigation. A small amount of unusually tight clays have also been placed in this class. It can be anticipated that detailed studies will increase the amount of Class 6 land. This will be due to more refined soil studies, and to a more critical examination of topographic features.

Types of Classification

There are three usual types of land classification performed by the Bureau of Reclamation--reconnaissance, semidetailed, and detailed. The classification performed for the Blue Nile Basin studies is a fourth type and is called subreconnaissance. This means it is less accurate than a normal reconnaissance-type survey. A brief description of these general types of classification should clarify the expected accuracy of a subreconnaissance classification.

A detailed land classification involves examination of land features in sufficient detail to provide accurate information concerning the extent of various types of land in each 16-hectare tract. Basic data with respect to various soil and subsoil conditions, topography, and drainage are obtained in detail for the purpose of determining proper land use, size of farm units, payment capacity, irrigable area, irrigation requirements, irrigation and drainage system, land development needs, and irrigation benefits. This type of classification is normally accomplished on maps having a scale of 1:4,800. Traverses are made at about 400-meter spacings and at least one soil boring is made on each 16 hectares. The rate of progress on this type of classification is about 65-75 hectares per man day. Accuracy should be 97 to 100 percent.

Semidetailed land classification involves careful examination of land features at 700- to 800-meter spacings. Separations between arable and nonarable are done with considerable accuracy, but boundaries between land classes are delineated in less detail. This type of classification is usually delineated on maps having a scale of 1:12,000. Soil profiles are examined at least once in every 60-70 hectares. The rate of progress on a semidetailed classification is usually about 250-500 hectares per day. An accuracy of 90 percent is normal.

Reconnaissance land classification involves a general outline of land features of conspicuous importance in preliminary planning of irrigation development. These surveys are normally accomplished on maps having a scale of 1:24,000. Traverses are usually made at about 1,500-meter spacings and soils are examined and sampled at least once in every 250 hectares. If transportation facilities are good, a man can classify about 800 hectares a day and secure an accuracy of about 75 percent.

Methods Used in Blue Nile Land Classification

Roads are so scarce in the Blue Nile Basin that it was not possible to accomplish a conventional reconnaissance land classification in the time available, therefore, a sub-reconnaissance classification was made using helicopters as the principal means of transportation.

The base maps consisted of aerial photographs (contact prints) having a scale of approximately 1:50,000. These photos were badly distorted and subsequent studies of project areas using topographic maps with accurate horizontal control showed that most land areas were larger than indicated by the photo measurements. Photo corners are shown on land class maps throughout this report. Wherever data were available the project maps were corrected for the distortion present in the original photos. It can be anticipated that errors will result from this correction.

Traverses were made at spacings of 1 to 2 kilometers and land features examined at treetop height while cruising at relatively low speeds. Due to the prevalence of a forest cover over most of the basin, it was not possible to make landings to secure the desired number of soil borings. In some instances soil borings may be 10 to 20 kilometers apart. This is not good and the lack of soil information can contribute to major changes in arable acreages when more refined data are available.

A limited number of soil samples were collected for pH, soluble salts, lime, and other analyses. These were sent to the Imperial Ethiopian College of Agriculture and Mechanical Arts for the analyses.

In most instances fertility studies, including organic matter, available phosphorus, potassium and calcium were also made. These data are shown with the soil profile descriptions on maps of the various proposed project areas.

Following the traverses made with the helicopters in which delineations were made in the line of travel, connecting lines between traverses were made by stereoscopic study of the aerial photos. This was done in camp.

Land Classification Specifications

Field appraisal of land characteristics for irrigation suitability must be based on carefully selected and interpreted physical characteristics. This necessitates the establishment of minimum physical specifications for each land class. Such specifications should preferably be based on actual irrigation experience with accurate economic data and should be supported by farm budget studies to show how much money farms can net from various types of lands occurring within the project area. Costs of water should also be known so that lower limits of arability can be established. Basic economic data relating to crop adaptability, the productive capacities of various soils under irrigation, reliable costs of land development, and costs of irrigation water are not available. Therefore, it was not possible to develop a set of land classification specifications which are well supported by economic analyses. The specifications which were used are based on irrigation experiences in countries other than Ethiopia and therefore may need revision before any detailed studies are started. The upper limit of permissible slope was 12 percent. This slope was used because much steeper slopes are dry farmed with success even though subjected to intensive rainfall. However, there is evidence of severe erosion in some areas and irrigation will accelerate this. It seems likely that slope limits should be associated with the methods of irrigation. With the exception of some sprinkler irrigation, most successful irrigation in the United States is on slopes of less than 8 percent. Table IV-1 shows the land classification specifications which were used in the Blue Nile Basin.

In establishing the specifications it was assumed that land leveling and clearing of trees would be a project cost rather than a farmer cost. Therefore, the estimated average development costs shown in project discussions reflect costs for all land classes rather than a variable cost by land class. If in future classification work the decision is made that all land development costs should be a farm cost, there will be a need to adjust these specifications to provide an upper limit of cost which may be incurred within any land class.

GENERAL SOILS INFORMATION

Introduction

Very little irrigation experience is available on tropical soils other than with rice, cotton, sugarcane, and a few other specialty crops. Experience which is available has not been widely disseminated and there is a lack of knowledge regarding the productivity of such soils under various types of management and for a wide variety of crops.

The soils in the Blue Nile Basin are generally either latosols or grumusols. These soils have vastly different physical characteristics. The latosols are obviously excellent soils for irrigation but generally occur on steep rolling topography. The grumusols are less suitable for irrigation, but usually occur on smooth topography which is easily adapted to irrigation.

Latosols--Reddish brown latosols are well-drained upland soils which offer excellent possibilities for irrigation development. Because of their inherent permeability and free-draining characteristics, these soils are suitable for an unusually wide variety of crops. Any crop, with the possible exception of rice, can probably be grown on these soils. The only limitation of crop adaptability will be climate. Tobacco seems to be particularly well adapted.

Latosols are composed of nonexpanding or 1:1 lattice clay minerals and therefore have physical characteristics which are much different than is suggested by their high clay content. The usual great depth and high porosity of these soils are favorable to root development. Shallow latosols (i. e., less than 150 cm. to bedrock) are extremely erosive, but deep latosols are moderately resistant to erosion.

Fertility is normally medium to very low because the high permeability has resulted in excessive leaching. The use of organic and inorganic fertilizer is essential for successful irrigated crop production in these soils.

TABLE IV-1. SUBRECONNAISSANCE LAND CLASSIFICATION SPECIFICATIONS--BLUE NILE BASIN

Land characteristics	Class 1 arable	Class 2 arable	Class 3 arable	Class 3 arable
Soils	Latosols only	Latosols only	Latosols only	Grumusols only
Texture	Sandy loams to friable, very permeable clay of low plasticity	Loamy sand to permeable clay of low plasticity	Loamy sand to permeable clay of low plasticity	Highly plastic clay of very low permeability with cracking characteristics
Minimum depth (in cm.)				
To bedrock	150	105	75	--
To volcanic tuff	120	90	60	--
To sand, gravel, quartz fragments, or cobble	90	60	45	--
Topography				
Max. slope (percent)				
Uniform	3.0	7.0	12.0	5.0
Nonuniform	--	3.0	7.0	3.0
Min. slope (percent)	--	--	--	0.5
Surface				
Smoothing and grading	Low to moderate grading	Moderate grading	Moderate to heavy grading necessary	Moderate grading necessary
Clearing				
Cover--Loose stones and/or vegetation Removal cost	Low to moderate	Moderate	Moderate to heavy	Slight to moderate
Drainage				
Amount anticipated	None	Moderate	Moderate	(Surface only) Moderate

The properties and characteristics of the latosols are generally as follows:

1. The color is red to reddish brown, with yellow colors in the substratum of some profiles.

2. Horizon differentiation is rather indistinct and there is a gradual transition between horizons.

3. The structural elements are often granular and when larger structural development is observed, it is weak and easily broken into granular structure.

4. The consistency when dry is soft, but friable when moist, and nonsticky when wet.

5. Soil density is fairly low, porosity is high, and permeability is high.

6. Cation exchange capacity is moderate--being about the same as the-percentage of 2-micron clay.

7. Soils are mostly clay textures that have a friability and consistency much like a loam or light silty clay loam in a soil in the chernozen soil areas.

Grumusols--Most of the present irrigation in the Blue Nile Basin is on grumusol soils--probably because these soils usually occur on smooth plains which are easy to level and prepare for irrigation. A great deal of variation in soil characteristics may be anticipated in the grumusol soil group, and physical characteristics may vary from those nearly as good as a latosol to those which are nearly impervious to water. Insufficient data are available from this study to characterize these soils properly and accurately. However, some general characteristics can be stated with reasonable accuracy. These are as follows:

Figure IV-4 - Ethiopian latosols are typically reddish in color and offer better opportunities for successful agriculture.

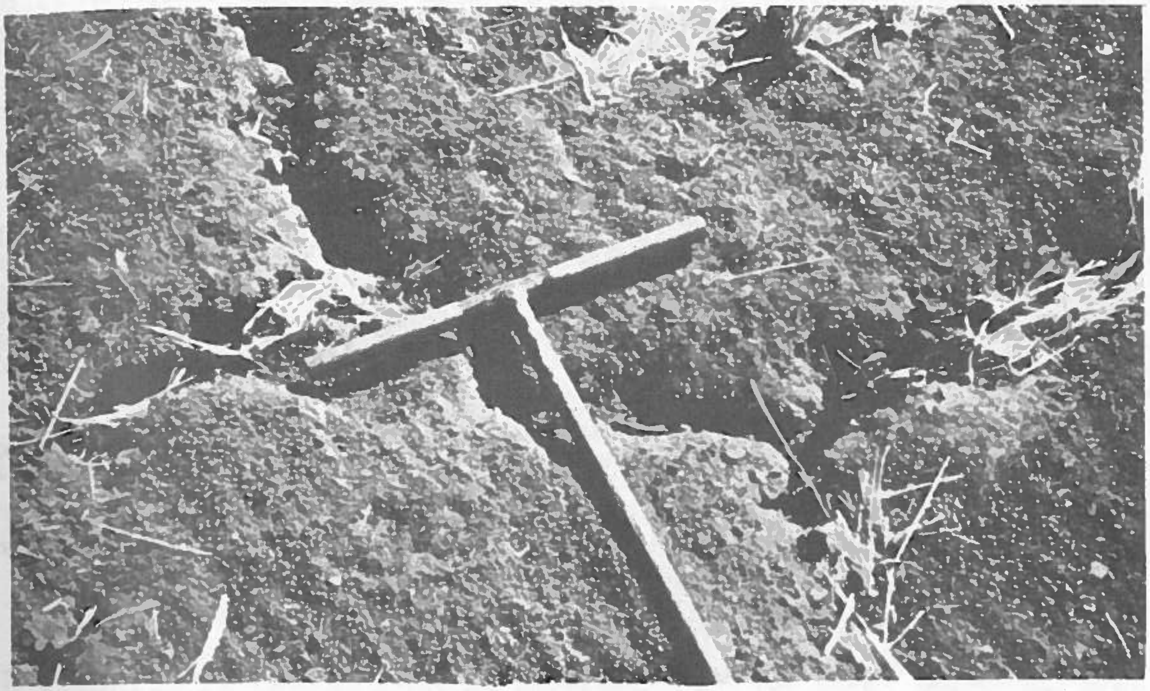


Figure IV-5 - Grumusols in the Blue Nile Basin exhibit severe cracking when dry.

1. Grumusols are dark gray to black and tend to crack severely when dry. Structural development is good.

2. Cultivation of grumusols requires more power than for latosols. Hence, grumusols are not well adapted to small farm units depending on hand labor. Large farms with tractors are best suited to maximize the production from these soils.

3. Large heads of irrigation water will be needed and a high degree of leveling is necessary so that a maximum amount of water can be entered through the cracks before the soils seal.

4. Cation exchange capacity is usually equal to two or three times the 2-micron clay content. This is due to a predominance of a 2:1 clay lattice structure which causes the swelling and shrinking properties.

5. Natural fertility, including calcium, is usually better than latosols because the restricted permeability has resulted in less leaching.

6. These soils are hard to farm because they form large clods, which are very hard to break when dry and are firm and plastic when moist. The surface soil can be easily puddled if cultivated when too wet.

7. Internal drainage is usually poor and drainage may have to be achieved by surface ditches because of restricted internal permeability.

8. Crop adaptation is limited to crops which can tolerate moderately restricted internal drainage. Pasture, small grains, cotton, and hay crops are probably best adapted. The crop rotation should include pasture as a means of improving the organic matter content and soil friability.

9. Grumusols are usually neutral to mildly alkaline and frequently have calcium carbonate in the subsoil.

10. These soils are less resistant to erosion than latosols, but occur on topography which is not so susceptible to erosion.

11. Soluble salts are very low in both the latosols and grumusols found in the Blue Nile Basin. Excessive salts could develop on some grumusols when irrigated because of the restricted internal drainage. However, this is not likely because of the high rainfall and excellent irrigation water quality.

DRAINAGE

The history of irrigation shows that drainage problems restrict crop production and result in more project failures than any other single factor. Therefore, this factor requires careful study.

Surface drainage is usually highly developed on the latosol soils. Natural drainageways are close together and waste water and deep percolation losses from ridge irrigation can be expected to flow into these channels. This water may result in "seeped" areas at the base of hills and most of the swales or lowland may be too wet to farm. Therefore, initial irrigation development should anticipate these problems and keep irrigation development and home construction out of the low areas.

Surface drainage is usually poorly developed on the grumusol soils. Some of these lands are currently subject to flooding and will require a good surface drainage system to remove excess rainfall and irrigation wastes. Careful studies of water table behavior should be made. Irrigation additions may have to be controlled on some of the tighter soils to avoid development of a high water table. Drainage studies are important and should receive a high priority in future investigations on these soils. Soils that develop a water table during the rainy season may also develop one under irrigation with a resulting low production.

CLASSIFICATION RESULTS

Table IV-2 sets forth a summary of the land classification and irrigability studies which have been made. As shown by these figures, a total of 433,754 hectares (including the German team's investigation) can be served from the proposed supply and distribution works.

In addition to the areas shown in Table IV-2, several other areas have been investigated and classified for irrigation. However, studies on serving these areas with irrigation water showed that at this time it is not economically feasible to provide irrigation water; therefore, these lands are not included in the general irrigation plan. Table IV-3 shows the acreage which the land classification showed to be suitable for irrigation.

TABLE IV-3 - LAND CLASSIFICATION RESULTS ON NONIRRIGABLE UNITS

Area	Hectares of arable land				
	Class 1	Class 2	Class 3	Presently irrigated	Totals
Upper Muger	250	8,490	--	--	8,740
Wama	--	23,665	19,465	--	43,130
Cheye	--	--	3,400	--	3,400
Fettam-Azena	44,666	49,830	18,113	17,881	130,490
Lekkemt	--	7,025	11,510	--	18,535

Plate 1 (back pocket) shows the location of the various units with respect to the Blue Nile Basin.

WATER QUALITY

Several water samples have been analyzed from the Blue Nile River and its tributaries. The results of these analyses show that the water is excellent for irrigation purposes. The low total salt content will generally require less than 5 percent deep percolation to maintain a proper salt balance. This will permit irrigation of soils with fairly tight subsoils which might otherwise be unsuitable. The low sodium content will be favorable for maintaining good soil structure. Table IV-4 summarizes water quality data available for the Blue Nile Basin.

LAKE TANA SUB-BASIN

Introduction

Lake Tana lies in a natural drainage basin of about 15,000 square kilometers (5,800 square miles). The lake has a surface area of 3,030 square kilometers (1,185 square miles). Its surface elevation is about 1786 meters (5858 feet) above sea level. The lake is fed by four major streams--the Gilgel Abbay, the Megech, the Gumara, and the Ribb. All of these rivers rise in the highland surrounding the basin. Because of restrictions at the outlet, the lake rises slowly to reach its maximum stage at the end of the season of heavy rains and recedes slowly to its minimum discharge during the dry season.

The upper Gilgel Abbay area, approximately 2,000 square kilometers, was investigated in some detail by a German team. Their preliminary report was made available early in 1963. The Bureau of Reclamation made a preliminary reconnaissance study of the land resource capabilities of the Gilgel Abbay area and the data were furnished to the German team. Therefore, it is assumed that the German report on this area includes Reclamation data plus any additional data which they secured. For information relating to their findings the reader should secure their report. This report is dated 1962 and was prepared by the Lahmeyer Consulting Engineers.

Several other project areas in the vicinity of Lake Tana have been investigated in addition to the Gilgel Abbay area. Among these are the Gumara River Project, the Ribb River Project, the Northeast Tana Pump Project, the Megech River Gravity Project, and the Megech Pump Projects. The latter involves east and west project areas. The general locations of these projects with respect to Lake Tana are shown on Figure IV-7.

Land classification of the projects listed above was completed prior to the time the project separations were known. Because of this factor and because physiographic conditions are similar in all areas, results are summarized in this presentation but any pertinent data applicable to a particular project such as the soils data are discussed by project area.

General Description

The Lake Tana Sub-basin is in Gojjam and Begemidir Provinces of northwestern Ethiopia.

Transportation and Marketing

An all-weather highway to serve Shewa, Gojjam, and Begemidir Provinces, with a connecting road extending from Addis Ababa to Asmara via Debre Markos, Dangila, and Gondar, is nearing completion and will be effective in providing marketing opportunities to lands to the south, east, and north of the lake. Additional roads will be needed as the economy expands. Transportation across Lake Tana is provided by regularly scheduled boats of 65-ton capacity which operate between Gorgora on the north shore and Zege on the west side of the lake.

The principal towns and villages in or near the project areas include Gorgora, Bahir Dar, Cenher, Jangua, Sarua, Kolla Dibba, Iancaru, Gazara, Addis Zemin, Stella Taraghedam, Ifag, Lega, and Muscat. Gondar is the largest trading and marketing center near the proposed projects.

Figure IV-6 - The Gilgel Abbay Valley is near and south of Lake Tana.

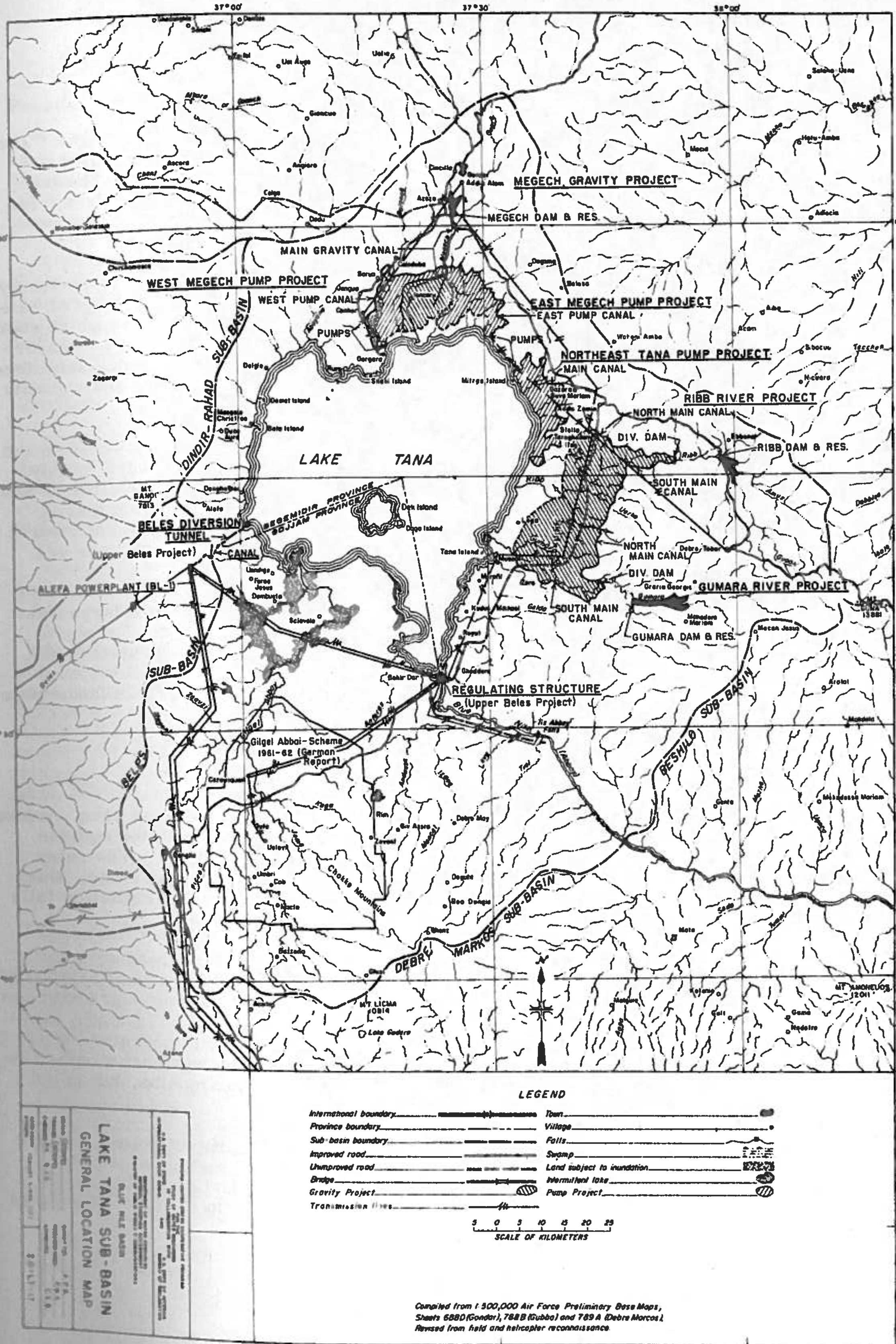


Figure IV-7 - General Location Map, Lake Tana Sub-basin

Geology and Physiography

Lake Tana Basin is surrounded by volcanic mountains composed of basaltic lava. The lake beds to the northwest are the only sedimentary rock formations in the vicinity and these consist of siliceous shales, sandstones, lignite beds, and cherty marl. The lake beds have been faulted and tilted, indicating recent movement along the rift. Except for the lake beds, the rocks in the vicinity are all extrusive and represent three or more phases of volcanic activity.

The present lake was formed by a younger volcanism which dammed off the previously eroded valley and drainage systems, impounding a broad, relatively shallow body of water. Some of the younger lava flows poured downstream in syrup-like flows. Although no sedimentary rocks are exposed in the basin, it is believed that the volcanic rocks are underlain by bedded sedimentary rocks of the Mesozoic age, consisting of limestone, sandstone, and shale. The basement complex consists of granitics, gneisses, schists, and variably altered meta-sediments and meta-volcanics.

Of most importance to the soil formation are the depositions following the most recent volcanic depositions. The arable lands within the proposed project areas were mostly formed on deltaic depositions from the tributary flows into the lake. Lake sediments also occur at depth which indicates that the lake was formerly at a higher elevation than in recent years. In addition, there are recent alluvial depositions near the several rivers and some alluvial fans near the hills. Interspersed within the alluvial depositions are some nonarable hills of volcanic origin.

Because of the mode of origin, the Lake Tana Basin is characterized by a large flat or very gently sloping plain bordering the lake on the north and east sides. Extensive areas of gently rolling or hilly uplands occur on the higher portion of the project areas. Intermingled with the arable lands, or in the general area, are recent lava flows with very little soil, hilly and rocky lands, and low marshy areas. Such nonarable lands were excluded from the proposed project areas.

Climate

Like most of the central highlands, the elevated position of the Lake Tana area makes for a temperate, subtropical, and equable climate despite its proximity to the equator (approximately 12° north latitude). There are two seasons--rainy and dry. The rainy season has two periods--the little rains, during April and May, and the big rains, which last from mid-June to mid-September. About 80 percent of the annual precipitation falls during the latter period.

The Gondar station, at about 2120 meters elevation (6900 feet), is representative of the northern portion of the lake basin. This station reported an average annual rainfall of 121 cm. for the 1952-1960 period. Rainfall generally occurs in heavy downpours with considerable runoff. Uniformity of temperature throughout the year is also a climatic characteristic. Data from the Gondar station indicates an annual average temperature of 19° C. The coldest months are November, December, and January, and the warmest months are March, April, and May. Frost damage may occur during the colder months, but is not likely in any particular year.

The Dangila station, although a considerable distance from the project areas, reports an average annual precipitation of 147 cm. At an elevation of 2100 meters above sea level the station indicates an average annual temperature of 17° C and a monthly range from 15° C to 19° C. Project conditions are expected to be similar to the data from these two weather stations.

Present and Potential Land Use

The Lake Tana area lies in a vegetative region where noncultivated lands generally have a cover of grass, brush, and small trees. There are extensive areas of grasslands. These include Bermuda grass, marsh grass, and many other varieties. Thornbush, various species of acacia, and other small trees occupy portions of the upland and mountainous areas.

The vast near-level plain adjacent to the lake on the north and east is the major agricultural area in the region. A variety of dryland crops are produced, the major ones being teff, barley, noog, chick peas, lentils, sorghum, and peppers. Wheat, guaya, millet, corn, coffee, and sunflowers are also grown. Dryland cotton is raised on a very limited scale. Of the major crops, teff, barley, noog, and peppers are planted in June or July after the small rains and are harvested in November and December. Chick peas, lentils, and sorghum are planted in October after the rains and are harvested in April and May.

Cultivated fields are usually small subsistence plots of less than 1 hectare size. Produce surplus to the family needs may be marketed locally. Soil fertility is generally low but fertilization is not often practical. No chemical fertilizer is used at present but should benefit production greatly if irrigation is introduced. Soil erosion is active in the higher portions of the project lands.

Livestock plays an important part in the farm economy of the area. Large herds of zebu-type cattle are grazed on the extensive pastures of the lake plain, and to a lesser extent on the uplands. Small numbers of sheep, goats, and donkeys are also found.

Irrigation would permit more diversified cropping and would increase present crop yields. It would also permit cropping during the entire year. The lack of irrigation experience in the basin emphasizes the need for experiment stations and development farms to determine the crops best suited. Due to the prevalence of the black sticky clays which are poorly drained, crop selection will be confined to fewer crops in this area than in some of the better drained projects elsewhere in the Blue Nile Basin. With proper drainage, barley, sorghum, wheat, beans, oilseeds and pasture may be the most profitable. Fruits or vegetables should be confined to the Class 1 and 2 lands.

Project Lands

Topography and Land Development

Topography is generally uniform and quite well adapted to irrigation development in the project areas surrounding Lake Tana. The usual slope of land is in the range of less than 0.1 to 0.6 percent. Slopes into drainageways are generally so moderate that farming can be done from the top of the ridge to the bottom of the drains. The river bottoms are usually less than 5 meters below the level of the main land bodies.

The relief of the land is smooth and large-sized uniformly sloping areas are present which are well adapted to modern mechanized equipment. For the most part very little land grading or smoothing would be necessary to develop the lands for irrigation. The flatter lands lie nearest the lake and will be more difficult to irrigate because of lack of gradient. Water distribution may be a problem here unless rather large heads of water are used. Border irrigation would likely be the most successful way of irrigating to minimize the problems of the flat terrain.

The uplands have a more diverse type of topography than the smooth plain adjacent to the lake. Surface relief in the uplands is more pronounced and in general is a more rolling type of topography with the arable lands on the ridge. In these areas well incised drainageways occur at fairly frequent intervals. The higher lands are alluvial plains in narrow valleys between the surrounding hills. Slopes increase with distance away from the lake, but most of the arable land occurs on slopes of less than 4 percent.

In summary, the topographic conditions are generally good in the Lake Tana area. Some clearing will be needed on the upland soils, and there are small areas that need rock removal. Average land development costs, exclusive of any drainage control, is expected to be about Eth$125 per hectare.

Drainage

The flat nature of the land and the large area of contributing upland drainage toward the lake has resulted in a generally poorly drained area in the smooth plain surrounding Lake Tana.

Many swampy areas exist even during the dry season. Although the wetter areas have been eliminated as nonarable, most of the dark soils areas, and particularly the western portion of the Gumara River and Ribb River Projects and most of the Northeast Tana Project, develop a high water table during the rainy season. Some of these lands develop water tables to the soil surface and some to only slightly below the surface. During the dry season the water tables now drop to about 3 meters. Lowering of the water table during the dry season could be due mostly to crop production rather than deep percolation losses. More information is needed on this phase.

Control of a water table will probably be the primary problem in a considerable portion of the Lake Tana area. Insufficient data are now available to determine the costs for correcting this problem, but it can be assumed that subsequent detailed studies will show that proper control will be quite expensive.

Because of the obvious drainage problems which will arise in portions of the Lake Tana area, irrigation development should proceed very cautiously and first stages should be limited to better drained areas such as in the southeast corner of the Gumara River Project.

It may be that limiting water use during the dry season on the poorer drained areas with careful control to prevent a detrimental water table buildup would be successful. It should be remembered that when these lands are irrigated the water table will remain high and may be a greater problem during the rainy season than now.

The presence of high water tables under present conditions furnishes an opportunity to determine the probable costs of a drainage system prior to actual irrigation. Sufficient surface and subsurface drains could be established under present conditions to determine the drawdown characteristics and necessary drain spacing for proper control. It seems likely that a drainage system would be beneficial to dry farming as well as to irrigation.

Flooding. Flood hazards are believed to be greater in the Lake Tana Basin projects than elsewhere in the Blue Nile Basin. As has been indicated previously, torrential erosive rains occur occasionally during the rainy season. Such rains accumulate in the natural drains and flow toward Lake Tana. As the drainages approach the lake the slope flattens, the water loses its sediment and may flood adjacent lands or the stream channel may change its course. There is considerable evidence that this has happened in the past. The worst flood hazards are believed to be in the area of the Megech River Gravity Project, but to some extent flooding is a hazard on all the lowlying lands in these projects. Such flooding may be difficult and expensive to control. If it is not controlled, canals might be broken, farm lands covered with debris, drainage channels filled with sediment and general operation and maintenance expenses increased. At the time of detailed investigations careful consideration should be given to this possible problem.

Soils

Because of the great important of the soils to project success, a separate discussion of soil conditions in the various projects within the Lake Tana area follows.

Gumara River Project

Most of the arable soils in the Gumara River Project occupy the extensive, nearly flat or only very gently sloping, smooth topography bordering Lake Tana. These are deltaic soils overlying deep lacustrine deposits. The parent materials were washed in from the fine-textured volcanic uplands, and were deposited on the alluvial plain under still water conditions favorable for deposition of fine textures. The outstanding characteristics of the soils occupying the extensive deltaic plains are the dark gray color, the iron mottling to or near the surface which indicates poor drainage, the high percentage of clay, and the high coefficients of expansion and contraction. Due to the latter characteristics, deep and wide cracks form during the dry period.

A typical profile consists of a dark gray to dark grayish brown, noncalcareous, nonsaline, slightly acidic granular to fine subangular, blocky, clay surface soil rich in organic matter (0 to 15 cm.). The subsoil from 15 to 45 cm. is likely to be a dark gray or very dark grayish brown mottled, nonsaline, noncalcareous, slightly acidic, weakly prismatic clay, breaking to coarse subangular blocky structure. Below 45 cm. the soil retains its mottling and dark gray color, but is occasionally flecked with lime. This layer has a massive structure to an unknown depth and is very slowly permeable. Careful examination of the profile shows stratification but texture and colors are well integrated by the intensive chemical weathering. Sample 30, listed in Table IV-5, has some laboratory data typical of these soils.

Cracks up to 20 cm. in width and a meter or greater in depth were observed during the dry season in the black soils. As a result of this characteristic the soils are self-mulching, with residues from the surface falling into the cracks and being mixed with the lower horizons. This permits organic matter accumulation to a greater than normal depth. The cracking characteristic allows ready penetration of irrigation water into the soil when dry, but the soil is nearly impermeable when wet.

A subsoil sample of the dark clay (grumusol) soils in the Gumara River Project was analyzed for mineral content in the U.S. Bureau of Reclamation Laboratories in Denver, Colorado. The analysis showed that the clay fraction consists largely of a calcium beidellite mineral (moderately expanding type) with minor amounts of iron oxide, quartz, feldspar, kaolinite, and organic matter. The clay fraction had a free swell of 230 percent.

The well-drained red clays represented by sample 2 in Table IV-5 occupy the areas of gently sloping, rolling and hilly topography which occurs in the eastern portion of the Gumara River Project. Many of these lands are covered with brush and trees. These soils are slightly more acidic than the black clays and are probably not as fertile. The lower fertility and greater acidity are a result of their permeable nature. The favorable permeability of these soils will result in their being good irrigated soils. However, fertilizers will be needed under irrigation for maximum production. The largest acreage of these soils occurs in the Class 1 area near the southeast corner of the project (see Figure IV-8). Some basalt rocks occur on these soils, but not enough to affect the land class.

Recent alluvial soils also occur in the Gumara River Project and are found near the river in the flood plain area. Most of such soils occur on the north side of the river within the project area. These soils are probably the best adapted for irrigation within the project boundaries because they are generally permeable and fertile. Topographic deficiencies are common, however, so most of these lands are Class 2. The recent alluvial soils vary in profile description greatly, but are generally medium textured rather than fine textured. Borings No. 31, 32, 33, and 4 shown in Table IV-5 represent typical recent alluvial soils.

As will be noted in Table IV-5, the upland soils and river flood plain (recent alluvial) soils are quite acidic and probably would respond to lime. It is suggested that trials of 2,000 kg. per hectare be used on some of these soils to determine the value of this amendment. The main body of the Gumara River Project has dark clay soils that usually contain adequate lime. Although the dark soils are more fertile than the red soils, they owe their deficiency to physical problems.

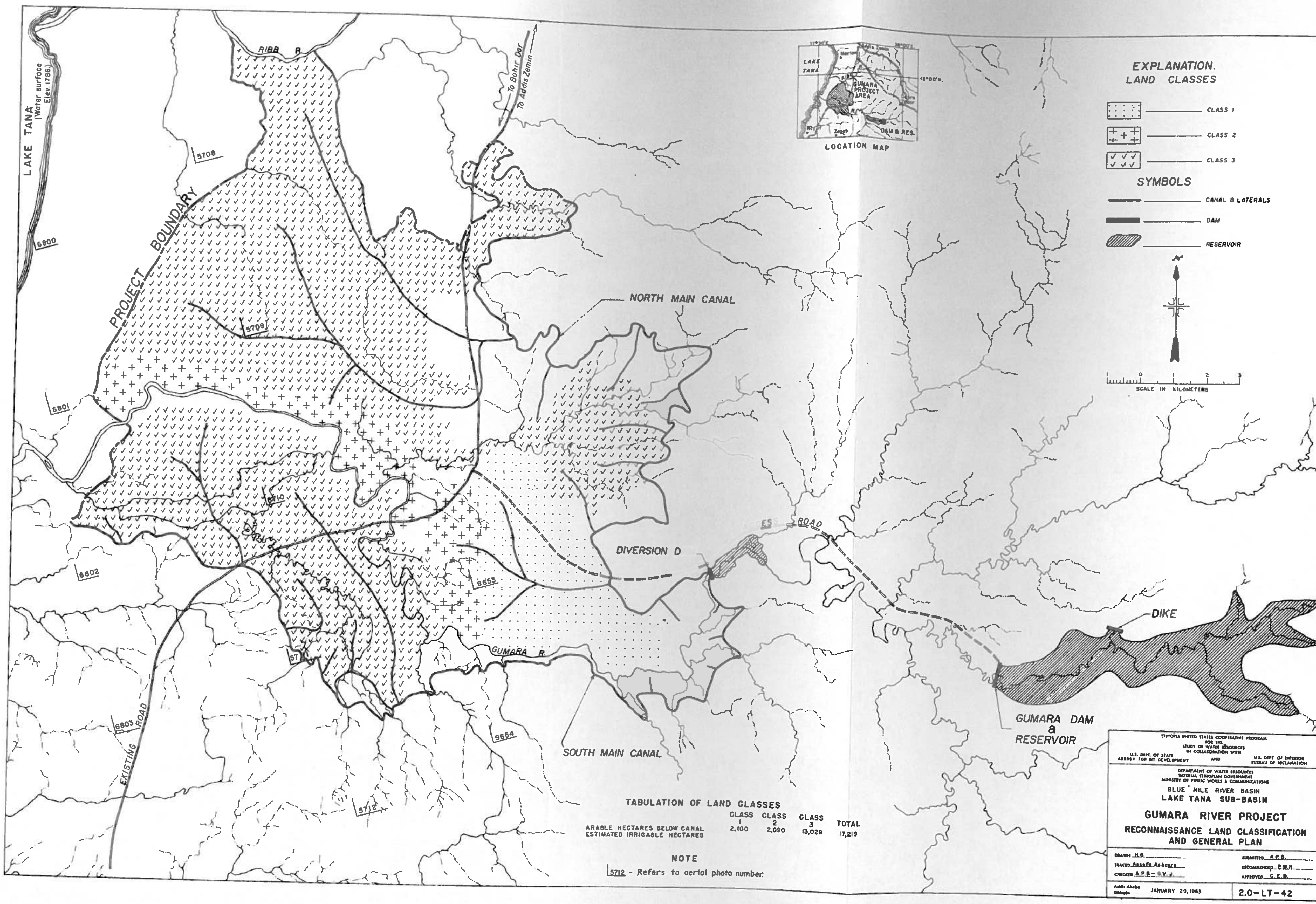


Figure IV-8 - Reconnaissance Land Classification and General Plan, Gumara River Project

TABLE IV-5 - TYPICAL SOIL ANALYSES--GUMARA RIVER PROJECT

Sample no.	Photo	Depth (cm.)	Color	Texture	pH	Percent salinity	Remarks
31	5711	0-25	Dk gr-br	Clay loam	-	-	River flood plain
		25-150	Dk gr-br	Clay loam	-	-	
32	5711	0-30	Dk br	Silt loam	-	-	River flood plain
		30-150	Dk br	Clay loam	-	-	
33	9655	0-15	Red br	Loam	5.2	Trace	River flood plain
		15-90	Red br	Silt loam	5.3	Trace	
		90-150	Red br	Clay loam	5.5	0.02	
1	1963	0-15	Dk gr-br	Lt si clay	-	-	Mottled clay below 15 cm.
		15-150	Dk gr-br	Clay	-	-	
2	2413	0-15	Red	Loam	5.4	Trace	Upland area. Some dark iron concretions present in subsoil
		15-120	Red br	Si loam	5.6	Trace	
		120-150	-	Bedrock			
3	2415	0-22	Dk br	Lt clay	4.7	Trace	Deltaic plain soil
		22-60	Dk gr-br	Clay	4.8	0.03	
		60-100	Dk gr	Heavy clay	4.8	0.03	
		100-150	Dk gr	Heavy clay	-	-	
4	2417	0-30	Dk gr	Lt clay	5.4	0.06	Recent alluvium
		30-60	Dk gr	Clay	6.4	0.07	
		60-120	Dk gr	Lt clay	6.9	0.08	
		120-150	Dk gr	Loamy sand	7.0	0.05	
30	6803	0-30	Dk gr-br	Lt clay	6.2	0.03	Grumusol
		30-60	Dk gr	Clay	6.7	0.09	
		60-150	Dk gr	Heavy clay	7.6	0.10	

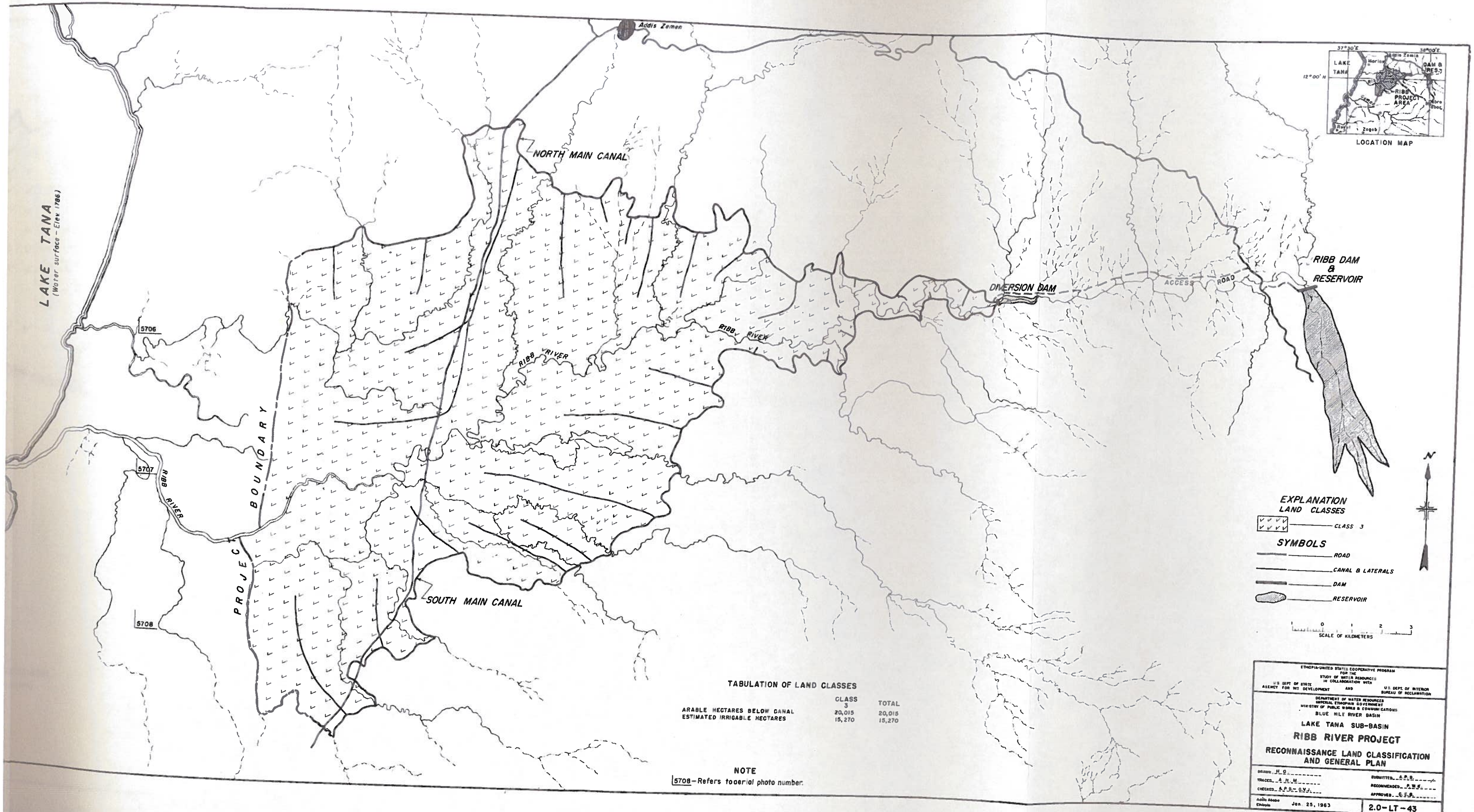


Figure IV-9 - Reconnaissance Land Classification and General Plan, Ribb River Project

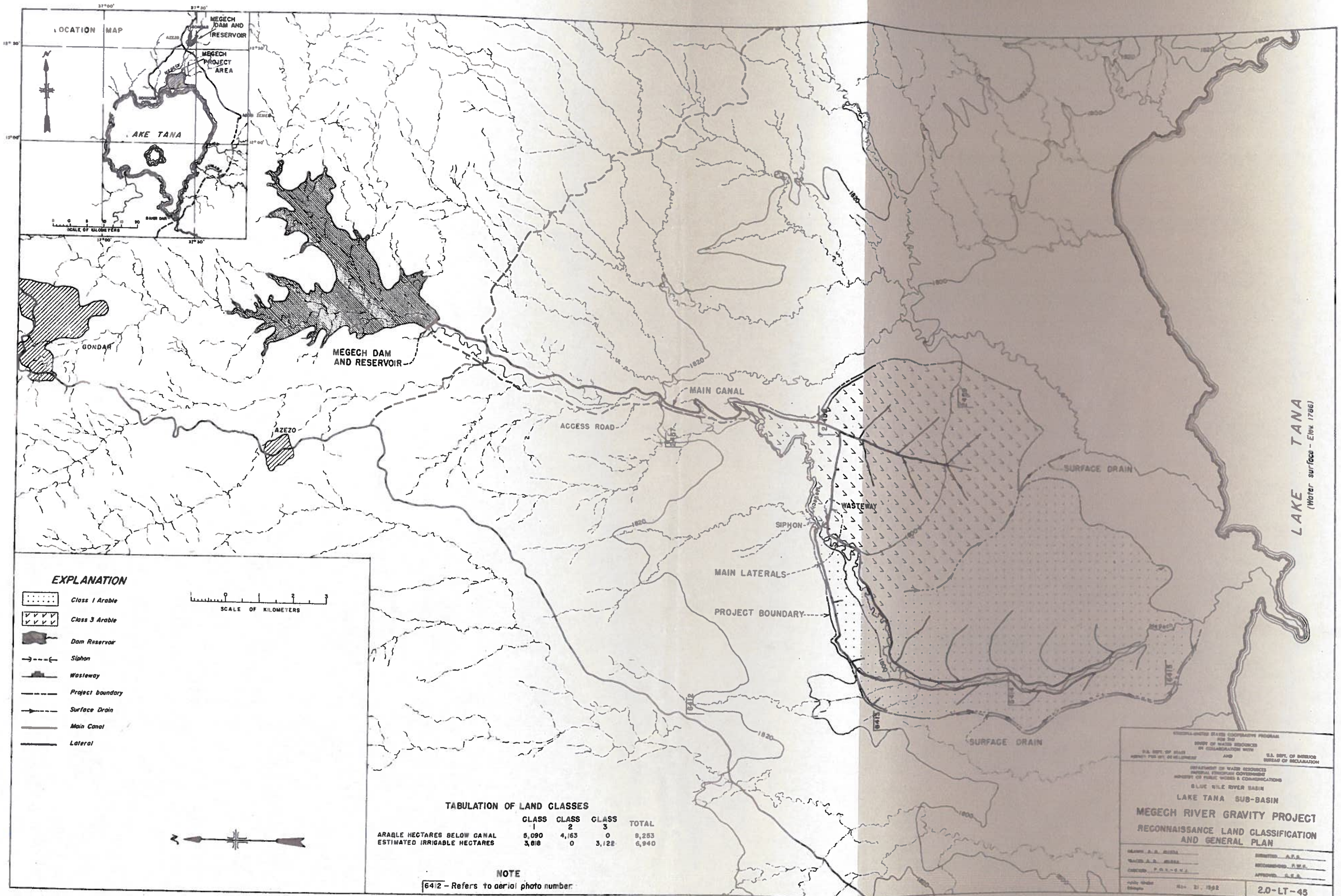


Figure IV-11 - Reconnaissance Land Classification and General Plan, Megech River Gravity Project

Ribb River and Northeast Tana Pump Projects

The Ribb River and Northeast Tana Pump Projects are principally developed on deltai deposits overlying deeper lacustrine deposits. With the exception of a relatively narrow band of recent alluvial soils adjacent to the Ribb River, the soils are uniformly fine textured and are poorly drained. Water table problems will be very difficult to control in these two projects because of the very slowly permeable substrata conditions.

The Northeast Tana soils, while very similar to the Ribb River Project, are generally of more recent origin and are somewhat more stratified. Flooding occurs occasionally in this project area and the floodwater deposit sediments over the land. However, becaus of the fine texture of soils on the adjacent uplands (mostly dark clays here) the recent sediment deposits are difficult to distinguish from previous deposition.

It will be noted from Table IV-6, which shows typical laboratory data in these two projects, that these soils are neutral to slightly alkaline. Such soils will not respond to additional lime.

The soil structure associated with these soils is usually as follows: 0-15 cm., large weak prismatic breaking readily to strong subangular blocky. Below 60 cm. the structure is usually massive. These structural properties contribute to a very low substrata permeability below 60 cm. Figures IV-9 and IV-10 show the location of the project lands and general features.

Megech River Gravity Project

The Megech Project areas have greater diversity in soil conditions than the Gumara River, Northeast Tana Pump, or Ribb River Projects. Therefore, the Megech River Gravity Project is discussed separately from the Megech Pumping Projects. Figure IV-1. shows the location and general plan for service to the Megech River Gravity Project.

Soils in this project are generally well suited to irrigation because of the nature of their formation. These soils are a mixture of deltaic and recent river alluvial deposits. Consequently they are not homogeneous. A deep, all dark clay profile may be found in one spot and nearby an entirely different texture may be found. Strata of medium and coarse texture may be found in some profiles. Table IV-7 shows typical profile textures and laboratory data on these soils.

Flood hazards are worse in this project than elsewhere in the Lake Tana area but the frequent floods which have occurred have had a generally favorable influence on the soil formation. Like the Northeast Tana Pump and Ribb River Projects, the Megech River Gravity Project has sufficient calcium and needs no lime additions at present. Drainage control and improvement is needed but it is believed that such control can be secured for nominal investments and with considerably less cost than in the projects on the east side of the lake. Soil fertility is likely to be better in the Megech River Gravity area than the average in the Lake Tana Sub-basin because of the nature of the soil formation.

Megech Pump Projects

Nearly every soil type occurring in the Blue Nile Basin may be found in the Megech Pump Projects. Typically the soils are not well suited to irrigation, although individual areas are very good. Figure IV-12 shows location and general plan.

Hardpans or indurated horizons occur throughout the Megech Pump Projects. These layers are generally due to iron and silica cementation. In some places a very dense and impermeable iron hardpan exists within 10 to 30 cm. of the surface. In other areas the volcanic tuff is indurated and apparently cemented by iron and silica. Such soils are intermingled with typical dark clay grumusols on flatter terrain and with the red earth or latosol soils on upland, well-drained positions. Detailed studies will probably show

TABLE IV-6 - TYPICAL SOIL ANALYSES--RIBB RIVER AND NORTHEAST TANA PUMP PROJECTS

Project	Sample no.	Photo	Depth (cm.)	Color	Texture	pH	Percent salinity	Remarks
NE Tana	35	6795	0-30	Dk gr-br	Clay	6.4	0.07	Typical grumusol
			30-60	Dk gr	H clay	6.8	0.09	
			60-150	Dk gr	H clay	7.3	0.11	
Ribb	36	9649	0-30	Dk gr-br	Clay	6.8	0.08	Grumusol
			30-60	Dk gr	H clay	6.8	0.10	
			60-90	Dk gr	H clay	7.4	0.11	
			90-120	Dk gr	H clay	7.4	0.11	
Ribb	6	9651	0-30	Dk gr	Clay	-	-	Some lime below 13
			30-130	Dk gr	Clay	-	-	Subangular blocky
			130-150	Dk gr-br	Clay	-	-	structure 30-130 cm.
Ribb	14	5709	0-15	Dk gr-br	Lt clay	6.2	0.03	Strongly mottled b
			15-75	Dk gr-br	Clay loam	6.7	0.09	75 cm.
			75-120	Dk gr	Clay	7.6	0.25	
			120-150	Dk gr-br	Clay	-	-	

TABLE IV-7 - TYPICAL SOIL ANALYSES--MEGECH RIVER GRAVITY PROJECT

Sample no.	Photo	Depth (cm.)	Color	Texture	pH	Percent salinity	Remarks
19	6411	0-150	Dk gr	H clay	-	-	
20	6413	0-15	Gr-br	Clay loam	6.3	0.10	Deeply cracked clay
		15-90	Br	Silt loam	7.0	0.03	Recent alluvium, mot below 90 cm., stru
		90-150	Br	F sandy loam	7.6	0.09	below 90 cm., with of fine texture
21	6413	0-90	Dk gr	H clay	6.0	0.12	Grumusol--cracks 20
		90-150	Dk gr	H clay	6.8	0.14	wide and 75 cm. dee
22	6413	0-15	Dk gr-br	Clay	6.1	0.10	Some lenses of loam
		15-105	Dk gr-br	Clay	6.8	0.13	sand, 105-150 cm.
		105-150	Br to gr-br	Clay loam	7.8	0.12	
23	6755	0-60	Dk br	Clay loam	-	-	
		60-120	Br	Silt loam	-	-	Typical recent allu
		120-150	Br	V F S L	-	-	Mottled subsoil
26	6755	0-15	Dk gr-br	Clay loam	6.1	0.07	
		15-90	Dk br	Silt loam	6.7	0.08	
		90-150	Dk gr	Lt clay	-	-	

TABLE IV-8 - TYPICAL SOIL ANALYSES--MEGECH PUMP PROJECTS

Sample no.	Photo	Depth (cm.)	Color	Texture	pH	Percent salinity	Remarks
7	6753	0-15 15-75 75-150	Dk gr Dk gr-br Dk gr	Clay Clay Clay	6.4 6.8 7.5	0.03 0.09 0.12	Typical of flatter area Strongly mottled below 15 cm
11	4297	0-30 30-60 60-150	Dk br Dk gr Red br	H clay Clay Clay	- - -	- - -	Indurated at 3 feet Probably lateritic
12	4297	0-50 50-75 75-150	Dk gr Dk gr Gr	H clay Clay Tuff loam	- - -	- - -	Consolidated tuff below 75 cm.
15	6409	0-10 10-30 30-150	Red br Gr bl Gr br	Loam Iron hardpan Clay	- - -	- - -	Lateritic, gr-black iron Hardpan 10-30 cm. Indurated clay below 30 cm.
16	6409	0-45 45-150	Dk gr-br Yellow	Clay Tuff loam	- -	- -	-
17	6409	0-10 10-120 120-150	Dk gr Br-gr Rhyolite	Clay Clay Rock	- - -	- - -	Decomposed rhyolite at 10 cm Bedrock at 120 cm.
27	6757	0-15 15-90 90-150	Gr-br Dk br Dk br	H clay H clay H clay	5.8 6.0 7.1	0.07 0.09 0.10	-
28	6757	0-105 105-150	Dk gr Gr-br	H clay Clay	- -	- -	0-150 cm. prismatic structu strongly mottled below 105 Lime below 105 cm.

TABLE IV-9 - ARABLE AND IRRIGABLE AREAS (HECTARES)--LAKE TANA SUB-BASIN

Project	Arable below canal				Irrigable			
	Class 1	Class 2	Class 3	Total	Class 1	Class 2	Class 3	Tota
Gumara River	2,100	2,090	13,029	17,219	1,570	1,570	9,780	12,92
Ribb River	0	0	20,015	20,015	0	0	15,270	15,27
Northeast Tana Pump	0	0	6,430	6,430	0	0	5,000	5,00
Megech River Gravity	5,090	0	4,163	9,253	3,818	0	3,122	6,94
West Megech Pump	0	0	9,435	9,435	0	0	7,080	7,08
East Megech Pump	0	0	7,850	7,850	0	0	5,890	5,89
Totals	7,190	2,090	60,922	70,202	5,388	1,570	46,142	53,10

that the laterites (particularly with shallow hardpan) are not arable. The soils with cemented tuff horizons are infertile, will require careful management, and may not permit deep root penetration. These soils were not determined as nonarable in this classification because of the lack of data and time needed to make an accurate separat

Some soils shallow to bedrock also occur in the Megech Pump Project (see Boring in Table IV-8). These soils comprise a minor portion of the area, but may be found o higher ridges near the outer edges of the project area. These areas usually have num surface rocks.

Land Classification

The subreconnaissance land classification of the Lake Tana area was accomplished the dry season of 1959. The classification was made from a four-wheel drive vehicle utilizing aerial photos as base maps. Due to the flat nature of the terrain, and the roa traversing the north and east side of the lake, access was reasonably good. Soil profi representing the various geomorphic units were secured and soil analyses were made.

Figure IV-13 shows the results of the arable classification work accomplished in the basin and the location of soil borings which were secured. Tables IV-5 through IV-8 show the results of typical soil borings within the projects included in the Lake Tana Sub-basin. The location of the irrigable lands together with the canal locations are sh on drawings:

Project	Drawing No.	Figure No.
Gumara River	2.0-LT-42	IV-8
Ribb River	2.0-LT-43	IV-9
Northeast Tana Pump	2.0-LT-44	IV-10
Megech River Gravity	2.0-LT-45	IV-11
Megech Pump	2.0-LT-46	IV-12

Description of Land Classes

Class 1--Arable. This class represents only 10 percent of the arable lands in the p ects studied in the Lake Tana Sub-basin. Class 1 lands are very well suited to irrigat and can be expected to produce high yields with minimum difficulties. These lands are mostly located in the Gumara River and Megech River Gravity Projects. The soils are red to reddish brown, well drained, medium to fine textured but will require fertilizer in addition to irrigation for maximum production. Clearing of trees and brush is neede on some of these lands.

Class 2--Arable. This class represents only 9 percent of the arable lands for these projects. Generally the soils are near Class 1 in productivity level, but the lands have been downgraded for topographic considerations. Land leveling and clearing of trees and brush are the deficiencies contributing most to downgrading these lands. They occ mostly in the river bottoms of the Gumara and Megech Rivers.

Class 3--Arable. This is the predominant land class, as is evidenced by the fact th 81 percent of the lands are placed in it. Class 3 lands are marginal for irrigation deve ment and depend more on good management and proper land development than Classes or 2. Most of the Class 3 lands, and particularly those in the Gumara River, Ribb Riv and Northeast Tana Pump Projects, result because of the presence of heavy black clay which is difficult to till and difficult to irrigate. Drainage problems will likely be seve on these lands unless controlled irrigation application is practiced or unless a close ne work of deep drainage channels is constructed. These lands are best adapted to such crops as pasture and cereals but can also raise peppers, oilseeds, pulses, and other crops if the water table is well controlled. Soil fertility is probably fairly good.

Class 6--Nonarable. The large acreage of swamp lands adjacent to Lake Tana and steep slopes along the outer fringes of the project make up the bulk of the Class 6 land.

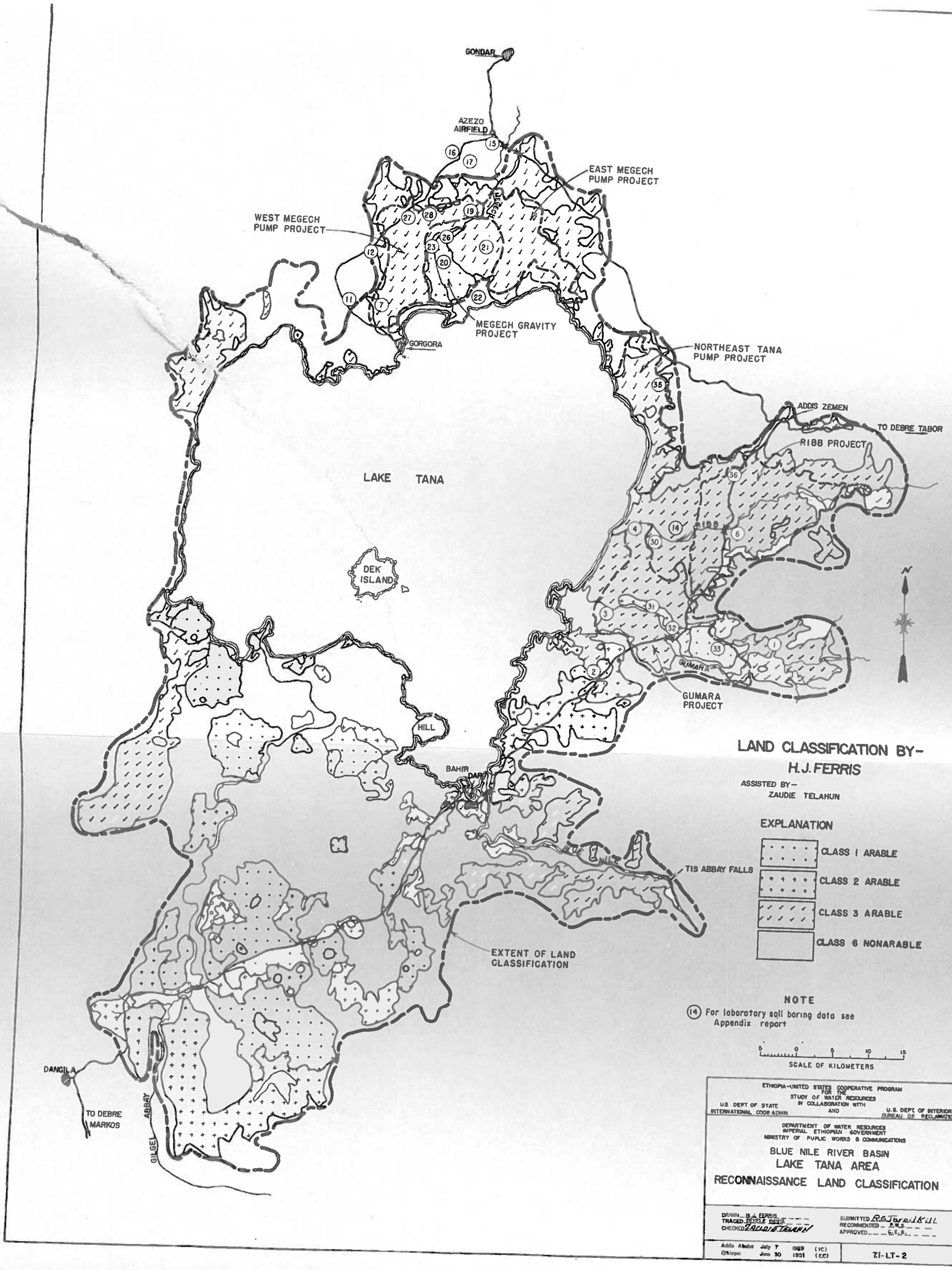


Figure IV-13 - Reconnaissance Land Classification, Lake Tana Area

Land Classification Results

At the time of the original classification work a total of 285,620 hectares were delineated as arable. Following the initial work, the Gilgel Abbay Project area was investigated by a German team which found 66,600 hectares arable. Substantial acreages in the remainder of Lake Tana Basin could not be economically reached by irrigation water so the arable acreage below the proposed canal system totals only 70,202 hectares (this in addition to Gilgel Abbay). The irrigable acreage was further reduced to 53,100 hectares in recognition of the severe soil and drainage problems involved. Table IV-9 shows the arable and irrigable acreages by land class for these project areas.

Conclusions

1. The high percentage of Class 3 lands shows that the proposed projects in this area are of marginal quality for irrigation development.

2. Topography is generally well adapted to irrigation in the Lake Tana area but severe soil, drainage, and possible flooding problems exist.

3. Under irrigation the major portion of the proposed project will develop detrimental water table conditions unless a well-planned adequate deep drainage system is provided.

4. The low salinity of the soils, the high rainfall, and the low salinity of the proposed irrigation water supply are favorable for successful irrigation with a reasonably high water table. However, the water table must be controlled to be at least 75 cm. for most crops and preferably considerably deeper.

5. Flood-induced damage to some arable lands may arise because of the fast slopes on the outer fringes of the project and the flat slopes near the lake. This change of slope causes sediments in water to drop, and in cases of severe storms may cause tributary drainage channels to overflow.

6. Weather conditions are well suited to the production of many crops.

7. Good management will be necessary for successful irrigation because of these soil features: The soils are mostly sticky clays that are subject to structural deterioration if they are cultivated too wet; most of the soils crack badly if allowed to dry and the cracking may damage crop roots; and irrigation water intake rates will be slow so that it will require well-leveled fields to secure uniform infiltration.

8. Drainage control would be beneficial to crop production on most of the project lands even under dryland conditions.

Recommendations

1. Initial irrigation developments in the Lake Tana area should be confined to the Classes 1 and 2 lands in the Gumara River and Megech River Gravity Projects.

2. Detailed studies on land classification and drainage are needed prior to any construction for irrigation.

3. Because of the high water table on project lands during the wet season, it is suggested that some drainage channels be constructed to determine the cost of such channels and their lateral effectiveness in controlling water table conditions. This work is needed prior to detailed land classification studies.

4. One or more experiment stations are needed in the Lake Tana area to determine the best crops suitable for irrigation and the management practices necessary.

5. Studies on present water table behavior are needed. Such studies should be d[illegible] to resolving these questions: (1) What percent of the water in the soils at saturation [illegible] lost by deep percolation? (2) Are deep percolation capabilities of the dark clays ade[illegible] to provide a salt balance under irrigation? (3) How many inches of water are prese[illegible] the upper 1.5 meters in typical soil profiles at the wilting point, at field capacity, a[illegible] saturation? (4) What are the highest water table levels that anticipated crops will to[illegible] and what water table level is needed for maximum production? (5) What is the in-pl[illegible] hydraulic conductivity of the substrata at depths from 1 to 3 meters?

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BELES RIVER PROJECT

General Description

The proposed Beles River Project is in the west central portion of the Blue Nile Basin. The area extends southwesterly along both sides of the Beles River from near its headwaters to near the village of Mambuk, a distance of about 75 km. At its widest point the area is about 35 km. wide and it averages about 22 km. in width. The project area is bounded on the north and west sides by rolling hilly terrain which divides it from the Dindir drainage basin. On the east and southeast sides there is a precipitous escarpment nearly 1,000 meters high, terminating in a broad plateau. There is considerable dry farming on the adjacent high plateau but very little in the project area.

The area lies in the east central portion of Gojjam Province about 100 km. southwest of Bahir Dar. The only usable road through the area leaves the Addis Ababa-Bahir Dar highway near the village of Injibira and extends westward to the village of Metekkel. It then turns northwestward over the escarpment and enters the Beles River Valley. It continues through the southwest portion of the area to Mambuk, and on to Guba.

Geology and Physiography

Metamorphic and granitic rocks are exposed along the incised river channels. However, residues of basaltic rock frequently appear in the lower part of some soil profiles, so it appears that weathering of basalt has had more influence on soil development than have the metamorphic rocks. Local alluviums occur throughout the area but more extensively in the northeastern portion. In this area there are many recent alluvial depositions of colluvium and outwash fans. Much of the northwest area appears to be ancient alluvial fan depositions which have weathered considerably in place. The southern half, except for land near the escarpment, appears to be residual soils weathered from ancient basalt.

The physiography also varies from north to south. The southern half is generally characterized by a well defined, well incised, dendritic drainage pattern with many narrow ridges. The northern half, and particularly the northwest portion, has a broad smooth gently rolling plain with much broader ridge tops and less distinct natural drainageways.

Climate

No data are available on the climate, but the elevation (average about 1150 meters) suggests it should be warm and subtropical. An average annual temperature of near 25° might be anticipated, with fluctuations in the range of 8° to 35°. Precipitation is estimated to total 100 cm. per year. Accurate climatic data are needed for any advanced planning. Several years record are needed to indicate the fluctuations in temperature and precipitation that may be anticipated.

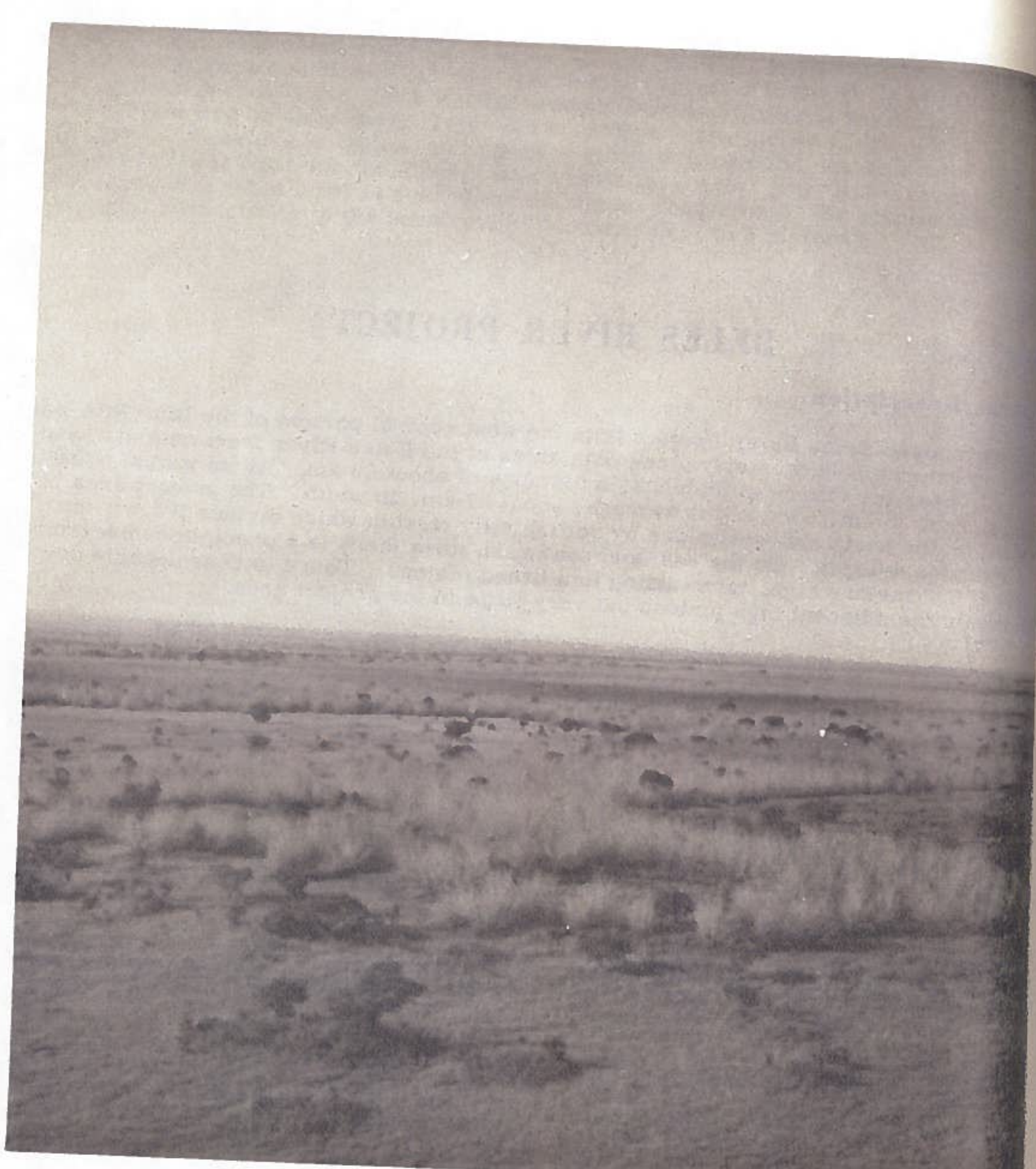


Figure IV-14 - Beles Valley, looking northwest toward the skyline which is the Beles-Dindir divide. Mt. Belaya is at the left in the background. The bamboo clumps in the middle ground are dry. (Lat. 11° 35' N., long. 36° 32' E.)

Present and Potential Land Use

At the time of the land classification most of the northwestern portion of the area had open grass savannah. The northwestern portion had a mixture of open grass savannah and dense groves of bamboo and there were occasional thickets or clumps of bamboo in the grassland. In the southern half of the project the principal natural vegetation was woodland savannah composed of various species of acacia, figs, and associated small trees. This open forest is interspersed with a dense growth of tall grass. Some bamboo occurs throughout this area as well. Two small communities occur within the area. They have cleared some bamboo and are raising dagussa, teff, and sorghum. Some sheep and cattle are grazed nearby.

Because of soil conditions, it would be preferable to concentrate on the production of pasture, hay, small grain, corn, sorghum, and possibly rice. Crops requiring a well drained friable root zone can be grown on the better quality soils, but the majority of soils are heavy plastic clays which will be difficult to farm.

Project Lands

Topography and Land Development

Topography and associated land development problems vary considerably, but might be broadly separated into three types, the broad smooth plains in the northwestern sector; the rough alluvial fan area of the northeast; and the narrow ridge type topography in the southern portion.

The broad smooth plains in the northwest are generally covered with tall grass and can be developed for irrigation easily. Slopes average about 1 to 1.5 percent down the ridges and about 2 percent toward the side drainages. Ridges are very broad and long and this area is well adapted to large fields and heavy modern equipment. Moderate leveling, ditching, and fertilizer applications are expected to produce on the average about Eth$75 to Eth$175 per hectare.

The rough alluvial fan area in the northeast part of the project is subject to considerable flooding and changing water courses following torrential rains. These lands will be difficult to stabilize and will require considerably more development costs than those of the preceding group. The bamboo areas in this sector are best adapted to irrigation, but will require clearing. In general, this area will require some flood protection and will be the poorest area for irrigation in the project. There are numerous isolated high areas which cannot be reached by gravity. Development costs of clearing and leveling, and including flood protection, flumes, fertilizers, and rock removal are estimated to average about Eth$375 to Eth$500 per hectare.

The approximate southern half of the project is characterized by undulating topography varying from gentle to severe. Numerous well incised natural drainageways in the form of a dendritic drainage pattern typify the area. Ridges are the choicest topography for irrigation in this area, but these are usually narrow (50 to 150 meters) and have a slope of 2 to 3 percent parallel to the ridge. Slopes are steep into the side drainages, ranging from 3 to 11 percent or greater. Scattered timber occurs over most of this area (acacia and fig are most common) with some dense groves of bamboo. Tall grass grows in the open timbered areas. Farm and project irrigation distribution systems will require numerous drop structures to stabilize against excessive erosion and numerous flumes and siphons to cross the many drainageways will be necessary. Irrigated field sizes will generally need to be small because of excessive slopes and the irregular nature of the topography. Irrigation labor requirements are expected to be higher in this topographic group than elsewhere in the project. There are some isolated high areas, but they are less common than in the northeast sector. Farm costs for erosion control structures, clearing of trees, flumes, and land leveling are estimated to be in the range of Eth$310 to Eth$435 per hectare.

Drainage

Drainage problems are also associated with the three types of topography. The northwest area, which has the smoothest topography, can be expected to have the most drainage problems. This is because the natural drainageways are mostly shallow and widely spaced, and soils are slowly permeable and have poor internal drainage characteristics. An improved surface drainage system will be needed concurrent with irrigation development. It is probable that an intensive subsurface drainage system may also be needed. Drainage conditions should be studied very carefully in this area prior to development as a means of estimating the water table behavior which may be anticipated with irrigation.

The northeast area has a flood-plain type of natural drainageway at present, with intermittent, narrow, moderately deeply eroded drainageways. Flood hazards need further study in this area before development plans are finalized. The area nearest the escarpment may be so expensive to protect from rainy season floods that it should be considered nonirrigable. If this area can be protected from floods which would normally destroy many irrigation facilities, the main drainageways will need to be enlarged and stabilized. Internal drainage characteristics of these soils are generally considerably better than in the northwest sector. However, further studies on drainage are needed.

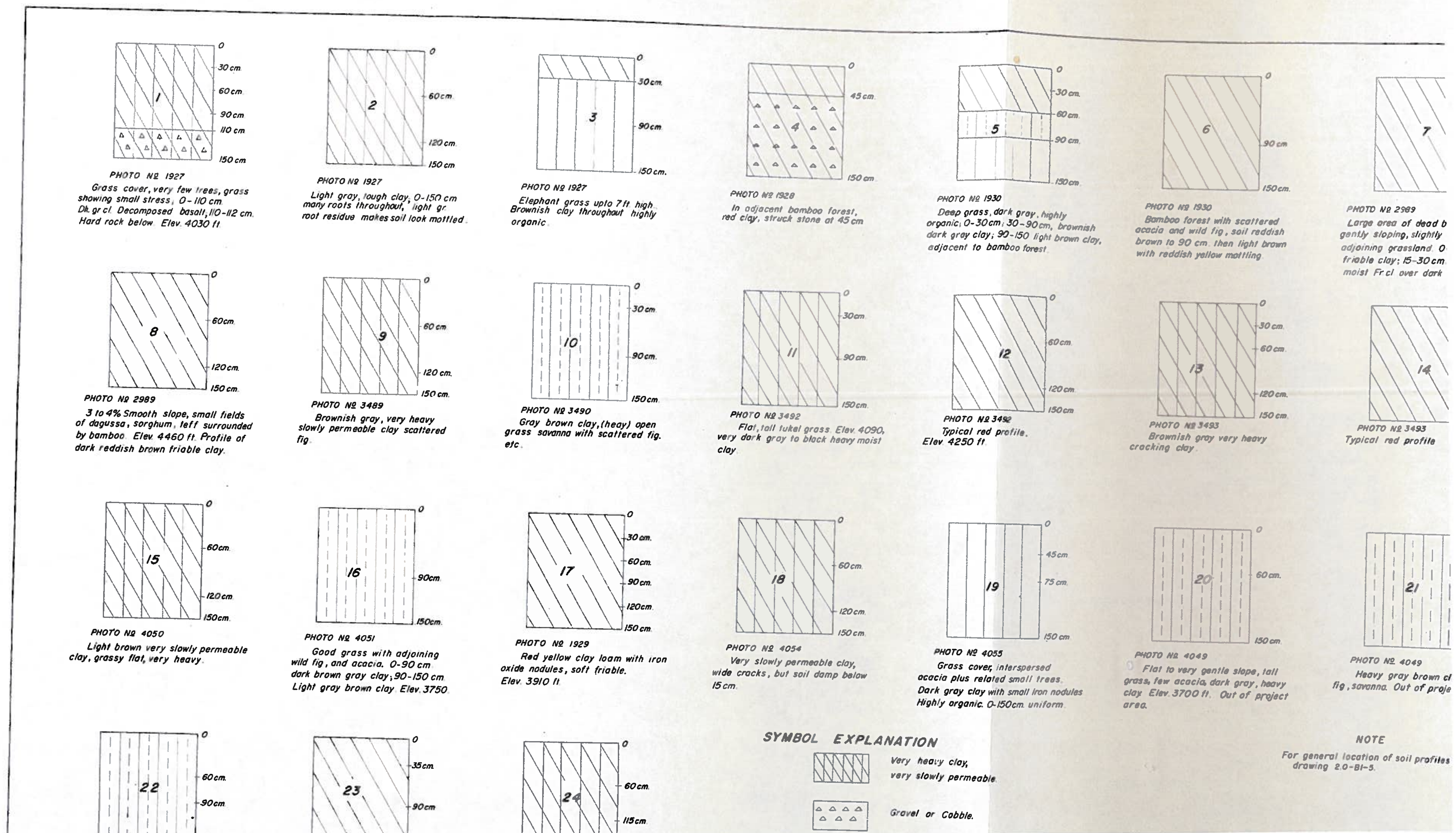
The approximate southern half of the project has a well developed drainage system and the need for further construction is expected to be minimal. It can be anticipated that bottom lands may become wet and unproductive due to the irrigation on the adjacent slopes and ridges. It may be uneconomical to attempt to protect such low areas by additional drains. Initial development should start with the ridge tops and defer any low land development until experience has shown whether or not these lands will become we

Soils

Grumusols or blackland clay soils predominate in the Beles River Basin and particularly in the northwest area where topographic conditions are best for irrigation. Although these soils are inherently more fertile than the latosols, their physical characteristics are poor. They exhibit marked contraction and cracking when dry. They are qu plastic and nearly impermeable when wet. Calcium carbonate is usually found either a concretions below a depth of about 30 cm. or in a disseminated form. The latter form usually does not occur above 60 cm. depth. Most of these soils have a pH near 6.0 in t surface horizon and a gradually increasing pH with depth. The clay content is usually high (over 60 percent) throughout the profile. Soluble salts are low. Cation exchange capacity is high.

The grumusol soils are best adapted to close-growing crops such as pasture or small grains but can be used for rice. Tillage is very difficult because of the tough clay soils. Irrigation is secured through the cracks. Erosion hazards are high. In the natural sta these soils have a dense grass cover which protects them from erosion, but when farm the organic matter decreases and they erode rapidly. For this reason it is preferable have a pasture or hay crop in the rotation so as to increase the organic matter.

Reddish brown lateritic (latosol) soils occur most frequently in the southern half, an least frequently in the northwest sector. They comprise about 40 percent of the total project area and are usually on rougher topography than the grumusols. These soils generally are covered with trees. The best lands in this group have a dense bamboo forest cover. Erosion hazards are high and further studies should be made prior to a detailed classification to determine the maximum slopes that can be successfully irrig for sustained production with these soils. The pH usually ranges from 5.0 to 5.8. They have a moderate to strong coarse granular structure in the surface. The subsurface is firm with a moderately coarse, subangular blocky structure. The clay content usually increases with depth. The surface soil is usually a clay loam or light clay texture.


1
0
30 cm
60 cm
90 cm
110 cm
150 cm
PHOTO Nº 1927
Grass cover, very few trees, grass showing small stress, 0-110 cm
Dk. gr. cl. Decomposed basalt, 110-112 cm.
Hard rock below. Elev. 4030 ft
2
0
60 cm
120 cm
150 cm
PHOTO Nº 1927
Light gray, tough clay, 0-150 cm many roots throughout, light gr root residue makes soil look mottled.
3
0
30 cm
90 cm
150 cm
PHOTO Nº 1927
Elephant grass upto 7 ft high
Brownish clay throughout highly organic.
4
0
45 cm
150 cm
PHOTO Nº 1928
In adjacent bamboo forest, red clay, struck stone at 45 cm
5
0
30 cm
60 cm
90 cm
150 cm
PHOTO Nº 1930
Deep grass, dark gray, highly organic; 0-30 cm; 30-90 cm, brownish dark gray clay; 90-150 light brown clay, adjacent to bamboo forest
6
0
90 cm
150 cm
PHOTO Nº 1930
Bamboo forest with scattered acacia and wild fig, soil reddish brown to 90 cm. then light brown with reddish yellow mottling
7
PHOTO Nº 2989
Large area of dead b
gently sloping, slightly
adjoining grassland. O
friable clay; 15-30 cm
moist Fr. cl over dark
8
0
60 cm
120 cm
150 cm
PHOTO Nº 2989
3 to 4% Smooth slope, small fields of dagussa, sorghum, teff surrounded by bamboo. Elev. 4460 ft. Profile of dark reddish brown friable clay.
9
0
60 cm
120 cm
150 cm
PHOTO Nº 3489
Brownish gray, very heavy slowly permeable clay scattered fig.
10
0
30 cm
90 cm
150 cm
PHOTO Nº 3490
Gray brown clay, (heay) open grass savanna with scattered fig. etc.
11
0
30 cm
90 cm
150 cm
PHOTO Nº 3492
Flat, tall tukel grass. Elev. 4090, very dark gray to black heavy moist clay
12
0
60 cm
120 cm
150 cm
PHOTO Nº 3492
Typical red profile.
Elev. 4250 ft.
13
0
30 cm
60 cm
120 cm
150 cm
PHOTO Nº 3493
Brownish gray very heavy cracking clay.
14
PHOTO Nº 3493
Typical red profile
15
0
60 cm
120 cm
150 cm
PHOTO Nº 4050
Light brown very slowly permeable clay, grassy flat, very heavy.
16
0
90 cm
150 cm
PHOTO Nº 4051
Good grass with adjoining wild fig, and acacia. 0-90 cm dark brown gray clay; 90-150 cm Light gray brown clay. Elev. 3750
17
0
30 cm
60 cm
90 cm
120 cm
150 cm
PHOTO Nº 1929
Red yellow clay loam with iron oxide nodules, soft friable.
Elev. 3910 ft.
18
0
60 cm
120 cm
150 cm
PHOTO Nº 4054
Very slowly permeable clay, wide cracks, but soil damp below 15 cm.
19
0
45 cm
75 cm
150 cm
PHOTO Nº 4055
Grass cover, interspersed acacia plus related small trees.
Dark gray clay with small iron nodules
Highly organic. 0-150 cm. uniform.
20
0
60 cm
150 cm
PHOTO Nº 4049
Flat to very gentle slope, tall grass, few acacia, dark gray, heavy clay. Elev. 3700 ft. Out of project area.
21
PHOTO Nº 4049
Heavy gray brown cl
fig, savanna. Out of proje
22
0
60 cm
90 cm
23
0
35 cm
90 cm
24
0
60 cm
115 cm
SYMBOL EXPLANATION
Very heavy clay, very slowly permeable.
Gravel or Cobble.
NOTE
For general location of soil profiles
drawing 2.0-B1-5.

The latosol soils are permeable and well adapted to irrigation. They are usually less fertile than grumusols because much of their fertility has leached out due to their permeable nature. They can grow any climatically adapted crop and seem to be particularly well suited to coffee production. These soils are low in soluble salts, low in cation exchange capacity, and may respond to lime applications.

Land Classification

Most of the land classification was done by helicopter because only a small portion of the project could be reached by truck. Aerial photos were used as base maps. These photos were badly distorted and unrectified. A topographic (20-meter contour interval) map was prepared for layout purposes and the classification data transferred to this base after the classification was completed. The topographic map has horizontal distances measured by a tellurometer and has an accuracy of 1 meter in 7,500 meters. A comparison of the photos with the topographic maps shows the photos are usually 20-25 percent short in horizontal distances due to distortion. Figures IV-15 and IV-16 show the general location of arable lands on the improved topographic base map. Photo locations and sites of borings are also shown. Figure IV-17 shows the available data and description of soil borings secured in the project area.

The classification was of subreconnaissance nature and considerable changes may be anticipated when detailed studies are made.

Description of Land Classes

Class 1 lands occur on about 5 percent of the project area. Most of these lands occur in bamboo forests. Controlled burning may be a means of clearing these lands with minimal costs. The soils are generally deep, well drained latosol type, and the topography is usually smooth with very gentle slopes. Most slopes are near 1 percent with some slopes up to 3 percent.

Class 2 lands of intermediate suitability occupy about 31 percent of the project area. The largest concentration of these lands is in the southern half of the area. They are usually undulating lands of 3 to 8 percent slopes with an associated open forest composed primarily of acacia and fig trees with considerable grass. Some Class 3 and Class 6 lands are included in this land class because of the subreconnaissance nature of the classification. Detailed studies can be expected to reduce the percentage of Class 2 lands. This reduction is expected to be mostly due to topographic deficiencies rather than soil deficiencies. Most of the Class 2 lands have latosol-type soils.

Class 3 lands are the least suitable for irrigation, but can be irrigated if proper recognition is given to their deficiencies. These lands occupy 64 percent of the project area according to this classification and this percentage can be expected to increase moderately when detailed studies are made. Most of the Class 3 lands have been downgraded because of soil conditions (grumusols) and therefore detailed studies are not expected to change the present status as much as in the Class 2 lands. The exception may be in the Class 3 lands near the escarpment which are subject to flooding, and some of the Class 3 lands in the southern half of the project which were downgraded because of rough topography. Further studies can be expected to delete some of these lands as Class 6.

Class 6 lands are not suitable for irrigation. They occupy the natural drainage channels and adjacent rough terrain, obvious high isolated areas, slopes in excess of 12 percent, and rough, rocky or severely eroded areas.

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Classification Results

Table IV-10 shows the results of the classification:

TABLE IV-10 - ARABLE AND IRRIGABLE AREAS--BELES RIVER PROJECT

Land type	Land areas (hectares)			
	Class 1	Class 2	Class 3	Total
Total arable	5,700	35,000	67,200	107,900
Arable under canal	4,900	30,100	62,200	97,200
Irrigable	3,200	19,600	40,400	63,200

The irrigable area is estimated to be 65 percent of the arable land under the canal. This substantial reduction indicates that considerable changes in the location and land class designations may be anticipated when detailed studies are made.

Conclusions

1. The Beles River area has a majority of soils which are not well adapted to irrigation unless the land use can be adjusted to the capabilities of the soils.

2. Canal, lateral, and farm distribution facilities may be difficult to maintain below the escarpment on the east and southeast side because of flood hazards.

3. The best lands will require clearing of timber before irrigation can be attained.

4. Access to a gravel, all-weather road system will require an extensive road construction program.

5. Settlers will need to be imported into the area since it is now essentially a virgin area.

6. Crops will need protection from damage by wild animals, especially baboons and hogs.

7. Erosion hazards are great and further studies are needed to determine the proper slope limitation permissible for the conditions of land use and management anticipated on this project.

Recommendations

1. A detailed land classification should be made prior to construction to accurately delineate the various land classes and to better characterize the suitability of the grumusol soils for irrigation.

2. An agricultural experiment station is needed on the grumusol soils to determine the best crop rotations, crop varieties, and fertilizer practices for the project.

3. Water applications should be carefully managed to avoid excessive erosion.

BIRR RIVER AREA PROJECTS

Introduction

Three separate large projects, in addition to a small initial development area, are contemplated for irrigation in the Birr River area. These projects are called the Lower Birr, the Debohila, and the Upper Birr. The small demonstrational plot is called the Jiga Springs Pilot Project area.

The Upper Birr Dam and Reservoir, near the confluence of the Birr and Talya Rivers, would provide a source of irrigation for the Upper and Lower Birr Projects, while a dam and reservoir on the Debohila River would service the remainder of the project lands. Irrigation water for the proposed Jiga Springs Pilot Project would come from a spring rising near the town of Jiga.

Lands which will be serviced in these proposed developments were classified during the same period. Separable data on the irrigable acreage within each of the projects are presented. Although a total gross arable area of 69,772 hectares was delineated during the classification, only 46,965 hectares of arable land lie under the proposed canal system. Due to the isolation and rough drainageways included in the arable lands, plus the questionable irrigability of some Class 3 lands, this area has been reduced 25 percent in estimating the irrigable land.

Location and Extent

The Birr River area projects are situated in the central portion of the Blue Nile Basin in Gojjam Province. The basin within which these projects lie is in that portion of the great Debre Markos plateau bounded on the north by the Chokke Mountains, which rise to an elevation of about 4200 meters, and on the east by the Mangestu Mountains which reach an elevation of about 4500 meters. The southern edge has some irregular nonarable topography which opens to the Blue Nile River. The western edge joins the Azena-Fettam Project area. The basin area generally occurs within the broad boundaries of 10°22'N to 10°50'N latitude and 37°5'E to 37°35'E longitude. Most project lands occur at elevations between 1400 and 2000 meters and average about 1800 meters.

The arable lands extend along the Birr River (nearly all on the west side) and its tributaries for a distance of about 70 kilometers. The investigated area was about 20 kilometers wide at its widest point and the irrigable lands are about 16 kilometers wide at the widest point. The project areas encompass the towns of Jiga, Bure, Finote Selam, and Mankusa, as well as numerous small villages. The all-weather graveled road from Addis Ababa to Bahir Dar passes through the project area. In addition to this road, there are numerous trails, some of which can be traveled by four-wheel drive vehicles in dry weather.

Geology and Physiography

The Birr River Projects are in an elongated upland valley on the Debre Markos volcanic plateau. Very little detailed data are available concerning the number of volcanic eruptions or the extent and distribution of each flow. Due to the very large area covered by volcanic deposits, it can be assumed that there were numerous flows laid down at different times, one above the other, and occasionally alternating with lake beds, stream deposits, layers of volcanic ash, and weathered lava. No single flow is likely to be coextensive with the plateau, but the flows interfinger with each other. The volcanic strata are underlain by sedimentary sandstone and shales of Triassic age. The underlying basement complex includes Precambrian granites, gneisses, and schists.

Physiographically the area is a submature upland valley which has been strongly influenced by water erosion. The lands are mostly sloping southward toward the Birr River but are dissected at variable intervals by tributary drainageways or streams. The upper portion with greater slopes has a rolling type of topography which gradually flatten and approaches a terrace-like appearance near the Birr River. Poorly drained areas a coincident with the flatter slopes. The Birr River is entrenched well over 100 meters through the lower portion of the project area.

Climate

Weather data from the Bure station near the western edge of the project indicate that the average annual rainfall is approximately 125 centimeters (50 inches) and the major portion falls during the period from June to October.

The average annual temperatures are usually between 20° and 22° C and the extreme temperatures are 12° and 35° C. The coldest months are December and January, while the warmest months are March, April, and May. The average relative humidity is 60 to 70 percent. It may be anticipated that a considerable portion of the Lower Birr River Project would have a warmer climate than is indicated by the data from the Bure station because of the considerable difference in elevation involved. The Debohila Project will probably have a climate nearest to that indicated by the Bure station.

Present and Potential Land Use

Approximately 30 percent of the total arable land area is presently being dry farmed. There are also several rather small irrigated areas. These are mostly located near Finote Selam.

Crops being grown include corn, teff, millet, barley, wheat, horse beans, field peas, chick peas, peppers, coffee, oil seeds, and some spices and onions. Irrigation would substantially increase the yield of these crops and would also permit a greater variety of crops to be grown. Such crops as barley, castor beans, sunflower, pepper, noog, sorghum, flax seed, and coffee could be grown under irrigation, if desired.

Areas not under cultivation have open acacia forests which will need to be removed prior to irrigation. Tall grass dominates the ground cover over much of the noncultivat areas. The people who live in the area burn off the grass each year. They also raise a considerable number of zebu cattle, sheep, and goats which are grazed in the uncultivat areas. Irrigated pastures might be a possible irrigated crop when the area becomes developed and native pastures are less readily available.

Project Lands

Topography and Land Development

The lower portion of the Birr River area roughly represented by the Lower Birr Riv Project has fairly smooth uniformly sloping lands with natural drainages well incised bu rather widely separated. In this portion of the project the Birr River is incised about 80 to 100 meters, and the river channel is only about 100 to 200 meters wide. Three major drainageways enter the Birr River in this project area. These are usually about one-third as deep as the Birr River and are fairly narrow. The uncultivated land is co ered with brush and trees but would be relatively easy to clear for irrigation at costs ranging up to an estimated Eth$350 per hectare but averaging much less. Generally speaking, the Lower Birr Project has the smoothest topography in the Birr River area and would be the easiest to develop for irrigation. Land leveling costs are expected to be moderate. Slopes average about 1 percent. However, soil and drainage problems are greatest in the Lower Birr Project.

That portion of the Birr River area shown on the land classification drawings (Figures IV-18 and IV-19) as the Debohila Project has the greatest percentage of Class 1 land among the three projects. There are also more villages, more people per unit of land, and a higher percentage of dry farming here than in the other project areas. However, the irrigable acreage is greater in the other two projects.

Although the Debohila and Selale Rivers are deeply incised within the project, most of the natural drainageways are not excessively deep and dry farming is accomplished on most of the slopes. The approximate eastern half of the Debohila Project area has a need for more surface drainage outlets under irrigation. The western half, particularly that portion west of the proposed Debohila Dam, has a well developed surface drainage system and probably will not require extensive surface drains when irrigated.

Surface slopes of the arable lands in the Debohila Project area vary but are generally steeper than in the Lower Birr Project area. It is estimated that about 60 to 70 percent has slopes of about 2 percent. Both the extreme eastern and the extreme western portions have steeper slopes, averaging 3 or 4 percent. Some land having slopes up to 12 percent is included as arable.

The Upper Birr Project represents the largest area suitable for irrigation, and also has the greatest variation in topographic conditions. One problem in this area is that there are a number of isolated hills which cannot be serviced by gravity. Insufficient topographic data are available at this writing to determine the magnitude of this problem, but it can be anticipated that refined topography with a small vertical contour interval will show a substantial acreage that cannot be reached by gravity diversion.

Slopes vary greatly in the Upper Birr Project area. An estimated 20 percent has slopes of 1 percent or less and 20 percent more has slopes from 1 to 3 percent. The remaining 60 percent is steeper. This area is estimated to average about 8 percent in slope, with the extreme eastern edge having the greatest concentration of slopes approaching 12 percent. It can be anticipated that as detailed classification is accomplished, a greater percentage of nonarable land will be found in the steeper slopes than in the flatter lands.

The Birr River, while deeply incised, lies in a rather broad valley with fairly gentle side slopes in the upper part of this project and flows in a narrow, deep canyon toward the southern end. Surface drainage patterns are well developed.

The western half of the Upper Birr River Project is generally of higher quality for irrigation development than the eastern half.

The proposed Jiga development area is drained on the west by the Leza River which is incised in a narrow valley about 20 to 40 meters below the adjacent lands. On the east it is drained by the Upper Birr River which is in a broad, deep valley. The land in this small development area generally has a brush, tree, and grass cover, but is fairly smooth and has slopes averaging 2 to 3 percent. The topography is well suited to irrigation.

Drainage

Much of the flatter areas and lands with the dark gray soils is poorly drained. Some of these areas are inundated during high flow periods because of the lack of sufficient natural drainage channels. The worst portions of such lands have been deleted from the project as nonarable.

Large portions of the Lower Birr Project area will require a network of surface drainage channels and an unknown amount of subsurface drains for control of deep percolation irrigation wastes. This will be necessary because: natural drainage channels are too widely spaced for effective ground-water control; the volcanic substrata are likely to be nearly impermeable and will require subsurface channels to prevent a detrimental water table buildup; and the irrigation wastes, surface and subsurface, from the Upper Birr and the Debohila Projects will contribute to the drainage problems in the Lower Birr Project.

In addition to the anticipated drainage problems in the Lower Birr area, the lack of a well developed natural drainage pattern in the eastern half of the Debohila Project may require considerable drainage construction to alleviate ground-water problems.

A careful evaluation of surface and subsurface drainage needs under irrigated agriculture should be made at the same time other detailed investigation studies are made. Because of the need for several years' records on the present ground-water level fluctuations during and following the rainy season, it would be highly desirable to install several rows of ground-water observation wells at right angles to the various tributary rivers at least 1 year prior to initiating other detailed investigations.

It may be necessary to install canal lining in portions of the Upper Birr and Debohila canals where they traverse the latosolic soils. This would be particularly important in drainage control where the canals make a loop. Ponding tests along the proposed canal lines would provide further data to evaluate the need for such lining.

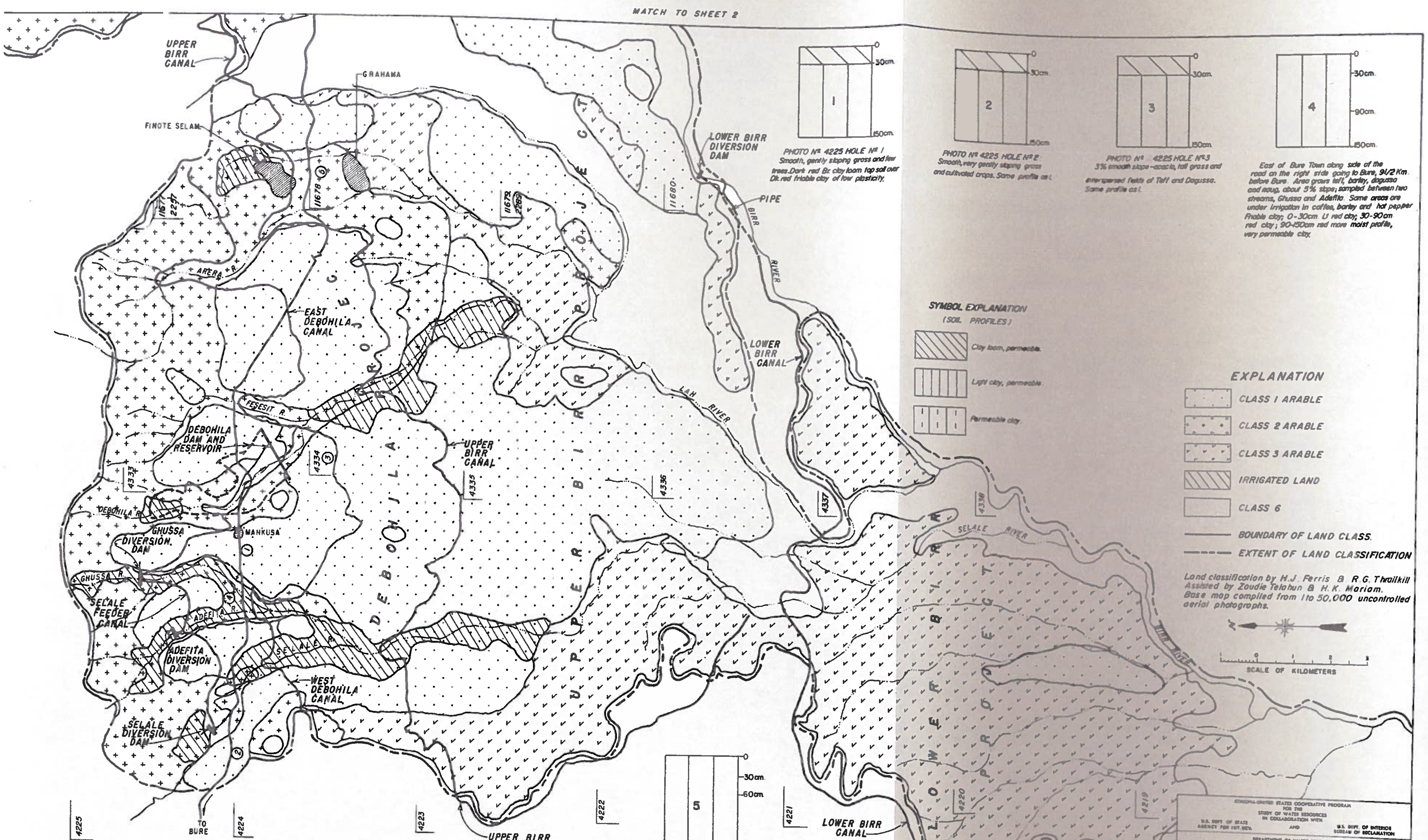
Soils

The origin of the soils is assumed to be from weathering of the volcanic deposits which underlie the entire basin. The depth of soils varies from shallow exposed basalt in some eroded hills to 20 meters or more in the lower areas. The depth variations show that much of the soil has been reworked and redeposited by alluvial action.

Even though there are considerable variations in depth, the soils are basically only two types, the upland red latosolic soils and the usually lower lying dark clays (grumusols). The upland latosolic soils, although of clay texture, are permeable and well drained and are well suited to irrigation. The dark gray clay grumusol soils which occur in the lower areas are rather poorly drained, and it is believed that this variation in the soil forming environment has resulted in the development of a different clay mineral complex. The free drainage of the latosols is responsible for the red color. As has been previously mentioned in the discussion of grumusols in connection with other projects, these soils are very fine textured, very slowly permeable when wet, crack badly when dry, and are not nearly as well adapted for general irrigated agriculture as the red latosolic soils. However, under proper management and with adequate drainage control, the grumusol soils should produce good crop yields.

Table IV-11 sets forth some typical laboratory data for the latosolic and grumusol soils in the Birr River area. Two profiles of latosolic soils and one grumusol profile are shown. The Birr River area arable lands have about 2 hectares of latosolic soils to 1 hectare of grumusol soils. As will be noted from the laboratory data, the soils are very low in available nutrients, are quite acidic, are nonsaline, and all contain a high percentage of clay. Disturbed hydraulic conductivity data have been secured in some samples. These show minimums of about 1 cm. per hour for the dark gray soils and 4 cm. per hour on the red latosols. Although these rates do not reflect actual permeability rate because the soil structure has been destroyed, they do indicate the substantial difference in permeability between these two soils.

Rocks are a development problem on some portions of all the projects--particularly in the Upper Birr and to a lesser extent in the Debohila. These are generally basalt cobble and are usually small enough to be picked up by hand. Detailed studies will likely show that some soils are shallow to solid rock, but this was not observed in the arable area during the classification.



TABULATION OF LAND CLASSES

LAND CLASS	TOTAL ARABLE (HA)	ARABLE UNDER CANAL (HA)	IRRIGABLE HECTARES UPPER BIRR	DEBO-HILA	LOWER BIRR	JIGA SPRING
1	22,767	22,465	12,500	3,240	300	224
2	8,577	3,520	1,600	960	—	—
3	36,240	20,980	10,250	—	6,300	—
PRESENTLY IRRIGATED	2,188	—	—	—	—	—
TOTALS	69,772	46,965	24,350	4,200	6,600	224

Figure IV-18 - Reconnaissance Land Classification and Soil Profiles, Birr River Area (Sheet 1 of 2)

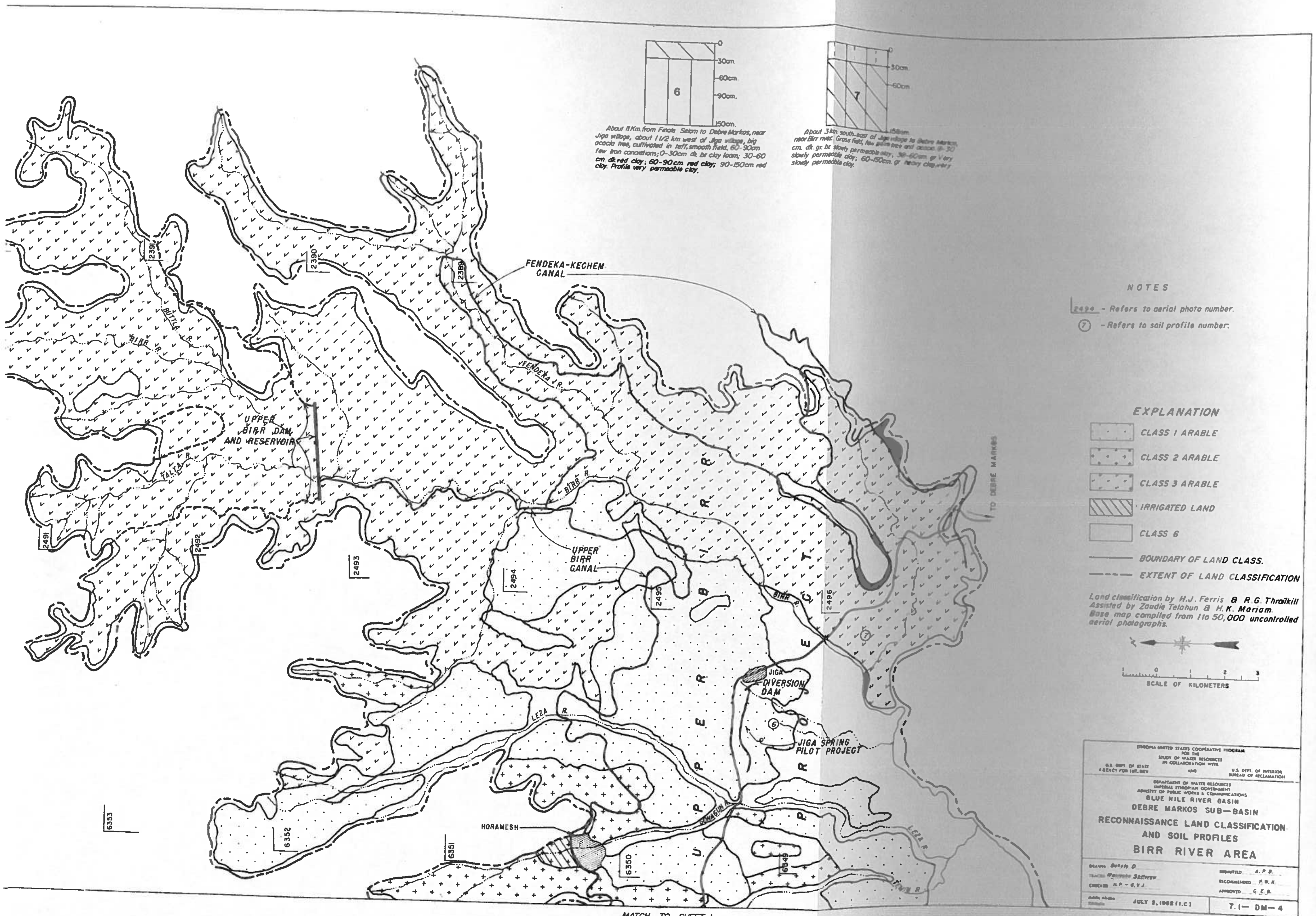


Figure IV-19 - Reconnaissance Land Classification and Soil Profiles, Birr River Area (Sheet 2 of 2)

TABLE IV-11 . LABORATORY DATA--BIRR RIVER AREA SOILS

Locations	Depth (cm.)	Color	M.A. results: Percent sand	Percent silt	Percent clay	Texture	$CaCO_3$	pH	Percent salts	Percent OM	Available nutrients: P	K	N
Photo 4285	0-30	Dk Red-Br	-	-	-	clay	0	5.3	0.12	4.8	VL	L	L
	30-90	Red-Br	-	-	-	clay	0	5.3	trace	2.1	VL	L	L
	90-150	Red	-	-	-	clay	0	5.7	trace	1.1	VL	L	L
Photo 2287	0-30	Dk Gr	22	11	67	clay	0	5.2	0.06	4.1	VL	M	MH
	30-90	V D Gr	21	10	69	clay	0	5.1	0.07	3.0	VL	L	M
	90-150	D Gr	21	8	71	clay	0	6.1	0.06	2.5	VL	L	M
Photo 4333	0-30	Dk Red-Br	23	18	54	clay	0	5.8	trace	5.7	VL	L	M
	30-75	Dk Red	19	10	71	clay	0	5.4	trace	2.8	L	L	L
	75-150	Red-Br	15	10	75	clay	0	5.0	trace	2.4	VL	L	L

Land Classification

The land classification in the Birr River area was a subreconnaissance type similar to that accomplished over most of the Blue Nile Basin. Only a very limited portion of the area was accessible to surface vehicles due to the many deep, natural drainageways which occur. In addition, the presence of high grass restricted the surface view so it was difficult to classify land in the noncultivated areas. Therefore, a helicopter was used to view the area from the air. By flying at low level (just above the treetops), terrain irregularities were observable and slopes could be estimated. Landings were made in small clearings in the trees and borings were made at representative locations. In addition, observations of soil depths were made on some of the deep channel profiles. Helicopter traverses were made at approximately 1 kilometer intervals. Lands immediately below the helicopter were classified in a strip by air observation. Later the initial delineations were extended by photo interpretation to connect all of the classification lines. Representative samples were secured for analysis at the laboratory of the Imperial College of Agriculture at Alamaya. Three arable land classes were delineated in this area because of the unusually favorable conditions for irrigation in some portions of the area and the very marginal conditions in other areas.

Class 1--Arable. Lands placed in this category are the highest quality lands for irrigation in the valley. They are generally not cultivated at present and are sometimes lacking in a sufficient amount of natural surface drainage for control of irrigation waste water. They are also often covered with tall grass, shrubs, and scattered trees which will need to be removed for irrigation. However, these soils are deep, friable, permeable, well aggregated clays which, when fertilized, will respond well to irrigation. They generally have slopes of 1 to 3 percent and therefore will not require much land leveling. These lands occupy about 48 percent of the arable project area.

Class 2--Arable. These lands generally have similar soils to the Class 1 lands (permeable red latosols) but are less desirable for irrigation because of steeper slopes, undulating topography, or surface stoniness. A higher percentage of these lands is presently cultivated than the Class 1 lands, but greater care will be needed for irrigation to prevent erosion and it can be anticipated that yields will be lower because of the greater skill required to maintain fertility and to secure uniform irrigation water penetration. These lands occur on about 7.5 percent of the arable project areas.

Class 3--Arable. The lands included in this class are typified by dark gray clay (grumusol) soil having the same general characteristics as other dark gray clays occurring in the Blue Nile Basin. Their severe cracking characteristic on drying, and their very slowly permeable infiltration rates when moist make them difficult to manage and particularly difficult to farm with crops requiring cultivation.

Further studies are needed on these soils to substantiate their arability and to determine the crops which are best suited to their use. These soils were discussed in the section, General Soils Information. In addition to inclusion of the grumusol soils, Class 3 lands also include lands with a slope of 7 to 12 percent, lands with very restricted field size, and lands with numerous stones. These lands comprise a total of 44.5 percent of the total arable lands of project. It can be anticipated that detailed studies on these lands will reduce the arable acreage substantially. This is because of the major concentration of drainage problems, soil problems, and topographic deficiencies in this land class.

Class 6--Nonarable. Lands delineated in this class are considered to be permanently unsuited to irrigation development. In the Birr River area they include lava flows, shallow and stony lands, poorly drained areas, rough or steep topography, high isolated areas, and some large tracts of poorly drained, flat, grumusol clays.

Classification Results

Table IV-12 sets forth the arable and irrigable areas in the various projects in the Birr River area.

TABLE IV-12 - ARABLE AND IRRIGABLE AREAS--BIRR RIVER AREA LANDS

Land class	All projects (ha.)		Irrigable area (hectares)				Total irrigable (hectares)
	Total arable	Arable under canal	Upper Birr	Debohila	Lower Birr	Jiga Spring	
1	22,767	22,465	12,500	3,240	300	224	16,264
2	8,577	3,520	1,600	960	-	-	2,560
3	36,240	20,980	10,250	-	6,300	-	16,550
Presently irrigated	2,188	-	-	-	-	-	-
Totals	69,772	46,965	24,350	4,200	6,600	224	35,374

Table IV-12 shows a substantial difference in area between the total of arable and the total of irrigable land. The reduction allows for service to lands below proposed canal lines and permits a reduction of 25 percent of the land below the canal when detailed studies are made. It is believed that this is a fairly conservative approach, reflecting the lands most suitable for irrigation.

The base maps used for the classification of these lands were unrectified. Later studies, where correct horizontal controls were available, show that the unrectified photos were usually considerably smaller than the scale indicated. Therefore, the planimetered arable areas which are presented are probably low. This error in base maps may be as much as 20 or 30 percent in some maps, and contributes an additional safety factor that should assure the present irrigable area will not be lower than later detailed studies can confirm.

Irrigated Lands

Several small farms are being irrigated at present in the Debohila Project area. They are located on red latolic soils and, although rather poorly managed, could be useful in evaluating irrigation response in this area if technical and financial help were provided. These lands total 2,163 hectares and are not included in the irrigable area because it is assumed that these lands will continue to receive water from their present diversions.

Conclusions

1. The Birr River area has good possibilities for successful irrigation.

2. The climate will permit many crops to be grown. However, it is not well suited for tropical crops or for some temperate crops. No frosts have ever been recorded.

3. Drainage construction costs will be substantial if water control is to be provided.

4. Irrigation should be beneficial to some outlying villages as a ready source of municipal water during the dry season.

5. Land development costs will be moderate and will be necessary mainly for clearing, farm distribution systems, and erosion control.

6. The good highway through the project area should facilitate project development.

7. Construction of the project distribution facilities will be expensive because of the numerous deeply incised drainageways which will have to be crossed.

Recommendations

1. A detailed land classification survey should be completed on all the lands below the canal lines prior to initiation of construction.

2. Detailed drainage studies, including observation well installation, pump-in tests for substrata permeability, studies to determine the proper side slopes for channel stability, channel erosion control studies, and similar studies, are needed before or during future detailed land classification investigations.

3. In addition to starting an early experimental project near Jiga, by utilizing spring flow for irrigation, studies should be made on the existing irrigation farms in the Debohila Project. Fertilizer trials, water use efficiency studies, cropping trials, and studies on proper irrigation methods should be done under controlled conditions at the earliest opportunity.

UPPER GUDER RIVER AREA

General Description

The upper Guder Area lies about 140 kilometers west of Addis Ababa on the main road to Lekkemt, and is the project most accessible from Addis Ababa that is proposed for irrigation within the Blue Nile Basin. It is in Shewa Province in the southeastern portion of the Blue Nile Basin along the west side of the Guder River. Although the town of Guder is the principal market center within the proposed project area, Ambo lies only 6 kilometers from the east boundary on the road to Addis Ababa and would also be an important market center if irrigation is developed. The area lies within the coordinates of 8°40' to 9° north latitude and 37°40' to 37°50' east longitude. It is bounded by the Guder River on the west, the Dabissa River on the north, the large Boggi ravine on the east, and rough upland areas on the south. In addition to the Fato, Indris, Chanchon, Dhemua, and Challis Rivers, which cross the area from south to north, there are numerous unnamed deep drainage channels that also carry large flows of water in the wet season. All of the tributaries to the Guder in the project area dry up after the rainy season.

Transportation

The all-weather highway which extends westward from Addis Ababa to Lekkemt in Wellegga Province passes through the north third of the area. One dry-weather road extends southeastward from the town of Guder and passes through the project area. Foot and donkey trails, traveled the year around, serve the outlying villages and communities. Additional all-weather roads are needed in the project area.

Geology and Physiography

The area is characterized by extrusive volcanic deposits, largely basalt and trachyte. In places these deposits are exposed--particularly in the beds of stream channels. Small, localized remnants of Triassic? sandstone, limestone, and travertine are also found, but are not extensive enough to affect soil development significantly. Most of the soils are residual from basalt, and are mature.

The area has a highly developed, well-entrenched dendritic drainage pattern. The project lands occur on the ridges and smoother sideslopes between the drainages. The ridges are characteristically long, narrow, relatively smooth, and vary in slope from less than 1 percent to lands too steep for irrigation. Most ridge tops have slopes of 1 to 3 percent, and are generally 200 to 500 meters in width, but occasionally are as narrow as 50 meters or as wide as 1 kilometer. Sideslopes from 3 to 12 percent account for approximately 40 percent of the project land. Most drainageways are 10 to 20 meters deep. The large ravine bordering the irrigable area on the east is well over 100 meters deep.

Figure IV-20 - Farms and houses on the plateau near the edge of a small tributary to the Blue Nile River between the Guder and Muger Rivers.

Figure IV-21 - Intensive cultivation near Ambo in the upper Guder watershed.

Climate

The Upper Guder River area, like most of the plateau and highlands, has a temperate and equable climate. Climatic data* from the Ambo Agricultural School, which are generally applicable to the Guder River area, indicate an average annual rainfall of 110 cm. (43 in.) for the period 1951 to 1957. The greater part of this precipitation falls during June, July, August, and September. Temperature data show an average annual maximum of 25° C and an average annual minimum of 11.5° C. Absolute maximums of 31° C have occurred during March, April, and May. Absolute minimums of 3° C have been recorded in November, December, and January.

Present and Potential Land Use

Nearly all of the drainageways have thick tree and brush cover. Within the proposed service area a substantial proportion of the arable lands are presently dry farmed. Subsistence crops, such as noog, teff, wheat, barley, rape, and false banana are grown. In addition, grazing of cattle and sheep is an important source of income. The proposed service area has the highest percentage of presently farmed land of any area proposed for irrigation within the Blue Nile Basin.

Two irrigated areas are located near the Guder River in the northern portion. One is a plantation which produces a rather wide variety of field crops as well as grapes, lemons, oranges, and limes. The other is an experimental farm where grapes, papayas, citrus fruits, and common field crops are grown.

Although not in the proposed project area, the Agricultural School at Ambo is producing a wide variety of truck crops as well as fruit, bananas, citrus, papaya, and field crops. However, the soils, topography, and climate are not as favorable for maximum production as would be desired. Such crops as small grain, sorghum, pulses, noog, and flax are possible crops for the project area.

The Galla people inhabit the project area, and the largest population is in the northern portion.

Project Lands

Topography and Land Development

The project area slopes to the northward at an average slope of 1 to 2 percent and the average elevation is about 2150 meters. Micro relief is very pronounced. Although the regional slope averages only about 45 meters per kilometer, much steeper slopes in the drainage channels are common.

A dendritic erosional pattern exists and the numerous, well-incised drainageways will create many problems in water distribution and waste disposal. Arable lands occur mostly on ridges between drainageways and on the smoother slopes into the drainage. It is estimated that the majority of the arable land has slopes of less than 5 percent, but approximately 40 percent has slopes of 5 to 12 percent, which is the maximum considered to be suitable for development in this area. There needs to be further study to determine if these slopes are permissible. The very deep eroded channels throughout the project area are indicative of the highly erosive nature of the soils.

A large portion of the arable area has been dry farmed at one time or another. Some areas have scattered trees or brush which should be removed for irrigated agriculture. However, land development costs are expected to be low because the lands are fairly smooth and have sufficient slope to obviate the necessity of highly precise leveling. It is estimated that average land development costs of about Eth$125 per hectare will be sufficient to do the necessary clearing and land leveling.

*From the Climatogical Service, Civil Aviation Department, Addis Ababa. Records taken at the Ambo Agricultural School.

The highest quality lands for irrigation from a topographic consideration occur near the Guder River. The southern third of the area is the least attractive because of numerous deep drainageways, steep slopes, forested areas, and rougher surface topography.

Canal and lateral construction costs may be high because of the many deep drainageways which must be crossed to distribute the irrigation water.

Drainage

Natural deeply incised drainageways 5 to 30 or more meters deep occur in all parts of the project area. In most instances the deeper channels are little more than one-half kilometer apart and smaller drains which will assist in surface drainage are 100 to 200 meters apart.

Nearly all of the natural channels have rock bottoms and trees or bushes in and immediately adjacent to the channel. Although this will assist in stabilizing the channels from becoming wider, there will be some erosion hazards in allowing surface waste waters to enter these natural channels.

Practically all of the project area is underlain by basalt or trachyte. No water table problems were observed in the course of the land classification. Although it is possible that some water table problems may develop with irrigation, it does not seem likely to be a general problem because of the numerous natural drains. Time did not permit a study of subsurface drainage conditions. Several rows of deep observation wells are needed to evaluate the present ground-water behavior and to determine the permeability of the underlying basalt.

Soils

Three major soils occur in the Guder area: grumusols, latosols, and an intermediate brown soil.

The grumusol soils predominate. These are black tropical soils which have a clay or silty clay texture and crack deeply on drying. They usually have a mulchy granular structure at the surface and a massive structure at depth. The grumusols in this area have a near-neutral to mildly acidic surface and gradually become more alkaline with depth. At 1.5 meters the soils usually have a pH of near 8.0. A typical profile has these characteristics:

Depth (cm.)	Texture	% Salt	pH Paste	$CaCO_3$	Color - Wet
0 - 30	clay	.21	5.4	0	10 YR 3/1
30 - 60	clay	.12	7.3	0	7.5 YR 3/0
60 - 112	clay	.08	6.7	0	10 YR 3/2
112 - 115	clay	.11	7.4	++	10 YR 3/2

Soluble salts and exchangeable sodium percentages are very low. However, the cation exchange capacity is high. A small amount of calcium carbonate is present throughout the soil and it is believed that calcium and magnesium are the predominant cations in the exchange complex. This soil is very erosive and care must be taken in disposal of surface wastes to prevent excessive gully-type erosion. The soils are usually slowly permeable and accept water mainly through cracks rather than from normal surface infiltration. When these soils reach field capacity they may become impermeable. Because the soil cracks soon after irrigation, it is believed that sufficient water will enter the soil to maintain crop production. These soils are difficult to till and require greater skill in management for good production than the other two soils. Because of the greater difficulty in farming and an anticipated average lower production, they are considered to be Class 3 or a marginal type for irrigation. Further detailed studies are needed to appraise more accurately the management difficulties and their irrigation potential.

The latosols, or red soils, occupy a small area between the Guder and Indris Rivers and in the extreme northern area near the junction of the Guder and Dabissa Rivers. Although these soils may contain 60 to 70 percent clay, they are much more permeable than the black soils, and behave more like a medium textured soil. This is due to the predominance of the clay minerals kaolinite and illite. The pH of these soils is mildly acid throughout the soil, and is more acid on the surface than in the subsoil. The pH usually varies from about 5.0 to 7.0. Cation exchange capacities are lower than for the black soils. Plant nutrients are low in these soils, but they are readily permeable and are easily managed.

The brown soils occur on the eastern third of the project and also occur on the ridge between the Indris and Fato Rivers. These soils vary in their characteristics but are usually more like the latosols than the grumusols. A typical profile of this soil group could be described as follows:

0 - 45 cm.	brown silty clay, pH 6.0
45 - 60 cm.	light brownish gray calcareous silty clay, pH 7.8
60 - 90 cm.	very dark brown clay, pH 7.0
90 - 120 cm.	dark brown, massive, slowly permeable clay.

The soils vary in depth to basalt or trachyte, but soils depths are nearly always more than 150 cm., and usually over 500 cm. to bedrock. Volcanic ash was found to occur in the plow soil of a few areas.

Because of the occurrence of both grumusols and latosols in this project, and the need for detailed mineralized studies of typical profiles in these soils, four soil samples from the area have been analyzed. The selected samples were submitted to the United States Bureau of Reclamation soils laboratory at Denver, Colorado. The samples are identified as follows:

No. 2--Red Soil

Laboratory No.	Depth
39H - 1	0 - 12 inches
39H - 3	24 - 60 inches

No. 3--Dark Soil

Laboratory No.	Depth
39H - 4	0 - 12 inches
39H - 6	36 - 54 inches

These samples were analyzed for mineral content by X-ray diffraction and differential thermal analyses. Free swell tests were also made. The petrographic description given to these soils by the laboratory follows:

No. 2--Red Soil, Laboratory Samples No. 39H - 1 and 39H - 3

These are reddish brown, slightly sandy and silty clays, the shallower sample, No. 39H - 1, being less red colored and containing more sand and silt. The sand is mostly finer than 1.5 mm. (0.75 mm. in Sample 39H - 3). The sand consists of a few various rock fragments; feldspar grains, mostly clear, tabular and etched, some deeply altered; bright doubly terminated quartz crystals; minor amounts of magnetite, hornblende and epidote; and traces of other minerals not identified. Clays are the major constituents of the soils. The clay minerals are very fine, slightly birefringent, with refractive index about 1.55. They are seen as red, aggregated particles with silt inclusions. The red color is provided by a small amount of iron oxide, probably of near-colloidal grain size. The principal clay mineral is a poorly crystallized kaolinite type clay. X-ray and DTA data indicate this is a mixture of kaolinite and metahalloysite with kaolinite predominating in Sample 39H - 1 and metahalloysite in Sample 39H - 3. There are also minor amounts of illite and beidellite clays present. The very noticeable weakness of the X-ray pattern suggests that part of the samples are amorphous.

TABLE IV-13 - ESTIMATED MINERALOGICAL COMPOSITION OF BLUE NILE SOILS1/

Mineral	Latosols 39H-1	Latosols 39H-3	Grumusols 39H-4	Grumusols 39H-6
Quartz	5-10	5-10	5-10	5
Feldspars	10-15	5-10	5	5
Iron oxides	5	5	Trace	Trace
Kaolinite	Major	Major	Minor	Minor
Halloysite	Moderate	Major	--	--
Beidellite2/	Minor	Minor	Major	Major
Illite	Minor	Minor	Minor	Minor
Calcite	--	--	--	5

1/Very small amounts of various other minerals are present, mostly unidentified.
2/Montmorillonitic-type clay responsible for swelling characteristic.

TABLE IV-14 - FREE SWELL TESTS

Laboratory no.		Depth (inches)	Free swell, percent	
			Soil	Clay fraction
Red soil (No. 2)	(39H-1	0-12	50	50
	(39H-3	24-60	50	50
Gray soil (No. 3)	(39H-4	0-12	225	310
	(39H-6	36-54	210	320

However, no distinctly amorphous material can be seen in significant amounts microscopically and, if present, it must be intimately associated with the clay. The weakness of the diffraction pattern may be due mainly to the poor crystallinity of the clays. Quantitative estimation of the clay minerals under these circumstances is virtually impossible.

No. 3--Dark Soil, Samples No. 39H - 4 and 39H - 6

These materials are gray, slightly silty clays. Sample 39H - 6 is also slightly calcareous. There is very little sand-sized material, most of it being feldspar and quartz grains, iron and manganese oxides, and very minor biological remnants (shells, etc.). The clay is moderately birefringent, with index of refraction above 1.55, and gives strong positive reaction for montmorillonite-type clay in the benzidine staining test. X-ray diffraction analysis and DTA indicate the principal clay mineral is beidellite, a low-swelling montmorillonite-type clay. There are also moderate amounts of kaolinite and minor amounts of illite in both these samples. The calcite in Sample 39H - 6 does not appear in the clay fraction, consequently it is mostly coarser than 2 microns.

The beidellite is rather poorly crystallized, but this is a fairly common state of occurrence of this mineral. It does orient fairly well on a glass slide while the kaolinite minerals in the red soil do not. The basal spacing of Sample 39H - 4 is about 13.4A, and that of No. 39H - 6 is about 14.5A for air-dry material. This indicates No. 39H - 6 contains considerably more exchangeable calcium than No. 39H - 4, but the data on cation exchange capacity and exchangeable sodium do not appear to bear this out. DTA results do indicate exchangeable calcium is present in both these samples but gives no clear-cut indication as to whether calcium or sodium predominates.

Mineral percentages, as well as they can be estimated, are given in Table IV-13. Free swell tests are reported in Table IV-14.

Additional laboratory data on these special samples, relating to pH, cation exchange capacity, electrical conductivity of the saturation extract, and exchangeable sodium percentages, are shown in Table IV-15. Table IV-16 shows the laboratory data secured on some routine samples secured during the classification. It will be noted from these latter data that available phosphate is low. Potassium and calcium are probably adequate, but nitrogen fertilizer can also be expected to provide a favorable crop response.

Field infiltration data were made on a very dark gray brown and on a very dark gray clay in the Upper Guder River area. These data are shown in Figures IV-22, IV-23, IV-24, and IV-25. It is believed that the favorable permeability shown in these two tests is not representative of a large percentage of the area, because much of the area appeared to be more impermeable than these data indicate. Further studies on infiltration rates are needed.

Land Classification

The land classification on the Upper Guder River area was completed in December 196[illegible]. This showed a total arable area of approximately 30,000 hectares, and the results are shown on Figure IV-26. Subsequent studies on irrigability showed that a substantial portion of the total arable area was too high in elevation and could not be economically served without expensive and infeasible pump lifts. An area of about 5,100 hectares was selected for irrigation. A more refined reconnaissance land classification was made on this smaller area for training purposes. This refinement was principally a more critical examination of the topographic features. No additional soil borings were made, but exposed profiles in drainageways were observed. Although not of usual semi-detailed accuracy, this classification is termed "semi-detailed" for lack of a better description. The results are shown on Figure IV-27. A comparison of the two drawings shows more land deleted as Class 6 and a lower general classification in the "semi-detailed" examination. The general discussion of land resource features is therefore confined to the proposed service area rather than to the much larger arable area originally classified.

TABLE IV-15 - LABORATORY DATA ON SPECIAL SAMPLES OF UPPER GUDER RIVER AREA SOILS

Kind of soil	Latosol			Grumusol			
Laboratory No.	B-6425	B-6426	B-6427	B-6428	B-6429	B-6430	B-6431
Earth Laboratory No.	39H-1	39H-2	39H-3	39H-4	39H-5	39H-6	39H-7
Identification	No. 2 0-12	No. 2 12-24	No. 2 24-60	No. 3 0-12	No. 3 12-36	No. 3 36-54	No. 3 54-60
pH (paste)	5.8	6.1	6.3	7.2	7.4	7.7	7.8
pH (1:10 dilution)	6.4	6.7	6.3	7.6	8.3	8.5	8.5
Cation exch. cap me/100 g. soil	57.6	57.9	54.6	148	145	128	128
K x 10^3 (saturation extract)	0.59	0.20	0.13	0.51	0.36	0.37	0.38
Exch. sodium percentage	1.67	1.42	1.74	0.66	0.98	2.01	2.62

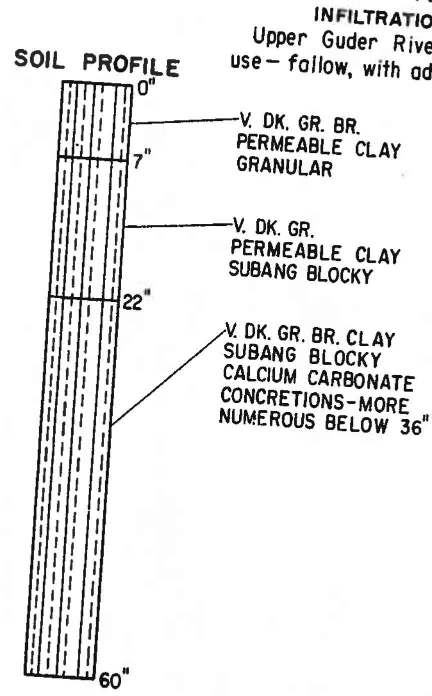
TABLE IV-16 - LABORATORY DATA ON ROUTINE SAMPLES OF UPPER GUDER RIVER SOILS

Photo no.	Hole no.	Depth (cm.)	Percent salt	pH	M. A. results				Color dry	Total N	Percent OM	Available nutrients			
					Percent sand	Percent silt	Percent clay	Texture				P	K	Ca	Mg
5085	2	0-30	0.21	5.4				clay	v dk gr					-	
5085	2	30-60	.12	7.3				clay	v dk gr					-	
5085	2	60-112	.08	6.7				clay	v dk gr-br					-	
5085	2	112-150	.11	7.4				clay	v dk gr-br					+	
5085	4	0-30	.05	5.2				clay	v dk gr					-	
5085	4	30-60	.08	6.0				clay	v dk gr					-	
5085	4	60-90	.09	6.9				clay	v dk gr					-	
5085	4	90-120	.11	7.4				clay	dk gr					-	
5085	4	120-150	.12	7.3				clay	dk gr					+	
7251	4	0-30	.06	6.0				clay	v dk gr					-	
7251	4	30-75	.08	6.6				clay	v dk gr					-	
7251	4	75-112	.11	6.8				clay	v dk gr-br					-	
7251	4	112-150	.12	7.6				clay	v dk gr-br					+	
10733	1	0-30	.03	5.4				si cl lo	dk rd-br					-	
10733	1	30-85	Tr	5.7				si cl lo	dk rd-br					-	
10733	1	85-150	.04	5.3				clay	rd-br					-	
5085	3	0-30	.12	5.4	20	19	61	clay	v dk br	0.27	3.15	M	MH	M	
5085	3	30-75	.02	6.4	18	14	68	clay	dk gr	.13	1.4	L	H	M	
5085	3	75-105	.11	7.4	20	14	66	clay	dk gr	.36	1.5	LM	H	MH	
5085	3	105-150	-	7.4	18	16	66	clay	dk gr	.16	1.5	MH	M	VH	

TEST SITE NO. 1

INFILTRATION DATA – CYLINDER NO. 1

Upper Guder River Area – Ras Abeba Farm – land use – fallow, with adjacent irrigated grapes and onions



INFILTRATION RATE – INCHES PER HOUR (FROM 12-INCH DIAMETER INNER CYLINDER)

TIME	1ST DAY	2ND DAY
1ST Hour	2.43	0.28
2ND Hour	1.70	0.28
3RD Hour	1.34	0.28
4TH Hour	1.34	0.28
5TH Hour	1.05	0.27
6TH Hour	1.05	0.27
7TH Hour	0.81	0.27
8TH Hour		0.27
TOTAL	9.72	2.20
AV. PER HOUR	1.39	0.27

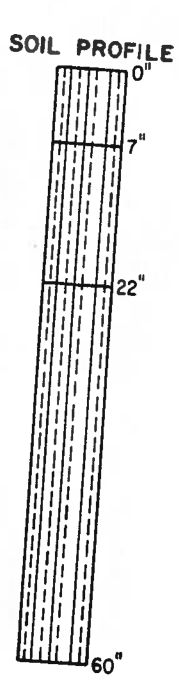
Moisture pattern could not be plotted due to uniformly moist subsoil.

Figure IV-22 - Infiltration data on very dark gray brown clay--Cylinder No. 1--Upper Guder Area

TEST SITE NO. 1

INFILTRATION DATA – CYLINDER NO. 2

Upper Guder River Area – Ras Abeba Farm – land use – fallow, with adjacent irrigated grapes and onions



See profile description for cylinder No. 1.

INFILTRATION RATE – INCHES PER HOUR (FROM 12-INCH DIAMETER INNER CYLINDER)

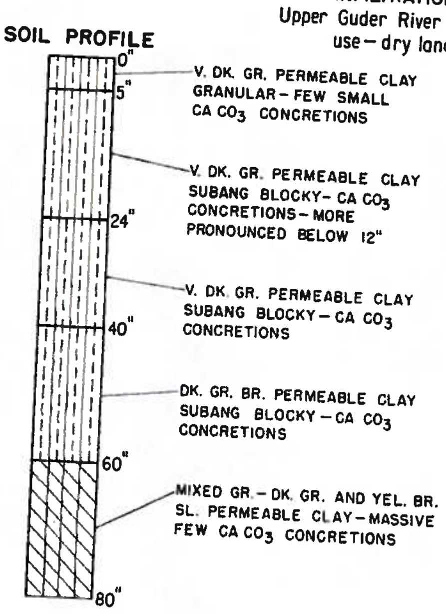
TIME	1ST DAY	2ND DAY
1ST Hour	3.72	0.61
2ND Hour	3.13	0.81
3RD Hour	2.86	0.64
4TH Hour	2.39	0.77
5TH Hour	2.15	0.71
6TH Hour	2.15	0.54
7TH Hour	1.88	0.54
8TH Hour		0.54
TOTAL	18.28	5.16
AV. PER HOUR	2.32	0.64

Figure IV-23 - Infiltration data on very dark gray brown clay--Cylinder No. 2--Upper Guder Area

TEST SITE NO. 2

INFILTRATION DATA – CYLINDER NO. 3
Upper Guder River Area – Ato Kaptymer farm – land use – dry land cultivation sorghum field

SOIL PROFILE



INFILTRATION RATE – INCHES PER HOUR
(FROM 12 – INCH DIAMETER INNER CYLINDER)

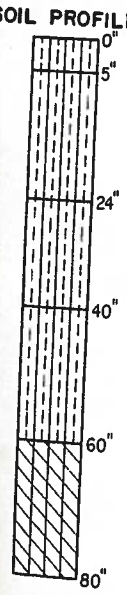
TIME	1ST DAY	2ND DAY
1ST Hour	6.94	1.22
2ND Hour	3.23	0.91
3RD Hour	2.42	0.91
4TH Hour	2.29	0.91
5TH Hour		0.87
6TH Hour		0.87
7TH Hour		0.87
TOTAL	14.88	6.56
AV. PER HOUR	3.72	0.93

Figure IV-24 - Infiltration data on very dark gray clay--Cylinder No. 3--Upper Guder Area

TEST SITE NO. 2

INFILTRATION DATA – CYLINDER NO. 4
Upper Guder River Area – Ato Kaptymer farm – land use – dry land cultivation sorghum field

SOIL PROFILE



See profile description for cylinder No. 3.

INFILTRATION RATE – INCHES PER HOUR
(FROM 12 – INCH DIAMETER INNER CYLINDER)

TIME	1ST DAY	2ND DAY
1ST Hour	3.18	0.54
2ND Hour	1.24	0.47
3RD Hour	1.07	0.44
4TH Hour	1.07	0.44
5TH Hour		0.45
6TH Hour		0.45
7TH Hour		0.48
TOTAL	6.56	3.27
AV. PER HOUR	1.64	0.46

Figure IV-25 - Infiltration data on very dark gray clay--Cylinder No. 4--Upper Guder Area

The land classification on the Upper Guder River area was made mostly by use of a four-wheel-drive vehicle rather than with a helicopter. Therefore, somewhat better observations of soil and topographic conditions were made than on most of the other projects.

Details of the specifications and other phases of classification are set forth elsewhere in this report.

Class 1 lands total 260 hectares or 4.8 percent of all the arable lands under canal. These lands occur at the extreme north portion of the project area and also west of the Indris River. Permeable latosol clay soils typify the soils in this class. The lands are smooth, free of rock, and considered to be the most productive in the area. Detailed studies are not expected to change this percentage substantially.

Class 2 lands in this area are so classed mainly because of sloping land or surface irregularities requiring some leveling. The soils are permeable latosol clays or the intermediate permeable brown clay soil. These lands total 1,240 hectares or 22.8 percent of the arable project area under canal. Detailed studies may lower the percentage of Class 2 because of the numerous topographic deficiencies.

Class 3 lands include all of the dark clay soils (grumusols) plus any of the three soils if found on rough, or steep slopes. Some stony lands are included in this class. The Class 3 lands total 3,950 hectares or 72.4 percent of the arable lands that can be served by canal. Detailed studies may exclude some of these lands as Class 6. Additional studies are needed to determine the proper slope limitation for irrigation on these soils.

Class 6 lands occur in the numerous drainageways throughout the area, and some isolated high areas which cannot be reached by a gravity system.

Classification Results

The following tabulation shows the results of the classification:

	Class 1 (hectares)	Class 2 (hectares)	Class 3 (hectares)	Total (hectares)
Total arable	2,110	27,980	-	30,090*
Arable under canal	260	1,240	3,950	5,450**
Irrigable acreage	240	1,160	3,700	5,100

*Based on subreconnaissance classification of area of investigation.
**Based on semi-detailed classification of service area.

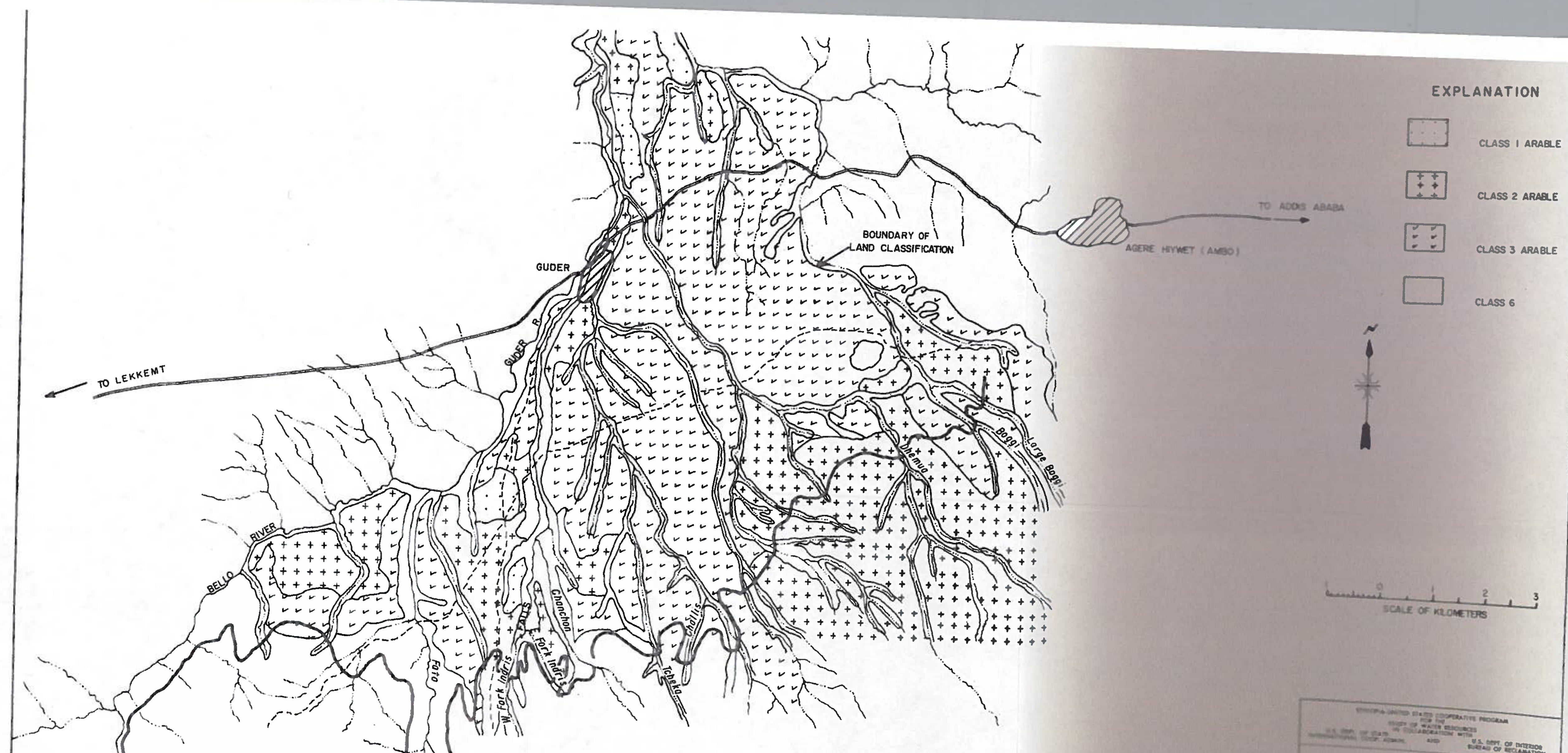
The estimated irrigable area represents only about a 6.5 percent reduction from the "semi-detailed" arable acreage. It is very doubtful if this high proportion of irrigability will be substantiated by detailed studies.

Conclusions

1. The location of the Upper Guder area is excellent with respect to markets and all-weather roads.

2. Since most of the proposed service area is presently dry farmed, the lands are generally cleared, and can be adapted to irrigation readily.

3. The numerous deeply entrenched stream channels will create problems in water distribution and high distribution costs, but should aid drainage.



TABULATION OF LAND CLASSES

	CLASS 1	CLASS 2	CLASS 3	TOTAL
ARABLE HECTARES BELOW CANAL	260	1240	3950	5450
ESTIMATED IRRIGABLE HECTARES	240	1160	3700	5100

ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM FOR THE STUDY OF WATER RESOURCES IN COLLABORATION WITH U.S. DEPT. OF STATE INTERNATIONAL COOP. ADMIN. AND U.S. DEPT. OF INTERIOR BUREAU OF RECLAMATION

DEPARTMENT OF WATER RESOURCES IMPERIAL ETHIOPIAN GOVERNMENT MINISTRY OF PUBLIC WORKS & COMMUNICATIONS

BLUE NILE BASIN

"SEMI-DETAILED" LAND CLASSIFICATION

UPPER GUDER RIVER AREA

SUBMITTED A.P.B.
RECOMMENDED P.W.K.
APPROVED C.E.B.

71-Gu-3

Figure IV-27 - "Semi-Detailed" Land Classification, Upper Guder River Area

4. The soils are erosive and care will be needed to prevent further soil deterioration from this cause.

5. Small fields will result from irrigation development because of the narrow ridges and complex topography.

6. The presence of irrigation now being used in the area is fortunate, and should aid in evaluating the general irrigation potential.

Recommendations

1. Further studies are needed on determining the maximum slopes which can be successfully irrigated without excessive erosion on project lands.

2. Detailed land classification is needed to accurately determine the area which can be successfully irrigated.

FINCHAA RIVER AREA

Introduction

The lower end of the Finchaa Valley west of the river was initially classified and evaluated on the assumption it would be serviced from a gravity diversion at the upper end of the Finchaa Valley like the remainder of the project. Subsequent studies show that this area can be more economically serviced from water stored in reservoirs on the Amarti and Neshe Rivers. This portion of the original Finchaa Project is now considered a part of the Amarti-Neshe Project. Additional lands in the Amarti and Neshe Valleys, as well as these near the Finchaa River, are included in the Amarti-Neshe Project. Due to the close integration of the Finchaa and the Amarti-Neshe Projects, the land resource data are consolidated and included here as a single presentation. That portion of the Amarti-Neshe Project situated in the Amarti-Neshe Valleys was not classified other than by aerial observation, and the data are projected primarily from the information available from the Finchaa Valley; therefore the accuracy of classification of this area is lower than that of the Finchaa Valley. The Finchaa Project area is about twice as large as the Amarti-Neshe. Separable data on the estimated irrigable acreages for both projects are included.

General Description

The Finchaa Basin occupies an upland valley position in the eastern portion of Wellegga Province near the center of the Blue Nile Basin. The Finchaa River rises in the mountains which lie to the north of the Addis Ababa-Lekkemt highway between the Guder River drainage and the village of Baco. The tributaries flow generally northward into the Chomen swamp, a vast flat area lying on the plateau between the mountains and the precipitous escarpment forming the northern limit of the plateau. After the river leaves the swamp, it plunges abruptly over the escarpment, which is several hundred meters high. It then flows through the Finchaa Valley and plunges downward through some rough terrain to its junction with the Blue Nile River.

The Finchaa Valley lies in a boxlike canyon about 12 km. wide and 37 km. long. It is bounded on the south, east, and west sides by high, near-vertical escarpments which terminate in a relatively flat plateau in the upland. The plateau lies approximately 750 meters (2,400 feet) above the valley floor. Near the lower end of the valley the western boundary is low hills which separate the Finchaa and Amarti-Neshe River drainageways.

The Finchaa and Amarti-Neshe River Valleys are contiguous with each other and are located within the general boundaries of 9°35' to 9°55' north latitude and 37°15' to 37°28' east longitude.

Transportation and Habitation

Both the Finchaa and Amarti-Neshe River Valleys are uninhabited and uncultivated. There are a few foot and game trails, but no roads exist. The nearest all-weather market road is at Gedo, approximately 60 km. from the upper end of the Finchaa Valley. The escarpment which virtually surrounds the Finchaa Valley is about 750 meters high and will create a problem in any attempt to construct a road from the plateau to the valley. The plateau areas which join the Finchaa and Amarti-Neshe River Valleys are inhabited and much of this area is cultivated.

Geology and Physiography

The plateaus which surround the major portion of the Finchaa Valley and form the southern boundary of the Amarti-Neshe Valley are volcanic-capped, massive, deep beds of Triassic sandstone.

The Finchaa River Valley has developed on an intervalley flow of basalt, deposited in an older, previously eroded valley. It is believed that the intervalley filling of lava is younger than the plateau volcanics and probably originated in the vicinity of the volcanic plugs and cones upstream within the swamp area of the plateau. The Finchaa River has eroded down to the basalt, and is generally 10 to 50 meters or more below the elevation of the adjacent lands.

Arable lands have developed under the influence of the underlying basalt and the massive sandstone deposits surrounding the project areas. Alluvial depositions brought about in flooding during early stages of the river entrenchment, colluvial debris from the high cliffs, and alluvial fan deposits from the numerous side intermittent streams have all influenced the soil properties considerably.

Due to the uneven flow of underlying basalt, differential erosion, and the present irregular topography, some soils have also developed by residual weathering of basalt.

The Finchaa Valley slopes to the northward at an average rate of slightly less than 1 percent, and the land areas on either side of the river slope to the center at an average rate of about 2 percent. The project lands are dissected by many tributary channels varying in depth from shallow swales to vertical cuts of 20 meters or more. The type of erosion indicates a young or very early maturity type of geologic development.

Although little data are available on the Amarti-Neshe Valleys, it is probable that there valleys are ancient alluvial depositions overlying metamorphic rock. These valleys have a dendritic-type erosional pattern similar to the Finchaa Valley.

Climate

No climatic data are available for the area, but the location and elevation are such that one can infer what the climatic conditions are likely to be. Typical of the upland valleys, the native vegetation indicates a warm, subtropical climate. With an average elevation of about 1450 meters (4700 feet), frost should be very rare. Annual precipitation is estimated to be about 50 to 125 cm. (30 to 50 inches). The bulk of the rainfall occurs in the months of June through September. Annual temperature should average about 22° C (72° F

Present and Potential Land Use

The vegetative cover over the project areas consists of a fairly dense growth of tropical savannah woodland, typified by acacia, fig, and other varieties of deciduous trees and shrubs, interspersed with a very dense growth of tall grass. With the exception of trees growing in the stream bottoms, which often reach a height of about 30 meters (100 feet), the usual trees on arable land attain a maximum height of about 9 meters (30 feet) and a maximum diameter of about 1/2 meter (20 inches). An occasional area of grass occurs, occupying a rather flat or lowland position, but these areas comprise a small percentage of the total area. Seasonal burning of the grass is practiced.

A large variety of crops could be grown because of the long growing season. However, the cool nights limit the production of some crops. The most likely crops under irrigation would include corn, sorghum, castor beans, field beans, coffee, tobacco, peppers, flax, and other oilseeds. Some subtropical fruits could also be grown.

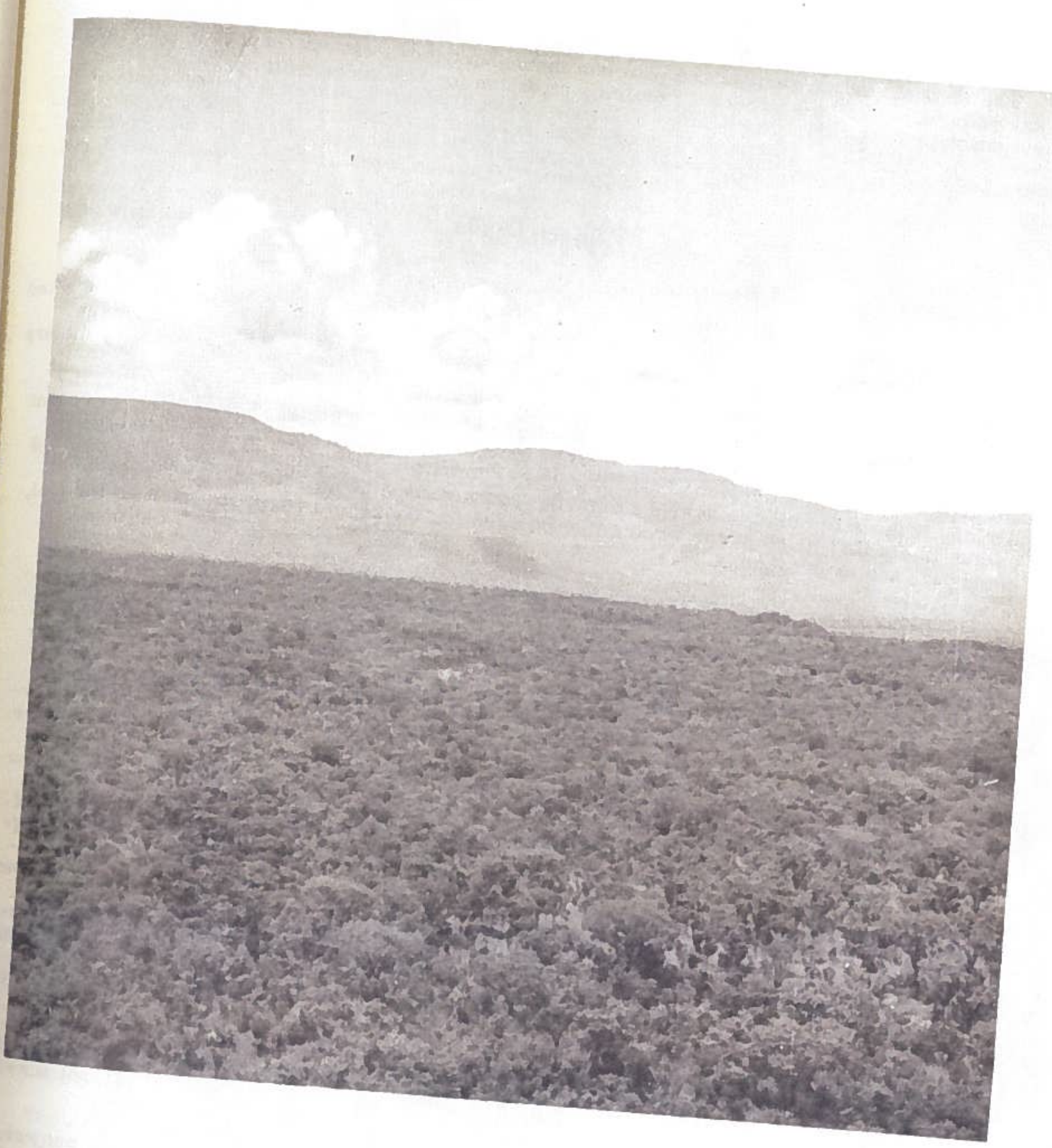


Figure IV-28 - Looking eastward across the Finchaa Valley near the upper end of the project area.

Tsetse flies and mosquitos are common throughout these valleys, and it is probable that malaria would be a problem requiring attention for the successful operation of an irrigation project.

Project Lands

Topography and Land Development

As previously indicated, the Finchaa and the Amarti-Neshe River Valleys are dissected by their respective river channels and each valley has numerous well incised tributary channels. The tributaries are usually entrenched into the valley soils from 2 to 15 meters or more.

Irrigation development will be faced with several problems associated with the present land use and topography. Clearing the land of brush and trees will be a prerequisite to any type of irrigation development. Based on prices for clearing in the United States and Africa, it is estimated the average clearing costs will be about Eth$230 per hectare. It seems likely that much of the wood could be used for household purposes such as for fuel, charcoal, and brush fences.

The slope of the valley is greater than would be desired for control of erosion, but it lends itself readily to water spreading with minimal expense for land leveling. Only a small portion of the land has slopes less than 1 percent. It is estimated that leveling costs for minimal land development would be about Eth$125 per hectare.

The arable lands occur on the ridges and side slopes of a valley plane dissected by a well entrenched dendritic-type immature drainage pattern. The tops of the ridges generally vary in width from 300 to 1,000 meters, and are usually from 1 to 2 percent in slope. On both sides of these ridges the land increases in slope to the bottom of the drainages. Side drainage from each ridge creates problems for water distribution. A substantial portion of the arable land area has slopes of 2 to 8 percent. There is also a considerable acreage of land with slopes 8 to 12 percent. Because of the subreconnaissance nature of the classification and the scale of the base maps, a considerable area of nonarable topography in and immediately adjacent to the drainageway was included in the arable delineations. More refined classifications will exclude most drainageway as nonarable. Further study is needed to determine the maximum slopes permissible for irrigation under the local conditions. Erosion hazards may indicate that lands with steep slopes are not suitable for irrigation. Slopes up to 12 percent were included as arable in this classification.

The slope of the land and the erosive nature of the soil are best suited to irrigation by sprinkler procedures. There is sufficient natural slope to develop gravity pressure of this system. However, it is most likely that a simple, gravity-type irrigation system, utilizing contour ditches, will be used. This method is a good first step to more refined irrigation system. Basin-type irrigation with adequate drop structures to control surface wastes from rain and irrigation would be an ultimate goal.

Disposal of rain and irrigation wastes could be an important problem in this project. Although there are a great number of natural wasteways, the erodibility of the soils and the relatively steep slope of the lands are such that without proper wasteways the erosion could wash away the soil resources and increase the costs for operating and maintaining the project.

Although most of the tributary drainages are well incised, it is possible that drainage waters emanating from the adjacent plateau areas could damage canals or other irrigation facilities during periods of unusually high runoff unless care is taken to assure that irrigation facilities are designed to accommodate such floods.

Drainage

Natural surface drainage facilities are generally excellent to excessive. Excess surface waters will quickly find a natural drainage channel for return to the river. However, as indicated in the discussion above, such surface wastes could cause serious erosion problems unless suitable erosion control drop structures or well-grassed drainageways are provided. This erosion problem could result in a substantial land development cost in areas where erosion hazards are worst. In some of the larger tracts, perhaps the surface wastes can be kept on the ridges for re-use to minimize this problem.

Because of the slope and generally permeable nature of the soil in association with the numerous deeply entrenched natural drains, control of a water table under irrigation should be easy. However, the underlying basalt in the project area is believed to be less fractured and less permeable than that which occurs in the high plateau areas, so very little percolation through the basalt can be anticipated. Prior to construction, detailed drainage studies should be made. This should include a study of the existing water table behavior, a study to determine if any dikes occur that would impound water, an evaluation of present vegetation for evidence of wet areas, and suitable pump-in tests to determine the in-place permeability. Studies on the requirement for and location of erosion control structures in present drainageways are also needed.

Soils

The red latosols occupy the bulk of the project areas. These soils are typical of those developed under well-drained conditions in tropical or subtropical areas. They have a deep and generally freely drained profile. The clay fraction usually has a high percent of kaolinite and lesser amounts of illite clay minerals. They have a low cation exchange capacity, low base saturation, and considerable acidity. A common characteristic of these soils is a high phosphate fixation.

Although the latosols are low in plant nutrients, they have physical properties well suited to irrigation. They are normally well aerated and they can be cultivated over a wide range of moisture conditions. The soil textures are usually clay. However, the nonexpanding-type minerals in these soils results in a physical condition about like a loam soil with expanding-type clay minerals. Soil crusting is not common.

Mulching of latosols is usually advocated for maximum production. To improve productivity, such mulches as banana leaves or elephant grass can be used to cover the soil where the developing crops are not grown. This treatment tends to reduce the soil temperatures, reduces evaporation, and maintains a favorable soil structure. This treatment should be a goal for future management of the project soils under irrigation.

Grumusols occupy a small percentage of the Finchaa and Amarti-Neshe Valleys. These soils have quite different properties than the latosols. The obvious difference is that grumusols are black as compared to the red color of the latosols. For this reason, these two soils are often called "black" or "red" when discussing tropical or subtropical soils.

The grumusols are composed of swelling-type clay minerals such as beidellite or montmorillonite. Therefore, these soils crack badly at the surface when drying. Grumusols usually develop in a warm humid climate whenever there is a large supply of calcium carbonate or when subsurface drainage conditions are restricted. They are usually neutral to alkaline in reaction and are relatively low in organic matter, even though their color is near black. When moistened, the clay swells and the soil becomes sticky, plastic, and almost impervious. Low productivity is usually due to these adverse physical features rather than to the inherent fertility. Grumusol soils are rich in lime, but are usually low in phosphorus and nitrogen, both they and latosol soils eroding rather easily.

It seems probable that the soil materials in these project areas were deposited in the valleys from the high plateau areas at an early stage of geology following the volcanic eruption that resulted in the basalt flow. Although the soils are mostly latosols and generally fine textured, there are considerable variations locally within the soils.

Near the escarpments on either side of the Finchaa Valley the soils are strongly influenced by the high, massive sandstone formations. Soils tend to be coarser near these escarpments and in the upper half of the project than near the river or in the lower half. Although a few sandy loam or coarser soils exist near the escarpment, the predominant surface textures are sandy clay loam, clay loam, and light clay. The subsoil textures below 45 cm. are clays in most instances.

A typical latosol profile consists of 15 cm. of dark reddish-brown, nonsaline, noncalcareous sandy clay loam, with a pH of about 5.2, followed by from 15 to 45 cm. of dark red clay which has a pH of near 6.0. Red friable clay having a mildly acid reaction occurs below 45 cm. to bedrock. The profile has a feeling of much lighter texture than the clay textural description, because the clays are nonsticky. These soils are friable, very permeable, and well suited for irrigation.

Sandstone cobbles occur on the surface of some soils, particularly in the upper part of the Finchaa Valley and also near the escarpments. Basalt cobbles also occasionally occur in some soils but are not believed to be any hindrance to irrigation development.

In the lower half of the Finchaa Valley and in the Amarti-Neshe Project, the soils are mixtures of latosols and grumusols with a large predominance of latosols. The soil textures in these areas tend to be finer throughout the profile than in the upper part of the Finchaa Valley, and the soils are all less friable and permeable than the soils in the upper basin. The grumusol soils crack when dry, and are quite sticky when wet. Permeability is low in such soils and greater skill will be needed in farming than in the latosol soils. Trees do not grow well in the grumusol soils, and these soils usually have only a grass cover under present conditions.

Land Classification

The subreconnaissance land classification of the Finchaa Basin was accomplished during the rainy season by use of helicopter, due to the inaccessibility of the valley to other forms of transportation. The mapping was done on 1:50,000 contact aerial photographs. Traverses were spaced at about 1 km. intervals and landings were made wherever possible. Owing to the dense forest cover, the only treeless spaces available for landings were the small areas of black soil or an occasional gravel bar on the streams. From these landings it was necessary to travel through the dense underbrush and tall grass on foot to appraise the various soil conditions. Under these conditions, most of the land appraisals necessarily had to be done from the helicopter without the benefit of soil borings and careful morphological studies. It is recognized that there will likely be a considerable reduction in area suitable for irrigation when detailed studies are made. Although it is believed that most soil conditions are reasonably favorable for irrigation, topographical conditions are less favorable. Detailed studies will eliminate some rough lands--particularly drainageways--which are presently not separated as nonarable. Because of the rough nature of the classification and the inability to study the variations of the land class determinating factors, only two arable land classes were delineated. These were Classes 2 and 3. Detailed studies may show that considerable Class 1 land exists. The classification standards used in classifying these lands are shown in Table IV-17.

Class 2 lands within the project areas consist of deep, friable, permeable, well drained latosol soils. Slopes are usually in the range of 1 to 3 percent, but a few areas of slopes to 7 percent are included. Nearly all of these lands are covered with grass, brush, and trees which must be removed prior to irrigation. A small amount of rock removal will also be needed on some lands. After they are developed for irrigation, Class 2 lands will be capable of growing any climatically adapted crop if properly managed. These soils are inherently low in fertility and will require commercial or animal fertilizer if full production is to be achieved. The Class 2 lands occupy 67 percent of the irrigable project areas, and are placed in this class mainly because of topographic deficiencies.

Class 3 lands generally are the lands which occupy the side slopes of the numerous drainageways, but also include some rougher, rolling-type topography, some stony lands, and the areas of grumusol soils which were observed. The greater portion of Class 3 lands has a slope ranging from 5 to 12 percent. These lands generally have more and

TABLE IV-17 - SUBRECONNAISSANCE LAND CLASSIFICATION STANDARDS

Land characteristics	Class 1--arable	Class 2--arable	Class 3--arable	Class 6--nonarable
Soils				
Texture	Sandy loam to friable, very permeable non-plastic clay	Loamy sand to friable, perme-able nonplastic clay	Loamy sand to plastic, slowly permeable clay	Sand and gravel
Minimum depth (cm.)				
to bedrock	150	105	75	<75
to volcanic tuff	120	90	60	<60
to clean sand, gravel, or cobble	90	60	45	<45
Topography				
Permissible slope				
Uniform	0 - 3.0%	3.1 - 7.0%	7.1 - 12.0%	>12.0%
Nonuniform	-	0 - 3.0%	3.1 - 7.0%	>7.0%
Surface leveling	Smoothing only	Moderate grading	Heavy grading	Very heavy grading
Clearing of rocks or vegetation	Low cost	Moderate cost	High cost	Very high cost
Drainage				
Anticipated cost	Low	Moderate	Moderate	High

larger trees than the Class 2 lands and will be more difficult to farm and will be less productive. Although most of the soils are latosols and are well adapted to diversified crop production, the steeper slopes and greater danger of erosion are such that these lands require better management than the Class 2 lands. More grass and close-growing crops and less cultivated crops should be used on these lands than on the Class 2 lands. Class 3 lands occur on 33 percent of the irrigable project area. It can be anticipated that a portion of these lands will be deemed nonarable in a detailed study.

Class 6 lands include some excessively stony lands, the steeper and rougher drainageways, and other complex, rough topography. These lands total approximately 10 percent of the gross area classified.

The results of the classification are set forth in Table IV-18 and the location of the lands is shown on Figures IV-29 and IV-30.

TABLE IV-18 - ARABLE AND IRRIGABLE AREAS--FINCHAA AND AMARTI-NESHE PROJECTS

Project	Land type	Land areas (hectares)			
		Class 1	Class 2	Class 3	Totals
Finchaa	Total arable	-	14,954	7,566	22,520
	Arable below canal	-	13,460	6,644	20,104
	Irrigable	-	10,000	5,000	15,000 1/
Amarti-Neshe	Total arable	-	7,967	3,696	11,663
	Arable below canal	-	7,800	3,520	11,320
	Irrigable	-	5,771	2,719	8,490 1/

1/Based on estimate that 75 percent of arable land below canal will be irrigable.

Conclusions

1. The climate in the project areas is subtropical and well suited to the production of many crops and to the production of more than one crop each year.

2. The soils are generally deep, friable, permeable, medium to fine textured latosols and are well suited to irrigation--particularly when properly fertilized.

3. Land slopes are slightly excessive for optimum irrigation conditions and the slopes of the lands are the principal reasons for downgrading land.

4. The moderately dense forest cover will need to be removed prior to irrigation, but the resulting wood should be useful for charcoal and firewood.

5. Construction of project irrigation works will be quite expensive because of the many drainage crossings needed.

6. Erosion hazards are fairly high and considerable care must be used in irrigation application and water disposal to maintain a permanent irrigated agriculture.

Recommendations

1. A detailed land classification study should be made prior to construction. Among other things, this study should: delineate the topographic variables accurately; determine the needs for subsurface drainage construction; separate and appraise productivity potentials for the various types of soils; ascertain a more exact cost of tree and brush clearing and land leveling; study the erosiveness of the soils and determine the need for and cost of erosion control; determine the type and quantity of fertilizer or soil amendments needed for maximum production; and determine the method of irrigation best suited to the land and people.

2. An experimental farm should be established early in the development period to determine the best crops and cultural practices to use.

3. Future studies should include the anticipated irrigation water quality and the effects that such a water will have on the project soils.

4. Any initial irrigation development should avoid developing the bottoms or lower side slopes of any deep drainageways because of the danger that these areas will become waterlogged when the adjacent higher lands are irrigated.

Conclusions

1. The climate in the project areas is subtropical and well suited to the production o[f] many crops and to the production of more than one crop each year.

2. The soils are generally deep, friable, permeable, medium to fine textured latos[ols] and are well suited to irrigation--particularly when properly fertilized.

3. Land slopes are slightly excessive for optimum irrigation conditions and the slop[es] of the lands are the principal reasons for downgrading land.

4. The moderately dense forest cover will need to be removed prior to irrigation, b[ut] the resulting wood should be useful for charcoal and firewood.

5. Construction of project irrigation works will be quite expensive because of the ma[ny] drainage crossings needed.

6. Erosion hazards are fairly high and considerable care must be used in irrigation application and water disposal to maintain a permanent irrigated agriculture.

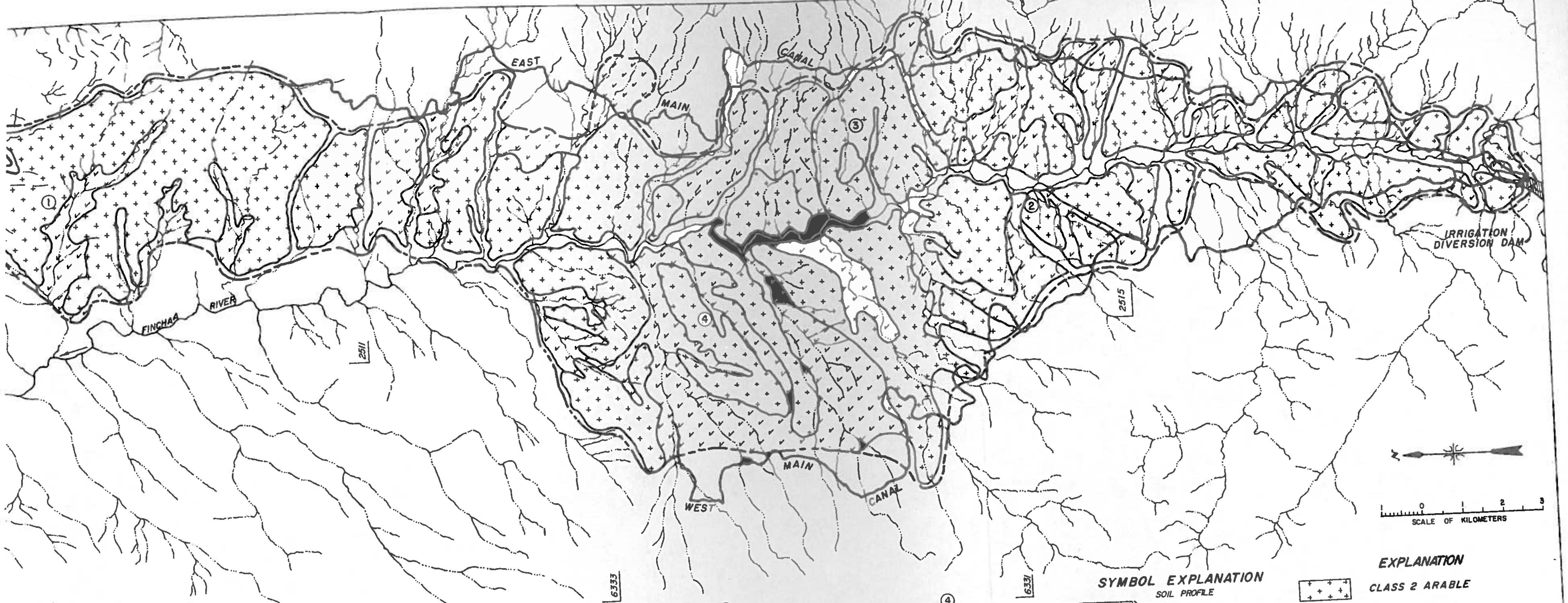
Recommendations

1. A detailed land classification study should be made prior to construction. Among other things, this study should: delineate the topographic variables accurately; determine the needs for subsurface drainage construction; separate and appraise productivity potentials for the various types of soils; ascertain a more exact cost of tree and brush clearing and land leveling; study the erosiveness of the soils and determine the need for and cost of erosion control; determine the type and quantity of fertilizer or soil amendments needed for maximum production; and determine the method of irrigation best suited to the land and people.

2. An experimental farm should be established early in the development period to determine the best crops and cultural practices to use.

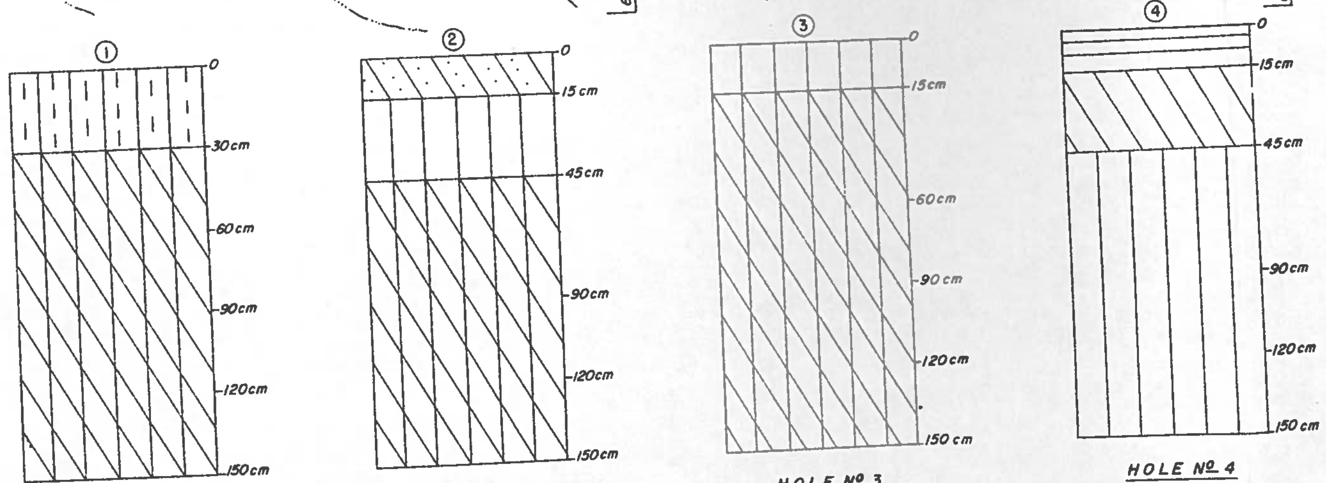
3. Future studies should include the anticipated irrigation water quality and the effects that such a water will have on the project soils.

4. Any initial irrigation development should avoid developing the bottoms or lower side slopes of any deep drainageways because of the danger that these areas will become waterlogged when the adjacent higher lands are irrigated.



ULATION OF LAND CLASSES

	CLASS 2	CLASS 3	TOTAL
ARABLE TARES	14,954	7,566	22,520
E HECTARES OW CANAL	13,460	6,644	20,104
9LE HECTARES	10,000	5,000	15,000



HOLE Nº 1

(PHOTO Nº 2511 HOLE Nº 1)
Smooth gently sloping area burned-shortgrass plus acacia, elevation 4200 ft. Surface cracks-very dark gray to very dark brown s.p. clay; area is an assoc. of red plus dark clays.

HOLE Nº 2

(PHOTO Nº 2515 HOLE Nº 1)
Gently sloping dissected by small drains-some sandstone cobble on surface - acacia, other trees and tall grass. 0-15 cm. dark red brown s.c.l.: 15-45 cm. dark red brown s.c. over very dark gray s.p. compact s.c. elevation 4800 ft.

HOLE Nº 3

(PHOTO Nº 2515 HOLE Nº 2)
4% smooth slope - some dissection by small drains-acacia, other trees and tall grass (hole in burned area) Elevation 4800 ft, 0-20 cm. very dark brown p. clay with grass roots over very dark brown compact s.p.c. few sandstone cobble on surface.

HOLE Nº 4

(PHOTO Nº 6331 HOLE Nº 1)
4% smooth slope acacia, other trees and tall grass - some small Quartzite (?) on surface many tetse flies, 0-15 cm dark red brown loam to c.l. 15-45 cm. dark red brown c.l. to v.p.c, 45 cm. plus dark red friable v.p.c.

SYMBOL EXPLANATION
SOIL PROFILE

- Permeable clay.
- Slowly and very slowly permeable.
- Very permeable clay.
- Permeable clay with some sandstone cobble on surface.
- Permeable, Alluvial, rolling with 3 to 4% slope.
- Clay loam textured soil, friable and permeable clay.

EXPLANATION

- CLASS 2 ARABLE
- CLASS 3 ARABLE
- CLASS 6
- BOUNDARY OF LAND CLASS.
- EXTENT OF LAND CLASSIFICATION.

Land classification by R.G. Thrailkill
Assisted by Zaudie Telahun.

Base map compiled from 1 to 50,000 uncontrolled aerial photographs. Elevations from altimeter.

THIS DWG. SUPERSEDES DWG. No. 7.1 — Fi — 2

ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM
FOR THE
STUDY OF WATER RESOURCES
IN COLLABORATION WITH
U.S. DEPT. OF STATE AGENCY FOR INT. DEV. AND U.S. DEPT OF INTERIOR BUREAU OF RECLAMATION

DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS
BLUE NILE RIVER BASIN
FINCHAA SUB-BASIN
RECONNAISSANCE LAND CLASSIFICATION
AND SOIL PROFILES
FINCHAA RIVER AREA

DRAWN R.G. Thrailkill
TRACED Mesretha Shiferow
CHECKED G.P. — P.W.K.
SUBMITTED R.G.T. - P.W.K.
RECOMMENDED H.L.P.
APPROVED C.E.S.

Addis Ababa Ethiopia — JUNE 27, 1962 (I.C) — 7.1 — Fi — 3

Figure IV-29 - Reconnaissance Land Classification and Soil Profiles, Finchaa River Area

ARJO-DIDDESSA PROJECT

General Description

The Arjo-Diddessa Project is located in the southern portion of Wellegga Province. The southern extremity lies about 45 kilometers north of Jima and the northern portion lies about 60 kilometers south of Lekkemt. The project configuration corresponds roughly to the shape of a "Y" with the upper right prong being lands along the Wama River and the remaining lands situated adjacent to the Diddessa River. It is approximately 42 kilometers from the damsite on the Diddessa River (bottom of the "Y") to the confluence of the Wama and Diddessa Rivers. From the confluence, project lands extend about 22 kilometers northeast up the Wama River valley and 55 kilometers northwest down the Diddessa River valley. Near the confluence of the two rivers the project lands reach a maximum width of about 6 kilometers. This approximate width extends for a distance of about 12 kilometers. Remaining portions of the project are about 2 kilometers in width. The Diddessa River flows from southeast to northwest through the project area.

Transportation

Existing transportation facilities are poor. The nearest all-weather road extends from Addis Ababa to Lekkemt through the upper Wama River Basin. It appears that a service road to the project area from this road would be the most economical way of securing roads to major markets. Road construction will be expensive because of the mountainous terrain surrounding the project area.

Geology and Physiography

The project area is in a plateau valley of the Diddessa and Wama Rivers. Volcanic rocks occur at depth through most the area and remnants of volcanic plugs occur in the valley. These areas are eroded somewhat, but take the form of high isolated areas in otherwise smooth grassy plains. Some metamorphic rocks are exposed along downstream portions of the project. Soils are mostly alluvial depositions and appear to vary in age from very old deposits to recent depositions.

Project lands occur mostly as alluvial fans on either side of the Diddessa and Wama Rivers. These fans are usually less than 2 kilometers in length and about 1 kilometer in width except for the area north of the rivers near their confluence where the fans are considerably larger. Most of the fans are smooth and gently sloping.

In addition to the alluvial fans there are a number of river terraces which are smooth and very gently sloping. Recent colluvial materials may be found near the upper portion of some of the alluvial fans. Flood plain deposits are fairly common where the major side tributaries enter the rivers.

Climate

The project area averages about 1340 meters above sea level which results in a tropical climate at this latitude. No weather stations on the project exist, but it is probable that annual precipitation will average about 100 cm., and the annual average temperature is estimated to be 20° C. Because the project lands are in a valley protected from winds by the surrounding mountains it is likely that temperatures will be warmer than similar elevations at this latitude having more exposed positions. The growing season is expected to be year-long and minimum temperatures of 10° or 12° C are probable.

Present and Potential Land Use

Elephant grass and other tall grasses with scattered small fig trees and acacia trees ranging up to 10 meters height occupy the majority of the project area. A dense riverine forest ranging in height to 30 meters generally occurs on both sides of the two rivers. This growth is usually less than 100 meters in width.

There are very few people living in the project area, probably because of the presence of malaria. On the adjacent hills above the project lands there are a considerable number of people who dry farm and graze cattle along the fringes of the project.

Unfortunately, most of the project soils are grumusols and are not well adapted to the wide variety of crops which the climatic conditions would permit. However, it is believed that the project soils are probably more permeable than usual for grumusols because of the mode of origin and fact that the pH is lower than usual. These suggest the soils may be more permeable than normal. Pasture, hay, and close growing crops would be well adapted, but other and more valuable crops possibly will be suitable. Additional studies are needed to determine the adaptability of various crops to the soils.

Project Lands

Topography and Land Development

Topographic conditions are generally very good for irrigation on the project lands. estimated that about 35 percent of the irrigable lands have slopes of less than 2 percent another estimated 35 percent have slopes of 2 to 5 percent, 20 percent have slopes of 5 to 8 percent, and about 10 percent have slopes of 8 to 12 percent.

Scattered small trees occur over most of the project lands in addition to a dense gr of tall grass. The lands are generally fairly smooth and can be developed for irrigatic at an estimated cost of Eth$200 per hectare. Large fields can be developed, if desirec

One of the biggest problems in land development and perhaps in canal maintenance be flood hazards from the surrounding hills. It is probable that some areas assumed be suitable for irrigation cannot be economically protected from floods and will need t deleted from the project.

Most of the project lands are suitable for border dike, bench terrace, or contour furrow-type irrigation. Any irrigation system developed should be designed to handle siderable surface wastes because the soils are slowly permeable.

Drainage

The Wama and Diddessa Rivers are incised about 8 or 10 meters below the surrou land surface and will likely be of material assistance in controlling the ground water small or narrow tracts of land. In the widest portion of the project, near the conflue of the two rivers, additional surface and subsurface drains will be needed. The perr ability of representative substrata should be determined in the field as a means of es mating drainage requirements. In addition, a series of water table observation wells should be installed and the water table behavior studied during the rainy season. The results should provide the data needed for calculating the anticipated drainage spacin

The grumusol soils common to this area are usually slowly permeable, dense, and ha restricted internal drainage characteristics. Therefore, it would be highly desirable to limit planting to crops which will tolerate restricted internal drainage.

Soils

Table IV-19 shows typical laboratory data for project soils. Although these soils are about 95 percent grumusols, and have the typical characteristics of heavy clay texture, cracking when dry, black color when wet, highly plastic condition when wet, and hard consistency when dry, the nature of their origin and their pH values suggests the permeability may be higher than normal. Most grumusol soils in the Blue Nile Basin were developed on calcareous materials, and are residual. Such soils are acid in the topsoil, but neutral to alkaline in the substrata. The soils in this project are quite acid to at least a depth of 150 cm. and are noncalcareous. This suggests good underdrainage, which is common in alluvial fan soils, or at least exhibiting more downward movement of moisture than normal. Studies should be made of the in-place permeability of these soils during the detailed classification. It is interesting to note that the potassium and calcium content as indicated by laboratory data are usually ample, but the phosphorus content is low. It is also of interest to note that the sand content usually exceeds the silt content. This is in contrast to most grumusols found in the Blue Nile Basin.

Red latosols are of minor importance in the project area, but do occur on some of the adjacent uplands. Approximately 5 percent of the project area has latosol soils.

Land Classification

The land classification was of subreconnaissance type and is subject to considerable changes when detailed data are available. Because of the inaccessibility of the area to travel by truck, the classification was done by helicopter. The land class delineations were mapped on contact aerial photographs scaled 1:50,000. Traverses were made at about 1-kilometer intervals, and landings were made at representative locations. Soils were examined to a depth of 150 cm. and some laboratory data were secured from representative soils at the Imperial College of Agriculture at Alamaya. The irrigable lands are shown on Figure IV-31. The location of the arable lands together with the description of the soil profiles examined are shown on Figures IV-32, IV-33, and IV-34.

Description of Land Classes

Class 1--No Class 1 land was delineated. It is probable that detailed studies will not delineate any Class 1 land because of the preponderance of grumusol soils.

Class 2--The arable Class 2 lands generally are too high for service from a gravity system. Although a total of about 4,000 hectares of Class 2 lands were delineated as arable, less than 100 hectares can be serviced.

For the purpose of rounding areas, no Class 2 land is shown in the estimated irrigable lands summary. Most of the Class 2 lands have latosol soils, but are located on undulating to severely undulating topography and would be difficult to service by a gravity system. Detailed studies may indicate that some of the Class 3 lands delineated in this classification should be Class 2 if further studies substantiate the indication that these soils are more permeable than the average grumusols.

Class 3--These lands comprise 100 percent of the irrigable area of the project and are an indication of the marginal quality of these lands for irrigation. Soil deficiencies due to clay texture occur on all the Class 3 lands. Unless future studies substantiate that these soils are more permeable than average grumusols, it will be necessary to restrict the irrigated cropping to hay, pasture, small grains, some pulses, and oilseeds. There is also an erosion hazard on these soils, and if the organic matter is depleted by improper farming serious sheet and gully erosion may occur.

TABLE IV-19 . TYPICAL LABORATORY DATA--ARJO-DIDDESSA PROJECT

Photo	Boring no.	Depth (cm.)	Percent salinity	pH	M.A. results: Percent sand	M.A. results: Percent silt	M.A. results: Percent clay	Per-cent OM	Available nutrients: P	Available nutrients: K	Available nutrients: Ca	Munsell Color: Wet	Munsell Color: Dry
4985	7	0-15	trace	5.2	27.5	12	60.5	5.4	LM	H	H	7.5 YR 3/0	7.5 YR 3/0
		15-60	trace	5.1	40	10	50	2.85	VL	H	H	10 YR 3/1	7.5 YR 3/0
		60-105	trace	5.4	30	8	62	2.0	VL	MH	H	10 YR 3/1	7.5 YR 3/0
		105-150	trace	5.3	28	8	64	0.45	L	H	H	10 YR 3/1	7.5 YR 3/0
4992	13	0-15	trace	5.2	22	14	64	5.35	VL	H	H	5 YR 2/1	5 YR 3/1
		15-60	trace	4.5	23.5	10	65.5	2.35	L	M	H	2.5 YR 4/1	2.5 YR 4/1
		60-105	trace	5.2	18	7.5	74.5	1.80	L	MH	H	7.5 YR 4/0	7.5 YR 3/0
		105-150	trace	5.2	35.5	6	58.5	1.05	VL	VH	H	7.5 YR 3/0	7.5 YR 3/0
5475 (Wama River)	1	0-30	trace	4.7	23.5	12	64.5	3.45	VL	-	-	Black	Dk Br Gr
		30-60	trace	4.8	19	10	71	1.15	VL	-	-	Dk Gr	Dk Gr
		60-105	trace	5.4	19.5	10	70.5	2.10	VL	-	-	V Dk Gr	
5039	3	0-30	trace	4.5	17	30	53	4.0	L	-	-	Black	Dk Br Gr
		30-90	trace	4.8	21	26.5	52.5	2.4	L	-	-	Dk Gr	Dk Gr
		90-150	trace	5.0	19	18.5	62.5	0.8	VL	-	-	V Dk Gr	

See Figures IV-32, IV-33, and IV-34 for location and description of soils.

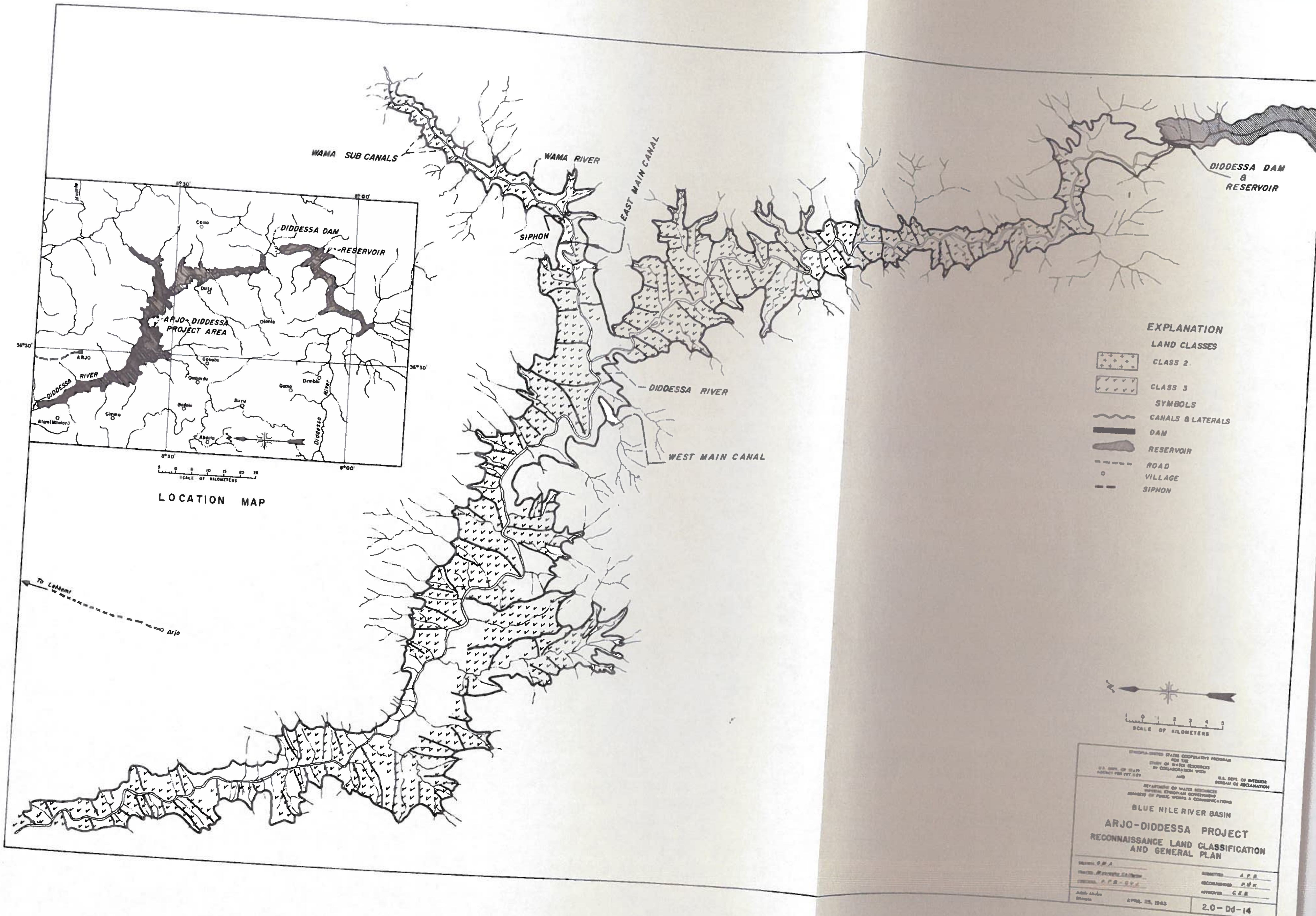


Figure IV-31 - General Plan, Arjo-Diddessa Project

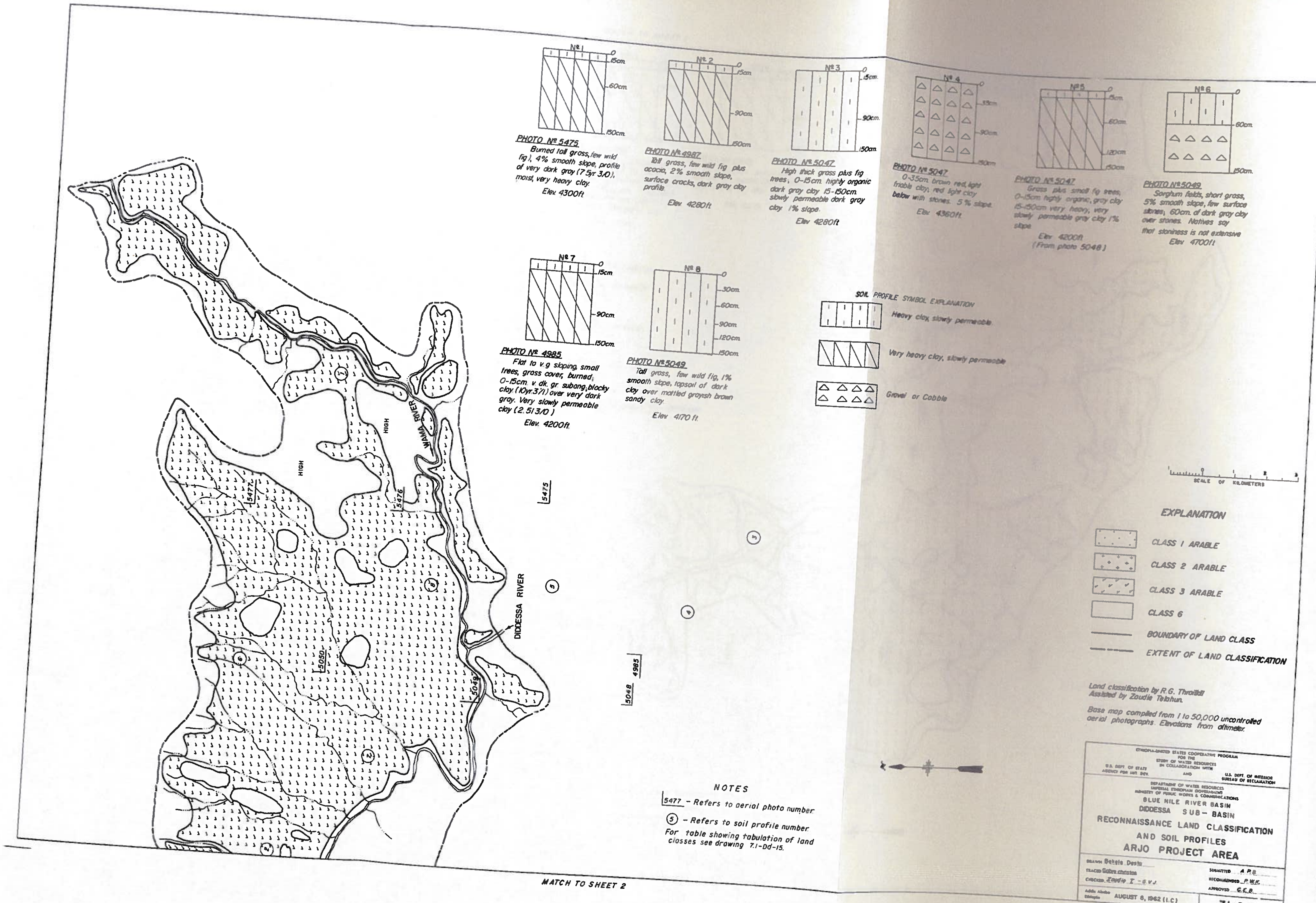


Figure IV-32 - Reconnaissance Land Classification and Soil Profiles, Arjo Project Area (Sheet 1 of 2)

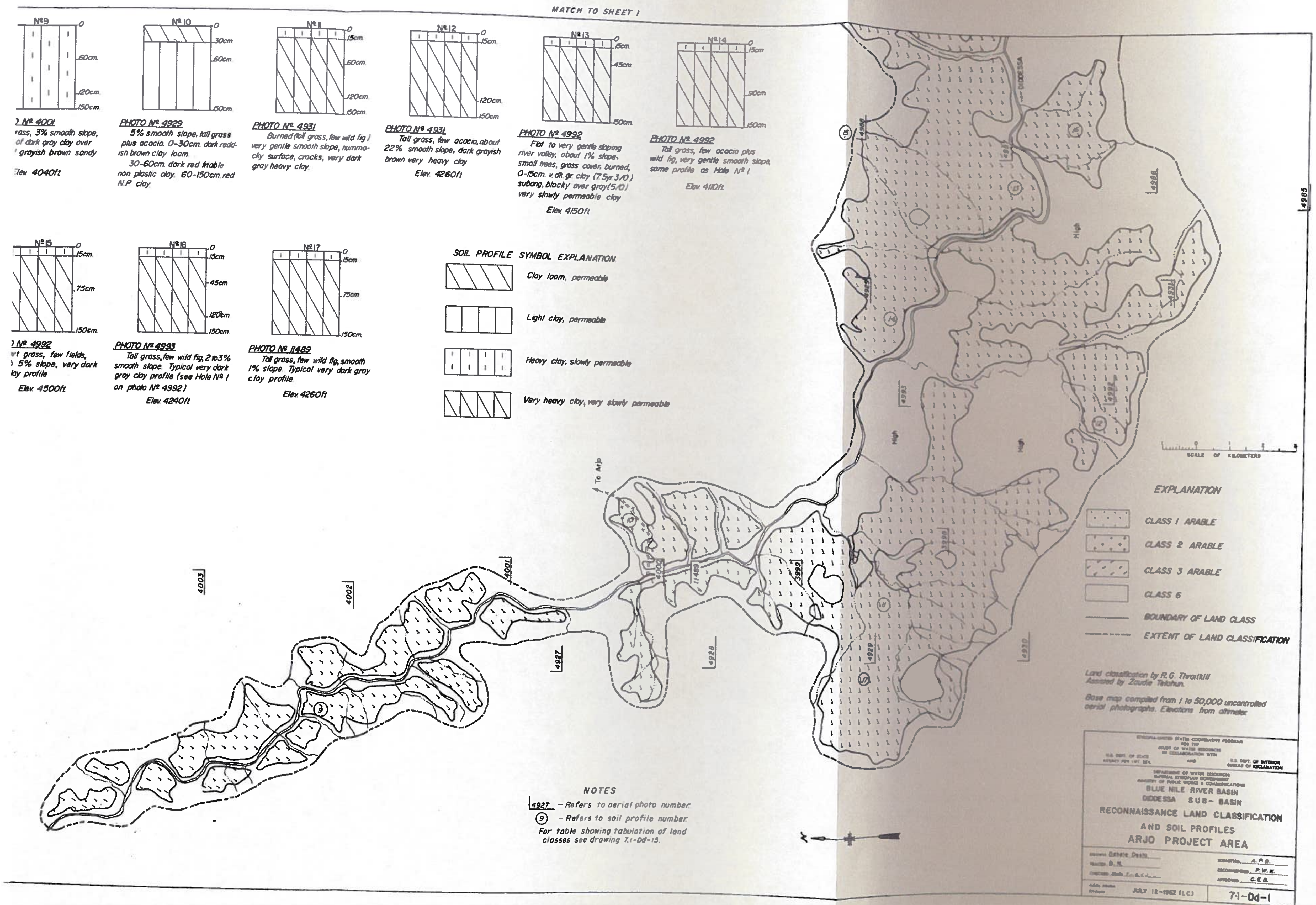


Figure IV-33 - Reconnaissance Land Classification and Soil Profiles, Arjo Project Area (Sheet 2 of 2)

TABLE IV-20 - LABORATORY DATA--DIDDESSA PROJECT

Photo no.	Hole no.	Depth (cm.)	Percent salt	pH	M. A. results: Percent sand	Percent silt	Percent clay	Texture	Color dry	Total N	Percent OM	Available nutrients: P	K	Ca	Mg
5039	1	0-30	-	4.5	17	30	53	clay	dk br		4.0	L			
5039	1	30-90	-	4.8	21	26	59	clay	gr		2.4	L			
5039	1	90-150	-	5.0	19	18	63	clay	dk gr		0.3	VH			
4406	2	0-15	-	5.5	34	6	60	clay	dusky red		4.7	L	H	L	
4406	2	15-60	-	5.4	35	8	57	clay	dusky red		4.15	LM	H	L	
4406	2	60-105	-	6.2	34	10	56	clay	dusky red		2.3	L	H	L	
4406	2	105-150	-	6.9	48	8	52	clay	dusky red		1.8	VL	L	H	
4406	5	0-15	-	4.9	44	8	48	clay	dk red		5.25	L	H	MH	
4406	5	15-60	-	4.7	26	10	64	clay	gr		3.3	VL	M	H	
4406	5	60-90	-	5.0	38	13	51	clay	dk gr		2.2	LM	H	H	
4406	5	90-150	-	5.1	20	8	72	clay	gr		1.15	VL	H	H	
4721	1	0-30	-	5.8	14	10	76	clay	v dk gr		5.4	M	H	H	
4721	1	30-60	-	5.1	22	12	66	clay	v dk gr		2.15	L	VH	VH	
4721	1	60-120	-	5.8	20	8	72	clay	dk gr		1.45	VL	H	H	
4721	1	120-150	-	6.8	22	10	68	clay	dk gr		0.3	VL	H	H	
4985	1	0-15	-	5.2	28	12	60	clay	v dk gr		5.4	LM	H	H	
4985	1	15-60	-	5.1	40	10	50	clay	v dk gr		2.85	VL	H	H	
4985	1	60-105	-	5.4	30	8	62	clay	v dk gr		2.0	VL	MH	H	
4985	1	105-150	-	5.3	28	8	64	clay	v dk gr		0.45	L	H	H	
4992	1	0-15	-	5.2	22	14	64	clay	v dk gr		5.35	VL	H	H	
4992	1	15-60	-	4.5	24	10	66	clay	dk br		2.35	L	M	H	
4992	1	60-105	-	5.2	18	8	74	clay	dk gr		1.8	L	MH	H	
4992	1	105-150	-	5.2	35	7	58	clay	v dk gr		1.05	VL	VH	H	
10,468	1	0-18	-	5.5	45	10	44	sa cl lo	dusky red		5.4	LM	H	L	
10,468	1	18-90	-	6.0	36	12	52	clay	dusky red		2.45	L	H	L	
10,468	1	90-150	-	5.0	28	22	50	clay	dk red		1.65	L	H	L	

Class 6--Nonarable. These are steep, rough, and stony slopes or drainageways which cannot be farmed economically, and are unsuitable for sustained irrigation agriculture.

Results

Results of the classification are shown in Table IV-21.

TABLE IV-21 - ARABLE AND IRRIGABLE AREAS --ARJO-DIDDESSA PROJECT

Land type	Land areas (hectares): Class 1	Class 2	Class 3	Total
Total arable	-	15,000	36,200	51,200
Arable under canal	-	-	24,000	24,000
Irrigable	-	-	16,800	16,800

No topographic data are available for the Arjo-Diddessa Project. A rough canal line has been determined from altimeter readings. Comparison of areas scaled from aerial photographs in other portions of the Blue Nile Basin with fairly accurate horizontally controlled base maps indicate the photographs are usually in error. Therefore, the areas shown in Table IV-21 are subject to more error than if they had been determined from a horizontally controlled base map.

Conclusions

1. Topographic conditions are generally very good for irrigation in the Arjo-Didessa area, and land development costs are expected to be low.

2. Unit construction and OM&R costs will be high because project lands occur on both sides of the river in a long, relatively narrow belt.

3. Project soils are heavy clays which crack severely when dry, and have a restricted land use capability.

4. Erosion hazards are great when the presently grassed areas are plowed and cultivated.

5. Soils will need phosphate fertilizer for maximum production.

Recommendations

1. Detailed land classification and drainage investigations are needed prior to developing a definite plan report.

2. Further studies on soil properties are needed to determine the land use best adapted to the project soils.

3. A development farm should be established at an early stage of detailed investigations as an aid in determining fertilizer requirements, crop varieties adapted to the soils, consumptive use of water, and yield levels for various crops.

DABANA PROJECT

General Description

The Dabana Project lies at approximately 9° north latitude and 32°15' east longitude. It is in the central portion of Wellegga Province in the Diddessa River Basin, and is approximately 55 kilometers southwest of Lekkemt, capital of the Province. The project is approximately 20 kilometers long and 9 kilometers wide at the widest point. It lies on the west side of the Diddessa River, just south of the confluence of the Dabana and Diddessa Rivers, and is near the southern end of the Blue Nile Basin.

Transportation

The nearest road passes the project area about 5 kilometers north of the Dabana River. This is a very rough, unimproved road, built during the Italian occupation of Ethiopia, and is suitable only for large trucks and four-wheel-drive vehicles. It extends from Lekkemt to Asosa. The Imperial Highway Authority are preparing plans for improvement in the near future. A bridge crossing on the Dabana River and a few kilometers of new road would furnish access to the project area from the existing road. Road construction within the project would require a great many bridges for drainage crossing if an all-weather road were to be secured.

Geology and Physiography

The project area occupies an oblong total basin of about 325 square kilometers in a plateau valley developed on Precambrian metamorphic and granitic rocks. The valley has either never been subjected to volcanic action or has eroded through any thin veneer of volcanic deposition which may have been present. The soils are mostly residual from the chemical weathering of the underlying metamorphic rocks, but also include small areas of alluvial soils from slope wash and flooding.

The project lands occur on a gently sloping plain just south of the confluence between the Dabana and Diddessa Rivers. A large unnamed tributary drainage channel to the Diddessa River traverses from south to north through the major portion of the project area. Smaller tributary channels to this drainageway dissect the project area into a large number of relatively narrow ridges sloping more to side drainage than to the central drain. Most of the tributary channels are 3 to 10 meters deep. The intervening arable land bodies occur as long and relatively narrow entities. Typically they vary from less than 500 to 2,000 meters wide and from less than 1,000 to 5,000 meters long.

Climate

The project lands average about 1240 meters in elevation above sea level, and based on the climatic data from higher elevations elsewhere in the Blue Nile Basin, it is concluded that there would be no frost hazard. Unfortunately, no climatic data are available for the immediate project area, but it is estimated that the average annual temperature would be about 22° C and the average precipitation is expected to be about 100 cm. per year. Seasonal distribution would be similar to other portions of the Blue Nile Basin.

A climatic station is needed in this area to provide a reliable basis for estimating irrigation requirements, flooding hazards, crop adaptation, heat units, and evaporative conditions.

Present and Potential Land Use

There were no people living on the project lands at the time of the classification. The nearest villages are on the east side of the Diddessa River on the road to Lekkemt. People living in these villages raise some corn, sorghum, barley, cotton, and peppers under dryland conditions.

Project lands are covered with a dense growth of elephant grass combined with numerous acacia and related deciduous trees. Along and in the drainage channels are tall trees, vines, and shrubs. Near the Diddessa River, in a belt varying in width from about 1,000 to 2,000 meters, a dense riverine forest exists. Most of this forest is on a ridge about 30 meters below the arable lands to the west.

Malaria and tsetse flies are hazards to human health, and in addition, preclude the successful raising of cattle. Both would need to be controlled if irrigation is introduced. There are no livestock grazed within the project area at present.

The climate and soil conditions are such that a wide variety of crops could be successfully grown. These include sorghum, sesame, millet, tobacco, castor beans, peppers, flax, corn, sisal, papaya, mango, sugar cane, pasture crops, and hay crops.

Project Lands

Topography and Land Development

Topographic considerations are the principal reasons for the Dabana Project lands being downgraded into land Classes 2, 3, and 6. Excessive slope is the greatest problem, although small field sizes are also a problem.

Land elevations vary from 1320 meters down to 1200 meters and average about 1240 meters above sea level.

Slopes from the main canal toward the main central natural drainage outlet average about 2.5 percent, but the well incised dendritic drainage pattern results in most slopes of the arable land exceeding this general slope. It is estimated that within the arable land area only about 10 percent has slopes of less than 3 percent. The bulk of the arable land (approximately 75 percent) has a slope from 3 to 6 percent. The remaining 15 percent has slopes of 6 to 12 percent.

Topographic data developed by multiplex projection completed subsequent to the land classification show that there are quite a few isolated high areas that could not be economically served by a conventional gravity irrigation system. The topography just mentioned has 20-meter contours. It seems probable that as more refined topographic data become available (1-meter or less contour interval) there will be additional areas that cannot be reached without expensive fills or siphons. This consideration may tend to lower the arable land acreage which will be found suitable for development by detailed studies.

The slopes within the Dabana Project are excessive for good irrigation because of the hazards of erosion, and the need for numerous drop structures to handle irrigation wastes or to convey water downslope within the farm units. Sprinkler irrigation using gravity pressure would appear to be the best method for irrigation if costs were no object. Bench terraces with zero gradient lengthwise and crosswise would be next best. Bench terraces with zero slope crosswise and slopes of less than 0.5 percent lengthwise would be third best. Contour ditches located at 1-meter vertical intervals would be fourth best. Corrugations having a downgrade slope twice the side slope would be fifth best. The poorest system would be wild flooding downslope with no land leveling.

The project area is mostly covered with tall elephant grass and acacia trees. The trees are usually less than 10 meters high and would be fairly easily removed with modern equipment. It is estimated that burning the grass and clearing the trees could be accomplished for about Eth$230 per hectare.

Land leveling costs would depend on the system of irrigation. The higher the type of irrigation development accepted, the greater the yield and the less the labor of irrigation. However, the investment cost would be greater for the better quality development. Contour ditch type of development would require relatively low development costs and is suggested for a start. Land preparation could probably be done for an estimated average of Eth$180 per hectare. Costs will vary according to slope.

Drainage

Surface and subsurface drainage conditions are generally excellent and no problems of water table control under irrigation are anticipated. However, additional substrata data are needed during the detailed study stage to determine the possibilities of seepage developing on the side slopes. Under most irrigated conditions seepy areas develop on the side slopes and near the bottoms of natural drainageways when the higher lands are irrigated. Care will therefore be needed to determine how far down into a drainageway irrigated farming will be possible and still avoid wet areas.

The present surface runoff within the project area mostly flows into the large natural drainageway which empties into the Diddessa River approximately 5 kilometers south of the confluence of the Diddessa and Dabana Rivers. However, about 8 percent of the area drains into the Diddessa by other than the main central drainage system and about 10 percent drains into the Dabana River.

Most of the present drainageways are covered with high trees and brush which reflect the more favorable moisture available to the plants. It is suggested that most of the present vegetation be retained in these natural drains as a means of reducing the erosion hazards.

Because of the permeable nature of the soils, some canal leakage may occur. If so, drainage problems below the canal line may develop. Percolation tests should be made along the canal route to determine the probable leakage so that an economic evaluation of the costs and benefits of canal lining can be made.

Soils

The Dabana Project soils are very well adapted to irrigation. Except for a few minor areas of dark gray grumusols, the project has rather deep, uniform, latosol-type soils. The typical soil in the project has a dusky red to reddish brown color and is generally a clay texture for the entire depth of the profile. The topsoil is sometimes clay loam or silt loam. There were no indications of iron hardpan or silica cementation in any of the profiles examined. Table IV-22 shows a few typical profiles. The location of these borings is shown on Figure IV-35, which also shows the location of the project lands and the principal features.

Although the project soils were developed from metamorphic materials, the intense chemical action in association with the rainfall pattern has produced soil profiles which appear to be very similar to those found elsewhere in Ethiopia on igneous rocks. Further detailed studies should be made of the clay mineral developed under the project environment to determine if any significant difference exists in soils derived from the two sources of parent material.

The typical soil profile had considerable organic matter and many roots in the upper 30 cm. The surface soil to a depth of 10-15 cm. is granular. Below 15 cm. the soil has a strong subangular blocky structure and appears very permeable. Throughout the profile the soil is nonplastic and crushes readily when dry. Waterholding capacity is good and the soils have physical properties closer to a loam than a clay because of non-expanding type clay minerals.

TABLE IV-22 - LABORATORY DATA--DABANA RIVER PROJECT

Photo	Boring no.	Depth (cm.)	Color	pH	Percent T.S.S.	Percent $CaCO_3$	Texture	Remarks
4405	7	0-30	Red-br	5.5	trace	0	clay	Grass land, 3 percent slope, friable
		30-60	Red-br	5.4	trace	0	clay	Nonplastic soil
		60-120	Red-br	5.8	trace	0	clay	
		120-150	Red-br	6.2	trace	0	clay	
9165	8	0-15	Dk red-br	-	-	0	clay loam	Undulating area, gently sloping
		15-90	Dusky red	-	-	0	clay	Ridge tops--side slopes of 6 percent
		90-150	Dusky red	-	-	0	clay	Friable nonplastic soil
9708	9	0-15	Dk gray	6.2	-	0	silt loam	2 percent smooth slope, top of ridge
		15-75	Red-br	6.6	-	0	clay	0-15 cm. highly organic--permeable
		75-150	Gray	7.2	-	4	clay	Profile--good structure
4403	10	0-150	Red-br	-	-	-	clay	Friable nonplastic clay
4403	11	0-150	Red-br	-	-	-	clay	Friable nonplastic clay

Fertility studies are needed to determine fertilizer requirements. The native vegetation and weak acidity of the soils indicate a lower rainfall than usual for the Blue Nile Basin. If this is true it is probable that soil fertility will be better in this project than average for the Blue Nile Basin. The limited soil data suggest that lime will not be needed for good crop production.

The dark plastic soils occupy a very small percent of the project area. It is suggested that these lands could be used for irrigated pasture and the rotational crops confined to the better soils.

Land Classification

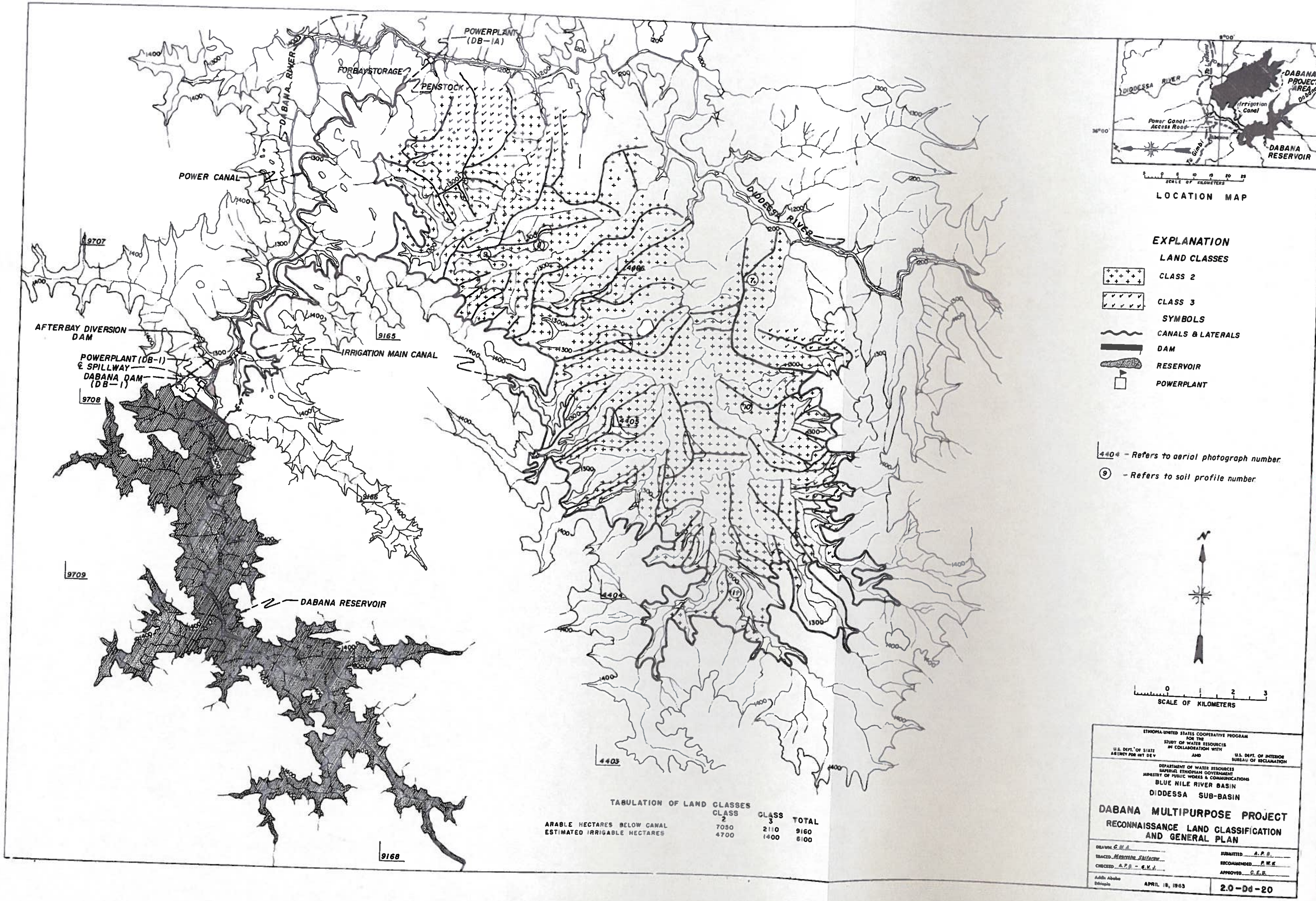
The land classification was a subreconnaissance type and was completed during March 1961. The work was done by helicopter because there are no roads or trails in the area. Landings were made in grassed areas for soil borings. The helicopter was flown at an elevation of about 30-50 meters above the ground level, traverses were made at approximately 1,000 meter intervals, and land features were noted on aerial photos. The introductory section includes the details of classification specifications used and provides more data on methods employed.

Land Class Descriptions

Class 1 lands were not delineated because most of the lands have slopes in excess of 3 percent, the upper limit of this class. Detailed classification may delineate up to 7 or 8 percent Class 1 land.

Class 2 lands comprise 77 percent of the arable lands as delineated in the subreconnaissance classification. These lands generally have slopes of 3 to 6 percent and are covered with tall elephant grass and acacia trees. Soils are uniformly good. Some of these lands are too high for gravity service and it can be anticipated that rough topography will further downgrade some lands when detailed studies are made. Therefore, at the detailed stage the classification will probably show that no more than 50 percent is Class 2.

Class 3 lands presently comprise 23 percent of the arable lands. These are steep and rough and are marginal for irrigation. Also included are some black clay soils that are not as good for irrigation as the red clay soils. It can be anticipated that a sizable portion of the Class 3 lands may be nonarable when a thorough detailed classification study is made.



TABULATION OF LAND CLASSES

	CLASS 2	CLASS 3	TOTAL
ARABLE HECTARES BELOW CANAL	7050	2110	9160
ESTIMATED IRRIGABLE HECTARES	4700	1400	6100

Figure IV-35 - Reconnaissance Land Classification and General Plan, Dabana River Project

Class 6 lands represent the very steep hillsides, the drainage bottoms, rock outcrops, and rugged hilly lands not suitable for irrigation.

Classification Results

Table IV-23 shows the results of the land classification and irrigability study. The difference between the arable and irrigable area reflects estimates of the lands which cannot be serviced because of elevation. It also reflects estimates of the reduction in area that will result when a more critical examination of the land features is made.

TABLE IV-23 - ARABLE AND IRRIGABLE AREAS --DABANA RIVER PROJECT

Land type	Land areas (hectares)			
	Class 1	Class 2	Class 3	Total
Arable under canal	-	7,050	2,110	9,160
Irrigable	-	4,700	1,400	6,100

Conclusions

1. Climatic conditions should be suitable for a wide variety of high-value irrigated crops.

2. The soils are generally excellent for irrigation.

3. The topography is steeper than desirable and is primarily responsible for the lowered land classes.

4. Detailed studies will show numerous isolations for gravity service. These studies will also show more topographic deficiencies than indicated by the present classification.

5. Drainage conditions appear to be good.

6. Malaria and cattle diseases will need to be controlled if irrigation is to be a success.

7. Erosion will be a severe problem in the cultivated fields when the present erosion-resistant grass is removed unless irrigation water is carefully controlled.

Recommendations

1. Detailed topography at 1-meter contour intervals should be obtained as a base map for detailed land classification studies.

2. Studies on erosion hazards on cleared land at various slope levels and for various velocities of water flow are needed prior to initiating detailed studies so that maximum permissible slopes for irrigation will be known.

3. Methods of irrigating sloping land should be studied to determine the method best adapted to the people and to the money which may be available for development work.

4. Deep borings are needed in connection with drainage studies to estimate how the water table will behave under irrigation.

5. Detailed studies of land classification should be made prior to initiating any construction program relating to irrigation of this project.

ANGAR PROJECT

General Description

The proposed Angar Project is located in the central part of Wellegga Province in the Angar River Valley. The area lies about 40 kilometers north of Lekkemt, the capital of Wellegga Province. It extends about 50 kilometers along both sides of the Angar River, and averages about 35 kilometers in width.

The Angar River flows southwest through the project area and a dam and reservoir are proposed on the main stem of the river at the northern extremity, and another dam and reservoir on this river in the south half of the area. The lower dam and reservoir would serve as a forebay for pumping to 13,200 hectares and for power production. Irrigable lands range in elevation from 1400 to 1300 meters, but are mostly about 1350 meters above sea level. A total of 30,200 hectares of irrigable land are proposed for service.

Transportation

One all-weather road extends from Addis Ababa to Lekkemt. This road terminates at Lekkemt, but an unimproved road only usable for four-wheel drive vehicles continues into the proposed project area. This road enters the area about 6 kilometers west of the southern tip and extends northward to an irrigated plantation on the south side of the river. There is no bridge over the river, but the road continues northward across the western part of the area. It is impassable during the rainy season. All-weather road construction for reaching all portions of the area will be expensive because of the need for many bridges to cross the numerous well entrenched drainageways.

Geology and Physiography

The Angar River drains a large area north of Lekkemt and flows westerly from the high plateau area through sharp, steep canyons into the basin-like project area. This area is apparently a peneplain. It is a wide, fairly flat basin which appears to have been formed by erosion. The "plateau" volcanics and Triassic? sandstone are weathered away and the project lies mostly on the basement crystalline rocks found beneath the volcanics and sandstone in the adjoining plateau. With the exception of some minor alluvial depositions near the river the soils are residual and are mature.

Irrigable lands occur in the basin, which is characterized by a well entrenched dendritic drainage pattern. Potential lands for irrigation lie on the relatively smooth and rounded ridge tops and on side slopes into drainageways. Natural drainageways are very numerous and narrow and are entrenched into the soil materials from 6 to 12 meters. Lands slope from an outer perimeter of about 1400 meters elevation towards the central portion of the valley where the Angar River flows at an elevation of about 1250 meters. Project lands occur in irregular patterns because of the variation in widths of ridge and the occurrence of many drainageways. Isolated high areas are common.

Climate

No climatic data from the immediate area are available, however, considering data from Lekkemt, the thick growth of trees in the drainageways, several live streams in side drainageways during the dry season, and the indications of erosion suggest that rainfall may be higher or of higher intensity here than in some other portions of the Blue Nile Basin. It is estimated that annual rainfall is likely to exceed 125 cm. At this latitude, based on the average elevation of about 1350 meters, it is estimated that a year-long average temperature of 20° C may be anticipated. No frost is expected to occur.

Present and Potential Land Use

The area supports a very dense growth of tall grass and open forests of fig and acacia trees. A dense riverine forest ranging from 50 to 300 meters in width occupies shoestring-like strips along all the perennial streams. Most drainageways have at least some adjacent riverine-type forest. The intensity of growth and number of trees and the greater thickness and width of the riverine forest, are indications of natural moisture conditions.

In the northwest part of the area there are several dense bamboo forests which occupy a large land area. These lands may be more expensive to clear than the open forested areas.

One plantation near the Angar River in the west central area irrigates about 50 hectares of land and dry farms another 30 hectares. Many different crops are grown on this plantation for experimental purposes and the success of these crops may be a useful criterion for project planning.

Soil conditions favor a wide variety of crops. Nearly any crop requiring a deep, friable, well-drained profile should do well. Such crops as millet, corn, sorghum, beans, tobacco, and peppers are likely to be the first crops grown with irrigation, but forage crops, sugar cane, subtropical fruit, and vegetables are adaptable and could be grown for higher incomes when proper varieties are developed.

It is said that this valley was inhabited many years ago, but because of malaria and a fly which transmitted a bovine disease from wild animals to cattle, the people abandoned the land and moved to higher and healthier locations. Any development plans should include provisions for disease control.

Project Lands

Topography and Land Development

The topography will likely prove to be the greatest deficiency in the land resource potential. It is estimated that about 5 percent of the proposed project irrigable area has slopes of less than 1 percent; 10 percent has slopes from 1 to 3 percent; 45 percent from 3 to 6 percent, 20 percent from 6 to 8 percent; and 20 percent has slopes of 8 to 12 percent.

Erosion hazards are great, as evidenced by the very numerous deep vertical walled drainageways present in the area. Irrigation waste water as well as run-off from rainfall should be controlled by inlet drop structures where head cut erosion is severe.

Contour-type irrigation or bench irrigation would be most desirable for the type of topography in this area. Down-slope irrigation should be avoided because of the soil erosion hazard.

Isolated high areas are fairly common throughout the area. Therefore, there will need to be numerous relift pumps if all the lands are served. It is likely that excessive costs will make it uneconomic to service all of these lands. Each relift area will need to be individually studied to determine if the service area will justify the investment and maintenance costs needed. Detailed topographic maps with contours at 1-meter intervals will be needed for detailed planning. This detail will be needed to determine the location and extent of relift pumping.

Drainageways are deep and numerous and it will be expensive to construct and maintain canals, laterals, and farm ditches in those section where natural drainage channels must be crossed.

Most of the project area is covered with an open forest of acacia and fig interspersed with tall grasses. Most trees are 5 to 10 meters in height and have a maximum diameter of 40 to 60 cm. It is estimated that these trees can be removed readily with bulldozers for a cost of about Eth$175 per hectare. Leveling needs will be minimal unless bench terracing is desired. Leveling can be done for about Eth$150 per hectare. Ditches, farm drains, turnout structures, and similar type investments are estimated to cost an additional Eth$75 to $125 per hectare. There are a few rocky areas, but these have been put in the nonarable category. Very few rocks occur in the arable area.

Drainage

Natural drainage facilities are good to excessive. Deep natural drains occur on the average about every 200 meters and are seldom more than 500 meters apart.

Pirating of drainage courses is common because of the erosiveness of the soil and the occurrence of intensive rainfalls in small areas which erode new channels and steal the drainage waters that normally flow elsewhere. Stabilization of some present drainageways is needed to prevent further deepening and encroachment on agricultural lands.

There was no evidence of water table problems during the classification. The larger drainageways had water flows from underground sources. Several large springs were also noticed, particularly in the southeast quadrant. Possibly some local irrigation could be developed from these sources.

The well drained appearance of the soils, the numerous trees along the drainage channels, the numerous well incised drainage channels, and the presence of springs in low areas, all indicate that the internal drainage characteristics are excellent.

It was previously remarked that most of the drainage channels are bordered by a riverine forest. Such trees are apparently stabilizing the drainages to a certain extent by their large root systems, but they are also acting as phreatophytes and will tend to reduce the return flows from the project area. Additional studies are needed to determine if the removal of these trees would be an erosion hazard.

Soils

With the exception of some alluvial deposits near the river and some other isolated generally nonarable areas, all of the soils are reddish-brown latosols. The typical profile has 15 cm. of a dark reddish-brown clay loam overlying reddish-brown to red-friable and permeable clay. Table IV-24 shows some laboratory data for three profiles. As will be observed from this table, the soils are acid in reaction and are low or very low in available phosphorus.

Soils in the project area are very well adapted to irrigation and, if protected from erosion and properly fertilized, should be readily adaptable to a wide variety of crops. Although these soils are clay loam and clay texture they have a low plasticity, are readily permeable, and can be tilled over a wide range of moisture conditions without structural disturbance.

TABLE IV-24. LABORATORY DATA--ANGAR RIVER PROJECT

Photo no.	Hole no.	Depth (cm.)	Percent salt	pH	M.A. results: Percent sand	Percent silt	Percent clay	Texture	Color dry	Total N	Percent OM	Available nutrients: P	K	Ca	
9257	1	0-45	Trace	6.2	23	40	37	cl lo	dk rd-br	0.23	7.25	L			
9257	1	45-60	Trace	5.9	21	16	63	clay	dk rd	.15	4.75	M			
9257	1	60-90	Trace	5.9	19	18	63	clay	dk rd	.09	2.75	VL			
9257	1	90-150	Trace	6.0	17	8	75	clay	dk rd	.02	2.75	VL			
3445	13	0-30	-	5.0	35	14	51	clay	dk br		4.7	VL			
3445	13	30-60	-	4.8	24.5	7	68.5	clay	dk rd-br		2.7	VL			
3445	13	60-90	-	4.8	31	6	63	clay	rd-br		2.0	VL			
3445	13	90-150	-	5.3	29	10	61	clay	rd-br		0.5	VL			
9793	16	0-30	-	5.0	29	15	56	clay	dk br		4.2	VL			
9793	16	30-60	-	4.8	22	16	62	clay	br rd		2.65	VL			
9793	16	60-150	-	4.5	25	15	60	clay	yel-rd-br		1.5	VL			

Typically the soils have a strong, coarse granular structure in the surface. The subsurface is firm with a moderately coarse, subangular, blocky structure. The cation exchange capacity usually ranges from about 17 to 20 milliequivalents per 100 grams of soil.

Land Classification

The land classification was performed by helicopter with some supplemental work from four-wheel drive trucks along the road passing through the western half of the area. A total of 20 logged borings to 150 cm. depth were recorded within the area. Photos at a scale of 1:50,000 were used as base maps. The classification delineated Classes 1, 2, 3, and 6, but was of subreconnaissance accuracy because of the distances between traverses (about a kilometer) and the few borings which were made. Land classification results with soil boring information are shown on Figures IV-36 and IV-37.

Class 1--About 3 percent of the project lands were delineated as Class 1. These highly desirable lands have a slope less than 3 percent and have permeable soils well adapted to irrigation. The tree cover is about the same as on the Class 2 lands. More lands qualified for a Class 1 designation, but were not delineated because of the subreconnaissance nature of the classification. It is estimated that detailed investigations may designate 10 to 12 percent as Class 1.

Class 2--These lands were downgraded mostly because of slope conditions. They comprise about 78 percent of the irrigable lands. Some Classes 1 and 3 lands are included in this land class at this stage. However, the project area is basically Class 2 and it is estimated that future studies will substantiate this general analysis.

Class 3--These lands range in slope from 7 to 12 percent and comprise about 19 percent of the irrigable area. Erosion hazards are great in these lands unless very careful irrigation applications are made. In the detailed investigations, further studies are needed to determine what upper limit of slope is suitable for irrigation development. Further studies are also needed to determine if variations in land use to include more close growing crops are needed on these steeper lands. Some lands now shown as Class 3 will be downgraded to Class 6 in the course of a more detailed investigation.

Class 6--Nonarable. These are lands which are steep, rough, or otherwise unsuitable for irrigation development.

Classification Results

The irrigable area shown in the Table IV-25 represents 65 percent of the arable land under the canal. This substantial reduction was made to reflect the inaccuracies of the

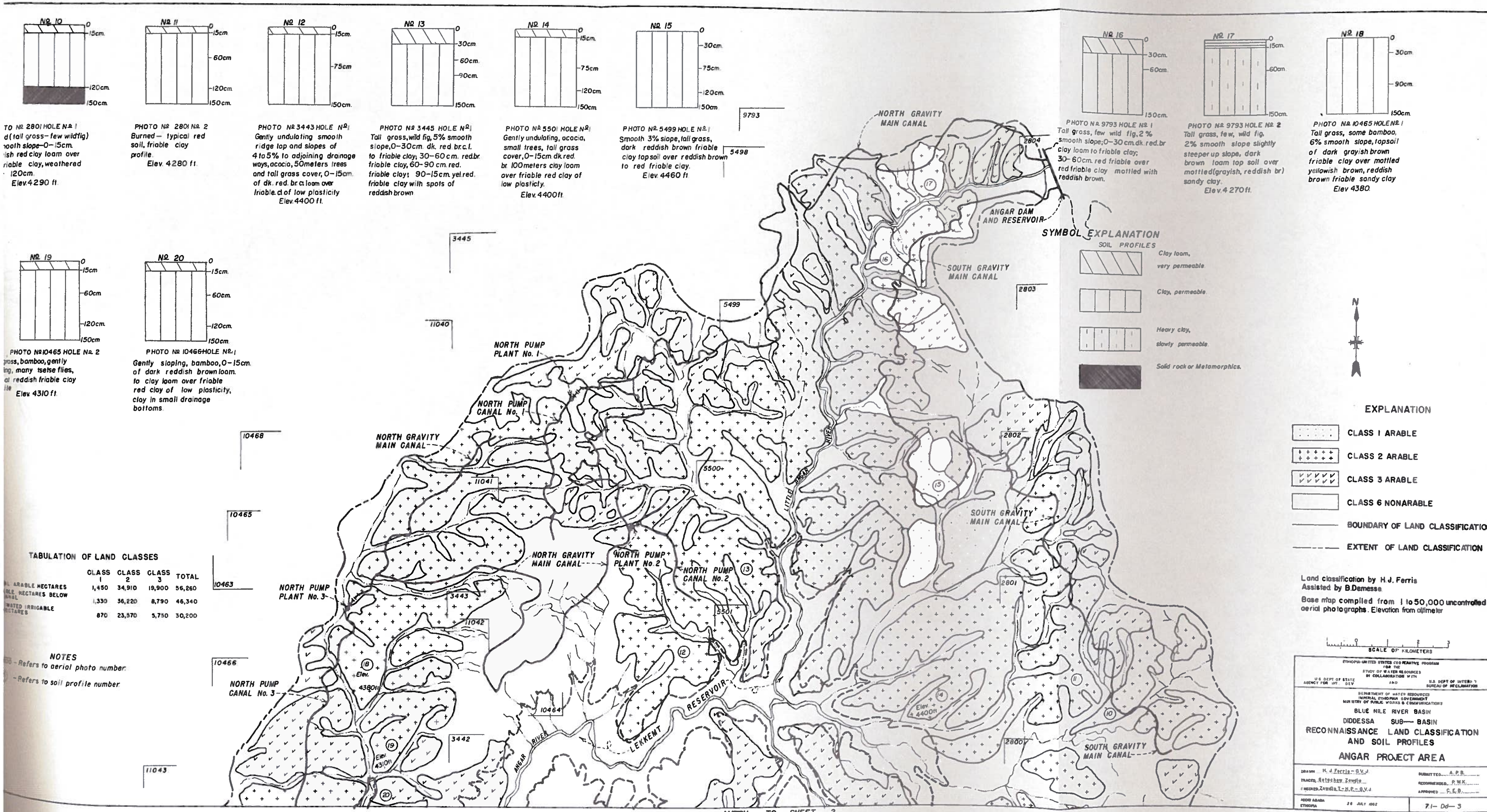


Figure IV-36 - Reconnaissance Land Classification and Soil Profiles, Angar Project Area (Sheet 1 of 2)

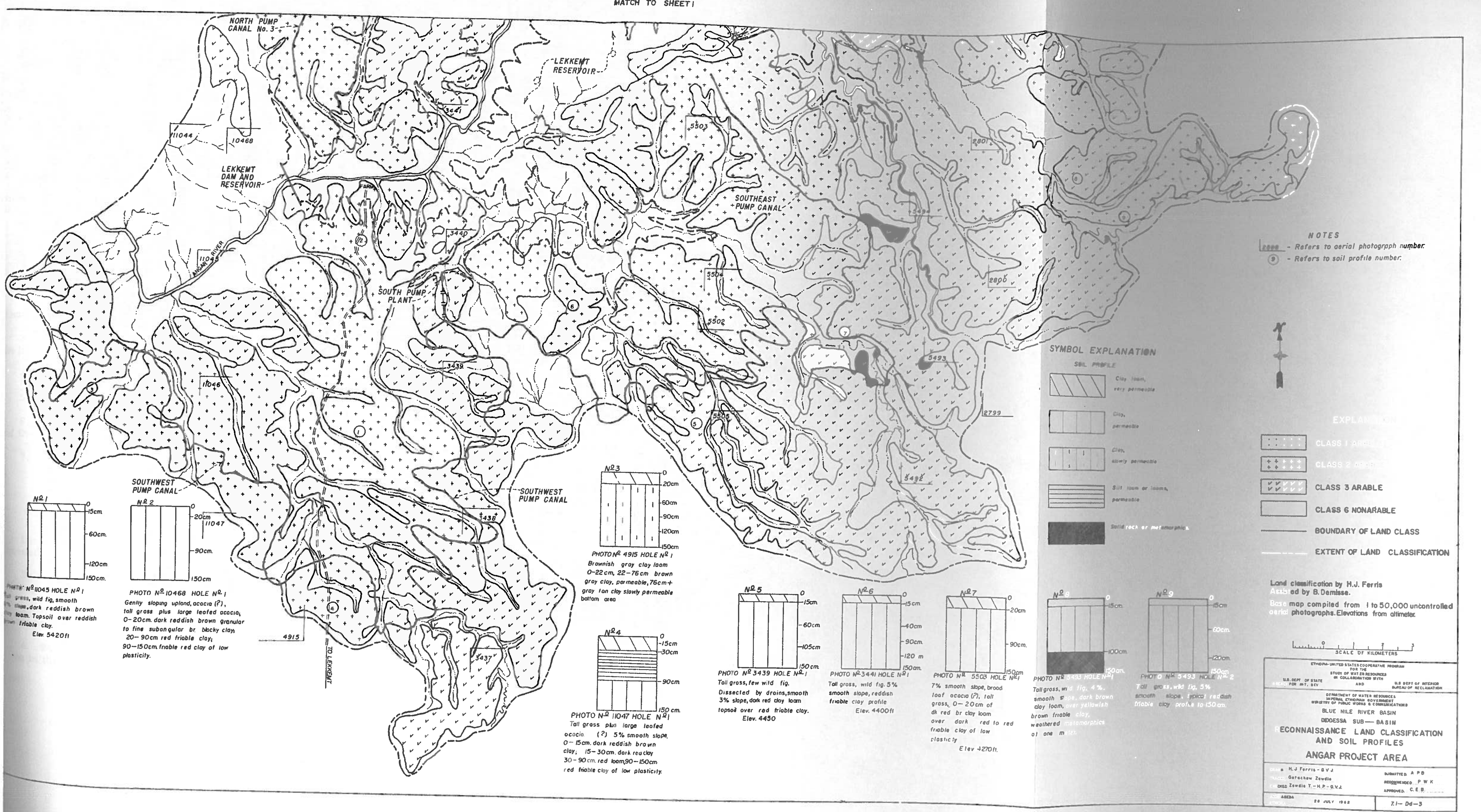


Figure IV-37 - Reconnaissance Land Classification and Soil Profiles, Angar Project Area (Sheet 2 of 2)

TABLE IV-25 - ARABLE AND IRRIGABLE AREAS--ANGAR RIVER PROJECT

Land type	Land areas (hectares)			
	Class 1	Class 2	Class 3	Total
Total arable	1,450	34,910	19,900	56,260
Arable under canal	1,330	36,220	8,790	46,340
Irrigable	870	23,570	5,760	30,200

photo base maps, and because further studies will show that there are many areas that lie above a gravity distribution system and cannot be economically served with irrigation water. Additional reductions in acreages suitable for irrigation along drainages will also occur when detailed studies are made.

Conclusions

1. Climatic and soil conditions are well suited to a wide range of irrigated crops.

2. Drainage conditions appear to be generally good, but will require stabilization of channels to protect agricultural lands.

3. Land slope is greater than desirable for optimum conditions and will require care in land development to reduce erosion hazards.

4. Numerous isolated high areas are present within the project area.

5. Land clearing will not be a difficult task because the trees are relatively small.

6. Canal, lateral, and farm distribution systems will be expensive to construct because of the numerous siphons, culverts, and flumes needed to cross the drainageways.

7. General conditions for irrigation are favorable.

Recommendations

1. Detailed land classification with an accurate 1-meter contour-interval base map is needed for detailed studies.

2. This project should be given a fairly high priority for irrigation development because it is generally well suited to irrigation.

3. Health considerations should receive careful thought in plans for irrigation development because of malaria and other hazards.

4. Further studies are needed to determine the maximum slope permissible for irrigation in this area.

DABUS RIVER PROJECT

General Description

The Dabus Project area lies in the west central portion of Wellegga Province, approximately 40 kilometers east of the town of Asosa at 10°10' north latitude and 34°55' west longitude. It is in a valley on both sides of the Dabus River in the west and lower side of the Blue Nile Basin. The area would receive irrigation water from a gravity diversion of the Dabus River to serve 15,000 hectares.

Transportation

Existing transportation facilities are very poor, consisting only of a few foot or donkey trails. At the time of the classifications, it was impossible to reach the area with a truck or automobile. The nearest road, a rather poor trail which extends from Asosa to Schogali, lies approximately 15 kilometers west over mountainous terrain. An improved road will be needed before the project can be constructed.

Geology and Physiography

The project area is in an ancient valley of the Dabus River overlying metamorphous and granitic rocks of Precambrian age. Fine- to coarse-grained quartzites, phyllites, marble, greenstone, schists and gneisses may be found. It appears that the soils in the area were deposited as alluvial outwash materials from the surrounding mountains, and have been subsequently modified and developed by weathering and erosion.

The Dabus River flows through the project area from southwest to northeast and drops into an extremely deep narrow canyon prior to leaving the area. Numerous small side drainages occur and approximately 10 major side drainages enter the river within the project area. The project lands lie within the elevation range of 950 to 1150 meters on ridges and side slopes of an area characterized by a wide entrenched natural dendritic drainage system. Side drainage channels usually vary from 3 to 12 meters deep, and the river channel is over 100 meters deep in most of the area.

Climate

The area has a tropical climate which should be adapted to a wide range of crops when a mature irrigated agriculture has developed. No data are available on actual climatic conditions, but judging from the location and elevation, it is estimated that the annual temperature will range from 12° to 38° C, and the annual precipitation should total about 100 cm. The greater part of this occurs during June, July, August and September.

Present and Potential Land Use

There are a few natives living in the area, raising dryland sorghum, corn, sesame, and cotton in small plots. The major part of the area is occupied by open forest composed of acacia, fig, and similar trees. Tall grass occupies the area between the trees. Except for some tall trees along the river and a few plantings of eucalyptus most trees are less than 10 meters high, and have trunks with diameters under 50 cm.

Crops which could be grown under the climatic and soil conditions include rice, millet, citrus, sisal, papaya, mango, sorghum, corn, figs, tobacco, and sesame. It is assumed that sorghum and millet will be the important irrigated crops because of the need for this type of crops in the area.

Some grazing is practiced on a small scale, mostly goats and donkeys, but no cattle were observed during the land classification. There are chickens around most of the homes.

Project Lands

Topography and Land Development

The best topography for irrigation development lies in an area near the center of the project and north of the Dabus River. This area has a length of about 8 kilometers parallel to the river and a maximum width of about 6 kilometers. Topographic conditions are very good in this area for irrigation, because it is a broad smooth plain which would be easy to develop. This land would be the choicest location for initial irrigation development.

The entire project area has a well entrenched dendritic drainage pattern. Natural main drainageways are about 0.5 to 1 kilometer apart, and small tributary drainages occur from 50 to 100 meters apart. Slopes parallel to the main ridge average about 1 percent, but usually are in the range of 0.5 to 3 percent. The side slopes vary considerably but are estimated to average 4 to 6 percent. Slopes of 8 to 12 percent are common--particularly in the Class 3 land areas.

High isolated areas which cannot be serviced by an all-gravity distribution system occur. Most of these are in Class 3 lands, and they are more common in the outer fringes of the area than near the center.

Land development costs will vary considerably within the project area because of differences in slope and density of tree cover. It is estimated that clearing and leveling can be accomplished for Eth$175 per hectare. Farm ditches, and structures are estimated to cost Eth$150 per hectare.

Except for the fairly smooth area mentioned earlier, field sizes should be kept fairly small to reduce land development costs. Fields will tend to be irregular in shape because of the large number of natural surface drains.

Water distribution, both for the project and on the farms, will have the problem of crossing drainageways. Numerous culverts, flumes, and siphons will be needed to protect these canals, laterals, or ditches from waste irrigation flows and from the high flows encountered during the rainy season.

Surface rocks will create minor development problems in some areas throughout the project. Most rocks were observed near the fringes of the project and close to the base of the surrounding mountains.

Drainage

No water table problems were observed within the irrigable land area during the classification. Surface drainage is generally excellent except that it may be too well developed and will create problems of water distribution and surface water losses. Some erosion control structures should be used to stabilize the existing drainageways where excessive erosion is occurring.

The project area is underlain with metamorphic rocks which may or may not be permeable. It appears likely that the present system of deep, numerous natural drains will be able to control the ground water. However, studies should be made of the water table behavior during the rainy season to determine the areas where problems may arise under irrigation.

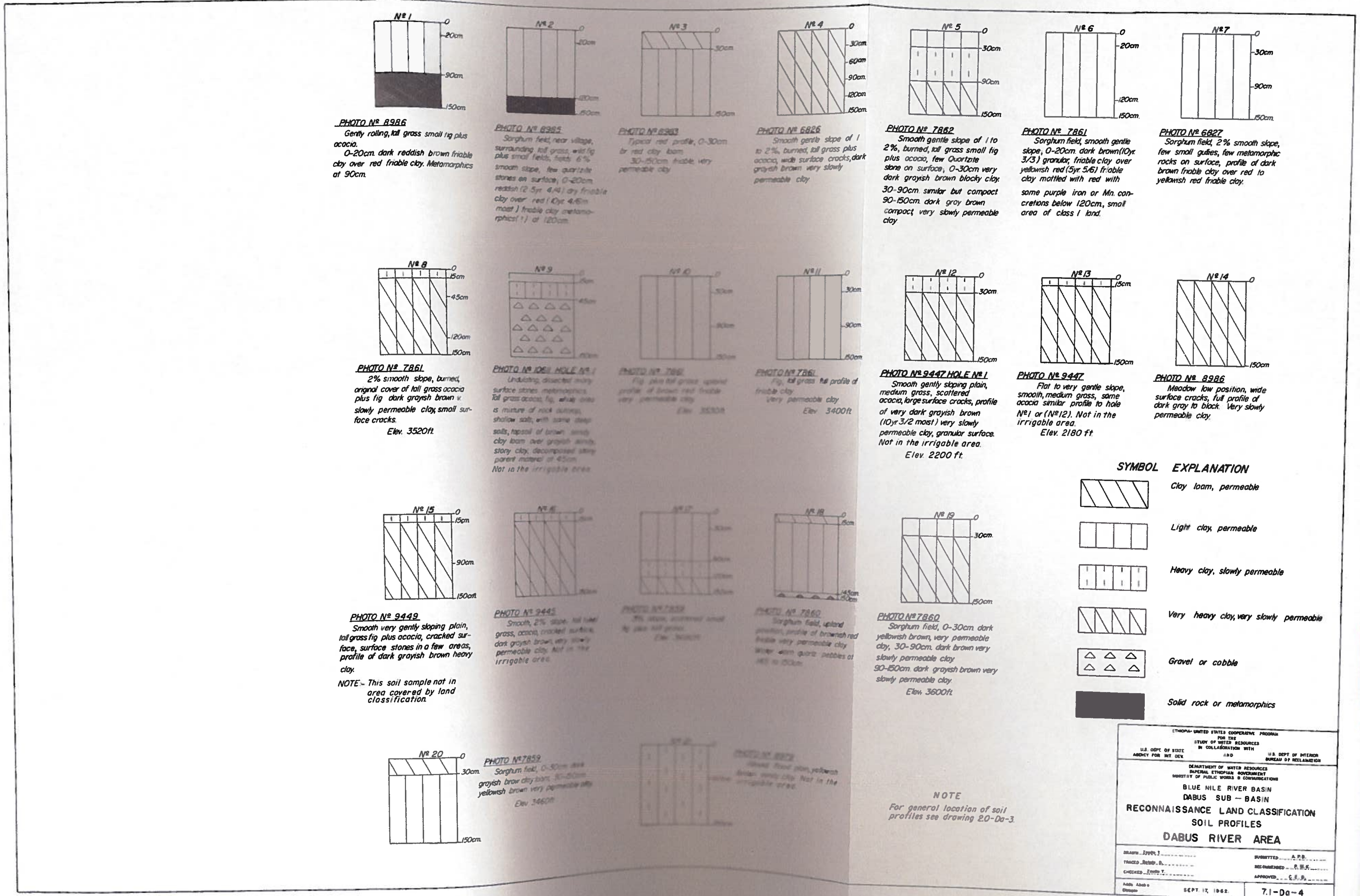
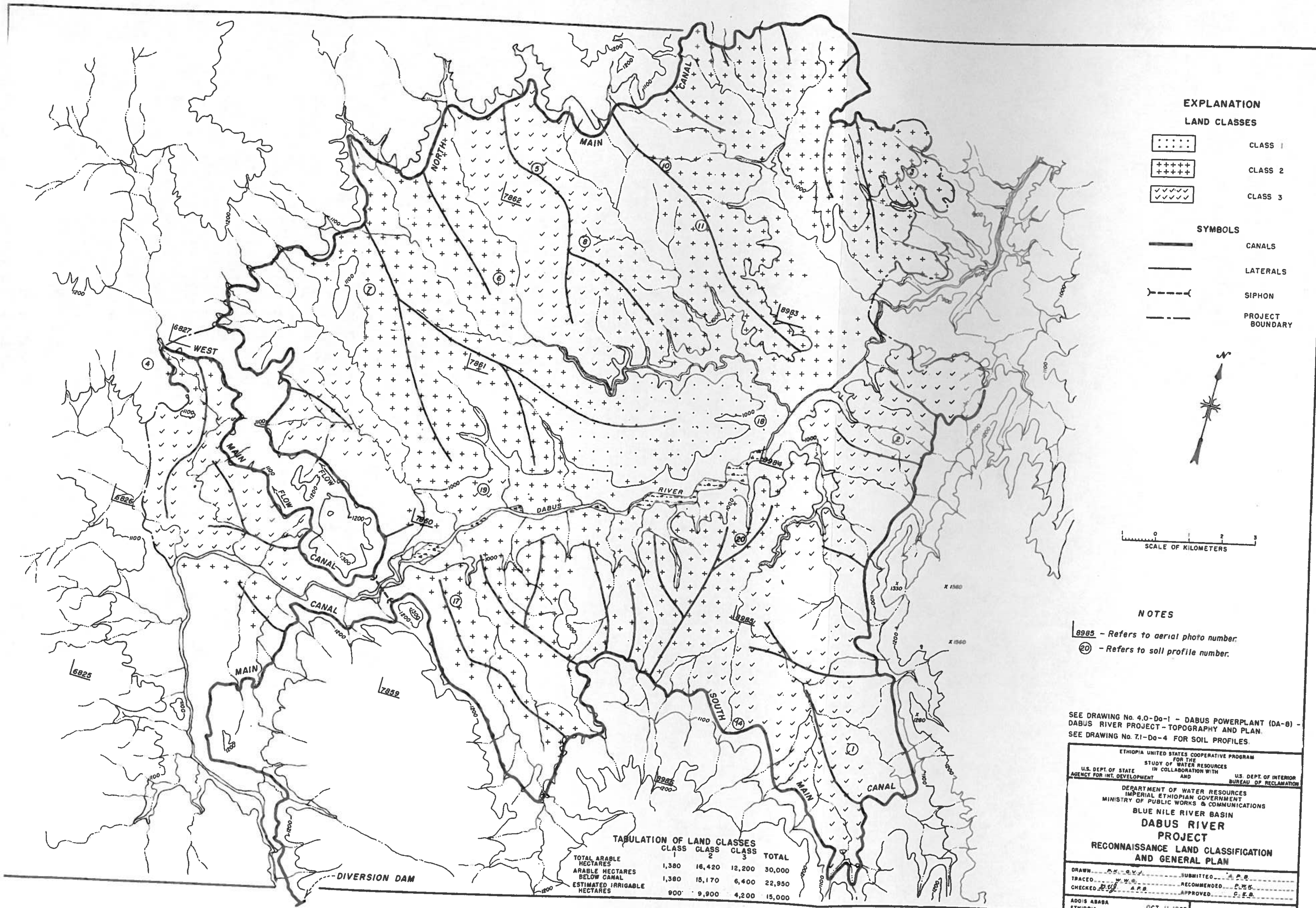


Figure IV-38 - Reconnaissance Land Classification Soil Profiles, Dabus River Project



TABULATION OF LAND CLASSES

	CLASS 1	CLASS 2	CLASS 3	TOTAL
TOTAL ARABLE HECTARES	1,380	16,420	12,200	30,000
ARABLE HECTARES BELOW CANAL	1,380	15,170	6,400	22,950
ESTIMATED IRRIGABLE HECTARES	900	9,900	4,200	15,000

Figure IV-39 - Reconnaissance Land Classification and General Plan, Dabus River Project

Soils

Three major soils occur in the project area--the red latosols, the brown intergrade latosols, and the black grumusols.

The red latosols occur over the majority of the project area. These soils are usually a clay texture but have physical properties much like a loam or clay loam. They have excellent structure, good permeability, good water holding capacity, and are easily tilled. Laboratory data show these soils are noncalcareous, acid in reaction, low in soluble salts, and low in fertility. Boring No. 2 in Table IV-26 shows representative laboratory data for these soils.

The brown intergrade latosols occupy nearly 40 percent of the project area. These soils have properties somewhat like the red latosols, but are less permeable, and have a slowly permeable substratum. The texture is clay throughout. The upper soil has structural properties similar to the red latosols, but are more sticky and harder to farm. These soils are brown to brownish-gray in contrast to the reddish-brown color of the red latosols. Typical laboratory data on these soils are represented by Boring No. 5 in Table IV-26.

Grumusols are of minor importance in this area and are estimated to occur on about 5 to 10 percent of the irrigable land. These soils are dark gray to black and are very slowly permeable clays which crack very severely when dry and are very sticky and hard to farm when wet. These soils are best adapted to pasture, but can be successfully tilled if farmed at the proper moisture content.

TABLE IV-26 - LABORATORY DATA--DABUS RIVER PROJECT

Photo no.	Boring no.	Depth (cm.)	pH	M.A. results: Percent sand	Percent silt	Percent clay	Texture	Color dry	Percent OM	Available phosphorous
8985	2	0-20	5.3	44	29	27	Loam	red-br	4.45	VL
	2	20-60	5.6	26	16	58	Clay	yel-red	2.25	M
	2	60-120	5.4	24	14	58	Clay	yel-red	1.80	VL
7862	5	0-30	5.1	39	12	49	Clay	dk gr	2.1	VL
	5	30-60	4.8	33	10	57	Clay	dk gr-br	3.25	VL
	5	60-105	5.7	31	8	61	Clay	dk gr-br	2.8	L
	5	105-150	6.9	31	8	61	Clay	dk gr	0.5	VL
7861	6	0-20	6.1	44	13	43	Sandy clay	br	3.95	VH
	6	20-90	6.0	27	5	63	Clay	dk br	0.56	VL
	6	90-150	6.2	29	12	59	Clay	yel-br	4.35	VL

NOTE: See Figure IV-38 for description of these profiles and Figure IV-39 for location.

Land Classification

The land classification was of subreconnaissance type and subject to considerable error--possibly in the range of 30 to 45 percent. A helicopter was used to make the classification because of the inaccessibility to surface vehicles. Landings were made at representative locations and soils sampled to a 150 cm. depth to study physical and chemical properties. Samplings were made at 6 to 20 kilometer spacings. Land class delineations are shown in Figure IV-39.

The initial classification was performed on aerial photos at the approximate scale of 1:50,000. Subsequent studies of the topography compiled from stereoscopic projection where there was considerable horizontal control showed that the aerial photos were highly distorted and had up to 40 percent error in horizontal distances. The classification results shown on Figure IV-38 reflect the correction of horizontal distances resulting from the multiplex projections.

The present classification should be replaced by a detailed or semi-detailed classification utilizing accurate base maps at a substantially smaller scale than the present work prior to developing a definite plan report.

Description of Land Classes

Class 1--Because of irregular relief, stones, and slopes in excess of 3 percent, only 6 percent of the irrigable land was delineated as Class 1. It is probable that a detailed classification will increase this percentage moderately. Many of the broader ridge tops will qualify as Class 1, but were not so delineated in this classification. Class 1 lands are well adapted to irrigation and will produce good yields with the least cost.

Class 2 lands occupy about 66 percent of the project area. These lands were downgraded mainly because of topographic deficiencies rather than because of soil deficiencies. Most of these lands have slopes in the range of 3 to 7 percent, and are more difficult to irrigate and less productive than Class 1 lands. Detailed studies can be expected to reduce the percentage of Class 2 lands. A small amount of Class 1 and nonarable Class 6 will be delineated and a substantial acreage of Class 3 may be separated. Class 2 lands are of intermediate suitability for irrigation. The soils are similar to Class 1 lands, but the slope of the lands will reduce productivity and increase costs.

Class 3 lands occur on about 28 percent of the project area. The Class 3 lands are quite rough and irregular, and some are quite stony. Numerous isolations of Class 6 are included which were not large enough to delineate. The slope of Class 3 lands is generally in the range of 7 to 12 percent. A substantial portion of the arable Class 3 lands may be downgraded to Class 6 under a rigorous detailed study because of the numerous topographic deficiencies. Most of the Class 3 lands have soils similar to Classes 1 and 2 except that the small amount of grumusols have been delineated as Class 3. There is a serious question whether slopes of 7 to 12 percent can sustain permanent irrigation without excessive erosion. Further studies are needed to determine the maximum slope that will remain productive under the technological level anticipated in this area.

Class 6--Nonarable lands are steep, rough, and stony slopes or drainages which cannot be farmed economically, and are unsuitable for sustained irrigated agriculture.

Results

TABLE IV-27 - ARABLE AND IRRIGABLE AREAS--DABUS RIVER PROJECT

Land type	Land areas (hectares)			
	Class 1	Class 2	Class 3	Total
Total arable	1,380	16,420	12,200	30,000
Arable under canal	1,380	15,170	6,400	22,950
Irrigable	900	9,900	4,200	15,000

The irrigable area was determined by reducing the arable area under the canals by 35 percent to account for estimated inaccuracy of the subreconnaissance type of classification. It is believed that the total irrigable area as determined by detailed studies will be approximately as shown in the above tabulation. However, the exact location of these various classes of lands may differ substantially from that shown in Figure IV-39.

Conclusions

1. The climate in the Dabus Project is ideal for a wide variety of tropical and subtropical crops.

2. The soils are generally well suited to irrigation physically, but will require considerable fertilization for maximum production.

3. Land development for irrigation will not be a serious problem.

4. Road improvement is needed at an early stage of development.

Recommendations

1. Initial irrigation development should start in the area of Class 1 and adjacent area to the west of Class 2 lands because of the ease of development in this area.

2. A detailed land classification is needed prior to finalizing any development plans.

3. Care will be needed with irrigation to avoid excessive soil erosion.

DINDIR-RAHAD AREA

Introduction

The Dindir-Rahad area is composed of three separate projects: Dindir River, Galegu River, and Rahad River. These projects all occur within the lowland area adjacent to the Sudan-Ethiopian border. Because of their similar elevations and soils these projects have been combined for reporting purposes. Differences in topography, drainage, or other characteristics and the irrigable acreages served within each project are discussed in the following presentation.

General Description

The Dindir-Rahad area is situated in the northwestern part of Gojjam Province along the Ethiopian-Sudan international boundary. The central part of the area lies at 12°10' north latitude and 35°05' east longitude. It extends along the boundary for a distance of about 145 kilometers. At its widest point the area which can be served by the proposed canal system has a depth of about 48 kilometers. However, the average width is only about 25 kilometers.

The Dindir River Project occupies the approximate southern half of the proposed service area. This project can be irrigated from water stored in a proposed reservoir on the Dindir River.

The Galegu River Project occupies only about 9.5 percent of the total irrigable lands. This project is situated on the southeast side of the Rahad Project and does not reach the international boundary as do the other two projects. It is proposed to service this project from a reservoir on the Galegu River.

The Rahad River Project is located in the northern half of the area and can be irrigated from a reservoir on the Rahad River. The Rahad River drainage area is considerably larger than that of the Galegu River. Therefore, lands along the lower Galegu River are planned to be served by diversions from the Rahad River. There is insufficient water available in the Galegu River drainage basin to service more than the small area shown for the Galegu Project itself.

Land surface elevations in the project areas range from 600 to 800 meters and average about 630 meters. This is the lowest elevation of any lands proposed for irrigation within the Blue Nile Basin in Ethiopia.

Because of the location of these projects, all return flows enter Sudan, and merge with the Blue Nile River at Khartoum, the capital. Possibilities for irrigation in Sudan also exist in the lands adjoining these projects on the west.

Transportation

Transportation facilities are very poor, but the generally flat terrain does make it physically possible to reach most parts of the area if this is attempted in the dry season with four-wheel-drive trucks. However, such trips require considerable time. An indistinct trail from Injibira to the southeast reaches Omedla, which is located next to the Dindir River near the Sudan boundary. A similar-type road passes north-south through the eastern tip of the Galegu Project. This road starts near Lake Tana and terminates at Metemma, near the Rahad River. Both of these roads are suitable only for dry weather use with four-wheel-drive vehicles equipped with winches. During the course of the project investigations, a similar-type road was developed north of the Dindir River from trips made during the installation and maintenance of a water recording gage east of the village of Giobai. The approximate locations of these roads are shown on Figures IV-40 and IV-41.

Geology and Physiography

The geological origin of the soils varies considerably according to location. Most of the Rahad River Project appears to be alluvial depositions with a considerable area of fairly recent alluvial deposits on an ancient flood plain. Soils in the Galegu Project are about equally divided between the residual soils developed from weathering of underlying rocks and alluvial fan depositions near the base of adjacent granitic hills. The Dindir River Project appears to be mostly a peneplain surface of residual soils developed from Precambrian metamorphic and granitic rocks. This project has some sizeable alluvial areas also. There are isolated remnants of sandstone and granitic knobs throughout the area. Volcanic materials have also contributed considerably to soil origins from alluviums originating in the volcanic-capped plateau to the east.

There are five streams generally flowing from southwest to northeast within the proposed service area. From north to south these rivers are the Rahad, Khor Dibaba, Galegu, Atesh, and the Dindir. The gradient of these streams, with the possible exceptions of the Dindir and Rahad, decreases rather rapidly toward the Sudan boundary. The project lands also flatten and decrease in elevation above the streambeds toward the boundary. As a result, large smooth plains with few drainageways typify the majority of the proposed project area. Most of the remaining areas upstream have a slightly rolling terrain, dissected by a dendritic drainage pattern. The flat plains near the Sudan boundary are only very slightly higher than the rivers and subject to flooding from high river flows.

Climate

No climatic data are available for the immediate project area. Because of its low elevation it should be the warmest area in the Blue Nile Basin of Ethiopia. At Khartoum, capital of Sudan, situated at about 15°35' north latitude and at an elevation of about 400 meters, considerable climatic data are available. These data show that average maximum temperatures of 38° C or over prevail for 8 months of the year (March through October). Average maximum temperatures of 32° to 37° C prevail during the day for the other 4 months. Temperatures on individual days often reach 46° in the shade, and above 55° in the sun. The nights are fairly cool, but temperatures rarely drop as low as 5° during the winter. Rainfall is only about 20 cm. at Khartoum, but the project area is known to have more rainfall than Khartoum. It is estimated that the rainfall within the project may approach 50 to 70 cm. per year. The frost-free period will likely be year-long. Daytime temperatures will usually approach or exceed 38° C during 8 months of the year. The very hot climate will be unpleasant, and a distinct hardship to the farmers.

Present and Potential Land Use

With the exception of a few areas of grass where the soils are least permeable, and a few areas of very dense forest where internal drainage is exceptionally good, the proposed project area is covered by an open forest of deciduous trees with an associated dense growth of elephant grass. The red bark acacia appears to be the most common type of tree. The trees occur at all densities, but usually are about 20 to 30 meters apart and 7 to 10 meters high. The elephant grass often exceeds 4 meters in height. This is burned off each year for protection against large animals and snakes.

There are occasional villages along the major streams, usually not exceeding 15 grass-thatched dwellings. Small plots of cotton, sesame, sorghum, and small grain are farmed. A few bands of goats are seen, and a few cattle.

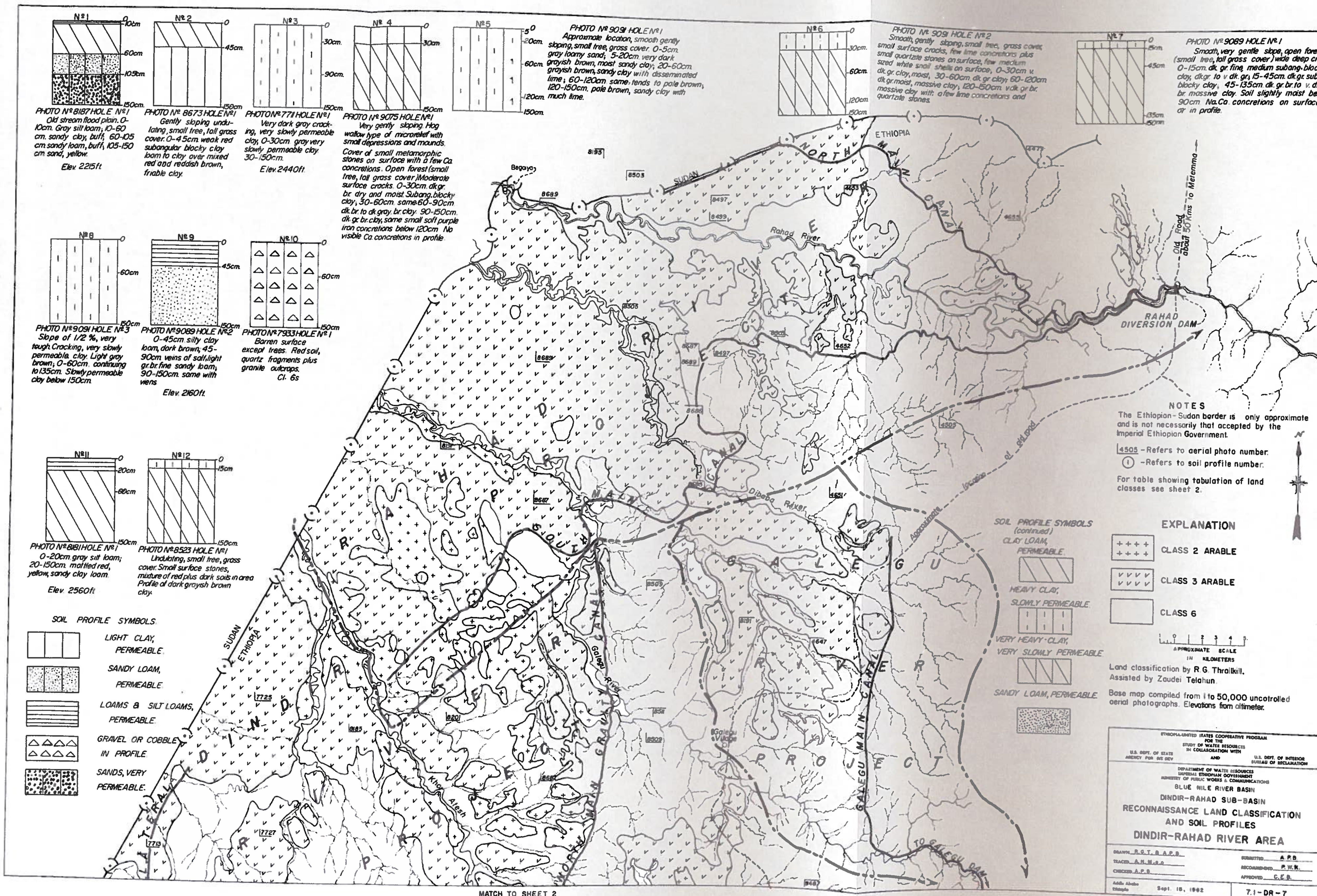
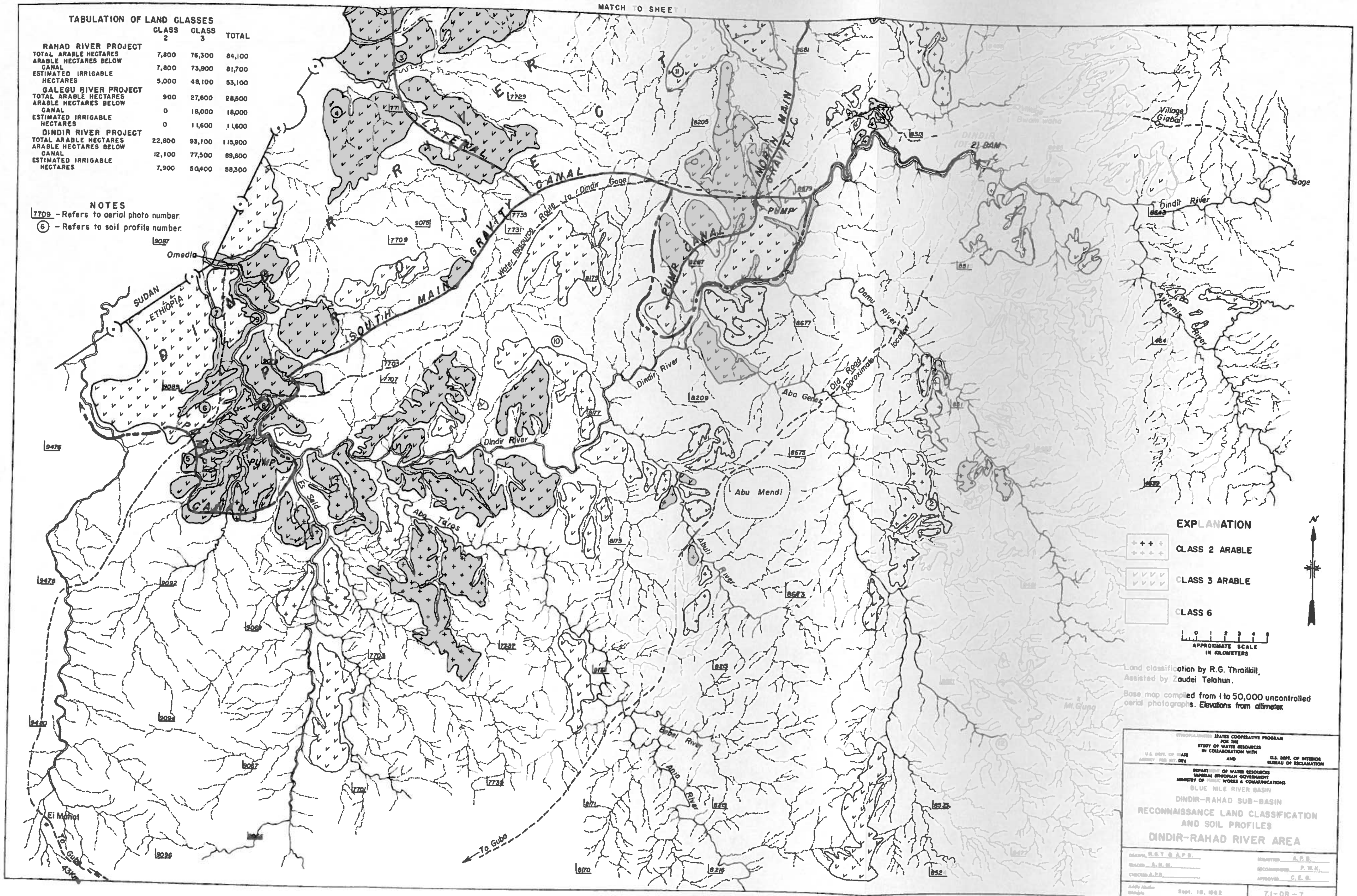


Figure IV-40 - Reconnaissance Land Classification and Soil Profiles, Dindir-Rahad River Area (Sheet 1 of 2)



TABULATION OF LAND CLASSES

	CLASS 2	CLASS 3	TOTAL
RAHAD RIVER PROJECT			
TOTAL ARABLE HECTARES	7,800	76,300	84,100
ARABLE HECTARES BELOW CANAL	7,800	73,900	81,700
ESTIMATED IRRIGABLE HECTARES	5,000	48,100	53,100
GALEGU RIVER PROJECT			
TOTAL ARABLE HECTARES	900	27,600	28,500
ARABLE HECTARES BELOW CANAL	0	18,000	18,000
ESTIMATED IRRIGABLE HECTARES	0	11,600	11,600
DINDIR RIVER PROJECT			
TOTAL ARABLE HECTARES	22,800	93,100	115,900
ARABLE HECTARES BELOW CANAL	12,100	77,500	89,600
ESTIMATED IRRIGABLE HECTARES	7,900	50,400	58,300

Figure IV-41 - Reconnaissance Land Classification and Soil Profiles, Dindir-Rahad River Area (Sheet 2 of 2)

The possibilities for irrigated crops are large because of the year-long growing season. However, the soils are generally slowly permeable and additional studies are needed to determine the crops which may be best adapted. It is believed the excessive heat will be detrimental to the production of many crops. Such crops as cotton, pasture, hay, sisal, small grain, sorghum, and corn are likely to be well adapted. The surface soils have a high clay content and are difficult to cultivate. Hay and pasture are best suited to the soils.

Project Lands

Topography and Land Development

It is estimated that about 75 percent of the proposed project areas slopes less than 1 percent, and part of these lands are nearly flat, so that rainwater collects in depressed areas. It is estimated that less than 5 percent of the total area exceeds 8 percent slope, and only about 10 percent exceeds 5 percent slope. The Rahad River Project has the flattest slopes of any of the three projects. Approximately 90 percent of this project has slopes less than 1 percent. The Dindir River Project has about 60 percent with less than 1 percent slope, and most of the rest have slopes of only 1 to 5 percent. The Galegu River Project has the greatest average slope and is least desirable topographically. This project is quite eroded and it will be difficult to service because of numerous cross drainages and isolated high areas.

Land development costs will be fairly low in the Rahad River Project because of the larger smooth plains. The open forest cover can be removed with modern heavy equipment for an estimated cost of Eth$225 per hectare, and leveling is estimated to cost Eth$65. Farm ditches and structures will require an additional cost estimated to be about Eth$100 per hectare. Surface drainage is needed and subsurface drainage may be required. Further studies and more topographic data are needed to develop a cost figure for subsurface drainage requirements.

Land development in the Dindir River Project area will be similar to that of the Rahad River Project, but may cost slightly more because of the undulating surface and slightly greater gradient. Tree cover is about the same for these two projects.

Land development costs for the Galegu River Project can be expected to be Eth$380 per hectare because of the rougher topography. Average slopes in this project are 4 or 5 percent. Erosion is active and careful water control with numerous turnout and drop structures will be needed. Tree removal costs will be approximately the same as for the Rahad and Dindir River Projects.

Topographic conditions favor large fields with modern equipment for efficient crop production in the Rahad and Dindir River Projects. Border dike irrigation with very slight gradient and large heads of water would be desirable. The rougher topography in the Galegu River Project will make smaller fields suitable and there will be a need for more hand labor and small equipment. Contour ditches and gradient furrows appear to be the best gravity type of irrigation on these lands. Small heads of water will minimize the erosion problem.

Drainage

Drainage problems--surface and subsurface--can be anticipated in the Rahad River Project, and to a lesser extent in the Dindir River Project. Because of the greater slope and more permeable soils, minimal drainage problems are anticipated in the Galegu River Project.

Surface drainage is poorly developed over a larger portion of the Rahad River Project, and on portions of the Dindir River Project. Surface drainage is poorest in that portion of the Rahad River Project near the Sudan border and between the Galegu and Khor Dibaba Rivers.

Subsurface drainage requirements need a complete detailed study. The nature of the soil origin and the occurrence of considerable sand along the river channels suggest that the subsurface permeability may be fair to good. However, it can be anticipated that deep drainage conditions will vary widely and will require careful study. Accurate topographic maps with 1-meter contour intervals are needed to determine whether there is adequate relief to assure proper surface and subsurface drainage.

Deep observation wells for water table studies should be established throughout the proposed service areas early in the detailed investigation so the water table behavior may be properly evaluated.

Soils

The rather dense tree cover over the bulk of the project area prevented helicopter landings so that soil borings were rather widely separated. Observations of river channel cuts and the color of the surface soil indicates that most of the near-level, smooth topography has dark gray or black soils (grumusols) while the steeper lands have reddish brown latosol soils. However, the limited amount of soil examined and sampled shows a greater variety of soil conditions than in any other portion of the Blue Nile Basin. The alluvial origin of many of the soils explains why a great diversification can be expected. Sands are common in the channels of all the rivers flowing through the area, and it is believed that future studies will show that substrata materials contain more sands than usual.

Most soil observations were made at tree-top level after the tall grass had been burnt. Wide cracks were present in most soils and surface indications showed that a dark-gray clay was common. However, the tree growth is generally more luxuriant than normal for typical grumusol soils in the Blue Nile Basin. This difference in tree vigor suggests substrata permeability may be better than normal grumusols. This observation was confirmed by the observation of sands in the profiles of some river channels.

Table IV-28 shows laboratory data secured on some soils from the proposed project areas. Phosphate availability is low on these soils as is shown by the laboratory data. Although the organic matter is usually fairly high, it can be anticipated that these soils will respond to nitrates because of the high lignin content of typical elephant grass root residues. It is believed that there is ample calcium in the soils and lime additions will not be needed.

TABLE IV-28 - LABORATORY DATA--DINDIR-RAHAD PROJECTS

Photo no.	Hole no.	Depth (cm.)	Percent salt	pH	M.A. results				Color dry	Total N	Percent OM	Available nutrients			
					Percent sand	Percent silt	Percent clay	Texture				P	K	Ca	Mg
9089	1	0-15	Trace	5.8	20	5	75	Clay			2.25	L			
9089	1	15-45	.05	6.0	24	8	68	Clay			2.25	L			
9089	1	45-90	Trace	6.6	20	12	68	Clay			1.75	L			
9089	1	90-135	.08	7.0	18	12	70	Clay			0.5	L			
9089	1	135-150	Trace	7.1	18	1	81	Clay			0.5	L			
4091	1	0-30	.04	6.8	66	14	20	Sa cl lo			1.75	VL			
4091	1	30-60	Trace	8.0	54	12	34	Sa cl lo			0.75	L			
4091	1	60-120	Trace	8.0	52	12	36	Sa cl lo			0.75	M			
4091	1	120-150	Trace	8.2	52	10	38	Sa cl lo			-	L			
9091	2	0-30	-	6.2						.09	1.75	VL			
9091	2	30-90	-	5.6						.07	2.25	VL			
9075	1	0-30	.03	6.2	28	32	40	Clay			1.00	VL			
9075	1	30-60	.03	6.6	26	13	61	Clay			1.00	VL			
9075	1	60-70	.04	7.0	29	12	59	Clay			1.00	VL			
9075	1	70-120	.05	6.8	31	8	61	Clay			1.00	VL			
9075	1	120-150	.05	7.0	28	10	62	Clay			1.00	VL			

Although the subsurface permeability and drainability may be superior to many grumusols, the problems of water intake, tilth, and cultural operations will be similar to normal grumusols. Therefore, care is needed in irrigation and cultural operations to preserve a good structure and prevent puddling the soils. Proper tilth and enhanced water intake rates may be achieved by including a soil-building crop such as hay or pasture in the rotation. Continuous clean cultivation should be avoided.

Land Classification

All of the land classification was performed by helicopter. A total of 12 soil borings were made to a depth of 150 cm. Unrectified aerial photos at a scale of 1:50,000 were used as base maps. These maps have considerable distortion. Traverses were made at approximately 1 kilometer intervals. Dense tree cover prevented many helicopter landings, but numerous tree-top observations were made. The classification has only a subreconnaissance accuracy because of the few soil borings and the unresolved questions of drainability. Land Classes 2, 3, and 6 were delineated. The results of the classification together with the tentative location of the major distribution facilities are shown on Figures IV-40 and IV-41. It should be noted that the scale of these drawing maps is different than other land classification maps. They were prepared to facilitate showing the classification data on two drawings rather than eight.

Class 2--This land class represents only 5.5 percent of the Rahad River Project lands, and only 13.5 percent of the Dindir River Project lands. Some of these lands will qualify for Class 1 when a detailed land classification is made. The lands as mapped are smooth, have less than 3 percent slope, have a permeable, well-drained profile, and are covered with a very dense growth of trees. No Class 2 lands were delineated in the Galegu Project because of the prevalence of steeper slopes and irregular topography.

Class 3--These lands are mostly from 0 to 2 percent in slope, are smooth and adaptable to large fields, but have been downgraded to Class 3 because of the highly plastic and slowly permeable surface soils and uncertain underdrainage. Some of these lands are well drained and others are poorly drained. Detailed studies are needed to properly delineate the numerous variations which are anticipated. Detailed studies may upgrade some of these lands to Class 2 and downgrade some to Class 6. Most of the Galegu Project lands and a small percentage of the other project lands were downgraded to Class 3 because of excessive slope, irregular fields, excessive erosion, and flood hazards. Soils on the rougher topography are generally permeable, reddish-brown latosols. Detailed studies can be expected to reduce the arable acreage in the Galegu River Project because of the difficulties in serving some lands.

Class 6--These nonarable lands represent recent nondrainable flood plains, isolated highs, and some high, severely eroded "badlands" type topography. The latter comprises the major portion of the Class 6 lands.

Irrigable Area Determination

As can be observed from Figures IV-40 and IV-41, most of the solid blocks of arable lands can be reached, but the scattered tracts of arable lands are generally too high and too expensive to service. The arable area below the proposed canal lines has been reduced by 35 percent to reflect the potential errors that may be present in the subreconnaissance land classification. Topographic conditions are excellent in the Rahad and Dindir River Projects, but future studies may find some soils or drainage conditions unsuitable for development. In the Galegu Project the soil and drainage conditions are believed to be good, but further studies may reduce arable lands because of a more critical topographic evaluation.

Topographic maps with 20-meter contour intervals were used to lay out the proposed distribution system. More refined topographic data can be expected to alter the location of these canals substantially. This will change the irrigable area.

Classification Results

TABLE IV-29 - ARABLE AND IRRIGABLE AREAS--DINDIR-RAHAD RIVER AREA

Location	Total arable (hectares)			
	Class 1	Class 2	Class 3	Total
Rahad River Project	-	7,800	76,300	84,100
Galegu River Project	-	900	27,600	28,500
Dindir River Project	-	22,800	93,100	115,900
	Total arable below canal (hectares)			
Rahad River Project	-	7,800	73,900	81,700
Galegu River Project	-	-	18,000	18,000
Dindir River Project	-	12,100	77,500	89,600
	Irrigable (hectares)			
Rahad River Project	-	5,000	48,100	53,100
Galegu River Project	-	-	11,600	11,600
Dindir River Project	-	7,900	50,400	58,300
Totals	-	12,900	110,100	123,000

Conclusions

1. Climatic conditions are suitable for a wide range of crops because of the year-long frost-free period. However, the intense heat may reduce some crop yields to less than those attained at higher elevations.

2. Many alluvial soils exist, and there appears to be more sand in the substrata than normal in the Blue Nile Basin.

3. Surface soils are generally fine-textured, highly plastic, and crack widely on drying.

4. With the exception of the Galegu Project lands, topographic conditions are generally excellent for irrigation.

5. Surface and subsurface drainage may be difficult to achieve in the Rahad River Project near the Sudan boundary because of flat terrain and low relief as contrasted with the Galegu and Khor Dibaba Rivers.

6. Land clearing can be achieved easily with heavy equipment such as bulldozers because the trees are small.

7. The high daytime temperatures may inhibit irrigation developments.

8. The presence of large numbers of snakes and scorpions may restrict irrigation to daytime operations at least in the initial stages of operation.

9. Construction of an all-weather marketing road will be very expensive unless products can be exported through the Sudan.

10. The Rahad River Project appears to be best adapted, of the three projects, to initial irrigation development.

Recommendations

1. Detailed land classification made with the assistance of accurate 1-meter contour-interval topographic maps is needed prior to initiation of any construction program.

2. An irrigation experiment station should be established on grumusol soils near one of the perennial streams to determine the type of crops best adapted to the project lands and climatic conditions.

OTHER IDENTIFIED PROJECTS

In addition to the foregoing projects, there were several others investigated during the land-classification work in Ethiopia. Descriptions of these projects follow. In the main, while the projects appeared feasible for irrigation before the investigations began, all were deemed unsuitable for irrigation at present for one reason or another on the basis of the subreconnaissance classification examination. Should circumstances in the future warrant re-examination of these projects for development of some sort, the findings of the land classification survey are included.

FETTAM-AZENA AREA

Introduction

A subreconnaissance land classification study of the area was completed during March 1961. The coverage was somewhat limited by lack of access to the inhabited areas because of the hostility of the people who populate the drainage areas of both the Azena and Fettam Rivers, making it unsafe to land the helicopter in the cultivated areas. This problem could have been solved had there been sufficient time available, but because of the loss of one of the American soil scientists in Ethiopia, field time was very limited.

The study was made to appraise the land resources with special reference to its potential value for irrigation development. Engineering studies later showed there is no suitable storage for irrigation, so none of the arable lands are considered to be irrigable.

General Description

The Fettam-Azena Project is in the Fettam and Azena River Basins in the central portion of Gojjam Province. The approximate center of the area is at 10°45' north latitude and 37°0' east longitude. (See Plate I.) The gross area investigated is approximately 275,000 hectares, of which 130,490 hectares are considered arable.

Four villages lie within the investigated area, Injibira is at the northern extremity of the area; Teltelle, about 15 kilometers southeast of Injibira; and Bure, about 15 kilometers south of Teltelle. These are all on the Debre Markos-Bahir Dar all-weather highway. Cima lies about 13 kilometers due south of Injibira and is connected to the highway by a very rough trail. These villages are market centers, served by transport lorries from Addis Ababa.

Transportation

A good, gravel all-weather road transects the area. The main highway from Addis Ababa to Bahir Dar enters the area in the east central portion and leaves at the northern extremity. It was completed through the project area during 1962. A trail leaves the main road near the northermost portion of the area near Injibira and traverses the upper portion of the Azena River Valley. It leaves the valley in the northwest portion and continues to Metekkel, the Beles River Valley, Guba, and reaches the Sudan-Ethiopia border in the vicinity of Omedla. This is a very difficult trail to traverse beyond Metekkel, and vehicles with four-wheel drive equipped with winches are required.

Geology and Physiography

Younger lava has flowed down previously eroded valleys and been deposited as thin, porous sheets. The porous nature of this lava has caused the natural streamflow to disappear and reappear in the stream channels.

The soil is residual over these flows and is generally fairly thin and in places stony. The Fettam and Azena Rivers follow parallel courses, separated by 25 kilometers or more of rolling countryside. They flow in a southerly direction and join the Blue Nile River about 45 kilometers southwest of the town of Bure.

The area is bounded on the north and west by rugged mountains; on the south by the breaks of the Blue Nile Canyon; and on the east by the divide separating the Fettam River drainage basin from that of the Birr River. The area investigated is roughly 50 kilometers long and 50 kilometers wide.

The Azena Valley is broad (about 8 kilometers wide) at the northern extremity and extends southward for about 45 kilometers, tapering to a point where the river enters a narrow canyon. The river has a classic dendritic drainage pattern, originating in many small spring-fed tributaries which join two major, rather deeply entrenched streams and which join near the valley outlet canyon. To the east of this drainage basin the land rises rather abruptly in an elevated, undulating to rolling plain which extends across the valley of the Fettam River. The upper portion of the Fettam drainage area is similar to that of the Azena, except that the continuity of the valley is broken by several volcanic plugs, a crater lake, and several flat areas where lakes are formed during the rainy season. The lower reach of the stream is confined in a narrow space between gently rising uplands to the east and west. These upland areas rise gradually and have gently undulating topography with deep soil, and were therefore included in the area investigated.

Present and Potential Land Use

The major portion of the area investigated is being dry-farmed and several areas are being irrigated. There is, perhaps, more area under irrigation in this project than in any other single area in the Blue Nile Basin.

The irrigated area, which is for the most part in the Azena Valley, is being utilized for the production of teff, barley, wheat, noog, millet, pulses, and oilseeds. The same general crops are produced under dry-farm conditions, and would be typical of additional irrigation. The uncultivated areas are supporting a growth of acacia, grass savannah on the red soils, and tall grass on the black soils. Riverine forest grows in narrow strips along the stream channels, and there are isolated rain forest islands in the valley. Heavy rain forest occupies the mountain slopes adjacent to the area investigated, especially to the west and north.

Many herds of cattle, sheep, and goats are being grazed on the uncultivated areas and in the upper valleys of the Fettam and Azena Rivers, and the largest concentration of horses and mules seen in the Blue Nile Basin are being raised. This is the only area in Ethiopia where horse-drawn plows were seen.

Project Lands

Soils

Soils of the project are largely reddish latosols but the low-lying, poorly drained areas are typified by dark gray to black grumusols. These areas are generally widely separated. For example, one area lies on the upper tributaries of the Fettam River, at the toe of the mountains southeast of Injibira. This wide, nearly flat valley is the meeting place of many meandering, slow-moving tributary streams. Certain limited tracts in the lowest portion of the bottom lands are subject to periodic flooding, which characterizes the typical position of the black soil throughout the Blue Nile Basin.

The reddish lateritic soils are characteristically friable, permeable clays which, because of their excellent structure, behave more like loam and clay loam than like clay. Analysis of typical profiles show them to have a moderate acid reaction, to contain no significant amounts of soluble salts, to have a moderate content of organic matter in the plow zone, and a high percentage of clay of low plasticity.

This latter characteristic is typical of latosolic soils in which the clay fraction is dominantly kaolinitic. Field examination shows physical properties which allow easy tillage, good permeability, and good water-holding capacity. They are well suited to development under irrigation. Fertility analysis shows them to be low in available phosphorus, and low in calcium.

Dark clays (grumusols) are typical of a minor portion of the project lands. They are dark gray to nearly black, highly plastic clays with very low permeability. The surface soil is often granular with prismatic or subangular blocky structured subsoils. When dry, these clays exhibit wide, deep cracks, a feature which is characteristic of soils with the clay fraction, dominantly montmorillonitic. Laboratory analysis shows them to be mildly acid, free from significant amounts of soluble salts, high in clay percentage, to have moderate organic matter in the plow zone, low to medium in phosphorus, medium to high in potassium, and medium in calcium. They have limited crop adaptability and are best utilized for pasture production in this area where there is likely more land with better soil than can be served with any foreseeable water supply.

Topography

The topographic characteristics of the Azena River Valley are good, being typified by fairly large areas gently sloping in the same plane, interspersed with isolated islands of volcanic plug remnants and basaltic ridges. These areas are traversed by winding, tree-lined tributary streams. On the upper reaches, the streams are only slightly entrenched (1 to 2 meters), but as they join and become two major drainageways they are 10 to 12 meters below the level of the valley floor, leaving the valley in one stream about 16 meters deep. The Fettam River Valley is similar topographically to the Azena in the upper reaches, except with a somewhat lower gradient; consequently ponds and small lakes are formed during the rainy season. Downstream the valley becomes narrower at a higher elevation, but the slopes adjacent to the uplands are less abrupt.

The upland areas separating these stream valleys are smoothly undulating to rolling in relief but have many large areas with gentle, smooth slopes, ideal for irrigation agriculture. These are associated with somewhat steeper slopes into the tributary drainageways. An occasional isolated butte rises above the plain. At rather widely spaced intervals, areas of nearly flat, tall grass savannah occur along the stream bottoms. These areas, subject to intermittent flooding, are where the black plastic clays are found.

Drainage

The drainage characteristics vary from good to poor. The surface drainage, with minor exceptions, is good because of the well-defined, dendritic drainage pattern established by the erosive effect of the annual torrential rains. The exceptions are in areas of minor extent along the slower moving streams where gradients are low and seasonal flooding occurs. These areas are further influenced by the invariable presence of black, highly plastic clays which, because of their nearly impermeable nature, give rise to internal drainage restrictions that may be considered noncorrectable. The major portion of the area is typified by lateritic soils which are permeable and occur on well-defined, gentle slopes. Therefore, no drainage problems of significant magnitude are likely to occur.

Land Classification

Description of Classes

Class 1--Arable. Lands in this class occupy large areas, sloping in the same plane. They are smooth, with deep, permeable lateritic soils of good permeability and water-holding capacity. The soils are mildly acid, a condition correctable at low cost. No significant drainage problems are expected to develop. These lands will produce sustained, high yields of all climatically adapted crops at a minimum cost in land preparation. The area of this class of land totals 44, 666 hectares.

Class 2--Arable. These lands were so classed primarily because of minor topographic deficiencies. Slopes may range from 3 to 7 percent in general gradient, or land areas may be undulating, which creates various rather small tracts sloping in different directions within an otherwise large area. This causes difficulties in water distribution and tillage because of short runs. From a soil and drainage viewpoint, these lands are equal to the Class 1 lands. On certain of these lands, light grading may be required in land preparation. The erosion hazard is greater than that of the higher class land. Class 2 arable comprises 49, 830 hectares.

Class 3. These lands were so classed because of greater deficiencies than those of Class 2. They include the black plastic clay soils with limited usefulness, as they should be utilized for pasture only on this project. Class 3 may include lands with good deep latosols but have slopes ranging from 8 to 12 percent in gradient or may include gently rolling lands where irrigation application and tillage problems would be greater than those of Class 2. Lands with stony soils, where a clearing problem exists or where tillage would be inhibited by the stones, were placed in this class. They total 18, 113 hectares.

Class 6--Nonarable. These lands are the rough, steep slopes, with isolated stony volcanic plugs, stream bottoms and swamps, and in some cases small, isolated areas of arable land within large areas of scabland. The location of the arable lands and a description of typical soil profiles may be found on Figures IV-42, IV-43, and IV-44.

Conclusions

1. The climate in this area will limit the crops to those usually produced on the plateau areas.

2. The soils are generally excellent for irrigation agriculture, but some areas of irregular topography will require judicious handling to avoid erosion.

3. Access to a good market road will not be a significant problem.

4. The area is settled by Ago people, considered to be good farmers and herdsmen. Many of them have had irrigation experience.

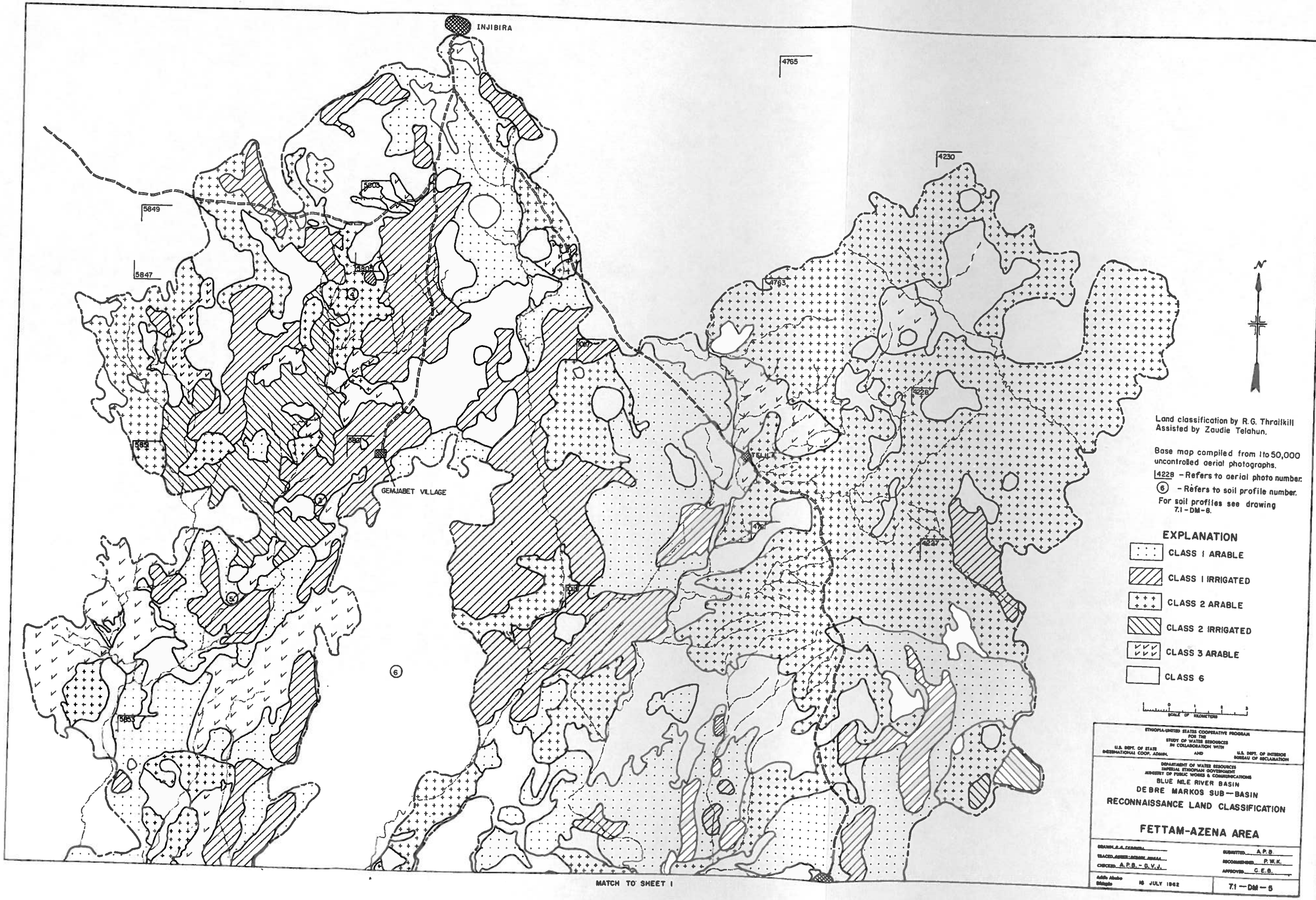


Figure IV-43 - Reconnaissance Land Classification and Soil Profiles, Azena-Fettam Area (Sheet 2 of 2)

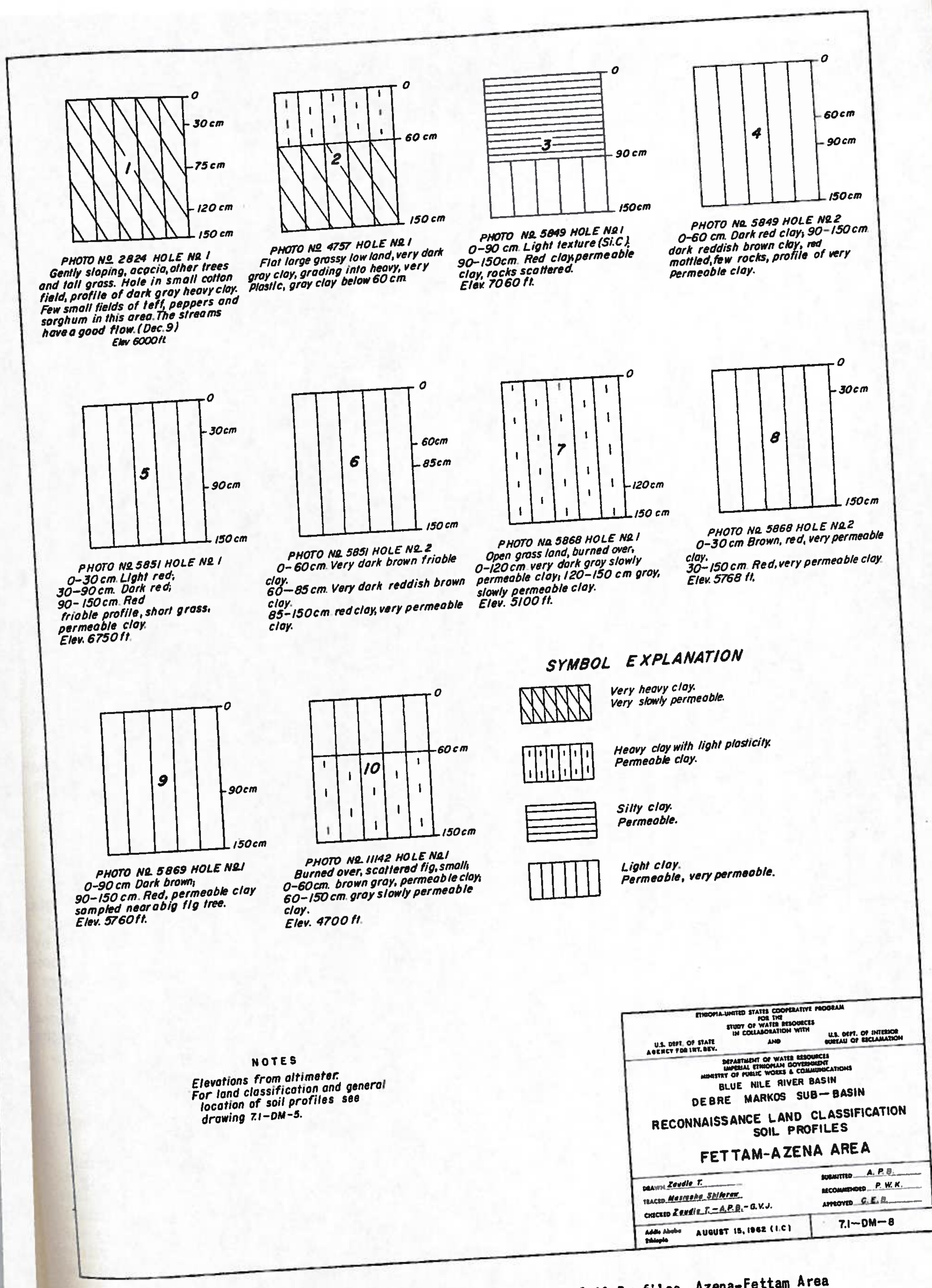


Figure IV-44 - Reconnaissance Land Classification and Soil Profiles, Azena-Fettam Area

Recommendations

1. No further studies on project irrigation is needed unless an adequate storage site can be found.

2. About 5,500 hectares may be irrigated with direct diversion.

WAMA RIVER AREA

General Description

The area investigated includes approximately 60,000 hectares, of which about 43,130 are arable. None of these lands are considered irrigable.

The area lies in the southeastern part of Wellegga Province, approximately 40 kilometers southeast of Lekkemt, the capital of the province. It is bounded on the north by the Addis Ababa-Lekkemt highway and extends southward along both sides of the Wama River to the junction of that stream with the Diddessa River. The area averages about 15 kilometers wide and 40 kilometers long.

Transportation

The main highway from Addis Ababa crosses the upper portion of the area. Construction of an access road into the area would be relatively simple, although several stream crossings would be required.

Geology and Physiography

This broad valley has been eroded through the plateau volcanics and rests on remnants of Triassic? sandstone and volcanic materials. It is an upland valley with soils formed from outwash materials and primarily from volcanics. The bottom land is surrounded by latosolic soils on the undulating to rolling higher lying hills which generally form the foothills of a large mountain to the north separating this area from the Angar River drainage basin. The Wama Valley is dissected by many tributary streams, not deeply entrenched but with sufficient channel capacity to provide outlets for foreseeable runoff accumulations. The Wama enters a rather narrow section in the central portion of the land area where the hills encroach on the bottom land from both sides.

Climate

The temperatures average about 20° C and the precipitation averages about 100 cm. annually. The climate in general is well suited for a wide variety of crops, including some of the semitropical and tropical types.

Present and Potential Land Use

At present the valley floor is uninhabited. This may be due to the presence of malaria or a combination of malaria and other diseases. In this area the grumusol soils are not used to produce crops under dry-farmed conditions, but are used for wild pasture. The adjacent hills are well populated and dry farming is practiced in this part of the area. A few small tracts of land along the tributary bottoms are irrigated by direct diversion. This is done on the higher, narrow portions of the stream where the lateritic soils occupy the stream flood plain. Crops raised on the dry-farm hilly areas are teff, sorghum, noog, millet, papaya, bananas, mangoes, barley, and wheat. Cattle, sheep, mules, burros, and horses are grazed on the uncultivated portion of the hills and on the bottom lands to a minor degree. All of the crops mentioned, except barley and wheat, can be produced under irrigation in the project area on the red soils, and perhaps some of them on the dark gray clays.

Project Lands

Soils

The bottom lands, identified on Figure IV-45 by a Class 3 designation, are composed of dark gray clays (grumusols). These are montmorillonitic plastic clays which exhibit wide cracks when dry. They are mildly acid in reaction, are very slowly permeable, and have good water-holding capacities. The usefulness of these soils under irrigation is proven, but their nature suggests that without very careful management they will go out of production.

The somewhat elevated areas adjacent to the bottom lands are typified by reddish latosols. These soils, although clay in texture, are permeable and friable, have moderate-to-good water-holding capacity, contain only traces of soluble salts, are moderately acid and react more like loams and clay loams rather than like clays. These are the best types of soil in the Blue Nile Basin, and are utilized under dry-farmed conditions to support the population by the production of a wide variety of crops. They have proven their usefulness for irrigation on small tracts in the vicinity.

Fertility analysis suggests these soils to be low in available phosphorus and calcium.

Topography

The bottom lands are characterized by large areas of low gradient (1/2 to 2 percent slope), nearly ideal for irrigation development. The surface relief on limited areas may require some smoothing because of the micro relief. This is true on the areas where gradients are very low. The elevated, undulating to rolling, adjacent red soil areas are identified on Figure IV-45 as Class 2 lands. While the gradients on these lands are not ideal, with the slopes ranging up to 7 percent, they could be successfully irrigated if properly managed. Some care would be required to keep erosion at a minimum.

Drainage

The external drainage characteristics are generally good, with natural drainageways in a dendritic pattern throughout the area. On the largest tracts some artificial channels will be required to carry excess waste water and precipitation runoff into the natural drains. This is true of the bottom lands where low gradients prevail. The internal drainage characteristics of the bottom lands is extremely poor, owing to the very low permeability of the soils in this area. If irrigation is to be successful on these soils, water applications should be carefully controlled.

The adjacent hilly lands have good internal and external drainage characteristics. Drainage problems are not expected to develop in these lands.

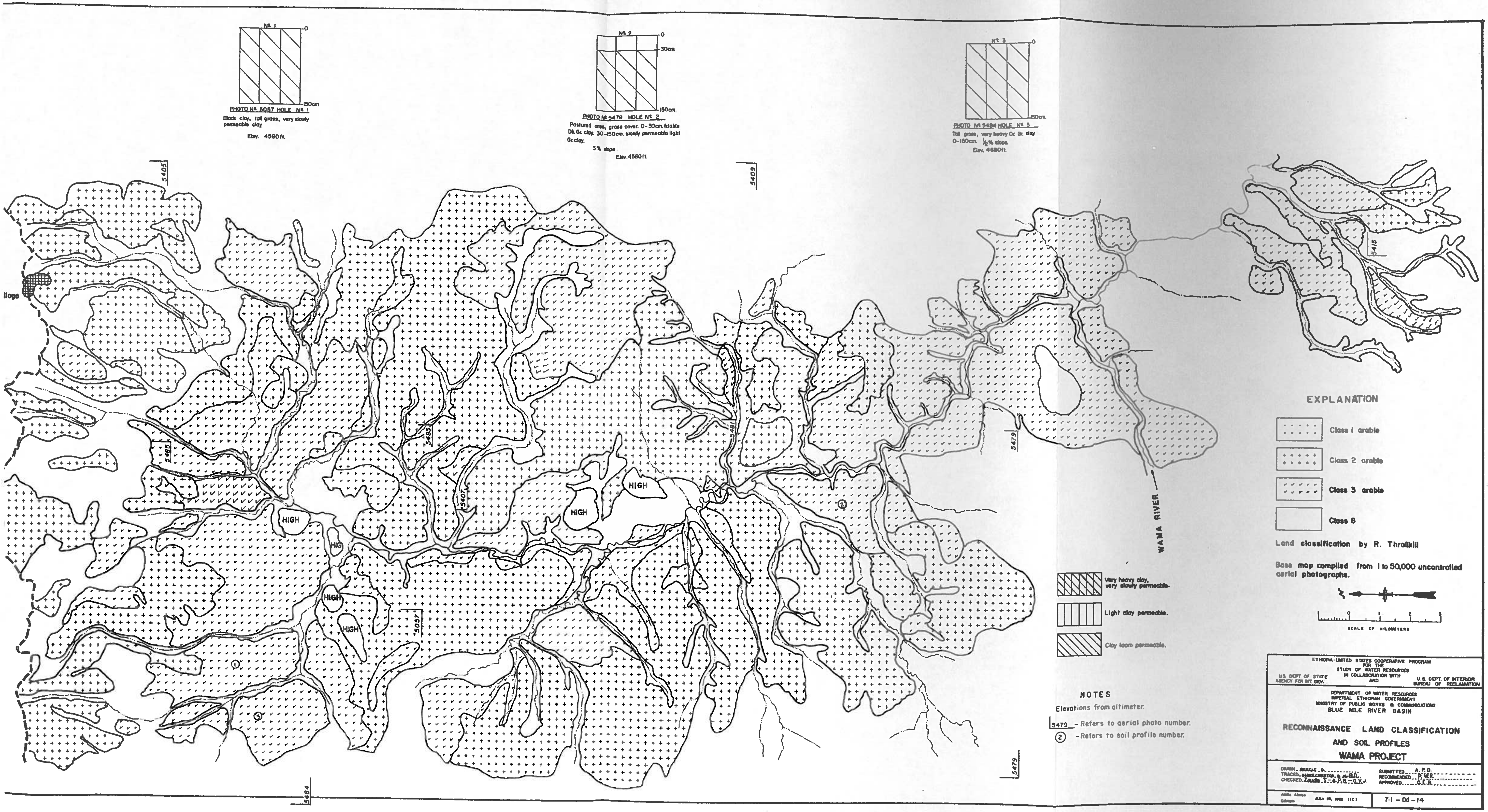


Figure IV-45 - Reconnaissance Land Classification and Soil Profiles, Wama River Area

Land Classification

The subreconnaissance land classification was accomplished by helicopter after an attempt to reach the area by motor vehicle failed.

Description of Land Classes

Class 1--Arable. No Class 1 land was mapped on this area. It is possible that a detailed land classification survey would reveal some small tracts of Class 1 land within the Class 2 as mapped.

Class 2--Arable. The land placed in this class was largely 2t, so classified because of topographic deficiencies. The soils are generally deep and permeable latosols. These lands will present some minor difficulties in preparation for irrigation and will be somewhat more difficult to irrigate than would Class 1, owing to steeper slopes and smaller tracts of land. These problems are not severe enough to be critical. Class 2, arable, will produce sustained yields of all climatically adapted crops. There are 23,665 hectares of this class in the area investigated.

Class 3--Arable. Lands placed in this class occupy bottom positions for the most part, and were so classed because of the heavy plastic clay soils of low permeability which uniformly occupy these positions. Some of the rougher slopes on the hilly areas were also placed in Class 3 because of a higher cost of land preparation and more expense needed to irrigate than those of Class 2. Class 3 lands occupy 19,465 hectares. See Figure IV-45.

Conclusions

1. The climate of this area is ideal for a wide range of irrigated crops.

2. The bottom land soils exhibit characteristics which indicate they are less suited to irrigation than the upland soils.

3. The red soils on the hill lands are excellent for irrigation development and will produce well.

4. No further studies are warranted, because of a lack of suitable storage in relation to the arable lands.

CHEYE VALLEY AREA

General Description

The Cheye Project lands are adjacent to the Cheye River at the bottom of a precipitous canyon, 85 kilometers northeast of Debre Markos in Gojjam Province. The Cheye River, tributary to the Blue Nile, lies approximately 1,000 meters below the level of the Debre Markos plateau. The land area examined is rather small, comprising only 4,000 hectares, of which 1,400 hectares are considered arable. Irrigability studies show that none of these lands are irrigable.

Transportation

An old caravan trail from Dejen, on the all-weather highway, extends into the plateau area overlooking the Cheye Valley. A portion of this trail has been used by transport trucks as far as Debre Werk, a village about 20 kilometers to the southwest of the Cheye Valley. It is a poor trail, passable with difficulty only during the dry season. The valley proper is accessible only by foot traffic at present, and construction of a road from the plateau into the Cheye Valley would be very difficult and expensive.

Geology and Physiography

The Cheye Valley was modified by a lava flow of younger volcanics. The soils were formed upon this lava flow from the decomposition of the volcanic material, more or less influenced by colluvium and slope wash from the canyon walls.

The Cheye River Valley, through a short stretch, is wider than most of the other valleys. This has resulted in a small area of agricultural land formed on the lava flow. The bulk of this land lies on the south of the Cheye River channel, which, through most of the year, carries a rather small stream in a large channel, adequate to contain the rainy season flood flows. The Cheye River is a wide, rather shallow waterway which does not exceed 2 meters in depth.

Climate

The elevation of the valley is such as to have a semitropical climate. Rainfall probably approximates that of the adjacent plateau, which is about 125 cm. per year. Most of this falls between June and October.

Present and Potential Land Use

The valley is presently under rather intensive dry-land cultivation. Cereal crops such as teff, barley, sorghum, and corn are being produced. Some irrigation is practiced by direct diversion, but without storage it is limited to a very small area during the dry season. There are no people living in the valley because of malaria. The people who farm the valley live on the plateau, descending into the valley each morning and returning to their homes some 300 meters higher at evening.

The climate is adapted to the production of most semitropical crops, with the exception of fruits requiring a better-drained soil condition.

Project Lands

Soils

The soils in the valley are entirely black grumusols, consisting of heavy, plastic, cracking clays with an occasional small stone occurring in the profile. The grumusols are typical of those found throughout the Blue Nile Basin and are described in many of the other project descriptions.

Topography and Drainage

General gradient ranges from 2 to 6 percent, providing good surface runoff characteristics. Surface relief is smooth, caused by many years of cultivation. Internal drainage characteristics are very poor in these extremely plastic clays, but, because of slope, it is doubtful if an excess quantity of water ever enters these soils.

Land Development

There are no problems in clearing and land development for irrigation would be easy because the entire area has been under cultivation for many years.

Land Classification

Access to the valley for land classification purposes was by helicopter as no roads enter the canyon.

Description of Classes

Class 3--Arable. The entire cultivated portion of the valley was placed in this class because of the uniform dark plastic clays throughout the valley. Because of the slopes, a topographic factor was used; therefore, the area was mapped 3st, which totals 3,400 hectares. Figure IV-46 shows the location of the arable lands.

Conclusions

Because of the inaccessibility of this valley, coupled with the malaria problem, and in view of the small area of land, it would appear that construction of project works would not be justified.

Recommendations

No project construction program should be further considered, owing to the high cost which would be associated with construction and the low quality of the soil.

UPPER MUGER RIVER AREA

General Description

This area lies in Shewa Province in the southeastern part of the Blue Nile Basin. It is situated in an intermountain basin on the upper tributaries of the Muger River which drain the northern slopes of the Entotto Hills. The central portion of the area is only 20 kilometers north of Addis Ababa (see Plate I).

The area which was investigated contains about 25,000 hectares, of which 8,740 hectares are considered arable. The area is bounded on the east by a range of high hills and on the west by rolling and hilly terrain. On the north it is bounded by rolling eroded breaks leading to the precipitous canyon escarpments over which the Muger River plunges toward its junction with the Blue Nile River. This area does not have any irrigable lands because of an insufficient readily available water supply.

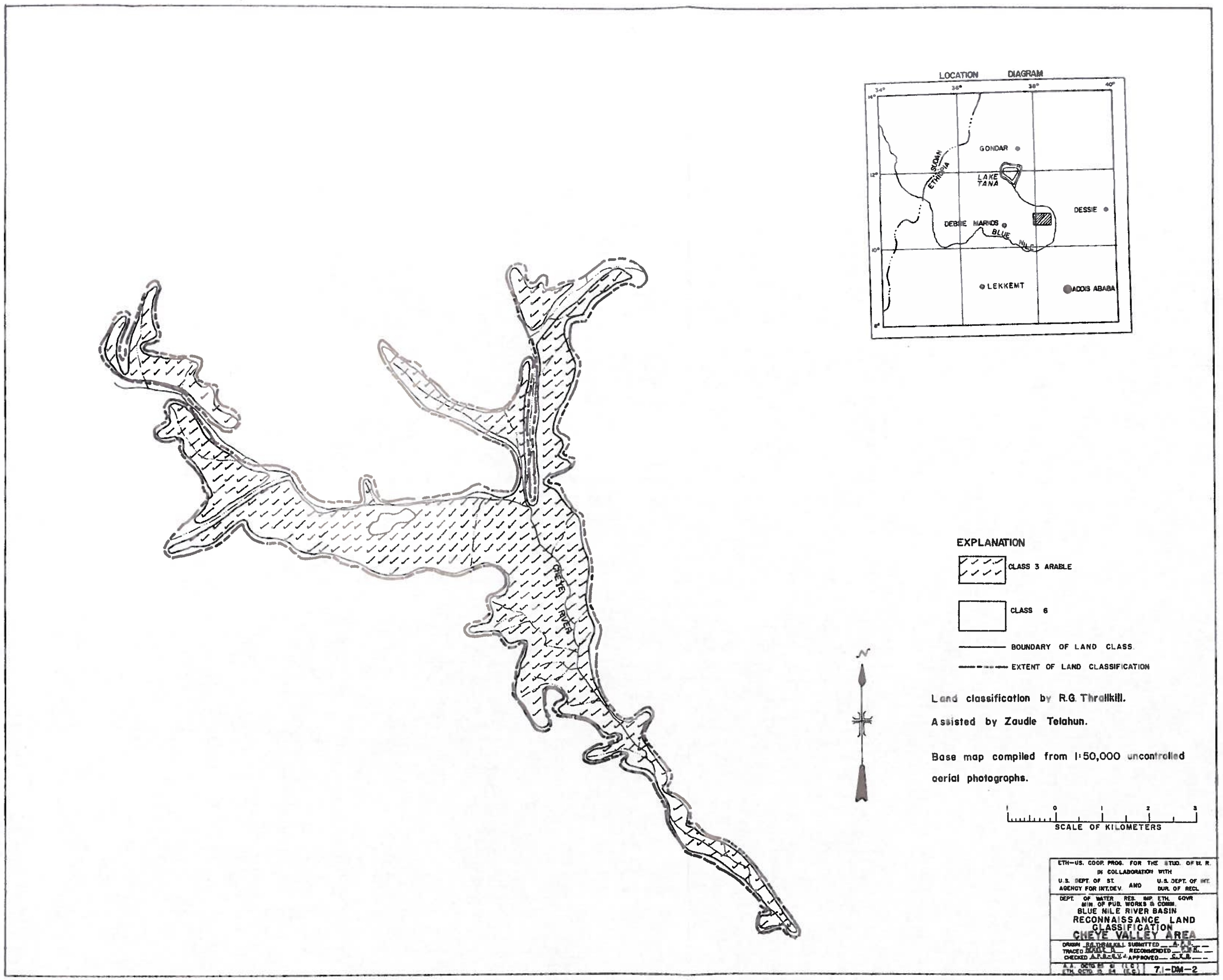


Figure IV-46 - Reconnaissance Land Classification, Cheye Valley Area

Transportation

The all-weather highway from Addis Ababa to Debre Markos, Bahir Dar, Gondar, and Asmara passes through the valley along its eastern side. This provides easy access to the Addis Ababa market. Daily buses and freight trucks serve the area. On market days, produce-laden donkeys plod between the valley and Addis Ababa.

Geology and Physiography

The Upper Muger area is situated in the plateau and highlands physiographic area. It is typical of a large part of the Blue Nile River Basin. It is characterized by extrusive volcanics, largely basalt and trachyte, with lesser amounts of tuff and cinders. It is from these materials that most of the soils were formed.

The area includes nearly flat to very gently sloping bottom lands adjacent to the Muger River and its major tributaries, smooth, gently sloping uplands; rolling and hilly lands; isolated erosional hills; and hilly to mountainous terrain.

The area is dissected by numerous drainageways. Elevations range from 2430 to 2740 meters above sea level.

Climate

The climatic data from the Addis Ababa station (37-year period) is typical of the Upper Muger River area. It indicates an average annual rainfall of 125 cm. The greater portion of this falls in July and August, during the season of the big rains. Hail frequently occurs during this period. Smaller amounts of precipitation fall during the season of the little rains in March and April.

Temperature data show an average annual maximum of 24° to 26° C, with an average annual minimum of 8° to 10° C. The coldest temperatures occur during the nights of December and January when lows of minus 4° C may damage agricultural crops.

The average relative humidity varies between 80 and 90 percent during the rainy season and 35 to 45 percent during the dry season. This may fall to 5 to 10 percent during November and December. The average number of clear days during the year is from 90 to 100. Moderate easterly winds usually are prevalent during the dry season.

Present and Potential Land Use

Native grasses are prevalent in the extensive pasture and hay lands of the Upper Muger River area. Hilly, rocky lands support a sparse cover of scrub and deciduous trees. Small groves of eucalyptus are found on some of the farm lands, with extensive eucalyptus plantations on the Entotto Hills. These trees are used for building materials and fuel.

The dominant type of agriculture combines the cultivation of dry land crops with the pasturing of livestock and commercial hay production. The principal cultivated crops raised are barley, wheat, noog, and horsebeans. Extensive areas of native grass support large herds of zebu-type cattle, sheep, goats, and donkeys and provide the native hay, marketed in Addis Ababa. Most families raise chickens, many of which are taken to market along with eggs.

Irrigation would permit an appreciable expansion of crop types which are climatically suited to the area.

Figure IV-47 - Intensive cultivation on the plateau overlooking the Muger canyon.

Project Lands

Soils

Two major soil groups are found in the Upper Muger River area, upland soils developed in place from underlying basaltic lava, trachyte, or tuff, and soils of the lowlands derived principally from alluvium washed from higher areas.

Lowland soils, which are the dominant group in the area classified, occupy the nearly flat to gently sloping grasslands that are seasonally wet. A typical profile includes the following horizons:

0-15 cm.	mixed dark brown to reddish brown, subangular blocky clay with many grass roots
14-75 cm.	gray, very plastic massive clay
75-120 cm.	grayish brown, mottled prismatic clay
120-150 cm.	dark brown mottled clay

Variations in this type include the depth to the gray, plastic clay, and the presence of a few concretions of calcium carbonate in this horizon. Analyses of these soils indicate that they are moderately to strongly acid, have only traces of soluble salts, are noncalcareous and have a relatively high organic matter content in the surface soils. Fertility analyses suggest that they have moderate contents of available phosphorus and potassium, and moderate to high total nitrogen in the surface soil. These soils are very slowly permeable to water. They are best suited to pasture and hay production rather than to cultivated crops.

The upland soils are of two kinds, the more prevalent reddish brown clays and the dark grayish brown clays. The former soil is found on the well-drained uplands, and is characterized by reddish brown, granular clay loam, or friable clay surface soils underlain by reddish brown or dark red friable subangular blocky clay of low plasticity. Soft, dark iron concretions are usually found in the subsoil. Typical analyses indicate that these soils are moderately to strongly acid, have only traces of soluble salts, are noncalcareous, have moderate contents of organic matter in the surface soils, and have a relatively high clay content of low plasticity. The clay fraction (less than 2 microns) is dominantly kaolinitic which accounts for its good permeability and friability. Fertility analyses suggest that these soils have moderate contents of total nitrogen, low to medium available phosphorus, and low available potassium. They have good permeability rates and good water-holding capacities. They are well suited to irrigated agriculture. Some of these soils are shallow and some are stony with limited utility for irrigation.

Dark grayish brown upland soils are confined to gentle or moderately steep slopes in the eastern part of the area studied. They consist of dark grayish brown clay loam or light clay surface soils, underlain by grayish brown, mottled clay below 75 cm. No analyses are available for these soils. They appear to be moderately well suited for irrigation.

Topography

The upland areas occur in fairly large tracts, sloping in the same plane. Their general gradients vary from gentle to moderate slopes.

The lowland areas vary from nearly flat to very gently sloping. Surface relief is generally smooth but some areas are somewhat dissected by drainage channels. Very little grading will be required, but on the moderate slopes contour ditches will be necessary in some instances. The lowlands should not be considered for irrigation because of low gradients, low position, and impermeable clay soils which cause most of them to be seasonally inundated when the big rains occur. Their present use as pasture and wild grass hay land under dry-farm conditions is the best use for them although the grass varieties could be improved and would result in a higher yield of more nutritious forage.

Erosion is a hazard on the upland red soils, especially when they are found on slopes in excess of 3 percent.

Land Development

The only problems in regard to land clearing are some limited areas where surface stones and stones within the soil profile occur. As this is the only important deficiency in these areas, hand labor in clearing the stones will result in an increase in land quality. A per hectare cost may be determined during the detailed land classification studies required prior to project development.

Since most of the arable land has been under cultivation for many years, surface irregularities have been corrected for the most part, so land leveling will not be a major cost. In some instances, where slopes are moderately steep, contour ditches will be required, probably resulting in more linear meters of ditch per hectare than will be needed on more gentle slopes. Again the cost will be determined by the detailed land classification study recommended.

Drainage

On the permeable upland lands having well-defined slopes, no abnormal drainage problems are expected to develop. This is owing to the well-defined drainage channels which resulted from the erosional effects of high runoff during the big rains. The bottom land areas have such low gradients and soils with such low permeabilities that large shallow lakes occurring during the rainy season remain for several weeks each year. Pasture is the best use for these lands under conditions of natural moisture. The flooding condition might be relieved by deepening the main channels and providing collector drains, but as these very plastic clay soils are not recommended for irrigation, the cost of constructing drains is not likely justified by any important foreseeable increase in crop returns.

Detailed quality-of-water analyses should be made on the proposed irrigation water supply as an adjunct to the detailed land classification studies.

Land Classification

An earlier section of this report discusses land classification as it applies to the entire Blue Nile Basin. Topics pertinent to this area are discussed here. The land classes mapped in this rough reconnaissance survey were Class 1 arable, Class 2 arable, Class 6 pasture land, and Class 6 nonarable.

Class 1--Arable. Lands placed in this class total only 250 hectares. It is typified by fairly large areas sloping gently in the same plane. It has deep, permeable red lateritic soils, free from harmful quantities of soluble salts, and no important deficiencies except for probable low levels in some of the plant nutrients.

Class 2--Arable. These lands have good deep permeable soils, some of which may have surface stones or occasional stoniness within the soil profile but not in sufficient quantities to require large outlays of money to correct this deficiency. The principal reason for placing land in this class was because of slope factors rendering the land somewhat more expensive to irrigate than the Class 1 land. While these lands will produce high yields of all climatically suited crops, they will require careful management practices in water distribution to avoid erosion and still provide adequate distribution of water. These lands total 8,490 hectares.

Class 6--Pasture. These lands include all of the low-lying bottom lands having heavy plastic clay soils and subsoils of very low permeability. The reason for including these lands was because of their value for pasture and hay production. They are not recommended for irrigation except for the use of waste water from the higher lying better land, but they contribute measurably to the economy of the area in the production of livestock and also provide a cash crop. The area was not determined but it is appreciably larger than the arable lands.

Class 6--Nonarable. Land placed in this class includes the rock outcrops, rolling and rough hills and canyons, and the stream sides and bottoms. It is considered permanently nonarable.

No irrigable lands are present in this unit.

Conclusions

1. The arable area is a series of widely scattered land tracts that would be hard to develop.

2. The arable lands have an erosion hazard and because of their sloping characteristics would require care in the application of irrigation water.

Recommendations

No further studies are recommended for irrigation development.

LEKKEMT AREA

General Description

Subsequent to the land classification study completed in February 1961, it was determined that these lands cannot be economically served. Therefore, there are no irrigable lands in this unit.

The Lekkemt Project area lies at 9°2' north latitude and 36°15' east longitude, and about 30 kilometers in a straight line to the westward from Lekkemt, capital of Wellegga Province. It occupies the upland and east portion of a valley along the Diddessa River. The area investigated extends eastward for about 17 kilometers from the old Italian bridge where the Lekkemt-Gimbi road crosses the river.

The area is about 30 kilometers long, lying in a northwest-southeast direction, and contains about 23,500 hectares, of which about 18,500 hectares are considered arable.

Transportation

A rough road extends westward from Lekkemt, traverses the project area, and continues to Gimbi, Nejo, Mendi, and Asosa. It is traveled regularly by freight trucks, but it is very difficult for light vehicles. Location surveys in progress during 1961 would indicate that an all-weather road is contemplated. If so, this area would have adequate access to markets.

Geology and Physiography

The area lies on an upland terrace underlain by a relatively thin flow of volcanic materials which, in turn, is underlain by metamorphic materials. The soils are residual from the volcanic understrata. The area is transected by many entrenched streams originating, for the most part, along the Lekkemt plateau escarpment to the east. The entrenchment of these streams varies from about 2 meters to about 10 meters. The area is bounded on the east and south by foothills of the escarpment, on the west by the Diddessa River, and on the north by an arbitrary line based upon elevation and potential water supply. The area ranges in elevation from 1000 to 1200 meters above sea level.

Present and Potential Land Use

Generally the area is a combination of open grass savannah and open forest with low trees of acacia, fig, and associated species. A scattering of cultivated subsistence plots is present, especially near the road, and one plantation lies astride the road.

The two villages are situated on the road about 5 kilometers apart. These people farm small plots and raise cotton, corn, tobacco, sorghum, peppers, and noog. A few goats are raised in the area, but no cattle, owing to a bovine disease called "yendi."

A dense riverine forest grows along the Diddessa River. The climate is ideal for a wide variety of crops, in addition to those mentioned above--sisal and other fibers, castor beans, papaya, mango, sweet potatoes, ground nuts, flax, melons, and many others adapted to a subtropical climate.

Livestock could be successfully raised if the cattle disease is eliminated. Nearly every family has a few chickens, producing eggs for home consumption.

Project Lands

Soils

The dominant soil is a typical reddish lateritic clay. It is characterized by reddish brown, friable, permeable clays which, because of their clay mineralogy, behave more like loam and clay-loam than like clay. Analyses of typical profiles show them to be moderately acid in reaction, to contain no significant amounts of soluble salts, to have moderate content of organic matter in the plow zone, and to have a high percentage of clay of low plasticity. The latter characteristic is typical of the latosolic soils in which the clay fraction is dominantly kaolinitic. They are easily tilled, are permeable, and have good water-holding capacity. They are well suited to development under irrigation.

A very small percentage of the project area has typically dark gray clays (grumusols). These are confined to the narrow bottoms in the drainageways. They are characterized by very plastic, slowly permeable clays which exhibit deep, wide cracks when dry. The surface soils are generally granular, with subangular blocky or prismatic structured subsoils. Laboratory analysis indicates that these soils have high clay contents, have mildly acid to neutral reaction, are very low in soluble salt content, and have very low permeabilities. They are limited in crop adaptability, and would probably be best utilized for the production of pasture on this project. Table IV-30 shows typical laboratory data for a latosol and grumusol soil.

Topography

This area is typified by a series of broad-topped ridges, irregular in shape because of the dissecting influence of the many natural drains. The gradient on these ridge tops is generally from 1/2 to 2 percent, but in some areas exceeds 6 percent. The side slopes

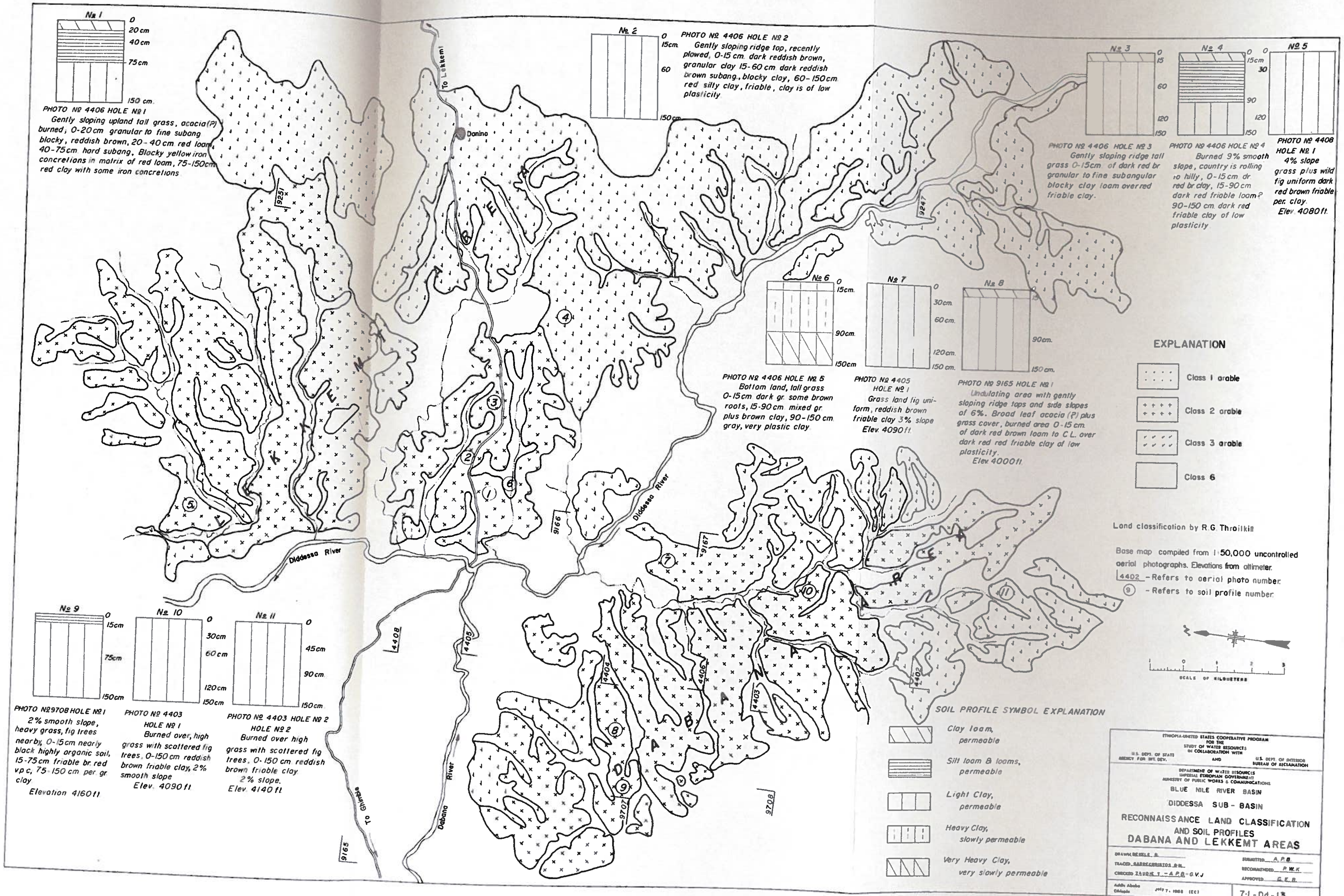


Figure IV-48 - Reconnaissance Land Classification and Soil Profiles, Dabana and Lekkemt Areas

TABLE IV-30 - SOIL LABORATORY DATA--LEKKEMT RIVER PROJECT

Photo no.	Boring no.	Depth (cm.)	Color dry	Percent salt	pH	M.A. results				Percent OM	Available nutrients		
						Percent sand	Percent silt	Percent clay	Texture		P	K	Ca
4406	2	0-15	10 YR 3/4 Dusky red	0	5.5	34	6	60	Clay	4.7	L	H	L
		15-60	10 YR 3/4 Dusky red	0	5.4	35.5	8	56.5	Clay	4.2	L-M	H	L
		60-105	2.5 YR 3/6 Dusky red	0	6.2	34	10	56	Clay	2.3	L	H	L
		105-150	2.5 YR 3/6 Dusky red	0	6.9	40	8	52	Clay	1.8	VL	L	H
4406	5	0-15	5 YR 4/1 Dk gr	0	4.9	44	8	48	Clay	5.2	L	H	MH
		15-60	5 YR 5/1 Gr	0	4.7	26	10	64	Clay	3.3	VL	M	H
		60-90	5 YR 5/1 Gr	0	5.0	38.5	13	48.5	Clay	2.2	LM	H	H
		90-150	7.5 YR 5/0 Gr	0	5.1	20	8	72	Heavy clay	1.15	VL	H	H

into the stream bottoms exceed 6 percent in places. The ridge tops rise from 2 to 10 meters higher than the stream bottoms. The general relief tends to be undulating to gently rolling, with no sharp-cut banks along the streams. No serious problems in development are anticipated. This area would have a fairly high erosion potential if irrigated, so care in water application would be a factor to be considered.

Land Development

A considerable portion of the area is tall grass savannah with a sparse growth of low fig- and acacia-type trees. No clearing problems of significance would occur if the land were to be irrigated. The construction of main canals and lateral ditches would be somewhat expensive because of the nature of the topography. There is no area where stoniness is serious.

Drainage

The natural dendritic drainage network existing in the area would provide adequate runoff channels for irrigation wastes and natural precipitation. The permeable nature of the lateritic soil is such that no significant drainage problems would likely develop if the lands were irrigated.

Most of the larger drainageways contain perennial water, indicating occurrence of springs near the headwaters in the rough foothills of the plateau escarpment, but no local springs were in evidence.

Land Classification

The land classification work in this area was done by a combination of surface travel, where possible, and by helicopter where surface travel was restricted by impassable drainageways. Borings were made at locations considered representative, and samples taken for laboratory analysis. See Figure IV-48 for location of the arable lands and soil profile descriptions.

Description of Classes

Class 1--Arable. No land was placed in this class during the survey, but a detailed land classification would likely delineate some very limited areas of Class 1 land.

Class 2--Arable. Land placed in this class approximates 30 percent of the total arable land. The soils in Class 2 are generally deep red latosols but the topography is somewhat less than ideal because general gradients vary from 2 to 6 percent, which renders the land somewhat more costly to develop and to irrigate than Class 1 land. Because of the excellent soil, sustained good yields of all climatically adapted crops are possible with good farm management. Lands in this class total 7,025 hectares of arable land.

Class 3--Arable. Lands placed in this class have steeper slopes (7 to 10 percent) than those of Class 2 and will, therefore, be more costly to prepare for irrigation and to irrigate. The erosion hazard is greater, requiring carefully controlled application of water. The soils are deep red latosols and the drainage characteristics are good. Lands in this class total 11,510 hectares.

Class 6--Nonarable.. Lands in this class are the very steep hillsides, the drain bottoms, rock outcrops, and rugged, hilly land not considered suitable for irrigation development.

Conclusions

1. The climate in this area, influenced by elevation, is ideal for a wide variety of crops adapted to tropical conditions.

2. The soils are generally excellent for irrigation agriculture.

3. No further land classification is needed unless a suitable water supply can be secured for these lands. In that instance, detailed land classification should be made.