IA002140

LAND AND WATER RESOURCES OF THE BLUE NILE BASIN

ETHIOPIA

United States
Department of the Interior

Bureau of Reclamation

NAIAO # 9152

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WASHINGTON, D.C. 20240

IN REPLY
REFER TO:

AUG 7 - 1964

Mr. Edmond C. Hutchinson
Assistant Administrator
Bureau for Africa
Agency for International Development
Department of State
Washington, D. C. 20523

Dear Mr. Hutchinson:

In accordance with the provisions of the special service agreement between the International Cooperation Administration, predecessor agency of USAID, and the Bureau of Reclamation, U. S. Department of the Interior, dated August 9, 1957, providing for technical assistance in Natural Resources in connection with the Cooperative Program between the United States and the Imperial Ethiopian Government, we are transmitting the reconnaissance report relating to the development of the land and water resources of the Blue Nile River Basin of Ethiopia.

The major objectives of the project, as set forth in the agreement, were threefold:

(1) To conduct an investigation of the land and water resources of the Blue Nile River Basin;

(2) To assist in the establishment of an appropriate administrative and engineering organization within the Imperial Ethiopian Government that would, in time, be capable of continuing this investigation and, at a later date, undertake similar investigations within other geographic areas of the country; and

(3) To train Ethiopian personnel as appropriate in the administration of this organization, departmental and field, consistent with the availability of engineering-educated Ethiopian personnel for training.

These objectives have been met. The investigation was initiated early in 1958 and the collection of data and field surveys was completed by June 30, 1963, when all Bureau of Reclamation personnel, except two hydrologists who remained to assist Ethiopian Water Resources Department personnel in the operation of the network of hydrologic stations through that session of heavy rains, were returned to the United States where ten were employed in the completion of the studies and preparation of the Blue Nile Report. By June 30, 1964, the report had been drafted and the remaining personnel reassigned to other Bureau of Reclamation projects.

The Ethiopian Water Resources Department was established in 1959 and prior to the departure of the Bureau of Reclamation personnel assumed the full responsibility for the operation of the Department.

The training of Ethiopian personnel continued throughout the field investigation and during the preparation of the report.

The land and water resources of the Blue Nile River Basin are extensive and will contribute much to the economic growth of the nation if the projects are properly planned, constructed, and operated. The report outlines plans for projects that would irrigate 433,754 hectares of land now contributing little to the national economy, and for power projects capable of producing 8,660,000 kilowatts to add to the present limited supply. The projects vary in size and complexity, and many are of such magnitude that their development should be delayed until significant advancement has been made in other areas of the national economy. Projects for initial development should be selected with consideration of the financial and technical capabilities of the Imperial Ethiopian Government, their rate of economic progress in other fields, and the ability of the Empire to absorb and export agricultural products or electric power. Both single and multiple-purpose projects have been identified. The investigation has resulted in the development of an engineering and administrative organization with some experience in planning projects for the development of land and water resources. It has provided the Ethiopian Government with technical data that made possible the expansion of the cement industry and the construction of a small hydroelectric powerplant on the Blue Nile River near Lake Tana. It has provided Ethiopia with an inventory of the land and water resources of a large portion of the nation and provides a general plan of development that will aid Ethiopia in strengthening the economy and improving the living conditions of the Ethiopian people.

Sincerely yours,

Commissioner

If a people has the firm determination to work, it can overcome any and all its difficulties and problems. We have no problem that is unsurmountable. Let us work in unity and diligence. What makes a people great and testifies to its greatness is its aspirations for the well-being of its country and the practical achievement of these same aspirations for its own benefit and for that of future generations.

H.I.M. Haile Selassie I

FOREWORD

This report consists of one principal volume, referred to as the Blue Nile Report, and 6 Appendices: I, Plans and Estimates; II, Geology; III, Hydrology; IV, Land Classification; V, Power; and VI, Agriculture and Economics. The Appendices deal in greater detail with specific subjects in appraising the land and water resources of the Blue Nile River Basin in Ethiopia, discussing the present situation and needs, and outlining very general plans for the development of those resources. The report has been prepared in accordance with the provisions of the Special Service Agreement, dated August 9, 1957, between the International Cooperation Administration, now U.S. Agency for International Development, and the Bureau of Reclamation.

In the investigation, several irrigation and hydroelectric power projects in the basin were studied and their potential evaluated, and from an economic standpoint the benefit-to-cost ratios are impressive. However, in the selection of projects for initial development, it should be understood that other factors must also be considered. The Blue Nile is but one of several major river basins in Ethiopia; and, although no investigation of the resources of these other river basins even approaching the limited reconnaissance of the Blue Nile has been made, there may be projects outside the confines of the Blue Nile Basin, particularly irrigation projects, that should be considered. It is important that the Imperial Ethiopian Government begin the collection of basic data, streamflow records, quality of water, soil samples, climatic data, and other pertinent data to support comparisons between projects when final selections must be made.

Ethiopia is richly endowed with potential projects, which if developed could greatly enhance the national economy and provide an improved standard of living consistent with the objectives of her long-range plan to provide a better life for her people.

The development of projects would increase agricultural productions, establish a basis for industrial expansion, create employment opportunities, aid in the control of floods and sediment, enhance the preservation of fish, wildlife, and points of historic interest, and bring about a transition from the traditional subsistence agricultural practice to a more commercial enterprise. Such a transition would support a higher standard of living, at the same time giving the farmer the opportunity to acquire ownership of his farm and enabling him to operate it in a manner that would increase his contribution to the national economy.

The projects discussed in this report should develop slowly, and initially on a small scale, to provide Ethiopian personnel the opportunity to gain additional experience and technical capacity before embarking upon complex developments. Initial development must serve to provide experience and to broaden the technical capabilities, permitting expansion to new projects as the administrative, managerial, technical, and agricultural skills develop. The projects must be scheduled to fit properly with other sectors of the over-all, long-range development program and must be well balanced and coordinated to achieve the full objectives of the national program. The initial development should occur in an orderly succession of one at a time, in harmony with the local and national needs, and consistent with the ability of the Ethiopian people to adjust to the more modern way of life.

The Blue Nile investigations have been conducted on a limited reconnaissance level. While they are in sufficient detail to permit the preparation of a general plan and a rough comparison of benefits and costs as a guide to feasibility, the report is <u>not</u> intended to serve as the basis for actual construction without further study of specific details. It <u>does</u>, when considered with other factors, including the possibility of feasible projects in <u>other</u> river basins, provide a guide for the selection of projects for early development.

It will be noted that at the present time there are few highways that lead to the interior of the Blue Nile Basin near the locations of proposed projects. The project estimates of costs do not include funds for major access highway construction since it is assumed that this construction is a part of the national highway program. The project plans do include access roads from the project to a point where it is assumed that the national highway system would be constructed to serve the general area. In the discussion of irrigation projects in some of the lower areas, the control of malaria and the tsetse fly is mentioned. It is important, in connection with the construction and operation of projects, that these controls be established. However, costs for the control were not estimated nor were they included in this report, since this, like the national highway program, is a part of another program and beyond the scope of the Bureau of Reclamation investigations.

In selecting projects for initial development there are many factors that the Imperial Ethiopian Government should consider that may influence their decision. They will need to compare the advantages of the various projects, among which will probably be the Finchaa Project in the Blue Nile Basin. This project, a multipurpose hydroelectric power and irrigation unit capable of producing 80,000 kilowatts of power and irrigating 15,000 hectares of virgin land, appears to offer the qualities compatible with initial development needs.

The project is about 175 kilometers northwest of Addis Ababa on the Finchaa River, which would provide an adequate water supply of excellent quality for both hydroelectric power and irrigation at a reasonable cost. The power is particularly attractive, since it appears that this plant or another of similar capacity will be required to meet power demands by the time the project could be constructed. The project works constructed for power would also serve for irrigation.

The additional agricultural production that can be gained from the project is badly needed in the economic structure. However, it appears that irrigation should develop at a slower pace, preferably on a stage development plan. The project can easily be adapted to this purpose. Several hundred hectares could be irrigated by a direct diversion from the stream without storage facilities. Initially, only a small diversion dam and canal would be required and could be constructed at low cost. The initial stage could serve as a farm training and demonstrational area and should be gradually expanded as required in the development program.

The project area is uninhabited at the present time, which would greatly reduce the problems of rights-of-way and subdivision of the land to adequate sized farms without having to move people from the area. The construction would present no unusual or difficult problems, and the area is nearer to the markets of Addis Ababa than many others. These are some of the factors that should be considered in selecting a project for initial development. They indicate the need for the Imperial Ethiopian Government to collect data in other river basins so that an intelligent comparison can be made.

Clyde E. Burdick

Clyde E. Burdick
Project Engineer
Blue Nile River Reconnaissance Project

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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

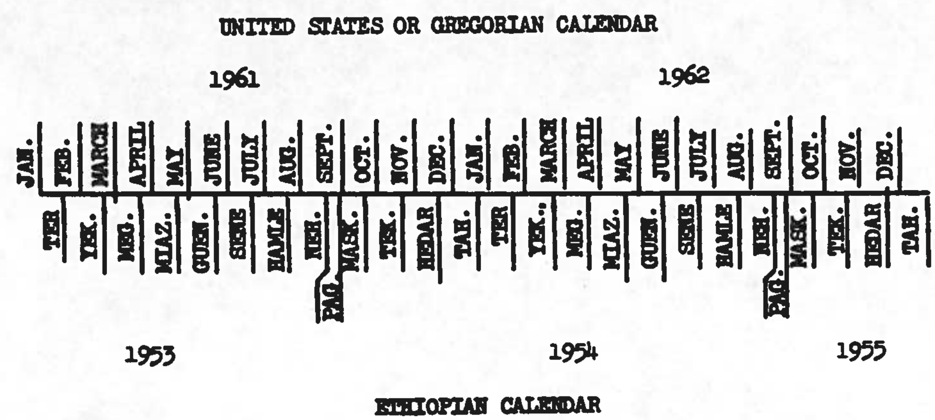
Temperature Conversion:

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



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.

INTRODUCTION

BACKGROUND

Ethiopia was a great power in Biblical times and has preserved its independence to this day. The people are basically Hamitic stock with a large infusion of Semitic by early invasion from the Arabic peninsula. Christianity became the religion of Ethiopia in 330 A.D., which makes Ethiopia one of the oldest Christian countries in the world. Despite her early trade and empire, Ethiopia was isolated from the rest of the world during the Middle Ages and thus developed her own culture somewhat independently. Moslem incursions and internal problems weakened the nation for nearly 1,200 years, but it was consolidated again under Emperors Theodore, John, and Menelik II. The traditional heroism and courage of its people, coupled with its rugged topography, have until recent years isolated Ethiopia to a large extent from foreign influence when modern means of transportation and communication have overcome the natural barriers.

His Imperial Majesty, Haile Selassie I, ascended the throne on November 2, 1930, and is the 255th monarch of the Solomonic dynasty established by King Solomon and the Queen of Sheba. His Imperial Majesty is world renowned for his vision and statesmanship and is personally responsible for the great progress in all fields during his reign.

In 1923, Ethiopia was elected by unanimous vote to membership in the League of Nations. In 1924, a new law was promulgated which provided for freeing slaves and their offspring, and in 1926 Ethiopia signed the League of Nations International Slavery Convention, designed to suppress slavery in all forms. In 1931, Ethiopia's first constitution, providing for a parliament, including a senate and a chamber, was granted by H. I. M. Haile Selassie I.

During the early 1930's, Italy's encroachment on Ethiopian territory became more sharply pronounced, and in 1936 Ethiopia was occupied by Italian military forces. The occupation continued until late in 1941 when the British armies of liberation with Ethiopian patriotic forces successfully forced the surrender of all Italian forces in Ethiopia.

Immediately following his triumphant return to his Empire, His Imperial Majesty, Haile Selassie I, vigorously set about the tremendous task of reconstructing, organizing, modernizing, and developing a stable economy for his war-torn nation. During the years of war, most of the educated and technically trained young men who, under normal conditions, would have carried on the responsibilities of governmental offices, were lost. Immediate emphasis was placed on education, with His Imperial Majesty retaining for himself the responsibilities of the Ministry of Education in order that he could give it his personal attention. New schools were established, foreign teachers employed, and training programs initiated. As secondary school graduates became available, many were sent to universities and colleges in foreign nations to return at the completion of their studies and occupy responsible positions in the government, replacing hired foreign technicians when they had gained sufficient experience to enable them to carry out the functions of the positions. By 1945, eight provincial elementary schools and 50 day schools were operating in centers of population. In 1946, 241 schools were reported to be in operation with an enrollment of 32,000 pupils. As engineers and other technically trained personnel became available, attention was directed to other phases of development.

The economic structure of Ethiopia is basically agricultural. However, agricultural practices are of the subsistence type which provide a standard of living below that desired in a modern world. His Imperial Majesty has long recognized the need for further development and utilization of the natural resources to expand the national economy and to improve conditions for the people of Ethiopia.

Through the agencies of the United Nations, other governments, and the economic assistance provided by the United States, progress in many fields has been made in Ethiopia during the period from 1945 to the present time, and many major improvements have been accomplished.

By 1952, it was apparent that the existing electrical power facilities would no longer meet the needs of the growing cities, and through the U.S. Operations Mission, preliminary studies of potential projects were initiated on the Awash River.

A very brief reconnaissance of the Blue Nile River was also made at this time to be used in a preliminary evaluation of the potential resources and to determine the nature and extent of investigations which would be required in a full scale reconnaissance of the area. In 1957, a few Ethiopian engineers became available, and plans were accelerated. A mapping and geography institute had been established in 1955, and technicians were being trained in map construction. Aerial photography of the Blue Nile Basin, under the supervision of the U.S. Army Map Service, and a geodetic survey establishing horizontal and vertical control points, under the direction of the U.S. Coast and Geodetic Survey, were performed as a part of the U.S. foreign aid program.

Early in 1958 Bureau of Reclamation personnel arrived in Ethiopia to begin the surveys and studies of the land and water resources of the Blue Nile River Basin. The results of these studies are discussed in the following sections of this report.

ACKNOWLEDGMENTS

The Ministry of Public Works and Communications of the Imperial Ethiopian Government has contributed greatly to this investigation and report by providing funds, facilities, and personnel to assist in its execution. The government officials who were closely associated with the investigation and whose interests and courtesies are gratefully acknowledged are H. E. Dejazmach Zaude Gabre Selassie, Vice Minister of Public Works; H. E. Dejazmach Mengasha Seyoum; Minister of Public Works and Communications during the early years of the investigation; and H. E. Balambaras Mahatema Selassie Wolde Meskal, Minister of Public Works and Communications in the final period. The Bureau of Reclamation team wishes specifically to acknowledge Dr. Haile Giorgis Workneh, Vice Minister; Ato Assefa Mengasha, Assistant Minister for Water Resources; and Ato Zaude Bessoufecad, Director General of the Water Resources Department, and their staff for direct and other assistance in making this report possible.

The United States Embassy in Addis Ababa and the U.S. Agency for International Development have made personnel and funds available and have provided facilities and administrative assistance in carrying out the investigation. Special recognition is given to Mr. John W. Robison, Chief, Engineering Division, USAID/Ethiopia, for his able assistance and cooperation in solving many of the administrative problems. The cooperation of the Ethiopian engineers, technicians, and other personnel is greatly appreciated.

The United States personnel responsible for the conduct of the investigation and for the preparation of the report were employees of the U.S. Department of the Interior, Bureau of Reclamation, under the direction of the Foreign Activities Division of the Commissioner's office. The investigations team was provided technical support and guidance by the Office of Chief Engineer.

Many individuals and agencies of both the United States and the Ethiopian governments, although not directly connected with this investigation, did make valuable contributions to the program which were appreciated and are here gratefully acknowledged.

PURPOSE AND OBJECTIVES

The Blue Nile investigation was a multi-purpose program designed primarily for the following purposes.

1. To train Ethiopian personnel in the process of investigation, evaluation, and planning of hydroelectric and irrigation projects, including the associated studies of hydrology, climate, sedimentation, floods, quality of water, geology, construction materials, designs, estimates, agriculture, economics, land classification, power potential and markets, minerals, and industry along with other related but less easily identifiable subjects; and to provide a field where, in the course of the investigation, the Ethiopian personnel in training could gain actual experience needed in this field if they were to continue the program of water resource development, after a reasonable period of time, without outside leadership and direction.

2. To assist the Imperial Ethiopian Government in the formation and establishment of an engineering and administrative organization to administer the resource development program.

3. To provide Ethiopia with an inventory of potential developments within the Blue Nile Basin and a general plan for the exploitation of the potentials. A network of hydrologic stations would provide the Imperial Ethiopian Government with data necessary in discussions concerning the international use of Blue Nile water.

Organization of the Water Resources Department

To assist the Imperial Ethiopian Government in the organization and establishment of an agency responsible for resource development programs, the Bureau of Reclamation assigned a specialist in the field of administration, management, and organization to the project for a period of 90 days late in 1958. The results of his studies were contained in a report, Recommendations Relating to the Organization of a Department of Surveys and Water Resources, dated March 1959, which made the following recommendations:

"1. An organization for the Department of Surveys and Water Resources is recommended, consisting of three main divisions and one smaller service division: (1) Basic Surveys and Mapping, (2) Project Development, (3) Construction, and (4) Administrative Divisions. Each division would be subdivided into appropriate branches.

"2. The Basic Surveys and Mapping Division should centralize work of this character for the entire government insofar as possible and set standards for all ministries. The services of the Topographical Institute being provided by the Federal Republic of Germany should be coordinated with this division. To make the best use of limited but specialized equipment and skilled personnel and to provide the best training facility these should be brought together. Likewise, mapping normally should follow surveys. The services of this division must be available to all Ministries of the I. E. G.

"3. The first and foremost emphasis of the Department's program will be on the Blue Nile River Basin. This will economize in personnel and build into the organization some experience that can be applied in other river designs, as may be later determined. The initial staffing of the Divisions of Basic Surveys and Mapping and of Project Development, insofar as the Imperial Ethiopian Government is concerned, will be with those persons provided by the I. E. G. for this program and the mapping services.

"4. Until an operating responsibility is determined by the Government for such structures as Koka Dam and Zula Dam now under construction, the Construction Division of this Department should be responsible for their operation and maintenance.

"5. Urban and rural water developments constructed by the central Government, should be the responsibility of this Department. Those I. E. G. personnel assigned to Well Drilling should become a part of this branch.

"6. When plans are made for specific river development projects, other Ministries of the I. E. G. must be consulted and informed to insure a balanced program.

"7. At such times as projects are completed further study should be made as to whether a Control Board should be established to coordinate the interests of the water and power or other interests and establish operating criteria.

"8. As Ethiopian engineers with appropriate education are trained for this work they will replace technical personnel temporarily obtained from other sources.

"9. At intervals, and five years is suggested as a desirable interval, the organizational structure of this Department should be reviewed by competent authority. Changes recommended and consistent with I. E. G. policy should then be made. "1/

The organization was informally established as an agency under the Ministry of Public Works and Communications, and the I. E. G. appointed a Director, Dr. Haile Giorgis Workneh, on January 7, 1959, to head the new Department of Surveys and Water Resources. During the period of the Blue Nile investigations the organization was modified from time to time as was required to meet the needs of the overall program of the Department.

In addition to the investigation program in which the Bureau of Reclamation participated, the Department was responsible to the Ministry of Public Works and Communications for several other projects, including the Aerial Surveys and Mapping Project that provided the Bureau of Reclamation with topographic maps of project areas, a Well Drilling Project directed jointly by USAID and the Department, and the Geodetic Survey Project under the direction of the U. S. Coast and Geodetic Survey.

Training of Personnel

Training of Ethiopian personnel was one of the major objectives of the program; and in 1958, as the work got under way, two Ethiopian engineers, recent graduates of United States colleges, and about twelve subprofessional trainees, generally graduates of the Ethiopian secondary schools, were assigned to the project by the Ministry of Public Works and Communications. The two engineers were the only technically trained Ethiopian personnel who could be made available to the project at that time. Their further training was accomplished by on-the-job work, side by side with experienced Reclamation personnel. From time to time they were rotated to the various divisions of the project. Their contributions to the project were considerable. They both resigned prior to the completion of the project to accept positions of greater responsibility elsewhere in the Government and in private industry. Their departure lessened the technical strength of the Department, but they are still providing a greater service to Ethiopia, and the training and experience gained during their employment on the project were important factors in their qualifying for the more responsible positions.

1/ Organizational Plan, Department of Surveys and Water Resources, Ministry of Public Works and Communications, Imperial Ethiopian Government; prepared for the ICA by the U.S. Department of the Interior, Bureau of Reclamation, March 1959.

Figure 1. Ethiopian personnel receive training.

The subprofessional trainees were selected and assigned to the project by the Ministry of Public Works and Communications. Their selection was based upon educational qualifications and a written examination prepared by Bureau of Reclamation personnel. Many of this first group assigned to the project remained throughout the investigation and became key men and leaders in their particular fields of assignment. As the work progressed, additional engineers and other technically educated personnel as well as trainees and administrative personnel became available and were assigned to the project. Unfortunately, the numbers of college graduates in the specific fields of civil engineering, electrical engineering, geology, soils, and agricultural economics were never adequate to meet the requirements of the project. As a result of these shortages, it was only possible to provide training at the professional level for about twelve Ethiopian employees. This group did not include an electrical engineer, geologist, soils scientist, or agricultural economist. The shortage of technical personnel resulted in the assignment of greater numbers of trainees and aids at the lower subprofessional levels, and at one time about 150 Ethiopian employees were assigned directly to the project.

Civil Engineers	6
Landscape Architect	1
Industrial Engineer	1
Agricultural Engineer	1
General Economist	1
Plant Scientist	1
Land Classification Technician Trainee	2
Agricultural Technician Trainee	1
Ecology Aid Trainee	3
Hydrology Technician Trainee	32
Gage Reader	8
Engineering Aid Trainee	26
Administrative--Clerk, Typist, Storehouseman, etc.	20
Draftsman	8
Driver and Mechanic	23
Cook	16

Each of the above personnel was given on-the-job training. The hydrology technician trainees and the engineering aid trainees were given special, short-term, classroom training. One hydrology technicial was sent to the United States for 1 year for specialized training in hydrography with the Bureau of Reclamation and the U.S. Geological Survey. Three civil engineers were given 1 year of training each, and one was given 6 months of training in the Office of Chief Engineer of the Bureau of Reclamation. In addition, the Director General of the Water Resources Department spent some time in the United States studying management and administrative procedures of the Bureau of Reclamation, and one engineer spent about 6 months in the United States assisting with the preparation of the Blue Nile report.

The training has provided the Water Resources Department with a staff of subprofessional personnel adequate to meet the immediate needs of the Department. At the professional level, however, there is a great need for additional college graduates with training and experience to fill the responsible positions requiring technical training, judgment, and managerial ability.

PRIOR INVESTIGATIONS AND REPORTS

The Blue Nile (Abbay) River rises on the high Ethiopian plateau, an area of seasonal high rainfall that produces high runoff during the rainy season and a total average annual runoff of about 55,000,000,000 cubic meters (45,000,000 acre-feet) at the Ethiopian-Sudan border. From the border westward to the Blue Nile's confluence with the White Nile at Khartoum and northward through Egypt, the country becomes progressively more arid. The people along the Nile have historically depended upon the water from the Blue Nile to irrigate their crops during the dry season and to maintain sufficient flow in the river to provide for river transportation and other uses.

As agricultural development progressed and additional water was needed to bring new lands under irrigation, the downstream countries began to consider the possibility of storing water in Ethiopia by converting Lake Tana, the source of the Blue Nile, into a storage reservoir by constructing a gated dam across the outlet to regulate the flow of the river.

The earliest date of the interest of the downstream countries was not indicated. However, it has been noted that Bruce, 1770 and 1771, and d'Abbadie, 1838, reported the annual rainfall at Gondar to be between 0.90 and 1.00 meter, and from this it is assumed that even at that early date some thought had been given to the subject. Negotiations between the downstream countries and Ethiopia, concerning the right of use and plans for storage, failed to bring about agreement that would permit such development. Several expeditions were made, generally under British sponsorship, from the main Nile to Lake Tana for the purpose of gathering data and preparing plans for development, but, as political agreement failed to materialize, the downstream countries began to construct works within their own national borders that would satisfy their immediate needs. These project works have been expanded from time to time, and perhaps today there is no longer the compelling interest in regulating Lake Tana water specifically for the improvement of agriculture in the Sudan and Egypt, but these countries still have a strong interest in regulating the flow of the Blue Nile.

Several investigations of various aspects of the basin were conducted and reports published. None of these investigations covered the entire Blue Nile Basin. The reports, while limited in depth and scope, were interesting and useful to this investigation and were taken into account in the consideration of plans for various projects. No attempt has been made to evaluate all of the previous reports and investigations. Those that were considered of greater interest are as follows in chronological order.

• • •

1903, Mr. C. Dupuis, Egyptian Irrigation Service

This investigation was for the purpose of determining the possibility of utilizing Lake Tana as a storage reservoir. Mr. Dupuis noted that maps at that time gave the surface area of the lake as approximately 3,000 square kilometers and the catchment area 14,000 square kilometers, exclusive of the lake area. He reported that the rainfall was assumed to be 1 meter per annum, falling almost wholly in the 4 months, June through September. The soils of the drainage area consisted of cracked black cotton soil in the undulating plains, but there were also large tracts of clay soils and, in the more hilly portions, extensive outcrops of rock and stone. The author estimated that the annual inflow to Lake Tana was 6,572 million cubic meters, the evaporation from the lake surface was 3,641 million cubic meters, and the discharge into the Blue Nile River was 2,924 million cubic meters. He suggested the construction of a control structure at the outlet of the lake that would store the water during the rainy season and release it during the dry season, as required for irrigation below.

He also noted that because of the peculiar position of the lake, its waters could be drawn off and its area reduced to any desired extent by boring a tunnel under the western watershed. Such a tunnel would be at least 7 or 8 miles long and would be expensive. It would convey the waters of the lake into the ravines of the headwaters of the Rahad River. The tunnel headworks would be near Delgi on the west shore of the lake.

In conclusion, Mr. Dupuis indicated that he doubted that the reservoir would be of sufficient value to justify its construction in the interests of Egypt alone, but that it was suitable for irrigating lands in the Sudan and that eventually the reservoir would be constructed, possibly in the near future, to provide a water supply for a large canal that was being considered to irrigate lands in the Gezira.

1904, Sir William Garstin, Undersecretary of State for Public Works in Egypt, ON THE BASIN OF THE UPPER NILE

This report, known as Egypt No. 2 (1904), dealt principally with the main Nile River, the White Nile, and related lakes. Only a small portion of the report was devoted to the Blue Nile River and Lake Tana. Sir William apparently relied heavily upon the previous report by Mr. Dupuis for technical data, as indicated by the fact that Mr. Dupuis' report was included as an appendix to Sir William's report.

Sir William reported that little was known of the Blue Nile between Lake Tana and the Sudan border, but concluded that it was not likely that a better scheme of storing the Blue Nile waters than in Lake Tana could be found. He thought that sites adapted to construction of a large reservoir might exist within this reach of the river, but that it seemed improbable. In reservoirs, other than Lake Tana, sediment would present a great problem, and he concluded that if a reservoir had to be constructed within a foreign territory--i.e., Ethiopia--Lake Tana should be selected for that purpose, as it would be most suitable.

He noted that, owing to the formidable political problems, the chance of any such work on Lake Tana being carried out had to be relegated to the future or perhaps abandoned. He hoped that in some future period in the world's history the political problems would be solved and advantage would be taken of the obvious suitability of Lake Tana as a great natural reservoir. He further concluded, apparently rather reluctantly, that the Lake Tana project had to be abandoned and a search made for other ways of providing a water supply for lands adjoining the Blue Nile in the Sudan.

1916, A. Burton Buckley, A.C.G.I., Associate Member of the Institute of Civil Engineers, Egyptian Irrigation Service, REPORT ON LAKE TANA

This report was published in Cairo in 1917 by the Ministry of Public Works, Egypt, Irrigation Department. An expedition was made to Lake Tana to ascertain how the lake could be made available for a storage reservoir and to provide for regulation of the Blue Nile flood for the benefit of the downstream nations. It was recognized that there were two ways to accomplish this.

1. Provide a regulator structure at the outlet for flood storage.

2. Provide a channel and a regulator structure.

The expedition to Lake Tana came about as the result of diplomatic negotiations in 1915, which resulted in the dispatch of a joint Egyptian, Sudanese, and Ethiopian commission to make further studies of Lake Tana. The party was led by Colonel H. D. Pearson, Director of the Sudan Survey Department, with Mr. A. Burton Buckley being loaned by the Ministry of Public Works to supervise the hydrological work. Political turmoil interfered with the work, and no discharge measurements were permitted at the outlet of Lake Tana. However, surveying was done in defining the extent of the Lake Tana shore areas liable to flooding by rise of the lake waters during the annual rains. Mr. Buckley recommended a control structure generally similar to those previously suggested. He established certain survey control points that are still identifiable and, after correction for elevation, were used in further surveys for the present Blue Nile investigation. He concluded that there was a need for additional investigations, since he was unable to complete his work at Lake Tana because of political difficulties.

1920-21, G. W. Grabham, Government Geologist, Anglo-Egyptian Sudan, and R. R. Black, Inspector, Physical Department, Ministry of Public Works, Egypt, REPORT OF MISSION TO LAKE TANA

The original report, prepared by Grabham and Black, exceeded 200 pages in length and contained numerous tables, charts, and drawings. It was one of the most comprehensive studies of Lake Tana that had been made, and the report carried much valuable information which proved to be helpful to others who were to make further studies at a later date.

The purpose of the Grabham and Black expedition was, in effect, to study the possibility of obtaining supplemental water during certain critical periods of the year for agricultural purposes in the Sudan and Egypt. Apparently no thought was given at that time to water regulation for the development of hydroelectric power.

They reported that the water from the main Nile River was in excess of the amount required to satisfy the agricultural needs of Egypt and the Sudan, except for the dry season between March and July. During these months, the river was low and the water supply sometimes inadequate to meet the needs of summer crops, such as cotton and sugar cane, in Egypt. A solution to the problem would be to make abundant supplies available by construction of reservoirs on the upper part of the Nile River where the surplus water from the annual rains could be stored for later use downstream during the dry season.

The Egyptian government believed that Lake Tana was one of the most suitable sites for providing storage. The regulation would also be welcomed by the Anglo-Egyptian Sudan for, although the water supply of the Sudan was at the time adequate, they could foresee the need for additional water in the future. The importance of converting Lake Tana to an artificial reservoir for regulating the flow of the Nile had been recognized for many years. In 1902, the Egyptian government was authorized by H. I. M. Emperor Menelik to dispatch an expedition to visit and collect all possible information concerning Lake Tana, with a view toward deciding whether it could be effectively utilized as a reservoir, should such a proposal ever come within the range of practical politics.

Grabham and Black advocated the construction of a regulating bridge of 14 openings of 5-meter span, with the floor level 7 meters below the natural flood level at the the outlet of Lake Tana. Aside from benefiting the Sudan and Egypt, Ethiopia would also be benefited, since the highest level of the lake would be limited and protection thus provided to the inhabitants of the lakeshore during periods of high floods. The lower levels, with slightly increased range, would decrease the area of swamps and would improve health conditions.

The authors, although they collected a great deal of new and additional data, appeared to have drawn heavily upon the reports of earlier investigations and in many cases confirmed their findings. They concluded that the lake is of recent geologic origin, being perhaps 5 to 10 thousand years old, and that the rate of sediment deposition is so small as to have no influence on its value for use as a reservoir.

1926-29, Major R. E. Cheesman, LAKE TANA AND THE BLUE NILE

Major Cheesman was the British Consul in northwest Ethiopia from 1925 to 1934, and during this period (1926-29) he followed the Blue Nile for most of its course from Lake Tana, its source, to its confluence with the White Nile. This was the first recorded exploration of the full length of the stream. He saw the river for most of the distance, but did miss two loops--one at a point he refers to as "Gonda" and one between two other points he refers to as "Siribanti" and the "Dabus River." He recorded elevations at a few points along the river and prepared a profile drawing of the river from Lake Tana to Roseires in the Sudan. The purpose of his investigation was to collect data for a map of the traverse of the river in Ethiopia and to settle three questions.

1. Were there other large lakes, in addition to Lake Tana, along the traverse of the Blue Nile River?

2. Were there, in addition to Tis Isat, other major falls in the river?

3. Were there irrigable lands in the Blue Nile valley?

He determined that the altitude of the lake's surface at maximum water level was 6002 feet and that the bottom of the lake was saucer shaped; that the maximum depth appeared to be about 36 feet; and that Lake Tana was the only large lake on the Blue Nile River. The elevations were arrived at by hypsometer and barometer, and the river gradient as plotted by Major Cheesman was not as steep as previously reported by others.

He located two possible reservoir sites on the Blue Nile--one upstream of Costanio's bridge near the confluence of the Guder and the Blue Nile Rivers, which appears to be the same as the Karadobi (BN-3) site discussed in the report of the Bureau of Reclamation; the second site, Yaringhe hill, near the Sudan border. As the result of his explorations, he concluded that there were no lands along the Blue Nile River that could be irrigated and that there were two possible storage sites, neither of which was considered good, which engineers in the future might study with some chance of success.

1931, J. G. White Engineering Corporation, New York City, REPORT ON LAKE TANA OUTLET WORKS AND ETHIOPIAN HIWAY FROM ADDIS ABABA TO LAKE TANA

Late in 1927 the Ethiopian government discussed with the J. G. White Engineering Corporation the preparation of a reconnaissance report regarding the location of a highway between Addis Ababa and Lake Tana and a similar report dealing with a proposed dam and control works at the outlet of Lake Tana. Agreement was reached and surveys were started on the Lake Tana project in 1930. A generous amount of work had already been done at the Lake Tana outlet site, including streamflow measurements. The J. G. White Corporation collected a large amount of other valuable information regarding water levels in the existing outlet of the lake, the nature of materials to be excavated, the availability of suitable construction materials, and locations satisfactory for construction camps.

After a study of all information available, it was concluded that adequate and safe works to control the outflow from Lake Tana could be constructed at a reasonable cost at either of two points near the existing outlet. In either case, the structures were designed in a manner to keep the high water level of Lake Tana at its present historical level, thus not endangering any existing tombs or churches on the islands in the lake. This investigation also considered the possible development of hydroelectric power, primarily for use in construction of the regulating structure at the outlet of Lake Tana. Several different methods of controlling the water at Tis Isat Falls to insure a constant supply for the hydroelectric plant could be used, but each method would include a structure across the Blue Nile immediately above Tis Isat Falls. They believed that the most economical method would be to erect a diversion dam, having flashboards that would be lost in high water, above the crest of the falls. It was reasoned that this diversion dam would probably exceed 1 kilometer in length and would be a major project. Also, they determined that construction of a powerhouse and erection of machinery in the narrow gorge below Tis Isat Falls would be difficult and expensive, and, since there would be no early demand for power in the entire region other than for the construction work at Lake Tana, the powerplant would be of little future economic value. Therefore, further consideration of a powerplant was abandoned.

The plan recommended for control of the water of Lake Tana was, in principle, little different from those previously proposed.

1935, J. G. White Corporation, New York City, REPORT ON LAKE TANA OUTLET CONTROL WORKS AND ETHIOPIAN HIGHWAYS

Following the 1931 expedition of the J. G. White Corporation, a report was published on December 31, 1931. This report indicated two possible plans for controlling the outlet of Lake Tana; both advocated the excavation of channels with regulating structure, and both would have maintained the lake surface at its present levels.

In 1933, this report was discussed in Addis Ababa by representatives of the Ethiopian, Sudanese, and Egyptian governments, and of the J. G. White Corporation. It was arranged for the J. G. White Corporation to investigate the project further to determine whether the cost of the control works would be reduced if the level of the water in the lake were to be raised slightly, assuming that materials for the work at the lake would be brought from the Sudan by a road from Roseires which would join the road from Addis Ababa. The further investigations were started in the fall of 1933 and completed in the late spring of 1934. It was concluded that this later scheme provided more economical construction. However, the war with Italy was soon to disrupt Ethiopia's plans, and the proposals were dropped.

1938, L. Pontecorvo, S. A. Tipografia, Castaldi, Rome, ENGINEERING PROBLEMS IN COLONIAL TERRITORIES

Contrary to the opinions expressed by others who have investigated the possible development of Lake Tana, Pontecorvo concluded that Lake Tana had little value as a source of irrigation water for Sudan and Egypt. He proposed the construction of three dams on the Blue Nile below Lake Tana and one on the Diddessa River that would provide 9,000 million cubic meters of storage for downstream irrigation if Lake Tana regulated water were also used. He also proposed a control structure at the outlet of Lake Tana but would have diverted the water through a tunnel about 7 kilometers long into the Beles River for the purpose of producing power, after which the water would be used for irrigation in the Sudan. The power would have been used primarily to make nitrogenous products.

1946, H. E. Hurst, R. P. Black, and Y. M. Simaika, THE FUTURE CONSERVATION OF THE NILE

This report was concerned with the ultimate development of agriculture and the required water supply in Egypt. It pointed out that after World War II attention was again directed to the need for additional projects to increase production and to protect Egypt against dangerous floods. It was an attempt to foresee the final development of agriculture in Egypt, and the Sudan up to the limit of the available water supply. It included consideration of a project to store water in Lake Tana for irrigation in the Sudan and Egypt and to provide some flood protection for both.

The authors pointed out that full advantage could only be obtained from annual reservoirs when they were supplemented by over-year storage or, as they sometimes referred to it, "century storage." They noted that the idea of over-year storage was applied many years ago in the time of Joseph to save Egypt from famine. They noted also that during the period 1869 to 1899, the Nile was very high and that from 1900 to 1945, it has been low. The required reservoir capacity would depend on the variation of the natural flow and on the length of period considered. This was taken as 100 years, or the century storage, as opposed to annual storage.

They suggested that a project to store water in Lake Tana would be a joint project to benefit Sudan and Egypt, and, if combined with the hydroelectric scheme, it could also benefit Ethiopia. They noted that in the past, except for the Grabham and Black project, no project for the control of Lake Tana envisaged more than routine storage and release of the normal lake discharge coupled with such small reserve as might be obtained without materially adding to the cost; that previous reports had indicated that the control of Lake Tana was not necessary to the Sudan; and that its value to Egypt was very small since most of the water stored in the lake could equally well be stored on the main Nile. They concluded that this assumption was erroneous.

Several possible future projects were considered, including the main Nile, the White Nile, and the Blue Nile, which would provide flood protection as well as a water supply for irrigation downstream during periods of low flows. Referring to the Blue Nile, they said, "... a dam in the Blue Nile canyon has been mentioned as a possibility but there is no definite knowledge about the canyon from this point of view, although it is very likely that there are suitable sites, though having regard to the big slope of the river, a high dam will be needed to give much capacity. It is almost certain that the nature of the country will make any such site difficult of access and there is also the question of silt to be considered. It is pure waste to build extra reservoirs on the Atbara, the Blue Nile, or any other tributary to store what can be put into an otherwise empty flood protection reservoir on the main Nile."

1952, Tom A. Clark, U.S. Bureau of Reclamation, PRELIMINARY RECONNAISSANCE REPORT ON THE WATER RESOURCES OF THE BLUE NILE

Following a request by the Ethiopian government to the United States for a study of the potential development of the water of the Blue Nile River, the Bureau of Reclamation through the U.S. foreign aid program made a preliminary reconnaissance of the Blue Nile River Basin for the purpose of gathering data and recommending the nature and extent of the investigations to be undertaken in succeeding dry seasons. The preliminary reconnaissance was conducted under the direction of Tom A. Clark, Bureau of Reclamation engineer, during the months of April and May, 1952. The report recommended the immediate installation of stream gaging stations and the collection of hydrologic data that could be used as the further investigations progressed. It was recognized that both irrigation and power potentials within the Blue Nile Basin in Ethiopia existed, and it was recommended that the survey should continue. It was estimated that the investigations could be completed in about 10 years.

This reconnaissance was the forerunner of the current Bureau of Reclamation investigation of the Blue Nile River Basin.

1954, J. Seymour Harris, Birmingham, England, <u>REPORT ON THE PROPOSED CONTROL AND UTILIZATION OF THE WATERS OF LAKE TANA</u>

The Ethiopian Minister of Public Works in April 1953 requested J. Seymour Harris and Partners to make a study of the proposed control and utilization of the waters of Lake Tana and to advise upon (a) maximum and minimum levels of Lake Tana; (b) site of outfall channel from Lake Tana, if any; and (c) position of Nile regulator, if any, and the rate of discharge from Lake Tana.

This firm was also developing plans for the Ethiopian Government for a new city on the shores of Lake Tana in the vicinity of Bahir Dar. The manner in which Lake Tana water level was to be controlled would affect the land available for development and would also have effects upon health, water supply, and generation of power. Mr. Harris recognized the needs for irrigation, hydroelectric power, and other uses and made the following comments:

1. The home demands of irrigation should be met in full.

2. The total discharge made available for use by the Sudan and/or Egypt during the "timely" period will amount to 1.636 milliards (thousand million cubic meters), that is, 1.136 millards more than the existing "timely" flow, and 1.864 milliards less than that proposed in previous reports. This discharge will amount to approximately 1.145 milliards at Aswan. The maximum practical contribution towards the economic and planned use of water of the Nile Basin would thus be made without imparing home requirements.

3. The minimum discharge occurring during the "untimely" period would be sufficient to meet all foreseeable demands for the production of electric power.

4. Variation in flow of the river between the "timely" and the "untimely" periods would not be such as to impair the beauty of the area and Tis Isat Falls.

1956, Seimens, <u>THE EXPLORATION OF LAKE TANA FOR IRRIGATION AND HYDRO-ELECTRIC POWER</u>

This report proposed diverting the water from Lake Tana by means of tunnels to the sources of the Rahad and Atbara Rivers for the purpose of irrigating 380,000 hectares of land northwest of Lake Tana within Ethiopia and utilizing the drop to produce hydroelectric power. The plan, like others, would provide for a regulating structure at the outlet of Lake Tana and two tunnels, 12 and 17 kilometers in length, to divert the water from Lake Tana to the Rahad and Atbara Rivers. The plan provided for the eventual development of five power stations with a possibility of generating 581 mw. for 16 hours a day for 9 months of the year and 1,036 mw. for 16 hours a day for 3 months per year, a total of about 4,000 million kilowatt-hours per year.

1957, H. E. Hurst, <u>THE NILE</u>

This report was an amendment to and refinement of the 1946 report of H. E. Hurst, R. P. Black, and Y. M. Simaika.

1958, P. Petridis, Legal Advisor, Ministry of Public Works and Communications, ETHIOPIA'S WATER RESOURCES

This discussion of Ethiopia's water resources, including the Blue Nile, recognized many of the problems with which Ethiopia is faced in developing her water resources, as is indicated by the author's summary.

"The integrated development of a national river basin lies within the responsibility and the sovereign rights of the country's own Government. The latter has all the powers and means to overcome local social, administrative and economic obstacles in the process of realization of its plans.

"But the situation is somehow different when we come to the development of international river basins. In such cases, there are particular rights and interests to protect; as well as common rights and interests to coordinate; upstream countries must not harm downstream countries, and reciprocally.

"Ethiopia has eleven major rivers whose sources are within her national territory and who flow outside it, thus becoming international rivers. These 11 rivers carry outside Ethiopia every year the tremendous mass of about 100,000,000,000 cubic meters of water.

"One can imagine the number and the importance of legal and other problems arising from such a generous flow to so many neighbor countries.

"The absence of an adequate international law adds to these difficulties to the point of despair.

"Nevertheless, the Imperial Ethiopian Government, conscious of Ethiopia's hydraulic position in the world, has dedicated a steady attention to this very important aspect of its water resources: A mass of documentation has been gathered and all the precedents carefully studied, while efforts for the completion and the general acceptance of an international code is followed with interest and sympathy."

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Undoubtedly, there have been other reports, investigations, and considerations of projects in the Blue Nile River Basin. However, only limited factual data have been available, since the country is unsurveyed and unmapped except for specific areas covered by some proposals. Information contained in the various reports, particularly hydrologic records, were found useful, and each of the reports helps the reader to better understand the problems of development of the water resources of the Blue Nile. The prior investigations and reports mentioned here are believed to be those of the greatest significance in consideration of the Blue Nile.

DESCRIPTION OF PRESENT BLUE NILE BASIN INVESTIGATION

The Blue Nile River Basin, an area of about 204,000 square kilometers (80,000 square miles) in central and western Ethiopia, has long been recognized as an area of considerable agricultural and hydropower potential. However, the extent of the potentialities has remained generally unknown until the Bureau of Reclamation undertook the investigation reported here. The area was unsurveyed, and maps were limited in detail and were unreliable. The Blue Nile River, a major tributary of the Nile, originates in Lake Tana and flows through deeply eroded canyons in a circuitous route through the high Ethiopian plateau. As it approaches the Ethiopia-Sudan border, the mountainous plateau is left behind and the river, now of great magnitude, flows northwestward across the gently rolling plains to its confluence with the White Nile at Khartoum in the Republic of the Sudan. The flow of the Blue Nile contributes about 55,000,000,000 cubic meters (45,000,000 acre-feet) annually and constitutes the major portion of the flow of the Nile.

Its major tributary streams also originate on the high plateau and after flowing through broad valleys for a few miles plunge into the deeply eroded canyons to join the main stream. The plateau area is generally quite heavily populated, and cultivated agriculture and livestock production are extensive. Farming operations provide subsistence for the rural population. However, no statistical data regarding production or crop yields were available.

Addis Ababa, the capital of Ethiopia, lies on the southern perimeter of the basin. From here, one all-weather highway skirts the eastern rim of the basin to Dessie; another extends westward along the southern rim to Lekkemt; and a third extends northward through the east central portion of the basin to Lake Tana. Other than on these highways, few of the streams are bridged, and the existing trails are passable only in dry weather with four-wheel drive vehicles. The Ethiopian Airlines provide domestic service to several towns within the interior of the basin and also maintain a fleet of helicopters which were used extensively in the investigation.

Headquarters for the operation was established in Addis Ababa, and the entire operation was directed from this point.

The project was financed jointly by the United States and the Imperial Ethiopian Government under an agreement between the two governments as a part of the U.S. foreign aid program. American personnel costs were borne directly by the U.S., and most of the Ethiopian personnel costs were borne by the I.E.G. A joint fund on a dollar-for-dollar matching basis was used to provide equipment, materials, supplies, and supporting facilities. The joint fund was initially administered by Co-Directors, one from USAID and one from the Ministry of Public Works and Communications. The Bureau of Reclamation, while dependent upon this organization for support, had no official authority or responsibility for its operation. However, the project cooperated closely with the supporting organization, giving assistance, advice, and guidance as required in the cooperative venture. During the last two years of the project operations, the Ethiopian Water Resources Department assumed the full responsibility for the management of the supporting activities with funds provided jointly by USAID and the I.E.G.

The first few months in 1958 were spent in assembling available data, collecting maps and aerial photographs, procuring equipment and supplies, and training Ethiopian personnel in the care and use of equipment. In September 1958, at the end of the season of big rains, field work was started. Two lake stage gages were installed on Lake Tana, and a gaging station that had previously been constructed on the Blue Nile River near Kese was reactivated. A program of streamflow measurements was started and eventually expanded to a full scale network of gaging stations, including 20 automatic recording stations and about 40 staff gage stations at strategic points throughout the basin. Since but very few of these stations were on or near established trails, the project was confronted with many problems in construction, particularly on the recording stations, which required the movement of a considerable amount of equipment and material.

Steel cable towers for the gaging stations were so designed to permit their transportation by helicopter, pack animal, or men if necessary. Generally they were hauled by truck as far as possible, then transferred to helicopter or other means of transportation for final movement to the site.

A program of streamflow measurements to establish rating curves at each of the stations was initiated as soon as Ethiopian personnel were trained in methods and became familiar with the equipment. During the first two seasons, it was possible to make these measurements only during the seasons of lower flows. However, as more men became available and as training was intensified, measurements were made throughout the year. Base camps were established at strategic points in the basin; and, since transportation during the heavy rains was very difficult, crews of hydrographers were assigned to each of the more remote stations to insure the collection of data. Sediment, quality of water, and weather data were collected at each of the stations.

Concurrently with the hydrologic investigations, a general reconnaissance was made of the entire basin by the U.S.B.R. field engineer and an Ethiopian engineer, using a helicopter operating from base camps from which they could cover the area within a radius of about 75 miles. Potential project areas were delineated on aerial photographs and maps. Potential damsites and powerplant sites were located for more detailed examination and consideration as project plans began to develop.

This reconnaissance reduced the area of investigation to specific locations of potential projects, designating the areas where land classification studies would be required and indicating locations of stream gaging stations to be constructed. Land classification surveys of the project areas were then accomplished by Reclamation soils scientists assisted by Ethiopian technicians and trainees. The areas were generally covered with brush and small trees, and without existing roads it was necessary to use helicopters to a large extent to cover the project areas. Soil samples were collected for laboratory analysis, and soils maps were prepared to delineate the irrigable areas.

Geological investigations were divided into two parts--general geology and site geology. The objective of the initial studies was to make a general geologic reconnaissance of the entire area from which a general geologic map of the basin could be drawn. The reconnaissance was accomplished by helicopter flights over the areas, surface observations of the geologic structure along roads and other points where it was possible to negotiate the terrain with surface vehicles, surveys of geologic sections exposed by erosion in the deep canyons, and stereoscopic examination of aerial photographs. Rock and mineral samples were collected for laboratory analysis, and after these data were collected, analyzed, and evaluated, a general geologic map of the area was compiled.

As collection of engineering, hydrologic, geologic, and land classification data progressed, the data were assembled in the project office and studies of the various potential projects were initiated. Since no Ethiopian electrical engineers were available to the project, the hydropower planning was done by the Reclamation power planning engineer with only minor assistance from Ethiopian personnel.

By June 30, 1963, the field work for the investigation had been completed; and the Bureau of Reclamation personnel, except for two engineers who remained to assist the Water Resources Department personnel through the 1963 June through September rainy season, returned to the United States for reassignment or to assist in the preparation of the Blue Nile project report.

GEOLOGY

GENERAL

The Blue Nile Canyon of Ethiopia, similar in many respects to the Grand Canyon of the Colorado River in the western portion of the United States, is considered a "geologist's paradise." In Ethiopia, as along the Colorado, a tremendously deep gorge has been cut into a high plateau exposing hundreds of meters of rock formations of the earth's crust and revealing ancient history in time and events on the east African continent. The geologic history indicates that starting with the sheared and folded Precambrian metamorphic and granitic rocks, referred to as the basement of East Africa, the land was uplifted, then intensively eroded and leveled to a lowland peneplain. Ancient valleys eroded in the Precambrian rocks, which are now filled with sedimentary rocks, were eroded an estimated 300 to 400 meters below the peneplained Precambrian rock surface, indicating that the continental mass was again uplifted and eroded before the transgression of the Mesozoic sea. Then subsidence from the southeast started a cycle of transgression and recession, extending the Mesozoic sea over the land. Within this large inland sea, extensive layers of sediments were deposited and became compressed and cemented to form hundreds of meters of sedimentary rocks, consisting of sandstone, shale, gypsum, limestone, and other varieties of layered rocks.

When the land was again raised and the sea had retreated, the wind, chemical erosion, rain, and streams of running water again eroded the land surface. This erosion cycle was interrupted by disturbances within the earth's crust, which formed great fissures, and extensive volcanic activity spread hundreds of meters of hot lava and ashes over the surface of a large land area. The lava congealed into a hard caprock layer that was relatively resistant to erosion. Later phases of volcanic activity continued to build high mountain masses. As the land mass was elevated thousands of meters above sea level, it became divided, thus forming the Great Rift Valley into the Ethiopian and Somaliland plateaus.

The plateaus were uplifted with relatively little fracturing or folding beyond the borders of the Great Rift Valley that cuts through the southern and eastern part of Ethiopia, but they have been altered by extensive erosion and local outpourings of more recent lava.

The largest portion of the Blue Nile River drainage system in Ethiopia lies entirely on or within the high Ethiopian plateau. The eroded plateau has an average elevation of 2400 meters with volcanic mountains and peaks rising to over 4200 meters above sea level.

The Blue Nile gorge was cut by the unceasing forces of erosion and transportation of rock and soil by the Blue Nile River, one of the major tributaries of the Nile River, supplying life-giving water to the Sudan and Egypt.

The Blue Nile drainage system starts with upstream tributaries, such as the Gilgel Abbay, Ribb, Gumara, and others, flowing into the 3,000-square-kilometer Lake Tana, a large, relatively shallow, flat-bottomed body of water with a surface elevation of about 1786 meters above sea level. The Gilgel Abbay, the largest of the upstream tributaries, originates on the northern and western slopes of the Chokke Mountains at an elevation of about 3600 meters and flows in a northerly direction across the lava plateau into the lake. Other large streams flowing into the lake are the Megech, Ribb, and Gumara Rivers.

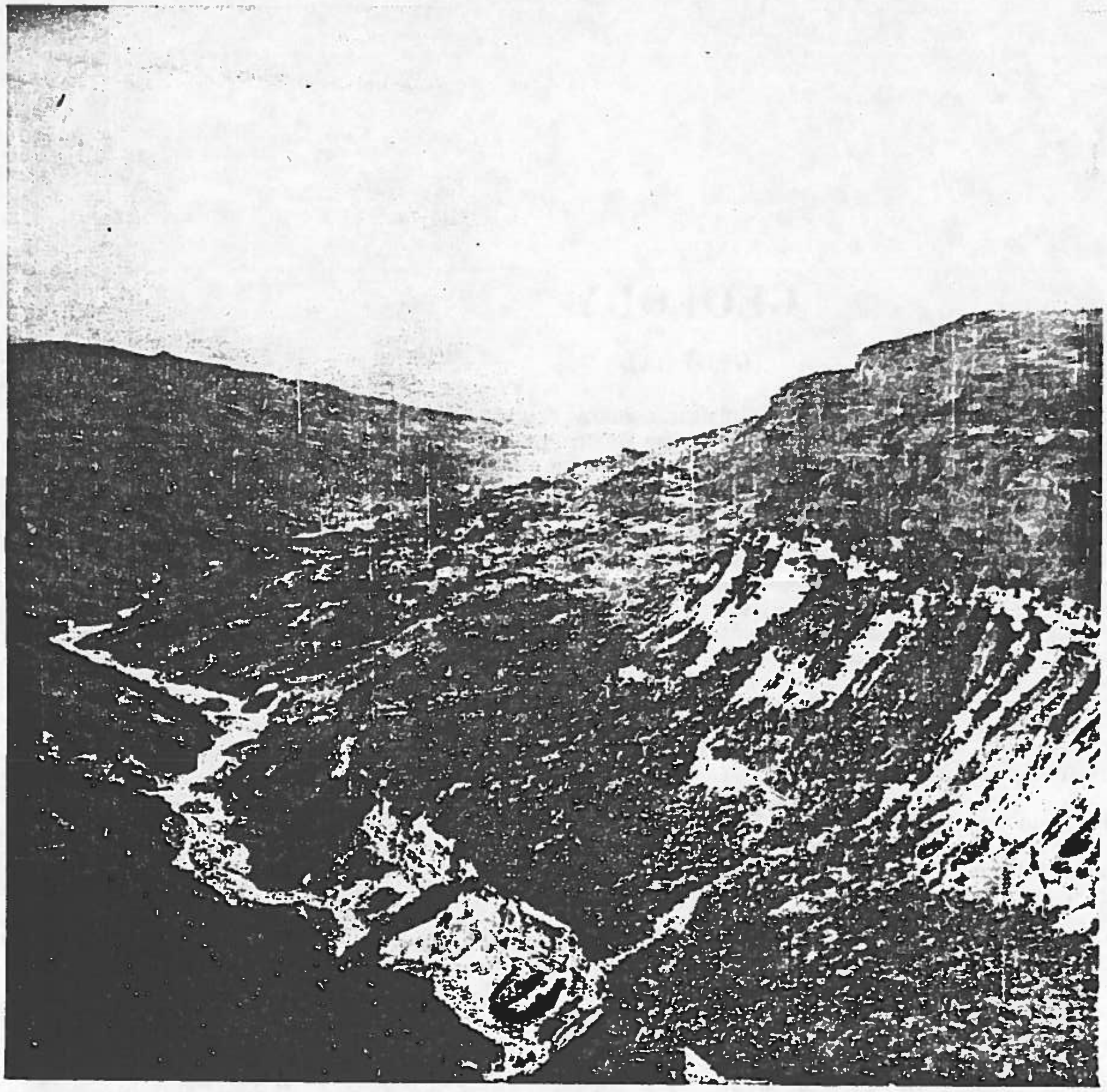


Figure 2. The canyon of a tributary of the Muger River, showing limestone outcrops.

The Chokke Mountains, like other mountains of volcanic origin surrounding Lake Tana, are one of the sources from which lava was spread over the land area that forms the Ethiopian plateau. The highest peaks rise approximately 1200 meters above the general level of the plateau to elevations approximating 3600 meters above sea level.

Lake Tana was formed primarily by very recent volcanic activity, which made a natural dam when lava was poured into the valleys and streams of a previously eroded Blue Nile drainage system. It is apparent that disturbances of the earth's crust have occurred, which contributed to the formation of the Lake Tana structural basin. Evidence for this consists of faults and eastward dipping volcanic rock on the west side of the lake; the lakebeds northeast of Lake Tana, which have been greatly tilted and faulted; and northerly trending dikes and faults on the east side of the lake. Although the dam of "younger" volcanic rock formed the lake, structural deformation was a major factor in the origin of the Lake Tana basin.

The "younger" volcanics that dammed the stream to form the lake originated in the general vicinity south of the present lake where there are several small craters and cinder cones. The molten lava poured down the valley in syrup-like streams and congealed into a hard, resistant rock. The flow extended down the valley at least as far as the mouth of the Beshilo tributary where remnants of basalt can be seen along the Blue Nile Canyon. Benches and remnants of other younger flows extended farther downstream, but these deposits, while probably contemporary in geologic time with the upstream volcanic activity, are believed to have originated from other recent sources noted on the nearby Amoneous Mountains and in the Cheye River Valley.

As the water level rose in the lake, it spilled over the lava and began cutting a new channel into the hard lava rock. In the upstream 30-kilometer stretch of the river above Tis Isat Falls, the most spectacular of the waterfalls, the stream channel is very rough but not deeply incised into the rock. It has a braided pattern of many small channels passing around small islands of rock masses and trees, brush, and grass. Here the water falls vertically for about 45 meters over the top "younger" lava flow. The vertical face of the falls is maintained by the upper hard lava bed, which is being undercut by faster stream erosion of the lower, friable, scoriaceous lava at the foot of the falls. From Tis Isat Falls to the mouth of the Beshilo River, approximately 155 kilometers, the river has carved a deep, narrow gorge with a relatively steep gradient, falling from about 1786 to 1230 meters. The water cascades over vertical falls through restrictions and swirling potholes--a white, foaming spectacle during and immediately following the season of heavy rains.

As the flow increases in volume along the river's course toward the Sudan border, the Blue Nile Canyon grows deeper and wider and the river cuts lower and finally through the "plateau" volcanic lava beds at a point about 30 kilometers downstream from the mouth of the Beshilo River, or about 190 kilometers below the outlet of Lake Tana. After cutting still deeper into the rock strata, through more than 610 meters of Mesozoic sedimentary rocks ranging in age from Cretaceous to Triassic, the river becomes entrenced in the Precambrian basement rocks at a point between the Muger and Guder Rivers, about 370 kilometers downstream from Lake Tana. This upstream exposure of basement rock is an isolated ridge surrounded by sedimentary rock, which dips below stream elevation for a short distance downstream. When the river again cuts into basement rock at about 380 river kilometers below the lake, upstream from the mouth of the Guder River, it remains entrenched in the Precambrian rock in an inner gorge eroded below the peneplained surface on crystalline rock for the remainder of the way into the Sudan.

The Blue Nile River passes through two short stretches of sedimentary rock between the Guder and Finchaa Rivers, where ancient river valleys were eroded 300 to 400 meters below the peneplain and were subsequently filled with sediments believed to be of pre-Adigrat, or probably equivalent to the Karroo formations of South Africa. The river flows in a narrow, V-shaped, intervalley gorge from the Guder River to the general vicinity of the Diddessa River where the peneplain on basement rock becomes more dissected and is less apparent. The canyon broadens to wide valleys and plains leading to the Sudan border, where the terrain has been extensively eroded and the masses of more resistant rocks form monadnocks rising above the general plain.

The Blue Nile River crosses the Ethiopia-Sudan border at an approximate elevation of 490 meters approximately 900 river kilometers below its outlet from Lake Tana.

The wedge of sedimentary rocks, although over 2,000 meters in thickness where it is exposed in the steep canyon walls, actually covers but a relatively small surface area of the Blue Nile River Basin in comparison with the area covered by volcanics and basement Precambrian rocks. The outcrop area of the wedge in the bottom of the canyon extends generally from the mouth of the Beshilo River to the mouth of the Guder River, where the Blue Nile becomes entrenched in basement rocks. However, the sedimentary rocks continue to form the sides of the canyons for a considerable distance to the west where precipitous cliffs of sandstone rise higher and spread farther apart until the sedimentary rocks disappear as a result of erosion, exposing basement rocks, or they become completely covered by the volcanic rocks.

The sedimentary rocks lie practically horizontal with a general and slight southeasterly dip, so that the higher or younger beds disappear consecutively beneath the plateau lavas in a westerly or downstream direction. For example, the Cretaceous formations do not crop out west of the Muger drainage whereas the basal Adigrat sandstone extends into the Diddessa River drainage. Erosion of the nearly horizontal layers of the hard and soft beds forms vertical cliffs and benches with a contour pattern of physiography along the canyon slopes.

The definite geologic ages of the sedimentary formations have not been determined. It is probable that the transgressive basal Adigrat sandstone, which has been described as Triassic age in the southeastern part of the continent, is of lower Jurassic age in central Ethiopia. The wedge of sedimentary rocks apparently represents a continuous and complete sequence of formations laid down during the transgression and regression of the Mesozoic sea, which advanced from a southeasterly direction to the northwest and then receded to the southeast. The complete sequence of beds is not present throughout the entire canyon section, either because of nondeposition or because of the removal of the upper formations by erosion before the land surface was covered by lava. Although the horizontal flows of volcanic rock generally conform with the bedding of the sedimentary rocks, an erosion surface on the Mesozoic is apparent at the contacts between the sedimentary formations and the overlying plateau volcanic rocks.

The basal Adigrat sandstone lies generally conformably on the peneplain surface on Precambrian basement rocks, consisting of contorted, folded, and sheared gneiss; schist; and the intruded masses of granitic rocks.

The most common structure or schistose pattern in the basement metamorphic rocks trends in a general northeast-southwest direction, varying in dip from vertical to horizontal.

The granitic rocks, although variably jointed and sheared, form a more or less structural pattern of very rough topography with extensive areas of loose blocks from erosion along joint patterns. The granitic rocks range from dark, basic gabbro and peridotite to light colored acidic granite. Some of the peaks in the areas of Precambrian rocks are granitic and therefore are old, eroded monadnocks. On the other hand, in the lower portion of the Blue Nile River Basin, several of the monadnocks are younger volcanic plugs or intrusions of trachytic type rocks which were injected into the basement rocks or rest on the eroded surface of crystalline rock. In areas covered by volcanic rocks, plugs of intruded rock, generally of trachyte composition, are common. In some places there are flows similar in composition to the plugs lying on top of the "plateau" basalts, indicating a later phase of volcanic activity. Thus it is apparent that there have been several distinct phases of volcanic activity. A general grouping of the volcanic activity consists of (1) basaltic, flat-bedded, "plateau" volcanics; (2) late phase trachytic and rhyolitic, mountain-building, volcanic activity, with associated intrusions of dikes and plugs; and (3) "younger" volcanics, very recent basaltic lava flows, cinder cones, and craters. Periods of erosion and deposition are indicated by beds of sediments between outpourings of volcanic rocks.

Table 1 is a generalized table showing the sequence of rocks in the Blue Nile River Basin.

TABLE 1--GENERALIZED SEQUENCE OF ROCKS

Age		Approximate thickness
Quaternary	"Younger" volcanics--mostly basalt, occurring in the Lake Tana Basin, and recent extrusions from the high mountains. Occur as well-preserved volcanic cones, explosion craters, and fresh lava flows. Some lake beds were also deposited in the Lake Tana Basin	
Middle Tertiary to Recent	Late-phase volcanics--mostly trachytes and rhyolite, central volcanoes form the highest mountain masses; flows, breccias, dikes, plugs, pipes	Up to 2,000 m.
Tertiary (mostly Oligocene)	Plateau volcanics. Thick, massive flood lavas chiefly of basalt. Form the extensive protective covering on the plateau. Flows are remarkably uniform in thickness and composition--Pre-Rift Valley age	200 to 1,500 m.
Mesozoic	Triassic to Cretaceous--wedge of sedimentary rocks between the Precambrian basement and the plateau volcanics	Up to 2,000 m.
	Measured Sections of Mesozoic Sedimentary Rocks in the Blue Nile River Basin	
Cretaceous	Sandstone, red to white, massive horizontally to cross bedded	250 m.
	Shaly sandstone, with shale, gypsum and cherty limestone, thin bedded, light gray to brown	300 m.
Jurassic	Limestone, oölitic, three hard massive beds, white to grayish brown, separated by thinly bedded marl and cherty limestone	500 m.
	Shale, variegated, red, green, brown	175 m.
	Gypsum, white to bluish gray, 50-meter plus or minus beds, interbedded with brownish shale	260 m.
	Shale, variegated, yellow, red, green	160 m.
	Siltstone, brown, transition zone between shale and Adigrat sandstone	50 m.
Jurassic-Triassic	Sandstone, (Adigrat) light gray to dark red, about four, thick, hard, massive beds separated by shaly sandstone	500 to 700 m.
Pre-Triassic Permian?	Sandstone and mudstone, preserved in river valleys in the Precambrian basement rocks	150 to 400 m.
Precambrian	Schists, gneisses, granitics, cleaved, sheared, folded. The crystalline basement complex has a peneplained surface and is overlain by basal Adigrat sandstone or by volcanics	

(See General Geology Maps and Sections)

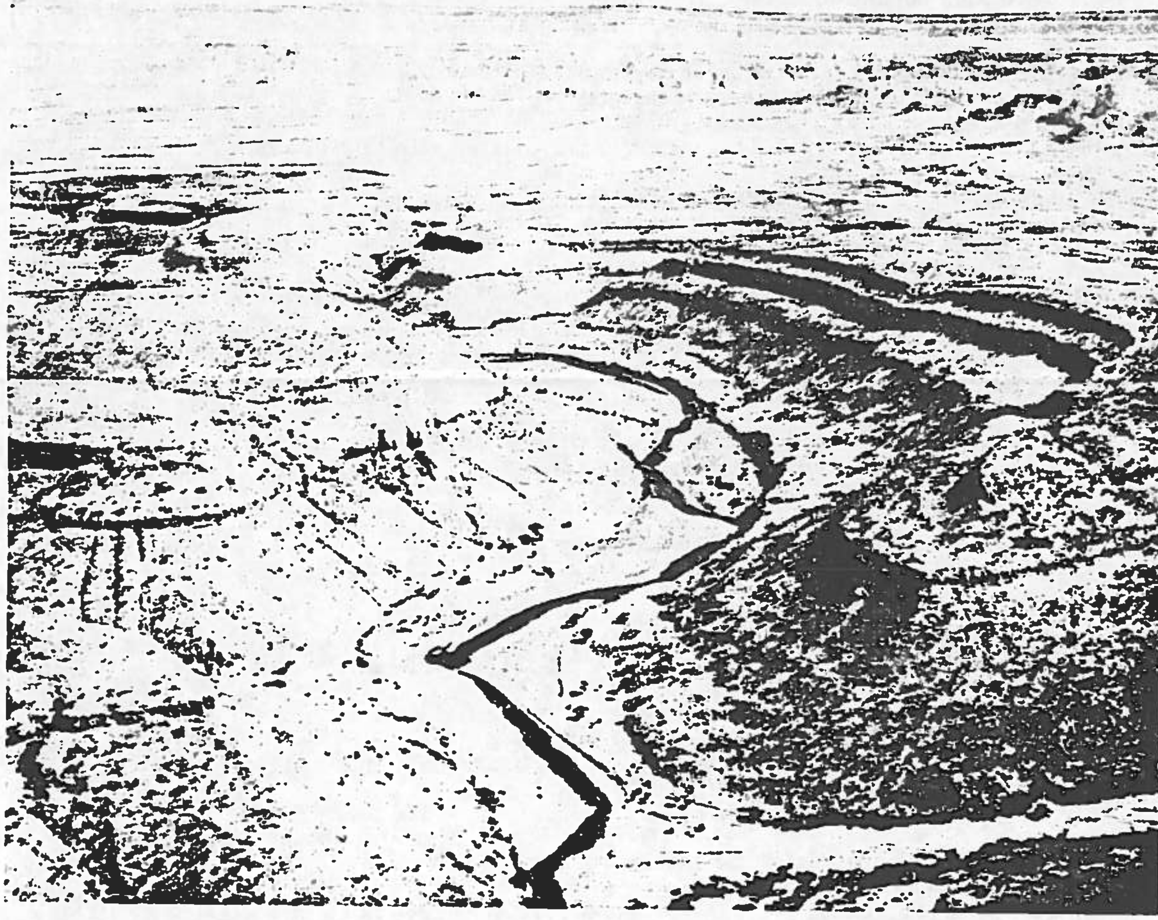


Figure 3. The eroded valley of the Giamma River.

PHYSIOGRAPHY

Plateau

East Africa is characterized by two very extensive, subtabular plateaus--the Ethiopian plateau of the northwest and the Somaliland plateau to the southeast. These are separated by a long, tectonic graben or rift valley in which are located the Galla lakes and Danakil depression. Perhaps in no other part of the world is the inter-relation of geology and human geography so pronounced as it is in this area, and the physiographic and geologic history has had a very important influence on the habits, health, and economy of the Ethiopian people.

The Ethiopian plateau, deeply cut and notched, slopes in a generally northwesterly direction towards the Sudanese plains and the valley of the Nile River. The Somaliland plateau slopes to the southeast, towards the Indian Ocean. The Great Rift Valley which separates them trends from southwest to northeast and is a continuation of the Great Rift Valley of South Central Africa, joining the Gulf of Aden and Danakil-Eritrean rift, a continuation of the Red Sea and the Jordan Valley. The original tectonic scarps of the plateau have been recessed by erosion.

The Blue Nile River Basin includes about 204,000 square kilometers of the Ethiopian plateau, drained by the Blue Nile River and its tributary streams. Its physiography and the stratigraphy exposed in the Blue Nile River canyon portray a pictorial view into ancient history, geologic processes, and rock types that form the East African continent. The eroded canyons, nearly a mile deep, represent an erosion of millions of tons of hard rock.

The Ethiopian plateau is impressive with its rolling ridges and flat, grassland meadows with meandering streams of water leading to white waterfalls over the vertical sides of the canyons and into the V-shaped canyons. Erosion has formed numerous, isolated, flat-topped plateaus, known as "ambas," with nearly vertical sides.

For the most part, the upstream or easterly portion of the Blue Nile River Basin is rolling volcanic plateau. The western portion of the basin is also high plateau, which has been recessed by erosion from the original tectonic scarp. It has been more maturely eroded and nearly all of the volcanics have been eroded away, exposing mostly Precambrian metamorphic and granitic rocks. The volcanic rocks forming the plateau are mostly basaltic materials which were poured out when the terrain was a flat, lowland surface. These volcanic rocks were deposited in rapid, massive flows that extended great distances from the central vent areas and are generally referred to as the "plateau" volcanics.

Mountains

Most of the mountains rising above the plateau were formed by the later phases of more explosive and intermittent ejections of volcanic material, consisting generally of more acidic volcanics, such as trachytes, rhyolite, and pyroclastics of agglomerates, ash, and tuff. These materials were deposited near the central vent areas and built high, generally cone-shaped mountains rising above the general plain or plateau that at present reach elevations of from 3050 to 4570 meters. The mountains have been greatly modified by erosion and in some cases by very late phases of volcanism manifested by cinder cones and flows of lava on the slopes and in the valleys.

The coalesence of these high mountains forms a rim or semicircular divide separating the Blue Nile drainage system from other drainage systems. The principal high mountains are Mt. Guna, Mt. Abuya Myeda, Mt. Woti, Mt. Meghezez, Mt. Foeta, Mt. Boti, Mt. Beda Roge, Mt. Great Jibata, and Mt. Amara. Within the central portion of the Blue Nile River Basin there are also a number of high mountain masses, such as the Chokke Mountains, Mangestu Mountains, Yecandach Mountains, Mt. Amba Farit, Mt. Salale, and Mt. Belaya. Some of the high mountains are crested with beautiful crater lakes, such as Lake Wenchi and Lake Dendi south of Agere Hiywet (Ambo). A very young phase of volcanism formed several other small crater lakes, such as the three lakes in the headwaters of the Birr River and Azena tributaries and the two small ones on the Yecandach Mountains.

No doubt these huge, erruptive centers controlled the course of the Blue Nile River, which makes a very long, semicircular route, flowing southeasterly from Lake Tana, then in large circular bend over the plateau area before heading west and then northwesterly from the plateau into the lowlands of the Sudan.

Canyons

The deep vertical entrenchment into the plateau has formed one of the world's most spectacular canyons, exposing thousands of meters of volcanic, sedimentary, and metamorphic rocks, each formation of which has its peculiar or distinctive physiographic features.

Generally speaking, erosion of the "plateau" volcanics forms rolling ridges and valleys with high, mostly vertical faces at the edge of the plateau and canyons. The sedimentary rocks are eroded into gentler slopes, but precipitous cliffs are formed by the harder beds, such as limestone and sandstone, and appear in contour patterns along the sides of the canyon. Where the harder beds cap the ridges, small intervalley plateaus are common. The metamorphic rocks erode into variable physiographic forms, depending upon the rock types and structure.

The physiography of Ethiopia involves chiefly two of the major rock types--volcanics of Tertiary age, and metamorphics and granitics of Precambrian age. The sedimentary rocks crop out in the canyons and occupy a relatively small portion of the total plateau area. However, the past history and present geologic structure are largely revealed by the wedge of sedimentary rocks between the volcanic cap and the "basement" metamorphic rocks.

The basement rocks were laid down in a shallow sea that spread over a small portion of southeastern Africa. The deposits left by this marine invasion provide a classic cycle of rocks laid down during the advance and retreat of the sea, which moved in gradually from the southeast or the Arabian Sea and Indian Ocean across Somalia, Ethiopia, and as far as the Sudan, and then retreated again. Rocks of Triassic, Jurassic, and Cretaceous periods of the Mesozoic era are all represented. This wedge of sedimentary rocks thickens in a southeasterly direction, with its thin edge extending into the present geographic boundaries of the Sudan. Except as interrupted by the Great Rift faulting, the general or regional dip is also to the southeast.

Erosion of the Blue Nile Canyon has exposed large sections of the sedimentary rock, consisting of sandstone, shale, gypsum, and limestone beds. As structural deformation has been minor on the Ethiopian plateau, the beds are essentially flat-lying and have been disturbed only by gentle folds and minor faults.

Because of the southeasterly dip and possible nondeposition, the top and younger beds crop out only in the southeasterly upstream part of the canyon and disappear in sequence from younger to older beds to the northwest. Remnants of the older Triassic sandstone crop out in the Dindir-Rahad valleys, indicating that the invasion of the sea extended at least as far as the present Ethiopia-Sudan border.

The ancient valley fillings of sedimentary rocks downstream from the Guder-Blue Nile junction may be older than Triassic and may possibly be of Paleozoic age. They consist of calcareous mudstones, dark sandstones, and shale from 300 to 400 meters in thickness, but studies have not determined the age of these sedimentary rocks.

Since the physiography is largely shaped by the rock types and structure, some interesting light might be shed on the pre-Mesozoic history by a careful study of the rocks in the vicinity of the Guder-Blue Nile junction area.

It is in this area that the most upstream exposures of the Precambrian, "basement" rocks are located. It is interesting to note that the Blue Nile River is entrenched in a very narrow gorge in an island or ridge of metamorphic rock surrounded by Adigrat sandstone. After crossing the metamorphic ridge, the river passes through a short stretch of Adigrat sandstone before it again becomes entrenched into an intervalley gorge in the peneplained basement rocks. The peneplained surface is very obvious in this portion of the canyon. Downstream from the vicinity of the Guder River, the Blue Nile remains in Precambrian rock all the way to and beyond the Ethiopia-Sudan border, except for the two small stretches upstream and downstream from the mouth of the Finchaa River, where dark sandstone and shale up to 400 meters or more in thickness appear to be ancient valley fillings in old drainage systems in the crystalline rocks.

The western half of the Blue Nile River Basin is almost all metamorphic and granitic rocks except for "younger" volcanics and small patches of "plateau" volcanics capping the high peneplained surfaces of Precambrian rock.

The old, arched, peneplained surface that is very prominent in the canyon downstream from the mouth of the Guder River has an apparent southeasterly dip, corresponding somewhat to the dip of the sedimentary formations and indicating that the entire land area may have been slightly arched with the general uplift of the plateau. Deep erosion has removed most of the old peneplained surfaces in the western part of the Blue Nile River Basin.

Some steep southeasterly dips have been noted in volcanics, but these dips may have been the result of local faults or very late tilting associated with the rift valley faulting.

Lakes

Lake Tana is the only well known lake in the Blue Nile River Basin and is generally considered to be the head of the Blue Nile River. It serves as a collecting basin for several large streams and a number of less important streams that are part of the Blue Nile River system. It is generally less than 14 meters deep, with an area of about 3,000 square kilometers. It is about 1786 meters above sea level and has potential value for development of hydroelectric power and irrigation.

Except for Lake Tana, other lakes in the Blue Nile River Basin consist of small volcanic crater lakes, generally located in the top of high mountains. Lake Dendi and Lake Wenchi, south of Agere Hiywet (Ambo), are locally known and are beautiful, semicircular bodies of water in the throat of old craters. They are about 2 and 1/2 to 3 kilometers in diameter and are above 3050 meters in elevation. There are several small crater lakes at the head of the Birr River and the Azena drainage systems and three small lakes are on the Mangestu and Amoneous Mountains.

The Chomen Swamp, at the head of the Finchaa River, and the Dabus Swamp were formed by flows of younger volcanic rock that reduced the rate of erosion and flattened the stream gradients.

MINERAL RESOURCES

From reconnaissance studies made in the Blue Nile River Basin and a review of the few existing reports, it is concluded that Ethiopia, and particularly the area within the Blue Nile River Basin, is not rich in mineral wealth. In Ethiopia, as elsewhere in Africa, metalliferous ores are almost entirely confined to the Precambrian rocks. A considerable variety of mineral occurrences has been reported but unfortunately never in sufficient concentration and extent to be an important source. The only metallic minerals of importance are gold and platinum.

Gold

Gold has been mined in Ethiopia since prehistoric times; from 1899 to 1934, 15,250 kilograms of gold were produced, mainly from Beni Shangul and Eritrea. In Beni Shangul, alluvial deposits occur in the Shirkole and Yabus streams west of Asosa and east of Kurmuk. At Shirkole the average tenor is 0.4 gram of gold per cubic meter. In Wellegga Province, alluvial and primary quartz-vein deposits occur in a belt extending north from Yubdo. The alluvial deposits average 0.3 gram of gold per cubic meter, together with some silver. The quartz veins intruded into various schists and gneisses contain accessory pyrite, chalcopyrite, marcasite, and tourmaline. In Gojjam Province, gold-bearing alluvial sands occur in the Blue Nile gorge at Walli, south of Wombera, in the Beles River north of Wombera, and in the hills north of the Beles River in laterite at concentrations up to two grams of gold per metric ton.

Most of the placer mining conducted in the Blue Nile River Basin is on a very limited scale in widely scattered locations. Mining is generally by excavation of small round pits along stream banks and gravel bars, and the sand and gravel containing the richest concentration of gold are carried to the streams for washing, which is done in a wood-carved bateau--a salad-bowl type of implement used for panning the gold. Mining is most active during the rainy season when water is available for washing the auriferous sands and gravels. Some mining is conducted by diversion and concentration of streamflows into gullies or channels to wash away the overburden soils from the hill slopes and then by panning the residue left in the bottom of the wash. It appears that extensive areas may contain gold that could be recovered by improved mining methods.

Platinum

Intensive platinum mining at Yubdo, near the confluence of the Yubdo and Bir Bir Rivers, Wellegga Province, was conducted between 1926 and 1938; but mining has nearly ceased. The platinum was recovered from a lateritic crust of a dunnite intrusion in the basement complex. The dunnite, associated with pyroxenite and gabbro, contains an average of 0.1 gram of platinum per cubic meter, together with associated chromite and gold. The weathered crust known as "birbirite" is all that has been exported. The platinous ore was concentrated magnetically after washing the birbirite with powerful water jets. The year of highest production was 1932 with 230.75 kilograms of platinum. In 1938, production was 110 kilograms with estimated reserves of between 2,000 and 4,000 kilograms.

The principal nonmetallic resources in the Blue Nile River Basin consist of limestone and gypsum located in the Blue Nile Canyon north of Addis Ababa and in the upstream drainage areas of the Giamma and Muger Rivers. Limestone deposits are also located in the upstream drainage area of the Guder River in the general vicinity of Agere Hiywet (Ambo).

SOILS

The soils in the Blue Nile Basin are generally either latosols or grumusols. These soils have vastly different physical characteristics. The latosols are the best soils for irrigation, but they generally occur on steep rolling topography which is difficult to develop for irrigation. The grumusols are less suited for irrigation from a soils standpoint, but usually occur on smooth topography which is fairly easy to develop for irrigation. The latosol soils are generally clay textured, but have a permeability and friability similar to a medium textured soil. Because of their inherent high permeability and excellent drainage characteristics, they are suitable for an unusually wide range of crops. Natural fertility is low, but these soils are easy to farm, will respond well to fertilization and irrigation and offer the best possibilities for successful irrigation development in the Blue Nile Basin.

The grumusols, or black soils, are also clay textured but because of a different mineral content they crack severely when dry and have a very low permeability. Irrigation would need to be done by filling the cracks rather than through normal infiltration processes. The poor tilth and restricted internal drainage characteristics of these soils may limit their crop adaptability to shallow rooted crops. Their natural fertility is higher than latosol soils, and for some crops, such as pasture grass, they may have a higher crop yield. These soils are better adapted to farming with tractors and other heavy equipment than with hand tools.

CLIMATE

The climate of the Blue Nile River Basin, particularly on the plateau, is generally considered to be temperate despite its tropical location, because of its altitude. However, there is considerable seasonal variation in climatic conditions. The major variation is from drought in the dry season (October through May) to the very heavy rainfall during the rainy season (June through September). During the rainy season the storms are of the intense but scattered thunderstorm type and of short duration. Such rains as do occur during the drought period are of a more gentle, widespread, cyclonic nature.

Three general climatic zones have been established with elevation and temperature the controlling factors. The K'olla zone lies below 1800 meters (5900 feet) and has a temperature range from 4° to 49° C (40° to 120° F). The average temperature ranges from 20° to 28° C (68° to 82° F), and the days are hot but the nights are usually moderate.

The Woina Dega zone lies between 1800 and 2400 meters (5900 and 7870 feet), and the average temperature ranges from 16° to 20° C (61° to 68° F). The days are warm but the nights are cool. The sun is hot during the day, but the air, because of the altitude, is cool, and to gain relief from the sun one has only to seek the shade.

The Dega zone, above 2400 meters (7870 feet), has a cool climate. The sun's rays are intense and the air is cool. Average temperature ranges from 10° to 16° C (50° to 61° F) and occasionally nighttime temperatures may fall below 0° C (32° F). The annual rainfall varies with elevation, and some locations in the Dega zone receive as much as 2,000 millimeters (79 inches), while some areas in the K'olla zone may receive as little as 500 millimeters (20 inches).

The rainy season brings with it a reduction in the variation between the daily highs and lows of temperature. The cloud cover and greater amount of moisture in the air are sufficient to prevent such wide daily ranges as occur during the dry season. No frosts occur during the rainy season. They do occasionally occur during the dry season at elevations above 2000 meters (6560 feet), primarily during the month of January, but they are so infrequent that they are not generally considered as a hazard to crops.

Debre Markos, which is near the upper limit of the Woina Dega zone at 2313 meters (7576 feet), is near the center of the Blue Nile River Basin and has a climate quite representative of the general plateau area. The table indicates the average temperatures and rainfall.

Temperature and Rainfall, Debre Markos

Month	Annual precipitation (mm.)	Average daily temperature (° C)	
		Maximum	Minimum
January	18	24	7
February	20	25	8
March	57	25	10
April	92	24	10
May	73	24	10
June	171	21	9
July	403	18	10
August	328	18	10
September	223	20	9
October	76	21	8
November	22	22	7
December	16	23	7
Year	1,499	22	9

Asosa, in the western part of the basin at an elevation of about 1665 meters (5460 feet), is more representative of the lower plains.

Temperature and Rainfall, Asosa

Month	Annual precipitation (mm.)	Average daily temperature (° C)	
		Maximum	Minimum
January	0	31	13
February	1	30	15
March	2	32	15
April	74	30	16
May	108	28	15
June	191	27	14
July	297	23	14
August	251	24	13
September	213	26	14
October	138	27	13
November	20	29	12
December	8	30	13
Year	1,303	28	14

The wind, although seldom more than a gentle breeze, is strongest during the period from March through September, and it tends to sustain the evaporation rates through this period. However, dryness of the air has a pronounced effect in sustaining evaporation during the dry period. Since killing frosts are rare and occur only at the higher elevations of cultivated areas, it is believed that use of water by crops varies in about the same way as evaporation.

The average precipitation, evaporation, and estimated consumptive use of water by plants at Addis Ababa, elevation 2400 meters (7870 feet), is shown in the accompanying table.

Precipitation, Evaporation, and Consumptive Use of Water
Addis Ababa

Month	Precipitation (mm.)	Pan evaporation (mm.)	Consumptive use (mm.)
January	15	149	81
February	33	163	77
March	67	166	87
April	88	165	89
May	85	164	94
June	139	141	-
July	280	126	-
August	290	107	-
September	201	164	-
October	26	139	85
November	11	153	76
December	8	155	79

Rainfall throughout the basin exceeds the consumptive use requirement for the period of June through September, and therefore no requirement has been computed for that period. Approximately 80 percent of the annual precipitation occurs from June through September. During the remainder of the year it fails to meet the full consumptive use demands of plants. Supplemental water must be provided during this period if full crop production is to be achieved.

Generally, the climate on the plateau is pleasant and healthful, but on the lowlands it is more harsh and presents more difficult problems to those who choose to live in the area under present conditions.

HYDROLOGY

SURFACE RUNOFF

The Blue Nile River Basin has a mean annual runoff of 55,000 million cubic meters (45 million acre-feet), supplying approximately two-thirds of the total Nile River flow below Khartoum in the Sudan. The Blue Nile River starts from Lake Tana with an annual outflow of 4,000 million cubic meters. In its 900-kilometer (560-mile) course between Lake Tana and the Sudan border, the river falls 1,299 meters (4,262 feet) from elevation 1786 meters (5860 feet) to elevation 487 meters (1598 feet). The major tributaries contribute the following quantities in millions of cubic meters: Beshilo, 4,000; Giamma, 2,000; Guder, 2,000; Birr, 3,000; Diddessa, 13,000; Dabus, 5,000; and Beles, 3,000. An additional 3,000 million cubic meters from the Dindir River and 1,000 million cubic meters from the Rahad River join the Blue Nile flow in the Sudan. This runoff distribution is shown schematically in Figure 4.

Since 80 percent of the annual precipitation is concentrated in the 4-month June-through-September period there is understandably a wide fluctuation in the runoff. In the basin as a whole, 83 percent of the annual runoff occurs in the 4-month July-through-October period, with the August quantity being 47 times the April quantity.

There were no gaging stations in operation in the Blue Nile River Basin when this investigation started. One automatic recording station, and a cableway across the river for making measurements, had been constructed a few years earlier at Kese. Only a few measurements had been made before the station was allowed to become inoperative. The records from this station were meager and of limited value.

During the course of previous investigations of the possible use of Lake Tana as a storage reservoir, measurements of the Blue Nile flow just below Lake Tana were made and records were available. There were no records to indicate that measurements in Ethiopia of the Blue Nile River at other locations or on any of the tributary streams had ever been made. The Government of the Sudan had operated a gaging station at Roseires a short distance below the Ethiopian border for many years, and these records were obtained.

The establishment of stream gaging stations was given a high priority. The gage at Kese was reactivated, and lake stage recorders were installed on Lake Tana prior to the beginning of the first rainy season. Plans were developed for a network of stations located at strategic points on the river system to provide the required data to estimate streamflows at various locations.

As the investigation proceeded, 59 stations were constructed and placed in operation, and all were operated for 1 year or longer. Twenty of these stations included cableways from which the stream could be measured; of these, three were bank-operated installations. At the other stations measurements were made by wading or from boats or nearby bridges. Twenty-one of the stations included stilling wells with instruments to record the water level on a continuous basis. From these recordings the streamflow could be determined after a rating curve was developed from a series of measurements. Eighteen of these were float-activated recorders and three were bubble type, which also recorded on a continuous basis. The remaining 38 were staff gages, which were read twice daily by local observers.

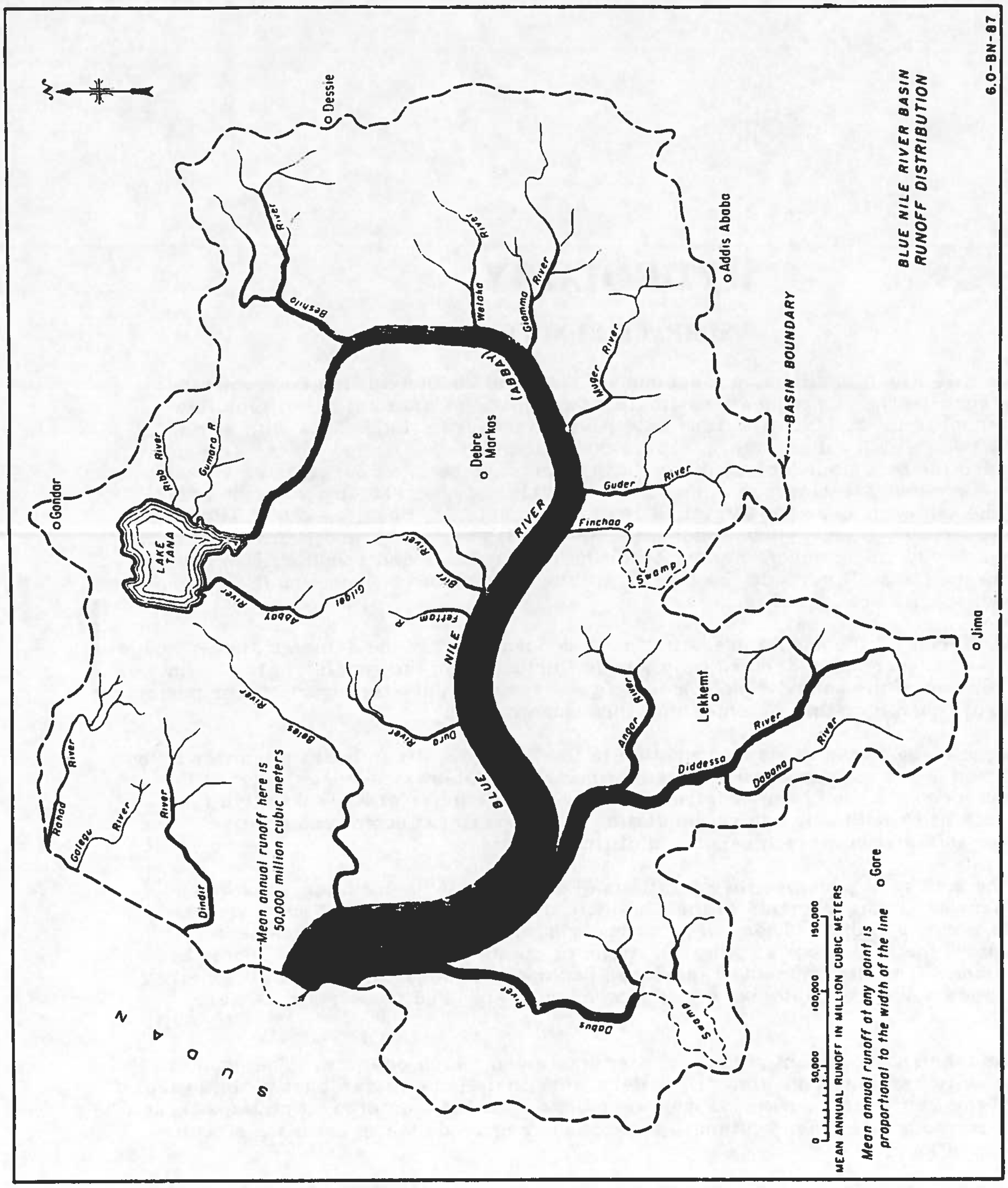


FIGURE 4--Runoff Distribution, Blue Nile River Basin

Figure 5. The Blue Nile as it emerges from Lake Tana.

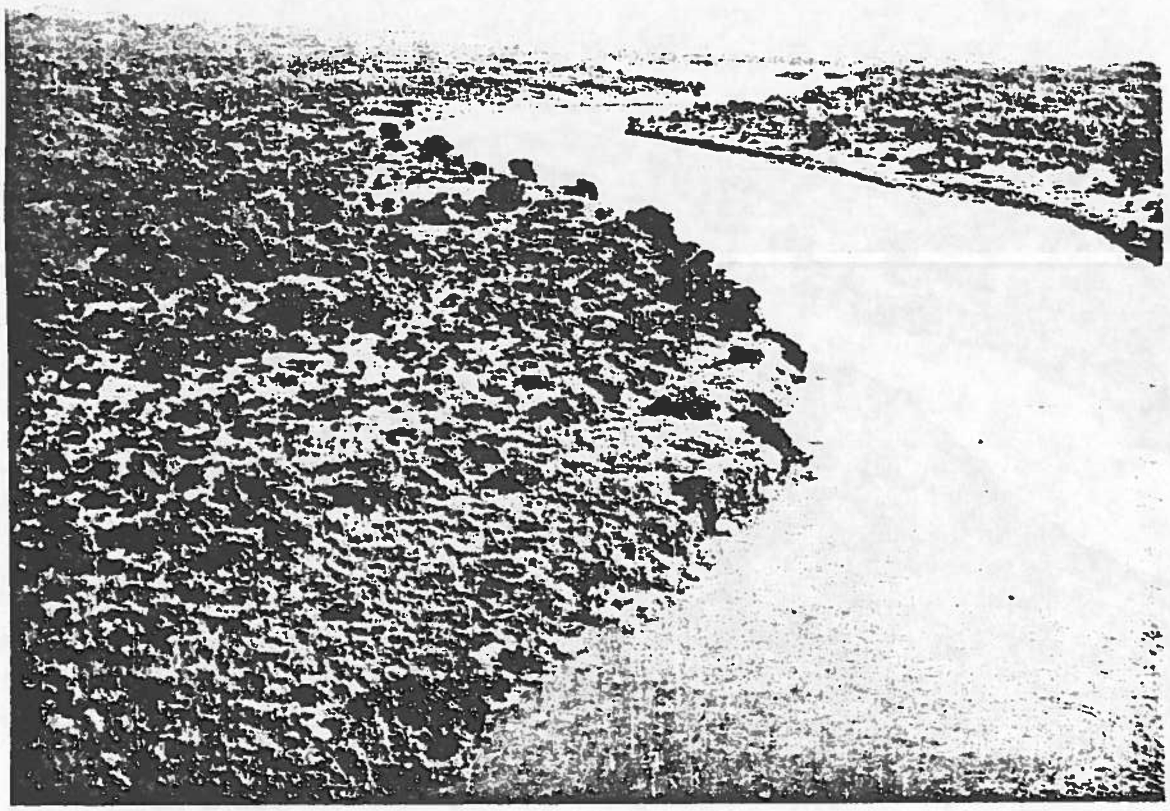


Figure 6. The Blue Nile River near Shegali during high water.

Figure 7. Blue Nile River as it flows through Karadobi Reservoir area.

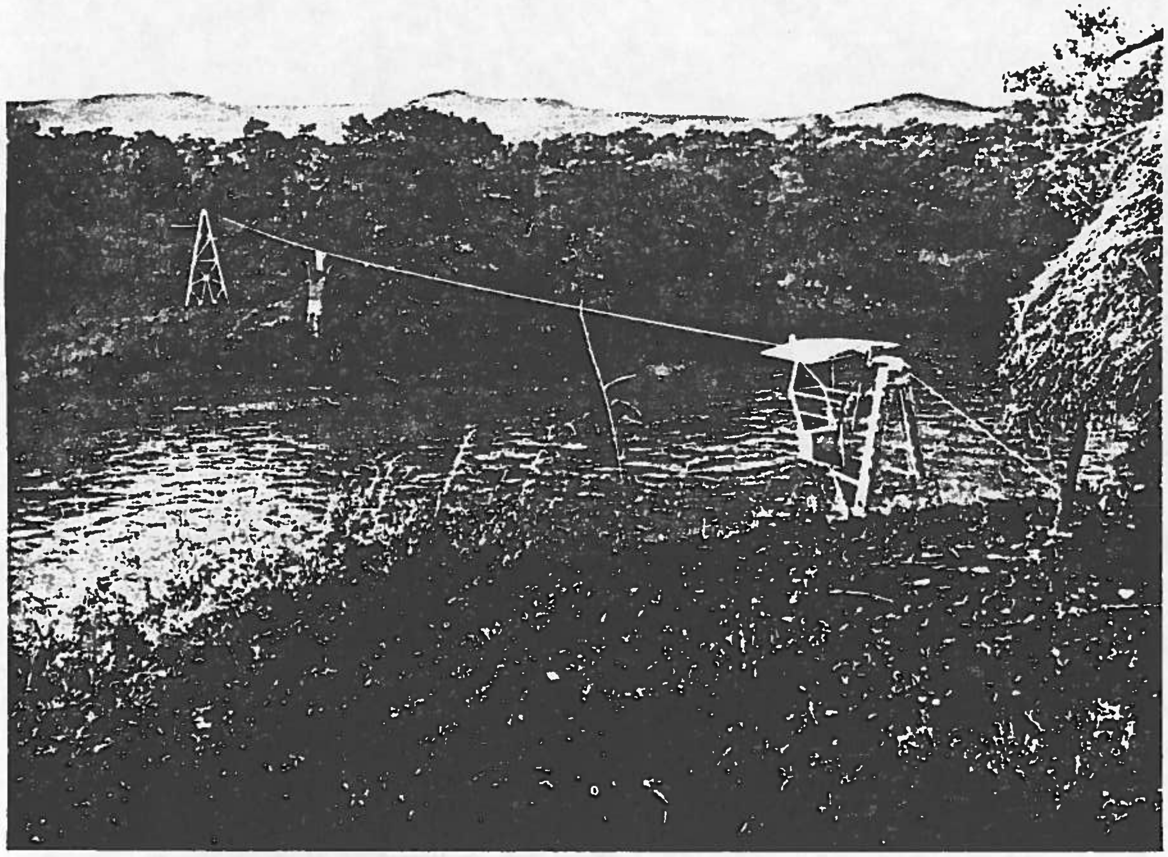


Figure 8. A cableway for measuring the flow of the Rahad River.

LAKES AND SWAMPS

Lake Tana is the only large lake in the basin. Although the mean annual inflow to the lake is about 9,000 million cubic meters (7.3 million acre-feet), over half of this is lost to evaporation on the 3,000 square-kilometer lake surface, so that the outflow is only about 4,000 million cubic meters (3.2 million acre-feet). Since the lake has such a large storage capacity, it acts as a regulator on the outflow.

The Chomen Swamp, from which the Finchaa River originates, covers an area of about 600 square kilometers (230 square miles) south of the Blue Nile and northwest of Addis Ababa. It is shallow, and although there is some fluctuation in the water surface between the dry and the rainy seasons, the swamp is covered with papyrus reed and water grasses.

The Dabus Swamp, in the southwest part of the basin, is at the headwaters of the Dabus River and is the largest swamp in the basin. About 900 square kilometers (350 square miles) in extent, it also is covered with papyrus and swamp grasses.

Rates of loss by evaporation and transpiration in the swamp areas are probably as great as those on Lake Tana, when compared on an area-for-area basis. However, Lake Tana has the largest surface and therefore the greatest effect on the basin as a whole.

There are a few small lakes and swamps that are of little significance from the standpoint of resource development. They are of local importance, as they generally provide the water supply for nearby villages or farms.

GROUND WATER

Ground water is defined as water from the zone of saturation or that zone below the water table in which all openings or interstices are filled with water. Naturally the occurrence, the quantity, and the quality are dependent upon many factors, including rainfall and geology. At the present time, utilization of the ground water in the Blue Nile River Basin is limited to the flow from springs, hand-dug shallow wells, and a few deep wells that have been drilled to obtain a potable water supply for municipal and domestic uses.

The limited scope of this investigation and the lack of drilling equipment that would have made possible some ground-water exploration, preclude more than a very rough evaluation of the ground-water potential of the basin.

The geology of the plateau, with its fairly tight basaltic cap covered with slowly permeable clays, and the scarcity of ground-water outcrop in the deeply eroded canyons do not suggest the presence of large quantities of ground water. The streams reflect only a very slow yield from ground water, since their flow is almost entirely depleted soon after the rains cease. However, the wells that have been dug and other observations indicate that generally an adequate water supply from ground-water sources for domestic use could be obtained at most locations within the basin. Some unsuccessful wells have been dug, but this is usually because they were dug too near the escarpment where the water was being lost down the steep slope of the ground-water surface. There may be aquifers in some parts of the basin where wells could be developed to yield adequate quantities for irrigation or for industrial uses. However, an extensive exploration program would be required to identify and evaluate the potentials of those areas. Wherever the water is drawn from the basaltic cap, it can be expected to be of good chemical quality.

The population is now concentrated on the plateau or higher mountain areas. Except for some of the larger towns, most water supplies come from nearby streams that dry up during the drought period and frequently it becomes necessary for the people to carry water for household use from streams or ponds far away from their homes.

WATER QUALITY AND SEDIMENTATION

Analyses of the water quality samples collected through the basin indicate that all significant flows in the basin are suitable for irrigation water.

A limited sediment sampling program indicates that sediment loads vary, depending upon such factors as runoff, topography, soil, and vegetation, but are fairly high in streams throughout the basin, averaging about 1 percent by weight of the total runoff.

WATER USE

Present use of water in the basin is limited. There are small hydroelectric plants at Agere Hiywet (Ambo) and Debre Birhan, of 210- and 125-kv.-a. capacity, respectively. A 9,600-kv.-a. capacity plant is under construction at Tis Isat Falls below Lake Tana. There are hydromechanical mills for grinding grain, and small, direct-diversion, irrigation canals 1 or 2 kilometers in length at several locations on the plateau. Domestic water is supplied in a very few towns in a municipal-, military-, or church-operated system having a water storage tank and a distribution system to a relatively few hydrants. However, most domestic water is obtained from lakes, streams, or wells on a single or several family basis.

To estimate the ultimate water use within the basin, promising hydroelectric, irrigation, and multipurpose projects were considered together in an Initial Development Plan.

The short-time streamflow records obtained within the basin were correlated with longer records downstream in the Sudan on the Blue Nile, Dindir, and Rahad Rivers to estimate flows at the various reservoir sites.

An examination of the record of the Blue Nile at Roseires disclosed that during the period of 1911 through 1917 there occurred the most severe drought of record, yet total flow for this period was about equal to total flow for other periods of equal length. For the purpose of this study, this was considered to be the critical period and was adopted for operation study purposes for all reservoirs except those on the Dindir and Rahad drainage systems where records in the Sudan permitted the selection of a longer study period.

Studies were made for the water supply of 26 reservoirs to provide storage and regulation for irrigation and hydroelectric power projects. It was assumed that each would be constructed essentially according to plans described elsewhere in this report and in an upstream-to-downstream sequence. The flow at each site was assumed to be somewhat smoothed out and to some extent depleted by regulation at each of the sites above it. Sediment reaching an upper site was assumed to be deposited there and prevented from reaching a lower site. In planning reservoirs, sufficient capacity was provided so that, after 50 years of sediment deposition between the spillway crest and a minimum operating level high enough to provide head for making required releases through the outlets, adequate storage would be provided to meet project requirements. The outlets were placed at an elevation where their operation would not be impaired by 100 years of sediment accumulation. In 50 years a total of approximately 20,000 million cubic meters of sediment would be intercepted in the 26 reservoirs.

Maximum probable inflow floods were estimated for all storage reservoirs for use in spillway designs and reservoir flood routing studies, and flood frequency estimates were made at all damsites (storage and diversion) in the Initial Development Plan.

In addition to the 26 reservoirs previously discussed, several small potential developments were studied with even less intensity. Very limited data were available. Therefore, only a brief discussion of these projects is included in the report. The studies of the 26 reservoirs did not consider depletions from these sites.

The average annual runoffs, both natural and as modified by the Initial Development Plan, have been tabulated by projects in million cubic meters for given study periods.

Below damiste or irrigation project	Study period	Natural runoff	Modified runoff
Ker Quosquam	1911-17	1,813	1,058
Megech	1911-17	82.4	35.8
Ribb	1911-17	308	215
Gumara	1911-17	256	164
Tana	1911-17	3,779	402
Beles Irrigation	1911-17	227	2,635
Dangur	1911-17	2,060	3,803
Giamma	1911-17	1,396	1,328
Chancho	1911-17	158	145
Bello	1911-17	193	163
Motto	1911-17	1,269	1,177
Finchaa	1911-17	371	249
Amarti-Neshe	1911-17	331	246
Lower Birr	1911-17	940	686
Debohila	1911-17	55.3	52.6
Diddessa	1911-17	1,479	1,340
Dabana	1911-17	1,461	1,380
Boo	1911-17	7,304	6,481
Angar	1911-17	948	804
Lekkemt	1911-17	2,414	2,086
Dabus	1911-17	4,149	4,034
Junction	1917-38	1,203	1,105
Dindir	1917-38	2,022	1,190
Galegu	1917-38	254	234
Rahad	1939-45	1,168	451
Karadobi	1911-17	17,830	14,455
Mabil	1911-17	25,802	21,345
Mendaia	1911-17	37,933	33,117
Border	1911-17	45,667	41,799

Hydrographs of the natural and regulated flows below the Border damsite are shown on Figure 9. The flows now reaching the Ethiopia-Sudan border would be depleted by irrigation uses and evaporation losses from reservoir surfaces by about 5,400 million cubic meters annually (10 percent). In addition, a smaller quantity may be required to meet domestic, municipal, and industrial requirements in future years as the population increases and economic developments cause the now sparsely used areas of the Empire to become utilized.

Regardless of the depletion to meet the needs of Ethiopia, where the stream originates, the developments as considered should have little if any adverse effect on projects of downstream nations dependent upon these flows for hydroelectric power, irrigation, navigation, and other minor uses, because of the regulation that can be provided by the upstream storage and the trapping of sediment before it reaches the reservoirs of the downstream nations. In fact, the upstream developments, if operated in the most efficient manner considering the requirements of all users, would benefit downstream users by extending the useful life of the reservoirs, providing an assured water supply even in drought years, and making available a source of electrical energy that would permit the downstream nations to utilize more of the water entering their countries in the beneficial use of irrigation for the production of crops.

Since this study was limited to the Blue Nile River Basin in Ethiopia, only the potential uses in Ethiopia of water stored in main stream reservoirs were evaluated. However, it is entirely possible that the Sudan may have large areas of irrigable land, for which they do not have a firm water supply, that could be irrigated with water stored in Ethiopian reservoirs if satisfactory arrangements between the two countries could be made.

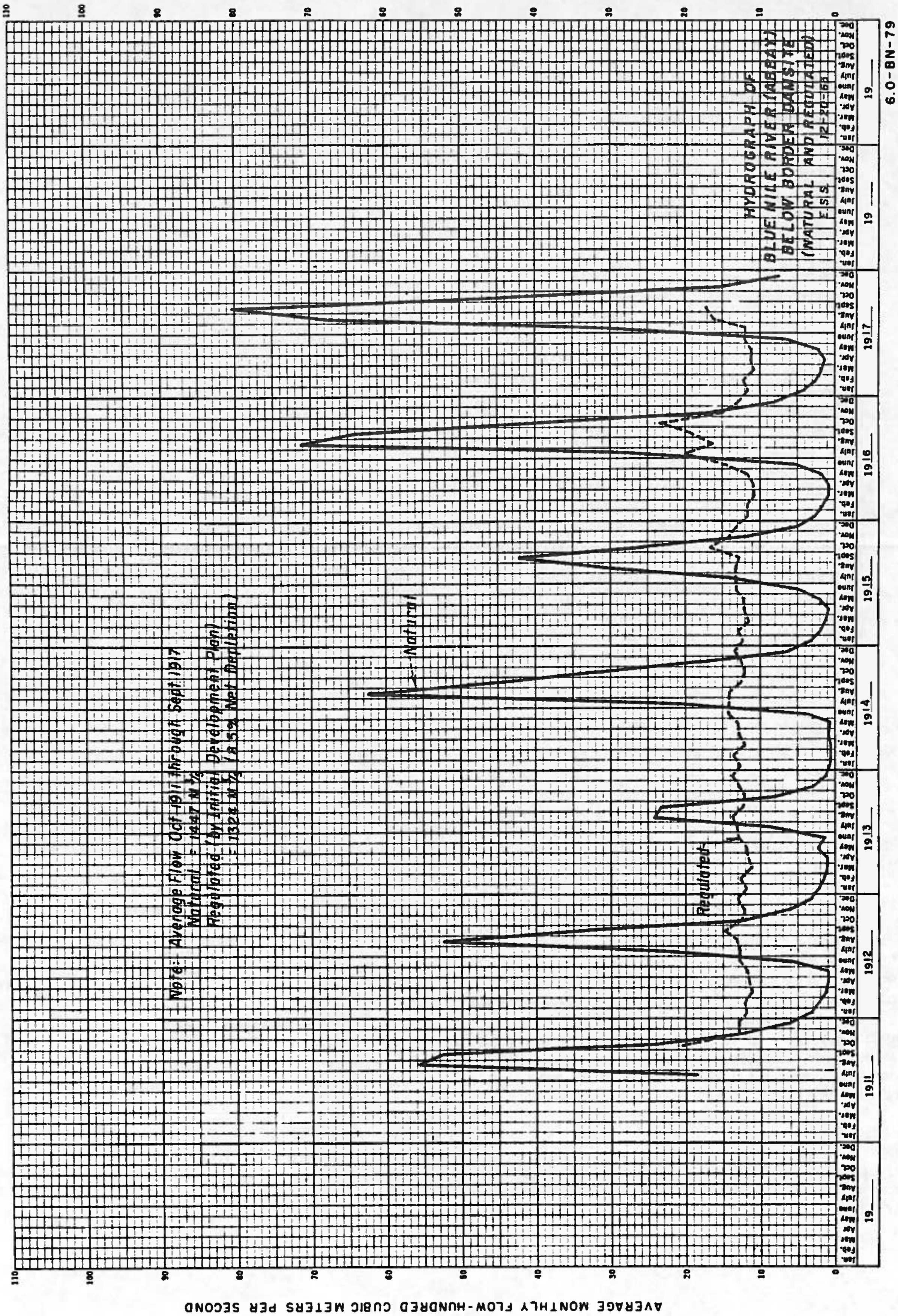


Figure 9--Hydrograph of Blue Nile River below Border Damsite

WATER REQUIREMENTS

The consumptive use of crops was estimated by the Blaney-Criddle procedure with k factors (empirical coefficients for various crops) recommended by Mr. Criddle, based partly on data from an experimental farm in Kenya. Effective precipitation was assumed to be limited to the consumptive use requirement in any month or 80 percent of the actual precipitation, whichever was the lesser. Farm irrigation losses were estimated to vary from 30 to 40 percent, depending upon topography. An 8-month irrigation season (October through May) was assumed as the maximum requirement. These criteria produced annual farm delivery requirements varying from 69.9 centimeters at an elevation of 2200 meters to 137.5 centimeters at an elevation of 610 meters.

Conveyance losses, seepage and operational waste before reaching the individual farms, were about a third of the total diversion requirement.

EXISTING CONDITIONS

FOREIGN TRADE

Ethiopia is primarily an importer of manufactured goods and an exporter of agricultural commodities. In value, cotton textiles represent the largest single import item, and coffee constitutes more than half of all exports as indicated on Figures 10 and 11. The second major import in value is manufactured items--steel, iron, machinery, and tools. These have shown a steadily increasing trend in recent years as has the import of vehicles, aircraft, and railway accessories. To a lesser degree, some items for domestic consumption--tobacco, beverages, etc.--have also been imported at increasing rates.

Next to coffee, hides and skins assume second place in export value, although the value of exported pulses or legumes has recently shown an increase as indicated on Figure 11, even in the face of falling prices on the Addis Ababa market, see Figure 12. Figure 13 indicates that the value of imports has consistently exceeded the value of exports during the period 1959 through 1961 and that the value of both imports and exports continues to increase.

The principal commercial cities in Ethiopia are Addis Ababa, Asmara, and Dire Dawa. All are outside the Blue Nile Basin, but these are the centers through which products from the basin flow. Addis Ababa is the major point of distribution for imports and for the collection of coffee, hides and skins, and other products for export.

For this reason, many of the principal firms engaged in foreign trade have offices in Addis Ababa. Government-bonded warehousing facilities are available at Addis Ababa, Dire Dawa, Asmara, Massawa, and Assab. Licenses are required for import and export of all commodities. The volume of imports is not limited; the licensing requirement is primarily to insure compliance with currency regulations. Exporters are required to surrender the foreign exchange proceeds of their efforts; but, in the case of re-export, the issuance of a license may also be subject to a determination of need for the item in the domestic economy.

The State Bank of Ethiopia, a government facility, is the only institution authorized to deal in foreign exchange. It has branches in the principal trading centers and in Khartoum, Sudan. Commercial financing is available at rates varying from 7 to 9 percent. The loans outstanding for a 4-year period are shown on Figure 14, which indicates their purpose and value.

Loans on a small scale for agricultural and industrial development projects are also available from the Development Bank of Ethiopia, also a government-owned facility. Figure 15 shows that loans made for agricultural purposes have slightly exceeded loans made for industrial purposes. The agricultural loans were largely for coffee.

Government planning agencies anticipate that foreign trade will constitute the third most important sector of the national economy, exceeded only by industrial and agricultural output. They recognize that unless an accelerated, sound, foreign trade is developed, the goals set for the agricultural and industrial expansion may not be achieved.

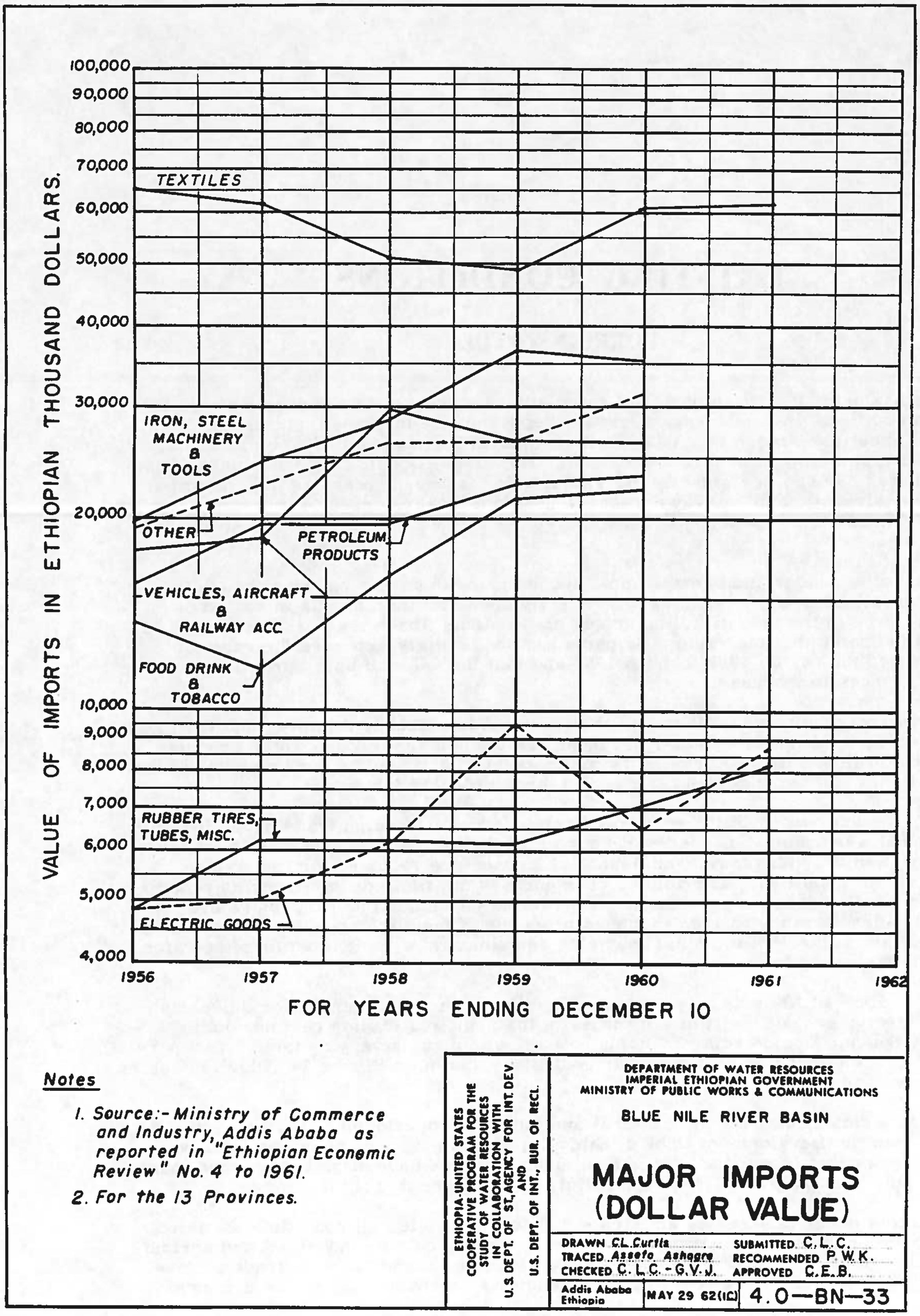


Figure 10--Major Imports (Dollar Value)

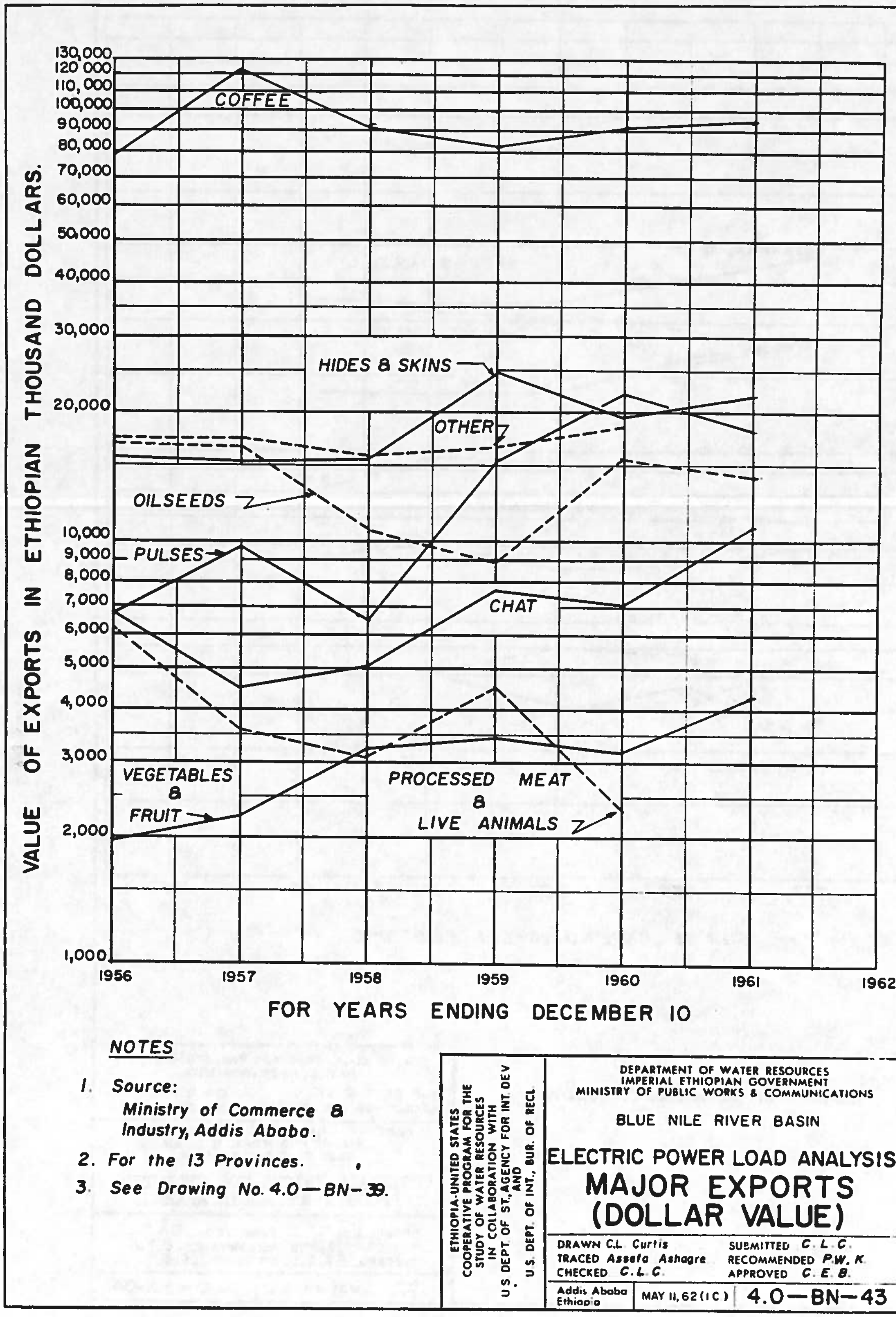
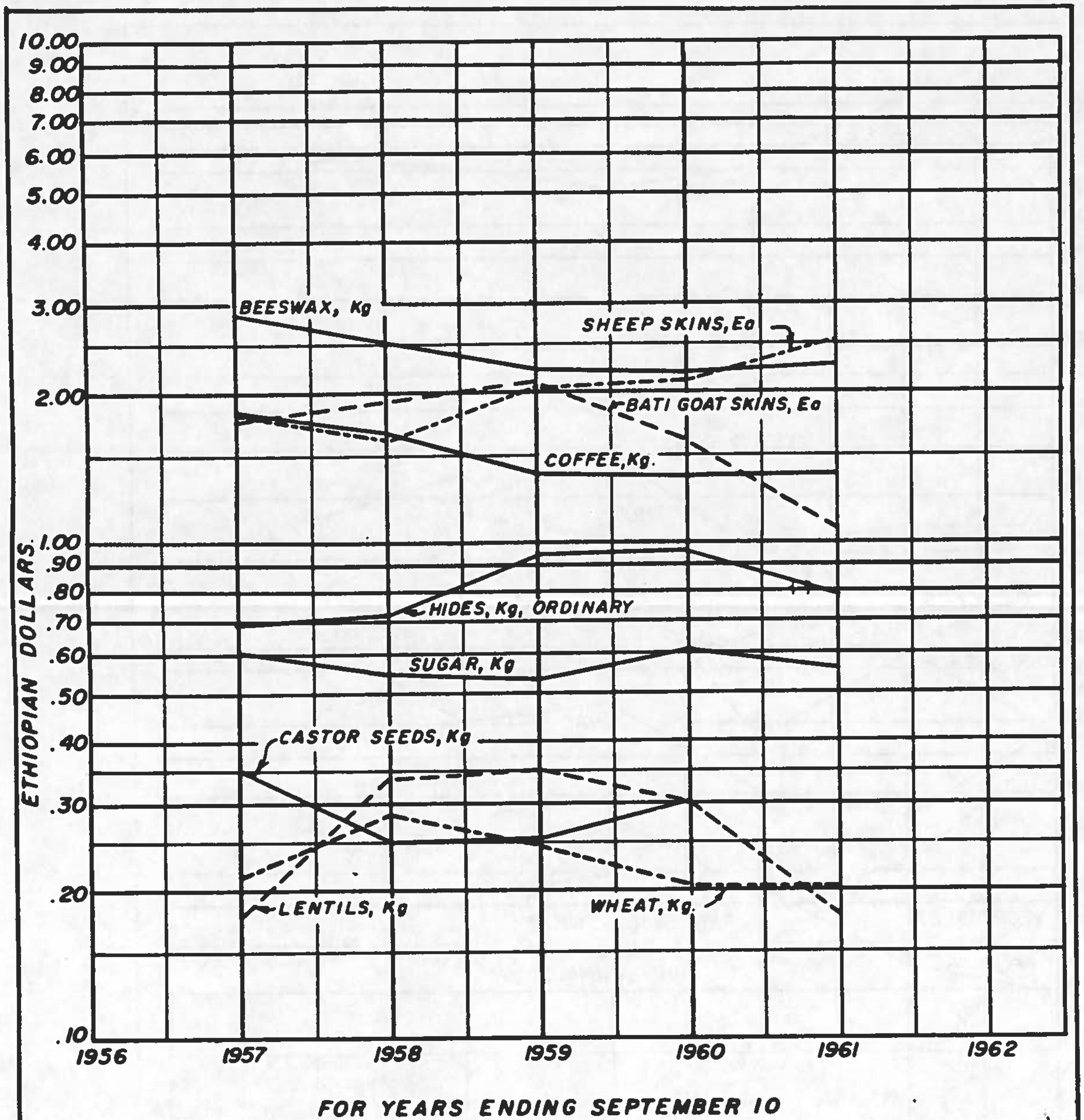


Figure 11--Major Exports (Dollar Value)



NOTES

1. Source:
   Ministry of Commerce & Industry.

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U.S. DEPT. OF ST. AGENCY FOR INT. DEV. AND U.S. DEPT. OF INT. BUR. OF RECL.

DEPT. OF WATER RES. IMP. ETH. GOVR. MIN. OF PUB. WORKS & COMM. BLUE NILE RIVER BASIN

WHOLESALE PRICES FOR SELECTED PRODUCE AT ADDIS ABABA

DRAWN C.L.C.	SUBMITTED C.L.C.
TRACED MASRESHA	RECOMMENDED P.W.K.
CHECKED C.L.C.	APPROVED C.E.B.
A.A. ETH. MAY 23, 1962	4-D-BN-34

Figure 12--Wholesale Prices for Selected Produce at Addis Ababa

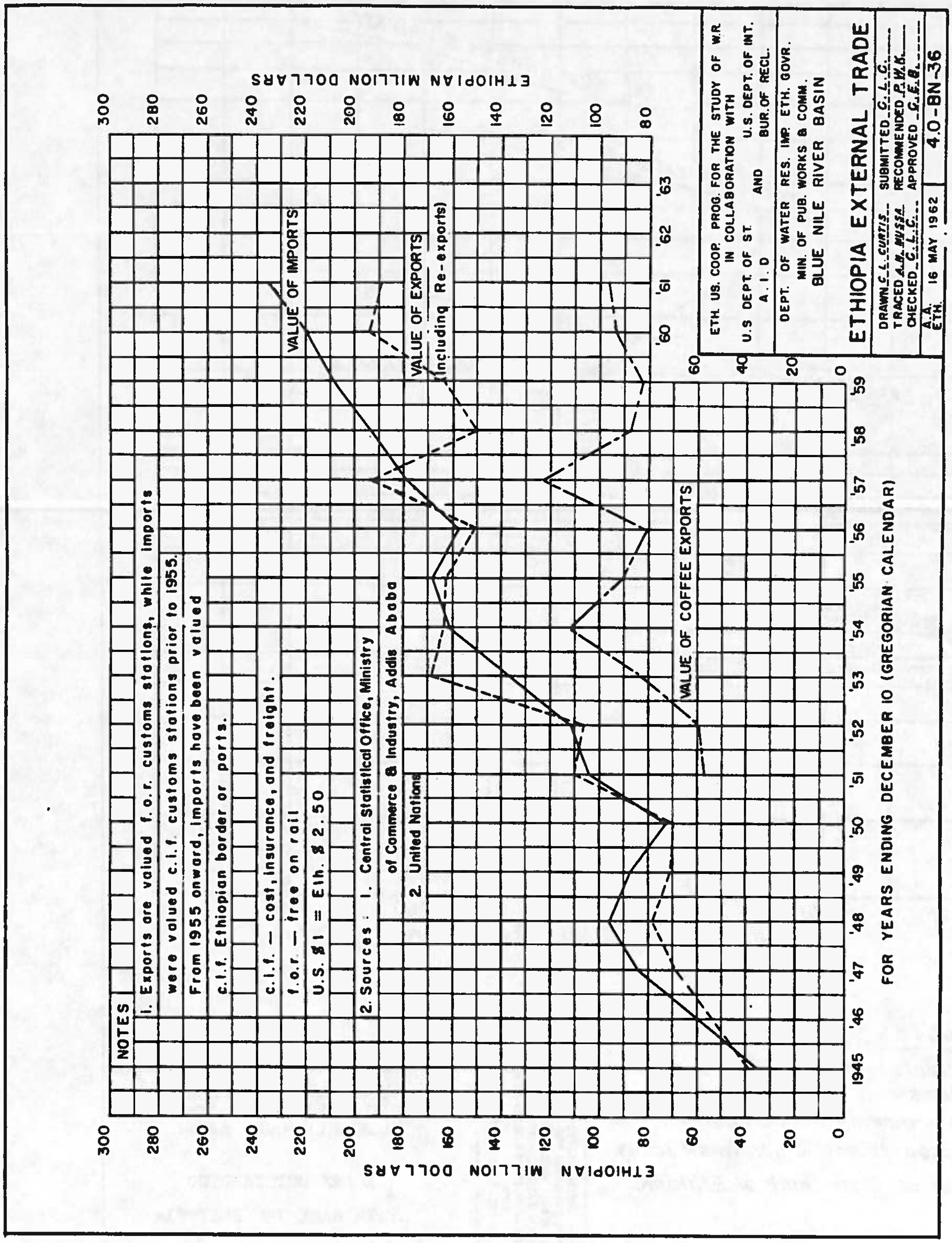
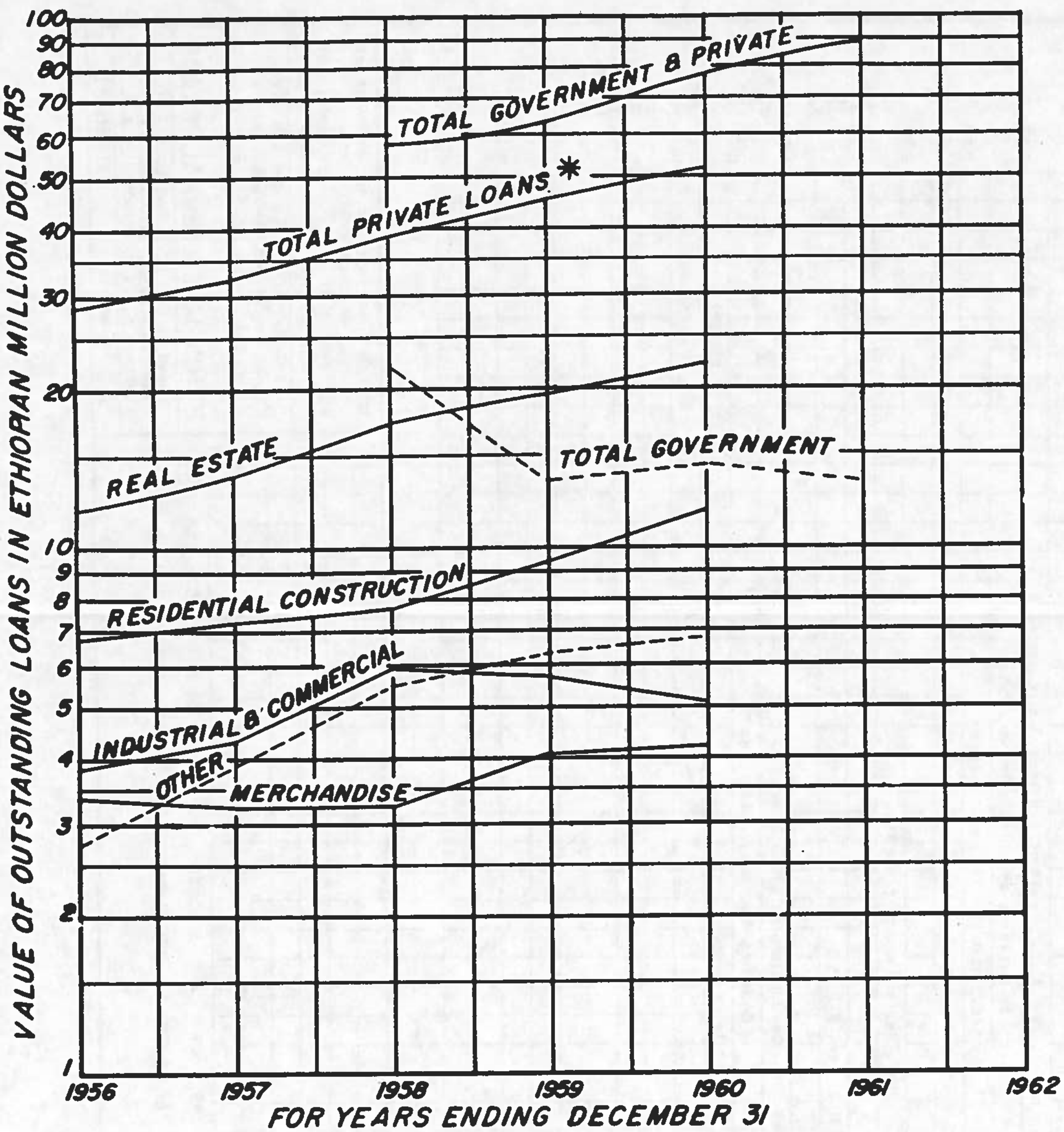


Figure 13--Ethiopia External Trade



NOTES

* 1. Private loans exclude Government loans and loans guaranteed by Government, loans on current accounts and other small loans.

2. Source: State Bank of Ethiopia.

ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM FOR THE STUDY OF WATER RESOURCES IN COLLABORATION WITH U.S. DEPT. OF ST. AGENCY FOR INT. DEV. AND U.S. DEPT. OF INT., BUR. OF RECL.

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

BLUE NILE RIVER BASIN

LOANS OUTSTANDING
STATE BANK OF ETHIOPIA

DRAWN	C. L. CURTIS	SUBMITTED	C. L. C.
TRACED	MASRESHA	RECOMMENDED	P. W. K.
CHECKED	C. L. C.	APPROVED	C. E. B.
Addis Ababa Ethiopia	JUNE 5, 1962	4-0-BN-41	

Figure 14--Loans Outstanding--State Bank of Ethiopia

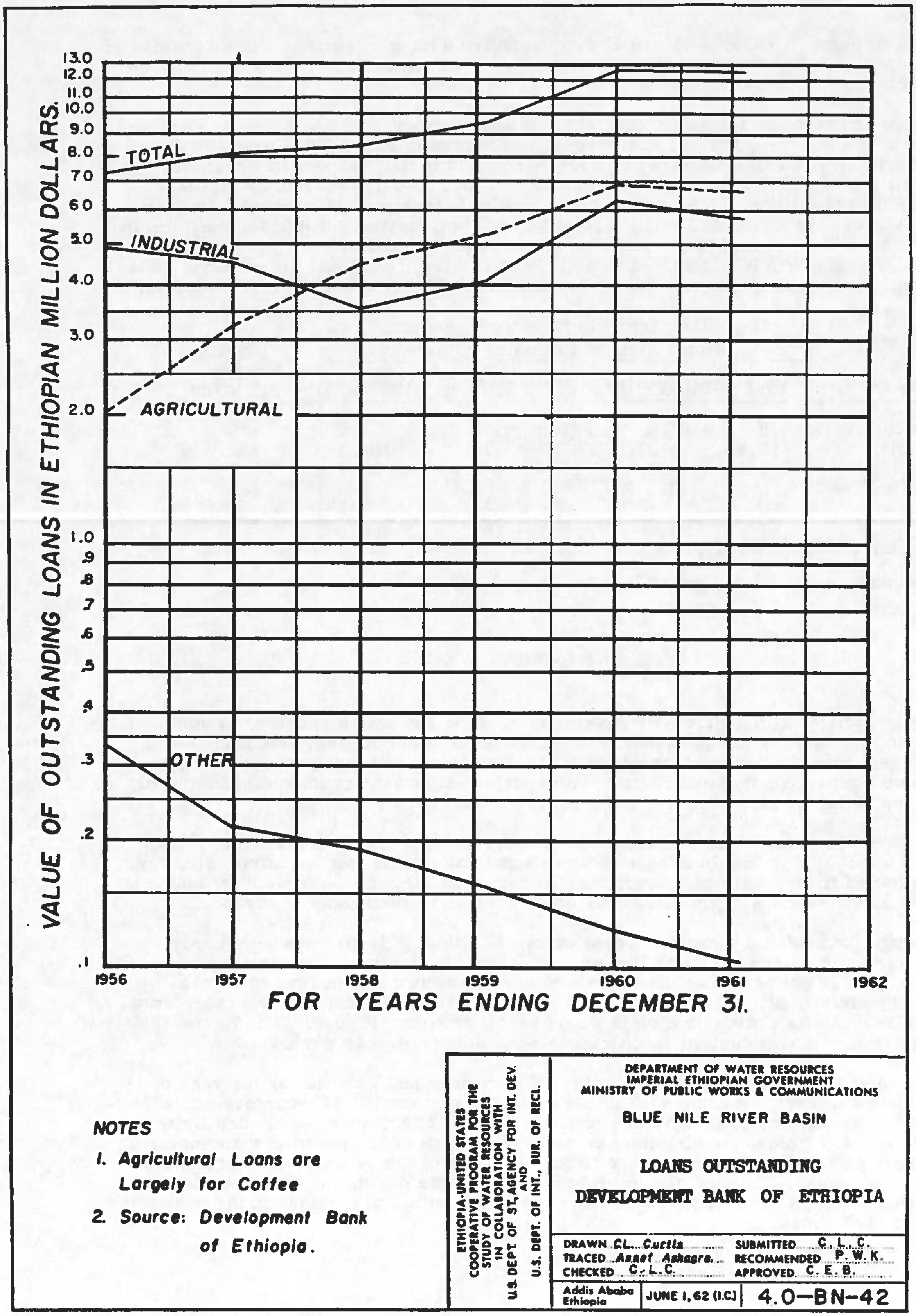


Figure 15--Loans Outstanding--Development Bank of Ethiopia

Of the total imports in 1959, Western Europe supplied 43.1 percent; the United States, 15 percent; Japan, 13.1 percent; Eastern Europe, 7.0 percent; India, 6.0 percent; and all other African countries, 2.3 percent.

The export pattern for the same year showed 26.6 percent going to Western Europe; 38.1 percent to the United States, 3.1 percent to Eastern Europe, 2.6 percent to Japan, 6.9 percent to all African countries, and 1.0 percent to India. Export forecasts for the period from 1962 to 1967 anticipate an increase of about 60 percent, from Eth$194.4 million to Eth$327 million, an average annual rate of increase of 11 percent. Imports have been forecast at Eth$319.2 million in 1967, as compared with Eth$234.2 million in 1962, for a total increase of 79 percent, or an average annual increase of 12.3 percent for the period. Exports will continue to be principally the traditional agricultural products, but it is anticipated that new industrial products will become of greater importance.

Forecast Trend in Exports by Sectors 1/

Sector	In millions of Ethiopian dollars					Index percent 1962 = 100
	Actual		Forecast			
	1962	Percent	1967	Percent	1963-67	
Agriculture	182.4	93.6	237.0	72.3	1,071.0	129
Industry	10.2	5.2	80.0	24.2	185.5	784
Mining	2.0	1.0	10.0	3.0	38.1	500
Handicrafts	0.3	0.2	0.7	0.5	2.3	233
Total	194.9	100	327.7	100	1,296.9	-

1/Second 5-Year Development Plan.

INDUSTRY

Industrial activity in the Blue Nile River Basin, as in the entire country, is confined primarily to the handling and processing of agricultural commodities; producing foods and beverages; manufacturing of items for domestic consumption; tobacco products; footwear and leather goods; construction; transportation; and the production of mineral products, including cement, bricks, salt, gold, and others.

The limited statistical data do not provide information by river basins; and, since industry in the Blue Nile Basin is to a great extent agricultural, the industrial situation is best reflected from a national standpoint. Industry in Ethiopia is expanding, and it is anticipated that the rate will accelerate as other sectors of the economy advance.

Long-range government plans foresee a change in Ethiopia from a predominantly backward agricultural economy to a modern, efficient, agricultural-industrial one by the year 1982. It is anticipated that the industrial development would occur, to a great extent, in the vicinity of Addis Ababa, but it would draw raw materials from other areas of the Empire, and its economic effects would be nationwide. Figures 16, 17, and 18 show gross industrial production comparisons over a 3- or 4-year period.

Tables 2 and 3 summarize industry in the 13 provinces and Eritrea for the year ending September 10, 1961. A study of Table 4 indicates that for the 11-year period, 1951 through 1961, the volume of industrial production for all of Ethiopia, excluding Eritrea, increased over 4.5 times. During the period 1956 through 1961, the total manufacturing output of Eritrea increased by about 1.4 times, and that of the remaining 13 provinces more than 1.8 times. The total for the Empire of Ethiopia during the same period--that is, from 1956 through 1961--showed an increase in the output of manufacturing industries amounting to 1.7 times.

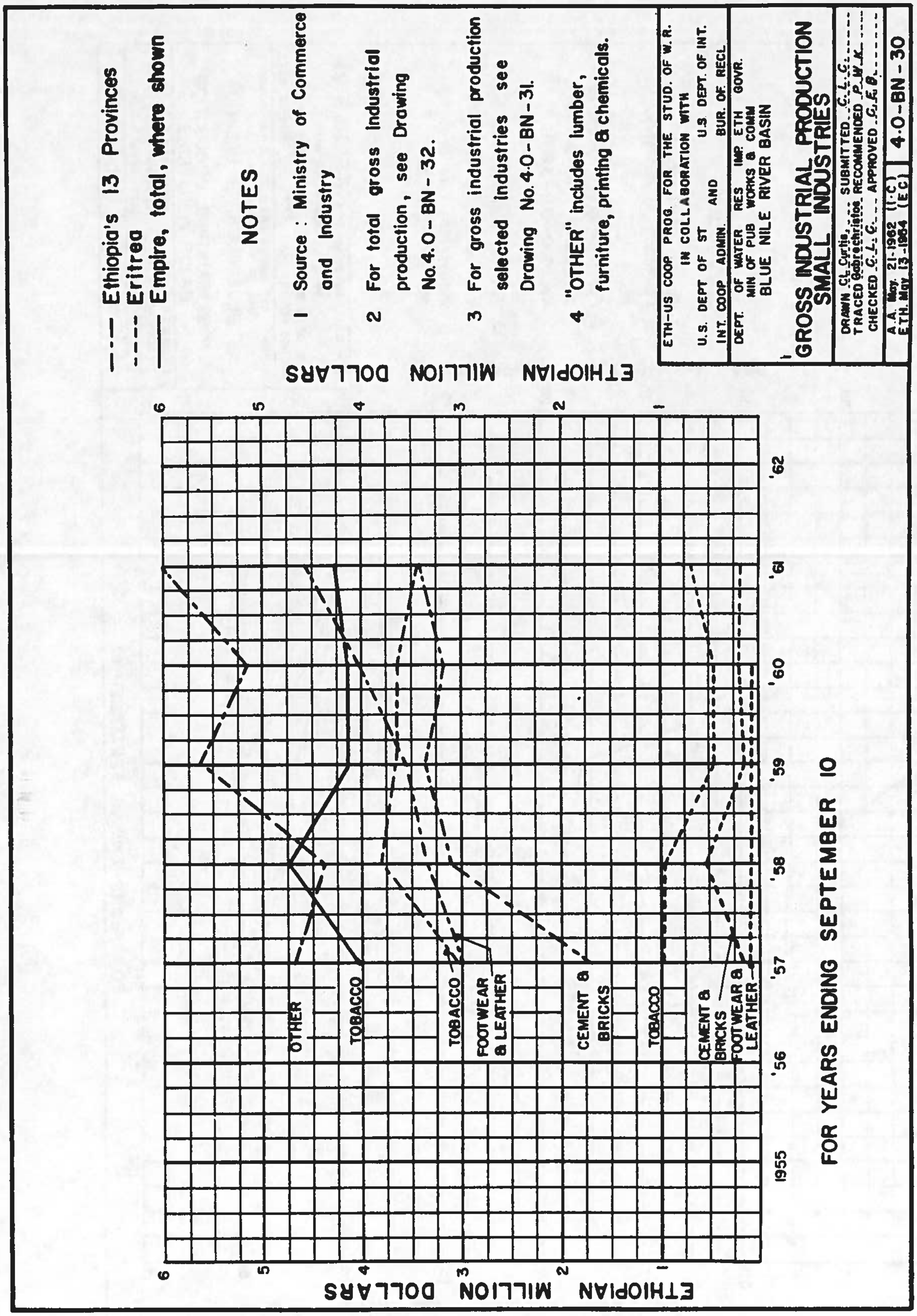


Figure 16--Gross Industrial Production--Small Industries

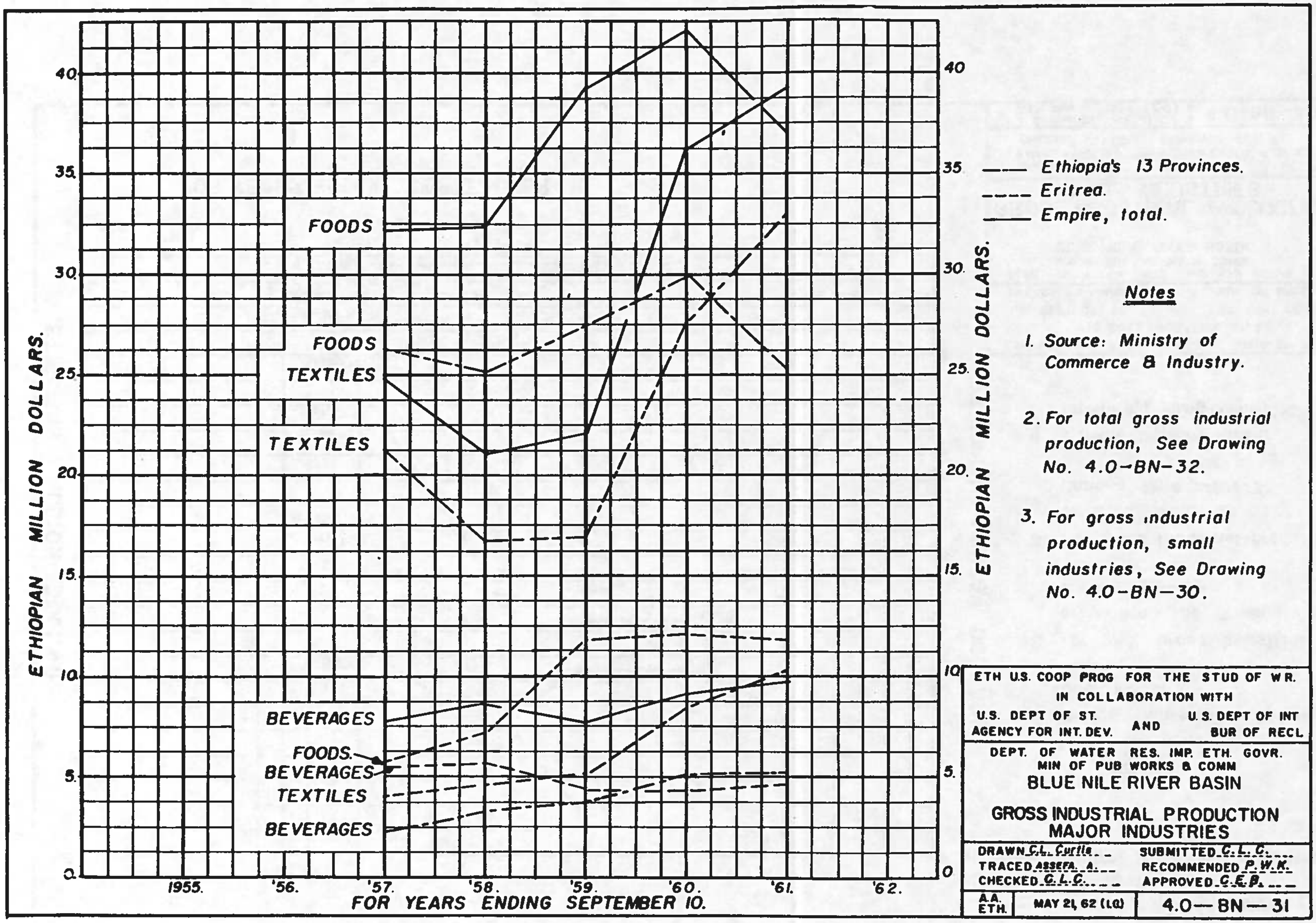
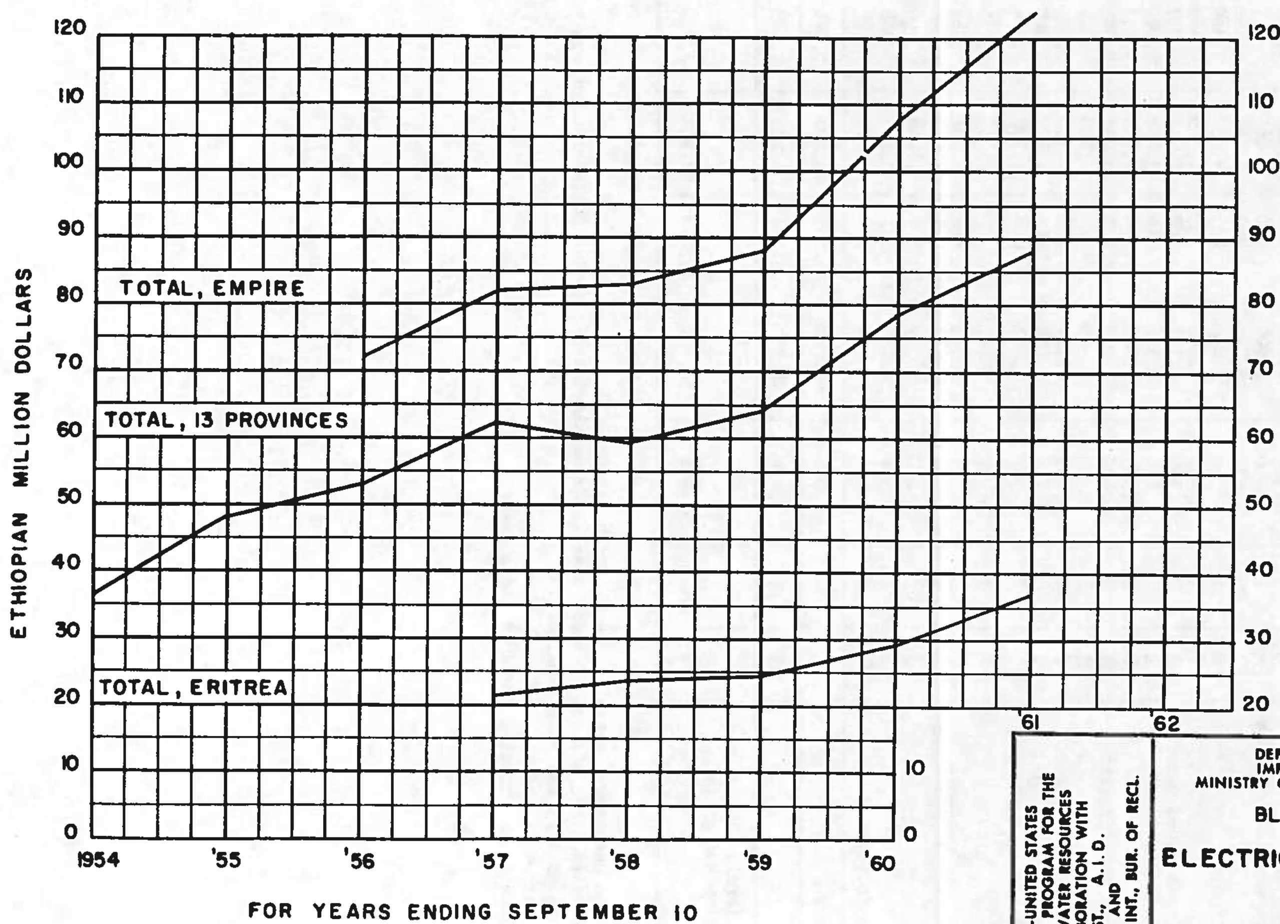


Figure 17--Gross Industrial Production--Major Industries



NOTES

1. Excludes production of rock salt in Danakil plains, certain printing presses, and some coffee and grain cleaning industries.

2. Source: Ministry of Commerce & Industry & United Nations.

3. For gross production of selected industries, see Drawings No. 4.0-BN-30 and 4.0-BN-31

ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM FOR THE STUDY OF WATER RESOURCES IN COLLABORATION WITH U.S. DEPT. OF ST., A.I.D. AND U.S. DEPT. OF INT., BUR. OF RECL.

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

BLUE NILE RIVER BASIN

ELECTRIC POWER LOAD ANALYSIS

TOTAL

GROSS INDUSTRIAL PRODUCTION

DRAWN C.L. CURTIS	SUBMITTED C.L.C.
TRACED A.N. MUSSA	RECOMMENDED P.W.K.
CHECKED C.L.C.	APPROVED C.E.B.

Addis Ababa Ethiopia | 21 MAY 1962 | 4.0-BN-32

Figure 18--Total Gross Industrial Production

TABLE 2--SUMMARY OF INDUSTRY IN THE 13 PROVINCES, 1961

Industrial Group	Number of establishments in operation		In thousands of Ethiopian dollars				
	1960	1961	Purchase of materials	Value of fixed assets 1/	Capital expenditure	Value of production Gross	Value of production Net
Food products	21	22	14,810	50,195	10,270	25,630	9,445
Flour, macaroni, biscuits	8	8	5,010	4,689	44	6,170	960
Edible oils and products	10	11	3,912	2,396	61	4,984	851
Sugar, tomato canning	2	2	5,882	41,610	10,065	13,816	7,017 2/
Slaughter and preparation of meats	-	-	6	1,500	100	660	617
Beverages	20	20	1,931	5,796	450	5,643	3,448
Alcohol, beer, liquors	6	6	549	3,036	235	3,062	2,362
Wines	7	7	1,023	1,003	33	1,569	489
Soft drinks and carbonated water	7	7	359	1,757	182	1,012	597
Tobacco manufactures	1	1	758	1,376	66	3,448	2,672
Textiles	8	9	18,569	15,868	2,934	32,722	13,053
Spinning, weaving, and finishing	3	4	16,400	14,095	2,825	28,232	10,941
Knitting mills, etc.	3	3	70	49	-	295	221
Cordage, sacks, rope, and twine	2	2	2,099	1,724	109	4,195	1,891
Leather tanning and footwear 3/	5	5	2,713	2,170	236	4,692	1,880
Sawmills, plywood, etc.	6	7	389	1,041	668	1,798	1,304
Furniture and fixtures 4/	3	3	1,012	485	52	1,660	633
Printing and publishing 5/	6	6	937	732	74	1,938	931
Chemicals and chemical products	-	-	192	715	165	606	392
Nonmetallic mineral products	3	3	304	1,880	84	3,477	2,906
Bricks	2	2	-	147	7	409	318
Cement	1	1	304	1,733	77	3,068	588
Miscellaneous manufactures	4	4	126	518	510	194	60
Total manufactures	77	80	41,741	80,776	15,509	81,808	36,724
Electricity	13	15	1,124	51,100	3,700	6,126	4,688
Total industry (excl. mining, construction, coffee and grain cleaning)	90	95	42,865	131,876	19,209	87,934	41,412

Source: Central Statistical Office

1/Includes plant and machinery, vehicles, land, and buildings.
2/Excludes an estimated Eth$5 million of sugar cane grown on plantations of the industrial concern.
3/Excludes small shoemakers and shoe repairers.
4/Excludes small carpentry shops.
5/Excludes Berhanena Selam Printing Press in Addis Ababa.

TABLE 4.-INDEX OF ECONOMIC TREND OF INDUSTRIAL PRODUCTION

For the Empire of Ethiopia, 1956 through 1961 (1955 = 100)

Industrial group	The 13 Provinces						Eritrea Province						Total, Ethiopia					
	'56	'57	'58	'59	'60	'61	'56	'57	'58	'59	'60	'61	'56	'57	'58	'59	'60	'61
Manufacturing																		
Foods	109	128	132	146	162	158	84	69	92	77	132	89	103	113	122	129	155	141
Beverages and tobacco	114	114	122	154	179	216	108	112	117	107	103	106	113	114	121	142	160	189
Textiles	112	128	115	123	185	227	-	100	152	164	183	243	112	121	124	133	185	231
Leather goods	151	168	168	162	182	193)												
Building materials, etc.	117	91	115	93	100	128)	83	80	87	55	89	122	112	103	113	94	112	135
Miscellaneous	84	69	62	56	69	70)												
Subtotal	112	124	124	134	165	183	92	102	124	110	145	141	107	119	124	128	160	173
Electricity (both public utility and industrial firms)	115	133	145	165	190	240	101	110	117	125	142	163	110	125	135	155	178	215
Total	112	123	123	134	163	181	93	103	122	111	142	139	107	118	123	128	158	171

For the 13 Provinces, 1951 through 1961 (1950 = 100) 1/

Industrial group	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61
Manufacturing											
Foods	104	100	119	137	223	242	286	295	325	361	352
Beverages and tobacco	121	152	188	204	199	227	227	243	306	356	430
Textiles	72	197	267	313	395	444	507	452	485	731	895
Leather goods	113	191	197	206	213	322	357	358	346	388	411
Building materials, etc.	102	100	114	156	221	259	201	254	205	220	283
Miscellaneous	113	112	126	136	161	134	111	100	90	111	113
Subtotal	101	133	163	187	249	280	308	308	333	410	455
Electricity (both public utility and industrial firms)	105	119	142	167	183	210	243	265	371	428	538
Total	101	130	161	184	235	263	288	290	314	382	425

1/Primarily Addis Ababa Complex.

Source: Central Statistical Office.

During the period 1963 through 1967, the government planners foresee that the total output of the manufacturing industry would, on the whole, be tripled. Production of the more important industrial products is forecast in Table 5. Table 6 shows that before 1963 the investment in the forecast manufacturing industry was only about 6 percent. By 1967, this will have reached 19 or 20 percent annually and will probably hold to that figure for some time in the future. The 103 new industrial projects to be completed and 18 more that are to be reconstructed during the period 1963 through 1967 is shown in Table 7. Of those to be completed, about 94 will actually go into operation within the same period, as shown by Table 8.

The emphasis being put on industrial development will require a corresponding increase in the availability of electricity supplies for supporting the increased industrial output. Some government planners foresee a 340-percent increase in the amount of electricity used for industrial purposes, using the year 1962 as a base. This increase would be for the period 1963 through 1967. Until 1967 and perhaps a few years later, industrial production will primarily be geared to meeting consumer demands.

COMMUNICATIONS

In 1952, telecommunications were established as a self-supporting public agency under the Imperial Board of Telecommunications. This organization provides the country with telephone, telegraph, and radio broadcasting facilities. Between 1955 and 1959, the urban telephone traffic in Addis Ababa increased 33 times, while the interurban traffic in the whole of Ethiopia increased about 1.7 times. The number of outgoing international calls about doubled, and the incoming international calls nearly tripled.

In 1953, the number of telephone instruments was slightly over 4,500, but at the end of 1959 there were about 11,000 telephones in the country. Radio broadcasting stations provide the primary link with the outside world. The major towns have post offices and airmail service where regular stops are made by the Ethiopian Airlines.

The following tables reflect the steady increase in the use of the telecommunication and postal facilities.

Telecommunications, 1953-1960 1/

	Telegrams (thousands)			Telephone calls (thousands)			
	Total	Inland	Foreign	Total	Local	Inter-urban	Inter-national
1953	191.1	110.0	91.1	-	-	410.0	-
1954	204.7	110.0	93.7	-	-	510.0	-
1955	215.2	119.2	96.0	-	3,868.0	539.0	-
1956	212.2	120.9	91.3	-	5,851.0	661.0	-
1957	217.4	113.5	103.9	-	8,375.0	745.0	-
1958	326.9	108.4	218.5	11,305.1	10,461.0	825.7	18.4
1959	369.9	131.8	238.1	16,145.3	15,232.5	890.1	22.7
1960	428.2	145.8	282.4	14,780.2	13,823.2	934.2	22.8

1/Ethiopian Economic Review, No. 5, February 1962.

TABLE 5--1969 PRODUCTION GOAL FOR SELECTED INDUSTRIAL PRODUCTS 1/

Article	Unit	Actual 1957	Actual 1962	Forecast 1967
Meat (frozen)	metric ton	683	5,500	35,000
Meat (canned)	metric ton	1,290	1,000	7,000
Sugar	metric ton	16,181	38,000	60,000
Salt	metric ton	132,292	158,000	275,000
Edible oil	metric ton	4,350	4,800	12,000
Flour	metric ton	23,000	24,000	51,000
Macaroni	metric ton	2,700	2,800	3,100
Beer	hectoliter	41,780	67,000	85,000
Wine	hectoliter	12,900	18,600	30,000
Cigarettes	1,000	252,000	370,000	500,000
Cotton fabrics	1,000 sq. m.	5,000	21,500	74,000
Rayon fabrics	1,000 sq. m.	-	-	6,000
Gunny bags	1,000	1,700	2,800	6,000
Shoes (leather)	pr.	203,000	248,000	2,150,000
Shoes (canvas, rubber)	pr.	-	-	1,300,000
Timber	cu. m.	16,300	12,500	20,000
Plywood	cu. m.	-	1,200	3,000
Furniture	Eth$1,000	350	450	1,300
Matches	1,000	11,800	16,000	25,000
Glass bottles	1,000	3,800	7,500	14,000
Cement	metric ton	26,860	29,000	210,000
Bricks	1,000	5,670	8,000	30,000
Mosaics	sq. m.	30,000	65,000	95,000

1/Second Five Year Development Plan.

TABLE 6--INVESTMENT IN MANUFACTURING INDUSTRY BY YEARS 1/

Year	Investment (Eth$1,000)	As percent of total
Before 1963	25,560	6.0
1963	35,795	8.4
1964	57,445	13.5
1965	65,255	15.3
1966	74,795	17.6
1967	85,175	20.0
After 1967	81,925	19.2
Total	425,950	100.0

1/Second Five Year Development Plan.

TABLE 7--NUMBER OF INDUSTRIAL PROJECTS TO BE CONSTRUCTED, 1963-1967 1/

Branch of industry	Total	Breakdown: Completed or reconstructed	Breakdown: New projects
Food	29	3	26
Beverages	3	1	2
Tobacco manufacturing	2	1	1
Textiles	15	6	9
Leather and shoes	9	1	8
Wood	3	-	3
Building and nonmetal	16	3	13
Printing and publishing	2	1	1
Chemicals	22	1	21
Metals, production and fabrication, and electrical manufacturing 2/	16	1	15
Other	4	-	4
Total	121	18	103

1/Second Five Year Development Plan.
2/Includes motor vehicle assembly, dockyard for ship repair, steel mill and rolling plant, petroleum refinery and agricultural tool factory.

TABLE 8--INDUSTRIAL PROJECTS TO BE PUT INTO OPERATION, 1963-1967

Year	Number of projects
1963	3
1964	19
1965	15
1966	24
1967	33
Total	94

1/Second Five Year Development Plan.

Posts, 1952-1961 1/

Year	Lettermail (thousands)				Foreign parcels (thousands)		
	Total	Inland	Foreign		Total	Out	In
			Out	In			
1952	553.8	18.0	51.3	464.5	155.9	-	155.9
1953	531.9	21.0	56.3	454.6	341.0	-	341.0
1954	684.8	25.8	140.0	519.0	374.4	9.8	364.6
1955	632.8	34.7	71.5	526.6	376.1	2.5	373.6
1956	889.1	37.9	129.6	721.6	275.4	2.2	273.2
1957	1,028.2	45.4	186.4	796.4	314.6	5.9	308.7
1958	1,089.5	50.2	185.9	853.4	332.6	3.3	329.3
1959	1,307.5	121.3	289.5	896.7	282.9	5.1	277.8
1960	1,495.1	171.8	359.2	964.1	209.6	3.1	206.1
1961	1,769.0	245.2	445.0	1,078.5	191.5	3.0	188.5

1/Ethiopian Economic Review, No. 5, February 1962.

These services will probably continue to grow with other segments of the developing economy of Ethiopia and the services can be expanded to meet the demands with little difficulty.

TRANSPORTATION

Transportation in Ethiopia is supplied by a national highway system, a railroad from Massawa on the Red Sea to Agordat, a second railroad from Djibouti in French Somaliland to Addis Ababa, and an airline with international flights that connects the principal Ethiopian cities with other African and European cities. Much of the agricultural produce has traditionally moved from farm to market over trails by porters and pack animals.

Highways

The highway system which radiates from the cities of Addis Ababa and Asmara, the principal centers of population and industry, consists at present of about 4,800 kilometers (3,000 miles) of all-weather road--about 1,440 kilometers of which are hard surfaced, the remainder gravel surfaced. These are the main arteries connecting the principal inland cities and towns and providing an outlet to the seaports of Massawa, Assab, and Djibouti. From these all-weather highways, some slightly improved roads continue toward the interior to connect the smaller centers of population. These subsidiary roads are generally passable for vehicular travel only during the dry season and then only with heavy-duty, four-wheel-drive vehicles. From these roads extend the primitive trails and foot paths connecting interior villages.

The Blue Nile River Basin is served by the all-weather highway that extends westward along the southern perimeter to Lekkemt, with a dry-season extension continuing on to Asosa near the Sudan border. Passenger busses operate on a daily basis between Lekkemt and Addis Ababa. Trucks provide the bulk of the freight service between the cities, and westward from Lekkemt, trucks provide freight service for that part of the year when the roads are passable, a few even operating as far west as Asosa. Towns and villages along the border receive some of their supplies through the Sudan, which also has semi-improved roads approaching the border from the west. The Addis Ababa-Asmara all-weather highway skirts the eastern rim of the Blue Nile River Basin, and busses and trucks provide passenger and freight service to the villages and towns. This is probably the most heavily traveled highway in the Empire. It is the principal supply line for Addis Ababa and is its main highway connection with the seacoast and port cities.

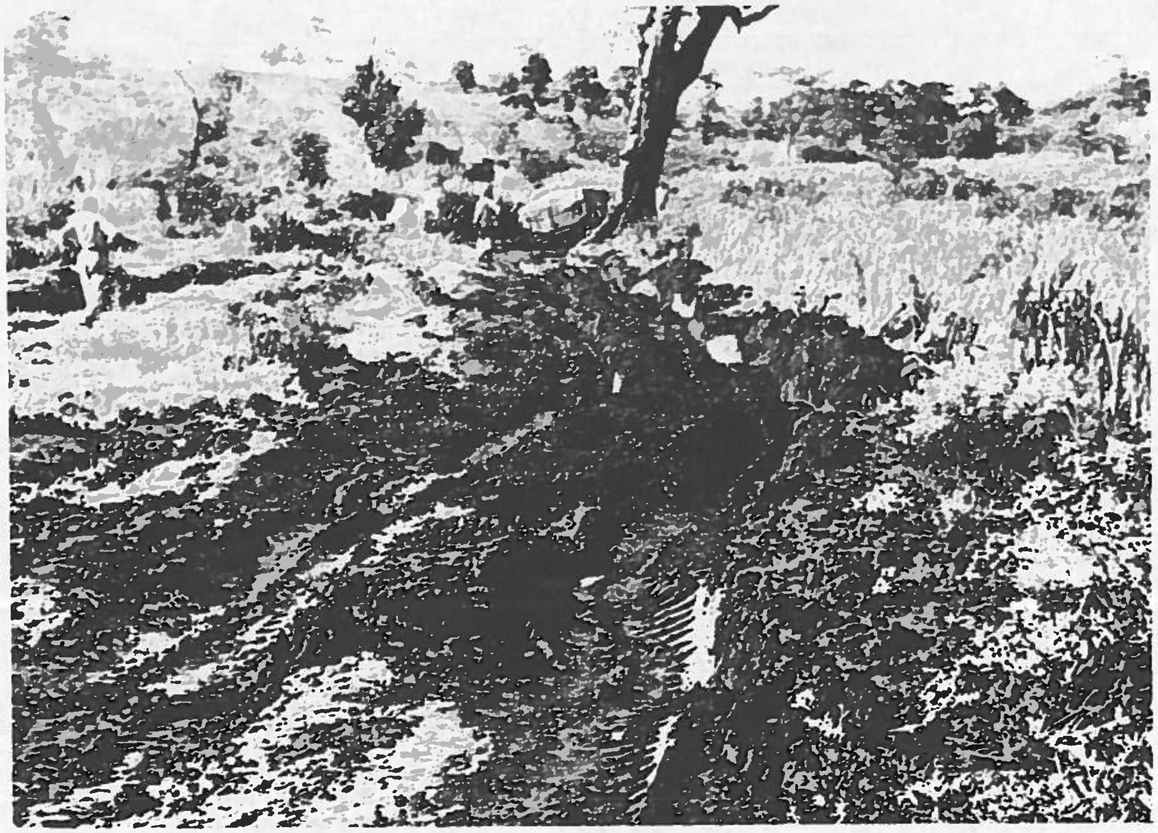


Figure 19. Unimproved highway during the rainy season.

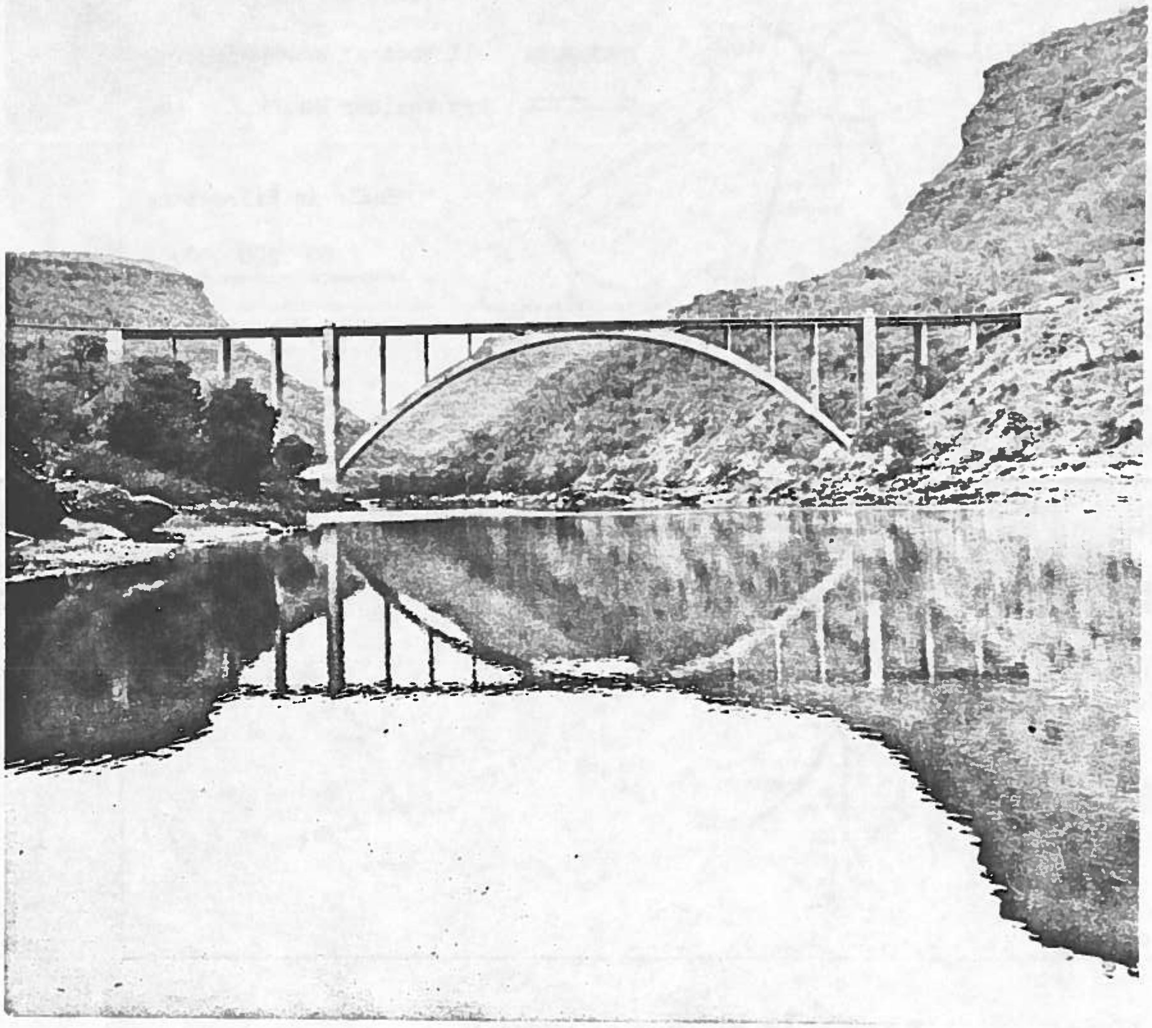


Figure 20. Bridge across the Blue Nile River north of Addis Ababa.

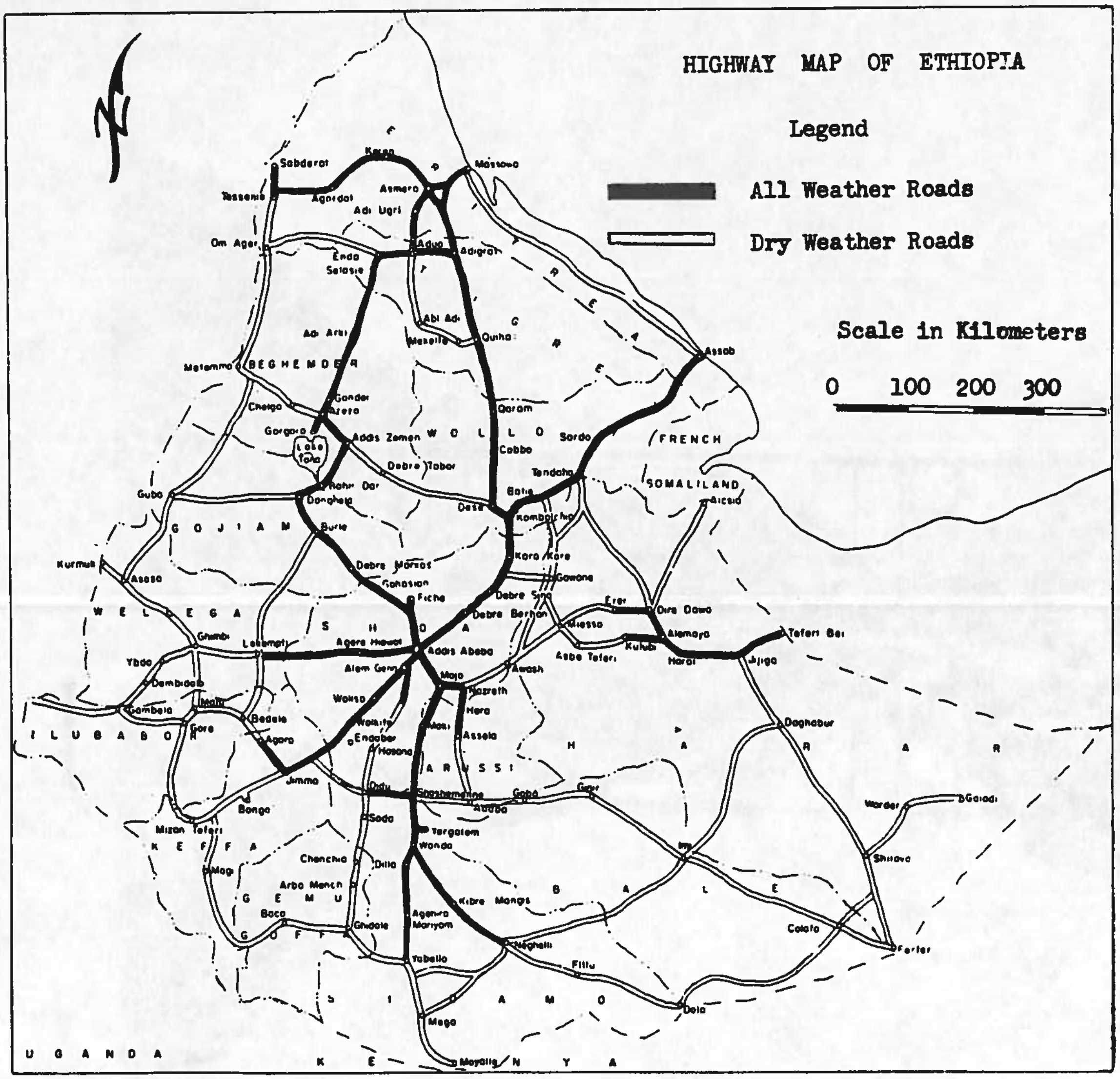


Figure 21--Highway Map of Ethiopia

Only one improved highway extends into the interior of the Blue Nile River Basin. This is the highway from Addis Ababa to Gondar. It is an all-weather highway from Addis Ababa to Bure, and the remainder is being improved. Within 2 or 3 years, the entire length will be an all-weather road. It carries considerable traffic and is of great importance to the basin. From this road, primitive trails lead to the interior communities.

In the past, Ethiopia's isolation and the barriers to the outside world imposed by her topographic conditions have historically had a retarding effect upon social and economic development. The lack of roads and other means of communication and transportation has hampered the exchange of ideas and techniques and has limited the exchange of goods and services. Away from the main highways, this situation still exists. However, the Imperial Ethiopian Government has undertaken a major program to improve and extend the national highway system to all parts of the Empire. From the standpoint of the agricultural segment of the economy, improvement and extension of the highway system are of extreme importance. The projected secondary road system will open areas for production of a variety of marketable crops and will extend the cash economy deeper into the countryside.

The use of existing improved roads is rapidly increasing and the rate is expected to continue to climb. Development of power and irrigation projects in the interior and increased production will accelerate the requirements for transportation facilities. Adequate roads to serve the rural centers of production and sufficient transport vehicles to move the produce to the central and regional markets will encourage increased production and will improve the economy of the Empire.

Most of the private passenger carrying automobiles are owned in the principal cities and are used very little on the highways. About 10 percent of the total vehicles registered are commercial trucks that do use the highways extensively.

It has been estimated that within the Blue Nile River Basin there is a total of about 2,851 kilometers of roads under the national network. Of this total, 717 kilometers are surfaced, all-weather roads; 682 kilometers are dry-weather roads; and 1,452 kilometers are unimproved feeder roads.

Railroads

The Massawa-Agordat Railroad climbs westward from Massawa, on the Red Sea, 306 kilometers (190 miles) to Agordat, on the plateau west of Asmara. Construction of this railroad began in 1899, reached Asmara in 1911, and its western terminus in 1932. It has a 950-mm. track gage and employs diesel-powered locomotives. It is owned and operated by the Ropeway Administration of Eritrea, a governmental organization. It provides both passenger and freight service and is an important transportation link for the import of industrial goods, consumer goods, and other products from Massawa to Asmara and on inland to Eritrean communities. It is also widely used for the export of hides, grains, and other agricultural products from Eritrea to the Red Sea port. It is a major facility in the movement of freight, but it is regional and therefore has little effect upon transportation in other provinces in Ethiopia. The freight hauled is quite evenly balanced between imports, exports, and local shipments.

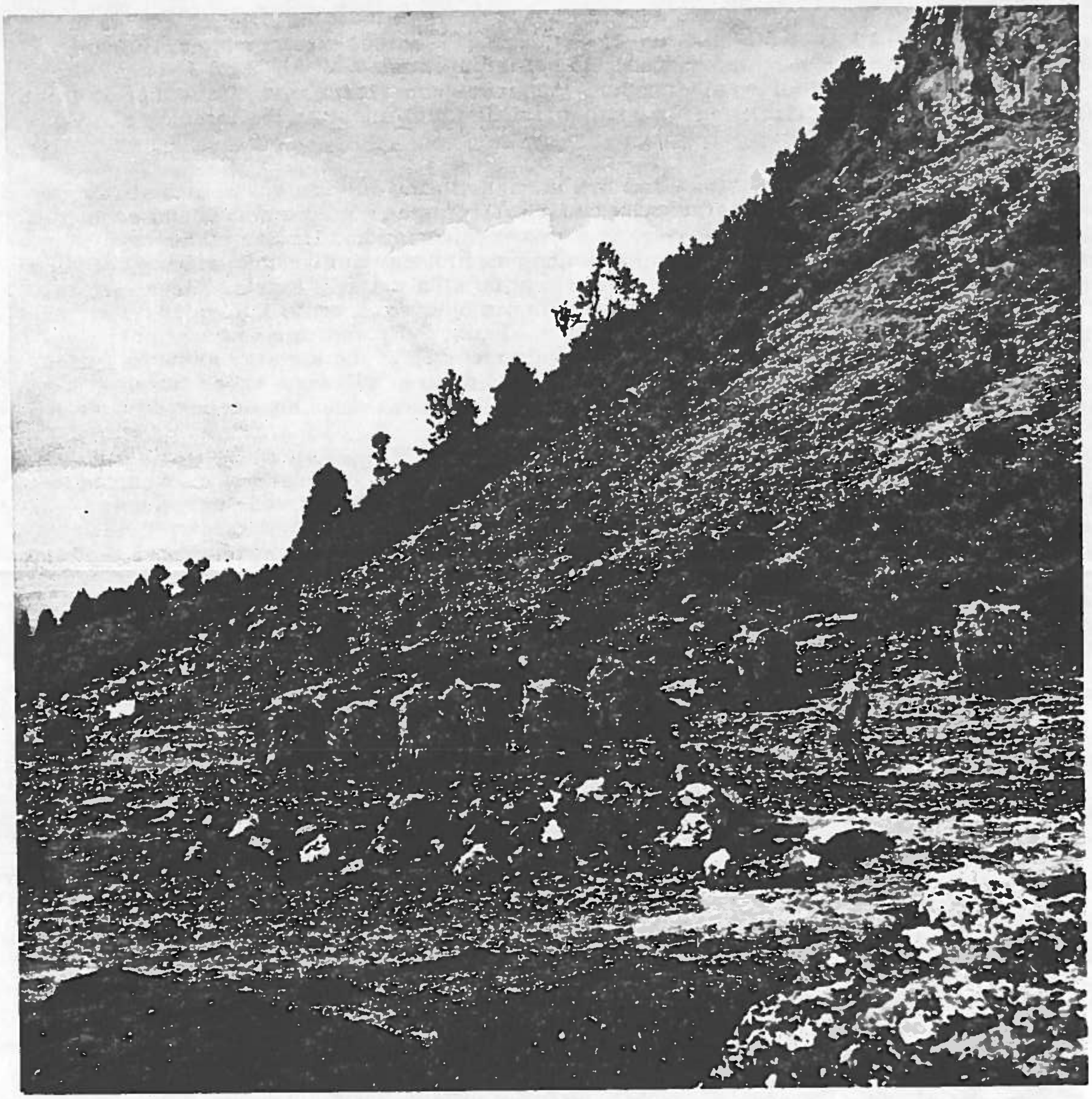


Figure 22. Pack animals headed for the Addis Ababa market.

Freight carried by
Massawa-Agordat Railroad 1/
(1,000 metric tons)

Year	Import	Export	Local	Total
1955	46.8	46.0	38.1	130.9
1956	32.0	48.1	39.0	119.1
1957	32.0	48.1	39.0	119.1
1958	33.3	46.8	34.2	114.3
1959	67.9	34.7	24.1	126.7
1960	46.5	64.2	43.2	153.9
1961	32.6	39.8	37.2	109.6

1/Ethiopian Economic Review, No. 5, February 1962

Extension of this railroad west to Tessenei on the Sudan border has been considered but, although feasible from a strictly engineering standpoint, production in the area at the present time is not sufficient to support the extension. However, as the population increases and other segments of the economy improve, it is entirely possible that this extension and others along the seacoast should be given further consideration.

The Addis Ababa-Djibouti Railroad was built principally with French capital, beginning in 1894. Construction reached Dire Dawa in Harar Province in 1902, and the line was completed to Addis Ababa in 1917. It has a 1,000-mm. track gage and is 781 kilometers (485 miles) in length. It begins at sea level and climbs to an elevation of 2400 meters (7870 feet) at its Addis Ababa terminus. It is operated by the Compagnie du Chemin de Fer Franco-Ethiopian, owned jointly by Ethiopia and France. Both freight and passenger service are provided. The line carries more imports than exports or local shipments, probably due to the fact that Addis Ababa is the central distribution point for most of the imports received from the Djibouti seaport.

Freight carried by
Addis Ababa-Djibouti Railroad 1/
(1,000 metric tons)

Year	Import	Export	Local	Total
1952	94.5	127.9	58.1	208.5
1953	108.3	140.2	55.5	304.0
1954	100.2	68.3	65.1	233.0
1955	87.4	75.3	92.5	255.2
1956	88.8	59.1	86.4	234.3
1957	103.0	76.4	74.6	254.0
1958	127.3	47.2	79.4	253.9
1959	131.0	62.4	92.6	286.0
1960	117.2	89.7	88.8	295.7
1961 2/	72.0	87.7	55.9	215.6

1/Ethiopian Economic Review, No. 5, February 1962.
2/Eight months only.

Although the railroad has been in operation for many years and is perhaps the most important transportation link of the Empire, the freight moved has provided only a moderate return to the management. The high shipping rates charged by the railroads have in recent years, since highways have been improved, placed truck transportation in a favorable competitive position on many commodities, and an increasing amount of freight has been moved by truck to the Ethiopian seaport of Assab. The railroad, nevertheless, provides a vital link between the central market of Addis Ababa and the Red Sea.

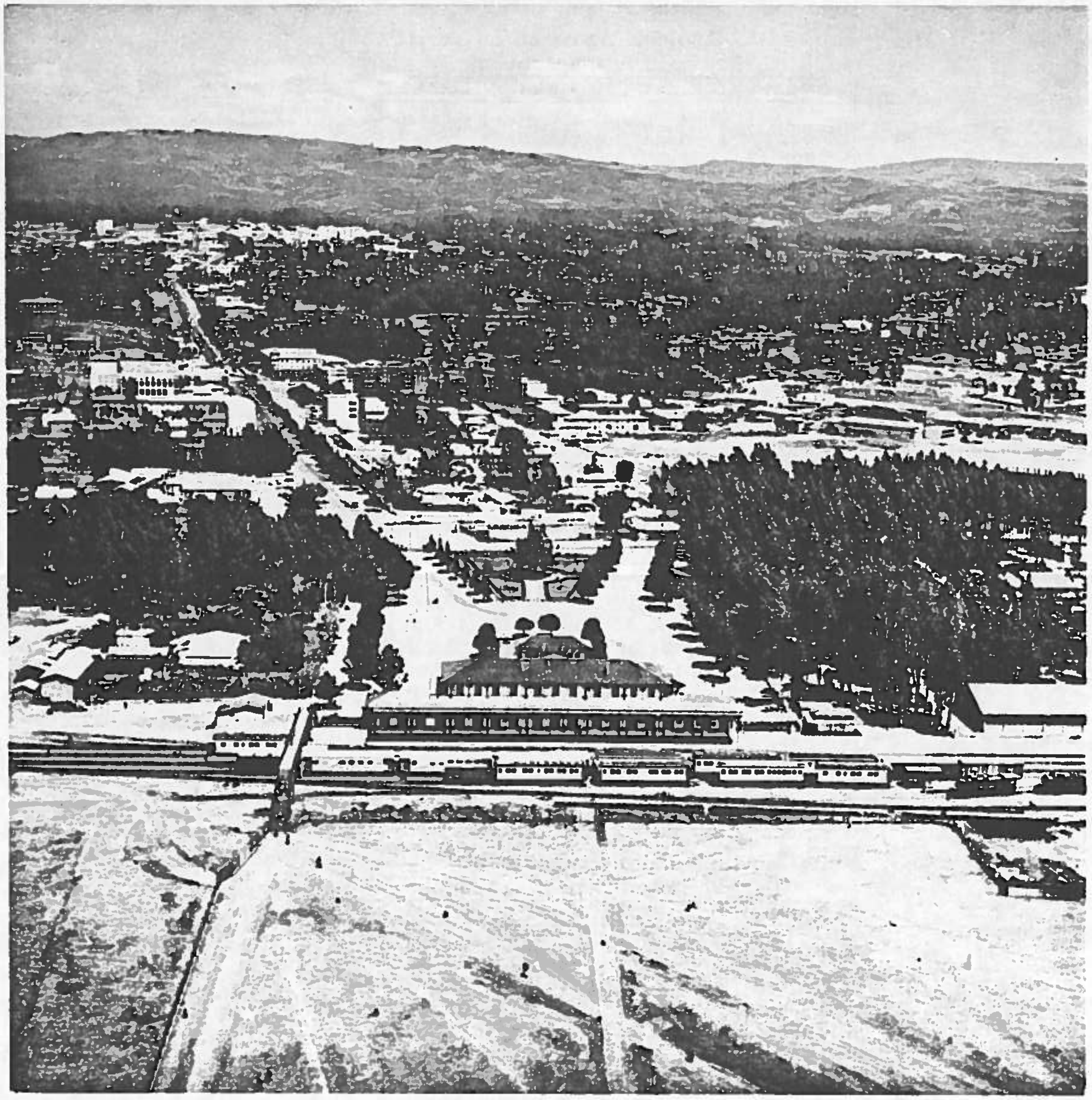


Figure 23. Addis Ababa railway terminal.

The railroad does not extend into the Blue Nile River Basin. However, extensions or branch lines could be constructed into the area. The railroad will be an important factor in the transportation of material and equipment if projects are constructed in the basin. It will also gain importance if agricultural production increases and creates greater demands on both imports and exports.

Seaports

Ethiopia is served by seaports at Massawa and Assab on the Red Sea and Djibouti on the Gulf of Aden. Djibouti has greater ship traffic and portside services for handling shipping than does either Assab or Massawa, although improvements at both of these ports are now underway. Storage facilities and an oil refinery are also being constructed at Assab.

The Red Sea ports became ports of the Empire at the time Eritrea was federated with Ethiopia in 1952. The Djibouti port in French Somaliland has been the key port for central Ethiopia since the construction of the railroad. The road to Assab is being improved, and truck traffic moving shipments to and from the port is increasing. The competition between rail and truck shipments and between the ports of Djibouti and Assab will increase as Ethiopia's volume of trade continues to expand.

Inland Water Transport

None of the streams in the basin is considered navigable. Lake Tana does have some shipping with docks at Bahir Dar and Gorgora. However, the traffic is light and as the highway around the lake is completed, the lake shipping will be of diminishing importance.

Air Transport

Ethiopian Airlines, operating since 1945, serves the Empire domestically and provides international connections to African and European cities. The airlines, operated under a management assistance agreement between Trans World Airlines and the Imperial Ethiopian Government, inaugurated jet plane service on its international service in January 1963. Domestic flights are made with DC-6's, DC-3's, and twin-engine Convairs while international flights utilize Boeing 720 jets. The airline has freight and passenger service to 29 points in Ethiopia and international flights to several African and European cities.

International passenger traffic exceeds domestic traffic in numbers of passengers and in passenger-kilometers. All flights carry freight as well as passengers.

Year	Freight carried (1,000 metric tons)			Passengers carried		
	Domestic	International	Total	Domestic	International	Total
1955	2.1	2.8	4.9	32,485	34,538	67,023
1956	2.3	2.8	5.1	31,588	39,027	70,615
1957	3.2	2.1	5.3	45,886	41,719	87,605
1958	2.6	3.0	5.6	46,964	45,748	97,712
1959	3.31	3.8	7.1	41,487	54,110	95,597
1960	3.1	3.6	6.7	40,806	63,270	104,067
1961 2/	2.5	2.5	5.0	29,045	44,341	73,586

Air Transport Statistics 1/

1/ Ethiopian Economic Review, No. 5, February 1962.
2/ Eight months only.

The airline also has a fleet of single-engine training planes and helicopters for short flights to interior points without airports. The airline has perhaps contributed more toward breaking the barriers of isolation for Ethiopia than any other factor. It is an important service in providing communication and transportation within the Empire, and its role is expected to increase as the Empire develops.

AGRICULTURE

Agriculture is the foundation of the present economy of the Blue Nile River Basin, as it is for the entire Ethiopian empire. It is estimated that at least 90 percent of the basin's population of approximately 4.87 million people are supported directly by basic agriculture--dry farming and animal husbandry. Agricultural production, although largely of a subsistence type, is able to meet the existing and expanding domestic demands to a degree consistent with the standard of living now known to the people of the area.

The land is not fully utilized. Only a small part, probably less than 10 percent, is under cultivation in any year, although perhaps 40 percent of the land is arable. A shifting cultivation pattern has been established from centuries of practice, and much of the land on the high plateau has at one time or another been cultivated.

The natural fertility of the soil is not sustained by the farming practices and, as the fertility of a field diminishes with cropping and its productivity is reduced, the field is abandoned to return to natural grass and bush for a number of years. The pressure of population upon the land area has not as yet developed to an extent that would limit this type of agricultural operation.

Most of the crops produced are consumed by the farm family, with only small surpluses bartered or sold on the local market. A very small proportion reaches the central market in the major towns and cities.

The average farm family numbers about 4.7 persons, and the majority of farms has less than 2 hectares (5 acres) under cultivation in any 1 year. The average Ethiopian farmer possesses a wooden plow made from a tree branch and a small assortment of handtools. Some farmers do not own oxen and must exchange their own labor in order to borrow oxen for plowing. The investment in equipment and tools is small, reflecting quite accurately the individual farmer's limitations in production potential.

The cropping season in Ethiopia is greatly affected by the recurring wet and dry periods and farming operations are closely geared to these season changes. Plowing is largely confined to the periods during or immediately following the "small" rains and the "big" rains. The "big" rains occur during the months of June, July, August, and September,

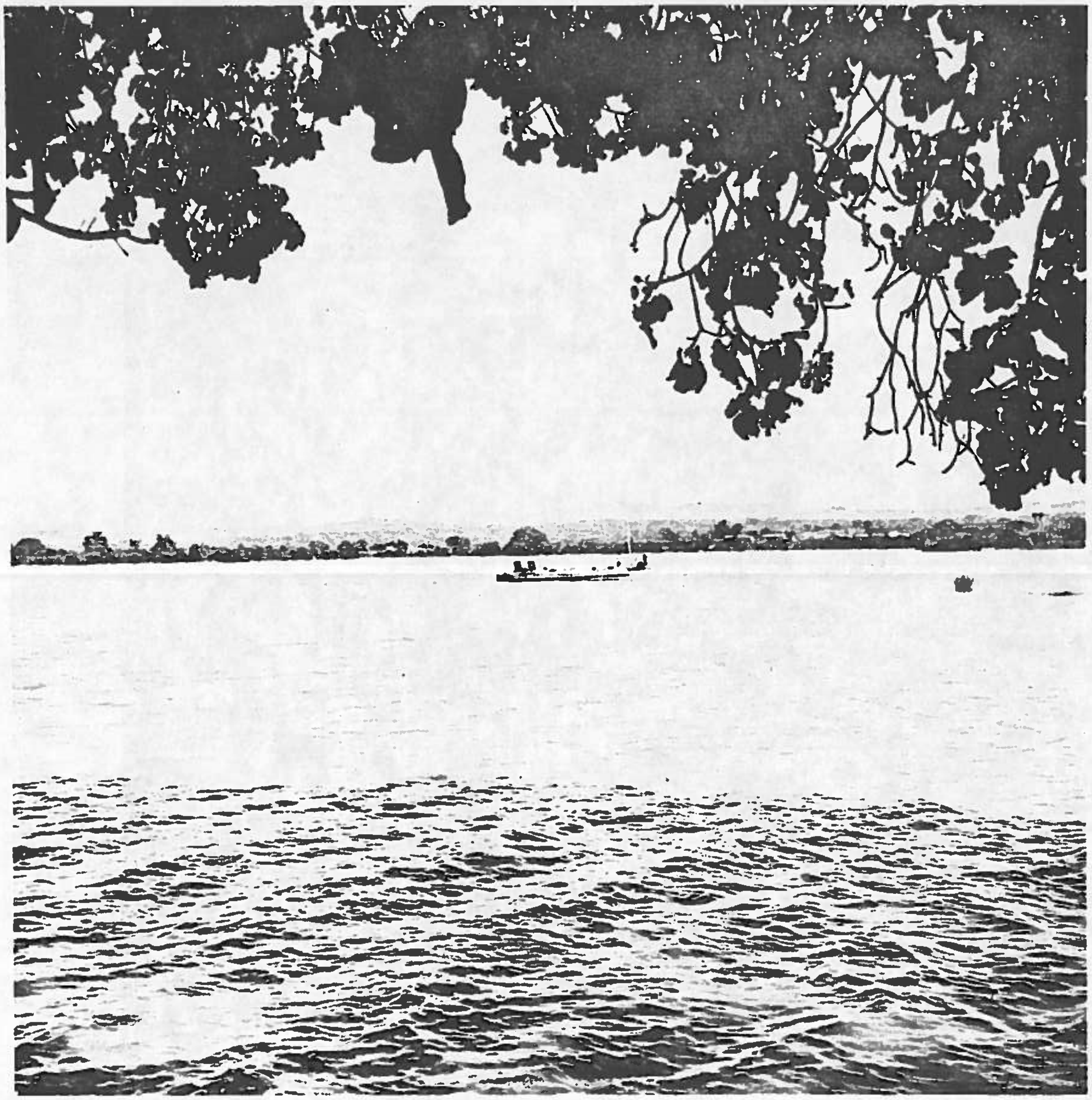


Figure 24. Boats carry freight on Lake Tana.

Figure 25. Sorghum is a common crop on the highland.

Figure 26. Harvesting cotton.

and the "small" rains occur during the months of March and April. Crops are generally planted with the rains to permit maturing and harvesting in the dry season.

The big rains fall in great abundance and are followed by periods of little precipitation. The Ethiopian farmer tries to plow and plant early in the rainy season hoping that the rains will carry his crops through the growing cycle and permit a good harvest.

At plowing time the farmer uses his ox-drawn wooden plow, often shod with an iron tip, which penetrates the soil only to a depth of about 7.5 centimeters (3 inches) and stirs, rather than turns, the soil. Fields are often plowed several times in varying directions. After a field is plowed, cattle are sometimes driven back and forth across the field to break up the larger clods which have remained intact. Seed is hand broadcast, and any further cultivation or weeding is done by hand. Standing grains are cut with hand sickles, and the grain is usually stacked for a short period of time before being threshed. Oxen are driven over the stalks piled upon an earthen threshing bed until the grain is separated from the head. The grain is further cleaned by winnowing with wooden forks or leather paddles so that the wind will further separate it from the straw and chaff. Oilseeds and pulses are cut and beaten or picked rather than threshed. The farmers generally have inadequate storage facilities and high storage losses are often experienced.

Soon after the rains have ended, the soil moisture is depleted and the fields become dry and hard. No further agricultural operations are carried out until the next plowing season.

The crops grown are generally consumed in the immediate area, and usually include most of the following: teff, barley, wheat, corn, sorghum, peas, beans, lentils, noog, and peppers. In some areas such specialties as cotton, tobacco, and coffee are grown. Very little fruit or vegetables are raised.

Large areas of land in the western portion of the Blue Nile Basin, apparently suitable for cultivation, are still in savanna with scattered tree and grass cover, in open forest, and in valley grassland. Some of this land is used for grazing, but most of it is unused.

The production of livestock is an important element in the agricultural economic pattern of the Blue Nile Basin. Many cattle, sheep, goats, horses, donkeys, and chickens are raised by the farmers. The animals are sold on the local market, traded among the farmers, and occasionally driven to Addis Ababa and other cities for marketing. Hides and skins are one of Ethiopia's major exports.

The livestock population is heavily concentrated on the plateau area of the Blue Nile Basin, and the pasture areas are generally overgrazed. The quality of livestock and of livestock products is low, largely due to the lack of control of animal disease, poor breeding, and to the lack of provision of fodder or other feed during the dry months when grass does not provide adequate food. The lack of an adequate water supply within a reasonable distance is also important. During the dry season, livestock often must be driven far to lakes or streams, and frequently they become thin and weak, resulting in poor quality for local consumption and in unsatisfactory condition for export.

Animal manure is little used for fertilizer but generally is utilized as a household fuel. In many areas livestock are penned at night in brush or pole enclosures. The animal droppings accumulated during the period of several weeks before the corral is moved to another location add to the fertility of the small area involved. Commercial fertilizers as such are not used by the local farmer.

With the present farming practices, the yields of crops and animal products are low, but the need for improved methods or for increased production is generally not recognized by the farmers, who have not had formal education or acquaintance with other systems, nor have had the opportunity to see more modern development which now exists in small areas in Ethiopia.

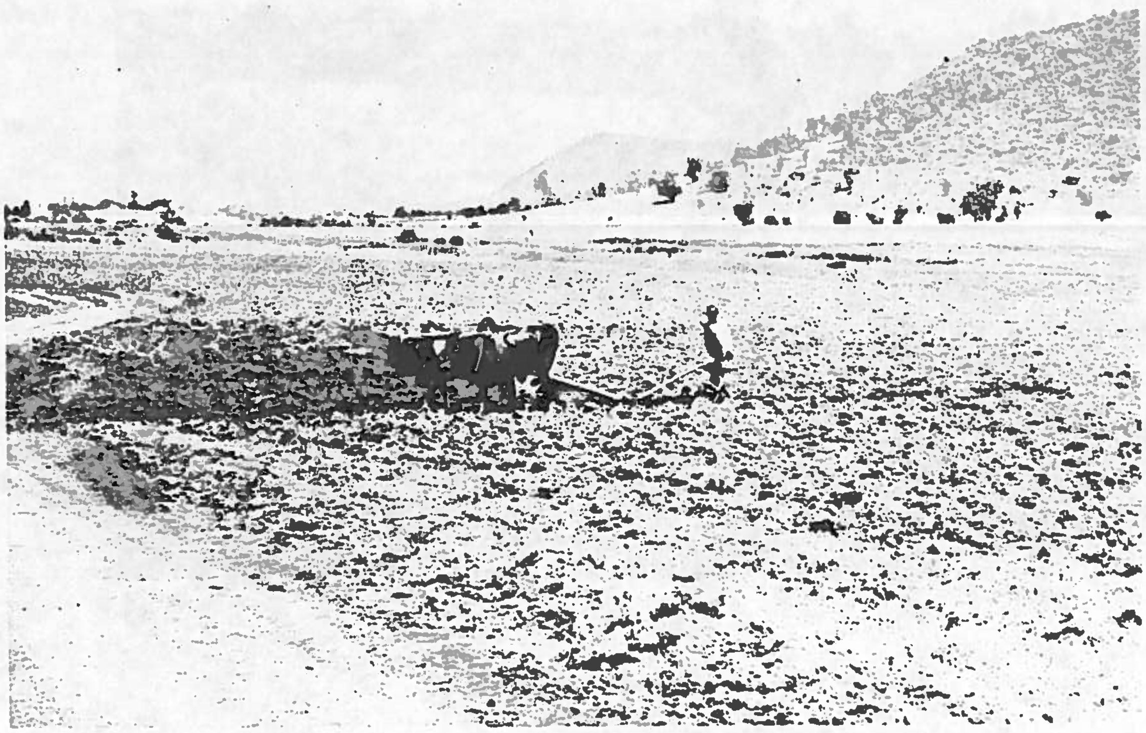


Figure 27. Plowing with oxen.

Figure 28. Harvesting teff.

Government officials and those educated persons who have experienced higher standards of living do recognize the need for improvement, and through education and demonstration are making efforts to implant the necessity for change in the minds of the people. In general, the Ethiopian farmer is slow to accept changes until the benefits are clearly demonstrated. The lack of transportation facilities and communications, the conservative attitude of the people, and the fact that they have never experienced higher standards, as well as the fact that existing production does meet the present requirements, are all factors which tend to retard progress.

Land tenure varies considerably, depending upon local custom, type of agriculture, and degree of influence by governmental agencies. There is no established system of land surveys or records; large tracts belong to government officials, the Ethiopian church, the central government, and kinship groups or tribes. Individual land holdings, similar to freeholds as understood in western countries, are not numerous. On the plateau in the Blue Nile Basin, which is traditional Amhara country, much of the land is owned by kinship groups and by the church.

The lowlands, only sparsely settled along the streams, are underdeveloped and are largely considered to be property of the Government.

Some irrigation is practiced along the small streams, which can be easily diverted during the dry season. However, there is not a significant increase in yields over the dryland methods because of the poor quality of seed, lack of fertilizers, poor farming practices, and a shortage of water which usually occurs at the critical time when crop demands are highest. Irrigation is not extensive, being usually reserved for fields of peppers or coffee, and as now practiced is of little importance to the overall economy of the basin.

On a few plantations small tracts have been irrigated in recent years and modern methods are practiced. These enterprises have produced a wide variety of crops with substantial yields, demonstrating the potential agricultural capacity of the area.

LAND UTILIZATION

The highlands of the Blue Nile River Basin are predominantly utilized for agricultural purposes in one form or another. The high plateau, because of its favorable climate, is the most heavily populated area and has the heaviest concentration of plow farming and agricultural activities. The severly eroded hill lands are little used, except that in some cases they do produce timber. The hot lowlands, because of unfavorable climatic conditions, the lack of water during the dry season, and the fact that population pressure has not made it necessary to utilize these lands, are little used and are covered with native vegetation, trees, and bush.

In the effort to evaluate the land utilization situation and in the preparation of a general utilization map of the area, information from various sources was drawn upon. The responsibility for the evaluation of data and preparation of the map was delegated by the United States Agency for International Development to Mr. Martin E. Johnson, a professional geographer assigned to the Aerial Surveys and Mapping Division of the Ethiopian Water Resources Department, as a part of the USAID direct contribution to the Blue Nile Reconnaissance Investigation Project. The Bureau of Reclamation contributed land utilization data obtained as a result of land classification of certain areas for project development and from field observations.

Mr. Johnson reported that the total area of the Blue Nile River Basin comprises 1,184,320 square kilometers, approximately 17.2 percent of the total area of Ethiopia. In area alone, a job of great magnitude; in terms of data available as bases for the study, even greater difficulties had to be overcome.

From the 1957-58 aerial survey of the basin, 11,992 aerial photographs were available at a scale of 1:50,000. Also available were U.S. Air Force preliminary base maps at 1:500,000 scale with 1,000-foot contour intervals and other general maps of limited accuracy.

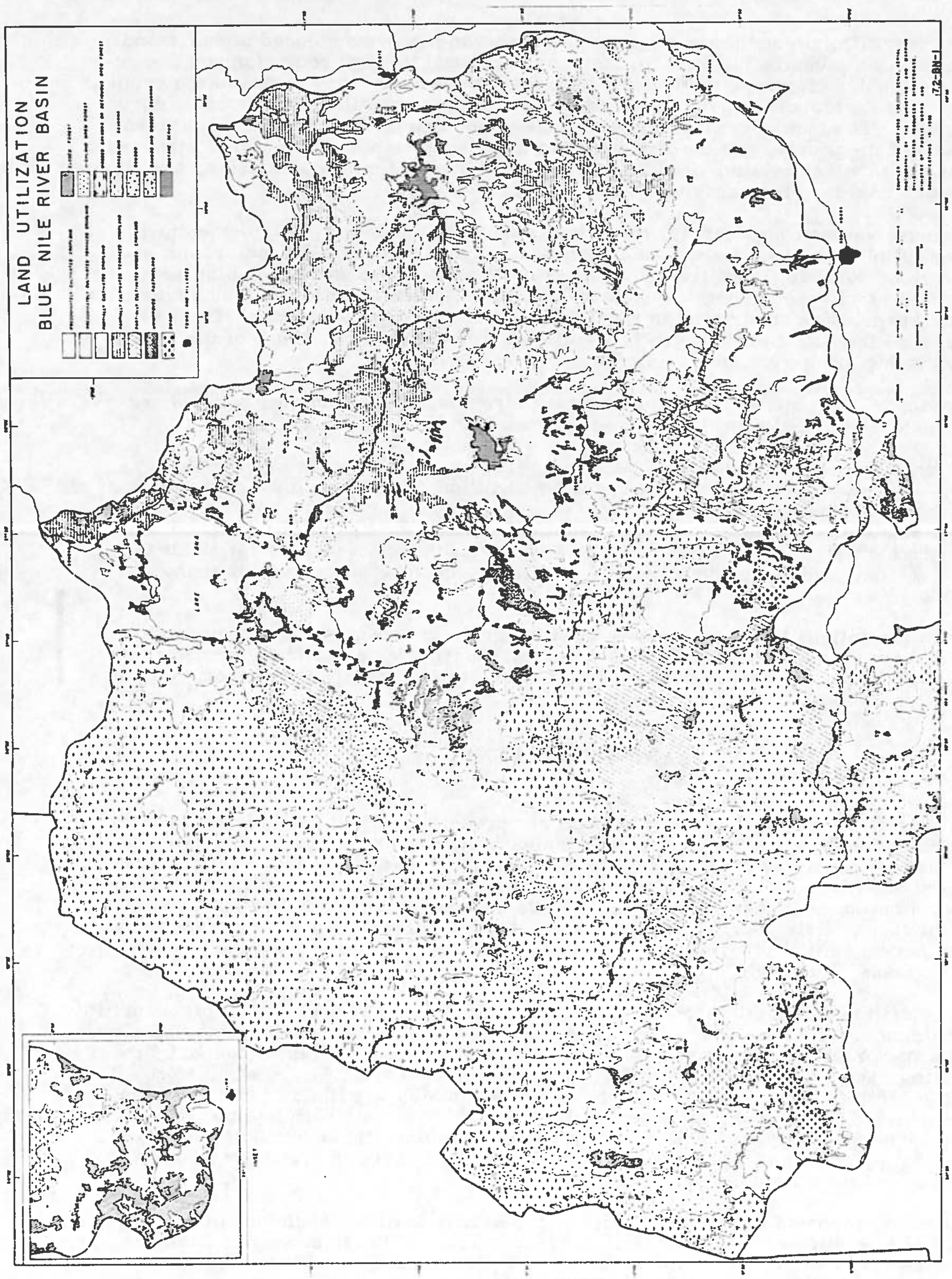


Figure 29--Land Utilization--Blue Nile River Basin

The Bureau of Reclamation land classification for specific project areas covered approximately 6 percent of the total basin area. The classification, in addition to providing data on the irrigability of the lands, included annotating land use on the 1:50,000 photographs under the following classes.

Predominantly cultivated
Partially cultivated
Pasture land
Closed forest
Open forest
Bamboo forest
Swampland
Wasteland

These categories were further related to land capability for project planning purposes. With this information and photo interpretation methods, a land use map was prepared. Mr. Johnson made five helicopter flights to various parts of the basin for spot-checking photo interpretation and one flight around the basin in a DC-3 plane, as well as several ground trips into the area.

The study was made using the World Land Use Survey Classification, modified to the special characteristics of Ethiopia. The following 15 classifications were adopted.

Predominantly cultivated cropland
Predominantly cultivated terraced cropland
Partially cultivated cropland
Partially cultivated terraced cropland
Partially cultivated wooded cropland
Unimproved pasture land
Swampland
Closed forest
Highland open forest
Wooded savanna or deciduous open forest
Grassland savanna
Bamboo forest
Bamboo and wooded savanna
Montane scrub
Towns and villages

Each category was defined and identified on aerial photographs in accordance with the following description of categories.

Predominantly Cultivated Cropland

Predominantly cultivated cropland is defined as land that is 60 percent or more in fields under plow cultivation. This includes fallow fields as well as fields with crops. In the agricultural complex in Ethiopia, grazing and pasture land are intermixed with plowed land, and cropland is grazed after the crops are gathered. Also, small areas of trees and compounds for homes and animals are included. Thus, this category has a combination of characteristics related to the traditional Ethiopian subsistence agriculture. Fields, fallow land, and pastures represent a complex that in the higher land is a repeating, clearly visible pattern.

Predominantly Cultivated Terraced Cropland

In some areas of the basin, the terracing is so intensive that well over 60 percent of the surface consists of cropland. Terraced land is easily identified on the photographs because of the linear pattern of fields following the contour. Also, this land is found below the escarpment rims and in canyon country that is roughly cut up. It represents not a different intensity of land use but merely a technique of utilizing steeper slopes for cropland. Investigations show it is still the traditional subsistence agriculture with no significant difference in crop production or type of crops, even though some of the terracing is under irrigation.

Figure 30. Predominately cultivated cropland near Ambo.

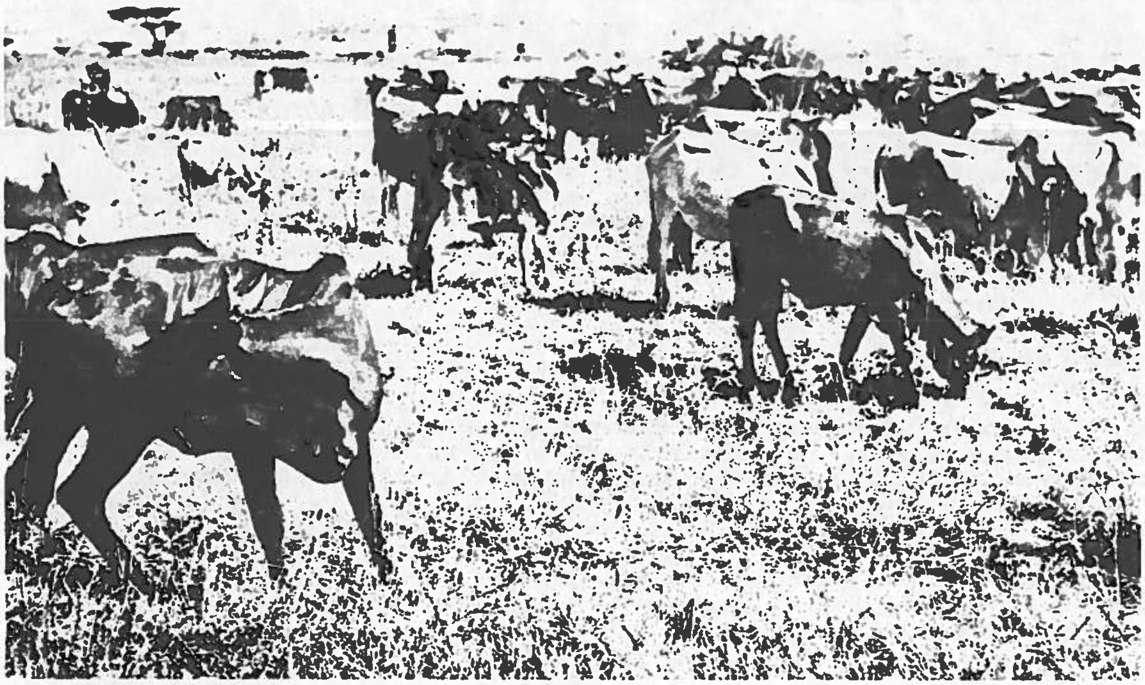


Figure 31. Cattle grazing on the plateau.

Partially Cultivated Cropland

Cropland that is less than 60 percent cultivated is in this category. It includes land with widely scattered fields and land that could be classified as woodland. However, since the area as a whole is used for agriculture, it is all classified as partially cultivated cropland. This land is in poorer regions, areas that are hotter than the high plateau, and on steeper slopes. It is also easily identified by photo interpretation since the scattered fields are regular in outline and different in tone, standing out in the total area.

Partially Cultivated Terraced Cropland

Most of the terraced land is only partially cultivated, since slopes too steep to use, forests, and unused areas are intermixed in the areas. Photographically, the terraces are plain, since field line boundaries tend to follow the contour. When viewed stereoscopically, the step-like character of the terraces is clearly identifiable.

Partially Cultivated Wooded Cropland

Since partially cultivated areas have less than 60 percent of the area in fields, it is self-evident that the remainder of the land has other uses or cover. Much is pasture land, part of the agricultural complex, but in many areas, especially where settlement is light, a considerable amount of forest is mixed with the partially cultivated land. Where these forests are easily identifiable and predominate over large areas, the land is classified as partially cultivated wooded cropland.

Unimproved Pasture Land

Unimproved pasture land is land used for pasturing animals exclusively with no cultivation occurring. They are large enough in area to be easily identifiable on the 1:50,000 photos and also large enough to be significant when reduced to 1:250,000 scale.

Two types are found in the basin. Most common are the large areas in the plateau uplands which are seasonally inundated by the heavy rains. Tight soil, with dense grass growth, precludes plowing by traditional methods. During the dry season, these areas become open grass-covered, natural meadows. Cattle trails leading from settlements or compounds can be seen converging on these areas in the aerial photographs, making them clearly identifiable.

The second type covers large areas in drier and lower valleys adjacent to and accessible to the cultivated lands at higher elevations. Most are really a type of savanna grassland which is grazed because of accessibility. Again, animal trails leading from the cultivated areas are keys to photo identification of these types of pastureland.

In the traditional agricultural complex, land for exclusive pasturing of animals is not improved. Thus, all of these pasture lands are grazed in their natural state. The only technique of improvement might be seasonal burning of the grass in some of the areas at lower elevations.

Swamp Land

Swamp areas, where standing water is intermixed with hydrophytic plants, occur in a few parts of the basin. These are clearly identifiable on the aerial photographs by tone and boundary, since adjacent types of land utilization differ sharply from swamp characteristics.

Closed Forest

Closed forest is one of the easiest patterns to identify on photographs. Where trees grow closely enough together so their crowns intermix, forming a continuous cover, the forest is classified as closed forest. By photo-identification methods, it is impossible to tell if these forests are used for a gathering economy or if people actually live beneath the canopy, but the definition of the area as a forest is clear. Most of these forests are being cut in a slash-and-burn type of agriculture, and there are many areas where a decrease in size is noticeable since the 1957-58 date of the photography. In general, throughout the basin, the forests are being cut back for agricultural expansion. Some authorities have surmised that the entire highland region, which is now predominately cultivated, was once part of a dense tropical forest.

Highland Open Forest

Where the forest has trees scattered in clumps or with individual trees spaced across the landscape and where there is no associated pasturing or cropland, the area is classified as open forest. It is considered highland open forest if the forest is above the escarpment rim or above the elevation of the deciduous and savanna open forests. This division is 1400 to 1800 meters (4600 to 5900 feet) in elevation. This category is small in extent and is usually associated with a type of wasteland, such as recent lava flows or very rough and eroded areas. Much of the area that would be classified as highland open forest has associated agriculture and it is classified as partially cultivated cropland.

Wooded Savanna or Deciduous Open Forest

The wooded savanna and deciduous open forest areas appear as similar patterns that are impossible to separate by photo interpretation. Below the highland rim there is a region of hilly land of intermediate elevation, up to 1400 meters, and there are also some higher regions like islands in the plain which sweeps toward the Sudan border. These areas are associated with species different from the common acacia which predominates in the savanna. Stereoscopically it is possible to identify some of these areas, but the boundary between the deciduous open forest and the wooded savanna is not clearly identifiable. Thus, these two types of open forest are grouped together.

Wooded savannas are located in semiarid regions of relatively low elevation. The patterns are grayish in tone, and considerable areas are burned by passing caravans so the grasses are clearly visible at 1:50,000. Individual trees, the umbrella-like acacia especially, show as dark, rounded, pinpoint-like patterns throughout the region. Wild animal trails show clearly, but settlement and agriculture are lacking. In the small patches where there is water, partial cultivation is carried on and these are therefore not classified as savanna.

Grassland Savanna

Very few areas of grassland savanna are found in the Blue Nile River Basin. Where found, there are riverine forests, but the interfluent areas are open high grass, showing as an even grayish tone on the photographs. Most of the grassland savanna merges with the wooded savanna, but the boundary is quite clear; so this category is classified separately.

Bamboo Forest

Large expanses of bamboo exist in the Blue Nile Basin. These show very clearly on the aerial photographs, since the edges are wall-like next to the open areas. The even height of the bamboo shows very clearly stereoscopically. The tone is much lighter than the wooded savanna, and of a distinctive granular pattern. Again, where there is cultivation in the bamboo, the land is classified as agricultural and not as bamboo. Where there are partially cultivated lands in bamboo regions, it is safe to assume the land that is not in fields is bamboo.

Bamboo and Wooded Savanna

The bamboo and wooded savanna are found in similar regions, although the bamboo is generally on better soils and in hillier areas. Yet, many areas have bamboo clumps intermixed in the acacia savanna, necessitating a separation of the category. Both are identifiable by photo interpretation, as stated in the separate descriptions.

Montane Scrub

Extremely high areas in the basin are too high for agriculture or have soils too thin for agriculture. The elevation is too great for a closed forest, and only small scrub-like trees grow. Most of the area is open and on the photographs the bare rock is often visible. These areas are thus classified separately, and all are found at elevations well over 3050 meters (10,000 feet).

Towns and Villages

Settlements in the Blue Nile Basin fall into three categories--groups of compounds in small agglomerations; scattered, non-agglomerated compounds; and villages and towns proper. Towns and villages are clearly identifiable because of the darker pattern of the associated eucalyptus groves. Where these are large enough to be clearly identifiable on the 1:50,000 photographs, they have been outlined in their true size. Most of these are major settlements and are found only on the main routes through the basin.

FORESTS

At one time, forests covered approximately 37 percent, or in excess of 40,000,000 hectares, of Ethiopia. The high plateaus in ancient times were almost completely covered with dense forest. These areas, because of the more favorable climatic conditions and the abundance of wood for building and for fuel, were, as they are today, the most densely populated areas of the Empire. As a result, this led to an eventual devastation of a major part of the original forests in this area. About 32 percent of the original forest area has been destroyed, and it is now estimated that only 4 to 5 million hectares remain in forest.

At about the turn of the century, the shortage of wood on the high plateau, particularly in the vicinity of Addis Ababa, became so critical that Emperor Menelik wisely imported and introduced to Ethiopia the white eucalyptus (Eucalyptus globulus), a tree native to Australia. Today the eucalyptus covers an area of about 15,000 hectares on the high plateaus and is spreading rapidly. It supplies a considerable portion of the wood production and market. The productivity is very high, and it has been estimated that the average annual harvest is about 100,000 to 150,000 cubic meters, of which about 20,000

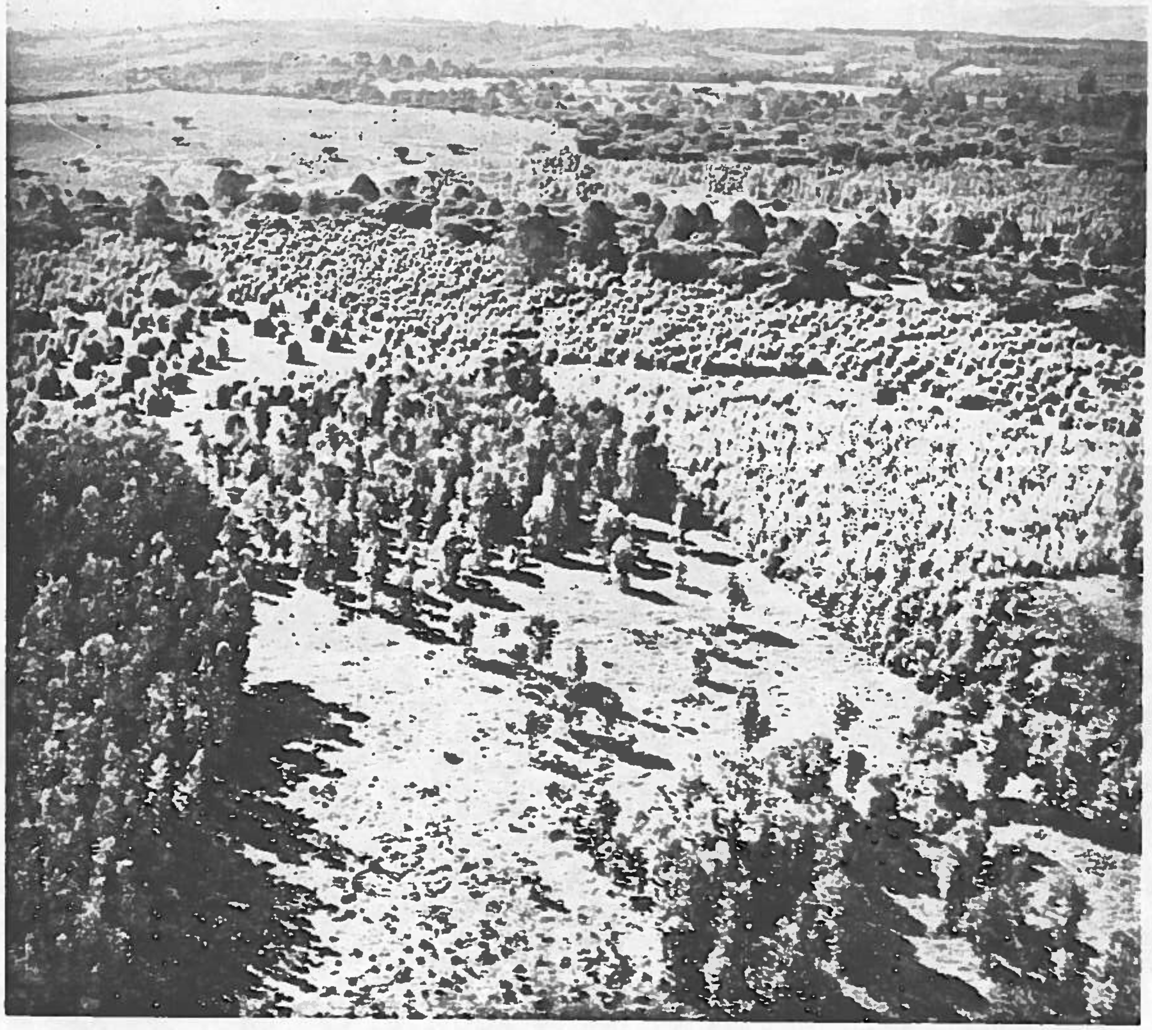


Figure 32. Eucalyptus provides fuel and construction material.

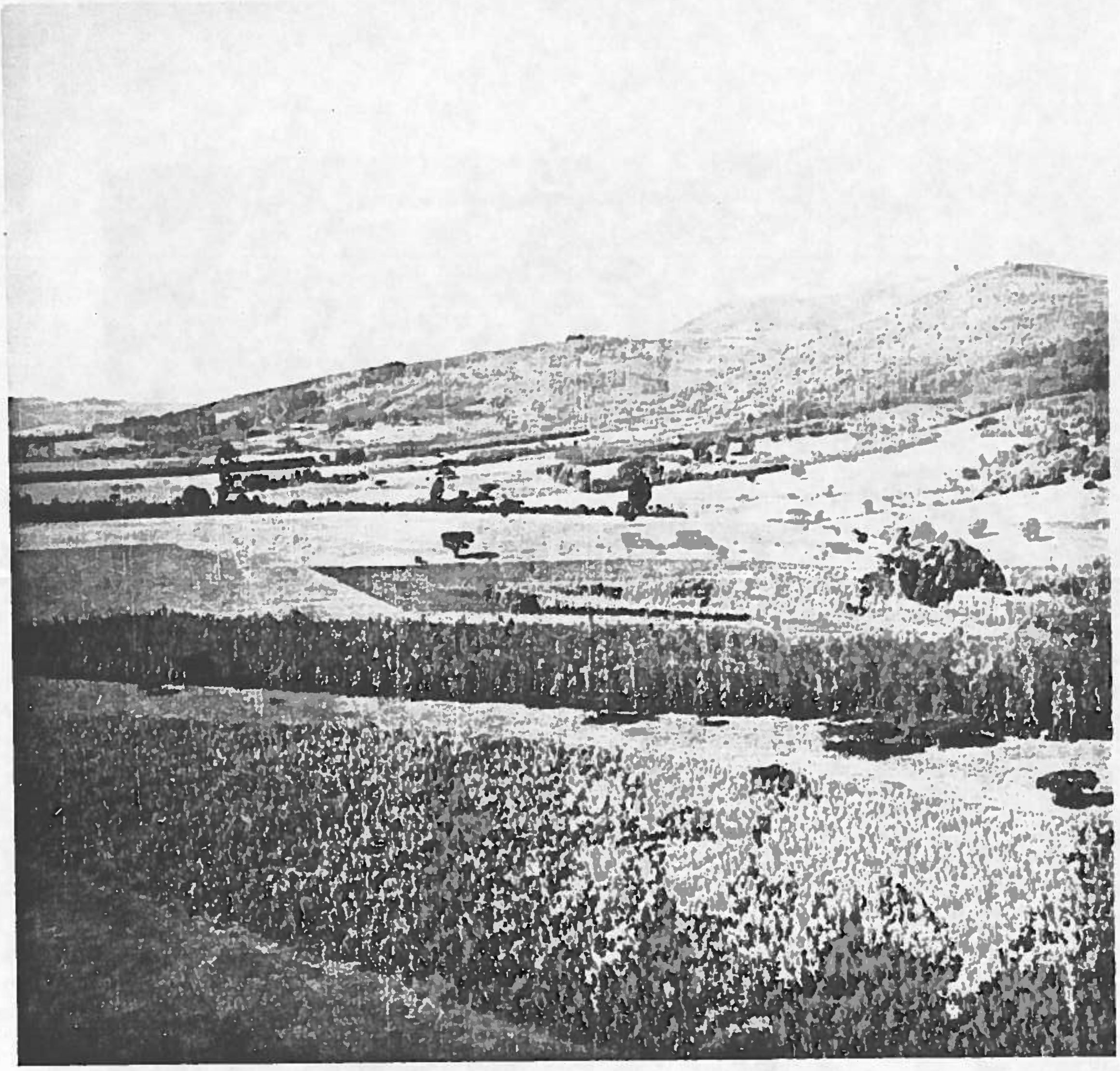


Figure 33. Eucalyptus groves near Addis Ababa.

cubic meters are used for building construction and for telephone and telegraph poles, while the remaining quantity is used for fuel for households and industry.

Depletion of the remnants of the remaining native forest or second growth trees continues at a rapid rate, and where there were once dense forests the areas are now covered with scrub trees or bush.

The annual removal has been estimated to be approximately as follows:

Saw logs and veneer	14,000 cubic meters
Building poles and other industrial wood	10,000 cubic meters
Fuel wood	5,000,000 cubic meters

In addition, about 25,000,000 cubic meters are removed from nonforest lands for fuel and charcoal. It has been estimated that about 99 percent of the wood is consumed as fuel. About 12,500 cubic meters of sawn lumber and 1,200 cubic meters of plywood are produced annually. About 5,000 tons of frankincense and about 60,000 tons of bamboo are harvested annually, the latter almost exclusively for local building material in the rural areas.

In addition to the identified forest areas, there are about a million hectares of bamboo thickets which are estimated to produce approximately 100,000,000 cubic meters of new bamboo each year. This is a natural resource yet untapped in Ethiopia. It is the equivalent of the production of 20,000,000 metric tons of raw cellulose. The more accessible bamboo areas are in the Blue Nile Basin near Lake Tana and Asosa.

Other than the eucalyptus, the remaining virgin forests are mainly Tedh and Zigba trees. The former resembles cedar or juniper, while the Zigba is a rather hard, white wood.

In the Blue Nile Basin, only minor remnants of the virgin forest remain. There is a wide variety of low grade trees and brush which is of little value except as fuel.

The Imperial Ethiopian College of Agriculture and Mechanical Arts offers a course in forestry, and the Ambo School of Forestry, a secondary school, provides a reservoir of trained personnel to help manage and conserve the forests of Ethiopia.

The economic development of Ethiopia depends, in part, upon the conservation and productive transformation of the remaining forest resources. The function of the forests is twofold--to supply an adequate and continuous supply of timber, and to provide soil and water conservation by controlling erosion and providing ground cover.

The forests constitute a substantial natural resource that, if properly conserved and wisely used, can add much to the national economy.

HEALTH

Although Ethiopia, through the Ministry of Public Health and other agencies, is making a concerted effort in cooperation with international agencies, USAID, and agencies of other foreign countries to create improved health conditions in the country, very serious problems remain to be solved. Many of these problems will have a direct bearing on the rate of development of the nation's natural resources.

Life expectancy is low and child mortality is high. Infestations of external and internal parasites, venereal disease, tuberculosis, malaria, leprosy, and infectious eye disease contribute to the high rates of mortality and seriously affect the general health of a large portion of the population.

There are few hospitals in the area, and most of these are lacking in equipment and seriously short of doctors. The ratio of patients to doctors is high, and the present transportation and communications generally limit the use of the existing facilities to those in the immediate vicinity. Because of this, most ill persons living in areas other than the principal towns usually rely, to a large degree, upon the traditional practitioner and the native healer. Modern medicine and professional medical practices are not well known to the people and are often considered with mistrust and suspicion and are not always immediately accepted as being superior to the traditional practices.

Much of the prevalent illness is due, to a large extent, to the almost total absence of sanitation and the low level of personal cleanliness. None of the towns within the Blue Nile Basin, in fact within Ethiopia, has a central sewage disposal system. Cesspools are used for the better homes and business establishments, but many of the houses within the towns and practically all those in the rural areas have no such facilities. The houses are not screened, and flies and other disease carrying insects breed freely and contribute in large measure to the spread of disease.

In the principal towns, open wells usually provide the water supply for the main area, but, as in the case of sewerage, many houses do not have water supply facilities. For the most part, the residents obtain their often inadequate and never treated water supply from open ditches, streams, and ponds.

During the dry season, the water supply often becomes very short and its use is limited to essential purposes. Some foreigners residing in Ethiopia boil and filter the water, thus avoiding many of the illnesses. The Ethiopians, however, use the untreated water, and, although they apparently build up resistance to some of the water-borne diseases, there are still very serious epidemics of disease that frequently occur which can be attributed directly to the polluted water supply.

Unsanitary and crowded housing conditions, especially where living quarters are shared with the family cow, sheep, chickens, or other animals, add to the problems of flies, mosquitoes, lice, and ticks which also carry and spread disease. The incidence and prevalence of tuberculosis in cattle and other animals is largely unknown. However, the disease has been or is present in both privately and governmentally owned herds near Addis Ababa. It was reported that one herd tested showed the incidence of tuberculosis to be 60 percent. This would indicate that it is an economic as well as a public health problem, and it will become increasingly important as the dairy industry develops. It was also reported that the incidence of brucellosis and anthrax is increasing annually.

Malaria and schistosomiasis are serious, particularly at the lower altitudes where much of the agricultural potential remains to be developed. The present control measures will have to be expanded to these now unpopulated areas as the population expands and these resources are developed.

Less data on health conditions and vital statistics are available for the Blue Nile Basin than for other localized areas or centers of population in Ethiopia. A wide range of communicable diseases is found within the basin. Medical facilities and personnel are located at strategic points throughout the more populous highland plateau area, but hospitals and medical technicians are not generally available to persons residing in low density population areas.

The Ethiopian Government, particularly the Ministry of Public Health, recognizes the problems with which it is confronted in improving conditions to safeguard the health of the nation and provided the following information on January 10, 1962, in a letter report to the Ministry of Public Works and Communications.

<u>Diseases Found</u>. Malaria (falicparus and vivax); smallpox; tuberculosis; venereal diseases; cerebro-spinal meningitis; yaws (Sudan border); typhus (louse-borne); relapsing fever; yellow fever (threatening from Sudan); auchylostomissis, filiariasis, schistosomiasis; trachoma and other communicable eye diseases; leprosy; nutritional diseases; typhoid (from Sudan); Kola Azar (leishamaniosis) from Sudan; tropical ulcers; and rabies.

Figure 34. A health center at Asosa, built with USAID assistance.

Vital Statistics

Birth rates. About 30 per 1,000--no exact figures found; varies with the different tribes.

Death rates. About 30 per 1,000--no exact figures are available.

Infant mortality. Below 1 year of age, 200 to 300 or more per 1,000 live births. All figures are only approximations.

Hospitals 1/

Gojjam Province. Debre Markos, 56 beds, Ministry of Public Health; 1 doctor and auxiliary personnel.

Wellegga Province. Lekkemt Hospital, 80 beds, Government hospital run in cooperation with mission; nursing training school; 2 doctors and 4 or 5 nurses. Gimbi Hospital, mission hospital, 50 beds; 1 doctor and 2 nurses. Just outside the basin, but partially serving it, is the Dembbi Dollo Mission Hospital, 50 beds; 1 doctor and 2 or 3 nurses.

Ilubabor Province. Just outside the basin, but serving part of it, is Gore Government Hospital and Health Center, 42 beds; 3 doctors, 1 health officer, 1 community nurse, and 1 sanitarian.

Shewa Province. Agere Hiywet (Ambo), Door of Life Mission Hospital, 50 beds; 1 or 2 doctors, 2 or 3 nurses. Just outside the basin, but serving parts of it, are several hospitals and medical facilities in Addis Ababa, and the Debre Birhan Government Hospital with 40 beds and 1 doctor.

Wello Province. Just outside the basin, but serving parts of it, are the Dessie Government Hospital and Health Center, 100 beds; 2 doctors, 2 health officers, 2 community nurses, and 2 sanitarians. Dessie Mission Hospital, 50 beds; 1 doctor, and 2 nurses.

Begemidir Province. Debre Tabor Mission Hospital, 50 beds; 1 doctor, and 2 or 3 nurses. Gondar Government Hospital, 100 beds; 5 doctors, and 10 nurses. Also, additional staff, doctors, and nurses for the Haile Selassie I Public Health College and Training Center.

Other Public Health Facilities

Gojjam Province. Debre Markos Health Center with two health officers, two community nurses, two sanitarians, and auxiliary personnel. Finote Selam Health Center (with Leprosy Hospital) with two health officers, two community nurses, one sanitarian, and auxiliary personnel.

Wellegga Province. Shambo Health Center with one health officer, two community nurses, and one sanitarian. Asosa Health Center with two health officers, two community nurses, and one sanitarian.

Shewa Province. Fiche Health Center with one health officer. Mullu Health Center with one health officer, two community nurses, and one sanitarian. Molale Health Center with one health officer, two community nurses, and one sanitarian.

1/Since the completion of the field investigation, it has been reported that the following additional facilities have become available:

Wellegga Province: One additional hospital, 63 additional beds, and 9 additional nurses.

Wello Province: One additional hospital, 74 additional beds, 2 additional medical officers, 11 additional nurses.

Begemidir Province: Seventy-five additional hospital beds.

Ilubabor Province. Buna-Bedele Health Center with one health officer, one community nurse, and one sanitarian.

Kefa Province. Agaro Health Center with two health officers, two community nurses, and one sanitarian.

Wello Province. No health center in the basin.

Begemidir Province. The Kolla Dibba Health Center and the Gorgora Health Center--both training centers with large staffs for teaching purposes.

Control Program. A malaria control program is going on in Gojjam Province under the auspices of the Ministry of Public Health, USAID, the WHO, and UNICEF.

Planned Situation. A new hospital with a training center is to be built in Bahir Dar with 100 beds, 3 doctors, 4 nurses, 2 health officers, 2 community nurses, and 1 sanitarian. In addition, the Debre Markos Hospital is to be reconstructed. As a part of the plans for expansion of health centers and health stations, new health centers are scheduled for Dangila and Metekkel in Gojjam Province and for Gidami in Wellegga Province. A list of the proposed health stations is not yet available. Adequate personnel are planned to staff the expanded services.

The malaria control program will be expanded with yellow fever vaccinations proposed for the western part of the Blue Nile Basin, which is threatened from the Sudan, and with a program of communicable diseases integrated in the basic public health services through health centers and health stations.

With properly developed basic public health services, it is anticipated that life expectancy will increase, population will increase, and infant mortality will be reduced.

EDUCATION

Probably no other sector of the general program for improvement and development of Ethiopia has received the attention or made the progress as has education. Although the school system has been expanded considerably in recent years, formal education is still available to only a fraction of the population. By present day educational standards, illiteracy probably exceeds 95 percent. The rugged terrain, the lack of roads resulting in the inaccessibility of much of the country, the critical teacher shortage, and the lack of schools, all contribute to the problem. The existence of many tribal languages and dialects, most of which have no written alphabet, and the fact that many are unfamiliar with the official language, Amharic, all add to the problem of expanding education.

The rate of enrollment in Government schools between 1956 and 1957, as reported by governmental agencies, reflects the upward trend in education. It is anticipated that the enrollment rate will accelerate as facilities become available.

Enrollment in Government Schools 1/
(First Term Reports)

Schools	1956/57	1957/58	1958/59	1959/60	1960/61
Primary	116,376	127,142	129,285	136,691	140,704
Middle	19,373	23,614	28,720	33,769	32,022
Secondary	7,390	9,735	12,640	5,273	5,626
Special secondary	2,134	2,479	3,648	3,646	3,598
Higher learning	466	605	760	784	939
Total	140,977	157,468	166,909	180,163	186,810

1/Ethiopian Economic Review, No. 5, February 1962.

The drop in secondary school enrollment in 1959 and 1960 is unexplained, and it seems likely that for some reason total enrollments were not reported.

The nation's schools fail, at this time, to provide an adequate number of graduate administrators, managers, teachers, engineers, and professional personnel to meet the expanding needs of Government and industry.

In addition to those who attend the Government schools, it is estimated that about 100,000 receive religious elementary education in schools of the Orthodox Church and approximately 45,000 in private and missionary schools. The great majority of the schools are located on the high plateau, and large areas in the lowlands are without schools. Because of inadequate preparation at the elementary level, it appears that many pupils enrolled in academic secondary schools may not be basically qualified for secondary studies. However, they are admitted because of the need to increase enrollment in the schools. Poor academic preparation handicaps the students entering college.

Most of the schools are coeducational, but the male students outnumber females. The oldest educational institutions are the primary schools of the Ethiopian Orthodox Church. Their curricula have fostered orthodox Christianity in the Amharic-populated areas for centuries and have preserved the Amhara culture and social customs.

The Emperor has shown keen interest in educational progress and has retained for himself the portfolio of Minister of Education and Fine Arts. The ministry has many foreign expert advisers, and the educational system is gradually changing to meet the needs of the nation.

With assistance and guidance from USAID and European professional experts and with UNESCO contributions, the Ministry of Education has entered into a program for the controlled expansion of Ethiopian education with the main emphasis on expanding the elementary school system, the decentralization of secondary schools, and the consolidation of the institutions of higher learning, as well as the intensification of teacher training. The U.S. Peace Corps has made valuable contributions to the program, starting in 1962.

The elementary and secondary schooling is organized in 3 levels of 4 years each: primary school, 1 through 4; middle school, 5 through 8; and secondary school, 9 through 12. The initial enrollment age is 6 years. However, many of the students are much older, since many of the areas have not had schools until recent years. Often the ages in a class may range from 6 to 16 years, the more predominating group being the 11- and 12-year olds. Since classroom construction still lags, there is a great deal of overcrowding of classrooms, especially in the primary schools. Classes average about 40 students, but larger numbers are also very common. At completion of grade 8, the students are given an examination to determine their eligibility for post-elementary schooling. Conversational English is introduced in the third or fourth grade as a subject in most schools, and it becomes the language of instruction in the sixth grade and is continued through college as the language of instruction.

At the secondary level, there are both academic and vocational schools. Upon completion of the secondary education the students are given the Ethiopian School Leaving Examination, which determines qualification for enrollment in institutions of higher learning. In addition, the students may take the examination for the General Certificate of the University of London, which is prepared, administered, and rated by the University College of Addis Ababa and determines qualification for foreign university enrollment.

Prior to the 1950's, the few Ethiopian students eligible for college were sent to Europe and the United States on Government scholarships. In 1951, Emperor Haile Selassie I inaugurated the University College of Addis Ababa, which was to be expanded by various faculties and extension departments and finally become a part of the Haile Selassie I University, as were the other institutions of higher learning.

The University College has faculties of art, science, and commerce which grant bachelor degrees upon completion of a 4-year course. It also grants degrees in education and business administration. 1/ College of Engineering, which is located in Addis Ababa, offers 4- and 5-year courses in civil, electrical, and mechanical engineering. The enrollment is not high, 30 to 50 students in the 1955 to 1959 period;2/ but its graduates are in great demand and they are making valuable contributions to the technical labor force of the nation. The Ethio-Swedish Institute of Building Technology provides 3- and 4-year courses in building and other technical subjects.

The Imperial Ethiopian College of Agriculture and Mechanical Arts was founded in 1956 at Alemaya with the assistance of Oklahoma State University and financed largely through the USAID program. It offers courses in general agriculture and specialized training in farm and livestock management, soil chemistry, and plant nutrition. By 1963, 154 students had graduated and are becoming available in increasing numbers. 3/ The early graduating classes were assigned to the Ministry of Agriculture, returned to school as teachers at Alemaya or at the Jima Agricultural and Technical School, or were sent abroad to continue their studies. Very few have become directly connected with farming operations. By the time Ethiopia can develop a large scale irrigation project, this college should be capable of producing adequate numbers of agriculturally educated men. They will lack experience, since this type of agriculture in Ethiopia is limited; but, with good management and leadership, they should soon be capable of assuming the responsibilities for which they have been educated.

The Public Health College at Gondar offers a 4-year program for public health officers, and 3- and 2-year programs for community nurses, sanitarians, and laboratory technicians. This institution has had marked success and is staffing health centers throughout the Empire. With the development of irrigation projects, the health centers will play an important part in providing services to newly settled areas.

POPULATION

A complete population census of Ethiopia is not available. Most current estimates place the population between 15 and 21 million. Recent census surveys reveal the population of Addis Ababa, the capital of the Empire, to be 450,000, and Asmara, the next largest city, to be about 100,000. Other cities and towns have been estimated to have populations as follows in the year 1961.

City	Population	City	Population
Begi4/	4,000	Jijiga	5,000
Gore	25,000	Negelli	5,000
Dessie4/	35,000	Massawa	25,000
Dire Dawa	40,000	Bahir Dar4/	10,000
Jima	35,000	Asosa4/	2,900
Agere Hiywet (Ambo)4/	10,000	Gimbi4/	5,000
Debre Birhan4/	10,000	Assab	9,000
Ghion (Woliso)	5,000	Lekkemt4/	25,000
Gondar4/	25,000	Debre Tabor4/	5,000
Yrgalem	5,000	Mendi4/	2,900
Debre Markos4/	15,000		

1/Reported Business Administration enrollment of 139 in 1963.
2/Reported enrollment of 179 in 1963.
3/Enrollment of 219 in 1963.
4/Within or on the rim of the Blue Nile Basin.

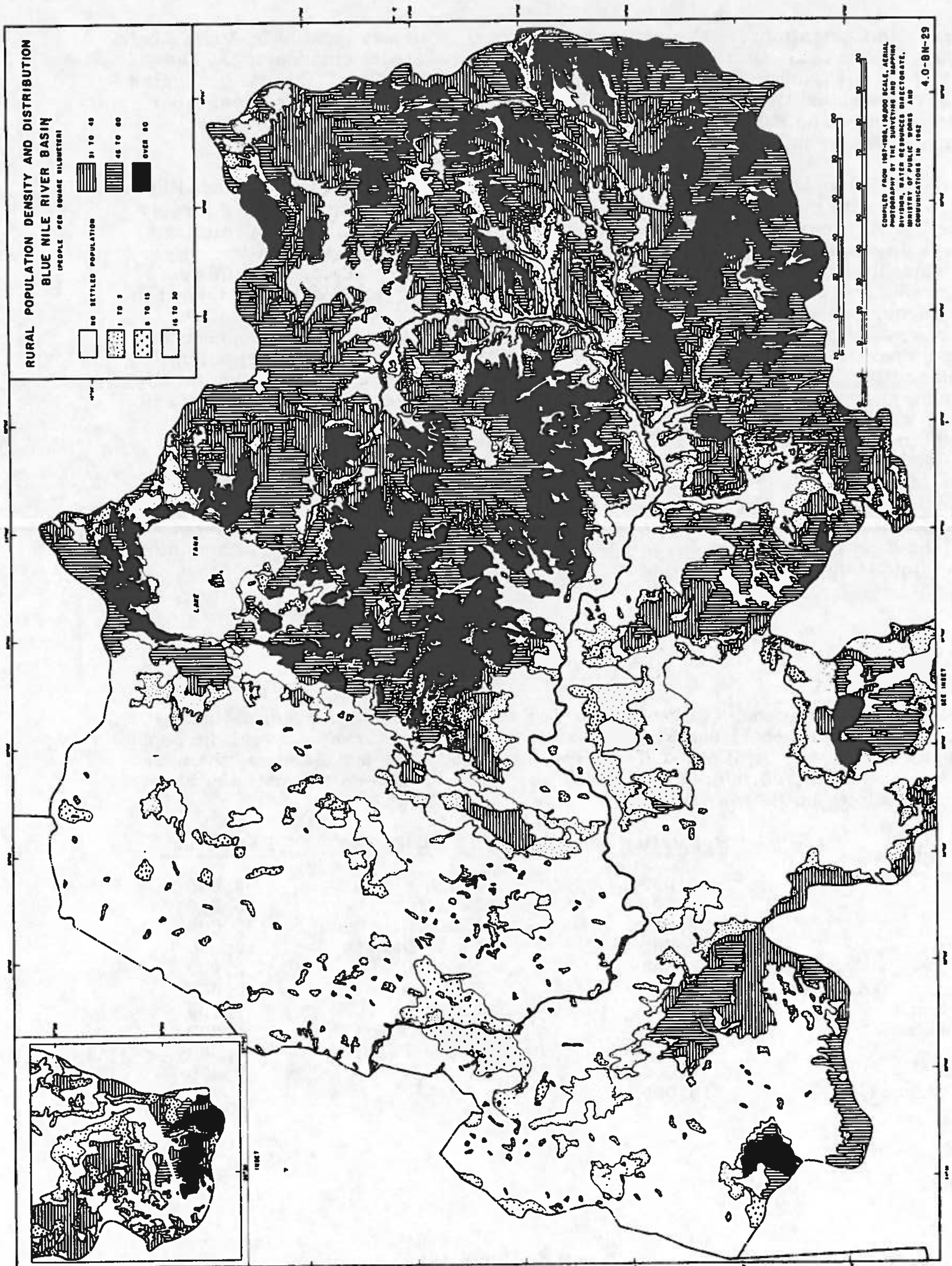


Figure 35--Rural Population Density and Distribution, Blue Nile Basin

The population of the Blue Nile Basin is estimated to be about 4,870,000 people, distributed to the provinces roughly as follows.

Province	Population
Wellegga	1,270,000
Gojjam	1,180,000
Shewa	1,090,000
Wello	640,000
Begemidir	450,000
Ilubabor	150,000
Kefa	90,000

The population density and distribution map indicates that the population is generally concentrated on the high plateau where climatic conditions are most salubrious. The low density in the areas of lower elevation can be attributed to a number of factors, including the high temperatures, lower precipitation, and prevalence of diseases, including malaria and livestock diseases.

The annual population increase is estimated to be about 1.5 percent. Some sources estimate the portion of the population under 15 years of age at 35 percent and the portion over 60 years of age at 8 percent. Therefore, it is assumed that the population of working age in Ethiopia (15 to 60 years) is about 57 percent of the total. The population between 55 and 60 years of age is estimated to be 3.5 percent.

Approximately 95 percent of the basin population lives in the rural areas on small farms or in small villages.

LABOR FORCE

The Blue Nile River Basin has a population of about 4.87 million people. Only a very few of these are skilled in modern trades. About 95 percent of the basin's labor force is self-employed in the subsistence farming operations. A small force of semiskilled workers, carpenters, mechanics, pottery makers, smiths, masons, and shopkeepers in towns provide service to those engaged directly in agriculture.

The number of those unemployed is not great, but the majority of those who are employed are underemployed--their employment in pursuit of a standard of living at a mere subsistence level does not occupy their full time. Other than in agriculture, industry has not developed to a significant degree within the basin. Therefore, one might say that there is no industrial labor force.

The present lack of a skilled labor force does not represent a serious shortage when it is considered in relation to the present level of advancement or the present demand. It would immediately become critical if modern agricultural practices on a large scale were introduced into the area or if other industry were to develop, even on a small scale. Labor's productivity is understandably low because of the underemployment, the prevalence of disease, the many holidays when work is not expected, the poor working conditions, and other reasons.

Government service seems to be the principal employment goal for most educated persons, regardless of the level of education. Many foreigners, largely European, occupy positions requiring skilled or supervisory labor. There is an acute shortage of well-qualified administrative and managerial personnel experienced in modern methods. Here again, there are many foreigners occupying key positions. However, as the result of intensive training programs in almost every field, a change is gradually being brought about.

The College of Agriculture, the University College, and the Jima and Ambo Agricultural Schools are now graduating an impressive number of students each year; unfortunately, very few of these find employment in the agricultural field at the farming level, the large majority becoming associated with a governmental agency. It would appear that this sector of the labor force could be more effectively employed. The service they have been trained to provide is definitely needed and they are willing and eager to apply their talents and deomonstrate their acquired abilities, but the program of agricultural development simply has not advanced at a rate consistent with educational development, resulting in a temporary situation where supply and demand are not efficiently balanced.

Advances in all fields of development--agriculture, industry, construction, education, health, and others--in this area will require a program of training for the labor force consistent with the rate of development. Irrigation projects will create labor demands, including extension workers, farm mechanics, service workers, shopkeepers, truck drivers, and many others; only through training can these demands be met.

ELECTRIC POWER

Background

Ethiopia is divided into 14 provinces including the province of Eritrea, recently joined to the Empire. The Ethiopian Electric Light and Power Authority (EELPA) is the only significant utility serving the original 13 provinces, and the Authority recently assumed responsibility for serving the seaport of Assab in southern Eritrea. Except for this and the utility serving the Massawa-Asmara area (SEDAO), the electric power requirements of Eritrea are supplied by very small utilities serving isolated loads.

The EELPA operates several isolated systems serving small towns and, in addition, serves the largest and fastest developing section in the country--the Addis Ababa-Dire Dawa centers--by means of an interconnected high-voltage transmission system from the Koka Hydroelectric Project on the Awash River, placed in operation in 1960. Prior to that time, most of the energy was generated by thermal plants using imported petroleum products. The Koka powerplant has a firm output of about 23,000 kilowatts.

The Addis Ababa-Dire Dawa centers essentially comprise the nuclei of the present interconnected system, and inasmuch as the Addis Ababa load is considerably larger than the Dire Dawa loads, the area served by this present system is referred to as the Addis Ababa Complex, South Region.

The Blue Nile River Basin is located adjacent to the area that has the largest load and load growth potential. Also, since ultimately it may be feasible to serve the South Eritrea load center (Assab, primarily) from the Interconnected System, it follows that these, together with other, much smaller, load centers, will represent a significant part of the Empire of Ethiopia. Thus, the principal power supply (Blue Nile) and the principal market areas will together cover the most populous zones and that substantial part of Ethiopia which determines the health of the national economy, and hence overall national load growth. Even though the Blue Nile power will not be marketed throughout Ethiopia, the fact that it can be the principal supply for these critically important areas means that the nation as a whole must be considered and not just the small, isolated, potential load centers within the Blue Nile Basin.

Hydroelectric Resources

The hydroelectric power potential of the Blue Nile Basin may represent one of the greatest natural resources of the country. The Blue Nile is but one of the major river basins in Africa, which has an estimated hydroelectric potential of 40 percent of the world total. Africa as a whole has developed only about 0.1 percent of its estimated total potential and, in the Blue Nile River Basin in Ethiopia, only something less than 0.01 percent.

On the basis of the studies made in this investigation, a total of almost 38,000 million kilowatt-hours in an average water year is technically possible of development in the Blue Nile River Basin within Ethiopia. This would amount to about 8,660,000 kilowatts at 0.5 plant factor. By the year 2000, 629,500 kw. (continuous) of power may be required, representing about 1,038,220 kw. of installed dependable capacity.

For comparison of total Blue Nile River Basin hydroelectric potential with some other countries from United Nations studies, see Table 9.

Degree of Electrification

An insight into the magnitude and degree of electrification of a country is helpful when considering some aspect of the power supply problem. Ethiopia has about the lowest per capita electrical energy in Africa--about 3 kw.-hr. per capita in 1954. In 1961 this had doubled to about 6 kw.-hr. and by 1965 should again double to about 12 kw.-hr. This corresponded in 1954 to something over 100 kw.-hr. per capita for Africa as a whole and about 500 kw.-hr. per capita for the world. In 1961 Africa produced 157 kw.-hr. per capita, and the world average was 766 kw.-hr.

Existing Power Systems

Figure 37 shows the total power supply installations in the Empire as of 1961, with the scheduled additions between 1961 and the end of 1963 noted. Substantially all of the installations are isolated, small, diesel-electric units, although the total of all such installations is considerably less than the present interconnected system, Addis Ababa Complex.

South Region. This region can be divided into two classifications--the present interconnected system (Addis Ababa Complex) and the isolated systems.

Interconnected System (Addis Ababa Complex). The present interconnected system has five powerplants, some of which are maintained as reserve capacity as noted in Table 10.

The largest existing powerplant is Koka Hydro, which is served by a reservoir on the Awash River having a capacity of 1,500 million cubic meters. Utilizing a head of 32 to 40 meters, the installed capacity consists of three generators, each rated at 18,000 kv.-a. or 54,000 kv.-a. total. The rated capacity at full load is 45 mw., but this includes one generator as a "spare." At the lowest reservoir level, the firm plant capacity as based upon two units is regarded as 23 mw.

Aba Samuel Hydroelectric Powerplant is about 35 kilometers south of Addis Ababa on the Acachi (Akaki) River, a tributary to the Awash. There are five generating units operating at 95-meter heads (different sizes) providing a total rated capacity of 8,250 kv.-a. or 6,600 kw. The reservoir has a storage capacity of 60 million cubic meters. Firm capability has been established as 4,750 kw.

The Ourso Hydroelectric Powerplant is 30 kilometers west of Dire Dawa and is served from a natural spring with no reservoir, having only forebay storage for a little regulation. It is rated at 525 kv.-a. with a head of 175 meters.

The Addis Ababa steam powerplant consists of one condensing steam turbine operating at a pressure of 29 kilograms per square centimeter at 425° C and one 6,250-kv.-a. generator. It has been in standby since the early or middle part of 1960 with the advent of Koka power.

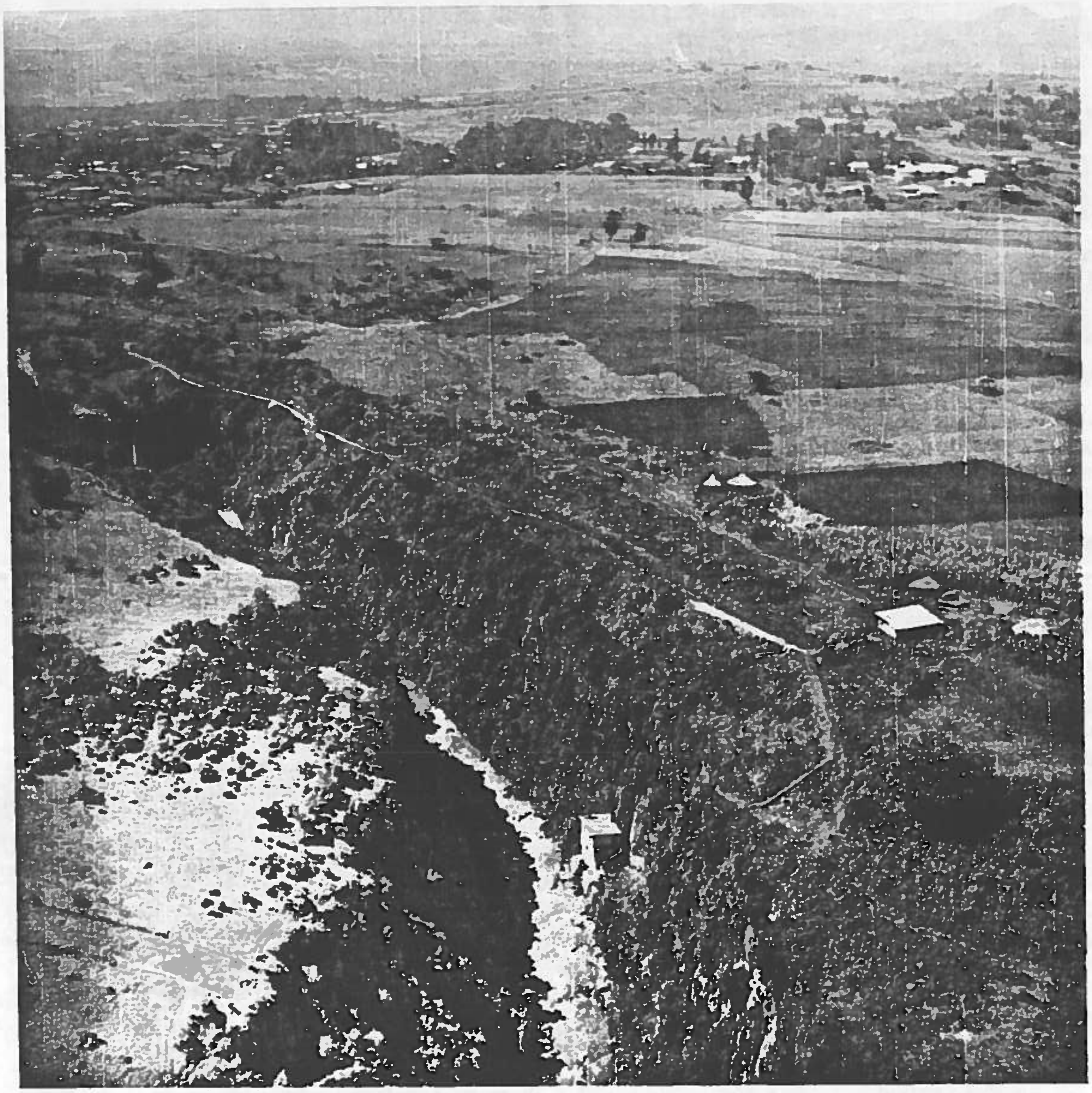


Figure 36. Small hydroelectric powerplant on the Guder River.

Industry	Number of establishments in operation 1960	1961	Purchase of materials 1961 (Eth$1,000)	Value of fixed assets Sept. 1961 (Eth$1,000)	Capital expenditures 1961 (Eth$1,000)	Value of production, 1961 (Eth$1,000) Gross	Net
Food products	23	23	6,285	13,517	2,655	11,344	4,521
Slaughtering and preparation of meat	6	6	3,768	2,351	343	4,682	794
Dairy products	2	2	51	291	2	878	803
Egg products	2	2	-	150	129	294	274
Flour, macaroni, biscuits	6	6	1,084	741	338	1,939	734
Salt (sea)	2	2	1,207	9,526	1,833	2,432	1,037
Edible oils and byproducts	5	5	175	458	10	1,124	879
Beverages	13	13	2,869	1,788	19	4,980	1,962
Alcohol, beer, liquors	3	7	2,280	999	-	3,505	1,117
Wines	7	7	398	330	-	1,040	637
Soft drinks and carbonated water	3	3	191	459	19	435	208
Tobacco manufactures	1	1	294	143	17	806	503
Manufactures of textiles	3	4	6,089	9,080	5,160	10,383	3,868
Printing and publishing	7	7	-	-	-	-	- 1/
Chemicals and chemical products	4	3	104	830	113	383	217
Oxygen and carbon dioxide	2	2	-	190	-	77	57
Matches	2	1	104	640	113	306	160
Nonmetallic mineral products	6	6	560	3,003	332	2,060	1,099
Bricks	4	4	N.A.	63	-	150	100
Glass, mosaics	2	2	N.A.	2,691	178	1,860	989
Cement products	-	-	N.A.	251	-	50	10
Miscellaneous manufactures	16	17	380	1,616	212	1,848	1,332
Paper	2	2	17	98	-	83	49
Buttons	2	3	98	900	-	458	392
Fishmeal	-	-	53	138	150	435	365
Other	12	12	212	479	62	812	526
Total manufacturing	73	74	16,581	30,179	8,508	31,804	13,502
Electric light and power	9	9	615	13,628	1,102	3,780	1,590
Total industry, excluding coffee and grain cleaning, mining, and							

TABLE 3.-SUMMARY OF INDUSTRY IN ERITREA, 1961

Industry	Number of establishments in operation 1960	Number of establishments in operation 1961	Purchase of materials 1961 (Eth$1,000)	Value of fixed assets Sept. 1961 (Eth$1,000)	Capital expenditures 1961 (Eth$1,000)	Value of production, 1961 (Eth$1,000) Gross	Net
Food products	23	23	6,285	13,517	2,655	11,344	4,521
Slaughtering and preparation of meat	6	6	3,768	2,351	343	4,682	794
Dairy products	2	2	51	291	2	878	803
Egg products	2	2	-	150	129	294	274
Flour, macaroni, biscuits	6	6	1,084	741	338	1,939	734
Salt (sea)	2	2	1,207	9,526	1,833	2,432	1,037
Edible oils and byproducts	5	5	175	458	10	1,124	879
Beverages	13	13	2,869	1,788	19	4,980	1,962
Alcohol, beer, liquors	3	7	2,280	999	-	3,505	1,117
Wines	7	7	398	330	-	1,040	637
Soft drinks and carbonated water	3	3	191	459	19	435	208
Tobacco manufactures	1	1	294	143	17	806	503
Manufactures of textiles	3	4	6,089	9,080	5,160	10,383	3,868
Printing and publishing	7	7	-	-	-	-	- 1/
Chemicals and chemical products	4	3	104	830	113	383	217
Oxygen and carbon dioxide	2	2	-	190	-	77	57
Matches	2	1	104	640	113	306	160
Nonmetallic mineral products	6	6	560	3,003	332	2,060	1,099
Bricks	4	4	N.A.	63	-	150	100
Glass, mosaics	2	2	N.A.	2,691	178	1,860	989
Cement products	-	-	N.A.	251	-	50	10
Miscellaneous manufactures	16	17	380	1,616	212	1,848	1,332
Paper	2	2	17	98	-	83	49
Buttons	2	3	98	900	-	458	392
Fishmeal	-	-	53	138	150	435	365
Other	12	12	212	479	62	812	526
Total manufacturing	73	74	16,581	30,179	8,508	31,804	13,502
Electric light and power	9	9	615	13,628	1,102	3,780	1,590
Total industry, excluding coffee and grain cleaning, mining, and construction	82	83	17,196	43,807	9,610	35,584	15,090

1/Data for the printing presses in Asmara not available.

Source: Central Statistical Office

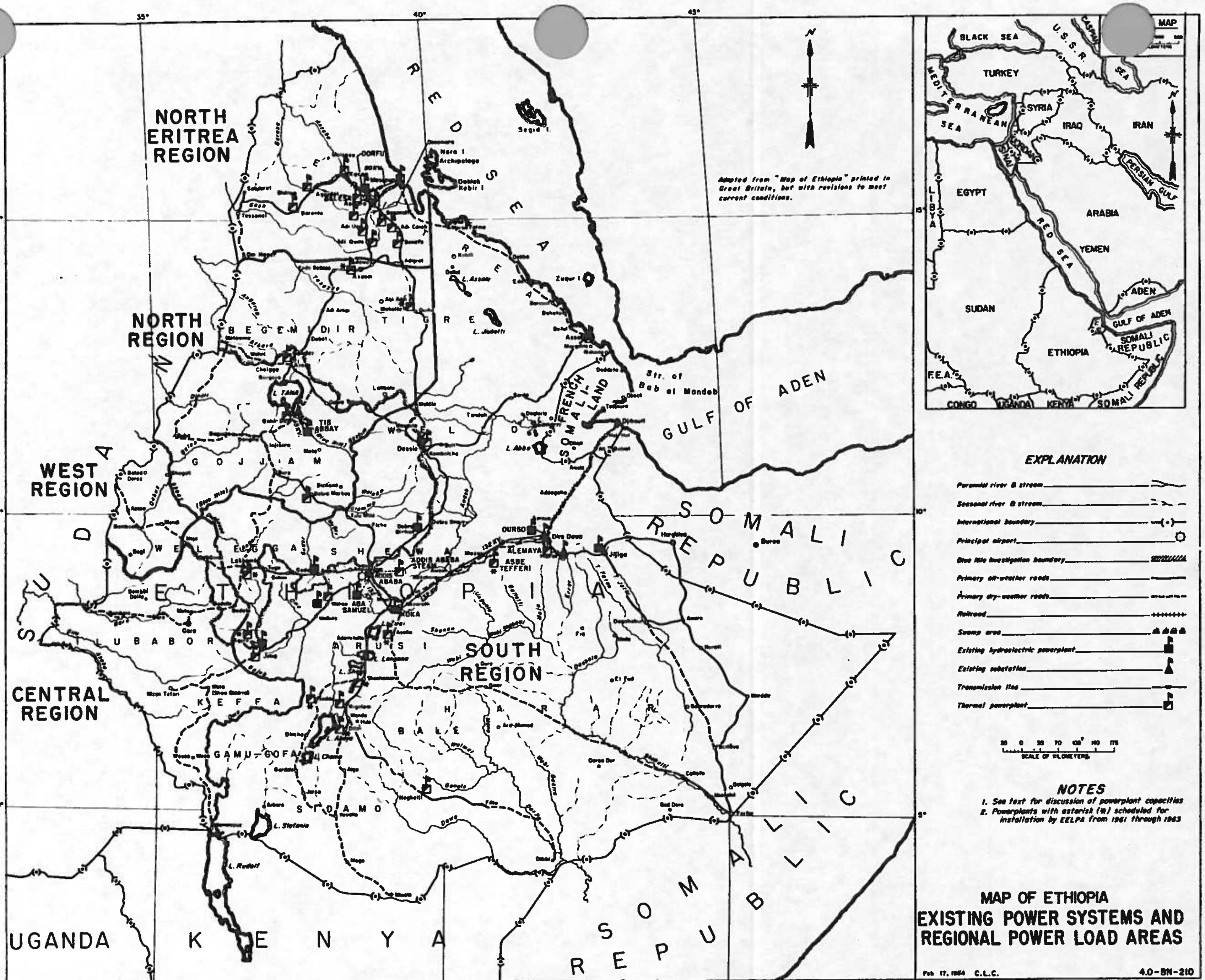


Figure 37--Existing Power Systems and Regional Power Load Areas

TABLE 9--COMPARISONS OF HYDROELECTRIC POTENTIAL

Country or area	Annual gross surface hydro potential (kw.-hr. x 10^9)	Gross density (kwh x 10^6 per km^2)	Practically exploitable (kw.-hr. x 10^9)	Percent (4)÷(2)
(1)	(2)	(3)	(4)	(5)
Switzerland	144.00	3.488	30.0	20.8
Austria	152.50	1.819	40.0	26.3
Blue Nile River Basin in Ethiopia	173.52	0.870	37.9 1/	21.9
Yugoslavia	205.90	0.806	66.5	32.4
Turkey	536.50	0.698	90.0	16.7
France	255.00	0.463	60.0	23.5
Czechoslovakia	39.30	0.307	12.5	31.9
Romania	64.00	0.269	21.6	33.7
Poland	31.90	0.102	5.5	17.2
Hungary	7.20	0.077	1.5	20.9
Netherlands	3.60	0.011	-	-

Source: United Nations publication E/ECE/EP/131/Add. 1

1/ For Ethiopia, about the same as "technically exploitable."

TABLE 10--1961 INTERCONNECTED SYSTEM--ADDIS ABABA COMPLEX, SOUTH REGION

Name and type	Installed capacity (kv.-a.)	Firm capacity (kw.)	Production capability (millions of kw.-hr.)		
			Good water years	Average water years	Adverse water years
Koka Hydro	54,000	23,000	120	110	90
Aba Samuel Hydro	8,250	4,750	27	23	18
Ourso Hydro	525	250	2	2	2
Addis Ababa Steam 2/	6,250	(5,000)	0	10	30
Alemaya Diesel 2/	2,910	2,000	1	5	10
Total	71,935	30,000	150	150	150

Source: EELPA

1/ Unchanged in 1963 except for loads.
2/ Normally maintained as reserves in good water years; possible operation as shown in average and adverse water years.

The Alemaya diesel powerplant is about 30 kilometers south of Dire Dawa. Three sets are installed with a total capacity of 2,910 kv.-a. It began operation in 1958 parallel with Ourso. It went into reserve status at the beginning of 1961 when Koka power was made available to this area over the 132-kv. transmission line.

For the interconnected system there were 418 kilometers of 132-kv. transmission lines, 62 km. of 45-kv. lines, and 97 km. of 15-kv. lines--all steel tower except for the 15-kv., some of which is steel pole. Since 1961, some impregnated wood-pole, 15-kv. lines have been constructed. The 132-kv. lines are operated with the neutral grounded by Petersen coils, while the 15- and 45-kv. lines have isolated neutrals.

No additional transmission lines are to be placed into operation from 1961 through 1963 in this region.

There are three main high-voltage substations in the Interconnected System totaling 39,100-kw. capacity.

Isolated Systems. Several isolated systems are operated in the South Region.

Construction activity was to continue after 1961 in accordance with a predetermined plan; and, if those plans materialized, additional isolated powerplants would have been placed into operation by the end of 1963, causing the total system to appear as in Table 11.

There are no transmission lines or high-voltage substations in the isolated systems, as each small powerplant is generally located within distribution voltage range of the load center.

North Region. Development in this region has just started, and there is no interconnected system, although the Tis Abbay hydroelectric installation was substantially completed by the end of 1963 with a provision to install a third unit when the need arises, possibly by 1972. Small isolated diesel electric installations exist at Gondar, Debre Markos, and Bahir Dar.

The Tis Abbay hydroelectric powerplant is about 30 kilometers from the town of Bahir Dar. The water is taken from the Blue Nile into a 300-meter-long, open head canal, then to a vertical shaft which divides into three galleries before reaching the vertical Francis turbines, each rated 5,380 hp., 375 r.p.m., 46-meter head, with a discharge of 10 cubic meters per second. The amount of water taken from the Blue Nile is regulated by means of bypass gates which are remotely controlled from the control room. For the first stage, there will be two units, each of 4,800 kv.-a., generating at 6 kv. This is transformed in the switchyard to 45 kv. and then transmitted at 45 kv. to Bahir Dar Substation where it is distributed at 15 kv.

At Bahir Dar the original diesel plant, suppled with American assistance, consisted of two electrically started Mercedes diesels driving alternators rated 380 volts, 3 phase, 50 cycles per second. The total station output at the site is 96 kw. Later, following the textile mill installation at Bahir Dar, two additional diesel sets, 25 years old, were moved to Bahir Dar. These are rated 450 kv.-a. each. This provides a total dependable diesel electric capacity of about 600 kw. at Bahir Dar plus the hydroelectric capacity from Tis Abbay.

Smaller installations are located at Debre Markos and Gondar with all North Region production facilities summarized by Table 12 for 1963. This latter is based upon what was planned by EELPA in 1961 and has assumed that the planned activities were substantially accomplished.

There is one transmission line in the North Region, the 45-kv., 30-km. line from Tis Abbay Powerplant (BN-10) to Bahir Dar. Steel towers are used with 110-sq. mm. ACSR conductor.

TABLE 11.-POWERPLANTS-1963 ISOLATED SYSTEMS, SOUTH REGION

Location	Installed capacity (kv.-a.) 1/		Firm capacity (kw.) 2/	Production capability (1,000 kw.-hr.)	
	Diesel	Hydro		Diesel	Hydro
Lekkemt	300	-	150	400	-
Jima	1,125	170	600	2,400	300
Dessie	1,125	-	600	2,400	-
Agere Hiywet	-	210	100	-	350
Assab	1,375	-	375	1,600	-
Debre Birhan	-	125	100	-	300
Ghion (Woliso)	40	30	50	100	50
Yirgalem	410	-	260	1,050	-
Jijiga	340	-	180	600	-
Neghelli	150	-	50	150	-
Shashamana	450	-	210	800	-
Asella	150	-	100	300	-
Soddu	300	-	150	400	-
Dilla	150	-	100	300	-
Asbe Tefferi	150	-	100	300	-
Agaro	150	-	100	300	-

1/ In absence of specific data, power factor assumed at unity.
2/ Estimated, based partially upon altitude derating for diesels and minimum number of units available in a 24-hour period.

TABLE 12.-POWERPLANTS-1963 ISOLATED SYSTEMS, NORTH REGION

Location	Installed capacity (kv.-a.) 1/		Firm capacity (kw.)	Production capability (1,000 kw.-hr.)	
	Diesel	Hydro		Diesel	Hydro
Tis Abbay (for Bahir Dar)	-	9,600	2,400 3/	-	12,000
Bahir Dar	1,050	-	600 2/	3,000	-
Gondar	760	-	300 2/	1,500	-
Debre Markos	250	-	140 2/	325	-
Makalle	150	-	100 2/	300	-
Axoum	150	-	100 2/	300	-

1/ Some diesel units assumed to have PF = 1.0 and others PF = 0.8.
2/ Estimated, based partially upon altitude derating and minimum number of units available in a 24-hour period.
3/ Without Lake Tana regulation at outlet. Regulation may provide 7,700 kw.

Central Region. There were no electricity supplies in this area in 1962 except for very small diesel plants serving missionary stations and small private plants that served a part of the towns of Gimbi and Gore.

West Region. There were no electricity supplies in this area in 1962.

North Eritrea. Massawa and Asmara and the villages in between make up the major load area in the North Eritrea Region, which is served by Societa' Elettrica dell' Africa Orientale (SEDAO). In May 1961 the installed SEDAO generating capacity was 15,180 hp., rated at 11,935 kv.-a., producing over 95 percent of the electrical energy used in North Eritrea. The only high-voltage transmission line in Eritrea is the SEDAO line from Massawa to Asmara, which is 50,000 volts and has aluminum conductor (an alloy), 35 sq. mm., but does not have an overhead ground wire. The distribution lines used between and within towns on this system total about 190 kilometers in length and operate between 5,540 and 3,200 volts.

The Compagia Imprese Elettriche Dell' Eritrea (CONIEL) serves isolated towns with small plants not interconnected. It owns and operates small thermal plants in the towns of Decamere, Keren, Adi Ugri, Adi Caieh, and Adi Quala.

In addition, the Department of Public Works and Mines, Government of Eritrea, owns small thermal plants at Saganeiti, Senafe, Barentu, and Nacfa.

Under a lease arrangement, these plants are operated by these utility contractors:

Saganeiti - CONIEL
Senafe - Venturino F.
Barentu - Government (not leased, but leasing arrangement to private operator now pending)
Nacfa - Government (not leased)

Other locations having small thermal plants are listed below along with owners.

Agordat - Societa Anonimo Industriale Dell' Bassopiano Orientale (SAIBO)

Tessenei - Societa Anonimo Electrica Tessenei (SAET)

None of these villages, towns, or cities are interconnected except for the Massawa-Asmara (SEDAO) system.

Very small plants are located at Om Hager, Maraba, and Godofellasi, the latter for pumping municipal water. Department of Public Works controls Om Hager and Godofellasi, whereas CONIEL operates Maraba.

Production

A summary of past production of electrical energy essentially for the South Region 1/ by years from 1943 through 1962 is given in Table 13.

The electrical energy produced for the Addis Ababa Complex, South Region (EELPA), as a percent of the total production in the Empire, varied from about 50 percent in 1957 to nearly 64 percent in 1962.

1/ Includes very minor amounts for Gondar and Debre Markos in later years.

TABLE 13--PAST TRENDS OF ENERGY REQUIREMENTS, SOUTH REGION

For year ended September 10	Interconnected and isolated systems				Remarks
	Production (in millions kw.-hr.)			Percent annual increase	
	Hydro	Thermal	Total		
1943	5.923	1.882	7.805	-	
1944	6.574	1.587	8.161	4.5	Source: EELPA as reported in Ethiopian Economic Review, Nos. 5 and 6.
1945	7.857	1.545	9.402	15.2	
1946	10.057	1.324	11.376	20.0	
1947	11.692	1.330	13.024	14.4	
1948	12.628	1.651	14.279	9.6	
1949	13.658	2.106	15.764	10.3	
1950	14.012	2.868	16.878	7.0	
1951	15.259	3.295	18.554	9.9	
1952	16.608	4.003	20.611	11.0	
1953	19.548	4.486	24.034	16.6	
1954	22.578	4.187	26.745	11.3	
1955	25.980	5.359	31.339	17.1	
1956	25.115	7.954	33.070	5.5	
1957	31.217	5.595	36.812	11.3	
1958	25.740	14.971	40.719	10.6	
1959	27.768	19.333	47.101	15.7	
1960	46.744	8.689	55.433	17.7	Koka on line, interconnected system created.
1961	68.106	6.316	74.422	34.3	
1962	-	-	96.500	29.7	

1/ Includes very minor amounts for Gondar and Debre Markos in later years.

For 1961, total production was as follows:

SUMMARY OF NORTH ERITREA PRODUCTION BY SOURCES FOR 1961

Source	Kilowatt-hours	Percent of total
SEDAO	29,944,578	95.2
CONIEL	1,173,720	3.7
Dept. Public Works	136,200	0.4
SAIBO	92,000	0.3
SAET	81,000	0.1
Miscellaneous	26,000	0.1
Totals	31,453,498	100.0

Figure 38 gives the total production from 1954 through 1962.

LOSSES

Actual losses, including distribution losses, for the South Region's Interconnected System (Addis Ababa Complex) from 1957 through 1961 have been reported as varying from 29 percent to 17 percent, respectively.

The principal North Eritrea utility, SEDAO, had losses ranging from about 24 percent in 1953 to about 19 percent for 1960.

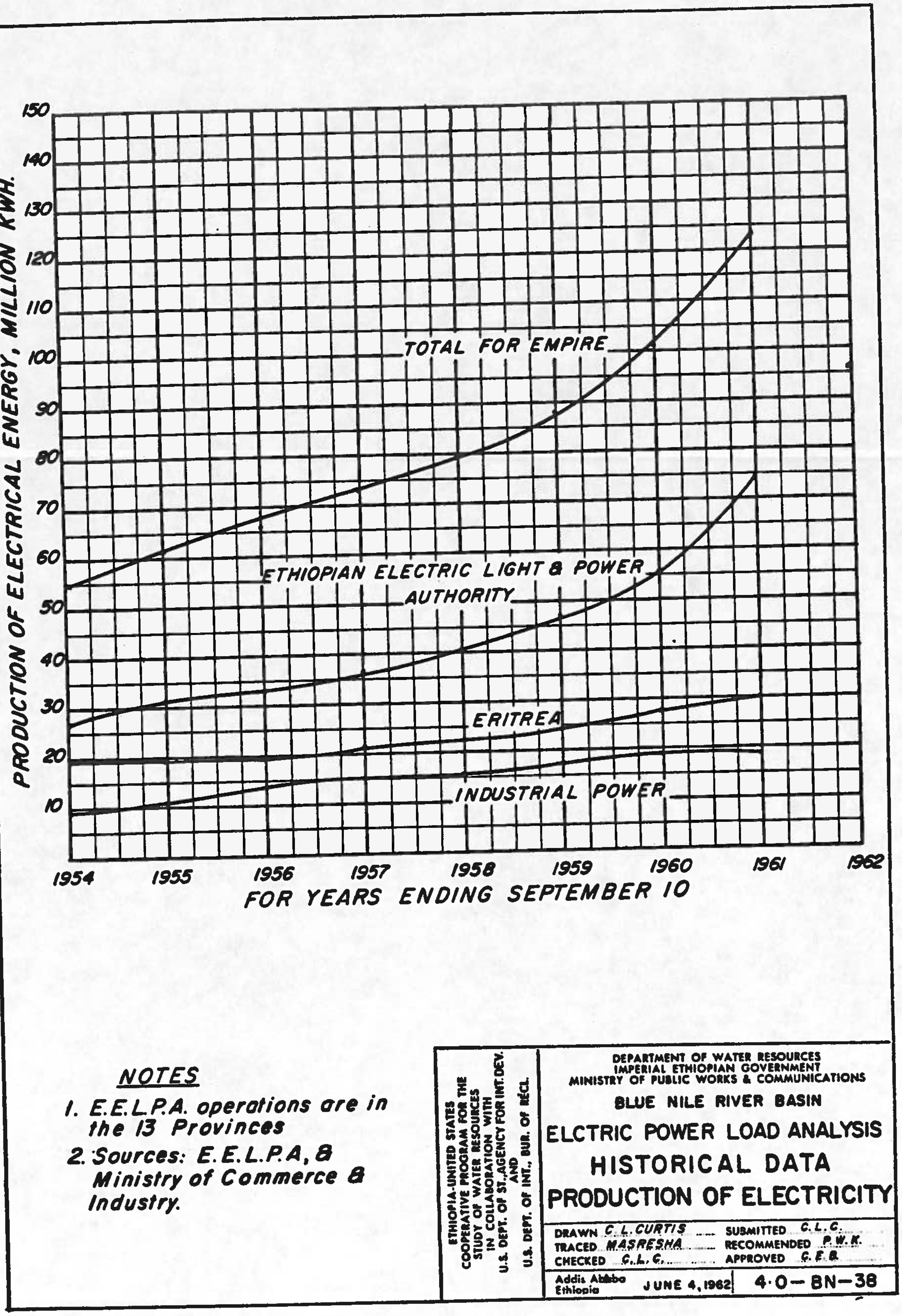


Figure 38--Historical Data--Production of Electricity

WILDLIFE, TRAVEL, AND RECREATION

NATIONAL RESOURCES

Since the beginning of recorded history man has sought relaxation from the strains of business and employment and has traveled far to see, explore, and enjoy the wonders of the world. As the nations have developed, so have there been increasing demands upon the skills and technical abilities of the people. As a result of technological advances, man finds less of his time consumed in procuring a livelihood and turns to other pursuits to satisfy his curiosity, to occupy his time, and to relieve the mental and physical strain of business pressures. The need for recreation has therefore increased to such an extent that it is an important factor in the economic structure of many countries.

Every country has its points of scenic beauty and of historical interest which should be preserved for the enjoyment of future generations. Without national patronage and careful planning for preservation many of these treasures will be lost forever.

Tourism is now recognized throughout the world as an established international industry. In many countries it constitutes a major source of foreign exchange income. Mexico, for example, lists tourism as her number one source of foreign exchange, and several of Ethiopia's neighbors realize substantial income from this source.

In recognition of the importance of tourism, Ethiopia has recently established the Ethiopian Travel Organization as an agency of the Government to promote and plan foreign travel.

Travel restrictions, currency exchange difficulties, customs regulations, and lack of advertising and information have prevailed in the past to discourage foreign travel in Ethiopia. As this situation is corrected, the natural courtesy and friendliness of the majority of the people will assure the visitor of a pleasant stay.

Attracting foreign visitors to Ethiopia may seem at first to be the most important aspect of the travel and recreation industry because of the national income of foreign exchange. However, the importance and value of developing facilities and preserving resources for present and future generations of Ethiopians should not be neglected or overlooked.

Tourism makes large economic contributions to nations and their people and is especially pertinent and interesting to Ethiopia as her development progresses. Outdoor recreation is often compatible with the use of other resources. It should be considered in many kinds of planning--urban renewal, highway construction, water resources development, and forest and range management.

Outdoor recreation brings about economic benefits and enhances community values by creating a better place to live and increasing land values. It is a basis of big business as large numbers of people seeking the outdoors generate a market for goods and services. Water is a focal point of outdoor recreation, which is a major leisure time activity and is growing in importance.

A national outdoor recreation policy, through the conservation and wise use of resources, will preserve, develop, and make accessible such quantity and quality of outdoor recreation as will be necessary and desirable for individual enjoyment and will insure the physical, cultural, and spiritual benefits of outdoor recreation.

Figure 39. Gondar is a city of many castles.

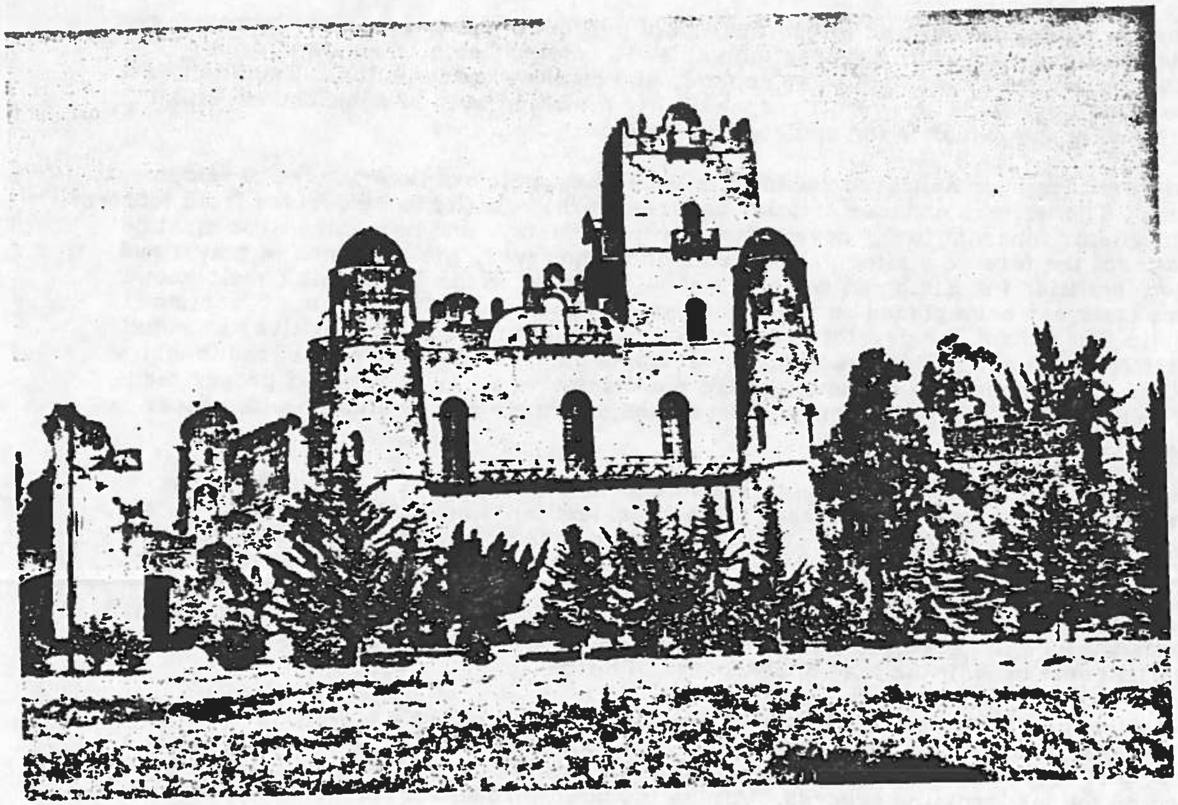


Figure 40. The castle of Fasile (1632-1665) in Gondar.

Expansion, modification, and intensification of present programs to meet increasing needs should include promoting recreation values in related fields, such as multiple-purpose water developments, pollution control, and highway construction. Establishment of a Government agency with overall responsibility for leadership of a nationwide effort will help to meet the demands for outdoor recreation.

Several articles have appeared recently in the Ethiopian press favoring the development of tourism. The writers of these articles understand the benefits to be derived from tourism and the problems inherent in the development of the industry, and recognize what must be done to attract the foreign visitor. As noted before, however, the provision of travel and recreation facilities for Ethiopian residents should go hand in hand with this development. Great emphasis has been placed on the immediate need for a crash program. Tourism need not, in fact cannot, be developed overnight. While tourism is competitive, as noted in one article, as long as the attractions for tourists exist the development of the industry is possible. The attractions for tourists are not dissipated by exploitation if proper management is employed, but rather may be developed and made more valuable with proper exploitation.

The entire industry requires careful planning for facilities, for access, and for the preservation and, in some cases, restoration of ancient buildings and monuments, as well as proper collection, compilation, and dissemination of information. In the process of developing natural resources and improving the national economy, the natural points of interest will become more accessible, use will increase, and new man-made points of interest will become available to meet recreational demands. Careful, sound, long-range planning will insure the greatest benefit to the people of Ethiopia and the greatest pleasure to those who come to visit the land of the Queen of Sheba.

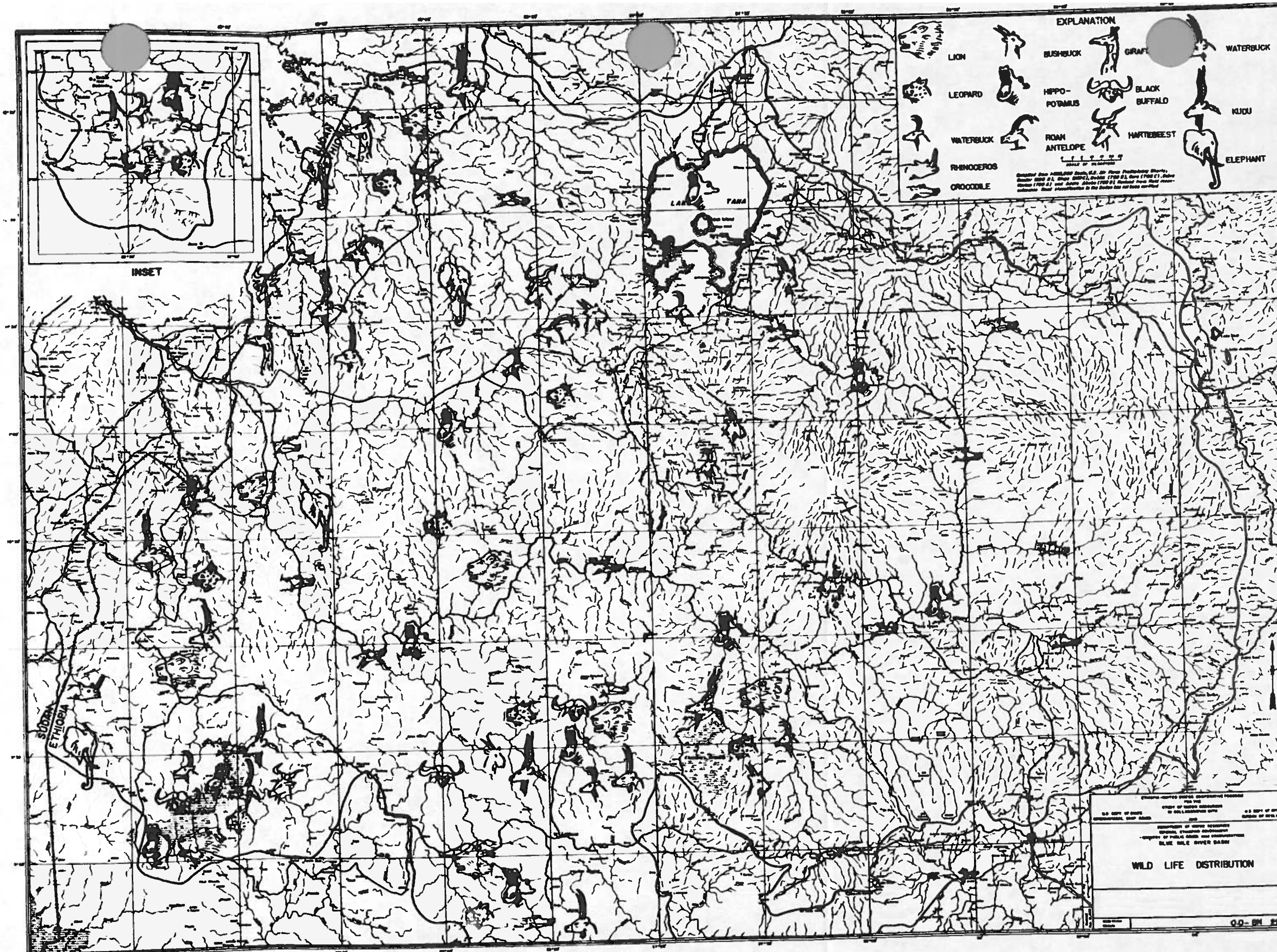
The continent of Africa has long been of special interest to people of other continents. This can probably be attributed largely to the voluminous writings of early explorers and travelers, and to the fact that relatively large areas remain unchanged and comparatively untouched by the modernizing process. Africa is known throughout the world as the home of big game and has furnished many specimens to circuses, zoos, museums, and private collectors, all of which have contributed to the desire of many people to see for themselves the continent, its people, and its animals in their natural settings.

Ethiopia has not been subjected to extensive outside influence. It has retained its own culture, which is wholly African. Within the country many of the people and the animals and much of the flora and geography usually associated with Africa in the minds of outsiders is found. Because of this, those interested in the Africa of the explorers can see it in Ethiopia.

By encouraging visitors from other countries, Ethiopia is in a position to promote a better understanding of Africa throughout the world and to satisfy the desires and curiosity of many people, whether they are motivated by an interest in anthropology, archeology, geology, zoology, geography, or simply a desire to travel to far and unusual places. In so doing, she can realize a substantial income to her national economy.

WILDLIFE

Wildlife in Ethiopia is one of the major potential attractions for visitors. This is not, however, an inexhaustible resource. Without effective management, present day pressure from agriculture and local hunting are contributing to the elimination of many of the larger species from some of their favorite habitat. A solution which has been found partially effective in the preservation of wildlife in other countries is the establishment of game refuges or sanctuaries, such as Queen Elizabeth Park in Uganda, Ngorongoro Crater in Tanganyika, Nairobi National Park in Kenya, and Yellowstone Park in the United States. This system can only be effective if sound game management is inaugurated, based on the laws of nature relating to habitat, migration, and concentration, and if rigid conservation measures are enforced. Other African countries are finding that hunting and poaching pressure plus the encroachment of agriculture on game areas are rapidly depleting their wildlife resource. Once this situation has gone too far the balance cannot be restored without the expenditure of large sums of money, and even then success is questionable.


EXPLANATION
LION
BUSHBUCK
GIRAFFE
WATERBUCK
LEOPARD
HIPPO-POTAMUS
BLACK BUFFALO
KUDU
WATERBUCK
ROAN ANTELOPE
HARTEBEEST
RHINOCEROS
CROCODILE
ELEPHANT
LAKE TANA
INSET
SUDAN
ETHIOPIA
BLUE NILE RIVER BASIN
WILD LIFE DISTRIBUTION
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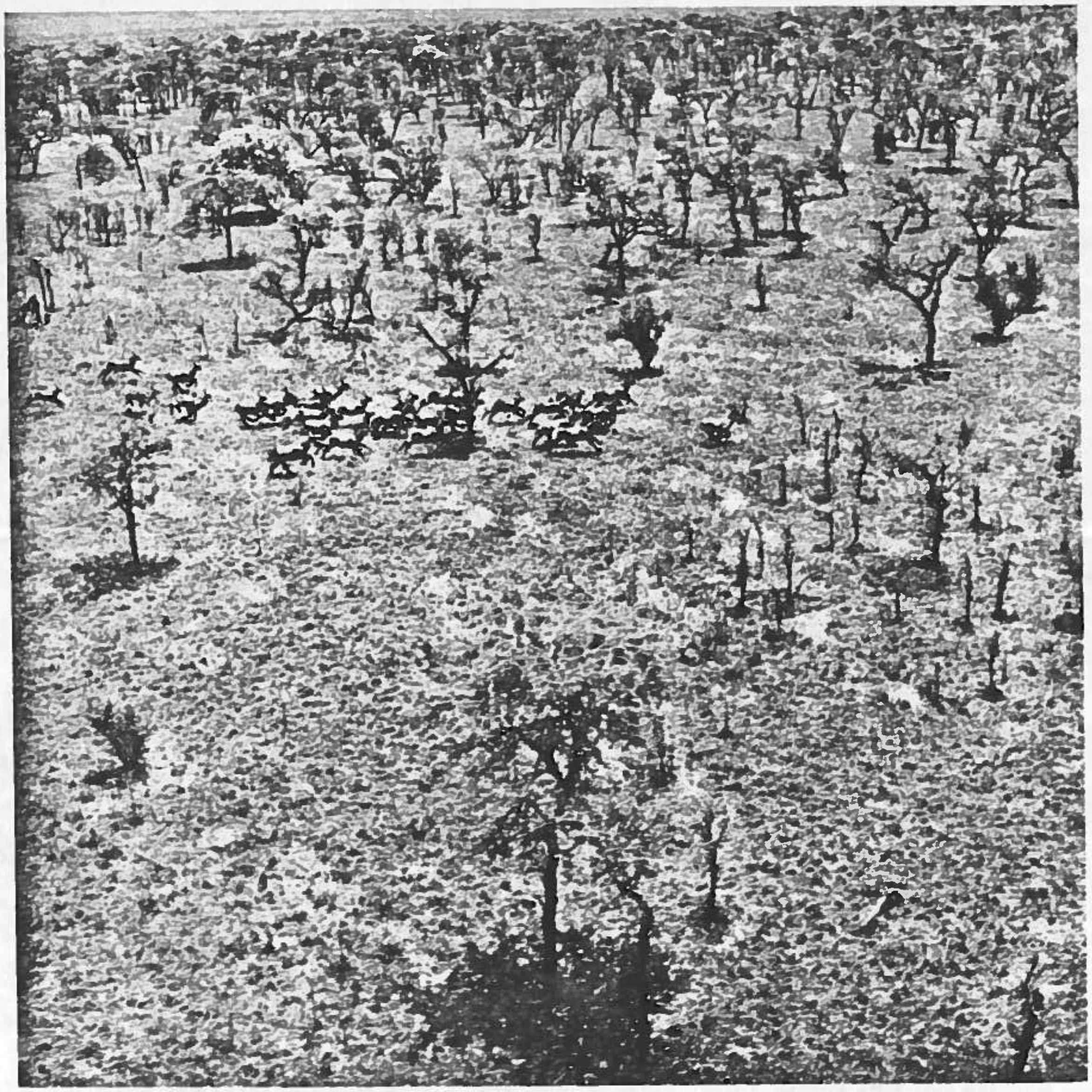


Figure 42. Herd of bushbuck in the Birr River Valley.

Ethiopia is fortunate in having an opportunity to provide for the perpetuation of her wildlife, both as a tourist attraction and for the enjoyment and benefit of her own people, before it is too late. If this is done effectively, in a few years she will probably be one of the few African nations with this resource.

Species

The following species of wildlife are found in the Blue Nile River Basin: elephant, giraffe, rhinoceros, hippopotamus, buffalo, roan antelope, hartebeest, greater kudu, mountain Nylal, waterbuck, reedbuck, bushbuck, duikerbok, oribi, lion, leopard, cheetah, civet cat, faro cat, serval cat, caracal, hyena, jackal, hunting dog, aardvark, forest hog, wart hog, bush pig, monkey, baboon, hyracoid or rock rabbit, bustard, vulture, duck, goose, heron, flamingo, ibis, marabou stork, guinea fowl, frankolin, cobra, python, crocodile, and monitor lizard.

In addition, great numbers and varieties of colorful smaller birds and reptiles live here. Many varieties of fish inhabit the waters of the basin, such as Nile perch, catfish, telaptia, and others, including some of the exotic, tropical varieties.

Not far from the Blue Nile Basin are found Grant's gazelle, zebra, oryx, sable antelope, eland, and Walia ibex. Some of these species, such as Walia ibex, are found only in Ethiopia and only in small areas.

This is a tremendous inventory and, while not complete, demonstrates the magnitude of the resource.

There are many people who are eager to hunt the larger species for trophies, and they are quite willing to pay for the privilege. If properly managed, trophy hunting can provide a sizable source of income. However, in order to perpetuate the resource and to realize the income from the many other people interested in seeing and photographing the animals, hunting must be closely limited to a perpetuating basis.

A practice which will require careful study and control if the maximum benefit is to be realized from the resource is the annual burning of grass and bush lands. This undoubtedly has a great effect on the wildlife, whether detrimental or beneficial and to what degree are unknown. A comprehensive study should be made to determine the effect on the wildlife. The results of the study should be used to amend or control the practice as required to remedy or minimize any detrimental effects on the wildlife.

Game Parks and Reserves

Figure 43 shows the location and approximate extent of several suggested wildlife sanctuary areas in the basin. A brief discussion of each area follows.

Dabus Game Park. Located in the southwestern section of the basin, this area includes a tremendous papyrus swamp and a large part of the headwaters of the Dabus River. In addition to the swamp, the higher ground adjacent to the swamp on the south and east is included with a wide corridor opening to the western border. The corrider will provide for unmolested migration of animals between the swamp and the Sudan. At present there are large numbers of hippopotamus, cape buffalo, waterbuck, reedbuck, bushbuck, hartebeest, and both forest hog and wart hog, as well as leopard, lion, and various scavengers in the swamp area. Just across the watershed divide to the west there are roan antelope, hartebeest, and many smaller animals. Elephant and rhinoceros are also reported in this latter area. By including the wide corridor to the border, and through correct management of the reserve, an excellent game park can be developed.

Tourist access can be provided immediately by air to Begi, which is on the regular domestic air route, and from Begi to park headquarters by car. Four-wheel drive vehicles will be required until such time as the roads are improved. The suggested location for park headquarters as shown can be reached from Begi. Buffalo are found in

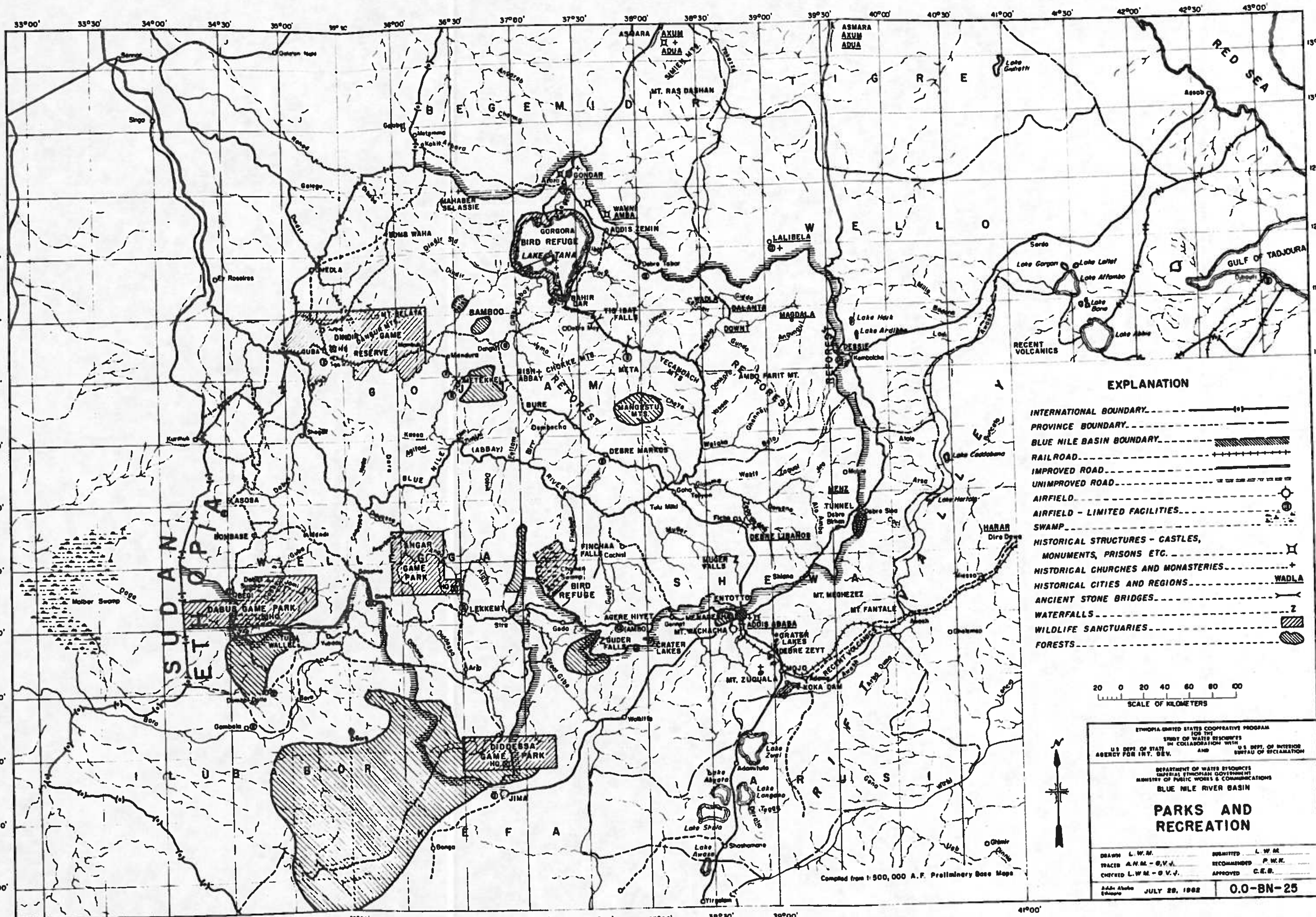


Figure 43- [illegible] and Recreation

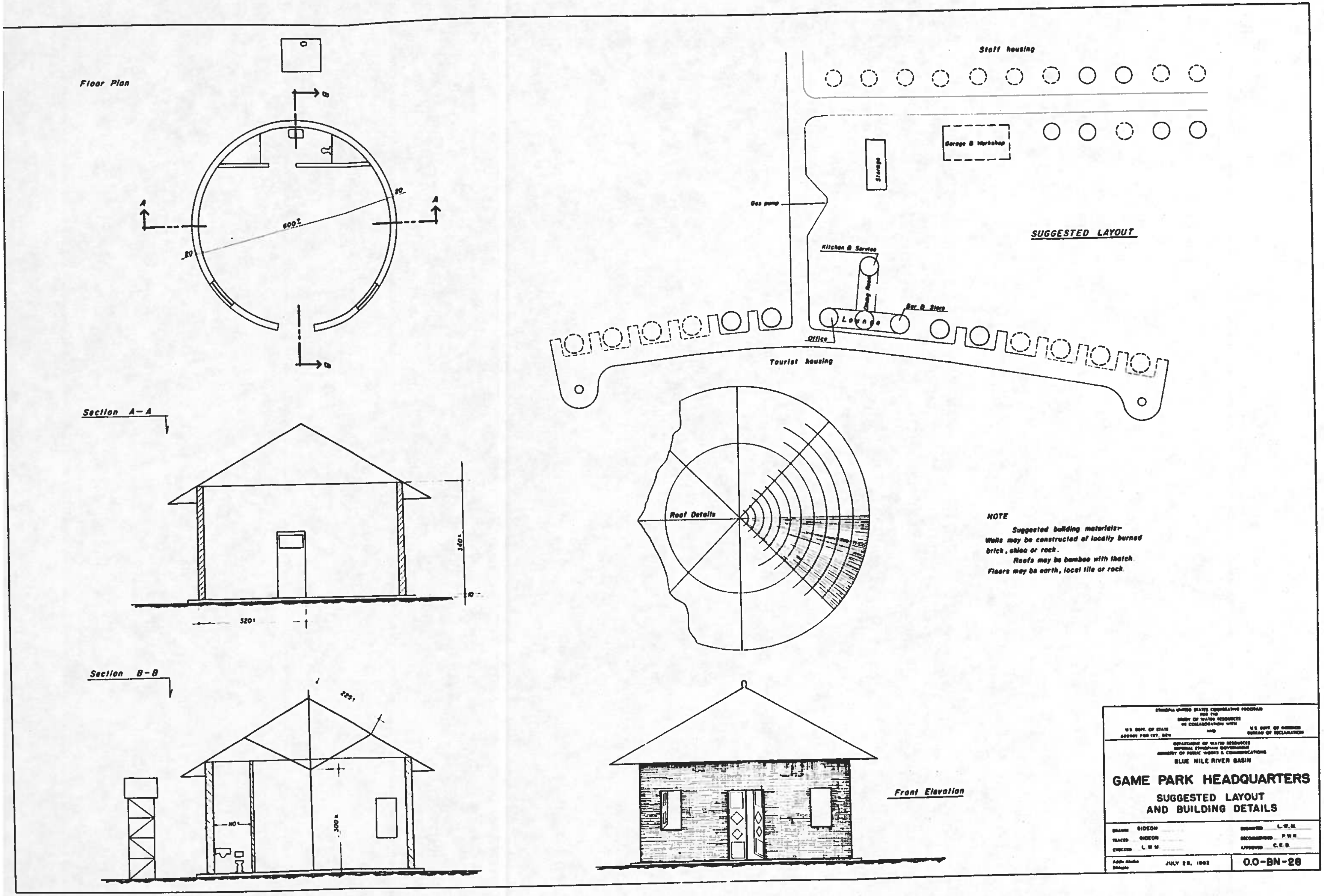


Figure 44--Game Park Headquarters--Suggested Layout and Building Details

this portion of the area and access is relatively easy. As highways are completed westward from Lekkemt, the journey by car from Addis Ababa will be about a 2-day drive through some very interesting country.

Travel over the swamp will have to be by swamp buggy, helicopter, air car, or similar means. Trails can be built around the swamp for four-wheel drive vehicles and can be developed later for regular passenger cars and busses.

Living facilities will be required for tourists, management personnel, and rangers. Buildings can be provided economically, utilizing local materials--chica, homemade brick, rock, local wood, bamboo and thatch. Refinements and additions will develop as income and demand require. The park headquarters are in the southern part of the Dabus area. To preserve the typical Ethiopian atmosphere, the basic unit is a round tukul, constructed of locally made brick or chica with a bamboo and thatch roof. Floors can be packed earth, brick, or locally burned tile, and perhaps eventually concrete.

The headquarters unit could be four of the basic units connected with breezeways as shown in Figure 44 to form dining and lounge areas. A minimum number of housing units should be built at the start, supplemented by safari-type tents to handle overflows and extra help. Additional units can be added as required.

The initial facilities could be tents, so that clients could be taken care of while the more permanent units were being built. Camp-type toilet and shower facilities should be installed until the permanent water supply and sewage disposal systems were completed. Lights would be furnished by a small, gasoline-driven generator with kerosene or gas lanterns or candles furnished for emergency use.

The site selected should be on ground high enough to assure that it would not be flooded during the rains and in a location where water for irrigation of lawns and trees and possible domestic use could be diverted by gravity from one of the small streams flowing into the swamp from the south. Some thought should also be given to the control of insect pests, such as flies and mosquitoes. These can be largely controlled by regular application of insecticides, but it may be possible to choose a site which is relatively free from them.

All materials and supplies which cannot be obtained locally can be trucked in from Addis Ababa during the dry season. The site lies only a short distance from the Gimbi-Gidami-Begi road, which is another favorable factor in selecting it for the initial installations. Very little roadwork would be required to provide access to the site.

With careful planning, giving due consideration to economy, further expansion, and above all satisfaction of the customer by providing an opportunity to see and photograph animals in their natural environment, an establishment can be started without a great outlay of capital, laying the foundation for a successful, permanent enterprise.

If the animals are given complete protection, they will undoubtedly, in a short time, become as oblivious to vehicles, buildings, and people as those in the game parks in Uganda, Kenya, Tanganyika, and the United States. In some of these parks animals can be seen and photographed along the roads and trails and even from the housing areas.

Grazing and farming pressure is increasing and there are numerous local hunters who pay little attention to game laws or seasons. This situation should receive immediate attention if the full national benefit is to be derived.

Diddessa Game Park. This area, which lies between Lekkemt and Jima, is actually very close to Jima. It includes the southern part of the Diddessa valley and the hills and mountains surrounding it. It joins the forested area on the west and south and extends over into the Gibe valley on the east. The actual boundaries should be adjusted to take into consideration existing agricultural developments. Study and experience may show that some revision of the existing agricultural development to provide for better game management may result in a higher economic benefit to the nation.

Several potential project features, mainly the dam and reservoir sites, lie in the area. The reservoir would enhance the value of the area as a game park and would provide additional recreational opportunities, such as fishing and boating. They would also permit boat excursions to see and photograph the birds and animals. Project planning should consider the effect on the wildlife.

Waterbuck, reedbuck, oribi, pigs, leopard, crocodiles, and hippopotamus are most numerous in the area. In addition, buffalo, kudu, and roan antelope are found in the area to the north in the hills bordering the Diddessa River. With proper management these species would undoubtedly thrive in the sanctuary area.

Access to the area could be provided either from Lekkemt or Jima or both. Road access from Jima would probably be less expensive. Landing strips for light planes or even DC-3's could be constructed with a minimum amount of grading in any of the broad flat areas of the valley floor.

Trails would be required for access within the area and to provide opportunity to see the game from the ground. This would not be particularly difficult throughout a great part of the area, however, as light grading would suffice. Some small boat travel is possible although limited by reefs across the river in spots. Helicopters would provide a more expensive, but for some people a more desirable, means of transport. Pack trips could also be arranged and would probably provide one of the best means of really seeing the area and its wildlife population.

Development plans for park headquarters could, in general, follow those suggested for the Dabus Park.

Angar Game Park. The Angar Park area lies just north of Lekkemt. It would extend from the forested hills and mountains on the east toward the Diddessa River on the west. Much of this area is privately owned at present, and development, if any, would probably be by private capital. Some agriculture exists now and will probably be expanded. Also, some additional agricultural project potential exists in the area, other than that now being developed. Such development, however, is not inconsistent with use of the area as a game park; and certainly the animals are there.

Roan antelope, kudu, waterbuck, reedbuck, oribi, crocodile, hippopotamus, leopard, lion, and pigs are the principal species found at present. Adequate management would undoubtedly improve the numbers.

Road access would be through Lekkemt. A dry weather road exists now which extends as far as the Angar River. There are numerous places where light plane landing strips could be constructed with only moderate grading, so access to the area presents no problems. Access within the area would require trail construction for surface vehicles. Small boats can be used on some stretches of the Angar during most of the year. Helicopter and pack trips could also provide access even to the most remote parts of the area.

Park headquarters could be located either on the higher ground near the southern border or on the Angar River at the end of the existing road. Living facilities for management and visitors would be required and could be provided in the same manner as previously discussed, utilizing local materials.

Dindir Game Reserve. This suggested game reserve occupies an extensive area in the northwestern corner of the Blue Nile River Basin. It extends from the Beles River northward and includes the Dangur Mountains and Mount Belaya. It is located near the largest potentially irrigable area in the Blue Nile River Basin. Also included or in the general vicinity are the adjacent potential dam and reservoir sites on the Rahad, Dibaba, Galegu, and Dindir Rivers. It is now a remote area and, except for some grassland along the border is mostly covered with bush and trees. Access at the present time is difficult. The area could be designated as a game reserve and management practices instituted to preserve and increase the animal population. At such time as agricultural development is economically feasible or desirable, the reserve areas could be redefined to exclude the project areas, if necessary.

The area indicated on the map as the Dindir Reserve at present has elephant, giraffe, kudu, roan antelope, lion, and leopard as well as many of the small varieties, such as pigs and oribi. There are also a great many birds.

Many species, especially the elephant, seem to migrate between the Sudan and the mountains in the eastern part of the proposed reserve. The Sudan has designated a 40-kilometer (25-mile) wide strip along the border as a game reserve. Perhaps by joint agreement the combined area could be preserved to the mutual benefit of both countries. There is an airstrip at Guba, which was cleared and used by DC-3's in 1960. It would require only a little work, mostly small bush clearing, to put the strip back in good condition. The road from Guba to Omedla is adequate for four-wheel drive vehicles, and there is a passable trail from Omedla to Bumb Waha. The road north from Bumb Waha would require considerable rehabilitation. There is an airstrip at Metekkel capable of taking DC-3's--in fact, this was a regular stop of the domestic airline until recently. The road from Metekkel to the Beles River requires considerable work to make a comfortable trip, but this consists mostly of repairing rocky stretches and building several short bridges or rehabilitating fords. There is also the possibility of clearing airstrips for light planes in many parts of the area.

The site suggested for headquarters is indicated on the map near Guba. This merely indicates the closest point of contact at present, and other sites may prove more desirable at such time as the region is opened up.

In spite of its present isolation, it is recommended that the area be designated as a game reserve and that it be managed and controlled to insure the perpetuation and conservation of the wildlife population. By so doing the nation will be assured of a reserve of wildlife to meet future needs. At present, primarily because of its isolation, the area will provide a great attraction for those hardy individuals who want a rough trip into the primitive bush far off the beaten track.

Accommodation for the present should probably consist of safari camps set up as the need arises. Permanent headquarters could await further development.

This area may in the future prove to be one of the richest in the country from the standpoint of wildlife resources. It is truly primitive and almost entirely out of contact with the rest of Ethiopia and, as such, preserves the "untouched" Africa that tourists desire to visit.

Lake Tana and Chomen Swamp Bird Refuges. These areas are suggested as bird sanctuaries solely for the purpose of providing for the future. At present, there is practically no hunting pressure on the many varieties of birds found here, but this situation may change in the future. All hunting should be restricted or closely controlled in both areas. As population expands, as more and more of the natural habitat of birds, such as guinea fowl and frankolin, is destroyed by agriculture, and as hunting pressure develops, these areas will provide for the perpetuation of both land and water birds. As an extra dividend, the areas adjacent to Lake Tana and the Chomen Swamp will provide sanctuary to the small gazell and other wildlife now found in limited numbers in the vicinity. Lake Tana will undoubtedly develop into a resort area. It is the largest body of water in Ethiopia and provides unlimited opportunity for boating and fishing. The climate is good and, located as it is in the historical center of Ethiopia, the lake will undoubtedly attract many visitors. The development of the lake as a resort area would in no way be incompatible with its designation as a bird refuge.

Other Areas. As development progresses, other wildlife areas should be created, especially adjacent to newly constructed reservoirs. The reservoirs will contribute a great deal to the total recreational resources of the nation and will have a considerable influence on the wildlife and its exploitation. There is at present little fishing done in the basin, either recreational or commercial. There are several varieties of fish in the streams and lakes, but sport fishing does not seem to have developed. As more visitors come to the basin this situation can be expected to change, especially if advantage is taken of the fishing opportunities which will be created by reservoir construction. Not only will the reservoirs themselves provide increased fishing opportunities because of the access by boat, but in addition, the streams below the dams will be cleared of sediment and cooled, possibly permitting the stocking of trout, bass, and similar game fish

Figure 45. Helicopters are used for transportation to remote areas.

varieties. This is an aspect of recreational development which should be carefully studied and planned.

In addition to the areas mentioned above, there are many others in the basin where wildlife constitutes a definite resource. In some parts of the basin, such as the Blue Nile Canyon and the lower Blue Nile Valley, the Asosa-Dabus area, part of the Beles River Basin, and similar areas where agricultural and local hunting pressure is not yet great, there is enough wildlife of sufficient variety to insure a reasonable degree of success to visitors willing to spend the money for a hunting or photographic safari into the area. There are many other areas where the numbers and variety of game have been reduced to the point where they are no longer a major attraction, but where there is still sufficient game to satisfy the hunting recreational requirements of a large number of residents for a long time. There are, of course, other areas where all types of game, including birds, have been practically eliminated.

If the game in Ethiopia is to be exploited to the continuing advantage of the country, it will be necessary to institute regulations and management programs to preserve it. Ethiopia may well profit by the experience of many other countries, both in Africa and abroad, where failure to recognize in time the value of the wildlife resource has resulted in the extinction of some species and almost complete extermination of many others.

Other factors, which will become increasingly important as the country develops and as the general standard of living is raised, are travel and recreation for the indigenous population.

In connection with preservation of wildlife through management and provision for recreational facilities, the forest areas of the nation will make a valuable contribution. The principal forest areas in and adjacent to the Blue Nile Basin are shown on Figure 46. The largest forests are located in the Metekkel area, the Mangestu Mountains area, the headwaters of the Guder River, the headwaters of the Diddessa River, and the area south of Begi. These forests are in themselves a valuable natural resource. In addition, under proper management, they provide an excellent refuge for wildlife and should be included, in this respect, in the same category as game parks. Forest areas also provide other recreational opportunities, such as camping, picnicking and hiking. An example is the Menagesha Forest near Addis Ababa. As access is developed, more and more people are visiting the area for pleasure drives and picnics.

Hunting and Photographic Safaris

Catering to hunting and photographic parties is big business in countries to the south of Ethiopia. However, as more and more of the game is killed off and crowded out by encroaching agriculture and poaching, the income is decreasing. Ethiopia can profit by the mistakes of her neighbors by providing these services on a sustained basis. This entails providing qualified guides, housekeeping facilities, and transport, and seeing that the customers are given a fair return for their money. An enthusiastic, satisfied visitor is the best possible advertisement.

In addition to privately arranged safaris, shorter tours should be available for the tourist who does not wish to go to the expense of an extensive jaunt. These will quite often promote the more expensive safaris. A great many areas outside the proposed game preserves will provide excellent hunting for both camera and firearms. The canyon of the Blue Nile is one of these places, and this suggests another attraction which can be developed into a most interesting activity. River safaris similar to those conducted on the Colorado and Snake Rivers in the United States will appeal to many; they afford an excellent opportunity to fish, hunt, and photograph. Other areas are the Asosa-Bombase country, the Dabus Valley and the Beles Valley. These regions should be subjected to the same management principles as the conservation areas, if the resource is to be perpetuated.

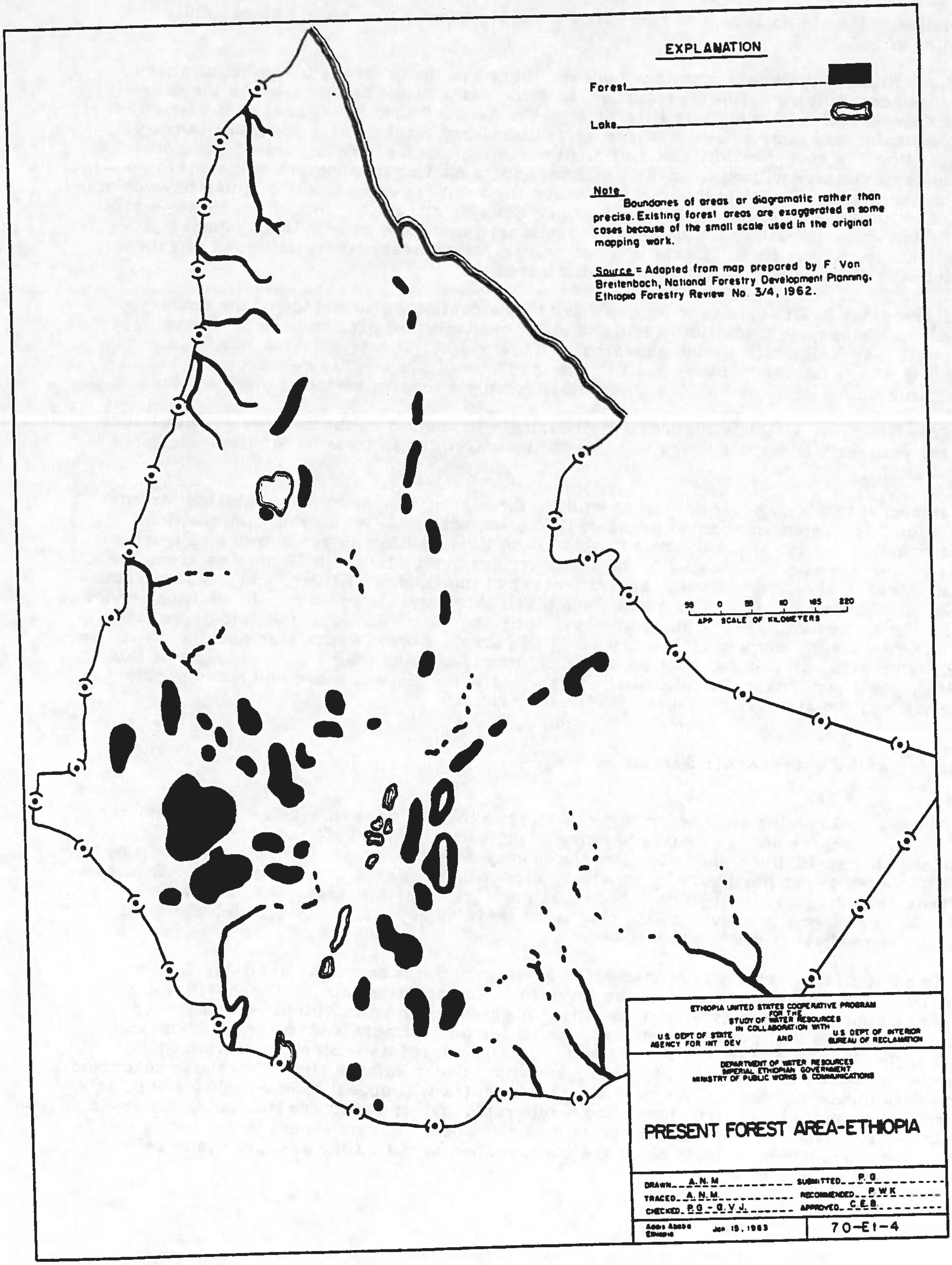


Figure 46--Present Forest Area, Ethiopia

Fish and Wildlife Management

All the foregoing references to game management and conservation support the desirability of establishing an effective management agency. The details of the establishment and operation of such an agency are beyond the scope of this report, but the perpetuation of, and the continual ability to exploit, the wildlife resource are entirely dependent upon its functioning properly and effectively.

There are many problems inherent in the organization and control of any aspect of national life which involves either real or imagined conflicts of interest. Wildlife management is no exception in this respect. There is now and there will be in the future increased competition for the use of land for agriculture or for wildlife sanctuaries. Divergence of opinion will always exist between those interested in conservation and those interested in unrestricted hunting, with a corresponding conflict of viewpoint between perpetuation of the wildlife as a continuing resource on the one hand and maximum exploitation for the greatest immediate return on the other.

Effective game management requires first of all a sincere, active interest in wildlife conservation throughout the Government. The people selected to manage the department will need the ability to see and appreciate all sides of every problem which will arise in connection with the establishment of wildlife sanctuaries and with wildlife management. They should be able to solve these problems wisely and in a manner that will result in maximum national benefit. Upon their decisions will rest the future of wildlife in Ethiopia.

The program should be administered by men who are truly interested in, and educated and trained for, the job of wildlife husbandry. They should have the knowledge to establish not only the boundaries of the sanctuary areas, so as to include the best possible habitat and to take into account the migratory habits of the wildlife, but also the programs and regulations to insure the maintenance of the habitat and the protection and perpetuation of the wildlife. They should be given the authority to implement their programs and enforce their regulations and should be able to use that authority in a wise and benevolent manner.

Each conservation area will need the services of a sufficient number of trained naturalists, rangers, guides, and other enforcement personnel to insure the success of the program. The areas should be patrolled to prevent poaching and to control the encroachment of grazing. The habitat should be protected and in some instances improved or rehabilitated. This will mean reforestation, soil conservation, range improvement, and possibly stock pond construction.

Programs should be started to restock some species, importing specimens from other areas and bringing the numbers and varieties into balance with the carrying capacity of the environment.

HISTORICAL MONUMENTS

Ethiopia is one of the few African countries south of the Arab world whose history has left interesting places worthy of a tourist's visit. The history of Ethiopia, which goes back thousands of years, adds another facet of interest for foreign visitors. While contemporary written records and antiquities of the very ancient history are scarce, enough exist in such references as the Bible, stories of the Kingdom of Prester John, Bruce's account of his travels, church records, the ancient city of Adulis on the Zula plain, Axum, Lalibela, and some of the older monasteries to provide a reasonable hisorical record.

Figure 47. Ruins of an ancient castle on the shore of Lake Tana west of Gorgora.

The Blue Nile Basin and the areas immediately adjoining contain many of these ancient historical sites. The more modern history of the Gondar kings is visible in the antiquities at Gondar, Gorgora, Wahni Amba, Addis Zemin, and many other locations in the Lake Tana area. By undertaking and encouraging archeological studies, establishing the locations of the sites of ancient activities, and linking the ancient past with more modern times, the history of the country can be brought to life, not only for the foreign visitor but for the Ethiopians as well. The history and antiquities of Ethiopia present a fascinating and spectacular picture of ancient Africa and its progress through the ages. Archeological exploration will undoubtedly bring to light a great deal more, which will add greatly to the knowledge of the world and to the historical attraction for visitors.

Some effort at restoration of ancient castles has been undertaken at Gondar. While undoubtedly desirable from the standpoint of preservation, restoration of the antiquities should be undertaken with caution. Authenticity should not be lost, and the air and feeling of the times of original construction should be preserved. As demonstrated by some of the restoration work at Gondar, these efforts do not always perpetuate the feeling of the original structure.

As mentioned earlier, planning for all types of development should take into account the effect of the particular project on all other phases of the national development. This is especially true in the preservation of the antiquities. Some of the old structures near Gondar have been partially destroyed by the construction of a highway, and some of the ancient treasures of Ethiopia have been removed to other countries.

The cities of Ethiopia and especially of the Blue Nile Basin and vicinity provide further attraction for the visitors. Addis Ababa has much of interest from the standpoint of history and culture. The palaces, churches, monuments, and museums; the University and Africa Hall; and the markets and craft centers all provide an excellent cross section of Ethiopian culture, development, and progress. Other cities, such as Jima, Dessie, Harrar, Debre Markos, Gondar, and Bahir Dar, have many points of interest, and all differ from Addis Ababa and from each other in culture, people, and character.

HUMAN INTEREST

People are always interested in others, their homes, clothes, customs, and crafts--in fact, their whole way of life and philosophy--especially when these are different from the familiar pattern. This interest is demonstrated by the people of Ethiopia themselves, by the large crowds that gather around the foreigner in less sophisticated parts of the country, and the extreme interest in everything strange and different.

There are many tribes in the Blue Nile Basin, representing different origins and many different ethnic backgrounds. Some have remained almost entirely aloof from the process of assimilation, while others have been more or less influenced by conquest and migration. Each tribe has its own culture and way of life so that, while Ethiopia is a united nation, its people represent an amazing wealth of cultures, many of which are different from those found elsewhere in the world. Here the casual visitor as well as the student can observe for himself some of the most interesting people to be found anywhere. While people from the many tribes can be seen in the cities, these have for the most part become urbanized. It is only when they are visited in their home country and seen in their natural environment that much can be learned about them. Here they can be seen as dignified, proud, yet not unfriendly people, who are just as curious about the visitor as the visitor is about them.

Some of the economic benefits of the tourist business can be derived by the local people through the sale of their handicrafts to the visitors, and the visitors can obtain from the local people authentic examples of the handicraft of the region.

While the people of the country constitute one of the major attractions for tourists, they should not be exploited by being displayed as curiosities or commercialized as exhibits. Certainly tribal dances or musical exhibitions can be arranged, but care should be exercised in preserving the authenticity of the performance and protecting the dignity of the performers. There are many religious festivals and celebrations throughout the year and throughout the nation. Any visitor fortunate enough to be privileged to witness one of these colorful, spectacular, yet solumn occasions will gather a deep insite into Ethiopian religious culture.

SCENIC ATTRACTIONS

Ethiopia has a wide variety of landscape within her borders--arid deserts, low, hot, bush country, high mountains, rugged escarpments, and high, cool plateaus cut by tremendous canyons, lakes, streams, rain forests, and gently rolling farmland. Most of these are found in or adjacent to the Blue Nile Basin and give this area some of the most beautiful and spectacular scenery in Africa. The deep-cut canyons of the Blue Nile and its tributaries; the Blue Nile River itself which heads in Lake Tana and flows over Tis Isat Falls into its canyon, where it stays for most of its course through the country, finally emerging into the low hot bush country of the west; the numerous waterfalls, especially in the rainy season when the swollen streams plunge off the highlands into the canyons below; the beautiful crater lakes near Agere Hiywet (Ambo), Bure in Gojjam Province, and Zebre Zeyt (Bishoftu) and Zuquala; the Dangur, Belaya, Chokke, and Simien Mountains, and Mt. Ras Dashan, the highest peak in Ethiopia and the only place in the world where the Walia ibex is found, the great forests, the Rift Valley; and the areas of recent volcanism in the Awash Valley all provide scenic variety and grandeur never to be forgotten.

Future consideration should be given to the establishment of a national park system whereby the natural beauties and attractions of the country may be preserved. The system should include all game parks and reserves, some reaches of the Blue Nile Canyon between Lake Tana and the mouth of the Diddessa, the Simien Mountains, and all national forests plus the mountain areas of the plateau.

ORGANIZATION AND MANAGEMENT

The details of the organization needed to develop the travel and recreation industry are beyond the scope of this discussion. However, attention is invited to some of the problems and situations which should be given consideration.

1. Education of the people to the value of travelers, and relaxation or simplification of regulations on travel, photography, and firearms. This will not be accomplished in a short time, but steps have been taken in this direction by the recently established Ethiopian Tourist Organization.

2. Protection and guide service will have to be arranged. Adequate guide and interpreter service will be one of the most important factors in determining whether or not the individual traveler is satisfied and pleased.

3. Travel arrangements, coordination of schedules, and reservations will require careful planning. This may be accomplished by using fixed schedules for group tours and providing a consulting service for others.

4. Housing and food service in Addis Ababa, outlying towns, and in the country will have to be considered in the planning.

5. Advertising and information services will be needed. This can probably be taken care of by existing Government organizations.

6. Availability of supplies and services should be checked and amplified where necessary. This includes photographic supplies and services, safari supplies, car rentals, hunting and fishing supplies, and souvenirs.

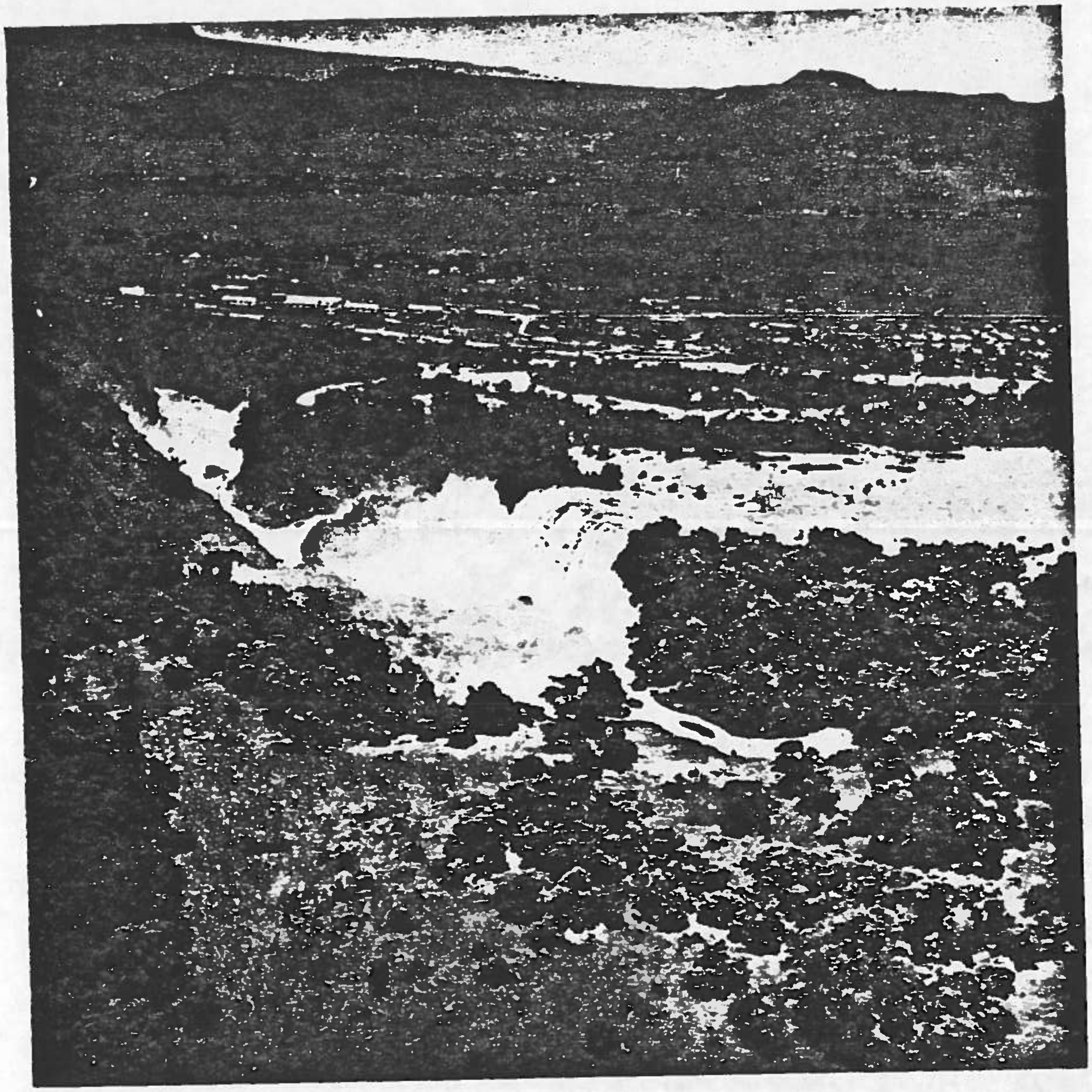


Figure 48. Tis Isat Falls on the Blue Nile River.

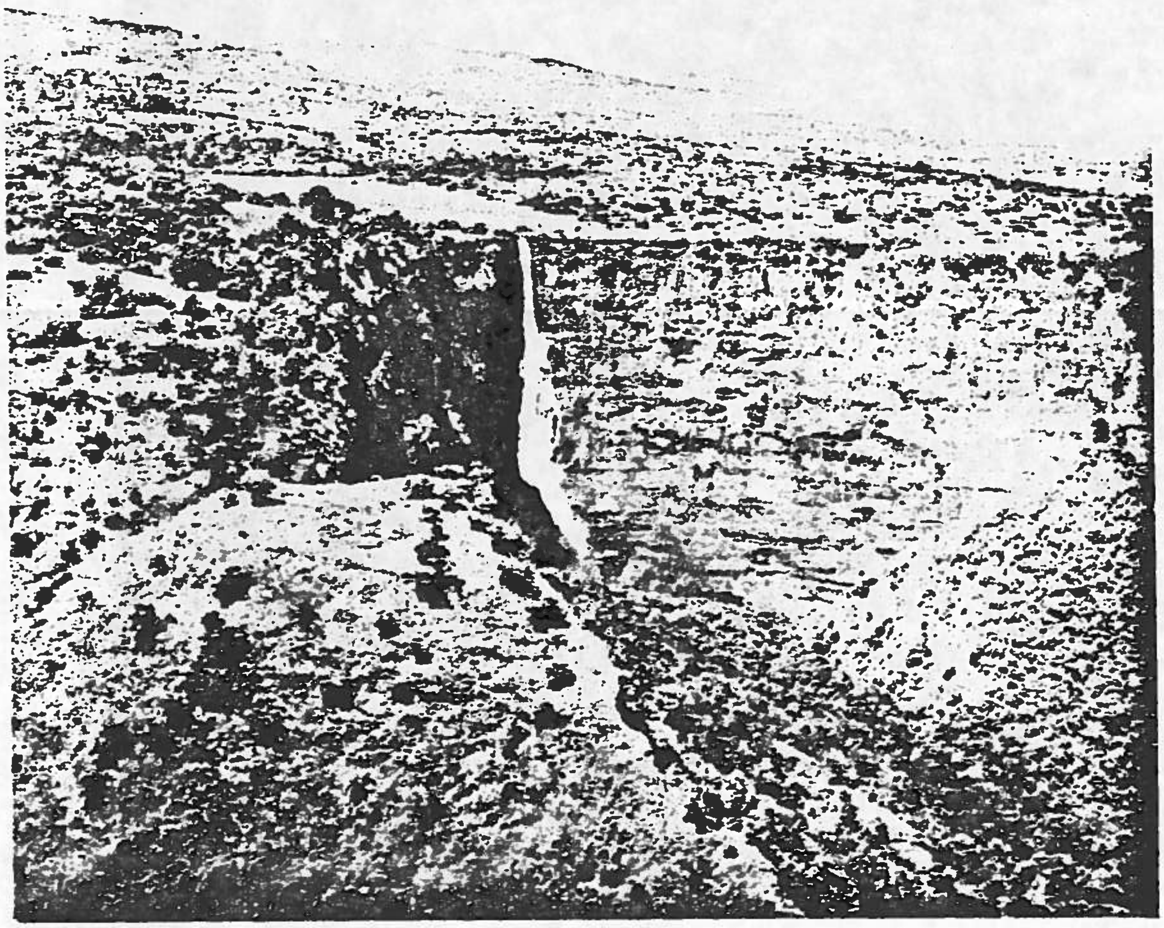


Figure 49. Waterfall on a tributary of the Guder River.

Some of these can be provided by private enterprises, especially the item of service. Regulatory matters need to be taken care of by the Government organization. Private enterprise should be encouraged and regulated so as to derive maximum benefit. While private capital exists in Ethiopia to finance adequate facilities, outside capital will undoubtedly be interested if the investment climate is favorable.

For the individual traveler, the advantage of advance knowledge is obvious. He can plan his itenerary to include, within available time limits, those places and subjects of greatest interest to him; he can insure his satisfaction by knowing his requirements for clothing, equipment, and accessories.

Complete, accurate information can be made available and the opportunities advertised. A glance through the National Geographic, the publication of the U.S. National Geographic Society, will demonstrate the value placed on advertising travel and recreation. Many states, nations, and transportation companies advertise to attract the traveler to a particular area or service. An advertising campaign, plus easily available, accurate information, will create the desire in potential visitors to see the continent of Africa and Ethiopia in particular.

Most travelers are collectors, and as a result a very profitable sideline of the tourist business is the trade in souvenirs. Examples of local crafts, such as metalwork, weaving, rug making, and artwork all make excellent souvenirs. In addition, objects of everyday life for the Ethiopian, such as tools, clothes, furniture, utensils, baskets, and weapons will be in demand as mementos. The souvenirs must be authentic and typical and should not be cheapened by mass production just for the tourist trade. This business will provide a source of income for individuals in every locality visited and will help spread the economic benefits of tourism among more of the people.

The majority of travelers will be photographers. Pictures prove the trip an adventure. Pictures can show what happened, what was seen, and what was done. Pictures and travel go hand-in-hand, and the sale of pictures is another commercial aspect of travel. Each traveler, even the avid camera fan, is a potential customer. Postcards, colored slides, and enlargements will fill the gap in the photographic record of the camera fan and may provide the bulk of the pictorial record for the not-so-enthusiastic photographer. Films, pictures, cameras, accessories, and repair services will be in demand.

CONCLUSIONS

Ethiopia has primarily an agricultural economy. While industry and other businesses will expand as development progresses, there is a most valuable resource in her natural attractions for travel and recreation. As facilities and access are developed, an opportunity will be available not only for foreign visitors to see and learn about the country, but also--perhaps more important from the standpoint of national unity--for many Ethiopians to travel and learn about their own country. At present, few Ethiopians have traveled outside their home district or province. Their knowledge of the country as a whole is based on tales or stories told by other people. As more people travel and see the country for themselves and come to know people other than their own, the ties of nationality will be strengthened and national pride will be intensified.

Perhaps the most favorable aspect in the development of travel and recreation is that, compared to other forms of industry, the initial capital investment can be quite limited. By taking advantage of existing facilities, concentrating on accessible areas, and insuring that each departing visitor is an enthusiastic salesman for Ethiopia, the foundation for a flourishing industry can be laid. By investing a reasonable amount of the national income from tourism in improving access and facilities, this resource can be developed over a period of years into a business of great economic significance.

This discussion is intended to demonstrate that a very real and important resource exists, that it can be exploited with great national benefit, that exploitation need not wait for any other development as substantial income can be derived now, and that expansion of the business can combine with future development of the country along other lines.

PLAN OF DEVELOPMENT

INTRODUCTION

Since Ethiopia regained her freedom from foreign occupation in 1941, the barriers of isolation which have traditionally kept her separated to some extent from the rest of the world have been broken, and dramatic changes have taken place in a relatively brief period of time.

His Imperial Majesty Haile Selassie I has reorganized the government, modernizing agencies, bringing modern ways to the people, and improving the social environment to bring about conditions that will permit development of the national resources. In part, this long range program is to improve the standard of living, make educational opportunities available to the people, provide facilities for improvement and protection of health, and improve the economic structure of the nation.

Ethiopia has a great agricultural potential and a dynamic and profound transformation is underway, with a contrasting mixture of old and new, from a solely local agricultural economy to one embracing imports, exports, and manufacturing. The future growth and development lie primarily in the development of major hydroelectric power and irrigation projects, which in the Blue Nile Basin would eventually be capable of producing 1/8,660,000 kilowatts of power and of irrigating 433,754 hectares of land now yielding crops below their productive capacity.

It is essential that this plan of development be viewed as a long-range plan, for at the present Ethiopia has not the demand for the total power that can be produced and she lacks the experience, technical, and financial resources to develop the entire irrigation potential over a short period of time. Other phases of the economic, political, and social structure are advancing at a gradual pace, and projects should be developed on a time schedule consistent with the needs of the nation as these changes occur. In addition to the national demands, it appears possible that the needs of the downstream nations could influence the rate of development of some projects, particularly those on the Blue Nile River proper, which might store water and provide electrical energy to the downstream nations.

Ethiopia has developed some hydroelectric power projects and has established the nucleus of a public power system. She has acquired experience and technical ability in this field and with some assistance should have little difficulty in expanding the hydroelectric power facilities by adding new plants in an orderly schedule consistent with the growing needs.

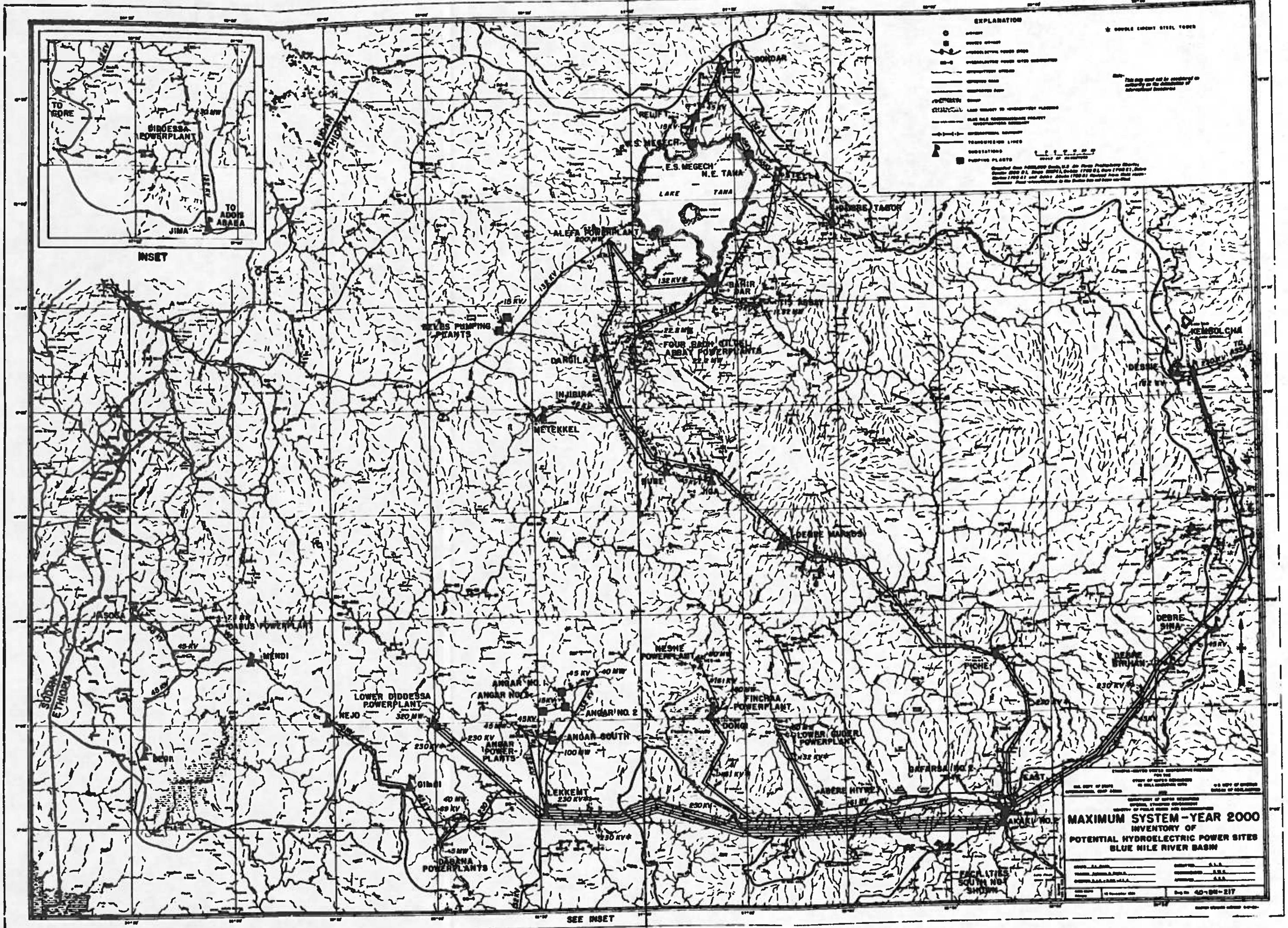
In the field of irrigated agriculture, it is anticipated that the rate of development would be greatly influenced by other factors--health, education, governmental policy on land tenure and ownership, taxation, and the ability of the people to adjust to new methods and crafts. Initially, only projects of moderate size should be developed. As experience and managerial ability are gained, the projects could then be expanded. The production of additional food crops is needed immediately, and development should proceed as rapidly as possible, consistent with the ability of the Ethiopian people to operate and manage the facilities successfully.

1/At 0.5 plant factor; of this total, 6,965,165 kw. are specifically identified with projects in this report.

Evaluation of the available data indicated that transbasin diversion of the waters from the Blue Nile River Basin would not be practical, with the possible exception of diversion of Lake Tana to the Atbara Basin located to the north of Lake Tana. However, in the present scheme, the waters of Lake Tana are being utilized within the basin for agricultural and hydroelectric power production. Minor quantities of water near the headwaters of the drainage areas could undoubtedly be diverted to other basins; the amount, however, would be negligible. Diversions of any appreciable amounts of water from the Blue Nile River would require an extremely long tunnel or very high head pumping due to the entrenchment of the Blue Nile River. For example, the Blue Nile River below the mouth of the Beshilo River has an average annual runoff of 11,000 million cubic meters (9 million acre-feet), but to utilize this water outside the basin without pumping would require a tunnel, 150 kilometers in length, east to the Awash River Basin.

The plan of development encompasses all major projects within the Blue Nile Basin that appear to be worthy of consideration at this time. Hydroelectric power projects are considered in two stages: (1) Those projects that may appear desirable to meet the power needs of the area up to the year 2000, and (2) those projects that could be developed after that date.

The cost and benefits of each project have been compared, and, when considered with other influencing factors, they should enable the Imperial Ethiopian Government to select for early development those projects best suited to the changing needs.



igure 50--Inventory of Potential Hydroelectric Power Sites--Maximum Sys ear 2000

TABLE 14.-SUMMARIZED DATA FOR POTENTIAL IRRIGATION AND POWER PROJECTS

Item	Project	Purpose	Reservoir: Source (river)	Reservoir: Initial capacity (million cu. m.)	Construction cost (Eth$1,000)	Irrigable area (hectares)	Installed kilowatts	Benefit-cost ratio	Remarks
1	Megech Gravity	Irrigation	Megech	225.3	76,028	6,940		0.46 to 1	
2	Ribb River	Irrigation	Ribb	312.6	78,405	15,270		0.95 to 1	
3	Gumara River	Irrigation	Gumara	236.7	79,633	12,920		0.83 to 1	
4	West Megech Pump	Irrigation	Lake Tana	12,987.0	12,617	7,080		1.49 to 1	Reservoir capacity of lake above elevation 1783.
5	East Megech Pump	Irrigation	Lake Tana	12,987.0	11,488	5,890		1.36 to 1	
6	Northeast Tana Pump	Irrigation	Lake Tana	12,987.0	9,634	5,000		1.47 to 1	
7	Upper Beles 1/	Multipurpose	Lake Tana	12,987.0	346,717	63,200	200,000	3.04 to 1	Water diverted by means of tunnel.
8	Middle Beles 2/	Power	Beles*	3,974.0	213,737		168,000	2.58 to 1	Supplemental water diverted from Lake Tana also utilized.
9	Upper Birr	Irrigation	Birr	537.4	140,718	24,350		1.00 to 1	
10	Debohila	Irrigation	Debohila	50.1	43,531	4,200		0.59 to 1	Plus flows of Selale, Adefita, and Ghussa.
11	Lower Birr	Irrigation	Birr	see remarks	12,300	6,600		3.30 to 1	No storage; run of river plus return flows of Upper Birr.
12	Giamma River 2/	Power	Giamma	3,169.0	269,040		60,000	0.72 to 1	
13	Muger River 2/	Power	Muger	300.7	31,088		26,000	2.42 to 1	
14	Upper Guder	Irrigation	Bello	70.6	13,962	5,100		1.54 to 1	
15	Lower Guder 1/	Power	Guder	2,557.0	126,848		50,000	1.21 to 1	
16	Finchaa 1/	Multipurpose	Finchaa	464.0	86,127	15,000	80,000	3.44 to 1	
17	Amarti-Neshe 1/	Multipurpose	Amarti and Neshe	847.6	123,020	8,490	80,000	2.38 to 1	Reservoir basins connected by open channel.
18	Arjo-Diddessa 1/	Multipurpose	Diddessa	2,130.0	161,211	16,800	30,000	2.11 to 1	Two powerplants
19	Dabana 1/	Multipurpose	Dabana	1,617.0	358,368	6,100	85,000	0.93 to 1	Two storage dams and three powerplants.
20	Angar 1/	Multipurpose	Angar	3,572.0	469,935	30,200	185,000	1.93 to 1	Dependable capacity for meeting peak loads, 152,000 kw.
21	Lower Diddessa 1/	Power	Diddessa	4,862.0	404,885		320,000	2.09 to 1	
22	Dabus	Irrigation	Dabus	see remarks	23,433	15,000		3.03 to 1	By direct diversion.
23	Dabus 1/	Power	Dabus	see remarks	9,622		7,500	2.08 to 1	No storage; run-of-river plant.
24	Dindir 2/	Multipurpose	Dindir	3,690.0	448,472	58,300	40,000	1.22 to 1	Two storage dams.
25	Galegu	Irrigation	Galegu	798.8	211,706	11,600		0.45 to 1	
26	Rahad	Irrigation	Rahad	1,902.0	243,130	53,100		1.55 to 1	
27	Karadobi 2/	Power	Blue Nile	32,500.0	1,031,002		1,350,000	3.16 to 1	
28	Mabil 2/	Power	Blue Nile	13,600.0	851,079		1,200,000	3.65 to 1	
29	Mendaia 2/	Power	Blue Nile	15,930.0	1,003,829		1,620,000	4.35 to 1	
30	Border 2/	Power	Blue Nile	11,074.0	942,805		1,400,000	3.74 to 1	
31	Addis Ababa-Assab Trans. 1/	Power*			84,891		-	-	Transmission and substation facilities only.
32	Jiga Spring Pilot	Irrigation	Spring	see remarks	210	224	-	-	Water supply from Tukur Spring; no storage.
33	German Gilgel Abbay 1/	Multipurpose	Jema, Koga, Gilgel Abbay	1,017.0	see remarks	62,390	63,665	-	Estimates of cost not available. 22,200 kw estimated firm.
	Totals			118,427.8	7,919,525*	433,754	6,965,165		Construction cost does not include development costs.

1/ Present century, power facilities.

2/ Next century, power facilities.

INVENTORY OF POTENTIAL PROJECTS

The plan of development contains 33 projects. Eight are multipurpose, having both power and irrigation facilities. Fourteen are irrigation only, while 11 are for power production and transmission purposes. These are summarized in Table 14 and represent those facilities which are included in the initial plan of development. Those projects capable of producing hydroelectric power are further divided into Present Century and Next Century categories.

AGRICULTURE

The pattern of irrigated agriculture will be similar in all proposed Blue Nile projects. It may vary with the altitude, climate, and soil, but the basic crops are dictated by the requirements of the Ethiopian diet.

The Ethiopian diet is based upon a combination of cereal grains, pulses, oilseeds, and spices. Small amounts of meat, milk, eggs, and other animal products are consumed, plus small quantities of fruit, vegetables, and sugar.

These crops are well known and many are indigenous to Ethiopia. They are well adapted to the climates and soils. Crops intended for domestic consumption are:

grains: barley, corn, millet, sorghum, teff, and wheat

pulses: chick peas, field beans, field peas, guaya, horse beans, and lentils

oilseeds: flaxseed, mustard, noog, rape, and sesame

specialties: peppers and coffee

Other crops are suggested for industrial processing in Ethiopia and to improve the trade balance. Cotton and tobacco are projected for local processing and sale, and castor beans, sunflower, and peanuts for export. Rape, field beans, and lentils may also have export possibilities.

Summary Sheet

A summary sheet reflecting land utilization, crops, yields, prices, and income is presented for each project.

Irrigation Season

The farming year in Ethiopia is divided into two distinct periods. The October 15 to June 1 irrigation season is the main period of project operations. This is a time of little precipitation when irrigation water is required for farming. The land will be utilized to its fullest capacity, and good yields are expected. The rainy season, June through September, will be secondary in importance.

Irrigated crop yield data in the Blue Nile Basin are limited and lack reliability. Precise measures of production and units of land are seldom known, and generally are expressed in local, nonuniform systems of weights and measures.

Present irrigated yields, therefore, are not a realistic base on which to project future yields expected on irrigation projects.

Irrigated yield data were collected from existing commercial farms, plantations, experiment stations, and Ethiopian experts; compared with secondary sources; and checked with agronomic advisors and agricultural research technicians. The figures were adapted to expected project conditions under irrigation by considering the broad influence

Figure 51. Rural family village on the plateau between Addis Ababa and Lekkemt.

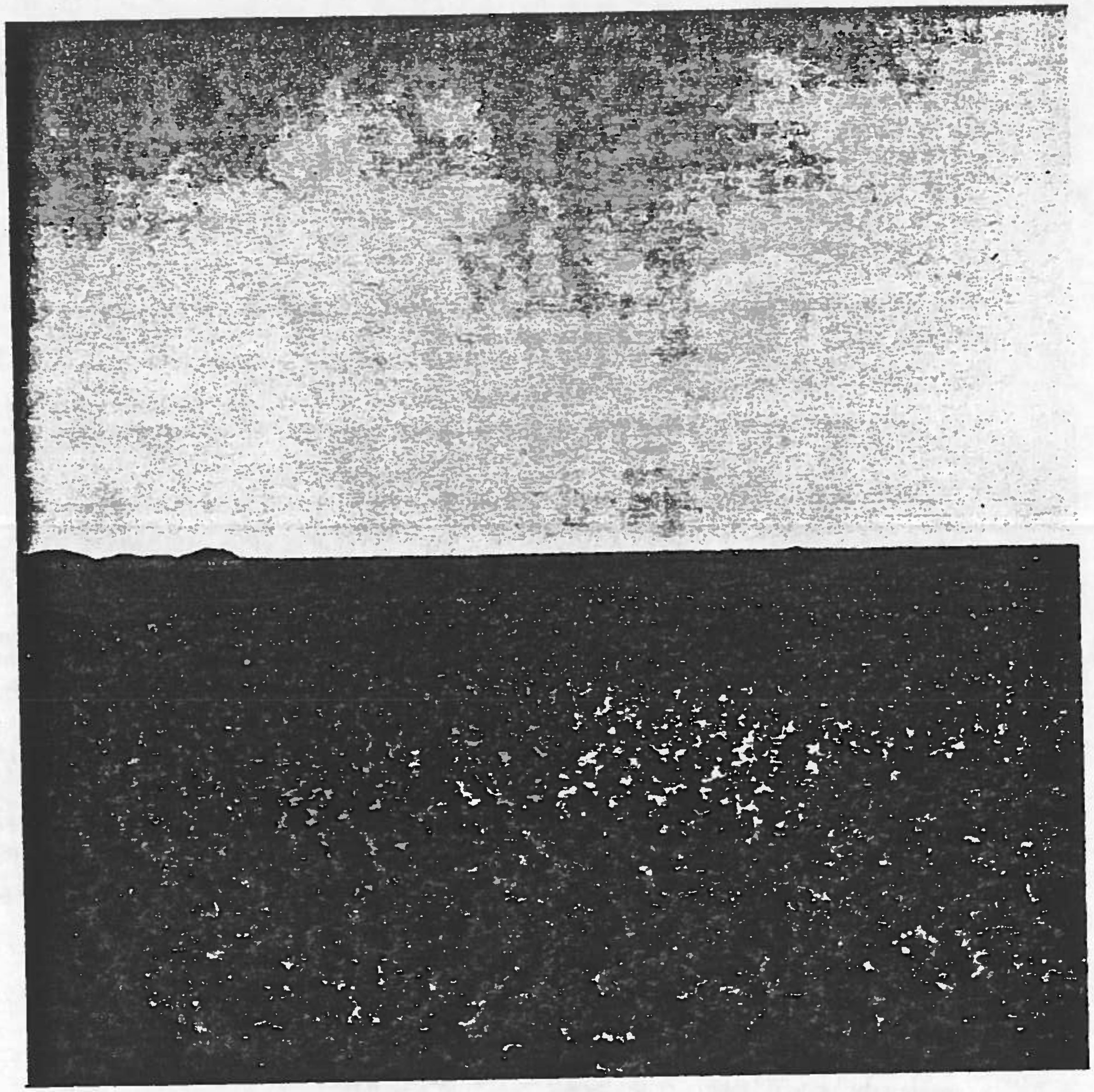


Figure 52. Project lands near Omedla in the Dindir-Rahad project area.

of climate. The climatic factors which influence plant growth, particularly temperature variation and frost probability, are considered to be functions of elevation. The precipitation factor is less important, since project operations will be concentrated during the dry season when irrigation is provided.

As altitude in the Blue Nile Basin increases, the daily minimum and maximum temperatures tend to decrease. It is suggested that the aggregate number of heat units decreases as the elevations increase, excluding local microclimatic effects. Therefore, the lowest elevations have the warmest climate, and the highest areas have the coolest climate.

Data and observation indicate that crops have altitude ranges in which they grow best. The warm season crops do poorly at the higher elevations, while those requiring cool temperatures do not thrive at the lower altitudes. The crops expected to have most favorable growth in various elevation categories are as follows:

Less than 700 meters: baltuk, corn, millet, sorghum, cowpeas, castor beans, peanuts, safflower, sesame, sunflower, peppers, tobacco, cotton, false banana, sisal, banana, citrus fruit, tea, sugar cane, and alfalfa.

700 to 1400 meters: baltuk corn, millet, sorghum, chick peas, cowpeas, field beans, lentils, castor beans, flaxseed, mustard, peanuts, rape, safflower, sesame, sunflower, peppers, coffee, tobacco, cotton, false banana, sisal, banana, onions, tea, sugar cane, and alfalfa.

1400 to 2100 meters: barley, corn, sorghum, teff, wheat, chick peas, fenugreek, field beans, field peas, guaya, horse beans, lentils, castor beans, flaxseed, mustard, noog, rape, safflower, sunflower, peppers, coffee, potatoes, onions, and alfalfa.

More than 2100 meters: barley, sorghum, teff, wheat, fenugreek, field peas, guaya, horse beans, castor beans, flaxseed, mustard, noog, rape, onions, potatoes, and alfalfa.

In this report, each successive 700-meter increase in altitude is assumed to reduce the expected crop yield by 15 percent, and each successive 700-meter decrease to increase the expected yield by 15 percent. Although this assumption is arbitrary to some extent, it reflects the observations of technicians familiar with Ethiopian agricultural conditions and the best secondary information available.

Nonirrigation Season

During the nonirrigation season, heavy rains fall and moisture is excessive; daytime temperatures are lower; and skies are frequently overcast. The fields cannot be worked with heavy equipment and lower yields are expected than during the irrigation season. Planting the land in short-season crops and cultivating them with hand labor, rather than fallowing the land during this rainy season, is recommended. The fields could be plowed, disked, and leveled by tractor after harvest of the irrigated crops, and sown with the rains. Land utilization would be more complete, more food would be produced, and personnel would be occupied on a year-round basis.

A possible detrimental effect of rainy season farming is damage to soil tilth from repeated working of wet or puddled soils. The latosols, however, while less susceptible to structural damage than the heavier grumusols, may be more subject to erosion. Mechanical plowing and row crop planting may have to be avoided in the rainy season in some project areas in favor of disking and seeding with annual cover crops or short season pasture grasses.

Nonirrigated crop yields are based largely on known yields recorded in Shewa, Wellegga, and Gojjam Provinces. These areas lie at the higher elevations at which irrigation projects are planned, and figures are adjusted for elevation in the same manner as for the irrigated crops.

Prices

Wholesale prices for a variety of agricultural products in Addis Ababa, Asmara, Gondar, Debre Markos, and Lekkemt have been compiled. Prices paid in rural area are assumed to be the central market (Addis Ababa) wholesale prices, with a reduction for transportation, handling, and agent's profits. The basic reduction used in arriving at prices expected at the project gates is Eth$0.80 per 100 kilograms of produce per 100 kilometers to the central market.

Livestock

For the purpose of a reconnaissance economic evaluation of potential irrigation projects in the basin, the integration of livestock with irrigated crop farming has been considered. The importance of livestock is recognized, but due to the lack of reliable data on production, breeding, disease control, marketing, and processing, it is believed that a more valid economic analysis of agricultural development can be made on the basis of crops alone.

Future studies may reveal the feasibility of integration of livestock and irrigated crop production in specialized areas. Livestock may eventually become more important in the higher altitude areas dominated by heavy soils, and proximity to major markets may also influence livestock development on irrigation projects.

Noncrop Income

In the rural economy of the Blue Nile Basin, farmers often supplement their income with work not directly related to crop production. A principal source of income is derived from cottage processing of cotton and wool, blacksmithing, hauling goods, writing letters, fermenting alcoholic beverages, blending spices, performing custom and day labor, and a host of small merchandising schemes.

Data seemed conclusive that farmers were obliged to enter an outside field to purchase salt, sugar, illuminating oil, manufactured cloth, shoes, or other trade items. Often farmers stated that crop income alone did not suffice for these purchases.

Data on sale of livestock and animal products indicated that cattle, sheep, or goats were occasionally sold to pay the land tax and tithe or to finance a large consumer purchase.

PROJECT LANDS

General Geology and Physiography

The principal land forms on which the project lands occur include ancient valley fills, upland peneplains, alluvial fans, lake deposits, river terraces, floodplains, colluvial deposits, and deltaic-like materials.

The land forms and soil conditions are strongly influenced by the high annual rainfall and the severe regional erosion which has resulted. Most of the basin lands proposed for development are underlain with basalt. These rocks are generally underlain by sedimentary sandstones and shales of Triassic age. The underlying basement complex includes Precambrian granites, gneisses, and schists.

Topography

Topographic conditions in the proposed project areas vary from excellent to poor. In a few areas there are broad smooth plains with slight slope which will be very easy to develop. However, the largest portion of the land area occurs on ridge tops and side slopes of ridges. Slopes of 3 to 7 percent are characteristic of most of the irrigable lands. There are also some lands with slopes of 8 to 12 percent, but these lands represent a relatively minor percentage of the total area.

Tree and/or tall grass cover is characteristic of most of the project lands. A relatively small percentage is cleared and presently dry farmed. Clearing of the present cover must necessarily precede any irrigation development. Leveling requirements will be moderately light on most lands because of the gradient conditions.

Some isolated high areas exist within most project areas that cannot be served by gravity systems, but could be served with pumps.

Drainage

Except for some relatively minor portions, surface drainage is excellent over the project area. Many drainage channels have eroded to the basalt and the channels generally have flow capacities considerably in excess of any irrigation waste requirements. Inlet structures may be needed for irrigation wastes to prevent head cut erosion.

Subsurface drainage characteristics are generally poor on the black (grumusol) soils, and excellent to good on the red (latosol) soils. Further studies are needed to define the need for additional subsurface drainage channels. In general, it appears that the black soils would not respond favorably to subsurface drainage construction because of the tight clay subsoil, while the red soils generally have a natural deep surface drainage system which will also serve for subsurface drainage purposes. Additional deep drains may be needed in some projects for water-table control.

Land Classification

A subreconnaissance land classification was conducted on an area of about 1,000,000 hectares during the process of project investigations. Most of the classification was done with the aid of helicopters. Nonrectified aerial photographs with an approximate scale of 1:50,000 were used as base maps. Classification specifications were used which reflect physical considerations rather than economic. A copy of these specifications may be seen in Appendix IV, "Land Classification." Traverses were made at approximately 1- to 2-kilometer spacings and land class delineations were made directly on the photos. Soils were examined to a depth of about a meter and a half and were sampled for laboratory testing where opportunities for helicopter landings existed. The prevalence of tree and tall grass cover prevented more extensive, and more to be desired soil investigation. It is estimated that the type of classification performed resulted in an accuracy of about 65 percent. Detailed land classification will be needed to refine the location and suitability of the various land bodies for irrigation before any project development.

Land Classes 2, 3, and 6 were delineated in all of the area classified. In addition, Class 1 was delineated in a few areas where conditions appeared to be unusually favorable. In this classification Class 1 lands were considered to be best for irrigation. Class 3 is least desirable, and Class 2 is an intermediate class. Lands which were considered to be unsuited for irrigation development were delineated as Class 6.

TABLE 15--RECONNAISSANCE LAND CLASSIFICATION, INITIAL DEVELOPMENT

Table 15

Area and project	Total arable (ha.)				Arable below canal (ha.)				Irrigable (ha.)			
	Class 1	Class 2	Class 3	Total	Class 1	Class 2	Class 3	Total	Class 1	Class 2	Class 3	Total
Lake Tana Area (incl. Gilgel Abbay)												115,490
Lake Tana Area (excl. Gilgel Abbay)	58,030	67,030	160,560	285,620	7,190	2,090	60,922	70,202	5,388	1,570	46,142	53,100
Megech Gravity					(5,090)	-	(4,163)	(9,253)	(3,818)	-	(3,122)	(6,940)
Ribb River					-	-	(20,015)	(20,015)	-	-	(15,270)	(15,270)
Gumara River					(2,100)	(2,090)	(13,029)	(17,219)	(1,570)	(1,570)	(9,780)	(12,920)
East Megech Pump					-	-	(7,850)	(7,850)	-	-	(5,890)	(5,890)
West Megech Pump					-	-	(9,453)	(9,453)	-	-	(7,080)	(7,080)
Northeast Tana Pump					-	-	(6,430)	(6,430)	-	-	(5,000)	(5,000)
Gilgel Abbay (German Team)					-	-	-	-	-	-	-	(62,390)
Beles River Area	5,700	35,000	67,200	107,900	4,900	30,100	62,200	97,200	3,200	19,600	40,400	63,200
Beles	(5,700)	(35,000)	(67,200)	(107,900)	(4,900)	(30,100)	(62,200)	(97,200)	(3,200)	(19,600)	(40,400)	(63,200)
Birr River Area	22,767	10,765	36,240	69,772	22,465	3,520	20,980	46,965	16,264	2,560	16,550	35,374
Upper Birr					(17,525)	(2,150)	(10,917)	(30,592)	(12,500)	(1,600)	(10,250)	(24,350)
Debohila					(4,244)	(1,370)	-	(5,614)	(3,240)	(960)	-	(4,200)
Lower Birr					(460)	-	(10,063)	(10,523)	(300)	-	(6,300)	(6,600)
Jiga Spring Pilot					(236)	-	-	(236)	(224)	-	-	(224)
Guder River Area	2,110	27,980	-	30,090	260	1,240	3,950	5,450	240	1,160	3,700	5,100
Upper Guder	(2,110)	(27,980)	-	(30,090)	(260)	(1,240)	(3,950)	(5,450)	(240)	(1,160)	(3,700)	(5,100)
Finchaa River Area	-	22,921	11,262	34,183	-	21,260	10,164	31,424	-	15,771	7,719	23,490
Finchaa					-	(13,460)	(6,644)	(20,104)	-	(10,000)	(5,000)	(15,000)
Amarti-Neshe					-	(7,800)	(3,520)	(11,320)	-	(5,771)	(2,719)	(8,490)
Diddessa River Area	1,450	56,960	58,210	116,620	1,330	43,270	34,900	79,500	870	28,270	23,960	53,100
Arjo-Diddessa					-	-	(24,000)	(24,000)	-	-	(16,800)	(16,800)
Dabana					-	(7,050)	(2,110)	(9,160)	-	(4,700)	(1,400)	(6,100)
Angar					(1,330)	(36,220)	(8,790)	(46,340)	(870)	(23,570)	(5,760)	(30,200)
Dabus River Area	1,380	16,420	12,200	30,000	1,380	15,170	6,400	22,950	900	9,900	4,200	15,000
Dabus	(1,380)	(16,420)	(12,200)	(30,000)	(1,380)	(15,170)	(6,400)	(22,950)	(900)	(9,900)	(4,200)	(15,000)
Dindir-Rahad Area	-	31,500	197,000	228,500	-	19,900	169,400	189,300	-	12,900	110,100	123,000
Rahad					-	(7,800)	(73,900)	(81,700)	-	(5,000)	(48,100)	(53,100)
Galegu					-	-	(18,000)	(18,000)	-	-	(11,600)	(11,600)
Dindir					-	(12,100)	(77,500)	(89,600)	-	(7,900)	(50,400)	(58,300)
Total (including Gilgel Abbay)												433,754
Total (excluding Gilgel Abbay)	91,437	268,516	542,672	902,685	37,525	136,550	368,916	542,991	26,862	91,731	252,771	371,364

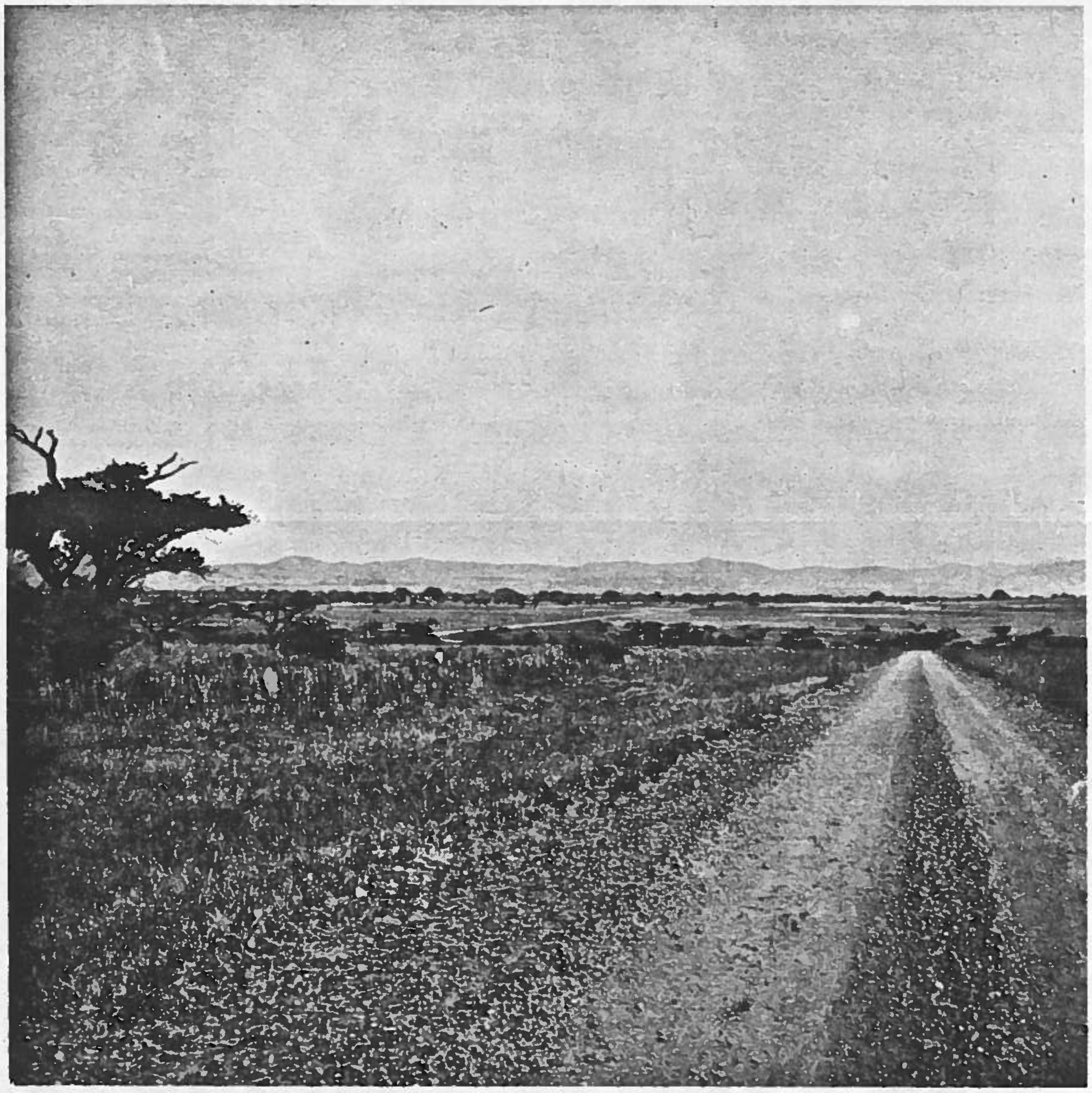


Figure 53. Birr River project area near the town of Jiga.

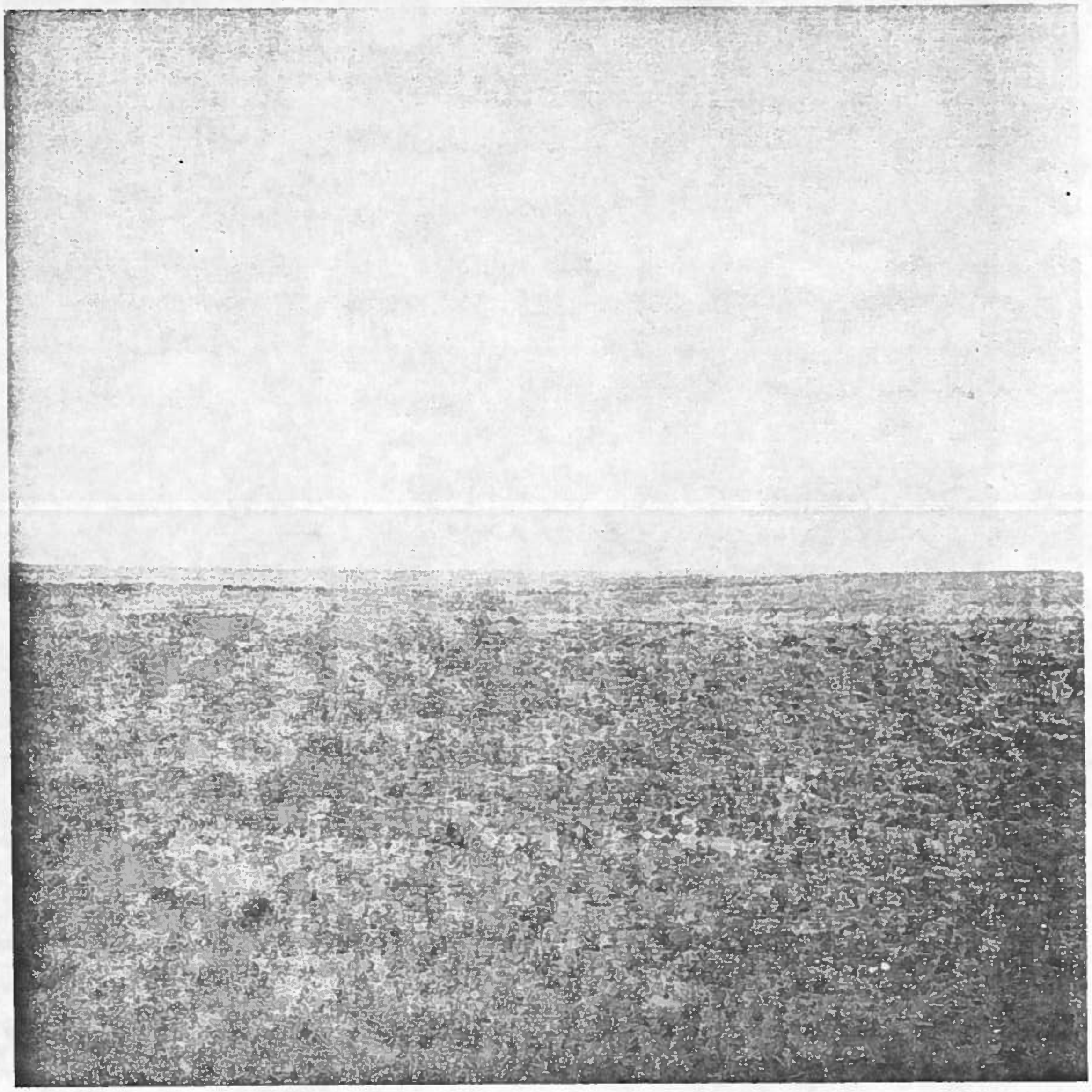


Figure 54. Finchaa project lands.

Irrigability

After the land classification was completed, topographic data were obtained for the areas which showed promise for irrigation development. New maps of the project areas were made, and the classification data were transferred to these new maps.

Canal and lateral distribution system layouts were made on the topographic maps and the land areas which could be serviced by these works were measured. Such land area measurements were then reduced by a percentage (usually 35 percent) to reflect the sub-reconnaissance nature of the investigation.

Classification Results

Table 15 sets forth the results of the land classification and irrigability studies. Lands shown in this table as "arable" are lands which have physical characteristics suitable for irrigation development. Lands shown as "irrigable" are lands which can be provided with irrigation water under the proposed plan of development.

POWER

GENERAL FACTORS IN POWER MARKET ANALYSIS

Ethiopian Government planners hope to change the economy of the nation from predominantly subsistence agriculture to an up-to-date, efficient, agricultural-industrial economy by the year 1982. To achieve this, it is hoped to maintain a rate of economic growth of about 4 or 5 percent per year on an average. This can only be achieved by a correspondingly rapid acceleration in the development of facilities to provide electrical energy to the principal industrial load centers.

Table 16 gives a cross section of the general economy by indicating the Gross National Product by economic sectors for the years 1957 and 1962 with forecasts for 1967.

Employment and Urbanization

Considering the country as a whole, over 90 percent of the population is engaged in agricultural pursuits. The other 10 percent can be considered as supplying the labor needs of government, commercial and industrial enterprises, and various miscellaneous categories. By far the largest urban area is Addis Ababa, and according to the Ministry of Commerce and Industry, in 1960 there were about 60,500 persons gainfully employed in the city.

In order to improve the employment on a national scale, a greater number of jobs must be created yearly to absorb the natural increase in population as well as to absorb the partially unemployed resulting from the spread of labor-saving devices. Opportunities for employment must be distributed evenly over towns and villages located throughout the various parts of the Empire. Even if this is done, 30 to 60 percent of the urbanized population will depend primarily upon employment by industry. In Ethiopia, the following conclusions are reached concerning urbanization:

1. As to the extent of urbanization, it ranks fairly low among African nations.
2. The trend toward urbanization has accelerated considerably in recent years.
3. Urbanization has been directed toward one city primarily--Addis Ababa.
4. Urbanization is encouraged directly by electrification.
5. Urbanization is encouraged through the growing industrialization of a community.
6. An abundance of electricity should be made available on a wide scale throughout Ethiopia so as to prevent the major concentration of urbanization in one area--Addis Ababa.

Other Energy Sources

These include firewood, charcoal, petroleum products, coal, and geothermal. Coal is an insignificant part of the total fuel sources used and can be neglected as a source of energy. Fuel oil used to fire the boilers of the Addis Ababa steam plant cost Eth$128 per metric ton, f.o.b. Addis Ababa, and diesel fuel delivered to Bahir Dar for operating the

TABLE 16--GROSS NATIONAL PRODUCT, 1957-1967 1/

	1961 prices in Eth$ millions			Index No. 1967/1962	Rate of growth
	1957	1962	1967		
Agriculture	1,328.0	1,453.6	1,632.3	112	2.3
Forestry	18.3	23.3	28.1	121	3.8
Fishing and hunting	1.1	1.8	2.9	161	10.1
mining	1.0	1.4	11.6	829	52.6
Power	4.4	7.5	18.2	243	19.4
Manufacturing	24.7	34.9	116.7	334	27.3
Handicrafts and cottage industry	60.9	77.0	93.1	121	3.9
Building and construction	24.2	44.5	72.4	163	10.2
Transport and communication	69.7	109.3	151.1	138	6.7
Trade and commerce	110.3	136.1	171.1	126	4.7
Catering and tourism	20.8	25.0	33.2	133	5.8
Financial intermediaries	10.5	15.4	26.6	173	11.6
Education and culture	11.2	28.0	48.0	171	11.3
Health	6.0	14.0	22.5	161	10.0
Community development	-	0.9	7.4	822	42.8
Other services	2.3	4.9	6.0	123	4.1
Government	63.3	95.4	119.4	128	4.6
Housing	19.6	25.8	35.4	137	6.5
Others	26.0	31.6	36.0	114	2.6
Gross domestic product	1,802.3	2,130.4	2,632.0	123	4.3
Rest of the world	- 30.1	+ 35.4	+ 85.5	-	-
Gross national product	1,770.2	2,165.8	2,717.5	125	4.6

1/ Second Five-Year Development Plan--Includes North Eritrea.

diesel electric plants there cost Eth$308 per metric ton, f.o.b. Bahir Dar. The cost of firewood ranged from Eth$6 per cubic meter to Eth$14, depending upon the location.

The following table indicates that the most economical fuels are wood, charcoal, furnace oil, and diesel oil in the order indicated:

ENERGY COST OTHER THAN ELECTRICITY

Fuel	B.t.u. per kg.	Cost per kg. (Eth¢)	B.t.u. for Eth$.01	Cost per million B.t.u. (Eth$)
Wood	15,400	2.9	5,310	1.88
Charcoal	28,160	6.0	4,693	2.13
Furnace oil	40,700	12.8	3,180	3.14
Diesel fuel	41,250	30.8	1,340	7.46

Assuming the use of furnace oil for a steam-electric generating plant and diesel fuel in a diesel-electric plant, it was found that for a small installation the cost of generating 1 kw.-hr. using furnace oil fuel was Eth¢9.2 and the cost per kw.-hr. using diesel fuel was Eth¢10.4. For a large hypothetical oil-fired steam-electric generating plant located near Akaki, the cost of production is slightly less than Eth¢5 per kw.-hr.

The average cost of electricity from the utility serving the central provinces in 1962 was over Eth¢8 per kw.-hr.

Generally, electricity, even at the present rates, is competitive with other forms of energy when considered from the industrial viewpoint. For domestic use, the low income groups will find wood and charcoal more economical than electricity for some time to come, although this will gradually change with time as the rates are lowered. For those in the higher income category, the other alternative to electricity is bottled gas, and, in this comparison, electricity at present rates is competitive with gas for residential and small commercial purposes.

Firewood is not always available. Charcoal is shipped into those areas where wood is not readily available, and the price varies considerably, being directly influenced by transportation costs.

Ethiopia has several hot springs that might successfully be developed for the production of electricity by operating steam turbines. Natural steam has long been used in other parts of the world.

A complete inventory and study of hot springs and other related geothermal phenomena have not been accomplished in Ethiopia, and therefore no evaluation of this untapped resource can be made at this time. In the Blue Nile River Basin, one significant hot spring exists at Agere Hiywet (Ambo). Nearby, outside of the basin, are the hot springs at Woliso. Others exist in the Awash River Valley, indicating generally that the Rift Valley area has the greatest geothermal activity.

Hydromechanical installations operate small grist mills throughout the Empire. Each serves the surrounding rural and village area as long as water is available. These installations will continue to be used as the primary source of power in many rural areas for this purpose.

A high percentage of the village and rural population depends upon cow dung for domestic fuel requirements. If this type of fuel were not available, the demand for charcoal and wood would greatly increase, driving the price upward practically out of reach of the lower income groups. The prices of wood and charcoal will continue to increase in the future, but the cost of electricity should actually decrease.

Therefore, it appears that electricity from hydroelectric sources offers the most stable long-range energy source, both as to supply and as to price.

Present Electric Rates and Power Production Costs

Generally, Ethiopia can be divided into two principal electric rate areas. The largest is the 13 provinces and the southern part of Eritrea (Assab)--south, north, central, and west regions--served principally by the Ethiopian Electric Light and Power Authority (EELPA). The other is the North Eritrea Region, served principally by the Societa' Elettrica dell' Africa Orientale (SEDAO).

As shown by Table 17, the present EELPA rates (1962) call for Eth¢15 per kw.-hr. for the first 100 kw.-hr. per month and Eth¢10 per kw.-hr. for all use in excess of that during the same period. This is for the General Tariff classification, which includes residential service.

The SEDAO tariff rates in 1962 were as follows:

	Rate per kw.-hr.
Light (127-volt)	Eth¢27
Public lighting	Eth¢15
Domestic appliances, 220-volt, single-phase	Eth¢17
Industrial power (220-volt or 5,500-volt) for:	
1 to 500 kw.-hr./month	Eth¢17
501 to 4,000 kw.-hr./month	Eth¢13
4,001 to 50,000 kw.-hr./month	Eth¢11
More than 50,000 kw.-hr./month	Eth¢10
Large industries can negotiate special lower rates.	

The cost of electricity can be considered in three general categories: (1) large hydro-electric installations (Koka); (2) steam-electric generation (Addis Ababa); and (3) a small, isolated, thermal installation (Bahir Dar).

1. "By imposing an interest of 5 percent on the capital to be used for construction of the project, and amortization over 30 years for machinery, etc., and over 50 years for civil structures, and by calculating normal maintenance costs, the price for electricity produced at Koka and delivered in Addis Ababa and Dire Dawa will be about 2.15 cents per kw.-hr. provided an average of about 110 million kw.-hr. are delivered per year."1/

2. The Addis Ababa steam plant has a generator output of 5,000 kw. at site and has a maximum energy production of about 21,900,000 kw.-hr., with a load factor of about 50 percent. The specific production costs at the plant vary from about 5.6 cents per kw.-hr. for full production to almost 11 cents for one-quarter production.

3. The Bahir Dar diesel electric plant is typical of a small thermal plant serving a village area, and the total output of the station at the site is rated at 96 kw. with a load factor of about 40 percent. The maximum energy to be produced per year is about 336,000 kw.-hr. The production cost per kw.-hr. ranged from almost Eth¢14 at full plant output to about Eth¢41 when loaded to about one-seventh of maximum.

ESTIMATED FUTURE POWER REQUIREMENTS, PRESENT CENTURY

Pattern of Development

For this study, the power load requirements will develop along regional lines with towns and villages being served first by small, self-contained, but isolated, diesel or

1/Koka Hydroelectric Project, Imperial Ethiopian Government, December 1958.

TABLE 17–TARIFF IN FORCE, ETHIOPIA ELECTRIC LIGHT AND POWER AUTHORITY

Tariff classification	Sales price
1. GENERAL	
First 100 kw.-hr. per month	Eth¢15 per kw.-hr.
Exceeding 100 kw.-hr. per month	Eth¢10 per kw.-hr.
Service charge, single phase	Eth$1 per month
three phase	Eth$5 per month
2. COMMERCIAL AND INDUSTRIAL	
First 1,000 kw.-hr. per month	Eth¢10 per kw.-hr.
Exceeding 1,000 kw.-hr. per month	Eth¢5 per kw.-hr.
Reactive consumption, power factor below 0.89	Eth¢1 per
Maximum demand charge, per month	Eth$5 per kw.-hr.
Service charge, three phase	Eth$5 per month
Rebate on total charges:	
Exceeding 100,000 kw.-hr. per month:	5%
Exceeding 400,000 kw.-hr. per month:	10%
Exceeding 700,000 kw.-hr. per month:	15%
Exceeding 1,000,000 kw.-hr. per month:	20%
3. OFF-PEAK	
All Consumption	Eth¢5 per kw.-hr.
Reactive consumption, power factor below 0.89	Eth¢1 per
Service charge, three phase	Eth$5 per month
Rebate on total charges:	
Exceeding 100,000 kw.-hr. per month:	10%
Exceeding 400,000 kw.-hr. per month:	20%
Exceeding 700,000 kw.-hr. per month:	30%
Exceeding 1,000,000 kw.-hr. per month:	40%

(The supply on the off-peak tariff is subject to special negotiations and to conditions of discontinuance of supply for certain periods.)

hydroelectric installations. A load base can thus be established at various small load centers within a given region. These loads, together with loads in adjacent regional areas, may justify a larger central station hydroelectric plant. When that occurs, suitable interconnections within the region will be made. The regional interconnected system may, at the appropriate time, be connected to and form a part of the National Grid. In the meantime, the smaller, diesel-electric plants will be moved to other towns to form another load base. As indicated on Figure 37, these regional load areas are expected to materialize eventually, but not all may develop to the extent that they will become a part of the National Grid.

An effort was made to develop the potential along regional areas and not concentrate all of the developments at one location, Addis Ababa. Selection of projects some distance from Addis Ababa will have a generally beneficial effect as far as the total Empire is concerned, even though substantial components of the produced power will be transmitted toward the capital city. Projects selected are generally located where accessibility is not too difficult. Five general regional areas are considered where Blue Nile River Basin power might be utilized: south, north, central, west, and the special case of North Eritrea.

For the latter, special studies revealed that during the 1980's, deficiencies in power supplies will begin to be manifest and these can be met either by additional thermal plants or by imported hydroelectric power. Whether importation would come from future Takazze River plants or from the Blue Nile is, of course, unknown at this time, pending completion of future studies of the Takazze River potential. In the event that Takazze power development proves infeasible, then reliance upon Blue Nile production facilities may be the result. However, because of this uncertainty, North Eritrea Region loads are not included in load forecasts that follow.1/

Load Characteristics

Peaks and Monthly Distribution of Energy. For purposes of the Blue Nile studies, the monthly distribution of the annual energy requirements was generally taken to be as shown by Figure 55. This would apply to conditions as they may exist beginning in 1980. It should be understood that there has been an insufficient operating period for the South Region Interconnected System to establish a definite pattern at the time this study was prepared.

Weekly heavy load duration and peak percent curves appear on Figure 56.

Losses. A systematic improvement in distribution facilities has gradually reduced distribution losses both in the Interconnected System, South Region, and the scattered isolated systems. Losses include meter errors and some system usage. For example, in 1960 the total losses were 21.3 percent, but in 1961 available data indicated an improvement to 14.7 percent for the isolated systems only. For the South Region Interconnected System, comparable figures were 21 and 17 percent for the years 1960 and 1961, respectively.

These losses were based upon the difference between total annual kw.-hr. production and total kw.-hr. sales, which include distribution losses. Forecasts by EELPA included average total losses from 1962 through 1971 of about 13 or 14 percent, most of which was due to distribution. For the Blue Nile, transmission losses in kw. at peak demand reach maximums of 10 percent, depending upon the particular transmission facility.

Load Factors. Figure 57 was used as a composite indication of expected load factors in the Blue Nile studies. It is based upon a study of load factor trends obtained from other developing countries, and generally follows what was experienced in the Addis Ababa area. This drawing, in the absence of more specific data, was used in developing maximum kilowatt demand at the several load centers.

1/For details, see Appendix V, "Power."

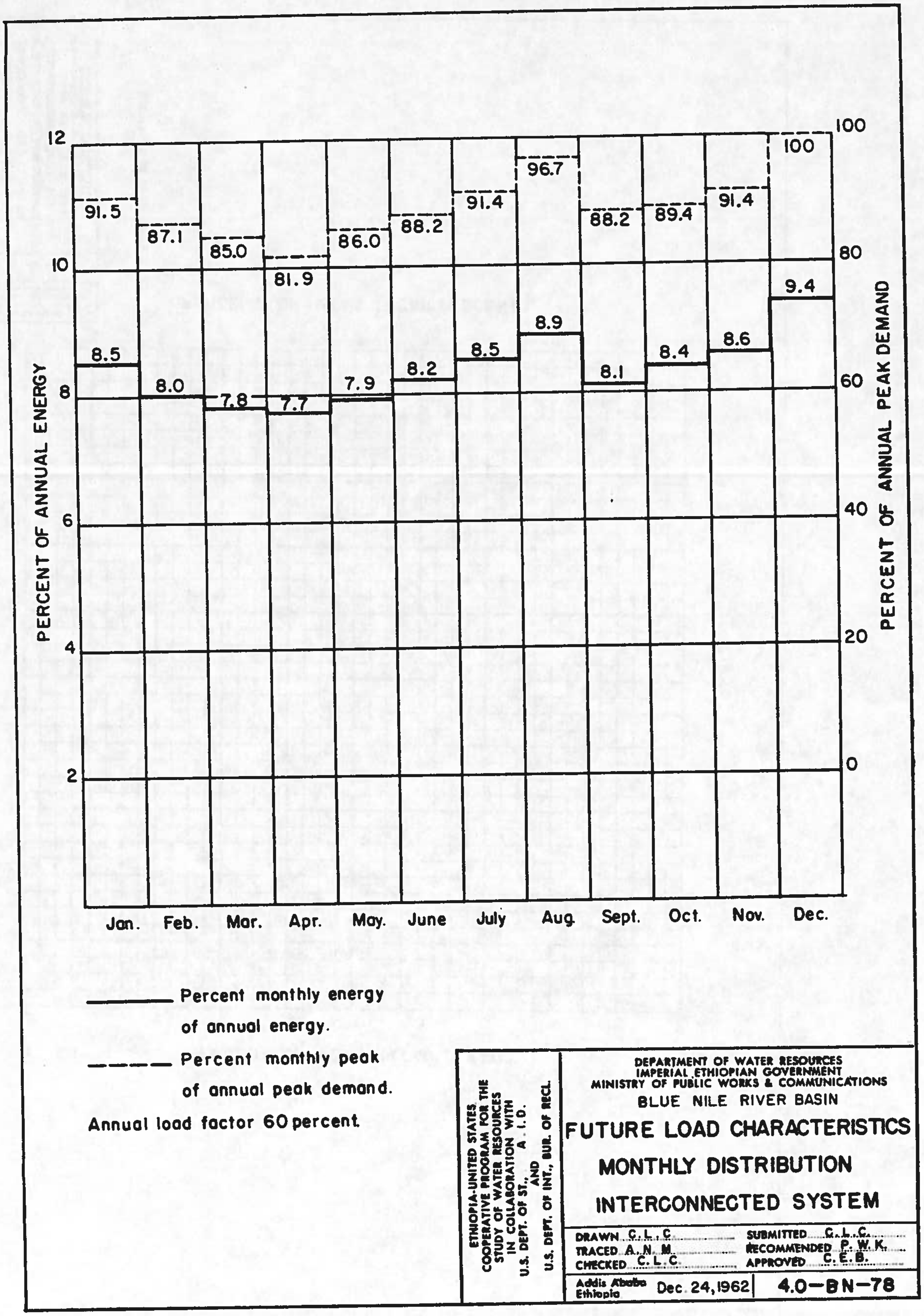


Figure 55--Future Load Characteristics--Monthly Distribution, Interconnected System

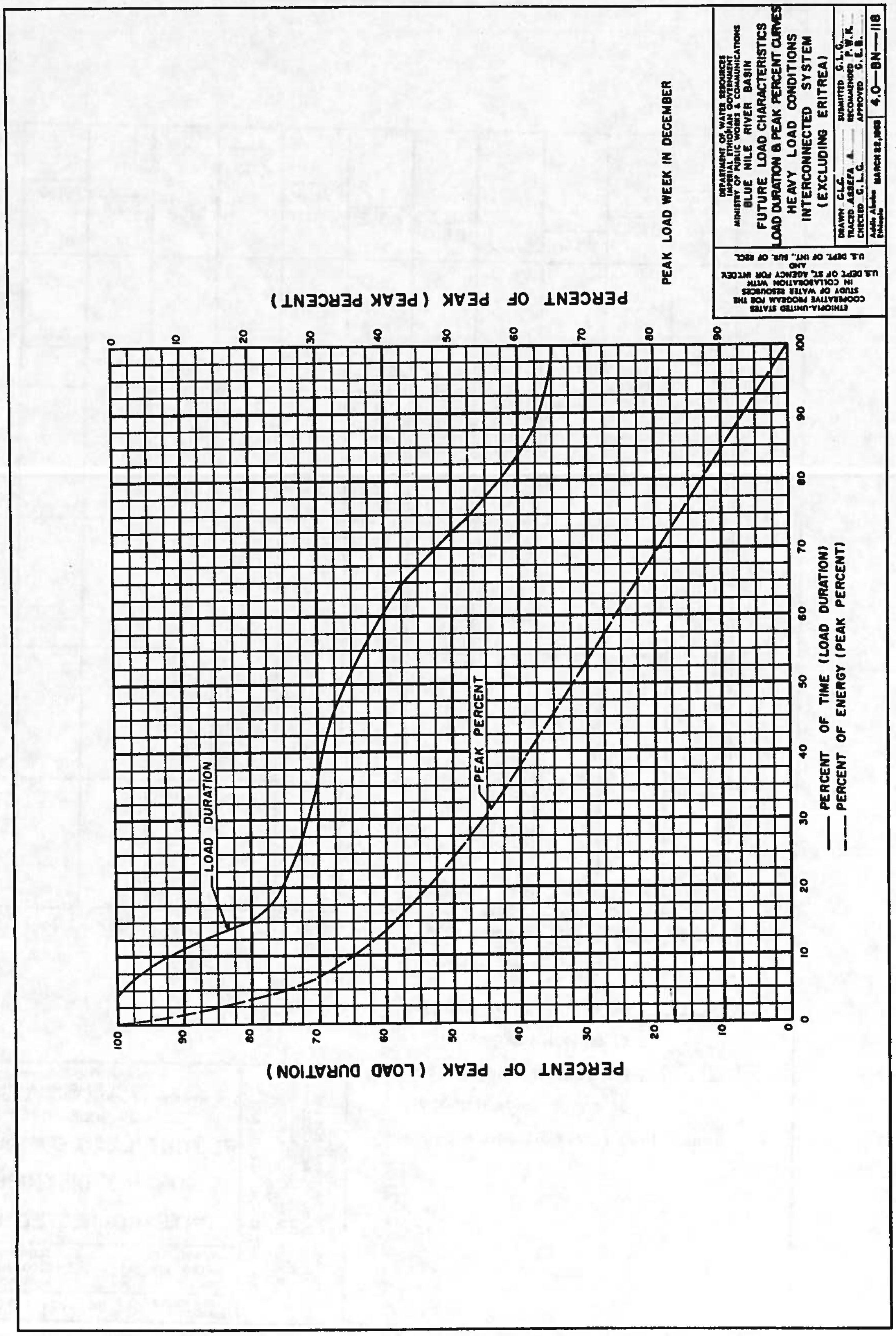


Figure 56--Load Duration and Peak Percent Curves--Heavy Load Conditions

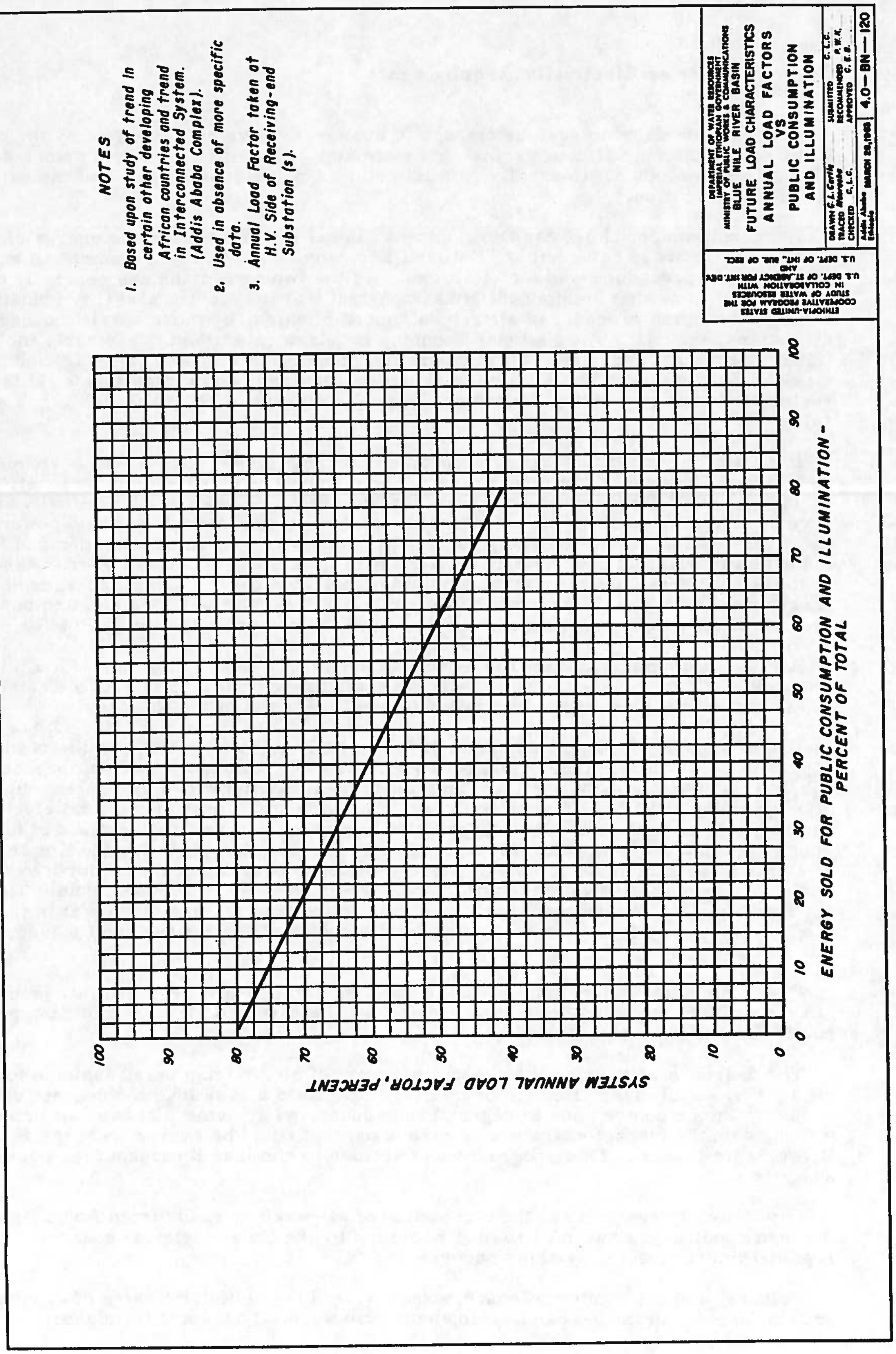


Figure 57--Annual Load Factors v. Public Consumption and Illumination

Future Trends of Electricity Requirements

Statistics on sales to various classes of customers have not been kept by the principal utilities in Ethiopia, although some spot estimates were available based upon a different classification method. Generally, statistics are available on the basis of the sales by tariff classification.

Because the second 5-Year Development Plan of the IEG breaks the energy classifications into two broad categories, "National Economy" and "Public Consumption and Illumination," this procedure was also followed. As the two categories are generally unsatisfactory and somewhat ambiguous, it is important that the electrical utility industry in Ethiopia establish procedures whereby a record of sales, by more specific consumer classifications, be kept. The National Economy requirements would presumably include (1) commerce and industry, (2) transport and communication, and (3) irrigation and municipal water pumping. The Public Consumption requirements would include (1) farm, urban residential, and government buildings; (2) public streets and highway lighting; and (3) other sales.

In an area where industrial and consumer markets for electric power have been well established, one method of forecasting future demands is by extending the existing curve of load growth. This method, however, cannot always be used in economically underdeveloped areas, because with the sudden availability of reasonably priced power and essential raw materials, industry usually develops a rapidly increasing demand for power, the extent of which is unpredictable. A study of developing countries where reasonable-cost electric power has been made available, indicates early annual increases of electric energy use as high as 30 percent. This method of forecasting future electric power requirements was used at some of the smaller load centers after the year 1970.

A reasonable long-term load forecast beyond 1971 is difficult to make for Ethiopia at the present time because the per capita consumption is so low, and where electricity supplies are available, they are limited to small sections of the Empire.

Use of various empirical formulae have had little meaning either, as the results given appear to be much too high. The avowed goal of transforming the present predominantly subsistence agriculture economy to an industrial-agricultural one by 1982 through a series of 5-year plans will have a decided impact upon the rate of growth and total electric power and energy required during the balance of this century. Thus, any analysis of future energy needs must be coordinated with the overall economic plans for the Empire. Every attempt has been made to adhere as closely as possible to the goals set forth by the economic planners in determining total overall power and energy requirements. These goals set forth by the planners appear to be optimistic, although it was noted that in the field of electric power development, the goal established by the first 5-Year Development Plan was considerably exceeded.

Use of electrical energy in the public consumption category (residential, primarily) is almost a direct function of per capita income. The expected increases in Ethiopian per capita income were also considered.

The diligence with which the present program of electrifying small isolated towns and villages by small diesel electric or hydrounits to build a base load to adequate proportions to justify future connections to regional interconnected systems will have an important influence on the market analysis of future loads that could be served from the Blue Nile River Basin source. This program was assumed to continue throughout the period of analysis.

In practically every case, the completion of all-weather roads from Addis Ababa to the load centers was assumed to have occurred by the time electrical connections to regional interconnected systems occurred.

Political stability, international tranquility, and the optimistic rates of economic growth forecast in the 5-Year Development Plan were all assumed throughout the period of analysis.

Regardless of methods used, it is usually possible to establish a hypothetical spectrum of load growth through future years ranging from minimum to maximum rates of growth. Actual development may fall somewhere within this spectrum. The results finally obtained represent the maximum development possible, and for the Blue Nile, it forms the top boundary of the load growth spectrum after 1971.

For this study and report, the future goals set by the economic planners are considered to be optimistic and on that basis, proposed electric power developments are scheduled. Hence, all load forecasts and scheduled project construction to meet load requirements after 1971 is considered the maximum possible which can be attained during this century. Should accomplishments fall short of the programmed goal, then project construction development will be at a slower pace than scheduled in subsequent sections. However, the order of development, even though slower, might remain substantially as outlined, barring unforeseen circumstances in certain regional areas such as a significant mineral or petroleum discovery. The maximum number of projects that could be constructed by the year 2000 to meet the maximum power load growth potential until that date has been scheduled in chronological sequence. In addition, several other projects have been studied and these probably would have little use prior to the year 2000. These are treated later in separate categories. As far as these reconnaissance studies are concerned, these rates of growth in effect determine when various potential water resource projects could be placed into operation. Since loads were estimated to the year 2000, this liberal approach was taken so that the maximum or upper limit of usage of Blue Nile Basin waters could be established at this time for the present century.

Rates of growth by regions in terms of production requirements are as shown by Table 18, which considers EELPA estimates for the Addis Ababa Complex through 1971.

Load Centers - Regional Development

Potential load centers within the four regional areas are as indicated below. Subsequently, they are summed into separate electrical systems, three of which are later interconnected to form the National Grid. North Eritrea is not in the same category and it was treated separately. Load centers generally within economic reach of the potential Blue Nile power producing centers were studied and future loads estimated for each.

SOUTH REGION

Addis Ababa Complex
Jima
Fiche
Agere Hiywet
Lekkemt
Dessie-Kembolcha
South Eritrea (Assab)
Finchaa Farm
Gedo
Angar Pumping and Farm
Debre Birhan
Debre Sina
Upper Guder Farm
Amarti-Neshe Farm

NORTH REGION

Bahir Dar
Gondar
Debre Tabor
Dangila
Debre Markos
Injibira
Jiga
Birr Farm
Metekkel
West Megech Farm
West Megech Pumping
Beles Farm
Beles Pumping

CENTRAL REGION

Dabana Farm
Gimbi
Nejo
Gore

WEST REGION

Asosa
Mendi
Begi

NORTH ERITREA

Asmara and Massawa

TABLE 18--ESTIMATED RATE OF INCREASES IN PEAK LOAD AT POWERPLANTS--REGIONAL INTERCONNECTED SYSTEMS ONLY

Year	Percentage by regions				National Grid	Remarks
	South	North	Central	West		
1957						
1958						
1959						
1960						
1961	20.1					
1962	33.7					
1963	27.7					
1964	-					
1965	13.1	9.0				
1966	35.1	5.9				
1967	19.6	-				
1968	19.3	8.0				
1969	20.0	11.0				
1970	16.5	6.7				
1971	14.3	6.3				
1972	14.1	15.8				
1973	13.8	32.5				
1974	9.8	12.4				
1975	11.5	12.8				
1976	12.0	11.8				
1977	24.7	11.2				
1978	11.5	12.8				
1979	8.9	11.6				
1980	10.6	11.8				
1981	10.6	9.7				
1982	2.5	10.9				
1983	9.0	12.2	14.8			South, North, and Central Interconnection for National Grid
1984	3.8	8.2	16.6		-	
1985	8.5	26.5	12.3		10.3	
1986	7.3	11.7	16.4	9.8	8.1	
1987	7.7	5.8	14.2	6.1	7.6	
1988	6.6	8.1	12.1	8.3	6.9	
1989	6.1	5.7	11.0	5.2	6.1	
1990	6.7	8.0	10.8	7.2	6.9	
1991	12.9	4.8	7.3	6.0	11.8	
1992	4.6	5.6	9.0	6.0	4.8	
1993	5.3	4.6	7.6	6.9	5.2	
1994	5.8	3.4	5.2	5.8	5.5	
1995	4.5	5.9	8.0	6.3	4.7	
1996	5.5	4.5	7.8	5.7	5.5	
1997	5.7	5.5	5.3	5.6	5.6	
1998	4.6	7.1	6.1	6.3	4.9	
1999	5.5	5.6	7.6	4.7	5.5	
2000	4.9	13.0	5.8	4.3	5.9	

Impact of Irrigated Farming

Table 19 indicates existing potential irrigation pumping areas with maximum annual energy and demand shown for full development. Ground-water pumping is excluded.

Within the Blue Nile River Basin, irrigation projects of over 430,000 hectares could ultimately require 58,000 kw. However, it may take several generations to develop all the potential projects.

Regional Summaries

Development of individual load centers within regional sectors was forecast through the year 2000. When conditions warrant it, larger load centers can be interconnected by transmission lines served by large regional powerplants.

South Region. Table 20 summarizes the development of peak loads within the South Region Interconnected System, beginning with 1957 and extending through the year 2000. Its independent status as an interconnected system within a regional area ceases to exist in the years 1982 and 1984 when connections to the then existing interconnected systems in the Central and North Regions come into existence, forming the National Grid.

North Region. Table 21 summarizes the development of peak loads for the North Region Interconnected System through the year 2000. It begins in the latter part of the year 1963 with the Tis Abbay Powerplant supplying energy to Bahir Dar over the 45-kv. transmission line in accordance with the published schedule by EELPA. At the beginning of the year 1984, the North Region's interconnected system might be connected with the South Region, forming the National Grid.

TABLE 19--PUMPING PLANT INSTALLATIONS

Projects and pumping plants	Hectares served	Total dynamic head (m.)	Annual energy requirements (kw.-hr.)	Maximum demand (kw.)
Upper Beles	7,600		34,750,000	12,500
North No. 1	3,000	91	14,100,000	
North No. 2	4,600	87	20,650,000	
Angar	19,300		79,900,000	28,730
South	13,200	100	71,000,000	
North No. 1	3,100	21	3,280,000	
North No. 2	1,060	21	1,120,000	
North No. 3	1,940	46	4,500,000	
West Megech	7,080		10,170,000	4,200
Main	7,080	17	5,840,000	
Relift	(3,430)	27	4,330,000	
East Megech				
Main	5,890	45	12,850,000	5,100
Northeast Tana				
Main	5,000	34.5	8,642,000	3,350
Dindir	13,240		42,960,000	15,000
Main No. 1	6,520	43	18,000,000	
Relift No. 2	(1,260)	32	2,595,000	
Main No. 3	6,720	42	18,165,000	
Relift No. 4	(2,840)	23	4,200,000	

Central Region. Table 22 indicates that the dominant load center may be Gore, and also that the Central Region Interconnected System comes into existence with the advent of initial generation from the Dabana Project powerplants. These two powerplants will export the bulk of their generation to the South Region, with the tie between the Central and South Regions accomplished simultaneously with the initial generation in 1982. Thus, the Central Region Interconnected System becomes a part of the National Grid as fast as the regional system is developed.

West Region. The hydroelectric potential of the Dabus River Sub-basin is substantial, but the modest load requirements will not develop until the latter part of this century even at the most optimistic rate of economic growth. Its generally sparse population (except immediately around Begi) will not warrant any large-scale hydroelectric developments; and this, together with the distance from the population and load centers in the highlands toward the east, may not warrant any connection to the National Grid during this century. The West Region, to the year 2000, is therefore developed on an isolated basis, having its own small system with anticipated peak loads as given by Table 23. From this table, the Begi load will be dominant, followed by Asosa.

Development of National Grid

The National Grid will gradually evolve as the result of regional interconnections and during this period of analysis, only the Central, South, and North Regions would be connected. The connection of these three regional areas will develop peak loads as indicated by Table 24.

Estimated Future Need For Additional Generator Capacity to Meet Deficiencies in Power Supply

In Table 24, Columns (1) and (11) indicate for the South Region that the first deficiency in system capability would occur in 1966, meaning that additional generating capacity would be required by the end of 1965 or during 1966. By that time, Awash No. 2 would be placed in operation, followed by Awash No. 3 at the end of 1967 or during 1968. Columns (1) and (11) further indicate the necessity of additional generating capacity for the South Region in 1971 or 1972 and the supposition is made that the fourth Awash plant would be installed in 1971. (The dependable capacity of the latter was estimated at 37 mw.)

Following the installation of the fourth Awash plant, deficiencies will again occur in 1974 or 1975, when comparing Columns (9), (10), and (11) of Table 24. Potential Blue Nile powerplants in various sub-basins are available for meeting these deficiencies.

In the North Region, with the first two units of the Tis Abbay Powerplant installed, and with some regulation of the riverflow at Bahir Dar considered a necessity, deficiencies will not occur until 1972, Table 24, Columns (5), (6), and (7). At that time, the third Tis Abbay unit will be needed. However, by 1974, deficiencies will again develop and it was assumed that the Gilgel Abbay plants (German Investigations) would become available.

In the North Region, following the use of the Gilgel Abbay plants, deficiencies will occur in 1984, but the Upper Beles Project (BL-1) will, at that time, provide the required power.

By the year 1984, the National Grid may have a peak demand of 356,525 kw. (Column (4) or (14) of Table 24) at the production facilities. Of this amount, 89 percent will be due to peak load requirements of the South Region where the Addis Ababa Complex is the dominant load. This compares with 86 percent in the year 2000.

Power Facilities Planned or Under Construction

The major power facility in the Blue Nile River Basin is the Tis Abbay Powerplant and related facilities, essentially completed in 1963. There were no other major power facilities actively planned or under construction in 1963 within the Blue Nile River Basin.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Load centers (9)	(10)	(11)	(12)	(13)
Year	Addis Ababa Complex	Agere Hiywet	Lekkemt	Jima	Dessie	S. Eritrea (Assab)	Finchaa Farm	Gedo	Angar Pumping	Angar Farm	Debre Birhan	Debre Sina	N. Village, Rural
		Isolated system until 1974	Isolated system 1962 until 1983	Isolated system until 1974	Isolated system until 1977	Isolated system until 1977		Isolated system 1970 until 1981			Isolated system until 1986	Isolated system 1965 until 1986	
1957	8,105												
1958	8,752												
1959	10,000												
1960	10,949												
1961	13,139												
1962	17,591												
1963	22,413												
1964	22,413												
1965	25,326												
1966	34,130												
1967	40,984												
1968	48,721												
1969	58,437												
1970	68,233												
1971	77,969												
1972	89,041												
1973	101,017												
1974	112,462	641		3,453									
1975	126,673	707		3,764									
1976	142,025	793		4,066									
1977	159,266	928		4,391	15,509	18,938							
1978	176,940	1,039		4,598	17,991	21,333							
1979	192,632	1,126		4,920	20,870	21,901							
1980	212,251	1,241		5,264	24,000	24,530							
1981	232,799	1,333		5,633	27,360	27,473	100	152					
1982	233,000	1,475		6,027	30,916	32,522	200	178					
1983	241,166	1,551	12,854	6,381	34,626	38,605	300	200					
1984	247,166	1,678	14,139	6,828	37,634	40,497	400	226					
1985	264,167	1,777	15,412	7,230	41,298	44,556	500	251					2,860
1986	280,000	1,917	16,283	7,736	45,538	49,000	600	274			1,309	382	3,469
1987	297,333	2,025	17,586	8,277	49,636	54,746	700	295			1,400	409	3,536
1988	314,333	2,179	18,992	8,774	53,607	60,222	800	319			1,485	428	3,608
1989	327,700	2,340	20,075	9,300	57,896	66,682	900	334			1,574	458	3,683
1990	347,300	2,511	21,682	9,999	61,251	73,851	1,000	357			1,668	490	3,753
1991	367,800	2,689	23,418	10,465	66,151	80,500	1,100	382	28,730	700	1,732	524	3,829
1992	380,200	2,877	24,764	11,062	70,782	87,744	1,200	409	28,730	800	1,836	549	3,907
1993	392,700	3,015	26,498	11,487	75,736	97,210	1,300	428	28,730	900	1,908	588	3,985
1994	412,400	3,217	28,352	12,176	81,379	105,956	1,400	458	28,730	1,000	2,022	629	4,063
1995	426,100	3,426	30,337	12,907	86,711	114,436	1,500	490	28,730	1,100	2,143	673	4,145
1996	447,300	3,642	31,798	13,680	92,780	123,553	1,600	524	28,730	1,200	2,271	720	4,228
1997	469,700	3,796	34,024	14,502	99,275	133,477	1,700	549	28,730	1,300	2,408	755	4,313
1998	485,500	4,024	36,405	15,065	103,127	146,550	1,800	588	28,730	1,400	2,553	808	4,400
1999	509,700	4,188	38,589	15,969	107,171	156,811	1,900	629	28,730	1,500	2,706	864	4,486
2000	535,230	4,439	40,087	16,928	113,601	167,787	1,980	673	28,730	1,600	2,868	925	4,500

TABLE 20.--ESTIMATED PEA[illegible]-SOUTH REGION INTERCONNECTED SYSTEM

(14) Upper Guder--Farm	(15) Amarti-Neshe--Farm	(16) Sum	(17) Diversity factor	(18) Peak demand of interconnected load	(19) Transmission losses at peak demand	(20) Peak demand at power-plants	(21) Annual production rate of increase, percent	Remarks
		8,105		8,105				
		8,752		8,752				
		10,000		10,000				
		10,949		10,949				Koka on line--Interconnected system in operation
		13,139		13,139	731	13,870	20.1	
		17,591		17,591	959	18,550	33.7	
		22,413		22,413	1,279	23,692	27.7	
		22,413		22,413	1,279	23,692	-	
		25,326		25,326	1,462	26,788	13.1	Awash No. 2 on line
		34,130		34,130	2,055	36,185	35.1	
		40,984		40,984	2,283	43,267	19.6	Awash No. 3 on line
		48,721		48,721	2,877	51,598	19.3	
		58,437		58,437	3,516	61,953	20.0	
		68,233		68,233	3,973	72,206	16.5	
		77,969		77,969	4,566	82,535	14.3	Awash No. 4 on line
		89,041		89,041	5,205	94,246	14.1	
		101,017		101,017	6,210	107,227	13.8	
		116,556	1.05	111,000	6,704	117,704	9.8	Finchaa FI-1A on line
		131,144	1.06	123,720	7,529	131,249	11.5	
		146,884	1.06	138,570	8,447	147,017	12.0	
		199,032	1.15	173,071	10,346	183,417	24.7	Addis Ababa-Dessie-Assab connected; Neshe NES-1A on line
		221,901	1.15	192,957	11,542	204,499	11.5	
		241,449	1.15	209,957	12,747	222,704	8.9	
		267,286	1.15	232,423	13,995	246,418	10.6	
		294,850	1.16	254,181	18,400	272,581	10.6	
		304,318	1.18	257,897	21,435	279,332	2.5	Interconnect with Central Region) For additional genera-
		335,683	1.19	282,086	22,567	304,653	9.0	) tion, see Central and
		348,568	1.19	292,914	23,433	316,347	3.8	Interconnect with North Region) North Regions.
		378,051	1.19	317,690	25,415	343,105	8.5	Rural village loads connected at Fiche
		406,508	1.19	341,603	27,328	368,931	7.3	
		435,943	1.19	366,339	31,139	397,478	7.7	
		464,747	1.19	390,543	33,196	423,739	6.6	
100		491,042	1.19	412,640	36,725	449,365	6.1	
200		524,062	1.19	440,388	39,195	479,583	6.7	
300		588,320	1.19	494,387	46,967	541,354	12.9	Angar pumping load connected
400		615,260	1.19	517,025	49,117	566,142	4.6	
500		644,985	1.19	542,000	54,200	596,200	5.3	
600		682,382	1.19	573,430	57,343	630,773	5.8	
675		713,373	1.19	599,473	59,947	659,420	4.5	
742	100	752,868	1.19	632,662	63,266	695,928	5.5	
786	200	795,515	1.19	668,500	66,850	735,350	5.7	
833	300	832,083	1.19	699,230	69,923	769,153	4.6	
883	400	874,526	1.19	734,896	76,262	811,158	5.5	
892	500	920,740	1.19	773,730	77,373	851,103	4.9	

TABLE 21—ESTIMATED PEAK DEMAND—NORTH REGION INTERCONNECTED SYSTEM

Year	Load centers																Sum
	Bahir Dar**	Gondar	Debre Tabor	Village-rural highway strip					Debre Markos**	Dangila**	Birr*** Farm	Metekkel	West Megech Farm	West Megech Pump*	Upper Beles		
				Bahir Dar	Dangila	D. Markos	Injibira	Jiga							Farm	Pump	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1957																	
1958																	
1959																	
1960																	
1961																	
1962	1,522	Isolated system until 1972	Isolated system 1965-1980						Isolated system 1960-1985	Isolated system 1980-1985		Isolated system 1977-1985					1,522
1963	4,077																4,077
1964	4,051																4,051
1965	4,419																4,419
1966	4,678																4,678
1967	4,678																4,678
1968	5,053																5,053
1969	5,614																5,614
1970	5,988																5,988
1971	6,363																6,363
1972	6,737	1,004															7,741
1973	8,889	1,135															10,024
1974	10,000	1,271															11,271
1975	11,300	1,423															12,723
1976	12,652	1,570															14,222
1977	14,136	1,754															15,890
1978	15,981	1,947															17,928
1979	17,684	2,141															19,825
1980	19,819	2,307	251														22,377
1981	21,749	2,514	274														24,537
1982	24,173	2,741	295														27,209
1983	27,231	2,987	319														30,537
1984	29,473	3,226	334														33,033
1985	31,818	3,484	357	2,420	1,870	1,870	990	990	1,188	101	100	178					45,366
1986	34,965	3,662	382	2,935	2,268	2,268	1,200	1,200	1,306	126	200	207					50,719
1987	37,650	3,919	409	2,992	2,312	2,312	1,224	1,224	1,424	153	300	236					54,155
1988	41,268	4,193	428	3,054	2,360	2,360	1,249	1,249	1,552	178	400	262					58,553
1989	44,305	4,487	458	3,115	2,407	2,407	1,274	1,274	1,692	207	500	292					62,418
1990	48,450	4,818	490	3,177	2,455	2,455	1,300	1,300	1,806	236	600	324					67,401
1991	50,917	5,137	524	3,240	2,504	2,504	1,326	1,326	1,969	262	700	338					70,747
1992	53,462	5,445	549	3,305	2,554	2,554	1,352	1,352	2,146	292	800	391	100	1,690			75,992
1993	56,040	5,656	588	3,371	2,604	2,605	1,379	1,379	2,339	324	900	418	200	1,690			79,493
1994	57,700	5,996	629	3,439	2,657	2,657	1,407	1,407	2,550	338	1,000	453	300	1,690			82,223
1995	61,443	6,355	673	3,509	2,710	2,710	1,435	1,435	2,699	391	1,100	490	400	1,690			87,040
1996	64,182	6,737	720	3,577	2,765	2,764	1,464	1,464	2,915	418	1,200	528	500	1,690			90,924
1997	68,158	7,000	755	3,650	2,820	2,820	1,493	1,492	3,148	453	1,300	555	600	1,690			95,934
1998	71,027	7,422	808	3,722	2,876	2,877	1,522	1,522	3,400	490	1,400	596	700	1,690	200	2,535	102,787
1999	75,284	7,866	864	3,797	2,934	2,934	1,553	1,553	3,637	528	1,500	638	800	1,690	400	2,535	108,513
2000	78,463	8,338	925	3,900	3,000	3,000	1,600	1,600	3,892	555	1,600	706	936	1,690	600	12,500	123,305

* Relift pump, West Megech, after year 2000. N. E. Tana Pump Project and East Megech Project also after year 2000.
** Urban loads only; rural and village in separate column. See text, "Bahir Dar," for explanation of peak loads and generation.
*** Upper Birr only.

TABLE 21

.versity 'actor (18)	Peak demand of interconnected load (19)	Transmission losses at peak demand (20)	Peak demand at power-plants (21)	Annual production rate of increase, percent (22)	Remarks
	1,522	83	1,605		
	4,077	224	4,301		Units 1 and 2, Tis Abbay on line
	4,051	224	4,275		
	4,419	243	4,662	9.0	
	4,678	257	4,935	5.9	
	4,678	257	4,935	-	
	5,053	278	5,331	8.0	
	5,614	305	5,919	11.0	
	5,988	329	6,317	6.7	
	6,363	350	6,713	6.3	
1.05	7,372	405	7,777	15.8	Unit 3, Tis Abbay on line; Bahir Dar Dam constructed
1.05	9,547	763	10,310	32.5	
1.05	10,734	859	11,593	12.4	All Gilgel Abbay units on line
1.05	12,117	969	13,086	12.8	
1.05	13,545	1,084	14,629	11.8	
1.05	15,133	1,211	16,344	11.2	
1.05	17,074	1,366	18,440	12.8	
1.05	18,881	1,699	20,580	11.6	
1.06	21,110	1,900	23,010	11.8	
1.06	23,148	2,083	25,231	9.7	
1.06	25,669	2,310	27,979	10.9	
1.06	28,808	2,592	31,400	12.2	Interconnect with South Region
1.06	31,163	2,805	33,968	8.2	Start Alefa (BL-1) units on line
1.15	39,449	3,550	42,999	26.5	
1.15	44,100	3,969	48,069	11.7	
1.16	46,685	4,201	50,886	5.8	
1.16	50,477	4,543	55,020	8.1	
1.17	53,349	4,801	58,150	5.7	
1.17	57,608	5,185	62,793	8.0	
1.17	60,468	5,442	65,910	4.8	
1.19	63,859	5,747	69,606	5.6	
1.19	66,800	6,012	72,812	4.6	
1.19	69,095	6,219	75,314	3.4	
1.19	73,142	6,583	79,725	5.9	
1.19	76,407	6,877	83,284	4.5	
1.19	80,617	7,255	87,872	5.5	
1.19	86,375	7,774	94,149	7.1	
1.19	91,187	8,200	99,387	5.6	
1.19	103,617	9,326	112,943	13.0	

TABLE 22--ESTIMATED PEAK DEMAND--CENTRAL REGION INTERCONNECTED SYSTEM

Year	Load centers				Sum (5)	Diversity factor (6)	Peak demand (kw) interconnected load (7)	Transmission losses (kw) at peak demand (8)	Peak demand (kw) at powerplants (9)	Annual production rate of increase, percent (10)	Remarks
	Dabana Farm (1)	Gimbi (2)	Nejo (3)	Gore (4)							
1957											
1958											
1959											
1960											
1961											
1962											
1963											
1964											
1965											
1966											
1967											
1968											
1969											
1970		Isolated system 1960-1982	Isolated system 1975-1982	Isolated system 1970-1982							
1971											
1972											
1973											
1974											
1975											
1976											
1977											
1978											
1979											
1980											
1981											
1982	200	409	76	4,047	4,732	1.05	4,507	128	4,635		Dabana Powerplants DB-1 and DB-1A on line in 1982 and interconnect with South Region
1983	300	428	92	4,613	5,433	1.05	5,174	151	5,325	14.8	
1984	400	458	110	5,429	6,397	1.06	6,035	175	6,210	16.6	
1985	500	490	129	6,197	7,316	1.08	6,774	199	6,973	12.3	
1986	600	524	152	7,304	8,580	1.09	7,872	244	8,116	16.4	
1987	700	549	178	8,400	9,827	1.09	9,016	254	9,270	14.2	
1988	808	588	200	9,358	10,954	1.10	10,000	400	10,400	12.1	
1989	848	629	226	10,575	12,278	1.11	11,061	483	11,544	11.0	
1990	899	673	251	11,843	13,666	1.11	12,312	478	12,790	10.8	
1991	953	720	274	12,854	14,801	1.12	13,215	513	13,728	7.3	
1992	1,010	755	295	14,139	16,199	1.12	14,463	513	14,976	9.0	
1993	1,070	808	319	15,412	17,609	1.14	15,446	674	16,120	7.6	
1994	1,107	864	334	16,283	18,588	1.14	16,300	652	16,952	5.2	
1995	1,173	925	357	17,586	20,041	1.14	17,580	724	18,304	8.0	
1996	1,214	989	382	18,992	21,577	1.15	18,763	977	19,740	7.8	
1997	1,287	1,059	409	20,075	22,830	1.15	19,852	938	20,790	5.3	
1998	1,364	1,110	428	21,682	24,584	1.17	21,013	1,037	22,050	6.1	
1999	1,412	1,188	458	23,418	26,476	1.17	22,629	1,101	23,730	7.6	
2000	1,497	1,259	490	24,764	28,010	1.17	23,940	1,155	25,095	5.8	

TABLE 23.-ESTIMATED PEAK DEMAND--WEST REGION ISOLATED SYSTEM

Year	Load centers: Asosa	Load centers: Mendi	Load centers: Begi	Sum	Diversity factor	Peak demand (kw) interconnected load	Transmission losses at peak demand	Peak demand at powerplant	Annual production rate of increase, percent	Remarks
1957										
1958										
1959										
1960										
1961										
1962										
1963										
1964										
1965										
1966										
1967										
1968										
1969										
1970										
1971										
1972										
1973										
1974										
1975										
1976										
1977										
1978										
1979										
1980										
1981										
1982										
1983										
1984										
1985	555	236	822	1,613	1.06	1,522	46	1,568		Dabus Powerplant DA-8 on line
1986	596	262	896	1,754	1.06	1,655	66	1,721	9.8	
1987	638	292	967	1,897	1.07	1,773	53	1,826	6.1	
1988	682	324	1,044	2,050	1.08	1,898	58	1,956	7.1	
1989	727	338	1,117	2,182	1.08	2,020	61	2,081	6.4	
1990	774	391	1,195	2,360	1.09	2,165	65	2,230	7.2	
1991	805	418	1,278	2,501	1.09	2,295	69	2,364	6.0	
1992	854	453	1,368	2,675	1.10	2,432	73	2,505	6.0	
1993	905	490	1,464	2,859	1.10	2,599	78	2,677	6.9	
1994	957	528	1,566	3,051	1.11	2,749	82	2,831	5.8	
1995	1,011	555	1,675	3,241	1.11	2,920	88	3,008	6.3	
1996	1,067	596	1,792	3,455	1.12	3,085	93	3,178	5.7	
1997	1,100	638	1,912	3,650	1.12	3,259	98	3,357	5.6	
1998	1,160	682	2,051	3,893	1.13	3,445	104	3,549	5.7	
1999	1,220	727	2,191	4,138	1.14	3,630	109	3,739	5.4	
2000	1,232	774	2,349	4,355	1.15	3,787	114	3,901	4.3	

Year	Peak demand at plants, regional loads: S. Region (From Col. 20, Table V-105) (1)	C. Region (From Col. 9, Table V-107) (2)	N. Region (From Col. 21, Table V-106) (3)	Coincidental peak, National Grid (4)	Dependable generation in North Region prior to interconnection with South Region (Use with Column 3): For reserve (5)	For load and losses (6)	Total (7)	Source (8)	Dependable generation in Sout prior to interconnection (Use with Columns: For reserve (9)	For loads and losses (10)	Total (11)
1957											
1958											
1959											
1960											28,000
1961	13,870										28,000
1962	18,550		1,605								28,000
1963	23,692		4,301		3,399	4,301	7,700	7,700 kw, Units 1 and 2			28,000
1964	23,692		4,275		3,425	4,275	7,700	(BN-10) Tis Abbay 1/	3/ 4,308	23,692	28,000
1965	26,788		4,662		3,038	4,662	7,700		3/ 1,212	26,788	28,000
1966	36,185		4,935		2,765	4,935	7,700		28,815	36,185	65,000
1967	43,267		4,935		2,765	4,935	7,700		21,733	43,267	65,000
1968	51,598		5,331		2,369	5,331	7,700		50,402	51,598	102,000
1969	61,953		5,919		1,781	5,919	7,700		40,047	61,953	102,000
1970	72,206		6,317		1,383	6,317	7,700		29,794	72,206	102,000
1971	82,535		6,713		987	6,713	7,700		56,465	82,535	139,000
1972	94,246		7,777		3,743	7,777	11,520	3,820 kw, Unit 3, Tis Abbay	44,754	94,246	139,000
1973	107,227		10,310		1,210	10,310	11,520		31,773	107,227	139,000
1974	117,704		11,593		2,727	11,593	14,320	2,800 kw, GA-4, 2/	101,296	117,704	219,000
1975	131,249		13,086		6,734	13,086	19,820	5,500 kw, GA-5, 2/	87,751	131,249	219,000
1976	147,017		14,629		5,191	14,629	19,820		71,983	147,017	219,000
1977	183,417		16,344		6,076	16,344	22,420	2,600 kw, GA-6, 2/	115,583	183,417	299,000
1978	204,499		18,440		3,980	18,440	22,420		94,501	204,499	299,000
1979	222,704		20,580		13,140	20,580	33,720	11,300 kw, GA-7, 2/	76,296	222,704	299,000
1980	246,418		23,010		10,710	23,010	33,720		52,582	246,418	299,000
1981	272,581		25,231		8,489	25,231	33,720		26,419	272,581	299,000
1982	279,332	4,635	27,979		5,741	27,979	33,720		100,033	283,967	384,000
1983	304,653	5,325	31,400		2,320	31,400	33,720	Interconnect with South	74,022	309,978	384,000
1984	316,347	6,210	33,968	356,525				Region to form National			
1985	343,105	6,973	42,999	393,077				Grid 1984			
1986	368,931	8,116	48,069	425,116							
1987	397,478	9,270	50,886	457,634							
1988	423,739	10,400	55,020	489,159							
1989	449,365	11,544	58,150	519,059							
1990	479,583	12,790	62,793	555,166							
1991	541,354	13,728	65,910	620,992							
1992	566,142	14,976	69,606	650,724							
1993	596,200	16,120	72,812	685,132							
1994	630,773	16,952	75,314	723,039							
1995	659,420	18,304	79,725	757,449							
1996	695,928	19,740	83,284	798,952							
1997	735,350	20,790	87,872	844,012							
1998	769,153	22,050	94,149	885,352							
1999	811,158	23,730	99,387	934,275							
2000	851,103	25,095	112,943	989,141							

1/ This is exception where peak load is expected to occur at maximum availability of water by adjusting loads to meet available capacity. Firm capacity is only 3,000 kw including
2/ Gilgel Abbay powerplants (German plan) with firm capability estimated based upon adverse water period.
3/ The 5-mw Addis Ababa steam and 2-mw Alemaya diesel plants are also available now, but these units will in all likelihood be moved elsewhere in the future.
* Dependable kw due to long canals.

TABLE 24

h and Central Regions with North Region 1 and 2)	Dependable generation, all regions to meet peak load National Grid after interconnection in 1984 (Use with Column 4)			
Source (12)	For reserve (13)	For loads and losses (14)	Total (15)	Source (16)
5,000 kw, Ourso and Aba Samuel				
23,000 kw, Koka				
37,000 kw, Awash No. 2				
37,000 kw, Awash No. 3				
37,000 kw, Awash No. 4				
80,000 kw, Finchaa FI-1A				
80,000 kw, Neshe NES-1A				
85,000 kw, Dabana				
Interconnect with North Region				
to form National Grid 1984	111,195	356,525	467,720	50,000 kw, Unit 1, Alefa BL-1
	124,643	393,077	517,720	50,000 kw, Unit 2, Alefa BL-1
	142,604	425,116	567,720	50,000 kw, Unit 3, Alefa BL-1
	160,086	457,634	617,720	50,000 kw, Unit 4, Alefa BL-1
	128,561	489,159	617,720	
	98,661	519,059	617,720	
	102,554	555,166	657,720	40,000 kw, Angar AG-2
	113,728	620,992	734,720	77,000 kw*, Angar AG-6A
	118,996	650,724	769,720	35,000 kw*, Angar AG-6B
	134,588	685,132	819,720	50,000 kw, Guder GU-1
	126,681	723,039	849,720	30,000 kw, Arjo-Diddessa DD-11
	172,271	757,449	929,720	80,000 kw, Unit 1, Boo DD-2
	210,768	798,952	1,009,720	80,000 kw, Unit 2, Boo DD-2
	245,708	844,012	1,089,720	80,000 kw, Unit 3, Boo DD-2
	284,368	885,352	1,169,720	80,000 kw, Unit 4, Boo DD-2
	235,445	934,275	1,169,720	
	180,579	989,141	1,169,720	

; 600 kw diesel electric.

Two major facilities on the Awash River were being planned in 1962 for early construction. The Awash River begins in several streams at the southern edge of the Blue Nile watershed.

A twin power station development is planned by EELPA 25 kilometers downstream from the existing Koka hydroelectric facilities, also known as Awash No. 1. The new powerplants, Awash No. 2 and Awash No. 3, will each be able to peak at about 37 mw.1/ Principal regulation is provided by the Koka Dam and these two plants are cascaded on the river below Koka. All Awash facilities serve the South Region Interconnected System, where the principal load is the Addis Ababa Complex.

About 90 km. of 132-kv., double-circuit transmission line, 2 km. of single-circuit 132-kv. line, and a 132/15-kv. substation at Akaki (Akaki No. 1) are planned.

Several other facilities, including small hydroelectric plants, diesel-electric plants, transmission and distribution facilities are also planned. 2/

The Blue Nile River Basin Projects as Sources in Meeting Future Deficiencies in Power Supply, Present Century

Available Capacity. The following major Blue Nile River powerplants with appropriate transmission plant facilities can supply the needs of the greater part of the Empire's electrical energy requirements through the year 2000:

Hydroelectric powerplants	Regional location	Firm capacity kw.	Project
Tis Abbay	North	11,520*	By EELPA
Gilgel Abbay	North	22,200	Gilgel Abbay (W. German Plan)
Finchaa (FI-1A)	South	80,000	Finchaa
Neshe (NES-1A)	South	80,000	Amarti-Neshe
Dabana (DB-1) and (DB-1A)	Central	85,000	Dabana
Upper Beles (BL-1)	North	200,000	Upper Beles
Angar (AG-2)	South	40,000	Angar
Angar (AG-6A)	South	77,000**	Angar
Angar (AG-6B)	South	35,000**	Angar
Guder (GU-1)	South	50,000	Lower Guder
Arjo-Diddessa (DD-11)	South	30,000	Arjo-Diddessa
Lower Diddessa (DD-2)	South	320,000	Lower Diddessa
Total		1,030,720	

*With third unit and regulation of Lake Tana water at outlet, Bahir Dar.
**AG-6A and AG-6B installed capacities may be 100,000 and 45,000 kw., respectively. Due to long canals and restricted forebay storage, dependable capacity is considered to be 77,000 and 35,000 kw., respectively, under certain conditions.

In addition, the four Awash powerplants and Aba Samuel would have a capacity of 139,000 kw., making an aggregate total available of 1,169,720 kw. Also, the isolated West Region will depend upon Dabus Powerplant (DA-8) having a capacity of 7,500 kw.

System Development. Figure 48 shows the maximum system for the year 2000, the end of the primary period of analysis.

1/One source indicates 35 mw., another 32 mw.
2/See Appendix V, "Power."

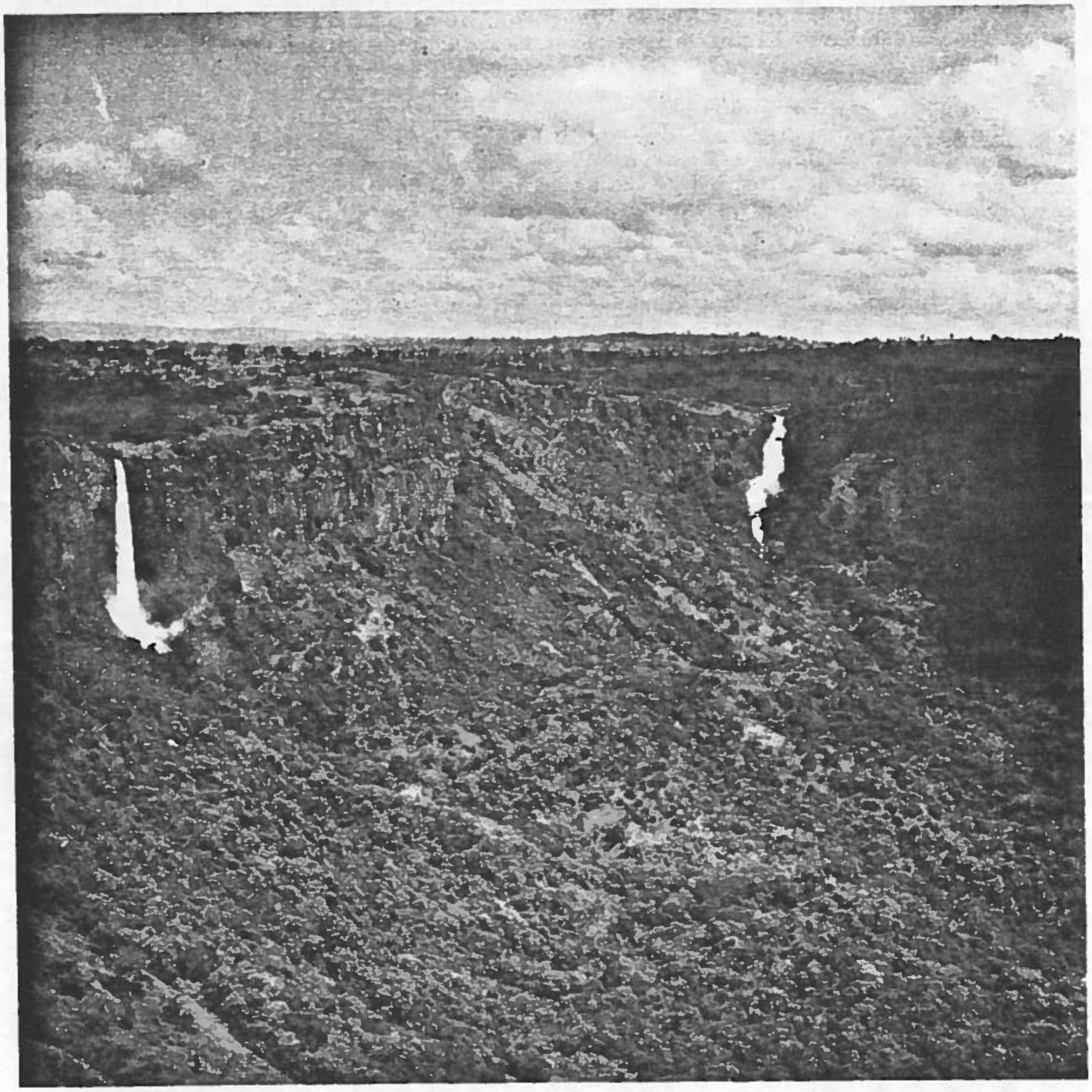


Figure 58. Finchaa River Falls.

Powerplant Installation Schedule. Figure 59 indicates desired generator installations to meet estimated peak generation requirements, including allowances for transmission losses in the North Region. The drawing covers the 20-year period of 1963 through 1983 when interconnection with the South Region might develop.

Figure 60 indicates desired generator installations to meet estimated peak generation requirements, including allowances for transmission losses, as the three regional areas combine to form the National Grid. The South Region interconnects with the Central Region in 1982, followed by interconnection with the North Region by the end of 1983. The West Region will not interconnect during the primary period of review. Allowances for loads in the Dessie-Assab areas have been provided for with an interconnection occurring in early 1977.

Reserves. In this study, once the National Grid is established, it is assumed that the margin between load and generating capacity to allow scheduled maintenance is provided in part by the seasonal variation in load. 1/ Also, there is reasonable margin in load forecasts to provide for the unexpected load increases. Therefore, generation reserve is considered as emergency reserve to meet chance failures of equipment.

In Ethiopia, reserve margins based upon December peaks will average about 26 percent from 1964 to 2000 for the South, Central, and the ultimately combined regions forming the National Grid.

POWER FACILITIES, NEXT CENTURY

Some additional projects for which data in a greater degree of detail were available permitting more extensive examination and evaluation were the following, which might include those for development in the early part of the next century. All are single-purpose power projects with the exception of (D1-7). These projects are shown on the Frontispiece.

Project	Possible installed capacity, kw.	Possible firm annual generation, kw.-hr.*
Giamma (GI-1)	60,000	270,810,000
Muger Project	26,000	121,600,000
MU-1**	(24,000)	(106,550,000)
MU-4	(2,000)	(15,045,000)
Karadobi (BN-3)	1,350,000	5,835,000,000
Mabil (BN-19)	1,200,000	5,314,000,000
Mendaia (BN-26A)	1,620,000	7,800,000,000
Middle Beles (BL-3)	168,000	741,700,000
Border (BN-28)	1,400,000	6,200,000,000
Dindir (D1-7)	40,000	178,700,000
Totals	5,864,000	26,461,810,000

*Assumes order of development in sequence tabulated except for (D1-7).
**Alternate B, higher head, for MU-1. Alternate A, lower head, used in operating study would produce 77,650,000 kw.-hr. per year.

The overall plant factor is approximately 50 to 51 percent and the studies made in establishing firm annual generation usually covered a 6-year period which included adverse water years. The available energy (kw.-hr.) that could actually be generated from these nine potential projects will in some years generally exceed that indicated in the preceding tabulations.

1/Prior to formation of the National Grid, however, there will be generators installed in some plants which might be considered as "spare" during the early formative years of the regional systems.

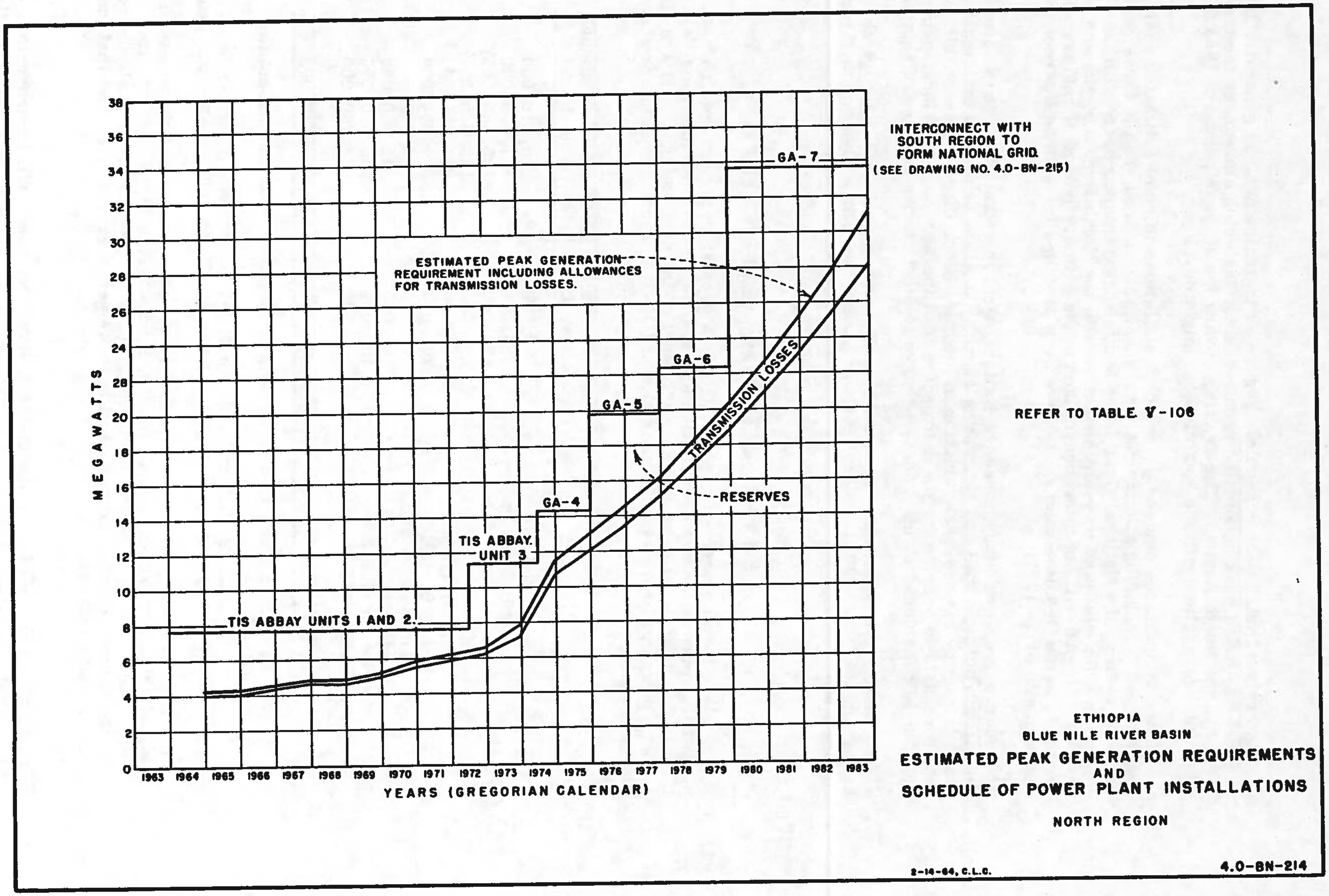


Figure 59--Estimated Peak Generation Requirements and Schedule of Powerplant Installations--North Region

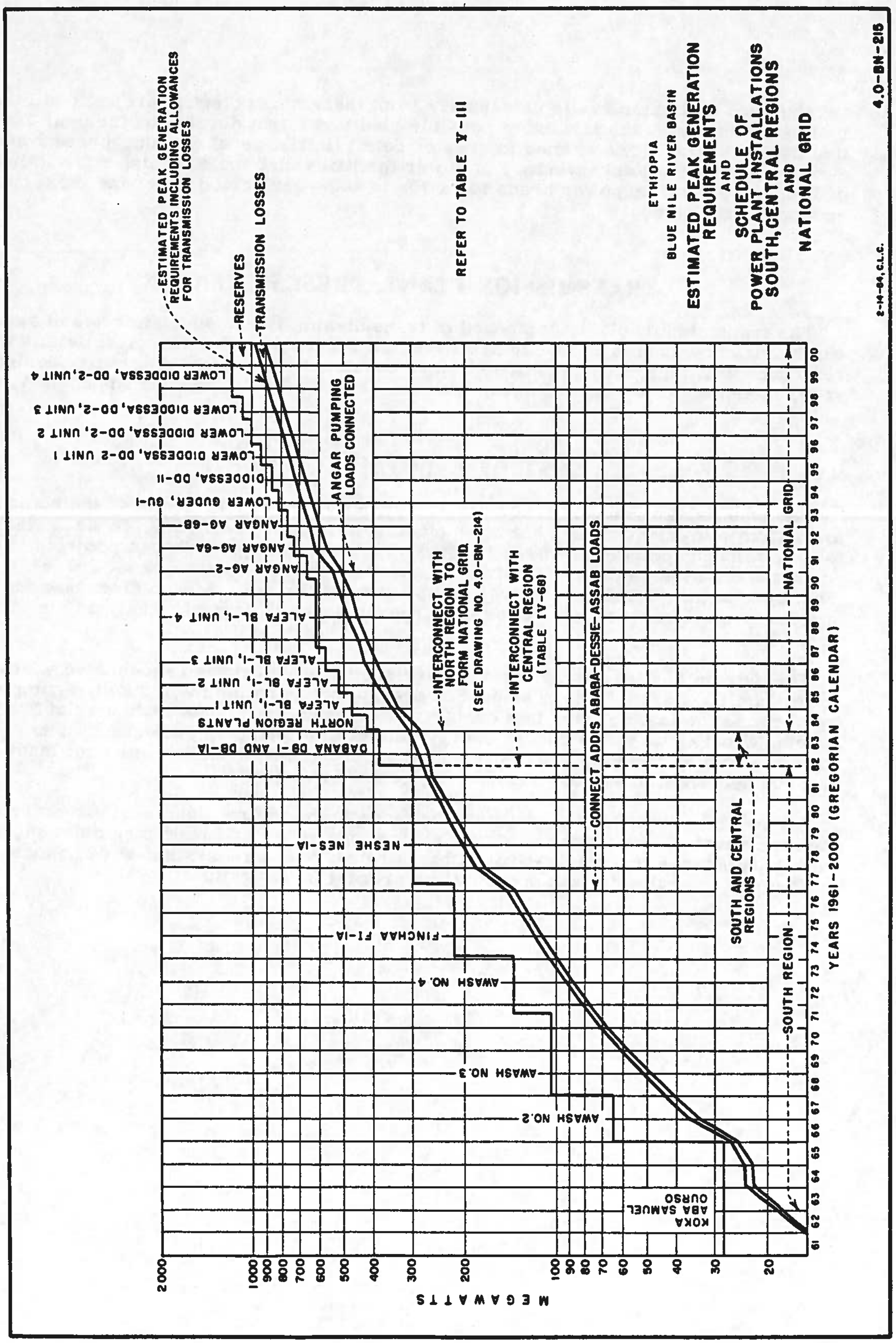


Figure 60--Estimated Peak Generation Requirements and Schedule of Powerplant Installations--South, Central Regions and National Grid

The total estimated available capacity from these nine potential projects will exceed by five or six times the maximum possible load that might develop by the year 2000. On that basis, all facilities studied in greater detail (initial development), present and next century, provide a total inventory of power facilities that could furnish substantially all of Ethiopia's electric power needs for a 75- to 100-year period under the most optimistic economic conditions.

TRANSMISSION PLANT, PRESENT CENTURY

The transmission plant, composed of transmission lines, substations, and switchyards, summarized by Tables 25 and 26 are shown on Figure 48. For technical details including reference drawings, identification of stage construction, system diagrams, design standards, isoceraunic levels, voltages, and other related items, see the Appendix V, "Power."

COST OF ELECTRICAL ENERGY

The cost per kw.-hr. of electrical energy delivered to load centers, including transformation to lower voltages, but not including distribution facilities, is estimated as follows for each project as shown by Table 27. For multiple-purpose projects, these costs are based upon power features plus power's share of joint-use facilities. Caution must be used in referring to energy costs here for the same reason discussed for multipurpose project benefit-cost ratios by purposes under "Economic Analysis" in this volume.

The system cost of energy will not vary significantly between successive years as new power facilities are added. The cost of energy for operating the irrigation pump motors (to occur in the last decade, this century, present analysis) was estimated at Eth$0. 03, it being about equal to the cost of energy delivered at pumping project electrical facilities. Lands served by pumping will represent about 7 percent of the total project lands, 433, 000 hectares, listed for possible irrigation development.

A more rigorous analysis that may be made in the future when feasibility studies including repayment analysis are made may show some reduction in pumping plant energy costs when handled on a project-by-project basis rather than on a system-wide basis as was considered desirable for the scope of this present investigation.

TABLE 25--SUMMARY OF TRANSMISSION LINES, PRESENT CENTURY

Sheet 1 of 2

Project	Voltage (kv.)	Description	Length (km.)	Conductor	Terrain	Earliest possible in-service date
Finchaa	161	Finchaa Switchyard-Dongi Substation --single circuit, steel tower.	1.8	954 MCM ACSR	Rough	1974
	161	Dongi Substation-Gafarsa Substation No. 2--double-circuit, steel tower, one circuit needed initially.	248	954 MCM ACSR	Average	1974
Amarti-Neshe	161	Neshe Switchyard-Dongi Substation--single circuit, steel tower.	8 24	954 MCM ACSR	Rough Average	1977
	161	Dongi Substation-Gafarsa Substation No. 2--installation of second circuit on above Finchaa towers.	248	954 MCM ACSR	Average	1977
Dabana	69	Powerplant tie from DB-1 to DB-1A--steel tower.	13	4/0 AWG ACSR	Average	1982
	69	Second powerplant tie from DB-1 to DB-1A--steel tower.	13	4/0 AWG ACSR	Average	1982
	230	Powerplant DB-1 to Lekkemt Substation--single circuit, steel tower.	70	795 MCM ACSR	Average	1982
	230	Lekkemt Substation-Akaki No. 2 Substation--double-circuit, steel tower; one circuit installed initially.	245	954 MCM ACSR	Average	1982
	132	Lekkemt Substation-Gore Substation --steel tower.	210	477 MCM ACSR	Average	1982
	132	Akaki No. 2 Substation-Akaki No. 1 Substation	12	4/0 AWG ACSR	Average	1982
	45	Powerplant DB-1 to Gimbi Substation--steel tower.	45	2/0 AWG Copper	Average	1982
	45	Gimbi Substation-Nejo Substation--steel tower.	60	2 AWG Copper	Average	1982
	230	Akaki No. 2 Substation-East Addis Ababa Substation--double-circuit, steel tower, one circuit initially.	10	795 MCM ACSR	Average	1982
Upper Beles	132	Alefa Powerplant (BL-1)-Bahir Dar Substation--double-circuit, steel tower.	20 45	636 MCM ACSR	Rough Average	1984-87
	230	Powerplant BL-1 to East Addis Ababa Substation--double-circuit, steel tower.	110 340	954 MCM ACSR	Rough Average	1984
	45	Bure Substation-Jiga Substation--steel tower.	37	2 AWG Copper	Average	1985
	45	Bure Substation-Injibira Substation-Dangila Substation--steel tower.	70	2/0 AWG Copper	Average	1985
	45	Injibira Substation-Metekkel Substation--steel tower.	50	2/0 AWG Copper	Rough	1985
	132	Bahir Dar Substation-Stella Substation-Gondar Substation--steel tower.	146	4/0 AWG ACSR	Average	1972
	45	Stella Substation-Debre Tabor Substation--steel tower.	40	2 AWG Copper	Rough	1980
	132	Powerplant BL-1 to Beles irrigation area Pumping Plant No. 2--steel tower (for irrigation facilities).	55 25	4/0 AWG ACSR	Rough Average	1998
	15	Pumping Plant No. 2 to Pumping Plant No. 1--steel pole (for irrigation facilities).	8	477 MCM ACSR	Average	1998
West Megech	45	Gondar Substation-West Side Megech Relift Pumping Plant--steel tower (for irrigation facilities).	23	1 AWG Copper	Average	1992
	15	West Side Megech Relift Pumping Plant-Pumping Plant No. 1--steel tower (for irrigation facilities).	18	3/0 AWG Copper	Average	1992
Northeast Tana	45	Northeast Tana Pumping Plant-Stella Substation--steel pole.	20	2 AWG Copper	Average	1/
East Megech	45	Northeast Tana Pumping Plant-East Side Megech Pumping Plant--steel pole.	13	2 AWG Copper	Average	1/

1/ Probably early next century.

Project	Voltage (kv.)	Description	Length (km.)	Conductor	Terrain	Earliest possible in-service date
Arjo-Didessa	132	Arjo-Didessa Powerplant (DD-11)-Jima Substation--steel tower.	60	4/0 AWG ACSR	Rough	1994
Angar	132	Powerplant AG-2 to Lekkemt Substation--steel tower.	75	4/0 AWG ACSR	Average	1990
	69	Powerplant AG-6B to Powerplant AG-6A intertie--steel tower.	5	266.8 MCM ACSR	Rough	1992
	132	Powerplant AG-6A to Lekkemt Substation--steel tower.	43	795 MCM ACSR	Average	1991
	230	Lekkemt Substation-Akaki No. 2 Substation--install second circuit on existing steel towers (see Dabana Project).	245	954 MCM ACSR	Average	1990
	45	Powerplant AG-2 to North Pumping Plant No. 1--steel pole (for irrigation facilities).	20	2 AWG Copper	Average	1991
	15	North Pumping Plant Substation No. 1 to North Pumping Plant Substation No. 2--steel pole (for irrigation facilities).	7	3/0 AWG Copper	Average	1991
	15	North Pumping Plant Substation No. 1 to North Pumping Plant Substation No. 3--steel pole (for irrigation facilities).	13	3/0 AWG Copper	Average	1991
	45	Powerplant AG-6A to South Pumping Plant Substation--steel tower (for irrigation facilities).	15	4/0 AWG Copper	Average	1991
Lower Diddessa (Boo)	230	Powerplant DD-2 to Akaki Substation No. 2--double-circuit, steel towers.	25 300	954 MCM ACSR	Rough Average	1995
	230	Akaki No. 2 Substation-East Addis Ababa Substation--steel tower. Install on existing steel towers, second circuit. See last item, Dabana Project.	10	795 MCM ACSR	Average	1995
	230	Powerplant Boo (DD-2)-Lekkemt Substation--single circuit, steel tower.	30 50	954 MCM ACSR	Rough Average	1998
	230	Lekkemt Substation-Akaki Substation No. 2--single circuit, steel tower.	245	954 MCM ACSR	Average	1998
Lower Guder (Motto)	132	Motto (GU-1) Powerplant-Agere Hiywet Substation--double-circuit, steel towers.	20 40	266.8 MCM ACSR	Rough Average	1993
	132	East Addis Ababa Substation-Central Addis Ababa Substation--steel tower (Dwg. No. 4.0-BN-213).	5	4/0 AWG ACSR	Average	1993
	161	Agere Hiywet Substation-East Addis Ababa Substation--steel tower.	110	397.5 MCM ACSR	Average	1993
Dabus Power	45	Powerplant DA-8 to Mendi Substation --steel pole.	30	2 AWG Copper	Rough	1985
	45	Powerplant DA-8 to Chera Gudde tap location--steel pole.	40	3/0 AWG Copper	Rough	1985
	45	Chera Gudde Tap-Asosa Substation--steel pole.	25	2 AWG Copper	Average	1985
	45	Chera Gudde Tap-Begi Substation--steel pole.	70	3/0 AWG Copper	Average	1985
Addis Ababa-Dessie-Assab Transmission	230	East Addis Ababa Substation-Kembolcha Substation--double-circuit, steel towers (1 circuit strung initially; 2nd strung in 1987).	75 215	954 MCM ACSR	Rough Average	1977 #1 1987 #2
	132	Kembolcha Substation-Dessie Substation--steel tower.	13	795 MCM ACSR	Rough	1977
	132	East Addis Ababa Substation-Gafarsa No. 2 Substation--steel tower.	5	4/0 AWG ACSR	Average	1977
	230	Kembolcha Substation-Assab Substation--single circuit, steel tower.	85 300	954 MCM ACSR	Rough Average	1977
	45	East Addis Ababa Substation-Debre Birhan Substation--steel pole.	110	2/0 AWG Copper	Average	1986
	45	Debre Birhan Substation-Debre Sina Substation--steel pole.	35	2 AWG Copper	Rough	1986

TABLE 26--SUMMARY OF H.V. SUBSTATIONS AND SWITCHYARDS, PRESENT CENTURY

Project	Switchyard or Substation	Reference drawing number	Stage	Maximum voltage (kv.)	Total transformer capacity (kv.-a.)	Earliest possible in-service date
Finchaa	Switchyard	4.0-Fi-8	Complete	161	100,000	1974
	Gafarsa No. 2	4.0-BN-174	01	161	100,000	1974
Neshe	Switchyard	4.0-BN-87	Complete	161	100,000	1977
	Dongi	4.0-BN-220	Complete	161	switch. only	1977
	Gafarsa No. 2	4.0-BN-174	02	161	100,000	1977
Dabana	Switchyard DB-1	4.0-BN-201	Complete	230	162,000	1982
	Switchyard DB-1A	4.0-BN-202	Complete	69	60,000	1982
	Nejo	4.0-BN-199	Complete	45	1,000	1982
	Gimbi	4.0-BN-198	Complete	45	1,500	1982
	Gore	4.0-BN-200	01	132	30,000	1982
	East Addis Ababa	4.0-BN-100	02	230	100,000	1982
	Akaki No. 2	4.0-BN-179	01	230	125,000	1982
	Lekkemt	4.0-BN-181	01	230	83,333	1982
Upper Beles	Switchyard	4.0-BN-161	Complete	230	375,000	1984
	Bahir Dar	4.0-BN-191	01	132	50,000	1972
	Bahir Dar	4.0-BN-191	02	132	50,000	1984
	Stella	4.0-BN-193	01	132	10,000	1980
	Debre Tabor	4.0-BN-192	Complete	45	1,000	1980
	Gondar	4.0-BN-194	01	132	15,000	1972
	Bure	4.0-BN-185	Complete	230	5,000	1985
	Injibira	4.0-BN-190	Complete	45	2,000	1985
	Metekkel	4.0-BN-188	Complete	45	1,000	1985
	Dangila	4.0-BN-189	Complete	45	4,000	1985
	Jiga	4.0-BN-187	Complete	45	3,000	1985
	Debre Markos	4.0-BN-186	Complete	230	30,000	1985
	East Addis Ababa	4.0-BN-100	03	230	switch. only	1984
	Pumping Plant No. 2 1/		Complete	132	10,000	
	Pumping Plant No. 1 1/		Complete	15	7,000	
West Side Megech	Gondar	4.0-BN-194	02 1/	45	5,000	1992
	Relift Pumping Plant 1/		Complete	45	2,500	next century
	Pumping Plant No. 1 1/		Complete	15	3,500	1992
Northeast Tana	Stella	4.0-BN-193	02	45	switch. only	next century
	Pumping Plant 1/		Complete	45	4,500	next century
East Side Megech	Pumping Plant 1/		Complete	45	7,500	next century
Arjo-Didessa	Switchyard (DD-11)	4.0-BN-207	Complete	132	40,000	1994
	Jima	4.0-BN-208	Complete	132	20,000	1994
Angar	Switchyard (AG-2)	4.0-BN-205	01	132	60,000	1990
	Switchyard (AG-2)	4.0-BN-205	02 1/	45	4,000	1991
	Switchyard (AG-6A)	4.0-BN-203	01	132	100,000	1991
	Switchyard (AG-6A)	4.0-BN-203	02 1/	69	30,000	1991
	Switchyard (AG-6B)	4.0-BN-204	Complete	69	60,000	1992
	Lekkemt	4.0-BN-181	02	132	123,333	1990-91
	North Pumping Plant No. 1 1/		Complete	45	5,000	1991
	North Pumping Plant No. 2 1/		Complete	15	1,000	1991
	North Pumping Plant No. 3 1/		Complete	15	2,500	1991
	South Pumping Plant 1/		Complete	45	33,000	1991
	Akaki No. 2	4.0-BN-179	02	230	50,000	1990
	Fiche	4.0-BN-117	Complete	230	15,000	1990
Lower Didessa (Boo)	Switchyard (DD-2)	4.0-BN-163	Complete	230	500,000	1995-98
	Akaki No. 2	4.0-BN-179	03	230	125,000	1995-98
	East Addis Ababa	4.0-BN-100	06	230	switch. only	1995
	Lekkemt	4.0-BN-181	03	230	switch. only	1995-98
	Gore	4.0-BN-200	02	45	5,000	1995
Lower Guder (Motto)	Switchyard (GU-1)	4.0-BN-162	Complete	132	80,000	1993
	Agere Hiywet	4.0-BN-178	Complete	161	85,000	1993 2/
	East Addis Ababa	4.0-BN-100	05	230	60,000	1993
Dabus Power	Switchyard (DA-8)	4.0-BN-206	Complete	45	10,000	1985
	Mendi	4.0-BN-197	Complete	45	1,000	1985
	Asosa	4.0-BN-196	Complete	45	2,000	1985
	Begi	4.0-BN-195	Complete	45	3,000	1985
Addis Ababa-Dessie-Assab Transmission	East Addis Ababa	4.0-BN-100	01	230	125,000	1977
	East Addis Ababa	4.0-BN-100	04	230	switch. only	1987
	Kembolcha	4.0-BN-183	01	230	125,000	1977
	Kembolcha	4.0-BN-183	02	230	switch. only	1987
	Dessie	4.0-BN-184	01	132	125,000	1977
	Dessie	4.0-BN-184	02	45	switch. only	1987
	Assab	4.0-BN-182	01	230	100,000	1977
	Assab	4.0-BN-182	02	230	100,000	1987-90
	Debre Birhan	4.0-BN-211	Complete	45	3,000	1986
	Debre Sina	4.0-BN-212	Complete	45	1,500	1986

1/ For irrigation facilities.
2/ 161-kv. section earlier.

TABLE 27--APPROXIMATE EFFECT OF BLUE NILE RIVER PROJECTS ON ELECTRIC RATES

Project	Type	Megawatts 2/	Project annual benefits 3/ (Eth$)	Project annual costs 4/ (Eth$)	Project benefit-cost ratio	Project cost per kv.-hr. 5/ (Eth¢)	Approximate system benefit-cost ratio	Approximate system cost per kv.-hr. (Eth¢)	Initial year of full benefit
Finchaa (FI-1A)	Multiple-purpose	80	16,400,000	5,367,000	3.06 to 1	1.56	3.06 to 1	1.56	1974
Amarti-Neshe (NES-1A)	Multiple-purpose	80	17,110,000	7,341,000	2.33 to 1	2.03	2.64 to 1	1.80	1977
Dabana (DB-1, -1A)	Multiple-purpose	85	20,173,000	21,603,000	0.93 to 1	5.90	1.56 to 1	3.21	1982
Addis Ababa-Assab Transmission	Power only	-	Included elsewhere	10,919,000					1987 6/
Upper Beles (BL-1)	Multiple-purpose	200	56,598,000	15,737,000	3.60 to 1	1.39	1.85 to 1	2.77	1987
Angar (AG-2,-6A,-6B)	Multiple-purpose	185	56,879,000	22,862,000	2.49 to 1	2.03	1.99 to 1	2.52	1992
Lower Guder (GU-1)	Power only	50	10,793,000	8,920,000	1.21 to 1	4.04	1.92 to 1	2.62	1993
Arjo-Diddessa (DD-11)	Multiple-purpose	30	14,908,000	5,459,000	2.73 to 1	3.80	1.96 to 1	2.66	1994
Lower Diddessa (DD-2)	Power only	320	62,274,000	29,856,000	2.09 to 1	2.18	1.99 to 1	2.53	1998
Giamma (GI-1)	Power only	60	12,864,000	17,818,000	0.72 to 1	6.68			After year 2000
Muger (MU-1, -4)	Power only	26	6,429,000	2,660,000	2.42 to 1	2.25			After year 2000
Middle Beles (BL-3)	Power only	168	39,377,000	15,289,000	2.58 to 1	2.09			After year 2000
Dindir (DI-7)	Multiple-purpose	40	10,870,000	9,222,000	1.18 to 1	5.28			After year 2000
Karadobi (BN-3)	Power only	1,350	260,964,000	82,643,000	3.16 to 1	1.46			After year 2000
Mabil (BN-19)	Power only	1,200	249,148,000	68,294,000	3.65 to 1	1.33			After year 2000
Mendaia (BN-26A)	Power only	1,620	361,909,000	83,202,000	4.35 to 1	1.10			After year 2000
Border (BN-28)	Power only	1,400	281,761,000	75,349,000	3.74 to 1	1.26			After year 2000

1/Power features plus power share of joint-use facilities in multiple-purpose projects.
See Appendix VI, "Agriculture and Economics," for "irrigation only" and multiple-purpose project analyses.
2/One megawatt (mw.) equals 1,000 kilowatts.
3/Tables V-123 and V-124, last column.
4/Tables V-117 and V-122, last column.
5/At load centers.
6/Some benefits beginning in year 1977.

PROJECT PLANS

The irrigation and power projects described in the following pages are discussed by sub-basins in the order indicated on Figure 61. The four main stem (Blue Nile River) power projects follow the discussion of the Dindir-Rahad Sub-basin (No. 10).

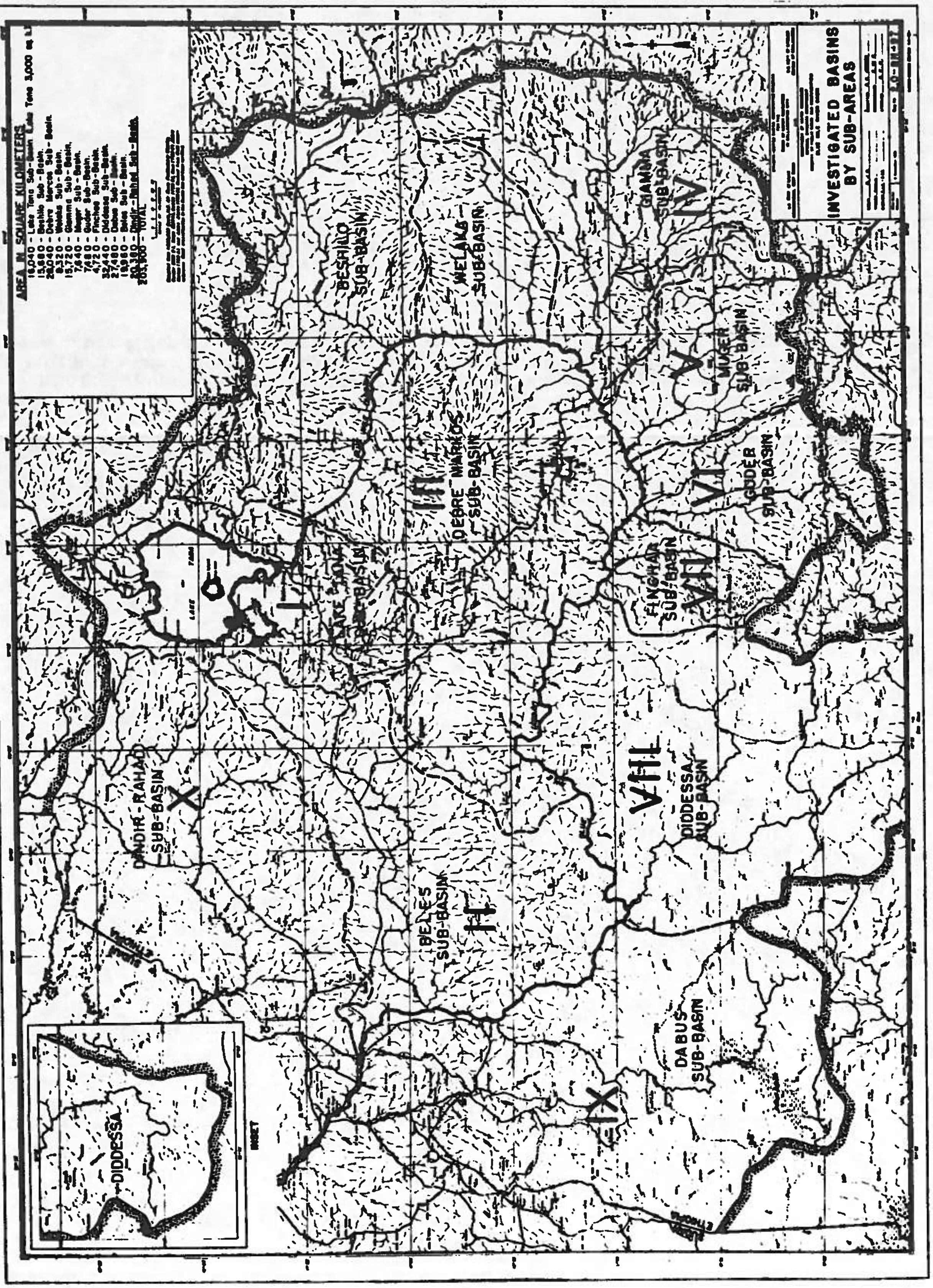


Figure 61--Investigated Basins by Sub-areas

2140-2

Projects in Lake Tana Sub-Basin

INTRODUCTION

Lake Tana Sub-basin is discussed in relation to four separate projects in the northern and eastern portions of the basin. The utilization of Lake Tana for purposes of development of the Beles River Projects and the Gilgel Abbay projects will be discussed separately.

For obvious reasons, the general descriptions applicable to the basin will include Lake Tana and the Gilgel Abbay drainage area.

Basin Description

The Lake Tana basin is in northwestern Ethiopia and has a drainage area of approximately 15,000 square kilometers (5,800 square miles). Situated at an elevation of 1786 meters (5860 feet) above sea level, the lake is fed by four major tributaries--the Gilgel Abbay, the Megech, the Gumara, and the Ribb--all of which rise in the highlands surrounding the lake. Because of the restriction at its outlet and its large storage capacity, the lake rises slowly to reach its maximum stage near the end of the season of heavy rains and recedes slowly to its minimum discharge during the dry season.

The sub-basin is characterized by a large, flat to very gently sloping plain bordering the lake on the north and east and by an extensive area of gently rolling to hilly uplands on the south. Recent lava flows, hilly rocky land, low marshy areas, and mountainous terrain comprise a sizable portion of the landscape.

Water for the Megech Gravity Project would be supplied from the Megech Reservoir for irrigation of about 7,000 hectares of land. The Ribb Dam and Reservoir would impound the rainy season flows to be released as required for irrigation of 15,000 hectares of land. The Gumara Dam and Reservoir would provide enough storage for irrigation of 13,000 hectares of land.

Lake Tana pumping plants would lift water from the lake to irrigate nearly 18,000 hectares of land as shown on Figure 63.

Principal Towns and Cities

The principal centers of population and local trade in the sub-basin are Gondar, Azozo, and Gorgora in the north; Addis Zemin and Debre Tabor in the east, Bahir Dar in the south; and Dangila in the southwest. Of these towns, Bahir Dar, at the southern end of the lake, has been selected by the IEG for development in the long-range plan. In support of this, a considerable amount of construction has been done recently. The construction includes a domestic water supply system, a concrete bridge over the Blue Nile River at the outlet of the lake, a small hydroelectric powerplant at Tis Isat Falls for service to the town, a textile factory, a technical school for 1,000 students, and improvement of the highways leading to Addis Ababa and to Asmara. It is expected that Bahir Dar may serve both as the nucleus for economic exploitation and as the administrative center for the northwestern section of Ethiopia. Population in 1962 was estimated to be about 10,000.

Figure 62. The Megech project area north of Lake Tana.

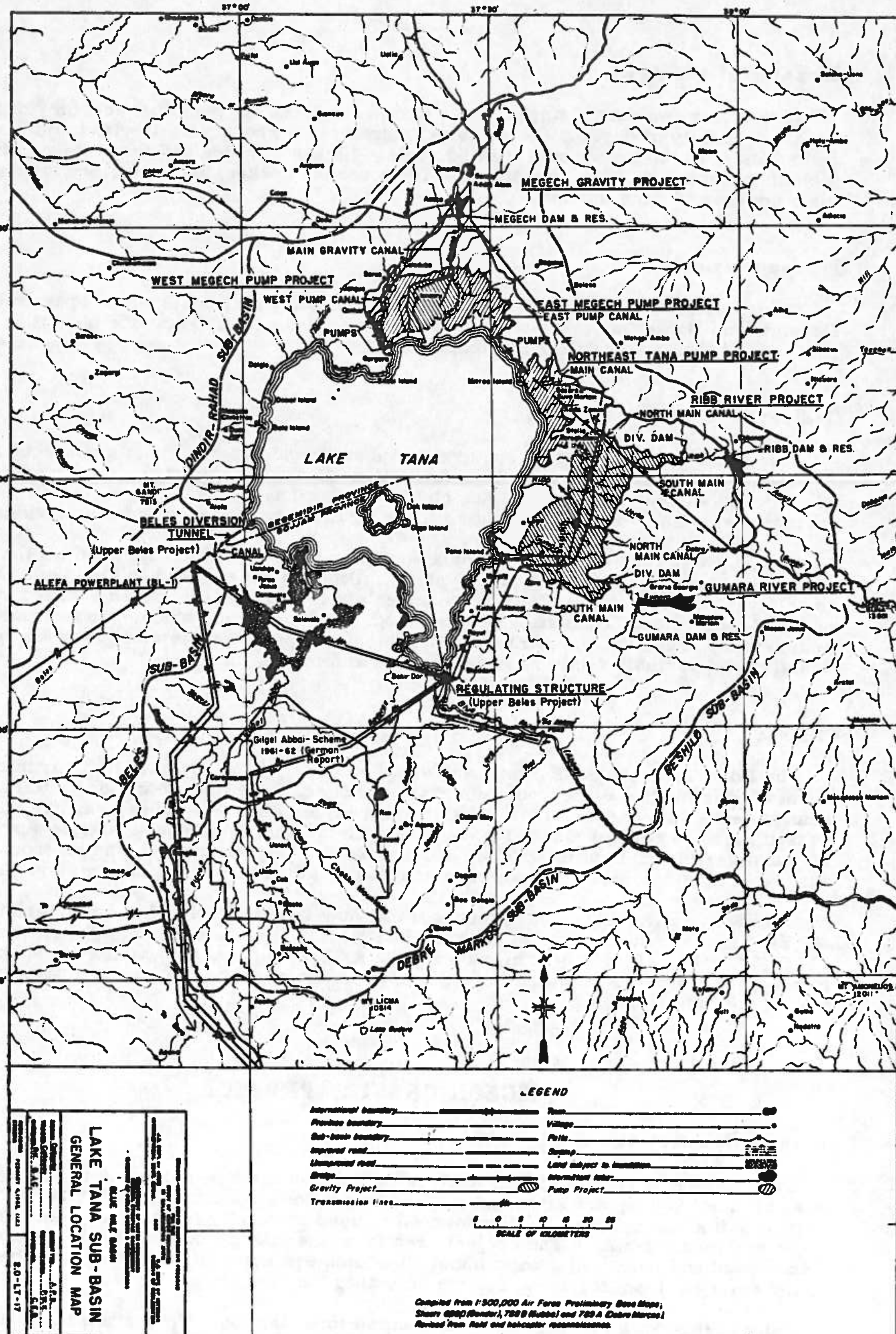


Figure 63--Lake Tana Sub-basin--General Location Map

Economy of the Area

Agriculture and the raising of cattle and sheep form the principal economy of the area. A variety of dryland crops--mostly grains--is produced. Dryland cotton, coffee, and herbs are also grown on a limited scale. Export of hides and the cottage industries, including tanning of hides, pressing oil from seeds, beekeeping, and cloth weaving, are main sources of cash income.

Transportation

Transportation is provided by regularly scheduled small boats which operate between Gorgora and Bahir Dar. All-weather roads around the lake to provide outlets to other parts of the Empire are nearing completion.

Geology

Lake Tana lies in a large structural basin surrounded by volcanic mountains composed mostly of basaltic lava. Rock formations in the vicinity of the lake consist mostly of siliceous shales, sandstones, and cherty marl. The rocks within the basin are all extrusive volcanic rocks representing three or more phases of volcanic activity.

The lake was formed primarily by a younger volcanism which dammed off the previously eroded valley and drainage system. Although not exposed in the lake basin, it is believed that the volcanic rocks are underlain by essentially bedded sedimentary rock of the Mesozoic age, consisting of limestone, sandstone, and shale. Underneath the sedimentary rock, the Precambrian "basement complex" consists of granitics, gneisses, schists, and variably altered metasediments and metavolcanics.

Climate

The Lake Tana area has a temperate and equable climate despite its proximity to the equator, due to its elevated position. The yearly climate may be divided into two broad seasons--the rainy season from June through September, and the dry season. The rainy season includes two general periods--the "little" rains, which occur during April and May and are insufficient for crop maturity; and the "big" rains, which last from mid-June to late September. The average annual rainfall is about 127 centimeters (50 inches).

Uniformity of temperature throughout the year is also a climatic characteristic. Average annual temperature is 19.2° C (66.6° F), and the average daily maximum is 26° C (78.8° F). The coldest months are December and January, while the warmest months are March, April, and May. Frost damage to crops may occur infrequently during the former period.

MEGECH GRAVITY PROJECT

General Description

This project is situated in the northern portion of the sub-basin and has a drainage area of about 700 square kilometers. The river flows generally in a southerly direction, emptying into Lake Tana. The watershed is used primarily for pasture, but there is some dry land farming. The project area is on the lake plain south of the Gondar-Debre Tabor road and begins at a point about 15 kilometers north of the lake where the Megech River emerges from the steep canyon area onto the lake plain.

Soils in this area are generally well suited to irrigation. They are a mixture of deltaic and recent river alluvial deposits. The land classification indicates that 6,940 hectares

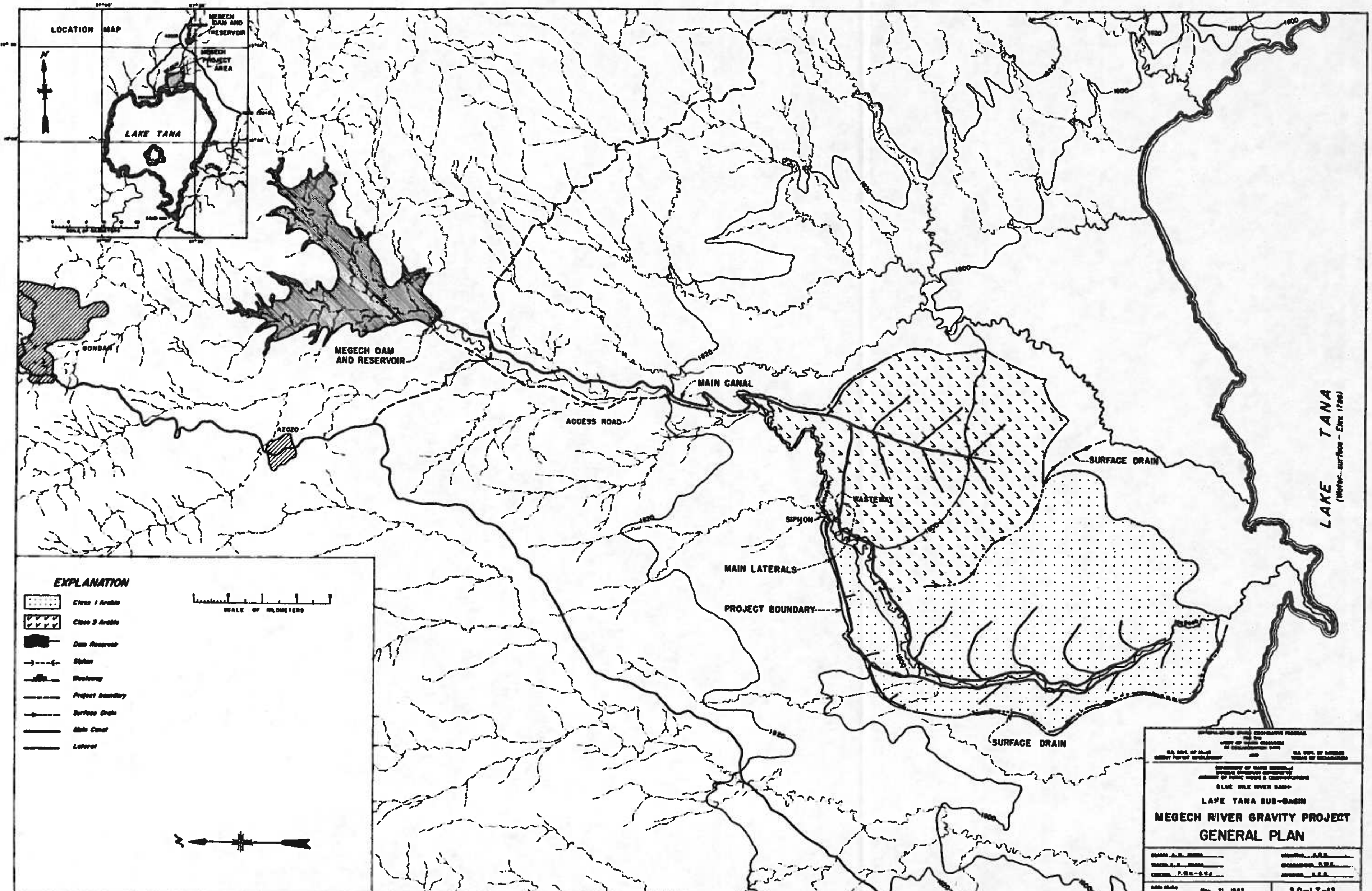


Figure 64--Megech River Gravity Project--General Plan

are suitable for irrigation, and an adequate water supply is available. Drainage control and improvement are needed, but it is believed that such controls can be accomplished with nominal investments.

The Megech River average annual runoff at the gaging station is estimated at 130 million cubic meters. Annual farm irrigation delivery requirements were estimated to be 0.938 meter, resulting in a diversion requirement of 13,400 cubic meters per hectare annually.

Plan of Development

The development plan includes a storage dam, a main canal and laterals, drains, and a distribution system. The dam and reservoir will impound the flows of the Megech River. Controlled releases would be made into the main canal, which would extend in a southerly direction for 16 kilometers to the project area. Sublaterals would distribute the water to the individual farms for agricultural crop production.

Project Features

The features of the project plan are shown on Figure 64. The damsite is on the Megech River, one-half kilometer downstream from its confluence with the Angereb River and 35 kilometers upstream from where it empties into Lake Tana. It would be an earth and rock fill dam as shown on Figure 65. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit.

Megech Dam Data

Type	earth-rock fill
Embankment volume (earth)	3,500,000 cu. m.
Embankment volume (pervious)	5,000,000 cu. m.
Top of dam	1952 m.
Freeboard	2 m.
Structural height	78 m.
Hydraulic height	76 m.
Length of crest	940 m.
Width of crest	10 m.

A side channel uncontrolled spillway on the right abutment of the dam, with a crest length of 60 meters, would pass 890 cubic meters per second at a surcharge head of 3.9 meters, elevation 1950 meters. Superstorage to store part of the flood has been provided, amounting to 42.5 million cubic meters.

Spillway Data

Type	uncontrolled side channel
Crest elevation	1946.13 m.
Inflow design flood	1,587 cu. m.
Total flood volume, 2.25-day period	88,500,000 cu. m.
Discharge at max. w. s. elevation	890 cu. m. per sec.

The outlet works to release the necessary irrigation water would be located on the left abutment and would include an intake structure, a concrete conduit leading to a gate chamber located about midway in the dam and equipped with a slide gate, and a steel outlet pipe housed in a horseshoe conduit.

Outlet Works Data

Sill elevation	1875 m.
Capacity at max. w. s. elevation	18.4 cu. m. per sec.
Type of gates (2)	slide gates

The reservoir basin is situated in the older volcanics, well blanketed with impermeable material. Initial reservoir capacity would be 225,300,000 cubic meters and would inundate 10.2 square kilometers.

Overburden, consisting of basaltic and rhyolitic talus and silty and slightly sandy clay, may be as deep as 15 meters along the left abutment. On the right abutment, weathered basaltic and rhyolitic rock with interbedded ash and tuff was observed. Impervious fill material can be obtained from the slump area upstream from the axis on the left side of the river and in the reservoir basin. Sand, gravel, and cobbles can be obtained along the stream channel downstream from the damsite. Riprap can be quarried from the harder rhyolitic or basaltic deposits upstream from the damsite.

Canal excavation will not present unusual problems, with rock excavation only expected on the initial reaches before the canal breaks out into the valley. Bridges, culverts, wasteways, turnouts, drops, and checks would be some of the typical structures required along the main canal.

Canal Data

Type	unlined
Length	63 km.
Initial capacity	9.1 cu. m. per sec
Initial w. s. elevation	1870 m.

Estimated Project Cost

Construction Cost.

Feature	Cost
Megech Dam and Reservoir	Eth$66,979,000
Canals and laterals	2,360,000
Distribution system	3,253,000
Drainage canals	1,518,000
Access road	253,000
Service facilities	1,719,000
Total	Eth$76,082,000

Development Cost. Prior to agricultural crop production, clearing the lands of trees, brush, and vegetative debris, and land leveling or grading are required. Costs for these items on the potential project area are expected to be minimal, as dry farming is practiced in the area and only a small scattering of trees and brush exists in the non-cultivated areas. The topography is also well adapted to irrigation development. Estimates of cost for these two items are Eth$875,000.

Operations, Maintenance, and Replacement Cost. The estimates of operation and maintenance cost for the Megech Gravity Project assume that adequate personnel and equipment will be provided to perform all operating requirements for the efficient utilization of the facilities and that proper maintenance programs will be carried out to minimize premature and costly replacements of equipment and structures.

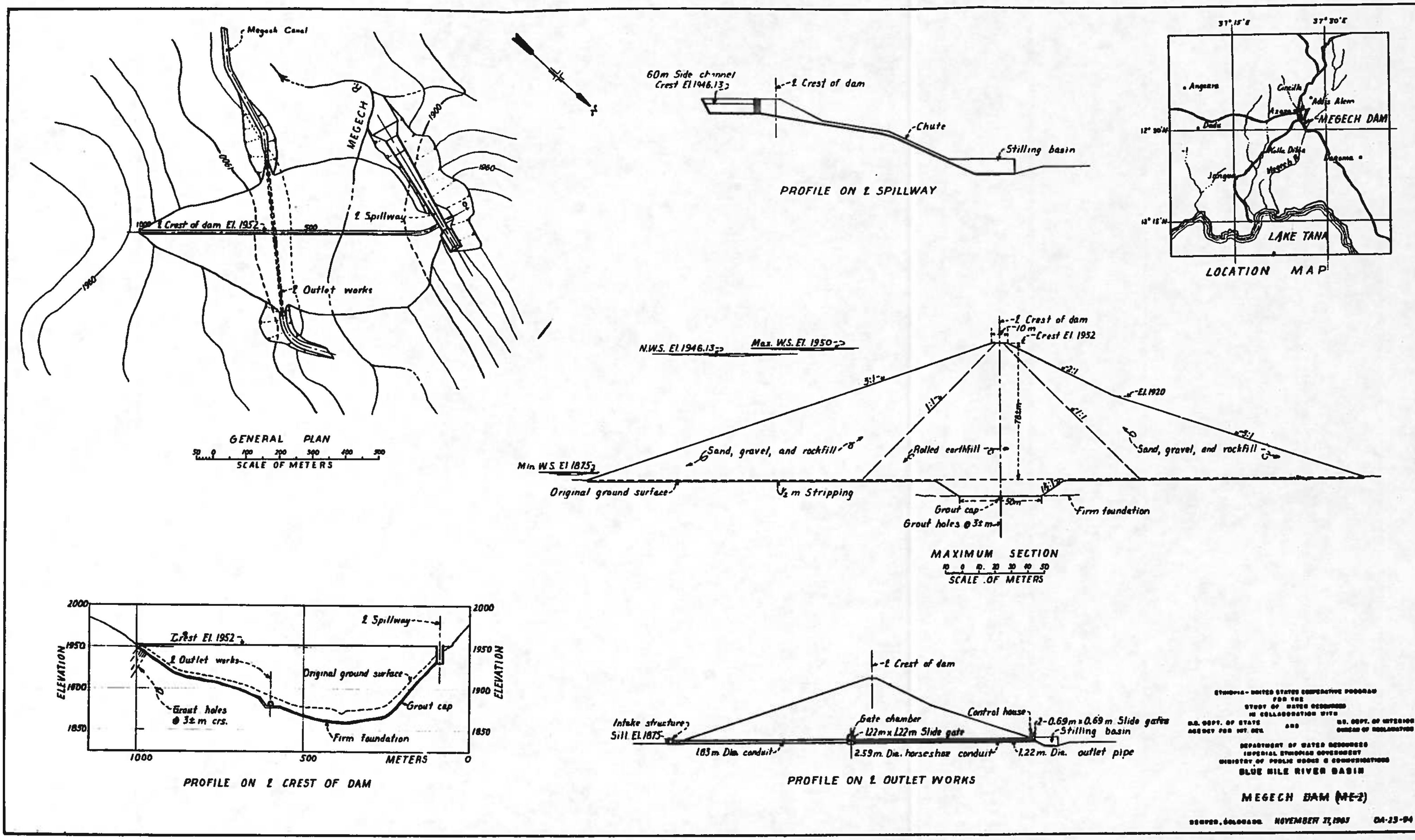


Figure 65--Megech Dam (ME-2)--Plan and Sections

TABLE 28--SUMMARY OF CROPS AND GROSS FARM INCOME--MEGECH GRAVITY PROJECT, 6,940 HECTARES

Table 28

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Preproject income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Barley	9.33		1,390	2,150	2,988,500	278,830	1,030	1,000	1,030,000	96,100	374,930	374,930
Sorghum	10.15		1,030	2,480	2,554,400	259,230	-	-	-	-	259,230	259,230
Teff	19.12		-	-	-	-	1,740	850	1,479,000	282,780	282,780	282,780
Wheat	17.35		1,390	2,150	2,988,500	518,500	1,030	975	1,004,250	174,240	692,740	692,740
Field peas	10.05		350	1,230	430,500	43,260	350	780	273,000	27,440	70,700	70,700
Horse beans	7.65		350	1,230	430,500	32,930	350	780	273,000	20,880	53,810	53,810
Castor beans	23.07		690	1,250	862,500	198,980	-	-	-	-	198,980	198,980
Flaxseed	17.59		-	-	-	-	350	560	196,000	34,480	34,480	34,480
Noog	18.53		690	1,000	690,000	127,860	-	-	-	-	127,860	127,860
Coffee	158.29		350	790	276,500	437,670	350	-	-	-	437,670	437,670
Peppers	52.38		350	765	267,750	140,250	-	-	-	-	140,250	140,250
Subtotal, crops			6,590			2,037,510	5,200			635,920	2,673,430	2,673,430
Fallow			-			-	1,390			-	-	-
Subtotal irrigated area			6,590			2,037,510	6,590			635,920	2,673,430	2,673,430
Noncultivated irrigable area			350			-	350			-	-	-
Total area		458,000	6,940			2,037,510	6,940			635,920	2,673,430	2,215,430
Income per hectare		65.99				293.59				91.63	385.22	319.23

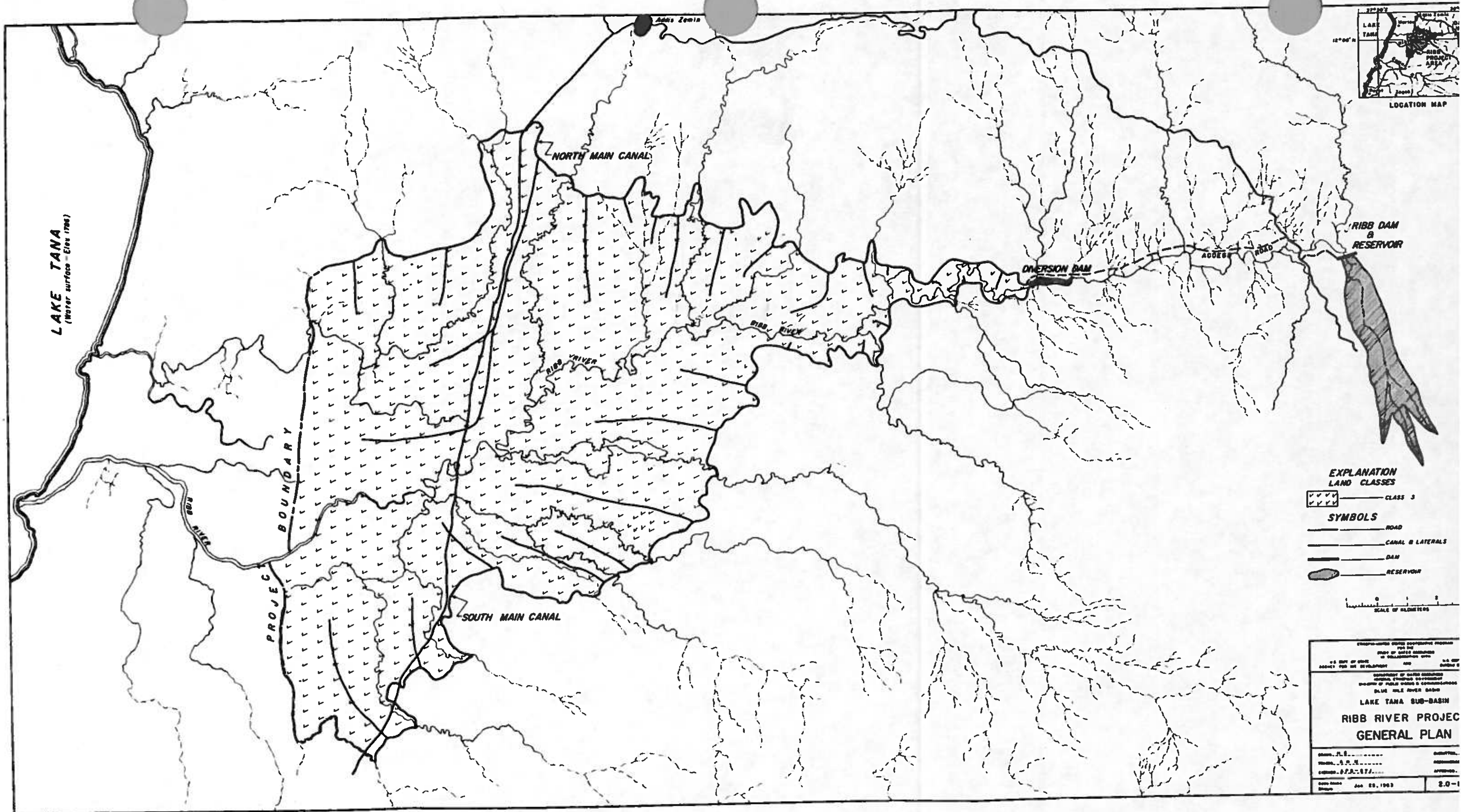


Figure 66--Ribb River Project--Gene

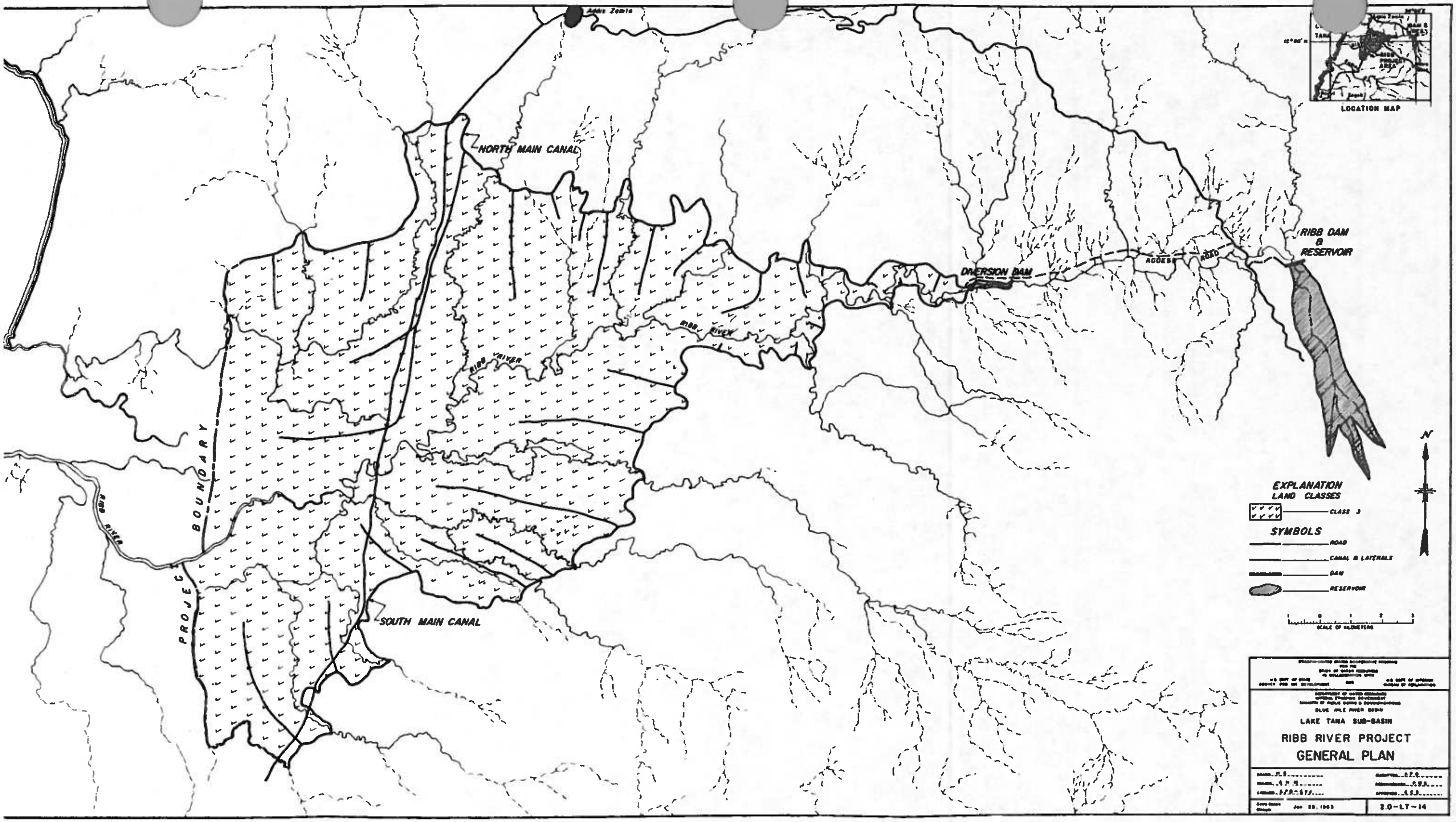


Figure 66--Ribb River Project--General Plan

Work division	Estimated annual cost
Megech Dam and Reservoir	Eth$ 20,000
Conveyance system	253,000

Benefit-Cost Ratio

The benefit-cost ratio of this project is 0.46 to 1.00.

RIBB RIVER PROJECT

General Description

The Ribb River is located on the east side of Lake Tana and has a drainage area of about 1,790 square kilometers.

The irrigation area under consideration is situated south of the Addis Zemin-Debre Tabor road and begins at a point on the river about 33 kilometers east of the shore of Lake Tana where the Ribb River approaches the lake plain from the mountainous area.

The predominant soils of the area are of the deltaic plain classification with minor areas of recent alluvial soils. The deltaic soils are dark gray, plastic clays (grumusols) that exhibit wide, deep cracks when dry. The soils are uniformly fine textured and are poorly drained.

The estimated average annual runoff at the gaging station on the Ribb River is 539 million cubic meters. Annual farm irrigation delivery requirement was estimated to be 0.889 meter and diversion requirements would amount to 12,700 cubic meters per hectare. From the reservoir operation studies, it was found that a yield of nearly 194 million cubic meters (157,195 acre-feet) would be obtained with storage in average years.

Plan of Development

The development plan includes a storage dam, a diversion dam, two main canals (one on each side of the river), a lateral distribution system, and drainage canals to provide full irrigation for 15,270 hectares of land.

Project Features

The general layout of the project features is shown on Figure 66. The Ribb River damsite is on the main stem approximately 1.5 kilometers upstream from the Addis Zemin-Debre Tabor road crossing and 44 kilometers east of Lake Tana. It would be an earth and rock fill structure as shown on Figure 67. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit.

Ribb Dam Data

Type	earth-rock fill
Embankment volume (earth)	2,700,000 cu. m.
Embankment volume (pervious)	3,600,000 cu. m.
Top of dam elevation	1936 m.
Freeboard	2.2 m.
Structural height	75 m.
Hydraulic height	72.8 m.
Length of crest	1,154 m.
Width of crest	10 m.

A U-shaped or bathtub spillway having a 200-meter crest length would discharge 1,906 cubic meters per second. Superstorage to store part of the flood at the aforementioned elevation will store 40.6 million cubic meters.

Spillway Data

Type	U-shaped uncontrolled
Crest elevation	1930.9 m.
Inflow design flood	2,246 cu. m. per sec.
Total flood volume, 2.5-day period	140,000,000 cu. m.
Discharge at max. w.s. elevation	1906 cu. m. per sec.

A conventional-type outlet works, consisting of an intake structure, conduit, gate chamber, steel outlet pipe, and a control house is proposed for irrigation releases. The conduit would be concrete, 1.83 meters in diameter, with the steel outlet pipe having a 1.12 meter diameter.

Outlet Works Data

Sill elevation	1869.3 m.
Capacity at min. w.s. elevation	5.7 cu. m. per sec.
Type of gates (2)	slide gates

The reservoir basin is situated in the older volcanics, overburden consisting of typical, reddish-brown, silty clay providing an impermeable blanket. At normal water surface elevation, it is expected that about 13.3 square kilometers will be inundated for initial storage of approximately 313 million cubic meters.

The foundations are composed of rocks variable in character and composition. In general, the rocks are of massive basaltic composition. Impervious fill material will be of the silty, plastic clay found in abundance within economical haul distance. Pervious materials of sand and gravel were observed near the site and downstream from the proposed location. Riprap can be obtained from the harder zones in the rhyolitic outcrops near the site.

Two main canals would originate--one on either side of the river--from the outlet works on each of the abutments of the diversion dam. The proposed routes of the canals would traverse rolling hills to flat topography as they emerge into the lake plain.

The North Main Canal, 35 kilometers long, would extend in a westerly direction to its terminus on the lake plain southwest of the town of Addis Zemin and is designed to serve approximately 8,500 hectares of irrigable land.

North Main Canal Data

Type	unlined
Length	35.2 km.
Initial capacity	12.4 cu. m. per sec.
Initial w.s. elevation	1828 m.

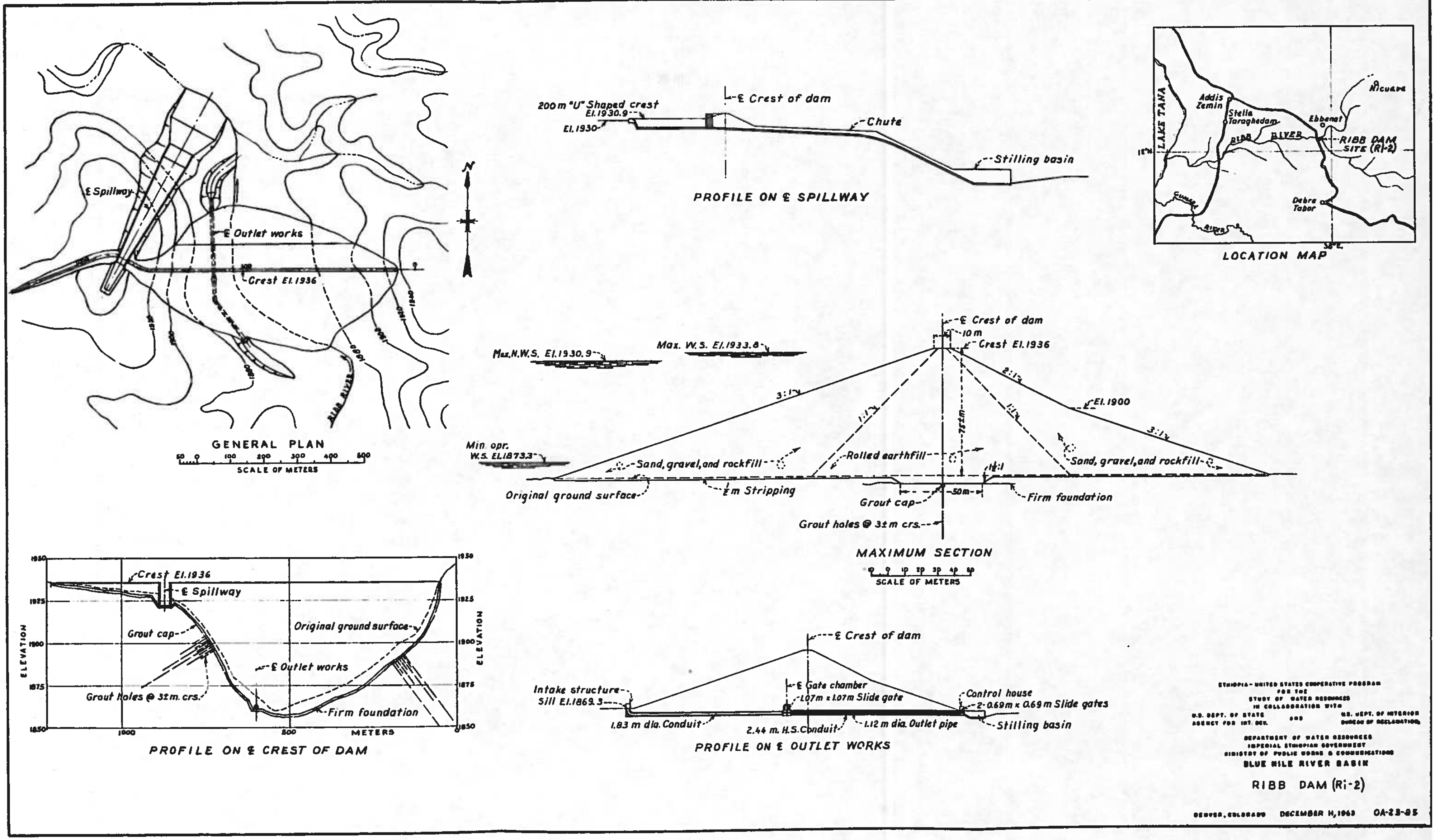


Figure 67--Ribb Dam (Ri-2)--Plan and Sections

Table 29

TABLE 29--SUMMARY OF CROPS AND GROSS FARM INCOME--RIBB RIVER PROJECT, 15,270 HECTARES

Crop pattern	Conditions before project: Price received per 100 kg. Eth$	Conditions before project: Preproject income Eth$	Future conditions, irrigation season: Crop distribution ha.	Future conditions, irrigation season: Yield kg./ha.	Future conditions, irrigation season: Production kg.	Future conditions, irrigation season: Value of production Eth$	Future conditions, nonirrigation season: Crop distribution ha.	Future conditions, nonirrigation season: Yield kg./ha.	Future conditions, nonirrigation season: Production kg.	Future conditions, nonirrigation season: Value of production Eth$	Post-project income Eth$	Gross crop income Eth$
Barley	10.18		3,050	2,150	6,557,500	667,550	2,285	1,000	2,285,000	232,610	900,160	900,160
Sorghum	11.00		2,285	2,480	5,666,800	623,350	-	-	-	-	623,350	623,350
Teff	19.97		-	-	-	-	3,825	850	3,251,250	649,270	649,270	649,270
Wheat	18.20		3,050	2,150	6,557,500	1,193,460	2,285	975	2,227,870	405,470	1,598,930	1,598,930
Field peas	10.90		765	1,230	940,950	102,560	765	780	596,700	65,040	167,600	167,600
Horse beans	8.50		765	1,230	940,950	79,980	765	780	596,700	50,720	130,700	130,700
Castor beans	23.92		1,530	1,250	1,912,500	457,470	-	-	-	-	457,470	457,470
Flaxseed	18.44		-	-	-	-	765	560	428,400	79,000	79,000	79,000
Noog	19.38		1,530	1,000	1,530,000	296,510	-	-	-	-	296,510	296,510
Coffee	159.14		765	790	604,350	961,760	765	-	-	-	961,760	961,760
Peppers	53.23		765	765	585,220	311,510	-	-	-	-	311,510	311,510
Subtotal, crops			14,505			4,694,150	11,455			1,482,110	6,176,260	6,176,260
Fallow			-			-	3,050			-	-	-
Subtotal, cultivated area			14,505			4,694,150	14,505			1,482,110	6,176,260	6,176,260
Noncultivated irrigable area			765				765			-	-	-
Total area		1,160,000	15,270			4,694,150	15,270			1,482,110	6,176,260	5,016,260
Income per hectare		75.97				307.41				97.06	404.47	328.50

The South Main Canal would follow the river in a westerly direction for approximately 9 kilometers and then turn in a southwesterly direction to its terminus at the end of the ridge dividing the Ribb and Gumara drainage basins for a total distance of 37.4 kilometers. It would serve 6,770 hectares of land.

South Main Canal

Type	unlined
Length	37.4 km.
Initial capacity	9.3 cu. m. per sec.
Initial w.s. elevation	1828 m.

Estimated Project Cost

Construction Cost

Feature	Cost
Ribb Dam and Reservoir	Eth$57,654,000
Diversion dam	320,000
North Main Canal	3,509,000
South Main Canal	3,420,000
Distribution system	7,635,000
Drainage canals	3,579,000
Access roads	569,000
Service facilities	1,719,000
Total	Eth$78,405,000

Development Cost. Some clearing of the scattered scrub trees and loose rocks will be needed. It is estimated to cost Eth$900,000. Land leveling costs are estimated to cost Eth$65 per hectare for a total cost of approximately Eth$1,000,000.

Operation, Maintenance, and Replacement Cost. Annual OM&R charges for the Ribb River Project are estimated as follows:

Work division	Estimated annual cost
Storage and diversion dams	Eth$ 25,000
Conveyance system	512,000

Benefit-Cost Ratio

The benefit-cost ratio of this project is 0.95 to 1.00.

GUMARA RIVER PROJECT

General Description

The Gumara River area is east of Lake Tana and has a drainage area of 1,500 square kilometers. The river rises in the high mountainous area south and east of the town of Debre Tabor at an approximate elevation of 3000 meters. It flows generally in a westerly direction and empties into Lake Tana about 35 kilometers north of the town of Bahir Dar. The project land area lies on the plains above the lake and blends into the Ribb River area to the north, the average elevation of the project lands being about 1840 meter.

The lake plain soils of the project were developed on deltaic deposits overlying deeper lacustrine deposits. Alluvium and red latosol soils, better suited to irrigation, are also found in the area and comprise about 25 percent of the project lands.

The irrigable lands that could be served by gravity irrigation are composed of the following land classes.

Land Classes

Class	Arable under canal (hectares)	Irrigable (hectares)
1	2,100	1,570
2	2,090	1,570
3	13,029	9,780
Total	17,219	12,920

Critical drainage problems on the lake plains resulted in the elimination of those lands bordering the lake. The seasonally inundated plain has internal drainage characteristics which probably would prevent the use of tile drainage. The more highly elevated lands of the project area should not present any undue problem in surface drainage in carrying away any irrigation waste and excess precipitation.

Hydrologic studies conducted indicate that there is an abundant water supply to irrigate the 12,920 hectares of land.

Plan of Development

The plan includes a storage dam, a diversion dam, two main canals (one on each side of the river), a lateral distribution system, and drainage canals to provide full irrigation service for 12,920 hectares of land. Storage would be provided by the Gumara Dam and Reservoir on the Gumara River. It would be turned into the two main canals for service to the project. The North Main Canal would extend in a generally northerly direction to its terminus at the end of the ridge between the Ribb and Gumara drainage basins. The South Main Canal would extend in a westerly and then northwesterly direction following the edge of the steeper ground south of the river. Laterals and feeders would branch off the main canals to the land.

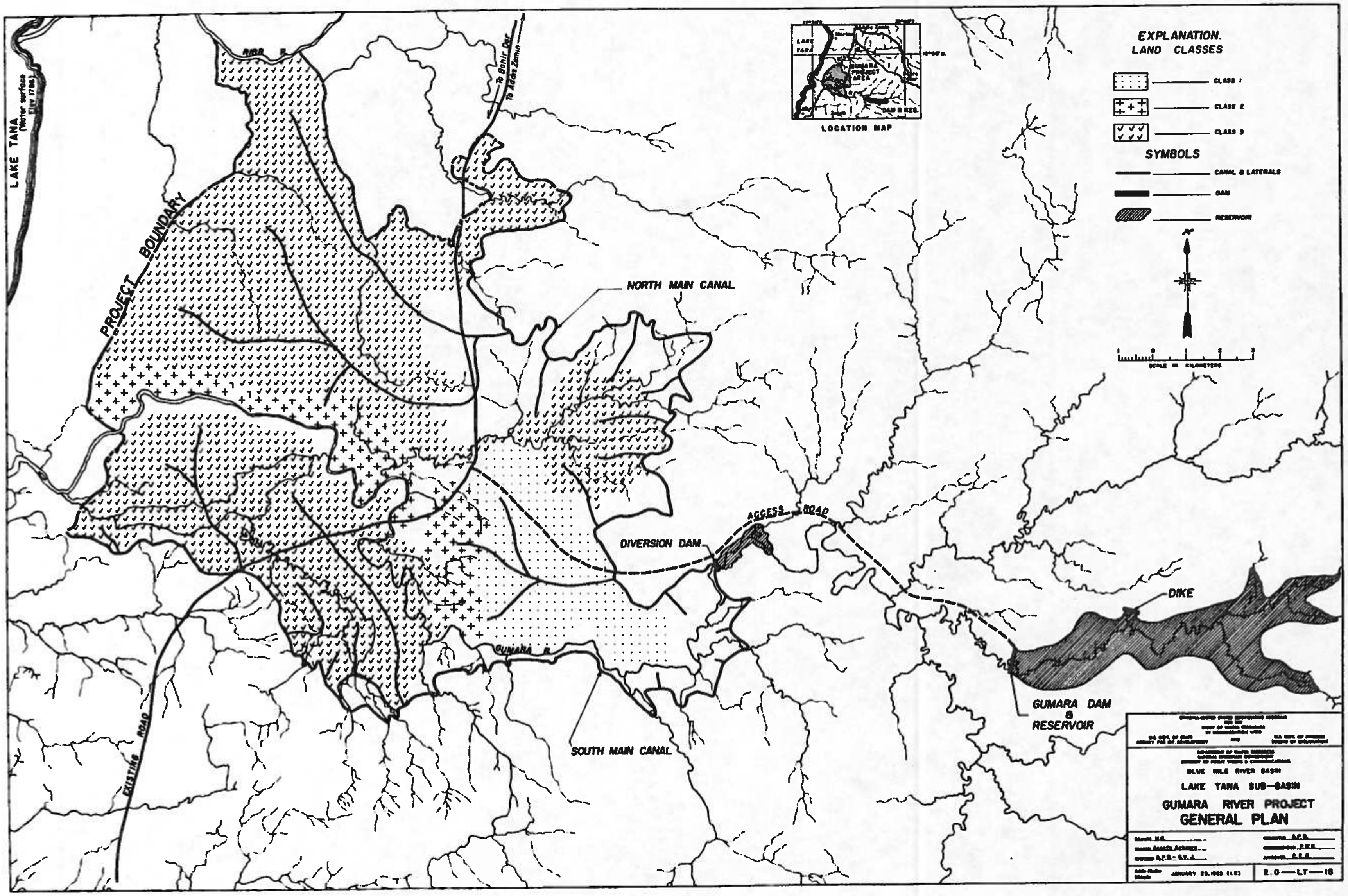


Figure 68--Gumara River Project--General Plan

Figure 69. Gumara River flowing across the plains toward Lake Tana.

Project Features

The general layout of the project is shown on Figure 68.

The damsite is on the main stem of the Gumara River, approximately 35 kilometers east of Lake Tana and 18 kilometers upstream from the Addis Zemin-Bahir Dar road. It would be an earth and rock fill structure as shown on Figure 70. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit.

Gumara Dam Data

Type	earth and rock fill
Embankment volume (earth)	2,600,000 cu. m.
Embankment volume (pervious)	3,100,000 cu. m.
Top of dam	1960 m.
Freeboard	1.7 m.
Structural height	71 m.
Hydraulic height	69.3 m.
Length of crest	683 m.
Width of crest	10 m.

Dike

Type	earth and rock fill
Embankment volume (earth)	1,300,000 cu. m.
Embankment volume (pervious)	1,300,000 cu. m.
Structural height	38 ± m.
Crest length	690 ± m.

The spillway would be a side channel, uncontrolled type, located on the right abutment of the dam. With a crest length of 50 meters, it is designed to pass a maximum flow of 926 cubic meters per second at elevation 1958.3 meters.

Spillway Data

Type	side channel, uncontrolled
Crest elevation	1954.3 m.
Inflow design flood, 2.25-day period	84,000,000 cu. m.
Discharge at max. w.s. elevation	926 cu. m. per sec.

An outlet works located on the left abutment of the dam would release water as required into the river channel for diversion into the main canals for irrigation.

Outlet Works Data

Sill elevation	1895.2 m.
Discharge at minimum optimum w.s. elevation	3.9 cu. m. per sec.
Type of gates (2)	slide gates
Size of pipe (diameter)	1.22 m.

The Gumara Reservoir Basin is underlain by younger volcanic flows, which are quite permeable. The thickness of these flows may not be great, and, since the basin is covered with impermeable overburden, seepage may not be a problem. Storage is estimated to be about 236.7 million cubic meters and will inundate an area of 8.7 square kilometers.

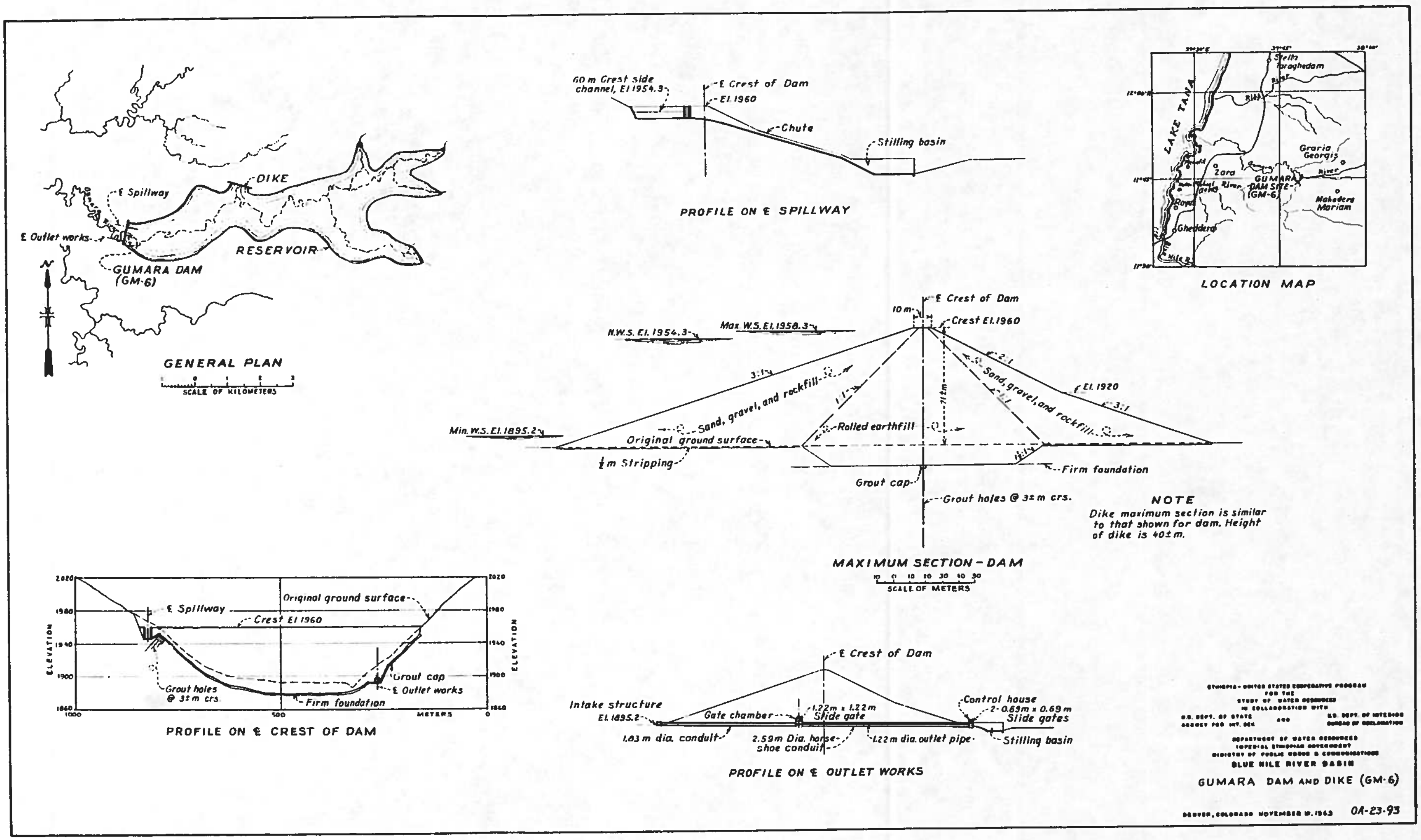


Figure 70--Gumara Dam and Dike (GM-6)--Plan and Sections

TABLE 30--SUMMARY OF CROPS AND GROSS FARM INCOME--GUMARA RIVER PROJECT, 12,920 HECTARES

Table 30

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Preproject income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Barley	10.33		2,590	2,150	5,568,500	575,230	1,940	1,000	1,940,000	200,400	775,630	775,630
Sorghum	11.15		1,940	2,480	4,811,200	536,450	-	-	-	-	536,450	536,450
Teff	20.12		-	-	-	-	3,240	850	2,754,000	554,100	554,100	554,100
Wheat	18.35		2,590	2,150	5,568,500	1,021,820	1,940	975	1,891,500	347,090	1,368,910	1,368,910
Field peas	11.05		640	1,230	787,200	86,990	640	780	499,200	55,160	142,150	142,150
Horse beans	8.65		640	1,230	787,200	68,090	640	780	499,200	43,180	111,270	111,270
Castor beans	24.07		1,300	1,250	1,625,000	391,140	-	-	-	-	391,140	391,140
Flaxseed	18.59		-	-	-	-	640	560	358,400	66,630	66,630	66,630
Noog	19.53		1,300	1,000	1,300,000	253,890	-	-	-	-	253,890	253,890
Coffee	159.29		640	790	505,600	805,370	640	-	-	-	805,370	805,370
Peppers	53.38		640	765	489,600	261,350	-	-	-	-	261,350	261,350
Subtotal, crops			12,280			4,000,330	9,680			1,266,560	5,266,890	5,266,890
Fallow			-			-	2,600			-	-	-
Subtotal, cultivated area			12,280			4,000,330	12,280			1,266,560	5,266,890	5,266,890
Noncultivated irrigable area			640			-	640			-	-	-
Total area		900,000	12,920			4,000,330	12,920			1,266,560	5,266,890	4,366,890
Income per hectare		69.66				309.62				98.03	407.65	337.99

The foundation materials should be thoroughly explored during preconstruction studies to determine the thickness and permeability of foundation materials and the corrective measures required to prevent excessive leakage. In excavating for the cutoff trench, it may be advisable to remove the scoriaceous basaltic lava to the sounder older volcanics to assure sealing off the reservoir at the damsite.

Impervious embankment materials are available from the valley floor downstream from the dam axis. Pervious fill and sand and gravel can be obtained from the gravel lenses in the stream channel downstream from the damsite. Riprap and pervious rockfill can be obtained at the site from the rhyolitic or basaltic lava nearby.

The diversion dam would be located about 8 kilometers downstream from the main storage dam. The masonry-concrete structure will divert the irrigation releases from canal headworks on each abutment.

Diversion Dam Data

Type	masonry-concrete with stoplogs
Structural height	4.6 m.
Weir length	44 m.
Volume of concrete	435 cu. m.
Volume of masonry	400 cu. m.
Normal w. s. elevation	1876 m.

The North Main Canal would extend in a northerly direction from the diversion dam headworks for a distance of approximately 59.5 kilometers and serve approximately 9,100 irrigable hectares.

North Main Canal Data

Type	unlined
Length	59.5 km.
Initial capacity	10.6 cu. m. per sec.
Initial w. s. elevation	1875 m.

The South Main Canal would extend in a westerly direction from the diversion dam headworks for a distance of 32.5 kilometers, and thence northwesterly for 8 kilometers to its terminus about 4 kilometers east of the lake shore. It would serve 3,820 hectares of land.

South Main Canal Data

Type	unlined
Length	32.5 km.
Initial capacity	4.65 cu. m. per sec.
Initial w. s. elevation	1875 m.

Estimated Project Cost

Construction Cost

Feature	Cost
Gumara Dam and Reservoir	Eth$64,450,000
Diversion Dam	315,000
North Main Canal	1,862,000
South Main Canal	1,444,000
Distribution system	6,056,000
Drainage canals	3,028,000
Access roads	759,000
Service facilities	1,719,000
Total	Eth$79,633,000

Development Cost. The development cost which includes clearing and land leveling is estimated to be Eth$1, 600, 000.

Operation, Maintenance, and Replacement Cost. Operation and maintenance cost for the project is estimated as follows by major divisions of work activities. No replacements are required within the period of analysis.

Work division	Estimated annual cost
Storage and diversion dams	Eth$ 20, 000
Conveyance system	440, 000

Benefit-Cost Ratio

The benefit-cost ratio of this project is 0. 83 to 1. 00.

MEGECH RIVER AREA--PUMPING PROJECTS

Introduction

Of the approximately 45, 000 hectares determined to be suitable for irrigation development in the Megech River area, less than 20 percent of the potential arable lands could be served by the Megech Gravity Project. A scheme involving two pumping projects to irrigate lands not served by the gravity project is proposed. The West Megech Pumping Project and the East Megech Pumping Project lie to either side of the Megech Gravity Project.

General Description

The project lands are situated on the broad alluvial plain. The topography is relatively flat to rolling. The elevation of the areas ranges from 1786 meters above sea level (the surface elevation of Lake Tana) to about 1820 meters at the upper extremity.

Nearly every soil type occurring in the Blue Nile Basin may be found in these areas. The soils are not of the best quality for irrigation and are intermingled with typical dark-clay grumusols on flatter terrain and with the red earth or latosols on upland, well-drained positions.

The irrigable lands within the potential projects were estimated to be about 12, 970 hectares.

From the data available, Lake Tana appears to be the only possible source of surface water supply for the two pumping projects. Annual pumping requirements from Lake Tana would be 173, 800, 000 cubic meters.

West Megech Pumping Project

Plan of Development. The development plan for the project includes the construction of two pumping plants, two main canals, a lateral distribution system, and drainage canals for irrigation of 7,080 hectares of land.

The main plant would pump the irrigation water from Lake Tana, discharging into the Lower Main Canal. The Lower Main Canal would extend on a northerly direction; and about 20 kilometers from the main plant a relift pumping plant, using the main canal as

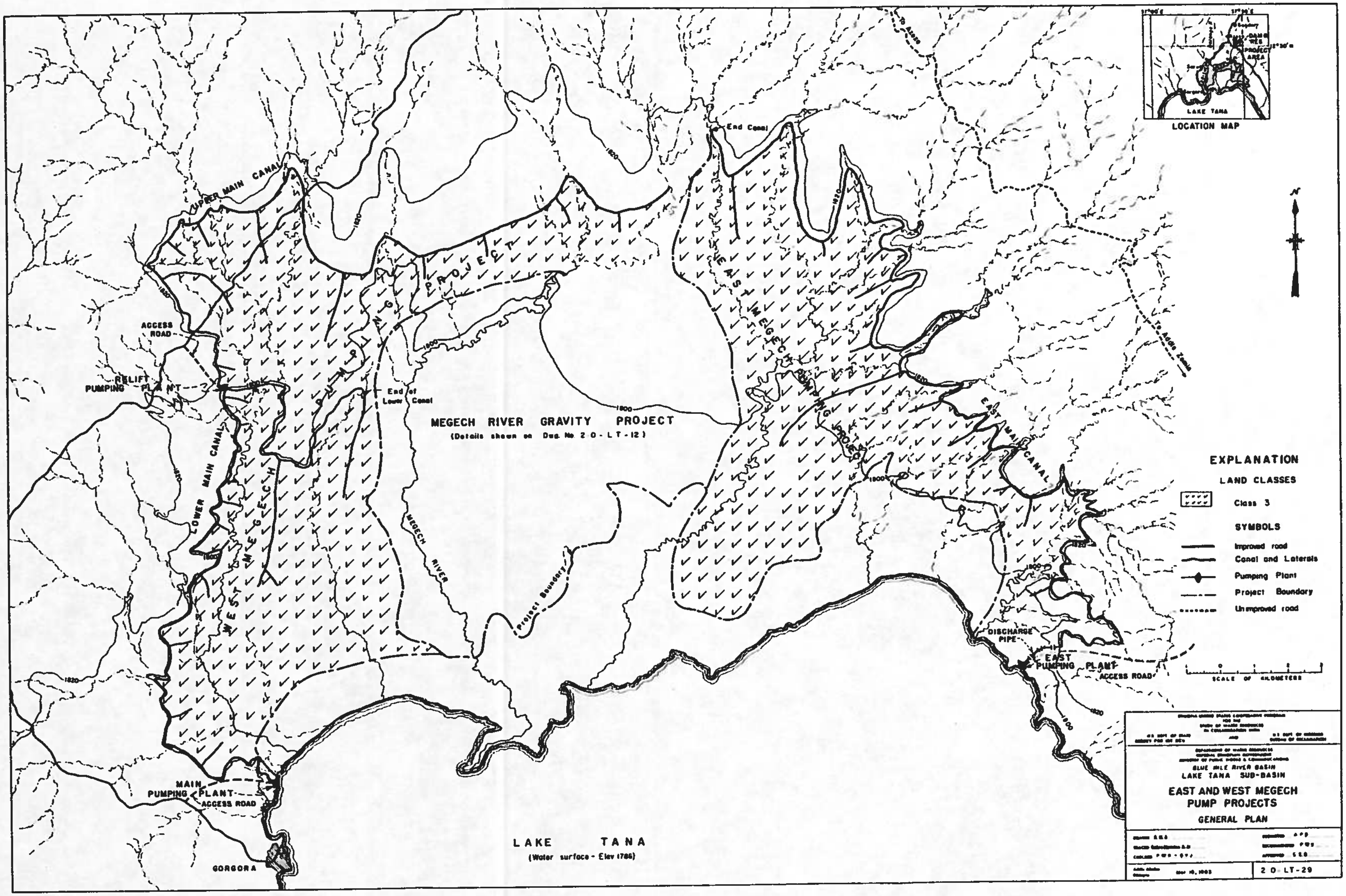


Figure 71--East and West Megech Pump Projects--General Plan

TABLE 31--SUMMARY OF CROPS AND GROSS FARM INCOME--WEST MEGECH PUMPING PROJECT, 7,080 HECTARES

Table 31

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Price received per 100 kg Eth$	Preproject income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Barley	9.18		1,420	2,150	3,053,000	280,260	1,070	1,000	1,070,000	98,230	378,490	378,490
Sorghum	10.00		1,070	2,480	2,653,600	265,360	-	-	-	-	265,360	265,360
Teff	18.97		-	-	-	-	1,770	850	1,504,500	285,400	285,400	285,400
Wheat	17.20		1,420	2,150	3,053,000	525,120	1,070	975	1,043,250	179,440	704,560	704,560
Field peas	9.90		350	1,230	430,500	42,620	350	780	273,000	27,030	69,650	69,650
Horse beans	7.50		350	1,230	430,500	32,290	350	780	273,000	20,470	52,760	52,760
Castor beans	22.92		710	1,250	887,500	203,410	-	-	-	-	203,410	203,410
Flaxseed	17.44		-	-	-	-	350	560	196,000	34,180	34,180	34,180
Noog	18.34		710	1,000	710,000	130,210	-	-	-	-	130,210	130,210
Coffee	158.14		350	790	276,500	437,260	350	-	-	-	437,260	437,260
Peppers	52.23		350	765	267,750	139,850	-	-	-	-	139,850	139,850
Subtotal, crops			6,730			2,056,380	5,310			644,750	2,701,130	2,701,130
Fallow			-			-	1,420			-	-	-
Subtotal, cultivated area			6,730			2,056,380	6,730			644,750	2,701,130	2,701,130
Noncultivated irrigable area			350			-	350			-	-	-
Total area		545,000	7,080			2,056,380	7,080			644,750	2,701,130	2,156,130
Income per hectare		76.98				290.45				91.07	381.52	304.54

a forebay, would relift the water to the Upper Main Canal. The Upper Main Canal would continue in a northwesterly direction, making a loop towards the east, and terminating at the Megech River.

Project Features. The features of the project plan are shown on Figure 71.

The main pumping plant would be located on the lake shore about 2 kilometers north of the village of Gorgora. The pump intake would be placed below the 1783 meter, minimum lake operational level. A total static lift of 14 meters--to elevation 1800, the beginning of the Lower Main Canal--will be required.

Pumping Plant Data

Type of forebay	lake
Forebay elevation (invert)	1783 m.
Total dynamic head	17 m.
Static head	14 m.
Size of discharge pipe (diameter)	2 m.
Capacity of pumps	9.24 cu. m. per sec.
Motor rating	3,175 hp.

Relift Pumping Plant

The relift pumping plant would be located at the end of the Lower Main Canal.

Type of forebay	canal
Forebay elevation (invert)	1795 m.
Total dynamic head	27 m.
Total static head	25 m.
Size of discharge pipe (diameter)	1.5 m.
Capacity of pumps	4.66 m.
Motor ratings	2,450 hp.

The Lower Main Canal would follow approximately along the 1800 meter contour for approximately 26 kilometers to convey water for irrigation of 3,650 hectares of land.

Lower Main Canal Data

Type	unlined
Length	47.5 km.
Initial capacity	9.24 cu. m. per sec.
Initial w. s. elevation	1800 m.

The Upper Main Canal would begin at the relift pumping plant. It would continue northward for about 5 kilometers and then proceed in an easterly direction to supply water for 3,430 hectares of irrigable land.

Upper Main Canal Data

Type	unlined
Length	31.5 km.
Initial capacity	4.66 cu. m. per sec.
Initial w. s. elevation	1820 m.

Estimated Project Cost

Construction Cost

Feature	Cost
Main Pumping Plant	Eth$ 1,976,000
Relift pumping plant	1,689,000
Transmission line and substation	877,000
Lower Main Canal	2,115,000
Upper Main Canal	859,000
Distribution system	3,319,000
Drainage canals	1,438,000
Access roads	156,000
Service facilities	188,000
Total	Eth$12,617,000

Development Cost. Clearing and land leveling costs are estimated to be about Eth$870,000.

Operation, Maintenance, and Replacement Cost. Annual OM&R charges are estimated to be as follows. Power has been assumed to cost Eth$0.03 per kilowatt-hour for both pumping plants.

Feature	Operation and maintenance	Special items and replacement	Power cost
Pumping plants	Eth$ 70,000	Eth$14,000	Eth$305,000
Electrical facilities of pumping plant	23,000	3,000	-
Conveyance system	260,000	-	-

Benefit-Cost Ratio

The benefit-cost ratio of this project is 1.49 to 1.00.

East Megech Pumping Project

Plan of Development. The plan of development for the East Megech Pumping Project would include a pumping plant, a main canal, a distribution system, and drainage canals for the irrigation of 5,890 hectares of land.

The plant would pump the water into a main canal which would extend in a northerly direction with its terminus at the Megech River, serving the lands between it and the eastern boundary of the Megech Gravity Project.

Project Features. The features of the plan are shown on Figure 71.

The pumping plant would be located on the shore of Lake Tana about 16 kilometers east of the mouth of the Megech River. The pump intake would be placed below the minimum water surface, at 1783 meters elevation.

TABLE 32--SUMMARY OF CROPS AND GROSS FARM INCOME--EAST MEGECH PUMPING PROJECT, 5,890 HECTARES

Table 32

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Preproject income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Barley	9.33		1,180	2,150	2,537,000	236,700	875	1,000	875,000	81,640	318,340	318,340
Sorghum	10.15		875	2,480	2,170,000	220,250	-	-	-	-	220,250	220,250
Teff	19.12		-	-	-	-	1,475	850	1,253,750	239,720	239,720	239,720
Wheat	17.35		1,180	2,150	2,537,000	440,170	875	975	853,120	148,020	588,190	588,190
Field peas	11.05		295	1,230	362,850	40,090	295	780	230,100	25,430	65,520	65,520
Horse beans	7.65		295	1,230	362,850	27,760	295	780	230,100	17,600	45,360	45,360
Castor beans	23.07		590	1,250	737,500	170,140	-	-	-	-	170,140	170,140
Flaxseed	17.59		-	-	-	-	295	560	165,200	29,060	29,060	29,060
Noog	18.53		590	1,000	590,000	109,330	-	-	-	-	109,330	109,330
Coffee	158.29		295	790	233,050	368,890	295	-	-	-	368,890	368,890
Peppers	52.38		295	765	225,670	118,210	-	-	-	-	118,210	118,210
Subtotal, crops			5,595			1,731,540	4,405			541,470	2,273,010	2,273,010
Fallow			-			-	1,190			-	-	-
Subtotal, cultivated area			5,595			1,731,540	5,595			541,470	2,273,010	2,273,010
Noncultivated irrigable area			295			-	295			-	-	-
Total area		365,000	5,890			1,731,540	5,890			541,470	2,273,010	1,908,010
Income per hectare		61.97				293.98				91.93	385.91	323.94

Pumping Plant Data

Type of forebay	lake
Forebay elevation (minimum water surface)	1783 m.
Total dynamic head	45 m.
Static head	37 m.
Size of discharge pipe (diameter)	1.8 m.
Capacity of pumps	7.54 cu. m. per sec.
Motor rating	6,850 hp.

The main canal would follow approximately along the 1820-meter contour for a distance of about 45 kilometers.

Canal Data

Type	unlined
Length	45 km.
Initial capacity	7.54 cu. m. per sec.

Estimated Project Cost

Construction Cost

Feature	Cost
Pumping plant	Eth$ 3,587,000
Transmission line and substation	351,000
Canals and laterals	3,014,000
Distribution system	2,761,000
Drainage canals	1,197,000
Access roads	406,000
Service facilities	172,000
Total	Eth$11,488,000

Development Cost. Clearing and land leveling are expected to cost about Eth$725,000.

Operation, Maintenance, and Replacement Cost. Annual OM&R and power costs are estimated as follows:

Feature	Operation and maintenance	Special items and replacements	Power cost
Pumping plant	Eth$ 73,000	Eth$8,000	Eth$386,000
Electrical facilities to pumping plant	14,500	1,500	-
Conveyance system	224,000	-	-

Benefit-Cost Ratio

The benefit-cost ratio of this project is 1.36 to 1.00.

NORTHEAST TANA PUMPING PROJECT

General Description

The area considered is on the lake plain on the northeast shore of Lake Tana. The area is about 14 kilometers in length and from 2 to 6 kilometers in width. The broad, flat-sloped area is cut by a few small streams and is interrupted by a few hills and knolls which are an extension of the hilly area occurring just north of the village of Addis Zemin.

The soils of the proposed project, while very similar to the Ribb River Project, are generally of more recent origin and are somewhat more stratified. Seasonal flooding occurs occasionally in this area, and deposits sediment over the land. However, because of the fine texture of the soils on the adjacent uplands (mostly dark clays), the recent sediment deposits are difficult to distinguish from previous deposition. Five thousand hectares were determined to be irrigable.

Lake Tana is the only source of water supply for the proposed project. Annual pumping requirements were determined to be 67,000,000 cubic meters for the 5,000 hectares of land.

Plan of Development

The plan of development includes a pumping plant, a main canal, a lateral distribution system, and drainage canals. Water would be pumped from Lake Tana and conveyed to the land by a main canal as shown.

Project Features

The features of the project plan are shown on Figure 72. The pumping plant would be located on the shore of Lake Tana at a point about 1 kilometer from Mitraa Island. It would have a concrete discharge pipe of about 70 meters long.

Pumping Plant Data

Type of forebay	lake
Forebay elevation (invert)	1783 m.
Total dynamic head	34.5 m.
Static head	34 m.
Size of discharge pipe (diameter)	1.67 m.
Capacity of pumps	6.44 cu. m. per sec.
Motor rating	4,550 hp.

The main canal would follow approximately along the 1820-meter contour for approximately 67 kilometers.

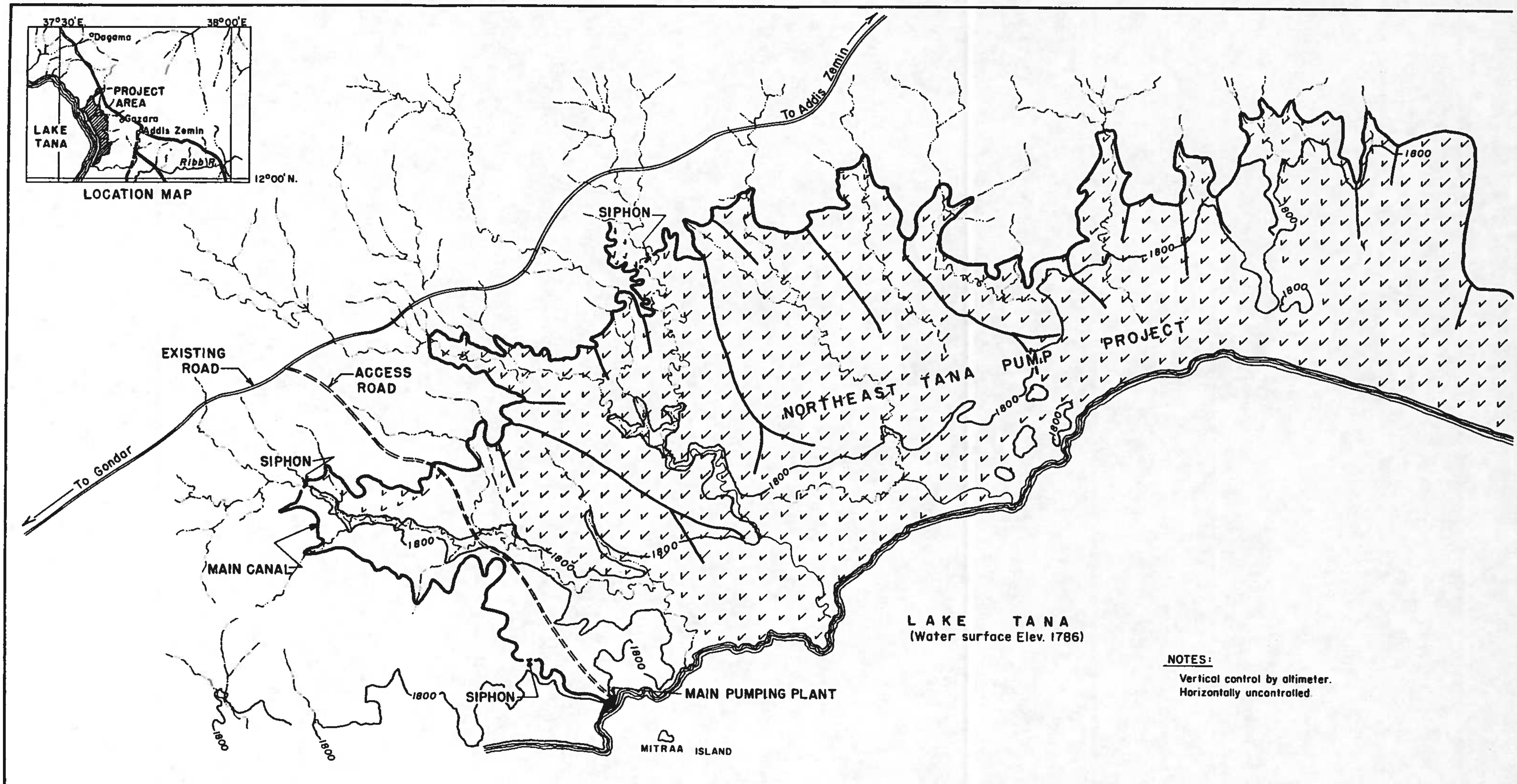
Canal Data

Type	unlined
Length	67 km.
Initial capacity	6.44 cu. m. per sec.
Initial w. s. elevation	1820 m.

TABLE 33--SUMMARY OF CROPS AND GROSS FARM INCOME--NORTHEAST TANA PUMPING PROJECT, 5,000 HECTARES

Table 33

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Preproject income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Barley	9.78		1,000	2,150	2,150,000	210,270	750	1,000	750,000	73,350	283,620	283,620
Sorghum	10.60		750	2,480	1,860,000	197,160	-	-	-	-	197,160	197,160
Teff	19.57		-	-	-	-	1,250	850	1,062,500	207,930	207,930	207,930
Wheat	17.80		1,000	2,150	2,150,000	382,700	750	975	731,250	130,160	512,860	512,860
Field peas	10.50		250	1,230	307,500	32,290	250	780	195,000	20,470	52,760	52,760
Horse beans	8.10		250	1,230	307,500	24,910	250	780	195,000	15,800	40,710	40,710
Castor beans	23.52		500	1,250	625,000	147,000	-	-	-	-	147,000	147,000
Flaxseed	18.04		-	-	-	-	250	560	140,000	25,260	25,260	25,260
Noog	18.98		500	1,000	500,000	94,900	-	-	-	-	94,900	94,900
Coffee	158.74		250	790	197,500	313,510	250	-	-	-	313,510	313,510
Peppers	52.83		250	765	191,250	101,040	-	-	-	-	101,040	101,040
Subtotal, crops			4,750			1,503,780	3,750			472,970	1,976,750	1,976,750
Fallow			-			-	1,000			-	-	-
Subtotal, cultivated area			4,750			1,503,780	4,750			472,970	1,976,750	1,976,750
Noncultivated irrigable area			250			-	250			-	-	-
Total area		335,000	5,000			1,503,780	5,000			472,970	1,976,750	1,641,750
Income per hectare		67.00				300.76				94.59	395.35	328.35



37°30'E.
38°00'E
Dagama
PROJECT AREA
Gazara
Addis Zemin
LAKE TANA
Ribb R.
12°00'N.
LOCATION MAP
To Addis Zemin
SIPHON
EXISTING ROAD
ACCESS ROAD
To Gondar
SIPHON
MAIN CANAL
SIPHON
MAIN PUMPING PLANT
MITRAA ISLAND
NORTHEAST TANA PUMP PROJECT
1800
LAKE TANA
(Water surface Elev. 1786)
NOTES:
Vertical control by altimeter.
Horizontally uncontrolled.

Estimated Project Cost

Construction Cost

Feature	Cost
Pumping plant	Eth$1, 815, 000
Transmission lines and substations	493, 000
Main canal	3, 536, 000
Distribution system	2, 344, 000
Drainage canals	1, 016, 000
Access roads	266, 000
Service facilities	164, 000
Total	Eth$9, 634, 000

Development Cost. Clearing and land leveling are expected to be roughly Eth$500, 000.

Operation, Maintenance, and Replacement Cost. Annual OM&R and power costs are estimated as follows. The annual energy requirement should be about 8, 642, 000 kilowatt-hours.

Feature	Operation and maintenance	Special items and replacement	Power cost
Pumping plant	Eth$ 55, 000	Eth$7, 000	Eth$260, 000
Electrical facilities to pumping plants	13, 000	2, 000	-
Conveyance system	195, 000	-	-

Benefit-Cost Ratio

The benefit-cost ratio of this project is 1. 47 to 1. 00.

Projects In The Beles Sub-Basin

INTRODUCTION

Reconnaissance studies performed on the Beles River drainage basin indicated a limited power potential and a fairly large block of land that was suitable for irrigation development but lacked sufficient water for economic exploitation. The plan of development for the basin conceives the importation of water from Lake Tana by regulating the lake. The development of the basin includes two projects--the Upper Beles Multipurpose Project and the Middle Beles Power Project. See Figure 73.

Basin Description

The Beles Sub-basin is in the west central portion of the Blue Nile Basin and has an area of about 20,000 square kilometers. It is situated at about an average elevation of 1150 meters above sea level. The Beles River originates on the face of the escarpment across the divide to the west of the southwestern portion of Lake Tana and runs in a southwesterly direction to its confluence with the Blue Nile River near the Sudan border.

The potential irrigation development extends along both sides of the Beles River, starting about 35 kilometers from its headwaters and continuing downstream to the old village of Mambuk, a distance of approximately 75 kilometers. At its widest point, the area is about 30 kilometers wide.

Soils

Grumusols or black clay soils predominate in the Beles River basin and particularly in the northwestern area where topographic conditions are best suited for irrigation.

Reddish-brown lateritic soils occur most frequently in the southern half and comprise about 40 percent of the total project area. The latosols are permeable and very well adapted to irrigation.

The accompanying table summarizes the land classification.

Land Classes (ha.)

Area	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

Drainage conditions are expected to be variable. The northwestern area can be expected to have the most drainage problems. It may be possible that subsurface drainage systems will be required. The northeastern area has a flood plain type of natural drainageways at present, with intermittent, narrow, moderately deep, eroded channels. Internal drainage characteristics of these soils are generally considerably better than in the northwestern sector.

Hydrology

Because of the irrigation project area being on the upper part of the drainage basin, the Beles River would provide only an insignificant amount of water compared to the requirements for the irrigable land. Water from Lake Tana, conveyed by means of a

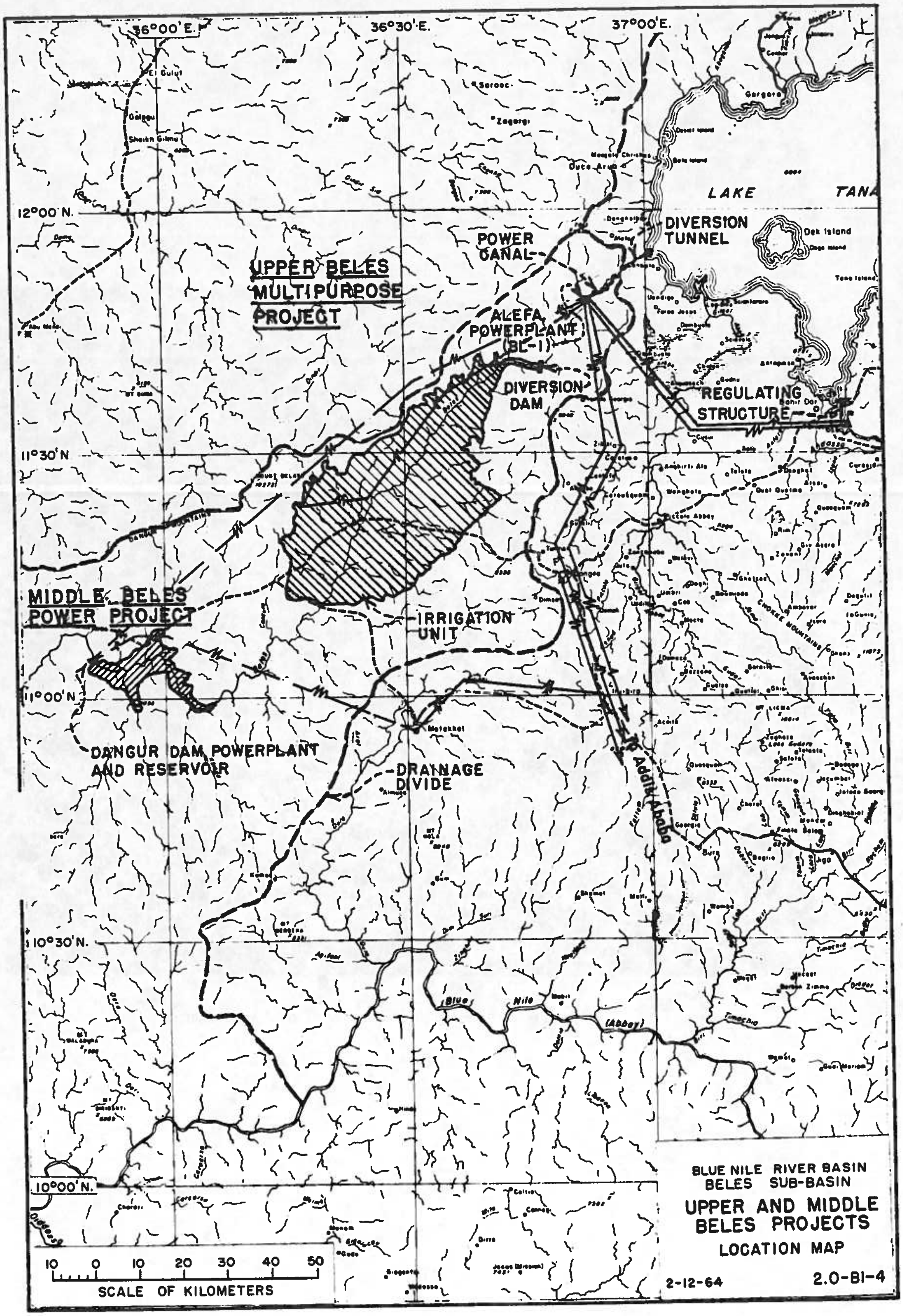


Figure 73--Upper and Middle Beles Projects--Location Map

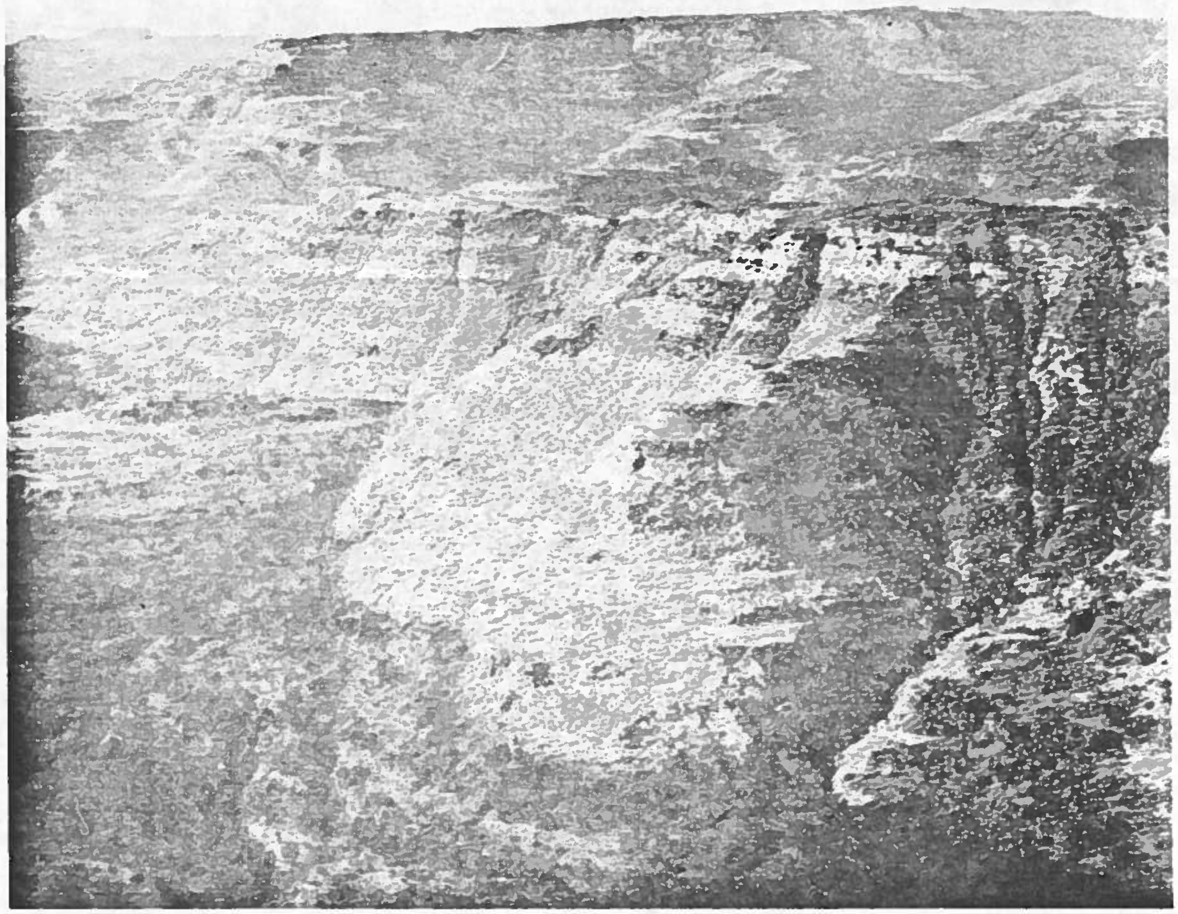
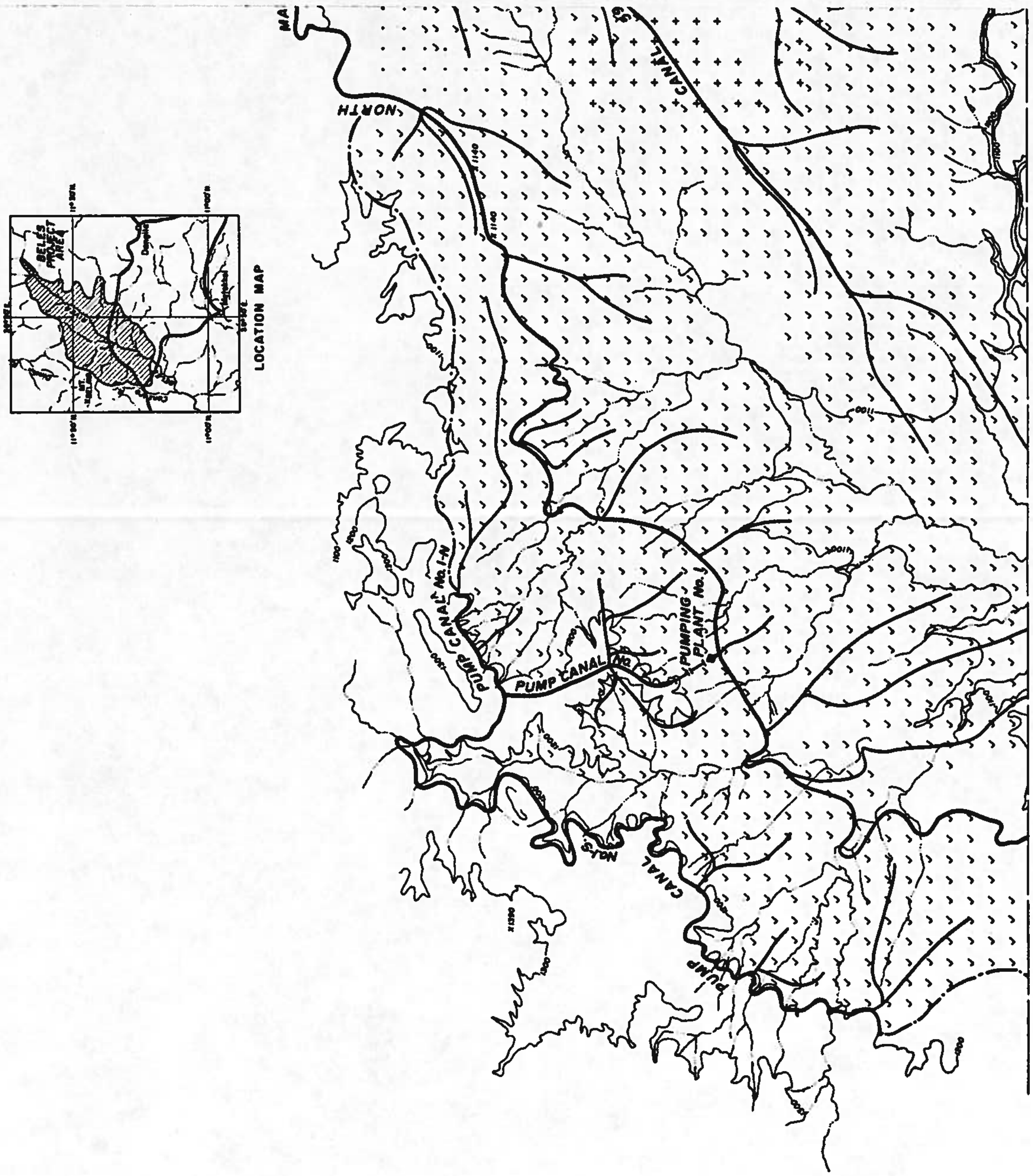


Figure 74. Escarpment west of Lake Tana.



NORTH
CANAL
PUMP CANAL No. 1-N
PUMP CANAL No.
PUMPING PLANT No. 1
PUMP
CANAL
BELES PROJECT AREA
LOCATION MAP

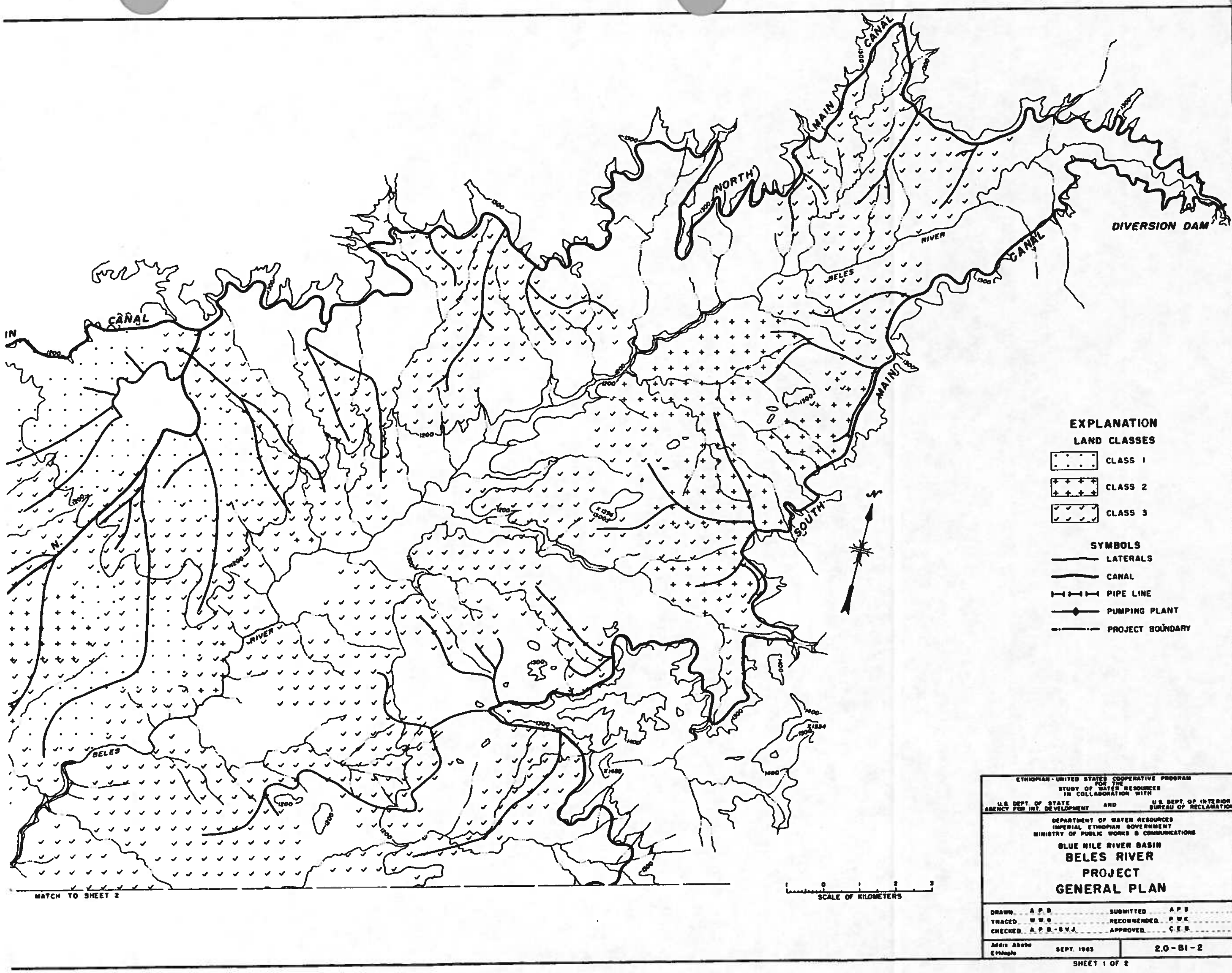
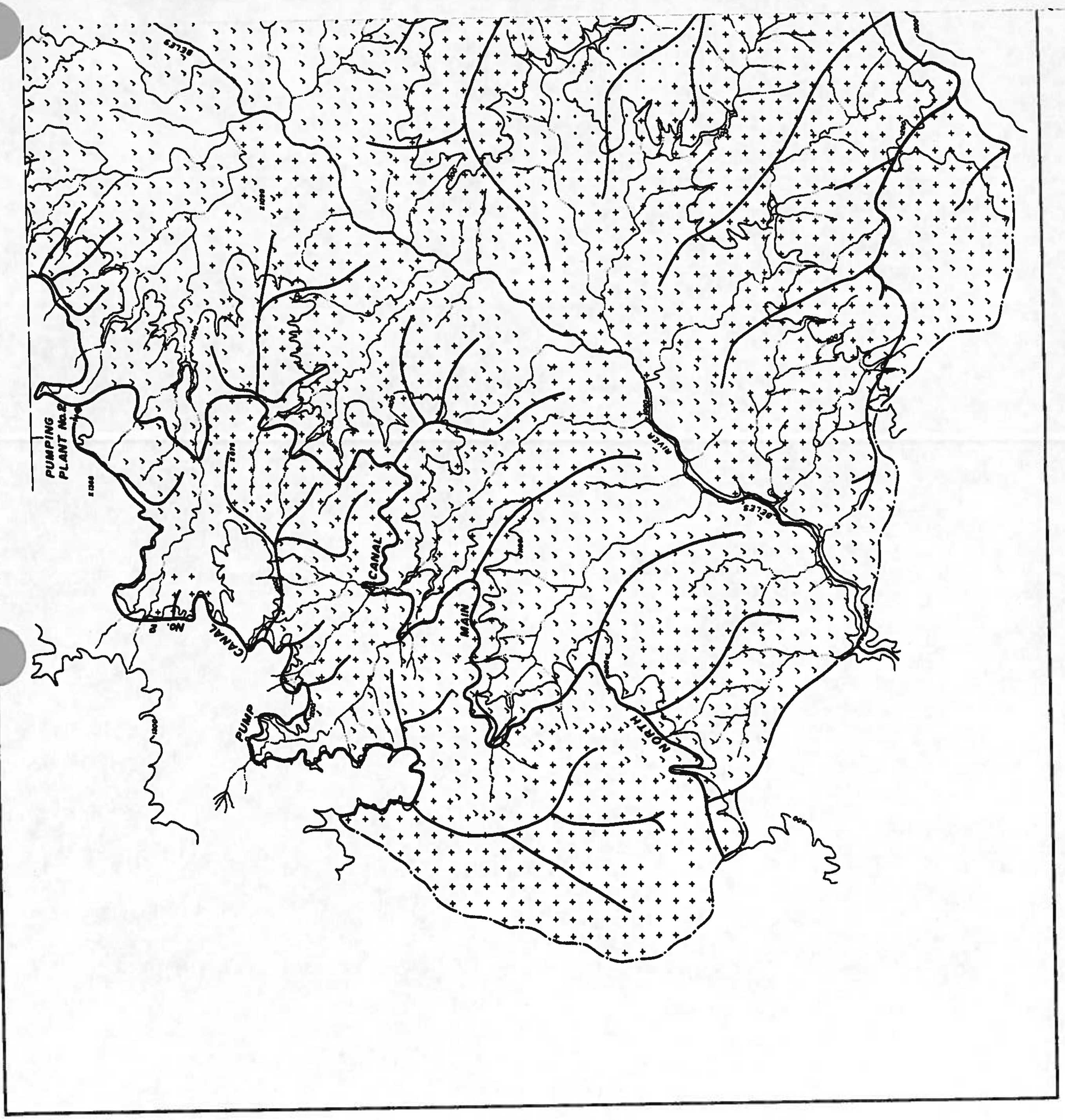


Figure 75--Beles River Project--General Plan, Sheet 1


PUMPING PLANT No.2
BELES
RIVER
CANAL
MAIN
NORTH
CANAL
No. 2
PUMP

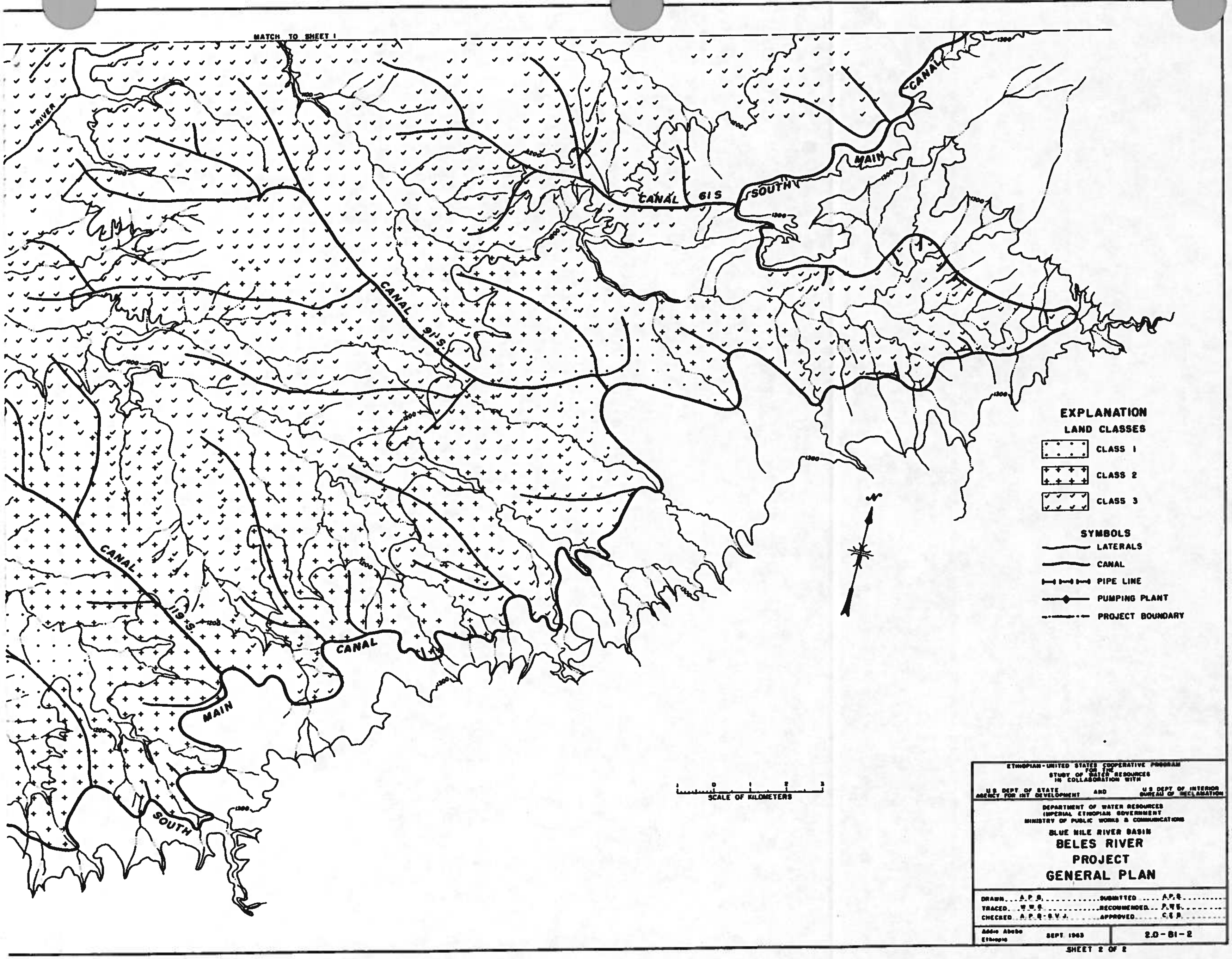


Figure 76--Beles River Project--General Plan, Sheet 2

diversion tunnel, is therefore planned for irrigation and for power production. It is planned to utilize only a portion of the water discharged from the Alefa Powerplant for irrigation, the balance being bypassed to the Dangur Reservoir farther downstream.

Studies of water requirement indicate the diversion requirements would then be 1.57 meters (5.15 feet) annually.

UPPER BELES MULTIPURPOSE PROJECT

The plan envisages the construction of a regulating structure at the outlet of Lake Tana; a diversion tunnel from the southwestern part of Lake Tana to the Beles drainage basin; a power canal leading into a shaft and tunnel; penstocks and a powerplant; an irrigation diversion dam, main canals, and two pumping plants; and a distribution system and drainage canals for irrigation of 63,200 hectares of land and 1,197 million kilowatt-hours of electric generation per year.

A low, masonry-concrete, gravity dam at the outlet of Lake Tana at the southern end of the lake would convert the lake into an artificial reservoir by controlling its maximum level at or near the maximum elevations now recorded.

The stored water would then be diverted by means of a 5.3-meter-diameter concrete tunnel, some 6.7 kilometers in length, to the water-deficient Beles basin. A power canal with a capacity of 110 cubic meters per second would then convey the water along the 1760-meter contour to discharge into a 245-meter drop shaft and tunnel. Four steel penstocks, each of 2.7-meter diameter, would be installed, discharging into the turbines of the Alefa Powerplant with four, 50,000-kw. capacity generators. The transmission lines would carry the generated power to the load centers of Addis Ababa, Gondar, Bahir Dar, and as far west as Metekkel.

Discharging directly into the Beles River channel, the portion of the water required for irrigation would be diverted by the Beles Irrigation Diversion Dam, located some 25 kilometers downstream from the powerplant. Two canals, the North Main Canal and the South Main Canal, would originate at the outlet works on each abutment of the diversion dam. Starting at the 1300-meter contour, the South Main Canal would extend in a southerly direction for 144 kilometers with an initial capacity of 38.8 cubic meters per second. The North Main Canal would also start at the 1300-meter contour and would extend in a southwesterly direction for 143 kilometers. The design capacity for this canal would be 36.1 cubic meters per second. Two pumping plants are included in the development plan to serve an additional 7,600 hectares of land. Pumping Plant No. 1 would be located at Kilometer 87.5, and Pumping Plant No. 2 at Kilometer 105, both on the North Main Canal.

A distribution system to convey the water to the farmers' turnouts and drainage canals to carry away the irrigation waste would be included in the facilities of the Beles Irrigation Unit of the multipurpose project.

LAKE TANA UNIT

The site of the low dam is on the Chara Chara cataracts a few hundred meters downstream from the lake outlet and some distance upstream from the recently completed concrete bridge. It would be a masonry-concrete structure abutted with compacted earthfill dikes and would be gated for practically the entire width of the channel. Plan, elevations, and section of the structure appear on Figure 77.

Dam Data

Type	masonry-concrete gravity
Volume of masonry	7,010 cu. m.
Volume of concrete	2,860 cu. m.
Structural height	9 m.
Hydraulic height	4.57 m.
Length of crest	150 m.
Sill elevation	1783 m.

Dikes and channel improvements will be necessary to contain the floods within the existing channel and to smooth out the approach flows to the regulating structure.

Abutting the concrete-masonry control structure would be compacted earthfill dikes totaling some 750 meters in length. The west dike would make a sharp bend downstream to close off the low sections through the reef for some 500 meters in length; the east dike would also bend somewhat downstream for some 250 meters.

Over 300,000 cubic meters of rock excavation to improve the channel hydraulically are estimated.

Lake Tana reservoir will have an active capacity of 10,604 million cubic meters. The stored water will be used for multiple-purpose development of the Beles drainage basin.

LAKE TANA-BELES DIVERSION TUNNEL AND ALEFA POWERPLANT

Conveyance System

The site for the inlet portal of the diversion tunnel would be on the southwestern shore of the lake on a small bay near the village of Alefa. The tunnel would be concrete lined and free flowing with a finished diameter of 5.3 meters and a capacity of 110 cubic meters per second. It would be about 6,700 meters in length.

Tunnel Data

Type	free flow
Volume of concrete	54,000 cu. m.
Length	6,700 m.
Diameter	5.3 m.
Design capacity	110 cu. m. per sec.

The power canal would be about 12 kilometers in length and would be masonry lined.

Power Canal Data

Type	masonry lined
Length	12 km.
Design capacity	110 cu. m. per sec.
Initial w. s. elevation	1760 m.

From the power canal, the water would be discharged into a vertical shaft which would extend from approximate elevation 1745 meters to elevation 1500 meters, a drop of 245 meters. The tunnel would then continue on the horizontal at elevation 1500 meters for a distance of 1,850 meters.

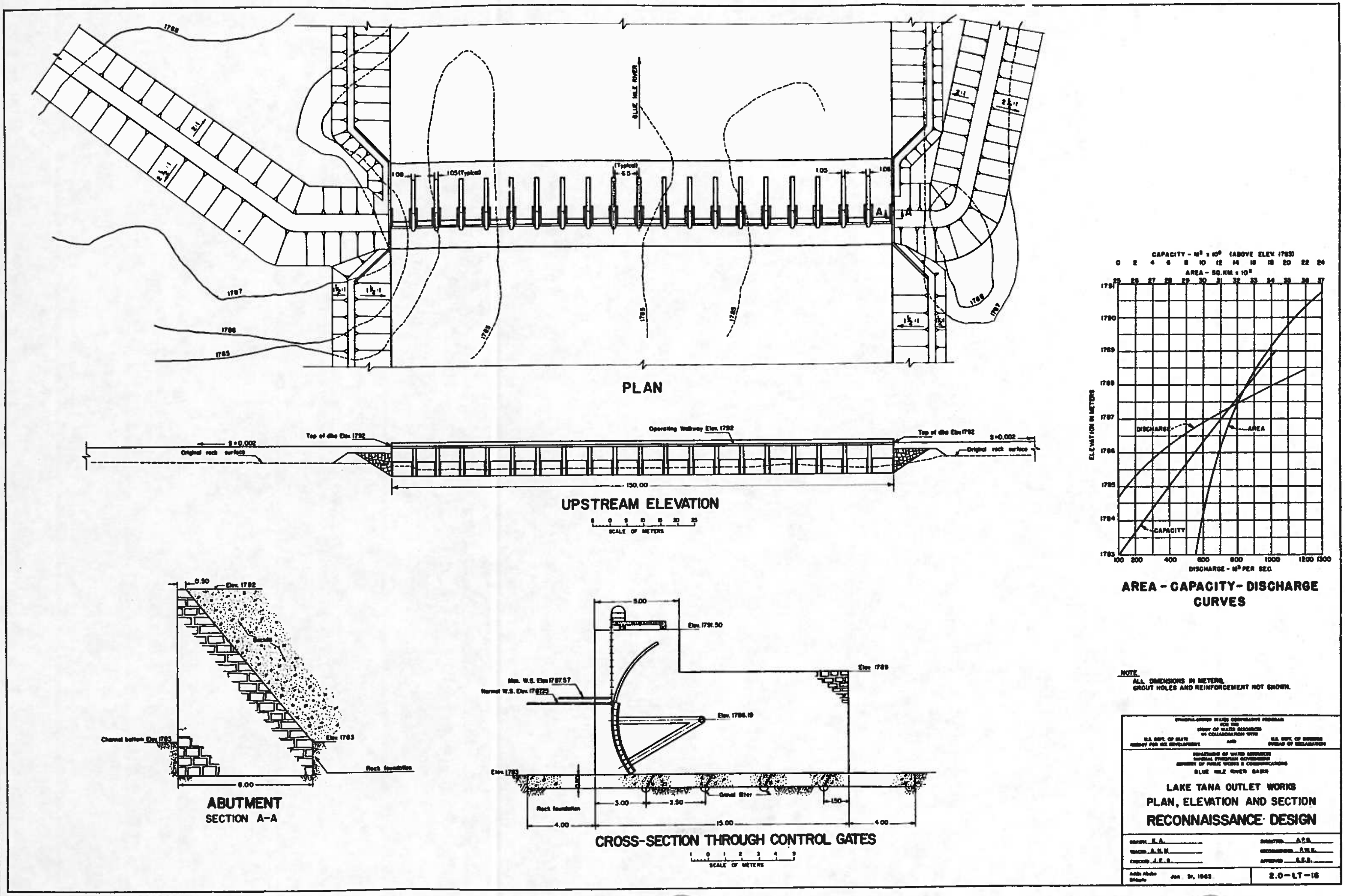


Figure 77--Lake Tana Outlet Works--Plan, Elevation and Section

Date	Unit	Shaft	Pressure tunnel	Two penstock tunnels (ea)	Four penstocks (ea)
Length	m.	245	1,850	1,200	1,200
Diameter	m.	6	6	6.65	2.7
Capacity	cu. m. per sec.	110	110	55	27.5

Penstock and Tunnel Data

Power System

The Alefa Powerplant would be located near the headwaters of the Beles drainage basin, adjacent to the Beles River.

Powerplant Data

Design head	239 m.
Number of generators	4
Rating of each generator	50,000 kw.
Total plant capacity	250,000 kv.-a.
Turbine ratings (English)	70,550 hp.
Synchronous speed	375 r.p.m.
Type of turbines	Francis

The switchyard for the Alefa Powerplant would be located near the powerplant and would include eight bays with single and double breakers with 132-kv. lines.

To transport the energy generated, transmission lines totaling some 758 kilometers are envisioned.

Transmission Lines Data

Facilities		Length (km.)	Voltage (kv.)	Structure (type)	Circuits (No.)
From	To				
Alefa Powerplant	Bahir Dar	65	132	Steel tower	double
Alefa Powerplant	E. Addis Ababa	450	230	Steel tower	double
Bure	Jiga	37	45	Steel pole	single
Bure	Injibira	70	45	Steel pole	single
Injibira	Metekkel	50	45	Steel pole	single
Bahir Dar	Gondar (via Stella)	146	132	Steel tower	single
Stella	Debre Tabor	40	45	Steel pole	single
Alefa Powerplant	Pump No. 2	80	132	Steel tower	single
Pump No. 2	Pump No. 1	8	15	Steel pole	single

Various substations at the terminals of the transmission lines will be required to step down the voltages at the different load centers. The substations would be of the outdoor type with controls and service equipment located indoors.

IRRIGATION UNIT

The general plan of the irrigation features appears on Figures 75 and 76.

The irrigation diversion dam would be located in a narrow canyon on the Beles River about 25 kilometers downstream from the powerplant. It would be a concrete-gravity, ogee type of dam. Two 5.2-meter-diameter short tunnels on either side of the river at elevation 1295 meters are planned, leading into a division structure installed with two slide gates having one opening to the river channel.

Irrigation Diversion Dam Data

Type	concrete-ogee
Volume of masonry concrete	4,908 cu. m.
Structural height	16 m.
Spillway crest length	25 m.
Discharge capacity	960 cu. m. per sec.

The two pumping plants included in the plan of development would be located off the North Main Canal to serve lands situated above the canals that cannot be reached by gravity.

Pumping Plant No. 1 would be located on the western part of the project area on the North Main Canal about 87.5 kilometers from the headworks of the main canal. The plant would provide irrigation water for 3,000 hectares of irrigable land. Power would be supplied from the Alefa Powerplant. A short intake channel for forebay purposes will be required from the North Main Canal.

Pump Data--Plant No. 1

Forebay, w. s. elevation	1137 m.
Total dynamic head	91 m.
Maximum lift	83 m.
Size of discharge pipe (diameter)	1.3 m.
Length of discharge pipe	1,000 m.
Capacity of pumps	3.86 cu. m. per sec.
Motor rating	6,500 hp.

Pumping Plant No. 2 would be located off the North Main Canal, 17.5 kilometers below the first pumping plant and about 105 kilometers from the diversion dam outlet works. The plant would provide irrigation water for 4,600 hectares of irrigable land. Power would be supplied from the Alefa Powerplant. A short intake channel from the North Main Canal will be required for forebay purposes.

Pump Data--Plant No. 2

Forebay, w. s. elevation	1128 m.
Total dynamic head	87 m.
Maximum lift	84 m.
Size of discharge pipe (diameter)	1.5 m.
Length of discharge pipe	300 m.
Capacity of pumps	5.5 cu. m. per sec.
Motor rating	9,225 hp.

Two gravity main canals and two pump canals have been included in the development plan for irrigating the project lands. The topography of the valley is typified by large areas of gently sloping land transected by more or less entrenched stream channels, generally widely spaced. Only in the southern portion of the area are there undulating to gently rolling ridges.

Canal excavation should not present any major problems, but rock may be encountered in some isolated reaches, especially near stream crossings. Canal structures, such as checks, drops, wasteways, turnouts, culverts, bridges, and siphons, would be provided as necessary.

Water will be released through the outlet works located on each side of the Beles Diversion Dam to the North and South Main Canals.

The North Main Canal would originate at the outlet works on the right abutment of the diversion dam. It would extend in a southwesterly direction for 143 kilometers. At Kilometer 59, the canal would start to drop so that at Kilometer 70, the canal would be at elevation 1140 meters. The North Main Canal would irrigate 23,000 hectares by gravity method.

North Main Canal Data

Type	unlined
Length	143 km.
Initial capacity	36.1 cu. m. per sec.
Initial w. s. elevation	1300 m.

Pump Canal No. 1 would originate at Pumping Plant No. 1 and would extend on a westerly direction, following a ridge for a short distance, where it would fork to the north and the south. It would serve 3,000 hectares of land.

Pump Canal No. 1 Data

Type	unlined
Length	30 km.
Initial capacity	3.86 cu. m. per sec.
Initial w. s. elevation	1220 m.

Pump Canal No. 2 would originate at Pumping Plant No. 2 and would extend on a southwesterly direction roughly paralleling the main canal for a distance of about 27 kilometers. The canal would convey water for irrigation of about 4,600 hectares of land.

Pump Canal No. 2 Data

Type	unlined
Length	27 km.
Initial capacity	5.5 cu. m. per sec.
Initial w. s. elevation	1212 m.

The South Main Canal would originate at the outlet works located on the left abutment of the diversion dam. It would extend in a southerly direction, making a loop and terminating near the southwestern portion of the project area. The canal has been designed to serve 32,600 hectares of irrigable land.

South Main Canal Data

Type	unlined
Length	144 km.
Initial capacity	38.8 cu. m. per sec.
Initial w. s. elevation	1300 m.

Construction of a distribution system to spread the water over the project lands will vary according to topography. In the northwestern sector, slopes average about 1.0 to 1.5 percent down the ridges and about 2.0 percent toward the side drainages. Ridges are very broad and long, and construction of a distribution system should not be unduly expensive. The rough alluvial fan area in the northeastern part of the project is subject to considerable flooding and contains numerous isolated high areas which cannot be reached by gravity. The southern half of the project is characterized by an undulating to severely undulating topography. Ridges are the choicest topography for irrigation in this area, but these are usually narrow (50 to 150 meters) and have a slope of 2.0 to 3.0 percent parallel to the ridge. Slopes are steep into the side drainages with 3.0 to 11 percent or greater. Numerous drop structures to stabilize against excessive erosion and numerous flumes and siphons to cross the many drainageways are expected to be required.

Drainage conditions associated with three types of topography are found in the project area. The northwestern area, which has the smoothest topography, can be expected to have the most drainage problems. The northeastern area has a flood plain type of natural drainageways with intermittent, narrow, moderately deep, eroded drainageways. Flood hazards may be the greatest problem here. The approximate southern half of the project has a well developed drainage system, and the need for further drainage is expected to be minimal. Surface drainage canals for the evacuation of irrigation waste and excess precipitation have been provided in the estimates of cost.

Estimated Project Cost

Construction Cost.

Feature	Total construction cost (in Eth$1,000)	Facilities: Joint use	Facilities: Irrigation	Facilities: Power
Lake Tana Dam and Reservoir	6,564	6,564		
Diversion tunnel	43,136	43,136		
Power canal	13,409			13,409
Tunnel and penstocks	74,852			74,852
Alefa Powerplant	17,863			17,863
Switchyard	9,725			9,725
Transmission lines	48,733			48,733
Substations	11,940			11,940
Access road	1,094			1,094
Service facilities--No. 1	1,719			1,719
Beles Diversion Dam	5,956		5,956	
Pumping Plant No. 1	3,327		3,327	
Pumping Plant No. 2	3,980		3,980	
Transmission lines and substations	2,348		2,348	
North Main Canal	22,841		22,841	
Pump canals	2,684		2,684	
South Main Canal	25,133		25,133	
Distribution system	32,588		32,588	
Drainage system	13,825		13,825	
Access road	2,344		2,344	
Service facilities--No. 2	2,656		2,656	
Total	346,717	49,700	117,682	179,335

Development Cost. Clearing of the lands prior to irrigation development will vary in the project area. The northwestern portion has a mixture of open grass savanna and dense groves of bamboo. There are also occasional thickets or clumps of bamboo in the grassland. In the southern half of the project, the principal natural vegetation is woodland savanna composed of various species of acacia, fig, and associated small trees. An average cost of Eth$115 per hectare is estimated for clearing requirements for a total of Eth$7,250,000. Land leveling is expected to be moderate to expensive due to the undulating nature of the topography. Costs are expected to average about Eth$125 per hectare for the 63,200 hectares determined to be suitable for irrigation for a total estimated cost of Eth$7,900,000.

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs for the multipurpose project are estimated to be Eth$6,297,000, including Eth$265,000 for taxes and insurance, as summarized below. Power costs for pumping were assumed to be Eth$0.03 per kilowatt-hour.

TABLE 34—SUMMARY OF CROPS AND GROSS FARM INCOME—UPPER BELES PROJECT, 63,200 HECTARES

Table 34

Crop pattern	Conditions before project: Price received per 100 kg. Eth$	Conditions before project: Pre-project income Eth$	Future conditions, irrigation season: Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Future conditions, nonirrigation season: Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Post-project income Eth$	Gross crop income Eth$
Corn	8.18		9,500	2,780	26,410,000	2,160,340	18,950	1,150	21,792,500	1,782,630	3,942,970	3,942,970
Millet	7.90		6,300	2,915	18,364,500	1,450,800	12,650	950	12,017,500	949,380	2,400,180	2,400,180
Sorghum	11.70		12,700	2,915	37,020,500	4,331,400	-	-	-	-	4,331,400	4,331,400
Chick peas	11.74		3,150	1,450	4,567,500	536,220	9,500	920	8,740,000	1,026,080	1,562,300	1,562,300
Lentils	22.04		3,150	1,450	4,567,500	1,006,680	-	-	-	-	1,006,680	1,006,680
Castor beans	24.62		3,150	1,470	4,630,500	1,140,030	-	-	-	-	1,140,030	1,140,030
Sesame	33.25		6,300	1,175	7,402,500	2,461,330	6,300	700	4,410,000	1,466,320	3,927,650	3,927,650
Sunflower	23.60		3,150	1,760	5,544,000	1,308,380	-	-	-	-	1,308,380	1,308,380
Cotton	28.90		6,300	1,000	6,300,000	1,820,700	-	-	-	-	1,820,700	1,820,700
Peppers	53.93		3,150	900	2,835,000	1,528,920	-	-	-	-	1,528,920	1,528,920
Tobacco	112.60		3,150	2,000	6,300,000	7,093,800	-	-	-	-	7,093,800	7,093,800
Subtotal, crops			60,000			24,838,600	47,400			5,224,410	30,063,010	30,063,010
Fallow			-			-	12,600			-	-	-
Subtotal, cultivated area			60,000			24,838,600	60,000			5,224,410	30,063,010	30,063,010
Noncultivated irrigable area			3,200			-	3,200			-	30,063,010	30,063,010
Total area		76,000	63,200			24,838,600	63,200			5,224,410	30,063,010	29,987,010
Income per hectare		1.20				393.02				82.66	475.68	474.48

Facility	Operation and maintenance	Replace-ments	Power cost
Joint use			
Diversion Tunnel	Eth$ 10,000		
Lake Tana Dam and Reservoir	100,000		
Irrigation Unit			
Conveyance System	2,022,000		
Pumping Plants (2)	160,000	Eth$ 10,000	Eth$1,042,000
Electrical facility to pumping plants	49,000	4,000	
Power Unit			
Power Canal	120,000		
Forebay	5,000		
Tunnel and Shaft	14,000		
Penstock Tunnels	18,000		
Powerplant	1,000,000	52,000	
Penstocks	67,000		
Transmission Plant	1,193,000	166,000	
Other	265,000		
Totals	Eth$5,023,000	Eth$232,000	Eth$1,042,000

Benefit-Cost Ratio

The benefit-cost ratio of this project is 3.04 to 1.00.

MIDDLE BELES POWER PROJECT

Plan of Development

The plan of development for the Middle Beles Power Project includes construction of a dam and reservoir, a 168,000-kw. powerplant, a substation, and transmission lines for an estimated annual generation of 741,700,000 kilowatt-hours.

Project Features

The site of Dangur Dam is about 185 kilometers from the headwaters of the Beles River where the structure would control a drainage area of about 9,000 square kilometers. It would be a double curvature, variable center, thin, concrete arch dam. For bypassing and controlling the river during construction, two 10-meter-diameter concrete-lined tunnels having an average length of 610 meters would be constructed, one on each bank of the river. The tunnels would be plugged after serving their purpose. The tunnels are designed to pass 3,400 cubic meters per second. The general plan and sections are shown on Figures 78 and 79.

Dam Data

Type	concrete thin arch
Mass concrete (volume)	961,500 cu. m.
Top of dam elevation	848.5 m.
Structural height	133.5 m.
Hydraulic height	133.5 m.
Base width at plane of centers	24 m.
Crest length	602 m.
Top width	8 m.

The service spillway would utilize on a convenient saddle near the left abutment of the dam. The control structure would be equipped with two radial-type gates with the discharge channel being open. At maximum water surface elevation of 848.5 meters, the service spillway will discharge 3,850 cubic meters per second. The river outlet works will discharge 198 cubic meters per second and the powerplant an additional 174 cubic meters per second for passing a combined total flood of 4,222 cubic meters per second.

Spillway Data

Type	gated open channel
Crest elevation	824.5 m.
Maximum capacity	3,850 cu. m. per sec.
Inflow design flood peak-- 6-day period	1,310,000,000 cu. m.
Type of gates (2)	radial

Four power outlet works are planned to drive the four turbines of the powerplant. A penstock would lead into the powerplant. In addition to these outlet works, two river outlet works located to the right of the power outlets are planned for greater operational efficiency. Figures 78 and 79 show location and details of outlet works.

The reservoir basin is considered to be excellent for storage purposes, as it is mantled with impervious clay material. Some clearing will be required. Initial active capacity of the reservoir to elevation 845 meters would be 3,408 million cubic meters with inactive and dead storage of 566 million cubic meters. The selected site is on Precambrian metamorphic rock considered to be suitable for the structure planned.

A cursory examination of the immediate vicinity did not reveal any natural deposits of aggregate materials for making concrete, but concrete aggregates can be crushed from quarried rock available in abundant quantities.

Construction of 8 kilometers of access road to the potential damsite will be required.

The powerhouse is at the downstream toe of the dam.

Powerplant Data

Minimum head	54.25 m.
Design head	87 m.
Number of generators	4
Rating of each generator	42,000 kw.
Total plant capacity	168,000 kw.
Turbine rating (English)	59,263 hp.
Synchronous speed	176.5 r.p.m.
Type of turbine	Francis

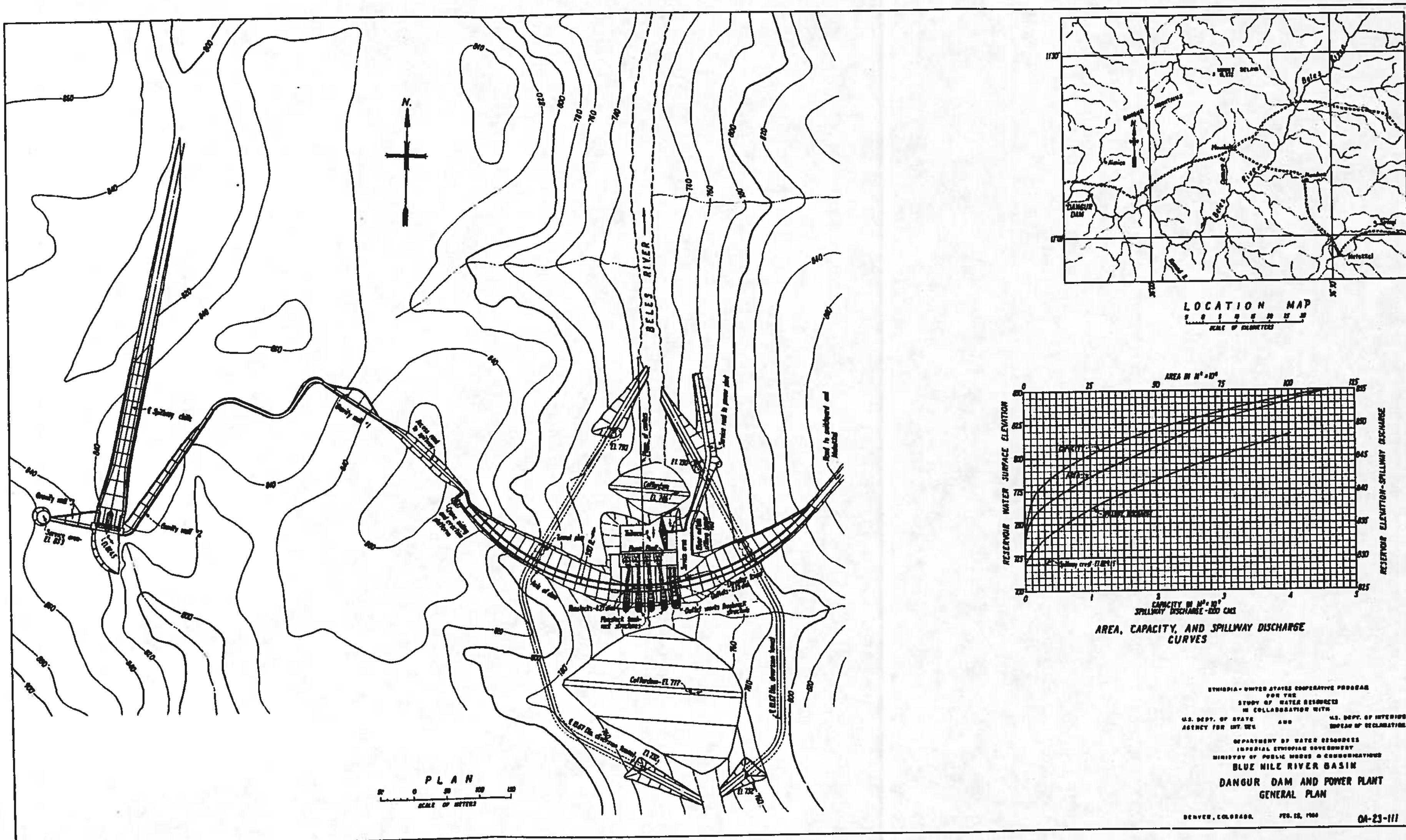


Figure 78--Dangur Dam and Powerplant--General Plan

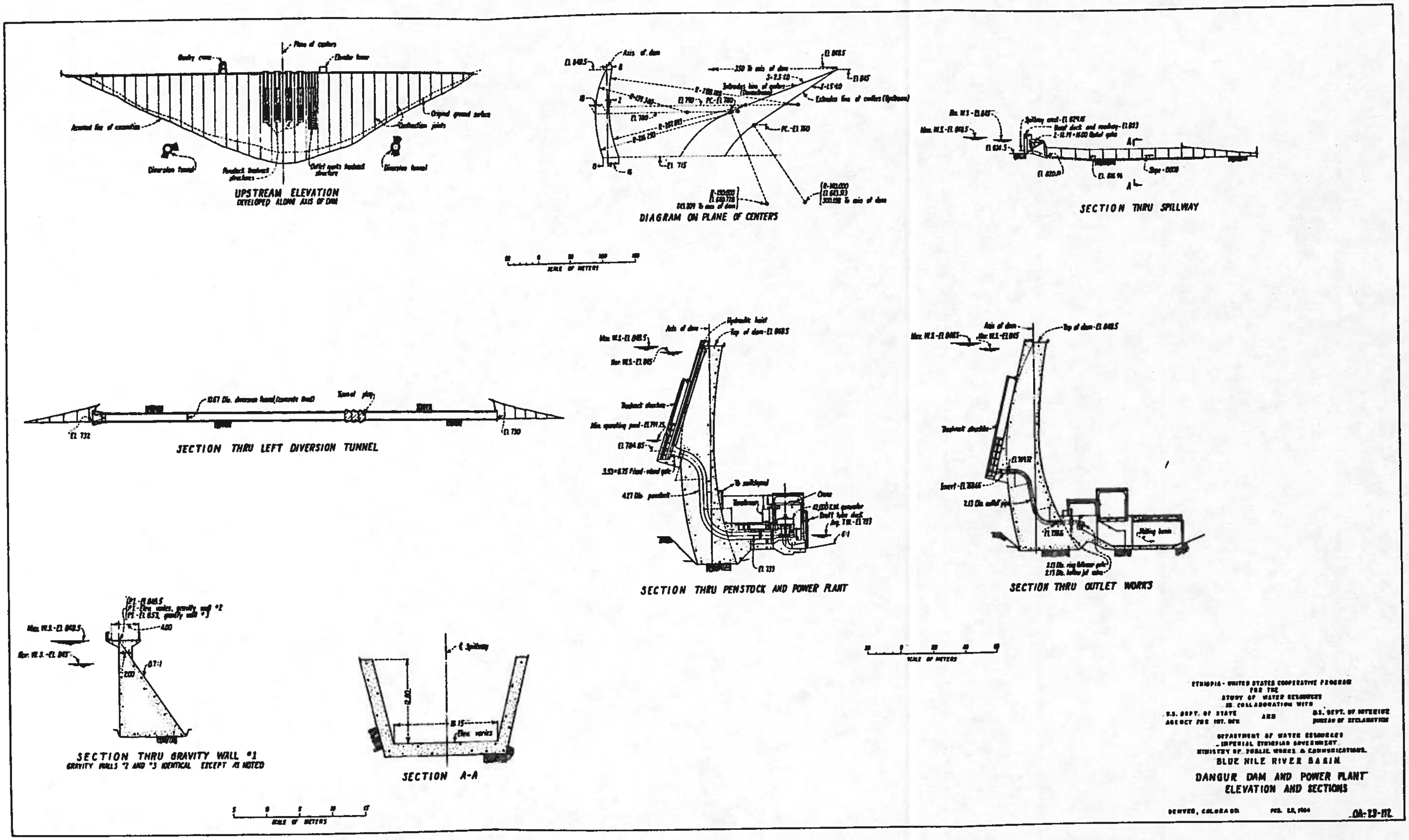


Figure 79--Dangur Dam and Powerplant--Elevation and Sections

Estimated Project Cost

Construction Cost.

Feature	Cost
Dangur Dam and Reservoir	Eth$149,963,000
Powerplant	33,750,000
Transmission lines, switchyard, and substation	26,090,000
Access road	250,000
Service facilities	3,684,000
Total Construction Cost	Eth$213,737,000

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$2,264,000, including Eth$315,000 for taxes and insurance, as summarized below.

Facility	Operation and maintenance	Replace-ments
Dam and Reservoir	Eth$ 100,000	
Powerplant	900,000	Eth$101,000
Penstocks	4,000	
Transmission plant	737,000	107,000
Other	315,000	
Totals	Eth$2,056,000	Eth$208,000

Benefit-Cost Ratio

The benefit-cost ratio of this project is 2.58 to 1.00.

Projects In The Debre Markos Sub-Basin

GENERAL DESCRIPTION

The Birr River area is a segment of the Debre Markos plateau in the central portion of the Blue Nile Basin, northwest of Debre Markos, the capital of Gojjam Province. The area is drained by many streams and is characterized by large stretches of gently rolling hills and wide grassy valleys surrounded by mountainous, severely eroded terrain. Because of their pleasant climate, the plateau valleys are relatively heavily populated in contrast to the sparsely settled lower plains.

The plan envisions a stage development of the area into two main projects--the Upper Birr Project and the Debohila Project. A third, the Lower Birr Project, is also proposed but is dependent upon prior construction of the Upper Birr Project so that the return flow from that development may be used to firm up the water supply of the Lower Birr Project.

The Birr River area is one of the valleys in the plateau, situated at an average of about 1820 meters (5300 feet) above sea level. The Birr River with its many tributaries drains an area of about 5,400 square kilometers (2,000 square miles). The area lies on a bench within the drainage area of the Birr River and its tributaries which rise along the southern slopes of the Chokke Mountains and flow southward before joining the Birr River.

Geology and Physiography

The Birr River area is part of the volcanic plateau. Geologically, the area is characterized by a thick capping of Tertiary and late Cretaceous volcanic rocks, with more recent lava flows in evidence in some sectors. The volcanic strata are underlain by sedimentary sandstones and shales of the Triassic age. The underlying basement complex includes Precambrian granites, gneisses, and schists. The volcanic understrata, which served as parent material for the majority of the soils, consist predominantly of basaltic lavas with minor amounts of rhyolitic lava, tuff, and ash.

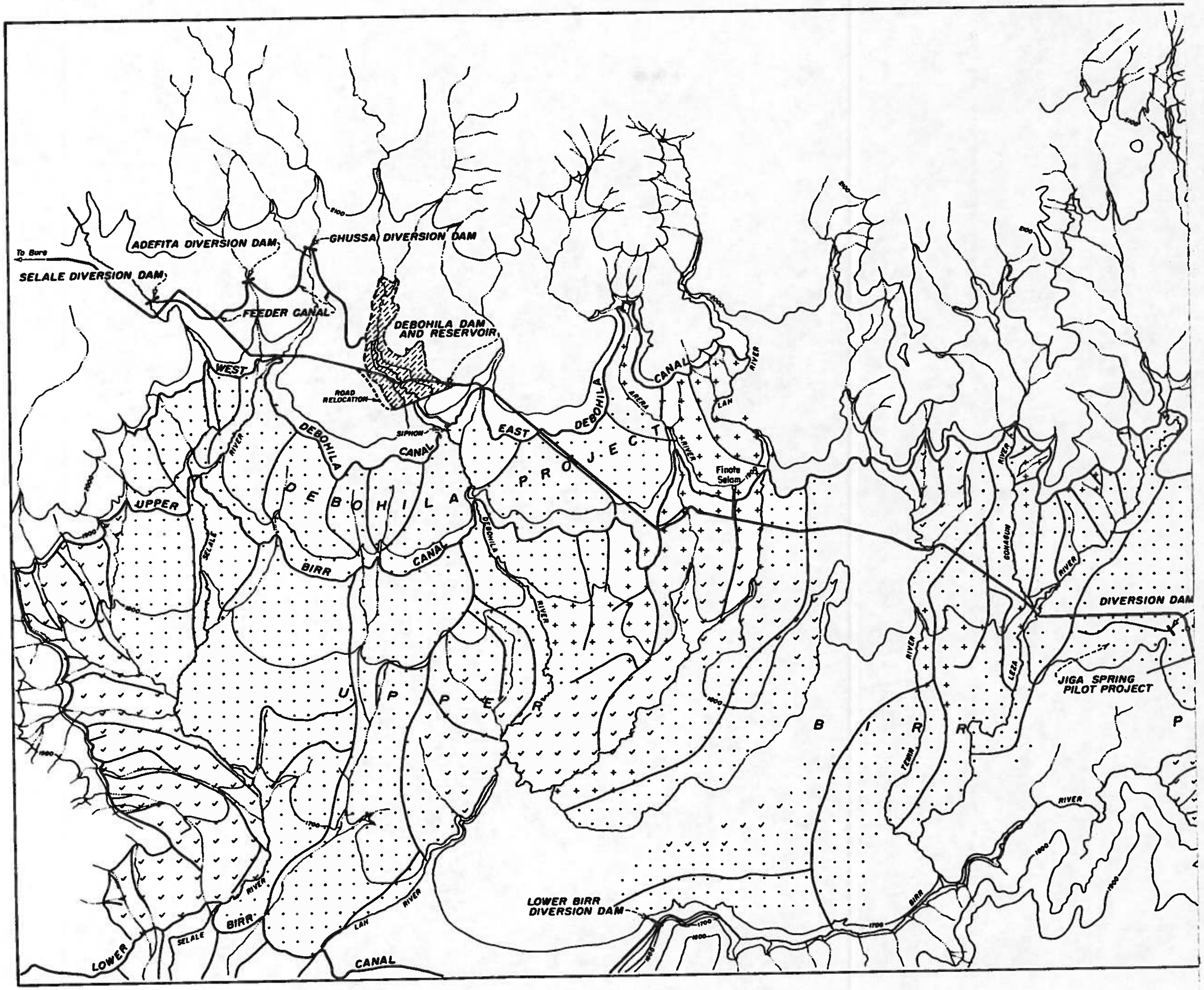
Physiographically, the area consists of a gently sloping upland, dissected to a limited extent by small streams and drainageways. Lowlying, flat, poorly drained land and rolling to hilly terrain comprise a sizable portion of the area.

Climate

There is no climatic station in the project area. However, at Dangila, which corresponds closely to the same elevation, the average annual rainfall is approximately 145 centimeters (57 inches). The majority of the precipitation falls during July and August, the period of the "big" rains. Average annual temperature is estimated at 18° C. (65° F.). The coldest months are December and January, while the warmest are March, April, and May.

Project Land

The soils of the Birr area may be grouped into two broad categories, based on physiographic position: (1) upland, red, latosolic soils, and (2) lower-lying, dark clays (grumusols). Upland soils are the most extensive group and comprise the best quality arable lands. They have developed in places from underlying volcanic materials, principally basaltic lava, tuff, and ash. The latosolic soils are easily tilled, are permeable, and have moderate water-holding capacities and are well suited for irrigation agriculture. The dark gray grumusols have slow rates of permeability, high water-holding capacity,



To Bure
SELALE DIVERSION DAM
ADEFITA DIVERSION DAM
GHUSSA DIVERSION DAM
FEEDER CANAL
DEBOHILA DAM AND RESERVOIR
ROAD RELOCATION
SIPHON
WEST
DEBOHILA CANAL
EAST DEBOHILA CANAL
DEBOHILA PROJECT
UPPER BIRR CANAL
UPPER BIRR PROJECT
ARERA
LAN RIVER
Finote Selam
SOHABUN RIVER
LEZA
TEMIR RIVER
DIVERSION DAM
JIGA SPRING PILOT PROJECT
LOWER BIRR DIVERSION DAM
LOWER SELALE BIRR LAN RIVER CANAL

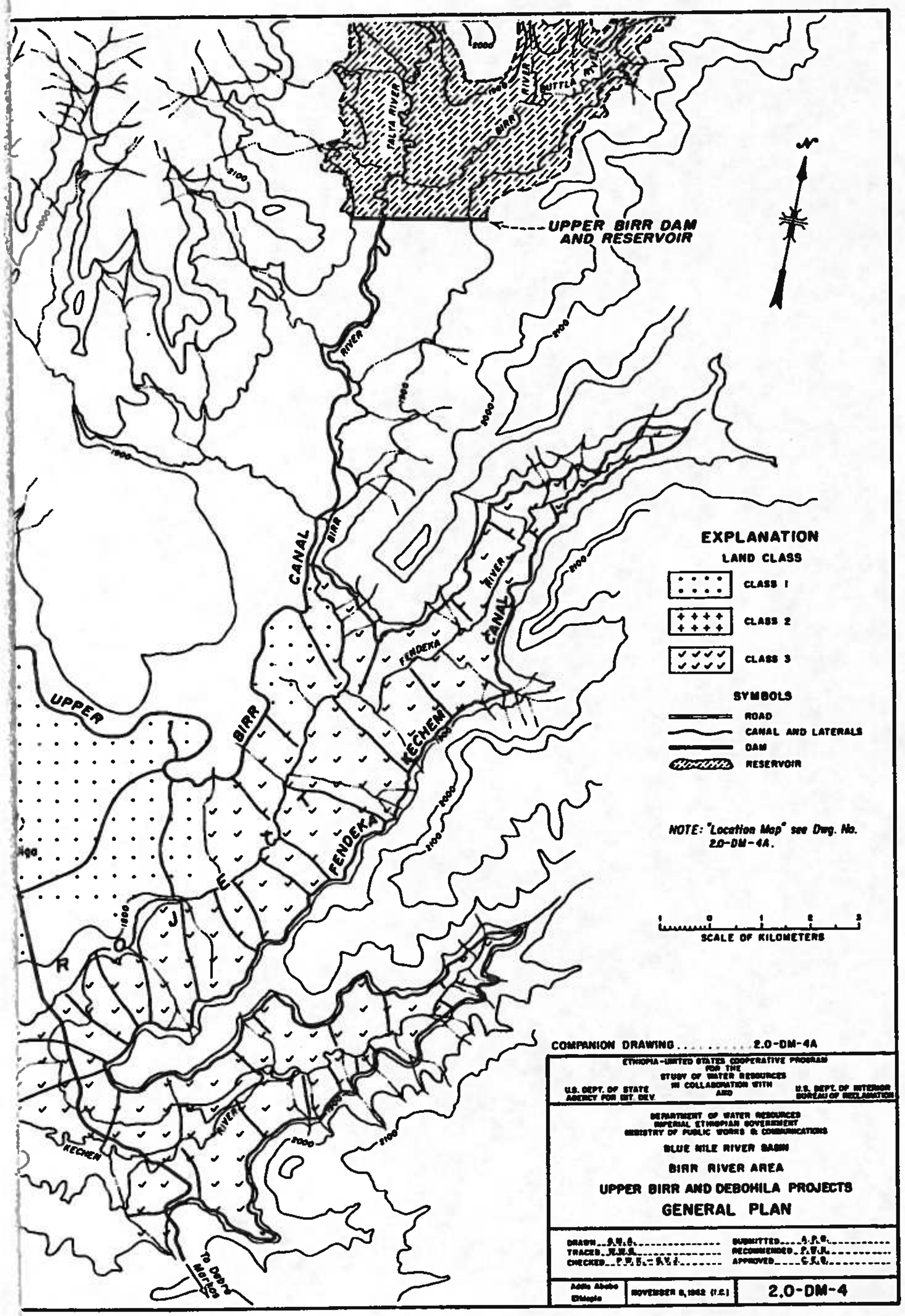


Figure 80--Upper Birr and Debohila Projects--General Plan

and moderate amounts of organic matter and total nitrogen. These soils appear to be only moderately well suited for irrigation agriculture because of the heavy texture and moderate to poor drainage features.

The following table summarizes the land classification for this area.

Land Classes

Class	Areas in hectares						
	Total arable	Arable under canal	Irrigable land by projects				
			Upper Birr	Debo-hila	Lower Birr	Jiga Spring
1	22,767	22,465	13,150	3,240	300	224
2	8,577	3,520	1,700	960	-	-
3	36,240	20,980	9,500	-	6,300	-
Presently irrigated	2,188	-	-	-	-	-
Total	69,772	46,965	24,350	4,200	6,600	224

Hydrology

The Birr River area has some 11 streams, which, if all the flow could be stored, would produce enough water to irrigate most of the land. However, it was found that the area lacked good storage sites and shortages on the irrigation projects will occur if water years similar to the 1912-1917 cycle occur. The project plan involves tapping the Selale, Adefita, and Ghussa streams into the Debohila Reservoir for the Debohila Project. The 55,500,000 cubic meters available annually in average water years will provide an adequate water supply. For the Upper Birr Project, flows from the Talya River, a tributary, and the Birr River itself are planned to be utilized. In normal water years, the yield from these two rivers was determined to be about 298,770,000 cubic meters. For the Lower Birr Project, the flows from the Birr River and its tributaries below the upper storage site have been planned to be utilized, plus the return flows from the Upper Birr Project.

The farm delivery requirements for the Debohila and the Upper Birr Projects lands have been determined to be 0.859 meter annually and for the Lower Birr Project, 0.929 meter annually.

UPPER BIRR PROJECT

Plan of Development

The plan of development for the Upper Birr Project includes a storage dam, two main canals, a lateral distribution system, and drainage canals for irrigation of 24,350 hectares of land.

Storage would be provided by the potential Upper Birr Dam and Reservoir. Water would be released into the Upper Birr Main Canal from the outlet works on the right (west) abutment of the dam. It would extend in a south and westerly direction for a total distance of 87 kilometers.

Project Features

The features of the project plan are shown on Figure 80. The damsite is on the Birr River about 1 kilometer downstream from its confluence with the Talya River. It would be a single-purpose earth and rock fill dam for irrigation, providing a total of 537,400,000 cubic meters of initial storage. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit. Figure 81 is a plan of the dam and appurtenant structures.

Dam Data

Type	earth-rockfill
Embankment volume (earth)	9,900,000 cu. m.
Embankment volume (rock)	2,900,000 cu. m.
Top of dam elevation	1928 m.
Freeboard	1.64 m.
Structural height	48.00 m.
Hydraulic height	46.36 m.
Length of crest	3,700 m.
Width of crest	10 m.

A side-channel ungated spillway having a 90-meter crest length would pass 822 cubic meters per second.

Spillway Data

Type	uncontrolled side channel
Spillway crest elevation	1923.56 m.
Inflow design flood peak	2,059 cu. m. per sec.
Total flood volume--2-1/2-day period	122,000,000 cu. m.
Discharge at maximum w.s. elevation	822 cu. m. per sec.

To release the water needed for irrigation, an outlet works discharging into the main canal has been provided on the right abutment of the dam. The water would be conveyed through a concrete conduit to the gate chamber, about midway in the dam, with a high pressure gate installed for emergency purposes. A horseshoe conduit would then be constructed to house the steel outlet pipe, and a control structure equipped with a high pressure gate and a stilling basin to dissipate the high energy flows before entering the main canal would complete the outlet works.

Outlet Works Data

Sill elevation	1884 m.
Capacity at minimum operating w.s. elevation	8.37 cu. m. per sec.
Type of gates	high pressure

The reservoir basin is in older plateau volcanics, well blanketed with impermeable material, and seepage should not be a serious factor. It is believed to be underlain by older volcanic rock. At normal water surface elevation of 1923.56 meters, the active storage capacity at the end of 50 years would be 519.4 million cubic meters, 18 million cubic meters of sediment being expected by that time.

Bedrock crops out at several places along the damsite axis, and overburden along the steeper slopes is probably quite shallow. The foundations will be entirely underlain by the older volcanics, which consist of basaltic flows with some softer, interbedded ash and tuff. The basalt is vertically jointed and blocky and weathers readily on exposed surfaces, but within a depth of about 2 meters it probably becomes quite sound.

Several kilometers downstream from the site are small, isolated gravel bars that may be a suitable source of pervious materials and aggregate. However, it is anticipated that the major source of pervious material will be weathered basalt from selected quarry sites near the damsite. Riprap is available at the damsite from the basaltic flows. Impervious fill material can be found almost anywhere in the vicinity of the proposed site.

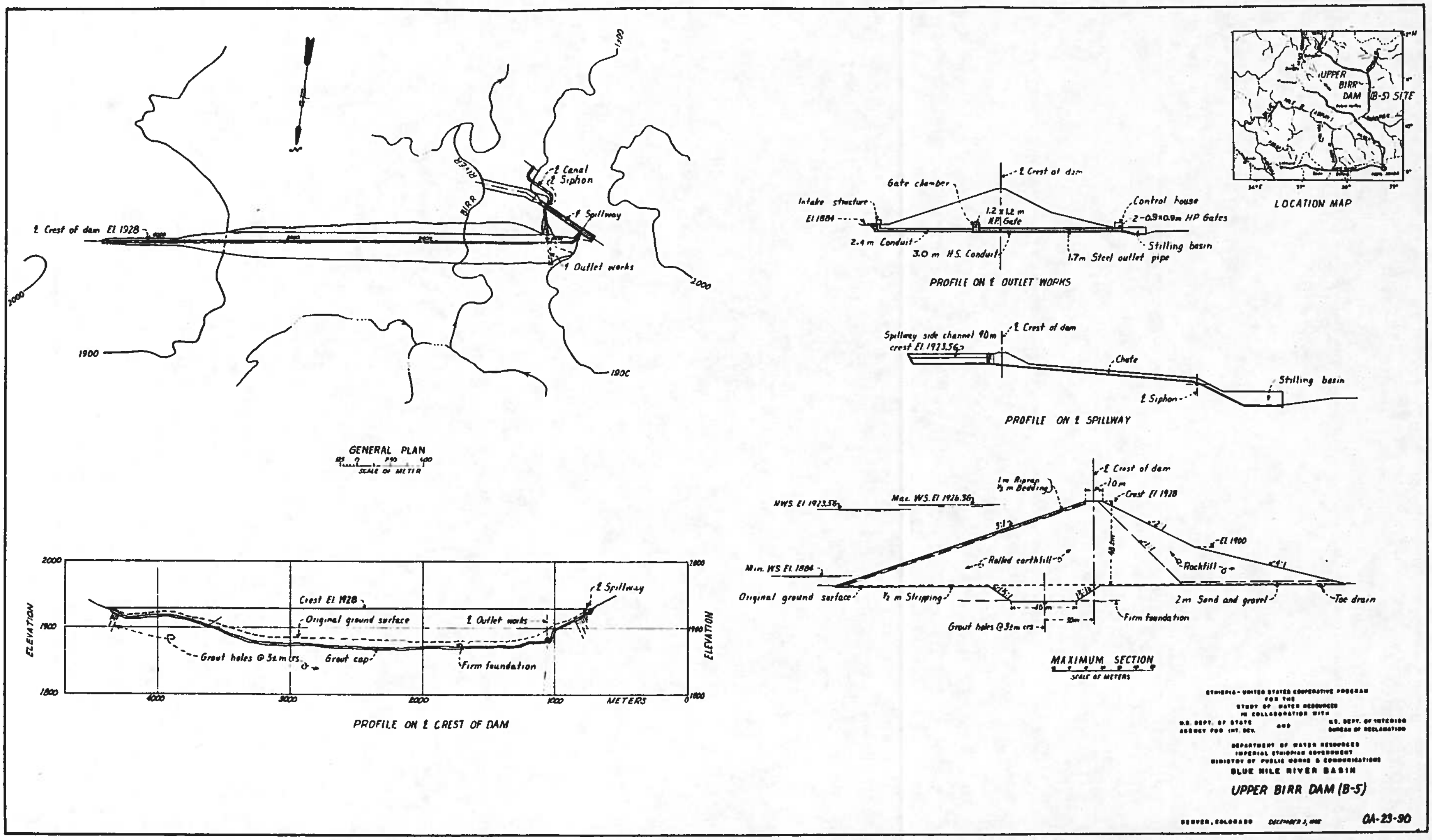


Figure 81--Upper Birr Dam (B-5)--Plan and Sections

TABLE 35–SUMMARY OF CROPS AND GROSS FARM INCOME–UPPER BIRR PROJECT, 24,350 HECTARES

Table 35

Crop pattern	Conditions before project					Future conditions, irrigation season				Future conditions, nonirrigation season					
	Crop distribution ha.	Yield kg./ha.	Production kg.	Price received per 100 kg. Eth$	Pre-project income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Postproject income Eth$	Gross crop income Eth$
Barley	1,360	588	799,680	12.23	97,800	4,870	2,150	10,470,500	1,280,540	3,650	1,000	3,650,000	446,400	1,726,940	1,629,140
Corn	2,240	740	1,657,600	9.53	157,970	-	-	-	-	-	-	-	-	-	-157,970
Millet	2,270	722	1,638,940	9.25	151,600	-	-	-	-	-	-	-	-	-	-151,600
Sorghum	-	-	-	13.05	-	3,650	2,480	9,052,000	1,181,290	-	-	-	-	1,181,290	1,181,290
Teff	2,310	747	1,725,570	22.02	379,970	-	-	-	-	6,080	850	5,168,000	1,137,990	1,137,990	758,020
Wheat	-	-	-	20.25	-	4,870	2,150	10,470,500	2,120,280	3,650	975	3,558,750	720,650	2,840,930	2,840,930
Field peas	190	750	142,500	12.95	18,450	1,220	1,230	1,500,600	194,330	1,220	780	951,600	123,230	317,560	299,110
Horse beans	150	647	97,050	10.55	10,240	1,220	1,230	1,500,600	158,310	1,220	780	951,600	100,400	258,710	248,470
Castor beans	-	-	-	25.97	-	2,430	1,250	3,037,500	788,840	-	-	-	-	788,840	788,840
Flaxseed	-	-	-	20.49	-	-	-	-	-	1,220	560	683,200	139,990	139,990	139,990
Noog	970	550	533,500	21.43	114,330	2,430	1,000	2,430,000	520,750	-	-	-	-	520,750	406,420
Coffee	-	-	-	161.19	-	1,220	790	963,800	1,553,550	1,220	-	-	-	1,553,550	1,553,550
Peppers	710	573	406,830	55.28	224,900	1,220	765	933,300	515,930	-	-	-	-	515,930	291,030
Subtotal, crops	10,200				1,155,260	23,130			8,313,820	18,260			2,668,660	10,982,480	9,827,220
Fallow	5,730				-	-			-	4,870			-	-	-
Subtotal, cultivated area	15,930				1,155,260	23,130			8,313,820	23,130			2,668,660	10,982,480	9,827,220
Noncultivated irrigable area	8,420				350,000	1,220			-	1,220			-	-	-350,000
Total area	24,350				1,505,260	24,350			8,313,820	24,350			2,668,660	10,982,480	9,477,220
Income per hectare					61.82				341.43				109.60	451.03	389.21

Access to the proposed damsite would have to be provided. The terrain from the town of Jiga to the site is gently rolling and would not require excessive costs for road construction. The length of the road is estimated to be approximately 15 kilometers.

In general, the proposed canals would traverse relatively smooth, evenly sloped land, although numerous rivers, draws, and ravines would be encountered and suitable structures would have to be provided to protect the canal from high flows during the rainy season. Flat cross slopes would be found throughout most of the length, but in a few reaches the cross slope would be quite steep.

Canal excavation will not present any major problems, but some rock excavation will be required in several reaches. The soils along most of the length of the canal are satisfactory for canal construction.

The Upper Birr Main Canal would start at the outlet works on the right (west) abutment of the dam and extend in a southwesterly direction for about 87 kilometers, terminating near the Selale River. It would serve approximately 20,600 hectares of irrigable land.

Canal Data

Type	unlined
Length	86.9 km.
Initial capacity	34 cu. m. per sec.
Initial w. s. elevation	1880 m.

The Fendeka-Kechem Main Canal would originate at the bifurcation works about 8 kilometers downstream from the outlet works. It would terminate near the Kechem River after traversing a distance of some 57 kilometers and would serve approximately 3,750 hectares.

Canal Data

Type	unlined
Length	57 km.
Initial capacity	5.7 cu. m. per sec.

The distribution system would consist of a number of main laterals and many small sublaterals, all of which is estimated to cost Eth$515 per hectare. Open, interceptor drainage canals to carry off the irrigation waste and excess precipitation nave been included.

Estimated Project Cost

Construction Cost.

Feature	Estimated cost
Upper Birr Dam and Reservoir	Eth$103,753,000
Upper Birr Main Canal	13,016,000
Fendeka-Kechem Canal	2,238,000
Distribution system	12,556,000
Drainage canals	5,327,000
Service facilities	3,125,000
Access roads	703,000
Total construction costs	Eth$140,718,000

Development Cost. Clearing the lands of trees and brush will cost about Eth$58 per hectare for a total of Eth$1,412,000 for 24,350 hectares. Land leveling costs per hectare should approximate Eth$125 for a total estimated cost of Eth$3,044,000.

Operation, Maintenance, and Replacement Cost. The estimated cost of operation, maintenance, and replacement costs for the dam and reservoir are Eth$25,000 annually. Annual OM&R costs for the canals and distribution system, including the headquarters facilities and roads, are estimated to be about Eth$785,000.

Benefit-Cost Ratio

The benefit-cost ratio for this project is 1.00 to 1.00.

DEBOHILA PROJECT

Plan of Development

The Debohila Project development plan includes a storage dam, three diversion dams, a feeder canal, a lateral distribution system, and drainage canals for irrigation of 4,200 hectares of land. The potential Debohila Dam and Reservoir would provide storage for the project. The three diversion dams and the feeder canal would divert the flows from the Selale, Adefita, and Ghussa Rivers into the Debohila Reservoir. The West Debohila and East Debohila Canals, each about 17 kilometers in length, would convey the water by gravity to the distribution system and thence to the farmers' headgates.

Project Features

The features of the project are shown on Figure 80. The site of the Debohila Dam is about one-half kilometer south of the main road between the towns of Finote Selam and Bure. It would be a single-purpose rolled earth dam for irrigation. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit. See Figure 82 for plan, sections, and profile of the dam.

Dam Data

Type	earth-rockfill
Embankment volume (earth)	1,800,000 cu. m.
Embankment volume (rock)	2,000,000 cu. m.
Top of dam elevation	2024.5 m.
Freeboard	2.2 m.
Structural height	59.5 m.
Hydraulic height	57.3 m.
Length of crest	1,800 m.
Width of crest	10 m.

The spillway design was based on a peak inflow estimated at 428 cubic meters per second, with a 1-3/4-day volume of 18.4 million cubic meters.

Spillway Data

Type	side channel
Crest elevation	2020.4 m.
Inflow design flood peak	428 cu. m. per sec.
Total flood volume, 1-3/4-day period	18,400,000 cu. m.
Discharge at maximum w.s. elevation	308 cu. m. per sec.

The outlet works on the left abutment of the dam would discharge into the feeder canal.

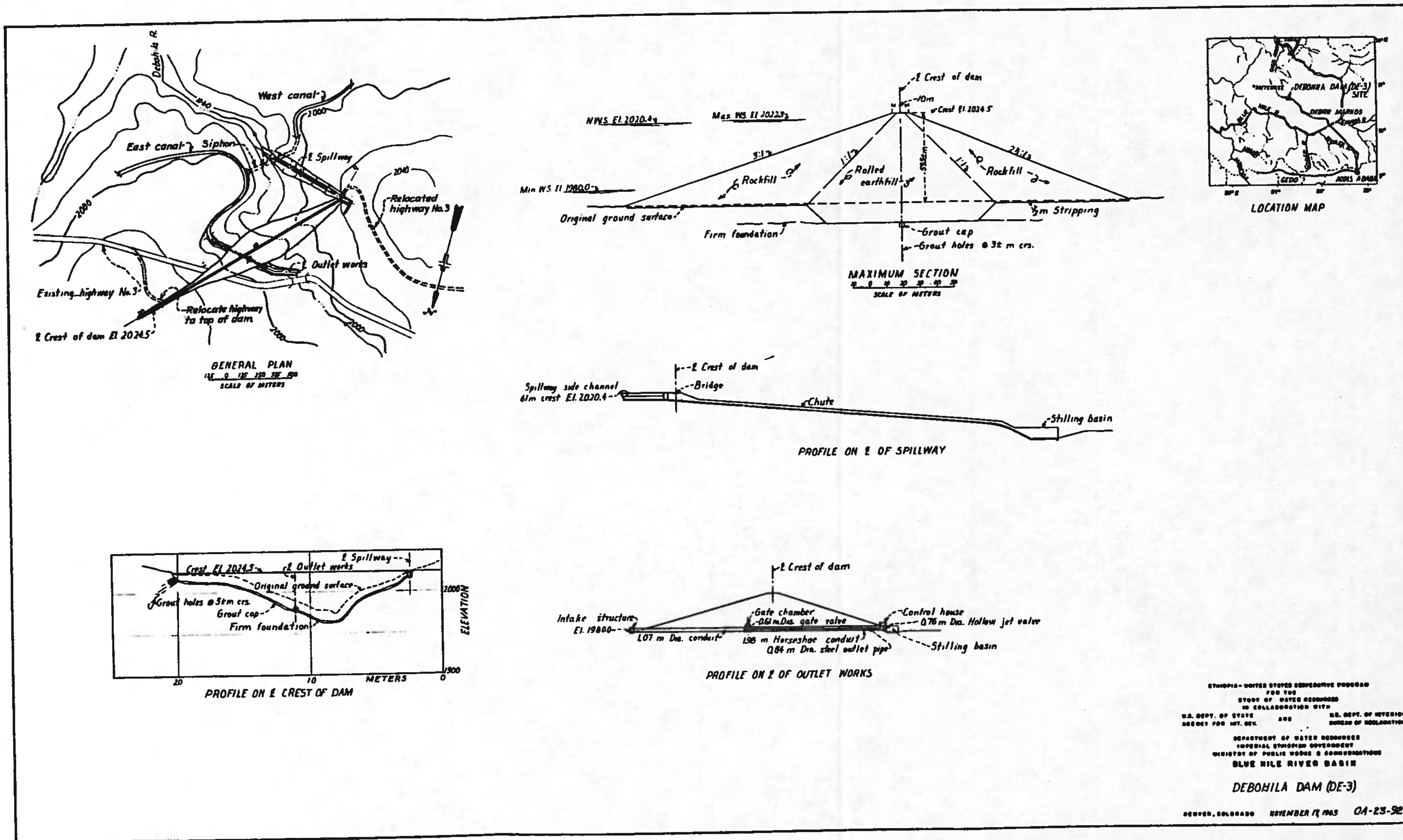


Figure 82--Debohila Dam (DE-3)--Plan and Sections

TABLE 36--SUMMARY OF CROPS AND GROSS FARM INCOME--DEBOHILA PROJECT, 4,200 HECTARES

Table 36

Crop pattern	Conditions before project					Future conditions, irrigation season				Future conditions, nonirrigation season				Postproject income Eth$	Gross crop income Eth$
	Crop distribution ha.	Yield kg./ha.	Production kg.	Price received per 100 kg. Eth$	Preproject income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Barley	235	588	138,180	11.98	16,550	840	2,150	1,806,000	216,360	630	1,000	630,000	75,470	291,830	275,280
Corn	385	740	284,900	9.28	26,440	-	-	-	-	-	-	-	-	-	-26,440
Millet	390	722	281,580	9.00	25,340	-	-	-	-	-	-	-	-	-	-25,340
Sorghum	-	-	-	12.80	-	630	2,480	1,562,400	199,990	-	-	-	-	199,990	199,990
Teff	400	747	298,800	21.77	65,050	-	-	-	-	1,050	850	892,500	194,300	194,300	129,250
Wheat	-	-	-	20.00	-	840	2,150	1,806,000	361,200	630	975	614,250	122,850	484,050	484,050
Field peas	35	750	26,250	12.70	3,330	210	1,230	258,300	32,800	210	780	163,800	20,800	53,600	50,270
Horse beans	25	647	16,170	10.30	1,670	210	1,230	258,300	26,600	210	780	163,800	16,870	43,470	41,800
Castor beans	-	-	-	25.72	-	420	1,250	525,000	135,030	-	-	-	-	135,030	135,030
Flaxseed	-	-	-	20.24	-	-	-	-	-	210	560	117,600	23,800	23,800	23,800
Noog	170	550	93,500	21.18	19,800	420	1,000	420,000	88,960	-	-	-	-	88,960	69,160
Coffee	-	-	-	160.94	-	210	790	165,900	267,000	210	-	-	-	267,000	267,000
Peppers	120	573	68,760	55.03	37,840	210	765	160,650	88,410	-	-	-	-	88,410	50,570
Subtotal, crops	1,760				196,020	3,990			1,416,350	3,150			454,090	1,870,440	1,674,420
Fallow	990				-	-			-	840			-	-	-
Subtotal, cultivated area	2,750				196,020	3,990			1,416,350	3,990			454,090	1,870,440	1,674,420
Noncultivated irrigable area	1,450				61,000	210			-	210			-	-	-61,000
Total area	4,200				257,020	4,200			1,416,350	4,200			454,090	1,870,440	1,613,420
Income per hectare					61.19				337.22				108.12	445.34	384.15

Outlet Works Data

Sill elevation	1980 m.
Capacity at minimum operating w. s. elevation	1.55 cu. m. per sec.
Type of gate valve	wedge
Size of outlet (hollow-jet)	0.76 m.

The reservoir area is well blanketed with impermeable material and seepage is expected to be at a minimum. Initial storage capacity at normal water surface elevation of 2020.4 meters would be 50,140,000 cubic meters covering an area of a little over 3 square kilometers.

Although rock is not exposed along the selected dam axis, bedrock is believed to be massive, fairly hard basalt with possibly some softer interflow zones of ash and tuff. With a cutoff trench and grouting, no serious seepage problem should be encountered. Overburden at the site is the typical, red, silty, plastic clay. The depth of this material may approach 12 meters in some places along the axis of the dam and average as much as 8 meters.

Unlimited quantities of impervious material are available near the site. Sand or gravel is not available within economical haul distance. Basaltic rock is plentiful for riprap and other purposes near the immediate vicinity.

For providing sufficient water supply for the Debohila Project, the Debohila Feeder Canal and the three diversion dams located on the Selale, Adefita, and Ghussa Rivers are necessary. The diversion dams would all be stone masonry, ogee-type structures with suitable provision for sluicing. The feeder canal would follow approximately along the 2030-meter contour in order to pass through the saddle on the west side of the Debohila Reservoir.

Feeder Canal Data

Type	unlined
Length	9.0 km.
Initial capacity	2.0 cu. m. per sec.
Discharge capacity	5.0 cu. m. per sec.
Initial w. s. elevation	2030 m.

Diversion Dams Data

Item	Unit	Selale	Adefita	Ghussa
Type	-	masonry ogee overflow		
Volume of masonry	cu. m.	2,846	1,098	5,498
Spillway crest length	m.	25	15	20
Crest length	m.	104	71	234
Structural height	m.	4	3.7	6.6

The East Debohila Canal would begin at the Debohila Dam, and it would be necessary for the West Debohila Canal to be siphoned across Debohila River.

The canals would be similar in design and would cross terrain similar to that crossed by the Upper Birr Main Canal.

East Debohila Canal Data

Type	unlined
Length	17 km.
Initial capacity	7.5 cu. m. per sec.
Initial w. s. elevation	1980 m.

West Debohila Canal Data

Type	unlined
Length	16.5 km.
Initial capacity	3.5 cu. m. per sec.

Estimated Project Cost

Construction Cost

Feature	Cost
Dam and reservoir	Eth$36,586,000
Feeder canal and diversion dams	1,455,000
Main canals	1,499,000
Distribution system	2,166,000
Drainage canals	919,000
Service facilities	906,000
Total construction cost	Eth$43,531,000

Development Cost. The cost for development of 4,200 hectares for irrigation purposes is estimated to be Eth$245,000 for clearing and Eth$525,000 for land leveling.

Operation, Maintenance, and Replacement Cost. The estimated operation, maintenance, and replacement cost for the Debohila Dam and Reservoir, although considerably less than that for the Upper Birr Dam and Reservoir, would require nearly as many personnel because of the three diversion dams and the feeder canal. Accordingly, the estimated cost for this item is approximated at Eth$23,000 annually.

The OM&R charges for the conveyance systems are estimated to be approximately Eth$175,000 annually.

Benefit-Cost Ratio

The benefit-cost ratio for this project is 0.59 to 1.00.

LOWER BIRR PROJECT

Plan of Development

The Lower Birr Project would provide water for irrigation of 6,600 hectares (16,300 acres) of land. No storage would be required. Return flows from the Upper Birr Project, plus flows from tributaries joining the river below the Upper Birr Dam would provide sufficient water supply for the project.

Project Features

The features of the project plan are shown on Figure 83. The Lower Birr Diversion Dam would be on the Birr River about 11 kilometers directly south of the village of Finote Selam. Here the canyon is very deep and steep. The structure is to be a concrete masonry, ogee-type dam, and no particular problem should be encountered in passing a 100-year frequency flood of 1,300 cubic meters per second (46,000 cubic feet per second). Outlet headworks to the conveyance system would have a capacity of 8.6 cubic meters per second and would be located on the right abutment of the dam.

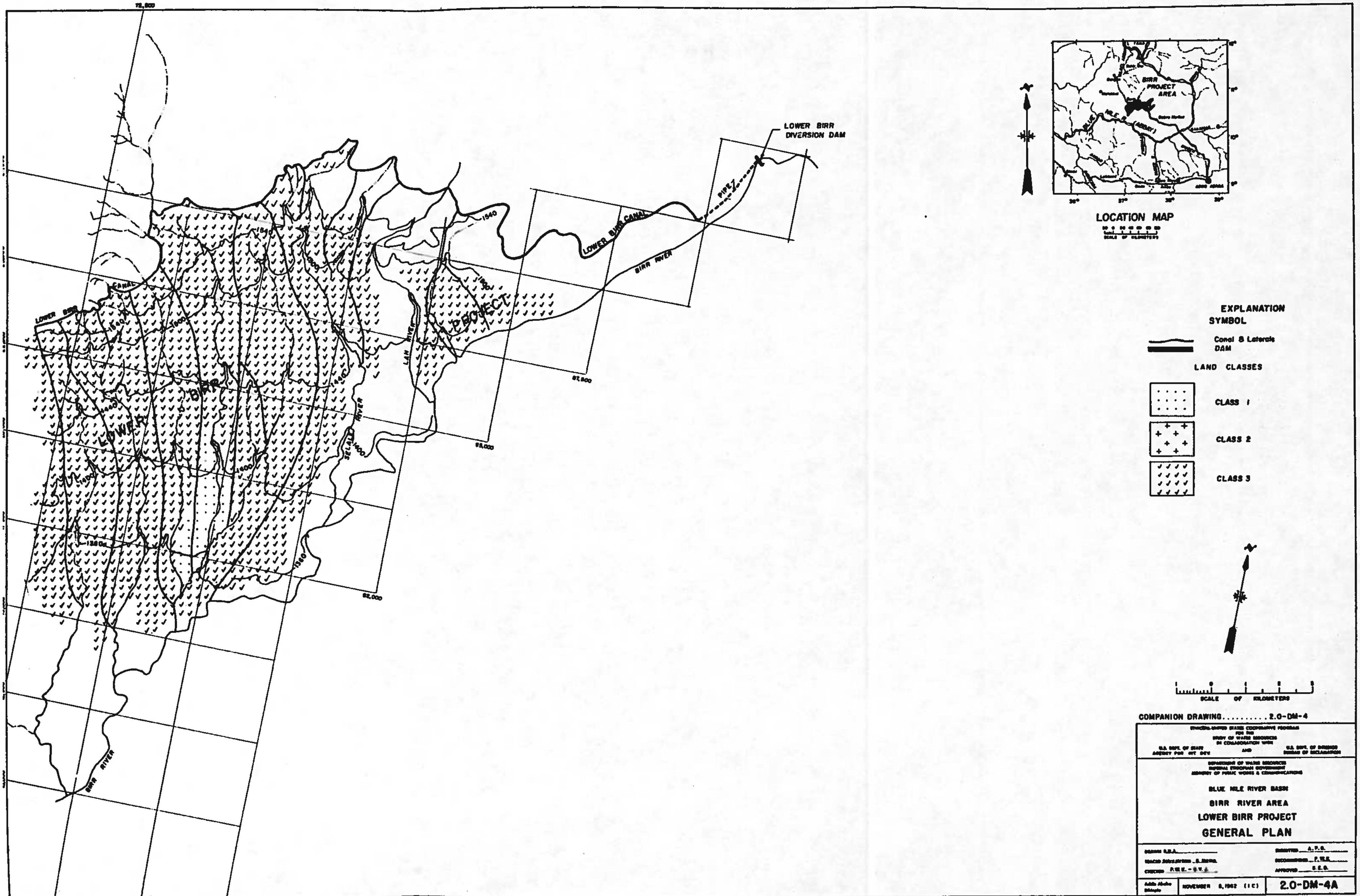


Figure 83--Lower Birr Project--General Plan

TABLE 37--SUMMARY OF CROPS AND GROSS FARM INCOME--LOWER BIRR PROJECT, 6,600 HECTARES

Table 37

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Pre-project income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Corn	9.18		1,000	2,780	2,780,000	255,200	1,670	1,150	1,920,500	176,300	431,500	431,500
Millet	8.90		660	2,915	1,923,900	171,230	1,300	950	1,235,000	109,910	281,140	281,140
Sorghum	12,70		1,300	2,915	3,789,500	481,270	-	-	-	-	481,270	481,270
Chick peas	12.74		330	1,450	478,500	60,960	660	920	607,200	77,360	138,320	138,320
Field beans	15.52		660	1,450	957,000	148,530	-	-	-	-	148,530	148,530
Castor beans	25.62		660	1,470	970,200	248,570	-	-	-	-	248,570	248,570
Flaxseed	20.14		-	-	-	-	660	660	435,600	87,730	87,730	87,730
Mustard	16.75		330	1,175	387,750	64,950	-	-	-	-	64,950	64,950
Sesame	34.25		330	1,175	387,750	132,800	-	-	-	-	132,800	132,800
Coffee	160.84		330	960	316,800	509,540	330	-	-	-	509,540	509,540
Peppers	54.93		330	900	297,000	163,140	-	-	-	-	163,140	163,140
Tobacco	113.60		330	2,000	660,000	749,760	330	-	-	-	749,760	749,760
Subtotal, crops			6,260			2,985,950	4,950			451,300	3,437,250	3,437,250
Fallow			-			-	1,310			-	-	-
Subtotal, cultivated area			6,260			2,985,950	6,260			451,300	3,437,250	3,437,250
Noncultivated irrigable area			340			-	340			-	-	-
Total area		80,000	6,600			2,985,950	6,600			451,300	3,437,250	3,357,250
Income per hectare		12.12				452.41				68.38	520.79	508.67

Diversion Dam Data

Type	masonry ogee overflow
Volume of masonry	2, 980 cu. m.
Spillway crest length	80 m.
Dam length	90 m.
Structural height	5 m.
Headworks w. s. elevation	1600 m.

At the proposed site, the river has carved a steep, nearly vertical-sided canyon several hundred feet deep through a thin veneer of younger volcanics into the older basaltic flows. Bedrock is basalt with interbedded interflow zones, ash and tuff layers. Due to the steep gradient in a narrow confined channel, very little overburden, except a few boulders, has been allowed to accumulate. Overlying the older basaltic flows, which are suitable for a dam foundation, are the very porous younger volcanic flows.

Impervious material available consists of a thin layer of the typical, reddish-brown or black, plastic clay along the canyon rim. Semipervious and pervious materials are not available in the area. Gravel and sand for concrete aggregate would probably have to be processed from the harder (older) basaltic flows at the site.

Access could be provided by constructing a road about 11 kilometers (7 miles) long, extending from the existing road near Finote Selam. Construction of this road would be relatively easy.

The first 2. 5 kilometers of the conveyance system will require low-head, concrete pipe conduit.

The main canal would extend from the end of the pipeline in the Birr River canyon for a distance of about 29 kilometers, proceeding along the northern edge of the Lower Birr area.

Estimated Project Cost

Construction Cost

Feature	Cost
Diversion Dam	Eth$ 397, 000
Conveyance system	6, 404, 000
Distribution system	3, 403, 000
Drainage system	1, 444, 000
Service facilities	652, 000
Total construction cost	Eth$12, 300, 000

Development Cost. Clearing of the lands for irrigated agriculture is expected to be at a minimum cost, as the area is sparsely covered with trees and brush. The cost for clearing of 6, 600 hectares of land is estimated to be about Eth$383, 000.

Generally speaking, the Lower Birr Project area has the smoothest topography in the Birr River area and would be the easiest and least costly to level for irrigation. The sum of Eth$400, 000 is estimated for this item.

Operation, Maintenance, and Replacement Cost. The OM&R for the Lower Birr Project on the conveyance facilities is estimated to be about Eth$250, 000 annually.

Benefit-Cost Ratio

The benefit-cost ratio for this project is 3.30 to 1.00, and the benefit-cost ratio for the combined Upper and Lower Birr Projects is 1.23 to 1.00.

Projects In Giamma Sub-Basin

GENERAL DESCRIPTION

The Giamma Sub-basin is in the southeastern sector of the Blue Nile River Basin draining an area of approximately 15, 700 square kilometers. The sub-basin is characterized by mountain ranges and high plateaus, progressively deepening steep canyons, and badly eroded lands as it drains into the Blue Nile River.

Irrigation development was considered to be unfavorable owing to the physical characteristics of the area. Hydroelectric power production was considered to be the only feasible exploitation of the water resources.

GIAMMA RIVER POWER PROJECT

Plan of Development

The plan for the Giamma River would be for the development of hydroelectric power. It includes the construction of a dam and reservoir with appurtenant structures, a 60, 000-kw. powerplant, a switchyard, and transmission lines. Annual generation of firm energy is estimated to be nearly 271 million kilowatt-hours.

Project Features

The features of the potential power project are shown on Figure 84.

The damsite, located on the Giamma River and controlling a drainage area of 6, 140 square kilometers, is about 82. 5 kilometers upstream from the confluence of the Giamma and Blue Nile Rivers. It would be an earth and rock fill dam. Diversion during construction would be accomplished by construction of two 10-meter-diameter concrete tunnels, with capacity to pass 2, 800 cubic meters per second. Plan, profile, and section of the dam and appurtenant structures appear on Figure 84.

Dam Data

Type	earth-rock fill
Embankment volume (earth)	11, 400, 000 cu. m.
Embankment volume (pervious)	16, 200, 000 cu. m.
Top of dam elevation	1389 m.
Freeboard	3. 19 m.
Structural height	139 m.
Hydraulic height	135. 81 m.
Length of crest	884 m.
Width of crest	10 m.

The spillway would utilize one of the 10-meter-diameter diversion tunnels on the left abutment of the dam and would consist of a morning-glory-type structure having a 26. 8-meter-diameter crest.

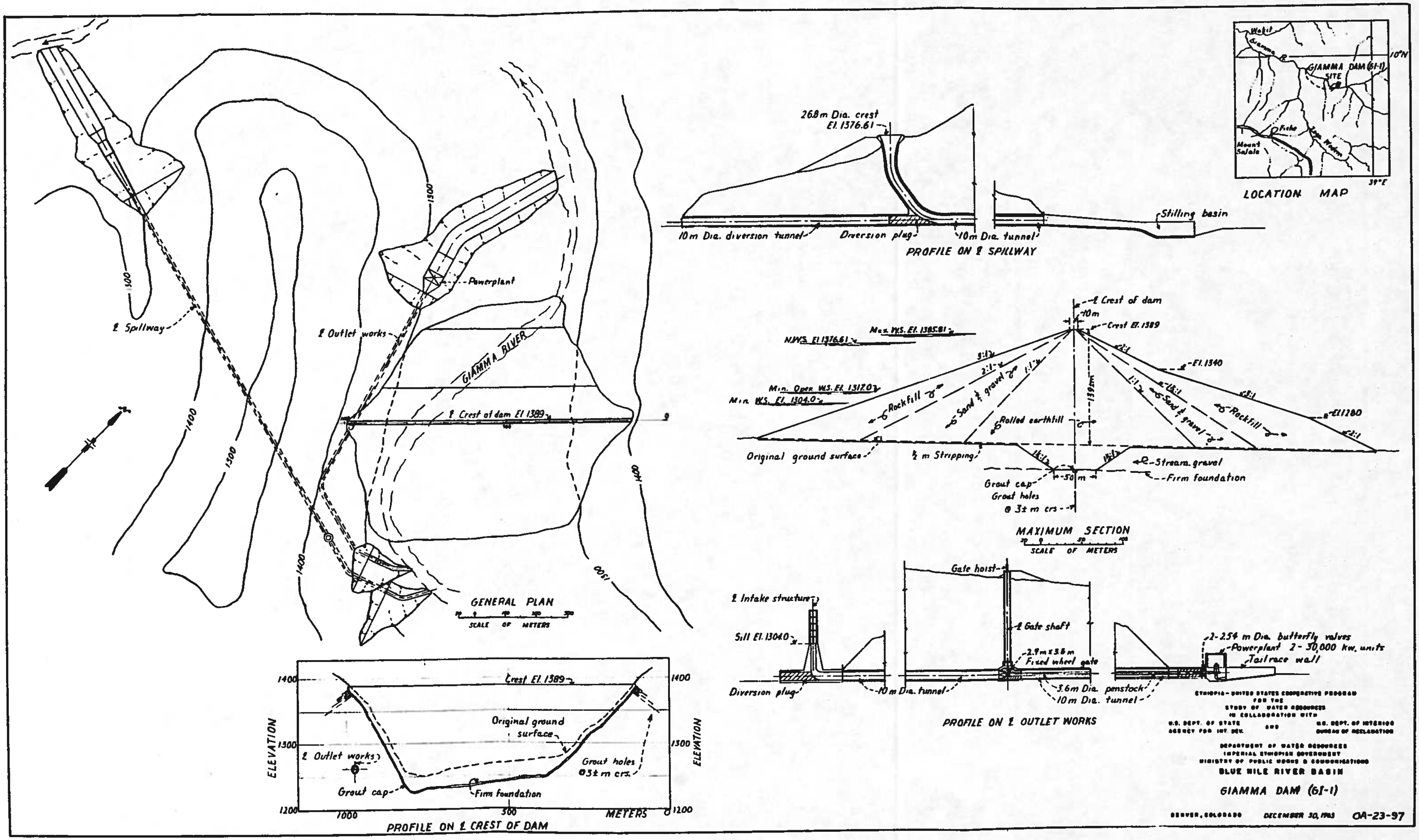


Figure 84--Giamma Dam (GI-I)--Plan and Sections

Spillway Data

Type	uncontrolled morning-glory
Crest elevation	1376.61 m.
Peak inflow	6,820 cu. m. per sec.
Total flood volume, 5-day period	885,000,000 cu. m.
Discharge at max. w.s. elevation	839 cu.m. per sec.

The outlet works would utilize the other diversion tunnel, and the intake structure would be constructed to intercept the tunnel for releases into the powerplant. The penstock would fork into two 2.54-meter-diameter pipes before being connected to the powerplant's turbines.

Leakage from the potential reservoir is not anticipated, as the materials are relatively tight. The reservoir would have an initial active capacity of 2,709 million cubic meters and 460 million cubic meters of inactive and dead storage.

The damsite is in massive Jurassic limestone and soft, marly limestone containing thinly bedded chert, which provides a satisfactory foundation for the type of dam proposed.

From visual examination of the area, sand and gravel deposits are believed to be adequate for construction purposes. Impervious material for the core is available in unlimited quantities near the site.

Access will require construction of approximately 28 kilometers of road through rolling and hilly terrain.

The powerplant would be located on the downstream toe on the left side of the dam, with the tailrace of the powerplant in the river channel. Two turbines and two generators would be installed.

Powerplant Data

Minimum head	58.75 m.
Design head	90.4 m.
Maximum head	118.50 m.
Number of generators	2
Rating of generators	30,000 kw.
Total plant capacity	75,000 kv.-a.
Turbine rating (English)	42,330 hp.
Synchronous speed	230 r.p.m.
Type of turbines	Francis

A switchyard with a single bay and a single-breaker, 161-kv. line initially is planned, located a couple of hundred meters south of the powerplant.

About 25 kilometers of transmission line will be required if it is to be connected to the basic network facilities.

Estimated Project Cost

Construction Cost

Feature	Estimated cost
Giamma Dam and Reservoir	Eth$243,578,000
Powerplant	15,000,000
Switchyard and transmission lines	6,790,000
Access road	1,094,000
Service facilities	2,578,000
Total	Eth$269,040,000

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$1,423,000, including Eth$398,000 for taxes and insurance, as summarized below.

Facility	Operation and maintenance	Replace-ments
Dam and Reservoir	Eth$ 70,000	
Powerplant	600,000	Eth$45,000
Communication	10,000	3,000
Penstocks	5,000	
Transmission plant	264,000	28,000
Other	398,000	
Totals	Eth$1,347,000	Eth$76,000

Benefit-Cost Ratio

The benefit-cost ratio for this project is 0.72 to 1.00.

Projects In Muger Sub-Basin

GENERAL DESCRIPTION

The Muger Sub-basin is in the southeastern part of the Blue Nile Basin, north of the capital city of Addis Ababa. The main stream of the basin is the Muger River, which drains an area of approximately 7,600 square kilometers, flowing from southeast to northwest until it joins the Blue Nile. The area is bounded on the east by a range of high hills and on the west by rolling, hilly terrain. On the approximate lower, northern, half of the basin, the area is characterized by rolling eroded breaks leading to the precipitous canyon escarpment over which the Muger River falls approximately 400 meters. The small upper valley is situated at about 2500 meters elevation, the area below the escarpment is less than 1000 meters above sea level. Because of the terrain and other factors the water resources of this basin can best be used for hydroelectric power development. The runoff with regulation would provide sufficient supply for this purpose.

MUGER RIVER POWER PROJECT

Plan of Development

Development of the Muger River would be limited to hydroelectric power. Its major structures and facilities would include a storage dam, a power canal, a diversion dam, and two powerplants. Switchyards and transmission lines would convey the power, estimated to be 121.6 million kilowatt-hours annually.

Chancho Dam, the first upstream feature of the project, would be located on the Muger River about 3 kilometers due west of the village of Chancho and about 35 kilometers north of the capital city of Addis Ababa. It would impound the water in the Chancho Reservoir. The canal would carry the water into the turbines of Chancho Powerplant, with the tailrace of the powerplant located in the river channel. The water from the discharges from this powerplant would again be diverted by a diversion dam about 12 kilometers downstream into the penstock and thence into the Falls Powerplant located at the bottom slope of Muger Falls, utilizing the natural drop of the falls of approximately 220 meters. General plan of the proposed power project appears on Figure 85.

Project Features

The storage structure, controlling a drainage area of about 500 square kilometers, would be a rock and earth fill dam. Diversion during construction would be accomplished by a gap in the dam, the gap to be closed after completion of the outlet works. Plan of the dam appears on Figure 86.

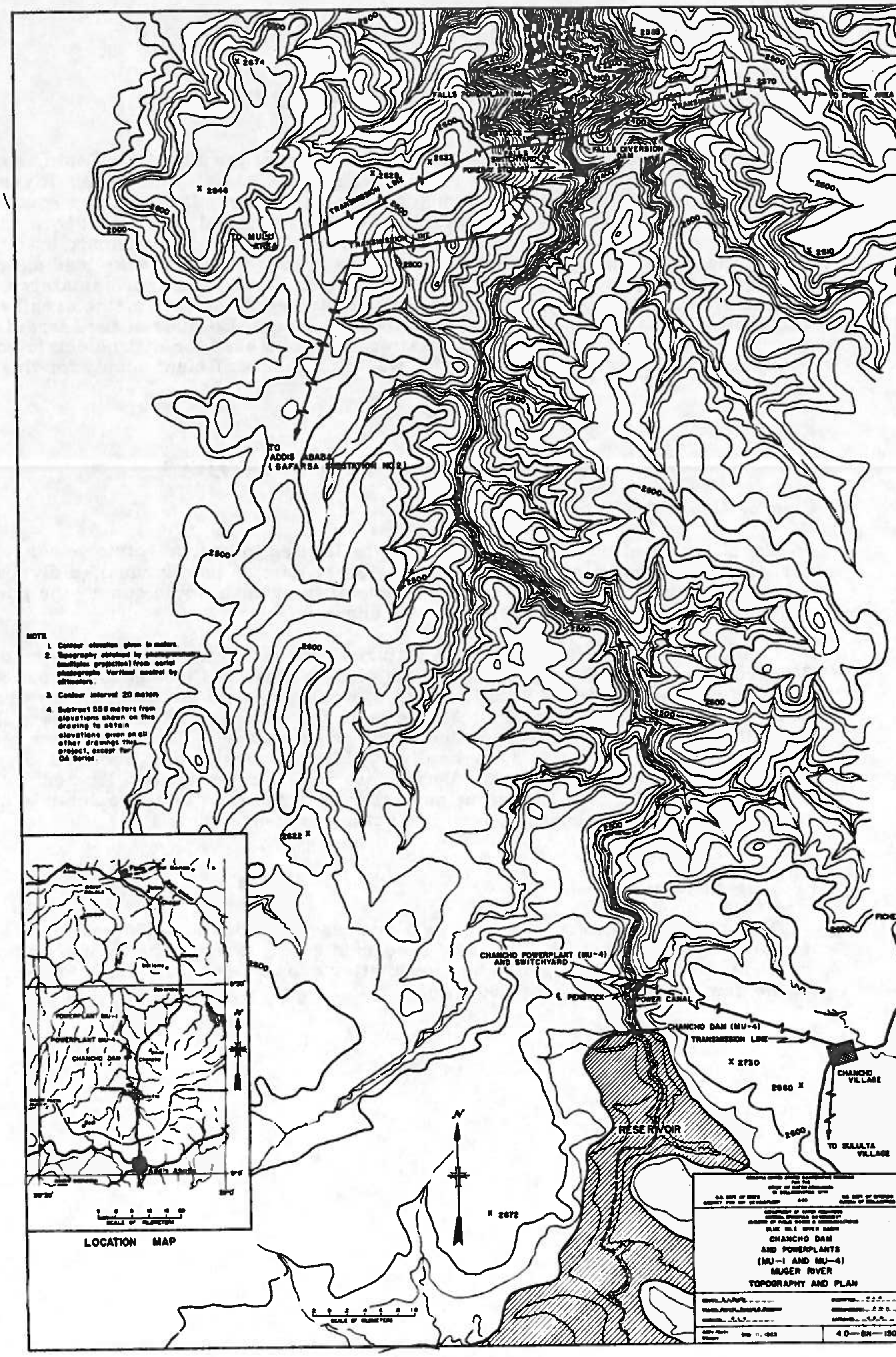


Figure 85--Chancho Dam and Powerplants (MU-1 and MU-4)--Topography and Plan

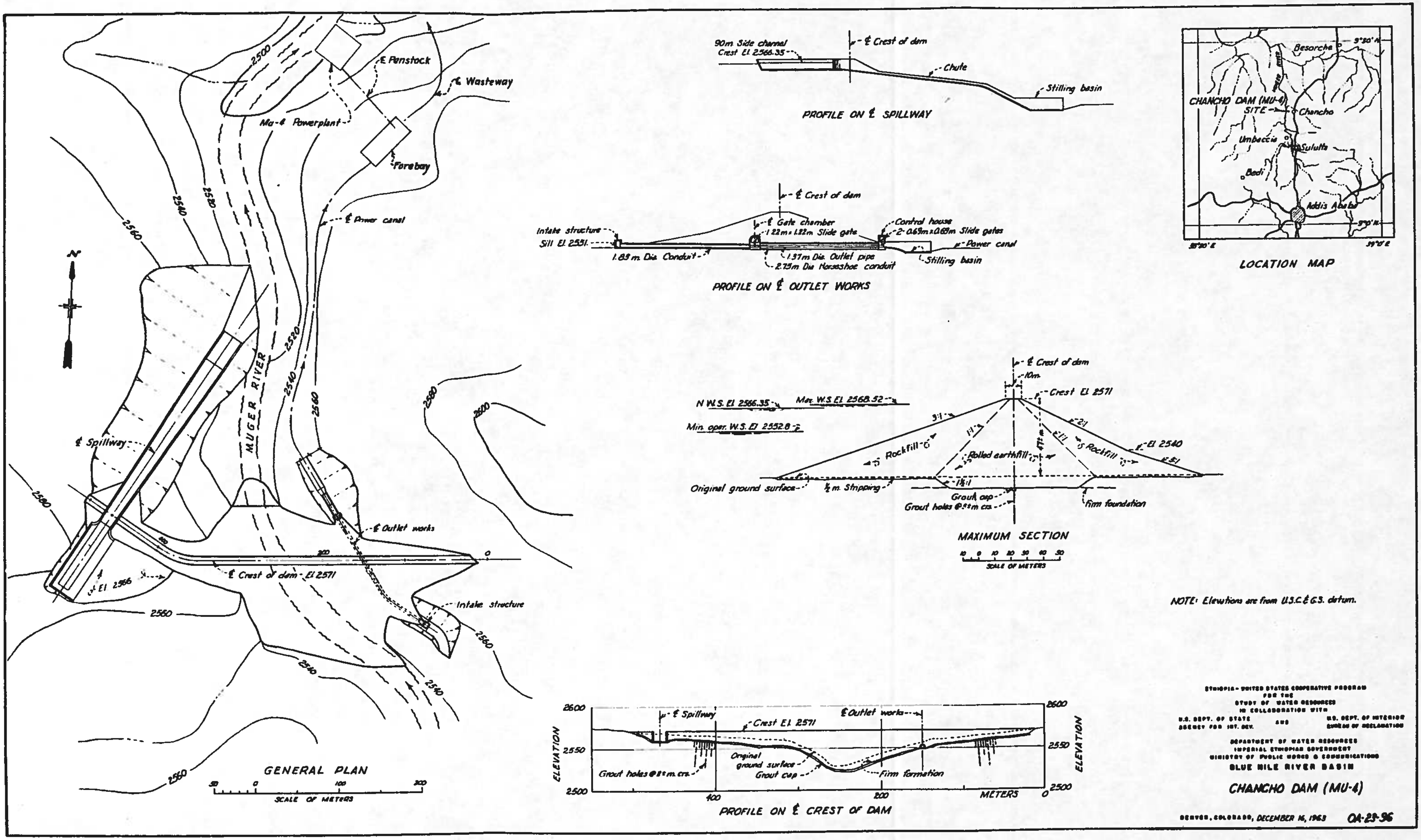


Figure 86--Chancho Dam (MU-4)--Plan and Sections

Dam Data

Type	earth-rock fill
Embankment volume (earth)	250,000 cu. m.
Embankment volume (pervious)	280,000 cu. m.
Top of dam elevation	2571 m.
Freeboard	2.48 m.
Structural height	47 m.
Hydraulic height	44.52 m.
Length of crest	504 m.
Width of crest	10 m.

The spillway would be on the left abutment of the dam and would consist of an uncontrolled, side-channel, ogee weir with a crest length of 90 meters, and a concrete-lined channel with a stilling basin. A channel would be excavated from the stilling basin to the river.

Spillway Data

Type	uncontrolled side channel
Crest elevation	2566.35 m.
Peak inflow flood	1,805 cu. m. per sec.
Total flood volume-- 2.5-day period	105,000,000 cu.m.
Discharge at max. w.s. elevation	556 cu. m. per sec.

The outlet works would be on the right abutment of the dam and would consist of an intake structure, a concrete pressure conduit to the gate chamber locacted about midway in the dam, and a horseshoe conduit from the chamber terminating at the control house located at the toe of the dam.

Outlet Works Data

Sill elevation of intake structure	2551 m.
Capacity at min. w.s. elevation	4.12 cu. m. per sec.
Type of gate (control house)	slide gates
Size of outlet pipe (diameter)	1.37 m.

The masonry-lined canal would originate at the discharge end of the stilling basin of the outlet works of Chancho Dam. It would extend for 550 meters and would have a capacity of 4.25 cubic meters per second.

The reservoir basin is entirely mantled with dark gray plastic clays, and no serious leakage problem is anticipated. The reservoir area is devoid of trees and would require very little clearing. The Chancho Reservoir would have an initial storage capacity of 270 million cubic meters of active and 30.3 million cubic meters of inactive and dead storage. It would inundate approximately 42 square kilometers of land.

The proposed site is located on basaltic rock. The basalt, although moderately weathered at the surface, is quite hard, dense, black, and only slightly scoriaceous. It is vertically jointed, with joint spaces ranging upward from 6 to 10 centimeters. With minor amounts of stripping of weathered material from the rock surfaces, good foundation rock can be exposed.

Impervious fill material is readily available from the silty clay overburden in the area of the damsite and in the reservoir. Concrete aggregate, pervious material, and rockfill materials will have to be processed from the basaltic rock at the site.

The powerplant would be located at the end of the power canal, about 750 meters downstream from Chancho Dam. It would have two turbine-driven generators. It would be served by a single, 0.80-meter-diameter penstock forking before being discharged into the two turbines.

Powerplant Data

Design head	60 m.
Number of generators	2
Rating of each generator	1,000 kw.
Total plant capacity	2,500 kv.-a.
Turbine rating, each (English)	1,415 hp.
Synchronous speed	750 r.p.m.
Type of turbines	Francis

The Falls Powerplant would be located on the bottom slopes of the Muger Falls on the left side, about 600 meters downstream from the diversion dam. It would be served by a 1.20-meter-diameter steel penstock, 595 meters in length, dividing into two smaller penstocks just before discharging into the turbines. It would have two turbine-driven generators.

Powerplant Data

Design head	362 m.
Number of generators	2
Rating of each generator	12,000 kw.
Total plant capacity	30,000 kv.-a.
Turbine rating, each (English)	16,933 hp.
Synchronous speed	374 r.p.m.
Type of turbines	Impulse

The Falls Diversion Dam would be about 12 kilometers from Chancho Dam on the Muger River and adjacent to the Muger Falls. It would be a masonry-concrete overflow structure. The outlet works of the dam would be located on the left abutment for releases into the penstock with a design capacity of 5.3 cubic meters per second.

Diversion Dam Data

Type	masonry ogee
Structural height	19 m.
Length of crest	106 m.
Length of spillway section	81 m.

The switchyard for the Chancho Powerplant would be located on the roof of the powerplant, and that for the Falls Powerplant would be about 150 meters west of the Falls Diversion Dam.

Access to the Chancho Dam and other features of the power project is not expected to be unduly costly, as the primary road passes through the village of Chancho about 3 kilometers east of the proposed site.

Estimated Project Cost

Construction Cost

Feature	Estimated cost
Chancho Division	
Chancho Dam and Reservoir	Eth$14,639,000
Waterways	502,000
Chancho Powerplant	3,625,000
Transmission lines, switchyard, and substation	240,000
Access road	141,000
Service facilities	781,000
Falls Division	
Falls Diversion Dam	1,011,000
Waterways (penstock)	1,070,000
Falls Powerplant	5,625,000
Transmission lines, switchyard, and substation	2,904,000
Access road	550,000
Total Construction Cost	Eth$31,088,000

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$808,000, including Eth$44,000 for taxes and insurance, as summarized below.

Facility	Operation and maintenance	Replacements
Chancho Division		
Dam and Reservoir	Eth$ 20,000	
Canal	250	
Forebay	3,000	
Wasteway	50	
Penstock	600	
Powerplant (Mu-4)	125,000	Eth$10,800
Transmission plant	9,300	1,400
Falls Division		
Diversion Dam	2,000	
Penstock	3,700	
Powerplant (Mu-1)	450,000	16,750
Transmission plant	109,250	11,900
Other	44,000	
Totals	Eth$767,150	Eth$40,850

Benefit-Cost Ratio

The benefit-cost ratio of this project is 2.42 to 1.00.

Projects In Guder Sub-Basin

BASIN DESCRIPTION

The Guder River area is in Shewa Province in the southeastern part of the Blue Nile River Basin. It has a drainage area of about 7,500 square kilometers (2,900 square miles). The Guder River rises in the mountain ranges south of the towns of Ambo and Guder at an elevation above 3000 meters (10,000 feet) and flows in a northerly direction to the Blue Nile River. Two single-purpose projects are planned for development in the sub-basin, an irrigation project and a hydroelectric power project, as shown on Figure 87.

UPPER GUDER PROJECT

Project Area Description

The Upper Guder Project area is contiguous to the town of Guder and mostly south of the main Addis Ababa-Lekkemt road. To the west, the area is surrounded by rolling hills to mountainous terrain; to the north, by deep gullies and ravines; and to the east toward the town of Ambo, by rolling hills and plains.

Geology and Physiography

Geologically, the project area is characterized by extrusive volcanics, largely basalt and trachyte, with lesser amounts of tuff and cinders. It is from these materials that the majority of the soils was formed. Small, localized remnants of Triassic sandstone, limestone, and travertine are also found.

Physiographically, the area is characterized by long, relatively smooth, gently sloping to steep, fan-like slopes which extend from the adjoining hilly to mountainous lands.

Climate

The project area, like most of the central highlands, has a temperate and equable climate. Climatic data from the Ambo Agricultural School indicate an average rainfall of about 108 centimeters (42 inches). The greater part of this falls from mid-June to late September. Temperatures recorded indicate an average daily maximum of 25 degrees C (77 degrees F) with an average daily minimum of 11 degrees C (52 degrees F).

Project Lands

Three major soil types are found in the project area--grumusols, latosols, and an intermediate brown soil, with the grumusols predominating. The grumusols are black tropical soils which have a clay or silty clay texture and crack deeply on drying.

The following table summarizes the land classification performed in the area.

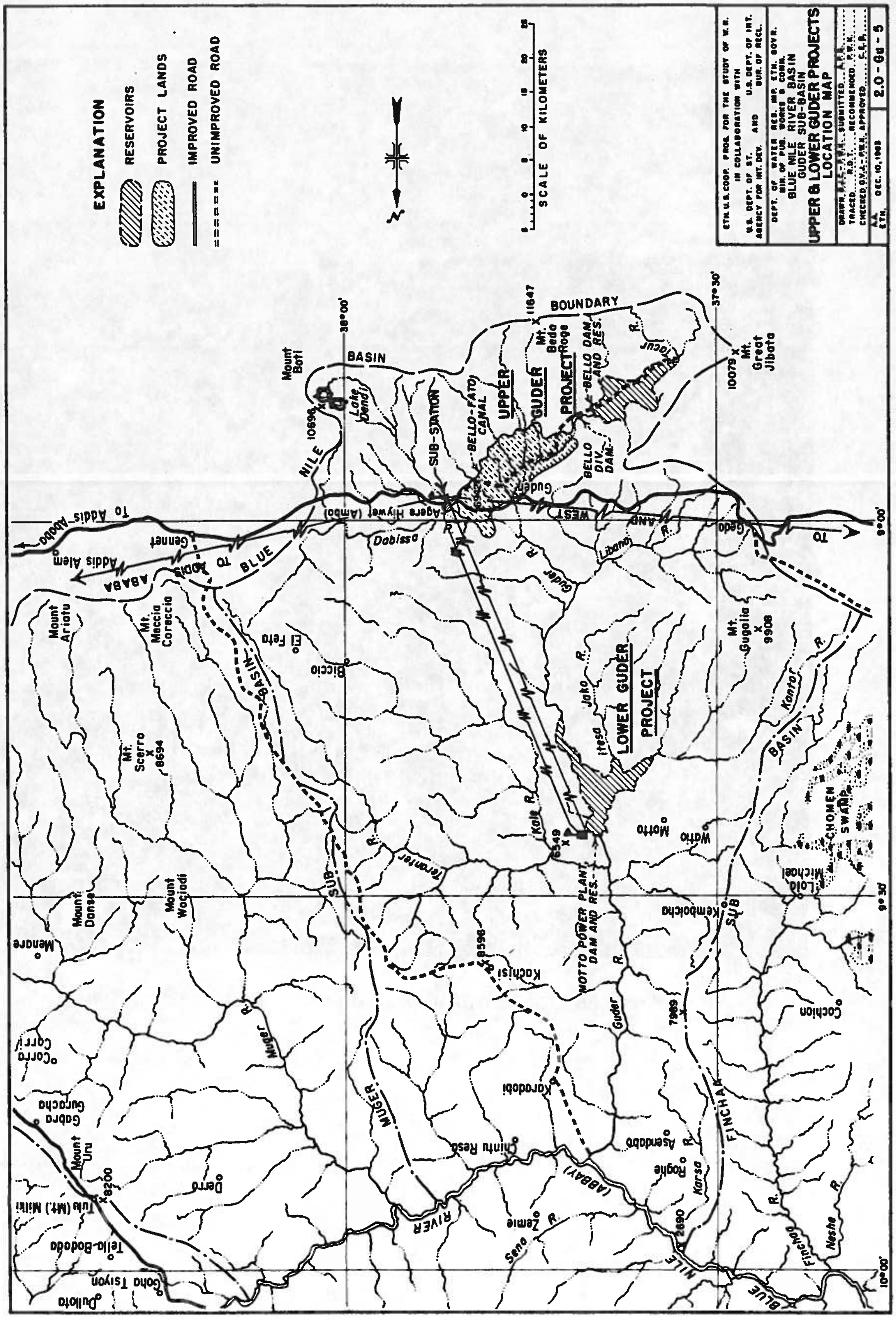


Figure 87--Upper and Lower Guder Projects--Location Map

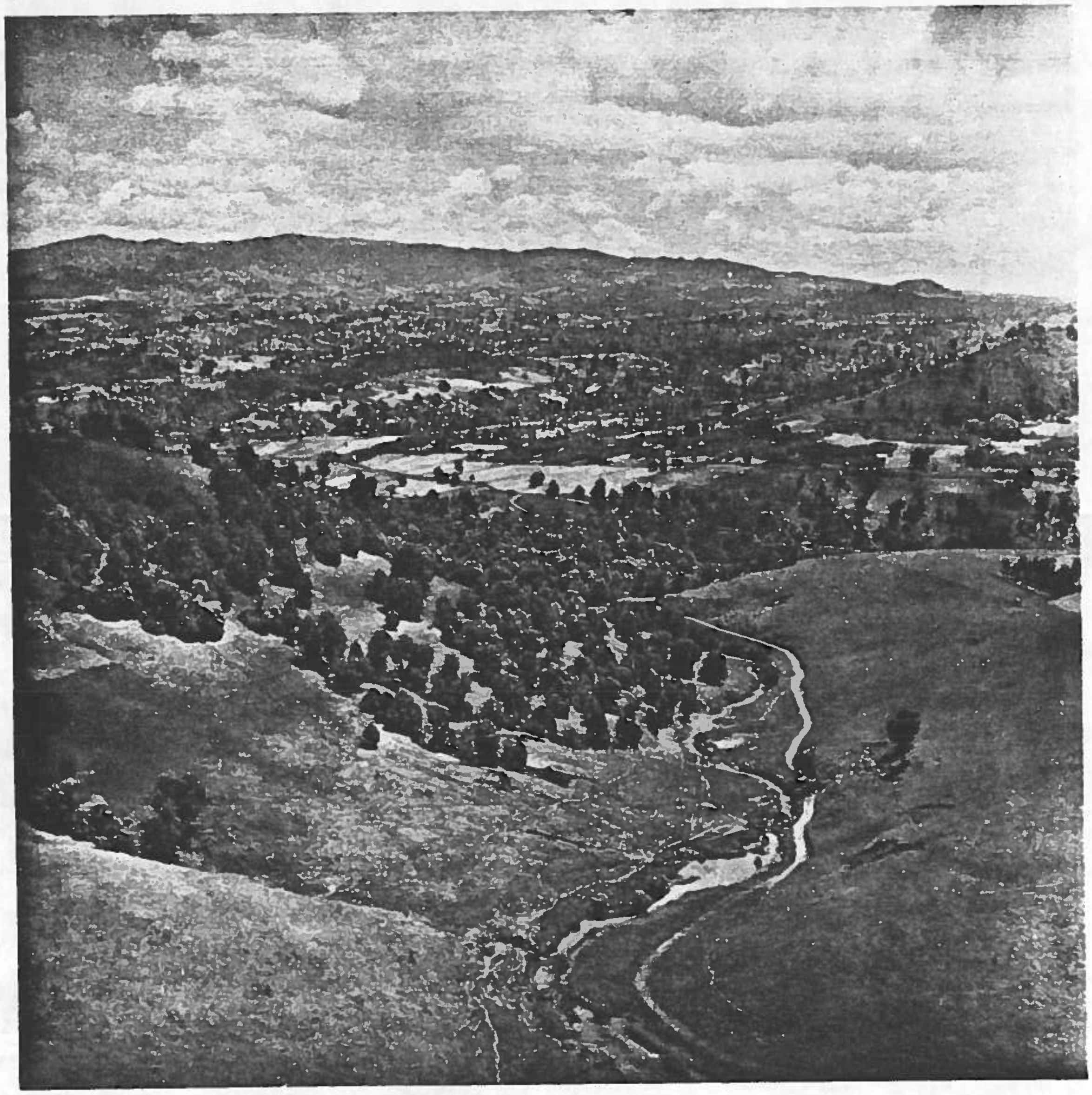


Figure 88. Bello (GU-4) damsite on the Bello (Guder) River.

Land Class Areas (in hectares)

Land type	Class 1	Class 2	Class 3	Total
Arable below canal	260	1, 240	3, 950	5, 450
Irrigable	240	1, 160	3, 700	5, 100

Hydrology

The Bello (Guder) River would provide an adequate water supply for the project lands that could be served by a gravity canal.

Monthly water requirements for irrigation were determined to be as follows:

Average Monthly Water (in millimeters)

Month	Requirement
October	110.1
November	127.8
December	93.0
January	122.7
February	95.4
March	39.2
April	50.4
May	60.5
Total	699.1

The total diversion requirement for 5, 100 hectares of irrigable land is 51, 000, 000 cubic meters (41, 000 acre-feet) annually.

Plan of Development

The development plan for the Upper Guder project includes a storage dam, a diversion dam, a main canal, a lateral distribution system, and drainage canals for a sustained irrigation of 5, 100 hectares (12, 600 acres) of land.

Storage would be provided by the potential Bello Reservoir on the Bello River. As needed for irrigation, water would be released through the outlet works and diverted into the main canal by the Bello Diversion Dam. The canal would extend for 36. 5 kilometers (22.7 miles) in a northeasterly direction to its terminus at Large Boggi Creek.

Project Features

The features of the project plan are shown in general plan on Figure 89. The selected site is on the Bello River about 19 kilometers (11 miles) upstream from its confluence with the Indris River adjacent to the town of Guder. It will provide a total of 70, 640, 000 cubic meters of initial storage. The dam will be a homogenous earthfill structure. Diversion during construction would be accomplished by a 4-meter-diameter concrete tunnel. Plan, profile, and section of the dam are shown on Figure 90.

Bello Dam Data

Type	earthfill
Embankment volume	380, 000 cu. m.
Elevation of crest	2432 m.
Freeboard	2 m.
Structural height	41 m.
Hydraulic height	39 m.
Length of crest	188 m.
Width of crest	10 m.

Spillway design capacity was based on peak inflow estimated to be 1, 085 cubic meters per second and a 2-day volume of 57 million cubic meters.

Spillway Data

Type	morning-glory
Spillway crest elevation	2428 m.
Inflow design flood peak	1, 085 cu. m. per sec.
Total flood volume, 2-day period	57, 000, 000 cu. m.
Discharge at max. w. s. elevation	518 cu. m. per sec.

The outlet works required to release water for irrigation would be a concrete conduit having an initial diameter of 1.8 meters to the gate chamber and then enlarging to a 2-meter-diameter horseshoe to house the 0.51-meter-diameter steel outlet pipe. Other structures required would include an intake structure, a control house with a 2-meter-diameter access shaft tunnel, and a hollow-jet valve.

Outlet Works Data

Sill elevation	2420 m.
Capacity at min. w. s. elevation	3.65 cu. m. per sec.
Type of gate	high-pressure
Size of outlet (hollow-jet)	0.46-m. valve

In general, it is believed that the cover of impermeable clays over most of the reservoir area will provide an adequate blanket, and no great seepage problems should arise.

At the site selected for the dam, the younger volcanic flows are primarily hard basalt. It is believed that, with an adequate provision for a cutoff trench and with a grout curtain in the basaltic rock, no serious foundation problem should arise.

Impervious fill material can be found almost anywhere in the vicinity of the proposed site. Semipervious or pervious materials are not available in the vicinity of the damsite. Weathered or broken rock may be possible sources of impervious fill material. Riprap can be quarried just downstream from the site from the hard basaltic flows cropping out there.

An access road from the town of Guder, a distance of about 22 kilometers (13.6 miles) could be constructed at a moderate cost.

The Bello Diversion Dam is planned as a concrete-masonry, ogee-type structure with suitable provisions for sluicing. The site chosen for the structure would be about 3.5 kilometers (2.2 miles) downstream from the storage dam, and no serious problem is expected to be encountered in constructing the structure. Outlet works to the main canal would be located on the right abutment of the diversion dam. The weir section would be 53 meters (174 feet) long and 3 meters (10 feet) high. Plan and sections are shown in Figure 91.

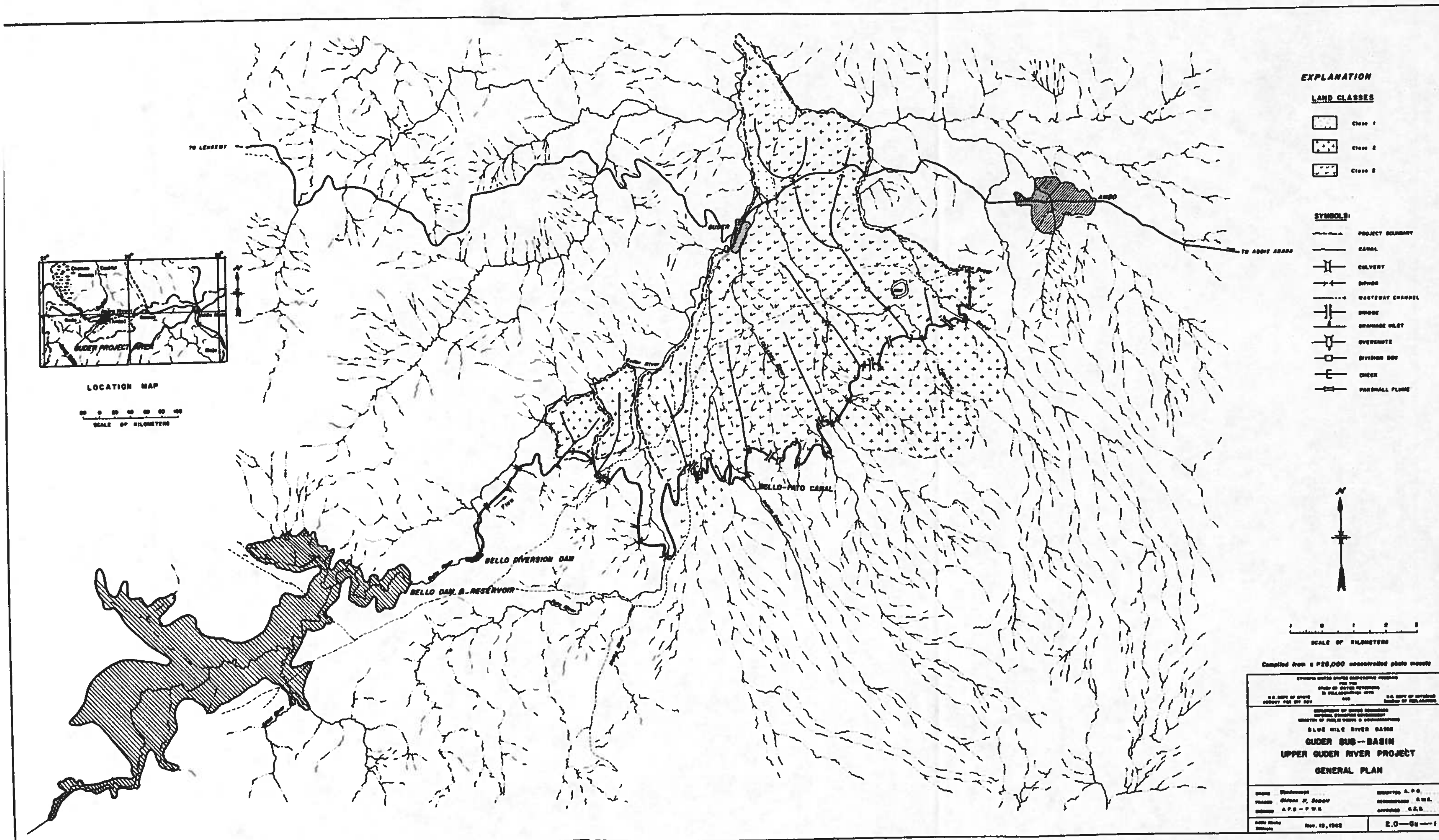


Figure 89--Upper Guder River Project--General Plan

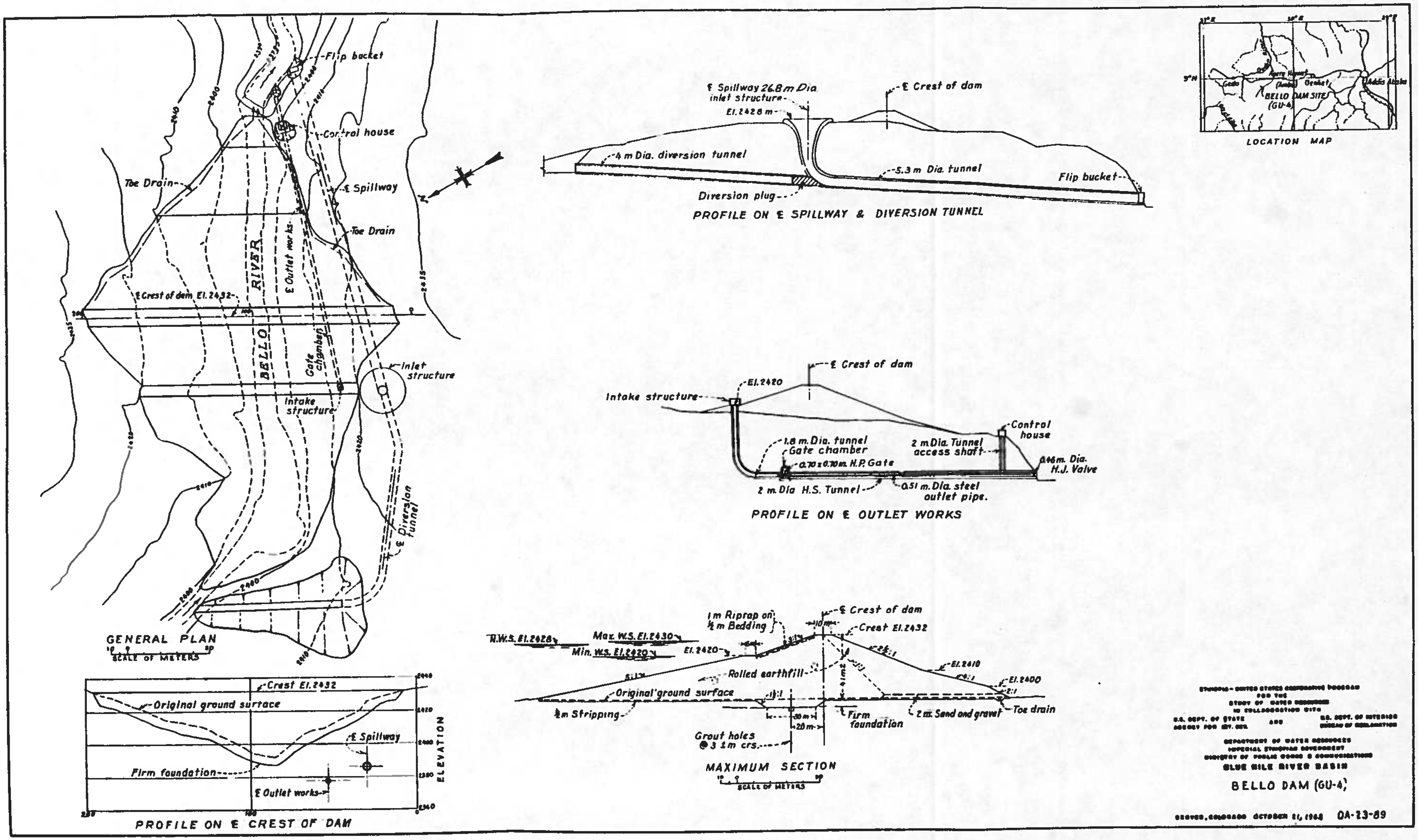


Figure 90--Bello Dam (GU-4)--Plan and Sections

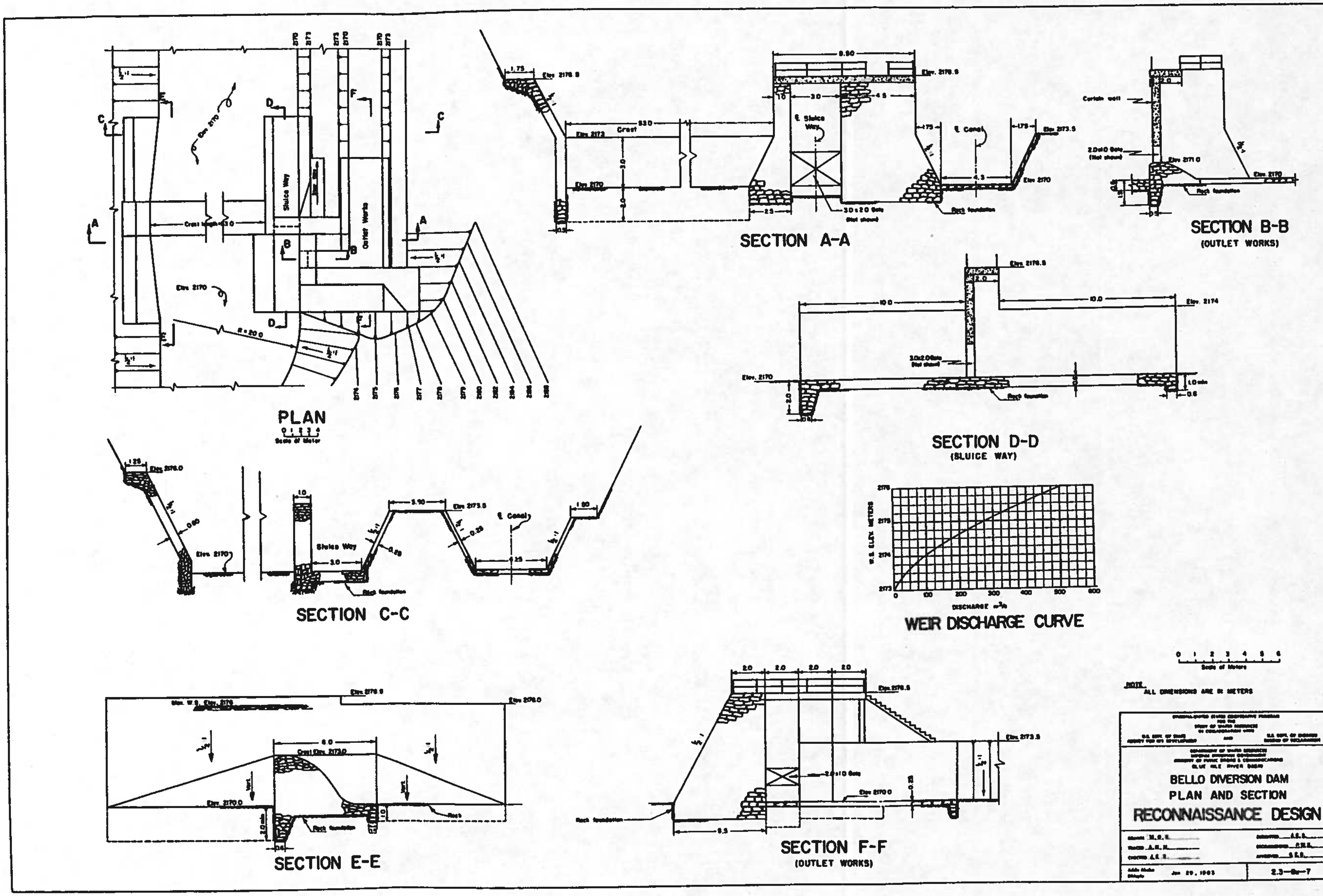


Figure 91--Bello Diversion Dam--Plan and Sections

TABLE 38--SUMMARY OF CROPS AND GROSS FARM INCOME--UPPER GUDER PROJECT, 5,100 HECTARES

Table 38

Crop pattern	Conditions before project					Future conditions, irrigation season				Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Crop distribution ha.	Yield kg./ha.	Production kg.	Price received per 100 kg. Eth$	Pre-project income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Barley	112	791	88,590	14.18	12,560	765	1,830	1,399,950	198,510	765	850	650,250	92,205	290,715	278,155
Corn	128	802	102,655	11.48	11,785	-	-	-	-	-	-	-	-	-	-11,785
Sorghum	148	732	108,335	15.00	16,250	1,275	2,100	2,677,500	401,625	-	-	-	-	401,625	385,375
Teff	729	566	412,615	23.97	98,905	-	-	-	-	1,530	720	1,101,600	264,055	264,055	165,150
Wheat	107	680	72,760	22.20	16,150	1,020	1,830	1,866,600	414,385	510	830	423,300	93,975	508,360	492,210
Horse beans	71	506	35,925	12.50	4,490	510	1,050	535,500	66,940	765	660	504,900	63,110	130,050	125,560
Castor beans	-	-	-	27.92	-	765	1,060	810,900	226,405	-	-	-	-	226,405	226,405
Flaxseed	51	362	18,460	22.44	4,140	-	-	-	-	255	480	122,400	27,465	27,465	23,325
Noog	184	556	102,305	23.38	23,920	510	850	433,500	101,350	-	-	-	-	101,350	77,430
Other 1/	117	-	-	-	5,100	-	-	-	-	-	-	-	-	-	-5,100
Subtotal, crops	1,647	-	-	-	193,300	4,845	-	-	1,409,215	3,825	-	-	540,810	1,950,025	1,756,725
Fallow	1,046	-	-	-	-	-	-	-	-	1,020	-	-	-	-	-
Subtotal, cultivated area	2,693	-	-	-	193,300	4,845	-	-	1,409,215	4,845	-	-	540,810	1,950,025	1,756,725
Noncultivated irrigable area	2,407	-	-	-	111,000	255	-	-	-	255	-	-	-	-	-111,000
Total area	5,100	-	-	-	304,300	5,100	-	-	1,409,215	5,100	-	-	540,810	1,950,025	1,645,725
Income per hectare					59.67				276.32				106.04	382.36	322.69

1/ Chick peas, field peas, guaya, peppers, onions, spices, vegetables.

Diversion Dam Data

Type	concrete-masonry overflow
Volume of masonry concrete	2,095 cu. m.
Structural height	6.5 m.
Spillway crest length	53 m.
Discharge capacity	340 cu. m. per sec.

The Bello-Fato Main Canal would extend northeasterly from the diversion dam to its terminus at Large Boggi Creek. The canal would have an initial capacity of 6.8 cubic meters per second (240 cubic feet per second).

It would traverse hilly terrain to reach as much of the project area as possible. Geologically, the canal route is underlain with basaltic flows. Overburden in some cases would extend to 15 meters and, on some of the steeper slopes, weathered basalt is expected to be encountered, especially on the initial reaches of the canal. Canal excavation will not present any major problems.

Water for irrigation of 5,100 hectares of land will be supplied from the Bello Reservoir.

Canal Data

Type	unlined
Length	36.5 km.
Initial capacity	6.8 cu. m. per sec.
Initial w. s. elevation	2710 m.

The irrigable lands occur mostly on ridges between drainageways. It is estimated that about 80 to 85 percent of the irrigable land has slopes of less than 2 percent and the remainder has slopes of 5 to 12 percent, which is considered maximum for suitable irrigation development. The distribution system would consist of a number of main laterals following the ridges with sublaterals emanating to convey the water to the farms.

Surface drainage has been provided for removal of irrigation waste and excess precipitation falling on the irrigable lands.

Estimated Project Cost

Construction Cost

Feature	Estimated cost
Bello Dam and Reservoir	Eth$ 7,590,000
Bello Diversion Dam	486,000
Bello-Fato Main Canal	1,172,000
Distribution system	2,630,000
Drainage canals	956,000
Access roads	928,000
Service facilities	200,000
Total	Eth$13,962,000

Development Cost. A large portion of the land area has only a scattering of trees and brush. Clearing costs for the 5,100 hectares are estimated to be about Eth$296,000.

Only moderate leveling is required because the land is fairly smooth with sufficient slope to obviate the necessity of highly precise leveling. Cost for leveling is estimated to be Eth$332, 000.

Operation, Maintenance and Replacement Cost. Annual operation, maintenance, and replacement costs for the conveyance system were estimated to be Eth$200, 000 and for the storage and diversion dams, Eth$19, 000.

Benefit-Cost Ratio

The benefit-cost ratio of this project is 1.54 to 1.00.

LOWER GUDER POWER PROJECT

Plan of Development

The plan of development for the Lower Guder Power Project includes construction of a dam and reservoir, a 50, 000 kw. powerplant, a substation, and transmission lines for an estimated annual generation of nearly 225 million kilowatt-hours.

Project Features

The site for the Motto Dam is about 60 kilometers north of the town of Guder on the Guder River. It would be an earth and rock fill dam. A dike on the west side of the river will be required on a low saddle approximately 660 meters long and 26 meters high. Plan, section, and profiles of the dam appear on Figure 92.

Dam Data

Type	earth-rock fill
Embankment volume (earth)	2, 600, 000 cu. m.
Embankment volume (rock)	4, 000, 000 cu. m.
Top of dam elevation	1376 m.
Freeboard	2.26 m.
Structural height	121 m.
Hydraulic height	118.74 m.
Length of crest	400 m.
Width of crest	10 m.

Based on inflow design flood studies, a morning-glory type of spillway was designed. The spillway would have a 30-meter-diameter crest and would discharge into one of the two tunnels constructed for diversion of the river.

Spillway Data

Type	morning-glory
Spillway crest elevation	1368.11 m.
Inflow design flood peak	5, 600 cu. m. per sec.
Total flood volume 4-day period	590, 000, 000 cu. m.
Discharge at max. w. s. elevation	1, 386 cu. m. per sec.

The reservoir outlet would be a conduit through the left side of the dam. The outlet works would consist of an intake structure with a fixed-wheel gate and a welded steel penstock in one of the two horseshoe conduits, constructed beforehand. The penstock would divide before reaching the turbines, each equipped with butterfly valve.

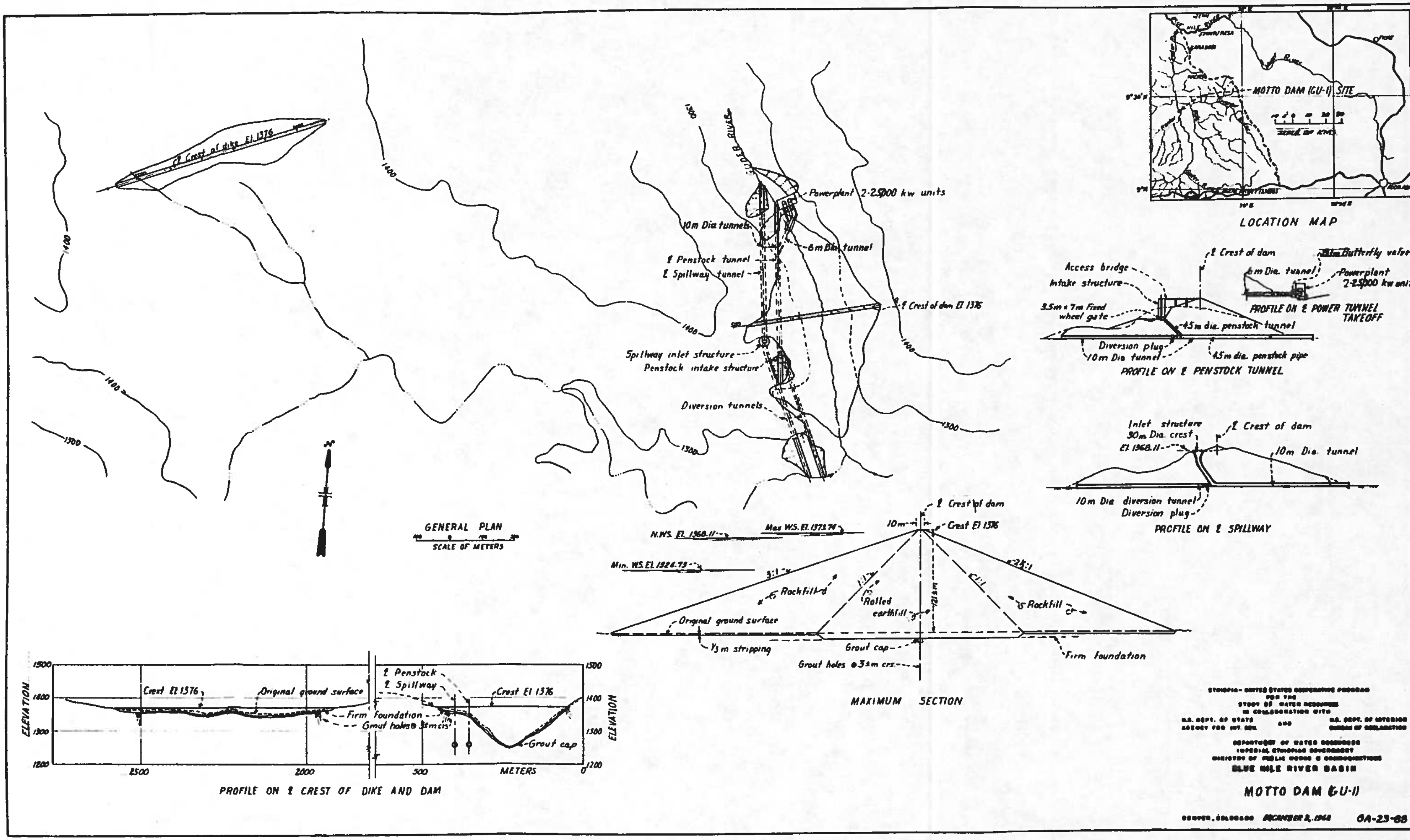


Figure 92--Motto Dam (GU-1)--Plan and Sections

Outlet Works Data

Sill elevation	1313 m.
Maximum capacity (each)	60 cu. m. per sec.
Type of gate	fixed-wheel
Size of outlet (diameter)	4.5 m.

The Motto Reservoir area is in sandstone except for the small area in Precambrian rock near the damsite. It is believed that the cover of impermeable clays over most of the reservoir area will provide an adequate blanket, and no serious seepage problem is anticipated. The initial storage capacity is estimated at 2,557 million cubic meters, covering an area of 7.45 square kilometers.

The damsite is in a narrow, V-shaped gorge in banded quartz diorite gneiss of Precambrian age. The rock is variably jointed, but a smooth, hard, rock foundation could be exposed. Foundation excavation to obtain fresh rock and a smooth surface may range from 3 to 10 meters.

There is an abundance of impervious material, and pervious or semipervious material will have to be quarried from the Precambrian rock.

An access road will have to be constructed through rolling and hilly terrain for a distance of approximately 60 kilometers.

The hydroelectric plant would be located adjacent to the dam at the toe of the downstream slope. It would contain two turbine-driven generators, each supplied by a steel penstock from the outlet works.

Powerplant Data

Design head, net	86.1 m.
Maximum head, net	107.6 m.
Minimum head, net	64.2 m.
Number of generators	2
Installed capacity (each)	25,000 kw.
Type of turbine	Francis
Synchronous speed	230 r.p.m.

About 175 kilometers of transmission lines are planned to conduct the energy generated to Agere Hiywet (Ambo) and to Addis Ababa.

Estimated Project Costs

Construction Cost

Feature	Estimated cost
Motto Dam and Reservoir	Eth$ 95,501,000
Powerplant	14,106,000
Switchyard	1,781,000
Transmission lines	5,681,000
Substations	5,997,000
Access road	2,813,000
Service facilities	969,000
Total	Eth$126,848,000

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$1,277,000, including Eth$185,000 for taxes and insurance, as summarized below.

Facility	Operation and maintenance	Replacements
Dam and reservoir	Eth$ 21,000	Eth$ -
Powerplant	550,000	42,000
Transmission plant	431,500	47,500
Other	185,000	-
Totals	Eth$1,187,500	Eth$89,500

Benefit-Cost Ratio

The benefit-cost ratio for this project is 1.21 to 1.00.

Projects In Finchaa Sub-Basin

GENERAL DESCRIPTION

Basin Description

The Finchaa River area is in the south central portion of the Blue Nile River Basin about 150 kilometers northwest of Addis Ababa.

It is distinguished by the Chomen Swamp, with an area of 600 square kilometers, lying on the plateau between the mountains and a precipitous escarpment. The swamp is situated at an elevation of 2210 meters (7250 feet) above sea level and several hundred meters above the valley considered for projected development.

The Finchaa River emerges at the northeastern end of the swamp and meanders in a southeasterly direction for about 5 kilometers, then plunges over an escarpment, falling some 500 meters (1,640 feet) in 2 kilometers. The Neshe River also forms on the plateau west of the lower valley. The Amarti River, a tributary of the Neshe, and the Neshe River together drain an area of high mountains, steep slopes, and rough topography. The two rivers flow in long, narrow valleys with a slight gradient, forming narrow swampy areas, and then drop over the edge of the escarpment to form the Neshe River, which in turn flows into the Finchaa near its confluence with the Blue Nile.

The development of the sub-basin (Figure 93) would extend over a long period of years. The plan envisions the development of approximately 23,500 hectares of land for irrigation and generation of 160,000 kilowatts of hydroelectric power.

The comprehensive plan is divided into two projects--the Finchaa and the Amarti-Neshe.

Projects Area Description

The area under consideration for irrigation in the Finchaa Project is the lower valley, bounded on the southwest and the east by a sandstone escarpment (in places, lava capped), on the north by rough breaks along the Blue Nile River canyon, and on the west in the lower portion of the valley by a low saddle forming a divide between the Finchaa Project area and the Amarti-Neshe Project area. It is situated about 1450 meters above sea level (500 meters below the escarpment) and is about 12 kilometers (7.5 miles) wide and 37 kilometers (23 miles) in length. The valley is fairly well covered with dense growth of tropical savannah woodland, interspersed with a dense growth of tall grass. The valleys of the tributaries support a dense growth of tall trees, which reach a height of 30 meters (100 feet). Shrubs and bushes are interspersed throughout the bottoms. The valley is uninhabited and uncultivated, probably due to the heat and the unfavorable health conditions, the tsetse flies, and malaria.

The Finchaa River bisects the valley, and its many tributaries generally approach and enter the main stream at right angles to the south-north direction of the river's flow. The tributaries are entrenched from 3 to 10 meters into the valley soil. These channels do not have precipitous side slopes as a rule but tend toward somewhat rolling topography. On the higher lying land areas, the streams provide adequate outlets for surface runoff. The slopes on these areas are usually quite gentle and smooth in surface relief. Steep slopes and dissected rough lands occur at the head of the valley, where the escarpment forms a canyon.

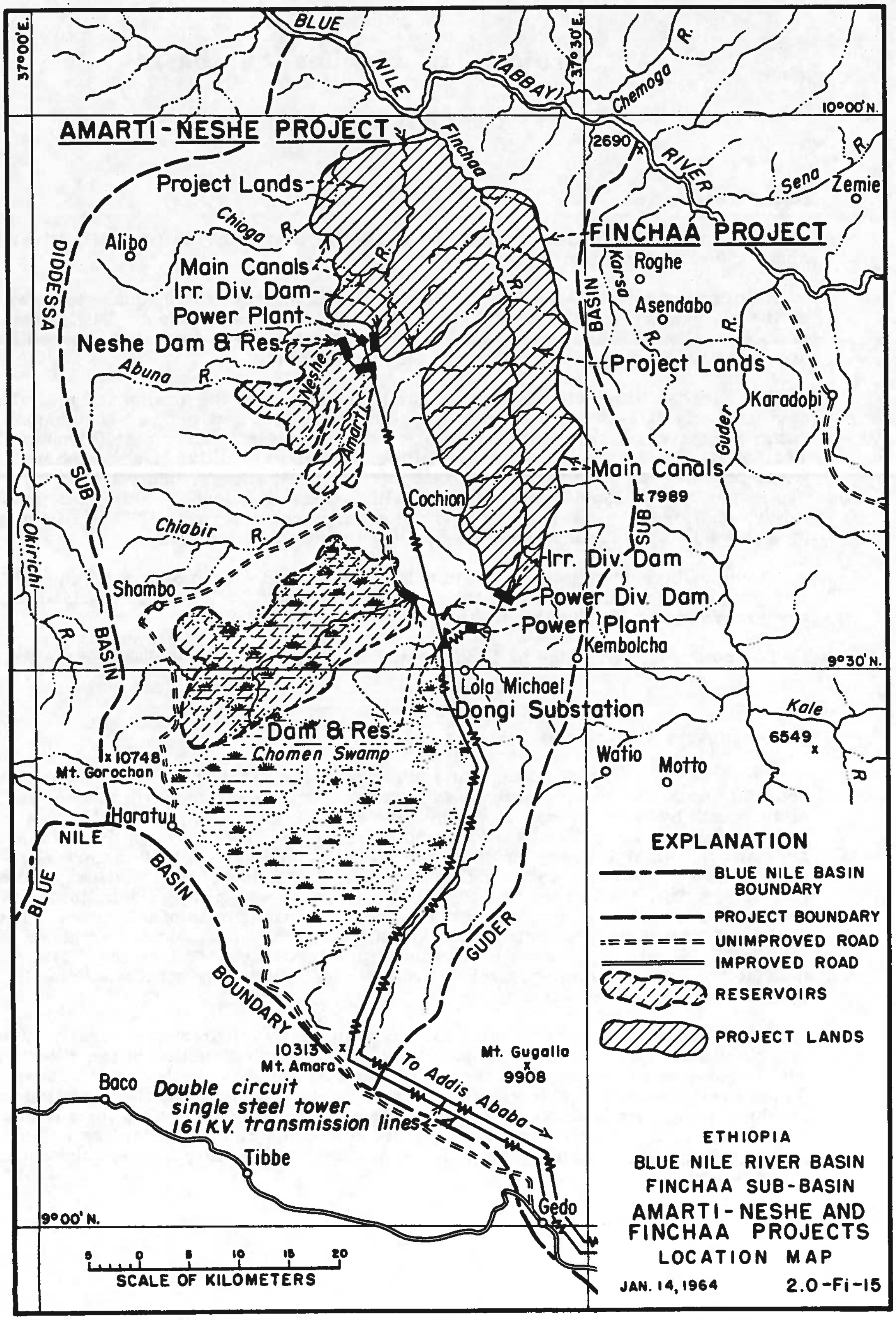


Figure 93--Amarti-Neshe and Finchaa Projects--Location Map

Geology and Physiography

The headwaters of the Finchaa drainage system originate in high volcanic mountains, composed mostly of basalt, which have been eroded into sharp steep ridges and valleys. Volcanic plugs, ranging from dark colored basalt to light colored rhyolite, are common physiographic features in this mountainous area.

Northward, at lower elevations, the volcanic material forms a wide, rolling plateau. In this northern or downstream direction--due to erosion and probably to the thinning of the volcanic lava flows--the streams have cut through the volcanic materials into flat lying, massive beds of Triassic sandstone which constitute the principal rock forming the plateau.

In the vicinity of the outlet of the swamp the ridges are composed of sandstone, but in the valley the Finchaa River is flowing on an intervalley flow of basalt which was 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. It is this intervalley filling of volcanic rock--harder than the sandstone--that is responsible for the vertical waterfalls. It has also retarded erosion and entrenchment of the streams in the swamp, resulting in a large, flat, poorly drained, land area on the high plateau. It is on the volcanic rock and in the valley immediately below the outlet of the swamp that dams and other engineering structures will be required to develop the project.

The intervalley volcanic rock is hard and jointed, but it is not extremely porous like most other "younger" volcanic rock in the Blue Nile River Basin. Apparently, it was deposited in thick, massive flows, whereas most other "younger" volcanics were deposited in intermittent, thin flows, causing them to be scoriaceous and badly broken.

Climate

The climate in the lower valley is warm and subtropical, favorable to the raising of a wide variety of crops. Average annual precipitation is estimated at 100 centimeters with average annual temperature being about 22° C (72° F).

Projects Land

Two types of soils are found in the basin, the red latosols which occupy the bulk of the project area and the black grumusols. Although the latosols are low in plant nutrients, they have physical properties which are well suited for irrigation. They are normally well aerated and they can be cultivated over a wide range of moisture conditions. The grumusols are composed of swelling-type clay minerals, such as beidellite or montmorillonite, and are not as desirable for irrigation.

The results of the land classification indicate the following classes.

Arable and Irrigable Areas--Finchaa and Amarti-Neshe Projects

Project	Land type	Land class (hectares)			
		1	2	3	Total
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
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

Natural surface drainage facilities are generally excellent to excessive. Excess surface water will quickly find a natural drainage channel for return to the river. However, such surface runoffs could cause serious erosion problems, and suitable structures will be required.

Hydrology

Sources of water supply for the project areas studied were the Finchaa and Neshe Rivers. The Chomen Swamp, which feeds the Finchaa, is composed of three main sections connected by narrow waterways. It is about 45 kilometers long with an average width of about 15 kilometers. Operation studies indicate that the annual yield of the Finchaa near the outlet would be 354.25 million cubic meters.

It is proposed to utilize both the Amarti and the Neshe Rivers for the development of the multipurpose Amarti-Neshe Project. This would be accomplished by a channel connecting the two reservoirs. Operation studies indicate that an annual firm yield of 310 million cubic meters would result from impounding the water in the two reservoirs.

Studies conducted to determine the monthly delivery requirements for project lands are summarized as follows.

Monthly Water Requirements

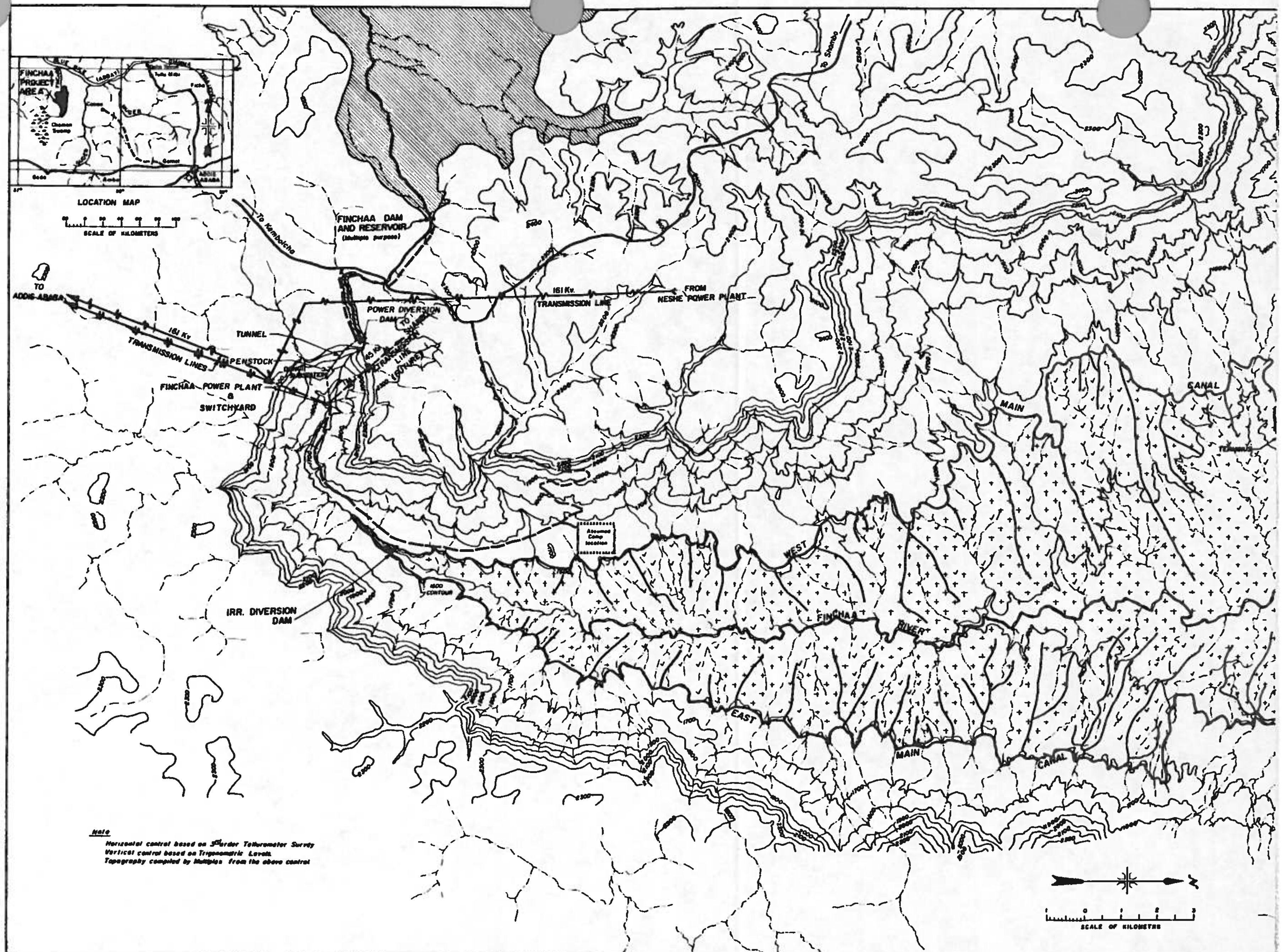
Month	mm.
October	94.3
November	128.0
December	136.3
January	136.0
February	122.3
March	122.8
April	116.3
May	108.0
Annual farm delivery requirements	954.0

Diversion requirements for the project lands would be a total of 210,450,000 cubic meters for the 15,000 hectares on the Finchaa Project and 115,710,000 cubic meters for the 8,490 hectares on the Amarti-Neshe Project.

FINCHAA PROJECT

The multipurpose development plan includes a storage dam, a power diversion dam, a power tunnel and penstocks, a powerplant, transmission facilities, an irrigation diversion dam, two main canals, a distribution system, and surface drains to provide irrigation for 15,000 hectares of land and 80,000 kilowatts of power installation.

Storage would be provided by constructing the Finchaa Dam at the outlet of Chomen Swamp. A continuous release would be made into the Finchaa River channel and diverted about 5 kilometers downstream through a tunnel and penstocks for production of hydroelectric power. The discharge from the powerplant would be again diverted into the two main canals to convey the water to the project lands. The canals would roughly parallel the river, the one on the east side being 56.7 kilometers in length and the one on the west side being 43.1 kilometers.


FINCHAA PROJECT AREA
LOCATION MAP
SCALE OF KILOMETERS
FINCHAA DAM AND RESERVOIR (Multiple purpose)
To Kombolcha
To Shambo
TO ADDIS-ABABA
161 Kv.
TRANSMISSION LINES
TUNNEL
PENSTOCK
FINCHAA POWER PLANT & SWITCHYARD
POWER DIVERSION DAM
161 Kv.
TRANSMISSION LINE
FROM NESHE POWER PLANT
Assumed Camp location
1600 CONTOUR
IRR. DIVERSION DAM
WEST
FINCHAA RIVER
EAST
MAIN
CANAL
N
SCALE OF KILOMETRES
Note
Horizontal control based on 3rd order Tellurometer Survey
Vertical control based on Trigonometric Levels
Topography compiled by Multiplex from the above control

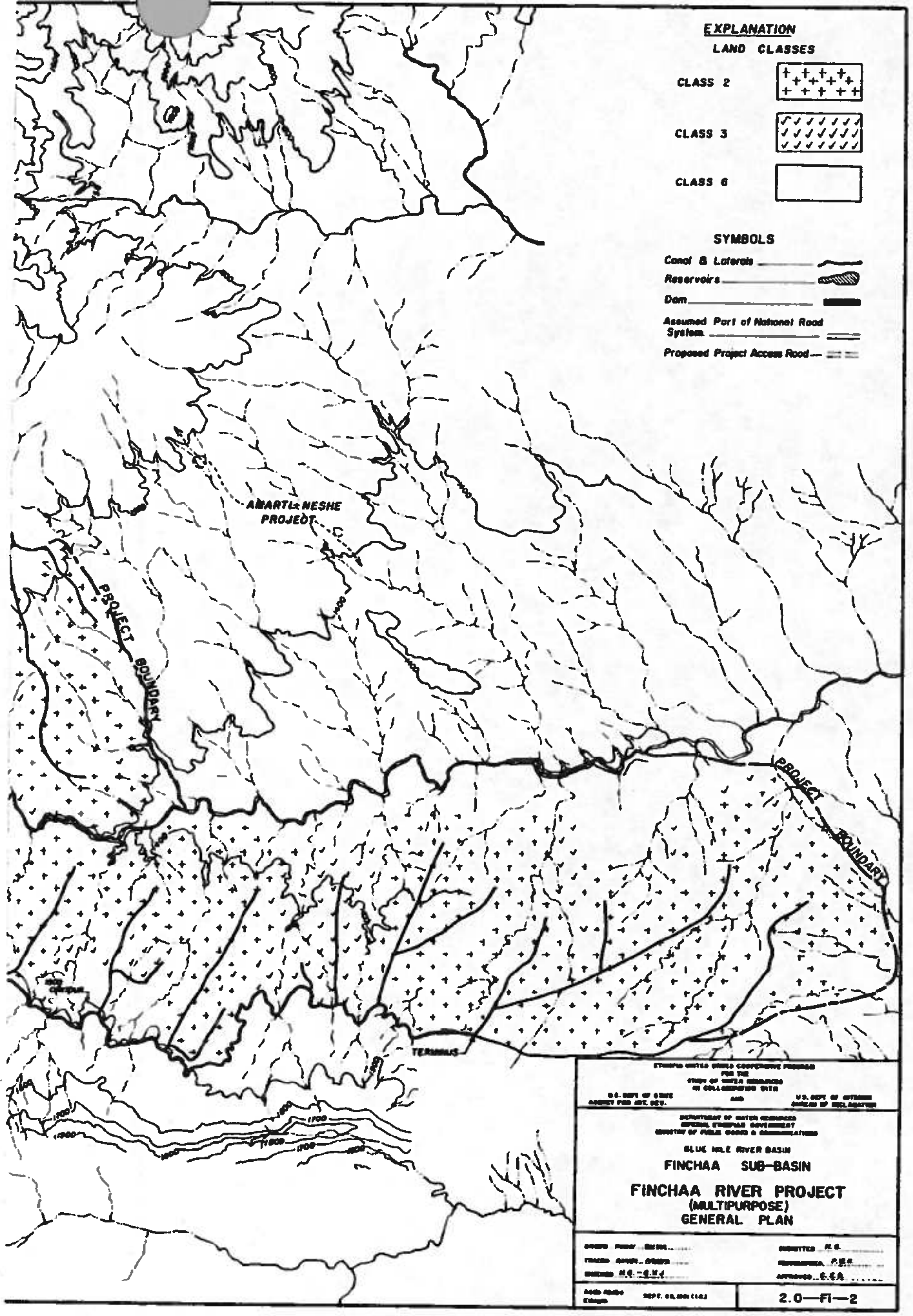


Figure 94--Finchaa River Project--General Plan

Project Features

The features of the multipurpose project plan are shown in general plan on Figure 94.

The site of the Finchaa Dam is near the outlet of the Chomen Swamp about 5 kilometers upstream from the Finchaa Falls. It would be a concrete-masonry dam with an ogee-type spillway at the center section. Diversion during construction would be accomplished by a gap in the dam, the gap to be closed during the dry season and the floods routed through the completed outlet and spillway section. See Figure 95 for plan, profile, and section of dam and appurtenant structures.

Finchaa Dam Data

Type	masonry-ogee
Volume of masonry in dam embankment	15,115 cu. m.
Elevation of spillway crest	2213.40 m.
Structural height	8.00 m.
Hydraulic height	7.23 m.
Length of crest	210 m.

The design of the spillway was based on an inflow design flood showing a peak inflow of 1,195 cubic meters per second and a 10-day volume of 280 million cubic meters. In routing the flood it was assumed that the reservoir would be at normal water surface elevation of 2213.40 meters at the beginning of the flood. The spillway would discharge 70 cubic meters per second at maximum water surface elevation of 2214.23 meters.

Spillway Data

Spillway crest elevation	2213.40 m.
Inflow design flood peak	1,195 cu. m. per sec.
Total flood volume, 10 days	280,000,000 cu. m.
Discharge at max. w.s. elevation	70 cu. m. per sec.

The outlet works would be located on the right abutment of the dam and would consist of two 2.0- by 2.0-meter slide gates with a capacity of 16 cubic meters per second at minimum water surface elevation of 2210 meters. Stoplogs have been suggested for closure of the gates if required in case of emergencies or repairs to the slide gates.

Outlet Works Data

Sill elevation	2208 m.
Discharge capacity at normal w.s. elevation (each)	23 cu. m. per sec.
Type of gate	slide gates

The reservoir would be located in the Chomen Swamp. The soil cover in the reservoir forms an excellent impermeable blanket, and seepage is not considered to be a serious factor. The reservoir at normal water surface elevation would impound 464 million cubic meters of water at initial storage covering an area of 188 square kilometers.

At the damsite the foundation rock is hard basalt, which is exposed along the stream channel and generally on the side of the valley. The volcanic bedrock is jointed, and grouting will be necessary to prevent excessive leakage. Cut-off trench excavation should not exceed an average depth of 1 meter to remove loose rocks, seams, tree roots, and other nongroutable material along the trench of the dam.

There is an abundance of good sandy clay for impervious materials near the damsite. The hard volcanic rock adjacent to the damsite can be quarried for rockfill, riprap, or masonry and can be crushed for concrete or mortar aggregate.

Access to the project would have to be improved from Gedo to the Finchaa damsite and is considered to be a part of the national road system. Thirty kilometers of access roads were included in the estimates of cost.

The power diversion dam is on the Finchaa River approximately 200 meters upstream from the lip of the falls. It would be a masonry overflow dam with a maximum height of about 7.5 meters above streambed. The inlet structure for the power tunnel would be located on the right abutment and gated for emergency closure to the tunnel.

Power Dam Data

Type	masonry-ogee
Volume of masonry	1,320 cu. m.
Normal w.s. elevation	2200 m.
Spillway crest elevation	2200 m.
Structural height	7.5 m.
Hydraulic height	5.5 m.
Length of crest	114 m.

The tunnel, starting at the inlet portal near the right abutment of the power diversion dam at elevation 2195.6 meters, would be of pressure type, requiring reinforced-concrete lining. The increased hydraulic head and the poor rock formations will require a welded steel pipe to be encased in the prolongation of the tunnel for a distance of 1,210 meters, thence under cut-and-cover section for another 320 meters. Two penstocks would then be connected, terminating at the powerplant.

Tunnel Data

Type	pressure
Length	330 m.
Diameter	2.2 m.
Design capacity (average)	11.2 cu. m. per sec.

Welded Steel Pipe and Penstock Data

Welded steel:	Length	1,530 m.
	Diameter	2.2 m.
	Design capacity	11.2 cu. m. per sec.
Penstocks (two):	Length (each)	1,280 m.
	Diameter (each)	1.524 m.

The powerplant at the base of the falls would produce an annual gross generation of 360,420,000 kilowatt-hours in an adverse water supply period. Two generator units of 40 megawatts each would provide a total plant capacity of 80 megawatts or 100 millivolt-amperes at 0.8 power factor. Because of the high head (467 meters net), the two turbines will be of the impulse type.

Powerplant Data

Design head	467 m.
Number of generators	2
Rating of each generator	40,000 kw.
Total plant capacity	100,000 kv.-a.
Turbine ratings (English)	56,500 hp.
Synchronous speed	429 r.p.m.
Type of turbines	impulse

Assuming that the Finchaa Powerplant will be the first Blue Nile plant to serve the Addis Ababa Complex, followed next by the Neshe Powerplant, a double-circuit steel tower transmission line with one circuit installed initially and rated at 161 kilovolts would be constructed simultaneously with the Finchaa Powerplant from the Dongi Substation to Addis Ababa. Later, the second circuit would be installed on the then existing towers when the Neshe Powerplant is constructed, thus completing the double-circuit line. The power line would run generally south along the east side of the swamp toward Gedo and thence along the main highway to Addis Ababa and would be about 250 kilometers in length. In spite of their greater initial investment, steel towers are planned for the project due to lower annual costs than wood poles.

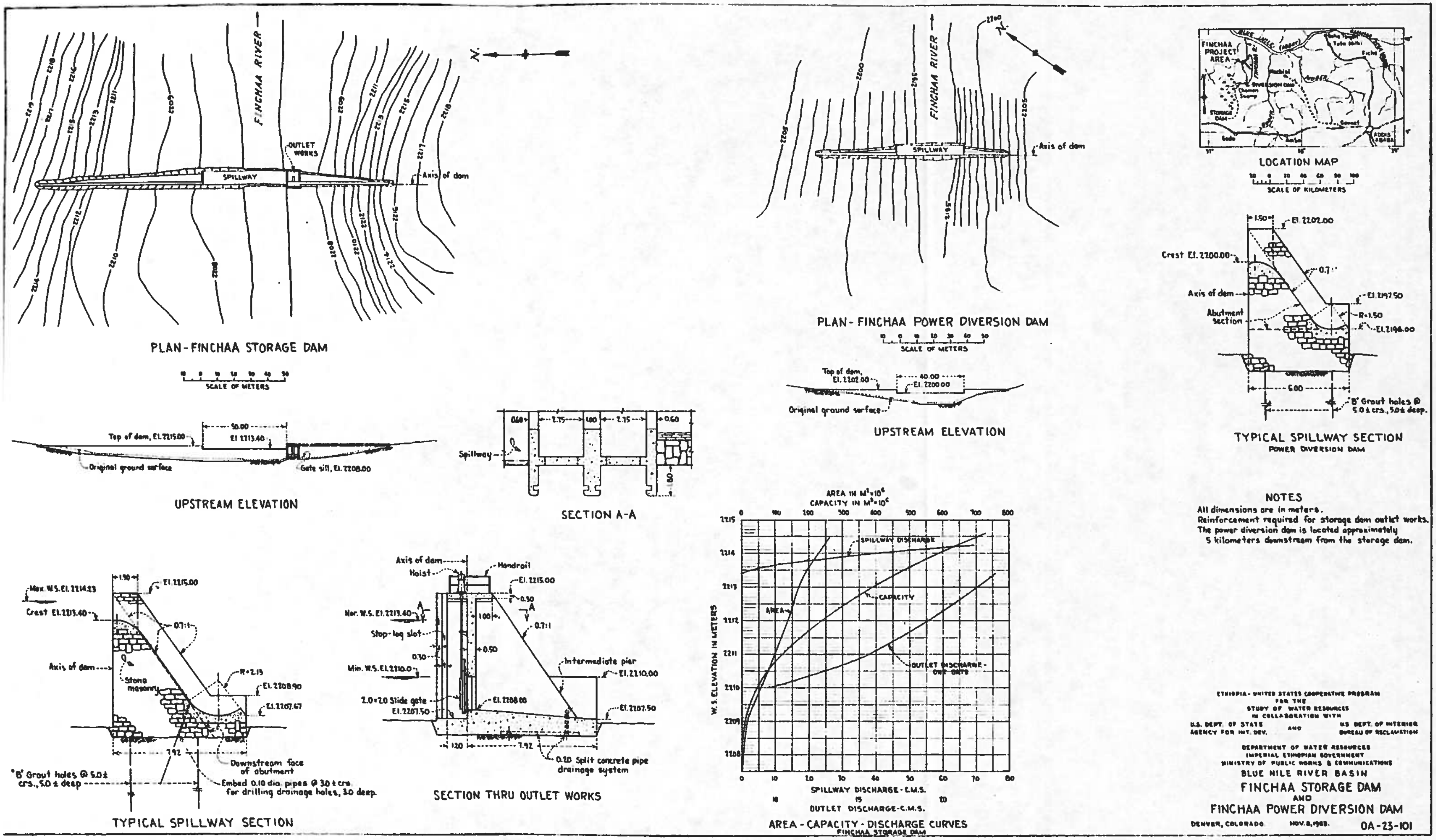


Figure 95--Finchaa Storage Dam and Finchaa Power Diversion Dam--Plans and Sections

Provisions have been made for future facilities to serve local loads, although it is believed that it will not be practicable to serve rural areas in the immediate future. Delivery of the entire plant output will undoubtedly be utilized in the Addis Ababa Complex or at other urban centers within transmission distance.

A 45-kilovolt, 110-kilometer line around the north and west sides of the swamp, serving Shambo, Haratu, and Gedo, may eventually be justified. Ultimately, with increased loads, a 161/45-kilovolt substation can be installed at Gedo, completing the loop.

By 1971, the Ethiopian Electric Light and Power Authority will have constructed the Sebeta and Gafarsa Substation No. 1 west of Addis Ababa as part of a basic plan to provide a 132-kilovolt ring bus around the city. The 161-kilovolt lines from the Finchaa Sub-basin powerplants can either terminate in 161- and 132-kilovolt additions to Gafarsa Substation No. 1 or in a separate substation which can eventually be expanded to include 230 kilovolts in the future.

The terminal facilities required in the receiving-end substation, Gafarsa No. 2, for the first 161-kilovolt line (from Finchaa Powerplant) will consist of a 161-kilovolt line bay, transformer bay, 161/132-kilovolt autotransformer bay, and three 132-kilovolt bays (two line bays). These facilities have been designated as Stage 01.

The irrigation diversion dam, approximately 11 kilometers downstream from the powerplant, would have headworks for two radial gates, one for the East Main Canal diverting 10.5 cubic meters per second, and the other for a flow of 8.5 cubic meters per second. The ogee-type spillway envisioned for this dam is estimated to be 210 meters in length.

Irrigation Diversion Dam Data

Volume of masonry	2,650 cu. m.
Maximum w.s. elevation	1602.25 m.
Normal w.s. elevation	1600.5 m.
Structural height	3.5 m.
Elevation at top of dam	1602.6 m.
Maximum flood discharge	900 cu. m. per sec.
Crest length	292 m.

The main canals have been planned to serve as much as possible of the lands determined to be arable. The location would traverse rolling hills, crossing ravines and draws which will require suitable structures to accommodate the high flows of the rainy season. The route would be for the most part in the fairly deep soils of the valley, but short reaches might possibly be in sandstone where soil cover is thin or entirely absent. No problem should be encountered from constructing the canal as an unlined section. Structures, such as bridges, culverts, turnouts, siphons, checks, and drops, would be provided as required.

The East Main Canal would extend in a northerly direction for a distance of approximately 56.7 kilometers and would have an initial capacity of 10.2 cubic meters per second. It would serve approximately 8,000 hectares of irrigable lands.

Canal Data

Type	unlined
Length	56.7 km.
Initial capacity	10.2 cu. m. per sec.
Initial w.s. elevation	1600 m.

The West Main Canal would extend from the left abutment of the diversion dam and proceed in a northerly direction for a distance of approximately 43.1 kilometers. It would have an initial capacity of 8.5 cubic meters per second and would serve approximately 7,000 hectares of irrigable land on the west side of the Finchaa River.

Canal Data

Type	unlined
Length	43.1 km.
Initial capacity	8.5 cu. m. per sec.
Initial w.s. elevation	1600 m.

The irrigable lands occur on broad topped ridges with slopes of 1 to 2 percent, lending themselves readily to water spreading with minimum expense of land leveling, and increasing in slope on the sides of the ridges up to 12 percent. Distribution of water on steeper gradients will be more difficult and costly to develop. The distribution system for the 15,000 hectares of irrigable lands is envisioned as an open-ditch, unlined canal to meet the peak demand of any lateral service area during the irrigation season.

Surface drainage canals will be required for removal of irrigation waste and excess precipitation falling on the irrigable lands. The erosiveness of the soils and the fast slope of the lands are such that, without proper drainage, the erosion would develop numerous drainageways that would wash away the soil resources. The natural drainage channels would be used for outlet purposes wherever practicable and would be protected and improved wherever necessary.

In more detailed future studies, the requirements and feasibility of subsurface drains should be given close attention. Such studies should include existing water table behavior, subsurface obstructions such as dikes that would impound water, an evaluation of present vegetation for evidence of wet areas, and suitable tests to determine subsurface drainage conditions.

Housing and administrative buildings will be required by government personnel who will administer and oversee construction. Estimates of cost have been obtained from curves.

Estimated Project Cost

Construction Cost

Feature	In thousands of Ethiopian dollars			
	Total construction cost	Facilities		
		Joint-use	Irrigation	Power
Finchaa Dam and Reservoir	682	682	-	-
Power Diversion Dam	210	-	-	210
Power tunnel and penstocks	32,948	-	-	32,948
Powerplant	11,015	-	-	11,015
Transmission plant	21,004	-	-	21,004
Irrigation Diversion Dam	545	-	545	-
East Main Canal	3,031	-	3,031	-
West Main Canal	1,989	-	1,989	-
Distribution system	7,734	-	7,734	-
Drains	2,813	-	2,813	-
Access roads	1,813	1,813	-	-
Service facilities	2,343	2,343	-	-
Total Construction Cost	86,127	4,838	16,112	65,177

Development Cost. Clearing the lands of the trees and brush will be required before irrigation of the agricultural crops. The vegetative cover over most of the project area consists of a fairly dense growth of tropical savanna woodland, typified by acacia, fig, and other varieties of deciduous trees and shrubs. The slope of the valley lends itself readily to water-spreading with minimal expense for land leveling. Only a small portion of the land has slopes of less than 1 percent. The total cost for clearing and leveling requirements for the 15,000 hectares would be roughly Eth$5,325,000.

TABLE 39--SUMMARY OF CROPS AND GROSS FARM INCOME--FINCHAA PROJECT, 15,000 HECTARES

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season					
	Price received per 100 kg. Eth$	Pre-project income Eth$	Crop distri-bution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distri-bution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Postproject income Eth$	Gross cro[p] income Eth$
Buckwheat	9.60		750	2,000	1,500,000	144,000	-	-	-	-	144,000	144,000
Corn	10.18		2,250	3,175	7,143,750	727,234	4,500	1,180	5,310,000	540,558	1,267,792	1,267,792
Millet	9.90		-	-	-	-	3,750	975	3,656,250	361,969	361,969	361,969
Sorghum	13.70		3,000	2,980	8,940,000	1,224,780	-	-	-	-	1,224,780	1,224,780
Field beans	16.52		1,500	1,780	2,670,000	441,084	1,500	950	1,425,000	235,410	676,494	676,494
Flaxseed	21.14		750	1,000	750,000	158,550	-	-	-	-	158,550	158,550
Mustard	17.75		750	1,170	877,500	155,756	1,500	700	1,050,000	186,375	342,131	342,131
Castor beans	26.62		1,500	2,000	3,000,000	798,600	-	-	-	-	798,600	798,600
Sunflower	25.60		1,500	1,800	2,700,000	691,200	-	-	-	-	691,200	691,200
Coffee	161.84		750	960	720,000	1,165,248	750	-	-	-	1,165,248	1,165,248
Peppers	55.93		750	920	690,000	386,116	-	-	-	-	386,116	386,116
Tobacco	114.60		750	2,000	1,500,000	1,719,000	-	-	-	-	1,719,000	1,719,000
Subtotal, crops			14,250			7,611,568	12,000			1,324,312	8,935,880	8,935,880
Fallow			-			-	2,250			-	-	-
Subtotal, cultivated area			14,250			7,611,568	14,250			1,324,312	8,935,880	8,935,880
Noncultivated irrigable land			750			-	750			-	-	-
Total area		-	15,000			7,611,568	15,000			1,324,312	8,935,880	8,935,880
Income per hectare		-				507.44				88.29	595.73	595.73

Operation, Maintenance, and Replacement Cost. The operation, maintenance, and replacement annual charges for the multipurpose facilities are estimated to be about Eth$1,870,000, including Eth$98,000 for taxes and insurance, as summarized below.

Facility	Operation and maintenance	Replacements
Joint-use		
Dam and reservoir, access road and permanent camp	Eth$ 106,000	-
Irrigation unit		
Conveyance system	540,000	-
Power unit		
Diversion dam	4,000	-
Tunnels and penstocks	13,700	-
Powerplant	653,000	Eth$32,800
Transmission plant	376,000	46,500
Other	98,000	-
Totals	Eth$1,790,700	Eth$79,300

Benefit-Cost Ratio

The benefit-cost ratio for this project is 3.44 to 1.00.

AMARTI-NESHE PROJECT

The plan for the multipurpose Amarti-Neshe Project includes a storage dam, a power canal and tunnel, penstock, powerplant, transmission facilities, irrigation diversion dam, two main canals, and a drainage system to irrigate 8,490 hectares of land and produce 80,000 kilowatts of power.

Storage is provided by dams in the Amarti and Neshe River basins, the reservoirs being connected by an open-ditch channel through a narrow saddle separating the two basins. The Amarti River channel is 42 meters higher in elevation than the Neshe, and water would be impounded by a low masonry dam on the Amarti that will serve as a spillway for both reservoirs.

Releases would be made from the outlet works located in the Neshe Dam into a power canal, then to a tunnel and penstocks connected to the powerplant. Below the powerplant the water would be diverted into the two main canals for delivery to the distribution system.

Project Features

The features of the multipurpose project plan are shown in general plan on Figure 96. The Neshe Dam would be about 1.3 kilometers upstream from the lip of the falls on the Neshe River. It would be an earth and rockfill structure. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit. Figure 97 shows plans, sections, and profiles of both the Neshe and Amarti Dams.

Neshe Dam Data

Type	earth-rockfill
Earth embankment, volume	1,900,000 cu. m.
Rock embankment, volume	2,500,000 cu. m.
Elevation of crest	2240 m.
Freeboard	2.41 m.
Structural height	57 m.
Hydraulic height	54.59 m.
Length of crest	1,100 m.
Width of crest	10 m.

By constructing an equalizing channel, the two reservoirs in effect will become one. The Amarti Dam is planned to serve as a spillway for the combined reservoir for passing the floodflows. It would have a concrete overflow section abutted by a compacted earth-fill dike. The spillway will discharge 962 cubic meters per second over the crest.

Amarti Dam Spillway Data

Type	concrete overflow
Top of dam	2237 m.
Spillway crest elevation	2233 m.
Inflow design flood peak	1,939 cu. m. per sec.
Volume of concrete in embankment	49,460 cu. m.
Volume of earth in embankment	100,000 cu. m.
Structural height	12 m.
Hydraulic height	9.59 m.
Length of spillway crest	250 m.
Discharge at max. w.s. elevation	962 cu. m. per sec.

The outlet works is located on the left abutment of the Neshe Dam. It would consist of an intake structure; a horseshoe concrete conduit under pressure to the gate chamber where a slide gate is provided for emergency control; and a steel outlet pipe from the gate chamber to release water through two metal slide gates discharging into a stilling basin.

Outlet Works Data

Sill elevation	2205 m.
Capacity at min. operating w.s.	20 cu. m. per sec.
Type of gate	slide gates

The basins of both the Amarti and the Neshe Rivers are covered with clay, forming an excellent impermeable blanket. Seepage is not considered a serious problem. The reservoir would impound 847 million cubic meters of water covering an area of 53 square kilometers.

The sites for the Neshe and Amarti Dams are geologically similar. The cutoff trench should extend into the volcanic rock and a grout curtain placed along the cutoff trench to assure against leakage.

Impervious fill material can be found almost anywhere in the vicinity of the proposed damsites. Riprap and rockfill can be obtained from the intervalley basaltic lava upstream or downstream from the damsites. Volcanic material can also be crushed for aggregate.

Access to the potential damsites will require construction of an access road for a distance of approximately 12 kilometers. Access to the powerplant from the proposed Finchaa access road would require 35 kilometers of new road construction. This same road would serve as an access to the project lands.

The power canal extending from the outlet works of the dam would convey the water to the tunnel which in turn would supply the powerplant through the penstocks.

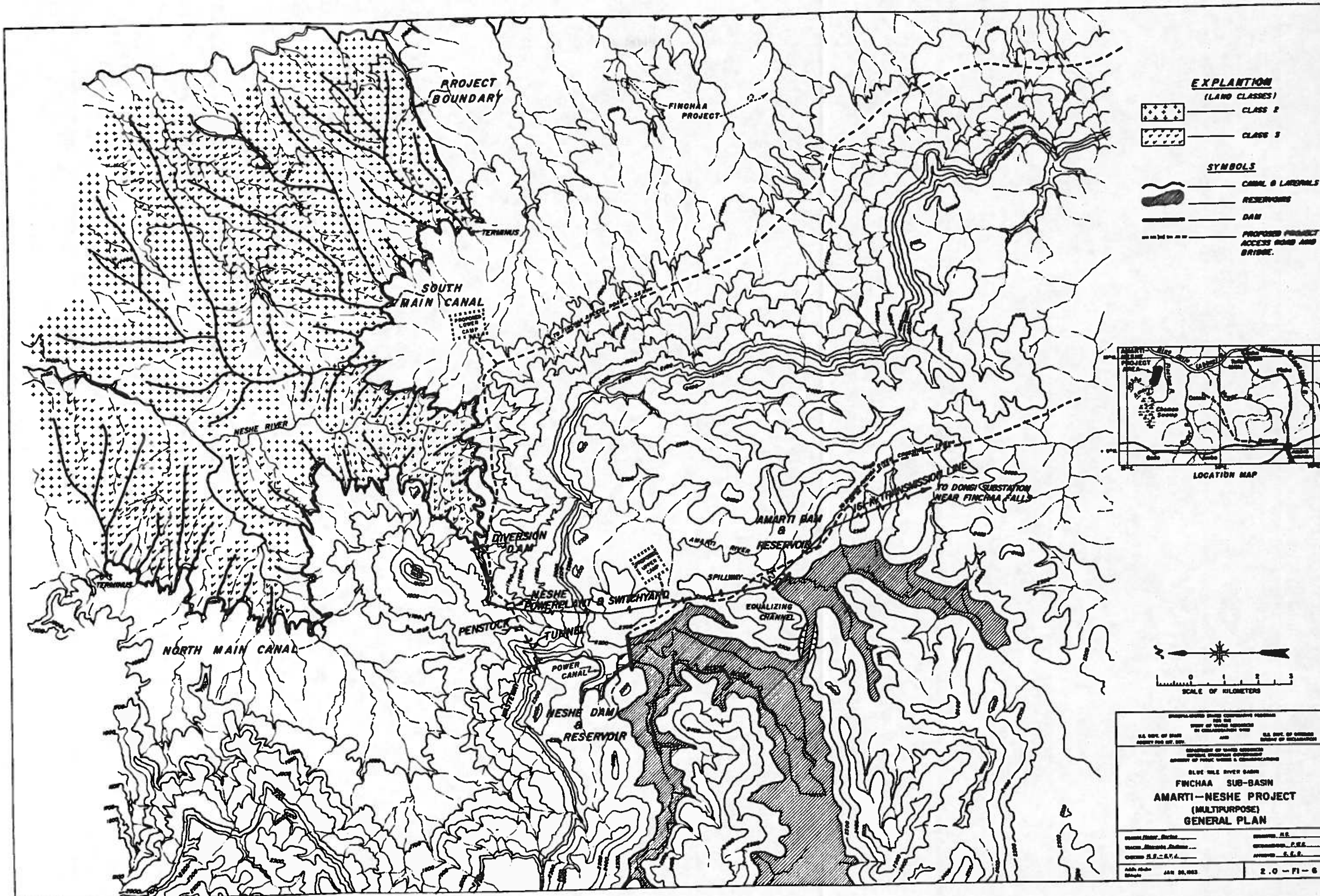


Figure 96--Amarti-Neshe Project--General Plan

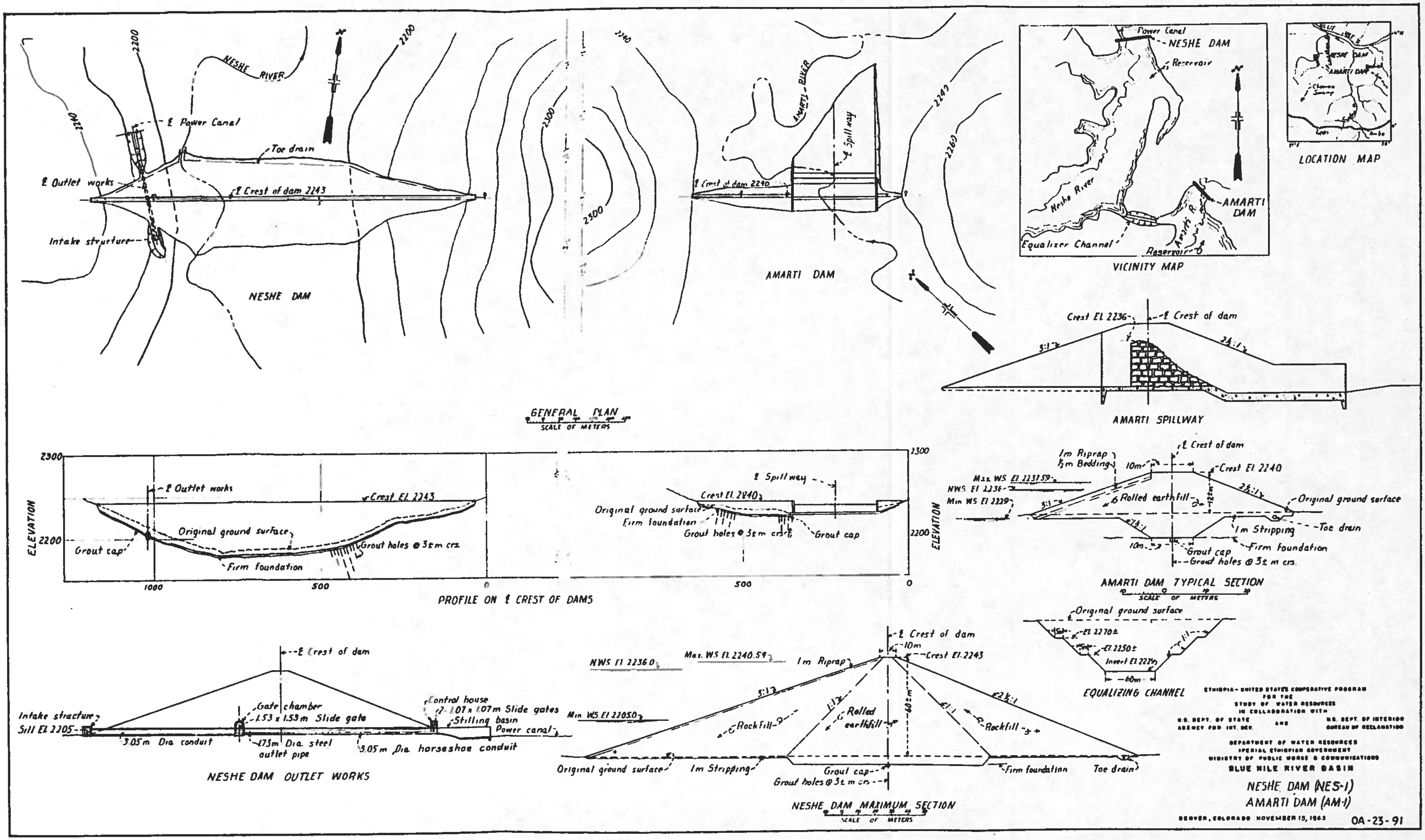


Figure 97--Neshe Dam (NES-1) and Amarti Dam (AM-1)--Plan and Sections

Canal Data

Type	masonry lined
Length	6 km.
Capacity	20 cu. m. per sec.
Initial w. s. elevation	2205 m.

The power tunnel at its beginning would be reinforced concrete-lined and would require an encased steel pipe at the lower end. Two welded steel penstocks with butterfly valves for emergency controls would be required at the downstream end just before entering the turbines.

Tunnel Data

Type	pressure
Length	433 m.
Diameter	2.4 m.
Design capacity	18.2 cu. m. per sec.

Penstock Data

Number	2
Length	1,467 m.
Diameter (each)	1.52 m.
Design capacity	9.1 cu. m. per sec.

The Neshe Powerplant would be located at the base of the escarpment. The annual gross generation is estimated at 378 million kilowatt-hours for an adverse water supply period. The plant would include two generator units of 40,000 kilowatts each, providing a total plant capacity of 80,000 kilowatts, or 100,000 kilovolt-amperes at 0.8 power factor.

Powerplant Data

Design head	560 m.
Number of generators	2
Rating of each generator	40,000 kw.
Total plant capacity	80,000 kw.
Turbine ratings (English)	56,500 hp.
Synchronous speed	375 r.p.m.
Type of turbines	impulse

The switchyard arrangement is identical to that of the Finchaa Powerplant. About 32 kilometers of single-circuit transmission lines on steel towers of 161-kilovolt capacity will be required to connect to the Dongi Substation. Also terminating at this substation would be one circuit of 248-kilometer, 161-kilovolt, double-circuit line to Addis Ababa.

The diversion dam would divert the flows from below the powerplant into the two main canals for irrigation. It is envisioned as an overflow, masonry-concrete dam with suitable outlet and sluice works provided.

Irrigation Diversion Dam Data

Volume of masonry	1,850 cu. m.
Normal w.s. elevation	1501.5 m.
Structural height	5.0 m.
Crest length of spillway	60.0 m.
Length of dam	83.0 m.

The South Main Canal would extend in an easterly direction for about 39 kilometers. It would originate on the right abutment of the diversion dam. It would be an unlined canal with suitable structures to accommodate the high flows of the rainy seasons. Canal excavation will not present any major problems. The canal is designed to irrigate 6,360 hectares of land.

Canal Data

Type	unlined
Length	39 km.
Initial capacity	11.65 cu. m. per sec.
Initial w.s. elevation	1500 m.

The North Main Canal would extend in a northerly direction. It would originate on the left abutment of the diversion dam and would serve approximately 2,130 hectares of land.

Canal Data

Type	unlined
Length	29.4 km.
Initial capacity	3.5 cu. m. per sec.
Initial w.s. elevation	1500 m.

Estimated Project Cost

Construction Cost

Feature	In thousands of Ethiopian dollars			
	Total construction cost	Facilities		
		Joint-use	Irrigation	Power
Neshe Dam and Reservoir	39,867	39,867		-
Amarti Dam and Reservoir	12,267	12,267		-
Power canal	2,213	-	-	2,213
Power tunnel	2,251	-	-	2,251
Powerplant and penstocks	37,247	-	-	37,247
Transmission plant	14,563	-	-	14,563
Irrigation Diversion Dam	280	-	280	-
South Main Canal	1,994	-	1,994	-
North Main Canal	979	-	979	-
Distribution system	4,377	-	4,377	-
Drains	1,857	-	1,857	-
Access roads	2,938	2,938	-	-
Service facilities	2,187	2,187	-	-
Total Construction Cost	123,020	57,259	9,487	56,274

Development Cost. Clearing and leveling for the project are estimated to be Eth$1,953,000 for clearing and Eth$1,061,000 for leveling.

Operation, Maintenance, and Replacement Cost. Annual operation, and maintenance cost for the multipurpose facilities is estimated to be Eth$1,724,000, including Eth$84,000 for taxes and insurance, as summarized below.

TABLE 40--SUMMARY OF CROPS AND GROSS FARM INCOME--AMARTI-NESHE PROJECT, 8,490 HECTARES

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season					
	Price received per 100 kg. Eth$	Pre-project income Eth$	Crop distri-bution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distri-bution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Postproject income Eth$	Gross crop income Eth$
Buckwheat	9.60		425	2,000	850,000	81,600	-	-	-	-	81,600	81,600
Corn	10.18		1,275	3,175	4,048,125	412,095	2,550	1,180	3,009,000	305,315	717,410	717,410
Millet	9.90		-	-	-	-	2,120	975	2,067,000	204,635	204,635	204,635
Sorghum	13.70		1,700	2,980	5,066,000	694,040	-	-	-	-	694,040	694,040
Field beans	16.52		850	1,780	1,513,000	249,950	850	950	807,500	133,400	383,350	383,350
Flaxseed	21.14		425	1,000	425,000	89,845	-	-	-	-	89,845	89,845
Mustard	17.75		425	1,170	497,250	88,260	850	700	595,000	105,610	193,870	193,870
Castor beans	26.62		850	2,000	1,700,000	452,540	-	-	-	-	452,540	452,540
Sunflower	25.60		850	1,800	1,530,000	391,680	-	-	-	-	391,680	391,680
Coffee	161.84		425	960	408,000	660,310	425	-	-	-	660,310	660,310
Peppers	55.93		425	920	391,000	218,690	-	-	-	-	218,690	218,690
Tobacco	114.60		425	2,000	850,000	974,100	-	-	-	-	974,100	974,100
Subtotal, crops			8,075			4,313,110	6,795			748,960	5,062,070	5,062,070
Fallow			-			-	1,280			-	-	-
Subtotal, cultivated area			8,075			4,313,110	8,070			748,960	5,062,070	5,062,070
Noncultivated irrigable land			415			-	415			-	-	-
Total area		-	8,490			4,313,110	8,490			748,960	5,062,070	5,062,070
Income per hectare		-				508.02				88.22	596.24	596.24

Facility	Operation and maintenance	Replacements
<u>Joint-use</u>		
Dam and reservoir	Eth$ 129,000	-
<u>Irrigation unit</u>		
Conveyance system	351,000	-
<u>Power unit</u>		
Power canal and tunnel	18,000	-
Powerplant	653,000	Eth$35,400
Penstocks	23,500	-
Transmission plant	370,800	58,500
Other	84,000	-
Totals	Eth$1,630,100	Eth$93,900

Benefit-Cost Ratio

The benefit-cost ratio for this project is 2.38 to 1.00.

Projects In Diddessa Sub-Basin

BASIN DESCRIPTION

The Diddessa River is the largest tributary of the Blue Nile River in terms of volume of water, contributing roughly a quarter of the total flow as measured at the Sudan border. Draining an area of nearly 34,000 square kilometers (13,100 square miles), the Diddessa River originates in the Mt. Vennio and Mt. Wache ranges, flowing in an easterly direction for about 75 kilometers, then turning rather sharply to the north until it reaches the Blue Nile River. The major tributaries of the Diddessa River are the Wama entering from the east, the Dabana from the west, and the Angar from the east. Four projects have been identified with the development of the basin, three being multipurpose and one being for hydroelectric power generation alone.

The Arjo-Diddessa multipurpose project is located downstream from the river's sharp turn. The Dabana Project is west of the Diddessa River. The Lower Diddessa Power Project would be located about 85 kilometers upstream from the Diddessa's confluence with the Blue Nile River and about 15 kilometers upstream from the Angar-Diddessa confluence. The Angar multipurpose project area is situated in a relatively wide site about 100 kilometers from the Angar-Diddessa confluence. Locations of the projects appear on Figure 98.

ARJO-DIDDESSA MULTIPURPOSE PROJECT

Project Area

The project area is located on both sides of the Diddessa River, about midway between the towns of Lekkemt and Jima. The area consists of low, relatively flat, bottom lands adjacent to the river and a smaller part of the adjoining higher and hilly lands. The lower reaches of the potential irrigation project are situated along the Diddessa adjacent to the village of Arjo.

Geology and Topography

The valley is underlain primarily by volcanic rocks and remnants of Triassic sandstone. Some metamorphic rocks are exposed along the downstream portions of the valley. The upper basin lies in a major fault zone which generally parallels the drainage system.

Topographically, the area is characterized by large expanses of gently sloping land, nearly ideal for irrigation agriculture. Gently sloping hills, becoming progressively steeper on both sides of the main stream, comprise the project boundary area.

Climate

The project area elevation averages about 1330 meters above sea level, which gives rise to the tropical climate at this latitude. Annual precipitation in this area averages about 100 centimeters and is concentrated mostly from June to September.

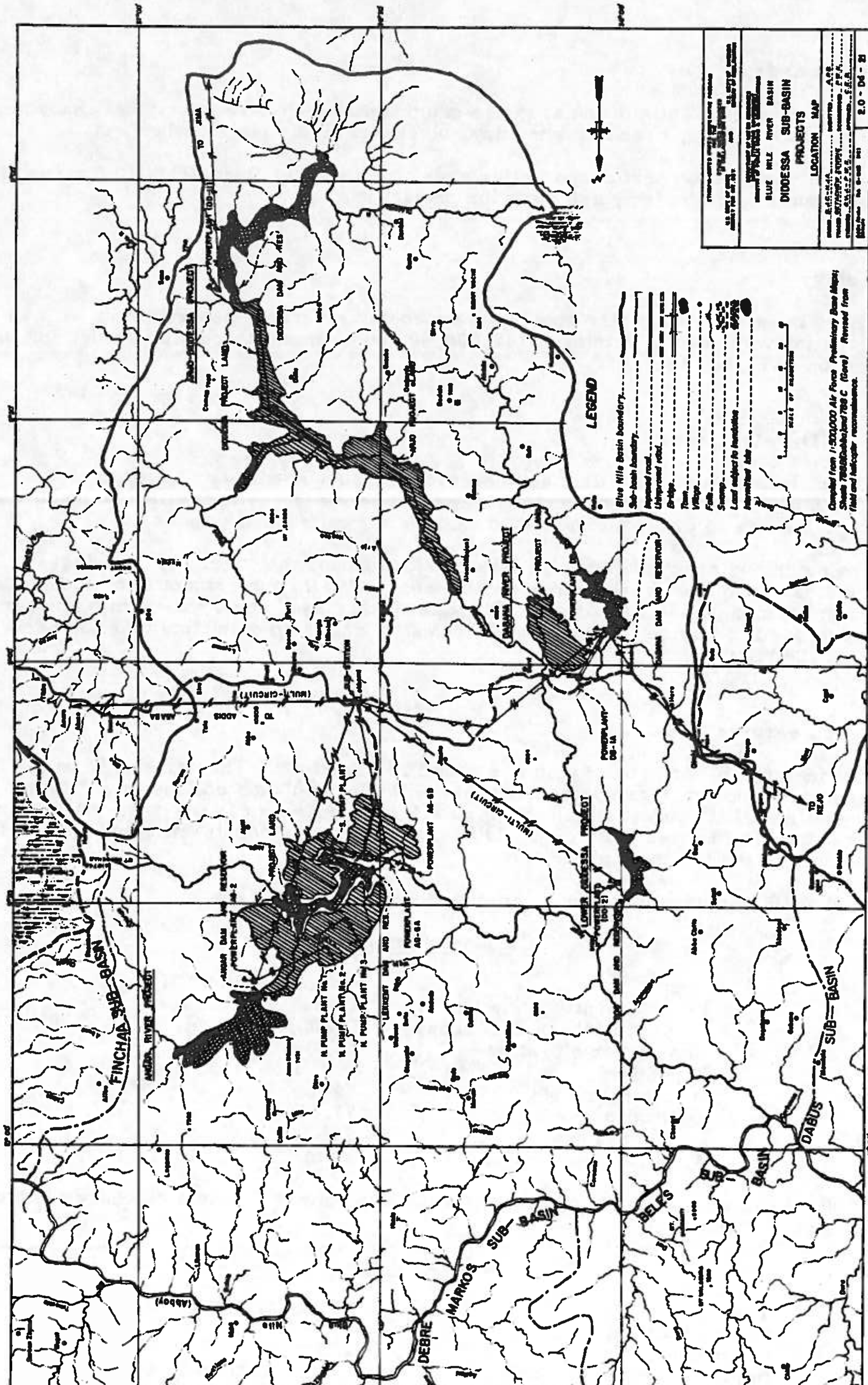


Figure 98--Diddessa Sub-basin Projects--Location Map

Project Lands

The predominant soils of the area are grumusols which have the typical characteristics of heavy clay texture, cracking when dry, black and highly plastic when wet.

Land classification performed in this area revealed that about 16,800 hectares of Class 3 lands could be irrigated from the project works.

Hydrology

There is an abundant water supply for hydroelectric power generation as well as for irrigation development. A total of 183,000,000 cubic meters would be needed for the irrigation of 16,800 hectares.

Plan of Development

The plan would include a dam and reservoir, a 30,000-kilowatt powerplant, two main canals, a distribution system, and drainage canals for irrigation of 16,800 hectares of land and the annual production of 145.5 million kilowatt-hours of power.

The earth and rock fill Diddessa Dam would impound the waters of the Diddessa River. It would have an outlet works, on each abutment, with the powerplant to be located at the toe of the dam on the left abutment. The East Main Canal would extend in a northerly direction for 192 kilometers with the West Main Canal also extending in a northerly direction for 204 kilometers.

Project Features

The features of the project plan are shown in Figure 99. The damsite is on the Diddessa River about 40 kilometers upstream from the Diddessa-Wama confluence. It would be an earth and rock fill dam. Two small dikes will be required near the west of left abutment of the dam. The Diddessa River would be diverted during construction by a concrete tunnel around on the left bank of the river.

Figure 100 includes the plan, section and profiles of the dam.

Diddessa Dam Data

Type	earth and rock fill
Embankment volume (earth)	2,400,000 cu.m.
Embankment volume (rock)	2,600,000 cu.m.
Top of dam elevation	1421 m.
Freeboard	1.95 m.
Structural height	79 m.
Hydraulic height	77.05 m.
Length of crest	833 m.
Width of crest	10 m.

A side-channel, uncontrolled-type spillway is planned. It would discharge 1,908 cubic meters per second.

Spillway Data

Type	uncontrolled side channel
Crest elevation	1414.97 m.
Crest length	120 m.
Inflow design flood--peak	5,390 cu.m. per sec.
Total flood volume--4-day period	565 million cu.m.
Discharge at max. w.s. elevation	1908 cu.m. per sec.

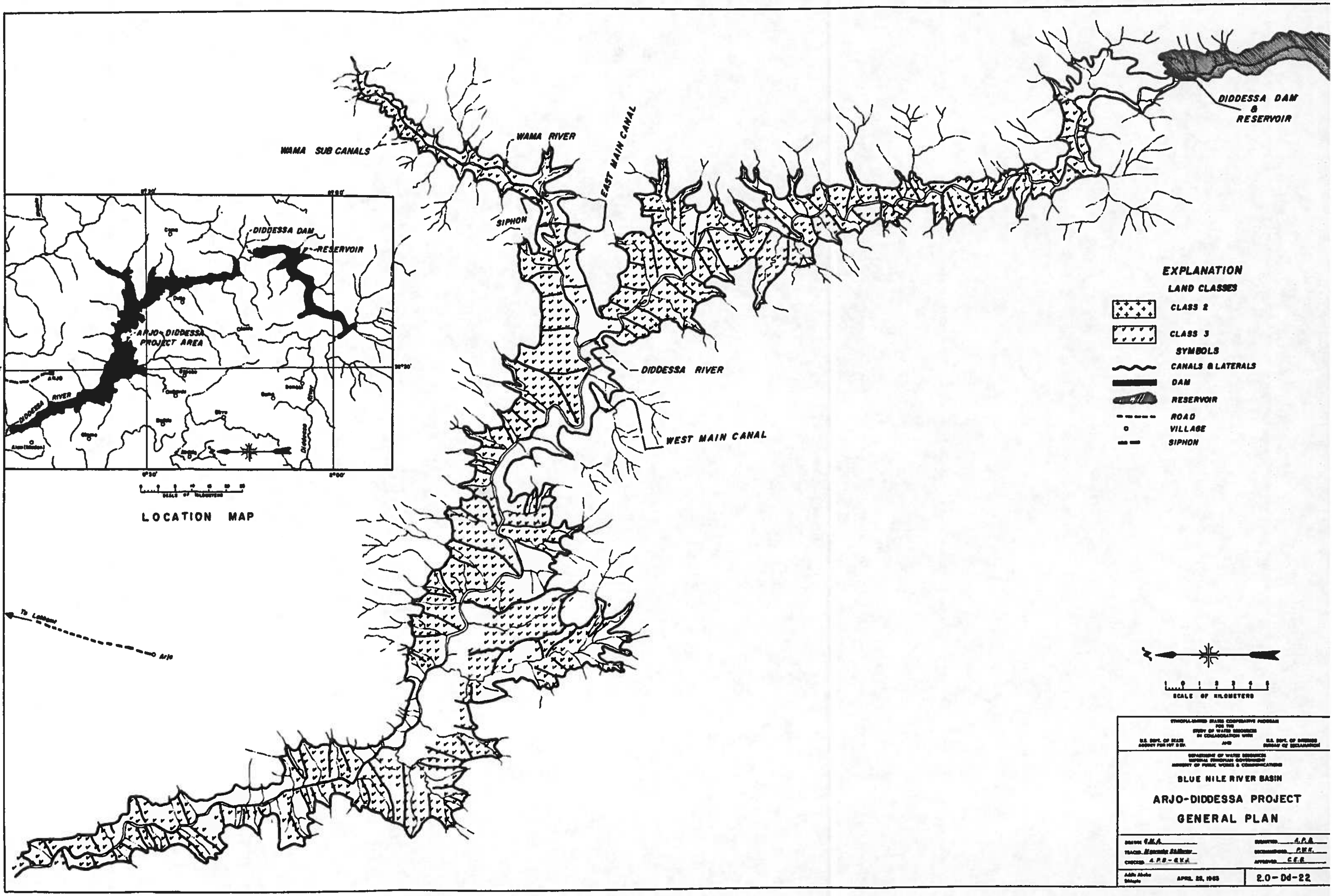


Figure 99--Arjo-Diddessa Project--General P

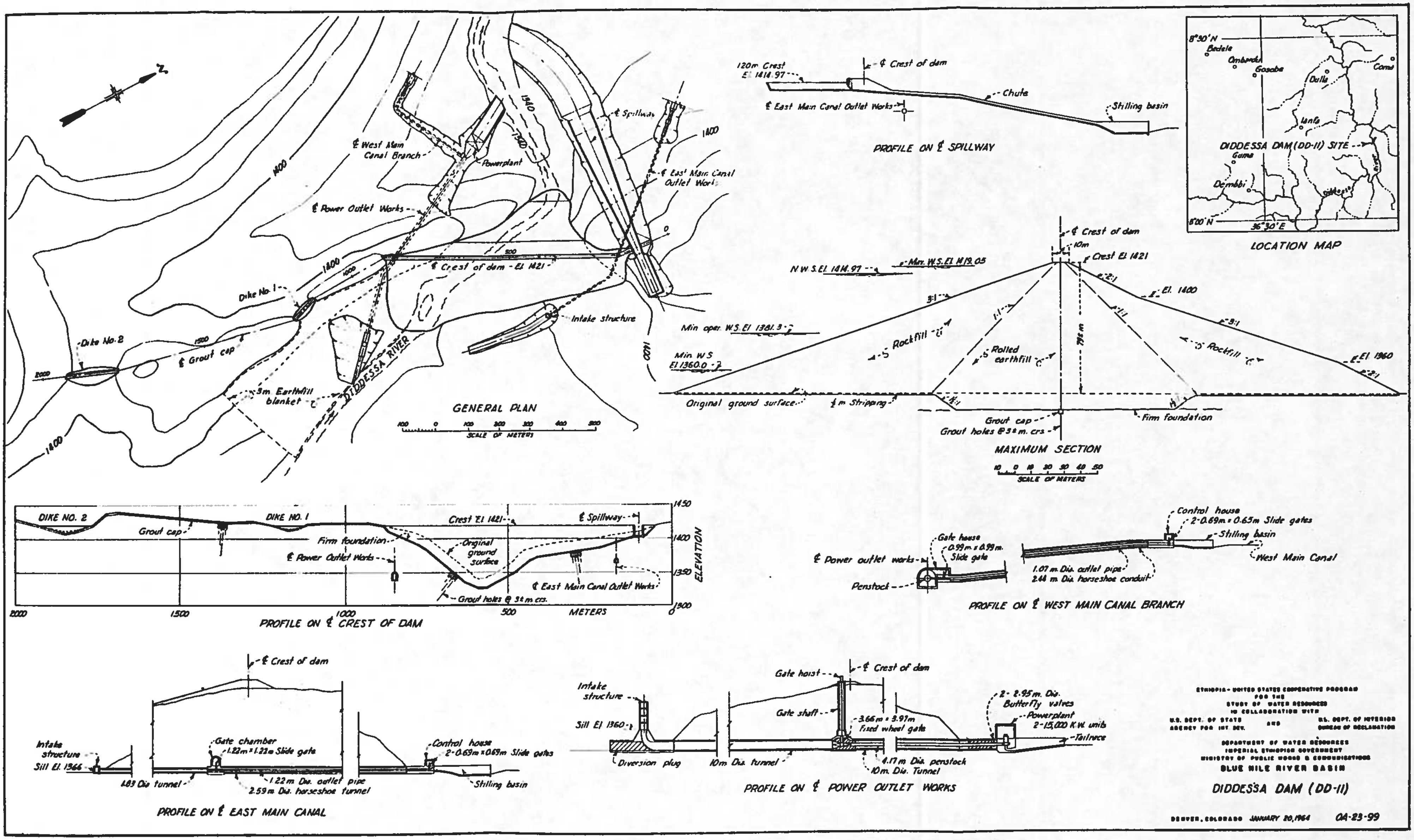


Figure IDD--Diddessa Dam (DD-11)--Plan and Sections

Two outlet works will be required to control releases for irrigation and hydroelectric power generation. The outlet works for the East Main Canal would be located on the right abutment of the dam. An outlet works, utilizing part of the diversion tunnel constructed beforehand for releases to the powerplant and the West Main Canal, is also incorporated in the design. Sill elevation of both outlet works has been located above the estimated 100-year sediment deposition elevation.

Outlet Works Data

	East Main Canal	Power--West Main Canal		
		Comb.	Power	Canal
Sill elevation--m.	1366	1360	--	--
Capacity--min. op. w.s. el--cu.m. per sec.	6.68	--	39	5.72
Emergency gate at chamber--type	slide	fixed-wheel	--	--
Regulating gate at control house	slide	--	butterfly	slide
Size of outlet--dia.m.	1.22	4.17	2.95	1.07

The reservoir basin is blanketed with impervious material, and leakage should not be a serious problem except at the immediate vicinity of the damsite. Blanketing with impervious material may be necessary in and around the ridges near the damsite due to the faults that occur in the area. The reservoir at initial stages of operation would have an active storage capacity of 1,859 million cubic meters.

The damsite is in volcanic rocks. The restriction of the valley is formed by remnants of "younger" volcanic rock which has been altered by faulting intrusion and subsequent filling by quartz veinlets throughout the rock mass. A major fault passes through the saddle on the narrow left abutment ridge and another crosses beyond the right abutment. The rock in general appears to be very porous and will require intensive grouting to prevent excessive leakage from the reservoir. For further details, see Appendix II, "Geology."

Impervious fill materials are available within a radius of 5 kilometers. Rock near the damsite can be quarried for riprap, rockfill, masonry stone, and concrete aggregates.

Access to the damsite will require a road from the town of Agaro, about 50 kilometers to the southwest.

The powerplant would be located near the toe of the dam on the left side. It would contain two generators rated at 15,000 kilowatts each.

Powerplant Data

Design head	53 m.
Number of generators	2
Rating of each generator	15,000 kw.
Total plant capacity	37,500 kv.-a.
Turbine ratings	21,165 hp.
Synchronous speed	214 r.p.m.
Type turbines	Francis

The switchyard for transmission of the energy generated would be located on the powerplant roof. About 60 kilometers of 132-kv., single-circuit line steel towers would be required to transmit the energy to the Jima Substation.

Two main canals, one on each side of the river and originating at the outlet works are planned to convey the water by gravity to serve as much as possible of the lands determined to be arable. No problem is expected to be encountered in constructing the unlined canal in view of the fact that much of the soil is clay and is impervious.

The West Main Canal would extend for 219 kilometers in a northerly direction and would irrigate approximately 7,600 hectares of land.

West Main Canal Data

Type	unlined
Length	219 km.
Initial capacity	9.9 cu.m. per sec.
Initial w.s. elevation	1366 m.

Originating from the outlet works of the Diddessa Dam, the East Main Canal would extend in a northerly direction for 223 kilometers for irrigation of 9,200 hectares of land.

East Main Canal Data

Type	unlined
Length	223 km.
Initial capacity	12 cu.m. per sec.
Initial w.s. elevation	1366 m.

The land area determined to be suitable for irrigation slopes gently to the river from the adjacent, rolling, low hills which border the valley. Distribution of water for the 16,800 hectares of land lying below the canal is expected to be fairly inexpensive except for the areas in the secondary reach of the West Main Canal and at the extremities of both canals.

Cost for construction of surface drainage provides for removal of irrigation waste and excess precipitation falling on the irrigable lands. The numerous natural drainageways would be used whenever practicable and would be protected and improved where necessary.

Estimated Project Cost

Construction Cost.

Features	In thousands of Ethiopian dollars			
	Total construction cost	Facilities		
		Joint-use	Irrigation	Power
Arjo-Diddessa Dam and Reservoir	89,666	89,666	--	--
Powerplant	10,000	--	--	10,000
Transmission facilities	4,116	--	--	4,116
East Main Canal	19,317	--	19,317	--
West Main Canal	19,575	--	19,575	--
Distribution system	8,925	--	8,925	--
Drainage canals	3,675	--	3,675	--
Access road	3,125	3,125	--	--
Service facilities	2,812	2,812	--	--
Totals	161,211	95,603	51,492	14,116

Development Cost. Clearing and leveling are estimated to cost about Eth$200 per hectare for a total of Eth$3,360,000.

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$1,303,000, including Eth$21,000 for taxes and insurance, as summarized below.

TABLE 41--SUMMARY OF CROPS AND GROSS FARM INCOME--ARJO-DIDDESSA PROJECT, 16,800 HECTARES

Table 41

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Postproject income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Pre-project income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Corn	9.13		2,520	2,780	7,005,600	639,610	5,040	1,150	5,796,000	529,170	1,168,780	1,168,780
Millet	8.85		1,680	2,915	4,897,200	433,400	3,360	950	3,192,000	282,490	715,890	715,890
Sorghum	12.65		3,360	2,915	9,794,400	1,238,990	-	-	-	-	1,238,990	1,238,990
Chick peas	12.69		840	1,450	1,218,000	154,560	1,680	920	1,545,600	196,140	350,700	350,700
Field beans	15.47		1,680	1,450	2,436,000	376,850	-	-	-	-	376,850	376,850
Flaxseed	20.09		-	-	-	-	1,680	660	1,108,800	222,760	222,760	222,760
Mustard	16.70		840	1,175	987,000	164,830	-	-	-	-	164,830	164,830
Rape	17.01		840	1,175	987,000	167,890	-	-	-	-	167,890	167,890
Castor beans	25.57		840	1,470	1,234,800	315,740	-	-	-	-	315,740	315,740
Sunflower	24.55		840	1,760	1,478,400	362,950	-	-	-	-	362,950	362,950
Coffee	160.79		840	960	806,400	1,296,610	840	-	-	-	1,296,610	1,296,610
Peppers	54.88		840	900	756,000	414,890	-	-	-	-	414,890	414,890
Tobacco	113.55		840	2,000	1,680,000	1,907,640	-	-	-	-	1,907,640	1,907,640
Subtotal, crops			15,960			7,473,960	12,600			1,230,560	8,704,520	8,704,520
Fallow			-			-	3,360			-	-	-
Subtotal, cultivated area			15,960			7,473,960	15,960			1,230,560	8,704,520	8,704,520
Noncultivated irrigable area			840			-	840			-	-	-
Total area		20,000	16,800			7,473,960	16,800			1,230,560	8,704,520	8,684,520
Income per hectare		1.19				444.88				73.25	518.13	516.94

Facility	Operation and maintenance	Replacements
Joint-use		
Dam and reservoir	Eth$ 50,000	--
Irrigation unit		
Conveyance system	555,000	--
Power unit		
Powerplant	500,000	Eth$30,000
Penstocks	5,000	--
Transmission plant	122,000	20,000
Other	21,000	--
Totals	Eth$1,253,000	Eth$50,000

Benefit-Cost Ratio

The benefit-cost ratio for this project is 2.11 to 1.00.

DABANA MULTIPURPOSE PROJECT

Project Area

The area under consideration is an oblong basin, 20 kilometers in length and about 9 kilometers at the widest point, located 55 kilometers southwest from the province capital of Lekkemt. It lies on the west side of the Diddessa River and just south of the Dabana-Diddessa confluence.

Geology and Topography

The project is situated in a gently sloping area, eroded through the volcanics into the Precambrian metamorphic and granitic rocks. 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.

Topographically, the project area is characterized by smooth, gentle slopes dissected by drainage channels 3 to 10 meters deep at irregular intervals, creating land areas that are long and relatively narrow.

Climate

The average elevation of the area is about 1280 meters above sea level. There would be no frost hazard and the average annual temperature would be about 22° C. with average annual precipitation being about 100 centimeters per year.

Project Lands

The 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 land classification survey indicates 6,100 hectares of Classes 1 and 2 irrigable lands.

The external drainage characteristics are excellent owing to the adequate natural drainage system incised into the land. No problems of water table control under irrigation are anticipated.

Hydrology

The source of water supply for the project is the Dabana River, from which 1,188 million cubic meters of water is available annually if regulation is provided for development of both irrigation and hydroelectric power production.

Diversion requirements would be 1.40 meters annually. Total annual irrigation diversion requirement for the 6,100 hectares would thus be 85.4 million cubic meters.

Plan of Development

The plan includes a storage dam and reservoir, two powerplants, totaling 85,000 kw., a small diversion dam, a power canal, an irrigation canal, a lateral distribution system, and drainage canals for irrigation of 6,100 hectares of land and hydroelectric generation of 414 million kilowatt-hours annually.

Project Features

The principal features of the project are shown in general plan on Figure 101.

The damsite is on the Dabana River about 23 kilometers upstream from its confluence with the Diddessa River. It would be an earth and rock fill dam. Diversion during construction would be accomplished by means of a 10-meter-diameter tunnel around the left bank with sufficient capacity to pass 25-year frequency flood flows. Plan, profile, and section of the dam and appurtenant works are shown on Figure 102.

Dam Data

Type	rock and earth fill
Embankment volume (earth)	11,400,000 cu.m.
Embankment volume (rock)	17,200,000 cu.m.
Top of dam elevation	1408 m.
Freeboard	2.5 m.
Structural height	122 m.
Hydraulic height	119.5 m.
Length of crest	1,570 m.
Width of crest	10 m.

A saddle near the left abutment of the dam will be utilized for the 120-meter-long uncontrolled spillway crest.

Spillway Data

Type	uncontrolled open channel
Crest elevation	1400 m.
Maximum inflow design flood peak	4,860 cu.m. per sec.
Total flood volume--4-day period	480,000,000 cu.m.
Maximum discharge	2,988 cu.m. per sec.

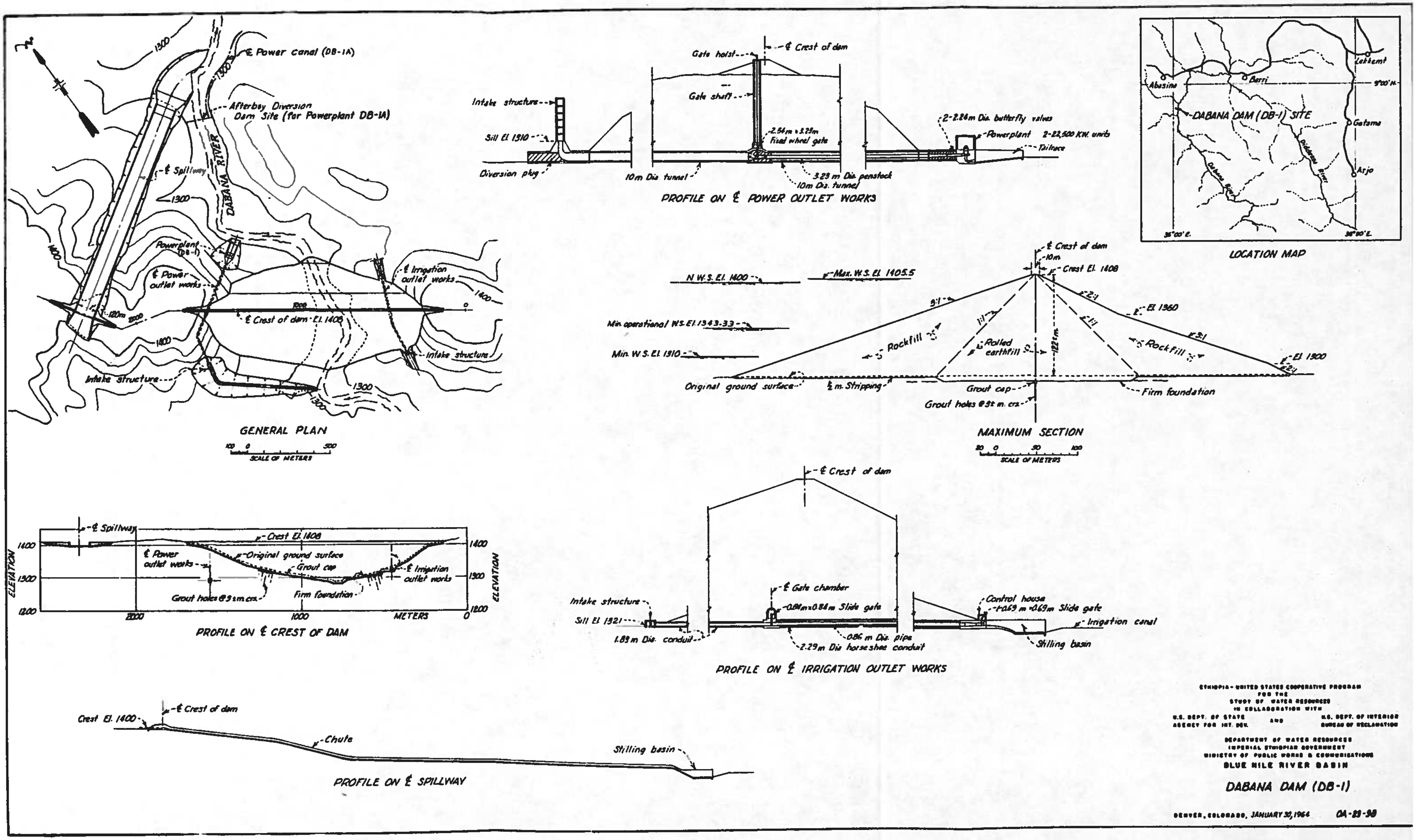


Figure 102--Dabana Dam (DB-1)--Plan and Sections

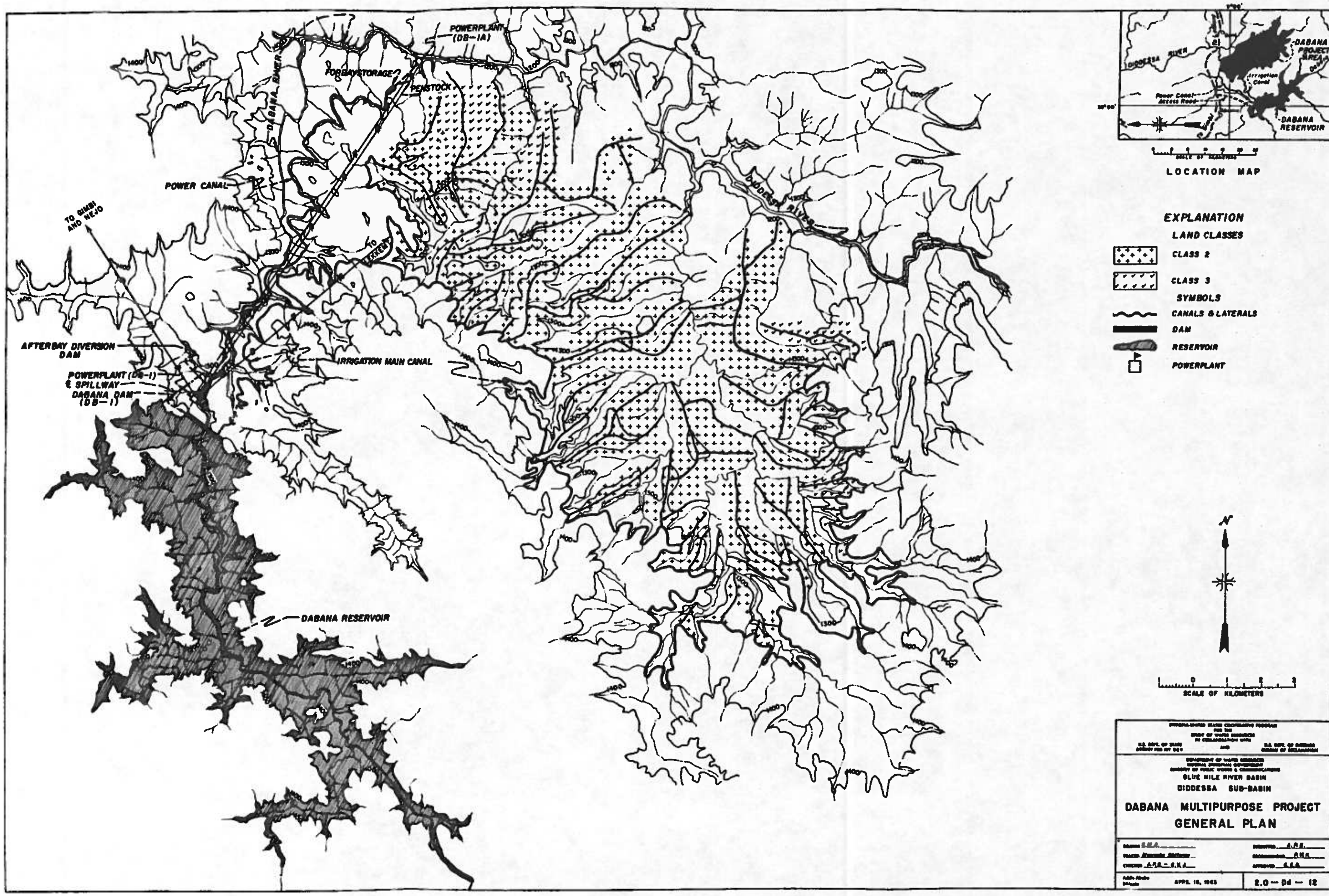


Figure 1D1--Dabana Multipurpose Project--General Plan

Two outlet works are planned for releases for irrigation and power purposes. The irrigation works would be located on the right abutment of the dam and would consist of a trashrack and a conduit upstream, a gate chamber containing an emergency slide gate near the dam axis; an outlet pipe inside a horseshoe conduit downstream; and a control house equipped with a high-pressure slide gate for controlled releases into the stilling basin. The power outlet works would intercept the diversion tunnel upstream after it has served its intended purpose. It would consist of a trashrack structure and the diversion conduit upstream; a gate chamber with an access shaft to the crest of the dam equipped with an emergency fixed-wheel gate; and a steel penstock inside the downstream tunnel, branching into two smaller pipes.

Outlet Works Data

Data	Unit	Irrigation	Power
Sill elevation	m.	1321	1310
Capacity at min. w.s. elevation	cu.m. per sec.	4.44	--
Type of gates	--	slide	butterfly
Diameter of pipe	m.	0.86	3.23

The Dabana Reservoir Basin is well blanketed with residual soils, and leakage is not expected to be a serious problem. The reservoir at initial stages of operation is expected to have an active capcity of 1,330 million cubic meters and 248 million cubic meters of inactive storage. Sediment at the end of 50 years is expected to occupy 59 million cubic meters of storage space.

The site is geologically suited for the proposed dam. It is located in highly dissected terrain in granitic Precambrian rocks. A thin mantle of clayey soil covers the lower gentle slopes on each side of the stream and on the lower part of the abutments.

Impervious embankment materials are located within 3 kilometers of the damsite. Most attractive sources are the clayey, alluvium, residual soil and weathered bedrock material on the gentle slopes downstream from the site. Rock near the damsite can be quarried for rockfill material. There are no natural aggregates in the immediate vicinity, but the bedrock may be crushed for this purpose.

It would be necessary to construct 12 kilometers of access road to the existing Lekkemt-Gimbi road which passes near the point where the Dabana River veers sharply to the east.

The power diversion dam would be located a few hundred meters downstream from the storage dam. It would be a concrete-masonry, ogee, overflow type of dam to provide a constant head. The canal headworks would be located on the right abutment of the dam, using stop planks for emergency controls.

Diversion Dam Data

Type	concrete-masonry ogee overflow
Volume of masonry and concrete in dam	1,135 cu.m.
Crest length	71 m.
Height	4 m.

From the outlet works of the Power Diversion Dam, the power canal would extend on the east side of the Dabana River approximately 16 kilometers in a northerly direction.

Power Canal Data

Type	masonry lined
Length	16 km.
Capacity	33.25 cu.m. per sec.
Initial w.s. elevation	1288 m.

Two powerplants, one located on the left side adjacent to the downstream toe of the storage dam (DB-1) and the other at the end of the power canal (DB-1A), are envisioned. Each powerplant would have two turbine-driven generators.

Powerplant Data

Data	Unit	DB-1 (at damsite)	DB-1A (at canal)
Design head	m.	84.6	86.3
Number of generators	each	2	2
Rating of each generator	kw.	22,500	20,000
Total plant capacity	kw.	45,000	40,000
Turbine rating	hp.	31,114	28,220
Synchronous speed	r.p.m.	250	250
Type of turbines	--	Francis	Francis

Two switchyards, 678 kilometers of transmission lines, and six substations for transmission of the electrical energy to the various load centers are included in the initial plan of development.

Transmission Line Data

From	To	Length (km.)	Voltage (kv.)	Structure (type)	Circuit (No.)
Powerplant DB-1	Powerplant DB-1A	26	69	steel tower	two lines
Powerplant DB-1	Lekkemt	70	230	steel tower	single
Lekkemt	Addis Ababa	245	230	steel tower	double
Lekkemt	Gore	210	132	steel tower	single
Akaki No. 1	Akaki No. 2	12	132	steel tower	single
Powerplant DB-1	Gimbi	45	45	steel tower	single
Gimbi	Nejo	60	45	steel tower	single
Akaki No. 2	East Substation	10	230	steel tower	double

The main canal that would convey the water to the project lands for irrigation purposes would extend in a northerly direction parallel to the river for 18 kilometers and would then veer eastward crossing a low saddle to the project lands. The soil is considered to be quite impervious, requiring no lining. The initial capacity of the canal would be 8 cubic meters per second.

Irrigation Canal Data

Type	unlined
Length	114 km.
Initial capacity	8 cu.m. per sec.
Initial w.s. elevation	1320 m.

Distribution of water to the farms will be relatively more expensive than for other irrigation projects, as much of the lands have slopes varying from 3 to 6 percent.

Open, interceptor, drainage canals will be necessary to carry off the irrigation waste and to prevent damage to the land. The numerous, small, natural drainageways and ravines will provide excellent outlets.

Subsurface drainage requirements are not expected to materialize under irrigation conditions.

TABLE 42--SUMMARY OF CROPS AND GROSS FARM INCOME--DABANA PROJECT, 6,100 HECTARES

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Postproject income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Pre-project income Eth$	Crop distri-bution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distri-bution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Corn	9.48		945	2,780	2,627,100	249,050	1,830	1,150	2,104,500	199,510	448,560	448,560
Millet	9.20		600	2,915	1,749,000	160,910	1,250	950	1,187,500	109,250	270,160	270,160
Sorghum	13.00		1,250	2,915	3,643,750	473,690	-	-	-	-	473,690	473,690
Chick peas	13.04		300	1,450	435,000	56,720	600	920	552,000	71,980	128,700	128,700
Field beans	15.82		600	1,450	870,000	137,630	-	-	-	-	137,630	137,630
Flaxseed	20.44		-	-	-	-	600	660	396,000	80,940	80,940	80,940
Mustard	17.05		300	1,175	352,500	60,100	-	-	-	-	60,100	60,100
Sesame	34.55		300	1,175	352,500	121,790	-	-	-	-	121,790	121,790
Castor beans	25.92		300	1,470	441,000	114,310	-	-	-	-	114,310	114,310
Sunflower	24.90		300	1,760	528,000	131,470	-	-	-	-	131,470	131,470
Coffee	161.14		300	960	288,000	464,080	300	-	-	-	464,080	464,080
Peppers	55.23		300	900	270,000	149,120	-	-	-	-	149,120	149,120
Tobacco	113.90		300	2,000	600,000	683,400	-	-	-	-	683,400	683,400
Subtotal, crops			5,795			2,802,270	4,580			461,680	3,263,950	3,263,950
Fallow			-			-	1,215			-	-	-
Subtotal, cultivated area			5,795			2,802,270	5,795			461,680	3,263,950	3,263,950
Noncultivated irrigable area			305			-	305			-	-	-
Total area		-	6,100			2,802,270	6,100			461,680	3,263,950	3,263,950
Income per hectare		-				459.39				75.68	535.07	535.07

Estimated Project Cost

Construction Cost.

Feature	In thousands of Ethiopian dollars			
	Total construction cost	Facilities		
		Joint-use	Irrigation	Power
Dabana Dam and Reservoir	249,684	249,684	--	--
Power Diversion Dam	240	--	--	240
Powerplant DB-1	11,875	--	--	11,875
Powerplant DB-1A	8,437	--	--	8,437
Power canal and penstocks	22,529	--	--	22,529
Transmission facilities	46,461	--	--	46,461
Irrigation Main Canal	8,711	--	8,711	--
Distribution system	3,241	--	3,241	--
Drainage canals	1,144	--	1,144	--
Access roads	750	750	--	--
Service facilities	5,296	5,296	--	--
Totals	358,368	255,730	13,096	89,542

Development Cost. The project area is covered at present with tall grass and acacia trees usually less than 10 meters high. It is estimated that burning the grass and clearing the trees could be accomplished for about Eth$230 per hectare for a total cost for the 6,100 hectares of Eth$1,400,000.

Land leveling is estimated to cost an average of Eth$180 per hectare for a total of Eth$1,100,000.

Operation, Maintenance, and Replacement Cost. The annual operation, maintenance, and replacement costs are estimated to be Eth$2,893,000, including Eth$134,000 for taxes and insurance, as summarized below.

Feature	Operation and maintenance	Replacements
Joint-use		
Dam and reservoir	Eth$ 20,000	--
Irrigation unit		
Conveyance system	232,000	--
Power unit		
Power diversion dam	5,000	--
Powerplant (DB-1)	520,000	Eth$ 35,500
Penstocks	3,000	--
Powerplant (DB-1A)	500,000	92,500
Penstocks	36,000	--
Power canal	72,000	--
Forebay	5,000	--
Transmission plant	1,111,000	127,000
Other	134,000	--
Totals	Eth$2,638,000	Eth$255,000

Benefit-Cost Ratio

The benefit-cost ratio for this project is 0.93 to 1.00.

ANGAR MULTIPURPOSE PROJECT

Project Area

The project is in the central part of Wellegga Province in the Angar River Valley, about 40 kilometers north of Lekkemt. The project extends about 50 kilometers along both sides of the river and for most of its length has a width of 20 to 25 kilometers. The land consists of numerous, irregularly shaped ridges separated by innumerable small streams which have cut the general benchland area. Upstream, the river enters the valley from broken country which blends into the mountains to the east. At the lower or western side of the project, the river enters rough, broken terrain and leaves the area through a precipitous canyon.

Geology and Topography

The Angar River drains a large area north of Lekkemt and flows from the high plateau through sharp, steep canyons into a low, wide, flat basin which has been eroded through the "plateau" volcanics and Adigrat sandstone into the basement crystalline rocks. Granitic masses of rock rise above the general valley level, indicating that the granitic intrusions are more resistant to erosion than the metamorphic rocks composed of gneiss and schist.

Climate

The average elevation of the project area being about 1350 meters above sea level renders the climate in this area suitable for growing a variety of crops. The average annual temperature is around 22° C. with average annual precipitation of about 100 centimeters per year, occurring mostly in the June through September period.

Project Lands

With the exception of some minor areas of alluvial deposits, all of the soils are latosols and are well adapted to irrigation. Although these soils are clay loams 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. Land classification revealed that 30,200 hectares were irrigable.

Hydrology

The source of water supply for the project would be the Angar River. Hydrologic studies indicated that there would be an abundance of water for irrigation and electric power production. Water requirements would be 13,800 cubic meters for a total irrigation demand of 416 million cubic meters annually.

Plan of Development

For the multipurpose development of irrigation and hydroelectric power two dams and reservoirs will be required. Facilities required in the 185,000 kw. hydroelectric power development would include three powerplants for the annual generation of about 1,148 million kilowatt-hours.

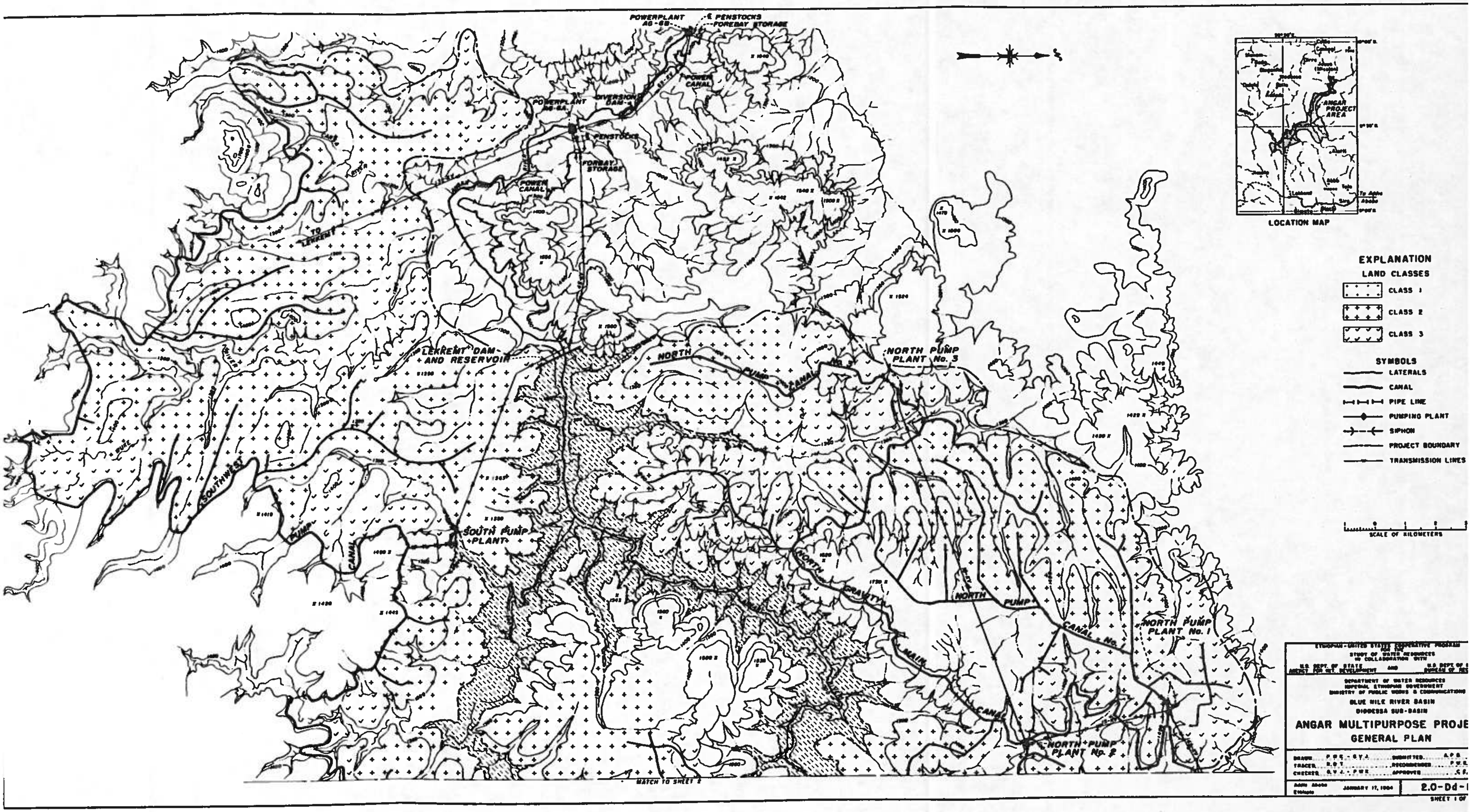


Figure 103--Angar Multipurpose Project--General Plan, Sh

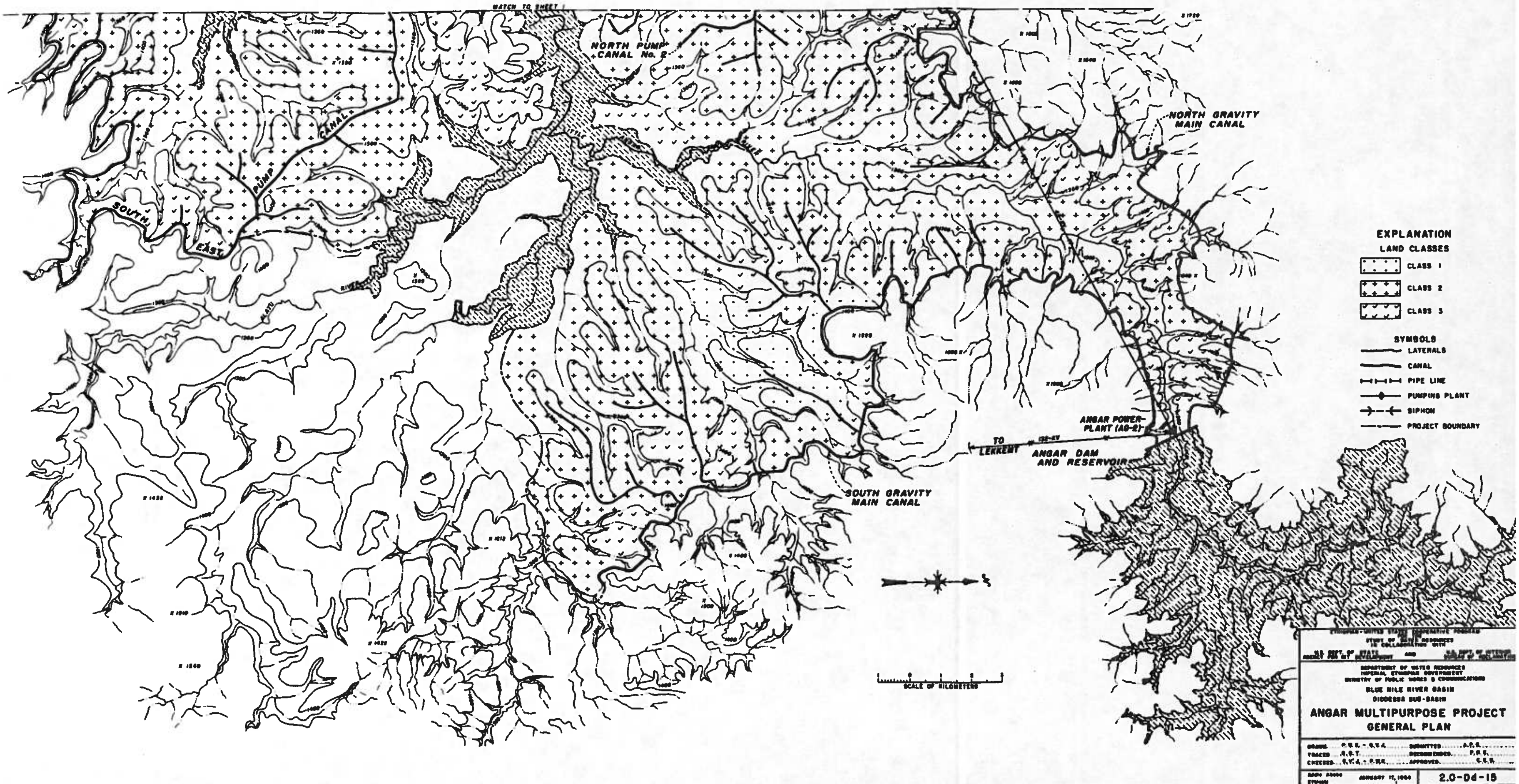


Figure 104--Angar Multipurpose Project--General Plan, Sheet 2

Project Features

The features of the project plan are indicated on Figures 103 and 104.

The site of the Angar Dam is about 23 kilometers upstream on the Little Angar River from the confluence with the Alatu River, controlling a drainage area of about 1,780 square kilometers. The two rivers combine to form the Angar River. A rolled, earth and rock fill structure would regulate the river to control releases for irrigation and hydroelectric power generation. Diversion of the river during the construction period would be accomplished by a conduit located to the left of the river channel. The conduit later would be utilized for the power outlet works. Plan, sections, and profile of the dam and appurtenant works appear on Figure 105.

Dam Data

Type	earth-rock fill
Embankment volume (earth)	8,600,000 cu. m.
Embankment volume (rock)	12,000,000 cu. m.
Top of dam elevation	1444 m.
Freeboard	2.68 m.
Structural height	98 m.
Hydraulic height	95.32 m.
Length of crest	1,900 m.
Width of crest	10 m.

Three outlet works, located as shown on the drawing, would be required for irrigation and power releases.

Outlet Works Data

Data	Unit	Power	Irrigation	
		Double-barrel (each)	North	South
Sill elevation	m.	1351	1401	1401
Design capacity	cu. m. per sec.	42.4	4.9	2.6
Type of gates	--	butterfly	hollow-jet	--
Size of outlet (dia)	m.	3.81	2.69	2.39

The reservoir basin is underlain with metamorphic rocks mantled with a thick layer of impervious material. No reservoir seepage losses of consequence would be expected. The reservoir would impound 2,510 million cubic meters at normal water surface elevation and would inundate at this elevation approximately 78 square kilometers.

The Lekkemt Dam would be about 52 river kilometers downstream from the Angar Dam and Reservoir. It would be a rolled earth and rock fill structure. During the construction of the dam, the Angar River would be diverted through a tunnel around the left bank of the damsite. Plan, profile, and maximum section of the dam with its appurtenant structures appear on Figure 106.

Dam Data

Type	earth-rock fill
Embankment volume (earth)	2,900,000 cu. m.
Embankment volume (rock)	3,300,000 cu. m.
Top of dam elevation	1338 m.
Freeboard	2.48 m.
Structural height	76 m.
Hydraulic height	73.52 m.
Length of crest	1,790 m.
Width of crest	10 m.

The service spillway for the Lekkemt Dam would be located on the left abutment and would be of an uncontrolled type discharging into an open, chute-type channel with a stilling basin at its terminal.

Spillway Data

Type	uncontrolled overflow
Crest elevation	1330 m.
Inflow design flood--5-day period	740,000,000 cu. m.
Maximum capacity	3,005 cu. m. per sec.

The outlet works for releases into the power canal would extend through the dam near the right abutment.

Outlet Works Data

Sill elevation	1300 m.
Design capacity each (3) (at min. w.s. elev.)	26 cu. m. per sec.
Type of gates (3)	high-pressure slide gate
Size of outlet (dia)	4.02 m.

The Lekkemt Reservoir is similar to the Angar Reservoir area. Clearing will also be required. The dam will impound and reregulate the flows from the Angar Reservoir. Controlled releases will be made from the reservoir into the power canal, and it will serve as a forebay for the South Pumping Plant. It will fill and be drawn down every year to the minimum operating level with dependence on the upstream reservoir for carryover storage during the dry cycle. At normal water surface elevation, the reservoir at initial stages of operation will have an active capacity of 903 million cubic meters and will cover an area of about 67 square kilometers.

The foundation, from visual examination, appears to be suitable for the structures as planned, being underlain with hard metamorphic rocks and overburdened with slopewash and alluvial materials. Construction material is available in sufficient quantities in the immediate vicinity of both damsites. Concrete aggregate material and riprap will have to be obtained from the quarried rock available in abundant quantities.

Three powerplants would be constructed to supply power for pumping irrigation water and to service the province capital of Lekkemt and the surrounding areas. Angar Powerplant (AG-2) would be located at the downstream toe of the Angar Dam near the right bank. Powerplant AG-6A would be located at the right bank about 12 river kilometers downstream from the Lekkemt Reservoir. Powerplant AG-6B would be located an additional 6 river kilometers downstream, also on the right bank.

Powerplant Data

Data	Unit	AG-2	AG-6A	AG-6B
Design head (net)	m.	69.1	168	74.5
Number of generators	--	2	2	2
Rating of each generator	kw.	20,000	50,000	22,500
Total plant capacity	kv.-a	50,000	125,000	56,250
Turbine rating (English)	hp.	28,220	70,550	31,748
Synchronous speed	r.p.m.	214	250	214
Type of turbines	--	Francis	Francis	Francis

A Power Diversion Dam, about 1.5 kilometers downstream from Powerplant AG-6A, would be required to divert the flows from the river channel into the power canal. It would be a concrete-masonry overflow structure providing a constant head, and it would bypass the excess flows of the river. The canal headworks would be located on the right abutment.

Diversion Dam Data

Type	concrete-masonry ogee overflow
Volume of concrete and masonry in dam	3,010 cu. m.
Crest length	150 m.
Height	5 m.

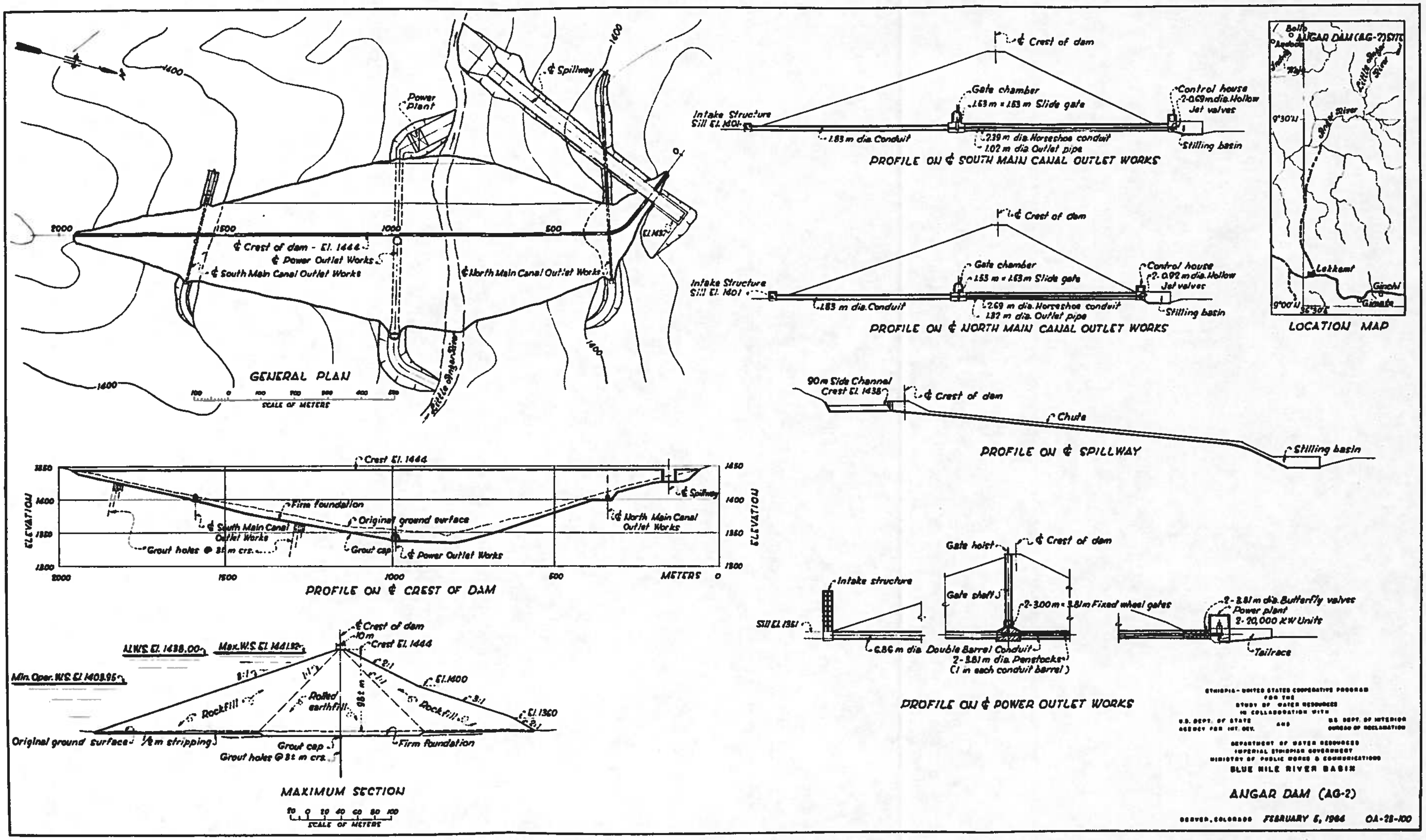


Figure 105--Angar Dam (AG-2)--Plan and Sections

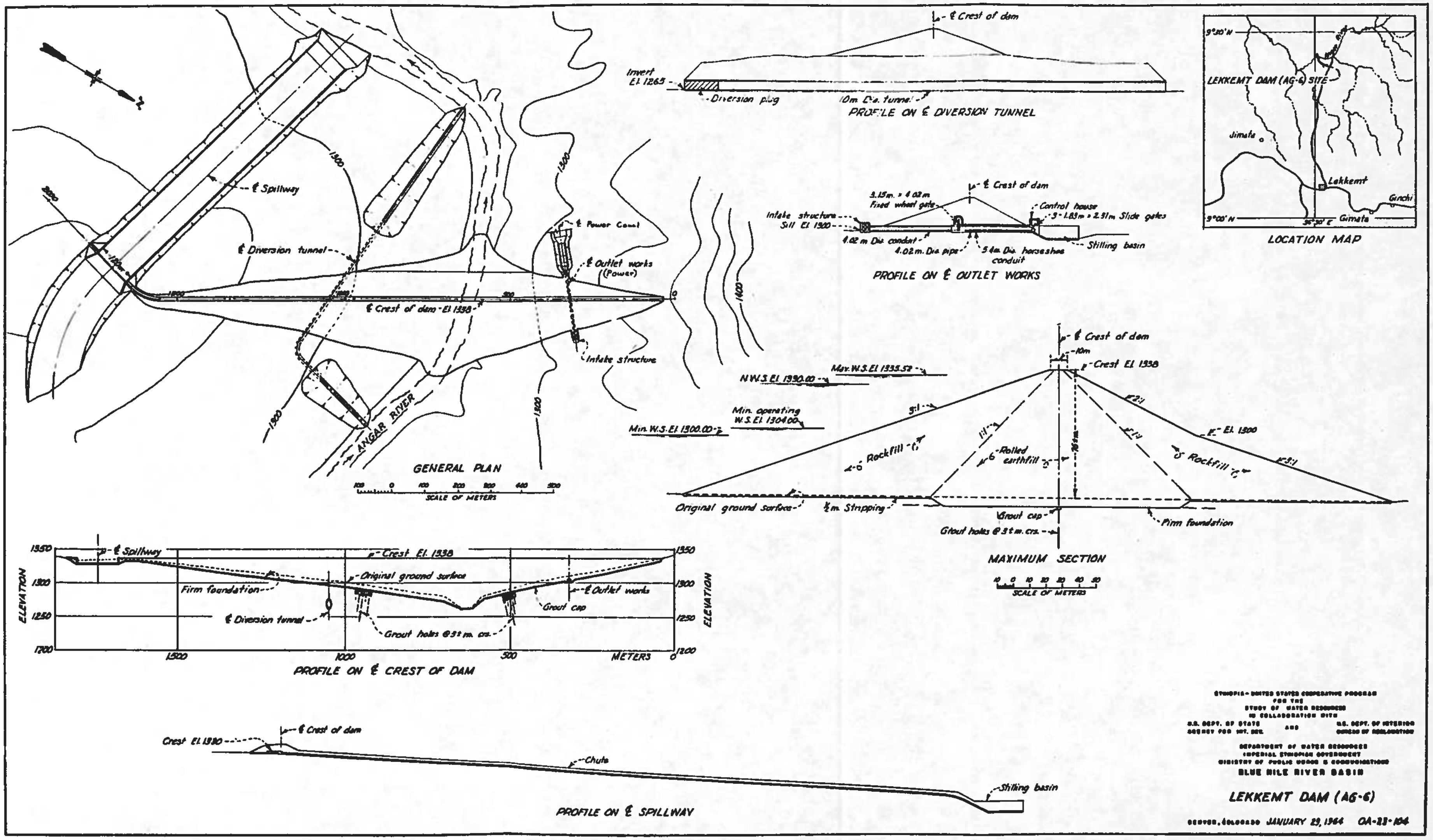


Figure 106--Lekkemt Dam (AG-6)--Plan and Sections

Two power canals are envisioned to convey the water into the penstocks of Powerplants 6A and 6B. The upstream canal (6A) would originate at the outlet works of Lekkemt Dam and Reservoir. The second downstream canal (6B), originating at the canal headworks of the Power Diversion Dam, would be similar to the first unit in design and carrying capacity. It would discharge into the penstocks of Powerplant AG-6B.

Power Canal Data

Data	Unit	Canal 6A	Canal 6B
Type	--	masonry-lined	
Length	km.	15	4.6
Initial capacity	cu. m. per sec.	78	78
Initial w. s. elevation	m.	1300	1100

The switchyard at Angar Powerplant AG-2 will be located at the powerplant. To interconnect the system and to supply power to the pumping plants as well as to the load center of Lekkemt and Addis Ababa, some 423 kilometers of various capacities of transmission lines are planned as summarized.

Transmission Line Data

From	To	Length (km.)	Voltage (kv.)	Structure (type)	Circuit (No.)
PP AG-2	Lekkemt	75	132	steel tower	single
PP AG-6B	PP AG-6A	5	69	steel tower	single
PP AG-6A	Lekkemt	43	132	steel tower	single
Lekkemt	Addis Ababa1/	245	230	existing steel	second
PP AG-2	Pump No. 1	20	45	steel pole	single
Pump No. 1	Pump No. 2	7	15	steel pole	single
Pump No. 2	Pump No. 3	13	15	steel pole	single
PP AG-6A	South Pump	15	45	steel pole	single

1/Akaki No. 2 Substation--install on existing double-circuit steel towers from Dabana Project.

Power for the four pumping plants planned for the Angar Project, one on the south side of the Angar River (South Pumping Plant) and three on the north side of the river (North Pumping Plants No. 1, 2, and 3) will be supplied from the system.

The South Pumping Plant would be located in the central southwestern part of the project area on the south side of the Angar River for irrigation of 13,200 hectares of irrigable land. Water is lifted and carried from Lekkemt Reservoir into the pump canals by three large turbine-type pumps with a total capacity of 16 cubic meters per second (565 cubic feet per second) at a 100-meter total dynamic head.

South Pumping Plant Data

Forebay, minimum w.s. elevation	1304 m.
Forebay, normal w.s. elevation	1330 m.
Total dynamic head	100 m.
Minimum lift	70 m.
Maximum lift	96 m.
Size of discharge pipe (diameter)	2.60 m.
Length of discharge pipe	1.70 km.
Capacity of pumps	16.00 cu.m. per sec.
Motor ratings, installed	32,625 hp.

North Pumping Plant No. 1 would be located on the north side of the Angar River about 30 kilometers from the outlet works on the North Main Gravity Canal. The plant would provide irrigation water for 3,100 hectares of irrigable land. An intake channel about 1.2 kilometers in length will be required to supply water from the North Gravity Main Canal.

North Pumping Plant No. 1 Data

Forebay, w.s. elevation	1390 m.
Total dynamic head	21 m.
Static lift	20 m.
Size of discharge pipe (diameter)	1.3 m.
Length of discharge pipe	400 m.
Capacity of pumps	4 cu.m. per sec.
Motor ratings, installed	1,725 hp.

North Pumping Plant No. 2 would be located on the north side of the Angar River about 10 kilometers downstream from Pumping Plant No. 1 on the North Gravity Main Canal or 40 kilometers from the headworks of the main canal. This plant would provide irrigation water for 1,060 hectares of irrigable land.

North Pumping Plant No. 2 Data

Forebay, w.s. elevation	1390 m.
Total dynamic head	21 m.
Static lift	20 m.
Size of discharge pipe (diameter)	0.8 m.
Length of discharge pipe	400 m.
Capacity of pumps	1.7 cu.m. per sec.
Motor ratings, installed	750 hp.

North Pumping Plant No. 3 would be located near the western boundary of the project area, about 18 kilometers downstream from Pumping Plant No. 2 and 58 kilometers from Angar Dam on the North Gravity Main Canal. The plant would provide irrigation water for 1,940 hectares of irrigable land.

North Pumping Plant No. 3 Data

Forebay, w.s. elevation	1376 m.
Total dynamic head	46 m.
Maximum lift	44 m.
Size of discharge pipe (diameter)	1 m.
Length of discharge pipe	400 m.
Capacity of pumps	2.7 cu.m. per sec.
Motor ratings, installed	2,525 hp.

The Angar Project lands are characterized by irregularly shaped, broad-topped, fragmented areas created by the dissecting influence of the streams and eroded swales. In order to reach these broad areas of classified lands, separated by lower valleys and by low divides, a series of pump canals is proposed to irrigate as much as possible of the land determined to be suitable for irrigation. About a third of the project lands will be irrigated by gravity method, the other two-thirds requiring pumping plants and canals. Canal excavation should not present any major problems. Water will be supplied for irrigation of 17,000 hectares of land from the Angar Reservoir. Two outlet works, one on each side of the dam abutments, will release water to the North and South Main Gravity Canals.

The South Gravity Main Canal would originate at the outlet works located on the left abutment of the Angar Dam. It will convey water by gravity to serve approximately 5,900 hectares of land.

South Gravity Main Canal Data

Type	unlined
Length	31.5 km.
Initial capacity	7.2 cu.m. per sec.
Initial w.s. elevation	1400 m.

The Southeast Pump Canal would originate at the discharge pipe outlet of the South Pumping Plant and would extend in an easterly direction to serve approximately 5,750 hectares of lands.

TABLE 43—SUMMARY OF CROPS AND GROSS FARM INCOME—ANGAR PROJECT, 30,200 HECTARES

Table 43

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season					
	Price received per 100 kg. Eth$	Pre-project income Eth$	Crop distri-bution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distri-bution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Postproject income Eth$	Gross crop income Eth$
Corn	9.58		4,530	2,780	12,593,400	1,206,450	9,060	1,150	10,419,000	998,140	2,204,590	2,204,590
Millet	9.30		3,020	2,915	8,803,300	818,700	6,040	950	5,738,000	533,630	1,352,330	1,352,330
Sorghum	13.10		6,040	2,915	17,606,600	2,306,460	-	-	-	-	2,306,460	2,306,460
Chick peas	13.14		1,510	1,450	2,189,500	287,700	3,020	920	2,778,400	365,080	652,780	652,780
Field beans	15.92		3,020	1,450	4,379,000	697,140	-	-	-	-	697,140	697,140
Flaxseed	20.54		-	-	-	-	3,020	660	1,993,200	409,400	409,400	409,400
Mustard	17.15		1,510	1,175	1,774,250	304,280	-	-	-	-	304,280	304,280
Sesame	34.65		1,510	1,175	1,774,250	614,780	-	-	-	-	614,780	614,780
Castor beans	26.02		1,510	1,470	2,219,700	577,570	-	-	-	-	577,570	577,570
Sunflower	25.00		1,510	1,760	2,657,600	664,400	-	-	-	-	664,400	664,400
Coffee	161.24		1,510	960	1,449,600	2,337,330	1,510	-	-	-	2,337,330	2,337,330
Peppers	55.33		1,510	900	1,359,000	751,930	-	-	-	-	751,930	751,930
Tobacco	114.00		1,510	2,000	3,020,000	3,442,800	-	-	-	-	3,442,800	3,442,800
Subtotal, crops			28,690			14,009,540	22,650			2,306,250	16,315,790	16,315,790
Fallow			-			-	6,040			-	-	-
Subtotal, cultivated area			28,690			14,009,540	28,690			2,306,250	16,315,790	16,315,790
Noncultivated irrigable area			1,510			-	1,510			-	-	-
Total area		-	30,200			14,009,540	30,200			2,306,250	16,315,790	16,315,790
Income per hectare		-				463.89				76.37	540.26	540.26

Southeast Pump Canal Data

Type	unlined
Length	51 km.
Initial capacity	7.0 cu.m. per sec.
Initial w.s. elevation	1400 m.

The Southwest Pump Canal would originate at the discharge pipe outlet of the South Pumping Plant and would extend in a westerly direction, forming the southern boundary of the project lands.

Southwest Pump Canal Data

Type	unlined
Length	55 km.
Initial capacity	9.0 cu.m. per sec.
Initial w.s. elevation	1400 m.

The North Gravity Main Canal would originate at the outlet works on the right abutment of the Angar Dam. It would extend in a westerly direction for a distance of about 58 kilometers and would be designed to serve approximately 11,100 hectares of land. Of this total, 5,000 hectares will be served by gravity irrigation with the remainder to be served by three pumping stations lifting water from the main canal.

North Gravity Main Canal Data

Type	unlined
Length	58 km.
Initial capacity	13.4 cu.m. per sec.
Initial w.s. elevation	1400 m.

North Pump Canal No. 1 would originate at the discharge pipe outlet of Pumping Plant No. 1.

North Pump Canal No. 1 Data

Type	unlined
Length	8.0 km.
Initial capacity	4.0 cu.m. per sec.
Initial w.s. elevation	1410 m.

The capacities for North Pump Canals No. 2 and 3 are relatively small (less than 3 cubic meters per second). Pump Canal No. 2 would serve 1,060 hectares, and Pump Canal No. 3 would serve 1,940 hectares.

The distribution system would consist of a number of main laterals and many small sublaterals, which would carry the water from the main canal to the boundary of each farm unit.

The drainage system would provide interception of the excess ground-water flows originating from the higher lying lands and ditches. Natural drainage channels would be used for outlet purposes wherever practicable and would be protected and improved where necessary and desirable.

There was no evidence of water table problems during the investigation. The larger drainageways had water flows from underground sources. Several large springs were also noticed, particularly in the southeast quadrant. The well-drained appearance of the soils, the numerous trees along the drainage channels, the well-incised drainage channels, and the presence of springs in low areas all indicate that internal drainage characteristics are excellent.

Estimated Project Costs

Construction Cost.

Feature	In thousands of Ethiopian dollars			
	Total construction cost	Facilities		
		Joint-use	Irrigation	Power
Storage Division				
Angar Dam and Reservoir	195,420	195,420	--	--
Lekkemt Dam and Reservoir	94,194	94,194	--	--
Power Division				
Powerplant AG-2	12,000	--	--	12,000
Powerplant AG-6A	20,000	--	--	20,000
Powerplant AG-6B	13,750	--	--	13,750
Diversion Dam	1,678	--	--	1,678
Canal 6A and penstocks	21,305	--	--	21,305
Canal 6B and penstocks	7,169	--	--	7,169
Transmission facilities	21,514	--	--	21,514
Irrigation Division				
South Pump Plant	28,876	--	28,876	--
North Pump Plant No. 1	1,827	--	1,827	--
North Pump Plant No. 2	719	--	719	--
North Pump Plant No. 3	1,597	--	1,597	--
South Gravity Canal	2,694	--	2,694	--
Southeast Pump Canal	4,263	--	4,263	--
Southwest Pump Canal	4,457	--	4,457	--
North Gravity Canal	5,941	--	5,941	--
North Pump Canal	548	--	548	--
Distribution system	16,044	--	16,044	--
Drainage canals	5,898	--	5,898	--
Headquarters Division				
Access road	891	891	--	--
Service facilities	9,150	9,150	--	--
Total	469,935	299,655	72,864	97,416

Development Cost. Most of the project area is covered with tall grasses and trees 5 to 10 meters in height. It is estimated that these trees can be removed for an average cost of approximately Eth$175 per hectare.

Leveling needs will be minimal and can be achieved at an average cost of about Eth$150 per hectare. Cost for clearing and leveling the estimated 30,200 hectares of irrigable lands would be Eth$9,815,000.

Operation, Maintenance, and Replacement Cost. The annual operation, maintenance, and replacement costs are estimated to be Eth$7,123,000, including Eth$146,000 for taxes and insurance, as summarized below.

Facility	Operation and maintenance	Replacements	Power cost
Storage Division			
Angar Dam and Reservoir	Eth$ 60,000	--	--
Lekkemt Dam and Reservoir	32,000	--	--
Irrigation Division and Hdqtrs.			
South Pumping Plant	250,000	Eth$ 30,000	Eth$2,130,000
North Pumping Plants (Nos. 1, 2, and 3)	71,000	5,000	267,000
Electrical facilities	133,000	16,000	--
Conveyance system	966,000	--	--
Power Division			
Powerplant (AG-2)	500,000	35,800	--
Powerplant (AG-6A)	720,000	123,100	--
Powerplant (AG-6B)	530,000	62,400	--
Penstocks (AG-2)	6,000	--	--
Penstocks (AG-6A)	22,700	--	--
Penstocks (AG-6B)	12,000	--	--
Power Canal (AG-6A)	120,000	--	--
Power Canal (AG-6B)	39,000	--	--
Forebays	10,000	--	--
Diversion Dam	5,000	--	--
Transmission plant	729,000	102,000	--
Other	146,000	--	--
Totals	Eth$4,351,700	Eth$374,300	Eth$2,397,000

Benefit-Cost Ratio

The benefit-cost ratio for this project is 1.93 to 1.00.

LOWER DIDDESSA POWER PROJECT

The plan of development for the Lower Diddessa Power Project includes the construction of a dam and reservoir, a 320,000 kw. powerplant, a switchyard, transmission lines, and substations for an estimated annual hydroelectric generation of 1,400 million kilowatt-hours.

Project Features

The features of the project plan are shown in general plan on Figure 107.

The selected site for the Boo Dam is on the Diddessa River about 85 kilometers upstream from its confluence with the Blue Nile River and also about 17 kilometers upstream from where the Angar River empties into the Diddessa. It would be an earth and rock fill dam. Diversion during construction would be accomplished by four tunnels located on the right abutment of the dam. Figure 107 depicts the plan, profile, and section of the dam and appurtenant works.

Dam Data

Type	earth-rock fill
Embankment volume (earth)	4,300,000 cu.m.
Embankment volume (rock)	10,200,000 cu.m.
Top of dam elevation	1081 m.
Freeboard	2 m.
Structural height	140 m.
Hydraulic height	138 m.
Length of crest	710 m.
Width of crest	10 m.

Two 30-meter-diameter morning-glory-type spillways would be required, having a maximum total discharge capacity of 3,060 cubic meters per second. Two of the diversion tunnels would be utilized for this purpose.

Spillway Data

Type	morning-glory
Crest elevation	1068.4 m.
Inflow design flood, 8-day period	2,450,000,000 cu.m.
Discharge at max. w.s. elevation (each)	1,530 cu.m. per sec.

The outlet works would utilize the two diversion tunnels nearest the river. Each outlet works, consisting of an intake structure leading into the 10-meter-diameter conduit, a gate chamber with emergency fixed-wheel gate operated through a shaft by the gate hoist located on top of the dam, a 7.5-meter-diameter steel penstock, and a butterfly valve, would discharge into the turbines of the powerplant.

Outlet Works Data

Number of outlet works	2
Sill elevation	1000 m.
Design capacity (each)	208 cu.m. per sec.
Type of gates	butterfly
Size of penstock, diameter (each)	7.4 m.

The Boo Reservoir area is in sandstone except for the small area in Precambrian rock near the damsite. The stream channel is generally narrow with very few alluvial deposits in the valley. Leakage in the reservoir should not be a serious problem. At normal water surface the initial active storage capacity is expected to be 4,248 million cubic meters with 235 million cubic meters of inactive storage. The reservoir will inundate approximately 116 square kilometers.

The damsite is in a narrow, V-shaped gorge in banded quartz diorite gneiss of Precambrian age. The rock is variably jointed, but with minor excavation a smooth, hardrock foundation could be exposed.

Impervious fill materials are available within economical haul distance. Stone and crushed aggregate could be processed from quarried Precambrian rock.

Construction of an access road from the present Lekkemt-Gimbi road would require approximately 50 kilometers of new road construction.

The powerplant would be located at the toe of the dam on the right (east) side of the river.

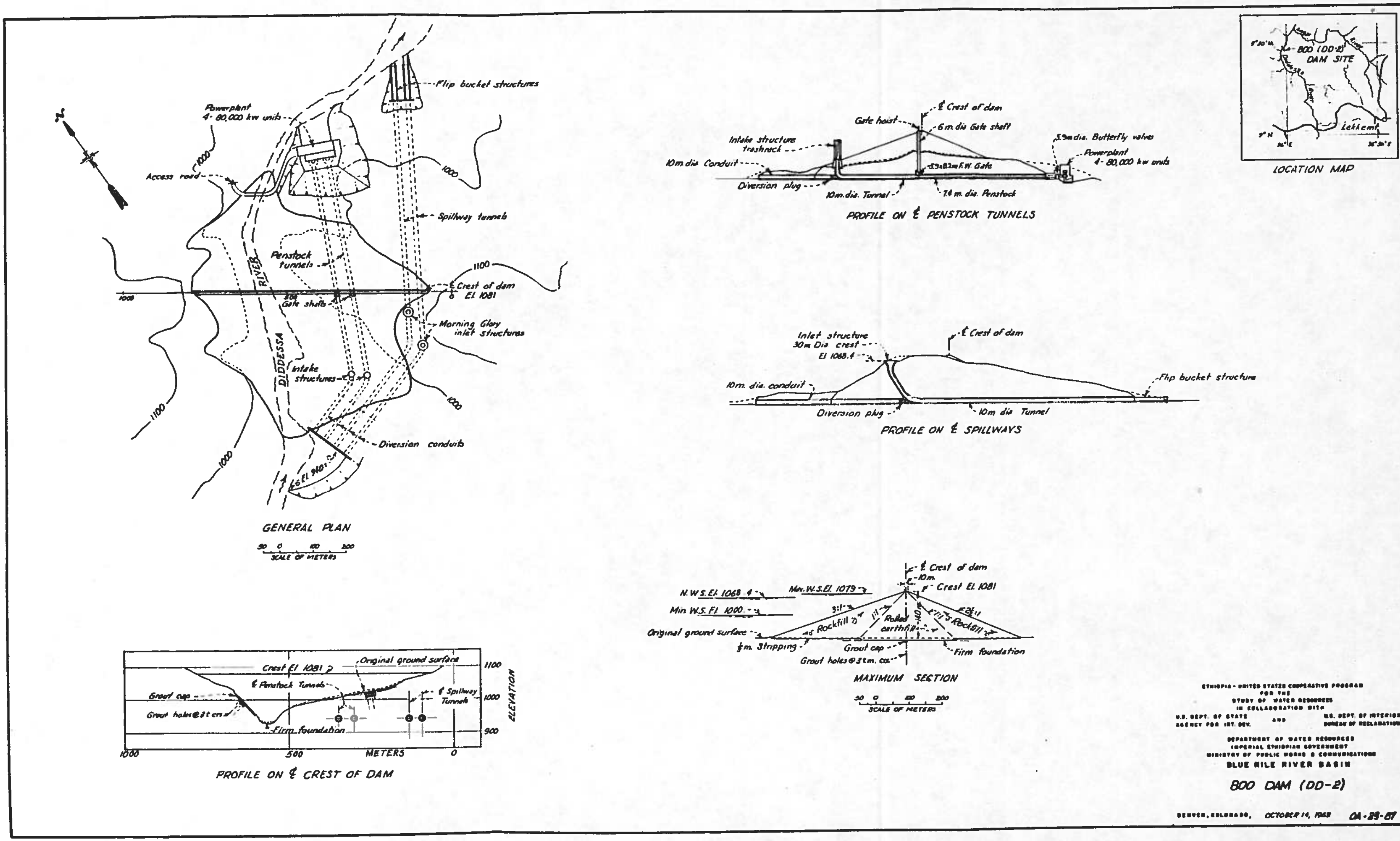


Figure 107--Boo Dam (DD-2)--Plan and Sections

Hydroelectric Plant Data

Design head	97.1 m.
Number of generators	4
Rating of each generator	80,000 kw.
Total plant capacity	400,000 kv.-a.
Turbine ratings (English)	112,883 hp.
Synchronous speed	150 r.p.m.
Type turbines	Francis

The switchyard would be about 1.2 kilometers from the powerplant and would consist of seven bays of 230 kv.

A total of 660 kilometers of transmission lines would be required to transmit the energy to the load centers of Addis Ababa and Lekkemt. Four substations are planned to receive the power generated by the Boo Powerplant.

Transmission Line Data

From	To	Length (km.)	Voltage (kv.)	Structure type	Circuit (No.)
Switchyard	Akaki No. 2	325	230	steel towers	double
Akaki No. 2	East Addis Ababa	10	230	(existing)	--
Switchyard	Lekkemt	80	230	steel towers	single
Lekkemt	Akaki No. 2	245	230	steel towers	single

Estimated Project Cost

Construction Cost.

Feature	Construction cost
Boo Dam and Reservoir	Eth$270,679,000
Powerplant	60,000,000
Switchyard	12,042,000
Transmission lines	47,096,000
Substations	9,443,000
Access roads	2,344,000
Service facilities	3,281,000
Total construction cost	Eth$404,885,000

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$3,796,000, including Eth$599,000 for taxes and insurance, as summarized below.

Facility	Operation and maintenance	Replacements
Dam and reservoir	Eth$ 100,000	--
Powerplant	1,400,000	Eth$180,000
Penstocks	20,000	--
Transmission plant	1,333,000	164,000
Other	599,000	--
Totals	Eth$3,452,000	Eth$344,000

Benefit-Cost Ratio

The benefit-cost ratio for this project is 2.09 to 1.00.

Projects In Dabus River Sub-Basin

GENERAL DESCRIPTION

Area Description

The Dabus River drains an area of approximately 14, 400 square kilometers. It originates in the high volcanic mountains to the south and flows generally northward into a large and flat basin known as the Dabus Swamp, then continues northward to the Blue Nile River. Proposed irrigation development is located on both sides of the river approximately 40 kilometers east of the town of Asosa. A 7, 500-kilowatt power project, located a few kilometers downstream from where the river emerges from the swamp, is also included. Figure 108 shows the location of the projects.

Geology and Physiography

The project area is situated in an ancient valley of the Dabus River overlying metamorphous and granitic rocks of Precambrian age. Fine- to coarse-grained quartzites, phillites, 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 erosional factors.

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.

Climate

The area has a tropical climate permitting wide range of crops with irrigated agriculture. Annual average temperature is 24° C., and annual precipitation totals about 100 centimeters.

Project Lands

Three major soil types 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 area. They have excellent structure--good permeability, good water-holding capacity, and are easily tilled. The brown intergrade latosols occupy about 40 percent, and have properties somewhat like the red latosols but are less permeable and have a slowly permeable substratum. The texture is clay throughout. Grumusols are of minor importance, comprising only about 5 to 10 percent of the irrigable lands. These soils are dark gray to black and are very slowly permeable clays which crack very severely when dry.

Results of the land classification in the area are as follows:

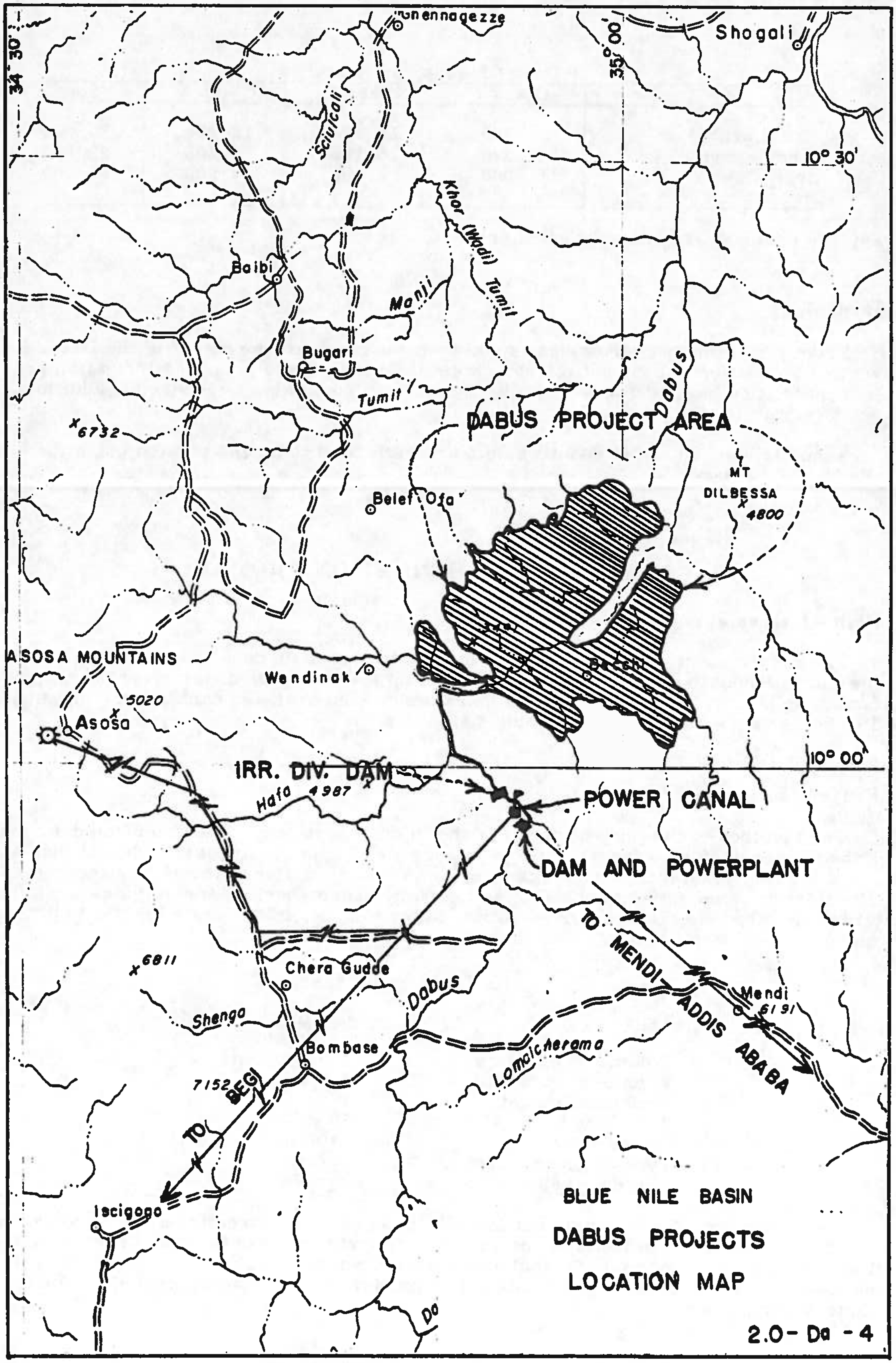


Figure 108--Dabus Projects--Location Map

Land Classes--in Hectares	Class 1	Class 2	Class 3	Total
Total arable	1, 380	16, 420	12, 200	30, 000
Arable under canal	1, 380	15, 165	6, 405	22, 950
Irrigable	900	9, 900	4, 200	15, 000

Surface drainage is generally excellent.

Hydrology

From preliminary hydrological studies, it appears that the runoff of the Dabus River without regulation will be sufficient to meet the needs of the proposed irrigation project. It is quite possible that flows from the Hoha River could also be utilized if additional water were required.

Annual diversion water requirements are estimated to be 205 million cubic meters for the 15, 000 hectares.

DABUS RIVER IRRIGATION PROJECT

Plan of Development

The development plan includes a diversion dam, a main canal, a major siphon crossing the Dabus River to convey water to the lands on the west side of the river, three principal canals or laterals, a lateral distribution system, and drainage canals for irrigation of 15, 000 hectares of new service lands.

Project Features

The features of the project plan are shown on Figure 109. The diversion dam, on the Dabus River upstream from the project lands, would be constructed with masonry and concrete and would utilize stoplogs to raise the water surface elevation of the river for diversion into the main canal. During the rainy season period, the stoplogs would be removed to bypass the floodflows. Canal headworks would be located on the right abutment of the diversion dam.

Diversion Dam Data

Type	masonry concrete with stoplogs
Volume of masonry	1, 080 cu. m.
Volume of concrete	490 cu. m.
Structural height	4 m.
Weir length	50 m.
Sill elevation	1100 m.
Type of gates (canal headworks)	radial gates

The South Main Canal starts out initially in an easterly direction and then veers northward for 54 kilometers to its terminus. A major structure of the canal system is the Dabus River siphon, about 17 canal kilometers downstream from the diversion dam headworks. It would be approximately 1 kilometer long with a capacity of 11. 3 cubic meters per second.

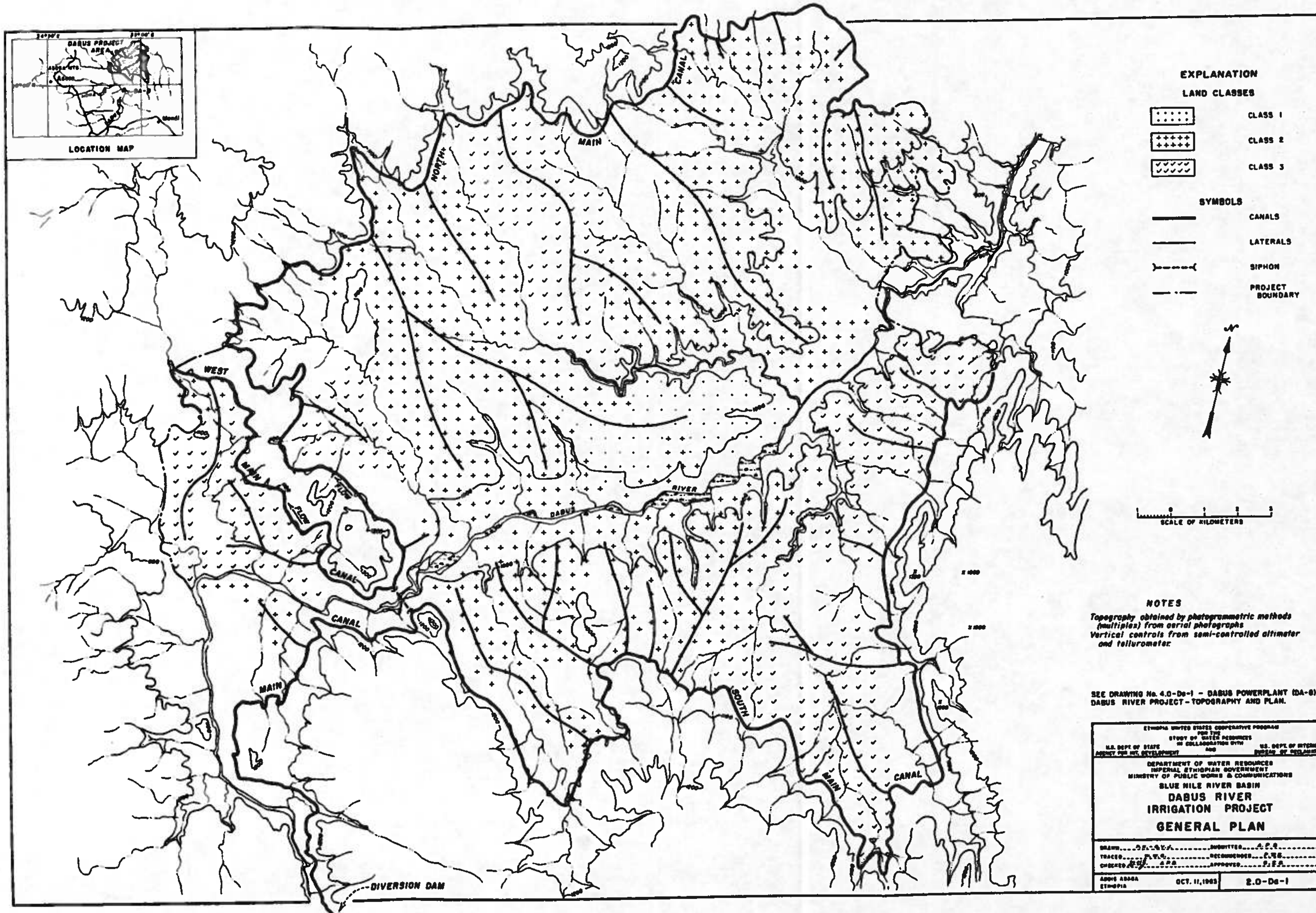


Figure 109--Dabus River Irrigation Project--General Plan

TABLE 44--SUMMARY OF CROPS AND GROSS FARM INCOME--DABUS PROJECT 15,000 HECTARES

Table 44

Crop pattern	Conditions before project			Future conditions, irrigation season			Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Pre-project income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Corn	7.68		2,250	2,780	6,255,000	480,380	4,500	1,150	5,175,000	397,440	877,820	877,820
Millet	7.40		1,500	2,915	4,372,500	323,560	3,750	950	3,562,500	263,620	587,180	587,180
Sorghum	11.20		3,000	2,915	8,745,000	979,440	-	-	-	-	979,440	979,440
Chick peas	11.24		1,500	1,450	2,175,000	244,470	1,500	920	1,380,000	155,110	399,580	399,580
Field beans	14.02		750	1,450	1,087,500	152,470	1,500	920	1,380,000	193,480	345,950	345,950
Castor beans	24.12		1,500	1,470	2,205,000	531,850	-	-	-	-	531,850	531,850
Sesame	32.75		750	1,175	881,250	288,610	-	-	-	-	288,610	288,610
Cotton	25.10		1,500	1,000	1,500,000	376,500	-	-	-	-	376,500	376,500
Peppers	53.43		750	900	675,000	360,650	-	-	-	-	360,650	360,650
Tobacco	112.10		750	2,000	1,500,000	1,681,500	-	-	-	-	1,681,500	1,681,500
Subtotal, crops			14,250			5,419,430	11,250			1,009,650	6,429,080	6,429,080
Fallow			-			-	3,000					
Subtotal, cultivated area			14,250			5,419,430	14,250			1,009,650	6,429,080	6,429,080
Noncultivated irrigable area			750			-	750			-	-	-
Total area		345,000	15,000			5,419,430	15,000			1,009,650	6,429,080	6,084,080
Income per hectare		23.00				361.30				67.31	428.61	405.61

The North and West Main Canals would originate at the downstream end of the siphon. The North Canal would extend in a westerly direction for 37 kilometers and serve 8,700 hectares of land. The West Main Canal would extend in the opposite direction to serve 1,100 hectares of irrigable lands.

Canal Data

Data	Main Canal	South Main Canal	North Main Canal	West Main Canal
Type	----------	---------- Unlined ----------	----------	----------
Length--km.	17	37	37	15
Initial capacity--cu. m. per sec.	17	6.2	10.1	1.7
Initial w. s. elevation--m.	1100	1099	1096	1096

This area runs parallel to the river with a maximum width of about 6 kilometers. Topographic conditions will permit relatively inexpensive irrigation distribution system construction. Water distribution, both for the project and the farms, will have the problem of crossing drainageways.

Cost estimates of surface drains are somewhat less on a per hectare basis than for other projects, due to the excellent natural drainage channels.

Access to the proposed project area and diversion is estimated to require the construction of about 40 kilometers of roads.

Estimated Project Costs

Construction cost.

Feature	Cost
Diversion dam	Eth$ 439,000
South Main Canal	4,433,000
North Main Canal	3,032,000
Dabus River siphon	2,355,000
Distribution system	7,969,000
Drainage canals	2,930,000
Access road	1,875,000
Service facilities	400,000
Total	Eth$23,433,000

Development cost. Land development cost will vary because of differences in slopes and intensity of tree cover. It is estimated that clearing and land leveling can be accomplished for about Eth$175 per hectare for a total cost of Eth$2,625,000.

Operation and maintenance cost. The annual cost for operation and maintenance is estimated to be Eth$500,000.

Benefit-Cost Ratio

The benefit-cost ratio for this project is 3.03 to 1.00.

DABUS RIVER POWER PROJECT

Plan of Development

The development plan of the hydroelectric power project includes a diversion dam, a power canal, and the Dabus Powerplant (DA-8) for annual firm generation of electric power estimated to be 65, 500, 000 kilowatt-hours. 1/

Project Features

The features of the project plan are indicated on Figure 110. The diversion dam and canal headworks would be about 75 river kilometers downstream from the outlet of the Dabus Swamp and about 50 airline kilometers east of the town of Asosa. It would be a concrete-masonry structure, with the canal headworks on the right abutment.

Diversion Dam Data

Type	masonry-concrete overflow
Structural height	8.5 m.
Crest length (spillway)	150 m.
Volume of concrete and masonry	2, 780 cu. m.
Normal w. s. elevation	1200 m.

The masonry-lined power canal with a capacity of 11 cu. m. per sec. would extend from the headworks of the diversion dam for a distance of 4 kilometers.

The powerplant would be located near the right bank, water being supplied by the penstocks from the forebay of the power canal. The tailrace of the powerplant would be in the Dabus River channel.

Powerplant Data

Design head (net)	89 m.
Number of generators	2
Rating of each generator	3, 750 kw.
Total plant capacity	9, 375 kv. -a.
Turbine ratings	5, 290 hp.
Synchronous speed	600 r. p. m.
Type of turbines	Francis

The switchyard will be adjacent to the powerplant and will include two bays, transformers and miscellaneous communication and station equipment. About 165 kilometers of steel pole, single-circuit, 45-kilovolt-capacity transmission lines to small towns south and west are included in the estimates of cost.

An access road from the town of Asosa to the construction site, consisting of about 45 kilometers of construction, is a substantial part of the total construction cost for the project.

1/If operated at 100 percent plant factor. Load characteristics will be such that for the isolated system served, 38, 511, 000 kw. -hr. will be the maximum energy requirements. Kilowatts, not kilowatt-hours, govern.

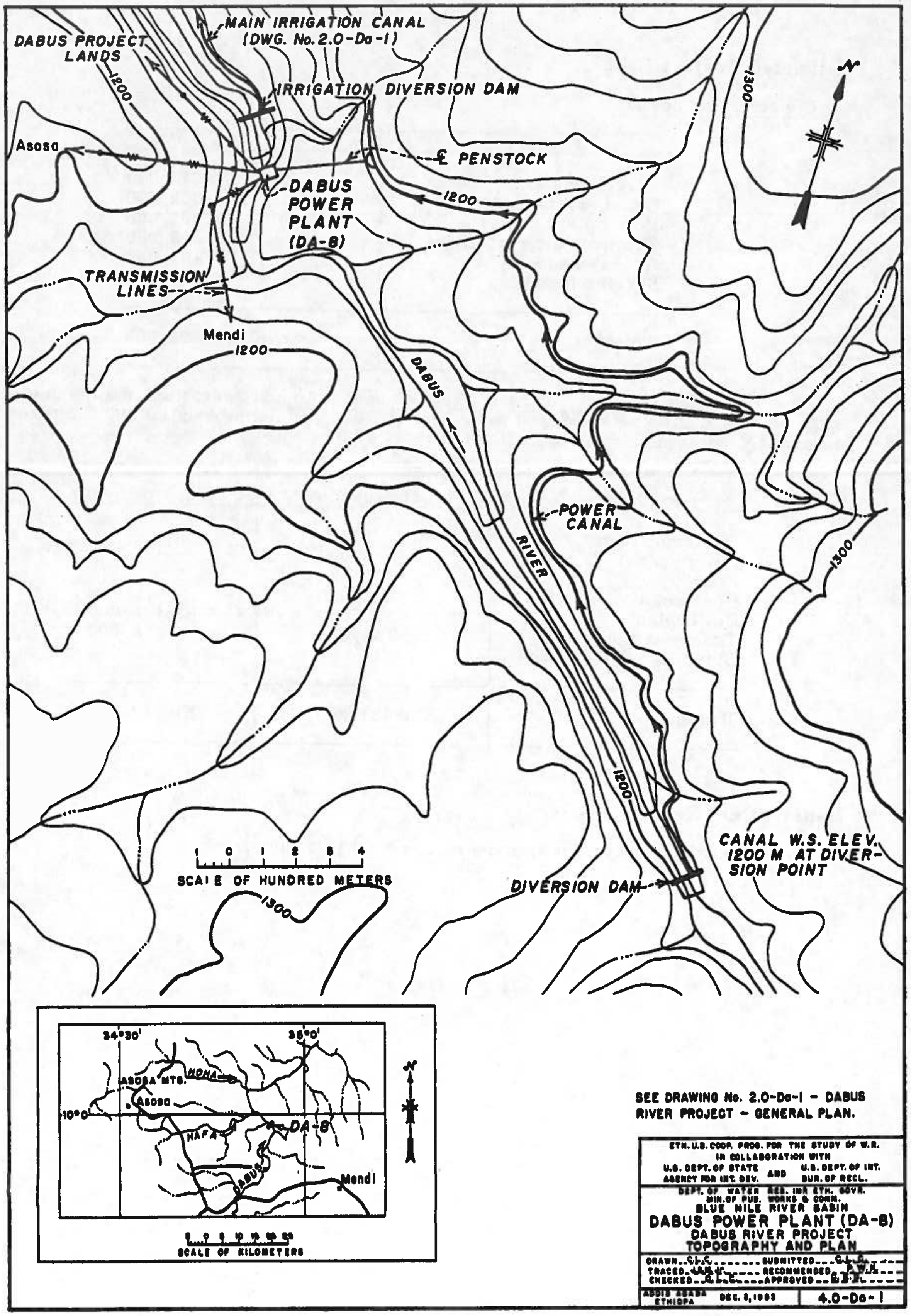


Figure 110--Dabus Powerplant (DA-8)--Topography and Plan

Estimated Project Cost

Construction cost.

Feature	Cost
Diversion dam	Eth$ 772, 000
Canal and penstocks	1, 802, 000
Powerplant	2, 063, 000
Transmission facilities	2, 698, 000
Access roads	2, 109, 000
Service facilities	178, 000
Total	Eth$9, 622, 000

Operation, maintenance, and replacement cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$439, 000, including Eth$11, 000 for taxes and insurance, as summarized below.

Facility	Operation and maintenance	Replacements
Diversion dam	Eth$ 2, 000	
Power canal	2, 000	
Forebay	500	
Penstock	2, 500	
Powerplant	360, 000	Eth$ 6, 000
Transmission plant	49, 000	6, 000
Other	11, 000	
Totals	Eth$427, 000	Eth$12, 000

Benefit-Cost Ratio

The benefit-cost ratio for this project is 2.08 to 1.00.

Projects In Dindir-Rahad Sub-Basin

GENERAL DESCRIPTION

The Dindir-Rahad Sub-basin is in the northwestern sector of the Blue Nile River Basin; the western boundary is the Ethiopian-Sudan Border. Two major rivers drain the 20, 500-square-kilometer area, the Rahad draining the northern portion, and the Dindir the southern part. Some of the larger tributaries to the two rivers draining the intermediate portions of the sub-basin, and later joining the two rivers below the border, are the Dibaba, Galegu, and the Atesh Rivers. The headwaters of the Dindir and Rahad Rivers are in the rough, broken areas below the plateau escarpment near Lake Tana on the eastern side of the basin.

The irrigation project areas extend along the international boundary, starting about 20 kilometers south of the Dindir River and continuing northeastward to just north of the Rahad River, a distance of approximately 145 kilometers. Elevations range from about 600 meters above sea level at the international border to about 800 meters at the upper reaches.

Three irrigation projects are considered in the area: the Dindir River Project occupying the southern half, the Galegu River Project occupying a small sector in the center, and the Rahad River Project situated on the northern half. Each of the irrigation projects would be served by gravity irrigation from storage provided on the river bearing the project's name. Included in the development of the Dindir River water resources would be a 40, 000-kw. hydroelectric powerplant to serve the surrounding area with needed electric energy and for the pumping plants. The projects are shown on Figure 111.

Geology and Physiography

The area is a vast, old peneplain surface on Precambrian metamorphics and granitics with thin, isolated remnants of sandstone. Near-vertical bedding planes largely control the drainage pattern. The soils were mostly formed in place from old volcanoes now completely removed. Flood plains along the intermediate meandering streams are composed of alluvium from granitics.

The gradients of the principal streams, with the possible exception of the Dindir and the Rahad, decrease rather rapidly toward the Sudan boundary. The project lands also flatten and decrease in elevation above the streambeds toward the Sudan. As a result, large smooth plains with a few drainageways typify the majority of the proposed project area.

Climate

Climatic data from nearby stations indicate that the average annual temperatures would be about 26° C. with the average annual precipitation approximately 80 centimeters. Most of the precipitation falls in the June through September period.

Project Lands

Soils of the area are of two general types, the reddish brown clays (latosols) and the dark clays (grumusols). A third type occupying a rather minor area is alluvium deposits along the meandering streams transecting the central portion of the plain. Observation of streambeds and tree growth suggest that the substrata soils may differ from the normal grumusols found in other parts of the Blue Nile. 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.

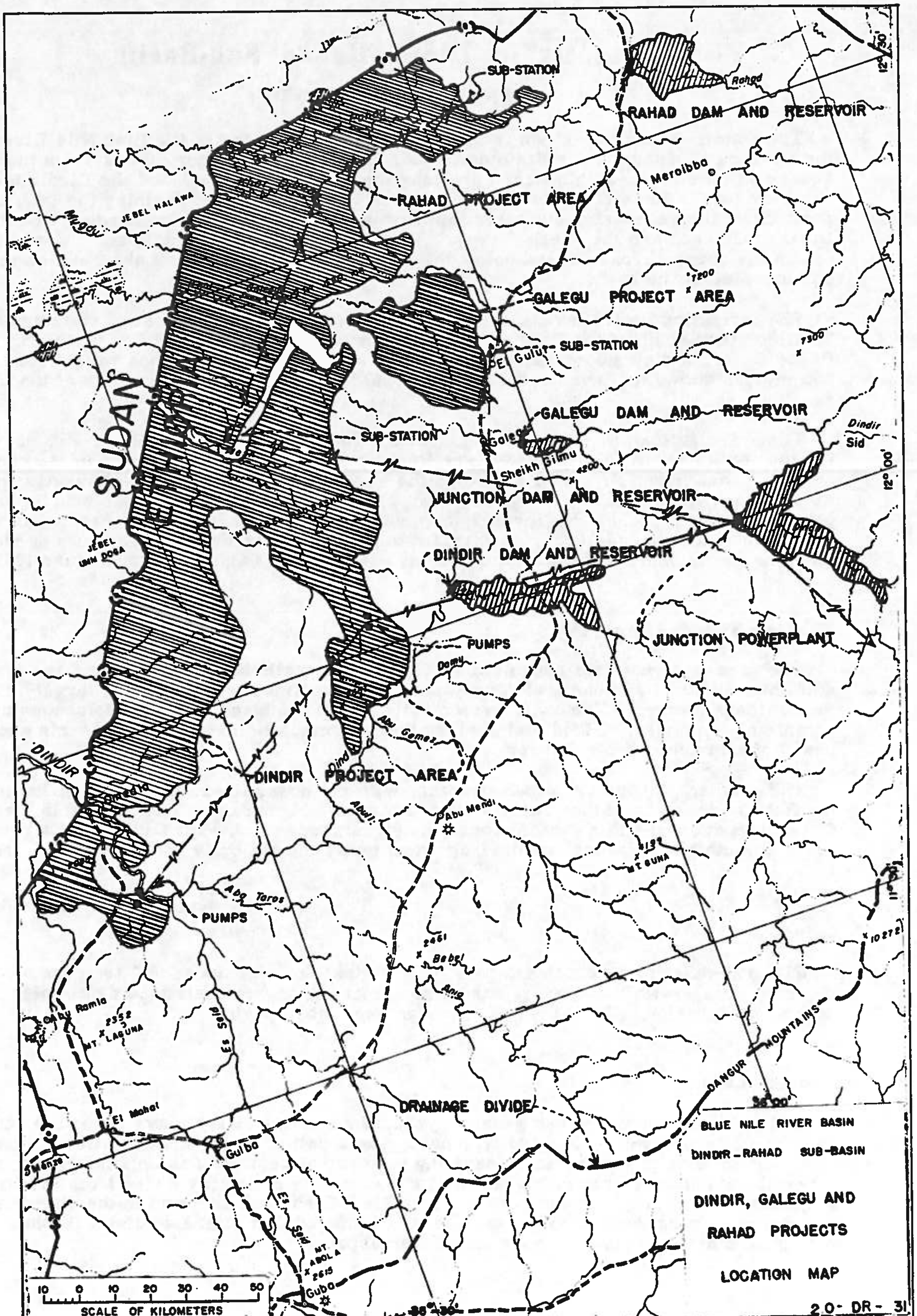


Figure III--Dindir, Galegu, and Rahad Projects--Location Map

Class	Total arable	Arable under canal	Irrigable land by project		
			Dindir	Galegu	Rahad
1	-	-	-	-	-
2	31, 500	19, 900	7, 900	-	5, 000
3	197, 000	169, 400	50, 400	11, 600	48, 100
Total	229, 500	189, 300	58, 300	11, 600	53, 100

Land Classes (In hectares)

Hydrology

Water supply for irrigation purposes can be made available by regulating the Dindir, Galegu, and Rahad Rivers. Hydrology indicates that the annual natural flows at the sites for storage would be 1, 340, 254, and 2, 022 million cubic meters, respectively. Based on these flows, it was determined that the Dindir River with regulation had about twice the water supply required for irrigation development, leading to multipurpose development.

Farm requirements were determined to be 1. 375 meters annually or 19, 640 cubic meters per hectare after adding conveyance losses.

DINDIR MULTIPURPOSE PROJECT

Plan of Development

The plan for the Dindir River area envisions the construction of two dams, a 40, 000-kw. powerplant for generation of 178. 7 million kilowatt-hours annually, a diversion dam, pumping plants, main canals, a lateral distribution system and drainage canals for irrigation of 58, 300 hectares of land.

Junction Dam and Powerplant, the most upstream feature of the project on the Dindir River, controls a drainage area of approximately 2, 700 square kilometers and would impound the annual flows for irrigation and for generation of electrical energy. The second major feature would be Dindir Dam and Reservoir, downstream from the first unit. The structure would serve to impound the releases from the upstream structure for reregulation and diversion into the main canals for irrigation water requirements to the land located below. The pumping plants would serve an additional 13, 240 hectares of land for irrigation development that could not be reached by gravity.

Project Features

The features of the project are shown on Figures 112, 113, and 114. The river regulating structure (Junction Dam) is on the Dindir River about 130 river kilometers upstream from the international border and just below the junction of the Dindir Sid and Dindir River. It would be a rolled earth and rock fill structure. Diversion during construction would be accomplished by a concrete tunnel around the dam on the right bank of the river. Plan of the dam and profiles of the outlet and spillway structures are indicated on Figure 115.

Dam Data

Type	earth and rock fill
Embankment volume (earth)	7,000,000 cu. m.
Embankment volume (rock)	25,100,000 cu. m.
Top of dam	999 m.
Freeboard	2.57 m.
Structural height	103 m.
Hydraulic height	100.43 m.
Length of crest	3,250 m.
Width of crest	10 m.

A channel spillway having a 90-meter crest length would discharge 1,028 cubic meters per second. It would be located on the left abutment of the dam. Superstorage for storing part of the flood temporarily would amount to 317 million cubic meters.

Spillway Data

Type	uncontrolled side channel
Crest elevation	993.16 m.
Peak inflow flood	4,890 cu. m. per sec.
Total flood volume 4-day period	480,000,000 cu. m.
Maximum discharge capacity	1,028 cu. m. per sec.

The outlet works would be located a little left of the center of the dam above the powerplant. The water from the intake structure would discharge into the turbines of the powerplant.

Outlet Works Data

Sill elevation	923 m.
Capacity at min. w.s. elevation	84.7 cu. m. per sec.
Types of gates	fixed wheel
Size of penstock (diameter)	4.95 m.

The Junction Reservoir basin is mantled with dark clays underlain with horizontal, massive, basaltic flows. No serious leakage problem is anticipated. Clearing will be required, as the potential reservoir area is covered with scrub trees. Capacity of the reservoir is, at initial stage of operation, 2,944,000,000 cubic meters. The reservoir at normal water surface elevation would inundate about 94 square kilometers of land area.

The proposed site of Dindir Dam is about 45 kilometers downstream from Junction Dam on the Dindir River. It will serve as a diversion and reregulating structure for irrigation development. It would be a rolled earth and rock fill structure. Diversion during construction would be accomplished by a 10-meter-diameter concrete tunnel located on the left abutment of the dam. When no longer needed for diversion purposes, the tunnel would be plugged at the upstream end. Plan, profile, and maximum section of the dam is shown on Figure 116.

Dam Data

Type	earth and rock fill
Embankment volume (earth)	650,000 cu. m.
Embankment volume (pervious)	780,000 cu. m.
Top of dam	762 m.
Freeboard	2.20 m.
Structural height	62 m.
Hydraulic height	59.80 m.
Length of crest	525 m.
Width of crest	10 m.

The spillway requirements are met with an uncontrolled chute spillway located on the right abutment. A stilling basin to dissipate the high energies of the flows would be required before discharging into the river channel.

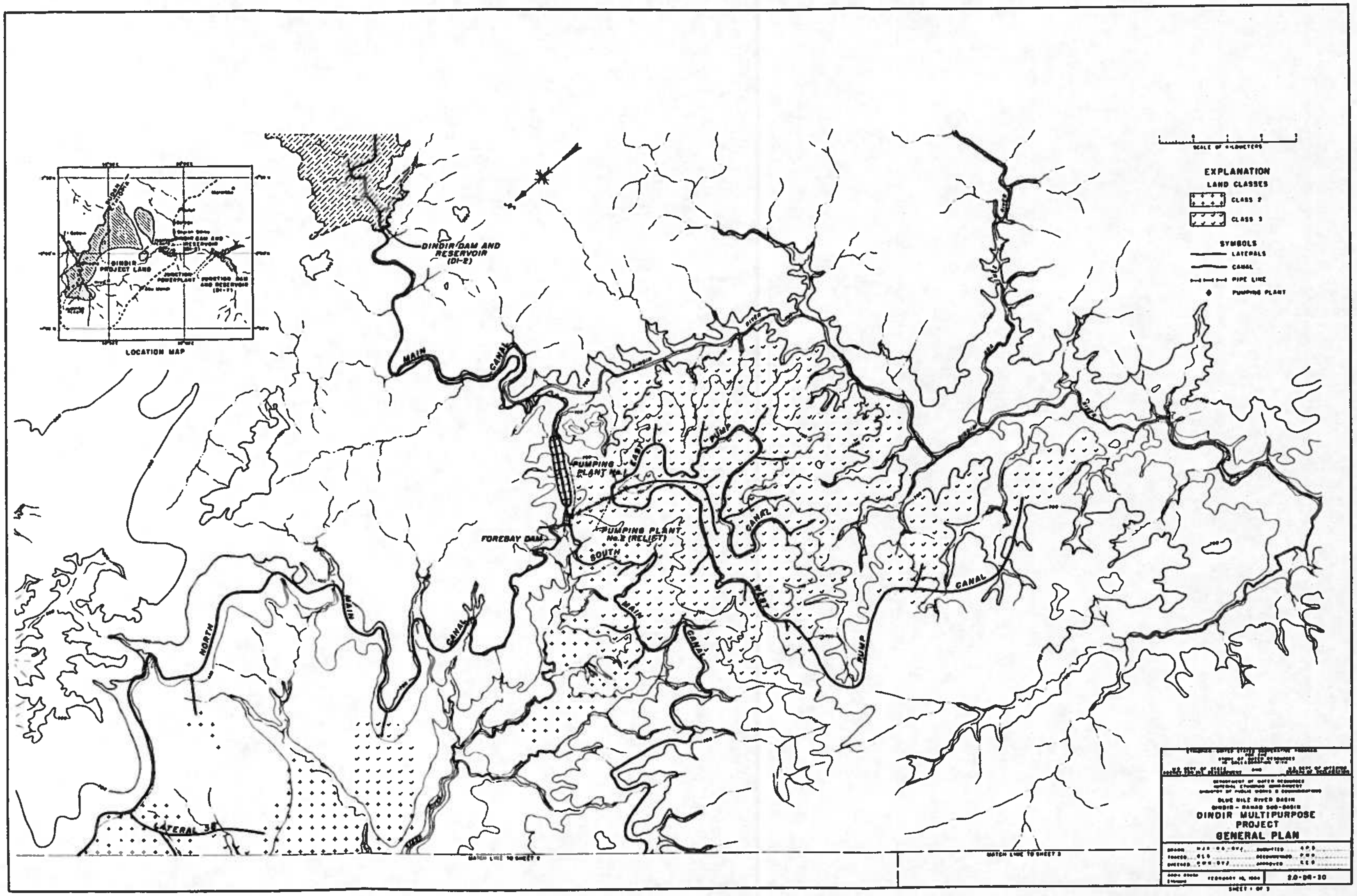


Figure 112--Dindir Multipurpose Project--General Plan, Sheet 1

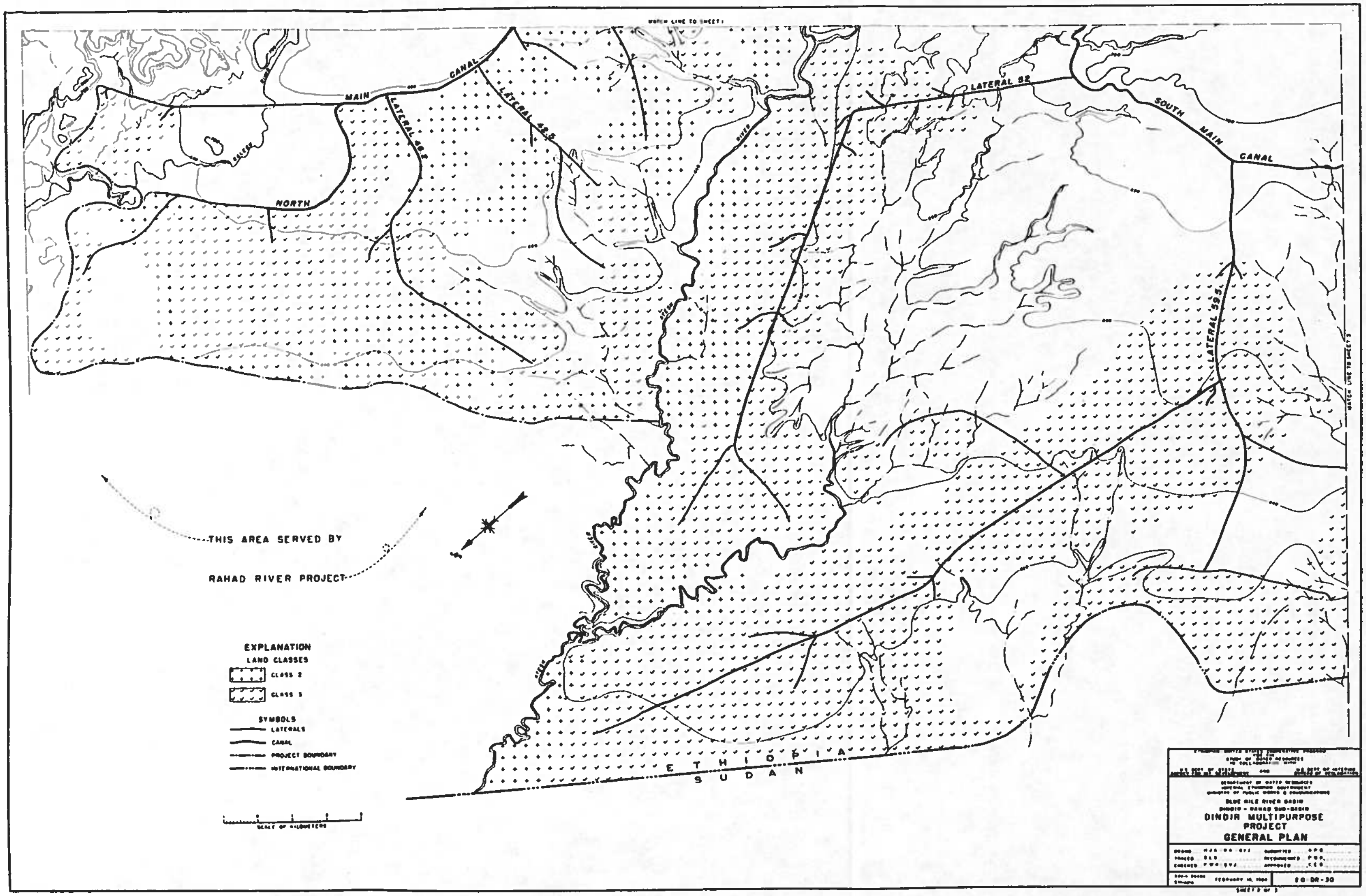


Figure 113--Dindir Multipurpose Project--General Plan, Sheet 2

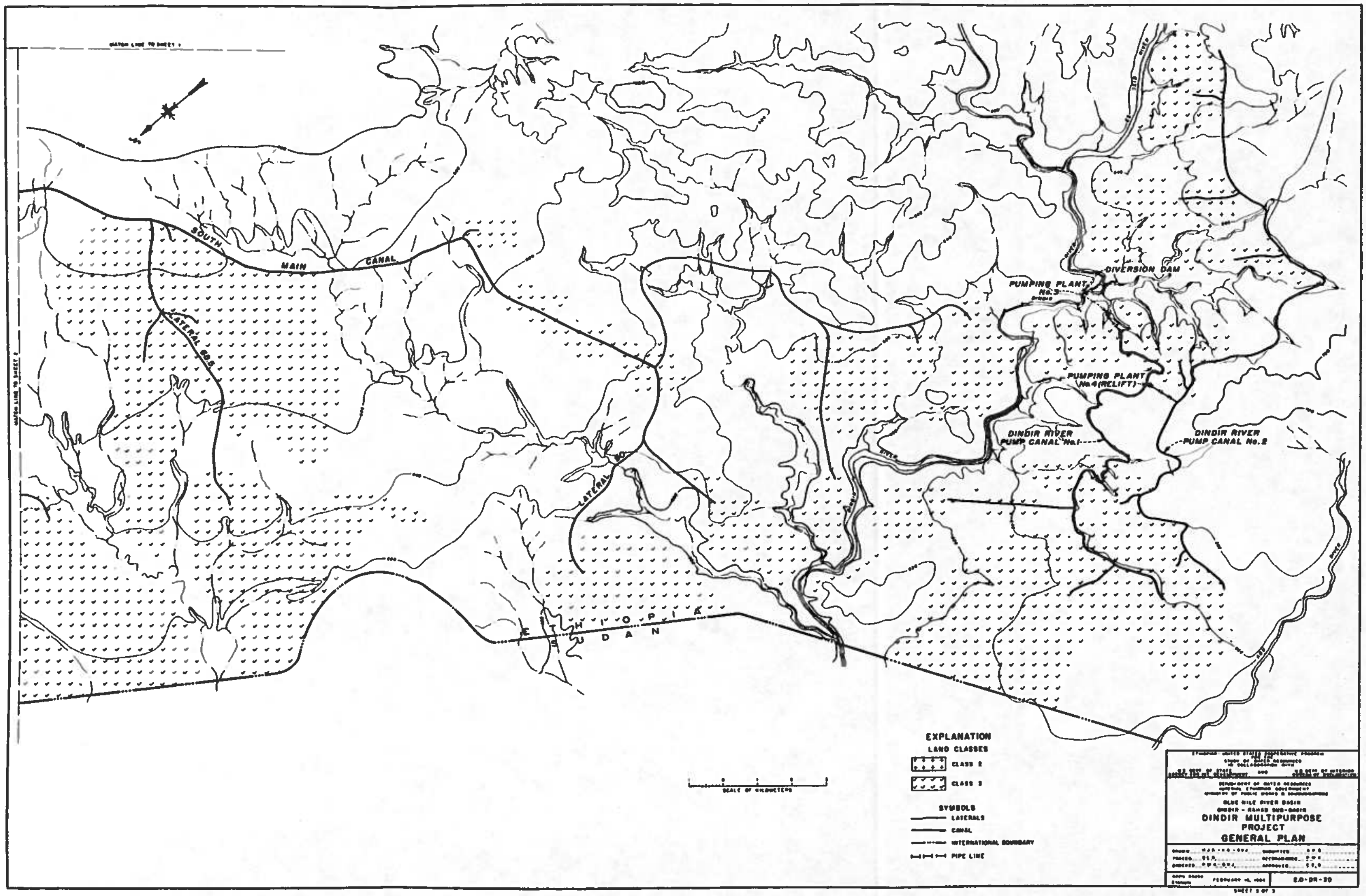


Figure 114--Dindir Multipurpose Project--General Plan, Sheet 3

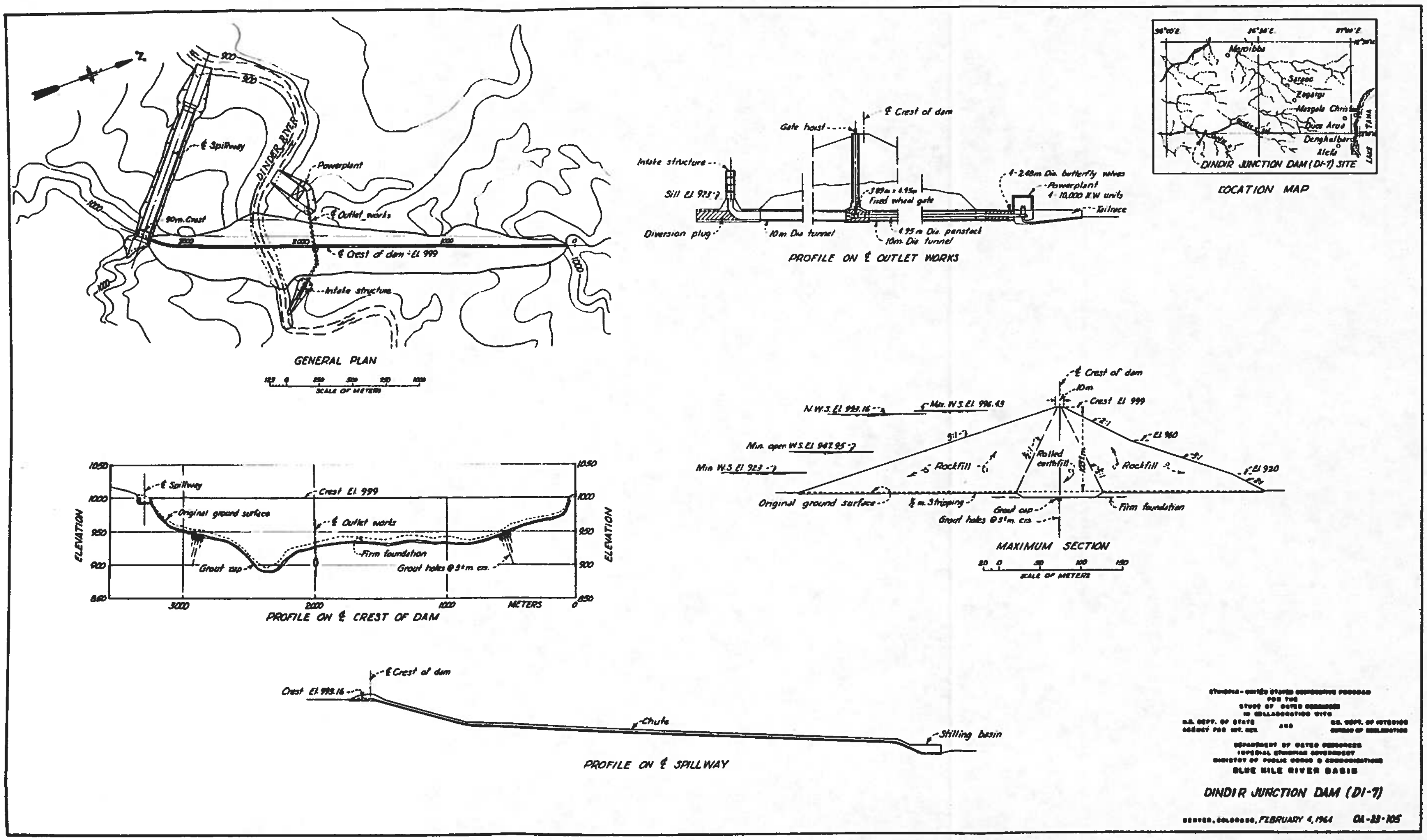


Figure 115--Dindir Junction Dam (DI-7)--Plan and Sections

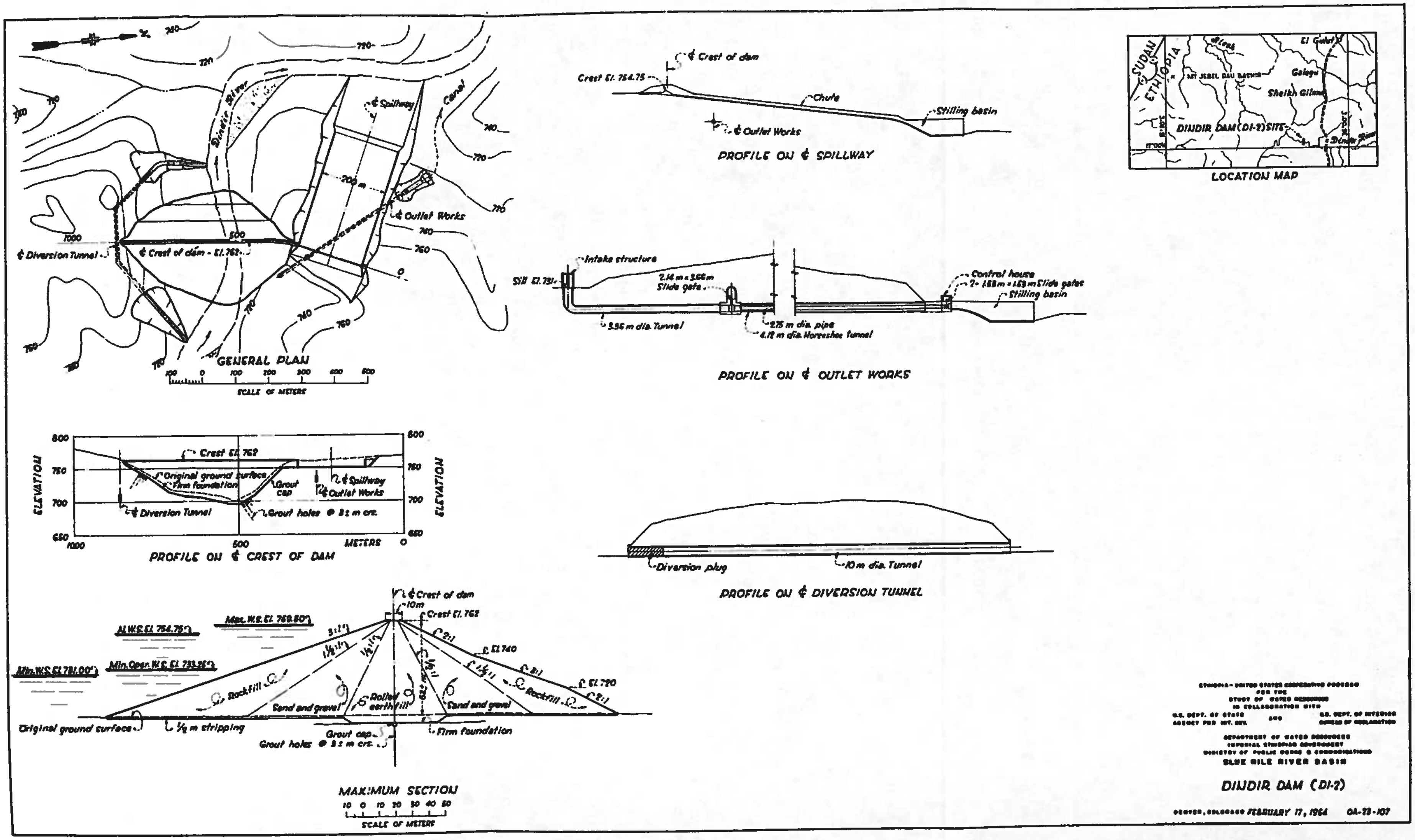


Figure 116--Dindir Dam (DI-2)--Plan and Sections

Spillway Data

Type	chute
Crest elevation	754.75 m.
Peak inflow flood	6,370 m.-
Total flood volume 5-day period	815,000,000 cu. m.
Maximum discharge capacity	4,380 cu. m. per sec.

The outlet works would be located on the right abutment with the conduit below the service spillway. It would consist of an intake structure, a concrete tunnel, a gate chamber equipped with an emergency slide gate, and a horseshoe tunnel housing an outlet pipe branching at the control house.

Outlet Works Data

Sill elevation	731 m.
Capacity at min. w.s. elevation	51.5 cu. m. per sec.
Type of gates (2)	slide gates
Size of outlet pipe (diameter)	2.75 m.

Geologic conditions for Dindir Reservoir are similar to the upstream Junction Reservoir. Clearing also will be required before the reservoir is put into operation. The initial capacity of the reservoir would be 746 million cubic meters at normal water surface elevation. It would inundate 48.4 square kilometers of land area.

The proposed damsites are located in a relatively wide valley underlain with horizontal, massive, basaltic flows. No undue foundation problems are expected to arise. Normal amount of grouting should be effective against leakage.

Sources of pervious and impervious materials in adequate quantities are available in the immediate vicinity of both damsites.

The Junction Powerplant would be located on the toe of the Junction Dam adjacent to the river with the tailrace of the powerplant extending into the river channel. The powerplant would have four turbine-driven generators.

Powerplant Data

Design head	72.3 m.
Rating of each generator (4)	10,000 kw.
Total plant capacity	50,000 kv.-a.
Turbine ratings (English) (each)	14,110 hp.
Synchronous speed	333-1/3 r.p.m.
Type of turbines	Francis

A switchyard would be located adjacent to the Junction Powerplant. About 338 kilometers of 69-kv.-capacity transmission lines is envisioned, radiating to anticipated load centers including the pumping plants.

A small river regulating structure (Dindir Diversion Dam) located about 75 kilometers downstream from Dindir Dam would be required for the purpose of creating a small forebay for Pumping Plant No. 3. The structure would be constructed of masonry and concrete materials.

Diversion Dam Data

Type	masonry with stoplogs
Embankment volume (concrete and masonry)	10,944 cu. m.
Structural height	11 m.
Spillway crest length	200 m.
Hydraulic height	5 m.

Pumping Plant No. 1 would be located near kilometer Station 22.5 of the Main Canal. The relift pump designated as Pumping Plant No. 2 would pump to land area situated about 30 meters above the main canal.

Pumping Plant Data

Data	Pump No. 1	Relift Pump No. 2
Total dynamic head (m.)	43	32
Static lift (dia., m.)	40	30
Size of discharge pipe (dia., m.)	2	1
Length of pipe (km.)	1.5	0.5
Capacity of pumps (cu. m. per sec.)	7.6	2.0
Motor rating (hp.)	6,610	1,300
Irrigable area served (ha.)	6,520	(1,260)

Pumping Plant No. 3 would pump from the reservoir created by the Dindir Diversion Dam. Pumping Plant No. 4 would be a relift pump structure to service additional higher situated lands.

Pumping Plant Data

Data	Pump No. 3	Relift Pump No. 4
Total dynamic head (m.)	42	23
Static lift (dia., m.)	40	20
Size of discharge pipe (dia., m.)	2.0	1.4
Length of pipe (km.)	1.0	1.2
Capacity of pumps (cu. m. per sec.)	7.8	3.7
Motor rating (hp.)	6,330	1,720
Irrigable area served (ha.)	6,720	(2,840)

The Main Canal, extending in a westerly direction, will traverse hilly and rough terrain until it emerges on the plain. A fairly sizable cut will be required shortly before branching out into the North and South Main Canals. A considerable amount of rock excavation is expected, and the cross slopes of the main canal will be rather steep.

Main Canal Data

Type	unlined
Length	22.5 km.
Initial capacity	60 cu. m. per sec.
Initial w.s. elevation	715 m.

The South Main Canal would start at the bifurcation works and extend in a westerly direction for about 40 kilometers. No undue difficulty is expected in constructing the canal as it would be mostly located in the plain. It would service 33,180 hectares of land.

South Main Canal Data

Type	unlined
Length	68 km.
Initial capacity	38.6 cu. m. per sec.
Initial w.s. elevation	710 m.

The North Main Canal would branch off from the bifurcation works and extend in a northerly direction for a distance of 54 kilometers. It would be designed to irrigate 11,880 hectares of land.

North Main Canal Data

Type	unlined
Length	54 km.
Initial capacity	13.8 cu. m. per sec.
Initial w. s. elevation	710 m.

Canals will be required to convey the water from the pumping plants to the project lands. A total of 5 kilometers of canals at Pumping Plants No. 1 and 2, and 16 kilometers of canals at Pumping Plants No. 3 and 4 were estimated to be required. The layout of the canals is shown in the general plan.

Distribution of water to the individual farm units should not present any undue problem, as about 60 percent of the area has slopes of less than 1 percent with the remainder ranging from about 1 to 5 percent.

Open interceptor drainage channels have been included in the estimates of construction cost. The control of water table may or may not arise under irrigation conditions and this phase of irrigation development should be given careful attention in subsequent detail studies.

About 40 kilometers of two-lane gravel access roads to the construction sites through average terrain are estimated to be required.

Estimated Project Costs

Construction cost.

Feature	In thousands of Ethiopian dollars			
	Total construction cost	Facilities		
		Joint-use	Irrigation	Power
Storage Division				
Junction Dam and Reservoir	257, 322	257, 322		
Dindir Dam and Reservoir	67, 627		67, 627	
Power Division				
Junction Power-plant	9, 250			9, 250
Transmission facilities	12, 933		3, 193	9, 740
Irrigation Division				
Diversion Dam	2, 434		2, 434	
Bifurcation works	866		866	
Pumping Plant No. 1	3, 742		3, 742	
Pumping Plant No. 2	632		632	
Pumping Plant No. 3	3, 644		3, 644	
Pumping Plant No. 4	1, 429		1, 429	
Main Canal	17, 104		17, 104	
South Main Canal	13, 930		13, 930	
North Main Canal	5, 808		5, 808	
Pump canals	1, 240		1, 240	
Distribution system	27, 328		27, 328	
Drainage canals	12, 753		12, 753	
Headquarters Division				
Access roads	2, 500	2, 500		
Service facilities	7, 930	7, 930		
Total	448, 472	267, 752	161, 730	18, 990

Development cost. Clearing the lands of trees, brush, and vegetative debris can be accomplished at an estimated cost of Eth$225 per hectare. Owing to the smooth plains, land leveling and grading cost will be fairly low, estimated to be Eth$65 per hectare. The development cost for these two items is estimated to require about Eth$16, 907, 000.

Operation, maintenance, and replacement cost. The operation, maintenance, and replacement costs are estimated to be Eth$4, 282, 800, including Eth$28, 000 for taxes and insurance, as summarized below.

TABLE 45–SUMMARY OF CROPS AND GROSS FARM INCOME–DINDIR PROJECT, 58,300 HECTARES

Table 45

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season					
	Price received per 100 kg. Eth$	Preproject income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Post-project income Eth$	Gross crop income Eth$
Corn	5.98		11,700	3,275	38,317,500	2,291,390	17,500	1,350	23,625,000	1,412,770	3,704,160	3,704,160
Millet	5.70		5,800	3,430	19,894,000	1,133,960	11,700	1,120	13,104,000	746,930	1,880,890	1,880,890
Sorghum	9.50		11,700	3,430	40,131,000	3,812,440	5,800	1,350	7,830,000	743,850	4,556,290	4,556,290
Castor beans	22.42		5,800	1,725	10,005,000	2,243,120	-	-	-	-	2,243,120	2,243,120
Sesame	31.05		2,900	1,370	3,973,000	1,233,620	5,800	825	4,785,000	1,485,740	2,719,360	2,719,360
Sunflower	21.40		2,900	2,070	6,003,000	1,284,640	-	-	-	-	1,284,640	1,284,640
Cotton	26.65		8,800	2,000	17,600,000	4,690,400	-	-	-	-	4,690,400	4,690,400
Peppers	51.73		2,900	1,060	3,074,000	1,590,180	2,900	760	2,204,000	1,140,130	2,730,310	2,730,310
Tobacco	110.40		2,900	2,300	6,670,000	6,363,680	-	-	-	-	6,363,680	6,363,680
Subtotal, crops			55,400			24,643,430	43,700			5,529,420	30,172,850	30,172,850
Fallow			-			-	11,700			-	-	-
Subtotal, cultivated area			55,400			24,643,430	55,400			5,529,420	30,172,850	30,172,850
Noncultivated irrigable area			2,900			-	2,900			-	-	-
Total area		-	58,300			24,643,430	58,300			5,529,420	30,172,850	30,172,850
Income per hectare		-				422.70				94.84	517.54	517.54

Feature	Operation and maintenance	Replace-ments	Power cost
Storage Division			
Junction Dam and Reservoir	Eth$ 68,000		
Dindir Dam and Reservoir	28,000		
Irrigation & Hq. Division			
Pumping Plants No. 1 & 2	90,000	Eth$ 5,000	Eth$ 617,850
Pumping Plants No. 3 & 4	109,000	7,000	670,950
Electrical facilities	42,000	8,000	
Conveyance systems	1,865,000		
Power Division			
Powerplant	510,000	27,800	
Penstocks	8,200		
Transmission plant	170,000	28,000	
Other	28,000		
Totals	Eth$2,918,200	Eth$75,800	Eth$1,288,800

Benefit-Cost Ratio

The benefit-cost ratio for this project is 1.22 to 1.00.

GALEGU RIVER PROJECT

The development plan for the Galegu River Project would include a storage dam, main canals, a distribution system, and drainage canals for irrigation of 11,600 hectares of land.

The Galegu Dam and Reservoir would be about 65 river kilometers east of the international border, controlling an area of about 543 square kilometers.

Project Features

The features of the project are shown on Figure 117. The damsite is on the Galegu River where two unnamed tributaries join the main river. It would be an earth and rock fill structure. Diversion during construction would be accomplished by constructing a concrete conduit to pass the floodflows during construction. Plan of the dam and the spillway and outlet works structures appear on Figure 118.

Dam Data

Type	earth and rock fill
Embankment volume (earth)	10, 600, 000 cu. m.
Embankment volume (rock)	17, 600, 000 cu. m.
Top of dam elevation	828 m.
Freeboard	2. 11 m.
Structural height	90 m.
Hydraulic height	87. 89 m.
Length of crest	1, 922 m.
Width of crest	10 m.

Designs of the service spillway were based on inflow design flood studies. A side-channel-type spillway located on the left abutment with the control structure 90 meters long would discharge 889 cubic meters per second. The chute-type discharge channel would include a stilling basin before discharging into the river channel.

Spillway Data

Type	uncontrolled side channel
Crest elevation	822. 92 m.
Peak inflow flood	1, 919 cu. m. per sec.
Total flood volume 2. 5-day period	116, 000, 000 cu. m.
Maximum discharge capacity	889 cu. m. per sec.

The outlet works would be located on the right abutment and would consist of an intake structure, a conduit, a gate chamber about midway in the dam equipped with an emergency slide gate, an outlet pipe inside a horseshoe tunnel, and a control structure housing two slide gates for control releases into the stilling basin.

Outlet Works Data

Sill elevation	774 m.
Capacity at min. w. s. elevation	10. 3 cu. m. per sec.
Type of gates (2)	slide gates
Size of outlet pipe (diameters)	1. 83 m.

The Galegu Reservoir basin is underlain with hard basaltic flows with occasional softer ash tuff and scoriaceous contact zones. The rock sequence is cut by long, narrow, vertical dikes of rhyolitic to basaltic composition. The dikes usually form straight lines, often intersecting each other and extending several kilometers in length across the terrain. A mantle of thick impervious clay with variable thickness ranges over the basin and leakage is not considered to be a serious problem. Clearing will be required, as the area is covered with fairly dense growth of small trees and bushes. Capacity of the reservoir at initial stages of operation is estimated to be nearly 800 million cubic meters. At normal water surface it would inundate about 21 square kilometers of land area.

The damsite is located in volcanic rocks which are exposed on the upper portion of the dam abutments and in the stream channel. Bedrock on the lower portion of the abutments and on both sides of the stream channels is covered by alluvium and slopewash soil estimated to be from 1 to 5 meters deep. Overlying the basement rock is a layer of Adigrat sandstone 50 to 100 meters thick. A grout curtain is expected to provide an acceptably tight dam and reservoir.

Impervious embankment materials are available on the gentle slopes and valleys within an average haul distance of about 4 kilometers from the damsite. Pervious sand and gravel are relatively scarce, and it is anticipated that pervious rockfill, masonry stone and rock for crushed aggregates will for the most part have to be quarried basalt near the damsite.

Assuming that the national road system will have been constructed as proposed by the Imperial Highway Authority, about 7 kilometers of access road will be required.

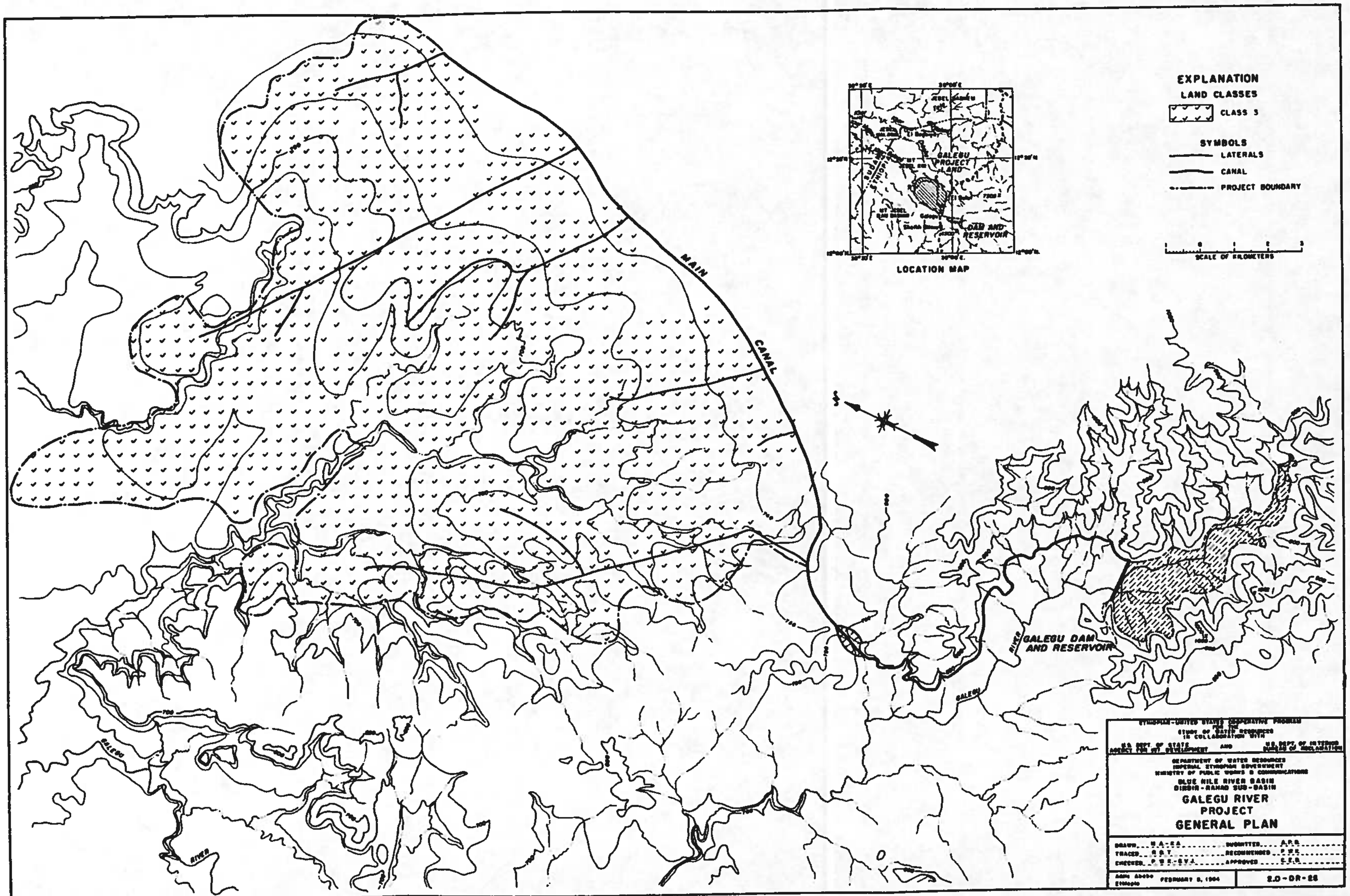


Figure 117--Galegu River Project--General Plan

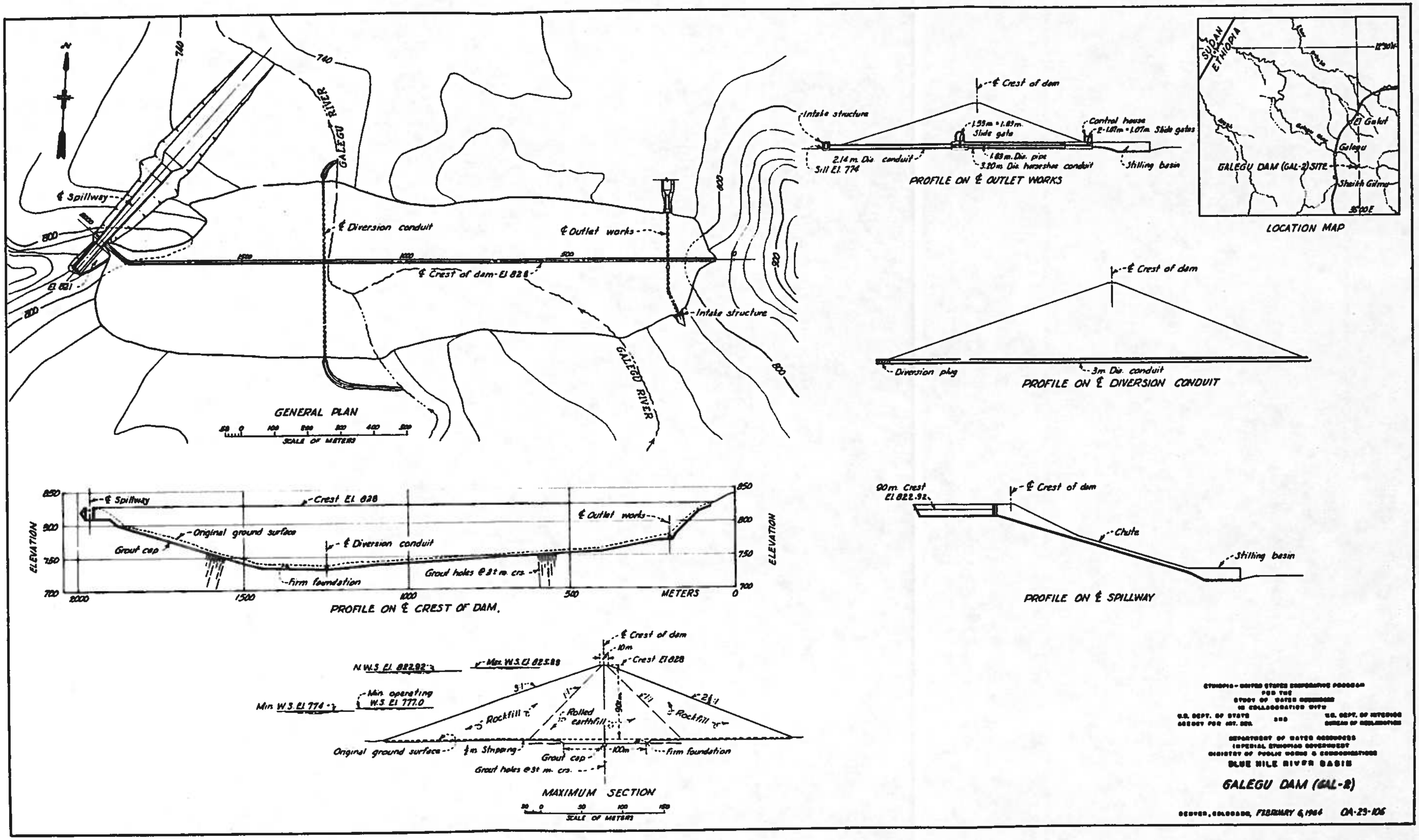


Figure 118--Galegu Dam (GAL-2)--Plan and Sections

Table 46

TABLE 46--SUMMARY OF CROPS AND GROSS FARM INCOME--GALEGU PROJECT, 11,600 HECTARES

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Preproject income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Corn	5.38		2,300	3,275	7,532,500	405,250	3,500	1,350	4,725,000	254,200	659,450	659,450
Millet	5.10		1,150	3,430	3,944,500	201,170	2,300	1,120	2,576,000	131,380	332,550	332,550
Sorghum	8.90		2,300	3,430	7,889,000	702,120	1,750	1,350	2,362,500	210,260	912,380	912,380
Castor beans	21.82		1,150	1,725	1,983,750	432,850	-	-	-	-	432,850	432,850
Sunflower	20.80		1,150	2,070	2,380,500	495,140	-	-	-	-	495,140	495,140
Cotton	26.20		1,750	2,000	3,500,000	917,000	-	-	-	-	917,000	917,000
Peppers	51.13		600	1,060	636,000	325,190	1,150	760	874,000	446,880	772,070	772,070
Tobacco	109.80		600	2,300	1,380,000	1,515,240	-	-	-	-	1,515,240	1,515,240
Subtotal, crops			11,000			4,993,960	8,700			1,042,720	6,036,680	6,036,680
Fallow			-			-	2,300			-	-	-
Subtotal, cultivated area			11,000			4,993,960	11,000			1,042,720	6,036,680	6,036,680
Noncultivated irrigable area			600			-	600			-	-	-
Total area		-	11,600			4,993,960	11,600			1,042,720	6,036,680	6,036,680
Income per hectare		-				430.51				89.89	520.40	520.40

A main canal and laterals extending in a northwesterly direction for about 36 kilometers would be required to serve the project area from the Galegu Reservoir. It will traverse rough terrain in the initial reaches of the canal, with some rock excavation expected to be encountered.

Canal Data

Type	unlined
Length	36 km.
Initial capacity	13.6 cu. m. per sec.
Initial w.s. elevation	774 m.

Average slope of the project lands is about 4 to 5 percent, and the cost of distribution system is anticipated to be somewhat higher than usual, as more drop structures are required.

Estimated Project Cost

Construction cost.

Feature	Cost
Galegu Dam and Reservoir	Eth$195, 107, 000
North Main Canal	3, 683, 000
Distribution system	6, 162, 000
Drainage canals	2, 538, 000
Access roads	328, 000
Service facilities	3, 888, 000
Total construction cost	Eth$211, 706, 000

Development cost. Clearing the open forest cover is estimated to cost about Eth$230 per hectare and land leveling is estimated at about Eth$150 per hectare, for a total development cost for both clearing and leveling for the 11, 600 hectares is estimated to be about Eth$4, 500, 000.

Operation, maintenance, and replacement cost. The total annual operation and maintenance costs (no replacement being required within the analysis period assumed) for the Galegu Dam and Reservoir are estimated to be Eth$30, 000 and for the Irrigation Unit, including the main canals and headquarters buildings, Eth$395, 000.

Benefit-Cost Ratio

The benefit-cost ratio for this project is 0.45 to 1.00.

RAHAD RIVER PROJECT

The plan for the Rahad River area includes the construction of a storage dam, a diversion dam, two main canals, a lateral distribution system, and drainage canals for irrigation of approximately 53, 100 hectares of land for agricultural production of crops.

The Rahad Dam and Reservoir, about 65 river kilometers upstream from the international border on the Rahad River, would control a drainage area of about 3, 800 square kilometers. It would impound the annual flows of the river for irrigation. The Rahad Diversion, about 8 kilometers downstream from the storage dam, would divert the flows into the main canals located on each side of the river. The North Main Canal would extend on a northwesterly direction, while the South Main Canal would extend on a southwesterly direction.

Project Features

The features of the project are shown on Figures 119 and 120. The Rahad Dam would be a rolled earth and rock fill structure with a height of 70 meters above streambed. It would require 18, 800, 000 cubic meters of materials for the embankment. For bypassing and controlling the river during construction, a concrete-lined tunnel on the right abutment of the dam with a 15-meter-high cofferdam would be required for passing the anticipated flows. When no longer needed for diversion purposes, the tunnel would be plugged near the upstream end and utilized for an outlet works by interception of the tunnel by the intake structure. A general plan of the dam is indicated on Figure 121.

Dam Data

Type	earth and rock fill
Embankment volume (earth)	4, 600, 000 cu. m.
Embankment volume (sand and gravel)	6, 800, 000 cu. m.
Embankment volume (rock)	7, 400, 000 cu. m.
Top of dam (elevation)	883 m.
Freeboard	2. 55 m.
Structural height	70 m.
Hydraulic height	67. 45 m.
Length of crest	2, 220 m.
Width of crest	10 m.

A side-channel service spillway on the right abutment, designed to pass the maximum probable flood, would be provided. A chute type of channel would spill into a stilling basin.

Spillway Data

Type	uncontrolled side channel
Crest elevation	876. 37 m.
Peak inflow flood	5, 650 cu. m. per sec.
Total flood volume 4. 5-day volume	630, 000, 000 cu. m.
Maximum discharge capacity	1, 910 cu. m. per sec.

The outlet works would intercept the diversion tunnel after it has served its intended purpose. A gate chamber with an emergency slide gate and an outlet pipe branching into two smaller diameter pipes at the control house, equipped with two slide gates discharging into a stilling basin, would also be components of the outlet works.

Outlet Works Data

Sill elevation	843. 88 m.
Capacity at minimum w. s. elevation	46. 67 cu. m. per sec.
Type of gates (2)	slide gates
Size of outlet pipe (diameter)	2. 16 m.

The Rahad Reservoir basin is mantled by sandy clay alluvium soils and leakage is not expected to be a serious problem. Clearing of the open forest growth will be required. Capacity of the reservoir at initial stage would be 1, 902 million cubic meters. It would inundate at normal water surface 92 square kilometers of area.

The damsite is on massive, horizontal beds of basaltic rock with alluvium overburden and should easily accommodate the proposed earth and rock fill structure.

Impervious clayey soils and gravel are available in sufficient quantities within economical haul distances. Riprap and rockfill can be quarried within 1 kilometer of the damsite.

About 10 kilometers of access road is estimated to be required.

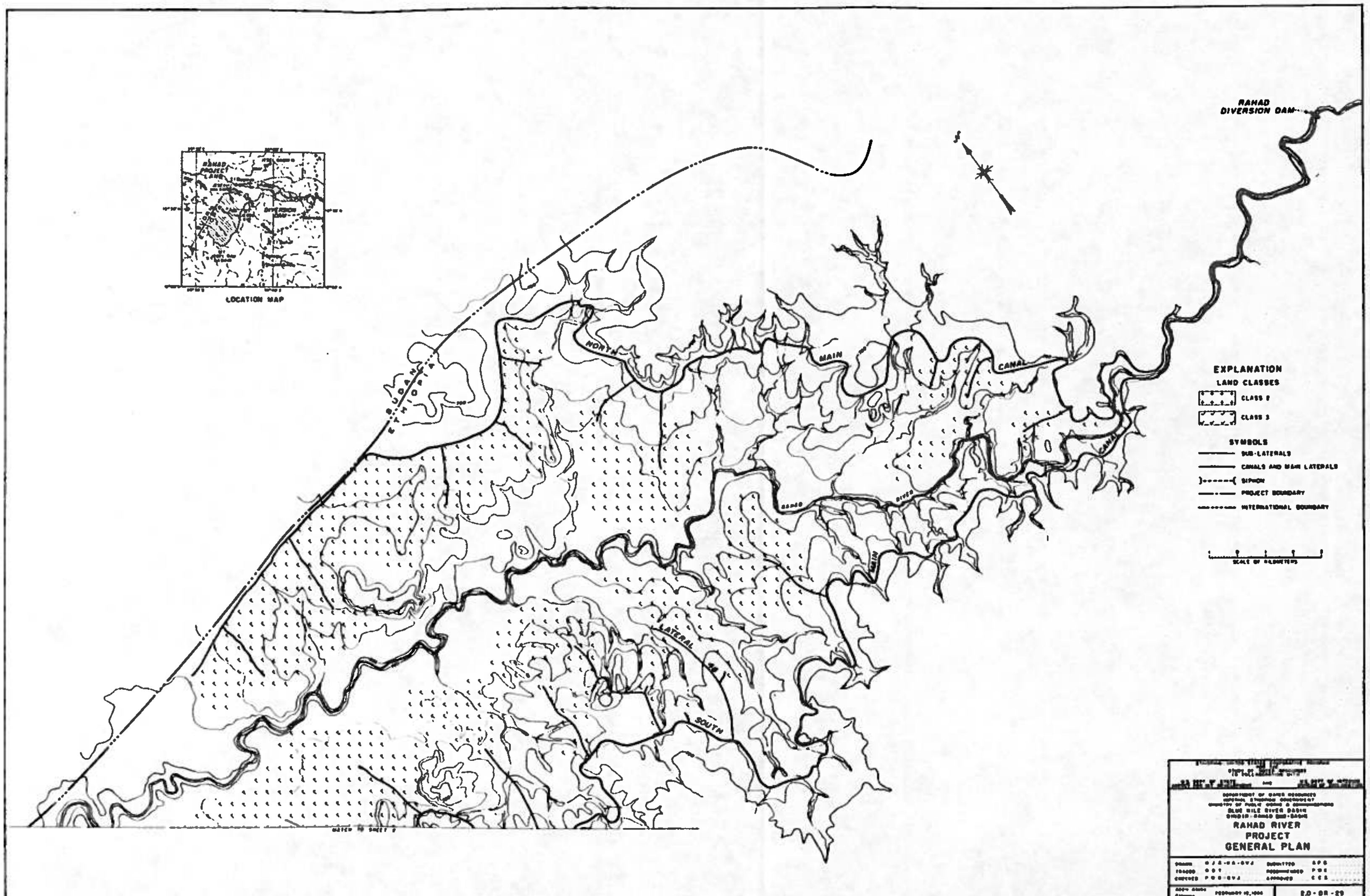


Figure 119--Rahad River Project--General Plan, Sheet 1

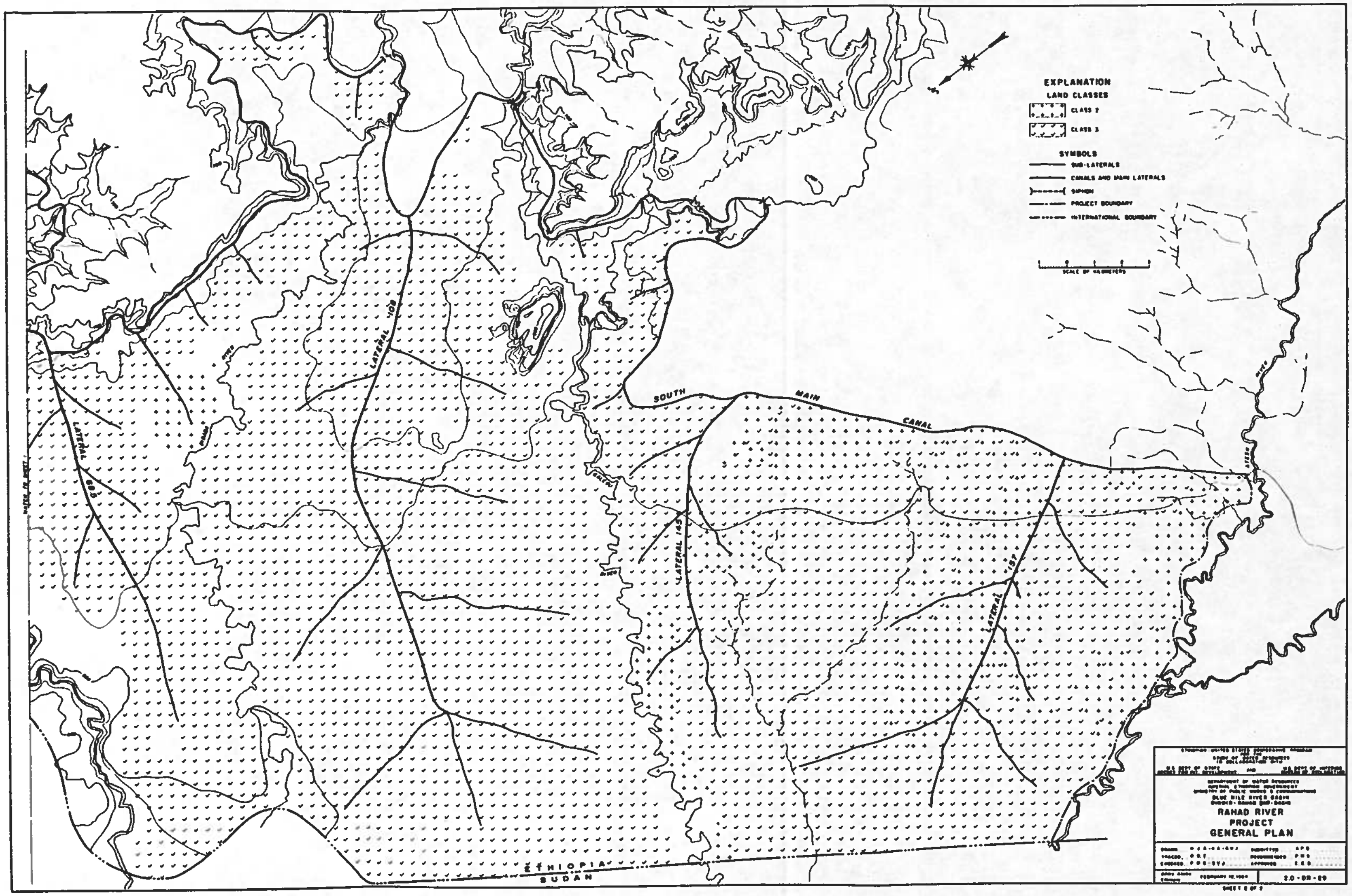


Figure 120--Rahad River Project--General Plan, Sheet 2

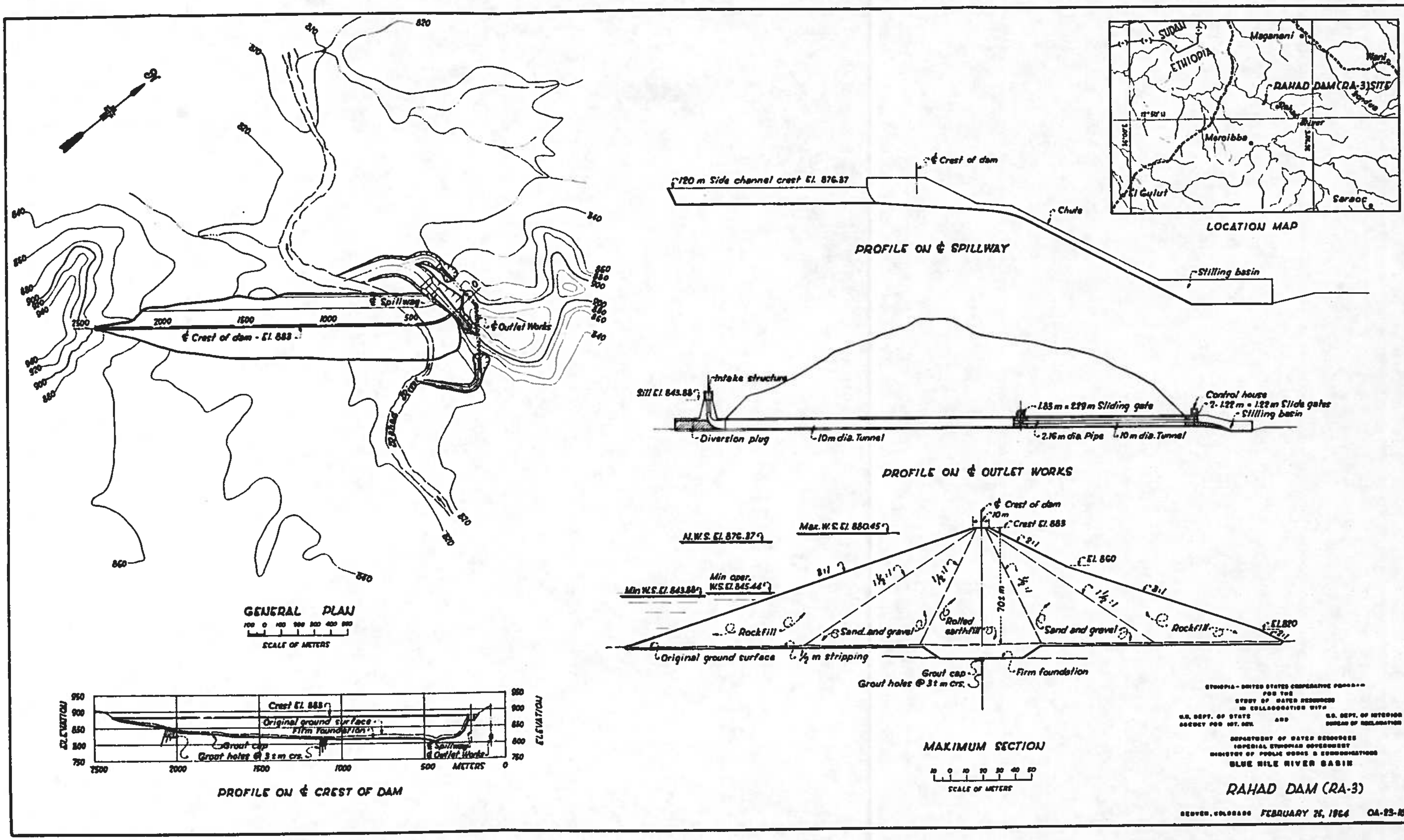


Figure 121--Rahad Dam (RA-3)--Plan and Sections

TABLE 47--SUMMARY OF CROPS AND GROSS FARM INCOME--RAHAD PROJECT, 53,100 HECTARES

Table 47

Crop pattern	Conditions before project		Future conditions, irrigation season				Future conditions, nonirrigation season				Post-project income Eth$	Gross crop income Eth$
	Price received per 100 kg. Eth$	Preproject income Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$	Crop distribution ha.	Yield kg./ha.	Production kg.	Value of production Eth$		
Corn	5.18		10,600	3,275	34,715,000	1,798,240	15,900	1,350	21,465,000	1,111,890	2,910,130	2,910,130
Millet	4.90		5,300	3,430	18,179,000	890,770	10,600	1,120	11,872,000	581,730	1,472,500	1,472,500
Sorghum	8.70		10,600	3,430	36,358,000	3,163,150	5,300	1,350	7,155,000	622,480	3,785,630	3,785,630
Castor beans	21.62		5,300	1,725	9,142,500	1,976,610	-	-	-	-	1,976,610	1,976,610
Sesame	30.25		2,650	1,370	3,630,500	1,098,230	5,300	825	4,372,500	1,322,680	2,420,910	2,420,910
Sunflower	20.60		2,650	2,070	5,485,500	1,130,010	-	-	-	-	1,130,010	1,130,010
Cotton	25.95		8,000	2,000	16,000,000	4,152,000	-	-	-	-	4,152,000	4,152,000
Peppers	50.93		2,650	1,060	2,809,000	1,430,620	2,650	760	2,014,000	1,025,730	2,456,350	2,456,350
Tobacco	109.60		2,650	2,300	6,095,000	6,680,120	-	-	-	-	6,680,120	6,680,120
Subtotal, crops			50,400			22,319,750	39,750			4,664,510	26,984,260	26,984,260
Fallow			-			-	10,650			-	-	-
Subtotal, cultivated area			50,400			22,319,750	50,400			4,664,510	26,984,260	26,984,260
Noncultivated irrigable area			2,700			-	2,700			-	-	-
Total area		-	53,100			22,319,750	53,100			4,664,510	26,984,260	26,984,260
Income per hectare		-				420.34				87.84	508.18	508.18

The Rahad Diversion Dam, a river regulating and canal headwork structure, would be about 8 kilometers downstream from the storage dam. It would be constructed with masonry and concrete materials.

Diversion Dam Data

Type	masonry concrete with stoplogs
Volume of masonry and concrete	8, 874 cu. m.
Structural height	8 m.
Weir length	148 m.
Checked w. s. elevation	696 m.
Type of gates (canal headworks)	radial

The North Main Canal would originate at the headworks located on the right abutment of the Rahad Diversion Dam and would extend in a northwesterly direction for 66 kilometers.

North Main Canal Data

Type	unlined
Length	66 km.
Initial capacity	5. 6 cu. m. per sec.
Initial w. s. elevation	695 m.

Originating on the left abutment of the Rahad Diversion Dam, the South Main Canal would extend in a southwesterly direction for 205 kilometers for irrigation of 48, 380 hectares of land.

South Main Canal Data

Type	unlined
Length	205 km.
Initial capacity	56. 3 cu. m. per sec.
Initial w. s. elevation	695 m.

Estimated Project Cost

Construction cost.

Feature	Cost
Rahad Dam and Reservoir	Eth$151, 831, 000
Rahad Diversion Dam	1, 535, 000
North Main Canal	4, 279, 000
South Main Canal	43, 468, 000
Distribution system	24, 891, 000
Drainage canals	11, 616, 000
Access roads	750, 000
Service facilities	4, 760, 000
Total construction cost	Eth$243, 130, 000

Development cost. Conditions are similar to the Dindir Project. Clearing and land leveling construction costs are estimated to be Eth$15, 665, 000.

Operation and maintenance cost. Annual operation and maintenance cost for the two major features (no replacement being required within the analysis period) are as follows: Rahad Dam and Reservoir, Eth$50, 000, and Conveyance System, Eth$1, 700, 000.

Benefit-Cost Ratio

The benefit-cost ratio for this project is 1. 55 to 1. 00.

Figure 122. Blue Nile River at the Karadobi damsite.

MAIN STREAM HYDROELECTRIC POWER PROJECTS

INTRODUCTION

The development of the main stream of the Blue Nile would be limited to hydroelectric power production. The deeply entrenched river, falling some 1,300 meters in 900 kilometers (Figure 123), makes it economically infeasible for large scale irrigation development or exportation of water to other areas. However, because of the fall and large volume of water, the hydroelectric power potential is very great. Incidental to the power that can be produced in Ethiopia, the downstream countries of Sudan and Egypt may receive large benefits from regulation of the flood waters and silt retention if the proposed dams are constructed.

Four dams and reservoirs on the main stream are proposed. The reservoirs will impound a total of 77,800 million cubic meters, or the equivalent average annual runoff of over 1-1/2 years without upstream depletion. Installed capacity of the four powerplants would be 5,570,000 kilowatts.

Karadobi Dam And Powerplant

The primary purpose of the Karadobi Dam and Powerplant would be to store the flood waters of the Blue Nile River for hydroelectric power generation. Secondary benefits would be the retention of the heavy silt load coming from a drainage area of about 60,300 square kilometers. Regulation would be provided by impoundment of the floodflows that occur during the June through September period; and estimated annual sediment load of 163 million metric tons would be retained. The reservoir created by the river structure would have sufficient capacity to nearly store 2 years average annual runoff at the Karadobi site.

Karadobi Dam would be located on the Blue Nile River a short distance upstream from its confluence with the Guder River and about 135 airline kilometers northwest of Addis Ababa, the capital city of Ethiopia. It would be by far the highest and largest dam envisioned in the development plan for the entire Blue Nile River Basin. By constructing Karadobi Dam, the floodwaters of the Blue Nile River are stored and released as required for the generation of an estimated 5,845 million kilowatt-hours of firm energy.

Project Features

The Karadobi Dam would be a double-curvature, variable-center, concrete thin-arch dam. It would require 5,270,000 cubic meters of concrete. For bypassing and controlling the river during construction, four concrete-lined tunnels would be constructed, two on each side of the river. Two coffer dams, bracketing the proposed site, would also be required for diversion into the tunnels and dewatering of the site. When no longer needed for diversion purposes, the tunnels would be plugged near the midpoint of the dam and the downstream section utilized for outlet works for the powerplant. General plan of the dam is shown on Figure 124, and elevations and section on Figure 125.

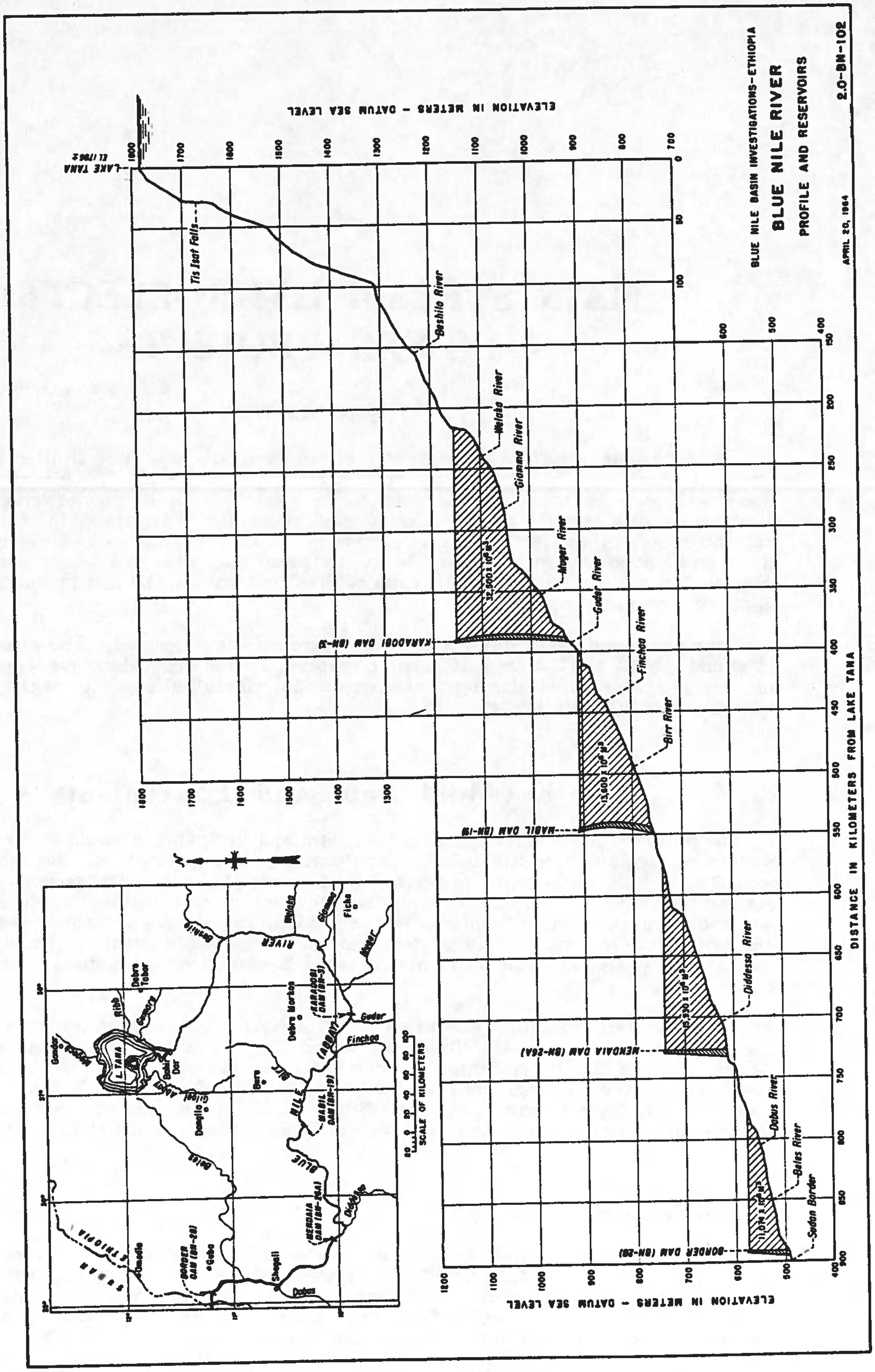


Figure 123--Blue Nile River--Profile and Reservoirs

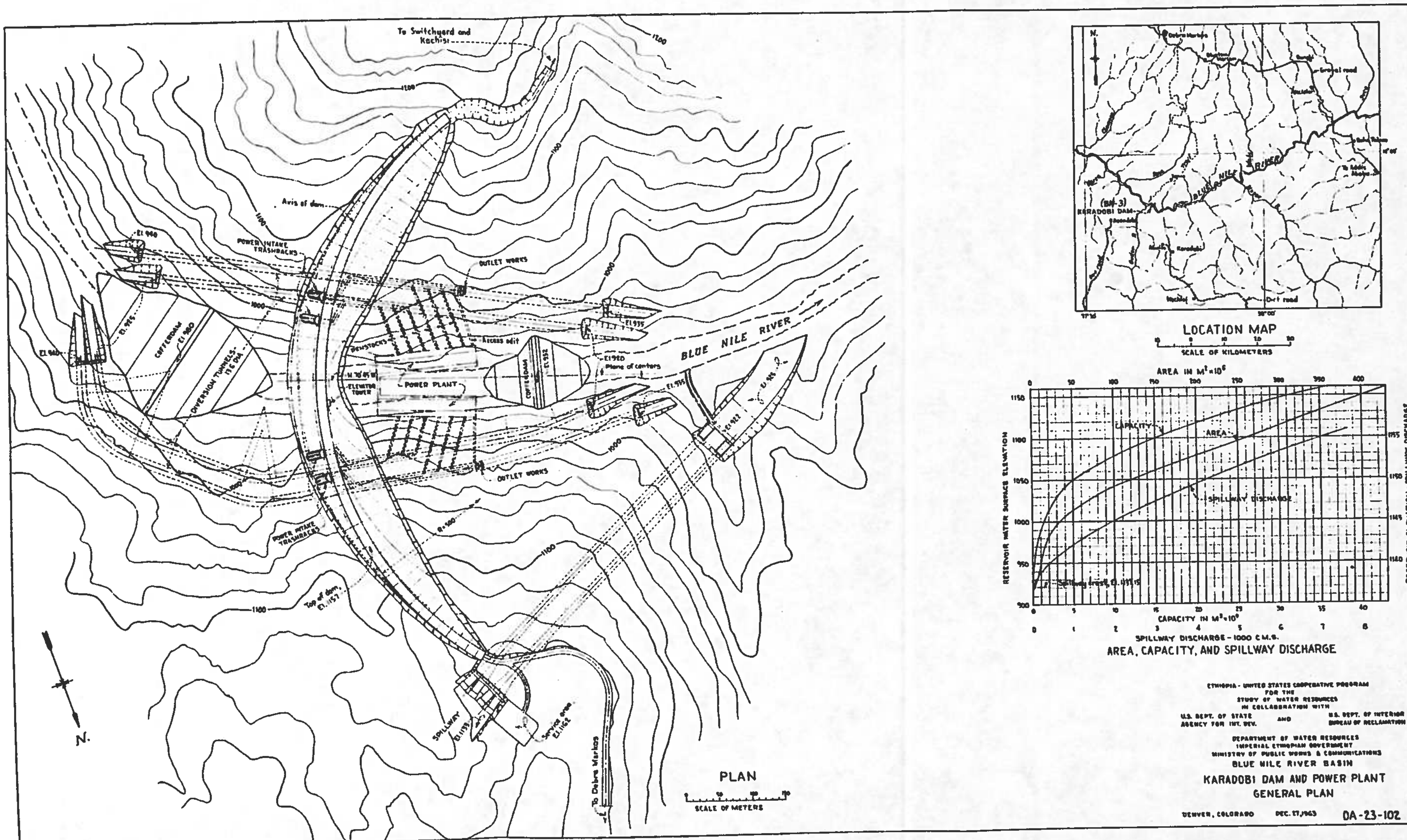


Figure 124--Karadobi Dam and Powerplant--General Plan

Karadobi Dam Data

Type	concrete thin-arch
Mass concrete (volume)	5, 270, 000 cu. m.
Top of dam (elevation)	1157 m.
Structural height	252 m.
Hydraulic height	251 m.
Base width at plane of centers	61 m.
Crest length	980 m.
Top width	15 m.

Design of the spillway was based on a peak inflow of 16, 400 cubic meters per second and a volume of 6, 750 million cubic meters in a 13-day period. It was determined that four drum gate-controlled spillway openings discharging into two concrete-lined tunnels would be required. The river outlet works is expected to pass 850 cubic meters per second of the total designed outflow of 8, 500 cubic meters per second; a superstorage of 1, 287 million cubic meters would be provided in the reservoir. The two concrete tunnels would be located on the right abutment of the dam, alined in respect to the river channel so that the discharges from the spillway would sweep the channel, minimizing the tailwater at the powerplant. The crest of the spillway is surmounted by three piers that divide it into four sections, each of which is equipped with an electrically operated radial gate.

Spillway Data

Type	gated tunnels
Crest elevation	1137.15 m.
Capacity of both spillway at maximum w. s. elevation	7650 cu. m. per sec.
Inflow design flood--13-day period	6, 750, 000, 000 cu. m.
Type of gates (4)	radial

Four penstocks, each equipped with a fixed-wheel gate for emergency purposes, would deliver water through the dam and a portion of the diversion tunnels, each branching into three penstocks leading to the powerplant sections on each side of the river. Each of the 12 power penstocks would be equipped with a butterfly valve. The two outer and upper conduits or tunnels would be combination power and river outlet works.

Except for some outcrop of Precambrian rock about 15 kilometers upstream from the selected site and in the vicinity of the dam, the Karadobi Reservoir area is almost entirely Adigrat sandstone where rapid erosion has formed a wide valley, making an excellent basin for storage of water. Clearing requirements will be minimal, as the reservoir area has only a scattering of small trees and scrub bushes. Relocation of existing structures will be limited to the Blue Nile bridge. It is proposed to use the road on top of the dam for crossing the river. Total capacity of the reservoir to elevation 1153 with 50 years of sediment deposition would be 26, 482 million cubic meters. The reservoir at this elevation would cover approximately 407 square kilometers.

The damsite is in Precambrian rocks of granitic and hornblende gneiss composition. The bedrock material is very hard, jointed hornblende gneiss. The gradient of the river is steep in this area, and the channel is scoured clean of alluvium. However, the rock has a variable jointed structure of semicircular pattern that should be carefully analyzed in any future detail investigations. Although the bedrock is exposed throughout the damsite area, it is anticipated that the blocky and open-jointed material will need to be removed to sound rock.

Numerous large gravel deposits, believed suitable for concrete aggregate material, were located in the proposed reservoir basin within a haul distance of 6 kilometers upstream from the damsite. It is roughly estimated that the deposits will yield about 9 million cubic meters. It is anticipated that there will be a shortage of sand, probably requiring crushing of the small-sized aggregates. The bedrock material near the damsite area would be suitable for riprap and masonry construction.

There are no roads into the vicinity of the damsite, and construction of an access road will be necessary. It is also proposed to utilize the construction roads for rerouting the present Debre Markos-Addis Ababa highway consequent upon the inundation of the Blue Nile bridge. Estimates of cost include the construction of some 55 kilometers of two-lane gravel road.

The Karadobi Powerplant would be located at the toe of the dam, extending downstream along each canyon wall. The ultimate installation includes 12 generator units of 112,500-kw. each, for a total plant capacity of 1,350,000 kilowatts.

Powerplant Data

Design head	181.4 m.
Number of generators	12
Rating of each generator	112,500 kw.
Total plant capacity	1,350,000 kw.
Turbine rating	158,800 hp.
Synchronous speed	200 r.p.m.
Type of turbines	Francis

The switchyard would be located on the south side of the river, on the assumption that the principal load center would be Addis Ababa and surrounding towns. Estimates of construction cost for these facilities reflect the magnitude rather than any close approximation to expected conditions due to the uncertainty as to where the energy will be utilized.

The cost of Eth$18,125,000 for the service facilities was estimated from curves based on Bureau of Reclamation practices and standards. As a comparison, the estimated cost for this item for the Glen Canyon Unit of the Upper Colorado Storage projects exceeds Eth$20,000,000. The amount estimated for the Karadobi Project appears to be reasonable in this respect.

Estimated Project Costs

Construction Cost.

Feature	Cost
Karadobi Dam and Reservoir	Eth$ 729,236,000
Karadobi Powerplant	125,000,000
Transmission lines, switchyards, and substation	174,750,000
Access roads	3,516,000
Service facilities	18,125,000
Total construction cost	Eth$1,050,627,000

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$15,897,000, including Eth$1,514,000 for taxes and insurance, as summarized below:

Facility	Operation and maintenance	Replacements
Dam and reservoir	Eth$ 400,000	-
Penstocks	15,600	-
Powerplant	6,210,000	Eth$ 372,400
Transmission plant	6,555,000	830,000
Other	1,514,000	-
Totals	Eth$14,694,600	Eth$1,202,400

Benefit-Cost Ratio

The benefit-cost ratio for this project is 3.16 to 1.00.

Mabil Dam And Powerplant

Mabil Dam would be constructed for the purpose of hydroelectric power production. It would be located about 25 kilometers downstream from the Birr-Blue Nile junction and about 145 kilometers downstream from Karadobi Dam.

The structure would be a double-curvature, variable-center, concrete thin-arch dam. Diversion during construction would be accomplished by four tunnels having a total length of 2,735 meters, two on each bank of the river. When no longer needed for diversion purposes, three of the tunnels would be plugged and the fourth tunnel on the left side nearest the canyon wall would be utilized for the main spillway. General plan of the dam is shown on Figure 126 and the elevation and sections on Figure 127.

Dam Data

Type	concrete thin arch
Mass concrete	3,207,000 cu. m.
Top of dam (elevation)	911 m.
Structural height	171 m.
Hydraulic height	170.6 m.
Base width at plane of centers	53 m.
Crest length	856 m.
Top width	10 m.

Two spillways--a main and an emergency--would be utilized for evacuation of the maximum probable flood flows. Spillway requirements were based on a peak inflow of 19,000 cubic meters per second and a 14-day volume of 9,200 million cubic meters. The main spillway would discharge into an inclined tunnel leading to the diversion tunnel. Control of the spill would be provided by two radial gates.

An emergency spillway to the right of the dam would also be constructed. It would be gated identically with the main spillway but would have twice the capacity, with four radial gates, and would discharge into two inclined tunnels. An additional 700 cubic meters per second would be passed by the river outlets and powerplant, for a combined flood evacuation of nearly 14,000 cubic meters per second.

Spillway Data

Type	gated tunnels
Total capacity	12,960 cu. m. per sec.
Inflow design flood--14-day period	9,200,000,000 cu. m.
Type of gates (6)	radial gates

Twelve power outlet works would extend through the dam to supply water to the powerplant located at the downstream toe of the dam. Each outlet works would consist of a trashrack structure with fixed-wheel gates and a 4.80-meter inclined steel penstock. In addition, four river outlet works for emergency and other purposes, located to the right of the power outlet works, would be constructed, each equipped with hollow-jet valves.

The reservoir basin would lie in Precambrian basement rocks and seepage losses are expected to be a minimum. The area is devoid of trees, and only light debris clearing will be required. The reservoir at normal water surface elevation will hold 13,600 million cubic meters (11 million acre-feet) and would cover an area of 244 square kilometers.

The proposed damsite is in Precambrian granitic rock and is considered to be geologically suitable for the proposed concrete structure.

It is believed that some rock crushing will be required to supplement natural aggregate sources. The availability of construction materials will have to be thoroughly explored during preconstruction investigations.

An access road of about 60 kilometers will be required to be constructed through rather rugged terrain. It has been estimated that it will cost in the neighborhood of Eth$3, 000, 000.

The Mabil Powerplant with a total installed capacity of 1, 200, 000 kilowatts would produce 5, 314, 000, 000 kilowatt-hours annually.

Powerplant Data

Design head	113.6 m.
Number of generators	12
Rating of each generator	100, 000 kw.
Total plant capacity	1, 200, 000 kw.
Turbine rating	141, 100 hp.
Synchronous speed	142 r.p.m.
Type of turbines	Francis

Costs for switchyards, transmission lines and substations, because of uncertainty as to load centers, reflect a rough approximation of cost for the purpose of determination of the overall cost of the project.

Estimated Project Cost

Construction Cost.

Feature	Cost
Mabil Dam and Reservoir	Eth$547, 985, 000
Mabil Powerplant	143, 750, 000
Transmission facilities	141, 588, 000
Access road	2, 891, 000
Service facilities	14, 865, 000
Total construction cost	Eth$851, 079, 000

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$13, 516, 000, including Eth$1, 250, 000 for taxes and insurance, as summarized below:

Facility	Operation and maintenance	Replacements
Dam and reservoir	Eth$ 300, 000	-
Penstocks	16, 000	-
Powerplant	5, 520, 000	Eth$ 429, 000
Transmission plant	5, 164, 000	838, 000
Other	1, 250, 000	-
Totals	Eth$12, 250, 000	Eth$1, 266, 000

Benefit-Cost Ratio

The benefit-cost ratio for this project is 3.65 to 1.00.

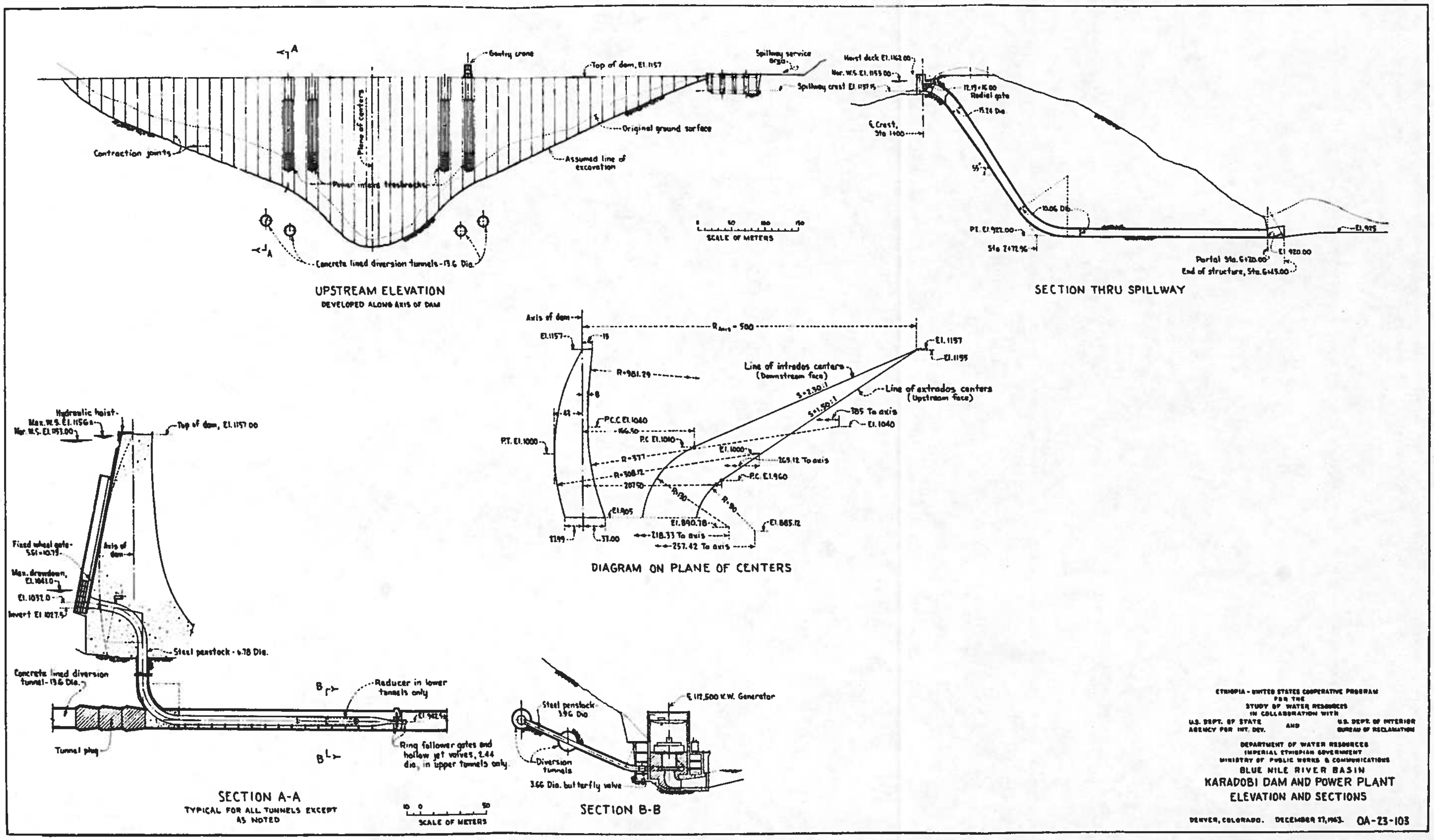


Figure 125--Karadobi Dam and Powerplant--Elevation and Sections

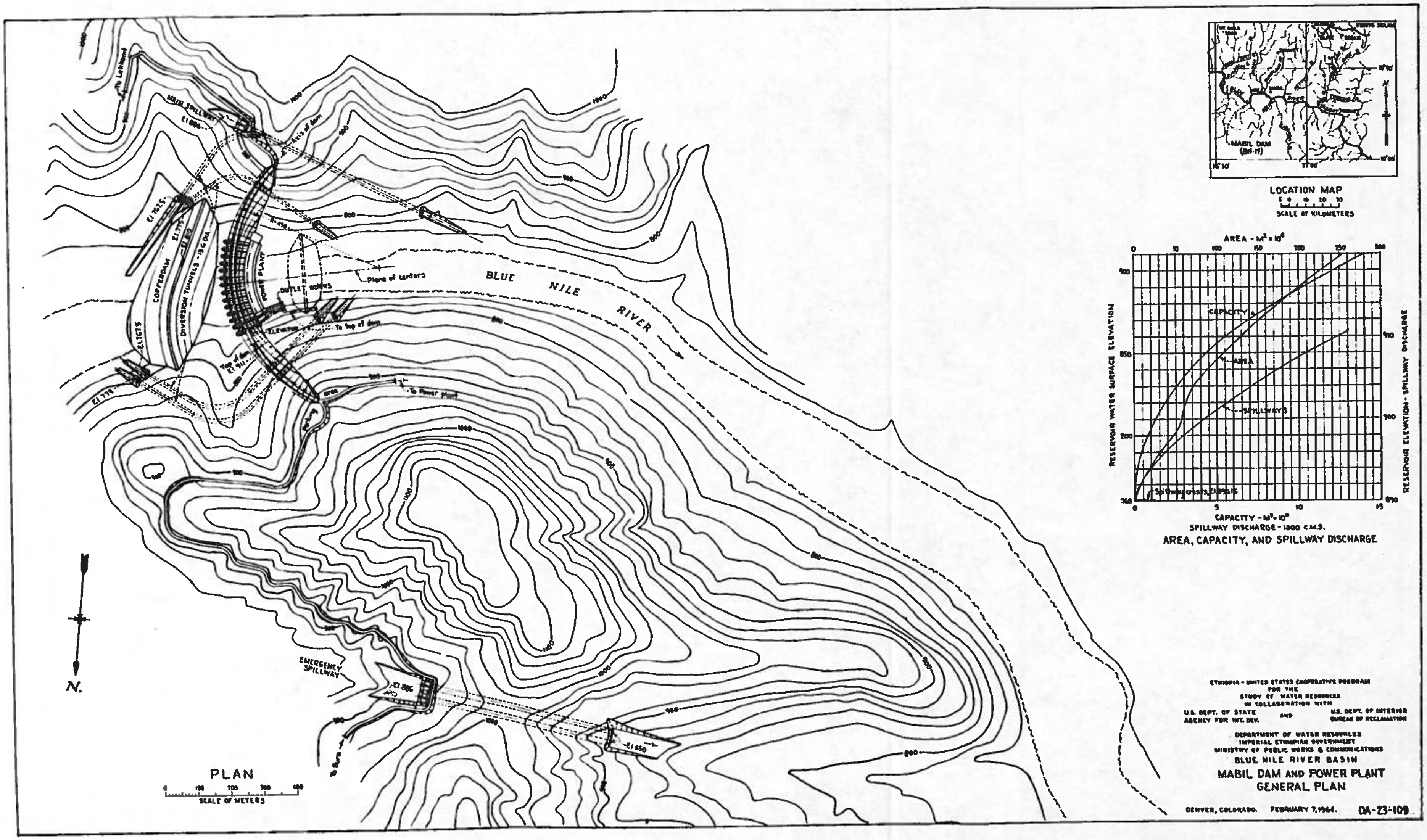


Figure 126--Mabil Dam and Powerplant--General Plan

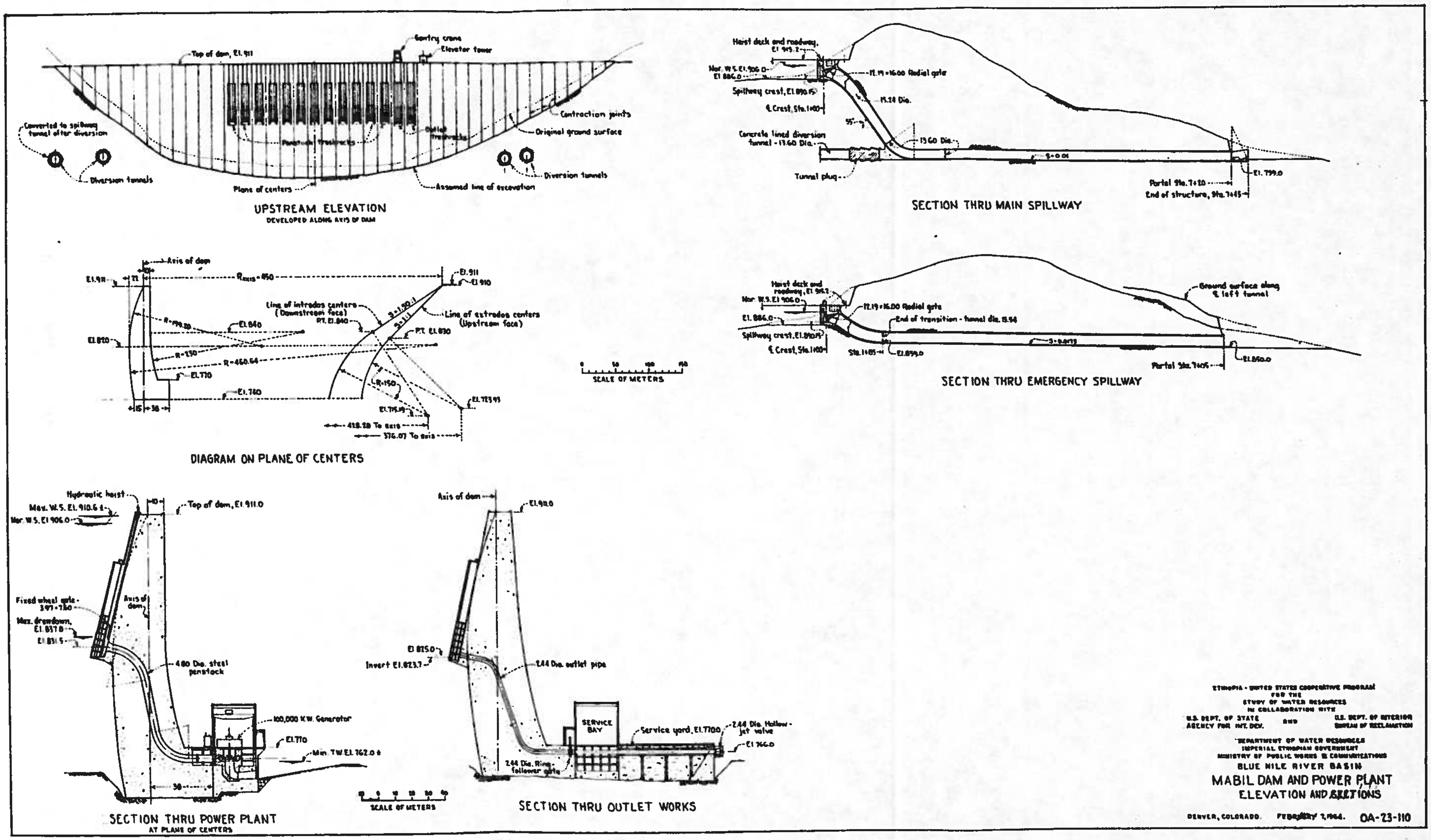


Figure 127--Mabil Dam and Powerplant--Elevation and Sections

Mendaia Dam And Powerplant

The plan of development would be the production of hydroelectric power. The dam would be located on the Blue Nile River about 20 kilometers downstream from its junction with the Diddessa River and about 175 kilometers upstream from the international border.

Project Features

The Mendaia Dam would be a concrete thick-arch structure. During the construction period, the river flow would be diverted by means of three concrete-lined tunnels around the left bank. The tunnels would be plugged after serving their intended purpose. The angle in relation to the river channel and the high flows preclude the use of these tunnels for other purposes. General plan and sections of the dam appear on Figure 128.

Dam Data

Type	concrete thick arch
Mass concrete	3, 630, 000 cu. m.
Top of dam (elevation)	744 m.
Structural height	164 m.
Hydraulic height	163.6 m.
Crest length	1, 134 m.

The main spillway would be a gated overflow in the middle of the dam, and an emergency spillway, consisting of two inclined tunnels controlled with four radial gates would be located on the right abutment. The main spillway is designed to pass 9, 433 cubic meters per second, the emergency spillway 7, 564, and the river outlets and powerplant an additional 850, for a total combined discharge capacity of 17, 847 cubic meters per second.

Spillway Data

	Main	Emergency
Type	gated overflow	gated tunnels
Total capacity (cu. m. per sec.)	9, 433	7, 564
Inflow design flood--16-day period (cu. m.)	13, 300, 000, 000	
Type of gates (10)	radial	

Twelve power outlet works would extend through the dam, each beginning at a trash-rack structure equipped with hydraulically operated fixed-wheel gates. The penstocks would be 5. 49 meters in diameter with a design capacity of 146 cubic meters per second. Four river outlets works below the overflow spillway would discharge when required through outlet pipes into the stilling basin. Each river outlet works would be controlled by tandem outlet gates.

Foundation rock materials at the reservoir site are of hornblende gneiss or diorite, determined to be suitable for the type of structure as planned. Visual examination of the site indicated that about 15 to 25 meters of overburden will be required to be removed before sound rock could be exposed.

No natural deposits of aggregates were noted in the immediate vicinity of the damsite; further surveys will be required to determine the availability of natural aggregates. Production of these materials by quarrying the abundant basaltic rock and crushing is an alternative possibility.

A total of about 40 kilometers of access road will be required, of which about half will be through mountainous terrain.

The Mendaia Powerplant, located on the right bank, will include 12 generating units of 135, 000 kilowatts producing an estimated 7, 800 million kilowatt-hours of firm energy annually.

Powerplant Data

Design head	117.4 m.
Number of generators	12
Rating of each generator	135,000 kw.
Total plant capacity	1,620,000 kw.
Turbine rating (each)	190,489 hp.
Synchronous speed	125 r.p.m.
Type of turbines	Francis

Transmission facilities are similar to the Karadobi and Mabil Powerplants.

Estimated Project Cost

Construction Cost.

Feature	Cost
Mendaia Dam and Reservoir	Eth$ 603,675,000
Mendaia Powerplant	187,500,000
Transmission facilities	191,186,000
Access road	4,688,000
Service facilities	16,780,000
Total	Eth$1,003,829,000

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$17,905,000, including Eth$1,474,000 for taxes and insurance, as summarized below:

Facility	Operation and maintenance	Replacements
Dam and reservoir	Eth$ 320,000	-
Penstocks	30,000	-
Powerplant	7,452,000	Eth$ 559,000
Transmission plant	7,092,000	978,000
Other	1,474,000	
Totals	Eth$15,368,000	Eth$1,537,000

Benefit-Cost Ratio

The benefit-cost ratio for the project is 4.35 to 1.00.

Border Dam And Powerplant

This dam and powerplant would be about 21 kilometers upstream from the Sudan border. Its purpose would be for generation of electric energy.

Project Features

The Border Dam would be a concrete gravity type, 84.5 meters high and 1,200 meters long at the crest.

The plan of operation for diversion of the river during construction may be accomplished similar to that employed for the Bureau of Reclamation's Grand Coulee Dam of the Columbia Basin Project. Three cofferdams would be constructed and, for purposes of discussion, designated as the left, right, and river coffers. Up to the time of turning the river, work would progress inside the left and right coffers. Part of the concrete dam would be left down at some level to provide an opening for the passage of water while the river coffer would be in place. After the concrete in the left coffer has been brought up to above high water, the river would be diverted and the shore arms of the cofferdam removed. Similar procedures would be repeated for the right coffer. The river coffer would then be formed by building two coffer dams connected to the left and right coffers, above and below the proposed structure of the river channel.

A plan of the dam is shown on Figure 129.

Dam Data

Type	concrete gravity
Mass concrete	2,195,000 cu. m.
Top of dam (elevation)	577.5 m.
Structural height	84.5 m.
Hydraulic height	82.0 m.
Crest length	1,200 m.

The momentary peak inflow would reach 23,900 cubic meters per second (843,670 cu. ft. per sec.), with a 17-day volume of 15,400 million cubic meters (nearly 12.5 million acre-feet). One main overflow and two emergency spillways, one on each abutment, are planned to evacuate the flood flows. The combined flood discharge of the three spillways would be 16,500 cubic meters per second. An additional 2,000 cubic meters per second could be passed by the river and power outlet works.

Spillway Data

	Main	Emergency (each)
Type	overflow	chute
Crest elevation--m.	564.47	554.5
Maximum discharge capacity--cu. m. per sec.	9,200	3,650
Type of gates	radial	radial
Number of gates	6	2

Fourteen power outlet works, each beginning at a trashrack structure with a fixed-wheel gate, would convey the water through inclined penstocks to the powerplant located at the downstream toe of the dam. Six river outlet works in pairs below the main overflow spillway, each pair having a common intake structure and controlled by a tandem outlet gate, would discharge into the stilling basin.

Outlet Works Data

Data	Power (14)	River (6)
Sill elevation--m,	550.02	552.78
Capacity--cu. m. per sec.		
At design head (total)	2378	
At minimum w.s. elevation (total)		123

The Border Reservoir basin is underlain by Precambrian rock mantled with clayey soil deposits, and leakage should not be a serious problem. Some clearing will be required. The capacity of the reservoir at normal water surface elevation would be 11,074 million cubic meters and it would inundate approximately 500 square kilometers.

The geologic conditions being similar to those of the upstream sites, the proposed type of structure is considered to be feasible. Like Mendaia Dam upstream, aggregates can be quarried from rock available in abundant quantities in the immediate vicinity.

Over Eth$1,000,000 is included in the estimates of cost for a 30-kilometer, two-lane gravel road from Guba.

The Border Powerplant would be located at the downstream toe of the dam and will include 14 generating units of 100,000-kilowatt capacity producing an estimated 6,200 million kilowatt-hours of firm energy annually.

Powerplant Data

Design head	75 m.
Number of generators	14
Rating of each generator	100,000 kw.
Total plant capacity	1,400,000 kw.
Turbine rating (each)	141,100 hp.
Synchronous speed	103.5 r.p.m.
Type of turbines	Francis

Estimated Project Costs

Construction Cost.

Feature	Cost
Border Dam and Reservoir	Eth$378,293,000
Border Powerplant	200,000,000
Transmission facilities	346,646,000
Access roads	1,266,000
Service facilities	16,600,000
Total	Eth$942,805,000

Operation, Maintenance, and Replacement Cost. Annual operation, maintenance, and replacement costs are estimated to be Eth$17,249,000, including Eth$1,387,000 for taxes and insurance, as summarized below.

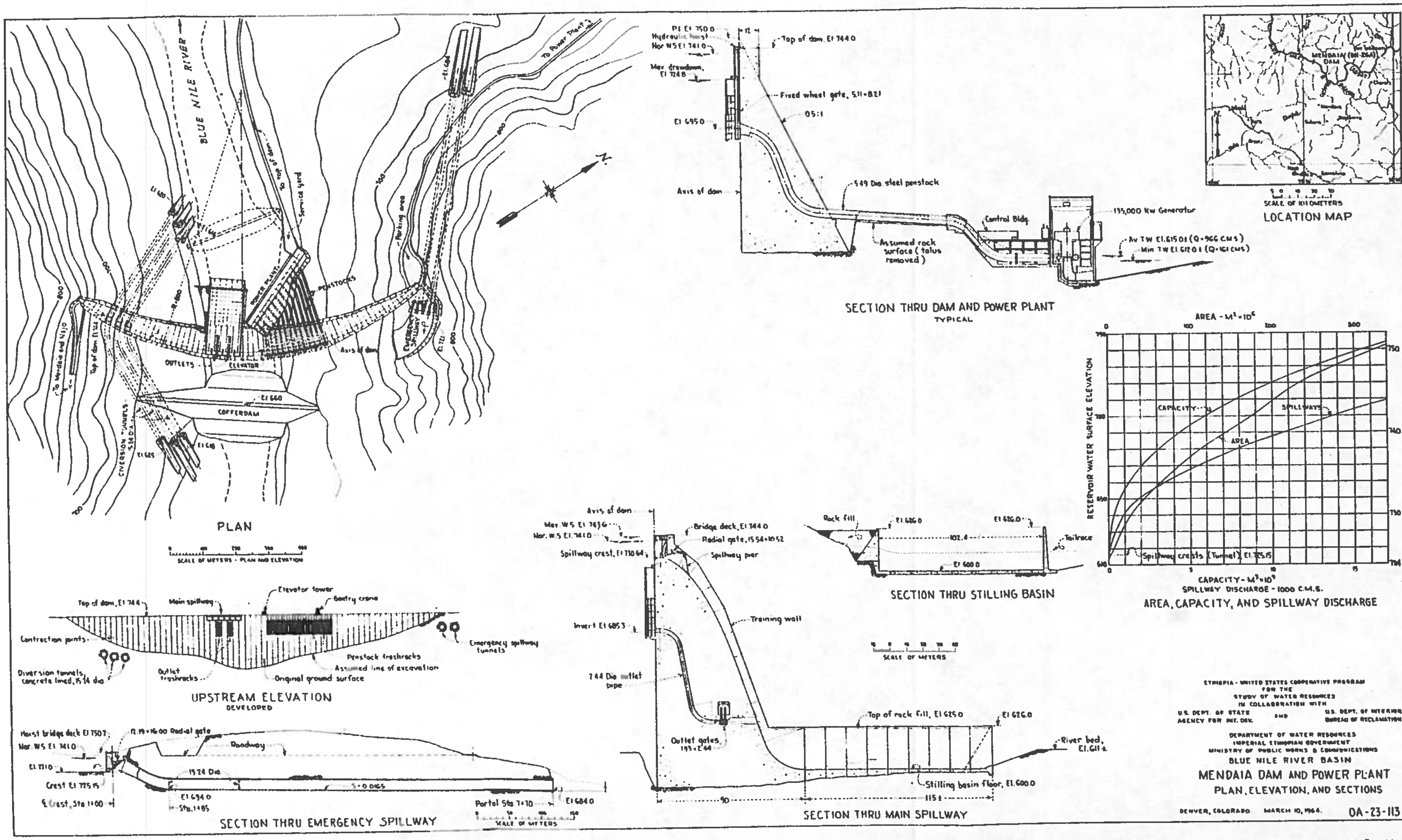


Figure 128--Mendaia Dam and Powerplant--Plan, Elevation, and Sections

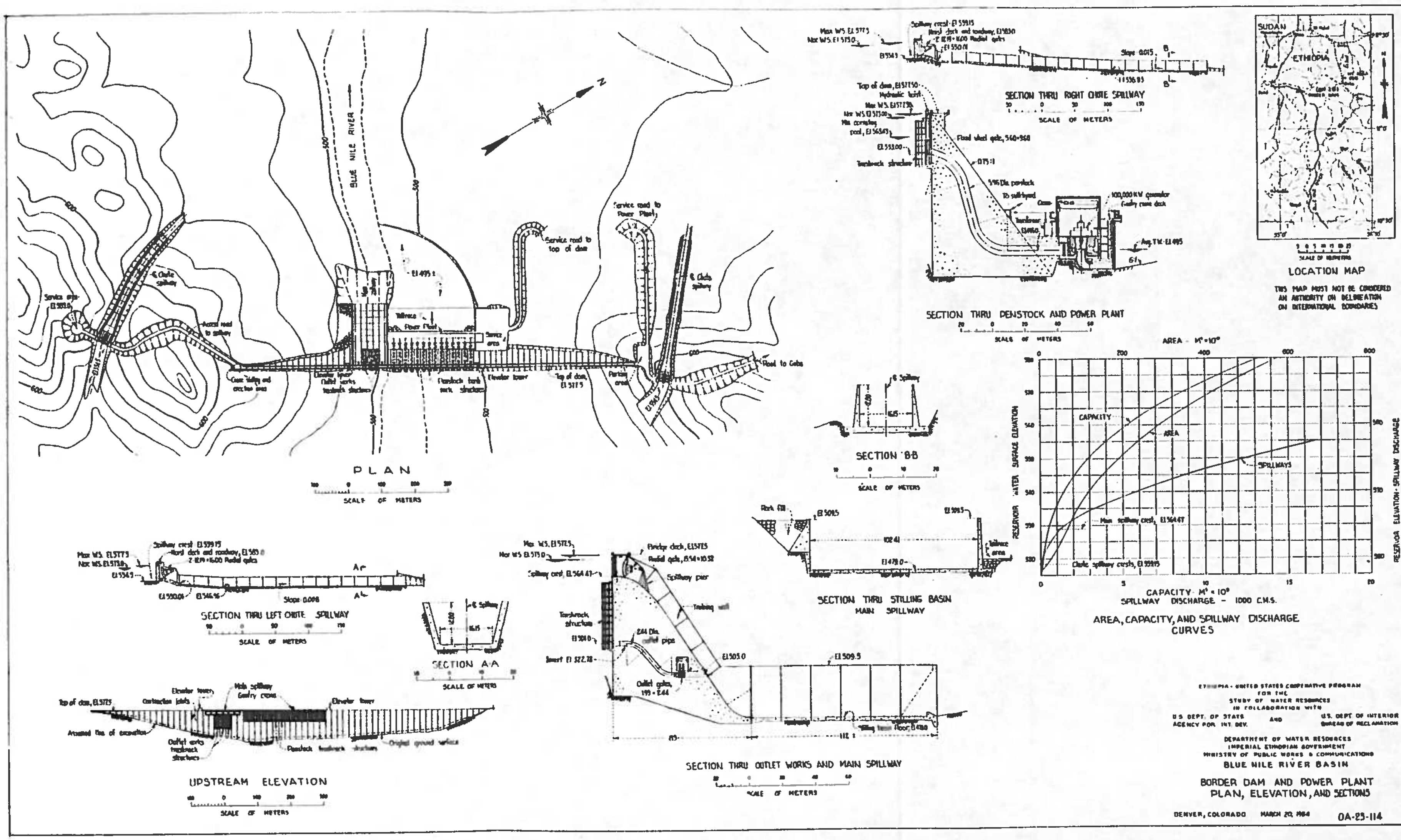


Figure 129--Border Dam and Powerplant--Plan, Elevation, and Sections

Facility	Operation and maintenance	Replacements
Dam and reservoir	Eth$ 280,000	-
Penstocks	25,000	-
Powerplant	6,440,000	Eth$ 596,000
Transmission plant	7,594,000	927,000
Other	1,387,000	-
Totals	Eth$15,726,000	Eth$1,523,000

Benefit-Cost Ratio

The benefit-cost ratio for the project is 3.74 to 1.00.

Addis Ababa-Assab Transmission Project

The enormous amount of electric energy produced even without the main stem powerplants cannot be effectively utilized within the Blue Nile River Basin and will be available for exportation to other parts of the Empire, perhaps even to other surrounding countries.

It appears that the Dessie-Assab area to the east of the Blue Nile River Basin would be a likely market for electrical energy in view of its recent rapid growth and strategic importance.

Transmission facilities to Dessie, consisting of about 290 kilometers of 230-kv., double-circuited transmission lines on steel towers and a 385-kilometer, 230-kv., single-circuited line to Assab, have been included in the initial network distribution system. Since it is not particularly identified with any specific power project, no generation facilities are included in the estimates of cost. Sources of electric power and energy for these facilities can originate at the various interconnected Blue Nile power sources, with the connection made at the East Substation on the outskirts of the capital city of Addis Ababa. Summary of the cost of Eth$84,891,000 follows:

Estimated Construction Cost--Transmission Lines

From	To	Length (km.)	Voltage (kv.)	Circuit (No.)	Estimated cost
East Substation	Kembolcha	290	230	double	Eth$26,676,000
Kembolcha	Dessie	13	132	single	655,000
East Substation	Gafarsa	5	132	single	96,000
Kembolcha	Assab	385	230	single	35,176,000
East Substation	Debre Birhan	110	45	single	1,135,000
Debre Birhan	Debre Sina	35	45	single	399,000
Total estimated cost					Eth$64,137,000

Equipment and facilities required at the various substations are estimated as follows:

Substation	Estimated cost
East	Eth$ 4,350,000
Kembolcha	5,260,000
Dessie	2,781,000
Assab	7,638,000
Debre Birhan	186,000
Debre Sina	119,000
Warehouse and service vehicles	420,000
Total estimated cost	Eth$20,754,000

OTHER IDENTIFIED PROJECTS

INTRODUCTION

The areas under discussion in this portion of the report concern only those projects for which only brief studies were performed and which were not included in the initial plan of development. Obviously, in an area as large as the Blue Nile Basin there may be many areas susceptible to development. However, the vastness of the area, the rugged terrain, and the lack of roads, among other factors, prevented further detailed surveys. It follows that there may be some areas in the Blue Nile Basin not identified at this time as being potential projects that could be developed.

Unquestionably, there also are many small areas that could be developed for irrigation agriculture by direct diversion. It is thought that some of the irrigation projects discussed in detail could very well be started in this manner. It would provide a number of advantages.

In the following paragraphs, six land areas classified and located as shown in Figure 130 are briefly discussed.

AZENA-FETTAM AREA

The area is in the central portion of the Blue Nile River Basin in the Debre Markos Sub-basin immediately to the west of the Birr River area.

The area consists of two distinct drainage areas, the Fettam and the Azena, named after the principal rivers that drain their respective areas. The Azena Valley is about 8 kilometers wide at the northern extremity and extends southward for about 45 kilometers, tapering to a point where the Azena River enters a narrow 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 drainage basin. The upper portion of the Fettam drainage basin is similar to that of the Azena Basin, 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 to 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. Elevation of the area is about the same as the Birr River area or 1820 meters above sea level.

The major portion of the area is presently being dry farmed with several areas of small plots being irrigated by direct diversions from the streams. There are more lands irrigated here than in perhaps 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, dagussa, and other similar crops. The same general crops are produced under dry conditions. Heavy rain forest occupies the mountain slopes adjacent to the area investigated, especially to the north and the west. Many herds of cattle, sheep, and goats are being grazed on the uncultivated areas and in the upper valleys of the Fettam and Azena Valleys.

A good all-weather road (gravel) transects the area. It enters from the east central portion and leaves at the northern extremity. This is the main highway from Addis Ababa to Bahir Dar.

A reconnaissance land classification indicated that about 130,500 gross hectares would be suitable for agricultural development by irrigation. Geological deficiencies for a potential dam and storage reservoir were the primary factors for the unfavorable consideration for development of the area for irrigation purposes. A major portion of the land area in these two drainage basins is underlain by younger lava, which was erupted from a large number of small volcanoes located in the upstream portion of the watershed. Several of these volcanoes contain crater lakes. Of the several potential damsites considered, it was found that in the most desirable locations the foundations consisted of the younger, very porous and fractured basalts, making them unsuitable for storage sites. Very preliminary hydrological studies indicate that about 5,460 hectares could be irrigated by direct diversion with an additional 3,350 hectares receiving partial supply adequate for raising one crop.

Consideration should be given to the possibility of underground sources of water supply in future investigations. Noting the springs, the discontinuous flow of the streams, and the general nature of the rock types, it is possible that there may be a potential for ground-water development, especially in the area underlain by the porous younger lavas. However, a drilling program will be required to determine the depth of the porous rock and whether the ground water is flowing in a few definite channels rather than being retained as a broad ground-water basin.

By utilizing a 170-meter drop at the escarpment, Site FE-1, Figure 130, 250,000,000 kilowatt-hours may be generated from the Fettam River with a powerplant installation of 55,000 kilowatts. More power could be generated using an additional 500-meter fall in the next 6 kilometers downstream. The reservoir may yield 675 million cubic meters of water, provided that the total required storage of 1,575 million cubic meters is available.

WAMA RIVER AREA

The Wama River Valley lies approximately 40 kilometers southeast of Lekkemt and is about 15 kilometers wide and 40 kilometers long on both sides of the Wama River. The valley is characterized by flat bottom lands, undulating to rolling, and by higher lying hills which generally form the foothills of a large mountain to the north separating this area from the Angar River drainage basin. It is dissected by many tributary streams, some of the large ones being the Negeso, Gimata, Guiso, Lagatora, Mudalu, and Uorghesa.

At present the valley floor is uninhabited. This may be due to malaria or to a combination of malaria and the black soils prevalent in the bottom lands. In this area these soils are not generally used to produce crops under dry-farmed conditions, but only 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.

Lack of good storage sites above the lands, the scattered tracts, and the rough terrain, led to the determination that the area would not be economical to develop. Approximately 43,120 hectares are considered arable. Brief preliminary hydrological studies indicate that there would be sufficient water to irrigate most of the land if storage could be provided. However, six reservoirs would probably be required with a total capacity of about 1,068 million cubic meters to service approximately 40,000 hectares.

CHEYE RIVER AREA

The land under consideration is at the bottom of a precipitous canyon 85 kilometers northeast of Debre Markos in Gojjam Province. The Cheye River, a tributary of the Blue Nile River, lies approximately 1,000 meters below the level of the Debre Markos plateau. The valley proper is accessible only to foot traffic. Construction of a road from the plateau into the Cheye Valley would be difficult and expensive. An old trail passable only during dry weather by motor vehicles as far as Debre Werk, a village about 20 kilometers to the southwest on the plateau, constitutes the present road system.

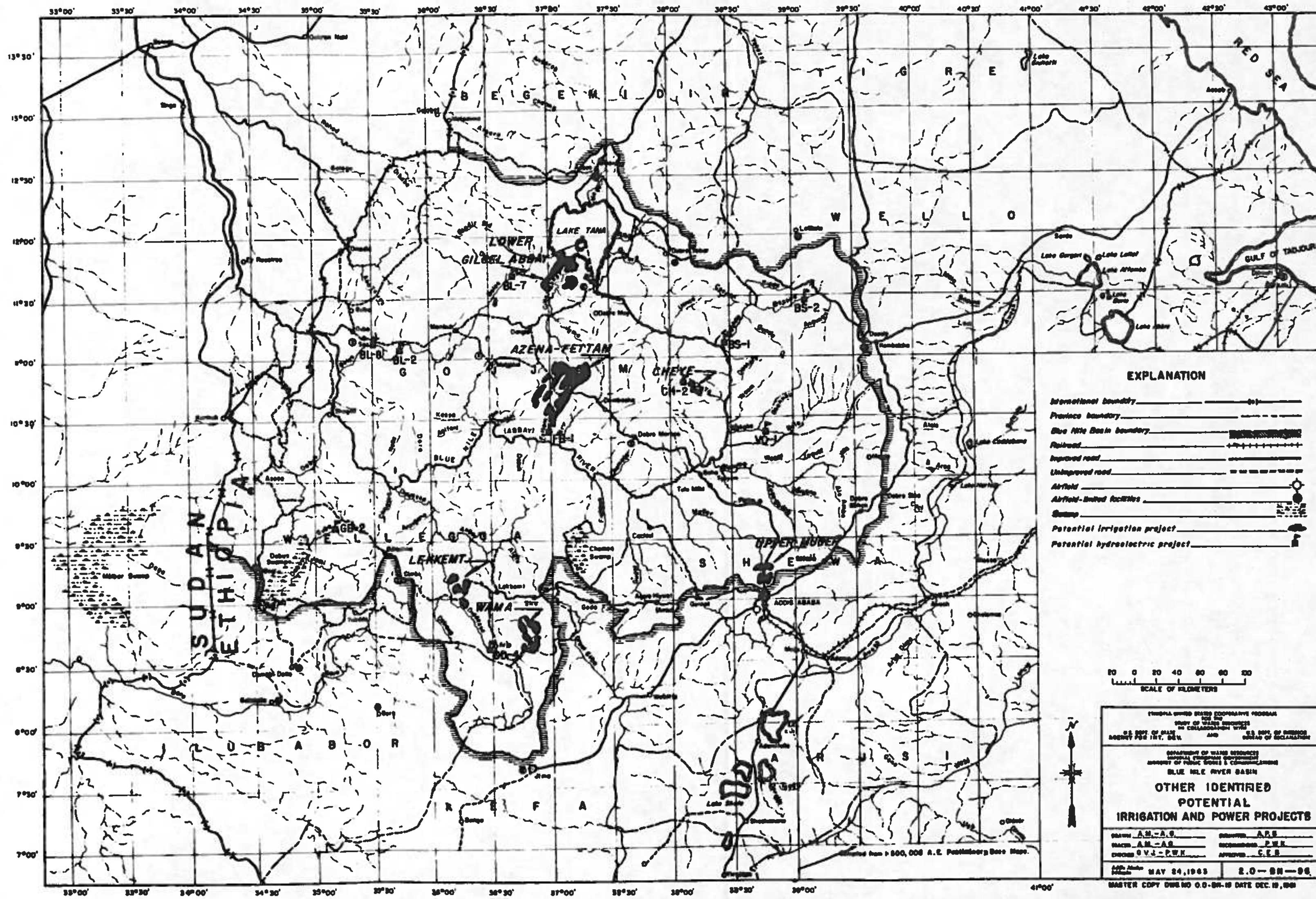


Figure 130--Other Identified Potential Irrigation and Power Projects

The valley has a small area of agricultural land formed from 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 small stream in a deeply eroded channel. The valley is under rather intense dry farming. A variety of grains are grown; such as teff, barley, sorghum, and corn. There are no people living in the valley, probably because of malaria. The farmers live on the plateau, descending into the valley each morning and returning to their homes in the evening.

The soils in the valley are entirely black grumusols, typical of those found throughout the Blue Nile Basin. Of the 4,000 hectares examined, it was found that some 3,400 hectares could be classed as arable land.

The problem here is the lack of good storage sites on the Cheye River to service the lands. From preliminary hydrologic studies, it is estimated that there is sufficient run-off to irrigate all the arable land if the flow were regulated. About 630 hectares could be fully supplied for irrigation by direct diversion and an equal amount partially served, with enough water for raising one crop.

Reservoir Site CH-1 would yield about 180 million cubic meters of water and produce about 200 million kilowatt-hours annually at Site CH-2, Figure 130. The installed power-plant capacity would be about 45,000 kilowatts, assuming that the reservoir site has a total storage capacity of about 480 million cubic meters.

UPPER MUGER AREA

The area 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 about 20 kilometers north of Addis Ababa. 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, dissected by numerous drainageways. Elevations range from 2500 to 2740 meters above sea level.

Present use consists of dry farming and livestock production. The principal crops raised are barley, wheat, noog, and horsebeans. Extensive areas of native grass support large herds of livestock. Some hay from the area is marketed in Addis Ababa.

Two major soil groups are found in the Upper Muger River area, the upland soils, developed in places from underlying basaltic lava, and soils of the lowlands, derived principally from alluvium washed from higher areas. The soils are suitable for irrigation production. A total of 8,740 hectares were considered arable. Like most of the Blue Nile Basin, the precipitation occurs during the June through September period with insufficient moisture for crops during the remaining dry months. Preliminary studies indicated that the area lacked good economical storage sites to provide water for the land determined to be suitable for irrigation.

A storage site that appeared the most promising was located near the falls on the Muger River and would inundate some of the arable lands. The decision was reached, in view of the hydroelectric power potential for possible use in Addis Ababa and surrounding territory, that the development favored power production rather than irrigation. It may be economically feasible to consider pumping in the future to irrigate small areas or the balance of the lands not inundated by the reservoir.

LEKKEMT AREA

The Lekkemt area is situated about 30 kilometers due west from the provincial capital of Lekkemt and about 17 kilometers from the Italian bridge where the Lekkemt-Gimbi road crosses the Diddessa River. The area investigated lies east of the Diddessa River, at about elevation 1100 meters above sea level.

Generally, the area is covered with a combination of open grass savanna and open forest with low trees of acacia, fig, and associated species. A scattering of cultivated subsistence farm plots presently exist, especially near the road. One plantation lies astride the Gimbi-Lekkemt road. The area is now served by a very rough road, passable only in dry weather. The general relief of the area tends to be undulating to gently rolling, with no sharp cut banks along the streams. Broad-topped ridges, irregularly shaped because of the dissecting influence of the many streams, are characteristic of the area.

The absence of good economical storage sites above the lands and their elevated position are the primary reasons for the area not being considered to be suitable for irrigation development. The streams head in the high mountains east of the project lands and the steep gradients preclude the development of economical storage reservoirs for the area in question. Preliminary hydrologic studies indicate that if flows on five streams could be regulated and stored, it would supply enough water to serve about 16,000 hectares. Roughly it would require a total capacity of about 600 million cubic meters of active storage to service the lands.

LOWER GILGEL AREA

The area is situated near Lake Tana at about average elevation of 1820 meters above sea level. The Gilgel Abbay River drains the northwestern portion of the Chokke Mountains and the southwestern part of the lake basin. The upper part of the basin was investigated by a West German team who published a report called the "Gilgel Abbai Scheme." The areas under discussion are those within the Gilgel Abbay Basin not covered by the German studies.

This portion of the basin is typified by rather large elevated areas surrounded by lower, flatter, grassland stream valleys, and in some instances, swampy area. Soils consist of the red (latosols) friable, permeable, clay loams suitable for irrigation agriculture.

Present land use consists of raising such cultivated crops as teff, noog, barley, chick peas, millet, and wheat under dry farm conditions. Livestock is raised extensively in the area. An unimproved road connects the towns of Dangila and Bahir Dar.

From preliminary studies, it appears that about 6,300 hectares which have been determined to be arable could be irrigated by a diversion dam on the Gilgel Abbay River at approximately contour elevation of 1821 meters. Rough estimates indicate that a canal approximately 13 kilometers long will be required to service the land by gravity flow. Diversion requirements for the 6,300 hectares have been estimated at 70 million cubic meters annually. Depending on the hydroelectric power operations of the German team studies, there could be shortages during the dry cycle, such as the 1913-17 period, which could seriously affect the multipurpose aspects of the plan.

OTHER AREAS

The following statements as to reservoir yield and power production are based upon the premise that the reservoir sites will provide adequate storage considering sedimentation and active storage requirements.

Beles River

Three additional hydroelectric projects may be possible of development on this river. Sites BL-7, BL-2, and BL-8, identified on Figure 130, have these estimated characteristics on the basis that water from Lake Tana is diverted to the headwaters of the Beles River.

Site BL-7 reservoir may yield 2, 592 million cubic meters of water and produce about 430 million kilowatt-hours annually with an installed powerplant capacity of about 100, 000 kilowatts.

Site BL-2 reservoir may yield 3, 847 million cubic meters of water and produce 220 million kilowatt-hours annually with an installed powerplant capacity of about 50, 000 kilowatts. This assumes that BL-3 (Dangur Dam--Middle Beles Power Project) is in operation and that the Beles Project lands are irrigated.

Site BL-8 reservoir may yield 4, 044 million cubic meters of water and produce 600 million kilowatt-hours annually with an installed powerplant capacity of about 135, 000 kilowatts. This is on the basis of the same upstream conditions as given for Site BL-2.

Beshilo River

Reservoir Site BS-2 may yield about 1, 690 million cubic meters of water producing 340 million kilowatt-hours annually with an installed powerplant capacity of about 75, 000 kilowatts.

Reservoir Site BS-1 may yield 4, 010 million cubic meters of water and produce 800 million kilowatt-hours annually with an installed powerplant capacity of 180, 000 kilowatts.

Diddessa River

Site DD-4 might yield 3, 870 million cubic meters, producing 1, 180 million kilowatt-hours annually from an installed powerplant capacity of 270, 000 kilowatts. This assumes that Diddessa Dam (DD-11) Arjo-Diddessa Project is in operation.

Gruba River

Site GB-2 might yield 1, 930 million cubic meters of water producing 290 million kilowatt-hours annually from an installed powerplant capacity of 65, 000 kilowatts.

Welaka River

This river, sometimes referred to as the Votaka, has a potential hydroelectric site designated as VO-1 on Figure 130. This may yield 870 million cubic meters of water producing 95 million kilowatt-hours annually from an installed powerplant capacity of 20, 000 kilowatts.

Special Reports

Two reports of a special nature should be discussed. The first report concerns the Jiga Spring Pilot Project and was prepared as a working paper during the course of the investigations. Only portions of the report concerning plans and estimates and supporting data are included here.

The second report presents a resumé of the Gilgel Abbai Scheme, a report prepared by a West German team, of which a preliminary portion was made available to the Blue Nile personnel.

JIGA SPRING PILOT PROJECT

The Jiga Spring area is near the village of Jiga in the central part of the Debre Markos plateau in southeastern Gojjam Province. This area, situated about 1800 meters (5905 feet) above sea level, is 65 kilometers (40 miles) northwest from the province capital of Debre Markos and 400 kilometers (248 miles) from the capital city of Addis Ababa. Dembecha, Finote Selam, and Bure are the larger villages in the vicinity of the project land.

Physiography and Geology

The general area consists of a gently sloping upland, dissected to a limited extent by small streams and drainageways. Low lying, flat, poorly drained lands and rolling to hilly terrain are characteristic of the area surrounding the project. Immediately to the north, the terrain becomes hilly to mountainous.

The spring is located within the area of geologically younger lava flows, originating from recent volcanic craters higher on the mountain slopes north of the project area. This late phase of volcanism spread a veneer of basaltic lava along the previously eroded slopes and valleys, forming wide or broad, gently sloping land areas.

The younger lavas were deposited in relatively thin, intermittent sheets or flows of rock, whose movements and rapid cooling produced a very porous, subsurface, bedrock material. Drainage in the younger volcanics is by intermittent surface and subsurface flow, and, where soils are thin, no surface drainage patterns are developed and the rainfall is rapidly absorbed into the porous lava. The porous younger lava serves as subsurface storage and regulation to provide a regulated flow of water from this spring over most of the dry season.

Soils and Land Classification

The soils of the area are reddish brown, friable, permeable clays (latosols). Laboratory studies show them to be moderately acid and to contain no significant amounts of salts, to have moderate content of organic matter in the plow zone, and to have clays of low plasticity. The latter characteristic is typical of latosolic soils in which the clay fraction is dominantly kaolinitic. Field examination shows textural properties comparable to loams or clay loams. They are easily tilled, are permeable, and have good water holding capacity. They are well suited to development under irrigated agriculture.

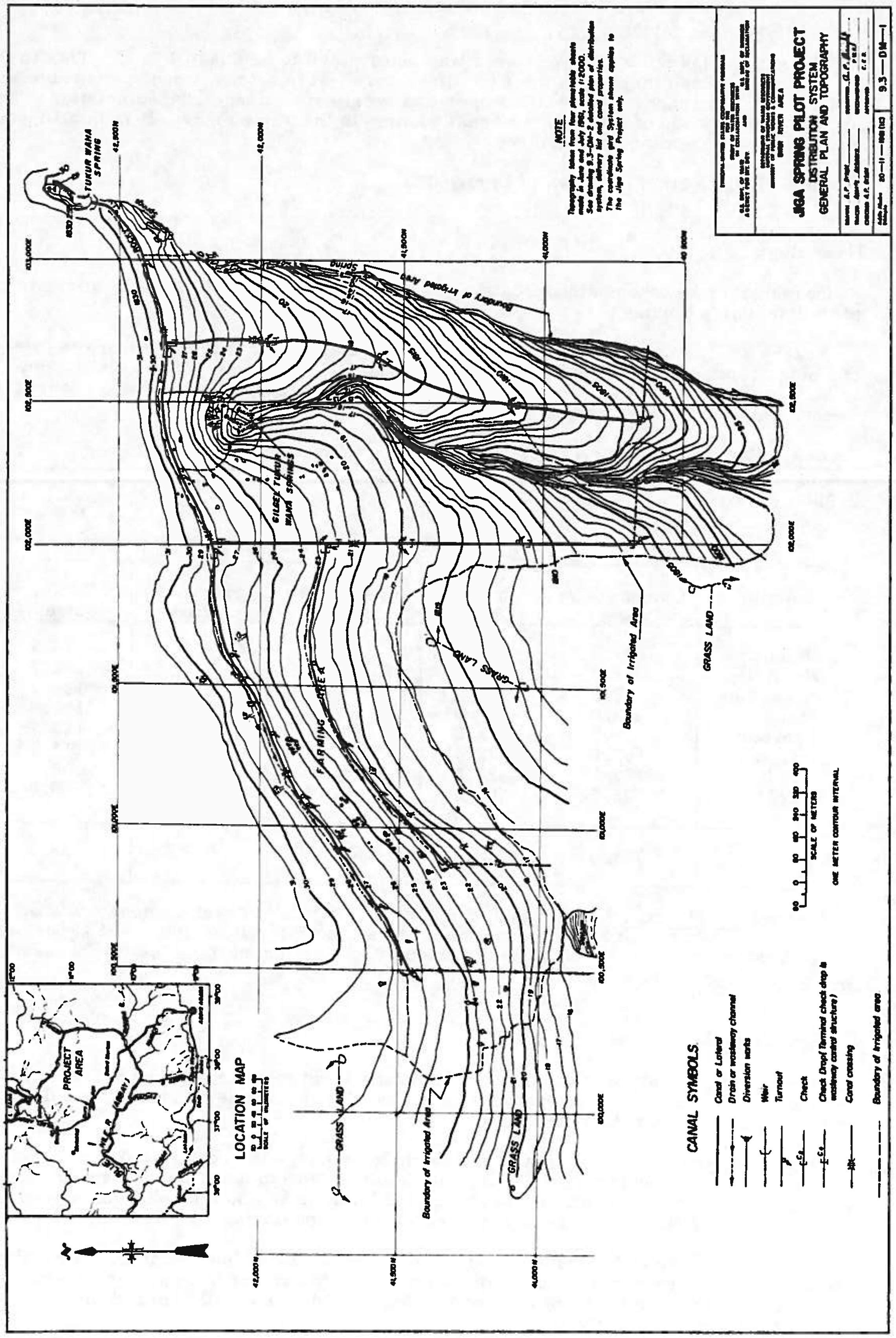


Figure 131--Jiga Spring Pilot Project--Topography and Plan

The entire Jiga Spring Project area was determined to be Class 1 land. This is the highest quality land mapped in the Birr River area. It has deep, open, permeable soils and smooth topography with gentle slopes and excellent drainage characteristics. The project is composed of fairly large areas sloping in the same plane. It is in all respects excellent for irrigation development.

Land classification is shown in Figure 132.

Hydrology

Occasional measurements indicate a yield of 0.4 cubic meter (15 cubic feet) per second at the main Jiga Spring.

Nearby weather stations indicate annual precipitation of about 1.2 meters (4 feet), most of which occurs in July through September. Irrigation consumptive use, in the dry October to May period, is estimated to be about 76 centimeters (2.5 feet), of which about 16 centimeters (0.5 foot) is met by usable rainfall.

Water Requirement. It was assumed that the irrigation season would begin in October and would end in May. The following table summarizes the water requirements for the project area.

Water Requirement

Average monthly data--Millimeters

Month	Consumptive use	Utilized rain (80%)	Net consumptive use	Farm irrigation efficiency	Water requirement
October	93.0	40.0	53.0	0.7	75.7
November	87.0	6.4	80.6	0.7	115.2
December	95.0	3.2	91.8	0.7	131.1
January	93.0	1.6	91.4	0.7	130.6
February	86.0	3.2	82.8	0.7	118.3
March	103.0	22.4	80.6	0.7	115.1
April	102.0	26.4	75.6	0.7	108.0
May	105.5	60.0	45.5	0.7	65.0
Total	764.5	163.2	601.3	0.7	859.0

Diversion and Canal Sizing Requirements. The diversion requirement would be 12,300 cubic meters per hectare. For canal capacities, about 1.8 liters per second per hectare is required for the method of irrigation adopted. Canal properties and typical sections are shown on Figure 133.

Design Criteria

In designing the project works, local conditions and other factors were taken into consideration. The distribution system was designed with sufficient capacity to deliver the water required during daylight hours.

Design of structures has been kept as simple as possible, realizing the lack of skilled construction crews and the difficulties that would be encountered in operating and maintaining the system. The abundance of local building stone and the relatively cheap labor available have dictated the use of masonry wherever possible.

More liberal use of turnouts was employed than would be the practice in the United States. An average of one turnout for every 8.3 hectares has been provided, due partly to topography and partly to the thought that this would be about the maximum size that could be utilized efficiently.

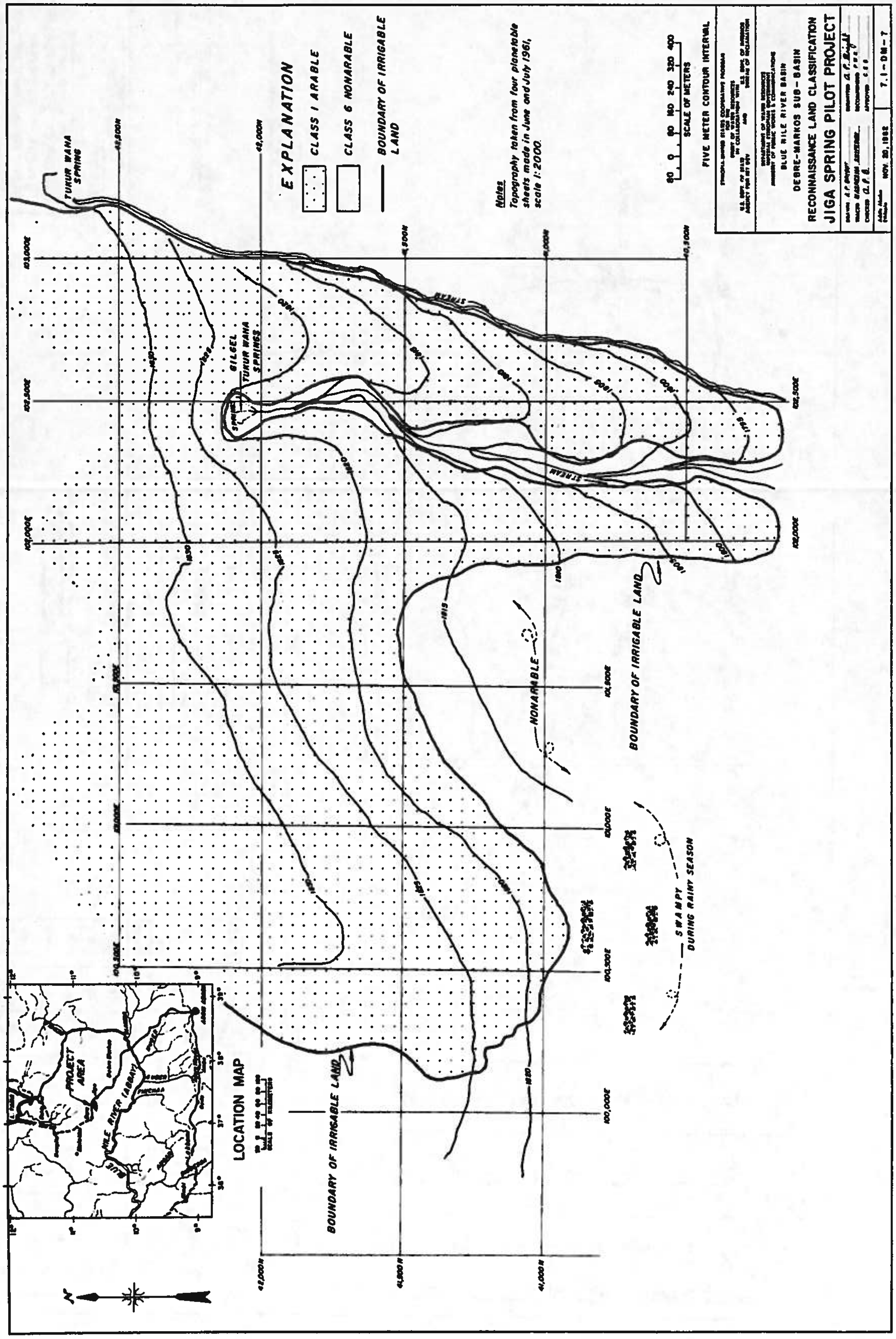
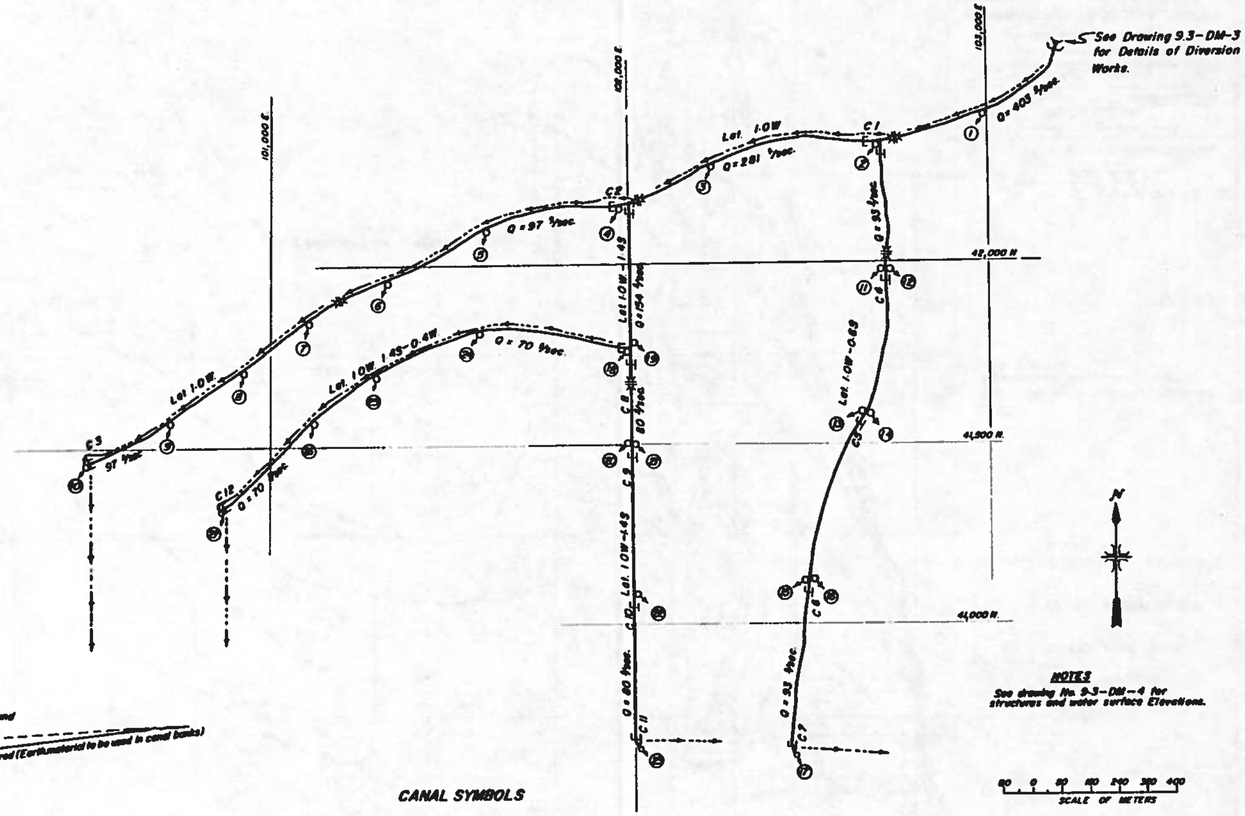


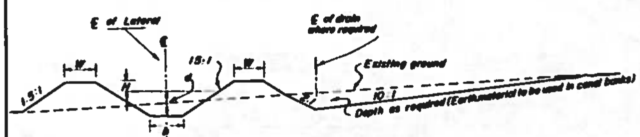
Figure 132--Jiga Spring Pilot Project--Reconnaissance Land Classification

DELIVERY	NET HECTARES (95% of Gross)	CAPACITY Liters/sec.
LATERAL 1·0W.		
0·3S	8·4	63
0·6S	7·7	58
1·1S	12·6	95
1·4S	8·8	69
1·7S	7·5	56
2·1S	6·1	46
2·4S	5·9	45
2·6S	6·2	47
2·8S	7·7	58
3·1S	12·9	97
LATERAL 1·0W — 0·6S		
0·4W	6·2	47
0·4E	6·2	47
0·8W	5·0	38
0·8E	8·7	65
1·3W	6·2	47
1·3E	7·9	59
1·7S	11·1	83
LATERAL 1·0W — 1·4S		
0·4W	10·8	81
0·4E	11·3	85
0·6W	4·3	32
0·6E	10·2	77
1·1E	9·2	69
1·8S	10·7	80
LATERAL 1·0W — 1·4S — 0·4W		
0·4S	8·2	62
0·7S	5·6	42
1·0S	6·1	46
1·3S	9·3	70
Total	223·8 ha. @ 1·8 = 403 Liters/sec.	



NOTES
See drawing No. 9-3-DM-4 for structures and water surface Elevations.

SCALE OF METERS



TYPICAL CANAL and DRAIN SECTION

CANAL SYMBOLS

CANAL PROPERTIES

Q Liters/sec	b cm	d cm	H cm	W cm	V cm/sec.	n	Slope
403	60	75	40	100	31	0·03	0·0003
281	60	62	34	90	28	0·03	0·0003
154	40	29	30	90	64	0·03	0·004
97	50	41	30	90	22	0·03	0·0003
93	40	23	30	90	56	0·03	0·004
80	40	21	30	90	54	0·03	0·004
70	50	35	30	90	20	0·03	0·0003

BIRR RIVER AREA

JIGA SPRING PILOT PROJECT

DISTRIBUTION SYSTEM PLAN

DELIVERY LIST and CANAL PROPERTIES

9·3 — DM — 2

Figure 133--Jiga Spring Pilot Project--Distribution System Plan--Delivery List and Canal Properties

The cost of permanent facilities was estimated on the basis that building construction would follow the locally accepted practice of framing with eucalyptus poles and covering with corrugated metal. Concrete floors and inside plumbing were also included as part of the estimate.

Plan of Development

The project plan is shown on Figure 131. A small masonry diversion dam will divert the water from the spring. Canals will convey the water to project lands with suitable turnouts and other appurtenant structures provided to control the water.

Project Features

The principal features of the project are the Jiga Spring diversion structure, distribution system with appurtenant structures, and drains to serve 224 hectare (553 acres) of irrigable lands.

The diversion works would consist of a concrete and masonry structure 85 meters in length and 1.2 meters in height. Two slide gates have been provided, one for the canal inlet and the other to drain the pool for maintenance purposes. A spillway 18 meters long has been incorporated in the structure to pass excess flows.

The canal has been designed with initial capacity to convey 403 liters per second (14.25 cubic feet per second). Suitable structures have been provided for passage of light farm machinery across the canals. Intercepting drainage ditches would be required to control runoff during the heavy rains and to prevent damage to the system and erosion of the land. The drains are designed to collect the surface runoff and irrigation waste and convey this water to the nonirrigated lands below or back into the stream as desired. Masonry drop structures have been provided where the gradient is excessively steep to prevent erosion.

Estimated Project Costs

Construction Cost. The estimate of construction cost is based upon material and labor conditions in Ethiopia. The estimate includes allowance for engineering, general expense, supervision during construction, and contingencies.

Feature	Cost
Diversion works	Eth$ 8,300
Distribution system	61,000
Land drains	24,700
Permanent facilities	92,000
Tools, vehicles, and equipment	24,000
Total	Eth$210,000

Development Cost. Clearing cost for the Jiga Spring Unit is considered to fall into the light clearing category with an average estimated cost of Eth$58 per hectare.

Project Land Clearing Cost Estimates

Intensity of clearing	Cost in Eth$ per ha. Range	Median
Light	15 - 80	58
Medium	81 - 150	115
Heavy	151 - 310	230

Farm drainage, farm structures, road crossings and land leveling or grading are estimated to be Eth$100 per hectare.

Operation and Maintenance Cost. In the Jiga Spring pilot farm, central control can be expected to be vested in a ministry or one of its subordinate agencies. The separation of costs, usually attributable to operation and maintenance, from the ordinary on-farm costs connected with application of water and the growing of crops will be incurred in keeping the diversion works in order, making diversions of water at the required time, cleaning the laterals, etc. Equipment for operation of the distribution system may be expected to be available from the pool of equipment maintained for the overall venture. The annual operation and maintenance cost for the Jiga Spring Project, is estimated to be about Eth$53 per hectare. Replacement costs are negligible for a project of this size.

GILGEL ABBAI SCHEME (GERMAN REPORT)

Early in 1961, the Ethiopian Government informed the Bureau of Reclamation investigation team through appropriate agencies that a team composed of about six or seven nationals from the Federal Republic of West Germany would be conducting a land and water resource investigation in a small sector of the Blue Nile Basin. Accordingly, after consultations and discussions, it was agreed that the Germans would investigate the Gilgel Abbay River area. Preliminary and inconclusive data, including land classification, stream runoff records, and engineering surveys gathered by Bureau of Reclamation personnel were made available to this German team.

The preliminary German report, made available to the Bureau personnel, consisted of five chapters, all of Part B. The following resumé of the report covers only that portion concerning the development plan.

The area studied is in the greater Lake Tana drainage basin, specifically the upper portion of the catchment basin drained by the Gilgel Abbay River (also known as the Piccolo Abbai). Investigation of the land and water resources covered approximately 2, 000 square kilometers of the drainage basin.

The development plan calls for three dams and four powerplants on the Gilgel Abbay River. A pilot farm with a small powerplant adjacent to middle structure also is included in the river development. Two other river regulating structures on each of the main tributaries would be required.

The first upstream structure on the main stem would be the Umbri Mariam Dam and Powerplant. This unit would include main canals for irrigation of 18, 450 hectares of land. A small diversion dam downstream from the storage dam would divert the waters from the main channel into a power canal to serve a second powerplant; the combined installed capacity for the two powerplants being 24, 000 kilowatts.

The second downstream unit would be the Debekan Mariam Dam and Reservoir. Serving about 4, 015 hectares of land, it would also produce power at the underground powerplant at the end of a power canal. Installed plant capacity at Station No. 3 would be 32, 000 kilowatts. Water would also be provided to the small pilot farm located to the east of the reservoir, with the small powerplant having a plant capacity of 165 kilowatts.

The third and last structure on the Gilgel Abbay River would be the Ker Quosquam Dam and Powerplant. The installed plant capacity at Station No. 4 is given as 7, 500 kilowatts. No irrigation service would be provided from this reservoir.

The Koga Tank and Reservoir would be located on the Koga River with an active reservoir capacity of 100 million cubic meters; providing water for irrigation of 23, 985 hectares of land.

The Sawesa Mariam Dam and Reservoir would be the most southerly feature, designed to impound the waters of the Jema River. It would also be single purpose to irrigate some 15, 940 hectares of land. Following is a summary of the proposed plan of development.

Features	Total Res. capacity ($m^3 \times 10^6$)	Irrigable area (ha.)	Installed capacity (kw.)
Umbri Mariam Dam and Reservoir	690	18,450	24,000
Debekan Mariam Dam and Reservoir	100	4,015	32,165
Ker Quosquam Dam and Reservoir	44	-	7,500
Koga Tank Dam and Reservoir	100	23,985	-
Sawesa Mariam Dam and Reservoir	83	15,940	-
Total	1,017	62,390	63,665

Structure drawings were not included in the data made available. Estimates of cost were also not included.

ORGANIZATION AND OPERATIONS

NATIONAL ORGANIZATION

Government organizations responsible for the development of natural resources may vary greatly, depending upon the objectives, laws, national policy, financial support, technical skills, and interest or enthusiasm. Responsibility for natural resource development is frequently divided among several agencies. The need for a central organization in Ethiopia to establish and apply uniform treatment to all sectors of development and to coordinate the multiple uses and demands upon resources is recognized.

Resource development, however, is so complex that its effects may extend to every unit of government, and many agencies will share an interest, some to a greater extent than others. Therefore, the agency which administers the program should be so constituted as to recognize and consider the requirements and the responsibilities of other governmental bodies.

Since the role to be performed in land and water resource development by the existing Water Resources Department of the Ministry of Public Works and Communication is not yet clearly defined, and since no determination has been made regarding the methods of financing projects or of repaying their costs, it would seem desirable for the Imperial Ethiopian Government to appoint an expert committee on resource development, consisting of representatives of the ministries and agencies interested in resource development, including representation from the existing Water Resources Department and supported by consultants if required. It would review and study existing legislation pertinent to utilization of land and water resources and the responsibilities of the various governmental agencies now concerned in this field. The committee should recommend legislation required to provide the authority for a centralized agency for the specific development of water and land resources. This development would occur through the construction, operation, and maintenance of irrigation, hydropower, and related projects.

Specifically, the committee should recommend:

1. A charter for the centralized agency, setting forth its authority, objectives, and responsibilities.

2. A plan to consolidate and coordinate the activities of the various agencies now operating in this field.

3. A water code insuring adequate control and regulation of the uses of water for irrigation, power, and municipal and domestic supply.

4. A plan for financing the costs of projects and for retirement of obligations.

The present Water Resources Department could logically become the agency best qualified to administer the program. It might serve the national needs better if it were autonomous, operating under the broad direction of a board composed of representatives from interested governmental ministries and agencies. The primary purposes of the Water Resources Department should be to conserve, safeguard, and promote orderly development of land and water resources; to provide for equitable distribution and allocation of water among the users; and to guide the development of resource-based projects to the greatest beneficial use possible for the enjoyment of the Ethiopian people.

A consolidation of various appropriate agencies should accelerate as the department responsible for resource development expands in function and scope. The Surveys and Mapping Division of the Water Resources Department and the Mapping and Geography Institute might well be consolidated into one separate Geodetic Survey and Mapping Agency. The Ethiopian Electric Light and Power Authority and the Water Resources Department could consolidate under a common board or directors with EELPA becoming the Power Division and the present Water Resources Department organization becoming the Engineering, Irrigation, and Development Divisions with a single Division of Administration. Consolidation would lower the cost of administration, provide more efficient management as multiple-purpose projects are planned, and combine the best features of the two organizations as suggested by Figure 134.

AGRICULTURAL OPERATIONS

General

Few Ethiopian farmers today could successfully operate a modern irrigated farm without training, guidance, and financial assistance. The average farmer has a subsistance income that only provides the bare necessities of life and permits him to contribute little to the national economy. Project development should encourage the emergence of farmers who can successfully own and operate commercial farms, hold title to their lands, enjoy an adequate standard of living, and have a voice in the affairs of their community.

This cannot be attained easily or quickly. Legislation providing for land ownership and an equitable system of taxation is necessary. Long term, low interest loans; intensive technical assistance in agricultural practices; and guidance in farm layout, farm operation, and direction of farm labor will be necessary. Responsibility should gradually be shifted from the project management to the farmer as he demonstrates his ability to initiate and execute appropriate decisions.

The income level under future project conditions should enable the farmer to purchase his farm over a reasonable period of years, pay farm operation costs and taxes, set aside a savings fund for necessities and emergencies in later life, and provide a family living with adequate food, housing, clothing, education, and medical care. Studies of potential production indicate that under full development conditions an average farm of 15 to 25 hectares, varying with the project area, can produce the income to meet this requirement. In addition, it would make a contribution to the national economy that would offset the national investment.

Farmers should be selected on the basis of qualifications and adaptability. The new concept considers farming as a business rather than as a traditional way of life. It is assumed that applicants would be carefully screened to insure the best selection, since good farmers are vital to the success of the project. The College of Agriculture at Alemaya and the agricultural high schools at Jima and Agere Hiywet are logical sources of candidates.

Each project would need an agricultural manager to supervise the field and general farming operations. This manager should be well acquainted with all phases of commercial agriculture and irrigation and should possess proven ability to direct and encourage personnel. Ideally, he should be recruited from a successful irrigated farm or plantation

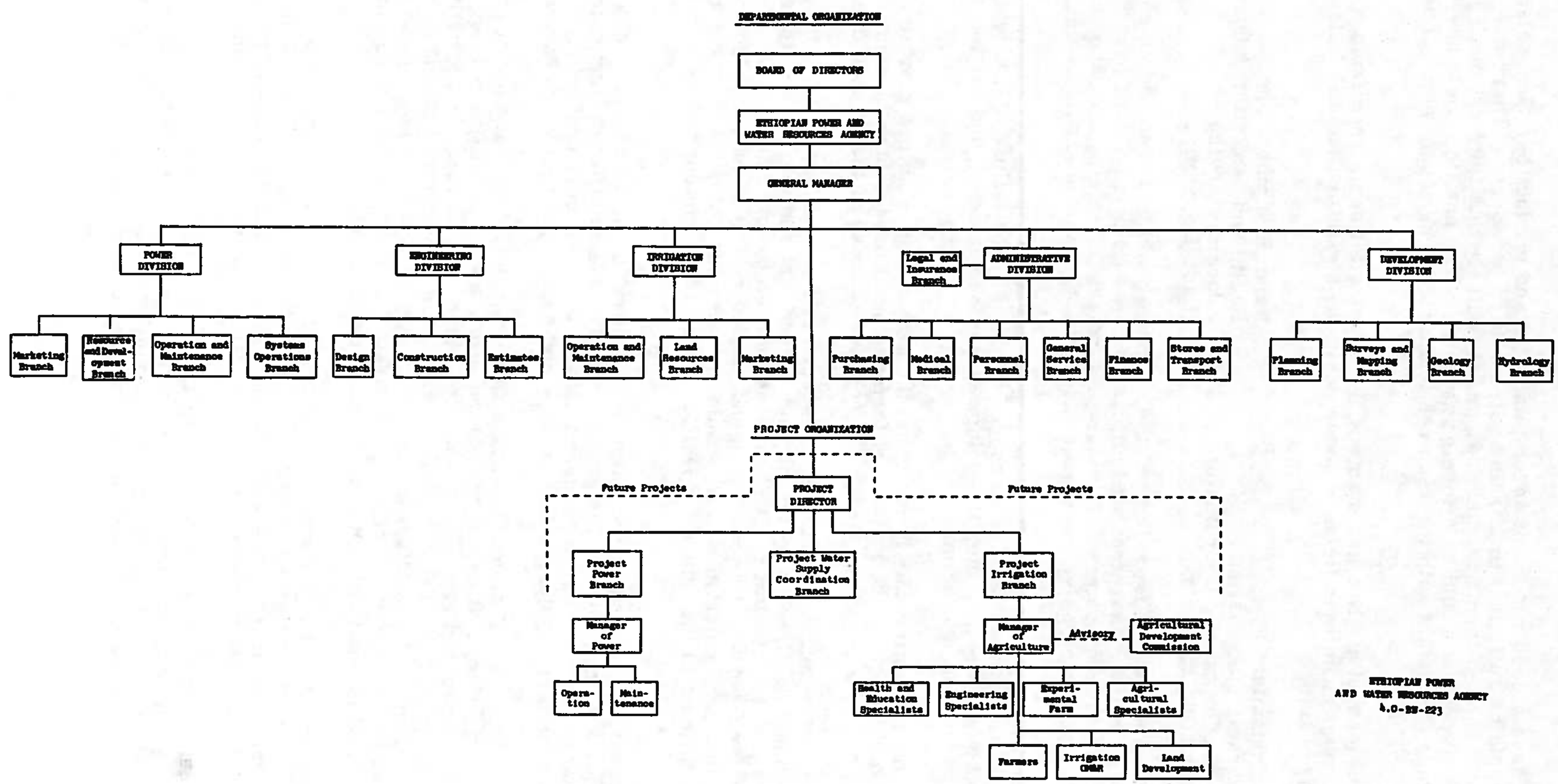


Figure 134--Ethiopian Power and Water Resources Agency

and should have a good record of accomplishment and production. The salary for this position should be sufficient to attract well-qualified personnel. There are very few large-scale irrigated farms in Ethiopia, and it is likely that the first manager of agriculture on any project would be a foreign national. This position could later be filled by an Ethiopian assistant with the required technical background, who had become well qualified on the job.

The manager and his line assistants will require staff assistance from technical specialists, expert in their fields. These positions should include the following staff on a continuing basis:

Agronomist	Farm Equipment Specialist
Marketing Specialist	Health and Sanitation Advisor
Field Operations Coordinator	Education Advisor
Irrigation Engineer	Home Economist

A training farm, distinct from the private farms, should be organized on each project. Under control of the manager of agriculture, men would be employed here in a temporary classification of hired, potential farmers or farmers in training. As they acquire competence and indicate a desire to operate independently, farms should be assigned to them.

The selection of farmers in training is less critical than the selection of independent farmers. Poor workers could be removed early, and the failure of a potential farmer is less costly in terms of time, financing, extension services, and social capital than the failure of an independent farmer.

The training farm initially might equal the size of the combined private farms. This operation would augment the number of farmers qualified to enter independent operations and would provide a gage to measure the relative success of the private operations.

Each project requires a permanent research and experimental farm of several hectares. It should be directed by the project agronomist and market specialist, responsible to the manager of agriculture. It should test, develop, and demonstrate methods and techniques pertinent to field production and marketing. It should provide constant check on the original crop selections, and should consider the potential of crops which may become significant in the future. Specific points of experiment and research should include the following.

Engineering. Consumptive water use; infiltration data and water-holding capacity of soils; rate and frequency of irrigation; effectiveness of different irrigation systems; types of machinery and degree of mechanization for least cost production; the effects of rainy season farming upon soil structure and erosion; and farm storage structures.

Agronomy. Evaluation of the suggested crops and determination of crops best adapted to irrigation; critical soil moisture levels and plant wilting points; selection and improvement of indigenous and imported varieties; optimum soil fertility and reaction levels; plant spacing and density of plant population; number and timing of cultural operations; crop rotations; disease, insect, and weed control; planting and harvest dates; and observations of the effect of Blue Nile altitudes, length of day, wind movement, and amount and intensity of sunshine upon imported crops.

Management. Comparison of costs and returns of competing crops; comparison of irrigated versus nonirrigated production of particular crops; crop marketing; double cropping during the irrigation season; integration of livestock and poultry with crop farming; and compilation of yield data, cost data, and other pertinent information.

A weather station to record high, low, and mean daily temperatures, relative humidity, wind velocity, amount and intensity of precipitation, rate of evaporation, hours of sunshine per day, and degree of cloud cover should be installed and operated in each area which is studied in detail. This station should also be maintained during the life of the project.

Irrigation Operation and Maintenance

The operation and maintenance of the constructed project facilities to insure continuous and efficient operation are of the greatest importance in the success of the project. The works must be so operated and maintained that a water supply for irrigation or power can be delivered in time and in the quantities needed. Too little water delivered at a period of peak demand will produce power shortages and can result in severe damage to crops in the irrigated areas; too much water can result in waste that may damage the project land or later cause shortage in the storage system. Specific operation and maintenance programs involved in irrigation projects require personnel to operate from established service facilities adjacent to the irrigation systems. The manager and his administrative staff should operate out of the headquarters buildings, the operating and maintenance personnel reporting to the manager. The necessary shops, warehouses and equipment should also be located near the service facilities headquarters.

Water users should not be permitted to waste water excessively, and the management should have full authority to reduce or shut off a head of water until the water user will take care of it. Good water measurements are essential for the efficient operation of an irrigation project and daily records should be maintained. These records would consist of canal diversions, total canal waste, total number of users, and future requirements.

A maintenance program should consist of annual repairs and maintenance performed before water is turned into the system at the beginning of the irrigation season plus regular inspections and when necessary repairs and maintenance during the irrigation season. Weeds should be cleaned from the canals and laterals and mowed and controlled on operating roads. Drains should be cleaned of all silt and debris with special attention to cross drainage structures. All ditch banks should be stabilized where abnormal erosion occurs. Painting should be performed at periodic intervals to prevent deterioration, especially on metal parts.

POWER OPERATIONS

General

Under the suggested consolidated organization previously described, the Power Division would have four branches--Marketing, Resources and Development, Operation and Maintenance, and System Operations.

The Marketing Branch would be responsible for negotiating power sales contracts, reading meters, billing, and collection. It would gather statistics and have available at all times a breakdown of sales by classes of loads--residential, rural, commerce, industry, street and highway lighting, transportation, and other.

The Resources and Development Branch is the power planning unit and as such would perform general planning activities. This would include load forecasting, feasibility studies for system additions, rate and repayment studies for the power function of all projects, and technical power studies.

Power Operation and Maintenance

This major function will be the responsibility of two branches--Operation and Maintenance, and Systems Operations. The Operation and Maintenance Branch might have three sections--Production, Transmission-Distribution Plant, and Inspection and Training.

The Production Section's prime responsibility will be in the operation of the isolated electric power systems, such as small diesel-electric or hydroelectric plants serving small towns and villages. The Transmission-Distribution Plant Section would be responsible for maintenance of all transmission and distribution lines as well as sub-stations and related equipment. It would also operate the wood-pole treating plants. In order to maintain an adequate supply of trained personnel, the Inspection and Training Section could train linemen, powerplant operators, meter installers, laboratory technicians, electricians, and inspectors. Both theoretical and practical training would be given. This section would be responsible for maintaining an adequate electrical wiring code and enforcing its provisions as well as providing maintenance for all communication facilities.

The Systems Operations Branch might also have three sections--Dispatching, Power Scheduling, and Technical Analysis--with its activities limited initially to the Interconnected Systems and ultimately to the National Grid. The Dispatching Section would be responsible for meeting load requirements and schedules as well as for controlling all clearances for electrical switching. The Power Scheduling Section would be responsible for developing system-wide scheduling on a day-to-day basis, consistent with scheduled water releases. The Technical Analysis Section would be responsible for system operation at maximum efficiency. Emergency switching programs and studies regarding system control would be the responsibility of this section.

Close liaison between the Systems Operation Branch and the Hydrology Branch under the Development Division would be required regarding reservoir operations.

At the project level, each project or convenient combination of projects, such as the Finchaa and the Amarti-Neshe, would be headed by a Project Director. Under the director is the Projects Power Branch, consisting of a Power Manager heading two sections--an Operation Section and a Maintenance Section. The former operates the powerplants, taking hourly instructions from the Systems Operation Branch, Central Office, and the latter maintains the powerplants and appurtenant works. For single-purpose power projects, the Project Director would have only two groups under him, one Operations and the other Maintenance, with the same responsibilities as before, except that activities would not be restricted to the powerplant and appurtenances but would apply to all features of the project, including the storage facilities.

ECONOMIC ANALYSIS

General

The development of the land and water resources of the Blue Nile River Basin should be planned and executed in coordination with other developing facets of the national economy. Ethiopia today is primarily an agricultural nation and plans to develop in the future from an agricultural base to an agricultural-industrial base. The irrigation and hydroelectric projects in the Blue Nile Basin will be of major importance, for such development of the economy will depend upon increased production of food and upon adequate supplies of reasonably priced electric power.

Production of food suffices for present consumption at the existing standard of living but would not be adequate to feed a large nonagricultural population. The typical Ethiopian farm produces little above immediate family needs. If the nation is to change to an agricultural-industrial base, the development of industry and agriculture must be balanced so that the industrial population can be fed and a broad market for its products can be established. Commercial agriculture, therefore, assumes an important position in the economy as the industrial sector enlarges and must be coordinated with electric power production, which is a necessary adjunct to manufacturing and agricultural processing.

The Blue Nile River Basin is capable of producing electric power, supplies of food, and such industrial crops as cotton and tobacco. Within the Blue Nile Basin are potential project areas which, if developed fully, could bring into production about 433,000 hectares of land capable of sustained high yields of a broad range of crops. Adequate water supplies can be delivered by construction of project works, and the 24 powerplants (identified in the report) with installed capacity of 6,965,165 kilowatts of power (0.5 power factor) will exceed forseeable power requirements.

Water resource development in the Blue Nile Basin must meet national needs and yet be within the financial and managerial ability of the nation. To establish the proper sequence of project development within the basin, it is necessary to evaluate the projects in such terms that they can be appraised in relation to each other and to other sectors of the economy. For this purpose, a benefit-cost comparison is used in this report.

A benefit-cost comparison is an indicator of the economic justification of the project and a guide to the selection of projects for future detailed studies.

Benefits

Two broad categories of project benefits are recognized--the irrigation benefits and the power benefits.

The increase in the gross value of crops produced in an average year after full development is used to evaluate the annual irrigation benefits of each project. These benefits represent the increased income expected by farmers and laborers due to project development, which should be significantly higher than the present agricultural pattern where the farmer produces little surplus over family needs and has little cash during the year. The irrigation projects will be commercially oriented and will provide cash returns to participating farmers and laborers. The farm family will benefit by having an adequate diet, improved housing and clothing, and being able to afford higher expenditures for education, health, and other needs.

Additional benefits will accrue to individuals in industries which handle project products or supply project requirements. Processors of raw farm products, final processors of such industrial crops as tobacco or cotton, firms which export agricultural goods, firms which handle byproducts, and firms which supply farming needs and consumer requirements will benefit from project development.

Other beneficial effects include the opportunity to settle on projects, to find employment in project areas, the ability of an area to support a higher population after development, and the improvement of social and community facilities after project development.

The power benefits are evaluated by the estimated cost of the most likely alternative source of equivalent power anticipated in the market area in the absence of the project. Steam and diesel plants are considered the most likely alternative sources of equivalent power.

Other beneficial power effects not evaluated in monetary terms include the contribution of the power facilities to industrial, commercial, and urban development; the greater dependability and continuity of power service; the reduction in imports of fuel oil or other natural fuel; and the availability of large blocks of power in times of national emergency.

Improvement of sediment control and fish conservation are benefits which may be associated with either irrigation or power.

The sum of the annual irrigation and annual power benefit is the total annual project benefit for multiple-purpose projects. For single-purpose projects the total annual benefits are those derived for the irrigation or the power purpose.

Costs

The costs of constructing and operating the irrigation and power facilities of each Blue Nile Basin project are identified, measured, and compared to the expected benefits to determine a measure of economic justification of the project. The costs include construction, interest during construction, access roads from a point of the national highway system to the project, land development, and operation, maintenance, and replacement. The cost of constructing roads as a part of the national highway system and the expenditures for education, disease control, and other social overhead factors are considered national rather than project costs; therefore, they are not evaluated in monetary terms.

Interest during the construction period is an economic cost of each Blue Nile project, applicable to expenditures made during the construction period prior to the realization of benefits. Interest during construction is calculated by applying a 5 percent interest rate against the average expenditures for the facilities for the number of years required for completion of the facilities.

Land development costs consist of costs of land clearing and leveling. Clearing costs are dependent upon the type and degree of vegetative cover, which may range from grass and partly cleared fields to forest. Land leveling costs are dependent upon the surface irregularities and upon the cost of installing structures which permit the uniform application of irrigation water and the removal of excess water.

The sum of the construction, interest during construction, and land development costs is called the capital cost of the project. The capital cost is reduced to an annual equivalent basis by amortizing it over the 50-year period of project analysis at an interest rate of 5 percent. The 50-year period is used for purposes of economic analysis of Blue Nile Basin projects. However, all major facilities are expected to have a useful life of 100 years.

Project costs also include the operation, maintenance, and replacement expenses necessary to insure continuous and efficient operation during the life of the project. Operation and maintenance includes average annual expenditures for personnel, equipment, supplies, and general expenses; replacement expenses are based upon a sinking fund. For irrigation projects where water is pumped to the land, an annual energy cost is added for pumping at 3 cents per kilowatt hour.

TABLE 48--SUMMARY OF BENEFITS AND COSTS 1/

Subbasin	Project	Purpose served	Capital cost 2/	Annual benefits	Annual costs	Benefit-cost ratio
Lake Tana	Megech Gravity	Irrigation	82,663	2,215	4,801	.46 to 1.00
	Ribb River	Irrigation	86,185	5,016	5,258	.95 to 1.00
	Gumara River	Irrigation	87,205	4,367	5,237	.83 to 1.00
	West Megech Pump	Irrigation	14,118	2,156	1,448	1.49 to 1.00
	East Megech Pump	Irrigation	12,787	1,908	1,407	1.36 to 1.00
	Northeast Tana Pump	Irrigation	10,616	1,642	1,114	1.47 to 1.00
Beles	Upper Beles	Irrigation and power	404,680	86,585	28,464	3.04 to 1.00
	Middle Beles	Power	237,782	39,377	15,289	2.58 to 1.00
Birr	Upper Birr	Irrigation	157,487	9,477	9,437	1.00 to 1.00
	Debohila	Irrigation	46,478	1,613	2,744	.59 to 1.00
	Lower Birr	Irrigation	14,006	3,357	1,017	3.30 to 1.00
	Upper and Lower Birr combined	Irrigation	171,493	12,834	10,454	1.23 to 1.00
Giamma	Giamma River	Power	299,307	12,864	17,818	.72 to 1.00
Muger	Muger River	Power	33,808	6,429	2,660	2.42 to 1.00
Guder	Upper Guder	Irrigation	15,463	1,646	1,066	1.54 to 1.00
	Lower Guder	Power	126,848	10,793	8,920	1.21 to 1.00
Finchaa	Finchaa	Irrigation and power	100,468	25,336	7,373	3.44 to 1.00
	Amarti-Neshe	Irrigation and power	138,573	22,172	9,315	2.38 to 1.00
Diddessa	Arjo-Diddessa	Irrigation and power	180,692	23,593	11,201	2.11 to 1.00
	Dabana	Irrigation and power	405,664	23,437	25,114	.93 to 1.00
	Angar	Irrigation and power	561,989	73,195	37,907	1.93 to 1.00
	Lower Diddessa	Power	475,740	62,274	29,856	2.09 to 1.00
Dabus	Dabus	Irrigation	27,523	6,084	2,008	3.03 to 1.00
	Dabus	Power	10,103	2,060	992	2.08 to 1.00
Dindir-Rahad	Dindir	Irrigation and power	534,213	41,043	33,546	1.22 to 1.00
	Galegu	Irrigation	234,730	6,037	13,283	.45 to 1.00
	Rahad	Irrigation	286,147	29,984	17,424	1.55 to 1.00
Blue Nile River	Karadobi	Power	1,218,502	260,964	82,643	3.16 to 1.00
	Mabil	Power	1,000,018	249,148	68,294	3.65 to 1.00
	Mendaia	Power	1,192,047	361,909	83,202	4.35 to 1.00
	Border	Power	1,060,656	281,761	75,349	3.74 to 1.00

1/ Eth$1.00 = US$0.40.

2/ Capital cost includes construction, interest during construction, and land development.

Benefit-Cost Analysis

The annual equivalent capital cost is added to the annual operation, maintenance, and replacement cost to determine the total annual project cost. This is compared to the annual project benefits to determine a benefit-cost ratio, as follows:

$$\frac{\text{Annual project benefits}}{\text{Annual project costs}} = \text{benefit-cost ratio}$$

A ratio of benefits to costs for each project indicates the extent to which the project appears economically justified in this report. Table 48 presents the capital costs, annual benefits, annual costs, and the benefit-cost ratio for each Blue Nile Basin multiple-purpose, irrigation, and power project.

Cost Allocation

In order to develop separate ratios for the irrigation and power purposes of the multiple-purpose projects, the joint costs of the projects must be allocated between the irrigation and the power purposes. The objective of cost allocation is the equitable distribution of costs of multiple-purpose irrigation and power facilities among the purposes served, so that both purposes share in the economies of joint construction. In this report the alternative justifiable expenditure method of cost allocation is used. This method employs the principle that no purpose should be assigned costs in excess of its benefits or in excess of the cost of its most economic alternative. Under this method the specific costs of each purpose are separated out, and the joint costs of irrigation and power are allocated and added to the specific costs of each purpose. The sums are the respective costs attributable to irrigation and to power.

The costs allocated to irrigation and power are reduced to an annual equivalent basis and compared to the annual benefits. The benefit-cost ratios for the irrigation and power portions of the multiple-purpose projects, however, must be used advisedly, for each purpose of a multiple-purpose project has a different ratio of benefits to allocated costs within a multiple-purpose project than it would have if constructed as a single-purpose project. In some instances it is impractical to construct the particular irrigation or power facilities as single-purpose projects.

Table 49 presents the capital costs and the operation, maintenance, and replacement costs allocated to irrigation and power for each multiple-purpose project in the Blue Nile Basin. Table 50 presents the annual benefits, annual costs, and the ratio of benefits to allocated costs for the irrigation and power purposes within each multiple-purpose Blue Nile Basin project.

TABLE 49--SUMMARY OF ALLOCATED COSTS OF MULTIPLE-PURPOSE PROJECTS

Subbasin	Project	Capital Cost 1/			Annual OM&R		
		Total	Irrigation	Power	Total	Irrigation	Power
Beles	Upper Beles	404,680	171,473	233,207	6,297	3,334	2,963
Finchaa	Finchaa	100,468	25,878	74,590	1,870	588	1,282
	Amarti-Neshe	138,573	29,055	109,518	1,724	382	1,342
Diddessa	Arjo-Diddessa	180,692	94,390	86,302	1,303	571	732
	Dabana	405,664	59,812	345,852	2,893	235	2,658
	Angar	561,989	203,523	358,466	7,123	3,896	3,227
Dindir-Rahad	Dindir	534,213	380,473	153,740	4,283	3,482	801

1/Capital cost includes construction, interest during construction, and land development.

TABLE 50—SUMMARY OF BENEFITS AND ALLOCATED COSTS BY PURPOSE FOR MULTIPLE-PURPOSE PROJECTS

Subbasin	Project	Purpose served	Capital cost 1/	Annual benefits	Annual costs	Benefit-cost ratio
Beles	Upper Beles	Irrigation	171,473	29,987	12,727	2.36 to 1.00
		Power	233,207	56,598	15,737	3.60 to 1.00
Finchaa	Finchaa	Irrigation	25,878	8,936	2,006	4.45 to 1.00
		Power	74,590	16,400	5,367	3.06 to 1.00
	Amarti-Neshe	Irrigation	29,055	5,062	1,974	2.56 to 1.00
		Power	109,518	17,110	7,341	2.33 to 1.00
Diddessa	Arjo-Diddessa	Irrigation	94,390	8,685	5,742	1.51 to 1.00
		Power	86,302	14,908	5,459	2.73 to 1.00
	Dabana	Irrigation	59,812	3,264	3,511	0.93 to 1.00
		Power	345,852	20,173	21,603	0.93 to 1.00
	Angar	Irrigation	203,523	16,316	15,045	1.08 to 1.00
		Power	358,466	56,879	22,862	2.49 to 1.00
Dindir-Rahad	Dindir	Irrigation	380,473	30,173	24,323	1.24 to 1.00
		Power	153,740	10,870	9,222	1.18 to 1.00

1/Capital cost includes construction, interest during construction, and for irrigation purpose land development.