Land and Water Resources of the Blue Nile Basin

Ethiopia

APPENDIX V - POWER

Prepared for the Department of State
Agency for International Development

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

LAND AND WATER RESOURCES OF THE BLUE NILE BASIN

ETHIOPIA

APPENDIX V - POWER

United States
Department of the Interior

Bureau of Reclamation

Frontispiece--Blue Nile River Basin, Plan of Development, Irrigation and Power Projects.

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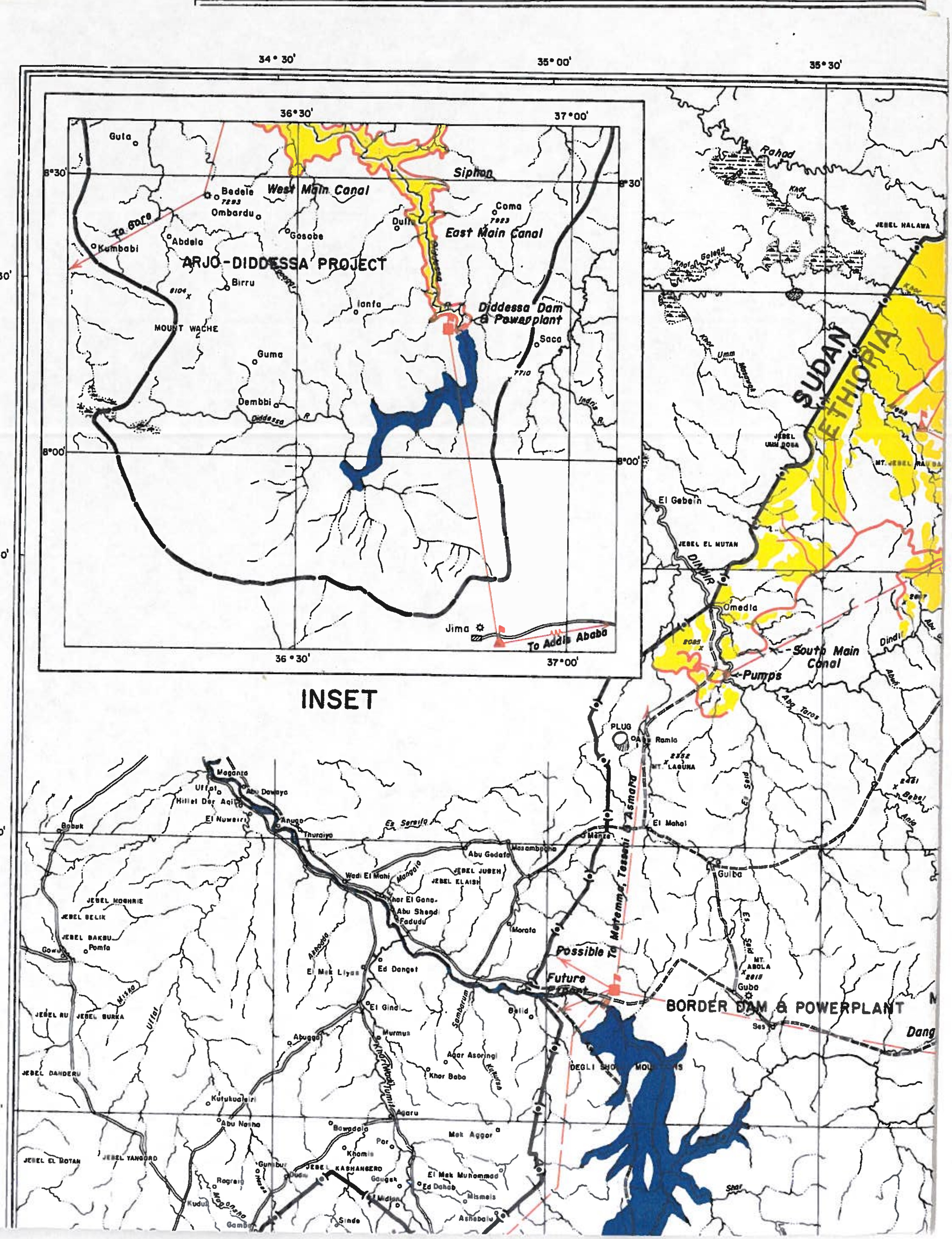
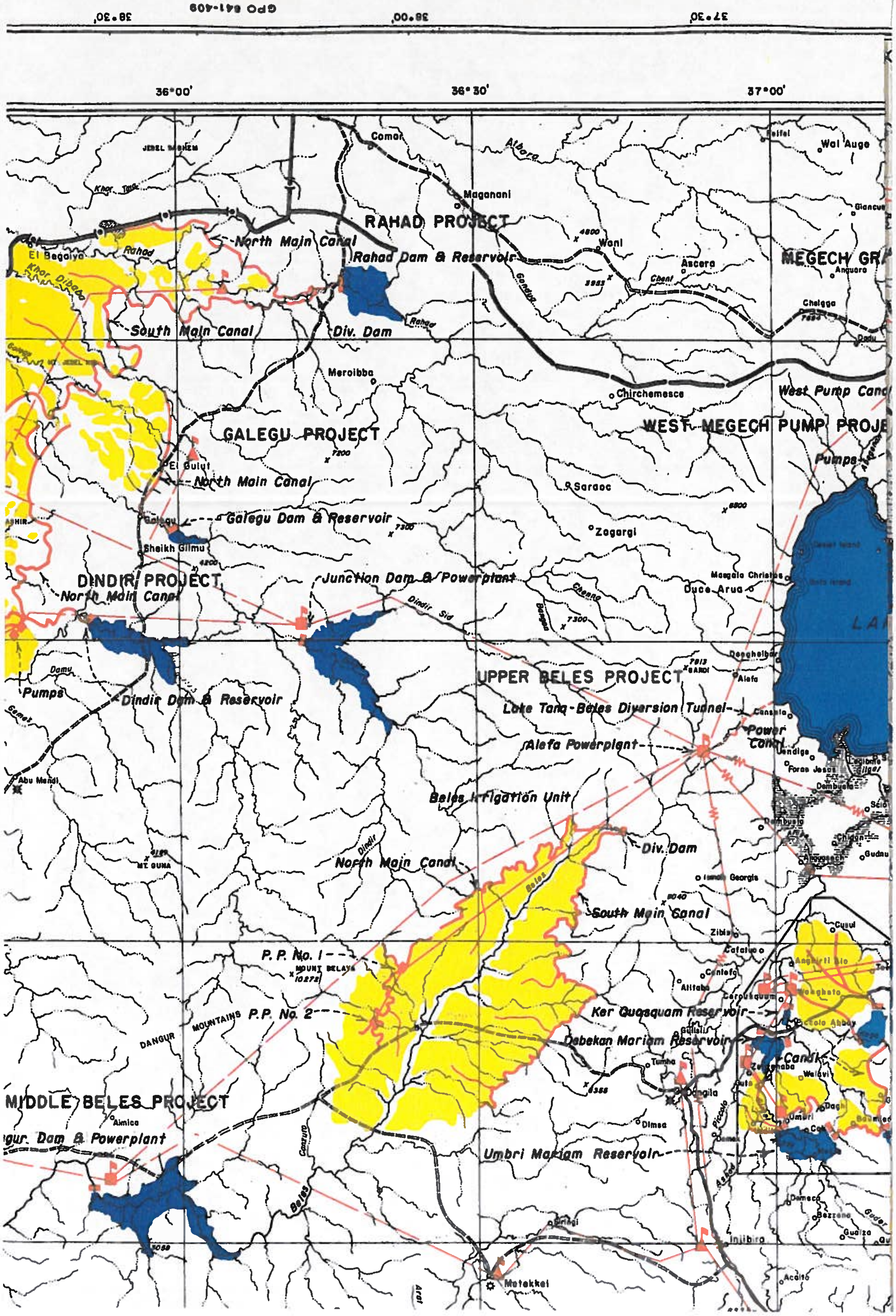
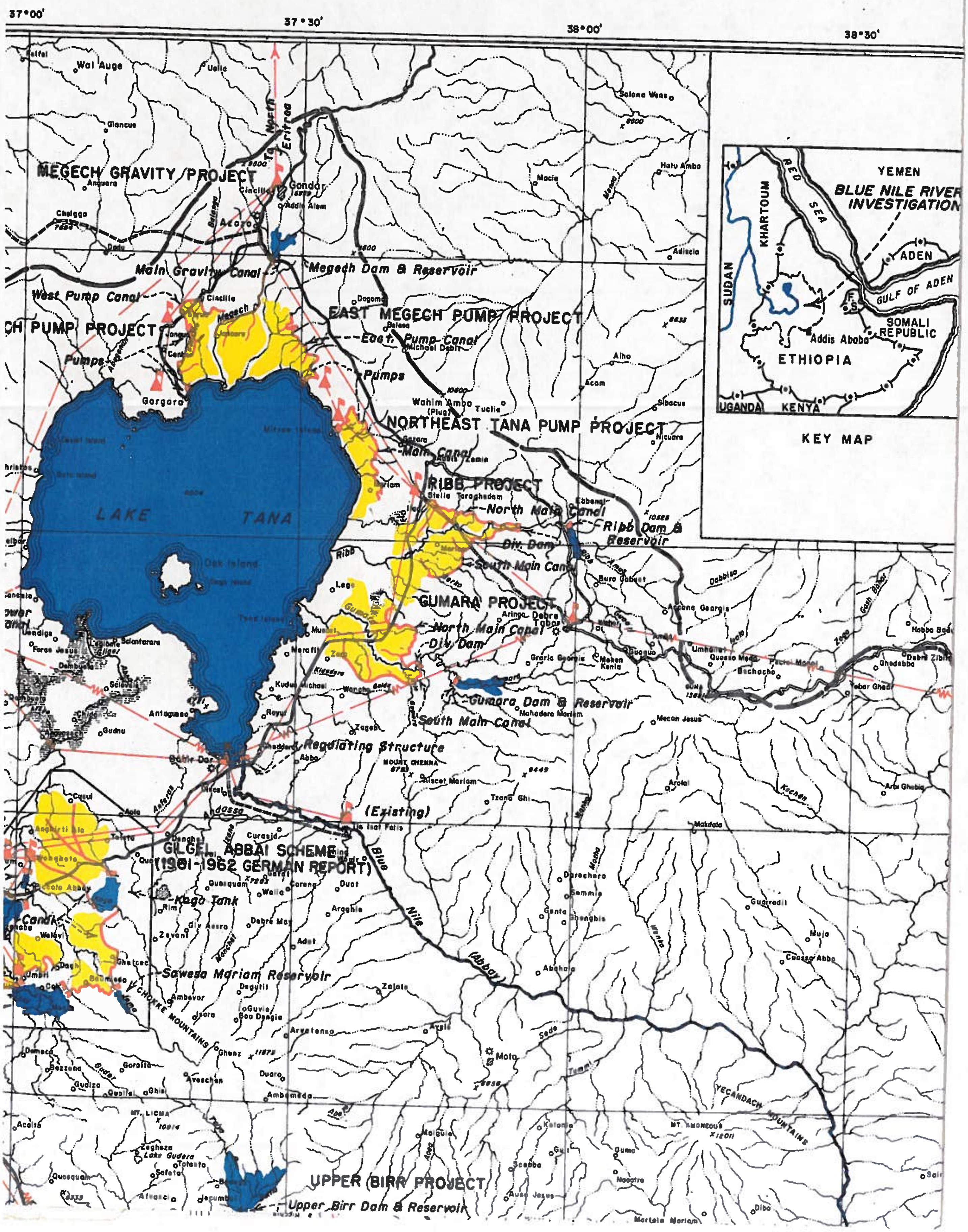


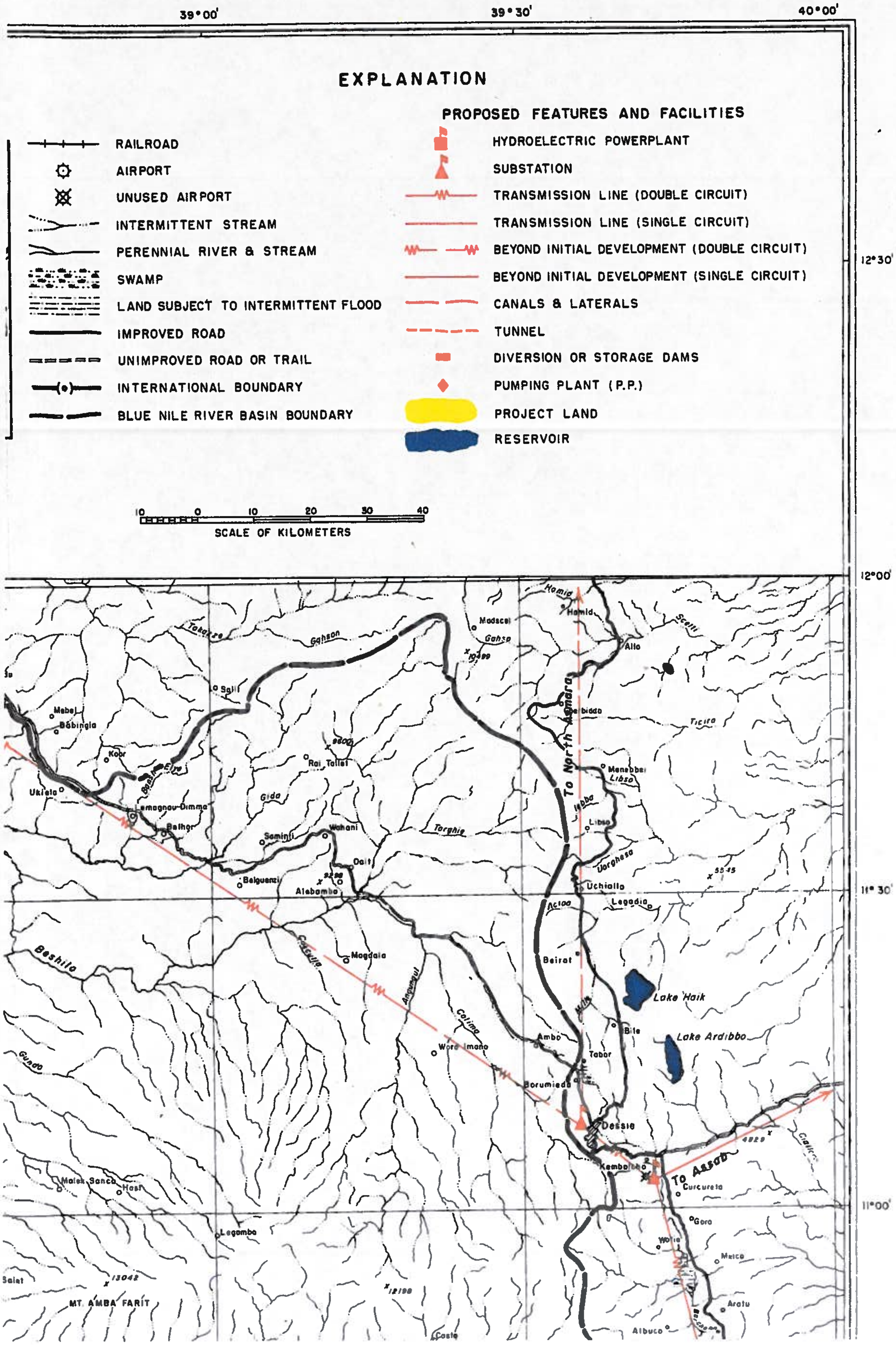


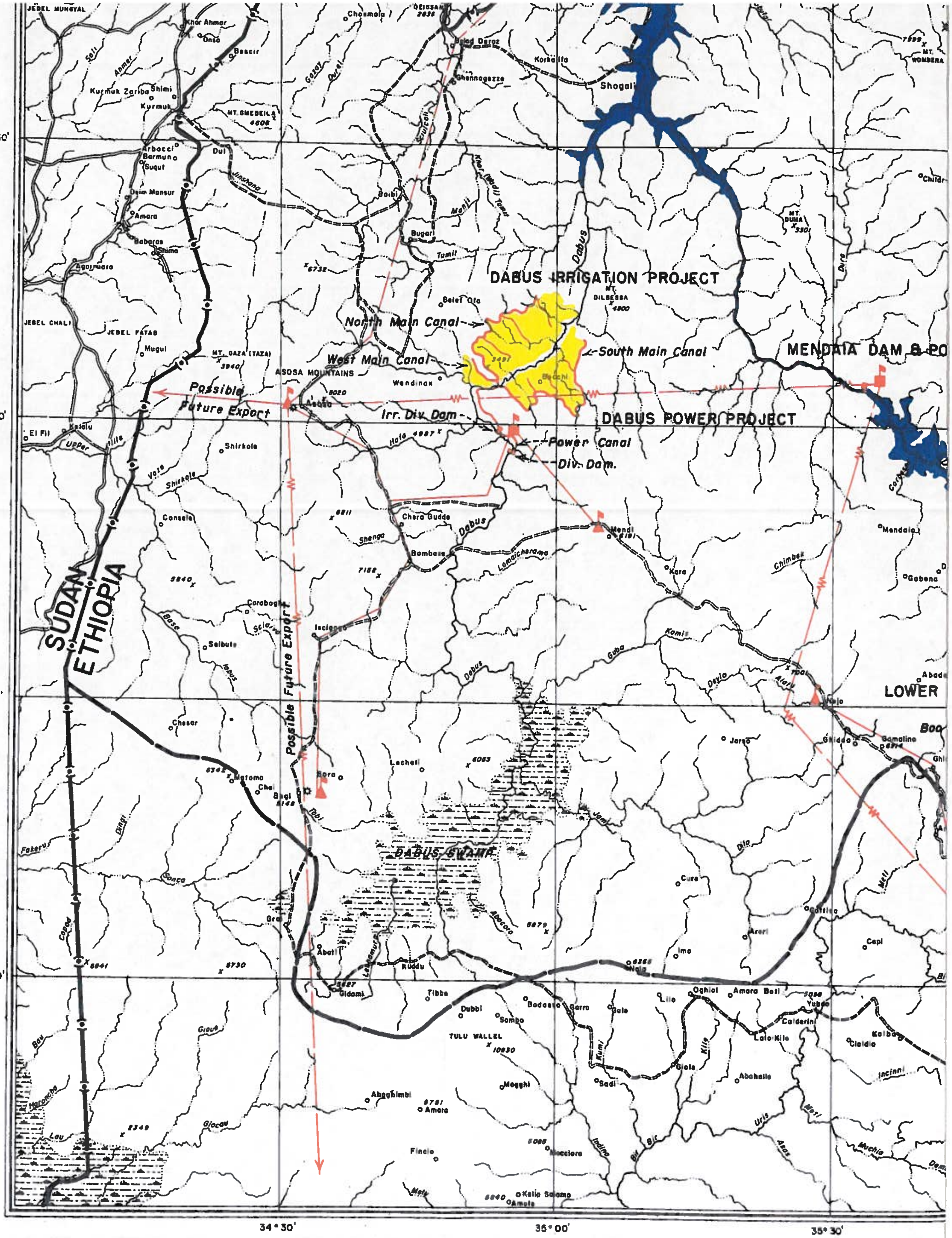
36°00'
36°30'
37°00'
Comor
Albara
Maganani
RAHAD PROJECT
North Main Canal
El Begaiya
Rahad
Khor Dibaba
Rahad Dam & Reservoir
South Main Canal
Div. Dam
Woni
Ascera
MEGECH GR
Chelgga
Meroibba
Chirchemesce
West Pump Canal
WEST MEGECH PUMP PROJE
GALEGU PROJECT
El Guiut
North Main Canal
Galegu Dam & Reservoir
Sheikh Gilmu
Pumps
Saraoc
Zagargi
DINDIR PROJECT
North Main Canal
Junction Dam & Powerplant
Dindir Sid
Duca Arua
Pumps
Dindir Dam & Reservoir
UPPER BELES PROJECT
Lake Tana-Beles Diversion Tunnel
Power Canal
Alefa Powerplant
Abu Mendi
Beles Irrigation Unit
Div. Dam
North Main Canal
South Main Canal
MT. GUNA
P. P. No. 1
MOUNT BELAYA
DANGUR MOUNTAINS
P. P. No. 2
Ker Quasquam Reservoir
Debekan Mariam Reservoir
MIDDLE BELES PROJECT
Aimica
gur. Dam & Powerplant
Umbri Mariam Reservoir
Dangila
Injibira
Metekkel

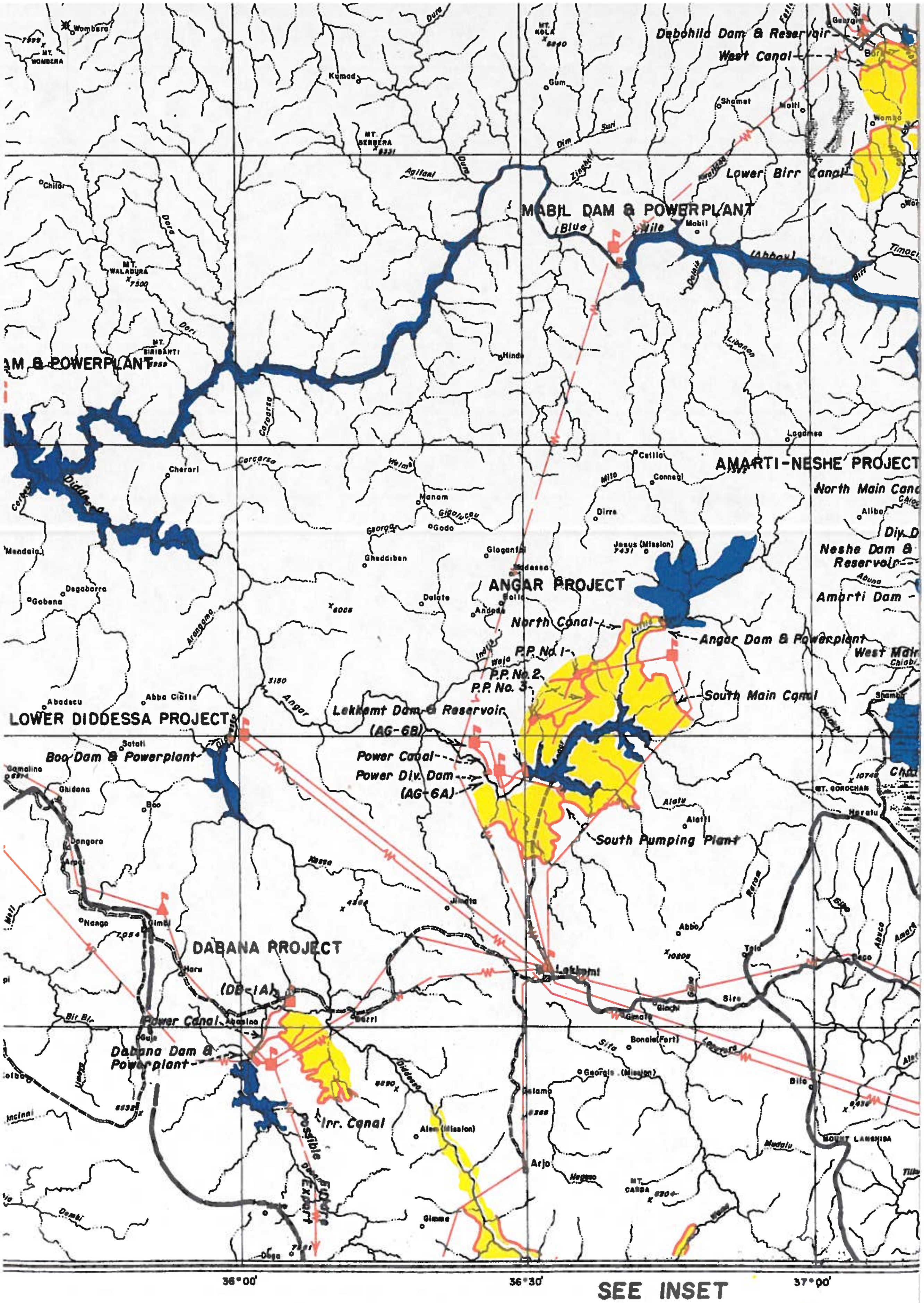


37°00'
37°30'
38°00'
38°30'
MEGECH GRAVITY PROJECT
Gondar
Main Gravity Canal
Megech Dam & Reservoir
West Pump Canal
CH PUMP PROJECT
EAST MEGECH PUMP PROJECT
East Pump Canal
Pumps
NORTHEAST TANA PUMP PROJECT
Main Canal
RIBB PROJECT
North Main Canal
Ribb Dam & Reservoir
Div. Dam
South Main Canal
LAKE TANA
GUMARA PROJECT
North Main Canal
Div. Dam
Gumara Dam & Reservoir
South Main Canal
Regulating Structure
(Existing)
Bahir Dar
GILGEL ABBAI SCHEME
(1961-1962 GERMAN REPORT)
Koga Tank
Sawesa Mariam Reservoir
CHOKKE MOUNTAINS
Blue Nile (Abbay)
YECANDACH MOUNTAINS
UPPER BIRR PROJECT
Upper Birr Dam & Reservoir
YEMEN
RED SEA
BLUE NILE RIVER INVESTIGATION
KHARTOUM
SUDAN
ADEN
GULF OF ADEN
SOMALI REPUBLIC
Addis Ababa
ETHIOPIA
UGANDA
KENYA
KEY MAP

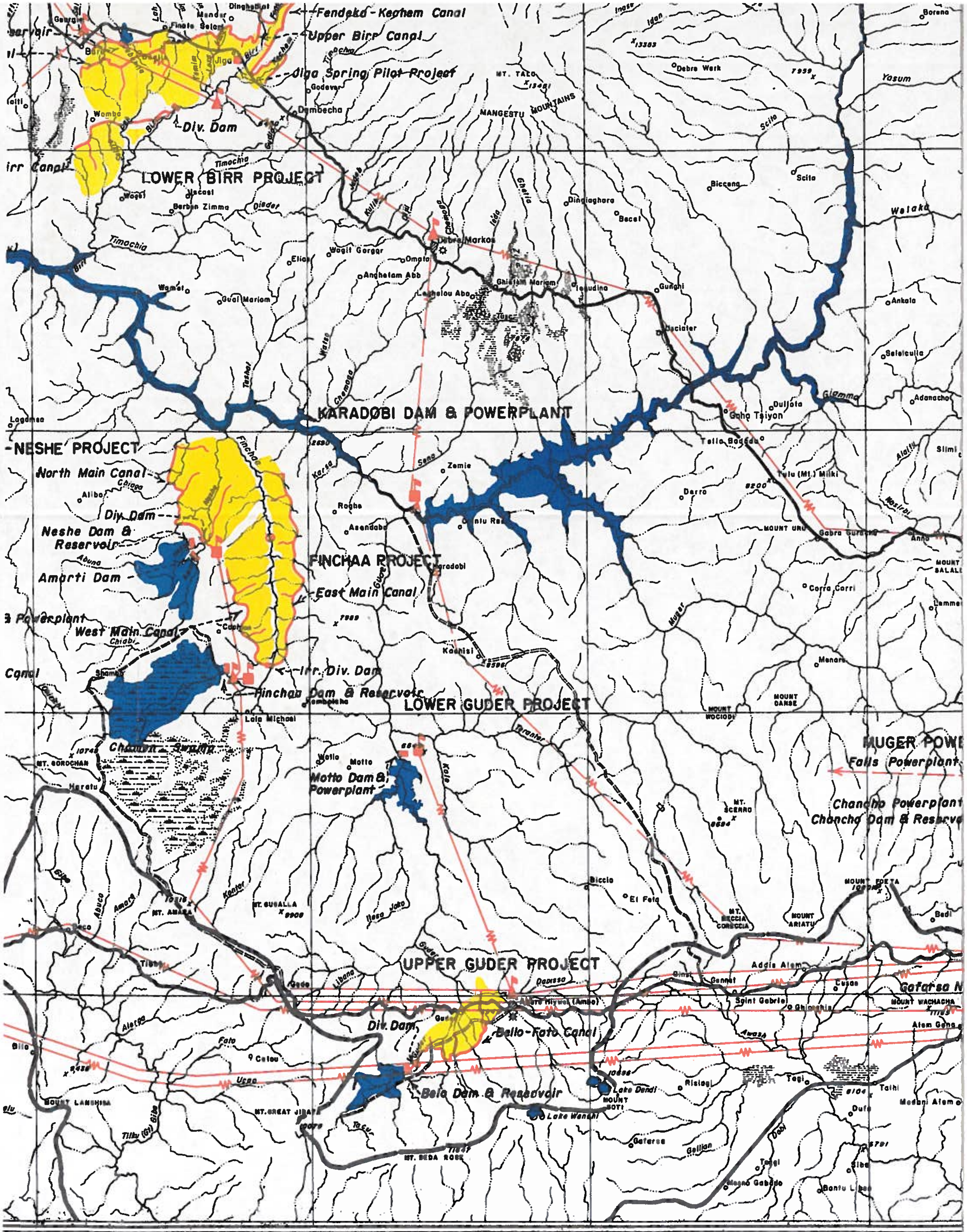
Frontispiece--Blue Nile River Basin, Plan of Development, Irrigation and Power Projects




DABUS IRRIGATION PROJECT
North Main Canal
West Main Canal
South Main Canal
Irr. Div. Dam
DABUS POWER PROJECT
Power Canal
Div. Dam.
MENDAIA DAM & PO
LOWER
Possible Future Export
Possible Future Export
ASOSA MOUNTAINS
DABUS SWAMP
SUDAN
ETHIOPIA
Dabus
Asosa
Mendi
Bombasa
Chera Gudde
Kurmuk
Shogali
TULU WALLEL
10° 30'
10° 00'
9° 30'
9° 00'
34° 30'
35° 00'
35° 30'

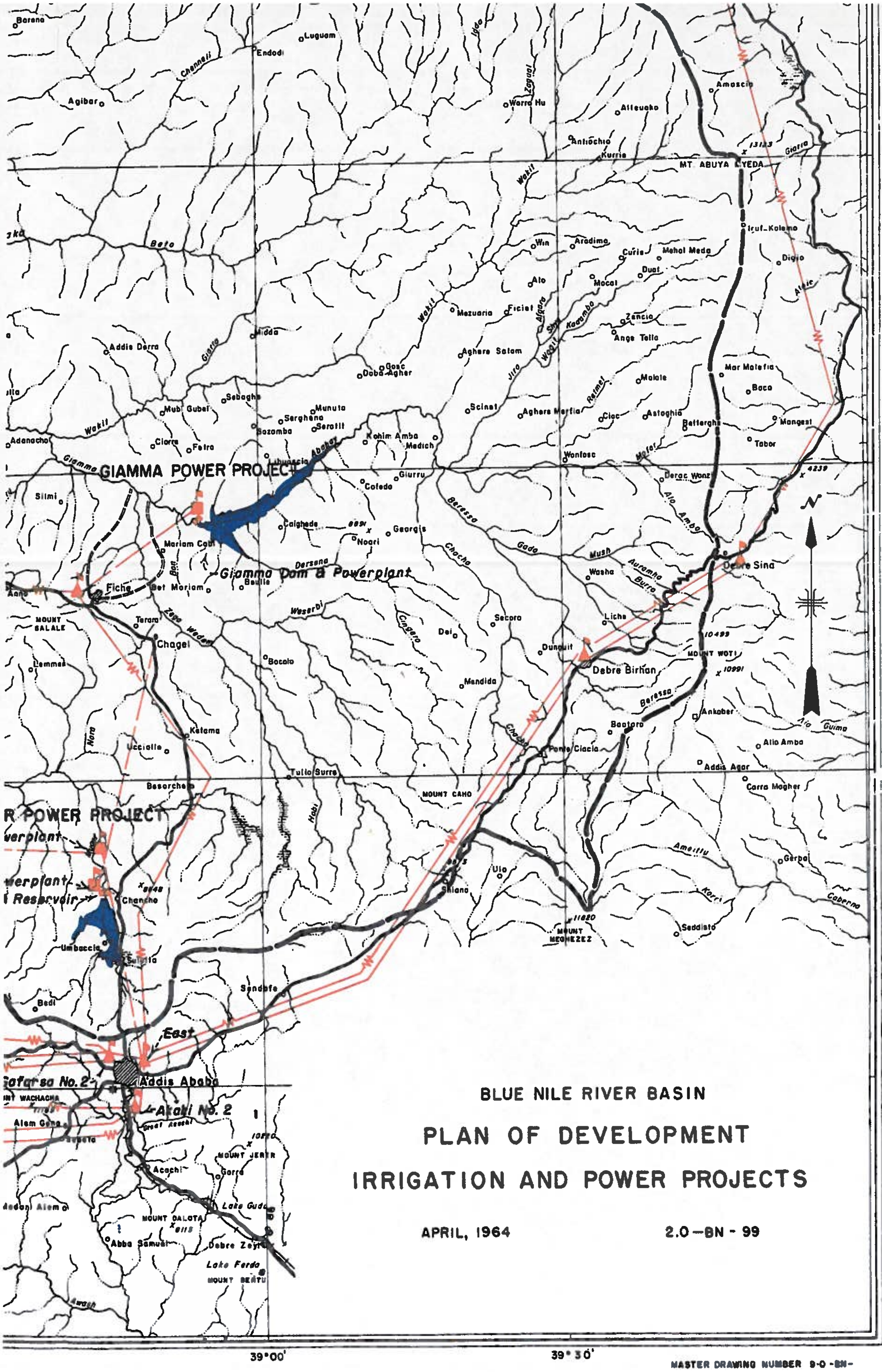


Debohila Dam & Reservoir
West Canal
Lower Birr Canal
MABIL DAM & POWERPLANT
Blue Nile (Abbay)
Mabil
AM & POWERPLANT
AMARTI-NESHE PROJECT
North Main Canal
Neshe Dam & Reservoir
Amarti Dam
ANGAR PROJECT
North Canal
Angar Dam & Powerplant
West Main
P.P. No. 1
P.P. No. 2
P.P. No. 3
South Main Canal
Lekkemt Dam & Reservoir
(AG-6B)
Power Canal
Power Div. Dam
(AG-6A)
South Pumping Plant
LOWER DIDDESSA PROJECT
Boo Dam & Powerplant
Diddessa
Angar
DABANA PROJECT
(DB-1A)
Power Canal
Dabana Dam & Powerplant
Irr. Canal
Possible Future Export
Lekkemt
Arjo
Gimbi
36°00'
36°30'
SEE INSET
37°00'



Fendeka - Kecham Canal
Upper Birr Canal
Jiga Spring Pilot Project
Div. Dam
LOWER BIRR PROJECT
MANGESTU MOUNTAINS
MT. TALO
Debre Markos
KARADOBI DAM & POWERPLANT
NESHE PROJECT
North Main Canal
Div. Dam
Neshe Dam & Reservoir
Amarti Dam
FINCHAA PROJECT
East Main Canal
West Main Canal
Irr. Div. Dam
Finchaa Dam & Reservoir
LOWER GUDER PROJECT
Motto Dam & Powerplant
MUGER POWE
Falls Powerplant
Chancho Powerplant
Chancho Dam & Reserve
UPPER GUDER PROJECT
Div. Dam
Bello-Fato Canal
Belo Dam & Reservoir
Lake Dendi
Lake Wenchi
Ambo Hiywet (Ambo)
Addis Alem
Gafarsa N
Muger
Guder
Awash
Birr
Finchaa
Giamma
37°00'
37°30'
38°00'
38°30'

GPO 841-409



Frontispiece--Blue Nile River Basin, Plan of Development, Irrigation and Power Projects.

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ANNEX "B"

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:

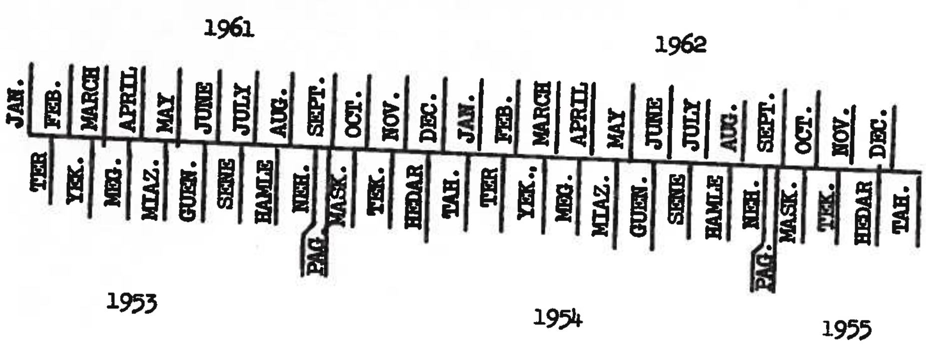
Centigrade: $C. = \frac{5}{9}(F° - 32)$ Fahrenheit: $F. = \frac{9}{5}C° + 32$

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

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

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

UNITED STATES OR GREGORIAN CALENDAR



ETHIOPIAN CALENDAR

TRANSLITERATION

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

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

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

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

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

GLOSSARY OF TECHNICAL TERMS

Angle Tower - An angle tower is employed where the line changes horizontal direction sufficiently to require special design of the tower to withstand the resultant pull of the wires and to provide adequate clearance.

Autotransformer - In an autotransformer part of the winding is common to both the primary and the secondary circuits.

Base Load - The minimum load over a given period of time. A generator operating on base load is set at a fixed output, with other generators on automatic control to take up the variations of load.

Connected Load - The connected load on a system, or part of a system under consideration, is the sum of the continuous ratings of the load-consuming apparatus connected to the system.

Continuous Power - Hydroelectric power available from a plant on a continuous basis for under the most adverse hydraulic conditions contemplated.

Corona - Corona is a luminous discharge due to ionization of the air surrounding a conductor around which exists a voltage gradient exceeding a certain critical value.

Dead-End Tower - A dead-end tower is designed to withstand, together with wind and vertical loads, unbalanced pull from all of the conductors in one direction.

Diversity Factor - Power intended to have assured availability to the customer to meet his load requirements.

Electric Power Substation - An electric power substation is an assemblage of equipment for purposes other than generation or utilization, through which electric energy in bulk is passed for the purpose of switching or modifying its characteristics. Service equipment, distribution transformer installations, or other minor distribution or transmission equipment are not classified as substations.

Note: A substation is of such size or complexity as to incorporate one or more buses, several circuit breakers, and is usually either the sole receiving point common to more than one supply circuit, or sectionalizes the transmission circuits passing through it by means of circuit breakers.

Electrolysis - Electrolysis is the production of chemical changes by the passage of current through an electrolyte.

Firm Power - Power intended to have assured availability to the customer to meet his load requirements.

Ground (Earth) - A ground is a conducting connection, whether intentional or accidental, between an electric circuit or equipment and the earth or some conducting body which serves in place of the earth.

Load Curve - Load curve is power plotted vs. time, showing the value of a specific load for each unit of the period covered.

Load Diversity - Load diversity is the difference between the sum of the demands of two or more individual loads and their coincident maximum demand.

Load Duration Curve - The load duration curve shows the total time, within a specified period, during which the load equalled or exceeded the power values shown.

Load Factor - Load factor is the ratio of the average load over a designated period of time to the peak load occurring in that period.

Loss Factor - The loss factor is the ratio of the average power loss to the peak load power loss, during a specified period of time.

Maximum Demand - The maximum demand of an installation or system is the greatest of all the demands which have occurred during a given period of time.

Note: The maximum demand is determined by measurement, according to specification, over a definitely prescribed time interval.

National Grid - An interconnected power system consisting fundamentally of two or more power systems made up of powerplants, transmission lines, and distribution systems connected together by strong tie lines. The composite system usually extends over a large area and may include both steam and hydro-electric power generation.

Peak Load - The maximum load produced or consumed in a stated period of time, such as hourly, daily, etc.

Phase Conductor - The phase conductors of a polyphase circuit are those conductors other than the neutral conductor.

Plant Factor (Plant Capacity Factor) - The plant factor is the ratio of the average load on the plant, for the period of time considered, to the aggregate rating of all the generating equipment installed in the plant.

Pole - A pole is a column of wood or steel or a similar structure of some other material supporting overhead conductors, usually by means of arms or brackets, span wires, or bridges.

Note: Broad-base lattice steel supporting structures are often known as "towers"; narrow-base steel supporting structures are often known as "masts."

Power Factor - The cosine of the angle by which the current leads or lags the voltage.

System Interconnection - In system interconnection, two or more power systems are connected together.

Three-Phase Three-Wire System - In a three-phase three-wire system, an alternating current is supplied to three conductors, between successive pairs of which are maintained alternating differences of potential successively displaced in phase by one-third of a period.

Three-Phase Four-Wire System - A three-phase four-wire alternating-current system comprising four conductors, three of which are connected as in a three-phase three-wire system and the fourth is connected to the neutral point of the supply, which may be grounded.

Voltage Drop (in a supply system) - Voltage drop in a supply system is the difference between the voltages at the transmitting and receiving ends of a feeder, main, or service.

With alternating current the voltages are not necessarily in phase, hence the voltage drop is not necessarily equal to the algebraic sum of the voltage drops along the several conductors.

Wye-Connected Circuit - A wye-connected circuit is a polyphase circuit in which all the current paths within the region that delimits the circuit extend from each of the points of entry of the phase conductors to a common conductor (which may be the neutral conductor).

Megawatt - One thousand kilowatts.

SECTION I--INTRODUCTION

OBJECTIVES

Among the objectives of the reconnaissance study of the Blue Nile River Basin, Ethiopia, were a basic plan for over-all development of the basin within Ethiopia supported by requisite surveys, and analysis of and recommendations for several projects for potential development out of the total that might be noted within the basin.

In support of these objectives, this appendix provides the following information:

1. Presentation of brief background information leading up to the present study.
2. The potential hydroelectric power resources with inventory for the Blue Nile River Basin, Ethiopia.
3. The influencing factors affecting the power market analysis of Ethiopia and its Blue Nile River Basin.
4. An analysis of past, present, and estimated future power requirements.
5. A selection of specific hydroelectric power sites as part of one basic plan of several possibilities for over-all development of an electric power system capable of serving Ethiopia's future power requirements. The use of Blue Nile River Basin inventoried sites to meet maximum future deficiencies is emphasized.
6. A suggested electric transmission system for integrating certain Blue Nile River Basin powerplants.
7. An analysis of costs relating to the selected plants recommended for possible future development to meet the load requirements to the year 2000.
8. Power costs of alternative sources and a discussion of power benefits.
9. Recommendations concerning administration and operation of the expanded electric power system.

BACKGROUND

An insight into the magnitude and degree of electrification of a country is helpful when considering some aspect of the power supply problem. In 1954 Ethiopia had about the lowest per capita electrical energy production in Africa--about 3 kw.-hr. per capita. In 1961 this had doubled to about 6 kw.-hr. and by 1965 should again double to about 12 kw.-hr. For Africa as a whole in 1954 production amounted to something over

100 kw.-hr. per capita 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. Figure V-1 illustrates this trend and shows the production for Ethiopia increasing to around 70 kw.-hr. per capita by 1980. Figure V-2 shows the world power data for 1961 for the more advanced countries, led by Norway, Canada, Sweden, and the United States in that order.

Ethiopia, whose economy depends almost entirely upon generally subsistence agriculture, has had little need for electrical energy in the past. Most surplus agricultural products were exported directly with little processing; and electrical energy was not needed for processing those commodities consumed domestically.

There has been an awareness in Ethiopia that to raise the standard of living would require a gradual shift from an agricultural economy to one which processes agricultural surpluses for foreign export as well as the development of other basic light and heavy industries. This will require substantial quantities of energy, but because Ethiopia is poor in all sources of energy except for hydroelectric power, emphasis has been placed on hydro developments in recent years.

Prior investigations of hydro possibilities in certain areas of the Blue Nile River Basin attracted early interest. Some of the data obtained, regardless of the time, purpose, and intent of the investigations, have proven to be useful for present-day hydroelectric studies.

Comprehensive investigation of the resources of all of the Blue Nile River had not been made before the investigation conducted jointly by the U.S. Bureau of Reclamation and the Water Resources Department of the Imperial Ethiopian Government from 1958 to 1963. A number of investigations, studies, field reconnaissance expeditions, and opinions based upon field data obtained by others have been written during the past 40 to 60 years.

Some of the early investigations and reports were not specifically concerned with hydroelectric power generation, but with storage and regulation of water flows to meet deficient supplies for irrigation downstream beyond the Ethiopian-Sudanese international boundary. The studies and conclusions reached are of interest in that any reservoir developed on the Blue Nile River within Ethiopia would have been solely for hydroelectric power production, and any early study made of Lake Tana as a storage reservoir at the headwaters of the Blue Nile is of importance from the hydroelectric viewpoint. This is especially pertinent as the hydroelectric power resulting from the water regulation that could be provided by the use of Lake Tana as a reservoir is important whether Lake Tana water is allowed to continue its natural flow into the Blue Nile River or whether a portion of the water is diverted to an adjacent watershed.

The scheme advanced in early investigations for diverting water from Lake Tana to the west by means of tunnels under the watershed is of particular importance now in view of the foreseeable need for hydroelectric power production.

The sequence of historical events concerning prior investigations of certain Blue Nile River Basin areas may be of interest.

<u>1902</u>. In 1902 the Egyptian government was authorized by H.I.M. Emperor Menelik to dispatch an expedition, which was led by C. E. Dupuis, "to visit and collect all possible information concerning Lake Tana in Abyssinia with a view of deciding whether it could be effectively utilized as a reservoir for the Nile should such a proposal ever come within the range of practical politics." The results of Mr. Dupuis' visit were embodied in his <u>Note on Lake Tana and the Possibilities of its Utilization as a Reservoir</u>, published in 1904 as an appendix to Sir William Garstin's historic <u>Report on the Basin of the Upper Nile</u>.

Sir William thought it improbable that, due to the very heavy fall in the riverbed levels, large reservoir sites on the Blue Nile River could be found. He thought it would be impossible to store water during floods due to the heavy silt deposits, and storage would be limited to the period following the floods when silt deposits would be low.

<u>1915</u>. Twelve years later, the matter again came under consideration; and in 1915, diplomatic negotiations resulted in the dispatch of a joint Egyptian, Sudanese, and Ethiopian Commission to make further studies of Lake Tana. The party was led by

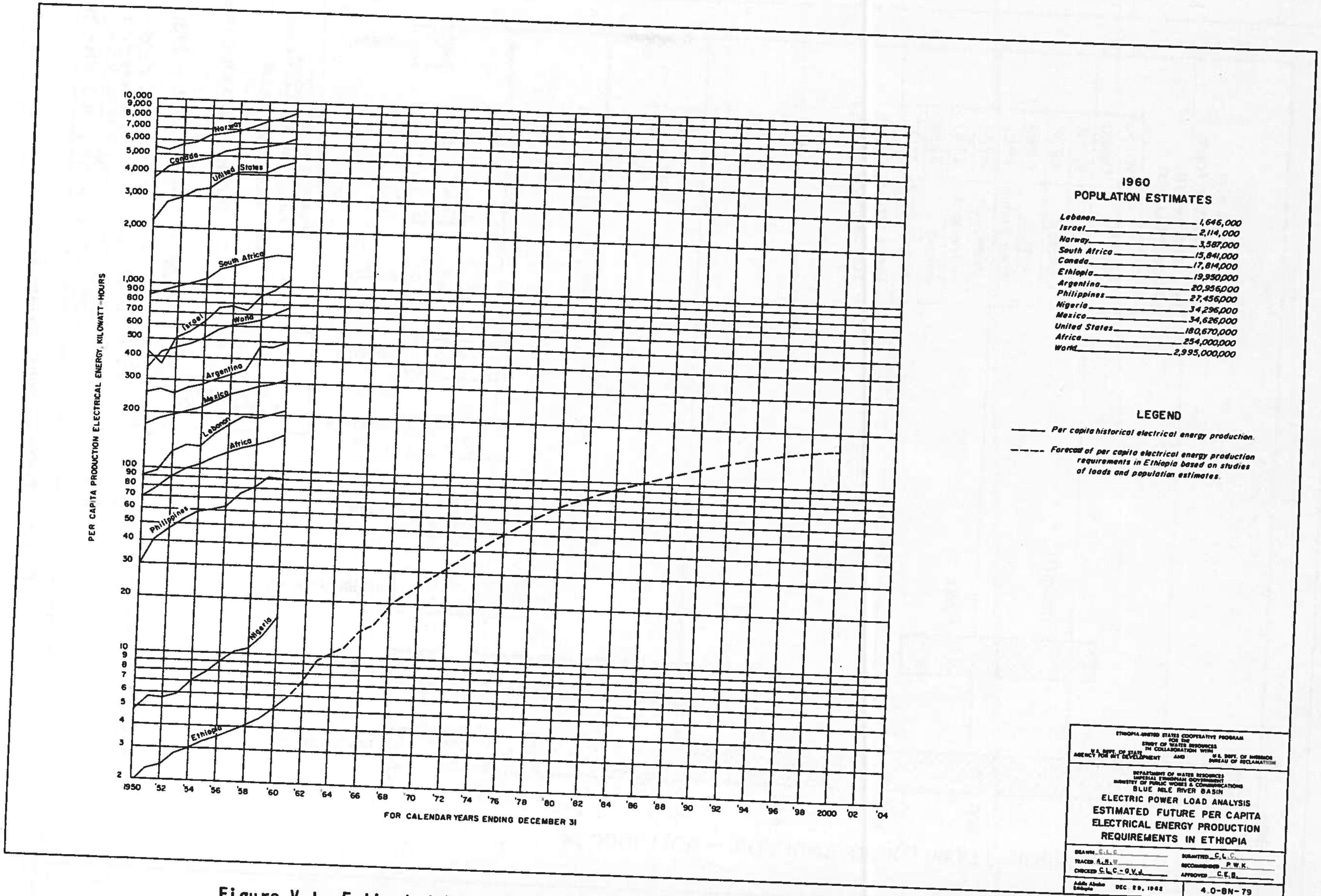


Figure V-1--Estimated Future per Capita Electrical Energy Production Requirements in Ethiopia

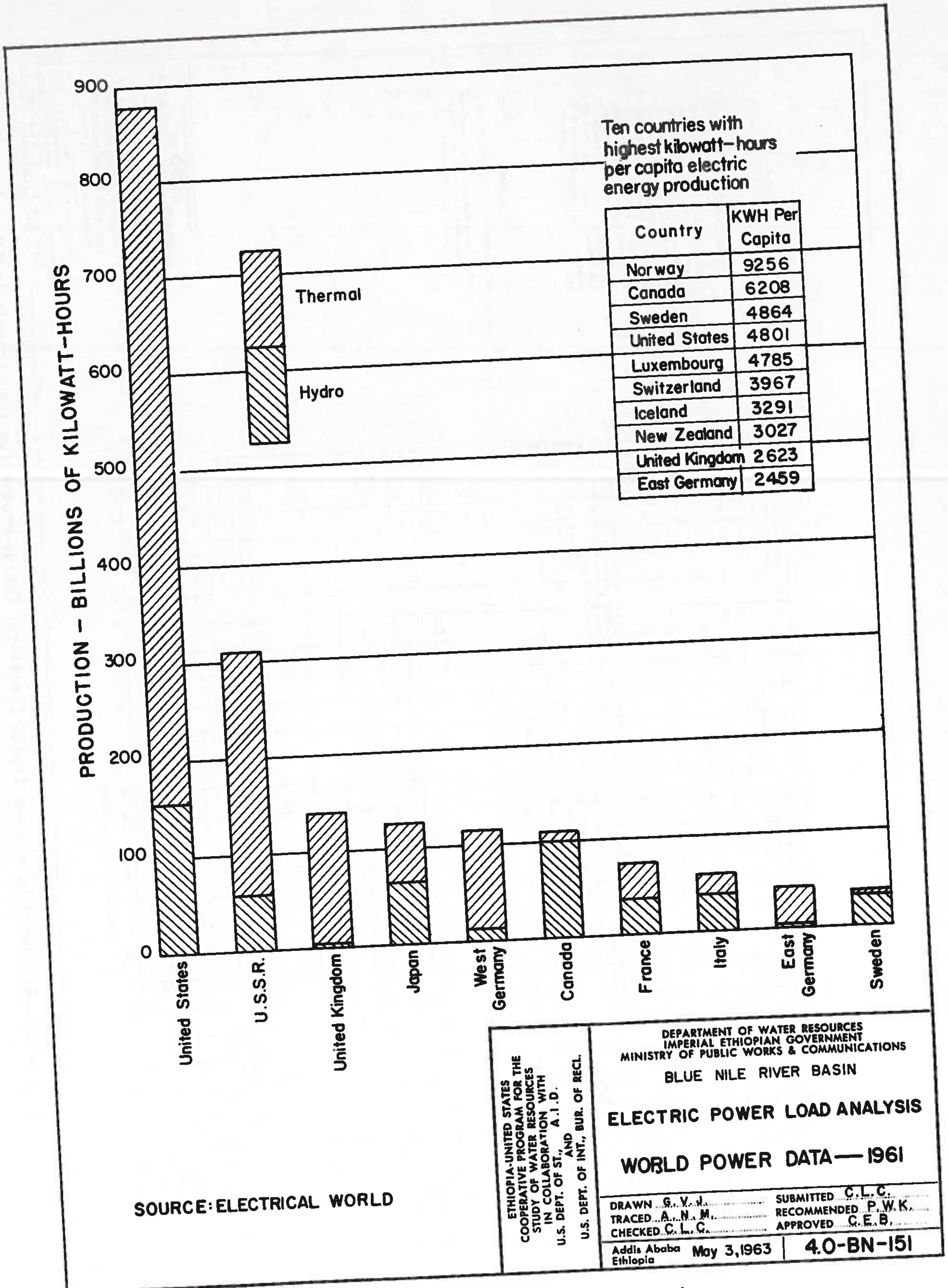


Figure V-2--World Power Data--1961

Col. H. D. Pearson, Director of the Sudan Survey Department, A. Burton Buckley being loaned by the Ministry of Public Works to supervise the hydrographical work. Political turmoil in Ethiopia interfered with the work, and no discharge measurements were permitted at the outlet.

1920. Five years later, in early 1920, it was arranged for the Egyptian Ministry of Public Works to send another mission to make further studies of the lake. G. W. Grabham and R. P. Black were to lead this mission. Instructions were to obtain as much information as possible about the nature and conditions of the lake and its outlet, the levels and volume of water available, and generally to collect all data having a bearing on the regulation of the Lake Tana waters.

1926-1929. Major Cheesman was the British Consul in northwestern Ethiopia from 1925-1934, and during the periods 1926-27 and 1928-29, he followed the Blue Nile River from its source at Lake Tana for most of its length to its mouth, but did miss two loops of the river. This was the first recorded expedition to follow the Blue Nile River in Ethiopia for most of its length.

Major Cheesman located only two possible reservoir sites on the entire length of the Blue Nile River in Ethiopia and, in his estimation, even these did not represent natural sites of outstanding suitability. He felt that reservoirs at these points would collect large quantities of silt and, in this respect, were inferior to Lake Tana as storage reservoirs. The two sites he selected were a site upstream from Castanio's bridge at the confluence of Guder and Blue Nile Rivers (according to Cheesman this was 100 miles from Addis Ababa in a river bend nearest to that city. This appears to be site BN-3 as discussed in Section II.); and the Yaringhe Hill site near the Sudan border. (This appears to be site BN-27.) The river cuts a groove between two hills--the Yaringhe Hill on the right bank and another hill on the left bank.

He reached the following conclusions as a result of his explorations:

1. There are no lakes on the Blue Nile but Lake Tana.
2. There are no falls except Tis Isat.
3. There are no lands along the Blue Nile River that can be irrigated.
4. There were two possible storage sites, neither of which was considered good, but which engineers in the future might study with some chance of success.

1927-1931. In 1927, His Majesty King Tafari Makonnen (later to become H. I. M Haile Selassie I) sent a special representative to the United States with instructions to call upon President Calvin Coolidge and ask that the United States send a diplomatic representative to Ethiopia. He urged that teachers, physicians, and engineers also come to Ethiopia and cooperate with the government in assisting Ethiopia to take its proper place in the modern world. The J. G. White Engineering Corporation, New York City, was invited to submit plans for the construction of the control works on the Blue Nile at Lake Tana and for a highway between Addis Ababa and Lake Tana. Conferences in 1930, involving the corporation, a representative of the British Sudan government, and the Ethiopian government, were held with the conclusion that a reconnaissance report by the corporation would first be required. In addition to surveying the outlet of Lake Tana for the control works, the J. G. White Engineering Corporation also made field surveys as to a suggested route for an electric power transmission line from Tis Isat Falls to the outlet of Lake Tana. The purpose of such a transmission line was to transfer electric power to the lake outlet for construction purposes. Field work was completed in 1930 and the report published in 1931.

1933-1935. Following the publication of the 1930-31 report of the J. G. White Corporation's expedition, a conference was held in 1933 in Addis Ababa with the Ethiopian government, representatives of Sudan, Egypt, and the corporation participating. The outcome of the conference was that the J. G. White Corporation was to obtain further data in Ethiopia on a different proposal for the construction of a dam at the Lake Tana outlet. Field work was started in 1933, completed in 1934, and the report published in 1935.

1935-1942. During the Italian occupation, which began in 1935 and lasted until 1942, further investigations were carried on by the Italians with several expeditions made to various areas of Ethiopia to gather information. One scientific expedition to Lake Tana was initiated in 1937 and culminated in a comprehensive report of several volumes published in 1940. This was conducted by the Reale Accademia d'Italia which organized the Missione Di Studio Al Lago Tana.

Engineering Problems in Colonial Territories, by L. Pontecorvo, was published in Rome in 1938 and provides a good summary of the physiological characteristics of the Blue Nile River Basin and its comparison with other river basins in Ethiopia. This publication generally reaches conclusions based upon field data obtained by others. In one of the studies made by Pontecorvo, a dam was proposed on the Diddessa River as well as three reservoirs on the Blue Nile. The first was planned within the 210- to 270-kilometer reach of the Blue Nile River, measured from the mouth of Lake Tana, with a proposed storage capacity of two billion cubic meters.1/ This location apparently would correspond to site BN-17.2/ The second reservoir would lie within the 340- to 430-kilometer reach of the river and could store one million cubic meters. It appears to be site BN-18. The lowest reservoir would fall within the 793- to 810-kilometer reach of the Blue Nile and would store 400 million cubic meters and apparently corresponds to site BN-24. In all three projects, Pontecorvo reasoned that dams 30 meters or more in height would be necessary. He further recommended that Lake Tana water be diverted to the Beles River through the adjacent western watershed by means of a tunnel 6 to 8 kilometers in length. A central hydroelectric power station, capable of producing a continuous power output of 660,000 kilowatts, would be located at the outlet of the tunnel, and he reasoned that the major quantity of power could be used to make nitrogenous products. Under this plan, water would first be used for producing power and then for irrigation downstream, both in Ethiopia and Sudan. Pontecorvo noted that because the Beles River joins the Blue Nile downstream within Ethiopia, this plan provided a course 400 kilometers shorter, and thus would reduce evaporation loss by 60 percent.

A publication in Rome in 1936 by Cesari and Testa, Information about the Possibility of using Hydro-electric Power Sources in East Africa, provides an analysis of the hydroelectric potential of the Blue Nile River Basin, particularly possibilities for development between Lake Tana and the Tvol River junction. Between the Lake Tana outlet and the confluence of the Tvol River with the Blue Nile River, three schemes for the utilization of hydroelectric power were proposed by these engineers. Scheme A called for a canal on the right bank with two or three powerplants installed along the canal down to Tis Isat Falls, providing a total power head of about 110 meters. About 12 kilometers of canal would be required. Scheme B called for a canal on the left bank, resulting in one powerplant at the falls. The canal would be 12 kilometers long providing a power head of about 110 meters. Scheme C called for a canal on the right bank with the first powerplant below Arafami Falls. The drop would be about 30 meters, and the canal would be about 3 kilometers long. Then, a small dam downstream from the Arafami Falls would back water at 1810 meters elevation. A second canal on the left bank, extending downstream to Tis Isat Falls, with a length of about 7 kilometers, would then be required. The second powerplant would be at Tis Isat with a head of about 80 meters. In each of the three schemes, there is another powerplant at the confluence of the Tvol and Blue Nile Rivers. See Figure V-3. The two engineers thought the more important suitable sites were that near Lake Tana noted above and the other between Shafartak and Zemie, probably one of those identified as BN-1, BN-2, BN-3, or BN-4.

1946. Messrs. Hurst, Black, and Simaika of the Ministry of Public Works, Egypt, in 1946 released Volume VII of a series on the Nile Basin, The Future Conservation of the Nile. This report was reprinted in 1951 in Cairo and emphasized the importance of new storage works in the Nile system, which included an "over-year" storage reservoir at Lake Tana. This project would be a joint effort for the benefit of Sudan and Egypt, and if combined with hydroelectric power schemes would also be of benefit to Ethiopia. The proposal was to convert Lake Tana into a reservoir by a low dam at the outlet of the lake. It was noted that Tis Isat Falls would be suitable for a power scheme, since there is a considerable drop in the river, and a small flow would produce a great deal of power. It

1/2,000,000,000
2/For site symbols and locations, see Plate I, back pocket.

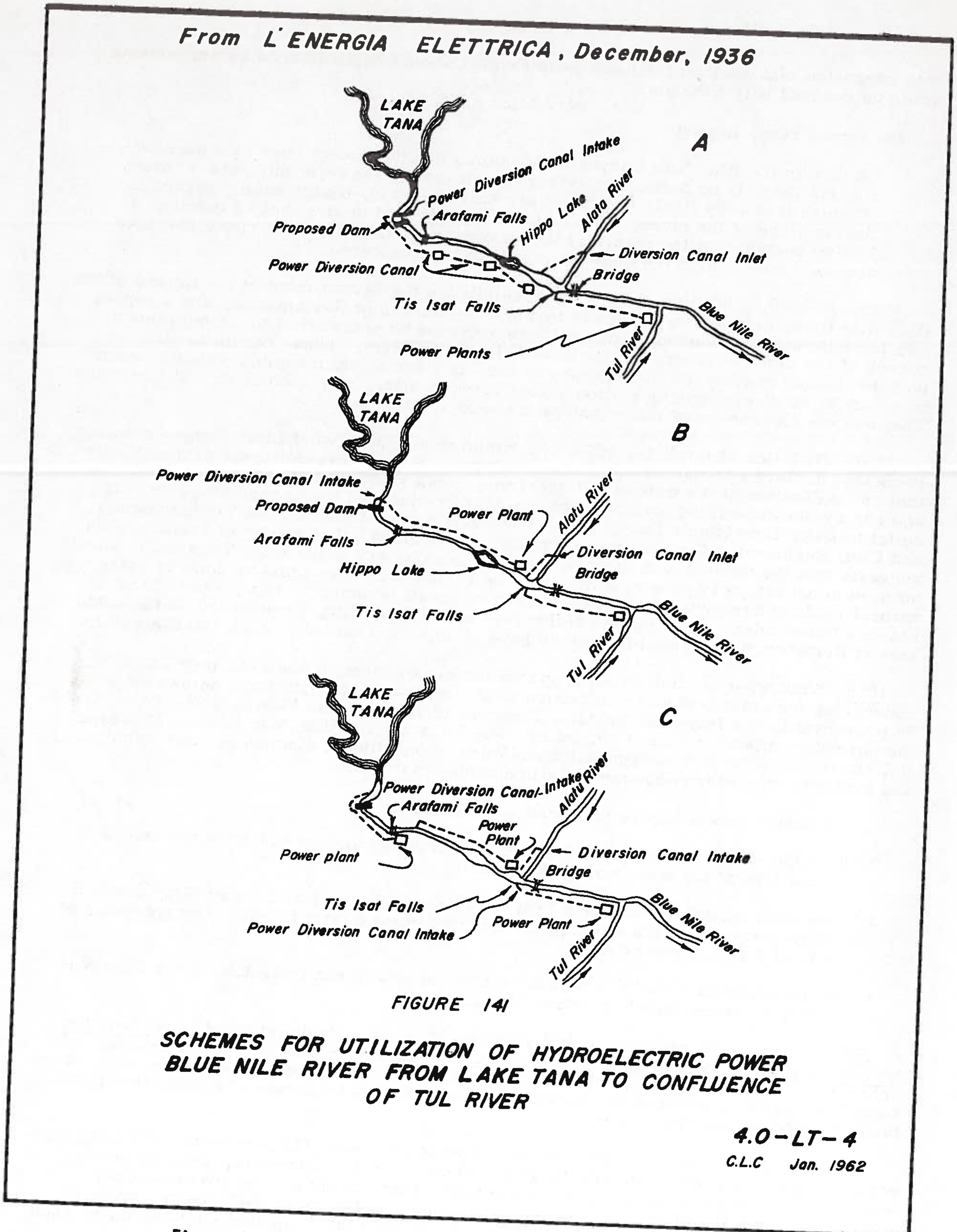


Figure V-3--Schemes for Utilization of Hydroelectric Power--Blue Nile River from Lake Tana to Confluence of Tul (Tvol) River was suggested that work on the Lake Tana Project should begin as soon as agreements could be reached with Ethiopia.

The report read, in part:

> "A dam in the Blue Nile Canyon in Abyssinia 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 also certain that the nature of the country will make any such site difficult of access; there is also the question of silt to be considered."

1952. In 1952, a 60-day study of the possibilities for development of the waters of the Blue Nile River in Ethiopia was made by the U.S. Bureau of Reclamation, and a report was later issued recommending that a 10-year period be established for completing a survey of the water resources of the Blue Nile River Basin. These recommendations included initiation of aerial photography of the basin for aerial mapping, establishment of a number of stream gaging stations, land classification, power studies, and irrigation. That was the forerunner of the investigation reported here.

1953. By letter of April 14, 1953, the Ministry of Public Works and Communications requested J. Seymour Harris and Partners to make a study regarding the proposed control and utilization of the waters of Lake Tana. This study, dated January 29, 1954, with another by the same firm, dated November 1956, concerned a proposed new city at the outlet to Lake Tana (Bahir Dar). J. Seymour Harris and Partners are Town Planning and Civil Engineering Consultants, Birmingham, England. The report of January 1954 suggests that the natural lava dam forming the existing sill at the Lake Tana outlet should be used to advantage in constructing a dam or regulator. This could be done by using the natural reefs in damming between its numerous small islands. It was proposed that a low-head powerplant, utilizing the entire flow of the Blue Nile, be installed on the south side of Eggirbar Hill. This plant would have an installed capacity of 13,100 kilowatts.

1955. Professor B. Hellstrom prepared a memorandum, dated February 23, 1955, concerning the electrical power situation in Ethiopia together with some proposals which he presented to His Imperial Majesty, Emperor of Ethiopia, on February 25, 1955. This memorandum offered opinions regarding Lake Tana and the Blue Nile River. Professor Hellstrom was with Vattenbyggnadsbyran (VBB), Consultants, Engineers, and Architects, and made the following recommendations and observations:

1. Construct a dam across the outlet of Lake Tana.
2. It would not be practical to construct a hydroelectric powerplant at the lake outlet, as the size of the plant would be small.
3. The most suitable place for a hydroelectric plant would be downstream, south of Debre Markos. (This would possibly correspond to site BN-3.) Storage would be in Lake Tana, primarily.
4. He recommended that the need for water for power and irrigation in the Blue Nile Valley be investigated by a firm of consultants.

1956. A study and report, dated September 1956, The Exploitation of Lake Tana for Irrigation and Hydroelectric Power, was made by Siemens-Schuckertwerke Aktiengesellschaft of the Federal Republic of Germany. The report proposes diverting the water from Lake Tana to the sources of the Rahad and Atbara Rivers by means of tunnels to irrigate land and produce electric power.

A regulating weir was proposed at the outlet of the lake. Three tunnels were to be constructed (stage development) with lengths of from 12 to 17 kilometers, starting on the western side of the lake near Delgi. Ultimately, there would be five power stations. Canal headworks would be located in compensating reservoirs at the tailwater areas of three of the five stations so that 24-hour water delivery for irrigation could be made when the powerplants were shut down part of the time.

The possibility of generating 581 megawatts for 16 hours per day for 9 months of the year and 1,036 megawatts for 16 hours per day for 3 months of the year, giving a total attainable annual energy generation of about four billion kilowatt-hours, was advanced in the report.

1957. Later, H. E. Hurst in 1952 published The Nile (revised 1957), which included pertinent reference to the Blue Nile River in Ethiopia and its importance toward contributing water to the main Nile River. To place the importance of the potential hydroelectric possibilities on the Blue Nile River in proper perspective, he presented the following comparisons of water discharges from the Nile tributaries.

The maximum discharge of the Main Nile at Aswan, occurring on about September 8, is made up as shown below.

White Nile	70,000,000 cubic meters per day or 10 percent
Blue Nile	485,000,000 cubic meters per day or 68 percent
Atbara	157,000,000 cubic meters per day or 22 percent
Total Main Nile	712,000,000 cubic meters per day

Minimum discharge is about 45,000,000 cubic meters per day on about May 10.

White Nile	37,500,000 cubic meters per day or 83 percent
Blue Nile	7,500,000 cubic meters per day or 17 percent
Total Main Nile	45,000,000 cubic meters per day

1958. P. Petridis, Legal Adviser, Ministry of Public Works and Communications, Imperial Ethiopian Government, prepared in 1958 an opinion entitled "Ethiopia's Water Resources," which includes a discussion of the Blue Nile River Basin. He provided estimates of the hydroelectric power potential of the basin.

1961. The Blue Nile Geodetic Survey was completed in 1961 and the report published by the U.S. Department of Commerce, Coast and Geodetic Survey. The Report on Horizontal and Vertical Control Surveys of the Blue Nile River Basin gave, for the first time, a complete and basic horizontal and vertical control network throughout approximately 120,000 square miles of west-central Ethiopia. These provided controlled elevations to which subsequent Blue Nile River Basin project surveys could be tied; and one that could be expanded to all of Ethiopia.

Miscellaneous. The foregoing list of early investigations by no means includes all of the reports and books that have been written concerning some aspect of the Blue Nile River Basin. Some good unpublished reports exist, and of interest was the one prepared by an Italian engineer during the Italian Occupation of Ethiopia. Sr. Pitsugalli completed a comprehensive study of the diversion of Lake Tana water to the Beles, developing hydroelectric power at the tunnel outlet and irrigating land on the upper Beles River area as well as on the lower Beles River area. A review of the report revealed that it was based upon meager topographic data. Most of the study was still in pencil form, and nowhere could the size of the powerplants contemplated be found. One purpose, however, in addition to hydroelectric power, was the production of cotton on irrigated land.

The Dainelli and Kiessig reports as well as others are of interest and contain certain recommendations concerning small powerplants in the Bahir Dar area.

Today, there may not be the compelling interest in regulating Lake Tana waters specifically for agriculture in Sudan or Egypt, but there is now an interest in regulation for possible agricultural and hydroelectric power purposes within Ethiopia, although the downstream water requirements for agriculture (and perhaps power) beyond the borders of Ethiopia still exist.

However, it should be recognized that Sudan and Egypt may still have a strong interest in regulating the flow of the Blue Nile River. The new Roseires Dam will be but a 1-year storage reservoir, resulting in acute shortages during persisting low annual flows. The shortages may be alleviated by construction of a reservoir at Lake Tana or the construction of several reservoirs on the Blue Nile that should be capable of storing an amount equal to the largest annual flow that could occur in a 100-year period. The Sudanese report, *The Nile Waters Question*, as well as the *Annual Report of the Ministry of Irrigation and Hydroelectric Power* (1954-55) did not overlook the need for the Lake Tana Project. Also, even Egypt seems not to have forgotten the project on Lake Tana, judging from the report published at Cairo, May 1955, by Colonel Samir Helmy, Corps of Engineers, as well as *High Dam*, published by the Egyptian Ministry of Information.

Prior Studies and Opinions

Because of the lack of data (mainly topographical and hydrological), there has been very little information made available as to the estimated potential hydroelectric power resources of the Blue Nile River Basin as a whole. Some estimates have been made and opinions expressed regarding the Blue Nile River alone, but comprehensive estimates for the entire basin have not been made because adequate data were not previously available. The following have made superficial estimates or have written opinions in prior years which are subsequently discussed in more detail.

Cesari and Testa, Civil Engineers, Italy, 1936.
Petridis, Legal Adviser, Ministry of Public Works and Communication, Imperial Ethiopian Government.
Ethiopian Electric Light and Power Authority.
Water Resource Department, Ministry of Public Works and Communication.
L. Pontecorvo, Italy, 1938.

Others have made estimates for individual projects that might be developed.

Cesari and Testa. In the December 1936 issue of the Italian publication, *L'Energia Elettrica*, Fasc. XII, Vol. XIII, Ettore Cesari and Angelo Testa, Civil Engineers, gave an interesting discussion of the Blue Nile River hydroelectric potentialities in an article entitled "Information about the Possibility of Using Hydroelectric Power Sources in East Africa." They state that from Lake Tana to the Sudan border the Blue Nile River could give a potential annual energy of 8 to 10 billion kw.-hr. when regulated by a Lake Tana Reservoir. This was further defined as a maximum available potential of 40×10^9 kw.-hr., of which 20 to 25 percent was estimated available for industrial use, or 8 to 10×10^9 kw.-hr. Pontecorvo later stated that the latter amount of energy resulted after transforming Lake Tana into a reservoir and taking into account "the need for power production in addition to irrigation problems." Thus, these figures consider some regulation and possibly some irrigation depletions. No estimates were given for the Blue Nile River Basin as a whole.

Petridis. "Ethiopia's Water Resources" was written in 1958 by Mr. P. Petridis, Legal Adviser, Ministry of Public Works and Communication, Imperial Ethiopian Government. He estimated the hydroelectric power potential as 50×10^9 kw.-hr. annually on a theoretical basis and, on a practical basis, reduced this figure to 14 to 18×10^9 kw.-hr. per year. No other information is available on the criteria used in arriving at this figure. It is apparently for the Blue Nile River only and does not include the Blue Nile River Basin as a whole.

Ethiopian Electric Light and Power Authority. Estimates were prepared by this authority for several of the major Ethiopian river basins and included the Blue Nile River Basin. The publication, *Ethiopian Observer*, Vol. V, No. 3, quotes the EELPA figures as follows:

Blue Nile River Basin: $79,863 \times 10^6$ kw.-hr., Total
$24,900 \times 10^6$ kw.-hr., Utilizable

Water Resources Department, Ministry of Public Work and Communication. The same issue of the *Ethiopian Observer* quotes the Water Resources Department as stating that the annual hydroelectric potential of the Blue Nile River Basin is 1.355×10^9 kw.-hr. A printing error is possible in that the figure might well be 1.355×10^{12} kw.-hr. However, nothing is known regarding the criteria established in obtaining this figure.

L. Pontecorvo. "Engineering Problems in Colonial Territories," written by this author and published by S. A. Tipografia Castaldi, Rome, 1938, contained some comments and observations relative to the Blue Nile River Basin in Ethiopia. Pontecorvo does not provide any direct data regarding the hydroelectric potential of the Blue Nile River other than quoting the estimates of Cesari and Testa, already given. However, Pontecorvo stated that the main Nile could produce more than 5, 000, 000 kw.

Ambiguities. Estimates of hydroelectric potential developed by various sources occasionally do not define the parameters used in arriving at the potential. Or, if the parameters are defined, there is a tendency for different authorities to use different parameters, thus making it impossible to place various studies on a comparable basis. Of the varying parameters used in different studies, the most inconsistent was the flow (Q) used, if identified at all. Among the different flows used to measure the hydroelectric potential, the following were most commonly used.

Average Q--The flow observed for an average water year.
Q-95--The flow available in not less than 95 percent of the time.
Q-50--The flow available in not less than 50 percent of the time.

It is not clear what criteria were used in the prior studies and opinions concerning the Blue Nile River Basin prepared by others. Hence, this ambiguity must be kept in perspective when making comparisons of results from different sources or with the results obtained in the present study, the parameters of which are specifically defined.

SECTION II--POTENTIAL HYDROELECTRIC POWER RESOURCES

WITH INVENTORY FOR THE BLUE NILE RIVER BASIN, ETHIOPIA

POWER RESOURCES

Introduction

The theoretical hydroelectric power potential in the Blue Nile Basin, the largest in Ethiopia, is tremendous and may represent one of the greatest natural resources of the country. In Africa, which has an estimated hydroelectric power potential of 40 percent of the world total, the Blue Nile is but one of the major river basins. 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 has been developed.

There is now an awakening of the need for economic development in Africa, and it is significant that the impetus for economic development has taken the form of the provision of capital for hydroelectric power projects. South of the Sahara, Africa, like Ethiopia, is poor in all sources of energy except hydroelectric power. Therefore, emphasis is on hydrodevelopment to raise the standard of living generally by providing a source of energy at reasonable cost which can be used by the people and in the development of local economic resources.

From the long range economic viewpoint, the Blue Nile River Basin is especially important because of its tremendous energy potential. Lack of commercially valuable coal deposits or petroleum places considerable importance on hydroelectric energy. The lack of a complete survey and study of the energy potential of the basin left a void in the economic planning for the future of Ethiopia. Therefore, one of the purposes of the present investigation was to determine the total power potential of the Blue Nile Basin and to select specific hydroelectric power sites as a part of a recommended basic plan for overall development of a future power system.

Ethiopia in its present stage of electrification cannot justify the investment of large sums of money in a detailed stream-by-stream project survey. This reconnaissance survey was to locate the more promising hydroelectric sites on major streams, and approximately 100 sites were found.

To arrive at an overall estimate of hydroelectric potential capability in the basin, use was made of streamflow records, topographic maps, on-site inspections, stereoscopic studies of aerial photographs, and rainfall and other climatic data. Reports of prior investigations, studies, or opinions were researched. Using these data, as explained later, an academic approach was taken to the problem to determine overall potential. From among the many sites located and studied some were selected to provide sources of energy for the future.

The study of potential hydroelectric power resources is presented in two main categories: (1) The total potential power resources, and (2) the inventory of many specific

Figure V-4--Average Annual Precipitation sites that can be studied in more detail in the future. In Section IV of this Appendix, a specific plan of development is outlined, using Blue Nile River Basin hydroelectric sites selected from the inventory listing, Table V-6.

Source of Data

Hydrology. The isohyetal map, Figure V-4, shows the average annual rainfall. It was developed from a study of available climatological data and was used in hydrologic studies, although the actual runoff figures were based essentially upon direct streamflow measurements.

Several stream gaging stations were established as shown by Figure V-5, with the years of record varying from 1 to 9. Only one of these stations has about 9 years of record but the majority range from 2 to 4 years. Outside Ethiopia, a few kilometers downstream on the Blue Nile River at Roseires, Republic of the Sudan, almost 50 years of record are available. No major tributaries enter the Blue Nile between the Ethiopia-Sudan international boundary and the city of Roseires, a river distance of about 110 kilometers.

The year 1932 was an average water year at Roseires and probably an average water year for the upper portion of the Blue Nile River Basin in Ethiopia, whence perhaps 98 percent of the water measured at Roseires originated. Therefore, the Ethiopia Blue Nile River Basin runoff and resultant streamflows were correlated to Roseires, using 1932 as an average water year. Where stream gaging stations did not exist at the mouths of small tributaries, runoff estimates were computed for the drainage area concerned (see Figure V-6), based upon the records for 1932, using the unit runoff applicable to the general area concerned. Unit runoffs came from gaging station records. For further information, see Appendix III, Hydrology.

The analysis of the estimated gross hydroelectric potential is based upon an average water year. The results given by this study undoubtedly will be modified somewhat as more years of hydrologic records become available. Changes in water runoff data alone however, are not likely to influence the gross figures significantly.

Topography. Where recently developed photogrammetry multiplex sheets were available, the topography shown thereon was used. The profile of the Blue Nile River (Figure V-7) was developed for the greater part of its length using elevations obtained from this source. Other elevations along the river were obtained from altimeter readings or from other sources as listed on that drawing.

Most of the Blue Nile River Basin elevations used in Tables V-1 and V-2 came from United States Air Force preliminary charts compiled in 1954.

Some elevations were obtained from U.S. Coast and Geodetic Survey data where such stations were conveniently located near points needed in determining gross head.

Methods of Analysis

During the past, investigators attempting to evaluate the hydroelectric potential have not made it wholly clear as to whether their evaluations concerned the Blue Nile Basin as a whole or whether they were confined to the main river alone, and the results have been confusing. In no case were the results based upon the degree of hydrological and topographical data now available and used in the present study. In studying the possibilities for developing the full resources of underdeveloped countries, some international agencies place great emphasis on the gross surface and gross river hydroelectric potential for major river basins, especially where little prior data or knowledge using standardized parameters exist.

Because the Blue Nile River is an international river of major importance it is necessary that any assessment of the land and water resources be presented in a manner that is generally understood and accepted internationally. Methods similar to those employed by the United Nation's Committees on Electric Power of the Economic Commissions for Europe, Asia, and the Far East have been used in this volume.

Definitions and Procedures Employed. Theoretical maximum and theoretical exploitable potentials comprised the principal types of hydroresource assessments employed herein. Theoretical maximum potentials include the gross surface potential, giving specific maximum values in kilowatt-hours based upon surface runoff and also expressible in kilowatt-hours per square kilometer of surface area.

Exploitable potentials are divided into two main groups known as technical potentials and economic potentials. Technical potentials in this study are defined as the aggregate output of all sites considered exploitable for power production in 1962 without reference to economic or other considerations. They might also be thought of as the limit of the practicable value of the exploitable potential. Economic potentials in this study are defined as the aggregate output of all sites considered exploitable by the year 2000, as seen from 1962, based upon a forecast load diagram. See Section IV.

It is assumed further that the most economical Blue Nile River Basin sites will be developed following development of the Awash River Basin. Techniques for developing and constructing hydroelectric powerplants and related facilities prevailing in 1962 are also assumed throughout the period.

To arrive at the technical and economic potentials, using the gross surface potential as a base, a percentage factor is applied, based upon knowledge of the streams, terrain, and geology. Actually, the exploitable possibilities can be properly judged only by a detailed project survey of each stream, which was beyond the scope of our investigations. The theoretical exploitable potentials (technical and economic) vary as percentages of the gross potential and will vary year by year under changing conditions. Some of the changing conditions which will eventually affect these percentage factors are: Rate of technical progress in the art of developing hydroelectric sites; better streamflow records; better topographic maps; demand for hydroelectric power; rate of economic growth; changes in population centers; rate of population growth; rate of growth of industrial development, and location of these centers; and irrigation and flood control requirements.

Specific items which influence the percentage factors used in determining economic potential in any river basin, the more pertinent of which, as they may affect the Blue Nile River Basin, are discussed in detail in a later section are these: Projects already completed or under construction; fluctuations in flow for the various streams during a year; availability of good storage sites; silt content; distance of project from load centers; availability of good damsites and construction material; geology; shape of the load curve; and benefit-cost ratio.

The relationship of technical to gross surface potential for a study conducted in Turkey was as follows:

	Percent of gross potential
Gross surface	100.0
Technical	27.3

In Europe as a whole, the ratio of technical to gross surface seems to be about 20 percent. In Greece, for example, the ratio of technical to gross surface appears to be about 12. percent.

Gross Surface Hydroelectric Potential. This defines the upper limits of hydropotential available in an average year, based upon surface runoff, and assumes that the physical resources of the Blue Nile River Basin are fully available for power production (no depletion allowances for irrigation and other uses and no restrictions on flooding lands that could be used for agricultural purposes).

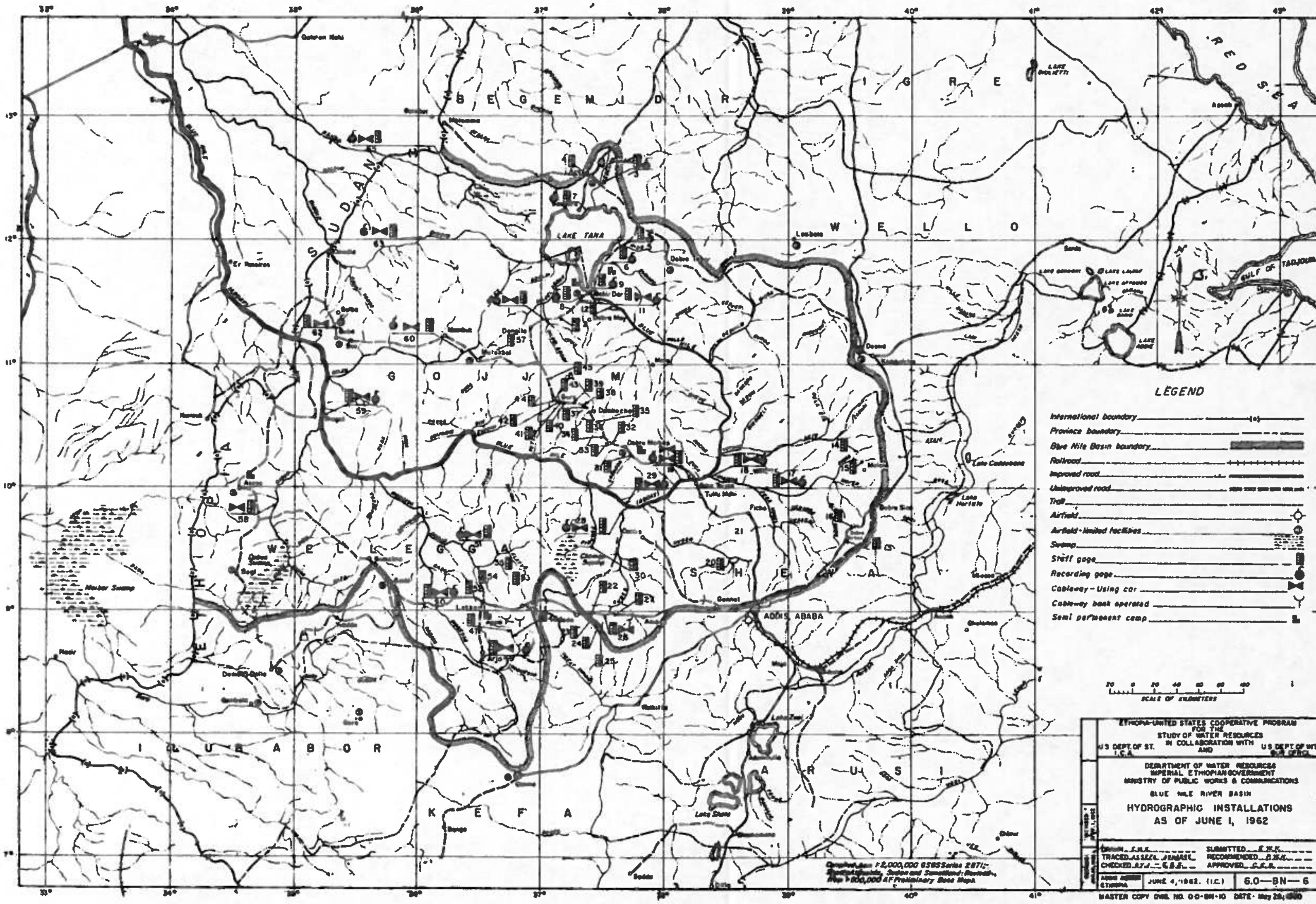


Figure V-5--Hydrographic Installations as of June 1, 1962

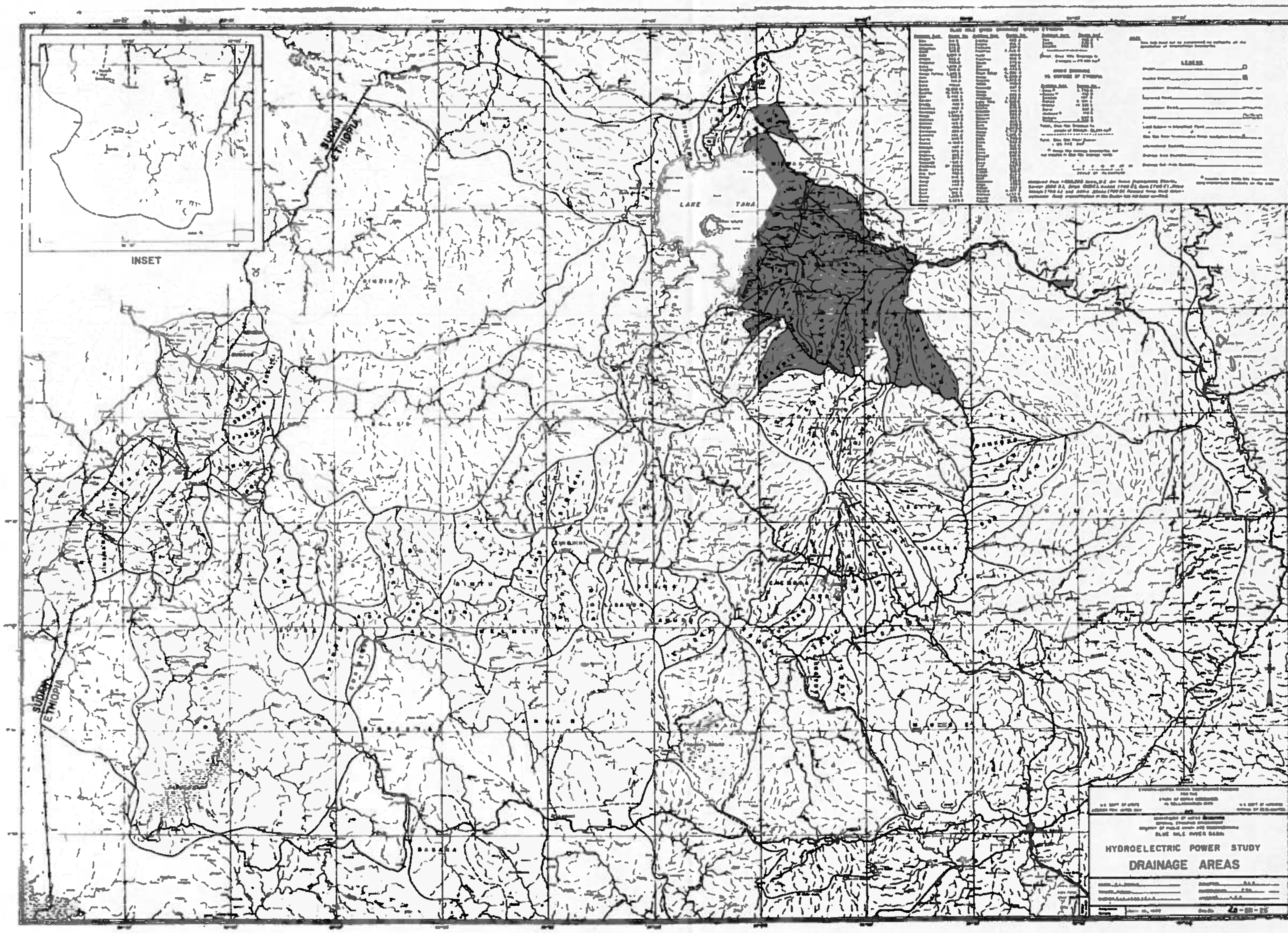


Figure V-6--Drainage Areas, Hydroelectric Power Study

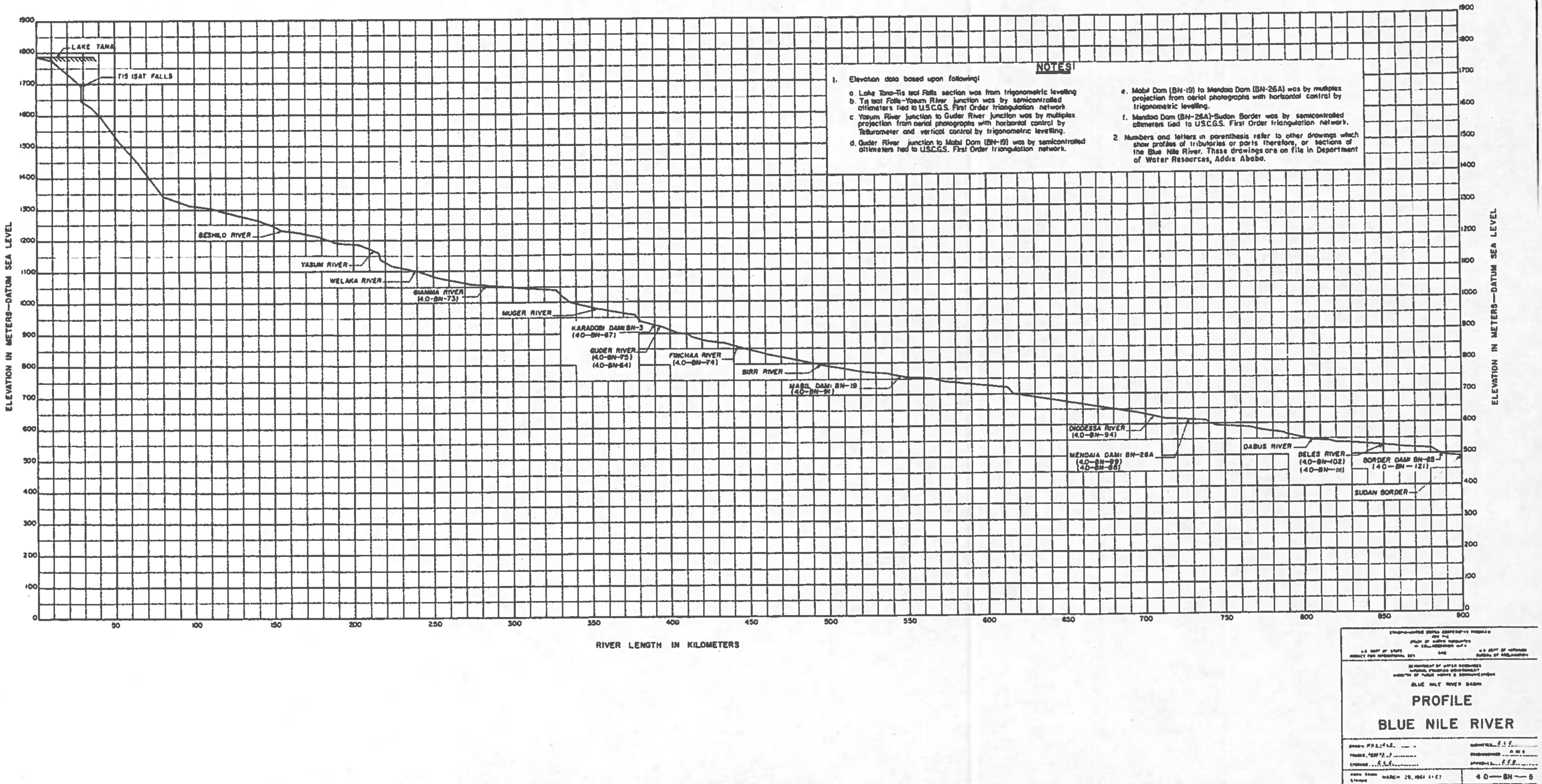


Figure V-7--Profile, Blue Nile River

The Blue Nile River Basin was divided into two parts, the Blue Nile River drainage within Ethiopia, and river drainage to the outside of Ethiopia. The first part was divided into 95 separate catchment areas as indicated on Figure V-6. The second part was divided into six separate catchment areas, the most important of which are the Rahad, Dindir, and Tumit Rivers, which originate within the Blue Nile Basin in Ethiopia but join the Blue Nile River in the Sudan. For each small catchment area in the Blue Nile River Basin, Figure V-6, the mean annual water runoff value and the median elevation for each small catchment area was determined.

For the first part, the theoretical gross head for each catchment area applicable to Ethiopia's part of the Blue Nile River Basin is the difference between the median elevation of the catchment above sea level and the elevation of the river at the Sudan border, 487 meters. (See Tables V-1 and V-2.) The gross surface potential for each small catchment area is then determined in millions of killowatt-hours by using the gross head and the mean flow originating in the catchment.

For the second part (representing about 10 percent of the area in the first,) the elevations of the rivers (Rahad, Dindir, and Tumit) at the international boundary were used as bases in determining the gross head applicable to these six catchment areas.

The results obtained fix the upper limits of the theoretical hydropower available because of these assumed conditions: Complete utilization of seasonal flows with no flow losses; complete utilization of head; generating efficiency at 100 percent; and theoretical plant utilization factor at 100 percent. These assumptions permit comparability between various catchment areas.

To arrive at the exploitable segments (technical and economic) of the gross surface potential, each of the different catchment areas was treated individually, considering the factors previously set forth. The most promising catchment area from the standpoint of hydroelectric potential (Finchaa) was investigated in detail as were two or three more typical catchment areas (Giamma, Beles, and Guder), and from these some idea of the exploitable resources was obtained. The gross surface potential obtained for each area is therefore the theoretical maximum that would be obtained if all the runoff available in an average year could be utilized to generate electricity continuously at the head equivalent to the area's median elevation above the river elevation at the Sudan border.

Gross Surface Hydroelectric Potential, Blue Nile River Basin

From Tables V-1, V-2, V-3, and V-4, the following information is obtained:

	Average water year conditions: Blue Nile River drainage within Ethiopia	Average water year conditions: Blue Nile River drainage to outside Ethiopia	Totals
Gross surface electrical energy, 10^6 kw.-hr.	162,743	10,777	173,520
Gross surface electrical power potential, 10^6 kw., continuous rating	18.58	1.23	19.81
Technical electrical energy potential in average percent of gross surface energy for basin as a whole	21.7	24.9	21.9
Technical electrical energy potential, 10^6 kw.-hr.	35,252	2,682	37,934
Technical electrical power potential, 10^6 kw., continuous rating	4.02	0.31	4.33
Economic electrical power potential, 10^6 kw., continuous rating, to meet maximum load requirements by year 2000	0.6295	1/0	0.6295

1/Assumes that Dindir (DI-7) Junction powerplant, Dindir Project, would not generate power prior to the year 2000.

TABLE V-1—GROSS SURFACE HYDROELECTRIC POTENTIAL, BLUE NILE RIVER DRAINAGE WITHIN ETHIOPIA

Sheet 1 of 2

Drainage area designation	Area (sq. km.)	Maximum elevation (meters)	Minimum elevation (meters)	Median elevation above sea level (meters)	Gross head relative to river elevation at Sudan Border (meters)	Runoff ($m^3 \times 10^6$) (avg)	Total theoretical gross surface electrical energy (kw.-hr. $\times 10^6$)	Theoretical gross surface energy density (10^6 kw.-hr. per km^2)
Aba	315.0	1219	615	917	430	12.79	14.9	0.05
Abahala	265.0	2420	1350	1885	1398	21.58	82.2	0.31
Abegenan	275.0	2130	1785	1957	1470	28.88	115.7	0.42
Alata	325.0	2420	1640	2030	1543	83.03	361.0	1.11
Amo	1,227.5	3350	1250	2300	1813	324.96	1,605.3	1.31
Amuru	422.5	2280	900	1590	1103	28.97	87.1	0.21
Andassa	780.0	2740	1725	2232	1745	276.93	1,316.7	1.69
Aoea	1,878.0	3050	1370	2210	1723	745.75	3,501.2	1.86
Araghie	545.0	3050	1515	2283	1796	150.77	737.8	1.35
Azena-Fettam	1,282.5	2420	840	1630	1143	190.44	593.1	0.46
Azir	350.0	2134	736	1435	948	113.69	293.7	0.84
Bakh	705.0	2130	640	1385	898	64.44	157.7	0.22
Bata	740.0	2130	1785	1957	1470	87.32	349.7	0.47
Beles	13,555.0	2130	495	1312	825	2,571.33	5,780.2	0.43
Beshilo	12,530.0	2440	1250	1845	1358	2,711.72	10,600.0	0.85
Birr	5,432.5	3050	875	1963	1476	2,803.56	11,275.4	0.21
Border	235.0	610	490	550	63	2.12	0.4	-
Bridge	452.5	1980	1025	1503	1016	38.80	107.4	0.24
Carcarsa	482.5	1520	650	1085	598	29.38	47.9	0.10
Chemoga	1,137.5	3200	922	2061	1574	123.39	529.1	0.47
Cheye	1,305.0	3353	1150	2250	1763	1,122.79	5,393.7	4.13
Chimbek	907.5	2591	595	1593	1106	1,018.03	3,068.0	3.38
Chimbil	125.0	2085	1785	1935	1448	24.13	144.8	1.16
Chioga	455.0	2440	900	1670	1183	31.19	100.5	0.22
Corbessa	325.0	2440	620	1530	1043	337.44	1,043.0	3.21
Curasid	122.5	2040	1710	1875	1388	20.92	79.1	0.65
Curve	500.0	2440	965	1703	1216	36.92	122.3	0.24
Dabus	14,400.0	1830	520	1175	688	4,726.99	8,861.5	0.62
Dagoma	437.5	2280	1785	2033	1546	123.81	521.6	1.19
Danab	575.0	1000	505	753	266	10.93	7.9	0.01
Dankoro	392.5	3200	1190	2195	1708	30.66	142.7	0.36
Degga	577.5	2134	875	1505	1018	52.80	116.5	0.20
Denghes	315.0	762	495	628	141	3.21	1.2	-
Diddessa	27,300.0	1829	625	1227	740	15,851.72	31,963.0	1.17
Didin	575.0	1980	755	1368	881	48.43	116.3	0.20
Dim Suri	705.0	2134	738	1436	949	208.56	539.3	0.76
Dimtu	512.5	1524	685	1105	618	31.22	52.6	0.10
Dingi	565.0	2896	1010	1953	1466	171.27	684.2	1.21
Doal	140.0	2134	1750	1942	1455	23.55	92.6	0.66
Dora	1,145.0	2134	655	1395	908	109.05	269.8	0.24
Dori	312.5	1982	650	1316	829	23.30	52.6	0.17
Duma	1,220.0	1000	562	781	294	39.47	31.6	0.03
Dura	2,322.5	2287	735	1511	1024	998.77	2,786.7	1.20
Ebelizi	452.5	915	495	705	218	4.84	2.9	0.01
Evantu	812.5	2134	750	1442	955	77.39	201.4	0.25
Fadocha	297.5	915	495	705	218	3.75	2.2	0.01
Finchaa	3,515.0	3050	910	1980	1493	856.87	3,485.8	0.99
Furti	450.0	1982	1080	1531	1044	8.49	24.2	0.05
Gabicura	592.5	2073	1785	1929	1442	106.65	419.0	0.71
Gelda	375.0	2134	1785	1960	1473	172.50	692.3	1.85
Get	467.5	1890	1140	1515	1028	16.21	45.4	0.10
Giamma	15,442.5	2896	1065	1980	1493	2,713.00	11,036.0	0.71
Gilgel Abbay	4,590.0	2439	1785	2112	1625	2,712.16	12,008.8	2.62
Guder	6,625.0	2896	940	1918	1431	1,744.00	6,800.2	1.03
Gumara	1,525.0	2128	1785	1957	1470	900.07	3,605.1	2.36
Hinde	450	1677	725	1201	704	37.85	72.6	0.16
Karadobi	307.5	2287	955	1621	1134	21.08	65.1	0.21
Karsa	442.5	2134	924	1529	1042	16.58	47.1	0.11
Kassa	872.5	1982	720	1351	864	67.82	159.7	0.18
Kwatlana	1,352.5	2591	800	1696	1209	101.21	333.4	0.25
Lake Tana	3,035.0	-	-	-	-	-	-	-
Libanon	802.5	2134	805	1470	483	73.36	196.5	0.24
Macha	645.0	2134	1080	1607	1120	41.19	125.7	0.19
Makdala	585.0	2591	1280	1936	1449	47.24	186.5	0.32
Mariam	722.5	2287	1440	1864	1377	113.33	425.2	0.59
Megech	707.5	2744	1785	2265	1778	157.85	764.7	1.08
Mitraa	825.0	2592	1785	2188	1701	119.63	554.5	0.67
Moni	800.0	1220	550	885	398	39.91	43.3	0.05
Mozha	1,028.0	2896	1325	2111	1624	294.60	1,303.6	1.27
Muger	7,715.0	2744	975	1860	1373	1,404.14	5,252.9	0.68
Naga	1,612.5	1829	580	1205	718	65.47	128.1	0.08

TABLE V-1--GROSS SURFACE HYDROELECTRIC POTENTIAL, BLUE NILE RIVER DRAINAGE WITHIN ETHIOPIA

Drainage area designation	Area (sq. km.)	Maximum elevation (meters)	Minimum elevation (meters)	Median elevation above sea level (meters)	Gross head relative to river elevation at Sudan Border (meters)	Runoff ($m^3 \times 10^6$) (avg)	Total theoretical gross surface electrical energy (kw.-hr. x 10^6)	Theoretical gross surface energy density (10^6 kw.-hr. per km^2)
Ribb	1,790.0	2439	1785	2112	1625	495.66	2,194.7	1.22
Scita	832.5	3049	1140	2095	1608	153.17	671.1	0.81
Sea	610.0	3049	1220	2135	1648	71.46	320.9	0.53
Sede	450.0	3049	1322	2186	1699	89.65	415.0	0.92
Sena	842.5	2744	924	1834	1347	151.49	556.0	0.66
Shogali	207.5	720	520	620	133	4.19	1.5	-
Sirbe	715.0	2287	580	1434	947	457.86	1,181.5	1.65
Suca	702.5	3659	1050	2355	1868	313.83	1,597.4	2.27
Tashai	615.0	2134	920	1527	1040	63.50	179.9	0.29
Tummi	685.0	2659	1320	2490	2003	376.29	2,053.7	3.00
Tvol	537.5	3354	1625	2490	2003	261.11	1,425.1	2.65
Uatzau	227.5	2134	925	1530	1043	6.79	19.3	0.08
Ueni	467.5	1677	675	1176	689	34.87	65.5	0.14
Uscinater	730.0	3354	1030	2192	1705	289.88	1,346.7	1.84
Wabi	730.0	2896	980	1938	1451	234.53	927.3	1.27
Wamet	437.5	1677	900	1289	802	165.46	361.6	0.83
Welaka	4,417.5	3659	1100	2379	1892	1,166.81	6,015.3	1.36
Welmet	1,197.5	2134	700	1417	930	134.48	340.7	0.28
Wenka	705.0	3049	1300	2175	1688	119.45	549.4	0.78
Yasum	872.5	3354	1148	2251	1764	125.31	602.3	0.69
Yew	380.0	2744	1175	1960	1473	29.68	119.1	0.31
Zemie	320.0	2134	970	1552	1065	20.10	58.3	0.18
Zinghini	292.5	1220	742	981	494	7.88	10.6	0.04
Total	173,984					52,145.0	162,743.0	0.94

TABLE V-2--GROSS SURFACE HYDROELECTRIC POTENTIAL, BLUE NILE RIVER DRAINAGE TO OUTSIDE ETHIOPIA

Drainage area designation	Area (sq.km.)	Maximum elevation (meters)	Minimum elevation (meters)	Median elevation above sea level (meters)	Gross head relative to river elevation at Sudan Border (meters)	Runoff ($m^3 \times 10^6$) (avg)	Total theoretical gross surface electrical energy (kw.-hr. x 10^6)	Theoretical gross surface energy density (10^6 kw.-hr. per km^2)
Bumbos	197.5	915	650	782	132	2.01	0.7	-
Rahad	6,351.1	2073	600	1336	736	1,735.39	3,480.2	0.55
Dindir	15,592.5	2287	610	1448	838	3,145.34	7,182.0	0.46
Durel	687.5	1220	915	1067	152	8.66	5.9	-
Mehera	207.5	915	760	838	78	2.51	0.5	-
Tumit	2,225.0	1524	850	1187	337	116.81	107.3	0.05
Total	25,261						10,777	0.43

TABLE V-3--GROSS SURFACE EXPLOITABLE ENERGY, BLUE NILE RIVER DRAINAGE WITHIN ETHIOPIA

Sheet 1 of 2

Drainage area	Theoretical: Gross surface electrical energy potential (kw.-hr. x 10^6) (average water year)	Technical electrical energy potential (percent of gross)	Technical electrical energy potential (kw.-hr. x 10^6) (average water year)	By Year 2000: Economic electrical energy potential (percent of gross)	By Year 2000: Economic electrical energy potential (kw.-hr. x 10^6)
Aba	14.9	10	1.5		
Abahala	82.2	12	9.9		
Abegenan	115.7	16	18.5		
Alata	361.0	15	54.2		
Amo	1,605.3	10	160.5		
Amuru	87.1	12	10.5		
Andassa	1,316.7	20	263.3		
Aoea	3,501.2	20	700.2		
Araghie	737.8	12	88.5		
Azena-Fettam	593.1	15	89.0		
Azir	293.7	12	35.5		
Bakh	157.7	20	31.5		
Bata	349.7	15	52.5		
Beles	5,780.2	35	2,023.0	12	1/ 697
Beshilo	10,600.0	25	2,650.0		
Birr	11,275.4	20	2,255.0		
Border	0.4	0	-		
Bridge	107.4	9	9.7		
Carcarsa	47.9	15	5.1		
Chemoga	529.1	12	63.5		
Cheye	5,393.7	12	647.2		
Chimbek	3,068.0	15	460.2		
Chimbil	144.8	8	11.6		
Chioga	100.5	15	15.0		
Corbessa	1,043.0	12	125.2		
Curasid	79.1	8	6.3		
Curve	122.3	10	12.2		
Dabus	8,861.5	20	1,772.3	0.4	33
Dagoma	521.6	15	78.2		
Danab	7.9	12	9.5		
Dankaro	142.7	11	15.7		
Degga	116.5	10	11.7		
Denghes	1.2	0	-		
Diddessa	31,963.0	40	12,785.0	10	3,108
Didin	116.3	15	17.4		
Dim Suri	539.3	15	80.9		
Dimtu	52.6	10	5.3		
Dingi	684.2	12	82.1		
Doal	92.6	8	7.4		
Dora	269.8	20	54.0		
Dori	52.6	12	6.3		
Duma	31.6	12	3.8		
Dura	2,786.7	10	278.7		
Ebelizi	2.9	5	-		
Evantu	201.4	15	30.2		
Fadocha	2.2	0	-		
Finchaa	3,485.8	30	1,045.7	21	738
Furti	24.2	12	2.9		
Gabicura	419.0	16	67.0		
Gelda	692.3	14	96.9		
Get	45.4	9	4.1		
Giamma	11,036.0	10	1,103.6		
Gilgel Abbay	12,008.8	15	1,801.3	1	113
Guder	6,800.2	20	1,360.0	3	225
Gumara	3,605.1	8	288.4		
Hinde	72.6	10	7.3		

1/See Lake Tana, next sheet

Sheet 2 of 2

Drainage area	Theoretical: Gross surface electrical energy potential (kw.-hr. x 10^6) (average water year)	Technical electrical energy potential (percent of gross)	Technical electrical energy potential (kw.-hr. x 10^6) (average water year)	By Year 2000: Economic electrical energy potential (percent of gross)	By Year 2000: Economic electrical energy potential (kw.-hr. x 10^6)
Karadobi	65.1	10	6.5		
Karsa	47.1	12	5.7		
Kassa	159.7	20	31.9		
Kwatlana	333.4	20	66.7		
Lake Tana	-	-	-		
Libanon	196.5	15	29.5		2/ 500
Macha	125.7	12	15.1		
Makdala	186.5	10	18.7		
Mariam	425.2	12	51.0		
Megech	764.7	16	122.4		
Mitraa	554.5	15	83.2		
Moni	43.3	12	5.2		
Mozha	1,303.6	10	130.4		
Muger	5,252.9	12	630.3		
Naga	128.1	20	25.6		
Ribb	2,194.7	8	175.6		
Scita	671.1	12	80.5		
Sea	320.9	11	35.3		
Sede	415.0	12	49.8		
Sena	556.0	12	66.7		
Shogali	1.5	10	-		
Sirbe	1,181.5	12	141.8		
Suca	1,597.4	12	191.7		
Tashai	179.9	12	21.6		
Tummi	2,053.7	10	205.4		
Tvol	1,425.1	13	185.3		
Uatzau	19.3	10	1.9	7	3/ 100
Ueni	65.5	10	6.6		
Uscinater	1,346.7	12	161.6		
Wabi	927.3	12	111.3		
Wamet	361.6	12	43.4		
Welaka	6,015.3	25	1,503.8		
Welmet	340.7	15	51.1		
Wenka	549.4	10	55.0		
Yasum	602.3	10	60.2		
Yew	119.1	10	11.9		
Zemie	58.3	9	52.5		
Zinghini	10.6	10	1.1		
Total	162,743.0		35,252.0		5,514
Total kw 4/	18,577,968		4,024,200		629,500

2/Additional energy obtained from transwatershed diversion of Lake Tana water to Beles River. Subbasin credited here.
3/Tis Abbay
4/Continuous

NOTES: Total technical energy potential as percent of gross surface = 21.7 percent.

Economic energy potential as percent of gross surface = 3.4 percent, based upon meeting load requirements to year 2000.

The 629,500-kw. continuous rating may require powerplant installations totaling 1,038,220-kw. dependable capacity, as shown in subsequent sections.

Considering reserves and losses, it appears that by the year 2000, a maximum of about 629,500 kw., continuous (1,038,220 kw. in installed plant capacity), may be economically feasible for development in the Blue Nile River Basin. This would use about 16 percent of the probable potential existing in that part of the basin that drains within Ethiopia.

On the basis of the studies shown in Tables V-1 through V-4, a total of almost 38 x 10^9 kw.-hr. is technically possible of development in an average water year without regard to economics in the total Blue Nile River Basin within Ethiopia. This would amount to about 4,330,000 kw. in capability on a continuous basis that would be theoretically available (8,660,000 kw. at 0.5 plant factor).

TABLE V-4--GROSS SURFACE EXPLOITABLE ENERGY, BLUE NILE RIVER DRAINAGE TO OUTSIDE ETHIOPIA

	Theoretical			By year 2000 1/	
Drainage area	Gross surface electrical energy potential kwh x 10^6 (average water year)	Technical electrical energy potential (percent of gross)	Technical electrical energy potential kwh x 10^6 (average water year)	Economic electrical energy potential (percent of gross)	Economic electrical energy potential kwh x 10^6
Bumbos	0.7	5			
Rahad	3,480.2	25	870.0		
Dindir	7,182.0	25	1,795.5		
Durel	5.9	12	0.6		
Mehera	0.5	5	-		
Tumit	107.3	15	16.1		
TOTAL	10,777		2,682	0	0
Total kw, 2/	1,230,000		306,100		

1/ Assumes Dindir (DI-7) Junction powerplant development occurs after this date.

2/ Continuous.

Comparisons and Conclusions

Regarding the gross surface hydroelectric energy potential, it was previously stated that the ratio of technical-to-gross was about 20 percent for a recent study in Europe, but for Turkey, these results were obtained as compared with the Blue Nile River Basin in Ethiopia:

	Gross surface	Technically exploitable	Gross surface density 10^6 x kw.-hr./km.^{2}
Turkey, percent of gross	100.0	27.3	-
Blue Nile River Basin, percent of gross	100.0	21.9	-
Turkey, kw.-hr. x 10^6	536,535	146,630	0.698
Blue Nile River Basin, kw.-hr. x 10^6	173,520	37,934	0.870

In the Blue Nile Basin in Ethiopia the theoretical technical potential of 21.9 percent is somewhat low, and this may improve with successive studies in the future when longer records of streamflow become available. However, the following factors were considered.

In an average year*, over 70 percent of the rainfall occurs in 25 percent of the time and the remaining 30 percent is distributed over the rest of the year. Thus, most of the numerous streams indicated on Figure V-6 are intermittent.

The hydraulic gradient of the Blue Nile River in Ethiopia is about 1.47 meters per kilometer as compared with the following rivers:

River	Average declivity (m./km.)	Length (km.)
Blue Nile 1/	1.47	900
Missouri 2/	0.32	2,962
Dnieper 3/	0.11	833
Volga 4/	0.04	3,167
Tennessee 5/	0.21	1,333
Wabi Shabelli 6/	1.41	995
Niobrara 7/	1.66	513
Ohio 8/	0.13	1,666

1/From Lake Tana outlet to Ethiopia-Sudan international boundary.
2/From source at Three Forks, Montana, to Yankton, South Dakota, USA.
3/From above Kiev Dam to Kahhouka Dam, USSR.
4/From above Ivankovo Dam to Volgograd Dam, USSR.
5/From confluence North-South Forks to mouth at Paducah, Kentucky, USA.
6/From confluence Hoko River to Ethiopia-Somali boundry.
7/From Box Butte, Nebraska, to confluence with Missouri River, USA.
8/From Pittsburgh, Pennsylvania, to a point below Mound City, Illinois, USA.

In selecting those areas in the Blue Nile River Basin from which future generation requirements can be met, several factors had to be considered from an economic viewpoint.

1. Nearly all major rivers are deeply entrenched in narrow gorges for a part of their length.

2. The terrain between load centers and potential major hydroelectric sites in nearly every instance is such that transmission line access is generally only possible on foot, by donkey, or by helicopter.

3. Construction access to nearly all of the potential hydroelectric sites will require extensive road construction.

*For 1932, 36,130 x $10^6 m^3$ was the total flow that was attributable to July, August, and September in the Blue Nile River at the Sudan Border, with 50,194 x $10^6 m^3$ occuring during the full year. These results were obtained by correlation with the riverflows at Roseires.

4. The availability of good undeveloped sites in other river basins within reasonable distance of principal load centers in Ethiopia also must be considered in relation to the long-range load curves for major load centers.

5. The heavy silt content of the Blue Nile River in Ethiopia during flood has long been known and for centuries has been a factor in the agricultural economy in Egypt. Now that reservoirs have been constructed at Roseires, Sennar, and Aswan, this sediment does not reach the Egyptian lands but is deposited in these reservoirs.

6. Good damsites can generally be found in the Blue Nile River but natural sand and gravel deposits are a rarity.

Table V-5 shows comparisons on a gross surface and density basis and will give some indication of the potential of the Blue Nile River Basin when compared with other countries.

TABLE V-5--COMPARISONS OF HYDROELECTRIC POTENTIAL, INTERNATIONAL

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."

The following Blue Nile Basin comparisons are made with results of prior studies and reports although again it is emphasized that it is not fully known what parameters were used by others in obtaining these figures and they may not be directly comparable.

USBR Study, Blue Nile Basin, Ethiopia, as a whole:

Gross surface potential	173,520,000,000 kw.-hr./year
Technical	37,934,000,000 kw.-hr./year

Cesari and Testa, Blue Nile River, Ethiopia, only:

Maximum available potential	40,000,000,000 kw.-hr./year
Available for industrial use with Lake Tana regulation and possible irrigation depletions	8 to 10,000,000,000 kw.-hr./year

Petridis, Blue Nile River, Ethiopia, only:

Theoretical potential	50,000,000,000 kw.-hr./year
Practical potential	14 to 18,000,000,000 kw.-hr./year

Ethiopian Electric Light and Power Authority, Blue Nile River Basin, Ethiopia:

Total potential	79,863,000,000 kw.-hr./year
Utilizable potential	24,900,000,000 kw.-hr./year

INVENTORY OF HYDROELECTRIC POWER SITES

Because of the nature of the topography in the greater part of the Blue Nile River Basin, there is almost an unlimited number of possible damsites along certain streams.

Where the determination of relative suitability of alternative sites requires study beyond the scope of the reconnaissance investigations, only one site is named for that length of the river where the several alternative possibilities exist.

During the annual wet season from June to September, most streams reach flood stages, while only the main stream and major tributaries have any appreciable flow during the annual dry cycle. Thus, a potentially satisfactory hydroelectric power site, on further investigation, may prove to be inadequate from a hydrologic viewpoint or even from a topographic viewpoint, if the declivity of the stream provides little reservoir storage capacity. However, the more promising ones were studied in detail and recommended for a future program of development as outlined in Section IV.

Purpose of Inventory

Table V-6 identifies specific sites that appear to offer possibilities for development of hydroelectric power, pinpoints locations by latitude and longitude, and avoids possible confusion in this study by assigning site symbol numbers. For those that were studied in some detail and are included in the final plan of development, names were also assigned. More than 100 such locations are listed in this inventory by approximate latitude and longitude as determined by inspection of the map (Plate I, in pocket on back cover) on which locations are based. The inventory listing also includes a few comments as to estimated elevations of water surface, spillway, abutments, and general data. In nearly all cases picture references are to aerial photographs on file in the Water Resources Department, Ministry of Public Works and Communication, Imperial Ethiopian Government, Addis Ababa, Ethiopia.

Criteria Used

Elevations. All elevations are approximate and based upon unadjusted data except where noted in the listing. Where elevations are quoted, "abutment" refers to the highest point observed along an imaginary dam axis. The crest elevation in some cases would actually fall at some point considerably lower.

TABLE V-6--INVENTORY OF POTENTIAL POWERSITE LOCATIONS, BLUE NILE RIVER BASIN, ETHIOPIA

(See Plate 1, in pocket on back cover.)

Sheet 1 of 5

Powersite Symbol No.	River	North latitude	East longitude	Comments
AB-1	Abegenan	12°23'15"	37°12'20"	Small storage; damsite questionable. Picture No. 4,296.
AG-1	Angar	9°34'0"	36°14'0"	Excellent damsite; narrow canyon; good reservoir area. Picture No. 10,475. About 122-meter dam.
AG-2	Angar	9°41'30"	36°45'42"	Water surface 1329 meters elevation; abutment 1418 meters elevation. Long earth dike may be required for dam. Good reservoir. Picture No. 2,806. Minimum generation, 76 x 10^6 kw.-hr. per year in conjunction with irrigation. Name: Angar.
AG-3	Angar	9°48'30"	36°54'54"	Water surface 1418 meters elevation; abutment 1494 meters elevation. Picture No. 5,549.
AG-4	Angar	9°31'20"	36°19'30"	Good damsite in gorge. Good foundation. Geology good. Stream gradient steep. Little storage. Good powersite if river regulated by upstream reservoirs. Picture No. 10,404.
AG-5	Angar	9°24'0"	36°28'0"	Crest length much longer than AG-6 with less storage due to sudden increase in stream gradient upstream of damsite. Storage not great. Picture No. 10,404.
AG-6	Angar	9°26'0"	36°31'0"	Downstream of this site, stream gradient drops very rapidly. Nearly flat to this site upstream. Storage possibilities good. A power canal fed from this reservoir, taking advantage of the steep gradient downstream, will provide considerable head for power generation. Possibility of two powerplants taking advantage of steep gradient. No power generation at this site; but downstream at Sites AG-6A and AG-6B. This will provide the storage for 6A and 6B. Picture No. 10,467. Name: Lekkemt.
AG-6A	Angar	9°26'30"	36°26'0"	Fixed head powerplant fed from 17.6-km. masonry-lined canal originating at Storage Site AG-6. Gross power head about 177 meters. Picture No. 10,405. About 674 x 10^6 kw.-hr. per year.
AG-6B	Angar	9°28'45"	36°24'30"	This is a constant head powerplant served by another canal about 5.0 km. long. Takeoff is from small diversion structure below Powerplant AG-6A. Gross head is about 77 or 78 meters. Water supply regulated by Dam AG-6. Picture No. 4,912. About 300 x 10^6 kw.-hr. per year.
AS-1	Ashad	11°20'20"	36°58'24"	Small. Little data. Picture No. 4,849.
AS-2	Ashad	11°19'42"	36°57'30"	Small. Little data. Mill diversion at present. Picture No. 4,849.
AU-1	Abubutar	10°39'40"	35°30'30"	Not much project potential. Picture No. 7,684.
B-3	Birr	10°34'45"	37°15'45"	150-meter-high dam. Perhaps 5,000 kw. 142,000,000 cu. m. storage. 700-meter crest length. Probably not feasible for power if developed in conjunction with a major irrigation project. Picture No. 11,678 or 2,288.
B-5	Birr	10°38'30"	37°25'15"	Long crest length, 2 or 3 km. Earth, probably. Little prospect for hydroelectric power development if irrigation planned, due to water supply. Picture No. 2,493.
BA-1	Balanga	12°36'0"	37°21'0"	Abutment, 2250 meters elevation; water surface 2225 meters elevation. Small reservoir. Perhaps .056 cu. m. per sec. flow noted in May. Very small site. Picture No. 6,760.
BL-1	Beles	11°51'0"	36°55'0"	6.7-km. tunnel diversion from Lake Tana. Large power potential, perhaps 1,200,000,000 kw.-hr. firm power. Picture No. 3,138. Name: Alefa.
BL-2	Beles	11°4'12"	35°44'10"	Water surface 768 meters elevation; abutment 884 meters elevation. Spillway on north side river in a notch in hills. Good reservoir area, but in heavy brush. Picture No. 8,225. 220 x 10^6 kw.-hr. per year with Lake Tana water and BL-3 operating.
BL-3	Beles	11°7'16"	35°50'30"	Sharp, steep canyon with excellent damsite. Valley spreads out for reservoir upstream. Abutment 870 meters elevation; water surface 732 meters elevation. Picture No. 8,532. 742 x 10^6 kw.-hr. per year. Name: Dangur.
BL-4	Beles	11°4'26"	36°0'24"	Water surface 762 meters elevation; abutment 884 meters elevation. Spillway on the west side behind the abutment hills. Good reservoir area. Picture No. 4,624.
BL-5	Beles	10°58'48"	36°3'36"	Abutment 884 meters elevation. River on rock and cuts through a ridge but height of dam probably less than BL-4. River gradient steep, small falls, rapids. Picture No. 4,535.
BL-6	Beles	11°44'0"	36°50'0"	Water surface at 1418 meters elevation, abutment at 1524 meters elevation Picture No. 3,077.
BL-7	Beles	11°40'50"	36°47'30"	Water surface 1315 meters elevation; abutment at 1440 meters elevation. Picture No. 3,076. 430 x 10^6 kw.-hr. per year with Tana diversion.
BL-8	Beles	11°7'30"	35°28'20"	Water surface 686 meters elevation. Abutment 823 meters elevation. Low dam required. At 798-meter contour, too much dike required. Picture No. 7,693. 600 x 10^6 kw.-hr. per year with Tana diversion, BL-3 in operation, and irrigation depletion.
BN-1	Abbay	9°53'40"	37°50'30"	10 km. downstream from mouth of Muger River. Sandstone and shale foundation. Earthfill dam of tremendous volume. Instability requiring deep excavation for foundation indicated. Site does not appear feasible. Picture No. 5,604. Site BN-3 favored by economic studies.
BN-2	Abbay	9°52'18"	37°48'8"	Water surface 965 meters elevation; abutment at 1160 meters elevation. Good storage site for power. Picture No. 6,695. Site BN-3 favored by economic studies.
BN-3	Abbay	9°51'0"	37°42'55"	Water surface 927 meters elevation; top of gorge at 1160 meters elevation on right abutment. Good storage site for power. See Picture No. 6,879. Firm power about 5.835 x 10^9 kw.-hr. Name: Karadobi.
BN-4	Abbay	9°52'0"	37°40'0"	Water surface 920 meters elevation; top of dam probably at 1150 meters elevation. Good storage site for power. BN-3 favored. Picture No. 9,557.
BN-5	Abbay	9°57'30"	35°38'20"	About 5 kilometers downstream from Diddessa-Blue Nile junction. Suitable for either earth or concrete dam. Picture No. 8,139.
BN-6	Abbay	10°2'48"	35°35'30"	About 1.6 km. abutment to abutment. North abutment 1045 meters elevation; south abutment 1050 meters elevation; water surface 750 meters elevation. Granite. Picture No. 7,769.
BN-7	Abbay	10°5'30"	35°30'0"	About 28 kilometers downstream from Diddessa-Blue Nile junction in narrow gorge cut through low ridge of metamorphic rock. Large dike required on left side of river to obtain any appreciable storage. Abutments about 60 meters above water surface. Not large capacity reservoir site. Pictures No. 10,593 and 10,589.
BN-8	Abbay	11°8'30"	35°11'0"	About 28 kilometers downstream from Beles-Blue Nile junction where river cuts through Degli Shogli Mountains. Large earth dike needed to close reservoir on right side of river. Dam would be very large and costly. Metamorphic rock. Picture No. 9,489.

Sheet 2 of 5

Powersite Symbol No.	River	North latitude	East longitude	Comments
BN-9	Abbay	11°32'30"	37°24'20"	Damsite at rapids; Eggirbar Hill below Lake Tana outlet. Rapids reported to be 10 meters below maximum lake level. Others have visualized three powerplants--one at each site, BN-11, BN-10, and BN-9. Picture No. 3, 725.
BN-10	Abbay	11°29'20"	37°35'0"	Tis Isat Falls. Ethiopia Electric Light and Power Authority has 14-mw. plant under construction. Picture No. 6, 810. Name: Tis Abbay.
BN-11	Abbay	11°29'15"	37°36'40"	At confluence of Tul River. Picture No. 6, 810.
BN-12	Small tributary to Abbay near Lake Tana	11°35'0"	37°38'12"	Falls; top 2070 meters elevation; bottom 1950 meters elevation. Very small power potential. Small storage site upstream above falls; water surface 2150 meters elevation, abutment 2195 meters elevation. Flow in April 1959 only .056 cu. m. per sec. Picture No. 6, 808.
BN-13	Small tributary to Abbay near Lake Tana	11°32'12"	37°42'42"	Falls; one-half to one-fourth head of BN-12. Small storage site available. Very small power potential. Picture No. 9, 660.
BN-14	Abbay	11°15'0"	37°49'50"	Abutment at 1670 meters elevation. Extremely rugged gorge. Picture No. 5, 636.
BN-15	Abbay	11°13'20"	37°51'30"	Rugged canyon. Abutment at 1645 meters elevation. BN-14 and BN-15 rival Glen Canyon in the United States. Picture No. 5, 635.
BN-16	Abbay	10°5'45"	38°17'30"	Water surface 1122 meters elevation; abutment at 1425 meters elevation. Not particularly attractive site. Sedimentary rock. Picture No. 2, 134.
BN-17	Abbay	10°5'0"	38°12'0"	30-meter-high dam suggested by Pontecarvo. Near Blue Nile bridge. 10-meter drop in reservoir claimed; storage at 2 x 10^9 m^3. Reservoir 60 km. long. Picture No. 2, 682.
BN-18	Abbay	10°2'18"	37°18'30"	Pontecarvos location. 9-meter-drop is claimed in river channel in length of reservoir. Supposed to store 1 x 10^9 m^3. Reservoir 90 km. Dam 30 meters high. Picture No. 2, 300.
BN-19	Abbay	10°18'42"	36°40'24"	Tremendous notch. Damsite in granite. Good reservoir area. 1100 meters elevation to top of notch (abutment). For a high dam, spillway is on the right-hand or north side of river behind hill. Elevation of natural spillway 1000 meters. Water surface 762 meters. Picture No. 11, 145. 5.314 x 10^9 kw.-hr. per year with BN-3 installed. Name: Mabil.
BN-20	Abbay	10°28'0"	36°32'30"	Water surface 730 meters; abutment 957 meters. Excellent reservoir area. Picture No. 3, 470.
BN-21	Abbay	10°7'54"	36°15'0"	Dam of very long crest required. High mountains each side. Picture No. 10, 487.
BN-22	Abbay	10°6'54"	36°11'36"	Damsite in granite. Abutment 1000 meters elevation. Water surface 640 meters elevation. Picture No. 4, 428.
BN-23	Abbay	10°8'0"	36°4'20"	Rocky channel. Pictures No. 4, 606 and 4, 551.
BN-24	Abbay	11°25'20"	35°12'30"	Pontecarvo's location. Reservoir 17 km. long. Supposedly will store 400 x 10^6 m^3. Dam 30 meters high. Picture No. 9, 493.
BN-25	Abbay	11°1'40"	38°28'0"	Little storage. Run-of-river powerplant possible. Picture No. 1, 030.
BN-26A	Abbay	10°5'30"	35°30'0"	Abutment 860 meters elevation. Water surface 611 meters elevation. Picture No. 7, 769. 7.8 x 10^9 kw.-hr. per year with BN-3 and BN-19 installed. Name: Mendaia.
BN-27	Abbay	11°0'30"	35°11'0"	Water surface about 545 meters elevation; Yaringhe Hill, right abutment, at 244 meters above water surface; left abutment hill 122 meters above water surface. This site especially attractive to Major R. E. Cheesman. Picture No. 9, 492.
BN-28	Abbay	11°13'0"	35°6'0"	Water surface about 497 meters elevation; abutment 580 meters elevation for a reasonable height dam. Picture No. 9, 459. 6.2 x 10^9 kw.-hr. per year with BN-3, -19, and -26A installed. Name: Border.
BS-1	Beshilo	11°3'48"	38°27'50"	Good storage possibilities. Reservoir small but deep. Picture No. 1, 031. 800 x 10^6 kw.-hr. per year possible.
BS-2	Beshilo	11°28'30"	39°10'48"	Narrow, sharp canyon. Reservoir probably yield 1, 690 x 10^6 m^3 of water; 340 x 10^6 kw.-hr. annually. Picture No. 3, 659.
CH-1	Cheye	10°35'0"	38°25'0"	CH-1 is reservoir which might yield 180 x 10^6 m^3 per year.
CH-2				CH-2 powersite has 600-meter drop. 200 x 10^6 kw.-hr. per year with both constructed. Picture No. 2, 665.
DA-1	Dabus	10°17'15"	35°2'0"	Water surface 863 meters elevation; abutment 945 meters elevation. Natural spillway on the east behind abutment hill. Small reservoir. Picture No. 10, 606.
DA-2	Dabus	10°13'0"	35°2'20"	Water surface 942 meters elevation; abutment 1037 meters elevation. Small storage. Two falls upstream. Pictures No. 8, 983 and 8, 985.
DA-3	Dabus	9°2'0"	34°50'0"	1646 meters elevation, ground. On Dabus south side road to Becchi. Small storage. Picture No. 8, 852.
DA-4	Hoha--Tributary to Dabus, 13 miles from Asosa, bearing 60°	10°6'12"	34°42'30"	Water surface 1370 meters elevation: abutment 1525 meters elevation ±. Possible power supply for Asosa. Little storage; questionable water supply. Picture No. 8, 946.
DA-5	Dabus	10°0'40"	34°52'0"	Water surface 1200 meters elevation; abutment 1310 meters elevation. Good reservoir area upstream, narrowing down after first bend. Reservoir ends at a fall. Picture No. 6, 824.
DA-6	Dabus	10°5'0"	34°55'0"	Water surface 1150 meters elevation, abutment 1330 meters elevation. Broad valley. Picture No. 6, 825.
DA-7	Dabus	10°4'0"	34°52'20"	Water surface 1160 meters elevation; abutment 1220 meters elevation. Fair reservoir. Picture No. 6, 825.
DA-8	Dabus	9°29'0"	34°55'0"	7, 500-kw. powerplant fed by canal. No storage. Run-of-river type, 90-meter head, to serve Asosa, Mendi, and Begi. Picture No. 6, 823. Name: Dabus Power.
DB-1	Dabana	8°56'18"	36°0'48"	Water surface 1286 meters elevation; abutment 1400 meters elevation. Powerplant could be located near toe of dam with firm generation of about 200, 000, 000 kw.-hr. annually. Multiple-purpose--Power and irrigation possibilities. Picture No. 4, 582. Name: Debana.
DB-1A	Dabana	9°2'40"	36°6'0"	This is some 17 km. downstream from DB-1. A constant-head plant fed by a canal which takes water from the river downstream of DB-1. Gross head, slightly over 90 meters. Powerplant generation about 186, 000, 000 kw.-hr. firm, annually. Picture No. 4, 573.
DB-2	Dabana	8°59'50"	36°2'0"	Fair damsite; good reservoir. Picture No. 4, 583.
DB-3	Dabana	8°42'50"	36°9'0"	Reservoir better than DB-2. Picture No. 4, 400.

Powersite Symbol No.	River	North latitude	East longitude	Comments
DB-4	Dabana	8°41'50"	36°9'0"	Best reservoir site on Dabana except for Site DB-1. Picture No. 4,399.
DD-1	Diddessa	9°5'10"	36°22'0"	Good storage site; good reservoir area. Water supply questionable. Picture No. 9,254.
DD-2	Diddessa	9°29'18"	35°59'12"	Water surface 944 meters elevation; abutment 1067 meters elevation. Good damsite as valley opens out above for reservoir. Large firm power potential of about 1.4 x 10^9 kw.-hr. per year. Dam height probably about 100 meters. Picture No. 4,594. Name: Boo.
DD-3	Diddessa	9°0'24"	36°9'36"	Waterfalls. Upstream from bridge. Good flow. Picture No. 4,406.
DD-4	Diddessa	8°42'24"	36°24'42"	Water surface 1310 meters elevation; abutment 1450 meters elevation; and spillway 1450 meters elevation. Damsite crosses stream below downstream end of island. Natural spillway back of abutment hill on left side of river. Large dam required and would flood out potentially irrigable land upstream. Picture No. 4,928. 1,180 x 10^6 kw.-hr. per year with DD-11 operating.
DD-5	Diddessa	8°4'0"	36°22'0"	Sharp gorge. Waterfalls. Power for timber products, perhaps. Picture No. 11,500.
DD-6	Diddessa	9°43'0"	36°0'30"	Water surface 838 meters elevation; abutment 1070 meters elevation. In gorge. River gradient steep upstream. Crest length of dam short. Good dam possibilities from DD-6 downstream anywhere. Picture No. 4,598.
DD-7	Diddessa	9°50'12"	35°51'0"	Abutment 885 meters elevation. Excellent damsite. River valley spreads out for good reservoir. Picture No. 8,557. BN-26A preferable, which would flood this site.
DD-8	Diddessa	9°51'42"	35°46'36"	Water surface 700 meters elevation; abutment 825 meters elevation. Excellent damsite and good storage area. Picture No. 8,622. BN-26A preferable, which would flood this site.
DD-9	Tributary to Diddessa	9°11'24"	36°13'48"	Waterfall; good flow. Picture No. 4,410.
DD-10	Diddessa	7°59'24"	36°35'18"	Water surface 1295 meters elevation; abutment 1500 meters elevation. Good damsite. Picture No. 4,974.
DD-11	Diddessa	8°12'50"	36°48'30"	Water surface 1343 meters elevation; abutment 1420 meters elevation. Geology may be a problem. Multiple purpose. Firm yield from powerplant at toe of dam about 145 x 10^6 kw.-hr. per year. Picture No. 5,422.
DD-12	Diddessa	8°4'20"	36°32'10"	Small damsite. Picture No. 5,003.
DI-1	Dindir	11°49'48"	36°29'30"	Alternative site. Of no value unless water is diverted from Lake Tana and this does not appear economical. Lake Tana diversion to Beles River better. Picture No. 4,689.
DI-2	Dindir	12°1'0"	35°52'40"	Water surface 790 meters elevation; abutment 840 meters elevation. Little power potential if major irrigation project developed. Picture No. 8,514.
DI-3	Dindir	12°2'30"	36°20'30"	Left abutment elevation 1020 meters; water surface elevation about 930 meters. Gradient may be steep. Distance from load centers and isolation of site are problems. Picture No. 5,899.
DI-4	Dindir	11°54'0"	36°17'30"	Water surface 953 meters elevation; abutment 1000 meters elevation. Picture No. 5,897.
DI-5	Dindir	11°52'30"	36°3'0"	Water surface 864 meters elevation; abutments 900 meters elevation. Crest length at 900 meters elevation, about 1000 meters. Picture No. 4,517
DI-6	Dindir	11°50'0"	36°4'30"	Water surface 905 meters elevation; abutments 960 meters elevation. Crest length at 960 meters elevation, about 700 meters. Picture No. 4,518.
DI-7	Dindir	12°0'15"	36°12'0"	Water surface 868 meters elevation; abutments 1020 meters elevation. Crest length at 1020 meters elevation, about 3 kilometers. Estimated firm power generation about 190 x 10^6 kw.-hr. per year. Picture No. 3,547. Name: Junction.
DU-1	Dura	10°58'26"	39°28'40"	Waterfalls. Possible source of power for Metekkel. Picture No. 3,480.
FE-1	Fettam	10°28'0"	37°2'0"	Lower Fettam. 170-meter drop with 500 meters more drop in next 6 kilometers. 250 x 10^6 kw.-hr. annually in first drop. Storage limited. Picture No. 4,219.
FI-1 and FI-1A	Finchaa	9°34'24"	37°21'0"	Small storage dam located at mouth of Chomen Swamp on Finchaa River. Multiple-purpose, probably, with lands served with water downstream in the Finchaa River Canyon. Power diversion damsite, FI-2, about 5 kilometers downstream, would divert water into a power tunnel. River drops over escarpment below FI-2 with possible powerplant FI-1A location in canyon below falls. Firm power generation per year about 360 x 10^6 kw.-hr. Picture No. 6,326. (Latitude and longitude given for FI-1.) Name: Finchaa.
GA-4	Gilgel Abbay	11°12'30"	37°0'30"	Based upon West German plan. About 44-meter head with maximum capability and generation about 8,000 kilowatts and about 40 x 10^6 kw.-hr. Identified as Powerplant No. 1. Regulation by proposed Umbri Mariam Reservoir. Picture No. 10,108.
GA-5	Gilgel Abbay	11°17'45"	36°58'30"	Based upon West German plan. About 82-meter head with maximum capability and generation about 16,000 kilowatts and about 80 x 10^6 kw.-hr. Identified as Powerplant No. 2. Regulation by proposed Umbri Mariam Reservoir. Constant head powerplant fed from canal leading from this reservoir. Picture No. 10,106.
GA-6	Gilgel Abbay	11°24'0"	37°0'30"	Based upon West German plan. About 68-meter head with maximum capability and generation about 32,000 kilowatts and 141 x 10^6 kw.-hr. Underground powerplant envisioned. Water taken from canal fed from Debekan Mariam Reservoir. Constant-head plant. Identified as Powerplant No. 3. Picture No. 4,848.
GA-7	Gilgel Abbay	11°23'30"	37°1'30"	Based upon West German plan. About 27-meter head with maximum capability and generation about 7,500 kilowatts and 20 x 10^6 kw.-hr. Located at toe of small dam. Regulation upstream by proposed Sawessa Mariam Reservoir and Koga Tank and small reservoir at powerplant. Identified as Powerplant No. 4. Picture No. 4,848.
GA-8	Gilgel Abbay	11°21'15"	37°2'0"	Based upon West German plan. A very small plant for early proposed Pilot Farm use. Perhaps 22-meter head with installed capacity of 165 kilowatts. Picture No. 4,775.
GAL-2	Galegu	12°10'30"	35°59'45"	Water surface about 880 meters elevation; abutments above 1000 meters elevation. Probably insufficient water supply for power generation if full-scale irrigation development planned. Picture No. 8,488.
GB-1	Guba	9°32'30"	34°59'15"	Water surface 1525 meters elevation; abutment 1585 meters elevation. Long dam may be required. Picture No. 8,997.
GB-2	Guba	9°36'24"	35°9'0"	Water surface 1495 meters elevation; abutment 1570 meters elevation. Much storage. Picture No. 9,375. 290 x 10^6 kw.-hr. per year.

Powersite Symbol No.	River	North latitude	East longitude	Comments
GC-1	Gabicura	12°28'42"	37°21'42"	Water surface 2010 meters elevation; abutment 2045 meters elevation. Some storage. Picture No. 6, 757.
GC-2	Gabicura	12°27'42"	37°20'0"	Some storage but larger dam than GC-1. Picture No. 6, 757.
GI-1	Giamma	9°55'0"	38°54'15"	Junction Dersena and Giamma Rivers. Water surface at 1252 meters elevation. Abutment elevations in excess of 1500 meters. Dam height probably at elevation 1378 meters. Large-volume dam required. Firm yield about 270 x 10^6 kw.-hr. annually. Powerplant near toe of dam. Good reservoir. Picture No. 633.
GL-1	Guaali	11°54'0"	38°2'20"	Small storage. Might serve Debre Tabor. Picture No. 7, 055.
GM-2	Gumara	11°49'0"	38°0'20"	Waterfalls. Broad bowl-shaped basin sunken about 300 meters below surrounding country; might serve Debre Tabor. Picture No. 5, 150.
GM-6	Gumara	11°45'0"	37°48'0"	In conjunction with irrigation, 4, 500-kilowatt (continuous rating) could be installed, but might not be feasible due to the extra cost of the higher dam chargeable to the powerplant. Water surface elevation 1890 meters, approximately. Abutments possible at 1990 meters. Dam height something less. Picture No. 1, 962.
GU-1	Guder	9°25'48"	37°39'36"	Near junction Annonu River with Guder River. In a narrow canyon and dam, would have a height of about 114 meters with a maximum crest length of 430 meters. Firm generation, about 225 x 10^6 kw.-hr. per year. Powerplant near toe of dam. Picture No. 9, 548. Name: Motto.
GU-2	Guder	9°29'48"	37°38'42"	Near junction Cale River with Guder. Declivity of river very substantial from GU-1 site to GU-2 site. GU-2 site precludes use of reservoir area behind GU-1 due to this problem. Future powerplant might be developed in conjunction with GU-1. Picture No. 9, 549.
GU-3	Guder	8°51'42"	37°43'30"	Actually located on a small tributary, the Fato River. Small waterfalls on Fato River near junction with Melke River. Less than 500-kilowatt potential. Damsite upstream, a few meters from the falls. Picture No. 7, 226.
GU-4	Guder	8°53'30"	37°41'30"	Located on a tributary, the Bello River. Damsite above a series of three waterfalls and rapids. To take advantage of maximum head, penstocks, tunnel, or canal would be costly. Water supply for maximum irrigation development downstream would not be sufficient for power generation too at this site unless storage was increased considerably. Increased cost of higher dam may not be justified. Picture No. 9, 536.
IZ-1	Izane	11°28'30"	37°23'24"	Waterfalls. Very small flow; perhaps .17 cu. m. per sec. in April. Picture No. 2, 475.
J-4	Jema Tributary to Gilgel Abbay	11°4'12"	37°20'0"	Water surface 2340 meters elevation; abutment 2400 meters elevation. Good damsite; good storage. Picture No. 11, 668.
KO-1	Kontor	9°16'30"	37°25'50"	Large falls. Southeast Chomen Swamp on or near junction with Annonu River. Large flow in late December. Picture No. 9, 892.
LE-1	Lechamura	9°1'42"	34°40'20"	Waterfalls. Good storage above falls; good reservoir area. Southeast Becchi and south of road crossing over Lechamura River. Picture No. 8, 925.
ME-2	Megech	12°31'30"	37°28'0"	Probably earthfill dam, 76 meters high and crest length of 815 meters. Water supply satisfactory for irrigation development but may not be economical for power development considering the storage costs chargeable to the very small powerplant that could be installed. Picture No. 2, 455.
MU-1	Muger	9°25'20"	38°43'30"	Waterfalls in excess of 200 meters with greater head available if advantage taken of rapids below base of main falls. Little storage available immediately above falls, except at Site MU-4. Storage at MU-4 would provide in excess of 60 x 10^6 kw.-hr. firm energy at this site using the approximate 200-meter head. Without upstream regulation, annual energy would fall to less than one-fourth of this value. Picture No. 3, 327. Name: Falls.
MU-2	Muger	9°32'0"	38°32'54"	Fair reservoir. Long dam. Geology questionable due to gypsum in this area. Water surface at about 1500 meters elevation at damsite. Picture No. 475.
MU-3	Muger	9°39'50"	38°21'40"	Water surface 1360 meters elevation; abutment 1460 meters elevation. Not considered feasible, although a natural damsite, due to heavy gypsum beds. Picture No. 777.
MU-4	Muger	9°18'50"	38°44'20"	West of Chancho village. A good damsite but may require a large dam in comparison to reservoir storage. Would provide regulation for a small powerplant about 0.8 kilometer downstream, and for Powerplant MU-1. Firm output from Powerplant MU-4 would be about 15 x 10^6 kw.-hr. for local use. Picture No. 3, 328. Better used for future municipal water supply, Addis Ababa. Name: Chancho.

Note: The following Negeso sites are possible early-stage power sources for Lekkemt although development on the Angar River appears more favorable for a long-range program:

Powersite Symbol No.	River	North latitude	East longitude	Comments
NE-1	Negeso	8°52'10"	36°32'48"	Waterfalls. Picture No. 11, 056.
NE-2	Negeso	8°54'50"	36°41'0"	Abutment 1770 meters elevation; about 30-meter-high dam. River has steep gradient. Picture No. 5, 513.
NE-3	Negeso	8°54'10"	36°44'20"	Abutment 1430 meters elevation; about 30-meter-high dam. Picture No. 5, 482.
NE-4	Negeso	8°54'30"	36°36'0"	Downstream from waterfall. Questionable storage. Picture No. 3, 431.
NES-1A	Neshe	9°46'45"	37°16'30"	560-meter head plant possible producing 378 x 10^6 kw.-hr. per year regulated by reservoir impounded behind Dams NES-1 and AM-1. Picture No. 9, 959. Name: Neske.
RA-1	Rahad	12°15'54"	36°57'12"	Diversion to west from Lake Tana. 13- to 15-kilometer tunnel required. An alternative scheme for diversion of Lake Tana waters. Perhaps greater head for power development available at this site but Lake Tana water is not needed for irrigation development on the Rahad or Dindir Rivers. Better diversion scheme is to the Beles River where Lake Tana water (1) is needed for irrigation development, and (2) also keeps the water in Ethiopia for further use before crossing an International Boundary. Picture No. 3, 130.
RA-2	Rahad	12°9'30"	36°42'0"	Excellent storage. Picture No. 4, 682.
RA-3	Rahad	12°32'30"	36°22'20"	Water surface at about 820 meters elevation with abutments somewhat above elevation 900 meters. Long dam required and probably would be about 2 kilometers long. May not be economically and technically attractive for power development due to nature of water supply if full irrigation development is programed downstream. Picture No. 4, 074.
S-1	Shye	10°15'30"	39°31'15"	200-meter falls, 15 kilometers from Mehal Meda. Storage above. Possible power source for Mehal Meda or wool factory, although thermal power source would appear to be more economical. Picture No. 891.

Powersite Symbol No.	River	North latitude	East longitude	Comments
T-1	Timochia	10°20'0"	37°9'10"	Many rapids, steep canyon, rough country. Cascades. Vertically walled canyon. Falls. Heavily populated rural area beginning 5 kilometers from site. Possible long-range future power supply. Picture No. 4,219.
T-2	Timochia	10°33'30"	37°30'0"	An example of a small village hydroelectric powersite which might be developed for a reasonable cost. Five-meter-high masonry-type diversion dam required. Produces around 330,000 kw.-hr. per year. Supply Dembecha Village. Picture No. 2,386.
TA-1	Talya	10°51'30"	37°24'10"	40-meter dam. Long dam may be required. About 1,000 kilowatts. Picture No. 2,490.
VO-1	Welaka	10°22'24"	38°48'0"	Storage site on Welaka River. Not much storage. Picture No. 1,704. 95 x 10^6 kw.-hr. per year possible.
WA-1	Wama	8°34'20"	36°44'55"	30-meter-high dam with long dike. Not economically attractive at this time due to extremely high storage costs per unit of electrical energy potential. Picture No. 5,475.

Intermittent Streams. There are innumerable rivers and streams that flow only during and for a variable period following the annual rains which occur generally from June into September. The gradient of many streams is generally steep, requiring high dams for any appreciable reservoir storage. A further limit to storage capability is the depth to which many of the rivers are entrenched in narrow gorges for part of their length. By considering all facets of the problem--intermittent flows, steep gradients, and other peculiarities of reservoir topography--the potential hydroelectric sites in these locations were not generally as economically attractive because of higher investment costs per unit of installed generator capacity than would be the case on perennial streams. Since the construction of the higher-cost plants would normally be deferred until the demand threatens to exceed the availability of power from the lower-cost plants, it was considered advisable to omit most of the intermittent stream development potentials from the inventory listing. If the better sites on perennial streams as shown in Table V-6 were developed, the supply of electrical energy would be sufficient to meet all demands for more than a century.

Capacities. Generally, Table V-6 includes sites which appear to be capable of producing at least 500 kw. of firm power and fall within the foregoing criteria. There are some exceptions where a few sites of less than 500 kw. potential capacity have been included because of strategic location near villages or towns with little prospect of being served from other sources. There are numerous sites near villages where plants of less than 100 kw. potential could be developed in the future. Lack of sufficient local capital generally deters development of small hydroelectric installations, because they usually require higher initial investment than alternative power sources. 1/

The most practical approach often is the installation of small diesel electric stations. Once the diesel sets have been installed, the loads may gradually build to the point where it would be economical to install hydroelectric generators. Because of these circumstances, which incidentally seem to be a basis for planning by the Ethiopian Electric Light and Power Authority, it was not considered feasible to catalog and list every small potential village power supply site.

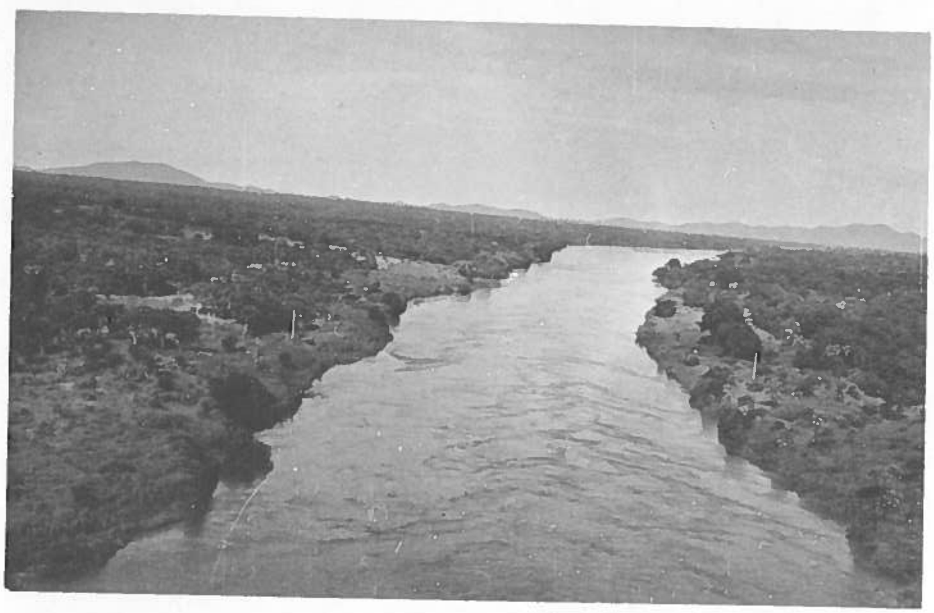


Figure V-8--High water on the Blue Nile River at the Ethiopia-Sudan international boundary, which is a short distance beyond the cableway. Hydroelectric power potential upstream from this point is in excess of 8,000 mw. at 50 percent plant factor for the Basin.

1/See Annex "D", this Appendix.

SECTION III--GENERAL FACTORS IN POWER MARKET ANALYSIS OF ETHIOPIA AND ITS BLUE NILE RIVER BASIN

BACKGROUND

Several factors in power market analysis of future loads in Ethiopia must be considered. These factors include the geographical location of future potential load centers; various physical features, such as topography and climate; the extent of natural resources, such as land, water, forests, minerals, and people; the economic trends of the various sectors of the economy; the degree and trends of urbanization; occupations of labor; per capita income; other energy sources; present electric rates and power production costs; and the potential demand for electricity.

In considering the general factors in a power market analysis in Ethiopia, one must recognize that the principal load center is the Addis Ababa Complex, and will remain so in the future. Addis Ababa lies on the Blue Nile River Basin boundary and the area having the greatest potential for supplying the energy needs of the Addis Ababa Complex is the Blue Nile Basin, so the two situations are compatible in that the one area can supply the needs of the other. The Complex is a large one encompassing what is generally known as the "Interconnected System" extending from Addis Ababa via Koka Dam and Powerplant to the Dire Dawa-Harar area. Blue Nile power can be brought to the Addis Ababa area, and by displacement, the Awash River plants would gradually assume a greater part of the periphery loads in this Complex as the Blue Nile plants assume a greater share of the Addis Ababa area loads (Addis Ababa, Akaki, and Debre Zeit). Also, since ultimately it may be feasible to serve the South Eritrea load center (Assab, primarily) from the Interconnected System, it follows that the foregoing centers, together with the other much smaller load centers described in Section IV, will constitute the great majority of the load 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 part of Ethiopia which determines the health of the national economy, and the 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 in this study and not just the small, isolated potential load centers within the Blue Nile Basin.

The Complex is important for another reason. A very important factor in the power market analysis is the political structure of the country. Addis Ababa is the capital city from which the national government operates.

The electric utility serving the Addis Ababa Complex is the Government-owned Ethiopia Electric Power and Light Authority (EELPA) whose board of directors and manager are appointed or approved by the Emperor. This utility is generally responsible for the electric power development in all of Ethiopia, except for North Eritrea, where older concessionaires were established under the former Italian regime. The Authority 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. This system was placed in operation in 1960. Prior to that time, most of the energy was generated by thermal plants using imported petroleum products.

The nation's economy is guided by state planning set up on the basis of a series of 5-year plans. It is now in its Second 5-year Development Plan.

LOCATION

The Blue Nile River Basin lies in two countries, Sudan and Ethiopia, but the Blue Nile River originates in Ethiopia, and it is that part of the Basin with which these studies are concerned. The Blue Nile River Basin in Ethiopia lies in the west-central portion of the country, as shown on Figure V-9.

Ethiopia is on the east coast of Africa, generally east of longitude 33°, and immediately north of the equator, ranging from about 4° north latitude to perhaps 18° north latitude. The maximum distance from east to west is about 1,600 kilometers, about the same as the maximum distance from north to south. Ethiopia is bounded on the north by the Red Sea and the Gulf of Aden, on the west by the Republic of the Sudan, on the east by the Somali Republic, and on the south by Kenya.

GENERAL DESCRIPTION

Physical Features

Ethiopia has about 12 large lakes and 35 major rivers within 6 large watersheds known as the Western, the Northern, the Central, the Southern, the Eastern, and the Great Lakes. The Western watershed includes the Blue Nile and the Dindir and Rahad Rivers which join the Blue Nile in Sudan.

The Blue Nile (Abbay) River originates in Lake Tana, largest lake in Ethiopia, and is the principal river in the basin (See Plate I, back pocket). From the relatively narrow outlet at the southern end of the lake, the Blue Nile River emerges and flows southeasterly over the hard volcanic rocks for a distance of about 30 kilometers (19 miles) and then plunges over the Tis Isat Falls, dropping some 45 meters (150 feet) into a deep, narrow gorge with vertical cliffs caused by the rapid erosion of the softer lava. The river remains entrenched in this deep canyon until it finally emerges near the Ethiopia-Sudan border. There is a wide, irregular loop to the west, and some 900 kilometers (540 miles) from its source, the river enters Sudan at approximate elevation 487 meters. The Blue Nile River joins the White Nile near Khartoum, forming the main Nile River some 760 kilometers (470 miles) below the Ethiopia-Sudan border.

Many tributaries join the Blue Nile River, the principal ones coming from the left. These include the Beshilo, Welaka, Giamma, Muger, Guder, Diddessa, and Dabus; joining from the right side are the Birr and Beles Rivers. Other major rivers in the Blue Nile Basin which originate in Ethiopia but join the Blue Nile in the Sudan are the Dindir and the Rahad. Both of these originate near Lake Tana. The total Blue Nile river drainage in Ethiopia is 173,984 square kilometers. The total Blue Nile drainage to outside of Ethiopia is 25,261 square kilometers, giving a total drainage area for Ethiopia's Blue Nile River Basin of 199,245 square kilometers. 1/

Ethiopia's water resource potential is among the greatest in the world, and the country is sometimes known as the "watershed of eastern Africa." Rough estimates indicate that Ethiopia supplies about 100 billion cubic meters of water annually to her neighbors. On the average, about 80 percent of the total annual flow of the main Nile River comes from Ethiopia's Blue Nile.

Details concerning the various river basins and lakes are given in Tables V-7 and V-8.

1/Total Blue Nile Project investigations area was 203,900 square kilometers, which included 4,655 square kilometers of White Nile drainage.

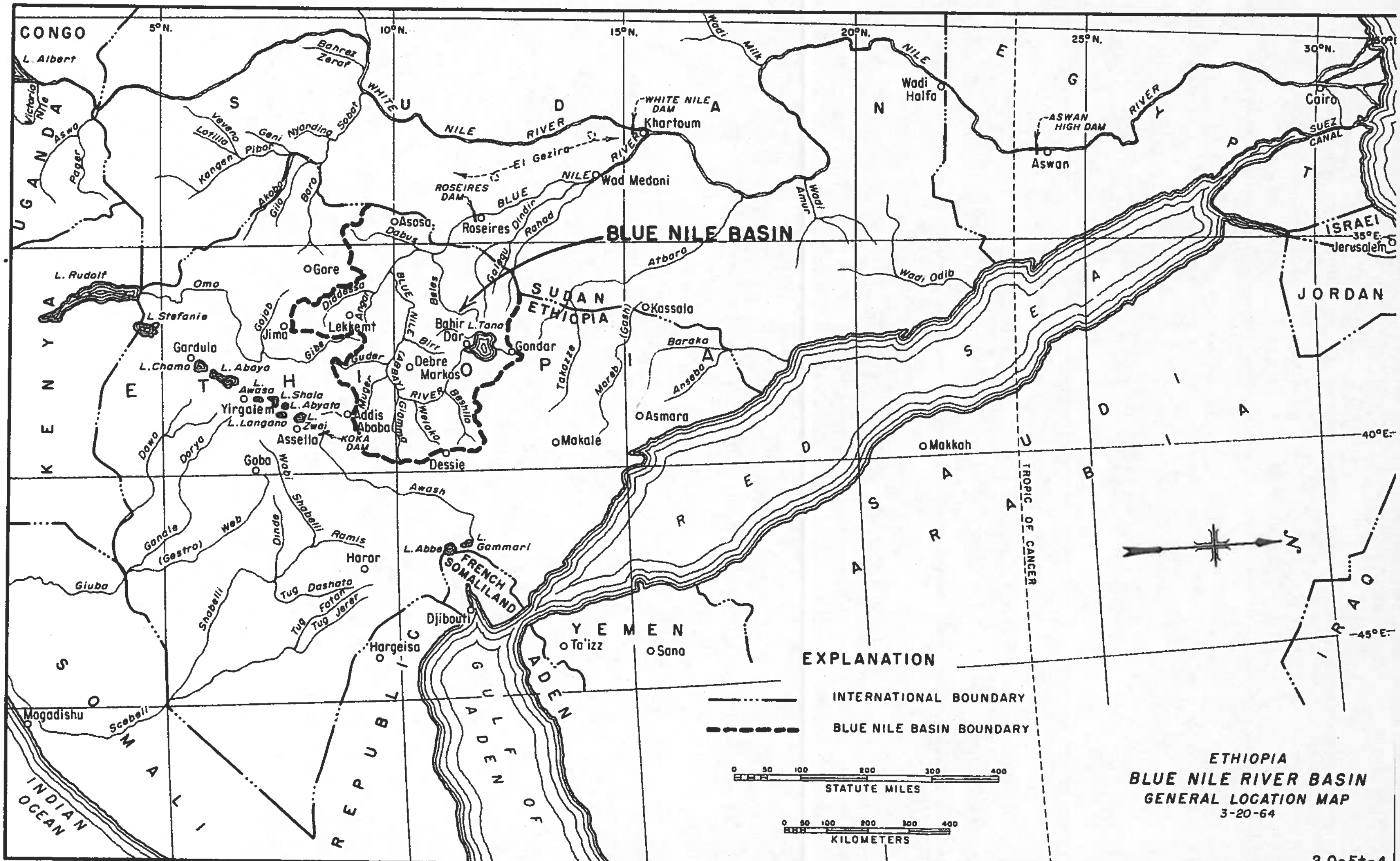


Figure V-9--General Location Map, Blue Nile River Basin

TABLE V-7--RIVER BASINS IN ETHIOPIA1/

Name of river	Area in square kilometers		Length of river kilometers		Total annual flow in cubic meters x 10^9	
	Each	Total	Each	Total	Each	Total
Blue Nile						
Rahad 3/	6,351	2/ 199,245				
Dindir 3/	15,593					
Tumit 3/	2,225					
Miscellaneous 3/	1,092					
Blue Nile 4/	173,984			925		50
Atbara						
Takazze-Setit	67,910	88,960	220	570	9.129	11
Angereb	14,310		217		1.397	
Gandua	6,740		130		0.845	
Baro	26,000	58,000		277		11.825
Akobo/Gila (Ghelo)	32,000					
Wabi Shabelli		197,000		1,130		10.254
Giuba						
Dawa		186,000	640	1,757		10.304
Ganale			603			
Gestro			514			
Awash		60,940		700		5.414
Omo		67,450		829		10.166
Gash (Mareb)		21,630		440		1.974
Baraka (Anseba)		16,500				

1/ Data on all except Blue Nile and tributaries from Ethiopia's Water Resources, by P. Petridis, December 1958.
2/ Total Blue Nile River drainage basin, including those tributaries joining Blue Nile River outside Ethiopia.
3/ Tributaries that join Blue Nile River in Sudan.
4/ Blue Nile River drainage basin with only those tributaries joining Blue Nile within Ethiopia.

TABLE V-8--MAJOR LAKES IN ETHIOPIA 1/

	Altitude (meters)	Maximum depth (meters)	Surface area (sq km.)	Volume of water (cu. m. x 10^9)
Tana	1786	14	3,035	2/ 12.987
Zwai	1848	7	433	1
Langano	1585	4	230	4
Abyata	1573	14	205	1.6
Shala	1555	266	450	37
Awasa	1708	21	129	1.4
Abaya	1285		1,256	
Chamo	1233		550	
Stefanie	518		500	

1/ Data on all except Lake Tana from Ethiopia's Water Resources, by P. Petridis, December 1958.

2/ Storage between elevations 1787.25 and 1786. For storage below 1786, add about 10 x 10^9 cubic meters.

In this specific analysis concerning use of Blue Nile electric energy, the extent of the Blue Nile market areas is determined, in part, by the proximity and power potential of other river basins. Table V-9 indicates, by comparison, estimates of hydroelectric power potential for various river basins in the country.

TABLE V-9--ESTIMATES OF HYDROELECTRIC POTENTIAL FOR MAJOR ETHIOPIAN RIVER BASINS 1/

Basin	(A) Total million kw.-hr.	(B) Utilizable million kw.-hr.	(B) as a percentage of (A)
Awash	4,106.2	1,304.0	31.8
Blue Nile 2/	173,520.0	37,934.0	21.9
Wabi Shabelli	21,562.3	7,044.6	32.7
Omo	16,067.1	4,595.9	28.7
Takazze-Setit	14,846.5	5,047.7	33.9
Baro	3,017.0	1,211.0	40.2
Giuba	2,273.0	654.0	29.3
Gash (Mareb)	1,745.6	569.2	32.6
Miscellaneous 3/	1,661.4	416.8	25.1
Totals	238,799	58,777	24.6

1/ Blue Nile Basin estimate by U.S. Bureau of Reclamation; others by Ethiopian Electric Light and Power Authority. Blue Nile Basin includes all Blue Nile River tributaries in Ethiopia, including Dindir, Rahad, etc.

2/ Blue Nile Basin may not be on comparable basis with other basins. Total is maximum theoretical, based upon gross surface runoff. Utilizable is that considered technically exploitable for power production in 1962 without regard to nontechnical considerations (See Section II).

3/ Includes Baraka, Angareb, Akobo, and others.

TABLE V-10--GROSS NATIONAL PRODUCT, 1957-1967 1/

	1961 prices in Eth$ millions			Index No.	Rate of
	1957	1962	1967	1967/1962	growth
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.

PRINCIPAL ECONOMIC ACTIVITIES AND THE NATIONAL POTENTIAL DEMAND FOR ELECTRICITY

Table V-10 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.

Government planners hope to change Ethiopia from a predominantly subsistence agricultural economy to an up-to-date, efficient, agricultural-industrial one 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. The Gross Domestic Product and corresponding rate of growth are projected as shown by Table V-11 for 20 years in the future. Over 12 billion Ethiopian dollars (total from government and private sources) will have to be invested over the next 20 years, as indicated by Table V-12, according to the Office of the Planning Board, in order to achieve these goals. If this is the objective, it can only be achieved by a corresponding rapid acceleration in the construction of facilities to provide electrical energy to the principal industrial load centers.

TABLE V-11--GROSS DOMESTIC PRODUCT ESTIMATES, 1958-1982 1/

Periods	Gross domestic product (in million Eth$, 1961 prices)	Index number	Rate of growth
1958-1962	2,130	100	3.2
1963-1967	2,632	124	4.3
1968-1972	3,310	155	4.7
1973-1977	4,270	200	5.2
1978-1982	5,650	265	5.8

1/ Second Five-Year Development Plan.

TABLE V-12--ESTIMATED INVESTMENT DURING A 20-YEAR PERIOD 1/

Five-year plan	Total investment (million Eth$)	Five year investment as percent of total	Index number (First Plan = 100)
Second	1,696	13.4	202
Third	2,420	19.1	288
Fourth	3,516	27.7	419
Fifth	5,050	39.8	601
Total	12,682	100.0	

1/ Second Five-Year Development Plan.

Agriculture

Although there will be a substantial shift toward more industrialization within 20 years, agriculture has traditionally been the foundation of the Ethiopian economy (70 percent of national income), and the livelihood of perhaps 90 percent of the country's population is derived from basic farming activities or from the processing and exchange of farm-produced crops and goods. Table V-13 indicates the forecast trend in the export of certain agricultural products, which is an indication of a trend in anticipated future agricultural production.

TABLE V-13--FORECAST TREND IN EXPORT OF CERTAIN AGRICULTURAL PRODUCTS1/

	In million Eth$, 1962 prices			Index (1962 = 100)
	1962 (Actual)	1967	1963-67	
Coffee	99.6	135.0	601.0	135
Hides and skins	22.7	28.7	125.0	126
Pulses	17.0	18.9	90.0	111
Oilseeds	14.9	21.2	96.0	142
Chat	10.2	11.0	54.0	107
Fruits and vegetables	4.7	6.2	27.0	131
Other	13.3	16.0	78.0	118
Total	182.4	237.0	1,071.0	

1/ Second Five-Year Development Plan.

Mining and Some Related Industries

General. Most of the mining activity is hand work, there being very little machinery used. However, in the Adola region in the Bore valley, work is underway to install a 1,500-kilowatt hydroelectric plant which will produce approximately 7,300,000 kilowatt-hours per year to run the machinery and workshops in mining for gold. Modern mining techniques, of course, are being used in the Dallol potash area too.

Predictions are that future electric power requirements in the mining industry will remain low but should show some increase by 1966. Small hydroelectric plants constructed to serve a single mining area will be the pattern followed to meet future mining loads for some time.

The most important center for gold mining is at Adola in Sidamo Province where the IEG is working alluvial deposits. Additional small alluvial deposits are being mined on the Akobo River in Ilubabor Province, at Wombera in Gojjam Province, and at several places in Wellegga Province, but production probably does not average more than a few thousand dollars annually at each point. Eritrea has long been a small producer of gold from veins of quartz, but production has fallen to low levels since 1950. However, 350 kilograms were produced in 1956, and there are signs of renewed activity in the gold fields.

Marine salt is produced in Eritrea, largely at Massawa and Assab at rates from 60,000 to 200,000 metric tons per year. In addition, some 10,000 to 20,000 metric tons of rock salt are mined annually in the Danakil Depression in the northeastern section of Wello Province.

Explorations are now underway in the Dallol area by an American firm, under contract with the IEG, for potash, sulfur, and magnesium. Drilling was completed in 1962, and it is anticipated that commercial production is to start in the Spring of 1964. In several locations the potash deposits are found to be lying only 15 meters below the surface in veins varying in thickness from 0.3 meter to more than 8.0 meters. The quality of the ore is medium, and the potash deposits so far discovered and assessed run into several million tons. The concession was amended to include other minerals. Ore bodies of sylvite, carnallite, and other salts have been discovered, and production will be at the rate of 300,000 tons per annum. China clay and feldspar have been produced in Eritrea in the past. The Yubdo area in Wellegga Province is one of the principal producers of platinum in Ethiopia, the mine having been in operation for about 30 years. Production in recent years has been very small.

A small amount of manganese ore from a deposit 18 kilometers southwest of Dallol is exported. In addition, there is a substantial deposit of 60 percent iron ore (hematite and magnetite) near a point 30 kilometers southwest of Massawa. No commercial production is underway at present.

Mica deposits have been worked intermittently near Jijiga in Harar Province, and reports persist of substantial deposits of high-grade ruby mica. Among the nonmetallic minerals, pumice, talc, gypsum, travertine, and others have been mentioned as possibilities for commercial exploitation. Among the fuels, only lignite has been found, and the deposits found have not proven to be of commercial interest.

Petroleum

There was no oil produced in Ethiopia in 1962, but oil exploration continued on the Red Sea coast, including the islands, with some favorable results obtained which would warrant a drilling program. In the eastern area of Ogaden, exploration by the Gewerkschaft Elwerath Oil Company continued with the results unpublished in 1962. Construction planning has started on an oil refinery at Assab with a capacity to handle about 500,000 tons yearly. This will be increased (double) if domestic crude oil is discovered, and the addition of a lubricating oil plant is planned later.

The power requirements of the Assab refinery will be substantial, with a 2,000-kw. load and an annual requirement of more than 11,650,000 kw.-hr. Maximum development may require 5,000 kw. and 40,000,000 kw.-hr. annually.

Cement and Cement Products

The Ethiopian Cement Corportation, a state-owned firm, quarries clay and Jurassic limestone at Dire Dawa to produce portland cement. Production in 1959-1961 has been from 25,000 to 30,000 tons. A new cement factory was started in 1962 in Addis Ababa, capable of producing 70,000 metric tons of cement per year from limestone deposits in the Muger canyon about 45 kilometers north of the city. The erection of another cement factory, costing about Eth$15,000,000 and probably located in the Massawa area, is foreseen in 1965. It would have an annual output of 150,000 metric tons, primarily for export. In addition, a new factory for asbestos-cement products will be established, probably in or near Addis Ababa. The estimated power and energy requirements are shown in Table V-14.

TABLE V-14--POWER AND ENERGY REQUIREMENTS FOR PROPOSED CEMENT FACTORIES

Plant	Place	Requirements	
		kw.	kw.-hr.
Cement (70,000 metric tons)	Addis Ababa	1,400	11,000,000
Cement (150,000 metric tons)	Massawa	2,500	20,000,000
Cement products	Addis Ababa	100	210,000

By 1967, the total output of cement plants will have reached 210,000 tons with the full production--probably 250,000 tons--of the three primary plants to be realized shortly thereafter. Long-range plans also include a cement factory at Bahir Dar.

Bricks. In 1957, 5,670,000 bricks were produced, which increased to 8,000,000 in 1962. Total production is forecast to reach 30,000,000 by 1967. This will be accomplished by the erection of new brickyards, total capacity of which will be 20,000,000 bricks annually. Electric power requirements will be limited to motor loads, the main heat source being nonelectrical. During the period 1967-1970, it is planned to construct a refractory materials plant to meet the needs of the metallurgical and other industries. Modern techniques require the use of electric furnaces to produce high quality refractories, such as will be required for boiler linings and locomotives, open hearth steel furnaces, heat-treating furnaces, and the glass and ceramic industry.

Lime. Lime factories are proposed which will produce 5,000 metric tons annually. Suitable limestone deposits exist in many areas of the Empire. Electric power requirements will be for motor loads, and if a rotary kiln is used, the amount of power required will be about 550,000 kw.-hr. per year (70 kw.) by the end of 1967, if the goals of the Second 5-year Development Plan are realized.

Porcelain. During the period 1967-1970, a porcelain factory will be established to manufacture porcelain items for electrical products, primarily insulators of all types and porcelain parts for switches, receptacles, and fixtures. The capacity of the factory has not been fixed. Kaolin clays have been located by USBR geologists in or near the Giamma Canyon, not far from Addis Ababa. A tunnel kiln will probably be used, and fuel is generally oil, coal, gas, or even electricity. At present, Ethiopia would have to import these fuels, except for electricity. Considering the small plant required initially, electricity may be used and would require 4,000,000 kw.-hr. annually at 450 kw. for three-shift operation to produce 500 metric tons of porcelain products per year. A total of 13 new plants will be erected or started during the period 1962-1967, devoted to producing mineral products for the building and nonmetal industries.

Table V-15 shows the proposed increases by years in mineral production to 1967. Table V-16 shows the gross value of mineral production in dollars anticipated as a result of mineral production estimates given in Table V-15.

Since the greater part of Ethiopia, especially in the southwest, is largely unexplored insofar as mineral reconnaissance is concerned, the IEG believes the possibility of obtaining favorable results from a stepped-up investigations program is good, and this optimism is reflected in these two tables.

TABLE V-15--SCHEDULED MINERAL PRODUCTION, 1963-1967 1/

Mineral	Unit	1963	1964	1965	1966	1967
Gold, concentrate	kg.	800	1,000	1,200	1,200	1,200
Platinum, concentrate	kg.	10	15	15	15	15
Iron ore	metric ton	--	--	--	--	200,000
Manganese ore	metric ton	2,000	2,000	2,000	2,000	2,000
Potash	metric ton	--	150,000	300,000	300,000	300,000
Salt	metric ton	25,000	25,000	25,000	25,000	25,000
Quartz sand	metric ton	2,000	2,000	2,000	10,000	12,000
Clays	metric ton	--	--	--	--	5,000
Asbestos	metric ton	--	--	500	1,000	1,000

1/ Second Five-Year Development Plan.

TABLE V-16--FORECAST GROSS VALUE OF MINERAL PRODUCTION 1/

Year	Gross value (Eth$1,000)	Index number (1963 = 100)
1963	2,730	100
1964	7,435	272
1965	12,285	450
1966	12,740	465
1967	16,935	620

1/ Second Five-Year Development Plan.

Manufacturing and Processing Industries

General. Industrial activity in Ethiopia is confined primarily to processing agricultural commodities, to producing foods and beverages, to manufacturing some items for domestic consumption--tabacco products, footwear and leather products, and to producing mineral products--cement, bricks, salt, and others. Figures V-10, V-11, and V-12 show gross industrial production comparisons over a 3- or 4-year period.

Tables V-17 and V-18 summarize industry in the 13 provinces and Eritrea for the year ending September 10, 1961. A study of Table V-19 will indicate that for the 11-year period, 1951 to 1961, inclusive, the volume of industrial production for all of Ethiopia, excluding Eritrea, increased over 4.5 times, and in the same period the production of electricity increased more than 5 times. During the period 1956 through 1961 (6 years), 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.

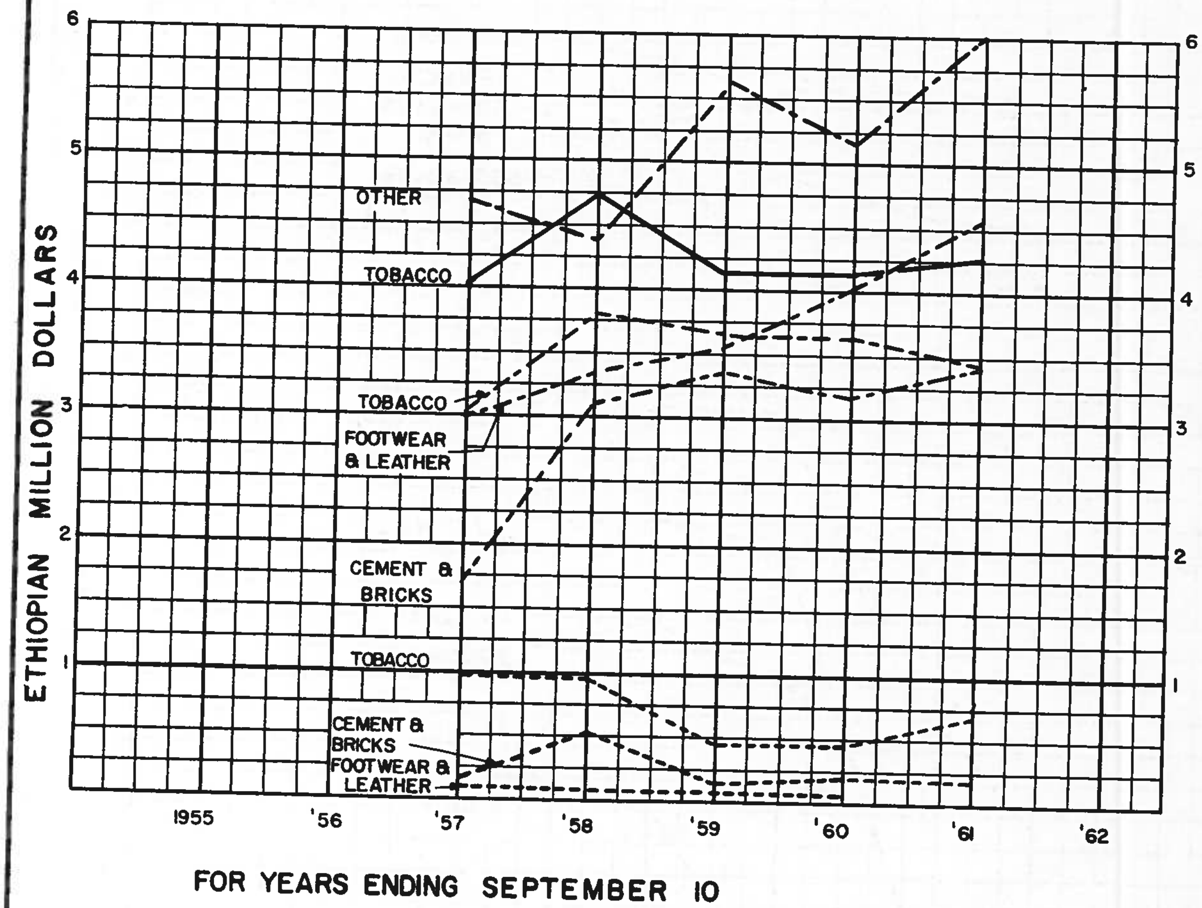
During the same 6-year period, the output of electricity increased as follows:

Eritrea	1.6 times
13 provinces	2.4 times
Total Ethiopia	2.2 times

During the period 1963-1967, 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 V-20. Table V-21 shows that before 1963, the investment in the 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. A tabulation of 103 new industrial projects to be completed and 18 more reconstructed during the period 1963-1967 is shown in Table V-22. Of those to be completed, about 94 will actually go into operation within the same period as shown by Table V-23.

Food Processing

Meat. The Second 5-year Development Plan forecasts the erection of several slaughterhouses in cattle raising regions and, after these establishments are placed in operation, the annual processing of more than 600,000 head of livestock. This would represent an increase of 600 percent in the production of processed meats by the end of 1967. Ethiopia is classed among the countries of the world with the most numerous livestock in relation to the population. Markets will depend upon disease control, and, thus, measures for livestock improvement on a wide scale are planned by the Government. Table V-20 indicates the probable growth of the industry.



—·— Ethiopia's 13 Provinces
---- Eritrea
—— Empire, total, where shown

NOTES

1. Source : Ministry of Commerce and Industry
2. For total gross industrial production, see Drawing No.4.0-BN-32.
3. For gross industrial production selected industries see Drawing No.4-0-BN-31.
4. "OTHER" includes lumber, furniture, printing & chemicals.

ETH-US COOP. PROG. FOR THE STUD. OF W. R.
IN COLLABORATION WITH
U.S. DEPT OF ST INT. COOP ADMIN. 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

ELECTRIC POWER LOAD ANALYSIS
GROSS INDUSTRIAL PRODUCTION
SMALL INDUSTRIES

DRAWN CL. Curtis SUBMITTED C. L. C.
TRACED Gebrechristos RECOMMENDED P. W. K.
CHECKED C. L. C. APPROVED C. E. B.
A.A. May. 21-1962 (I.C)
ETH. May 13-1954 (E.C)
4-0-BN-30

Figure V-10--Gross Industrial Production, Small Industries

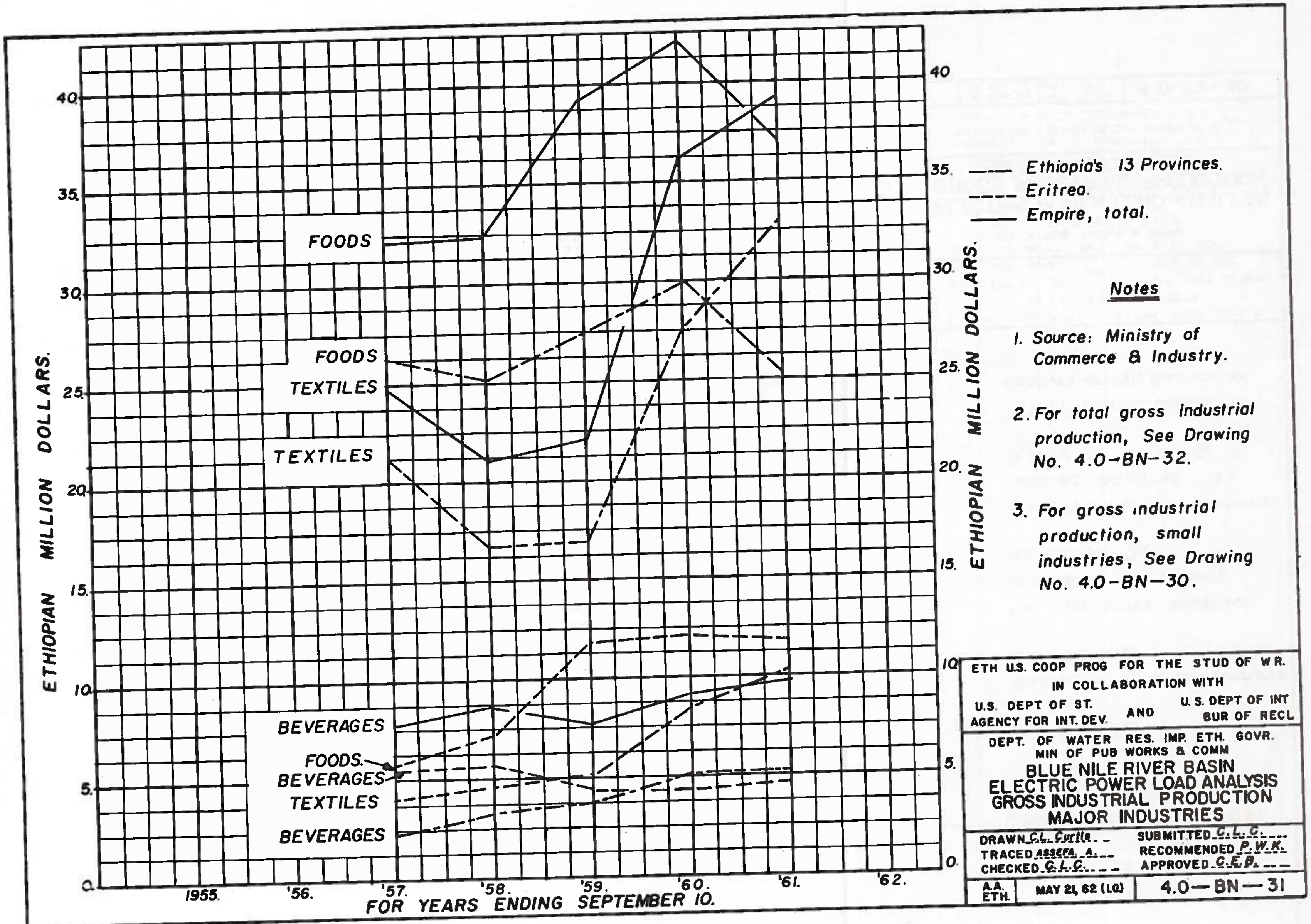


Figure V-11--Gross Industrial Production, Major Industries

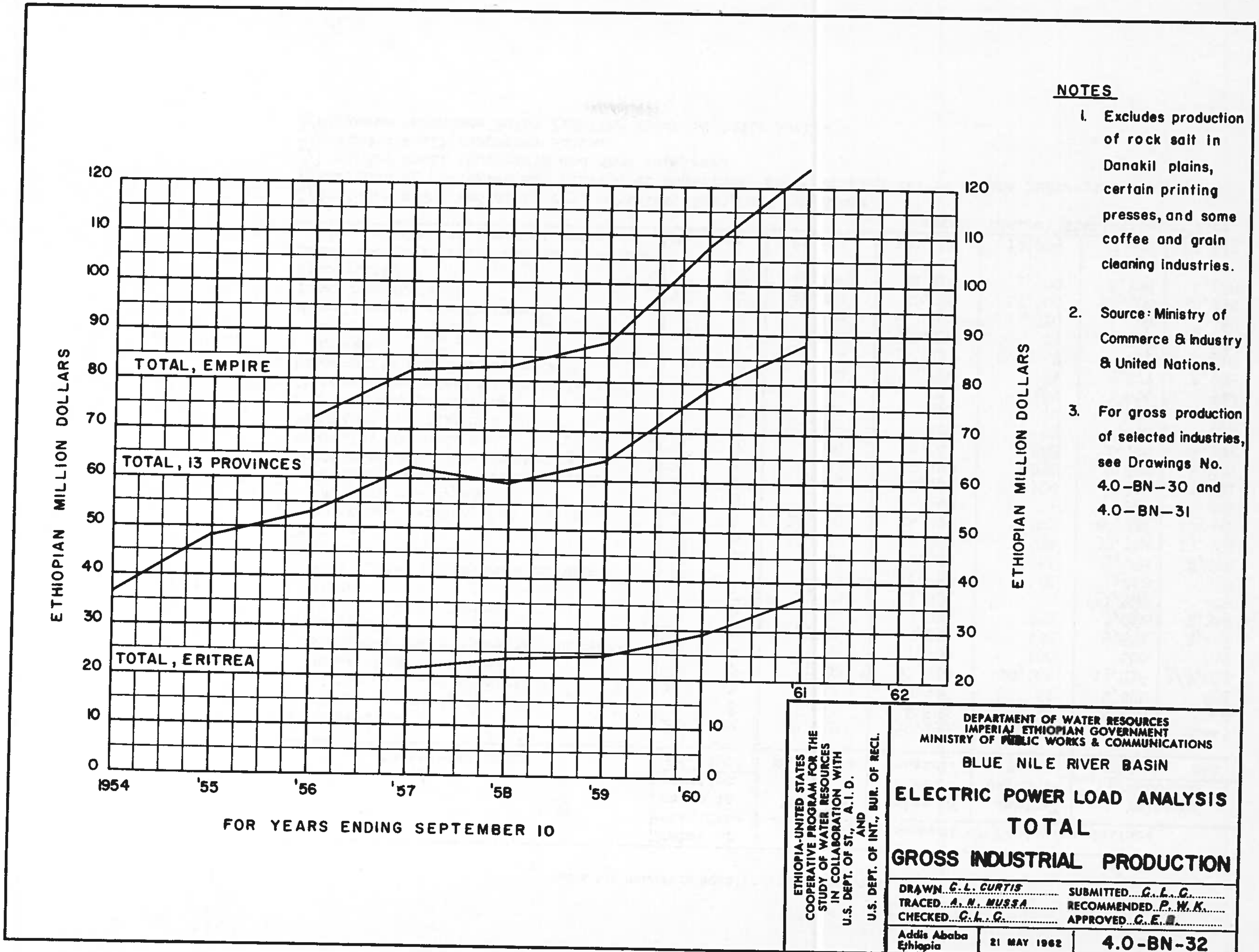


Figure V-12--Total Gross Industrial Production

TABLE V-17--SUMMARY OF INDUSTRY IN THE 13 PROVINCES

Industrial Group	Number of establishments in operation		In thousands of Ethiopian dollars				
			Purchase of materials	Value of fixed assets1/	Capital expenditure	Value of production	
	1960	1961				Gross	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	2/7,017
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 E$5 million of sugarcane 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 V-18--SUMMARY OF INDUSTRY IN ERITREA

Industry	Number of establishments in operation		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)	
	1960	1961				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

TABLE V-19--INDEX OF ECONOMIC TREND OF INDUSTRIAL PRODUCTION 1/

Industrial group	For the Empire of Ethiopia, 1956 through 1961																	
	The 13 Provinces						Eritrea Province 1/						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	83	80	87	55	89	122	112	103	113	94	112	135
Building materials, etc.	117	91	115	93	100	128												
Miscellaneous	84	69	62	56	69	70												
Total Manufacturing	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 Mfg. and Elec.	112	123	123	134	163	181	93	103	122	111	142	139	107	118	123	128	158	171

Industrial group	For the 13 Provinces, 1951 through 1961 (1950 = 100) 2/										
	'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
Total Manufacturing	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 mfg. and Elec.	101	130	161	184	235	263	288	290	314	382	425

Source: Central Statistical Office.

1/North Eritrea load center.
2/Primarily Addis Ababa complex.

TABLE V-20--1967 PRODUCTION GOAL FOR SELECTED INDUSTRIAL PRODUCTS1/

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
Cigarets	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 V-21--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 V-22--NUMBER OF INDUSTRIAL PROJECTS TO BE CONSTRUCTED 1/

Branch of Industry	Total	Breakdown	
		Completed or reconstructed	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	16	1	15
Other	4	--	4
Total	121	18	103

1/Second Five-Year Development Plan.

TABLE V-23--INDUSTRIAL PROJECTS TO BE PUT INTO OPERATION 1/

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

1/Second Five-Year Development Plan.

To process 600,000 head of livestock per year (1967) would require about 18,000,000 kw.-hr. of energy with a maximum demand of about 6,000 kw., operated on an average of one 8-hour shift per day. The power and energy requirement will, of course, depend upon the degree of electrification of the processing plants. Likely locations for processing plants are in Addis Ababa, Dire Dawa, Nazret, and Shashamane, all within the Addis Ababa Complex, South Region.

Dairy. Agriculture as a whole is expected to keep its pace of growth faster than the growth of population in order to supply adequate food for domestic consumption and more products for the processing industry and for export.

Provisions are made in the Second 5-year Development Plan for milk and dairy processing plants. Plants totaling about 1,000 metric tons of annual capacity in Addis Ababa may possibly develop toward the end of the period. If this does, the annual energy requirement, 75,000 kw.-hr., would be very small, requiring a maximum demand of not more than about 50 kw.

Fruit and Vegetables. A small vegetable canning industry exists in Ethiopia, but vegetables are often only a small part in the diet of people in many parts of Ethiopia. In order to improve the nutrition of the people, emphasis is being put on increasing the production of fruits and vegetables in the Government's planning activities as evident in the Second 5-year Development Plan. For supplying the canning industry and larger towns, vegetable and fruit production is planned on a broader scale on large farms.

Present Ethiopian canned vegetable products are of good quality, and demand for them will undoubtedly increase in the future. During the next few years it is anticipated that at least one large fruit and vegetable canning plant may be established. A conservative annual energy requirement of 290,000 kw.-hr. with a maximum demand of 100 kw. is estimated by 1970, and increases after that date are expected. This is based upon Government planners' recommedations that during 1967 some 2,000 tons of quality fruit and vegetable products be raised, largely on big farms.

Fish. The existing fishing industry is small and is generally limited to the Red Sea area, although fish are found in many of the inland lakes and could be developed into a thriving industry. With this in mind, the Government planners have estimated that about 10,000 tons of fish products will be processed in the new plants to be erected on the Red Sea and on the lakes. In addition to supplying domestic needs, considerable quantities of fish products will be exported. Initially, the Red Sea fish processing plants will probably be established in Assab and Massawa. Each of these plants may require 250,000 kw.-hr. per year at about 80-kw. maximum demand. Initial production is estimated to begin during the period 1967-1970. Also, pending the results of studies of the inland lakes south of Mojo, it may be possible to erect a fish processing plant for drying and canning the better varieties of fish and processing the inferior varieties into fish meal and oil. This plant may require an investment of Eth$2,000,000, and for that size plant, the initial energy requirement will be 250,000 kw.-hr. per year, with a maximum demand of 80 kw. Substantial increases are possible later.

Sugar. Sugar production in prior years, compared with the Government planning goal in 1967, is given by Table V-20. In 1967, 60,000 tons of sugar cane will be produced. Sugar production in the past has not depended to any extent upon external electrical energy sources because processing plants have generally supplied their own energy. This was due partially to the lack of external electrical power sources. Also, sugar processing requires steam, of which a portion was utilized for conversion to electrical energy where required. However, Government planners anticipate that during the period 1967 to 1972 a large sugar factory will be erected, the size of which has not been precisely determined. There is some indication that it might be capable of producing 30,000 tons of sugar per year, and on this basis the total annual energy requirement would be about 14,600,000 kw.-hr., with a maximum demand of about 4,000 kw. indicated. Part or all of this energy may be supplied from external sources. Sugar production will steadily increase in the future.

Confectionery. Practically all confectionery items are imported, but a small chocolate and candy factory is under way and others will undoubtedly follow because most of the major ingredients, sugar and oils (shortening), are available in Ethiopia. It is estimated that the first plant in Addis Ababa will require 135,000 kw.-hr. per year, having a maximum demand of 47 kw. This is but a modest beginning, and this industry should expand considerably in the future.

Oil Pressing and Margarine. The production of oilseeds will increase from 351,000 metric tons in 1961 to 424,000 metric tons in 1967, an increase of 20 percent. However, of the increase, 40,000 tons will be used by existing and planned industries, including cottage and handicraft industries, by 1967. Conversion to edible oil will be in the amounts indicated by Table V-20, which will require additional oilseed pressing mills. Construction of additional pressing mills is planned. Before 1970, it is likely that a 6,000-ton-per-year mill to supply processed oil for a margarine plant, the first in Ethiopia, to be established in Addis Ababa. The annual energy requirement for such a mill will be quite small, something on the order of 290,000 kw.-hr. per year with a maximum demand of about 100 kw.

Beverages. This category includes the production of wines, liquors, alcohol, soft drinks, and tej, the latter a local, popular wine using honey as a base. Production, past and future, of principal beverage items is as shown by Table V-20. The Government planners foresee an increased production in 1967 of 85,000 to 100,000 hectoliters of wine. Substantial increases in soft drinks, alcohol, and tej are also forecast. One new brewery will be established by 1967 to provide for the increase in beer production. Also, there is some indication that a small whiskey distillery may develop during this period. While annual energy and power requirements will initially be very small, these industries form the nucleus of a promising industry in Ethiopia with substantial power requirements in the future.

Initially, the small distillery would not use much more than 60,000 kw.-hr. per year at a maximum demand of 20 kw. To increase the production of beer in the amount indicated by Government planners, modern brewing principles would call for an annual energy requirement of 3,285,000 kw.-hr. with a maximum demand of 400 kw.

Miscellaneous. The production of certain other food items is to be stimulated, according to Government planners, and this applies particularly to such items as flour, powdered coffee, macaroni, and eggs. Ethiopia had been an exporter of wheat until quite recently, when it began to import small quantities of wheat to provide for the needs of the increasing population. In 1957 and 1962, flour and macaroni were processed in the amounts shown by Table V-20. For 1967, the goal is 51,000 metric tons of flour and 3,100 metric tons of macaroni, representing increases of over 100 percent for flour and about 10 percent for macaroni. Flour milling will require additional power and energy; requirements for 1967 would amount to 3,100,000 kw.-hr. with a maximum demand of 700 kw. Some six flour mills are planned.

A new factory for the production of powdered coffee is to be constructed during the 1962-1967 period, to have an annual capacity of 3,000 tons; in the year 1967 it will produce 1,500 tons of powdered coffee for export.

Textiles and Wearing Apparel. The per capita consumption of cotton textiles in 1961 was estimated at 2.3 square meters, with the estimated consumption to reach 4.3 square meters (an 88 percent increase) by 1967. The consumption of cotton in 1967 will be 24,000 tons, according to Government planners.

The gross value of the total textile industry production in 1961 was Eth$39,000,000, and the gross value in 1967 is forecast at Eth$88,860,000, or an increase of 128 percent. The bulk of the textile industry production will therefore be in cotton textiles. The estimated production of cotton fabrics will increase from 21.5 million square meters in 1962 to 74 million square meters in 1967. A new rayon factory of 1,500-ton capacity is to be completed in 1964. The increased production of cotton and synthetic fabrics is intended to satisfy the domestic needs. Cottage industries will increase and will require cotton yarn, the production of which will be increased. Along with this, the manufacture of such final goods in the textile industry as blankets, hosiery, and knitted wear is also being planned.

A new woolen products factory is planned that will produce about 270,000 blankets a year in addition to other goods, reducing the need to import these items. Using basic domestic raw materials, primarily flax, another factory will be constructed to produce 500 tons of flax products (linen and oil) yearly. The erection of a factory to produce 100,000 umbrellas yearly will also be accomplished by the end of 1966. A factory for processing musa (a fiber plant), with an annual capacity of 1,000 metric tons, is to be built by the same target date. The output from this factory will be added to other sources to increase production of sacks and rope from 2.8 to 6.0 million pieces, in part from another planned new factory having an annual capacity of 2,000 tons. The erection of a ready-to-wear clothing factory is also planned, which will supply the immediate needs of military and civilian demands.

A cotton mill in operation in Asmara in 1962 started with a 200-kw. load but was later increased to 500 kw. and extended to a 24-hour operation. This is indicative of the trend in load growth in the textile industry. Also in that area, an agava plant fiber mill is now in operation which produces rope and bags. Operation is 8 to 10 hours per day with a demand of 200 kw., with expansion predicted.

In summary, there will be nine new textile factories developed by the end of 1967, in addition to six existing ones, some of which will have been reconstructed. This trend may continue in the future to provide the basic needs of the expanding population, and the requirement for electricity will increase greatly.

Existing leather and shoe factories, with tariff protection from external imports, will be able to produce about 1,000 tons of leather and 650,000 pairs of leather shoes in 1967. The erection of the new slaughterhouses will make available an increased quantity of hides and considerably increase the production of leather and shoes. Government planners expect to establish several new leather and shoe factories with a total capacity of 8,000 tons of leather and 5,000,000 pairs of shoes to be produced.

To meet the demand of the domestic market for low-priced footwear, the erection of a canvas and rubber shoe factory has been planned with a production of about 1,300,000 pairs in 1967. All told, one leather and shoe factory will be completed and eight new ones started by the end of 1967. By that year, 2,150,000 pairs of leather shoes will be produced annually (Table V-20).

Chemicals and Related Items. A chemical industry, as such, barely existed in Ethiopia as late as 1961. However, the discovery of some basic minerals and the domestic demand for chemicals now imported have led Government planners to forecast a very intensive development of the chemical industry, beginning with the period 1962-1967 and continuing into the future. The new capacities of this industry are to be based mainly upon domestic raw materials for the production of pulp for paper and viscose, caustic soda, sulphuric acid, carbon bisulfide, pharmaceutical products, soap, glass, leather tanning material, and others.

As Ethiopia is badly in need of a nucleus for a chemical industry, a logical site for early establishment of plants to provide the basis for the industry may be in the vicinity of Assab. (Even though adequate supplies of nonsaline water are questionable, the only large oil refinery in Ethiopia will be located there.) The availability of salt (sodium chloride) in abundance and the availability of sylvite and carnallite (potassium salts) as well as other salts in the Danakil area (vicinity of Dallol) will provide some of the raw materials. Production will be initiated at the rate of 300,000 tons per annum. This includes the building of a new, deep-water port and a new, 97-kilometer (58-mile) road. Table V-24 indicates the chemical plants which could be developed at Assab, assuming adequate electrical power at reasonable rates becomes available.

TABLE V-24--CHEMICAL PLANTS POSSIBLE OF DEVELOPMENT NEAR ASSAB

Plant	Maximum demand (kw.)	Annual energy requirement (kw.-hr.)
Caustic soda; and salt electrolysis and chlorine	3,770	33,000,000
Sulphur extraction	60	470,000
Potassium fertilizer	195	800,000
Nitric acid and fertilizer	40	350,000

From the large quantities of NaCl available either as rock salt in the Danakil area or from sea water by evaporation, electrolysis will produce caustic soda (NaOH), an essential basic chemical for a diversified industry. Chlorine and hydrogen are also released in this process. Chlorine can be liquified and transported. Hydrogen gas can be used to produce ammonia and hydrochloric acid, both essential industrial chemicals.

Fused salts at high temperatures, free from water, can also be decomposed. Fused salt is electrolyzed at a very low cost to produce metallic sodium, used in the preparation of a number of other chemicals which could not otherwise be processed, including sodium peroxide and sodamide, essential for any chemical industry.

Sodamide is made by the action of dry amonnia on metallic sodium. It is used for the synthesis of indigo and in other organic reactions. When heated with carbon, sodamide is changed to sodium cyanide, in great demand for electroplating, in fumigation, in the extraction of gold, silver, zinc, and lead from ores, and in a mixture with sodium chloride and sodium carbonate for case-hardening of steel.

The direct synthetic ammonia process passes pure nitrogen and hydrogen over a catalyst under pressure and at high temperature. By catalytic oxidation, ammonia is easily changed into nitric acid and this in turn into nitrates (fertilizers).

Crude carnallite, such as is available around Dallol, can be refined to potassium chloride by treating the crushed ore with a hot solution of magnesium chloride. Some sylvite is also available, as is potassium chloride in a crude, natural state. Two grades of potassium chloride (KCl), one for higher grade chemical uses and one for fertilizer, can be produced. These have important uses in making liquid and soft soaps, in photography and medicine, in explosives, and in glass making.

Chemically pure hydrochloric acid can be produced by burning electrolytically produced chlorine in excess hydrogen.

Magnesium chloride is available in a natural state 18 kilometers southwest of Dallol. Magnesium can be made by the electrolysis of fused anhydrous magnesium chloride in an electrolytic cell containing potassium chloride.

In the Dallol area, sulfur minerals from which sulfur can be extracted have been found. Most important use of sulfur is in the manufacture of sulfuric acid, essential to any chemical industry. It is also necessary for possible future industries, such as the manufacture of paper, matches, gunpowder, insecticides, fertilizers, and vulcanizing in the rubber industry.

In 1962, the gross value of production of the chemical industry was estimated at Eth$950,000 as contrasted with a forecast production in 1967 of Eth$36,100,000 or an increase of 38 times. To indicate the degree of emphasis being placed upon this industry, Government planners forecast a total investment of Eth$51,050,000 in this segment during the period 1963-1967 as compared with Eth$740,000 for the previous 5-year period, or an increase of 69 fold.

According to Government planners, the chemical industry will expand by 21 new plants during the period 1963-1967 (Table V-22). Early emphasis seems to be directed toward supporting synthetic fiber plants and pulp mills with the necessary raw materials. Production of wood pulp will be initiated to support a new 8,500-metric-ton capacity paper factory and a 12,000-metric-ton viscose factory. These factories will need chemicals, and to supply their needs a caustic soda factory (12,000 metric tons), a carbon bisulfide factory (6,000 metric tons), and a sulfuric acid factory (20,000 metric tons) will be required.

Availability of domestic raw materials will justify the erection of a 6,000-metric-ton soap factory.

Two tanning material factories will be established, having a total annual output of 2,000 metric tons. Source of raw material is domestic trees, and the output from the factories will be used primarily in the domestic leather industry.

Deposits of quartz sands will be used to increase the output of existing glass factories as well as a basis for erecting a new glass factory with an annual output of 1 million square meters. (In 1957, the output of glass bottles was 3,800,000; in 1962, 7,500,000; and in 1967, the forecast is 14,000,000 bottles, and increase of 1.87 times.) The Asmara glass factory has been completely automated with an increase in demand to 200 kw., which is not as much as was originally expected. However, with the increased production of beverages, the demand will continue to increase.

All pharmaceutical products are imported, but during the period 1962-1967, Government planners expect that a pharmaceutical factory will be constructed. In addition, a plastic product factory and a tire plant are to be constructed.

Near 1966, a start will be made on one of these factories: fertilizer plant, paint plant, pharmaceutical Plant No. 2, Soap Factory No. 2, lubricating oil plant (expansion of the then existing refinery), and of PVC plant (polyvinyl chlorides).

By 1967, or shortly thereafter, the industrial power requirements will be significant and will be supplied primarily from hydroelectric sources. Some industrial plants, such as the sugar factories, may not initially depend upon electricity from an external source, but at present the most economical source of energy in Ethiopia is hydroelectric power and it probably will remain so in the future. Although complete purposed production information for every factory is unknown at this time, an estimate of future power and energy requirements is included in the totals shown in subsequent charts and graphs.

Tobacco. In 1957, about 252,000,000 cigaretts were produced, and in 1962 this increased to 370,000,000 with the proposed production in 1967 to reach 500,000,000. This will be accomplished by constructing one additional factory, probably to be started very late in the plan. Small motor loads are anticipated.

Printing and Publishing. Existing plants are to be expanded and one new plant of larger capacity is to be constructed by 1967. Small motor and some minor heating loads will develop, perhaps 50 kw. and 450,000 kw.-hr.

Iron, Steel and Some Related Items. Except for the iron ore deposit in Eritrea Province, a domestic commercial source of iron ore was not known to exist in inland Ethiopia as of 1962, but Government planners are confident that a comprehensive prospecting program will reveal iron ore deposits in the future; thus, they are hopeful that before the end of the 5-year period, 1962-1967, a steel plant with a forecast capacity of 80,000 metric tons output will be built. This, together with the Akaki Iron Works, completed in 1962 with an annual output of about 20,000 metric tons (using scrap iron), should be sufficient to start a metal and electric products industry which will serve the basic needs of the country. On this basis, these plants may be erected by 1967 according to Government planners:

Agricultural Machine and Tool Factory
Metal Processing Plant
Metal Construction Plant
Household Appliance Plant
Tractor and Motor Car Assembly Plant
Aluminumware Factory
Electro Installations Factory
Electric Light Bulb Factory

By 1967, the following additional plants may be started according to the same source:

Metal Processing Plant No. 2
Shipyard
Electric Motor Factory
Electric Wire and Cable Factory
Ship Repair Plants
Automobile Battery Factory
Steel Mill (discussed above)

All told, 15 new factories will be completed or started by the end of 1967 in this particular industrial segment, and all will have substantial electrical power and energy requirements which will steadily increase in the future. Maximum power and energy requirements for these 15 new factories, when completed, cannot be definitely determined at this time, as plant output was not established in all cases in 1962. However, using data available, the maximum requirements are estimated in Table V-25.

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 1963-1967, inclusive. Until 1967 and perhaps a few years later, industrial production will primarily be geared to meeting consumer demands, although a start will be made in heavier industries, such as steel.

Forestry and Related Industries

The productive potential of the Eucalyptus plantations has been represented theoretically by a total annual yield of about 500,000 cubic meters. The total annual harvest varies from 100,000 to 150,000 cubic meters, on the average, out of which about 20,000 cubic meters are used for building poles, telegraph masts, etc., while the remaining quantity serves as a fuel for households and industries.

The present natural forest utilization is limited primarily to one of the state forests, Shasamanno, and a series of private forests1/ in the more accessible regions. The annual removal of wood from these forests is estimated at the following volumes:

Saw logs and veneer bolts	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 of fuel wood, including that converted to charcoal, is also removed from nonforest lands, giving the overall total annual wood removal of slightly over 30,000,000 cubic meters, of which about 99 percent is consumed as fuel. About 12,500 cubic meters of lumber and 1,200 cubic meters of plywood are produced annually. In addition, there are minor quantities, amounting to about 5,000 tons of frankinsense and 60,000 tons of bamboo, harvested annually, the latter used exclusively for local building material in rural districts.

In 1962, about 12,500 cubic meters of lumber were produced from domestic timber, and this is expected to rise to 20,000 cubic meters by 1967. A new sawmill will be constructed, but it will not in all probability be driven by electric motors. In 1962, about 1,200 cubic meters of plywood were manufactured, and by the end of 1967, this is expected to increase to 3,000 cubic meters, Table V-20. Also in 1962, there were 22 major sawmills; and, to meet the rising demand for wood products, this quantity will have to be gradually enlarged. This factor must be considered in the power market analysis, as electricity is an economical source of energy for operating these mills. Except for a very small amount of paper manufactured in the Asmara area, none is manufactured in Ethiopia and it has to depend upon imports for its supplies. Bamboo may thus be an economical source of raw material for an Ethiopian paper industry. For instance, a small area of about 10,000 hectares, properly handled, could supply a pulp mill of about 40,000 tons of raw cellulose output from an annual cutting area of about 2,000 hectares.

Increased production of furniture and other final wood products will occur as a result of the construction of a new furniture factory which is planned by 1965. Three new wood products industrial projects are to be established by 1970, including the sawmill and furniture factory already noted, plus a new, 10,000-ton annual capacity mill.

1/According to "Ethiopian Forestry Review" No. 3/4-1962, the Revised Constitution of 1955 declares all forests State domain. The Civil Code of 1960, however, recognizes private ownership on forest lands, reserving only nonpossessed land to the State.

TABLE V-25--ESTIMATED POWER REQUIREMENTS FOR SOME FACTORIES PLANNED BY 1967

Plant	kw.-hr.	Maximum kw. demand
Steel Plant, 80,000 tons	32,000,000	3,650
Agricultural Machine Tool Factory	845,000	1/ 300
Metal Processing Plant	4,000,000	2/ 600
Metal Construction Plant	260,000	3/ 40
Household Appliance Plant	260,000	4/ 90
Tractor Assembly Plant	580,000	5/ 225
Ship Repair Plants	1,000,000	6/ 450
Aluminumware Factory	200,000	7/ 75
Automobile Battery Factory	200,000	8/ 65
Electro Installations Factory	200,000	65
Electric Light Bulb Factory	200,000	65
Metal Processing Plant No. 2	8,000,000	9/ 1,200
Shipyard	6,000,000	750
Electric Motor Factory	440,000	10/ 150
Electric Wire and Cable Factory	600,000	11/ 375

Estimated Capacities:

1/Output 2,500 metric tons, 3 shifts.
2/Rolling mill, 18,000 metric tons, 3 shifts.
3/Structural steel, 600 metric tons, 3 shifts.
4/Iron cooking utensils, 400,000 pieces annually, 120 hp., one shift.
5/Eth$2,000,000 investment assumed, 1 shift.
6/Two plants (Massawa and Assab), 1 shift.
7/Aluminum cooking utensils, 300,000 items annually, 1 shift.
8/Annually 12,000 units, using 4,000 gallons oil per year in addition.
9/Rolling mill, 36,000 metric tons.
10/Annually 3,000 motors of 1/6 to 10 hp., 200 hp. connected load.
11/Copper wire, 120 tons annually, 500 hp. connected load.

The electrical power load requirements will be significant as industrialization progresses, and these loads are included in the totals shown in subsequent charts and graphs.

Transport and Communications

This sector of the economy includes railways, road transport, air transport, water transport, city traffic, postal system, and radio and telephone communication facilities. Electricity requirements for these facilities up to this time have been limited to control of city traffic, airports, harbors, and the radio-telephone communication facilities and, in total, have been rather modest.

The Addis Ababa International Airport, going into initial operation in 1963, will have a demand of 800 kw. and will require about 3,500,000 kw.-hr. annually. The airport at Asmara requires about 400 kw. and the annual estimated energy requirement will be about 1,750,000 kw.-hr. eventually.

Ethiopian Airlines, provides internal air service throughout the Empire to some 20 or more airports. In addition, regular international services are provided to other places in Africa, Asia, and Europe.

Domestic airports throughout the Empire are to be improved to accommodate all types of propeller-driven and small jet aircraft. With two or three exceptions, the domestic airports in 1962 were mainly grass strips to accommodate DC-3 or C-47 cargo planes. Government planners foresee an improvement of these airport facilities, and it is not unlikely that many within the next 15 or 20 years will have modern facilities, including night lighting. Demand should reach 2,000 kw. and energy requirements approach 9,000,000 kw.-hr. per year.

Two principal railroads are now in operation, the Addis Ababa-Djibouti Railroad and the Agordat-Massawa Railway. Both are diesel and diesel-electric operated, and the two are not connected. Government planners during the period 1962-1967 will prepare studies and designs to construct new railroads--Hazret-Dilla, Agordat-Tessenei, and Awash-Tendaho-Assab. Railway electrification requires a high traffic density in order to justify the installation, as the initial investment required is high. Therefore, the immediate prospects for electrification are very unlikely.

However, from the long range viewpoint, electrification of some road sections is a possibility. This will be particularly true if the major source of energy in the Empire continues to be water power. The Awash-Tendaho-Assab road may become a principal transportation artery in the Empire and may eventually be electrified. Streets are being widened in Addis Ababa preparatory to the introduction of trolley bus transportation. The terrain in the city and the abundance of electric power, coupled with the growing demand for improved city transportation, have resulted in planners scheduling the installation of electric trolley buses during the period 1962-1967.

With the gradual development of the Imperial Ethiopian Navy, a ship repair plant at either Massawa or Assab is likely. Estimated annual energy requirement is about 470,000 kw.-hr., with a maximum demand of 225 kw., using a one-shift-per day operation. The naval base at Massawa has about 600 kw. demand, and the other harbor facilities require an additional 200 kw. with prospects for increase. The total annual energy requirements are about 4,200,000 kw.-hr. and could easily double by 1970.

Two main seaports have modern facilities--Assab and Massawa, both on the Red Sea and connected to the inland area by good roads. A recently completed modernization program has improved port facilities.

Inland water transport is very small, being limited primarily to Lake Tana and to the Baro River. The latter, in the southwestern part of the country, has as its principal port the town of Gambela. Part of the Ethiopian foreign trade is carried on with Sudan over the Baro River. Small harbors and lighthouses have been built for day and night traffic on Lake Tana. For the future, opening of traffic associated with the development of fishing in Lake Abaya is a possibility. Electric power needs will be limited to navigation aids and lighthouses and to dockside and maintenance requirements and will be very modest for several years.

Figure V-13--Bahir Dar dock and warehouse are in the foreground, the airport is to the right and the new road leading to Tis Abbay powerplant extends into the distance on the left.

TABLE V-26--TELECOMMUNICATION STATISTICS, 1953-1960

Year	Telegrams			Telephone calls			
	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

Source: Ethiopian Economic Review No. 5, February 1962

TABLE V-27--PLANNED INVESTMENT IN TRANSPORT AND COMMUNICATIONS, 1963-1967 1/

Branches of transportation and communication	1963-1967 (planned) thousands of Eth$	As percent of total	Index number, ratio 1963-1967 / 1958-1962
Transportation:			
Railways	10,000	3.2	143
Roads	155,600	49.2	122
Water	24,163	7.6	90
Air	89,153	28.2	187
Subtotal	284,916	90.1	131
Communication:			
Posts	5,000	1.6	--
Telecommunications	26,500	8.3	265
Subtotal	31,500	9.9	315
Total	316,416	100.0	139

1/Second Five-Year Development Plan.

In 1952, telecommunications was established as a self-supporting public agency under the Imperial Board of Telecommunications. This organization provides the country with telephone, telegraph, and broadcasting facilities. Radio broadcasting stations provide the primary link with the outside world. The new LWF radio station will require 600 kw. and 2,500,000 kw.-hr. annually and will begin full scale broadcasts in 1963. I.B.T.E. radio station will require 600 kw. and 2,500,000 kw.-hr. and will begin broadcasting during the period 1963-1967.

The major towns throughout the country have post offices and airmail service available where regular stops are made by Ethiopian Airlines. Table V-26 provides telecommunications statistics for a 7-year period.

According to Government planners, additional post offices will be opened throughout the country, and the postal services will introduce their own means of transportation. The expansion of the postal system and telecommunications facilities will not require substantial amounts of electricity, since it will be limited to the needs of the new buildings required, with minor amounts for the telephone system.

During the period 1963-1967, further development of transport and communications is expected to average about 7.1 percent annually. The rate of growth of transport and communications will therefore be about twice as large as the rate of development of the whole economy, which has been estimated at an average of 4 or 5 percent annually. The emphasis of this sector is in anticipation of the expanded industrial production, volume of trade, and marketable agricultural products. Table V-27 indicates the planned amount of investment during the period 1963-1967 for various segments of transport and communications.

URBANIZATION

In 1956, the percentage of urban population was 3.8 for Ethiopia, disregarding Eritrea. In 1940, data showed that the urban population was 9 percent of the total for Africa, 10.5 percent for Asia, 17.7 percent for Latin America, 33.7 percent for Europe, 51.6 percent for North America, and 53.3 percent for Oceania. Some sources estimate that early in the next century, as much as 30 to 60 percent of the population of Ethiopia may become urbanized and industrialized. The stimulus for urbanization is generally initiated by industrialization.

In order to prevent the growth of unemployment 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. If the population is to be stabilized to reduce the rate of urbanization, opportunities for employment must be distributed evenly over towns and villages located throughout various parts of the Empire. Even if this is done, 30 to 60 percent of the population that has become urbanized will depend primarily upon employment by industry. If industrialization does not develop at this pace, a situation will develop whereby a very high rate of unemployment will exist. Therefore, every opportunity must be taken to develop the industrial potential of the country.

The fact that the second 5-year plan places great emphasis upon industrial development indicates that serious study is being given to this problem. In Ethiopia, it may be necessary to extend the processing and manufacturing sequences (as applied to agricultural products) wherever financially feasible in order to provide sufficient jobs to absorb the labor available. Therefore, the inescapable conclusion is reached that electricity at the lowest possible cost must be provided to all of the major regional centers in Ethiopia.

This raises a question of whether electricity is the cause of expansion or whether expansion follows the availability of electricity. The results of some studies in other African areas indicate that urban expansion is definitely stimulated by the availability of electricity. Urbanization is encouraged, not only directly by electrification but also by the growing industrialization of a country. The two go together, and actually it is the urbanization to date which has brought about the greatest change in the way of life for the average African. It can, therefore, be said that urbanization provides the greatest stimulus to raising the standards of living. In Ethiopia, the following conclusions are reached concerning urbanization:

1. As to the present extent of urbanization, it ranks among the lower of the African nations.

2. The trend toward urbanization has accelerated considerably in recent years.

3. Urbanization has been directed primarily toward one city--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 Addis Ababa.

OCCUPATIONS OF LABOR

Considering the country as a whole, more than 90 percent of the population is engaged in agricultural pursuits. The other 10 percent supply the labor needs of government, commercial and industrial enterprises, and various miscellaneous categories. In the 10-percent group would fall the labor employed in urban areas. According to the Ministry of Commerce and Industry, in 1960 there were about 60,500 persons gainfully employed in Addis Ababa. This labor was distributed as follows:

	Percent
Domestic service	24.75
Civil service	21.50
Commerce	17.25
Manufacture	15.00

In Asmara, the other large urban center in Ethiopia, no exact figures are available, although the commerce and manufacture categories would be somewhat higher than those given for Addis Ababa, with a corresponding reduction in civil service and domestic service. Figure V-14 gives an indication of those employed in various types of industries in the 13 provinces, and perhaps 75 percent of those shown are located in the Addis Ababa Complex. In the Blue Nile River Basin, as shown by examining Figures V-15 and V-16, the predominantly agricultural areas having the greatest population density occur along the northern and northeastern sides of Lake Tana, along the Bahir Dar-Addis Ababa highway, and along the inside loop of the Blue Nile River on the highlands. Many of these agricultural areas in the heavy population zone are nearly saturated now, relative to the number of people that the land can support with a decent standard of living. Therefore, it is reasonable to expect that while the heavily populated areas will remain substantially static, new areas will have to be opened up for agricultural purposes and the development of new industry will be required to provide jobs for the remaining excess population.

Based upon a 1960 population of about 20,000,000, including Eritrea, the population of the Empire will probably double to 40,000,000 by the year 2000. This conclusion is illustrated by the population trend curves of Figure V-17.

With the trend toward urbanization and the correlary development of industry that is anticipated by the year 2000, some authorities conservatively estimate that 65 to 70 percent of the population will, at that time, be engaged in agricultural activities. This means that the present 10 percent of nonagricultural occupations will increase to at least 30 to 35 percent by the year 2000. On this basis, the rate of increase for nonagricultural jobs would average around 150,000 to 170,000 jobs per year. On the other hand, the rate of increase in agricultural jobs would be about 500,000 per year. The opening up of new lands to farmers by appropriate redistribution, by controlling diseases and other problems in certain undeveloped locations, and by providing water and power from multipurpose projects in still other areas will generally take care of the anticipated annual rate of increase in agricultural fields. But the rate of increase in the nonagricultural

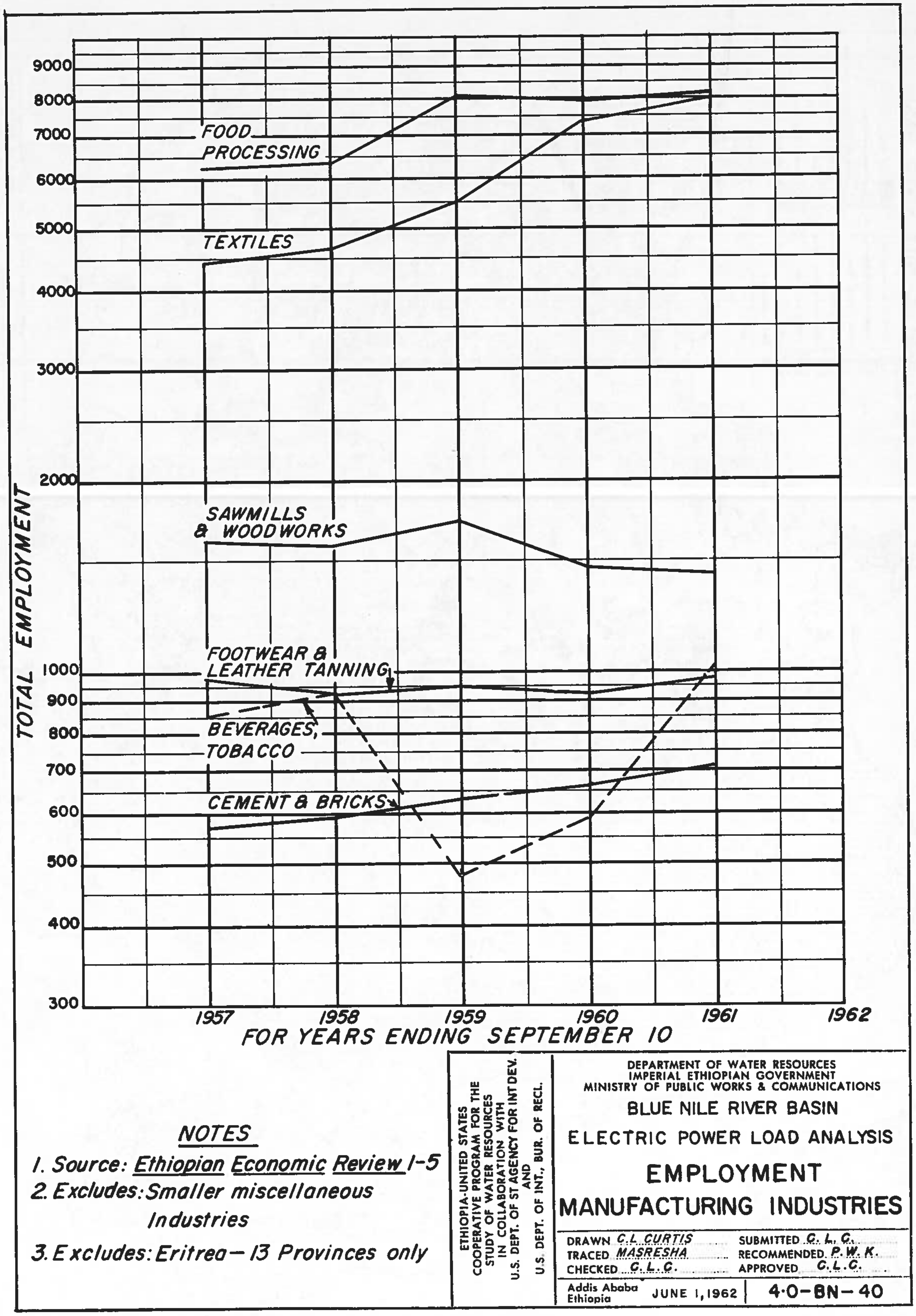


Figure V-14--Employment, Manufacturing Industries

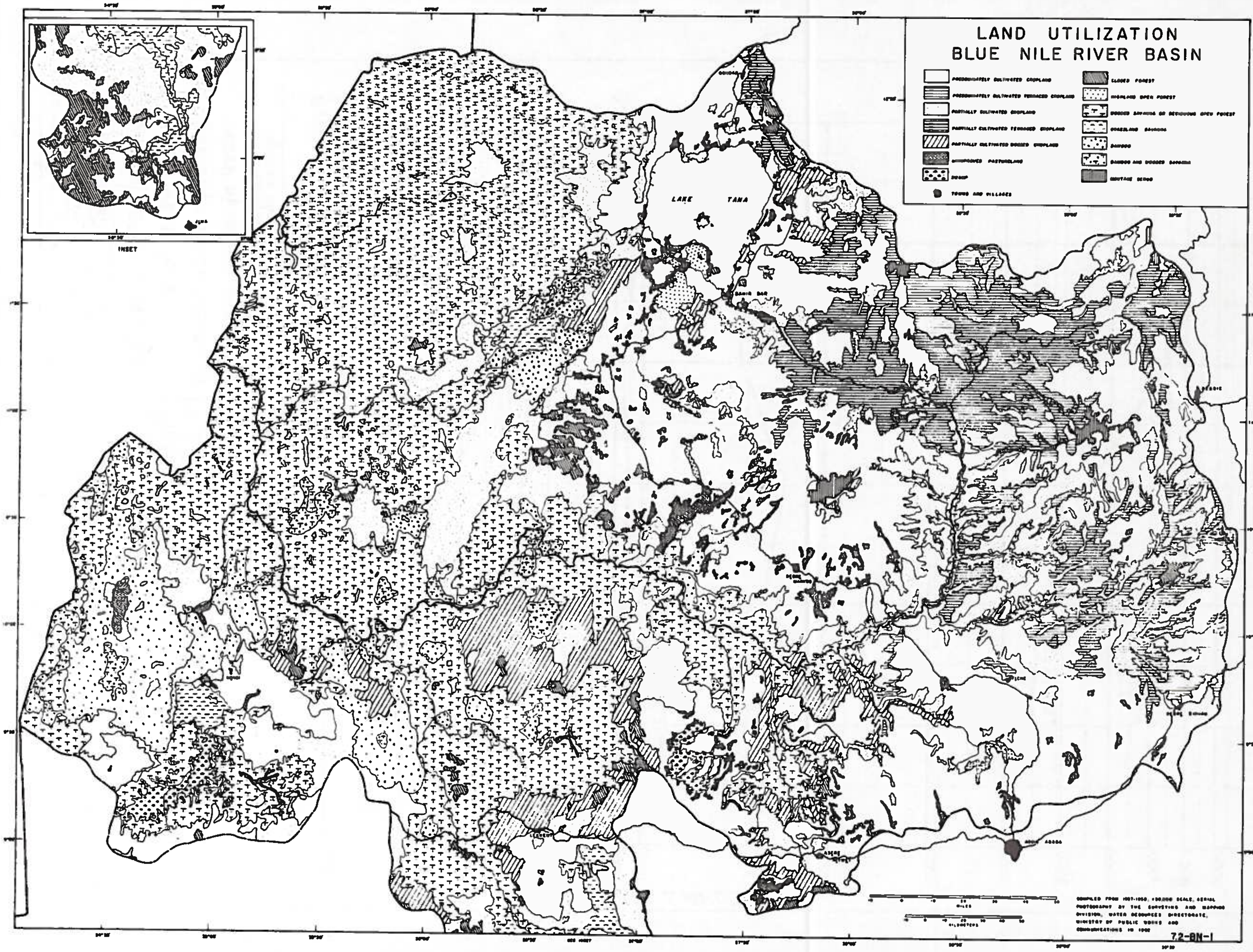


Figure V-15--Land Utilization, Blue Nile River Basin

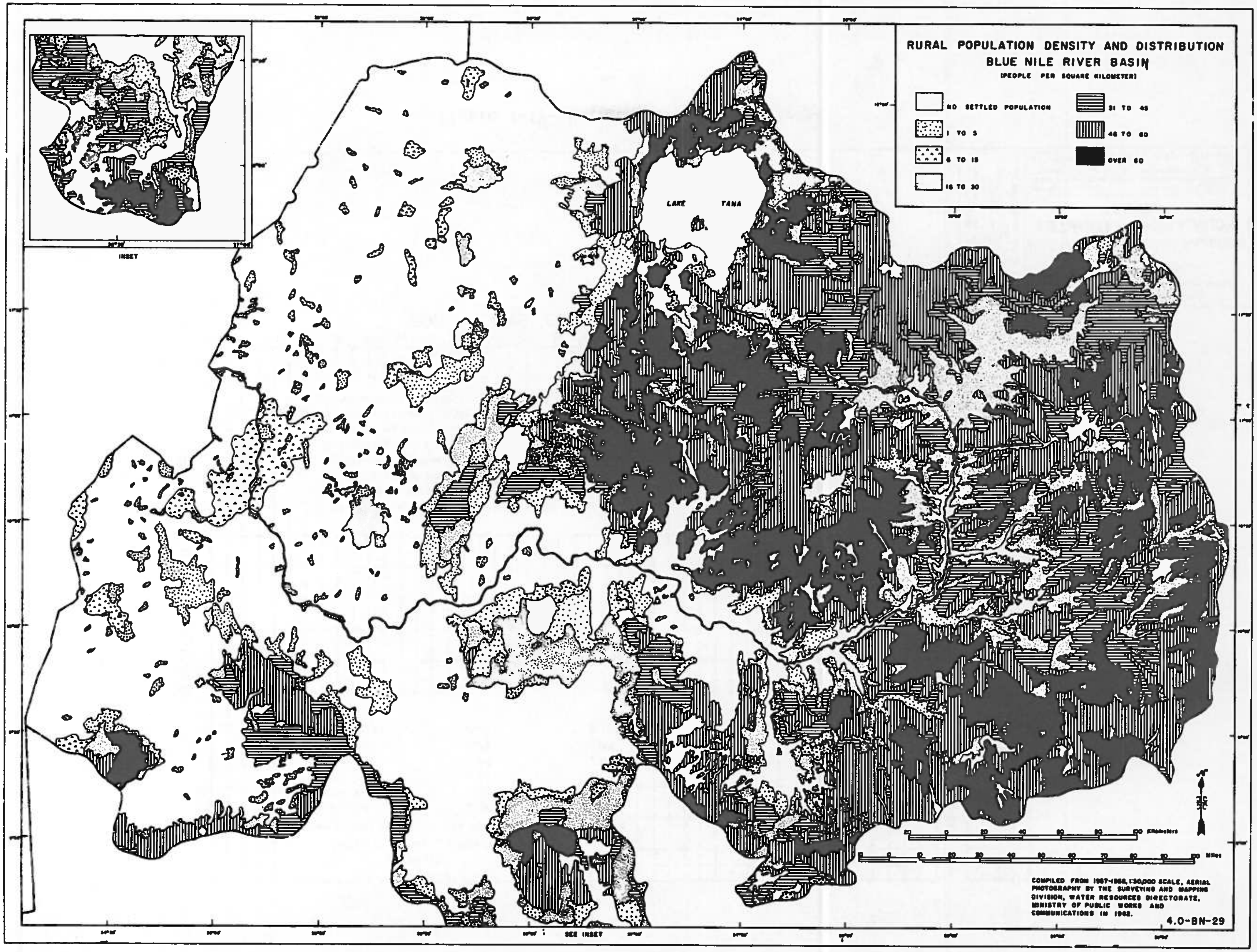


Figure V-16--Rural Population Density and Distribution, Blue Nile River Basin

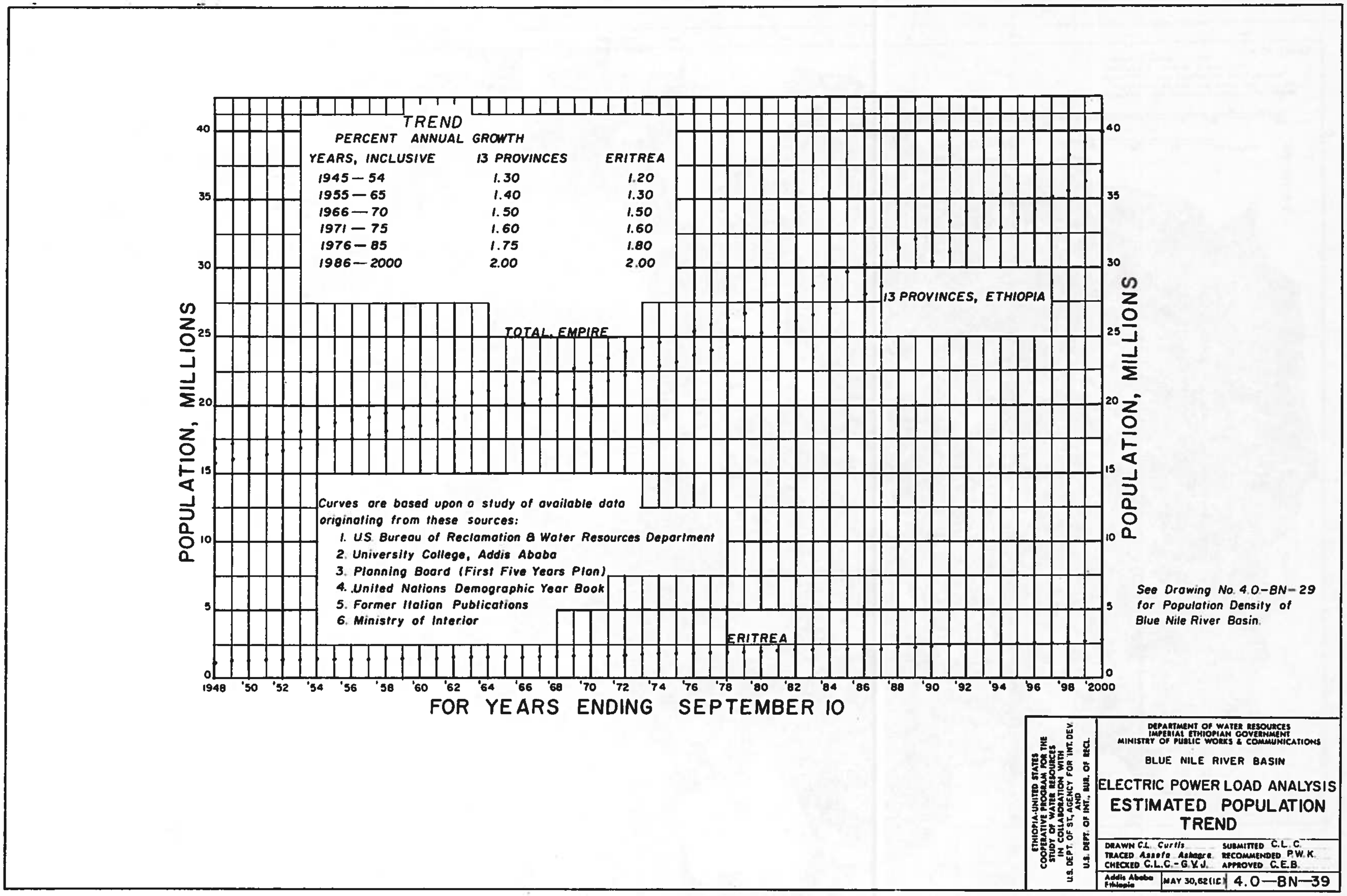


Figure V-17--Estimated Population Trend

TABLE V-28--EMPLOYMENT AND WAGES IN MANUFACTURING AND INDUSTRY. ALL ETHIOPIA 1961 1/

Industrial group	Total number of employees 3/	Annual wages and salaries paid (Eth$)2/	
		Total	Average per employee
Foods (meats, grains, sugar, canning, edible oils, and byproducts)	10,031	6,412,000	631
Beverages (alcohol, beer, liquor, wine, soft drinks, and carbonated water)	1,194	1,143,000	999
Tobacco manufactures	436	406,000	931
Textiles (spinning, weaving, finishing, knitting, sacks, cordage, rope, and twine)	9,675	5,757,000	595
Footwear and leather tanning	990	905,000	914
Sawmills, planing mills, and plywood	1,458	569,000	390
Furniture and fixtures	627	449,000	716
Printing and publishing (excl. Berhanena Selam Printing Press in Addis Ababa)	465	504,000	1,083
Chemicals and chemical products (incl. oxygen, carbon dioxide, matches)	514	135,000	263
Nonmetallic mineral products (brick and cement)	1,039	1,107,000	846
Miscellaneous manufactures	1,615	483,000	300

1/Based upon data from Statistical Office, Ministry of Commerce and Industry, Addis Ababa.
2/About 75 percent in Addis Ababa Complex.
3/Includes 4,600 nonfactory sugarcane and tomato plantation workers and some 400 forest woodcutters, but excludes some 5,000 women handpickers employed in the coffee cleaning industry.

fields will have to be provided for in industry, and industry needs electric power in abundant and economical quantities. It is apparent that a reservoir of labor is available for industrial expansion.

INCOME

The per capita annual income was estimated to have been Eth$89 in 1955, but by 1961 the per capita income was about Eth$97. A sample survey of rural areas conducted in four general agricultural sections of the country gave these per capita estimates of income for the year 1960-1961.

Ambo-Guder	Eth$40
Sululta-Chancho	65
Lekkemt-Sire	50
Bure-Jiga	37

It was found that in the rural areas about 4.7 people per family was the average, while in the urban areas the number of people per family was 3.7 (in only one specific sample area surveyed).

The upward trend of future per capita income probably will not greatly exceed the 1.12 percent experienced in the period 1955-1961. The upward trend in the real per capita income probably will lie between 1 and 2 percent per annum, and by the year 2000, may reach Eth$175 per year. Employment and wages and salaries paid by the manufacturing industry in Ethiopia during 1961 are shown in Table V-28.

A family budget study of 106 households in Addis Ababa was made in 1957 and 1959. 1/ This urban area is located where electricity supplies were generally available but at a time when abundant electricity supplies were not available at reasonable costs. Lower rates did not occur until Koka power supply became available in 1960. Therefore, if such a sample survey had been taken after the availability of lower cost electricity from the Koka supply, the results might have been somewhat different insofar as the use of electricity was concerned.

The 106 families or households were divided into four income groups, and the distribution of households in the sample (by disposable income) was as shown in Table V-29.

TABLE V-29--DISTRIBUTION OF HOUSEHOLDS IN SAMPLE BY DISPOSABLE INCOME

Income group	Number of households	Average income	Average expenditure
Eth$ 15- 34	31	Eth$ 25.99	Eth$ 49.88
35- 49	22	43.08	59.01
50- 99	34	71.85	73.13
100-300	19	154.42	106.73

The results of the sample survey are generally summarized as follows:

1. The average size of the 106 households was 3.7 persons.

2. About two-thirds of the 106 households were paying tenants, while the remaining one-third owned and occupied their own homes. The average number of rooms occupied was 1.4 per household, excluding the kitchen.

3. Of the 106 households, 71 used piped water, another 30 used well water, and 5 used spring or river water for drinking and cooking purposes.

1/Ministry of Commerce and Planning.

4. The number of households using electricity and kerosene for lighting were about equal, with those in the lower income brackets using kerosene.

Table V-30 provides a percentage distribution of household expenditures for the 106 households.

TABLE V-30--PERCENTAGE DISTRIBUTION OF HOUSEHOLD EXPENDITURES

Item	Income group				Average for 106 households
	Eth$ 15-34	Eth$ 35-49	Eth$ 50-99	Eth$ 100-300	
Food	48.20	50.60	49.90	51.50	49.80
Beverages	6.70	8.00	7.00	3.80	6.50
Tobacco	0.80	0.00	0.20	0.70	0.40
Clothing	13.60	8.00	10.20	9.30	10.60
House rent	12.00	13.90	14.70	18.50	14.50
Fuel	7.00	7.60	7.10	5.50	6.90
Light and water	4.50	4.70	3.90	3.90	4.20
Household goods	2.90	3.60	1.60	1.30	2.30
Entertainment	0.80	0.80	2.00	0.00	0.10
Other	3.50	2.70	3.60	5.40	3.70
Total	100.00	100.00	100.00	100.00	100.00
Number of households in group	31	22	34	19	106

It was noted that the higher the income group, the greater the percentage of the households that used electricity. On the average for the 106 households interviewed, the distribution of those using electricity and kerosene was about equal. In the higher income group--that is, in the Eth$100-300 bracket--of the 19 families included, only 3 used kerosene and the other 16 used electricity for lighting.

The cost of electricity to the average householder during the period of this survey was about 25 Ethiopian cents per kw.-hr. This was later reduced to about 15 cents for the first 100 kw.-hr. per month. The sample survey was taken prior to the reduction in electrical rates.

OTHER ENERGY SOURCES

Other energy sources 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. An indication of the use made of different types of energy sources, by industry, can be obtained by comparing the costs of energy used by various segments of industry, as shown on Table V-31.

Fuel oil used to fire the boilers of the Addis Ababa steam plant cost Eth$128 per metric ton, f.o.b. Addis Ababa, while diesel oil delivered to Bahir Dar for operating the diesel electric plants there cost Eth$308 per metric ton, f.o.b. Bahir Dar. The expenditure for firewood was for the purchase of some 50,000 cubic meters, and would represent a cost of about Eth$6.00 per cubic meter. Large quantities of firewood purchased in Addis Ababa by the USAID Mission in 1962 were about Eth$9.50 per cubic meter. In other locations, such as Dire Dawa and Harar, Eth$2.90 per 100 kilograms was quoted, which would amount to around Eth$14 per cubic meter.

The most economical fuels are wood, charcoal, furnace oil, and diesel oil in the order indicated in Table V-32.

TABLE V-31--COMPARISON OF ENERGY COSTS BY SEGMENTS OF INDUSTRY, 1958

Energy	Costs
Electricity from public utility services	Eth$1,146,000
Petroleum products	2,030,000
Charcoal	239,000
Firewood	299,000
Total	Eth$3,714,000

Source: Ethiopian Economic Review No. 2, June 1960

TABLE V-32--ENERGY COST OTHER THAN ELECTRICITY

Fuel	B.t.u./kg.	Cost Eth¢/kg.	B.t.u. for Eth¢1	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 oil	41,250	30.8	1,340	7.46

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

Assuming the use of furnace oil for a steam-electric generating plant and diesel oil in a diesel-electric plant, for a small type installation, the cost of generating 1 kw.-hr. using furnace oil fuel was Eth¢9.2, and the cost per kw.-hr. using diesel oil 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.

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 commerical 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. Likewise, the prices of fuel oil, diesel oil, and related petroleum products are influenced by transportation costs that vary in different parts of the Empire.

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

Figure V-18--The eucalyptus tree, an important energy source, was imported by Emperor Menelik II to replace the denuded forests of harder woods. View showing these trees in several stages of growth near Addis Ababa.

parts of the world. For example, Iceland has long piped natural steam to heat the homes of more than 50,000 persons; the Wairakei steam fields in New Zealand produce 192,000 kw. of electric power, and will eventually produce 282,000 kw.; steam fields near Laradello, Italy, were tapped for electric power before World War I and now have a capacity of 300,000 kw. at a cost of 0.625 Ethiopian cents per kw.-hr.; at the Geysers steam field in northern California, USA, the steam powerplant produces 28,000 kw.; and in the Salton Sea area of California, a total steam electric potential of hundreds of thousands of kilowatts is believed to exist, and initial development started in 1963.

Scientists at a 1961 United Nations conference on new sources of energy pointed out that geothermal areas exist, not only in known volcanic regions, but also in belts across entire continents. These are areas where magma, or molten rock, is especially close to the earth's surface, often evidenced by geysers, hot springs, and the like.

A complete inventory and study of hot springs and other related geothermal phenomena has not been accomplished in Ethiopia, therefore, no evaluation of this untapped resource can be made. 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, showing that the Rift Valley area has the greatest geothermal activity.

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

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. As living standards and per capita income increase in the future, the lower income village and rural groups will turn to other traditional fuels, such as petroleum products, wood and charcoal, and electricity. The prices of wood and charcoal will continue to increase in the future, but the cost of electricity should actually decrease.

The conclusion is inescapable 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

Ethiopia can be divided into two principal electric rates areas. The largest area is the 13 provinces and the southern part of Eritrea, 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).

The 13 Provinces and South Eritrea

The Blue Nile River Basin and adjacent areas fall within the marketing area of the EELPA, and the rate schedule of that authority is of primary interest. Electric rates recently underwent a substantial reduction with the advent of the Koka Project hydroelectric power, which made a large block of economical hydroelectric energy available for the first time in Ethiopia. Several small thermal and hydro units are operated in, and adjacent to, the Blue Nile River Basin. The reduction in rates throughout the area served by the EELPA resulted in subsidizing the higher unit cost of power generated at some of the smaller thermal and hydro units. In this way, the lower rates throughout the system encourged greater use of electricity, and sales of electricity have increased greatly. As shown by Table V-33, the present rates (1962) call for 15 cents per kw.-hr. for the first 100 kw.-hr. per month and 10 cents 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.

Table V-34 lists the comparative revenue from electric power sales in various African countries.

TABLE V-33--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.)

TABLE V-34.-AVERAGE REVENUE PER KILOWATT-HOUR SOLD IN SELECTED COUNTRIES 1/

Country	Ethiopian cents per kilowatt-hour
Cameroon	17.38
Central African Republic	21.25
Ethiopia	8.95
Fed. Rhodesia and Nyasaland	3.56
Gabon	16.85
Gambia	11.68
Ghana	13.13
Kenya	7.20
Mali	25.50
Morocco	19.60
Nigeria	11.10
Reunion	20.30
Senegal	5.00
Somali	38.5 - 42.0
Sudan	15.00
Togo	25.03
Tunisia	12.32
Uganda	3.65

1/ Adapted from United Nationa Document E/CN. 14/EP/3, Part II

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 diesel-electric 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." Koka Hydroelectric Project, Imperial Ethiopian Government, December 1958.

(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, as indicated by Table V-35.

TABLE V-35.-SPECIFIC PRODUCTION COSTS, ADDIS ABABA STEAM PLANT

Million kw.-hr./yr.	In Ethiopian cents per kilowatt-hour					
	Fuel	Lub. oil	Per-sonnel	Mainten-ance	Deprecia-tion	Total
5.0	7.68	0.012	1.20	0.60	1.448	10.940
10.0	6.53	0.006	0.60	0.30	0.724	8.160
15.0	5.63	0.005	0.40	0.20	0.483	6.718
20.0	5.10	0.004	0.30	0.15	0.362	5.916
21.9	4.85	0.003	0.27	0.14	0.330	5.593

Source: EELPA

(3) The Bahir Dar diesel-electric plant is typical of a small plant serving a village area, and the toal 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. Table V-36 shows that the production cost per kw.-hr. ranged from almost 14 cents at full plant output to about 41 cents per kw.-hr. when loaded to about one-seventh of its maximum.

TABLE V-36--SPECIFIC PRODUCTION COSTS, BAHIR DAR DIESEL-ELECTRIC PLANT

Annual (kw.-hr.) production	In Ethiopian cents per kilowatt-hour					
	Fuel	Lube oil	Per-sonnel	Mainten-ance	Deprecia-tion	Total
50,000	13.50	3.60	9.20	10.00	4.57	40.87
100,000	9.40	1.80	4.60	5.00	2.29	23.09
150,000	8.63	1.20	3.34	3.34	1.52	18.03
200,000	9.40	1.35	2.75	2.50	1.14	17.14
300,000	8.63	1.20	2.00	1.67	0.76	14.26
336,000	8.63	1.07	1.79	1.49	0.68	13.66

Source: EELPA

In summary, the preceding tabulations are representative of production costs per kw.-hr. of energy produced for different types of generating installations. It should be noted that the costs for the Koka hydroelectric energy production were based upon economic studies completed prior to the construction of the plant. This is also true, to a certain extent, for the Bahir Dar installation, as full production from the plant had not been realized at the time the estimates were obtained. For the Addis Ababa steam plant, the costs given were based upon about 5 years of production experience.

North Eritrea 1/

The major supplier to the Massawa and Asmara load centers is SEDAO. Other suppliers are CONIEL, Public Works Department of Eritrea, SAIBO, and SAET. The latter four serve isolated towns and villages. The SEDAO tariff rates in 1962 were as follows:

	(Ethiopian cents) rate per kw.-hr.
Light (127 volts)	27
Public lighting	15
Domestic appliances, 220-volt, single phase	17
Industrial power (220-volt or 5,500-volt) for:	
1 to 500 kw.-hr./month	17
501 to 4,000 kw.-hr./month	13
4,001 to 50,000 kw.-hr./month	11
More than 50,000 kw.-hr./month	10

Large industries can negotiate special lower rates.

The electric rates (tariff) for CONIEL apply to the towns listed:

1/See Annex "B".

Town	Rate per kw.-hr. (Ethiopian cents)	
	Light (127 volts)	Power (220 volts)
Adi Caieh) Adi Quala) Adi Ugri) Decamere) Keren)	37	25

The Pubic Works Department of Eritrea either operates or leases small thermal plants, and the rates (tariff) for each of these towns is as follows:

Town	Rate per kw.-hr. (Ethiopian cents)	
	Light (127 volts)	Power (220 volts)
Barentu	24	14
Saganeiti	32	32
Senafe	32	32
Nacfa	--	--

The small town of Agordat is served by a very small thermal electric unit owned by SAIBO (Societa Anonimo Industriale Dell' Bassopiano Oriental).

Town	Rate per kw.-hr. (Ethiopian cents)	
	Light (127 volts)	Power (220 volts)
Agordat	38	25

A small utility having internal combustion units driving electric generators serves the town of Tessenei and is known as SAET (Societa Anonimo Electrica Tessenei).

Town	Rates per kw.-hr. (Ethiopian cents)	
	Light (127 volts)	Power (220 volts)
Tessenei	44	55

Rates are high due to small isolated thermal plants serving small towns, high distribution losses in some areas, and a heavy loss in efficiency in some units operating at 6000 to 7000 feet (2000 meters) above sea level. Losses in efficiency due to altitude alone range from 20 to 35 percent. All equipment, materials, fuel oils, and lubricants are imported. Transportation costs are high from Massawa up over the escarpment to points inland.

Direct production costs per kw.-hr. could not be obtained for the North Eritrea area, although some data were secured regarding fuel costs, wages, and plant investments for SEDAO.

Regarding the production costs of all others in North Eritrea, the distribution and marketing costs will run higher per kw.-hr. produced, because CONIEL, Public Works, SAIBO, EELPA (Assab), SAET, and the miscellaneous plants are very small and operate independently without benefit of an integrated system. Retail rates reflect the high costs of production (all thermal-diesel), and at Tessenei, for example, the rate is 55 Ethiopian cents per kw.-hr. for power and 44 Ethiopian cents for lights. It was stated by Public Works officials that in some localities, even with these rates, it is difficult to install a small plant and insure sufficient return on the investment to justify operation. Since SEDAO produced about 91 percent of the electrical energy generated in Eritrea in 1961, no specific production cost figures for the remaining producers are given here.

Cost of production, distribution, and marketing was estimated about Eth$0.109 per kw.-hr. produced. This compares to an approximate average of Eth$0.136 received for each kw.-hr. produced and allows a 25 percent margin for profit, contingencies, or other.

SECTION IV--PAST, PRESENT, AND ESTIMATED FUTURE POWER REQUIREMENTS, PRESENT CENTURY

CRITERIA

Economic Planning and Future Power Requirements

The preceding sections emphasized Governmental Economic Planning for the future development of the Empire through the series of 5-year Development Plans. The avowed goal of transforming the present predominantly subsistence agriculture economy to an industrial-agricultural one by 1982 will have a decided impact upon the rate of growth and total electric power and energy required during the remainder of this century. 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. Although the goals set forth by the planners appear to be optimistic, in the field of electric power development, the goal established by the first 5-year development plan was considerably exceeded.

For this study and report, all load forecasts and scheduled project construction to meet load requirements after 1971 are considered the maximum possible which can be attained during this century. The maximum number of projects that could be constructed by the year 2000 to meet the maximum power load growth potential until that date have been scheduled in chronological sequence. Several additional projects have been studied that probably would have little use prior to the year 2000. These are treated later under Section V--Power Facilities, Next Century.

Project Categories and Periods of Analysis

In the conduct of the Blue Nile investigations and in this report, both power and irrigation projects have been treated in two general categories as to the degree of detailed examination made.

One category embraces those projects for which a greater degree of detail data were available, permitting more extensive examination and evaluation, and including those projects that appeared to be more favorable for consideration during the initial development period. Projects in this category are referred to as "initial development."

The second category included those projects identified as potential developments, but for which data were not available to permit evaluating as in the first category. These include some projects that may not be needed in the foreseeable future. Projects in this category are referred to as "other identified projects."

Power studies consider a schedule for constructing power facilities required to best satisfy the growing demand to the year 2000. The power studies have also been further separated into two groups, "Present Century" and "Next Century," as deemed desirable in the presentation.

"Present Century" includes a selection of hydroelectric projects, single and multiple purpose, to meet the maximum possible total power load requirements as estimated through the year 2000, providing for an orderly and systematic development of various sections of the Empire within reach of the projects. These projects were selected for assessibility, distances to load centers, reasonableness of power production costs, and other items. Projects falling within this class represent only about 16 percent of the Basin's exploitable power potential.

The planned hydroelectric power system to the year 2000 represents one of several alternatives and may be considered one reconnaissance plan of development of several possibilities, but is not claimed to be superior over all other alternatives. The most economical solutions will gradually develop in future feasibility studies as the need for power projects gradually arises.

"Next Century" classification includes potential power projects that might be developed after the year 2000, including some favorable for initial development and some less favorable, but no specific recommendations are made as to suggested sequence of construction. Those selected and studied in some detail were also included in water depletion studies along with the projects within the "present century" classification. Those projects are included that might yield very low-cost energy, but due to the high capital costs involved are considered beyond the economic reach of the Empire during this century. Among others, the four sites BN-3, BN-19, BN-26A, and BN-28 are included. Other potential projects falling in this class include some having benefit-cost ratios and power production costs which are less attractive but with improvement possible within the next 40 or 50 years. Also included are those which can develop electric power now, but in the future may prove to be of more benefit to the Empire for other nonpower production uses such as municipal water supplies (MU-4). These also include "other identified projects," and were not considered in the depletion and other hydrological studies. However, for a few of the more promising, some estimates based upon less intensive studies have been made of possible annual kilowatt-hour yields. This includes such sites as BS-2, BS-1, VO-1, DD-4, GB-2, BL-7, BL-2, BL-8, FE-1, and CH-2, listed in Table V-6.

In addition, field examination revealed the presence of additional sites that were not studied in any detail. They represent an additional inventory of potential projects that might be investigated in the future and are also listed in Table V-6.

Pattern of Development

For this study, it was assumed that the power load requirements will develop along regional lines, with towns and villages being served first by small, self-contained, but isolated, diesel or hydroelectric installations. A load base can 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. Figure V-19 shows the regional load areas that are expected to eventually materialize, but not all may develop to the extent where they will become a part of the National Grid.

An effort was made to develop the potential along regional areas and not to concentrate all of the developments at one location, Addis Ababa. Selection of projects some distance from Addis Ababa will have a generally beneficial effect insofar as the total Empire is concerned, even though substantial amounts of the produced power will be transmitted toward the capital city. Projects that were 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, treated in Annex "B."

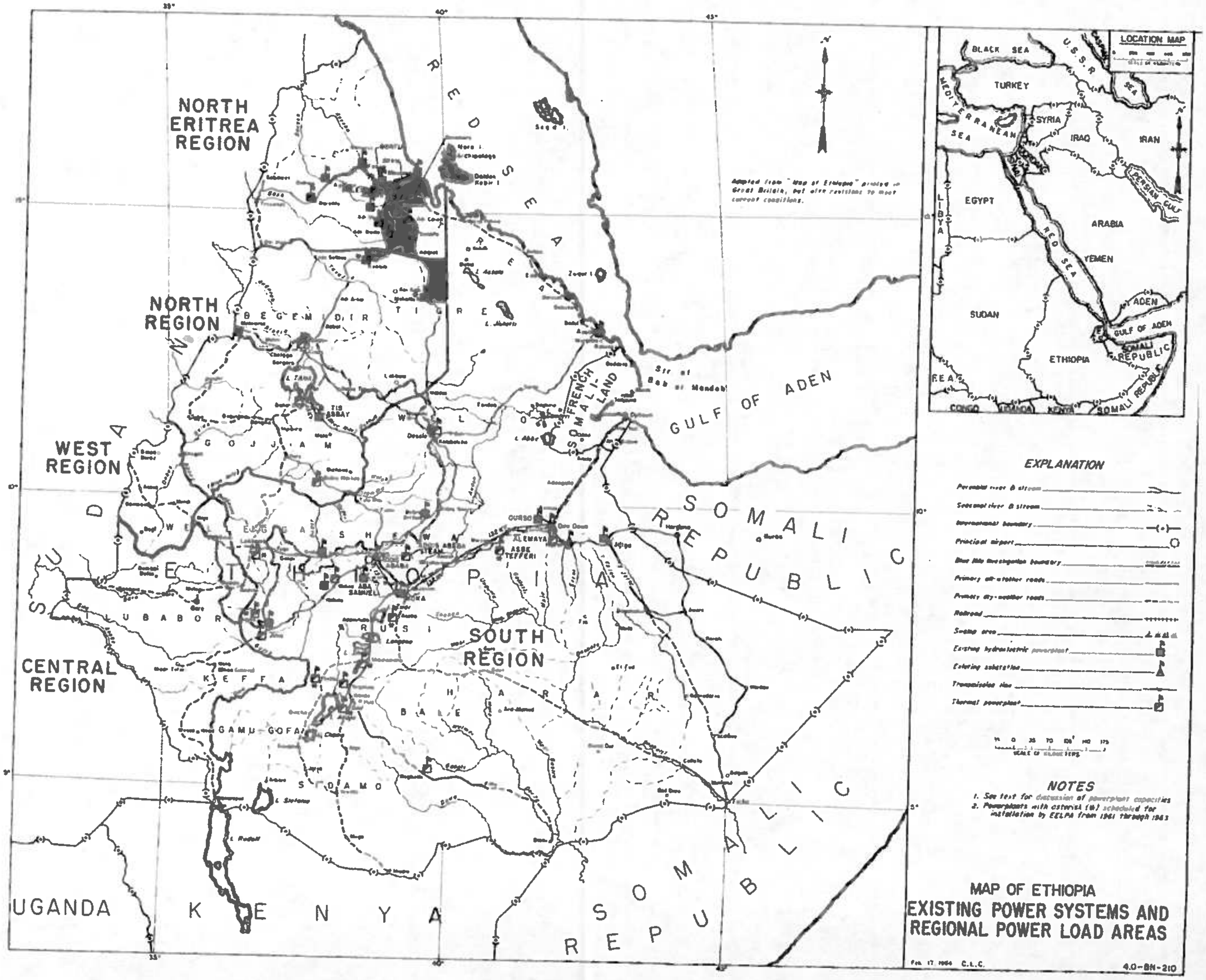


Figure V-19--Existing Power Systems and Regional Power Load Areas

EXISTING POWER SYSTEMS

Figure V-19 shows the total power supply installations in the Empire in 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, the Addis Ababa Complex.

South Region

The South region can be divided into 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 V-37. The 1961 (existing) interconnected system serving the Addis Ababa Complex is shown by Figure V-20.

TABLE V-37--1961 INTERCONNECTED SYSTEM--ADDIS ABABA COMPLEX--SOUTH REGION 1/

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.

By far the greatest source of energy at present is the Koka hydroelectric plant, which is served by a reservoir on the Awash River having a capacity of 1,500 million cu. m. Utilizing a head of 32 to 40 meters, the installed capacity consists of three generators, each rated at 18,000 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 based upon two units is regarded as 23 mw. as noted in Table V-37. Koka Powerplant may also be considered as "Awash No. 1." Figure V-19 shows the location. Koka's concrete gravity dam has a total length of 458 meters, a maximum height of 42 meters, and a volume of 42,000 cu. m. Four gates, each measuring 10 by 6 meters, control the spillway. The power intake is of reinforced concrete with two emergency sliding gates with free openings of 2.3 by 5.4 meters. The headrace tunnel is 67 m. long and has a free area of 23.8 m^2; it continues as a 132-meter-long reinforced concrete headrace pipe to a surge tank 18 meters in diameter. Three 3.5-m. diameter steel penstocks supply Francis-type turbines.

Aba Samuel hydroelectric powerplant is about 35 kilometers south of Addis Ababa on the Akaki (Acachi) River, a tributary to the Awash. There are five generating units

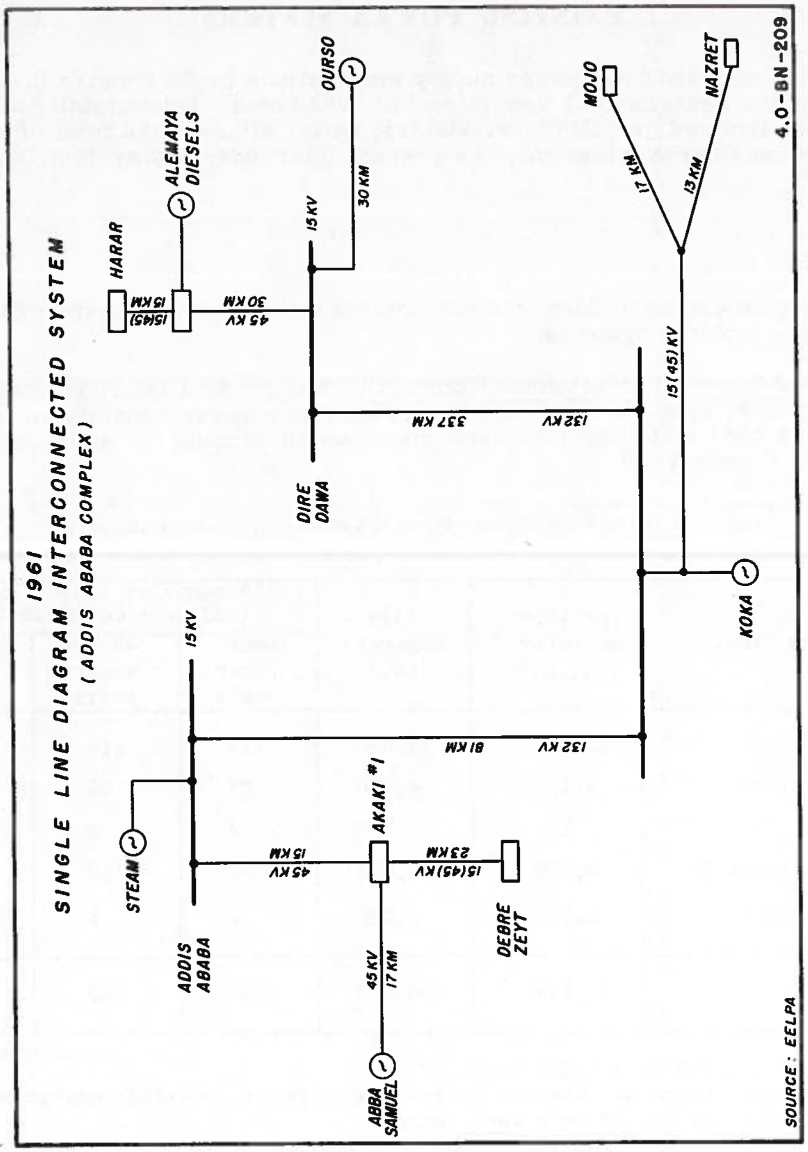


Figure V-20--Single-line Diagram, Interconnected System (Addis Ababa Complex)

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 cu. m. Firm capability has been established as 4,750 kw.

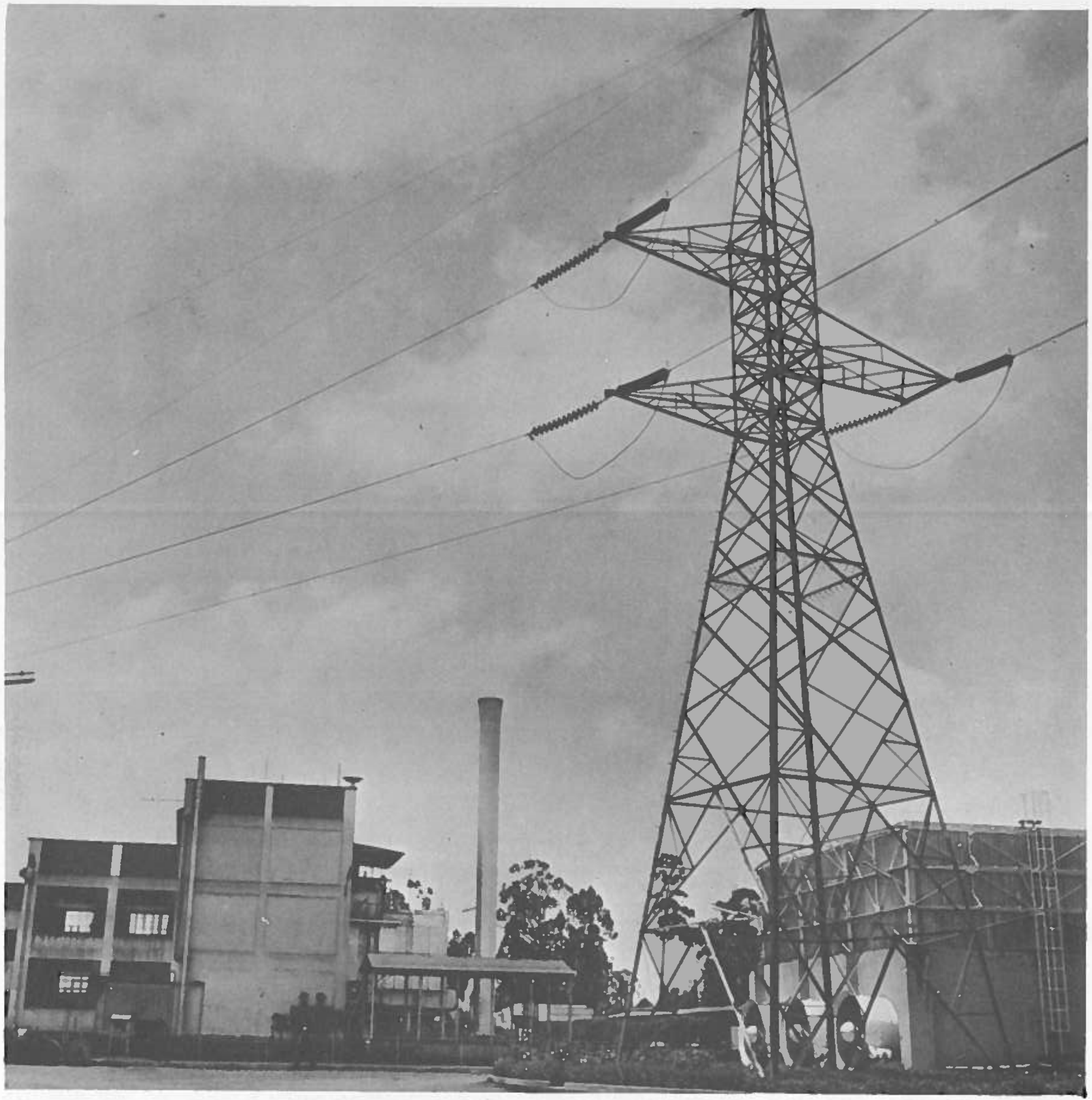
The Ourso hydroelectric powerplant is 30 km. west of Dire Dawa and is served from a natural spring with no reservoir, having only forebay storage for a little regulation. It is rated at 525 kv.-a., with a head of 175 meters.

The Addis Ababa steam powerplant consists of one condensing steam turbine operating at a pressure of 29 kg. per sq. cm. at 425° C driving one 6,250-kv.-a. generator. It has been in standby since the early or middle part of 1960, when Koka power became available.

The Alemaya diesel powerplant is about 30 km. south of Dire Dawa. Three sets with a total capacity of 2,910 kv.-a. are installed. It began operation in 1958 parallel with

Figure V-21--Koka hydroelectric powerplant utilizes a head of 32 to 40 meters and has three generating units, each rated 18,000 kv.-a. It has a firm generating capability of about 23,000 kw.

Figure V-22--Koka Dam, reservoir, powerplant, switchyard and surge tank on the Awash River southeast of Addis Ababa. The Dire Dawa and Addis Ababa areas are served by 132-kv. transmission lines from this power source.



COURTESY EELPA

Figure V-23--Typical 132-kv. dead-end steel tower with one overhead ground wire, Koka-Addis Ababa transmission line. Addis Ababa 5,000 kw. steam-electric plant in background. This is the type of single-circuit construction considered for 132-, 161-, and 230-kv. transmission lines in the Blue Nile River Basin studies.

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 (summarized in Table V-38), there were 418 km. or 132-kilovolt 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 Petersen1/ coils, while the 15- and 45-kv. lines have isolated neutrals.

No additional transmission lines are to be placed into operation between 1961 through 1963.

TABLE V-38--TRANSMISSION AND DISTRIBUTION LINES, 1961 INTERCONNECTED SYSTEM--ADDIS ABABA COMPLEX--SOUTH REGION

Location	Voltage (kv.)	Length (km)	Conductors mm²	Conductors Type	Capacity (kw)
Koka-Addis Ababa	132	81	3 x 150	ACSR	40,000
Koka-Dire Dawa	132	337	3 x 150	ACSR	10,000
Koka-Nazret 1/	15	12	3 x 53	ACSR	1,000
Koka-Mojo 1/	15	17	3 x 53	ACSR	1,000
Aba Samuel-Akaki	45	17	3 x 22	Cu	5,000
Akaki-Addis Ababa	45	15	3 x 45	Cu	5,000
Akaki-Debre Zeyt 1/	15	23	3 x 53	ACSR	500
Ourso-Dire Dawa	15	30	3 x 12	Cu	250
Alemaya-Dire Dawa	45	30	3 x 22	Cu	2,500
Alemaya-Harar 1/	15	15	3 x 22	Cu	750

Source: EELPA

1/ Constructed for 45 kv.

Three main high-voltage substations in the Interconnected System total 39,100-kw. capacity as shown by Table V-39.

Between 1961 and 1963, no major high-voltage substations were scheduled for installation, except for the construction program at Akaki No. 1, where two 3,000-kv.-a. transformers, 45- to 15-kv., and related appurtenances, and at Aba Samuel, where two 3,000-kv.-a. transformers, 45- to 15-kv., and related appurtenances were to be added in 1963.

Isolated Systems. Several isolated systems are operated in the South Region with characteristics as listed in Table V-40.

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 V-41, as compared with Table V-40.

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. Table V-42 provides information on these distribution systems in the South Region.

1/Ground-fault neutralizers.

TABLE V-39--SUBSTATIONS--1961 INTERCONNECTED SYSTEM--ADDIS ABABA COMPLEX--SOUTH REGION

Location	Ratio (kv.)	Rating (kv.-a.)	Capacity (kw.) 1/
Addis Ababa	132/15	2 x 22,000	18,000
	45/15	4 x 1,500	5,000
Akaki (Acachi) No. 1	45/15	1 x 1,500)	1,700
		1 x 630)	
Dire Dawa	132/15	2 x 15,000	12,000
	45/15	1 x 3,000	2,400

Source: EELPA

1/ In some instances spare units not included.

TABLE V-40--POWERPLANTS--1961 ISOLATED SYSTEMS--SOUTH REGION

Location	Installed capacity (kv.-a.)		Firm capacity (kw.)	Production capability (1,000 kw.-hr.)	
	Diesel	Hydro		Diesel	Hydro
Jima	1,125	170	600	2,400	300
Dessie	1,125	-	600	2,400	-
Agere Hiywet (Ambo)	-	210	100	-	350
Assab	375	-	-	-	-
Debre Birhan	-	125	100	-	300
Ghion (Woliso)	40	30	50	100	50
Yirgalem	110	-	80	300	-
Jijiga	40	-	30	100	-
Neghelli	150	-	50	150	-

Source: EELPA

TABLE V-41--POWERPLANTS--1963 ISOLATED SYSTEMS--SOUTH REGION

Location	Installed capacity (kv.-a.) 1/ Diesel	Installed capacity (kv.-a.) 1/ Hydro	Firm capacity (kw.) 2/	Production capability (1,000 kw.-hr.) Diesel	Production capability (1,000 kw.-hr.) 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 V-42--1961 DISTRIBUTION PLANT DATA--ISOLATED SYSTEMS--SOUTH REGION

Location	15-kv. lines (km)	Substations No.	Substations kva	Consumers
Jima	13	10	850	1,250
Dessie	6	9	900	1,250
Agere Hiywet	15	8	450	550
Debre Birhan	7	5	200	550
Ghion (Woliso)	-	-	-	250
Assab 1/				
Yirgalem	7	4	250	350
Jijiga	-	-	-	300
Neghelli	-	-	-	150

1/ Specific data not known.

Figure V-24--Small hydroelectric powerplant near Agere Hiywet, part of isolated (self-contained) system. About 210-kv.-a. installed but with firm capacity of about 100 kw. Agere Hiywet (Ambo) is in distance. Powerplant served by canal along river bank from diversion works upstream.

North Region

Development in the North Region has just begun and there is no interconnected system, although the nucleus of one was substantially completed by the end of 1963. This is the Tis Abbay hydroelectric installation near Bahir Dar; in addition to this installation, small isolated diesel-electric installations exist at Gondar, Debre Markos, and Bahir Dar.

The Tis Abbay hydroelectric powerplant is about 30 km. from the town of Bahir Dar in the Province of Gojjam on the Blue Nile at the Tis Isat Falls.

The water is taken from the river into a 330-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 m^3/sec.

The amount of water taken from the Blue Nile is regulated by bypass gates 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 to Bahir Dar Substation, where it is distributed at 15 kv.

Provision is made to install a third unit when the need arises, possibly by 1972.

At Bahir Dar, the original diesel plant supplied with American assistance, consisted of two electrically started Mercedes diesels driving 380-volt, 3-phase, 50-cycles-per-second alternators. The total electrical output per set is 75 kv.-a. (60 kw. at sea level), making the total station output at site of 96 kw. due to altitude derating. After the textile mill installation at Bahir Dar, two additional diesel sets, 25 years old, were moved from the former Addis Ababa power station to Bahir Dar. These are rated 450 kv.-a. each. This provides a total dependable diesel electric capacity of about 600 kw. in Bahir Dar, plus the hydroelectric capacity from Tis Abbay.

Smaller installations are located at Debre Markos and Gondar. North Region production facilities are summarized by Tables V-43 and V-44 for 1961 and 1963, respectively. The latter table is based upon what was planned by EELPA in 1961 and assumes 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 (BM-10) to Bahir Dar. Steel towers are used with 110 mm^2 ACSR conductor. Distribution systems associated with these towns are as indicated by Table V-45.

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

This is a special case treated separately in Annex "B" to this volume.

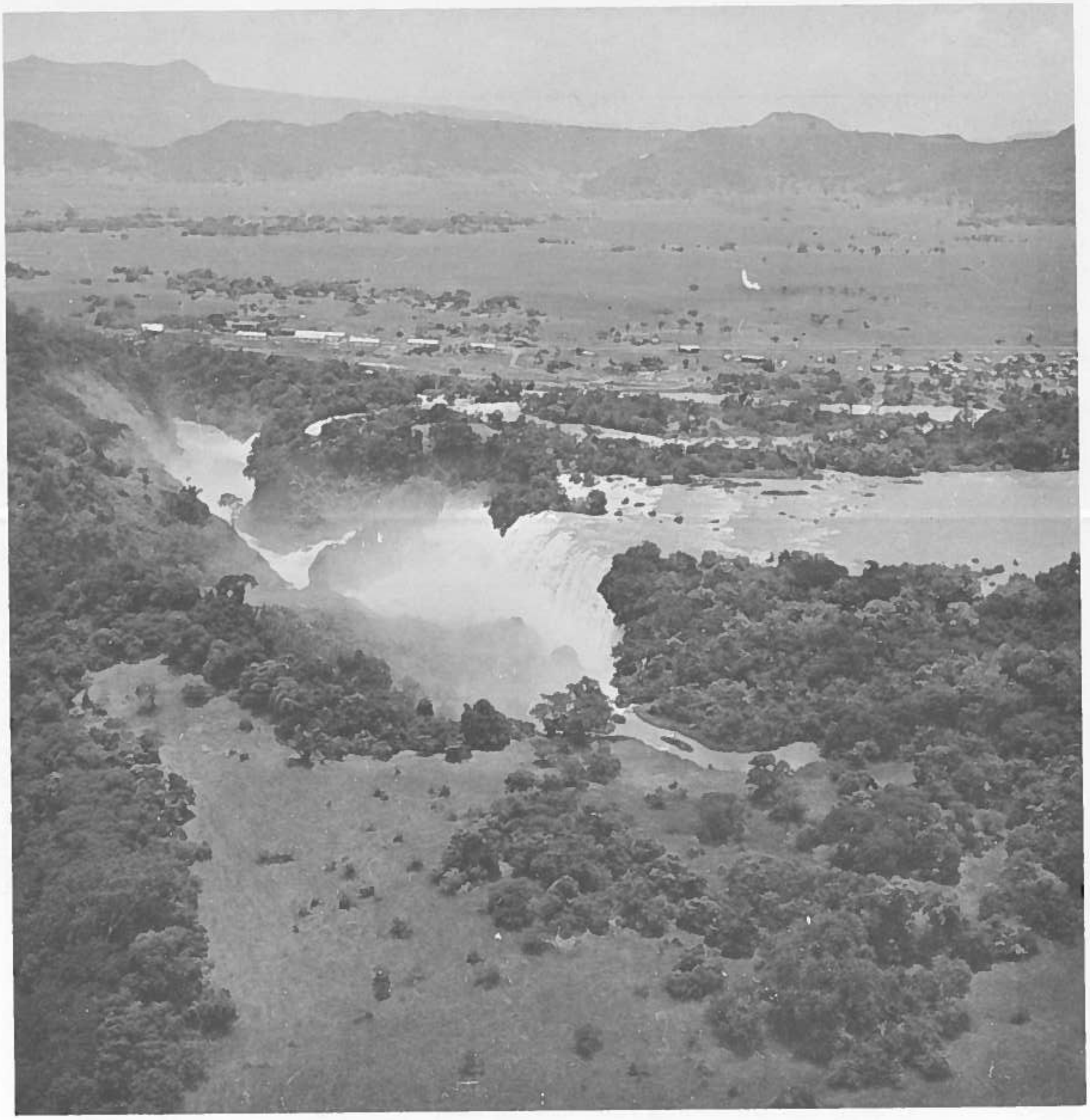


Figure V-25--Tis Isat Falls, Blue Nile River, south of Bahir Dar. The Tis Abbay powerplant is under construction (1962) on the far side and the powerplant construction camp is on the far bank. This is the first hydroelectric powerplant to be built on the Blue Nile River.

TABLE V-43--POWERPLANTS--1961 ISOLATED SYSTEMS--NORTH REGION

Location	Installed capacity (kv.-a.)		Firm capacity (kw.)	Production capability (1,000 kw.-hr.)	
	Diesel	Hydro		Diesel	Hydro
Bahir Dar	150	-	60	250	-
Gondar	200	-	100	400	-
Debre Markos	60	-	40	150	-

Source: EELPA

TABLE V-44--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.

TABLE V-45--1961 DISTRIBUTION PLANT DATA--ISOLATED SYSTEMS--NORTH REGION

Location	15-kv. lines (km.)	Substations		Consumers
		No.	(kv.-a.)	
Bahir Dar	3	4	300	125
Gondar	17	9	550	800
Debre Markos	-	-	-	350

Source: EELPA

PEAKS AND MONTHLY DISTRIBUTION OF ENERGY

The heaviest load in the Addis Ababa Complex (and for that matter, in Ethiopia) is the city of Addis Ababa. The daily load diagrams for heavy and light load conditions are indicated by Figure V-26. These diagrams do not necessarily imply that the heaviest and lightest loads occurred on the days indicated, but are merely examples of a heavy condition and a light condition.

A study of variations in monthly electricity production for several other African countries made in 1962 revealed that for Ethiopia's southern neighbor, Kenya, the largest usage occurred in August, followed with about the same usage in November and December. In Tunisia, December usage is the greatest, followed by August. The Tanganyika peak month was October, followed by August. Uganda's peak months were August and October, followed by November and December.

Two peaks seem to occur in Ethiopia during the year--August and December--but not consistently so for several reasons. The year's peak seems to occur during the coldest part of the year, which is usually in December. However, most of the precipitation occurring during the June 15 to September 15 rainy season falls in August, and in a "wet" year, the coolness and dampness resulting from cloud cover at these high altitudes can also produce a high demand. Figure V-27 indicates that for one particular period, the kilowatt peaks occurred in the fall (November-December). However, in 1961-62, Figure V-28 shows that the greatest monthly energy requirement occurred in August. This was a particularly wet year. For the Blue Nile studies1/, the monthly distribution of the annual energy requirements was taken to be as shown by Figure V-29. This would apply to conditions as they may exist 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.

For weekly heavy load duration and peak percent curves, see Figure V-30.

PAST AND ESTIMATED FUTURE TRENDS OF ELECTRICAL ENERGY REQUIREMENTS

A study of the past historical energy production is of value in obtaining the magnitude of produced energy. However, a study of the trend in energy production prior to 1960 will be of little use in forecasting future load growth because the tariff structure and availability of adequate supplies influenced a slower rate of growth than otherwise would have been the situation. In 1960 when Koka hydroelectric power became available and the revised tariff structure reflecting lower rates was placed in effect, the annual trend of energy requirements began to rise.

A summary of past production of electrical energy essentially for the South Region2/ by years from 1943 through 1962 is given in Table V-46. In 1960, 99.99 percent of the total production by EELPA was for the Addis Ababa Complex (Interconnected System), whereas in 1961 the figure was 99.55 percent. Other production was in and for the isolated systems. These figures do not include the North Eritrea Region nor the industrial plants which have generating capacity for their own use as shown by Figure V-31.

Table V-46 includes both the interconnected and isolated systems for the South Region and, in addition, contains the two small isolated loads in the North Region. These isolated systems are shown separately in Table V-47.

1/Operation studies prepared for the Finchaa, Giamma, and Muger Sub-basin facilities assumed a constant monthly energy requirement equaling about 8.33 percent of the annual. This was done before more definite data were obtained, which were not available following at least a year's operation of the South Region Interconnected System starting in mid-1960. Other projects studied later use the distribution shown by Figure V-29.

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

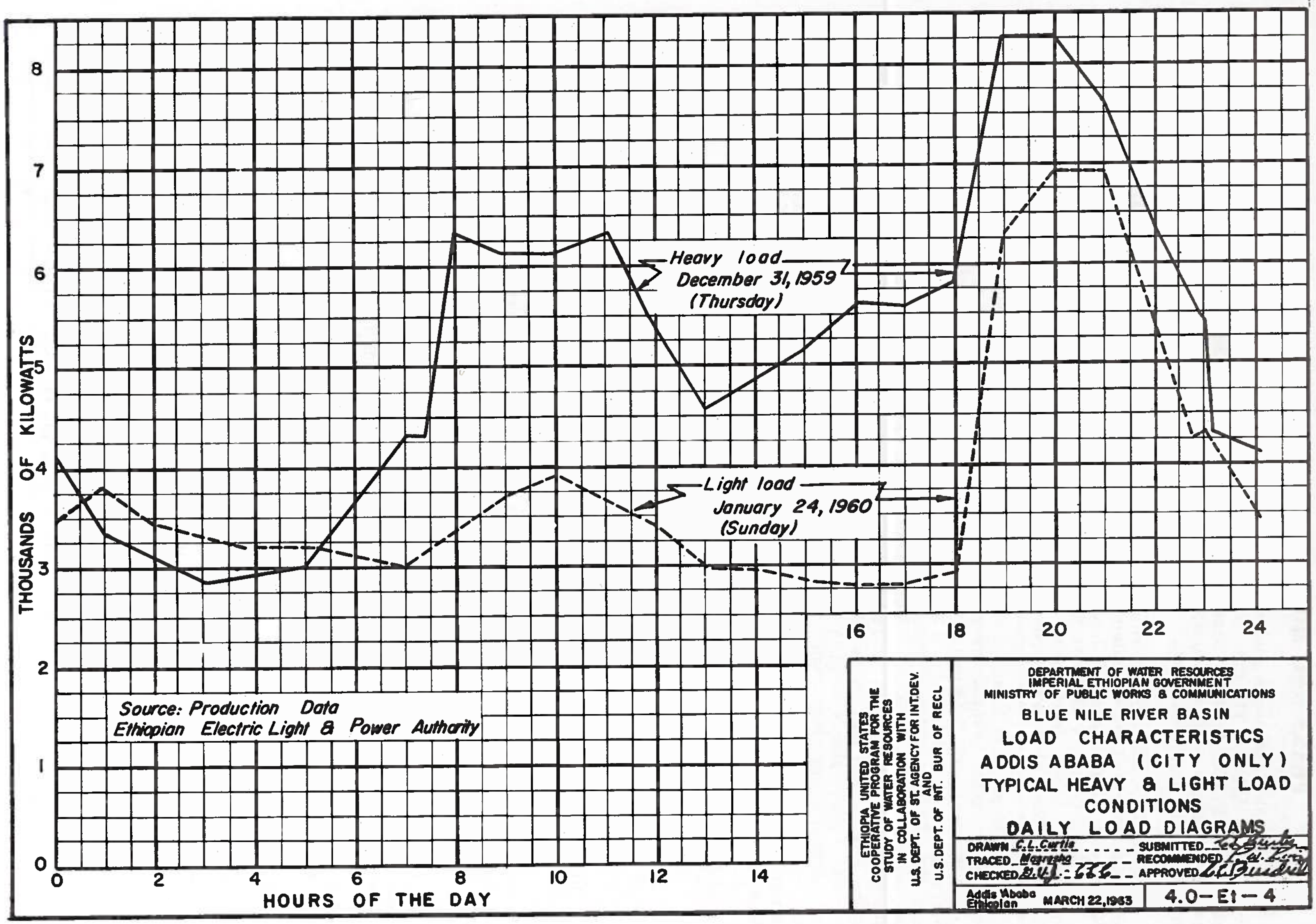


Figure V-26--Load Characteristics, Addis Ababa, Typical Heavy and Light Load Conditions, Daily Load Diagrams

LOCATION	1951 (1958-59) Average Load in KW	Peak Load in KW	Load Factor	Power Factor	1952 (1959-60) Average Load in KW	Peak Load in KW	Load Factor	Power Factor	1953 (1960-61) Average Load in KW	Peak Load in KW	Load Factor	Power Factor	Peak demand in KW
ADDIS ABABA (CITY ONLY)	4113	8000	0.514	0.84	5002	9300	0.538	0.87	5200	10200	0.510	0.885	10200 on Hidar 1953 (Nov. 1960) *
DIRE DAWA & HARAR	366	1230	0.298		452	1300	0.348		731	1700	0.430		1700 on Tahsas 1953 (Dec. 1960) *
NAZARETH	175	257	0.680	0.80	184	300	0.613	0.86	157	320	0.491		320 on Hidar 1953 (Nov. 1960) *
JIMA	86	195	0.441		104	305	0.341		105	365	0.288		365 on Meskerm 1953 (Sept. 1960)
DESSIE	55	135	0.407		59	270	0.218		97	360	0.269		360 on Tahsas 1953 (Dec. 1960)
GONDAR	37	100	0.37		40	140	0.286		52.5	150	0.350		150 on Tahsas 1953 (Dec. 1960)
AGERE HIYWET (AMBO)	27.6	65	0.425		28	92	0.304		32	85	0.376		92 on Guenbot 1952 (May 1960)
DEBRE BIRHAN	31	75	0.413		35	75	0.467		35	75	0.467		75 KW
YIRGALEM					14	43	0.326		23	64	0.359		64 on Hidar 1953 (Nov. 1960)
DEBRE MARKOS					12.7	30	0.423		16.4	34	0.482		34 on Tekemte 1953 (Oct. 1960)
JIJJIGA					22.4	36	0.622		23.6	38	0.621		38 on Tahsas 1953 (Dec. 1960)
BAHIR DAR									10	32	0.313		32 on Meskerm 1953 (Sept. 1960)

NOTES:

1. Data from Ethiopian Electric Light and Power Authority.
2. Dates are according to Ethiopian calendar with parenthetical entry in equivalent Gregorian calendar.

* Part of Addis Ababa Complex.

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

LOAD CHARACTERISTICS
PRINCIPAL CITIES-ETHIOPIA
(EXCLUSIVE OF ERITREA)

DRAWN C.L.C. SUBMITTED
TRACED A.N.M. RECOMMENDED
CHECKED APPROVED

Addis Ababa Ethiopia | Mar. 23, 1963 | 4.0-E1.-5

Figure V-27--Load Characteristics, Principal Cities of Ethiopia

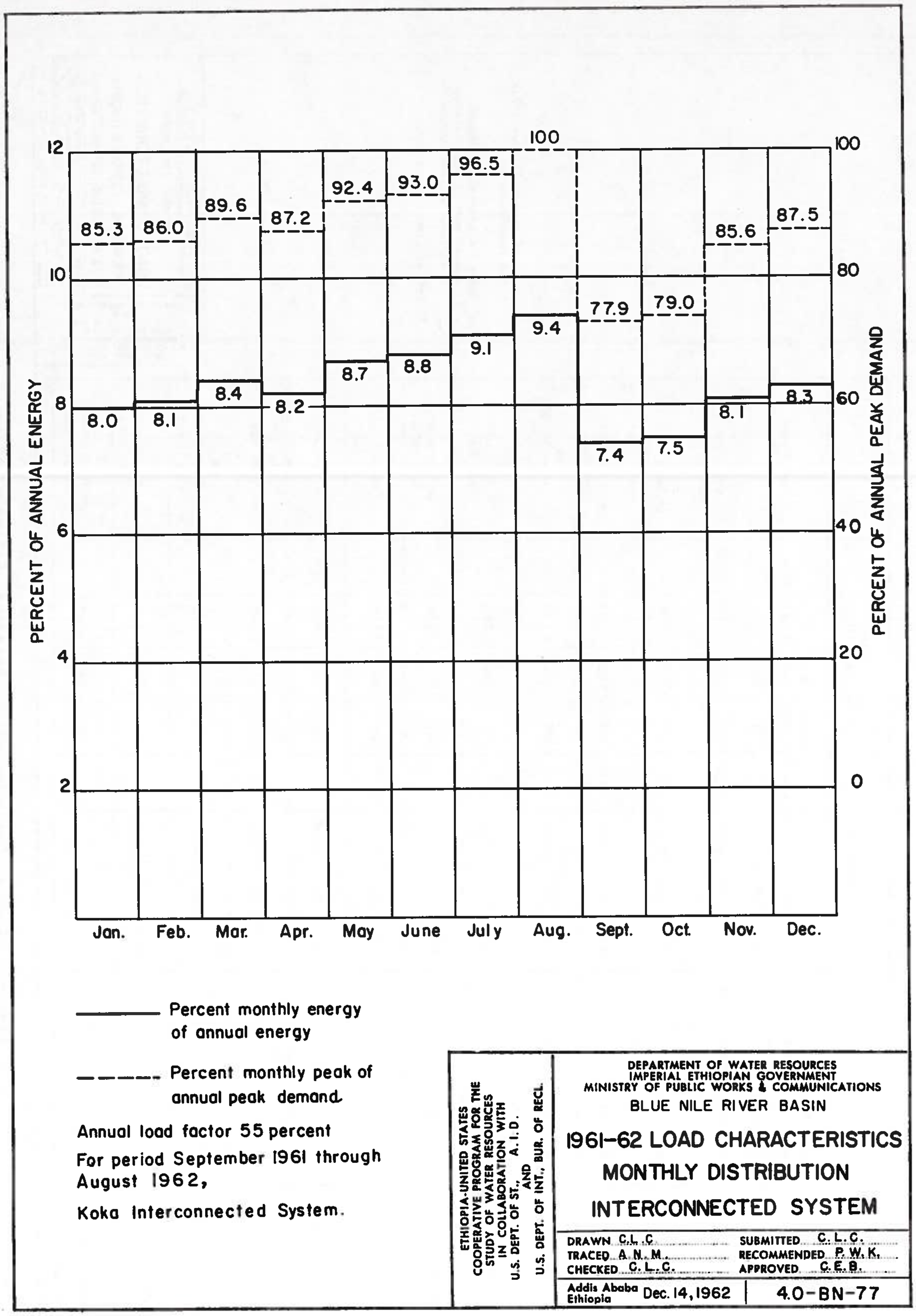


Figure V-28--1961-62 Load Characteristics, Monthly Distribution, Interconnected System

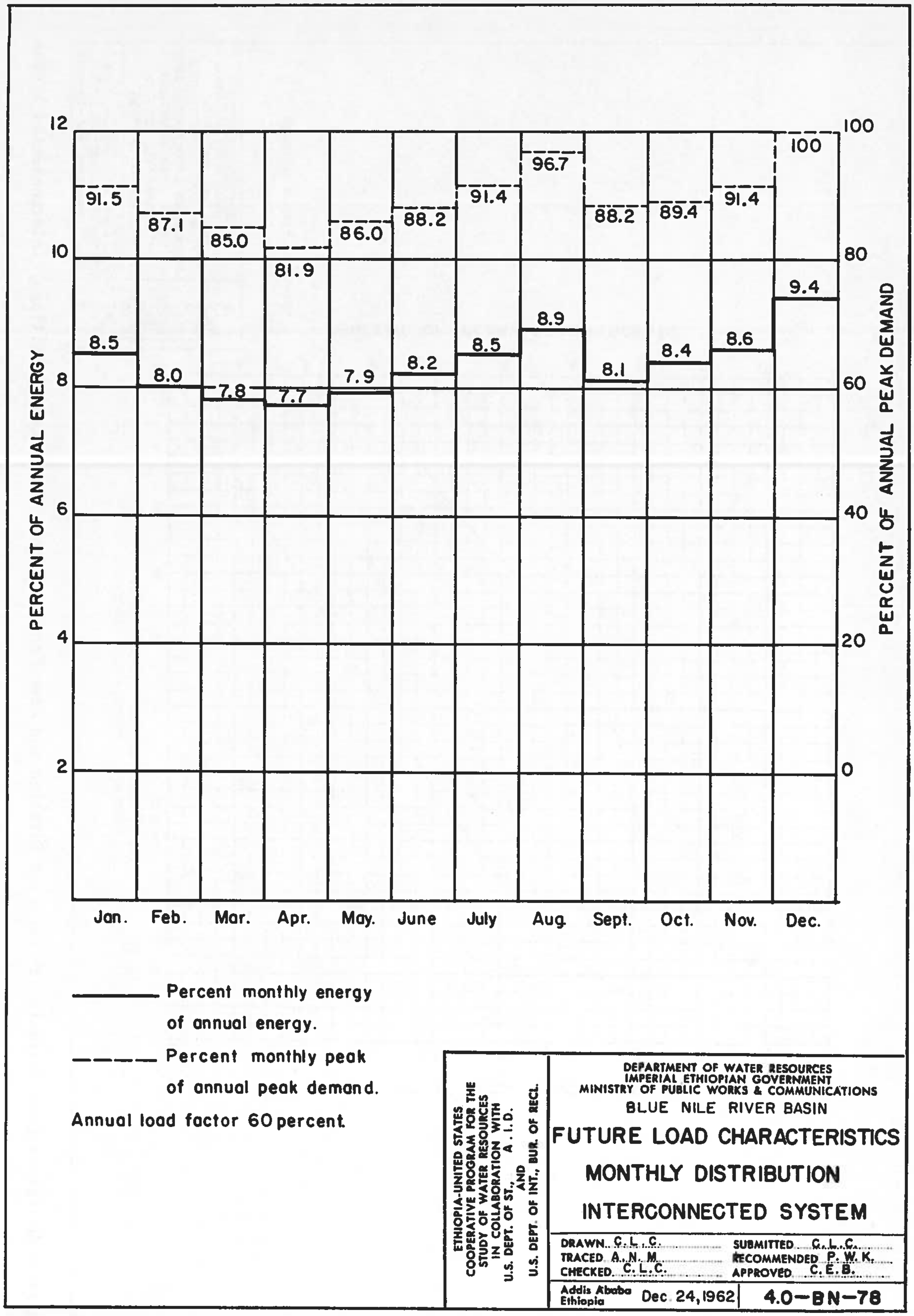


Figure V-29--Future Load Characteristics, Monthly Distribution, Interconnected System

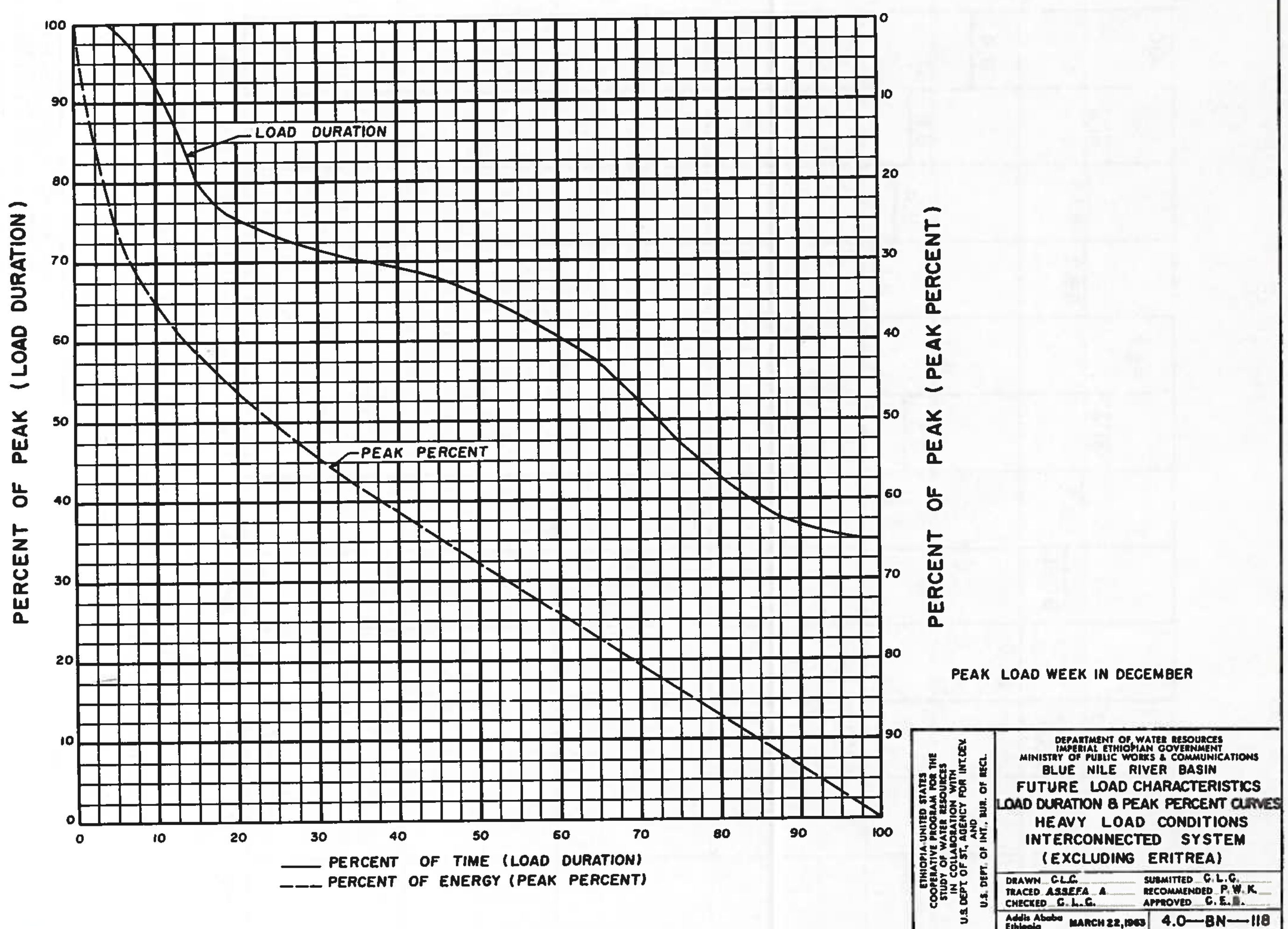


Figure V-30--Future Load Characteristics, Load Duration and Peak Percent Curves, Heavy Load Conditions, Interconnected System

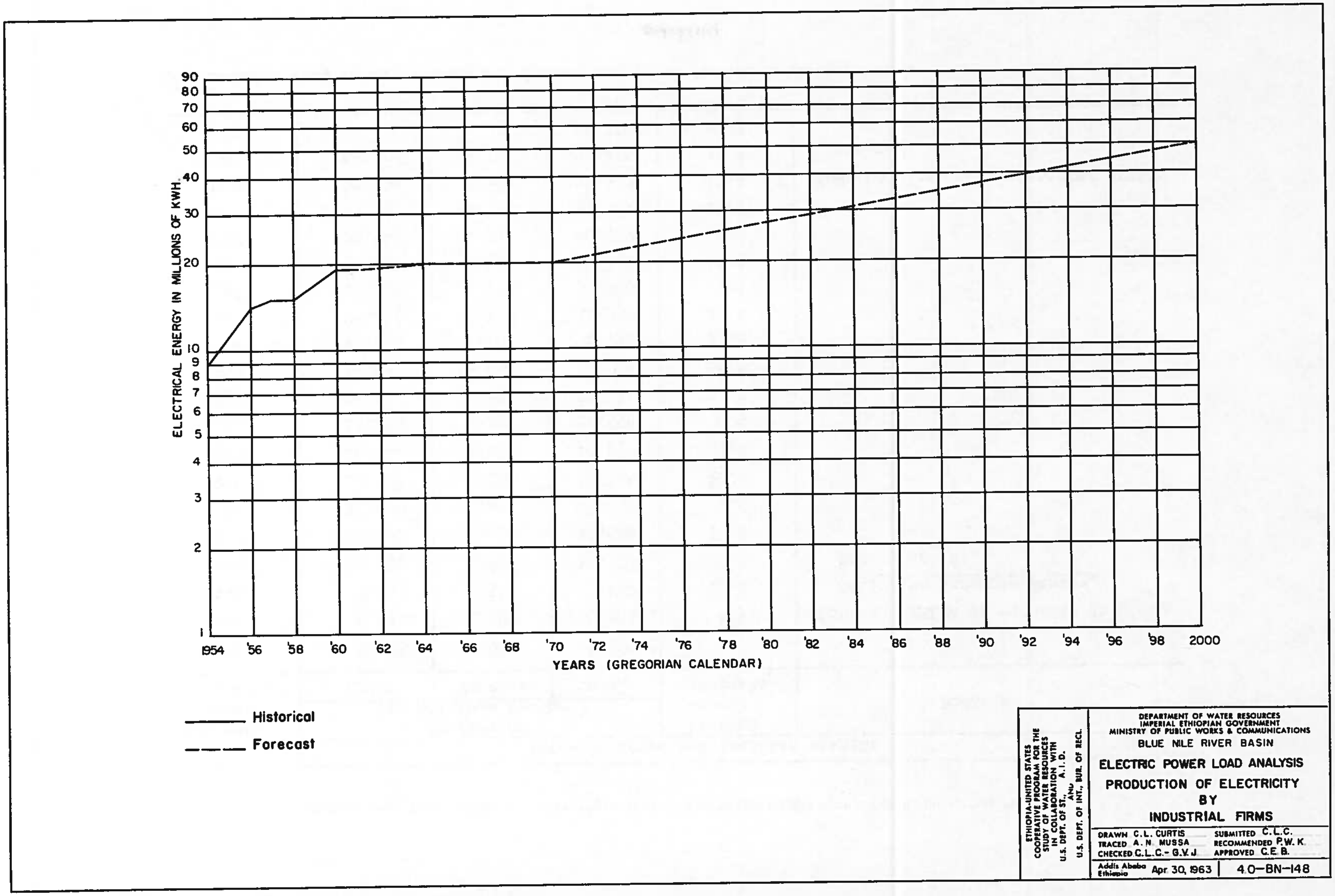


Figure V-31--Production of Electricity by Industrial Firms

TABLE V-46--PAST TRENDS OF ENERGY REQUIREMENTS--SOUTH REGION (EXCLUDING PRODUCTION BY INDUSTRIAL FIRMS)1/

For year ended September 10	Interconnected and isolated systems				
	Production (in millions kw.-hr.)			Percent annual increase	Remarks
	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.

TABLE V-47--PAST TRENDS OF ENERGY REQUIREMENTS--NORTH AND SOUTH REGIONS--ISOLATED SYSTEMS ONLY

For year ended September 10	Production (in thousands kw.-hr.)			Percent annual increase
	Hydro	Thermal	Total	
1957	645	640	1,285	24
1958	728	934	1,662	30
1959	782	1,135	1,917	15
1960	786	1,600	2,386	24
1961	996	2,785	3,781	59
1962*			6,000	59

* Estimated.

During the period 1957-1962, the isolated North Region loads, included above, showed these percentage increases:

	Gondar	Debre Markos
1957	-	-
1958	146	-
1959	49	-
1960	36	-
1961	50	256
1962	30	100

The electrical energy produced for the Addis Ababa Complex, South Region (EELPA), as a percent of the total production in the Empire was approximately as follows:

1957	50.2 percent
1958	51.5 percent
1959	53.2 percent
1960	54.4 percent
1961	59.6 percent
1962	63.9 percent

The remainder of the production was by industrial firms for their own use; and in North Eritrea, principally by SEDAO in the Massawa-Asmara area. This is covered in Annex "B" to this volume. (For 1961, the balance was 24 percent by North Eritrea and 16.4 percent by industrial firms.)

An important factor affecting the analysis of future loads is a reliable forecast of future power loads which can generally be built up from a forecast of electrical energy requirements by classes of customers. The various classes can generally be broken down into farm, residential, commercial and industrial, and other sales. The last class could include such subitems as uses of electricity for communication and transportation, public street and highway lighting, and sales to public authorities. Statistics on sales to these 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.

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 for 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. Statistics prior to 1960 on production of electricity are unsatisfactory for use in load forecasting for reasons previously given. Use of various empirical formulae have had little meaning either, as the results given appear to be much too high. For any successful method of forecasting electrical energy requirements in a developing country such as Ethiopia, all major branches of the economy should have a record of successful development toward established economic goals. Ethiopia has started in this direction, but concrete results will not be known until about 1980. Hence, any long-term load forecasts made at present must be considered as theoretical at best, recognizing that to be reasonable they must also take into consideration the costs of new power projects balanced against the ability of the economy to finance the projects. Also, to be realistic, good forecasting should discount any outside aid or grants as these cannot be considered as guaranteed items on a long-term basis.

Use of electrical energy in the public consumption category (residential, primarily) is almost a direct function of per capita income and the expected increase in Ethiopian per capita income is 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 system is carried out will have an important influence on the market analysis of future loads that could be served from the Blue Nile River Basin source. Continuance of this program is assumed throughout the period of analysis.

In practically every case, it is assumed that the completion of all-weather roads from Addis Ababa to the load centers will 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 are 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 form the top boundary of the load growth spectrum after 1971.

Load forecasts shown in subsequent tables generally were rounded to the nearest thousand or million kilowatt-hours. Peak demand in kilowatts at load and at powerplants was not rounded.

As far as these reconnaissance studies are concerned, these rates of growth effectually 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 present. Also, the maximum limit does match the broad economic goals set forth in the second 5-year Development Plant, at least to the year 1982. Should data within the next 5 to 10 years indicate a slower rate of economic growth than now indicated, then the same sequence of project development may still be valid, but delayed beyond the tentative target dates established later in this volume.

Rates of growth by regions in terms of production requirements are as shown by Table V-48, which considers EELPA estimates for the Addis Ababa Complex through 1971. Table V-51 shows these estimates for the latter in terms of actual demand.

A comparison of medium-range forecasting with other developing African countries will be of interest as shown by Table V-49.

TABLE V-48--ESTIMATED RATE OF INCREASES IN PEAK LOADS AT POWERPLANTS, REGIONAL INTERCONNECTED SYSTEMS ONLY

(See Tables V-107, V-108, V-109, and V-110)

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
1984	3.8	8.2	16.6		-	Central
1985	8.5	26.5	12.3		10.3	Interconnection
1986	7.3	11.7	16.4	9.8	8.1	for National Grid
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	

TABLE V-49--ACTUAL AND FUTURE RATES OF INCREASE IN ANNUAL USE OF ELECTRIC POWER PLANNED OR FORECAST FOR SELECTED AFRICAN COUNTRIES

Country	Actual percentage rate of increase in consumer use (1960-1961	Planned or forecast mean annual rate of growth in consumer use									
		Percent per year	Period								
			1963	1964	1965	1966	1967	1968	1969	1970	1980
1	2	3	4								
Central African Republic	16	19*									
Cameroon	4	12									
Dahomey	0	1-5*									
Ethiopia	24	22									
UAR (Egypt)	12(a)	11.5									
French Somaliland	19	18.8									
Gabon	11	(30.0(b) (7.0(c)									
Ghana	4	15-20						31			6.5
Ivory Coast	38	35*									
Kenya	8	7.5-15	7.5		10		15				
Liberia	13	20*									
Madagascar	5	7.2									
Mali	2	15									
Morocco	4*	14									
Nigeria	18*	17*	21		14				10		8
Reunion	17.5	17.5									
Fed. Rhodesia & Nyasaland	6	5(d)									
Somalia	6	3-6*									
Sudan	16	15*									
Tanganyika	7	7-10									
Uganda	3	10									

(a) 10-year annual average ending 1961.
(b) Refers to Libreville.
(c) Refers to Port Gentil and Lambarene.
(d) Earlier Federal Power Board estimates gave 7.2 percent which for various reasons has lately exceeded actual growth experienced.
* Provisional--Subject to change.

Source: United Nations Paper E/CN.14/EP/3, Part II, August 30, 1963.

LOSSES

Actual losses, including distribution losses, for the South Region's Interconnected System (Addis Ababa Complex) from 1957 through 1961 have been reported as follows1/:

Year	Millions of kw.-hr. Production	Sales	Losses	Percent losses
1957	35.5	25.3	10.2	29
1958	39.1	27.5	11.6	30
1959	45.0	33.5	11.5	34
1960	51.6	41.0	10.6	21
1961	60.3	50.2	10.1	17 2/

Losses for the South Region's isolated system3/ were about as follows:

Year	Percent losses
1957	32.3
1958	34.8
1959	31.1
1960	21.3
1961	14.7

Because the isolated system loads are so small in comparison with the interconnected system, they have a negligible effect upon total 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.

Anticipated distribution losses for the future system additions are included in subsequent tables. Transmission losses are summarized by Tables V-107 through V-110.

LOAD FACTORS 4/

Load factors during the early stages of village and town electrification tend to be erratic as the type of connected loads often varies. Load factors are usually low initially, improve considerably when village or town street lighting is established, then tend to reduce again as the ratio of consumer loads to street lighting loads increases. The addition of larger commercial or industrial loads can cause erratic variations in load factors. However, generally, after the base load is established, a more or less constant trend in load factors is noted. Figure V-32 is 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 given in subsequent sections.

1/Source, EELPA, January 1962 Report.
2/Includes transmission losses. Others are primarily distribution losses.
3/Gondar and Debre Markos from North Region included, but have negligible effect.
4/Ratio of average to peak loads occurring within a specified time interval.

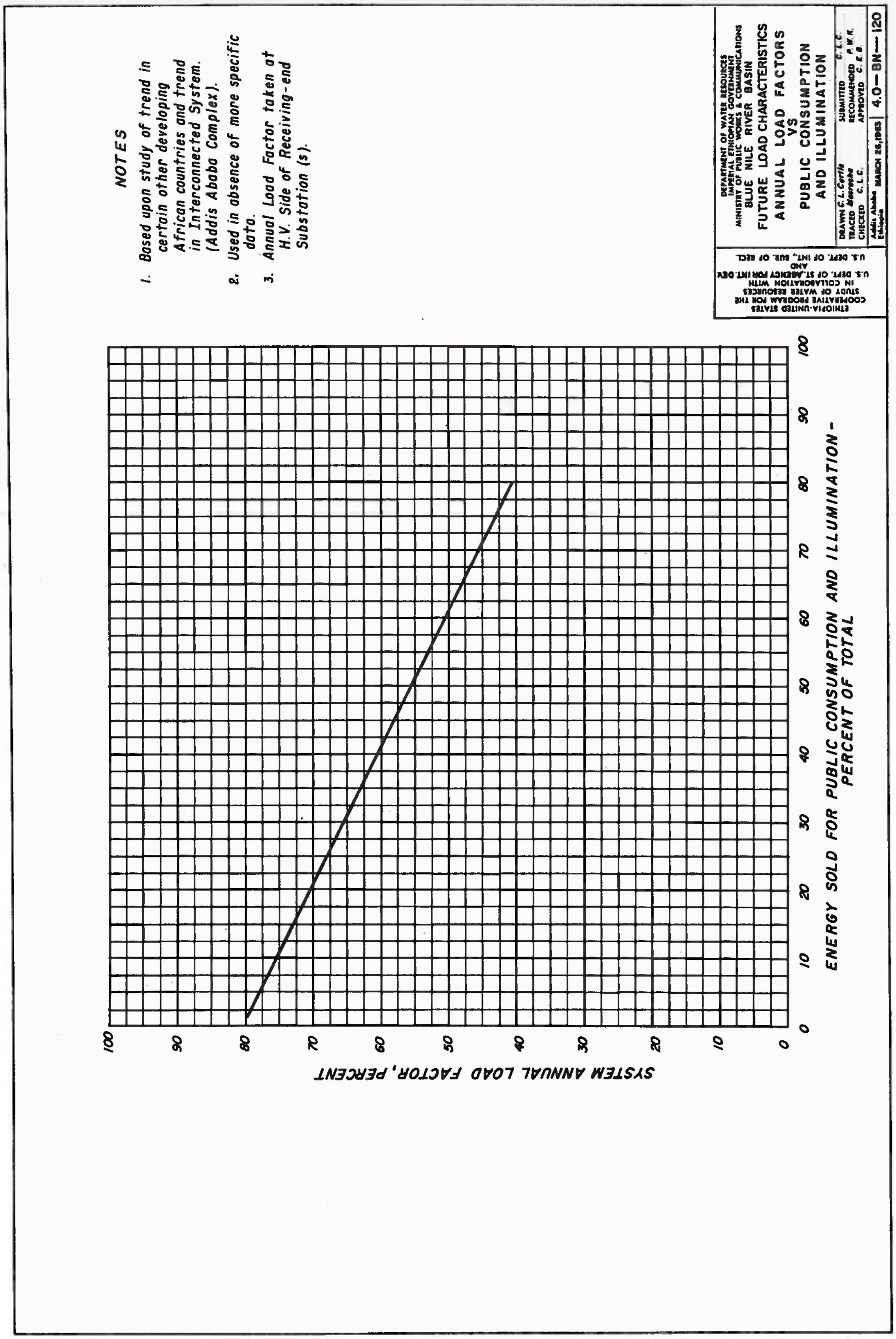


Figure V-32--Annual Load Factors vs. Public Consumption and Illumination

POTENTIAL LOAD CENTERS AND ESTIMATED FUTURE ELECTRICITY REQUIREMENTS

Possible future industrial developments on a generalized basis were discussed previously as established by the Empire's economic planners. The use of electric power and energy needed to operate these facilities was then analyzed to provide an all-embracing image of the total Empire economy and related energy requirements for specific industrial projects.

In the succeeding pages, this overall image is segregated into potential load centers within the four regional areas, and these are treated individually. Subsequently, they are summed into separate systems, three of which are later interconnected to form the National Grid.

These are the potential load centers or areas which are described in subsequent paragraphs:

SOUTH REGION	NORTH REGION
Addis Ababa Complex	Bahir Dar1/
Jima	Gondar
Fiche1/	Debre Tabor
Agere Hiywet	Dangila1/
Lekkemt	Debre Markos1/
Dessie-Kembolcha	Injibira1/
South Eritrea (Assab)	Jiga1/
Finchaa Farm	Birr Farm
Gedo	Metekkel
Angar Pumping and Farm	West Megech Farm
Debre Birhan	West Megech Pumping
Debre Sina	Beles Farm
Upper Guder Farm	Beles Pumping
Amarti-Neshe Farm	

CENTRAL REGION	WEST REGION
Dabana Farm	Asosa
Gimbi	Mendi
Nejo	Begi
Gore	

NORTH ERITREA

Asmara and Massawa2/

The second 5-year Development Plan forecasts two broad fields of electricity use in Ethiopia--use for the national economy and public consumption by the population and municipalities. The national economy requirements would presumably include commerce and industry, transport and communication, and irrigation and municipal water pumping. The public consumption requirements would include farm, urban residential, and Government buildings; public streets and highway lighting; and other sales.

Initially the potential demand for electricity in the public consumption and illumination category will be limited to residential and Government buildings and to public streets and security lighting in urban areas. As the standard of living is raised, the demand for electricity by the residents of these towns will increase but, initially, be limited primarily to lighting loads. Sales to entities such as schools, will increase with the expanding

1/Includes some village-rural loads served from these locations.
2/A special study was made of this and is not in the same category as the four regional areas given above. See "Annex B."

educational system. The nature of the loads will result in a generally low annual load factor. The future potential demands for electricity for rural use adjacent to these centers will be very limited and will be primarily by plantation-type farms. There is a possibility of some rural-village-type electrification along the Addis Ababa-Bahir Dar highway.

Because the second 5-year Development Plan breaks the energy classifications into two broad categories, "National Economy" and "Public Consumption and Illumination," this study also followed that procedure. As the two categories are somewhat ambiguous, it is highly important that the electrical utility industry in Ethiopia establish procedures whereby a record of sales according to more specific consumer classifications, be kept. Otherwise, obtaining future investment capital for electrical facilities may prove cumbersome due to lack of proper statistical data to support the need for new power installations.

Based upon very limited information, Table V-50 provides a reconciliation of classes of energy between the two broad categories cited above and for the more conventional classes for each load center.

Commerce and industry
Transport and communications
Irrigation and municipal water pumping
Rural, including farm and small villages
Urban residential
Lighting streets, highways, and Government buildings

South Region

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

Addis Ababa lies between 2300 and 2750 meters above sea level; the warmest periods are generally from March to May and the coolest in December and January. The temperature ranges between 3° and 29° C, and the average annual precipitation is about 1,200 mm. Most of the precipitation falls during the period from June 15 to September 15, with the heaviest amount usually falling in August. These conditions suggest that a possible December peak load and perhaps an August peak slightly below December will occur when the use of electric space heating becomes more widespread in the future.

The heart of Ethiopia's industry--its main load area--is the Addis Ababa Complex (63.9 percent of total national production for load in 1962), and probably most future development will be here also. Because of its size and political importance, Addis Ababa has good prospects for continued growth in population and as a source of labor for industry.

This is the main electrical load center and far exceeds anything else in the country. The 450,000 population of Addis Ababa in 1962 is far larger than the next largest city, Asmara, which has an estimated population of 100,000. Some authorities estimate a population of 1.5 million for Addis Ababa by 1982. The two cities probably will not be served from a common, interconnected electrical system in the foreseeable future.

Addis Ababa has the bulk of the foreign population, whose per capita use of electricity will range from 50 to 250 kilowatt-hours per month, making use of all types of electrical appliances.

Institutions of higher learning in Addis Ababa continue to attract young people, and the continued migration of people from the traditional agricultural areas indicates that the population growth will be continued and substantial. This, along with the higher per capita income in Addis Ababa will mean a continuing increase in demand for electrical power to serve residential areas and also to supply the needs of many Government buildings.

TABLE V-50--RECONCILIATION BY CLASSES OF ENERGY--PERCENT DISTRIBUTION OF TOTAL SALES TO CUSTOMERS

Sheet 1 of 2

Region	Load center	Year	National economy			Public consumption and illumination			Table reference
			Commerce and industry	Transport and communication	Irrigation and municipal water	Small village, rural	Urban residential	Lighting streets highways, Government buildings	
South	Addis Ababa Complex	1960	44	-	-		54	2	V-51
		1970	48	1	1		48	2	
		1980	53	1	2		41	3	
		1990	57	1	3		36	3	
		2000	60	2	3		32	3	
	Jima	1960	25	-	-		73	2	V-53
		1970	29	1	-		68	2	
		1980	33	1	1		63	2	
		1990	37	2	2		57	2	
		2000	40	2	2		54	2	
	Fiche	1985	-	-	-	50	49	1	V-55
		1990	-	-	-	60	39	1	
		2000	-	-	-	70	29	1	
	Agere Hiywet	1960	25	-	-		72	3	V-57
		1970	32	-	-		66	2	
		1980	38	-	1		59	2	
		1990	44	1	1		52	2	
		2000	50	1	2		45	2	
	Lekkemt	1970	28	-	-		69	3	V-59
		1980	31	1	-		66	3	
		1990	36	1	1		59	3	
		2000	40	1	2		54	3	
	Dessie-Kembolcha	1960	25	-	-		73	3	V-61
		1970	29	-	-		69	2	
		1980	33	-	-		65	2	
		1990	37	-	1		61	2	
		2000	52	2	1		46	2	
	Assab	1970	68				31	1	V-63
		1980	63	2	1		32	2	
		1990	66	2	2		27	3	
		2000	60	2	3		32	3	
	Finchaa Farm	1981	-	-	-	100	-	-	V-64
		1990	-	-	-	100	-	-	
		2000	-	-	-	100	-	-	
	Gedo	1980	25	-	-		72	3	V-66
		1990	30	-	-		68	2	
		2000	34	-	-		64	2	
	Angar Pumping and Farm	1991	-	-	97	3	-	-	V-67, V-68
		1995	-	-	96	4	-	-	
		2000	-	-	95	5	-	-	
	Debre Birhan	1960	25	-	-		75	-	V-69
		1970	29	-	-		68	3	
		1980	33	1	2		61	3	
		1990	37	2	2		57	2	
		2000	40	2	2		34	2	
	Debre Sina	1970	25	-			72	3	V-71
		1980	30	-			68	2	
		1990	34	-			65	1	
		2000	39	1			59	1	
	Upper Guder Farm	1990				100			V-73
		2000				100			
	Amarti-Neshe Farm	2000				100			V-74
North	Bahir Dar	1970	63	-	-		34	3	V-75
		1980	55	1	-		43	2	
		1990	41	1	-	5	51	2	
		2000	57	1	1	5	34	2	

Region	Load center	Year	National economy			Public consumption and illumination			Table reference
			Commerce and industry	Transport and communication	Irrigation and municipal water	Small village, rural	Urban residential	Lighting streets highways, Government buildings	
North--Cont	Gondar	1960	35	-	-		62	3	V-77
		1970	32	1	-		64	3	
		1980	35	1	1		61	2	
		1990	38	1	1		58	2	
		2000	40	2	2		54	2	
	Debre Tabor	1970	25				72	3	V-79
		1980	30				68	2	
		1990	34		1		63	2	
		2000	39		1		59	1	
	Dangila	1985				95	5	-	V-81, V-55
		1990				91	8	1	
		2000				84	14	2	
	Debre Markos	1970	29	-	-	-	68	3	V-83, V-55
		1980	13	1	-	61	23	2	
		1990	17	2	2	58	19	2	
		2000	22	2	2	44	28	2	
	Injibira	1985				88	10	2	V-55
		1990				83	15	2	
		2000				78	20	2	
	Jiga	1985				88	10	2	V-55
		1990				83	15	2	
		2000				88	20	2	
	Birr Farm	1990				100			V-85
		2000				100			
	Upper Beles Pump and Farm	2000			95	5			V-86, V-87
	W. Megech Pump and Farm	2000			65	35			V-88, V-89
	Metekkel	1980	25		-	72		3	V-91
		1990	31		-	67		2	
		2000	36		1	60		3	
Central	Dabana Farm	1990				100			V-92
		2000				100			
	Gimbi	1970	28	-	-		69	3	V-93
		1980	32	-	-		65	3	
		1990	35	1	2		60	2	
		2000	40	2	2		54	2	
	Nejo	1980	25				72	3	V-95
		1990	33				65	2	
		2000	39				59	2	
	Gore	1980	31				66	3	V-97
		1990	36	1	1		60	2	
		2000	40	1	1		56	2	
West	Asosa	1970	25	-			72	3	V-99
		1980	30	1			67	2	
		1990	34	1			64	1	
		2000	39	1			59	1	
	Mendi	1980	25				72	3	V-101
		1990	33				65	2	
		2000	36				62	2	
	Begi	1980	30				67	3	V-103
		1990	35		1		62	2	
		2000	40	1	1		56	2	

Figure V-33--Part of Addis Ababa, the largest city in the Empire. Most of the commercial and industrial activity in the Empire is centered here with some at Dire Dawa and Harar. These constitute the Addis Ababa Complex within the South Region.

An ambitious program of street and highway illumination in this area has greatly increased the demand for electricity for this purpose, but the total energy used is not separated from other use categories.

Sales of electricity to farms are negligible, but in the future may offer a possible outlet for power generated by Blue Nile River Basin powerplants.

Figure V-19 gave the extent of the South Region, including the Addis Ababa Complex. Anticipated energy requirements for customers and losses as well as expected load factors and peak demand in kilowatts at load are summarized by Table V-51.

In addition to becoming a major load center, Addis Ababa will become a large switching center as it will form the hub of the National Grid where high-voltage lines are interconnected from the north, south, east, and west. To accomplish this, the Blue Nile facilities would include three new substations, Gafarsa No. 2, East, and Akaki No. 2, forming a ring bus around the city as shown in Figure V-34. (Separate substations are indicated for convenience--Gafarsa No. 2 may be an addition to Gafarsa No. 1, now planned by EELPA. Similarly, Akaki No. 2 may be an addition to the one now planned at Akaki.) Figures V-64 and V-66 indicate the maximum substation facilities required at Gafarsa No. 2, Akaki No. 2, and East, all developed by stages until the year 2000.

Jima. Jima, the capital of Keffa Province, is about 250 kilometers southwest of Addis Ababa. The load area under consideration during the 40-year period of review is limited primarily to the city of Jima and makes no allowances for the rural electrification.

The elevation of Jima is about 1700 meters above sea level, and the temperature varies throughout the year from approximately 27° C down to 4° C, with a light frost occurring once every 2 or 3 years. The agricultural growing season is practically unlimited.

The 1961 population of Jima is estimated at about 35,000. It is in a heavily populated rural area that has an estimated population density of over 61 people per square kilometer. This area extends into the lower reaches of the Blue Nile River Basin. The future population growth of the area is conservatively estimated as follows:

1960-1970	1.5 percent
1971-1975	1.6 percent
1976-1985	1.75 percent
1986-2000	2.0 percent

The surrounding area is devoted primarily to agriculture, with the prime export crop being coffee and labor is primarily related to raising coffee and other agricultural crops.

The Jima area per capita income is slightly higher than the Sululta-Chancho area (Eth$65) because of the coffee income received there. The per capita income with Jima, where a small number of commercial enterprises exists, is perhaps approaching 150-250 Ethiopian dollars per year on the average. Jima, in 1961, had 1,250 consumers receiving electrical energy out of a population of about 35,000. There were about 13 kilometers of 15,000-volt line and about ten 15,000-volt distribution substations, averaging about 85 kv.-a. each, within the town. Generally, it appears that the present load in Jima is about 25 percent commercial and industrial, and the remaining 75 percent is residential loads. The growth of the industrial segment will be slow but progressive. In 40 years, the total percent of the load falling in the industrial and commercial category probably will not exceed 40 percent.

The only other sources of energy are imported petroleum products, firewood, and charcoal. Even at the present rate structure (tariff) for electrical energy, it appears that electricity is more economical than the imported petroleum products.

Historical data through 1961 are shown by Table V-52 with load forecasts from 1962 through 2000. Jima is served by its own isolated system, consisting of both hydro and

TABLE V-51--ENERGY AND DEMAND AT LOAD CENTER, ADDIS ABABA COMPLEX--SOUTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation: Load center losses	Load center total	Percent annual load factor	Peak demand kw
	Kilowatt-hours x 10^6				
1957*	25.3	10.2	35.5	50	8,105
1958*	27.5	11.6	39.1	51	8,752
1959*	33.5	11.5	45.0	51.4	10,000
1960*	41.0	10.6	51.6	53.8	10,949
1961*	50.2	8.5	58.7	51.0	13,139
1962	75.0	7.9	82.9	53.8	17,591
1963	95.0	12.2	107.2	54.6	22,413
1964	95.0	12.2	107.2	54.6	22,413
1965	110.0	11.8	121.8	54.9	25,326
1966	155.0	20.5	175.5	58.7	34,130
1967	185.0	20.0	205.0	57.1	40,984
1968	220.0	23.7	243.7	57.1	48,721
1969	260.0	32.3	292.3	57.1	58,437
1970	305.0	36.3	341.3	57.1	68,233
1971	350.0	40.0	390.0	57.1	77,969
1972	399.0	45.6	444.6	57	89,041
1973	450.0	54.4	504.4	57	101,017
1974	513.0	58.4	571.4	58	112,462
1975	578.0	65.6	643.6	58	126,673
1976	648.0	73.6	721.6	58	142,025
1977	726.0	83.2	809.2	58	159,266
1978	807.0	92.0	899.0	58	176,940
1979	894.0	101.6	995.6	59	192,632
1980	985.0	112.0	1,097.0	59	212,251
1981	1,080.0	123	1,203.2	59	232,799
1982	1,084	120	1,204	59	233,000
1983	1,140	127	1,267	60	241,166
1984	1,170	130	1,300	60	247,166
1985	1,249	139	1,388	60	264,167
1986	1,325	147	1,472	60	280,000
1987	1,407	156	1,563	60	297,333
1988	1,487	165	1,652	60	314,333
1989	1,576	175	1,751	61	327,700
1990	1,670	186	1,856	61	347,300
1991	1,769	197	1,966	61	367,800
1992	1,858	207	2,065	62	380,200
1993	1,950	217	2,167	63	392,700
1994	2,048	228	2,276	63	412,400
1995	2,150	239	2,389	64	426,100
1996	2,257	251	2,508	64	447,300
1997	2,370	263	2,633	64	469,700
1998	2,488	276	2,764	65	485,500
1999	2,612	290	2,902	65	509,700
2000	2,743	305	3,048	65	535,230

*Historical

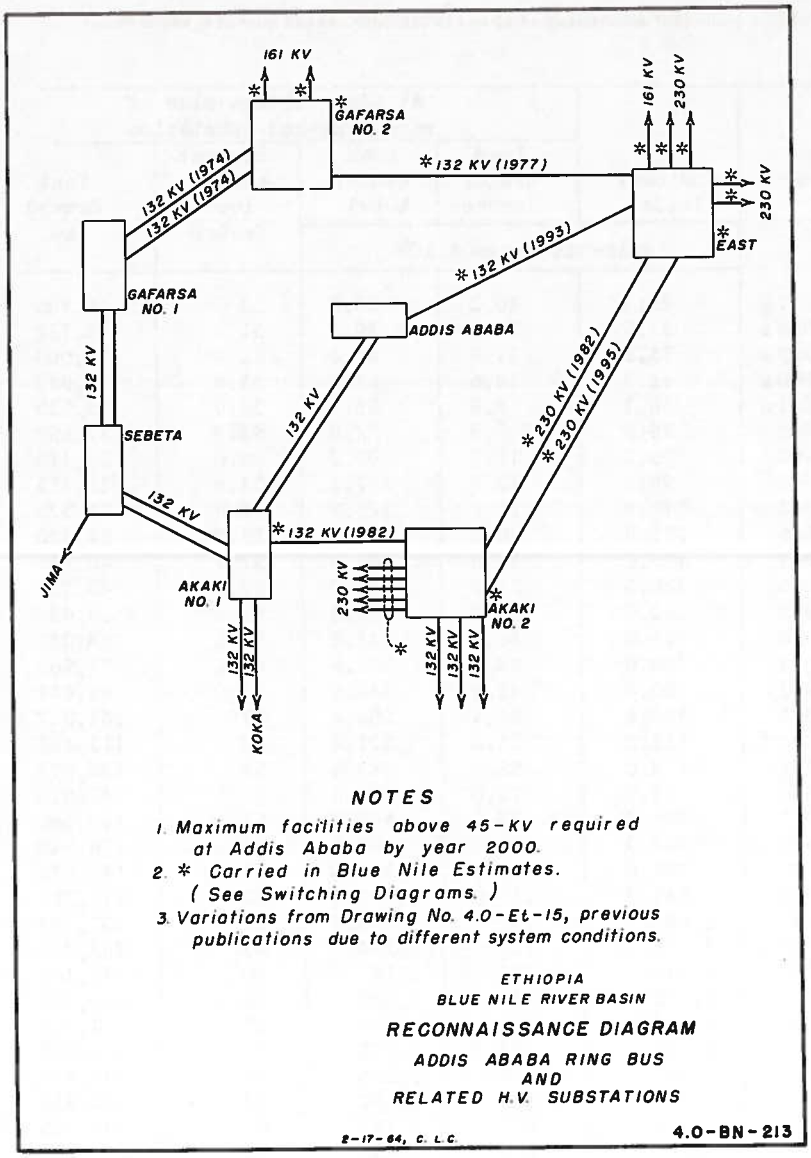


Figure V-34--Addis Ababa Ring Bus and Related H. V. Substations

TABLE V-52--ENERGY AND DEMAND AT LOAD CENTER--JIMA, SOUTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw	Remarks
	At high-voltage side of receiving-end substation					
	Kilowatt-hours x 10^6					
1957	325	153	478	25	218	Isolated system
1958	358	192	550	25	251	
1959	412	185	597	44	155	
1960	643	271	914	34	306	
1961	1,167	206	1,373	29	540	
1962	1,517	267	1,784	32	636	
1963	1,896	334	2,230	34	749	
1964	2,351	414	2,765	36	877	
1965	2,891	510	3,401	38	1,022	
1966	3,527	622	4,149	40	1,184	
1967	4,267	753	5,020	42	1,364	
1968	5,121	903	6,024	45	1,528	
1969	6,093	1,075	7,168	45	1,818	
1970	7,190	1,268	8,458	45	2,145	
1971	8,412	1,484	9,896	45	2,510	
1972	9,943	1,707	11,650	45	2,955	
1973	10,930	1,929	12,859	46	3,191	
1974	12,132	1,784	13,916	46	3,453	Interconnection
1975	13,224	1,945	15,169	46	3,764	Interconnected system
1976	14,293	2,092	16,385	46	4,066	
1977	15,425	2,268	17,693	46	4,391	
1978	16,505	2,427	18,932	47	4,598	
1979	17,660	2,597	20,257	47	4,920	
1980	18,896	2,778	21,674	47	5,264	
1981	20,218	2,973	23,191	47	5,633	
1982	21,634	3,181	24,815	47	6,027	
1983	23,148	3,404	26,552	47.5	6,381	
1984	24,768	3,643	28,411	47.5	6,828	
1985	26,501	3,898	30,399	48	7,230	
1986	28,358	4,171	32,529	48	7,736	
1987	30,342	4,463	34,805	48	8,277	
1988	32,164	4,729	36,893	48	8,774	
1989	34,093	5,014	39,107	48	9,300	
1990	36,730	5,314	42,044	48	9,999	
1991	38,307	5,697	44,004	48	10,465	
1992	40,544	5,972	46,516	48	11,062	
1993	42,986	6,322	49,308	49	11,487	
1994	45,565	6,701	52,266	49	12,176	
1995	48,299	7,103	55,402	49	12,907	
1996	51,196	7,529	58,725	49	13,680	
1997	54,268	7,981	62,249	49	14,502	
1998	57,525	8,459	65,984	50	15,065	
1999	60,976	8,968	69,944	50	15,969	
2000	64,635	9,505	74,144	50	16,928	

diesel. Connection to the South Region Interconnected System was assumed to occur by 1974. As is the situation with some of the other isolated systems, other facilities, such as larger hydroelectric systems, can be installed to serve an isolated system initially but can be connected later with the South Region Interconnected System when it expands. This possibility exists at Jima, where a larger plant on the Great Gibe River could be installed to carry the Jima load until interconnection was accomplished. Whether this is done or not is immaterial insofar as this particular study is concerned, except that when interconnection is made, all load is assumed to be carried by the Regional Interconnected System with diesel sets moved elsewhere and the small hydroelectric installations maintained for reserve or emergency use. Additional sources of generation exist nearby in the Upper Diddessa River Sub-basin and, as explained in a subsequent section, will be needed late in the century.

Total customer loads distributed by classes are as shown by Table V-53. Figure V-64 indicates the terminal facilities that may be required at Jima toward the end of the present century.

Highway Strip, Bahir Dar-Addis Ababa (Village and Rural). An important goal in the development of the Empire is to integrate the presently segregated economics. This is gradually being achieved by improving and extending transportation, communication media, and bringing electricity to some of the towns and villages.

The Bahir Dar area is being developed into an important economic segment of the Empire and the new highway being extended from Addis Ababa to Gondar via Bahir Dar will further emphasize the importance of the Bahir Dar area. Villages along this highway will benefit from the increased travel and greater accessibility to markets. Small commercial establishments should develop in the towns and villages.

The Alefa Powerplant (BL-1) will not only meet the energy needs of the entire North Region for several years, but will export surpluses to the South Region when the interconnection is effected. The interconnection can be accomplished by a double-circuit, 230-kv. transmission line, steel tower construction that will generally follow the new highway.

When they are justified, taps can be made at Bure to serve the North Region villages and rural sections along the highway, including Dangila, Injibira, Jiga, and Debre Markos, and at Fiche to serve the South Region towns and villages along the same highway. Thus, these loads are of secondary consideration.

Table V-54 gives the total estimated energy (kw.-hr.) and demand (kw.) for both the North and South Regions, while Table V-55 shows the division of load at peak demand (kw. only) between load centers. (Fiche is the only load center in the South Region in this category.)

Figure V-64 indicates the electrical facilities required at Fiche by the end of the present century to serve village and rural areas along the main highway.

Agere Hiywet. Agere Hiywet (Ambo) is near Addis Ababa, being slightly lower in elevation but having a little more precipitation. Temperature ranges are nearly the same.

In 1961, the population was estimated at about 10,000. It is the capital of one of the districts of awroja of Shewa Province and has headquarters to provide for administrative services for the area. Other facilities include a large primary school, commercial establishments which bottle spring water, stores and business places, and a large weekly market. It also has a hot-spring swimming pool and a modern hotel which attracts weekend and vacation visitors. A hospital maintained by a mission group serves both the town and the surrounding area. Livestock, particularly cattle, are raised in the area and this center provides the major portion of the manufactured and processed goods and products currently used in the adjacent areas.

Due to its proximity to Addis Ababa, it is not expected that large scale commercial developments will occur and that only modest growths in electrical energy and power requirements will occur.

TABLE V-53--SALES BY CLASSES--Kw.-hr. x 10^3--JIMA, SOUTH REGION

Year	National economy	Public consumption	Total
1957	81	244	325
1958	89	269	358
1959	103	309	412
1960	161	482	643
1961	296	871	1,167
1962	391	1,126	1,517
1963	497	1,399	1,896
1964	625	1,726	2,351
1965	780	2,111	2,891
1966	966	2,561	3,527
1967	1,186	3,081	4,267
1968	1,444	3,677	5,121
1969	1,742	4,351	6,093
1970	2,085	5,105	7,190
1971	2,473	5,939	8,412
1972	2,963	6,980	9,943
1973	3,300	7,630	10,930
1974	3,712	8,420	12,132
1975	4,099	9,125	13,224
1976	4,488	9,805	14,293
1977	4,905	10,520	15,425
1978	5,315	11,190	16,505
1979	5,757	11,903	17,660
1980	6,235	12,661	18,896
1981	6,753	13,465	20,218
1982	7,312	14,322	21,634
1983	7,917	15,231	23,148
1984	8,570	16,198	24,768
1985	9,275	17,226	26,501
1986	10,039	18,319	28,358
1987	10,862	19,480	30,342
1988	11,643	20,521	32,164
1989	12,478	21,615	34,093
1990	13,371	22,768	36,139
1991	14,327	23,980	38,307
1992	15,326	25,218	40,544
1993	16,420	26,566	42,986
1994	17,588	27,977	45,565
1995	18,836	29,463	48,299
1996	20,171	31,025	51,196
1997	21,598	32,670	54,268
1998	23,010	34,515	57,525
1999	24,390	36,586	60,976
2000	25,854	38,781	64,635

TABLE V-54--ENERGY AND DEMAND AT LOAD CENTERS--HIGHWAY STRIP. BAHIR DAR-ADDIS ABABA--VILLAGE, RURAL

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw
		At high-voltage side of receiving-end substation			
	Kilowatt-hours x 10^6				
1985	34.6	3.9	38.5	40	11,000
1986	42.0	4.7	46.7	40	13,340
1987	42.9	4.8	47.7	40	13,600
1988	43.7	4.9	48.6	40	13,880
1989	44.6	5.0	49.6	40	14,160
1990	45.4	5.1	50.5	40	14,440
1991	46.4	5.2	51.6	40	14,729
1992	47.3	5.3	52.6	40	15,024
1993	48.3	5.4	53.7	40	15,324
1994	50.6	5.6	56.2	41	15,630
1995	51.6	5.7	57.3	41	15,944
1996	52.6	5.8	58.4	41	16,262
1997	54.9	6.1	61.0	42	16,588
1998	56.1	6.2	62.3	42	16,919
1999	57.1	6.4	63.5	42	17,257
2000	58.2	6.5	64.7	42	17,600

(1) High-voltage substations at Fiche, Debre Markos, Dangila, Injibira, Bahir Dar, Jiga, and Bure

(2) See Table V-76.

TABLE V-55--DIVISION OF LOAD--HIGHWAY STRIP, BAHIR DAR-ADDIS ABABA--VILLAGE, RURAL

Year	High-voltage substations--North and South Regions Peak demand (kw)					
	Bahir Dar	Dangila	Injibira	Jiga	Debre Markos	Fiche*
1981						
1982						
1983						
1984						
1985	2,420	1,870	990	990	1,870	2,860
1986	2,935	2,268	1,200	1,200	2,268	3,469
1987	2,992	2,312	1,224	1,224	2,312	3,536
1988	3,054	2,360	1,249	1,249	2,360	3,608
1989	3,115	2,407	1,274	1,274	2,407	3,683
1990	3,177	2,455	1,300	1,300	2,455	3,753
1991	3,240	2,504	1,326	1,326	2,504	3,829
1992	3,305	2,554	1,352	1,352	2,554	3,907
1993	3,371	2,605	1,379	1,379	2,605	3,985
1994	3,439	2,657	1,407	1,407	2,657	4,063
1995	3,509	2,710	1,435	1,435	2,710	4,145
1996	3,577	2,765	1,464	1,464	2,764	4,228
1997	3,650	2,820	1,493	1,492	2,820	4,313
1998	3,722	2,876	1,522	1,522	2,877	4,400
1999	3,797	2,934	1,553	1,553	2,934	4,486
2000	3,900	3,000	1,600	1,600	3,000	4,500

* South Region; others all in North Region

Table V-56 indicates the conditions at load, historical through 1960 and projected after that date. Total customer loads distributed by classes are shown on Table V-57. The connection of this isolated load to the South Region Interconnected System was assumed to occur at the end of 1973.

Figure V-64 indicates the electrical facilities that may be required by the end of this century.

Lekkemt. This town is the capital of Wellega Province and has a population estimated at 25,000. Its altitude is approximately 1800-2000 meters above sea level and the average precipitation is around 2,000 mm. per year. Temperatures are about as follows:

Average daily minimum	13.4° C
Average daily	18.3° C
Average daily maximum	23.1° C

Small grains, livestock, wild honey, and related produce are important to the economy of Lekkemt and surrounding area. Lekkemt is on the main all-weather east-west highway to Addis Ababa. Local produce and much of the coffee grown around and to the north of Gore is transported through Lekkemt. The town is therefore, at present, somewhat dependent upon the coffee market. There are some scattered zigba forests in the area, but not of much commercial interest at present.

These are some of the future commercial and industrial possibilities at Lekkemt considered in establishing future loads.

Raw material	Secondary (Processing) industry	Products
Fibres musa ensete	Fibre	Rope, cord, cloth, twine, sacks
Hides and skins sheep cattle goat wild animal	Leather	Processed skins and hides for export; numerous leather products
Grain crops wheat barley maize	Flour biscuit and cake brewing	Flour; farinaceous products (biscuits, cakes, spaghetti, etc.); beer
Oil seeds	Soap and oil	Edible vegetable oils, cooking fats, soaps (by-product--cattle cake)
Fruits and vegetables	Canning dried fruits and vegetables	Canned fruits and vegetables; dried fruits and vegetables
Grapes	Wine and spirits dried fruit	Red and white wines, brandy, raisins and sultanas
Coffee	Coffee cleaning coffee processing	Coffee beans for export coffee products
Meat cattle sheep	Canning	Canned meat products (cooked meats, sausages, salami, etc.) meat by-products--horns, glue, fat extracts
Eggs	Egg processing	Dried eggs, albumin
Milk	Dairy	Canned and bottled milk, canned and bottled cream, cheeses, butter
Tobacco	Tobacco and cigarette	Pipe Tobacco; cigarettes; cigars
Sugar	Sugar	Various forms of processed sugar (granulated, cube), syrup, molasses; sweets
Wood	Lumber various wood processing	Constructional timber Furniture; plywood; pulp and paper; gums and resins; oils

TABLE V-56--ENERGY AND DEMAND AT LOAD CENTER--AGERE HIYWET (AMBO), SOUTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw	Remarks
	Kilowatt-hours x 10^6	At high-voltage side of receiving-end substation				
1957	137	64	201	30	76	Isolated system
1958	161	87	248	35	81	
1959	212	95	307	43	82	
1960	242	65	307	35	100	
1961	312	55	367	37	113	
1962	367	70	437	38	131	
1963	432	88	520	39	152	
1964	509	104	613	41	171	
1965	600	123	723	43	192	
1966	702	143	845	44	219	
1967	820	168	988	45	251	
1968	959	197	1,156	45	293	
1969	1,123	230	1,353	45	343	
1970	1,314	269	1,583	45	402	
1971	1,497	307	1,804	45	458	
1972	1,707	350	2,057	45	522	
1973	1,941	398	2,339	46	580	Interconnection
1974	2,198	383	2,581	46	641	Interconnected system
1975	2,477	432	2,909	47	707	
1976	2,779	485	3,264	47	793	
1977	3,251	568	3,819	47	928	
1978	3,641	636	4,277	47	1,039	
1979	4,030	704	4,734	48	1,126	
1980	4,441	776	5,217	48	1,241	
1981	4,872	851	5,723	49	1,333	
1982	5,321	929	6,332	49	1,475	
1983	5,783	1,011	6,794	50	1,551	
1984	6,257	1,093	7,350	50	1,678	
1985	6,758	1,180	7,938	51	1,777	
1986	7,292	1,273	8,565	51	1,917	
1987	7,853	1,371	9,224	52	2,025	
1988	8,450	1,476	9,926	52	2,179	
1989	9,074	1,586	10,660	52	2,340	
1990	9,737	1,700	11,437	52	2,511	
1991	10,428	1,822	12,250	52	2,689	
1992	11,158	1,949	13,107	52	2,877	
1993	11,917	2,081	13,998	53	3,015	
1994	12,715	2,221	14,936	53	3,217	
1995	13,542	2,365	15,907	53	3,426	
1996	14,395	2,514	16,909	53	3,642	
1997	15,287	2,670	17,957	54	3,796	
1998	16,204	2,831	19,035	54	4,024	
1999	17,176	3,000	20,176	55	4,188	
2000	18,207	3,180	21,387	55	4,439	

TABLE V-57--SALES BY CLASSES--Kw.-hr. x 10^3--AGERE HIYWET, SOUTH REGION

Year	National economy	Public consumption	Total
1957	34	103	137
1958	40	121	161
1959	53	159	212
1960	62	180	242
1961	82	230	312
1962	98	269	367
1963	118	314	432
1964	143	366	509
1965	172	428	600
1966	205	497	702
1967	244	576	820
1968	292	667	959
1969	348	775	1,123
1970	415	899	1,314
1971	482	1,015	1,497
1972	559	1,148	1,707
1973	648	1,293	1,941
1974	747	1,451	2,198
1975	857	1,620	2,477
1976	978	1,801	2,779
1977	1,163	2,088	3,251
1978	1,325	2,316	3,641
1979	1,491	2,539	4,030
1980	1,670	2,771	4,441
1981	1,862	3,010	4,872
1982	2,064	3,257	5,321
1983	2,279	3,504	5,783
1984	2,500	3,757	6,257
1985	2,740	4,018	6,758
1986	3,000	4,292	7,292
1987	3,280	4,573	7,853
1988	3,580	4,870	8,450
1989	3,900	5,174	9,074
1990	4,245	5,492	9,737
1991	4,609	5,819	10,428
1992	4,999	6,159	11,158
1993	5,410	6,507	11,917
1994	5,849	6,866	12,715
1995	6,311	7,231	13,542
1996	6,794	7,601	14,395
1997	7,307	7,980	15,287
1998	7,843	8,361	16,204
1999	8,416	8,760	17,176
2000	9,103	9,104	18,207

Table V-58 shows anticipated conditions through year 2000. Total customer loads distributed by classes were estimated as shown on Table V-59.

Because of its strategic location with respect to potential Blue Nile hydroelectric powerplants and load centers to the east and south, Lekkemt may become an important switching center and require the maximum electrical facilities indicated by Figure V-66 by the year 2000.

Dessie and Kembolcha. The pattern of major roads and highways has encouraged the growth of certain towns whose economy is influenced to a great extent by the trade and traffic using these facilities. One of the reasons for the recent growth of Dessie and Kembolcha is that they are natural stopping points for traffic toward Asmara and Assab.

The elevation at Kembolcha is around 1900 meters and Dessie is somewhat higher. Rainfall at Kembolcha averages about 1,100 mm. annually with temperature variations as follows:

Average daily minimum 10° C (January)

Average daily maximum 26° C (July)

Because of its favorable geographical location in regard to the Empire's transportation and communication systems, as well as having a pleasant climate and location with respect to the surrounding agricultural areas, Dessie and Kembolcha may have the greatest future growth potential of any of the other towns of comparable size considered in this study.

Dessie is also the capital of Wello Province with administrative centers located there for the various branches of Government. Wello Province, except for Tigre Province, contained the largest population of the 14 in Ethiopia in 1961. Dessie is one of the larger towns in the Empire and had an estimated population of 35,000 people in the same year.

Some products that may be available locally within economical transportation distance and could be processed in the future at Dessie include the following considered in estimating future loads. In later years, it was assumed that certain types of light industry would develop.

Raw material	Secondary (Processing) industry	Products
Cotton Wool	Textile	Yarn, cloth, clothing
Fibres musa ensete	Fibre	Rope, cord, cloth, twine, sacks
Hides and skins sheep cattle goat wild animal	Leather	Processed skins and hides for export; numerous leather products
Grain crops wheat barley maize	Flour biscuit and cake brewing	Flour; farinaceous products (biscuits, cakes, spaghetti, etc.); beer
Oil seeds	Soap and oil	Edible vegetable oils, cooking fats, soaps (by-product--cattle cake)
Vegetables	Canning dried vegetables	Canned vegetables; dried vegetables
Meat cattle sheep	Canning	Canned meat products (cooked meats, sausages, salami, etc.) meat by-products--horns, glue, fat extracts
Eggs	Egg processing	Dried eggs, albumin
Milk	Dairy	Canned and bottled milk, canned and bottled cream, cheeses, butter

TABLE V-58--ENERGY AND DEMAND AT LOAD CENTER--LEKKEMT, SOUTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation				Remarks
		Load center losses	Load center total	Percent annual load factor	Peak demand kw	
	Kilowatt-hours x 10^6					
1962	280	70	350	25	160	Isolated system
1963	454	106	560	30	213	
1964	781	171	952	35	311	
1965	1,264	259	1,522	36	483	
1966	1,897	388	2,285	37	705	
1967	2,655	544	3,199	38	961	
1968	3,586	734	4,320	39	1,264	
1969	4,661	955	5,616	40	1,603	
1970	6,059	1,241	7,300	40	2,083	
1971	7,574	1,551	9,125	41	2,541	
1972	9,088	1,862	10,950	41	3,049	
1973	10,907	2,233	13,140	42	3,571	
1974	12,979	2,267	15,246	43	4,047	
1975	14,879	2,499	17,378	43	4,613	
1976	17,408	3,041	20,449	43	5,429	
1977	19,815	3,528	23,343	43	6,197	
1978	23,423	4,091	27,514	43	7,304	
1979	26,936	4,705	31,641	43	8,400	
1980	30,707	5,364	36,071	44	9,358	
1981	34,698	6,062	40,760	44	10,575	
1982	38,861	6,788	45,649	44	11,843	
1983	43,135	7,535	50,670	45	12,854	Interconnection
1984	47,449	8,288	55,737	45	14,139	Interconnected system
1985	51,719	9,035	60,754	45	15,412	
1986	55,857	9,757	65,614	46	16,283	
1987	60,325	10,538	70,863	46	17,586	
1988	65,151	11,381	76,532	46	18,992	
1989	70,363	12,292	82,655	47	20,075	
1990	75,993	13,275	89,268	47	21,682	
1991	82,078	14,337	96,415	47	23,418	
1992	88,643	15,485	104,128	48	24,764	
1993	94,848	16,569	111,417	48	26,498	
1994	101,487	17,729	119,216	48	28,352	
1995	108,591	18,970	127,561	48	30,337	
1996	116,193	20,297	136,490	49	31,798	
1997	124,326	21,718	146,044	49	34,024	
1998	133,028	23,239	156,267	49	36,405	
1999	141,010	24,633	165,643	49	38,589	
2000	149,471	26,111	175,582	50	40,087	

TABLE V-59--SALES BY CLASSES--Kw.-hr. x 10^3--LEKKEMT, SOUTH REGION

Year	National economy	Public consumption	Total
1957			
1958			
1959			
1960			
1961			
1962	70	210	280
1963	114	340	454
1964	198	583	781
1965	326	938	1,264
1966	497	1,400	1,897
1967	706	1,949	2,655
1968	968	2,618	3,586
1969	1,277	3,384	4,661
1970	1,684	4,373	6,059
1971	2,136	5,438	7,574
1972	2,599	6,489	9,088
1973	3,163	7,744	10,907
1974	3,816	9,163	12,979
1975	4,434	10,445	14,879
1976	5,257	12,151	17,408
1977	6,063	13,752	19,815
1978	7,261	16,162	23,423
1979	8,458	18,478	26,936
1980	9,765	20,819	30,707
1981	11,173	23,525	34,698
1982	12,669	26,192	38,861
1983	14,235	28,900	43,135
1984	15,848	31,601	47,449
1985	17,481	34,238	51,719
1986	19,103	36,754	55,857
1987	20,872	39,453	60,325
1988	22,803	42,348	65,151
1989	24,909	45,454	70,363
1990	27,205	48,788	75,993
1991	29,712	52,366	82,078
1992	32,443	56,200	88,643
1993	35,094	59,754	94,848
1994	37,956	63,531	101,487
1995	41,047	67,544	108,591
1996	44,386	71,807	116,193
1997	47,990	76,336	124,326
1998	51,881	81,147	133,028
1999	55,558	85,452	141,010
2000	59,489	90,012	149,471

The Tendaho plantation developments producing cotton will find that to export raw cotton to the interior will require transportation through the Dessie-Kembolcha area, and Dessie may prove to be the most logical site for much of the future textile developments. The type of wool taken from sheep in the Mehal Meda area is not of the best quality, but may eventually prove to be a limited source of raw material for part of the future textile developments at Dessie.

Historical data from 1957 through 1960 are indicated in Table V-60 with the projections going to year 2000. The table also shows customer loads, losses, load factor, and peak demand by years for this load center with the tie to the South Region Interconnected System occurring in 1977. Sales by classes of energy are as indicated in Table V-61.

Because of its location with respect to topography and the highway network, Kembolcha may provide a suitable location for high-voltage switching with respect to the Assab load, and transformation with regard to the Dessie load. A short transmission line from Kembolcha to Dessie will adequately serve the latter. Stage construction will provide the ultimate electrical facilities anticipated for both Kembolcha and Dessie as indicated by Figure V-65.

South Eritrea (Assab). Assab is nearly at sea level, and its precipitation is less than 250 mm. per year. It has a hot climate with the average maximum around 28° C, and the average minimum probably around 20° C.

The South Eritrea load area, except for Assab, is sparsely settled, and there will be a negligible amount of energy sold in rural areas. Residential load for Assab will increase when and if a small industrial complex becomes firmly established around that town. The industrial load will become noticeable beginning in 1965 with the initial production from the Assab oil refinery and will become prominent by 1975 if the nucleus of a chemical industry is developed there. Also, the tourist industry in Ethiopia will develop in the future; and Assab will share in this, thus affecting power loads. The pleasant beaches, warm water, and continual ocean breeze will offset to some degree the high summertime temperatures.

A rough estimate places Assab's population in 1962 at 9,000. Considering the population increase that should result from increased port activities and a newly established petro-chemical industry, the loads have been estimated as shown in Table V-62 with total customer loads distributed by classes according to Table V-63.

The EELPA acquired the existing electric supply and distribution facilities from a private operator in 1962, and EELPA forecasts the production and sales as follows through 1971, using an increasing of 30 percent for 5 years and 20 percent for the last 5:

Year	Thousands of kw.-hr. Sales	Losses	Production
1962	5,000	1,000	6,000
1963	7,500	1,500	9,000
1964	9,500	1,500	11,000
1965	12,000	2,000	14,000
1966	16,000	4,000	20,000
1967	21,000	4,000	25,000
1968	26,000	5,000	31,000
1969	32,000	5,000	37,000
1970	39,000	5,000	44,000
1971	47,000	6,000	53,000

Studies using Table V-62 were prepared prior to the availability of this information; and, although in general it uses about the same rate of initial growth, the base loads for 1959-1961 are considerably lower. However, both estimates would approach about the same values at the assumed date of connection (1977) to the South Region Interconnected System. Sales by classes of energy are as shown on Table V-63.

TABLE V-60--ENERGY AND DEMAND AT LOAD CENTER--DESSIE, SOUTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw	Remarks
	At high-voltage side of receiving-end substation					
	Kilowatt-hours x 10^6					
1957	161	76	237	25	108	Isolated system
1958	166	89	255	25	116	
1959	206	93	299	41	83	
1960	370	98	468	22	243	
1961	762	134	896	26	393	
1962	1,487	305	1,792	30	682	
1963	2,603	533	3,136	33	1,085	
1964	4,165	853	5,018	35	1,637	
1965	5,831	1,194	7,025	37	2,167	
1966	7,580	1,553	9,133	40	2,606	
1967	9,400	1,925	11,325	43	3,007	
1968	11,656	2,387	14,043	44	3,643	
1969	13,986	2,865	16,851	45	4,275	
1970	16,783	3,438	20,221	46	5,018	
1971	20,140	4,125	24,265	46	6,022	
1972	23,967	4,908	28,875	46	7,166	
1973	28,520	5,841	34,361	46	8,527	
1974	33,652	6,893	40,545	46	10,062	
1975	39,710	8,133	47,843	46	11,873	
1976	46,460	9,516	55,976	46	13,891	Interconnection
1977	54,359	9,496	63,855	47	15,509	Interconnected system
1978	63,056	11,016	74,072	47	17,991	
1979	73,145	12,779	85,924	47	20,870	
1980	84,117	14,695	98,812	47	24,000	
1981	95,892	16,754	112,646	47	27,360	
1982	108,358	18,931	127,289	47	30,916	
1983	121,361	21,203	142,564	47	34,626	
1984	134,710	23,532	158,242	48	37,634	
1985	148,180	25,470	173,650	48	41,298	
1986	162,999	28,479	191,478	48	45,538	
1987	177,669	31,041	208,710	48	49,636	
1988	191,883	33,524	225,407	48	53,607	
1989	207,234	36,206	243,440	48	57,896	
1990	223,812	39,102	262,914	49	61,251	
1991	241,717	42,230	283,947	49	66,151	
1992	258,636	45,187	303,823	49	70,782	
1993	276,741	48,350	325,091	49	75,736	
1994	296,114	53,197	349,311	49	81,379	
1995	316,841	55,356	372,197	49	86,711	
1996	339,020	59,231	398,251	49	92,780	
1997	362,751	63,377	426,128	49	99,275	
1998	384,517	67,179	451,696	50	103,127	
1999	407,587	71,210	478,797	51	107,171	
2000	432,042	75,483	507,525	51	113,601	

1/ Includes smaller loads at Kombolcha

TABLE V-61--SALES BY CLASSES--Kw.-hr. x 10^3--DESSIE, SOUTH REGION

Year	National economy	Public consumption	Total
1957	40	121	161
1958	41	125	166
1959	52	154	206
1960	92	278	370
1961	194	568	762
1962	384	1,103	1,487
1963	682	1,921	2,603
1964	1,108	3,057	4,165
1965	1,574	4,257	5,831
1966	2,077	5,503	7,580
1967	2,613	6,787	9,400
1968	3,287	8,369	11,656
1969	4,000	9,986	13,986
1970	4,867	11,916	16,783
1971	5,921	14,219	20,140
1972	7,142	16,825	23,967
1973	8,613	19,907	28,520
1974	10,298	23,354	33,652
1975	12,310	27,400	39,710
1976	14,588	31,872	46,460
1977	17,286	37,073	54,359
1978	20,304	42,752	63,056
1979	23,845	49,300	73,145
1980	27,759	56,358	84,117
1981	32,028	63,864	95,892
1982	36,625	71,733	108,358
1983	41,505	79,856	121,361
1984	46,610	88,100	134,710
1985	51,863	96,317	148,180
1986	57,700	105,299	162,999
1987	63,606	114,063	177,669
1988	69,462	122,421	191,883
1989	75,848	131,386	207,234
1990	82,810	141,002	223,812
1991	90,402	151,315	241,717
1992	97,764	160,872	258,636
1993	105,715	171,026	276,741
1994	114,300	181,814	296,114
1995	123,568	193,273	316,841
1996	133,574	205,446	339,020
1997	144,375	218,376	362,751
1998	153,807	230,710	384,517
1999	163,035	244,552	407,587
2000	172,817	259,225	432,042

1/ Includes smaller loads at Kembolcha

TABLE V-62--ENERGY AND DEMAND AT LOAD CENTER--SOUTH ERITREA (ASSAB), SOUTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation				Remarks
		Load center losses	Load center total	Percent annual load factor	Peak demand kw	
	Kilowatt-hours x 10^6					
1959	1.20	.50	1.70	33	.588	Isolated system
1960	1.38	.46	1.84	40	.525	
1961	1.50	.48	1.98	45	.502	
1962	1.70	.43	2.13	52	.468	
1963	2.41	.57	2.98	59	.577	
1964	3.13	.74	3.87	60	.736	
1965	4.05	.95	5.00	55	1.038	
1966	5.26	1.24	6.50	50	1.484	
1967	6.85	1.60	8.45	48	2.009	
1968	15.25	3.35	18.60	65	3.267	
1969	22.90	4.20	27.10	65	4.759	
1970	22.94	5.04	27.98	64	4.991	
1971	30.34	6.66	37.00	65	6.498	
1972	38.54	8.46	47.00	65	8.254	
1973	46.03	9.43	55.46	64	9.892	
1974	53.40	10.93	64.33	62	11.845	
1975	61.93	12.69	74.62	60	14.197	
1976	72.08	13.73	85.81	59	16.603	Interconnection
1977	82.89	13.33	96.22	58	18.938	Interconnected system
1978	96.60	15.53	112.13	60	21.333	
1979	102.48	16.47	118.95	62	21.901	
1980	114.78	18.45	133.23	62	24.530	
1981	130.08	19.13	149.21	62	27.473	
1982	158.95	23.38	182.33	64	32.522	
1983	182.79	26.88	209.67	62	38.605	
1984	203.39	27.20	230.59	65	40.497	
1985	223.73	29.92	253.70	65	44.556	
1986	248.97	30.06	279.03	65	49.000	
1987	273.87	33.06	306.93	64	54.746	
1988	301.26	36.37	337.63	64	60.222	
1989	328.37	39.64	368.01	63	66.682	
1990	362.02	39.10	401.10	62	73.851	
1991	394.59	42.62	437.21	62	80.500	
1992	430.11	46.45	476.56	62	87.744	
1993	468.82	50.63	519.45	61	97.210	
1994	516.80	49.39	566.19	61	105.956	
1995	558.17	53.33	611.50	61	114.436	
1996	602.63	57.59	660.22	61	123.553	
1997	651.05	62.20	713.25	61	133.477	
1998	703.10	67.17	770.27	60	146.550	
1999	752.32	71.88	824.20	60	156.811	
2000	804.98	76.91	881.89	60	167.787	

TABLE V.63--SALES BY CLASSES--Kw.-hr. x 10^6--SOUTH ERITREA (ASSAB), SOUTH REGION

Year	National economy	Public consumption	Total
1957			
1958			
1959			
1960			
1961			
1962	1.19	0.51	1.70
1963	1.57	0.84	2.41
1964	1.88	1.25	3.13
1965	2.03	2.02	4.05
1966	2.10	3.16	5.26
1967	2.40	4.45	6.85
1968	10.68	4.57	15.25
1969	16.03	6.87	22.90
1970	15.60	7.36	22.94
1971	21.24	9.10	30.34
1972	26.98	11.56	38.54
1973	31.30	14.73	46.03
1974	35.24	18.16	53.40
1975	37.16	24.77	61.93
1976	41.81	30.27	72.08
1977	45.59	37.30	82.89
1978	57.96	38.64	96.60
1979	63.17	39.31	102.48
1980	72.31	42.47	114.78
1981	80.65	49.43	130.08
1982	111.27	47.68	158.95
1983	131.61	51.18	182.79
1984	142.37	61.02	203.39
1985	156.61	67.12	223.73
1986	174.28	74.69	248.97
1987	188.97	84.90	273.87
1988	204.86	96.40	301.26
1989	220.00	108.37	328.37
1990	238.93	123.07	362.00
1991	256.48	138.11	394.59
1992	275.27	154.84	430.11
1993	295.36	173.46	468.82
1994	320.42	196.38	516.80
1995	346.07	212.10	558.17
1996	373.63	229.00	602.63
1997	403.65	247.40	651.05
1998	428.89	274.21	703.10
1999	458.92	293.40	752.32
2000	482.99	321.99	804.98

If the petroleum refinery, tourism, chemical industry, and trade through the port facilities develop as is possible, the maximum electrical facilities required at Assab by the year 2000 may be as shown by Figure V-65. Stage construction is indicated to meet the continual increase in demand. This assumes that loads at Dessie and Assab will justify the construction of transmission facilities from Addis Ababa's East Substation.

Finchaa Project Farm Load. Table V-106 indicates that in the ultimate development of the Blue Nile River Basin irrigation projects a total of 15,000 hectares would be capable of development in the Finchaa Sub-basin; and on that basis, these forecasts on total development are anticipated:

Number farm units	880
New farm population	67,000
New farm peak demand	1,980 kw.

Table V-64 assumes that by starting the initial farm development in 1981, the total maximum development expected would occur in the year 2000, with the peak demand reaching 1,980 kw. in that year. Load factors, losses, energy requirements, and peak demand in kilowatts are all indicated by the table.

Loads would all be served directly from the Finchaa powerplant--see Figure V-64.

Gedo. Gedo is a small village on the main all-weather east-west highway having about 3,500 inhabitants. One of the access roads to the Finchaa Sub-basin projects starts at this location (the other at Baco to the west). Eventually, when the Finchaa Project develops, considerable stimulus to the Gedo economy may develop as a result, initially, of the construction activity, and utlimately, of the commercial stimulus by the producing project.

The altitude is around 2400 meters above sea level and aside from a highway maintenance center nearby, most of the population depends upon small commercial establishments associated with the predominantly agricultural economy.

Load increases are modest with a maximum of 600 to 700 kw. peak demand reached in 30 years. Sales by classes of loads, distribution losses, load factors, and kilowatt peak demand are indicated by Tables V-65 and V-66.

Gedo can be served by a 45-kv. line from the Agere Hiywet Substation.

Angar Project Irrigation Pumping and Farm Loads. These loads are associated with the Angar multipurpose project that is possible to develop north of Lekkemt. Two types of loads may develop--irrigation pumping and farm loads.

New farm loads possible of development are indicated by these statistics, which are derived from Table V-106.

Total irrigable hectares	30,200
Number farm units	1,776
New farm population	135,000
Peak demand at full development	4,000 kw.

However, as shown by Table V-67, it is not anticipated that a peak demand of more than 1,600 kw. will occur by the year 2000. The table indicates maximum energy requirements, losses, load factors, and peak demand expected during the period of review.

The Angar Project, when fully developed, will require irrigation pumping to serve 19,300 hectares of land, Table V-105. The gravity system would undoubtedly develop first, followed by pumping. There will be four pumping plants with installed horsepower as follows:

TABLE V-64.-ENERGY AND DEMAND, NEW IRRIGATION FARM LOADS--FINCHAA PROJECT, SOUTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation			
		Load center losses	Load center total	Percent annual load factor	Peak demand kw
	Kilowatt-hours x 10^6				
1981	236	26	262	30	100
1982	505	56	561	32	200
1983	805	89	894	34	300
1984	1,135	126	1,261	36	400
1985	1,498	166	1,664	38	500
1986	1,892	210	2,102	40	600
1987	2,207	245	2,452	40	700
1988	2,523	280	2,803	40	800
1989	2,838	315	3,153	40	900
1990	3,154	350	3,504	40	1,000
1991	3,469	385	3,854	40	1,100
1992	3,784	420	4,204	40	1,200
1993	4,099	456	4,555	40	1,300
1994	4,415	491	4,906	40	1,400
1995	4,731	525	5,256	40	1,500
1996	5,172	575	5,747	41	1,600
1997	5,629	626	6,255	42	1,700
1998	6,102	678	6,780	43	1,800
1999	6,591	732	7,323	44	1,900
2000	7,025	780	7,805	45	1,980

TABLE V-65--ENERGY AND DEMAND AT LOAD CENTER--GEDO, SOUTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation: Load center losses	Load center total	Percent annual load factor	Peak demand kw	Remarks
	Kilowatt-hours x 10^6					
1970	16	4	20	42	5	Isolated system
1971	57	11	68	42	18	
1972	79	16	95	42	26	
1973	103	21	124	42	34	
1974	129	26	155	42	42	
1975	159	33	192	42	52	
1976	196	40	236	43	63	
1977	239	47	288	43	76	
1978	289	59	348	43	92	
1979	347	71	418	43	110	
1980	413	84	497	44	129	Interconnection
1981	486	100	586	44	152	Interconnected system
1982	569	117	686	44	178	
1983	655	134	789	45	200	
1984	740	152	892	45	226	
1985	822	168	970	45	251	
1986	896	183	1,079	45	274	
1987	967	198	1,165	45	295	
1988	1,044	214	1,258	45	319	
1989	1,117	229	1,346	46	334	
1990	1,195	245	1,440	46	357	
1991	1,278	262	1,540	46	382	
1992	1,368	280	1,648	46	409	
1993	1,464	299	1,763	47	428	
1994	1,566	320	1,886	47	458	
1995	1,675	343	2,018	47	490	
1996	1,792	367	2,159	47	524	
1997	1,912	393	2,310	48	549	
1998	2,051	420	2,471	48	588	
1999	2,191	453	2,644	48	629	
2000	2,349	480	2,829	48	673	

TABLE V-66--SALES BY CLASSES--Kw.-hr. x 10^3--GEDO, SOUTH REGION

Year	National economy	Public consumption	Total
1970	4	12	16
1971	14	43	57
1972	20	59	79
1973	26	77	103
1974	33	96	129
1975	41	118	159
1976	51	145	196
1977	64	175	239
1978	78	211	289
1979	95	252	347
1980	115	298	413
1981	137	349	486
1982	163	406	569
1983	190	465	655
1984	218	522	740
1985	245	577	822
1986	271	625	896
1987	296	671	967
1988	323	721	1,044
1989	351	766	1,117
1990	380	815	1,195
1991	411	867	1,278
1992	446	922	1,368
1993	483	981	1,464
1994	523	1,043	1,566
1995	566	1,109	1,675
1996	613	1,179	1,792
1997	663	1,249	1,912
1998	718	1,333	2,051
1999	776	1,415	2,191
2000	840	1,509	2,349

TABLE V-67--ENERGY AND DEMAND, NEW IRRIGATION FARM LOADS--ANGAR PROJECT, SOUTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw
		At high-voltage side of receiving-end substation			
	Kilowatt-hours x 10^6				
1991	2,207	245	2,452	40	700
1992	2,523	280	2,803	40	800
1993	2,839	315	3,154	40	900
1994	3,150	350	3,500	40	1,000
1995	3,465	385	3,850	40	1,100
1996	3,878	431	4,309	41	1,200
1997	4,203	467	4,670	41	1,300
1998	4,635	515	5,150	42	1,400
1999	4,967	552	5,519	42	1,500
2000	5,424	603	6,027	43	1,600

TABLE V-68--ENERGY AND DEMAND AT IRRIGATION PUMPING LOAD CENTERS--ANGAR PROJECT, SOUTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw
		At high-voltage side of receiving-end substation			
	Kilowatt-hours x 10^6				
1991	79,900	3,995	83,895	28,730	Four pumping plants totaling 37,625 hp
1992	79,900	3,995	83,895	28,730	
1993	79,900	3,995	83,895	28,730	
1994	79,900	3,995	83,895	28,730	
1995	79,900	3,995	83,895	28,730	
1996	79,900	3,995	83,895	28,730	
1997	79,900	3,995	83,895	28,730	
1998	79,900	3,995	83,895	28,730	
1999	79,900	3,995	83,895	28,730	
2000	79,900	3,995	83,895	28,730	

North Pumping Plant No. 1	
Four synchronous motors totaling	1,725 h. p.
North Pumping Plant No. 2	
Three synchronous motors totaling	750 h. p.
North Pumping Plant No. 3	
Three synchronous motors totaling	2,525 h. p.
South Pumping Plant No. 4	
Seven synchronous motors totaling	32,625 h. p.

Toward the latter part of the century, conditions may warrant the irrigation pumping. Table V-68 provides an estimate of energy requirements, losses, and peak kilowatt demand expected.

These loads, both farm and irrigation pumps, will be served directly by Powerplants AG-2, AG-6A, and AG-6B, as shown by Figures V-40 and V-66.

Debre Birhan. Debre Birhan may have had a population of about 10,000 people in 1961. It is located on the important all-weather highway serving Asmara and Assab from Addis Ababa. Due to its proximity to Addis Ababa, no outstanding load growth is anticipated in the future, except for woolen textiles. Commercial establishments associated with the rural agricultural economy will continue to develop.

A woolen textile mill was under consideration for possible location at Debre Birhan, concentrating on the production of woolen clothes, hats, and blankets. Farmers have been advised to increase the production of sheep.

The elevation of Debre Birhan is about 2840 meters above sea level. Climate data are as follows:

Average daily temperatures	16.8° C
Average daily minimum temperatures	11.3° C
Average daily maximum temperatures	22.3° C
Average annual precipitation	925 mm.

Estimated sales of energy by classes are given by Table V-69 while total energy requirements, distribution losses, load factors, and peak demand in kilowatts are as estimated by Table V-70.

Figure V-65 indicates the maximum electrical facilities required by the year 2000 to supply the indicated loads.

Debre Sina. Debre Sina had an estimated population of 5,000 people in 1961, and like Debre Birhan, is on the important all-weather Addis Ababa highway to Asmara and Assab. It is an important stopping point for highway traffic to the east that has climbed the high watershed divide separating the Blue Nile Basin from the Awash Basin, or prior to the climb, going west. The temperatures and climate are similar to those given for Debre Birhan as the elevations are similar.

The economy of Debre Sina is tied to the local agriculture, except for a few commercial establishments related to highway transportation. Only a modest increase in energy requirements is foreseen as indicated by Table V-71, where the classes of energy are given.

Table V-72 shows the total energy requirements, distribution losses, estimated load factors, and peak demand in kilowatts. It is assumed that a small diesel installation can be made by the middle or later part of the 1960's. Load growth will be very small, developing to some 900 kw. on peak in 35 years.

Figure V-65 indicates the maximum electrical facilities that may be required by the year 2000 to serve the Debre Sina loads.

TABLE V-69--SALES BY CLASSES--Kw.-hr. x 10^3--DEBRE BIRHAN, SOUTH REGION

Year	National economy	Public consumption	Total
1957	29	86	115
1958	45	133	178
1959	50	149	199
1960	55	166	221
1961	61	181	242
1962	73	211	284
1963	89	261	350
1964	108	300	408
1965	131	355	486
1966	158	420	578
1967	191	496	687
1968	229	582	811
1969	274	683	957
1970	328	802	1,130
1971	388	933	1,321
1972	461	1,085	1,546
1973	537	1,240	1,777
1974	598	1,357	1,955
1975	661	1,470	2,131
1976	723	1,578	2,301
1977	790	1,695	2,485
1978	857	1,803	2,660
1979	927	1,918	2,845
1980	1,005	2,039	3,044
1981	1,088	2,169	3,257
1982	1,178	2,307	3,485
1983	1,276	2,454	3,730
1984	1,381	2,610	3,991
1985	1,495	2,775	4,270
1986	1,617	2,952	4,569
1987	1,750	3,139	4,889
1988	1,876	3,306	5,182
1989	2,010	3,483	5,493
1990	2,154	3,668	5,822
1991	2,308	3,864	6,172
1992	2,472	4,070	6,542
1993	2,649	4,286	6,935
1994	2,837	4,514	7,351
1995	3,039	4,753	7,792
1996	3,254	5,005	8,259
1997	3,484	5,271	8,755
1998	3,712	5,569	9,281
1999	3,935	5,902	9,837
2000	4,171	6,256	10,427

TABLE V-70--ENERGY AND DEMAND AT LOAD CENTER--DEBRE BIRHAN, SOUTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw	Remarks
		At high-voltage side of receiving-end substation				
	Kilowatt-hours x 10^6					
1957	115	54	169	30	64	Isolated system
1958	178	95	273	35	89	
1959	199	89	288	41	80	
1960	221	59	280	42	76	
1961	242	43	285	42	77	
1962	284	58	342	42	93	
1963	350	60	410	42	111	
1964	408	84	492	43	131	
1965	486	99	585	43	155	
1966	578	118	696	43	185	
1967	687	141	828	43	220	
1968	811	166	977	43	259	
1969	957	196	1,153	44	300	
1970	1,130	231	1,361	44	353	
1971	1,321	271	1,592	44	413	
1972	1,546	316	1,862	44	483	
1973	1,777	364	2,141	45	543	
1974	1,955	400	2,355	45	597	
1975	2,131	436	2,567	45	651	
1976	2,301	471	2,772	45	703	
1977	2,485	509	2,994	45	760	
1978	2,660	544	3,204	46	795	
1979	2,845	583	3,428	46	851	
1980	3,044	623	3,667	46	910	
1981	3,257	667	3,924	46	974	
1982	3,485	714	4,199	47	1,020	
1983	3,730	763	4,493	47	1,091	
1984	3,991	817	4,808	47	1,168	
1985	4,270	875	5,145	47	1,250	Interconnection
1986	4,569	936	5,505	48	1,309	Interconnected system
1987	4,889	1,001	5,890	48	1,400	
1988	5,182	1,061	6,243	48	1,485	
1989	5,493	1,125	6,618	48	1,574	
1990	5,822	1,193	7,015	48	1,668	
1991	6,172	1,264	7,436	49	1,732	
1992	6,542	1,340	7,882	49	1,836	
1993	6,935	1,420	8,355	50	1,908	
1994	7,351	1,506	8,857	50	2,022	
1995	7,792	1,596	9,388	50	2,143	
1996	8,259	1,692	9,951	50	2,271	
1997	8,755	1,793	10,548	50	2,408	
1998	9,281	1,900	11,181	50	2,553	
1999	9,837	2,015	11,852	50	2,706	
2000	10,427	2,386	12,813	51	2,868	

TABLE V-71--SALES BY CLASSES--Kw.-hr. x 10^3--DEBRE SINA, SOUTH REGION

Year	National economy	Public consumption	Total
1965	4	12	16
1966	14	43	57
1967	20	59	79
1968	26	77	103
1969	33	96	129
1970	41	118	159
1971	51	145	196
1972	64	175	239
1973	78	211	289
1974	95	252	347
1975	115	298	413
1976	137	349	486
1977	163	406	569
1978	190	465	655
1979	218	522	740
1980	245	577	822
1981	271	625	896
1982	296	671	967
1983	323	721	1,044
1984	351	766	1,117
1985	380	815	1,195
1986	411	867	1,278
1987	446	922	1,368
1988	483	981	1,464
1989	523	1,043	1,566
1990	566	1,109	1,675
1991	613	1,179	1,792
1992	663	1,249	1,912
1993	718	1,333	2,051
1994	776	1,415	2,191
1995	840	1,509	2,349
1996	909	1,603	2,512
1997	984	1,704	2,688
1998	1,064	1,813	2,877
1999	1,151	1,897	3,078
2000	1,245	2,049	3,294

TABLE V-72--ENERGY AND DEMAND AT LOAD CENTER--DEBRE SINA, SOUTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw	Remarks
	Kilowatt-hours x 10^6					
		At high-voltage side of receiving-end substation				
1965	16	4	20	42	5	Isolated system
1966	57	11	68	42	18	
1967	79	16	95	42	26	
1968	103	21	124	42	34	
1969	129	26	155	42	42	
1970	159	33	192	42	52	
1971	196	40	236	43	63	
1972	239	49	288	43	76	
1973	289	59	348	43	92	
1974	347	71	418	43	110	
1975	413	84	497	44	129	
1976	486	100	586	44	152	
1977	569	117	686	44	178	
1978	655	134	789	45	200	
1979	740	152	892	45	226	
1980	822	168	990	45	251	
1981	896	183	1,079	45	274	
1982	967	198	1,165	45	295	
1983	1,044	214	1,258	45	319	
1984	1,117	229	1,346	46	334	
1985	1,195	245	1,440	46	357	
1986	1,278	262	1,540	46	382	Interconnection
1987	1,368	280	1,648	46	409	Interconnected system
1988	1,464	299	1,763	47	428	
1989	1,566	320	1,886	47	458	
1990	1,675	343	2,018	47	490	
1991	1,792	367	2,159	47	524	
1992	1,912	393	2,310	48	549	
1993	2,051	420	2,471	48	588	
1994	2,191	453	2,644	48	629	
1995	2,349	480	2,829	48	673	
1996	2,512	515	3,027	48	720	
1997	2,688	551	3,239	49	755	
1998	2,877	589	3,466	49	808	
1999	3,078	631	3,709	49	864	
2000	3,294	675	3,969	49	925	

TABLE V-73--ENERGY AND DEMAND, NEW IRRIGATION FARM LOADS--UPPER GUDER PROJECT, SOUTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation			
		Load center losses	Load center total	Percent annual load factor	Peak demand kw
	Kilowatt-hours x 10^6				
1989	236	26	262	30	100
1990	505	56	561	32	200
1991	805	89	894	34	300
1992	1,135	126	1,261	36	400
1993	1,498	166	1,664	38	500
1994	1,892	210	2,102	40	600
1995	2,128	237	3,171	40	675
1996	2,339	260	2,599	40	742
1997	2,479	275	2,754	40	786
1998	2,627	292	2,919	40	833
1999	2,854	317	3,171	41	883
2000	2,952	328	3,280	42	892

TABLE V-74--ENERGY AND DEMAND, NEW IRRIGATION FARM LOADS--AMARTI-NESHE PROJECT, SOUTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation			
		Load center losses	Load center total	Percent annual load factor	Peak demand kw
	Kilowatt-hours x 10^6				
1996	236	26	262	30	100
1997	505	56	561	32	200
1998	805	89	894	34	300
1999	1,135	126	1,261	36	400
2000	1,498	166	1,664	38	500

Upper Guder Project Farm Load. A gravity-type irrigation project located southwest of Agere Hiywet (Ambo), will upon final completion, have the following data (see also Table V-106):

Hectares irrigable	5,100
Number farm units	300
New farm population	23,000
Peak demand	892 kw.

It is possible this project may be among those constructed toward the latter part of the present century, and on that assumption, load requirements may develop as outlined in Table V-73, which also gives estimated energy, load factor, and anticipated kilowatt demand.

Load requirements can be met by connecting to the Agere-Hiywet distribution system at 15-kv. initially, and ultimately by tapping into the 45-kv. line to Gedo.

Amarti-Neshe Project Farm Load. Table V-106 provides the following statistics concerning the rural loads that might occur when the Amarti-Neshe Project is fully developed:

Hectares irrigable	8,490
Number of farm units	500
New farm population	38,000
Peak demand	1,125 kw.

It does not appear that the Amarti-Neshe irrigation development will be initiated until very late in the present century; and on that premise, Table V-74 indicates what the project farm loads may be then.

Farm loads can be served directly from the Neshe Powerplant, NES-1A, Figure V-147 (Annex "C"), ultimately, or from an extension of the Finchaa electrical distribution system.

North Region

Bahir Dar. The extent of the power market area is limited primarily to the town of Bahir Dar, without electrical service to the surrounding rural village areas until about 1985 at the earliest. Bahir Dar is located at the southern tip of Lake Tana about 1800 meters above sea level. About 25 to 30 kilometers downstream, the river passes over the famous Tis Isat Falls, which have a height of about 45 meters. The Tis Abbay powerplant is located here.

The average annual temperature at Bahir Dar is about 19° C, while the average annual rainfall is about 1,050 mm. The present population has been estimated at from 8,000 to 10,000 inhabitants.

Since 1950, three studies have been made concerning the development of a major city at Bahir Dar. The first was a brief study made by Dr. F. Kiessig, Germany, primarily concerned with the possibilities of economic exploitation of the Lake Tana area. Incidental to this objective of his report, a brief plan was given for a town at Bahir Dar. He felt that the first goal would be to develop a city of about 500,000 inhabitants, with the utlimate objective of about 1,000,000 people. The best place for the city was given as a district east of the river outlet, which would be across the Blue Nile River from the present site of Bahir Dar. Later, the firm of J. Seymour Harris and Partners, England, also prepared a study for the development of a city at Bahir Dar. More recently, the Battelle Institute of West Germany prepared a plan for the city of Bahir Dar; and in this plan, the first stage of the city provided for 30,000 population; the second stage, 100,000; and a third and long-range plan for 300,000 inhabitants. The plan envisioned Bahir Dar as an industrial center and possibly the future capital of the Empire.

About 90 percent of the people in the area are engaged in agricultural occupations. In Bahir Dar, most of the inhabitants are involved in small commercial enterprises although quite recently there has been an influx of laborers to meet construction requirements at the new textile plant, a new hospital, a new technical school, highway and bridge construction in the area, and construction of the Tis Abbay hydroelectric installation.

The main natural resources of the area are related directly to agriculture. Cattle raising is a primary agricultural activity around Lake Tana, and there are small quantities of coffee cultivated. Around the lake there are the usual crops of cereals, oil seeds, pulses, etc. Near the middle course of the Beles River, there is a rather large bamboo forest area which can be used as a basic raw material for the manufacture of paper and paper products, possibly in Bahir Dar. However, one of the main natural resources of the area is probably the water of Lake Tana, part of which, diverted southwest through the watershed divide by a tunnel, could develop some 1 billion (10^9) kilowatt-hours of electrical energy.

In addition to the generation of electricity, Lake Tana waters can then be used to irrigate a large block of land in the Beles River valley.

The installation and operation of a new 3,000-ton annual capacity textile mill is of importance from the power load viewpoint. It employs a labor force of about 500, with a maximum force of 2,000 required when in full operation. This mill may be expanded to handle a maximum raw cotton tonnage of about 5,000 per year. A byproduct of this will be the processing of cottonseed through oil mills which are considered in the overall development.

Other processing industries such as cattle slaughter houses, meat canning, soap and gelatine factories, tannery, ceramics, casein, starch, margarine, brewery, coffee roasting, brickyards and others, to name a few, have been considered for development at Bahir Dar.

The overall industrial development will be a very gradual process, taking many years. It would appear that even under the most optimistic schedule consistent with capital that might become available for the Bahir Dar development without dislocating the overall national economy, the population probably will not exceed 50,000 by the year 2000.

Table V-75 provides an estimate of total electrical energy requirements broken down into classes, while Table V-76 indicates, in addition to total energy requirements, the distribution losses, load factors, and anticipated peak kilowatt demand at load.

In late 1963 or early 1964, about 7,700 kw. of installed capacity at Tis Abbay will be available and would produce a total of about 40,000,000 kw.-hr. per year. However, due to the unregulated condition of the water supply from Lake Tana, EELPA estimated that only 3,000 kw., including 600-kw. diesel, would be firm, producing 15,000,000 kw.-hr. per year. The load, principally the textile mill boilers, will be able to utilize the full Tis Abbay output, 40,000,000 kw.-hr. Hence, the peak load can be adjusted to meet peak hydroelectric generation from Tis Abbay.

Bahir Dar loads, together with the switching facilities required for incoming power circuits and the transmission line serving loads east and north of Lake Tana, may require the maximum electrical installations shown by Figure V-63. Stage development is indicated with the total installation considered adequate to the year 2000 considering maximum economic development.

Gondar. Gondar is the capital of Begemidir Province. Gondar's population was estimated in 1961 at about 25,000 people as compared to a total population of 1.77 million for the province. About 450,000 in this Province reside in the Blue Nile River Basin.

Produce for export passes through Gondar for some processing on the way to Massawa over the existing all-weather highway. Gondar's economy is tied to local agriculture and will receive some stimulus from the adjacent irrigation projects around Lake Tana when they develop. Processing of produce from around Lake Tana and outlying areas could develop in Gondar using local produce as follows:

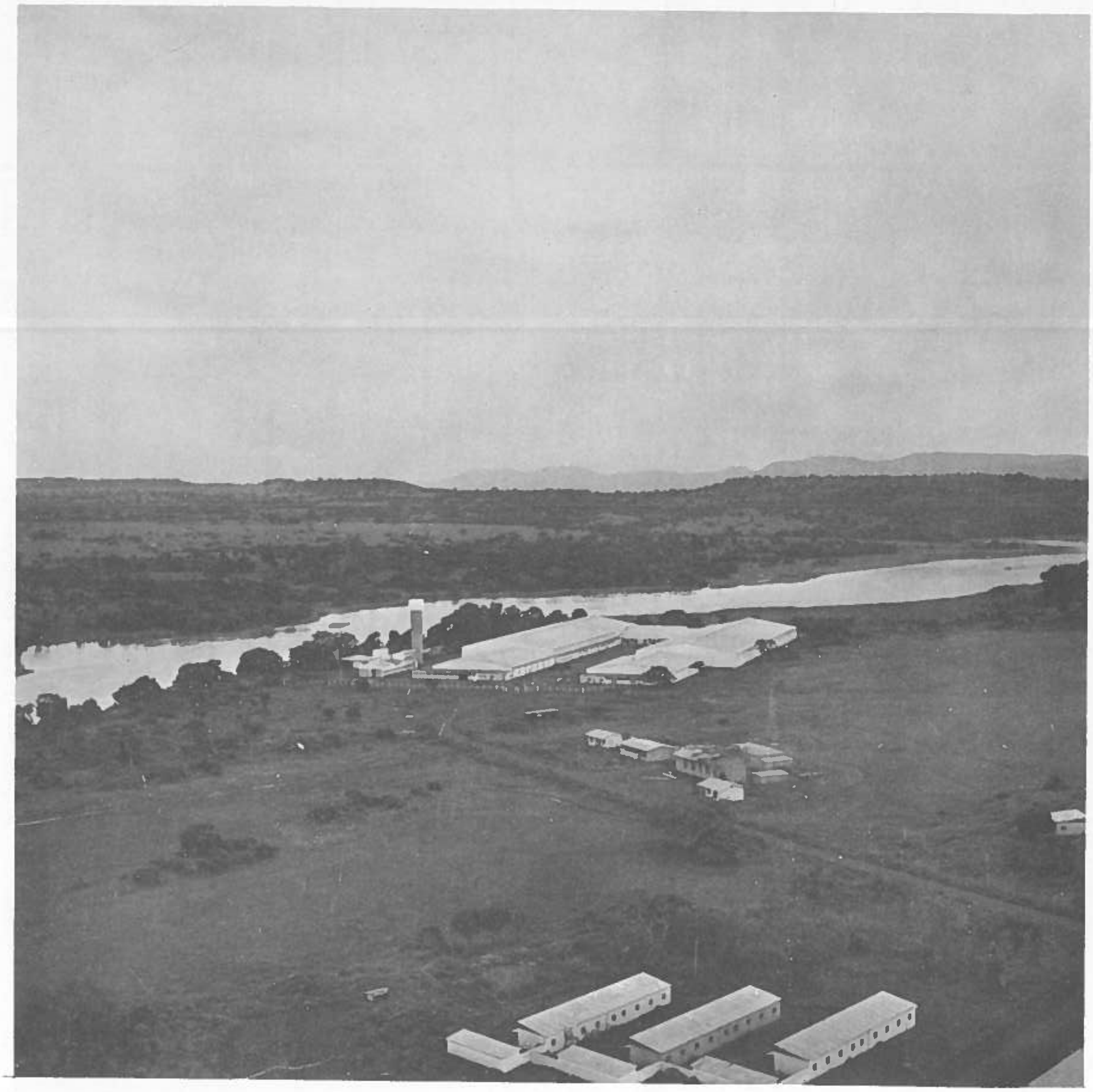


Figure V-35--The Bahir Dar textile plant with the Blue Nile River in the background. Most of the production of the new Tis Abbay hydroelectric powerplant will be for this industry.

TABLE V-75--SALES BY CLASSES--Kw.-hr. x 10^6--BAHIR DAR, NORTH REGION

Year	National economy	Public consumption	Total
1957			
1958			
1959			
1960			
1961			
1962	2.5	.5	3
1963	8.8	5.2	14
1964	13.2	6.8	20
1965	13.4	7.6	21
1966	13.9	8.1	22
1967	13.9	8.1	22
1968	15.1	8.9	24
1969	16.4	9.6	26
1970	17.6	10.4	28
1971	18.9	11.1	30
1972	19.5	11.9	31.4
1973	25.0	15.4	40.4
1974	27.5	17.5	45.0
1975	30.7	20.0	50.4
1976	33.9	22.6	56.5
1977	37.9	25.3	63.2
1978	40.7	29.5	70.2
1979	45.1	32.6	77.7
1980	47.1	38.5	85.6
1981	51.6	42.3	93.9
1982	53.3	49.3	102.6
1983	56.9	54.6	111.5
1984	60.3	60.4	120.7
1985	65.1	65.2	130.3
1986	67.5	73.1	140.6
1987	72.7	78.7	151.4
1988	73.3	89.6	162.9
1989	78.7	96.1	174.8
1990	80.7	106.9	187.6
1991	90.5	110.5	201.0
1992	103.2	111.8	215.0
1993	114.8	114.7	229.5
1994	127.3	117.6	244.9
1995	140.8	120.0	260.8
1996	152.5	124.7	277.2
1997	164.8	129.6	294.4
1998	177.8	134.2	312.0
1999	191.8	138.9	330.7
2000	210.3	140.2	350.5

TABLE V-76--ENERGY AND DEMAND AT LOAD CENTER--BAHIR DAR (URBAN LOADS ONLY), NORTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation				Remarks
		Load center losses	Load center total	Percent annual load factor	Peak demand kw	
	Kilowatt-hours x 10^6					
1957						
1958						
1959						
1960						
1961						
1962	3	1	4	30	1,522	
1963	14	1	15	42	4,077	Tis Abbay on line
1964	20	2	22	62	4,051	
1965	21	3	24	62	4,419	
1966	22	3	25	61	4,678	
1967	22	3	25	61	4,678	
1968	24	3	27	61	5,053	
1969	26	4	30	61	5,614	
1970	28	4	32	61	5,988	
1971	30	4	34	61	6,363	
1972	31.4	5.4	36	61	6,737	Third Tis Abbay on line. Bahir Dam constructed
1973	40.4	7.1	47.5	61	8,889	
1974	45.0	8.0	53.0	60	10,000	
1975	50.4	8.9	59.4	60	11,300	
1976	56.5	10.0	66.5	60	12,652	
1977	63.2	11.1	74.3	60	14,136	
1978	70.2	12.4	82.6	59	15,981	
1979	77.7	13.7	91.4	59	17,684	
1980	85.6	15.1	100.7	58	19,819	
1981	93.9	16.6	110.5	58	21,749	
1982	102.6	18.1	120.7	57	24,173	
1983	111.5	19.7	131.2	55	27,231	
1984	120.7	21.3	142.0	55	29,473	
1985	130.3	23.0	153.3	55	31,818	
1986	140.6	24.8	165.4	54	34,965	
1987	151.4	26.7	178.1	54	37,650	
1988	162.9	28.7	191.6	53	41,268	
1989	174.8	30.9	205.7	53	44,305	
1990	187.6	33.1	220.7	52	48,450	
1991	201.0	35.4	236.4	53	50,917	
1992	215.0	37.9	252.9	54	53,462	
1993	229.5	40.5	270.0	55	56,040	
1994	244.9	43.2	288.1	57	57,700	
1995	260.8	46.0	306.8	57	61,443	
1996	277.2	48.9	326.1	58	64,182	
1997	294.4	51.9	346.3	58	68,158	
1998	312.0	55.1	367.1	59	71,027	
1999	330.7	58.4	389.1	59	75,284	
2000	350.5	61.9	412.4	60	78,463	

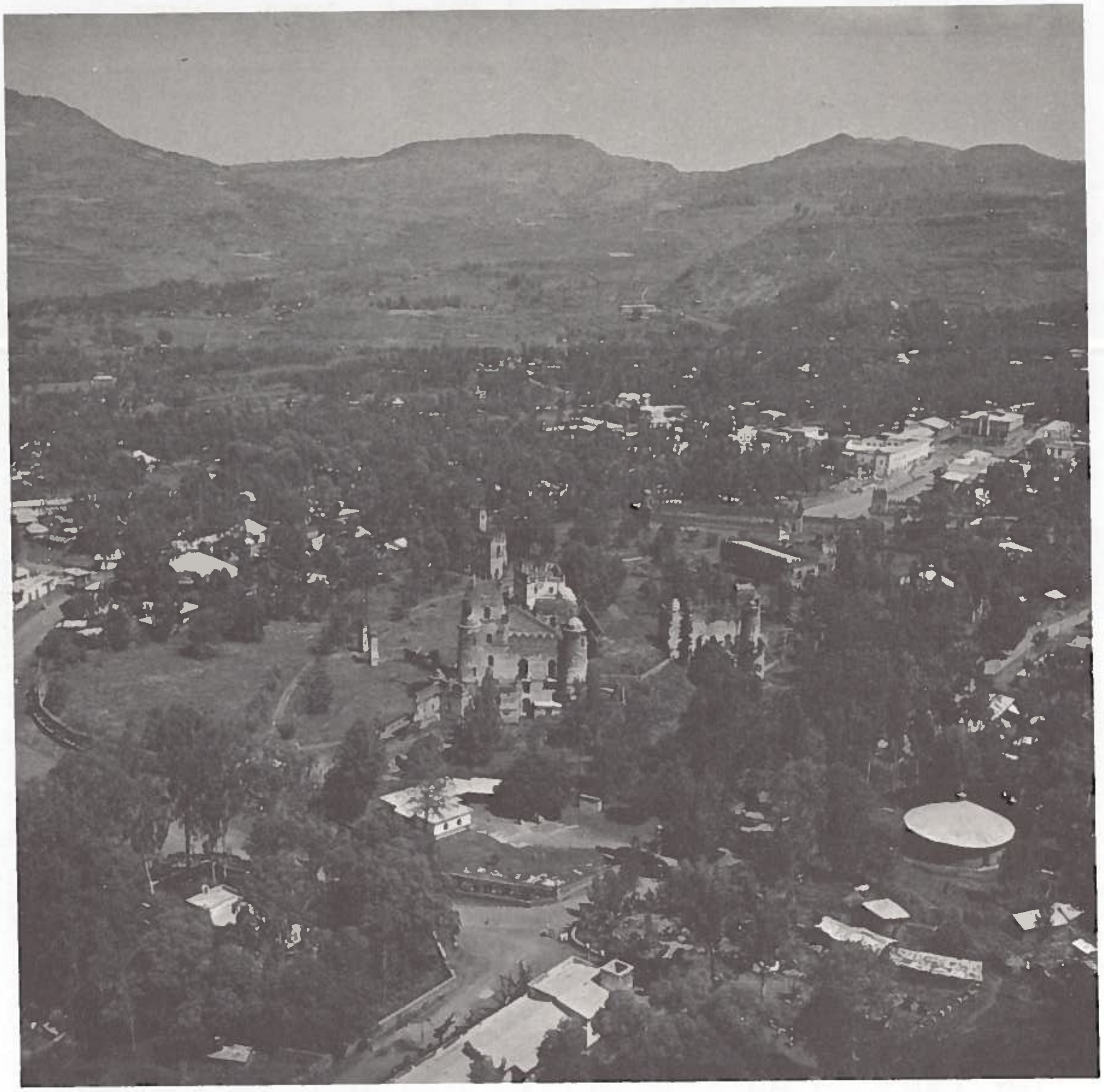


Figure V-36--A part of the city of Gondar with ancient castle compound in the foreground. City is now being served by an isolated diesel electric powerplant. The area may become a tourist attraction, but load growth will be modest for several years.

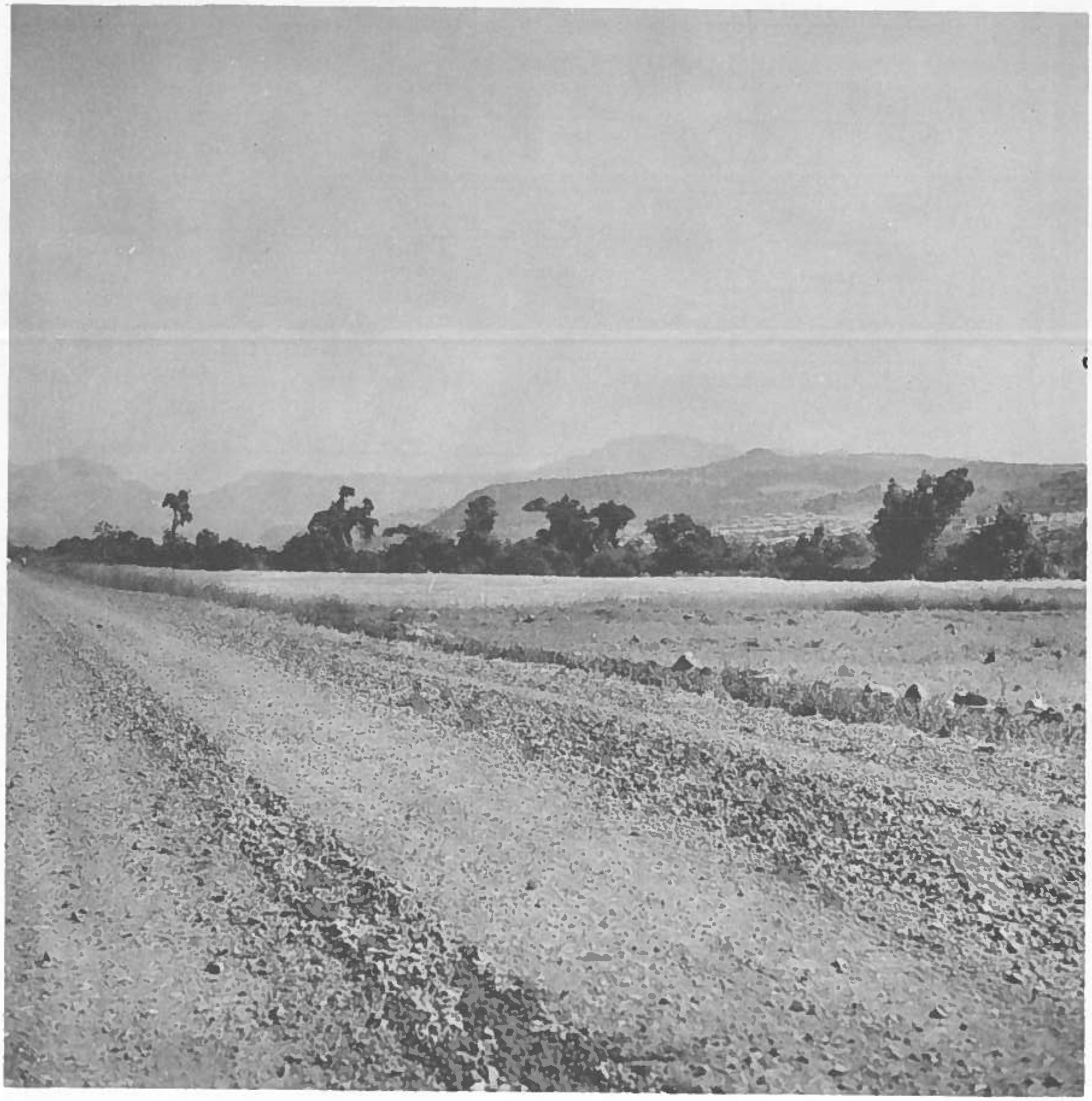


Figure V-37--New road connects Bahir Dar and Gondar along east side of Lake Tana. Large village in distance typical of small urban areas located along main roads and highways. Village and rural loads will develop first along these transportation arteries.

Raw material	Secondary (Processing) industry	Products
Hides and skins sheep cattle goat wild animal	Leather	Processed skins and hides for export; numerous leather products
Grain crops wheat barley maize	Flour biscuit and cake brewing	Flour; farinaceous products (biscuits, cakes, spaghetti, etc.); beer
Oil seeds	Soap and oil	Edible vegetable oils, cooking fats, soaps (byproduct--cattle cake)
Vegetables	Canning dried vegetables	Canned vegetables; dried vegetables
Coffee (Lake Tana)	Coffee cleaning coffee processing	Coffee beans for export coffee products
Meat cattle sheep	Canning	Canned meat products (cooked meats, sausages, salami, etc.)
Eggs	Egg processing	Dried eggs, albumin
Milk	Dairy	Canned and bottled milk, canned and bottled cream, cheeses, butter

Precipitation averages around 1,271 mm. per year with temperature variations as follows:

Average maximum	26° C
Average	19.2° C
Average minimum	12.4° C

The elevation is about 2100 meters above sea level.

Expected energy requirements are given in Table V-77 with the loads through 1960 being historical. Beyond 1960, estimates of maximum requirements are given, while in Table V-78 losses, load factors, and peak demands in kilowatts are estimated.

Figure V-63 shows the maximum electrical facilities that might be required by the end of this century to serve the town of Gondar and West Side Megech pumping and farm loads.

Debre Tabor. This town may have had a population of about 5,000 in 1961 and as nearly all Ethiopian towns, depends upon the local agricultural economy. Honey and butter are the major products.

The local precipitation averages over 1,715 mm. per year with these temperatures:

Average daily maximum	25.8° C
Average daily	16.5° C
Average daily minimum	7.1° C

The elevation is about 2950 meters above sea level.

During the Italian occupation, a road was constructed from Dessie to Gondar through Debre Tabor. In recent years, this road has been only partially open; but with the Tendaho cotton plantations, a shorter route to Bahir Dar will be needed for incoming raw material and to market the textiles produced at Bahir Dar. When this road is rebuilt, it no doubt will pass through Debre Tabor, opening up the possibility of greater commercial opportunities in the town. Development of the Ribb and Gumara Projects will also offer an economic stimulus to the Debre Tabor area. In 1965, the town is scheduled to receive a

TABLE V-77--SALES BY CLASSES--Kw.-hr. x 10^3--GONDAR, NORTH REGION

Year	National economy	Public consumption	Total
1957	16	49	65
1958	48	112	160
1959	88	150	238
1960	99	183	282
1961	178	246	424
1962	193	358	551
1963	207	482	689
1964	259	595	854
1965	317	720	1,037
1966	391	875	1,266
1967	472	1,041	1,513
1968	572	1,244	1,816
1969	688	1,474	2,162
1970	819	1,732	2,551
1971	967	2,017	2,984
1972	1,122	2,309	3,431
1973	1,279	2,598	3,877
1974	1,446	2,897	4,343
1975	1,634	3,230	4,864
1976	1,830	3,569	5,399
1977	2,050	3,943	5,993
1978	2,295	4,357	6,652
1979	2,547	4,771	7,318
1980	2,826	5,224	8,050
1981	3,106	5,669	8,775
1982	3,415	6,150	9,565
1983	3,753	6,673	10,426
1984	4,087	7,172	11,259
1985	4,450	7,709	12,159
1986	4,815	8,235	13,050
1987	5,194	8,769	13,963
1988	5,603	9,337	14,940
1989	6,042	9,944	15,986
1990	6,517	10,588	17,105
1991	7,028	11,275	18,303
1992	7,508	11,892	19,400
1993	8,020	12,544	20,564
1994	8,567	13,231	21,798
1995	9,150	13,957	23,107
1996	9,772	14,720	24,492
1997	10,385	15,578	25,963
1998	11,008	16,512	27,520
1999	11,668	17,503	29,171
2000	12,369	18,553	30,922

TABLE V-78--ENERGY AND DEMAND AT LOAD CENTER--GONDAR, NORTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw	Remarks
		At high-voltage side of receiving-end substation				
	Kilowatt-hours x 10^6					
1957	65	30	95	24	45	Isolated system
1958	160	86	246	30	94	
1959	238	107	345	37	106	
1960	282	75	357	29	140	
1961	424	75	499	35	163	
1962	551	97	648	40	185	
1963	689	121	810	42	220	
1964	854	150	1,004	44	260	
1965	1,037	198	1,235	45	313	
1966	1,266	241	1,507	45	382	
1967	1,513	310	1,823	45	462	
1968	1,816	372	2,188	45	555	
1969	2,162	442	2,604	46	646	
1970	2,551	522	3,073	46	763	
1971	2,984	611	3,595	46	892	Interconnection
1972	3,431	703	4,134	47	1,004	Interconnected system
1973	3,877	794	4,671	47	1,135	
1974	4,343	889	5,232	47	1,271	
1975	4,864	996	5,860	47	1,423	
1976	5,399	1,065	6,464	47	1,570	
1977	5,993	1,228	7,221	47	1,754	
1978	6,652	1,363	8,015	47	1,947	
1979	7,318	1,499	8,817	47	2,141	
1980	8,050	1,649	9,699	48	2,307	
1981	8,775	1,797	10,572	48	2,514	
1982	9,565	1,959	11,524	48	2,741	
1983	10,426	2,135	12,561	48	2,987	
1984	11,259	2,306	13,565	48	3,226	
1985	12,159	2,491	14,650	48	3,484	
1986	13,050	2,672	15,722	49	3,662	
1987	13,963	2,860	16,823	49	3,919	
1988	14,940	3,060	18,000	49	4,193	
1989	15,986	3,274	19,260	49	4,487	
1990	17,105	3,575	20,680	49	4,818	
1991	18,303	3,748	22,051	49	5,137	
1992	19,400	3,974	23,374	49	5,445	
1993	20,564	4,212	24,776	50	5,656	
1994	21,798	4,465	26,263	50	5,996	
1995	23,107	4,732	27,839	50	6,355	
1996	24,492	5,017	29,509	50	6,737	
1997	25,963	5,317	31,280	51	7,000	
1998	27,520	5,637	33,157	51	7,422	
1999	29,171	5,975	35,146	51	7,866	
2000	30,922	6,333	37,255	51	8,338	

small diesel-electric powerplant. Only modest increases in electric energy requirements are indicated by Table V-79. Anticipated losses, load factors, and peak demand in kilowatts are shown by Table V-80.

The Stella Substation, possibly located at Stella Taraghedam west of Lake Tana, provides step-down facilities from 132 kv. to 45 and 15 kv. to serve Debre Tabor and future irrigation pumping and project loads, Northeast Tana and East Side Megech Projects. By means of a 45-kv. line to Debre Tabor, the maximum electrical facilities required during this century are as outlined by Figure V-63.

Dangila. This village of 3,000 people in 1961 is on the main Addis Ababa-Bahir Dar highway reasonably close to the Gilgel Abbay Project as studied by the West German group in 1961. It will be the nearest town to the irrigated lands of the Upper Beles Project when it is constructed.

Dangila is located in a heavily populated rural zone, where most activity centers around the agricultural economy. Future prospects for small commercial establishments associated with the Upper Beles Project development and with the traffic on the north-south highway are good. Also, other small village and adjacent heavily settled rural areas offer future possibilities for rural-village electrification served from a centrally located substation at Bahir Dar.

The elevation is about 2300 meters above sea level, and these climatological features have been noted:

Average annual precipitation	1,410 mm.
Average daily maximum temperature	27.1° C
Average daily minimum temperature	9.6° C
Average daily temperature	17.3° C

Energy requirements by classes have been estimated as shown by Table V-81, while load factors, losses, and peak demand are all indicated by Table V-82.

Two 230-kv. transmission lines from the Alefa Powerplant (BL-1) to Addis Ababa may be required late in this century and might be tapped at Bure, Debre Markos, and Fiche to serve local loads as well as villages located along the main highway which this line will generally follow. The Bure tap substation will serve four areas--Jiga, Injibira, Metekkel, and Dangila--by means of 45-kv. transmission lines. See Figure V-40. Maximum electrical facilities required at Dangila by the year 2000 might be as shown by Figure V-63.

Debre Markos. A town of about 15,000 people, Debre Markos is the capital of Gojjam Province and is also located on the main north-south highway from Bahir Dar to Addis Ababa. Heavy concentrations of rural and village population are located in the surrounding areas.

A small diesel-electric powerplant serves the town at present, and another small hydroelectric installation can be developed on a tributary of the Chemoga River nearby when load conditions warrant.

Governmental administrative functions, agricultural marketing, and small commercial establishments associated with the highway and air traffic constitute the main activities at present. Exporting eggs to the Addis Ababa market has been one item of commercial interest.

Debre Markos is about 2400 meters above sea level with the following climate factors:

Annual precipitation	1,480 mm.
Average daily maximum temperature	21.7° C
Average daily minimum temperature	8.6° C
Average daily temperature	15.2° C

TABLE V-79--SALES BY CLASSES--Kw.-hr. x 10^3--DEBRE TABOR, NORTH REGION

Year	National economy	Public consumption	Total
1965	4	12	16
1966	14	43	57
1967	20	59	79
1968	26	77	103
1969	33	96	129
1970	41	118	159
1971	51	145	196
1972	64	175	239
1973	78	211	289
1974	95	252	347
1975	115	298	413
1976	137	349	486
1977	163	406	569
1978	190	465	655
1979	218	522	740
1980	245	577	822
1981	271	625	896
1982	296	671	967
1983	323	721	1,044
1984	351	766	1,117
1985	380	815	1,195
1986	411	867	1,278
1987	446	922	1,368
1988	483	981	1,464
1989	523	1,043	1,566
1990	566	1,109	1,675
1991	613	1,179	1,792
1992	663	1,249	1,912
1993	718	1,333	2,051
1994	776	1,415	2,191
1995	840	1,509	2,349
1996	909	1,603	2,512
1997	984	1,704	2,688
1998	1,064	1,813	2,877
1999	1,181	1,897	3,078
2000	1,245	2,049	3,294

TABLE V-80--ENERGY AND DEMAND AT LOAD CENTER--DEBRE TABOR, NORTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw	Remarks
	Kilowatt-hours x 10^6					
		At high-voltage side of receiving-end substation				
1965	16	4	20	42	5	Isolated system
1966	57	11	68	42	18	
1967	79	16	95	42	26	
1968	103	21	124	42	34	
1969	129	26	155	42	42	
1970	159	33	192	42	52	
1971	196	40	236	43	63	
1972	239	49	288	43	76	
1973	289	59	348	43	92	
1974	347	71	418	43	110	
1975	413	84	497	44	129	
1976	486	100	586	44	152	
1977	569	117	686	44	178	
1978	655	134	789	45	200	
1979	740	152	892	45	226	
1980	822	168	990	45	251	Interconnection
1981	896	183	1,079	45	274	Interconnected system
1982	967	198	1,165	45	295	
1983	1,044	214	1,258	45	319	
1984	1,117	229	1,346	46	334	
1985	1,195	245	1,440	46	357	
1986	1,278	262	1,540	46	382	
1987	1,368	280	1,648	46	409	
1988	1,464	299	1,763	47	428	
1989	1,566	320	1,886	47	458	
1990	1,675	343	2,018	47	490	
1991	1,792	367	2,159	47	524	
1992	1,912	396	2,308	48	549	
1993	2,051	420	2,471	48	588	
1994	2,191	453	2,644	48	629	
1995	2,349	480	2,829	48	673	
1996	2,512	515	3,027	48	720	
1997	2,688	551	3,239	49	755	
1998	2,877	589	3,466	49	808	
1999	3,078	631	3,709	49	864	
2000	3,294	675	3,969	49	925	

TABLE V-81--SALES BY CLASSES--Kw.-hr. x 10^3--DANGILA, NORTH REGION

Year	National economy	Public consumption	Total
1980	3	9	12
1981	5	13	18
1982	4	8	12
1983	38	112	150
1984	58	171	229
1985	80	230	310
1986	103	291	394
1987	128	352	480
1988	154	415	569
1989	181	480	661
1990	210	545	755
1991	241	613	854
1992	273	683	956
1993	308	752	1,060
1994	325	781	1,106
1995	382	899	1,281
1996	422	975	1,397
1997	464	1,052	1,516
1998	508	1,131	1,639
1999	554	1,212	1,766
2000	603	1,293	1,896

TABLE V-82--ENERGY AND DEMAND AT LOAD CENTER--DANGILA, NORTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation				Remarks
		Load center losses	Load center total	Percent annual load factor	Peak demand kw	
	Kilowatt-hours x 10^6					
1980	12	3	15	30	6	Isolated system
1981	18	4	22	35	7	
1982	12	3	15	40	4	
1983	150	30	180	40	51	
1984	229	46	275	42	75	Interconnection
1985	310	63	373	42	101	Interconnected system
1986	394	80	474	43	126	
1987	480	98	578	43	153	
1988	569	117	686	44	178	
1989	661	135	796	44	207	
1990	755	154	909	44	236	
1991	854	180	1,034	45	262	
1992	956	196	1,152	45	292	
1993	1,060	217	1,277	45	324	
1994	1,106	227	1,333	45	338	
1995	1,281	1,262	1,543	45	391	
1996	1,397	286	1,683	46	418	
1997	1,516	310	1,826	46	453	
1998	1,639	336	1,975	46	490	
1999	1,766	362	2,128	46	528	
2000	1,896	388	2,284	97	555	

Table V-83 provides an estimate of possible urban loads by classes and Table V-84 provides estimated load factors, losses, and peak kilowatt demand at load. For possible rural loads served from this center, see Tables V-54 and V-55.

By the end of the century, total urban and rural loads will approach 7,000 kw., but a considerably larger autotransformer was considered justified to account for increased demands soon after that date. Figure V-63 reflects the maximum electrical facilities anticipated.

Birr Projects Farm Loads. The Birr projects (Upper Birr, Lower Birr, and Debohila) when fully developed will have these statistics as noted from Table V-106.

Hectares irrigable	35,150
Number farm units	2,067
New farm population	157,000
New farm peak demand	4,651 kw.

If the projects were to be initiated late in the present century, then only modest amounts of electricity would be required as noted from Table V-85, with the losses and load factors as shown.

These requirements would be met by service from the Jiga Substation, Figure V-63.

Upper Beles Project Irrigation Pumping and Farm Loads. It has been assumed for purposes of this study that the initial energy requirements for rural and project purposes would not start before 1998.

Insofar as total future farm load requirements at full development are concerned, Table V-106 provides this information:

Hectares irrigable	63,200
Number farm units	3,717
New farm population	282,000
Peak demand	8,363 kw.

However, by the year 2000, only the amounts of energy given by Table V-86 will probably materialize insofar as new farm loads are concerned.

Irrigation pumping requirements will not start prior to 1998, although total requirements at full development will require two electrically driven pumping plants as follows:

Pumping Plant	Total synchronous motor horsepower	Maximum demand
No. 1	6,500	12,500 kw.
No. 2	9,225	

Table V-87 indicates that full pumping requirements are assumed in the year 2000.

This area will be served directly by a 132-kv. line from Alefa Powerplant (BL-1) as shown by Switching Diagram, Figure V-119 (Annex "C"), and Figure V-40.

West Megech Project, Irrigation Pumping and Farm Loads. Development of this area may not occur until the last decade of the present century. Pertinent data concerning this projects farm loads would be as follows at full development:

Irrigable hectares	7,080
Number farm units	416
New farm population	32,000
Peak demand	936 kw.

In addition, two pumping plants will be needed as follows:

TABLE V-83--SALES BY CLASSES--Kw.-hr. x 10^3--DEBRE MARKOS, NORTH REGION (URBAN LOADS ONLY)

Year	National economy	Public consumption	Total
1957	(In addition, see Table V-54 and V-55 for possible rural loads.)		
1958			
1959			
1960	4	12	16
1961	14	43	57
1962	30	85	115
1963	45	127	172
1964	57	158	215
1965	72	193	265
1966	87	231	318
1967	105	273	378
1968	127	324	451
1969	152	379	531
1970	182	445	627
1971	216	517	733
1972	255	602	857
1973	303	700	1,003
1974	359	815	1,174
1975	426	947	1,373
1976	491	1,074	1,565
1977	567	1,217	1,784
1978	649	1,366	2,015
1979	736	1,521	2,257
1980	834	1,693	2,527
1981	937	1,868	2,805
1982	1,053	2,061	3,114
1983	1,171	2,254	3,425
1984	1,304	2,464	3,768
1985	1,451	2,694	4,145
1986	1,614	2,945	4,559
1987	1,779	3,191	4,970
1988	1,961	3,456	5,417
1989	2,161	3,743	5,904
1990	2,381	4,054	6,435
1991	2,623	4,390	7,013
1992	2,890	4,755	7,645
1993	3,183	5,150	8,333
1994	3,506	5,578	9,084
1995	3,711	6,100	9,811
1996	4,175	6,421	10,596
1997	4,554	6,889	11,443
1998	4,944	7,415	12,359
1999	5,290	7,934	13,224
2000	5,660	8,489	14,149

TABLE V-84--ENERGY AND DEMAND AT LOAD CENTER--DEBRE MARKOS, NORTH REGION (URBAN LOADS ONLY)

Year	Customer loads	At high-voltage side of receiving-end substation				Remarks
		Load center losses	Load center total	Percent annual load factor	Peak demand kw	
	Kilowatt-hours x 10^6					
1957						
1958						
1959						
1960	16	4	20	42	5	Isolated system
1961	57	12	69	42	19	
1962	115	23	138	42	38	
1963	172	35	207	43	55	
1964	215	44	259	43	69	
1965	265	54	319	43	85	
1966	318	65	383	43	101	
1967	378	78	456	44	118	
1968	451	92	543	44	141	
1969	531	109	640	44	166	
1970	627	128	755	45	192	
1971	733	150	883	45	224	
1972	857	176	1,033	45	262	
1973	1,003	206	1,209	45	307	
1974	1,174	240	1,414	45	359	
1975	1,373	281	1,654	46	410	
1976	1,565	320	1,885	46	467	
1977	1,784	365	2,149	46	533	
1978	2,015	413	2,428	46	603	
1979	2,257	462	2,719	47	660	
1980	2,527	518	3,045	47	740	
1981	2,805	575	3,380	47	821	
1982	3,114	638	3,752	47	911	
1983	3,425	702	4,127	47	1,000	
1984	3,768	772	4,540	48	1,080	
1985	4,145	849	4,994	48	1,188	Interconnection
1986	4,559	934	5,493	48	1,306	Interconnected system
1987	4,970	1,017	5,987	48	1,424	
1988	5,417	1,109	6,526	48	1,552	
1989	5,904	1,209	7,113	48	1,692	
1990	6,435	1,318	7,753	49	1,806	
1991	7,013	1,437	8,450	49	1,969	
1992	7,645	1,566	9,211	49	2,146	
1993	8,333	1,707	10,040	49	2,339	
1994	9,084	1,860	10,944	49	2,550	
1995	9,811	2,009	11,820	50	2,699	
1996	10,596	2,170	12,766	50	2,915	
1997	11,443	2,344	13,787	50	3,148	
1998	12,359	2,531	14,890	50	3,406	
1999	13,224	2,708	15,932	50	3,637	
2000	14,149	2,898	17,047	50	3,892	

TABLE V-85--ENERGY AND DEMAND, NEW IRRIGATION FARM LOADS--BIRR PROJECTS, NORTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw
	At high-voltage side of receiving-end substation				
	Kilowatt-hours x 10^6				
1985	236	26	262	30	100
1986	505	56	561	32	200
1987	805	89	894	34	300
1988	1,135	126	1,261	36	400
1989	1,498	166	1,664	38	500
1990	1,892	210	2,102	40	600
1991	2,207	245	2,452	40	700
1992	2,523	280	2,803	40	800
1993	2,839	315	3,154	40	900
1994	3,150	350	3,500	40	1,000
1995	3,465	385	3,850	40	1,100
1996	3,878	431	4,309	41	1,200
1997	4,203	467	4,670	41	1,300
1998	4,635	515	5,150	42	1,400
1999	4,967	552	5,519	42	1,500
2000	5,427	600	6,027	43	1,600

TABLE V-86--ENERGY AND DEMAND, NEW IRRIGATION FARM LOADS--UPPER BELES PROJECT, NORTH REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw
	At high-voltage side of receiving-end substation				
	Kilowatt-hours x 10^6				
1998	505	56	561	32	200
1999	1,135	126	1,261	36	400
2000	1,892	210	2,102	40	600

TABLE V-87--ENERGY AND DEMAND AT IRRIGATION PUMPING LOAD CENTER--UPPER BELES IRRIGATION, NORTH REGION

Year	Kwh x 10^3 at high-voltage side of receiving-end substation			Peak demand kw at substation	Remarks
	Pump loads	Losses	Total		
1997					
1998	14,100	705	14,805	2,535	North No. 1
1999	14,100	705	14,805	2,535	North No. 1
2000	34,750	1,738	36,488	12,500	North No. 1 and No. 2

Pumping Plant	Total synchronous motor horsepower	Maximum demand
Main	3,175	4,200 kw.
Relift	2,450	

Table V-88 indicates estimated new farm load requirements while Table V-89 indicates pump load requirements on the assumption that the main pumping plant and relift plant would not reach full capacity until immediately following the year 2000.

The West Megech Project would be served from the substation at Gondar (Figure V-63) with a 45-kv. line to the relift pumping plant and a 15-kv. line from that pumping plant to the main pumping plant area. See Figure V-40.

Metekkel. Metekkel was estimated to have a population of about 4,000 people in the year 1961, and serves as a market center for a large area of Gojjam Province. It is located on the main unimproved road from Dangila to Guba which generally follows the Beles River westward. The only major export considered profitable by air has been honey for the Addis Ababa market. Only small commercial establishments will develop. Modest increases in the needs for electricity are as shown by Tables V-90 and V-91.

The altitude is about 1450 meters above sea level with less precipitation than Dangila but with higher average temperatures.

The normal pattern of developing a load base is anticipated with the installation of a small diesel-electric station or the development of the small hydroelectric potential existing at Site DU-1 adjacent to the town.

If the loads in this area justify further investment, a connection to the North Region interconnected system may occur by 1985 by means of a 45-kv. line from Injibira as shown by Figure V-40. Maximum substation requirements by the year 2000 may be as indicated by Figure V-63.

Central Region

Dabana Project Farm Loads. These loads are associated with the Dabana multipurpose project and represent saleable power and energy to the future new population growth in the project area. When initially developed to ultimate capacity, the characteristics will be as indicated by Table V-106:

Irrigable hectares	6,100
Number farm units	359
New farm population	27,000
Peak demand	808 kw.

Since this is one of the early projects considered in this century, load growth beyond the 808-kw. peak demand reached at full project development will occur at a rate of about 6 percent per annum with the results by the end of the century as indicated by Table V-92.

These loads can be served directly from the two Dabana Project powerplants at 13.8 kw. See Figure V-66.

Gimbi. This town, having about 5,000 people in 1961, is in another heavily populated zone and is the main commercial center between Begi and Lekkemt in western Ethiopia. Improvements in the highway west of Lekkemt should be completed soon which will greatly improve the prospects for the growth of small commercial establishments.

At present, there is a small internal-combustion engine driving an alternator which serves some select loads in the town. The electric rates are considerably greater than that of EELPA, consequently, the demand for electricity is limited. Table V-93 reflects

TABLE V-88--ENERGY AND DEMAND, NEW IRRIGATION FARM LOADS--WEST MEGECH PROJECT, NORTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation: Load center losses	Load center total	Percent annual load factor	Peak demand kw
	Kilowatt-hours x 10^6				
1992	236	26	262	30	100
1993	505	56	561	32	200
1994	805	89	894	34	300
1995	1,135	126	1,261	36	400
1996	1,498	166	1,664	38	500
1997	1,892	210	2,102	40	600
1998	2,207	245	2,452	40	700
1999	2,523	280	2,803	40	800
2000	2,952	328	3,280	40	936

TABLE V-89--ENERGY AND DEMAND AT IRRIGATION PUMPING LOAD CENTER--WEST MEGECH PROJECT, NORTH REGION

Year	Kwh x 10^3 at high-voltage side of receiving-end substation: Pump loads	Losses	Total	Peak demand kw at substation	Pumping plants in operation
1992	4,700	235	4,935	1,690	No. 1
1993	4,700	235	4,935	1,690	No. 1
1994	4,700	235	4,935	1,690	No. 1
1995	4,700	235	4,935	1,690	No. 1
1996	4,700	235	4,935	1,690	No. 1
1997	4,700	235	4,935	1,690	No. 1
1998	4,700	235	4,935	1,690	No. 1
1999	4,700	235	4,935	1,690	No. 1
2000	4,700	235	4,935	1,690	No. 1

TABLE V-90--ENERGY AND DEMAND AT LOAD CENTER--METEKKEL, NORTH REGION

Year	Customer loads	At high-voltage side of receiving-end substation				Remarks
		Load center losses	Load center total	Percent annual load factor	Peak demand kw	
	Kilowatt-hours x 10^6					
1975						Isolated system
1976						
1977	12	3	15	30	6	
1978	18	4	22	35	7	
1979	12	3	15	40	4	
1980	150	30	180	40	51	
1981	229	46	275	42	75	
1982	310	63	373	42	101	
1983	394	80	474	43	126	
1984	480	93	578	43	153	
1985	569	117	686	44	178	Interconnection
1986	661	135	796	44	207	Interconnected system
1987	755	154	909	44	236	
1988	854	180	1,034	45	262	
1989	956	196	1,152	45	292	
1990	1,060	217	1,277	45	324	
1991	1,106	227	1,333	45	338	
1992	1,281	262	1,543	45	391	
1993	1,397	286	1,683	46	418	
1994	1,516	310	1,826	46	453	
1995	1,639	336	1,975	46	490	
1996	1,766	362	2,128	46	528	
1997	1,896	388	2,284	47	555	
1998	2,036	417	2,453	47	596	
1999	2,180	447	2,627	47	638	
2000	2,330	577	2,907	47	706	

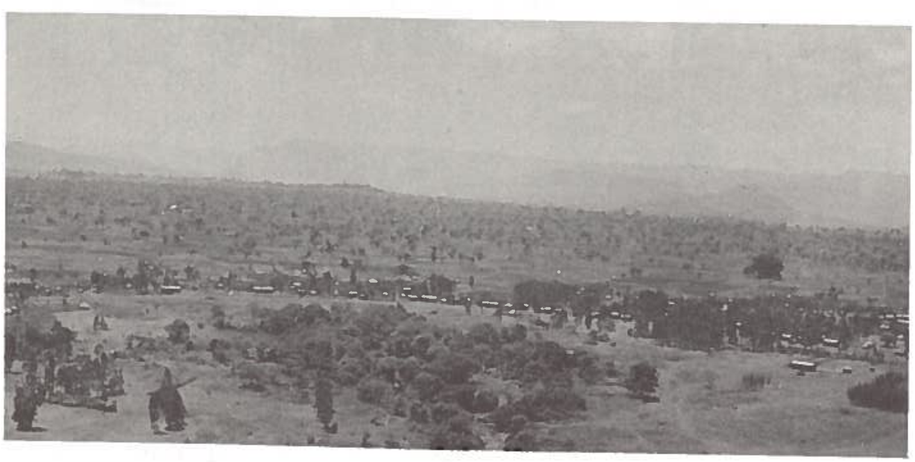


Figure V-38--Village of Jiga along main north-south highway from Addis Ababa to Bahir Dar. First rural load areas may develop along this highway during the latter part of this century.

TABLE V-91--SALES BY CLASSES--Kw.-hr. x 10^3--METEKKEL, NORTH REGION

Year	National economy	Public consumption	Total
1975			
1976			
1977	3	9	12
1978	5	13	18
1979	4	8	12
1980	38	112	150
1981	58	171	229
1982	80	230	310
1983	103	291	394
1984	128	352	480
1985	154	415	569
1986	181	480	661
1987	210	545	755
1988	241	613	854
1989	273	683	956
1990	308	752	1,060
1991	325	781	1,106
1992	382	899	1,281
1993	422	975	1,397
1994	464	1,052	1,516
1995	508	1,131	1,639
1996	554	1,212	1,766
1997	603	1,293	1,896
1998	656	1,380	2,036
1999	711	1,469	2,180
2000	769	1,561	2,330

TABLE V-92--ENERGY AND DEMAND, NEW IRRIGATION FARM LANDS--DABANA PROJECT, CENTRAL REGION

Year	Customer loads	At high-voltage side of receiving-end substation			
		Load center losses	Load center total	Percent annual load factor	Peak demand kw
	Kilowatt-hours x 10^6				
1980					
1981					
1982	505	56	561	32	200
1983	805	89	894	34	300
1984	1,135	126	1,261	36	400
1985	1,498	166	1,664	38	500
1986	1,892	210	2,102	40	600
1987	2,207	245	2,452	40	700
1988	2,523	307	2,830	40	808
1989	2,674	307	2,981	40	848
1990	2,834	315	3,149	40	899
1991	3,004	334	3,338	40	953
1992	3,184	354	3,538	40	1,010
1993	3,375	375	3,750	40	1,070
1994	3,577	398	3,975	41	1,107
1995	3,792	421	4,213	41	1,173
1996	4,019	447	4,466	42	1,214
1997	4,260	473	4,733	42	1,287
1998	4,515	502	5,017	42	1,364
1999	4,786	532	5,318	43	1,412
2000	5,074	563	5,637	43	1,497

TABLE V-93--SALES BY CLASSES--Kw.-hr. x 10^3--GIMBI, CENTRAL REGION

Year	National economy	Public consumption	Total
1957			
1958			
1959			
1960	4	12	16
1961	14	43	57
1962	20	59	79
1963	26	77	103
1964	33	96	129
1965	41	118	159
1966	51	145	196
1967	64	175	239
1968	78	211	289
1969	95	252	347
1970	115	298	413
1971	137	349	486
1972	163	406	569
1973	190	465	655
1974	218	522	740
1975	245	577	822
1976	271	625	896
1977	296	671	967
1978	323	721	1,044
1979	351	766	1,117
1980	380	815	1,195
1981	411	867	1,278
1982	446	922	1,368
1983	483	981	1,464
1984	523	1,043	1,566
1985	566	1,109	1,675
1986	613	1,179	1,792
1987	663	1,249	1,912
1988	718	1,333	2,051
1989	776	1,415	2,191
1990	840	1,509	2,349
1991	909	1,603	2,512
1992	984	1,704	2,688
1993	1,064	1,813	2,877
1994	1,151	1,897	3,078
1995	1,245	2,049	3,294
1996	1,347	2,178	3,525
1997	1,456	2,316	3,772
1998	1,581	2,474	4,055
1999	1,701	2,617	4,318
2000	1,822	2,755	4,577

the present loads and separation by classes with forecasts beyond 1961 indicated. Table V-94 estimates the total requirements as well as losses, load factor, and peak kilowatt demand.

The elevation is about 2000 meters, depending upon where the elevations are taken. The climatological data are as follows:

Annual precipitation	2,150 mm.
Average daily maximum temperature	28.5° C
Average daily temperature	21.2° C
Average daily minimum temperature	12.9° C

A missionary school and hospital are located in Gimbi.

Load growth is dependent upon the establishment of much lower tariff rates in the cost of electricity per kilowatt-hour.

Assuming that the multipurpose Dabana Project might be constructed early in the 1980-1990 decade with power facilities justified primarily by loads to the east, then it might be feasible to extend a 45-kv. line from Powerplant DB-1 (Figure V-40) to Nejo via Gimbi with maximum electrical facilities as indicated by Figure V-66.

Nejo. Nejo had an estimated population between 2,000 and 3,000 in 1961 and is on the Gimbi-Asosa road, a poorly developed dry-weather track. It is in the same population belt as Gimbi, where the rural population averaged about 40 per square kilometer in 1958. When the all-weather road is completed, some modest increases in energy requirements will occur as indicated by Table V-95. Produce from the surrounding area will funnel through Nejo to points east after the road improvements are made.

Nejo is at an elevation of about 2000 meters and has these climatological characteristics:

Average annual precipitation	1,870 mm.
Average daily maximum temperature	25.8° C
Average daily temperature	19.9° C
Average daily minimum temperature	14.1° C

Table V-96 assumes that by 1975, a small diesel-electric plant can start establishing a base demand for electricity. Estimates given for load factors and maximum demand take this into consideration.

The preceding comments concerning Gimbi apply with regard to permanent power supply facilities. Nejo could be served by a 45-kv. line from Gimbi with maximum electrical facilities required by the year 2000 as indicated by Figure V-128 (Annex "C").

Gore. Gore may have had a population of about 25,000 in 1961 and is the capital of Ilubabor Province. Governmental administrative functions as well as small commercial enterprises dominate the local economy. It is a center of primary education in the Province. Several commodities from the heavily populated rural area find their way through Gore for processing before being transported to marketing centers further east. Livestock are very plentiful and shipment of hides through Gore toward Addis Ababa is a natural trade route. Also, Gore is located in a coffee growing area and one of the coffee trade routes is through Gore toward Addis Ababa.

Large areas of tropical upper montane forests exist very near Gore. These tropical rain forests, especially the ones between Bonga and Gore, are characterised by 40-meter-high trees with dense evergreen undergrowth. Wild coffee shrubs also grow here as do a species which yields a rubber latex. Tea plantations are possibilities.

The local airlines serve Gore; and in 1960, the air traffic amounted to 250 tons of air freight and nearly 3,000 passengers.

TABLE V-94--ENERGY AND DEMAND AT LOAD CENTER--GIMBI, CENTRAL REGION

Year	Customer loads	At high-voltage side of receiving-end substation				Remarks
		Load center losses	Load center total	Percent annual load factor	Peak demand kw	
	Kilowatt-hours x 10^6					
1957						Isolated system
1958						
1959						
1960	16	4	20	42	5	
1961	57	11	68	42	18	
1962	79	16	95	42	26	
1963	103	21	124	42	34	
1964	129	26	155	42	42	
1965	159	33	192	42	52	
1966	196	40	236	43	63	
1967	239	49	288	43	76	
1968	289	59	348	43	92	
1969	347	71	418	43	110	
1970	413	84	497	44	129	
1971	486	100	586	44	152	
1972	569	117	686	44	178	
1973	655	134	789	45	200	
1974	740	152	892	45	226	
1975	822	168	990	45	251	
1976	896	183	1,079	45	274	
1977	967	198	1,165	45	295	
1978	1,044	214	1,258	45	319	
1979	1,117	229	1,346	46	334	
1980	1,195	245	1,440	46	357	
1981	1,278	262	1,540	46	382	
1982	1,368	280	1,648	46	409	Interconnection
1983	1,464	299	1,763	47	428	Interconnected system
1984	1,566	320	1,886	47	458	
1985	1,675	343	2,018	47	490	
1986	1,792	367	2,159	47	524	
1987	1,912	396	2,308	48	549	
1988	2,051	420	2,471	48	588	
1989	2,191	453	2,644	48	629	
1990	2,349	480	2,829	48	673	
1991	2,512	515	3,027	48	720	
1992	2,688	551	3,239	49	755	
1993	2,877	589	3,466	49	808	
1994	3,078	631	3,709	49	864	
1995	3,294	675	3,969	49	925	
1996	3,525	722	4,247	49	989	
1997	3,772	772	4,544	49	1,059	
1998	4,055	807	4,862	50	1,110	
1999	4,318	884	5,202	50	1,188	
2000	4,577	937	5,514	50	1,259	

TABLE V-95--SALES BY CLASSES--Kw.-hr. x 10^3--NEJO, CENTRAL REGION

Year	National economy	Public consumption	Total
1975	4	12	16
1976	14	43	57
1977	20	59	79
1978	26	77	103
1979	33	96	129
1980	41	118	159
1981	51	145	196
1982	64	175	239
1983	78	211	289
1984	95	252	347
1985	115	298	413
1986	137	349	486
1987	163	406	569
1988	190	465	655
1989	218	522	740
1990	245	577	822
1991	271	625	896
1992	296	671	967
1993	323	721	1,044
1994	351	766	1,117
1995	380	815	1,195
1996	411	867	1,278
1997	446	922	1,368
1998	483	981	1,464
1999	523	1,043	1,566
2000	566	1,109	1,675

TABLE V-96--ENERGY AND DEMAND AT LOAD CENTER--NEJO, CENTRAL REGION

Year	Customer loads	At high-voltage side of receiving-end substation				Remarks
		Load center losses	Load center total	Percent annual load factor	Peak demand kw	
	Kilowatt-hours x 10^6					
1975	16	4	20	42	5	Isolated system
1976	57	11	68	42	18	
1977	79	16	95	42	26	
1978	103	21	124	42	34	
1979	129	26	155	42	42	
1980	159	33	192	42	52	
1981	196	40	236	43	63	
						Interconnection
1982	239	49	288	43	76	Interconnected system
1983	289	59	348	43	92	
1984	347	71	418	43	110	
1985	413	84	497	44	129	
1986	486	100	586	44	152	
1987	569	117	686	44	178	
1988	655	134	789	45	200	
1989	740	152	892	45	226	
1990	822	168	990	45	251	
1991	896	183	1,079	45	274	
1992	967	198	1,165	45	295	
1993	1,044	214	1,258	45	319	
1994	1,117	229	1,346	46	334	
1995	1,195	245	1,440	46	357	
1996	1,278	262	1,540	46	382	
1997	1,368	280	1,648	46	409	
1998	1,464	299	1,763	47	428	
1999	1,566	320	1,886	47	458	
2000	1,675	343	2,018	47	490	

Besides hides and skins, beeswax and civet are exported.

Assuming that the highway program will provide better roads in the Gore area toward the latter part of the decade 1960-1970, energy requirements are estimated in Table V-97 with maximum kilowatt demand, load factor, and other data given in Table V-98.

The elevation at Gore is about 2000 meters, but the town is located on top of a plateau considerably higher than the surrounding countryside.

In 1960, the precipitation was about 2,800 mm. Other data based upon a 5- to 7-year average are as follows:

Average daily minimum temperature	13° C
Average daily temperature	18° C
Average daily maximum temperature	23° C

Electricity from the Dabana and Lower Diddessa Powerplants via transmission facilities to Lekkemt and then to Gore at 132 kv. is one possible means of meeting future loads as indicated by Figure V-40. Maximum electrical facilities required at Gore by the end of the century are as shown by Figure V-66.

West Region

Asosa. Except for a road that is passable only during the dry season and regular weekly stops by the local airlines, Asosa and this western part of Ethiopia are somewhat isolated from the rest of the Empire. Asosa is a trading center with an estimated 1961 population of slightly less than 3,000 people. The IEG maintains a customs post here and is engaged in other small governmental activities. The fact that Asosa is the most remote town in this part of Ethiopia will cause it to become more important in the future when the road improvement program materializes and permits stepped-up trade with Sudan through this port of entry. Placer-type gold mining activities occur east of Asosa; otherwise, the economy depends upon the present subsistence agricultural activities.

Asosa will benefit some from the Dabus River Irrigation Project when it develops. Bamboo thickets are abundant near the town.

The elevation in the town is about 1565 meters above sea level, and an average annual precipitation of about 1,300 mm. has been recorded. Recorded temperatures are as follows:

Average daily maximum	27.3° C
Average daily	21.1° C
Average daily minimum	14.1° C

Energy requirements assume that road improvements will occur by 1970 and that the town's economy will grow substantially toward the end of the present century. Tables V-99 and V-100 reflect the maximum power and energy needs.

Asosa, Begi, and Mendi can all be served by a 45-kv. transmission system energized by a small powerplant on the Dabus River (DA-8). This West Region's economy may be the slowest to develop, and whether a small interconnected system may be justified is open to question. Under the most optimistic conditions, the small system could develop, but there is no likelihood that it can be connected to the National Grid in the Dabana area during this century. See Figure V-40.

If conditions are very favorable, then the maximum electrical facilities required by the year 2000 at Asosa may be as indicated by Figure V-62.

Mendi. Mendi had a population of less than 3,000 people by 1961 estimates. It is located toward the western end of the unimproved Gimbi-Asosa road, now passable in the dry season only. In many respects it is similar to Nejo, except that the rural population density may be a little less around Mendi.

TABLE V-97--SALES BY CLASSES--Kw.-hr. x 10^3--GORE, CENTRAL REGION

Year	National economy	Public consumption	Total
1970	70	210	280
1971	114	340	454
1972	198	583	781
1973	326	938	1,264
1974	497	1,400	1,897
1975	706	1,949	2,655
1976	968	2,618	3,586
1977	1,277	3,384	4,661
1978	1,684	4,373	6,059
1979	2,136	5,438	7,574
1980	2,599	6,489	9,088
1981	3,163	7,744	10,907
1982	3,816	9,163	12,979
1983	4,434	10,445	14,879
1984	5,257	12,151	17,408
1985	6,063	13,752	19,815
1986	7,261	16,162	23,423
1987	8,458	18,478	26,936
1988	9,765	20,819	30,707
1989	11,173	23,525	34,698
1990	12,669	26,192	38,861
1991	14,235	28,900	43,135
1992	15,848	31,601	47,449
1993	17,481	34,238	51,719
1994	19,103	36,754	55,857
1995	20,872	39,453	60,325
1996	22,803	42,348	65,151
1997	24,909	45,454	70,363
1998	27,205	48,788	75,993
1999	29,712	52,366	82,078
2000	32,443	56,200	88,643

TABLE V-98--ENERGY AND DEMAND AT LOAD CENTER--GORE, CENTRAL REGION

Year	Customer loads	Load center losses	Load center total	Percent annual load factor	Peak demand kw	Remarks
		At high-voltage side of receiving-end substation				
	Kilowatt-hours x 10^6					
1970	280	70	350	25	160	Isolated system
1971	454	106	560	30	213	
1972	781	171	952	35	311	
1973	1,264	259	1,522	36	483	
1974	1,897	388	2,285	37	705	
1975	2,655	544	3,199	38	961	
1976	3,586	734	4,320	39	1,264	
1977	4,661	955	5,616	40	1,603	
1978	6,059	1,241	7,300	40	2,083	
1979	7,574	1,551	9,125	41	2,541	
1980	9,088	1,862	10,950	41	3,049	
1981	10,907	2,233	13,140	42	3,571	Interconnection
1982	12,979	2,267	15,246	43	4,047	Interconnected system
1983	14,879	2,599	17,378	43	4,613	
1984	17,408	3,041	20,449	43	5,429	
1985	19,815	3,528	23,343	43	6,197	
1986	23,423	4,091	27,514	43	7,304	
1987	26,936	4,705	31,641	43	8,400	
1988	30,707	5,364	36,071	44	9,358	
1989	34,698	6,062	40,760	44	10,575	
1990	38,861	6,788	45,649	44	11,843	
1991	43,135	7,535	50,670	45	12,854	
1992	47,449	8,288	55,737	45	14,139	
1993	51,719	9,035	60,754	45	15,412	
1994	55,857	9,757	65,614	46	16,283	
1995	60,325	10,538	70,863	46	17,586	
1996	65,151	11,381	76,532	46	18,992	
1997	70,363	12,292	82,655	47	20,075	
1998	75,993	13,275	89,268	47	21,682	
1999	82,078	14,337	96,415	47	23,418	
2000	88,643	15,485	104,128	48	24,764	

TABLE V-99--SALES BY CLASSES--Kw.-hr. x 10^3--ASOSA, WEST REGION

Year	National economy	Public consumption	Total
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965	3	9	12
1966	5	13	18
1967	4	8	12
1968	38	112	150
1969	58	171	229
1970	80	230	310
1971	103	291	394
1972	128	352	480
1973	154	415	569
1974	181	480	661
1975	210	545	755
1976	241	613	854
1977	273	683	956
1978	308	752	1,060
1979	325	781	1,106
1980	382	899	1,281
1981	422	975	1,397
1982	464	1,052	1,516
1983	508	1,131	1,639
1984	554	1,212	1,766
1985	603	1,293	1,896
1986	656	1,380	2,036
1987	711	1,469	2,180
1988	769	1,561	2,330
1989	830	1,654	2,484
1990	894	1,750	2,644
1991	961	1,849	2,810
1992	1,031	1,950	2,981
1993	1,182	1,976	3,158
1994	1,225	2,115	3,340
1995	1,263	2,265	3,528
1996	1,348	2,375	3,773
1997	1,436	2,488	3,924
1998	1,528	2,603	4,131
1999	1,651	2,694	4,345
2000	1,746	2,731	4,477

TABLE V-100--ENERGY AND DEMAND AT LOAD CENTER--ASOSA, WEST REGION

Year	Customer loads	At high-voltage side of receiving-end substation			
		Load center losses	Load center total	Percent annual load factor	Peak demand kw
	Kilowatt-hours x 10^6				
1957					
1958					
1959					
1960					
1961					
1962					
1963					
1964					
1965	12	3	15	30	6
1966	18	4	22	35	7
1967	12	3	15	40	4
1968	150	30	180	40	51
1969	229	46	275	42	75
1970	310	63	373	42	101
1971	394	80	474	43	126
1972	480	98	578	43	153
1973	569	117	686	44	178
1974	661	135	796	44	207
1975	755	154	909	44	236
1976	854	180	1,034	45	262
1977	956	196	1,152	45	292
1978	1,060	217	1,277	45	324
1979	1,106	227	1,333	45	338
1980	1,281	262	1,543	45	391
1981	1,397	286	1,683	46	418
1982	1,516	310	1,826	46	453
1983	1,639	336	1,975	46	490
1984	1,766	362	2,128	46	528
1985	1,896	388	2,284	47	555
1986	2,036	417	2,453	47	596
1987	2,180	447	2,627	47	638
1988	2,330	477	2,807	47	682
1989	2,484	509	2,993	47	727
1990	2,644	542	3,186	47	774
1991	2,810	576	3,386	48	805
1992	2,981	611	3,592	48	854
1993	3,158	647	3,805	48	905
1994	3,340	684	4,024	48	957
1995	3,528	722	4,250	48	1,011
1996	3,723	762	4,485	48	1,067
1997	3,924	803	4,727	49	1,100
1998	4,131	846	4,977	49	1,160
1999	4,345	890	5,235	49	1,220
2000	4,477	917	5,394	50	1,232

There are some deciduous woodlands nearby as well as bamboo thickets which may have commercial value once the transport problems have been resolved.

Precipitation is less than that at Nejo, perhaps around 1,760 mm. per year. The altitude is also less with temperatures as follows:

Average daily maximum	25.8° C
Average daily	19.9° C
Average daily minimum	14.1° C

If electricity supplies can be made available in 1975, assuming the economy warrants it, the total energy needs are as forecast by classes in Table V-101. Load factors, losses, and peak kilowatt demand are as forecast by Table V-102.

The same general comments apply to Mendi as were made concerning the Asosa area in regards to a small interconnected system serving the needs of the area. Maximum electrical facilities that might be required by the end of the century may be as suggested by Figure V-62.

Begi. Begi has every opportunity to develop into an important tourist center if the Dabus Swamp area becomes the Dabus Game Park as recommended. Begi had an estimated population of 4,000 people in 1961, but as noted on Figure V-16, the heaviest rural population concentration west of Lekkemt occurs around Begi. In excess of 60 people per square kilometer has been noted. Coffee, hides and skins, and honey are among the exports from this area.

The elevation of the town is around 1600 meters and the average precipitation is about 2,000 mm. per year.

It is assumed that by 1970, electricity will be made available to the town. Tables V-103 and V-104 reflect the anticipated loads developing to meet the needs of tourism as well as normal growth of commercial establishments.

Regarding the need for a small interconnected system to serve the West Region, see the comments made for Asosa. Maximum facilities that might be required to serve Begi by the end of the century are as indicated by Figure V-62.

IMPACT OF IRRIGATED FARMING

Except for minor diversions by gravity on some farms to irrigate small plots of special crops, such as peppers, large scale irrigation projects do not exist in the Blue Nile River Basin. Except for a very small pump installation on the southeastern shore of Lake Tana, no significant pump installations exist and none is driven by electric motor.

The potential irrigable land capable of being served by pumping installations is substantial. In the Blue Nile River Basin, the following potential irrigation pumping areas exist with maximum annual energy and demand indicated for full development. Groundwater pumping is excluded.

TABLE V-101--SALES BY CLASSES--Kw.-hr. x 10^3--MENDI, WEST REGION

Year	National economy	Public consumption	Total
1975	3	9	12
1976	5	13	18
1977	4	8	12
1978	38	112	150
1979	58	171	229
1980	80	230	310
1981	103	291	394
1982	128	352	480
1983	154	415	569
1984	181	480	661
1985	210	545	755
1986	241	613	854
1987	273	683	956
1988	308	752	1,060
1989	325	781	1,106
1990	382	899	1,281
1991	422	975	1,397
1992	464	1,052	1,516
1993	508	1,131	1,639
1994	554	1,212	1,766
1995	603	1,293	1,896
1996	656	1,380	2,036
1997	711	1,469	2,180
1998	769	1,561	2,330
1999	830	1,654	2,484
2000	894	1,750	2,644

TABLE V-102--ENERGY AND DEMAND AT LOAD CENTER--MENDI, WEST REGION

Year	Customer loads	At high-voltage side of receiving-end substation			
		Load center losses	Load center total	Percent annual load factor	Peak demand kw
	Kilowatt-hours x 10^6				
1975	12	3	15	30	6
1976	18	4	22	35	7
1977	12	3	15	40	4
1978	150	30	180	40	51
1979	229	46	275	42	75
1980	310	63	373	42	101
1981	394	80	474	43	126
1982	480	98	578	43	153
1983	569	117	686	44	178
1984	661	135	796	44	207
1985	755	154	909	44	236
1986	854	180	1,034	45	262
1987	956	196	1,152	45	292
1988	1,060	217	1,277	45	324
1989	1,106	227	1,333	45	338
1990	1,281	262	1,543	45	391
1991	1,397	286	1,683	46	418
1992	1,516	310	1,826	46	453
1993	1,639	336	1,975	46	490
1994	1,766	362	2,128	46	528
1995	1,896	388	2,284	47	555
1996	2,036	417	2,453	47	596
1997	2,180	447	2,627	47	638
1998	2,330	477	2,807	47	682
1999	2,484	509	2,993	47	727
2000	2,644	542	3,186	47	774

TABLE V-103--SALES BY CLASSES--Kw.-hr. x 10^3--BEGI, WEST REGION

Year	National economy	Public consumption	Total
1970	4	12	16
1971	14	43	57
1972	20	59	79
1973	26	77	103
1974	33	96	129
1975	41	118	159
1976	51	145	196
1977	64	175	239
1978	78	211	289
1979	95	252	347
1980	115	298	413
1981	137	349	486
1982	163	406	569
1983	190	465	655
1984	218	522	740
1985	245	577	822
1986	271	625	896
1987	296	671	967
1988	323	721	1,044
1989	351	766	1,117
1990	380	815	1,195
1991	411	867	1,278
1992	446	922	1,368
1993	483	981	1,464
1994	523	1,043	1,566
1995	566	1,109	1,675
1996	613	1,179	1,792
1997	663	1,249	1,912
1998	718	1,333	2,051
1999	776	1,415	2,191
2000	840	1,509	2,349

TABLE V-104--ENERGY AND DEMAND AT LOAD CENTER--BEGI, WEST REGION

Year	Customer loads	At high-voltage side of receiving-end substation: Load center losses	Load center total	Percent annual load factor	Peak demand kw
	Kilowatt-hours x 10^6				
1970	16	4	20	42	5
1971	57	11	68	42	18
1972	79	16	95	42	26
1973	103	21	124	42	34
1974	129	26	155	42	42
1975	159	33	192	42	52
1976	196	40	236	43	63
1977	239	47	288	43	76
1978	289	59	348	43	92
1979	347	71	418	43	110
1980	413	84	497	44	129
1981	486	100	586	44	152
1982	569	117	686	44	178
1983	655	134	789	45	200
1984	740	152	892	45	226
1985	822	168	990	45	251
1986	896	183	1,079	45	274
1987	967	198	1,165	45	295
1988	1,044	214	1,258	45	319
1989	1,117	229	1,346	46	334
1990	1,195	245	1,440	46	357
1991	1,278	262	1,540	46	382
1992	1,368	280	1,648	46	409
1993	1,464	299	1,763	47	428
1994	1,566	320	1,886	47	458
1995	1,675	343	2,018	47	490
1996	1,792	367	2,159	47	524
1997	1,912	393	2,310	48	549
1998	2,051	420	2,471	48	588
1999	2,191	453	2,644	48	629
2000	2,349	480	2,829	48	613

TABLE V-105--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	

In addition, perhaps 6,300 hectares of land might be irrigated in the lower Gilgel Abbay River valley, requiring 7,370,000 kw.-hr. per year of pumping energy. This is based upon energy requirements estimated at 39 kw.-hr. 1/ per hectare-meter per meter of pump lift.

Groundwater pumping may be possible in the Azena-Fettam area, but cannot be estimated with any degree of accuracy at this time for reasons previously stated. About 18,000 hectares are now irrigated by direct stream diversion (plus 2,000 more in the Birr area), but a far greater potential may lie in utilizing subsurface water from wells. If subsequent investigations prove the valve of subsurface water reserves for pumping and if, in the ultimate development, 25,000 hectares of the best land are irrigated, the annual pumping energy requirement would be 30,000,000 kw.-hr. This would correspond to a maximum demand of 10,000 kw.

1/One million cubic meters of water under one meter head equal 2,730 kw.-hr. at 100 percent efficiency. Allowing for expected efficiency gives 39 kw.-hr. per hectare-meter per meter of pump lift.

Within the Blue Nile River Basin, there are several potential irrigation projects and some multiple-purpose power and irrigation projects, which will total over 430,000 hectares. If divided into 17 hectares per farm unit as shown by Table V-106, over 25,000 new farm units can be brought into production. It will perhaps require 16 families (one worker per hectare) to operate one farm unit successfully. At the time each project is fully developed, it is probable that the standard of living will have improved to the extent that most farm units will want electricity supplies. Farm unit requirements will be small with the maximum demand averaging 30 watts per capita. 1/ On this basis, nearly 2 million new farm population (Table V-106) may have a maximum demand requirement of over 55,000 kw. when all projects are developed. It is not possible to provide a realistic estimate as to how long it may take to develop all of the projects indicated in Table V-106, but if the first eight were to be completely developed by the year 2000, a substantial contribution to the economy will have occurred. It may take several generations to develop all the potential projects listed.

REGIONAL SUMMARIES, PRESENT CENTURY

Development of individual load centers within regional sectors were 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 V-107 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. Percent distribution of load within the Region is estimated as follows according to Table V-107:

Year	Addis Ababa Complex	Dessie	Assab	Lekkemt	All others
1984	71	11	12	4	2
1990	66	12	14	4	4
1995	60	12	16	4	8
2000	58	12	18	4	8

North Region

Table V-108 summarizes the development of peak loads for the North Region's 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, according to EELPA's published schedule. At the beginning of the year 1984, the North Region's interconnected system might be connected with the South Region, forming the National Grid.

By way of comparison, Table V-108 indicates that Bahir Dar will be the predominant load center with the distribution of load within the Region estimated as follows:

Year	Bahir Dar	All other
1985	70	30
1990	72	28
1995	71	29
2000	64	36

1/ After fully electrified, the average annual increase is estimated at 6 percent.

TABLE V-106--ESTIMATED NEW FARM LOADS--ULTIMATE DEVELOPMENT

Projects	Hectares irrigable	Number farm units	New farm population	New farm peak demand kw.
Finchaa	15,000	880	67,000	1,980
Dabana	6,100	359	27,000	808
Angar	30,200	1,776	135,000	4,000
Upper Guder	5,100	300	23,000	892
West Megech	7,080	416	32,000	936
Amarti-Neshe	8,490	500	38,000	1,125
Upper Beles	63,200	3,717	282,000	8,363
Gumara	12,920	759	58,000	1,708
Arjo-Diddessa	16,800	990	75,000	2,228
Ribb	15,270	898	68,000	2,021
N. E. Tana	5,000	294	22,000	662
Megech Gravity	6,940	408	31,000	918
E. Megech	5,890	347	26,000	781
Dindir River	58,300	3,429	260,000	7,800
Galegu River	11,600	682	52,000	1,535
Rahad River	53,100	3,124	237,000	7,029
Upper Birr	24,350	1,432	109,000	3,222
Debohila	4,200	247	19,000	556
Lower Birr	6,600	388	29,000	873
Dabus	15,000	880	67,000	1,980
Gilgel Abbay 2/	62,390	3,486	278,000	8,340
Totals	433,530	25,312	1,930,000	57,757 Use 58,000 1/

1/Noncoincident, based upon about 30 watts average per capita maximum demand including losses until each project fully electrified.
2/West German Plan

TABLE V-107

(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				
	13,139		13,139	731	13,870	20.1	Koka on line--Interconnected system in operation
	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	
	491,042	1.19	412,640	36,725	449,365	6.1	
	524,062	1.19	440,388	39,195	479,583	6.7	
	588,320	1.19	494,387	46,967	541,354	12.9	Angar pumping load connected
	615,260	1.19	517,025	49,117	566,142	4.6	
	644,985	1.19	542,000	54,200	596,200	5.3	
	682,382	1.19	573,430	57,343	630,773	5.8	
	713,373	1.19	599,473	59,947	659,420	4.5	
100	752,868	1.19	632,662	63,266	695,928	5.5	
200	795,515	1.19	668,500	66,850	735,350	5.7	
300	832,083	1.19	699,230	69,923	769,153	4.6	
400	874,526	1.19	734,896	76,262	811,158	5.5	
500	920,740	1.19	773,730	77,373	851,103	4.9	

Year	(1) Addis Ababa Complex	(2) Agere Hiywet	(3) Lekkemt	(4) Jima	(5) Dessie	(6) S. Eritrea (Assab)	(7) Finchaa Farm	(8) Gedo	Load centers (9) Angar Pumping	(10) Angar Farm	(11) Debre Birhan	(12) Debre Sina	(13) N. Village, Rural	(14) Upper Guder Farm
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	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		
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	100
1991	367,800	2,689	23,418	10,465	66,151	80,500	1,100	382	28,730	700	1,732	524	3,829	200
1992	380,200	2,877	24,764	11,062	70,782	87,744	1,200	409	28,730	800	1,836	549	3,907	300
1993	392,700	3,015	26,498	11,487	75,736	97,210	1,300	428	28,730	900	1,908	588	3,985	400
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	500
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	600
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	675
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	742
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	786
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	833
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	892

…ech *	Upper Beles Farm (15)	Upper Beles Pump (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 (22)	Remarks
			1,522		1,522	83	1,605		
			4,077		4,077	224	4,301		Units 1 and 2, Tis Abbay on line
			4,051		4,051	224	4,275		
			4,419		4,419	243	4,662	9.0	
			4,678		4,678	257	4,935	5.9	
			4,678		4,678	257	4,935	-	
			5,053		5,053	278	5,331	8.0	
			5,614		5,614	305	5,919	11.0	
			5,988		5,988	329	6,317	6.7	
			6,363		6,363	350	6,713	6.3	
			7,741	1.05	7,372	405	7,777	15.8	Unit 3, Tis Abbay on line; Bahir Dar Dam constructed
			10,024	1.05	9,547	763	10,310	32.5	
			11,271	1.05	10,734	859	11,593	12.4	All Gilgel Abbay units on line
			12,723	1.05	12,117	969	13,086	12.8	
			14,222	1.05	13,545	1,084	14,62[illegible]	11.8	
			15,890	1.05	15,133	1,211	16,344	11.2	
			17,928	1.05	17,074	1,366	18,440	12.8	
			19,825	1.05	18,881	1,699	20,580	11.6	
			22,377	1.06	21,110	1,900	23,010	11.8	
			24,537	1.06	23,148	2,083	25,231	9.7	
			27,209	1.06	25,669	2,310	27,979	10.9	
			30,537	1.06	28,808	2,592	31,400	12.2	Interconnect with South Region
			33,033	1.06	31,163	2,805	33,968	8.2	Start Alefa (BL-1) units on line
			45,366	1.15	39,449	3,550	42,999	26.5	
			50,719	1.15	44,100	3,969	48,069	11.7	
			54,155	1.16	46,685	4,201	50,886	5.8	
			58,553	1.16	50,477	4,543	55,020	8.1	
			62,418	1.17	53,349	4,801	58,150	5.7	
			67,401	1.17	57,608	5,185	62,793	8.0	
			70,747	1.17	60,468	5,442	65,910	4.8	
0			75,992	1.19	63,859	5,747	69,606	5.6	
0			79,493	1.19	66,800	6,012	72,812	4.6	
0			82,223	1.19	69,095	6,219	75,314	3.4	
0			87,040	1.19	73,142	6,583	79,725	5.9	
0			90,924	1.19	76,407	6,877	83,284	4.5	
0			95,934	1.19	80,617	7,255	87,872	5.5	
0	200	2,535	102,787	1.19	86,375	7,774	94,149	7.1	
0	400	2,535	108,513	1.19	91,187	8,200	99,387	5.6	
0	600	12,500	123,305	1.19	103,617	9,326	112,943	13.0	

TABLE V-10.—ESTIMATED PEAK DEMAND

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

* 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.

At the time of interconnection, the first Alefa (BL-1) powerplant unit will be energized (50,000 kw.) with a part of this exported to the South Region. The National Grid will for several years have as its principal supplier the Alefa Powerplant, rated at 200,000 kw.

Central Region

Table V-109 indicates that the dominant load center may be Gore, and also that the Central Region's 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's 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; 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 V-110. This table shows that 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 the period of analysis in this appendix, only the Central, South, and North Regions would be connected to form the National Grid. See Figures V-63, V-64, and V-66. The connection of these three regional areas will develop peak loads as indicated by Table V-111.

Concerning Table V-111, the first year of the National Grid, when all three regions are interconnected, occurs in 1984. Beginning with that year, Column (4) gives the coincidental peak demand in kilowatts. Previously, Tables V-107, V-108, and V-109, as reflected by Columns (1), (2), and (3), respectively, of Table V-111, allowed for diversity factors within each region varying from 1.05 to 1.19.

ESTIMATED FUTURE NEED FOR ADDITIONAL GENERATOR CAPACITY

By the year 1984, the National Grid may have a peak demand of 356,525 kw. [Column (4) or (14) of Table V-111] 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.

Prior to the formation of the National Grid by regional interconnections, new generation requirements to meet regional loads will be a continual need.

If the objectives of the Second and subsequent 5-year Development Plans for the Empire are to be approached or reached, wherein the present agricultural economy is to be successfully transformed into an agricultural-industrial one by 1982, the need for energy to meet industrial as well as residential and commercial requirements will be substantial.

Table V-111, 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. In the same table, 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.)

However, it should be recognized that constructing four hydroelectric powerplants cascaded on one river (Awash), regulated by one reservoir and constituting 95 percent of the utility electrical energy source for the heart of the Empire, may not be the most desirable situation. This is especially true when one considers leakage problems associated with the one reservoir and the yet unknown consequences of reservoir sedimentation and other losses at Koka. Therefore, every effort should be made to develop other hydroelectric facilities as soon as possible in another river basin conveniently located near Addis Ababa. The Blue Nile River Basin powerplants offer a good solution to the problem; and at the same time, the other aspects of the multipurpose projects available in that Basin will be highly beneficial to the economy.

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 V-111. 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 V-111, 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.

Preliminary information gives these capacities for the four Gilgel Abbay plants. See Figure V-40.

GA-4 (No. 1)--	8,000 kw.
GA-5 (No. 2)--	16,000 kw.
GA-6 (No. 3)--	32,000 kw.
GA-7 (No. 4)--	7,500 kw.
Total	63,500 kw.

These capacities are apparently based upon average water years, hence, do not represent dependable capacities for meeting system peaks which are based upon adverse water periods. For the low-water period 1912-13, output of these plants is estimated to have totaled 112.8 x 10^6 kw.-hr. and still have water releases to meet full irrigation requirements. This has been estimated to be equivalent to 22,200 kw.

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.

A further study of Table V-111, beginning with the year 1982, will indicate estimated needs for additional generator capacity to the year 2000.

POWER FACILITIES UNDER CONSTRUCTION OR PLANNED

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.

TABLE V-109—ESTIMATED PEAK DEMAND, KILOWATTS—CENTRAL REGION INTERCONNECTED SYSTEM DEVELOPMENT

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		
1983	300	428	92	4,613	5,433	1.05	5,174	151	5,325	14.8	Dabana Powerplants DB-1 and DB-1A on line in 1982 and interconnect with South Region
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 V-110--ESTIMATED PEAK DEMAND, KILOWATTS--WEST REGION ISOLATED SYSTEM

TABLE V-110

Year	Load centers			Sum	Diversity factor	Peak demand (kw) interconnected load	Transmission losses at peak demand	Peak demand at powerplant	Annual production rate of increase, percent	Remarks
	Asosa	Mendi	Begi							
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		
1986	596	262	896	1,754	1.06	1,655	66	1,721	9.8	Dabus Powerplant DA-8 on line
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	

TABLE V-111--DEVELOPMENT OF NATIONAL GRID--PEAK LO

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)
1957								
1958								
1959								
1960								
1961	13,870							
1962	18,550		1,605					
1963	23,692		4,301		3,399	4,301	7,700	7,700 kw, Units 1 and 2 (BN-10) Tis Abbay 1/
1964	23,692		4,275		3,425	4,275	7,700	
1965	26,788		4,662		3,038	4,662	7,700	
1966	36,185		4,935		2,765	4,935	7,700	
1967	43,267		4,935		2,765	4,935	7,700	
1968	51,598		5,331		2,369	5,331	7,700	
1969	61,953		5,919		1,781	5,919	7,700	
1970	72,206		6,317		1,383	6,317	7,700	
1971	82,535		6,713		987	6,713	7,700	
1972	94,246		7,777		3,743	7,777	11,520	3,820 kw, Unit 3, Tis Abbay
1973	107,227		10,310		1,210	10,310	11,520	
1974	117,704		11,593		2,727	11,593	14,320	2,800 kw, GA-4, 2/
1975	131,249		13,086		6,734	13,086	19,820	5,500 kw, GA-5, 2/
1976	147,017		14,629		5,191	14,629	19,820	
1977	183,417		16,344		6,076	16,344	22,420	2,600 kw, GA-6, 2/
1978	204,499		18,440		3,980	18,440	22,420	
1979	222,704		20,580		13,140	20,580	33,720	11,300 kw, GA-7, 2/
1980	246,418		23,010		10,710	23,010	33,720	
1981	272,581		25,231		8,489	25,231	33,720	
1982	279,332	4,635	27,979		5,741	27,979	33,720	
1983	304,653	5,325	31,400		2,320	31,400	33,720	Interconnect with South Region to form National Grid 1984
1984	316,347	6,210	33,968	356,525				
1985	343,105	6,973	42,999	393,077				
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. Fir
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
* Dependable kw due to long canals.

TABLE V-111

Dependable generation in South and Central Regions prior to interconnection with North Region (Use with Columns 1 and 2)				Dependable generation, all regions to meet peak load National Grid after interconnection in 1984 (Use with Column 4)			
or reserve (9)	For loads and losses (10)	Total (11)	Source (12)	For reserve (13)	For loads and losses (14)	Total (15)	Source (16)
		28,000	5,000 kw, Ourso and Aba Samuel 23,000 kw, Koka				
		28,000					
		28,000					
		28,000					
4,308	23,692	28,000					
1,212	26,788	28,000					
28,815	36,185	65,000	37,000 kw, Awash No. 2				
21,733	43,267	65,000					
50,402	51,598	102,000	37,000 kw, Awash No. 3				
40,047	61,953	102,000					
29,794	72,206	102,000					
56,465	82,535	139,000	37,000 kw, Awash No. 4				
44,754	94,246	139,000					
31,773	107,227	139,000					
01,296	117,704	219,000	80,000 kw, Finchaa FI-1A				
87,751	131,249	219,000					
71,983	147,017	219,000					
15,583	183,417	299,000	80,000 kw, Neshe NES-1A				
94,501	204,499	299,000					
76,296	222,704	299,000					
52,582	246,418	299,000					
26,419	272,581	299,000					
00,033	283,967	384,000	85,000 kw, Dabana				
74,022	309,978	384,000	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	

pacity is only 3,000 kw including 600 kw diesel electric.

the future.

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. It flows in a deep "V" southeast until it reaches the Rift Valley, where it flows northeast until it reaches Lakes Gamarri and Abbe. A twin power station development is planned by EELPA at Malkassa immediately below the Awash bridge on the Assola highway, 25 kilometers downstream of the existing Koka hydroelectric facilities.

The first of the powerplants, Awash No. 2, utilizes a gross head of 62.7 meters and its turbines discharge directly into the upper end of the storage basin of its twin powerplant, Awash No. 3. Awash No. 2 will have a reservoir with maximum volume of 6 million cubic meters, while Awash No. 3 will have a storage basin with 1.5-million-cubic meter volume. Both powerplants will be served by tunnels and surge tanks. In the Awash No. 2 Powerplant, two vertical-axis, Francis turbines drive three-phase alternators rated at 50-cycle, 300-r.p.m., 0.8-power factor, 10-kv. Both powerplants will be able to peak at 37 mw.1/ The equipment for the two plants will be nearly identical. The main river regulation will be provided by Koka (Awash No. 1).

Summarizing, each installation will have a 5-meter pressure tunnel, surge tank, valve chamber, two penstocks of 3-meter diameter, a powerhouse for two Francis turbines with necessary service facilities, and an open-air switchyard. The effective head of each development is to be approximately 58 meters, and the distance between the intake and the powerhouse will be 2,000 meters for Awash No. 2 and 900 meters for Awash No. 3. Designs have been completed, and it appears that construction of Awash No. 2 will start in April 1964 with 2 years to complete. Construction of Awash No. 3 will follow immediately. On this basis, Awash No. 2 may be energized in 1966 and Awash No. 3 in 1968. See Table V-111, Column (12).

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

The cost of the total project, Awash No. 2 and No. 3, with transmission plant facilities, was estimated at Eth$56,000,000.

In addition to the above, the South Region's interconnected system through 1968 will be expanded to provide these additional facilities: 55 km. of 132-kv. line; about 80 km. of 45-kv. line; and about 400 km. of 15-kv. distribution line and 56-mv.-a. distribution transformer capacity.

Small hydroelectric facilities planned include these for the isolated systems:

Ghion (Woliso)	150 kw.
Debre Markos	185 kw.
Dembidollo	185 kw.

Of these, only Debre Markos is within the Blue Nile River Basin. There will be a continuing program to install small diesel sets in many towns as the initial step in a load-building program toward regional developments. By 1967, the number of isolated systems will increase to about 25, with the installed capacity reaching about 18,500 kv.-a., or an increase of 450 percent according to EELPA.

The corresponding firm capacity will be 10,000 kw. According to EELPA in 1962, the following schedule of installations was planned. See Figure V-19.

No attempt is made to schedule small diesel installations beyond 1966. As was previously noted, small diesel installations will probably be used initially throughout the period under study to develop a load base at each load center.

1/One source indicates 35 mw.; another 32 mw.

1962--Ten diesel sets of 150 kw., of which three are for Gondar, one is for Yirgalem, one for Jijiga, one for Debre Markos, and one each for the four new systems, Asella, Lekkemt, Shashamana, and Soddu.

At Assab three practically new sets of 125 kw. were to be taken over by the Authority from the original owner.

1963--Twelve diesel sets of 150 kw., of which one each is for Yirgalem, Jijiga, Asella, Lekkemt, and Soddu, two are for Shashamana, and one each is for five additional systems, Dilla, Makalle, Axoum, Agaro, and Asbe Teferi.

The first 1,000-kw. set is to be installed at Assab.

1964--Two diesel sets of 300 kw., one for Jima, and one for Dessie. Ten diesel sets of 150 kw., one each for Debre Birhan, Neghelli, Shashamana, Lekkemt, Soddu, Dilla, Makalle, Axoum, Agaro, and Asbe Teferi.

1965--Ten diesel sets of 150 kw., one each for Agere Hiywet, Yirgalem, Asella, Makalle, Axoum, Agaro, and Asbe Teferi, and one each for three new systems, Bonga, Debre Tabor, and Adoua.

The second 1,000-kw. set to be installed at Assab.

1966--Eight diesel sets of 250-300 kw., four each for Gondar and Shashamana. This would liberate eight sets of 150 kw. which could be transferred to Debre Markos, Jijiga, Dembidollo, Bonga, Debre Tabor, and Adoua, and two sets to Dilla.

THE BLUE NILE RIVER BASIN PROJECTS AS SOURCES IN MEETING FUTURE DEFICIENCIES IN POWER SUPPLY, PRESENT CENTURY

The North Region is supplied entirety by Blue Nile River Basin powerplants as outlined previously. Also, it was noted that even with the fourth Awash plant in the South Region, deficiencies would occur again in 1974 or 1975; and it was suggested that further hydroelectric projects be developed in other river basins.

Table V-111, Columns (8), (12), and (16), indicates that 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 1/	By EELPA
Gilgel Abbay	North	22,200	Gilgel Abbay (W. Germany)
Finchaa (FI-1A)	South	80,000	Finchaa
Neshe (NES-1A)	South	80,000	Amarti-Neshe
Dabana (DB-1) & (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 2/	Angar
Angar (AG-6B)	South	35,000 2/	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
		1,030,720 3/	

1/With third unit and regulation of Lake Tana water at outlet, Bahir Dar.

2/AG-6A and AG-6B installed capacities may be 100,000 kw. and 45,000 kw., respectively. Due to long canals and restricted forebay storage, dependable capacity considered to be 77,000 kw. and 35,000 kw., respectively, under certain conditions.

3/See last note, last page, Table V-3, SECTION II. Add 7,500 kw. for isolated Dabus (DA-8).

In addition, the four Awash powerplants and Abba Samuel would have a capacity of 139,000 kw., making an aggregate total available of 1,169,720 kw.

The isolated West Region will depend upon Dabus Powerplant (DA-8), having a capacity of 7,500 kw.*

System Development

There are many alternatives available in planning a National Grid over a future 35- to 40-year period, none of which will in all likelihood represent the finally constructed system. Using the preceding load estimates and analysis, the maximum system facilities can conveniently be indicated for any particular future date.

Figure V-39 portrays the maximum system for the year 1980, which date represents nearly the end of the fifth 5-year Development Planning period when a substantial transformation of the economy from predominantly agricultural to an agricultural-industrial one will have occurred, according to present plans.

Figure V-40 shows the maximum system for the year 2000, the end of the primary period of analysis. Both drawings represent a method of utilizing a small part of the Blue Nile River Basin's inventory of hydroelectric facilities. Section VI has supporting single-line electrical switching diagrams based upon the system plan developed for maximum utilization of the Blue Nile River Basin resources.

*See last note, last page, Table V-3, SECTION II.

Potential Blue Nile River Basin Projects Available For Hydroelectric Power Development (Present Century)

Several potential single-purpose power and multiple-purpose power and irrigation projects were investigated, and the ones appearing in Table V-111 represent one plan for meeting system requirements to the year 2000 under the most optimistic economic conditions. For example, the fact that the Dabana powerplants appear in full service initially in 1982 does not mean that a specific recommendation is implied at this time, 1963, for completion of its construction in 1982. Table V-111 implies no recommendation and merely represents one plan of several possibilities meeting specific criteria on maximum utilization of Blue Nile inventoried resources, all as outlined in previous sections of this report. Each project will require more detailed investigations to establish feasibility at later dates.

Section VI, Transmission Plant, provides details on transmission lines and substations included in the various Blue Nile River Basin projects. The locations are shown on Figure V-40.

Plant Capacities--General. It is determined from the reservoir operation study that a plant will have a firm output of a certain number of kilowatt-hours per year. It is estimated that the annual load factor of future National Grid loads will vary from the present 55 percent to nearly 65 percent by the year 2000, or average about 60 percent with little seasonal variation during the period when most plants are installed. Certain plants at the end of long canals, tunnels, or penstocks would be more suited for base operation; but as this is a small system, it is likely that in practice they will follow insofar as possible the system load curve. Generally, operation studies were based upon water releases to meet the monthly load pattern as shown by Figure V-29.

The best course to follow in this preliminary reconnaissance phase of investigation where plants are being selected from 10 to 35 years in the future is to be uniform insofar as possible and select plant capacity based, in general, upon the need for meeting the receiving-end load factor of about 60 percent. For a 60 percent annual load factor, the annual loss factor would be 42 percent (Figure V-41). For example, assuming 10 percent peak transmission losses, the annual load factor at the plant would be (0.90) (0.60) + (0.10) (0.42) = 58.2 percent. By using a plant factor of 0.50 (ratio of average annual load to the aggregate rating of total installed generating equipment) the total installed capacity will allow, on the average, about 16-17 percent for reserves.

Until industry loads assume a greater percent of the total load, there is only a small market for nonfirm energy, and the influence on installed capacity or economics of this segment is not considered in detail except to acknowledge that offpeak energy will be available from some plants in considerable quantity.

Finchaa Project

Specified detailed data are given in Appendix I, "Plans and Estimates." Power and joint use facilities included in this multiple purpose project are:

(1) Finchaa storage dam.

(2) Power diversion dam.

(3) Tunnel and penstocks.

(4) Finchaa hydroelectric powerplant (FI-1A), 80 mw.

(5) Switchyard.

(6) 1.8 km. 161-kv. transmission line, from switchyard to Dongi Substation.

(7) 248 km. 161-kv. transmission line, double circuit, steel tower, with one circuit installed initially.

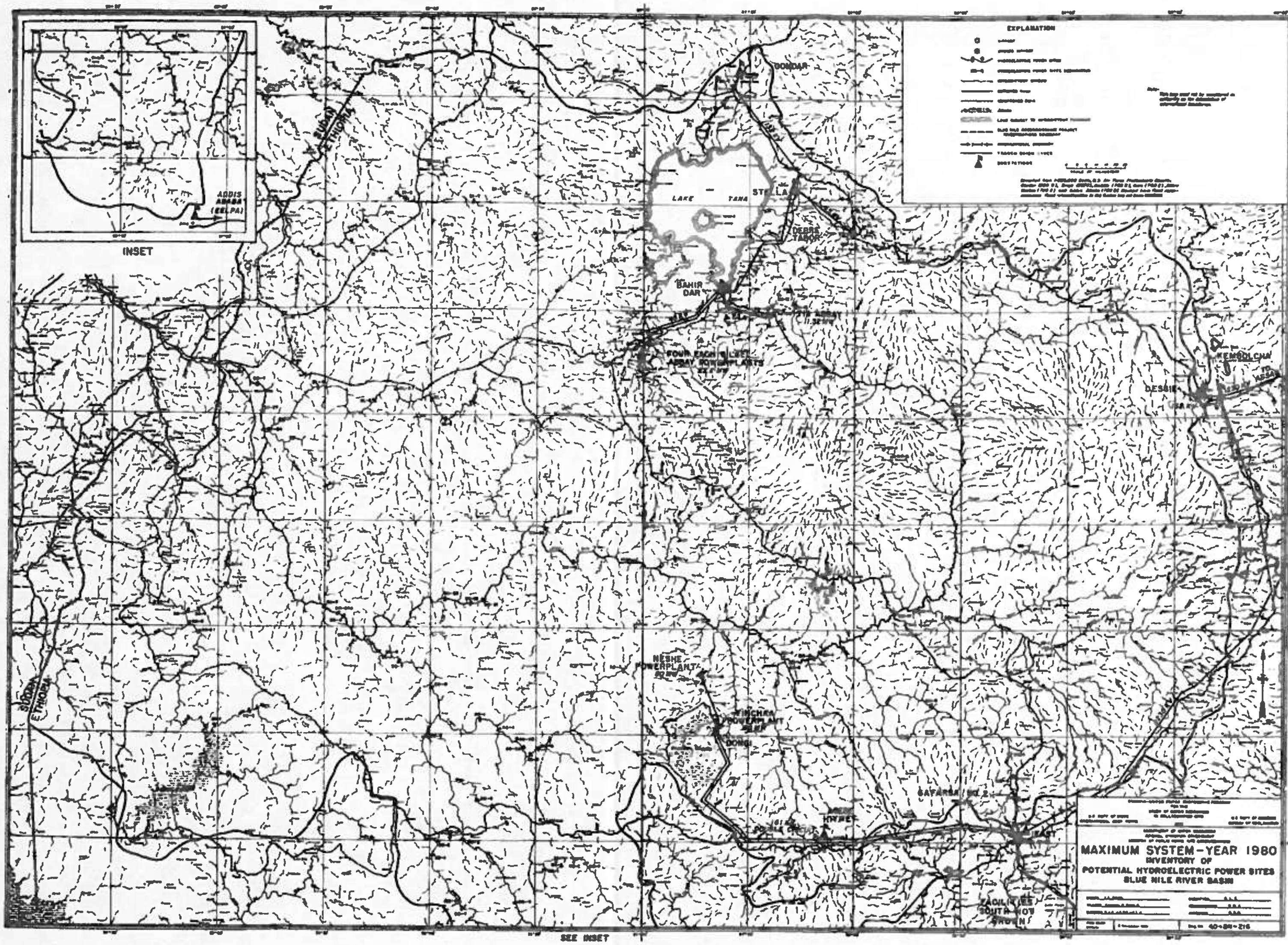


Figure V-39--Maximum System-Year 1980--Inventory of Potential Hydroelectric Power Sites--Blue Nile River Basin

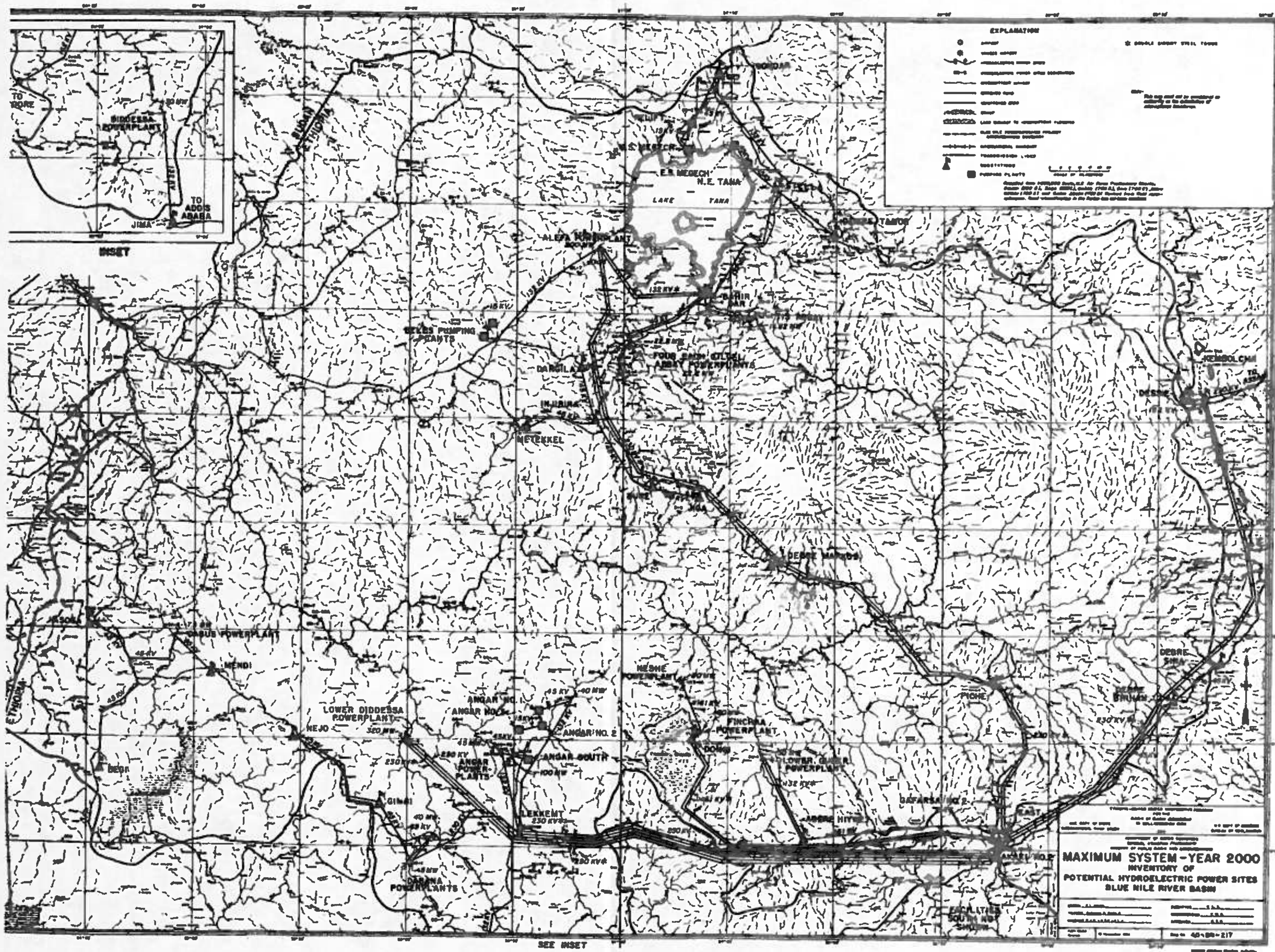


Figure V-40--Maximum System-Year 2000--Inventory of Potential Hydroelectric Power Sites--Blue Nile River Basin

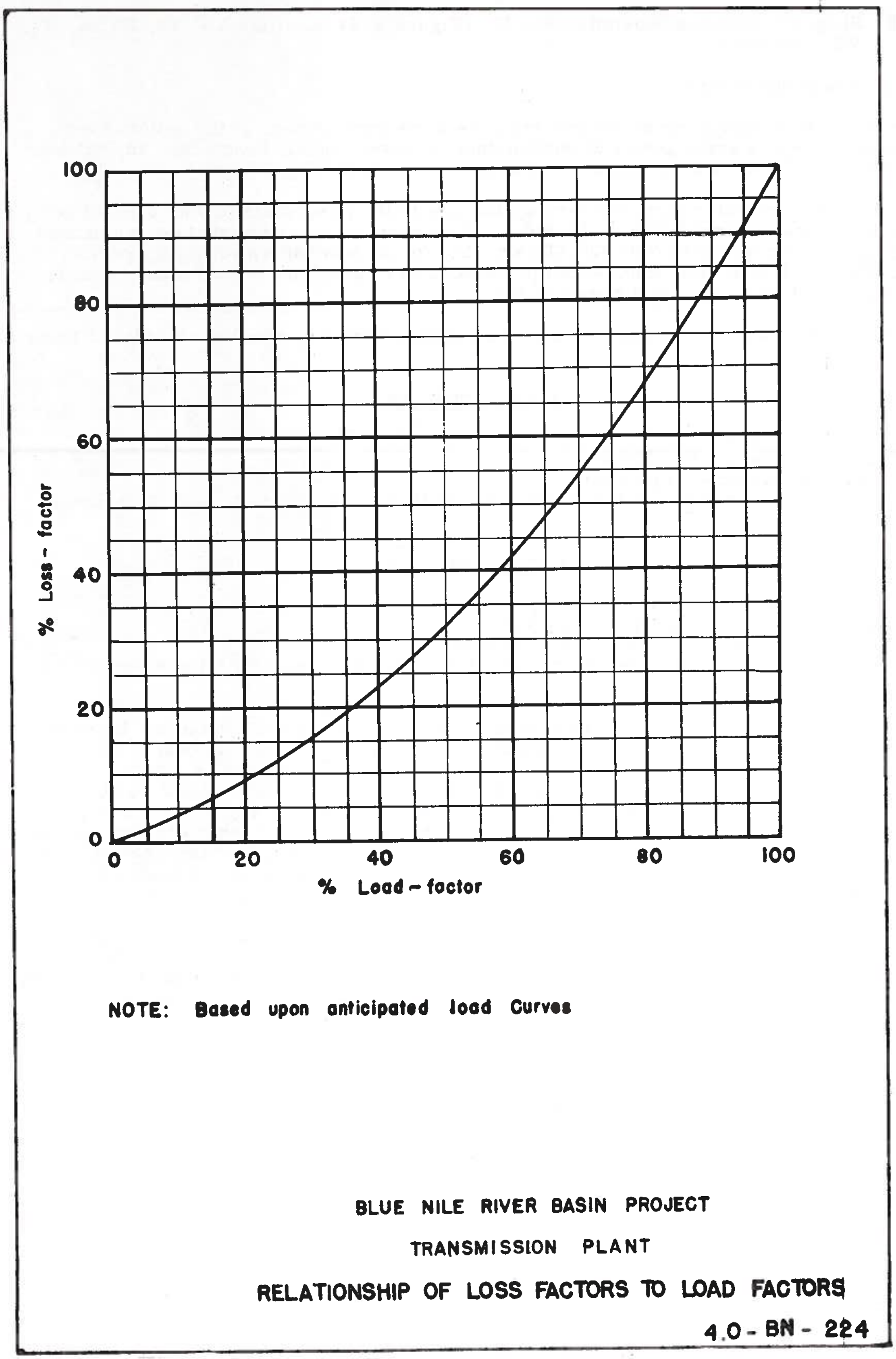


Figure V-41--Relationship of Loss Factors to Load Factors

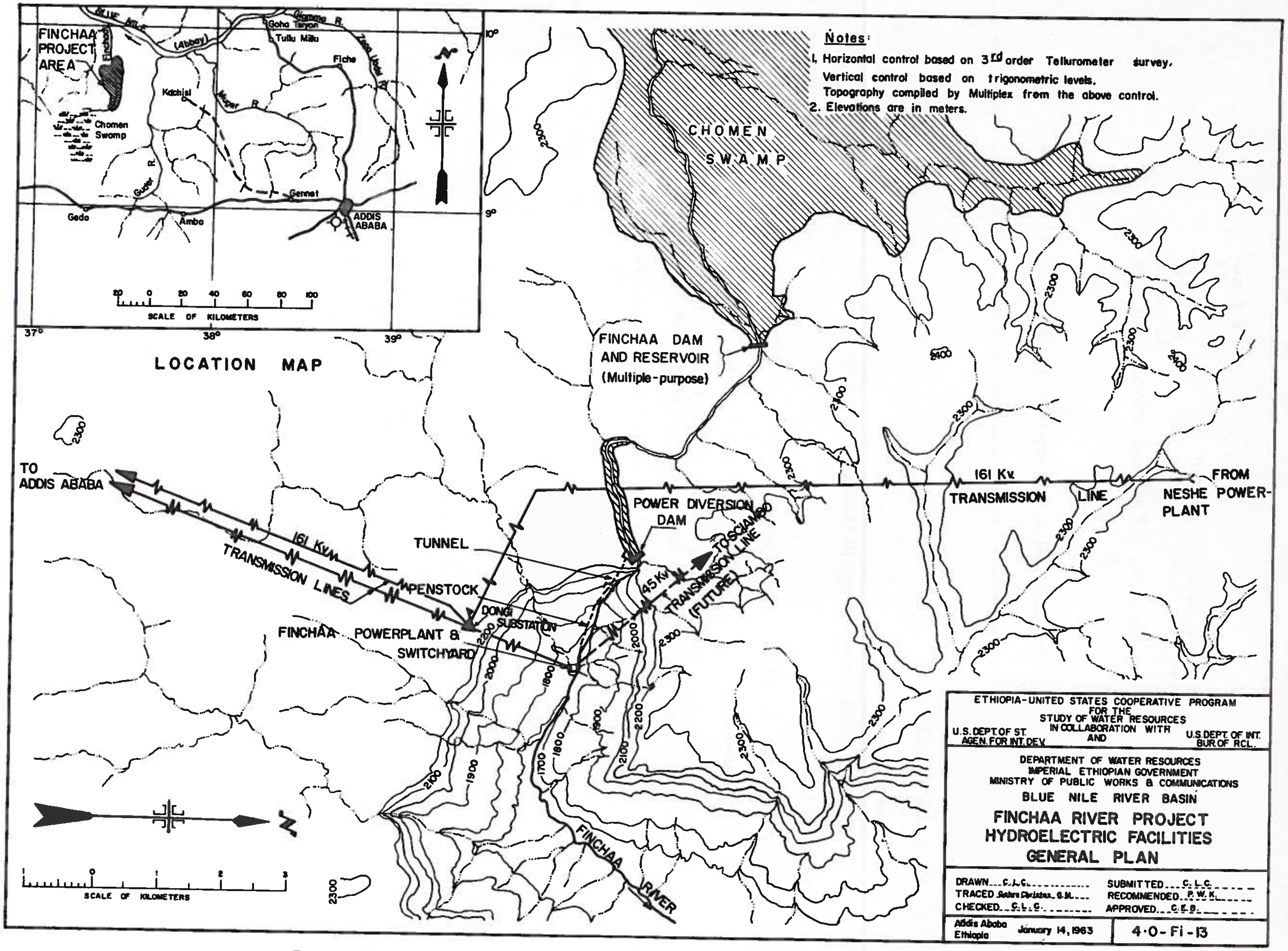


Figure V-42--Finchaa Project--General Plan, Hydroelectric Facilities

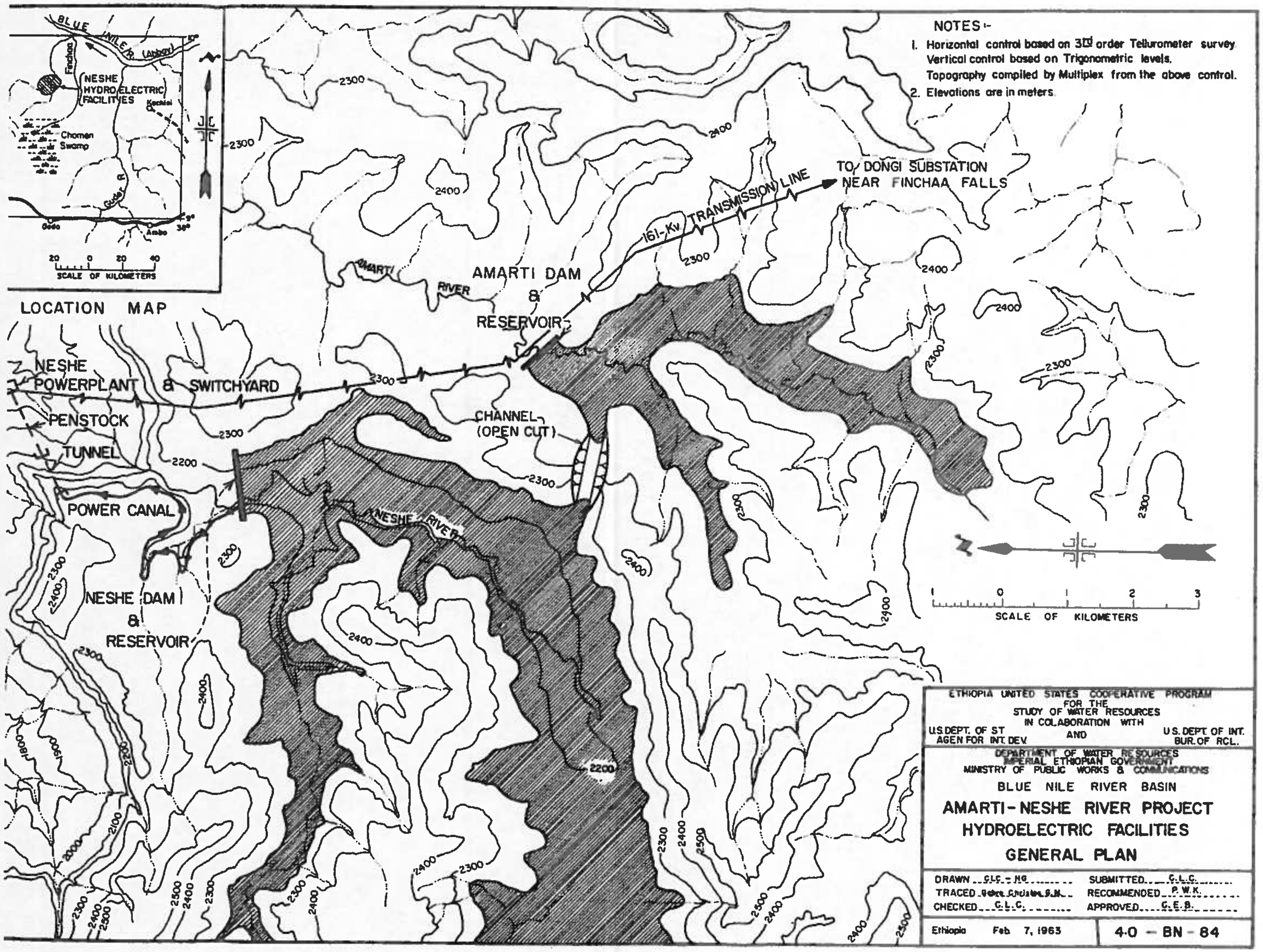


Figure V-43--Amarti-Neshe Project--General Plan, Hydroelectric Facilities to bypass water from the penstock, during load surges, to the tailrace. Energy absorbers are required to dissipate energy from the pressure regulators.

The two generators would have individual step-up transformers, as shown by Figure V-64, from 13.8-kv. generator voltage to 161-kv. transmission voltage, each transformer rated 50,000 kv.-a. Certain powerplant components have been made identical with the Finchaa Powerplant so as to ease the operation and maintenance problems and to reduce the investment in spare parts. The switchyard arrangement is identical to that shown for the Finchaa Powerplant.

Summarizing, the generators would have the general characteristics shown below.

Speed	375 r.p.m.
Number of poles	16
Horizontal shaft, direct connected	
Voltage (wye connected)	13.8 kv.
Frequency	50 cycles
Power factor, variable, 0.8 through unity, lag or lead	

Dabana Project

For the multiple-purpose project development plan, see Appendix I, "Plans and Estimates."

Briefly, power and joint-use facilities included in this multiple-purpose project are:

(1) Dabana Dam.

(2) Power diversion dam.

(3) Powerplant (DB-1) 45 mw., and switchyard.

(4) Powerplant (DB-1A) 40 mw., waterways, and switchyard.

(5) Two 69-kv. steel tower transmission lines from (DB-1) to (DB-1A), each 13 km.

(6) 70 km. 230-kv. steel tower line from (DB-1) to Lekkemt.

(7) 245 km. 230-kv. steel tower line Lekkemt to Akaki No. 2 Substation. Double circuit with one circuit installed initially.

(8) 210 km. 132-kv. steel tower line, Lekkemt to Gore.

(9) 12 km. 132-kv. transmission line from Akaki No. 2 Substation to Akaki No. 1 Substation.

(10) 45 km. 45-kv. transmission line (DB-1), to Gimbi.

(11) 60 km. 45-kv. transmission line, Gimbi to Nejo.

(12) 10 km. 230-kv. transmission line, double circuit, Akaki No. 2 Substation to East Substation. One circuit installed under this project.

(13) Stage 01, Lekkemt Substation (Figure V-66, facilities V8, V9, V10, W1, W3, X1, X2, KV10A, and station service).

(14) Stage 01, Akaki No. 2 Substation (Figure V-66, facilities V7, V8, V9, W5, W6, KV9A, and station service).

(15) Stage 02, East Substation (Figure V-64, facilities V7, W1, X3, X4, Z1, Z3, Z4, Z5, Z6, and KW1A).

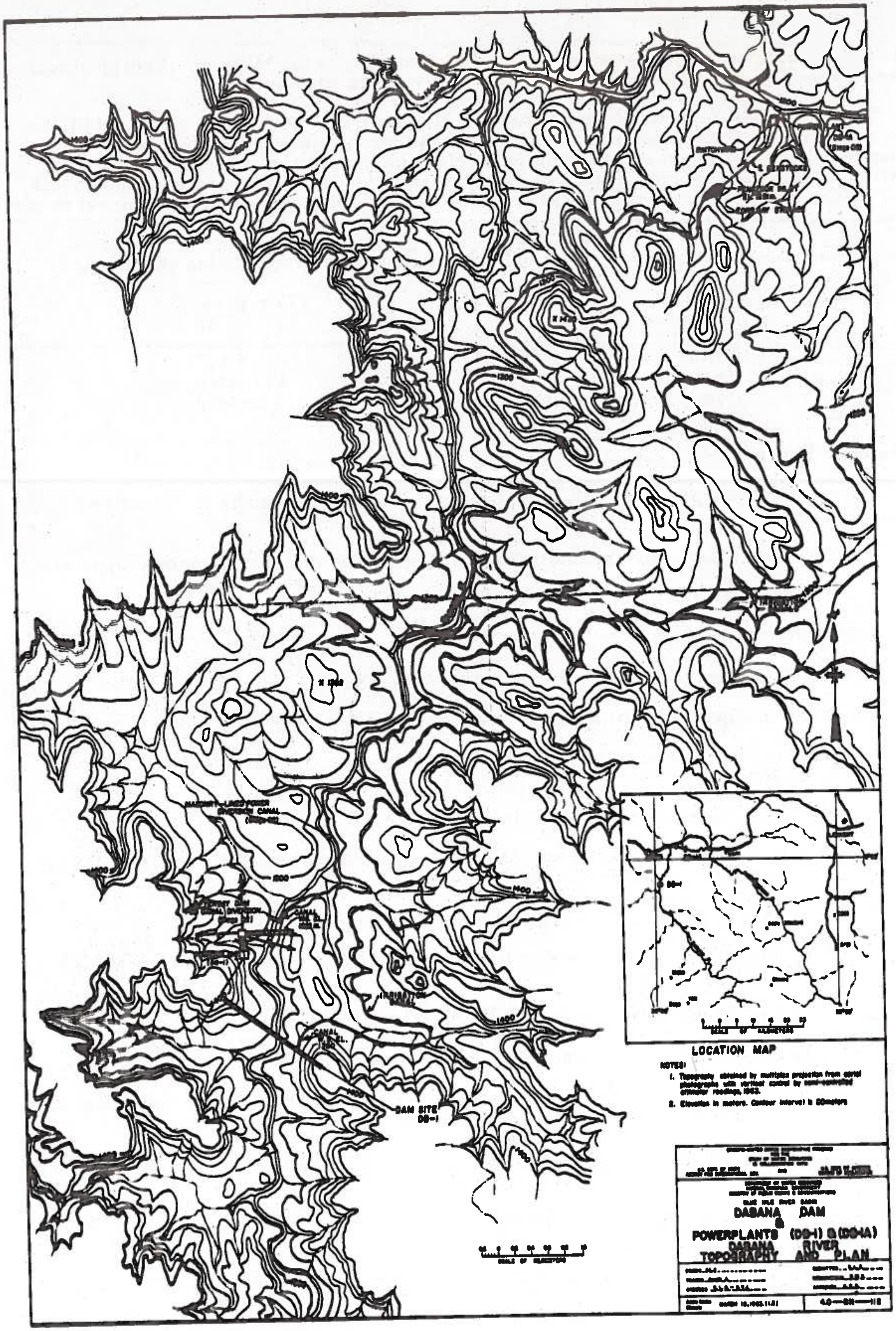


Figure V-44--Dabana Dam and Powerplants DB-I and DB-IA, Topography and Plan

(16) Gimbi Substation.

(17) Nejo. Substation.

(18) Gore Substation (Figure V-66, features W1, W2, X2, X3, X5, KW1A, and station service).

(19) Roads and camps.

Referring to Figure V-44, two powerplants can be developed on this project. The first (DB-1) will be located at the toe of the dam and will discharge water from its tailrace into an afterbay storage reservoir with the afterbay dam diverting water into a 17.25-km. power diversion canal which will serve a constant-head powerplant (DB-1A) located on the Dabana River. None of the water used for the powerplants is used for irrigation. (Irrigation needs are served by a second canal at higher elevation.) Characteristics of these plants are as indicated by Figure V-66 and as shown below:

Powerplant DB-1 (at damsite)

Number of generators	2
Rating of each generator	22,500 kw. at 0.8 PF, 50-cycle
Plant installed capacity	56,250 kv.-a.
Turbines, each	31,114 hp. (English) Francis
Synchronous speed	250 r.p.m.
Design head	84.6 m.

Powerplant DB-1A (from canal)

Number of generators	2
Rating of each generator	20,000 kw. at 0.8 PF. 50-cycle
Plant installed capacity	50,000 kv.-a.
Turbines each	28,200 hp. (English) Francis
Synchronous speed	250 r.p.m.
Design head	86.3 m.

With both powerplants in operation, 414,000,000 kw.-hr./year can be generated in an adverse water period.

DB-1A can peak at nameplate rating for a short time only due to canal and forebay limitations. However, this is considered satisfactory, in conjunction with other system plants, to meet the daily peaks expected. A larger canal of the length involved was considered too costly although future conditions might justify it.

Upper Beles Project

Briefly, power and joint-use facilities included in this multiple-purpose project are as follows:

(1) Lake Tana control structure.

(2) Diversion tunnel, including intake structure and stilling basin.

(3) Power canal and waterways including pressure tunnels and penstocks.

(4) Alefa Powerplant (BL-1) 200 mw., and switchyard, Figure V-63.

(5) 65 km. 132-kv. double-circuit steel tower transmission line from powerplant (BL-1) to Bahir Dar.

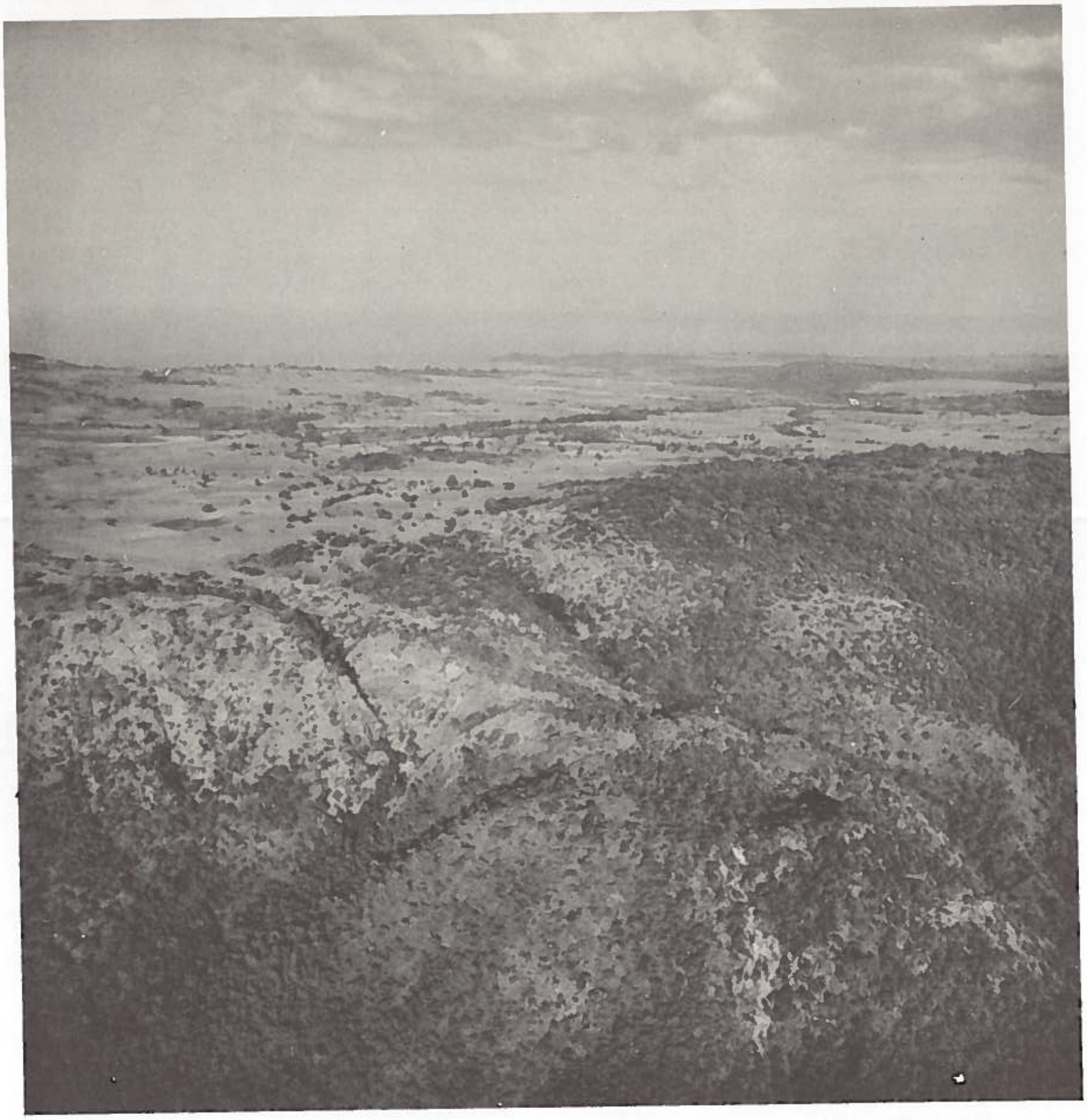


Figure V-45--Outlet portal area for the Beles diversion tunnel from Lake Tana. Lake Tana in background. About 239 meters of net hydroelectric power head available for the Alefa powerplant, rated at 200 mw.

(6) 450 km. 230-kv. double-circuit steel tower line from powerplant (BL-1) to East Substation.

(7) 45-kv. transmission lines as follows:

37 km. Bure to Jiga
70 km. Bure-Injibira-Dangila
50 km. Injibira to Metekkel
40 km. Stella to Debre Tabor

(8) 146 km. 132-kv., Bahir Dar to Stella to Gondar.

(9) Stage 01 and 02, Bahir Dar Substation (Figure V-63, facilities as follows:

Stage 01--W4, W5, X1, Z7, Z8, Z9, KW5A, and station service
Stage 02--W1, W2, W3, X2, Z1, Z2, Z3, Z4, Z5, Z6, and KW6A).

(10) Stage 01, Stella Substation (Figure V-63, features W1, W2, X1, Z2, and KW1A).

(11) Debre Tabor Substation.

(12) Stage 01, Gondar Substation (Figure V-63, features W1, W2, X2, X3, X4, X5, station service, and KW1A).

(13) Bure Substation.

(14) Injibira Substation.

(15) Metekkel Substation.

(16) Dangila Substation.

(17) Jiga Substation.

(18) Debre Markos Substation.

(19) Stage 03, East Substation (Figure V-64, features V5, V6, X1, X2, and Z2).

(20) Roads and camps.

Separate power facilities, for irrigation pumping only, include these features:

(1) 80 km. 132-kv. steel tower transmission line, Alefa (BL-1) Powerplant to Pumping Plant No. 2.

(2) 8-km. 15-kv. steel pole line, Pumping Plant No. 2 to Pumping Plant No. 1.

(3) Substations for Pumping Plants No. 1 and 2.

By means of a low dam to provide regulation of Lake Tana water at Bahir Dar, and a combination tunnel and power canal diverting water from Lake Tana through the western watershed to the headwaters of the Beles River, 1,197,400,000 kw.-hr. can be generated annually. This considers the effects of adverse water years, and at the same time, fully controlled releases from the Bahir Dar outlet will allow the full three-unit Tis Abbay Powerplant to operate and keep the Tis Isat Falls alive.

The power scheme is shown by Figure V-46. Releases from the Alefa Powerplant into the Beles River can be used downstream for irrigation and additional hydroelectric power developments.

Power output from the powerplant will be used to supply the North Region, supply the Upper Beles Project requirements such as irrigation pumping and farm needs, and to make up deficiencies in the South Region by means of interconnecting high-voltage transmission lines.

The limiting factor establishing powerplant capacity is the size of the 6.8-km. tunnel, which has a design capacity of 110 m^3/sec. This will support a powerplant rated at 200,000 kw. and a plant factor of about 0.68 in lieu of 0.50 is anticipated.

Figure V-63 indicates the electrical facilities required. Summarized characteristics of the powerplant are as follows:

Design head	239 m.
Number of generators	4
Rating of each generator	50,000 kw. at 0.8 PF, 50-cycle
Plant installed capacity	250,000 kv.-a.
Turbines	70,550 hp. (English) Francis
Synchronous speed	375 r.p.m.

Angar Project

For project details, see Appendix I, "Plans and Estimates." Briefly, power and joint-use facilities can be summarized as follows:

(1) Angar Dam (AG-2).

(2) Lekkemt Dam (AG-6).

(3) Power diversion dam.

(4) Powerplants and switchyards with connecting circuits:

(AG-2)	40 mw.
(AG-6A)	100 mw.
(AG-6B)	45 mw.

(5) Waterways for powerplants (AG-6A) and (AG-6B) consisting of canals, forebay structures, and penstocks.

(6) 75 km. 132-kv. steel tower transmission line from powerplant AG-2 to Lekkemt.

(7) 5 km. 69-kv. transmission line from powerplant (AB-6B) to (AG-6A), intertie.

(8) 43 km. 132-kv. steel tower transmission line from powerplant (AG-6A) to Lekkemt.

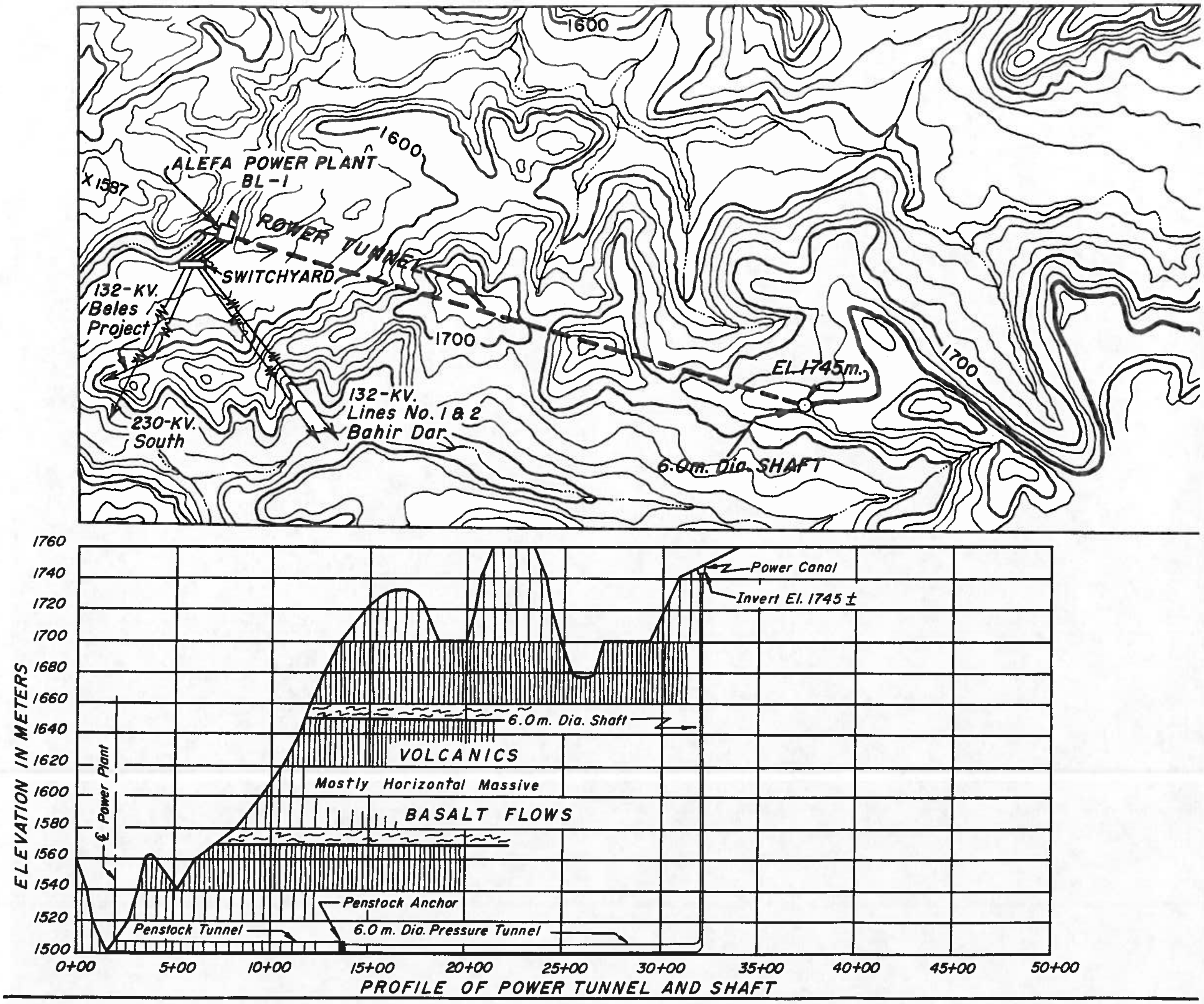
(9) 245 km. 230-kv. transmission line, conductors only, for one circuit, Lekkemt Substation to Akaki No. 2 Substation. Install on existing steel towers, Dabana Project.

(10) Stage 02, Lekkemt Substation (Figure V-66, features V1, V2, V7, W2, W4, W5, Z1, Z2, Z3, KV1A, and KV11A).

(11) Stage 02, Akaki Substation No. 2 (Figure V-66, features V0, V6, KV0A, Z1, Z2, and Z3).

(12) Fiche Substation.

(13) Access roads and camps.


1600
1600
ALEFA POWER PLANT
BL-1
X 1587
POWER TUNNEL
SWITCHYARD
132-KV.
Beles
Project
1700
El. 1745m.
1700
132-KV.
Lines No. 1 & 2
Bahir Dar
230-KV.
South
6.0m. Dia. SHAFT
ELEVATION IN METERS
Power Canal
Invert El. 1745 ±
6.0 m. Dia. Shaft
VOLCANICS
Mostly Horizontal Massive
BASALT FLOWS
℄ Power Plant
Penstock Anchor
Penstock Tunnel
6.0 m. Dia. Pressure Tunnel
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
40+00
45+00
50+00
PROFILE OF POWER TUNNEL AND SHAFT

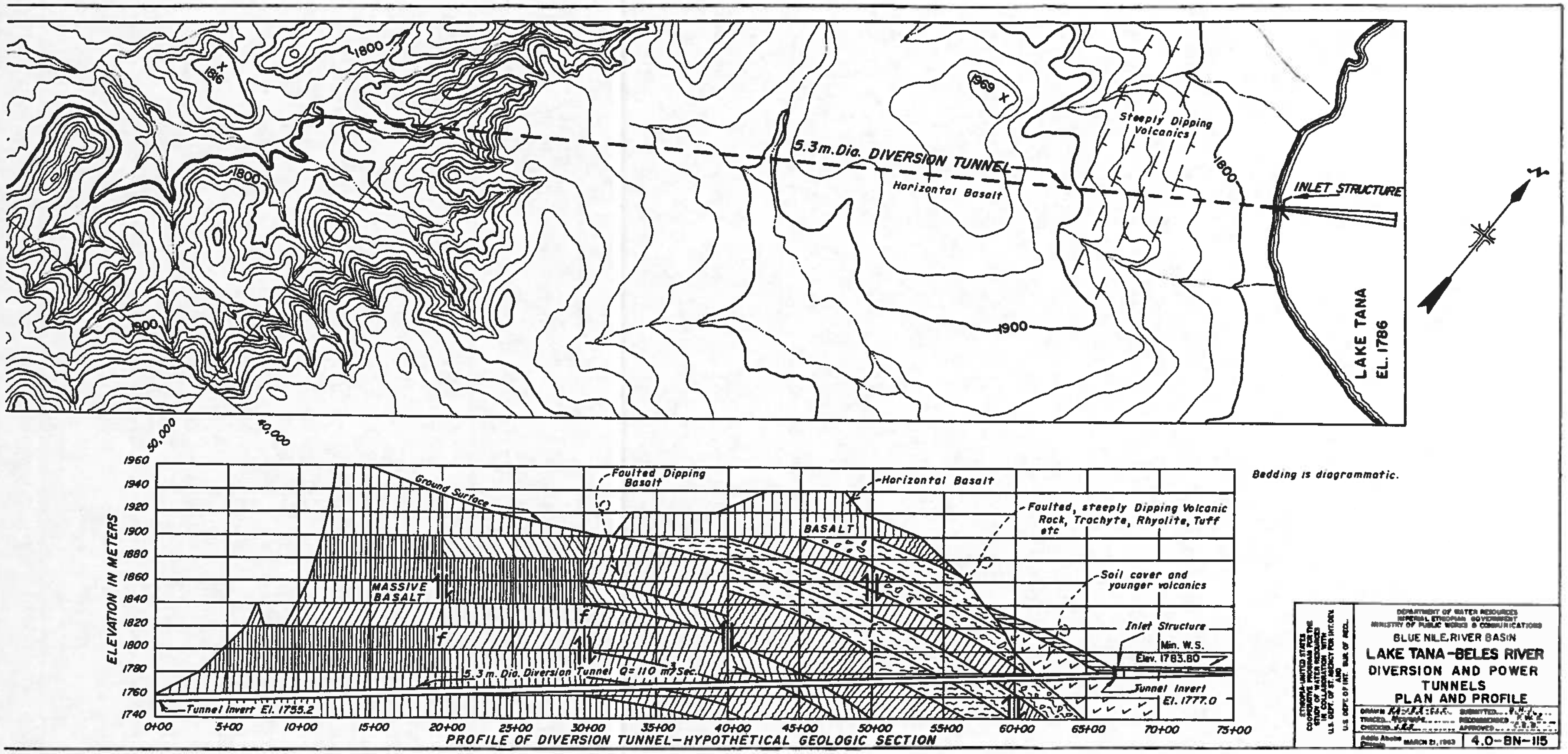


Figure V-46--Lake Tana-Beles River Diversion and Power Tunnels, Plan and Profile

Figure V-47--Angar Project's Lekkemt Damsite (AG-6) looking upstream. Water will be stored to serve two hydroelectric powerplants downstream. A system of canals and diversion dam will provide water to the powerplants. Direct pumping from the reservoir will serve irrigated lands.

The following transmission plant facilities are required for irrigation pumping:

(1) 20 km. 45-kv. transmission line, powerplant (AG-2) to N. Pump Plant No. 1.

(2) 7 km. 15-kv. line, N. Pump Plant No. 1 to N. Pump Plant No. 3.

(3) 13 km. N. Pump Plant No. 2 to N. Pump Plant No. 3.

(4) 15 km. 45-kv. transmission line, powerplant (AG-6A) to S. Pump Plant.

(5) Substations at North Pump Plant Nos. 1, 2, and 3, and S. Pump Plant.

It is possible to develop three powerplants on this project. The first is located at the toe of Angar Dam (AG-2), which is several kilometers upstream of Lekkemt Dam (AG-6). See location map, Figure V-48. Lekkemt Dam (AG-6) supplies a power canal some 17 kilometers long, which in turn supplies water to powerplant AG-6A. From the tail-race of powerplant AG-6A, the water returns to the Angar River and is again diverted by a small dam into another 5-kilometer canal, which in turn supplies water to a second powerplant, AG-6B. The profile of the river is given on Figure V-49, and indicates why this particular stretch of the river is adaptable to the project plan shown on Figure V-48.

Characteristics of the three powerplants are as indicated by Figure V-66 and as shown below:

Powerplant AG-2 (at AG-2 damsite)

Number of generators	2
Rating of each generator	20,000 kw. at 0.8 PF, 50-cycle
Plant installed capacity	50,000 kv.-a.
Turbines, each	28,220 hp. (English) Francis
Synchronous speed	214 r.p.m.
Design head	69.1 m.

Powerplant AG-6A (from AG-6 canal)

Number of generators	2
Rating of each generator	50,000 kw. at 0.8 PF, 50-cycle
Plant installed capacity	125,000 kv.-a.
Turbines, each	70,550 hp. (English) Francis
Synchronous speed	250 r.p.m.
Design head	168 m.

Powerplant AG-6B (from canal)

Number of generators	2
Rating of each generator	22,500 kw. at 0.8 PF, 50-cycle
Plant installed capacity	56,250 kv.-a.
Turbines, each	31,748 hp. (English) Francis
Synchronous speed	214 r.p.m.
Design head	74.5 m.

Special switchyard facilities are indicated for powerplants AG-6A and AG-2 to provide for the operation of pumping plants on the Angar Project.

Because of the long canals and anticipated limitation on forebay storage, powerplant AG-6A, with an installed capacity of 100,000 kw. would, in certain circumstances, in an adverse water year such as 1913-14 have a dependable peaking capacity of 77,000 kw.

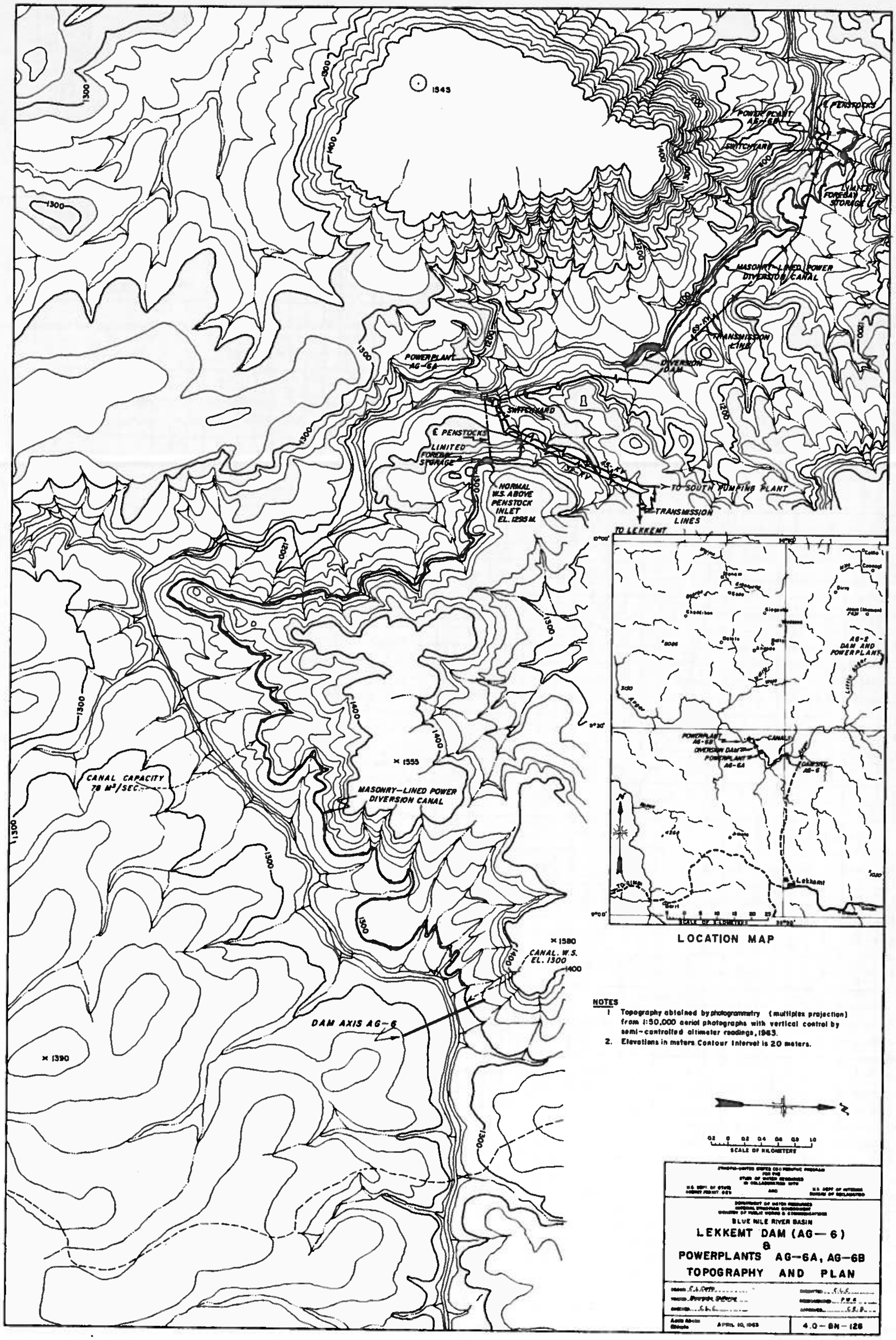


Figure V-48--Lekkemt Dam (AG-6) and Powerplants AG-6A, AG-6B--Topography and Plan

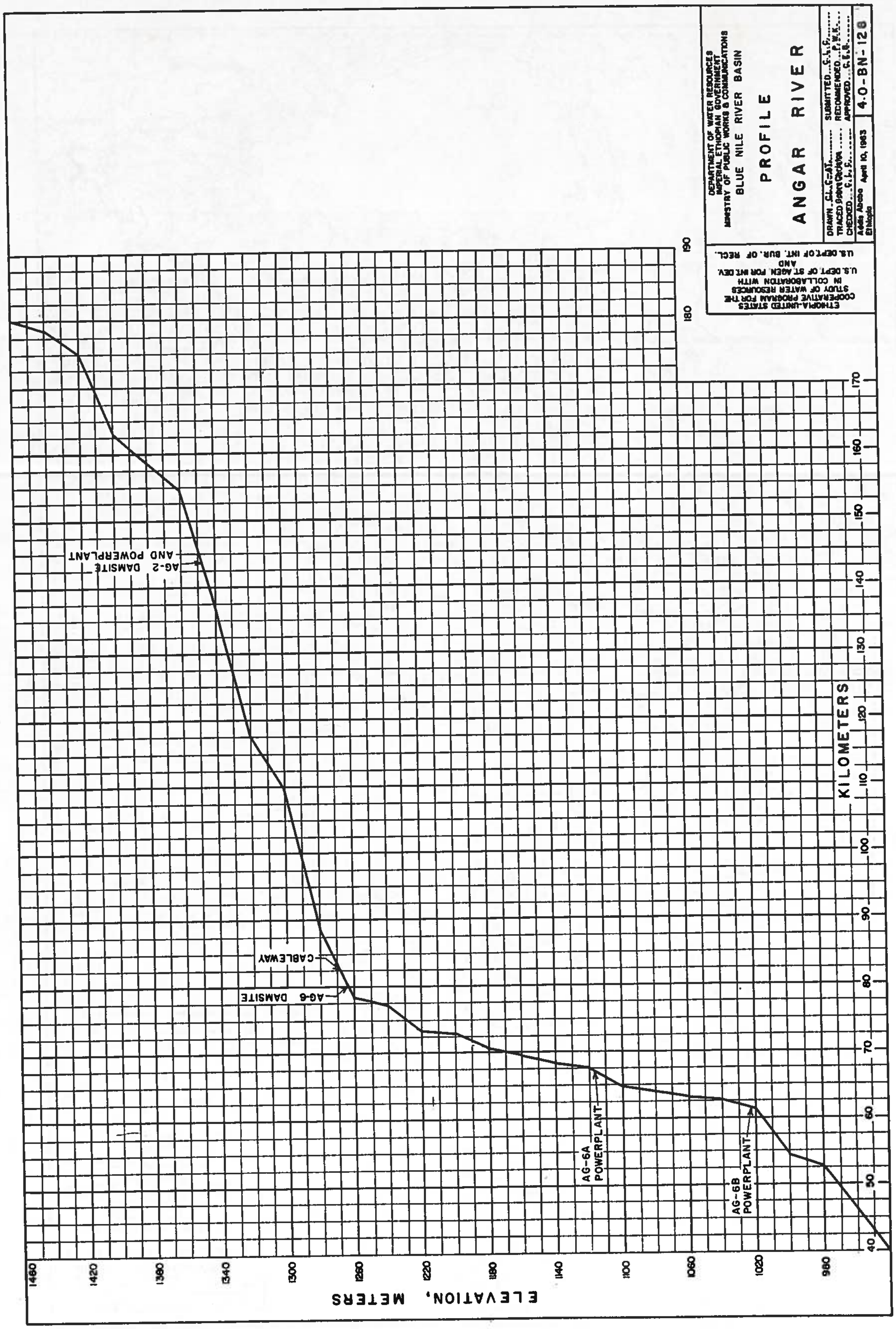


Figure V-49--Profile Angar River

Similarly, powerplant AG-6B would have a dependable peaking capacity of 35,000 kw. in these special circumstances.

Total energy available from all three plants in an adverse water year is estimated at 1,148,000,000 kw.-hr. under one type of operation.

Lower Guder Project

This single-purpose power project has these major facilities. (For details, see "Plans and Estimates," Appendix I.)

(1) Motto Dam.

(2) Powerplant (GU-1), 50 mw., and switchyard.

(3) 60 km. 132-kv. double circuit steel tower transmission line from (GU-1) to Agere Hiywet Substation.

(4) 110 km. 161-kv. steel tower transmission line from Agere Hiywet Substation.

(5) 5 km. 132-kv. transmission line tie from East Substation to Central Addis Ababa.

(6) Agere Hiywet Substation.

(7) Stage 05, East Substation (Figure V-64, features V1, W2, Y1, Y2, and KV1A).

(8) Access road and camp.

This powerplant is located near the toe of an earth-rockfill dam on the Guder River as shown by Figure V-50. It is capable of generating 224,900,000 kw.-hr. annually on a firm basis considering available water supplies over a period of time which included adverse water years. The electrical installations are as indicated by Figure V-64 with the powerplant characteristics as summarized below:

Number of generators	2
Rating of each generator	25,000 kw. at 0.8 PF, 50-cycle
Plant installed capacity	62,500 kv.-a.
Turbines, each	35,275 hp. (English) Francis
Synchronous speed	230 r.p.m.
Design head	86.1 m.

Plant output will be delivered to the South Region interconnected system at Agere Hiywet by means of 132-kv. transmission lines.

Arjo-Diddessa Project

Briefly, this multiple-purpose project will have these power or joint-use facilities:

(1) Diddessa Dam.

(2) Powerplant (DD-11) 30 mw. and switchyard.

(3) 60 km. 132-kv. steel tower transmission line to Jima.

(4) Jima Substation.

(5) Access road and camp.

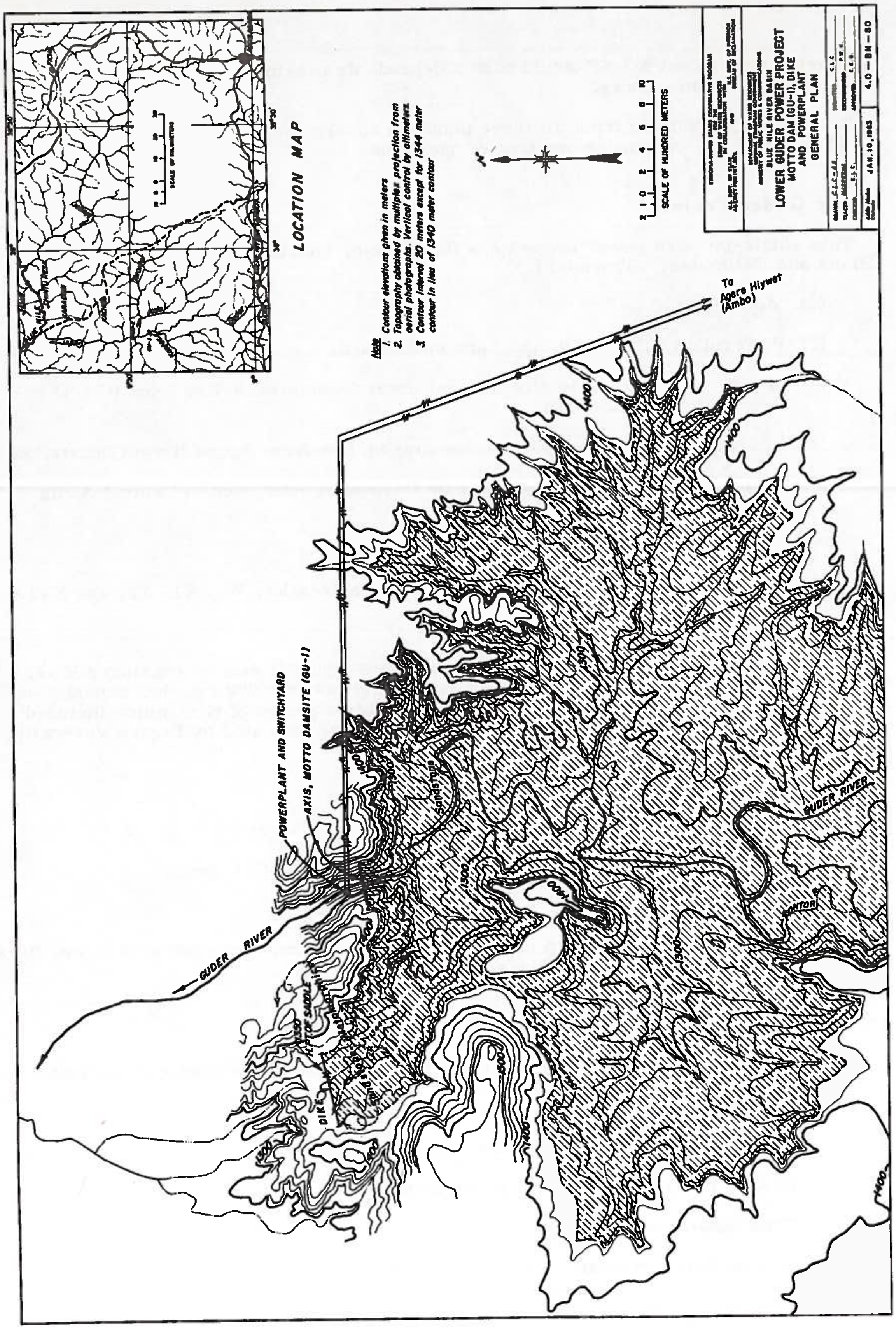


Figure V-50--Lower Guder Power Project--Motto Dam (GU-1), Dike, and Powerplant--General Plan

Figure V-51--Lower Guder Project damsite (GU-1) looking upstream. The dam, 50-mw. powerplant, and transmission facilities will be the major features of this single-purpose hydroelectric power project.

An earth-rockfill dam (DD-11) on the Diddessa River supplying water to a powerplant near the toe of the dam will provide a firm supply of 145,500,000 kw.-hr. per year in addition to providing water for irrigation purposes downstream. See Figure V-52.

The electrical facilities required are as indicated by Figure V-64. The powerplant will supply power to Jima and Addis Ababa over a 132-kv. line to Jima. The need for the development of this power facility is not anticipated in this study prior to the last decade of this century.

The powerplant characteristics may be summarized as follows:

Number of generators	2
Rating of each generator	15,000 kw. at 0.8 PF, 50-cycle
Plant installed capacity	37,500 kv.-a.
Turbines, each	21,165 hp. (English) Francis
Synchronous speed	214 r.p.m.
Design head	53 m.

Lower Diddessa Project

Facilities in this single-purpose power project include the following:

(1) Boo Dam.

(2) Powerplant (DD-2), 320 mw., and switchyard with related powerplant circuits.

(3) 325 km. 230-kv., double-circuit transmission line, from (DD-2) to Akaki No. 2 Substation.

(4) 10 km. 230-kv. steel tower transmission line tie, Akaki No. 2 Substation to East Substation.

(5) 80 km. 230-kv. (DD-2) to Lekkemt Substation.

(6) 245 km. 230-kv. transmission line, Lekkemt to Akaki No. 2 Substation.

(7) Stage 03, Lekkemt Substation (Figure V-66, features V5 and V6).

(8) Stage 03, Akaki Substation No. 2 (Figure V-66, features V1, V2, V3, V4, V5, W1, W2, W3, W4, X1, X2, X3, X4, X5, S1, S2, and KV10A).

(9) Stage 02, Gore Substation (Figure V-66, features X1, KX1A, and Z1).

(10) Stage 06, East Substation (Figure V-64, feature V3).

(11) Access road and service facilities.

The powerplant, located near the toe of an earth-rockfill dam as shown by Figure V-54, is capable of producing 1,400,000,000 kw.-hr. of firm annual energy considering the effects of adverse water years. The electrical installations are as indicated by Figure V-66 and as summarized below:

Number of generators	4
Rating of each generator	80,000 kw. at 0.8 PF, 50-cycle
Plant installed capacity	400,000 kv.-a.
Turbines, each	112,883 hp. (English) Francis
Synchronous speed	150 r.p.m.
Design head	97.1 m.

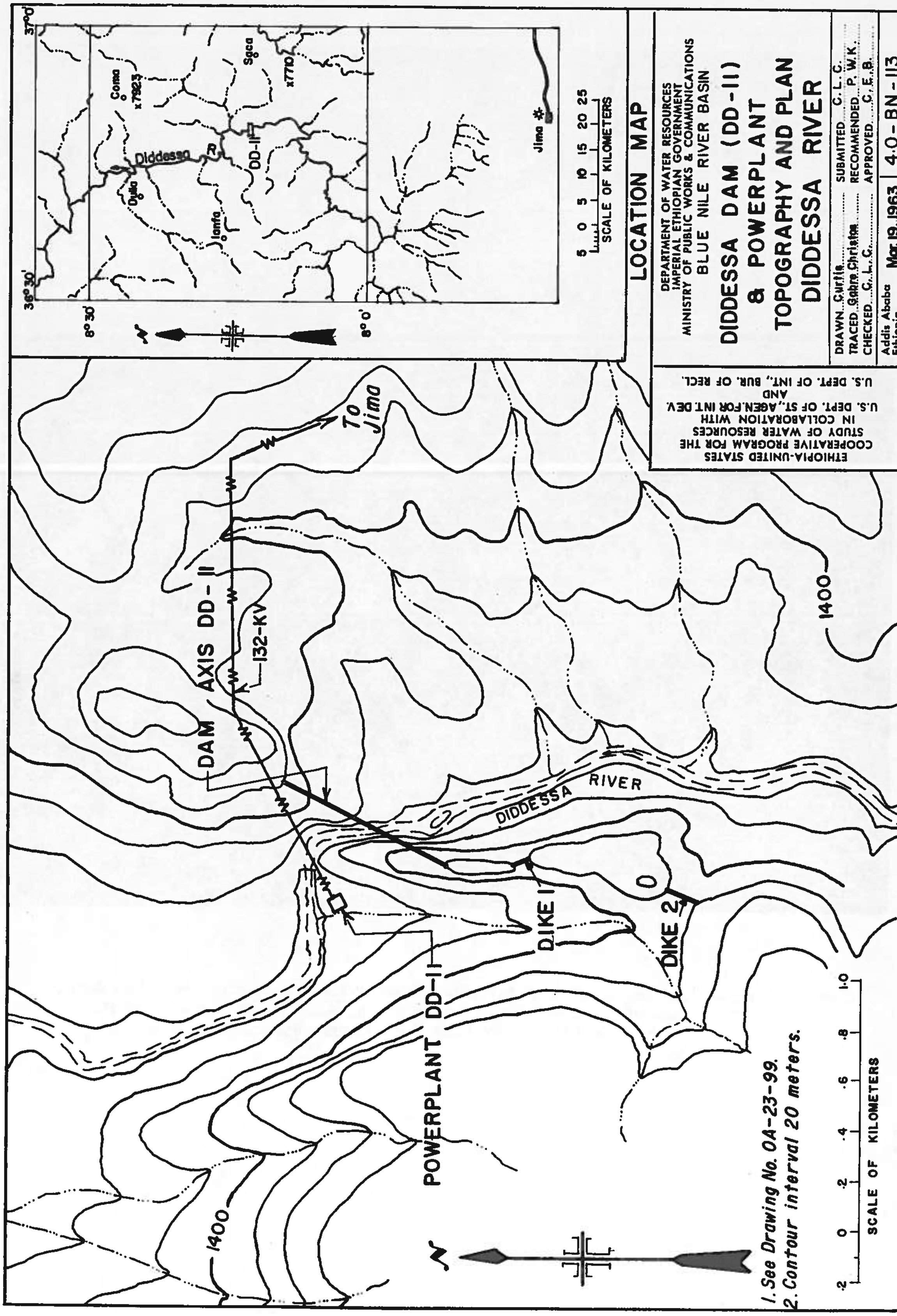


Figure V-52--Diddessa Dam (DD-II) and Powerplant--Topography and Plan

Figure V-53--Lower Diddessa damsite (DD-2), looking upstream. The dam, 320-mw. powerplant, and transmission facilities will be the major features of this single-purpose hydroelectric power project.

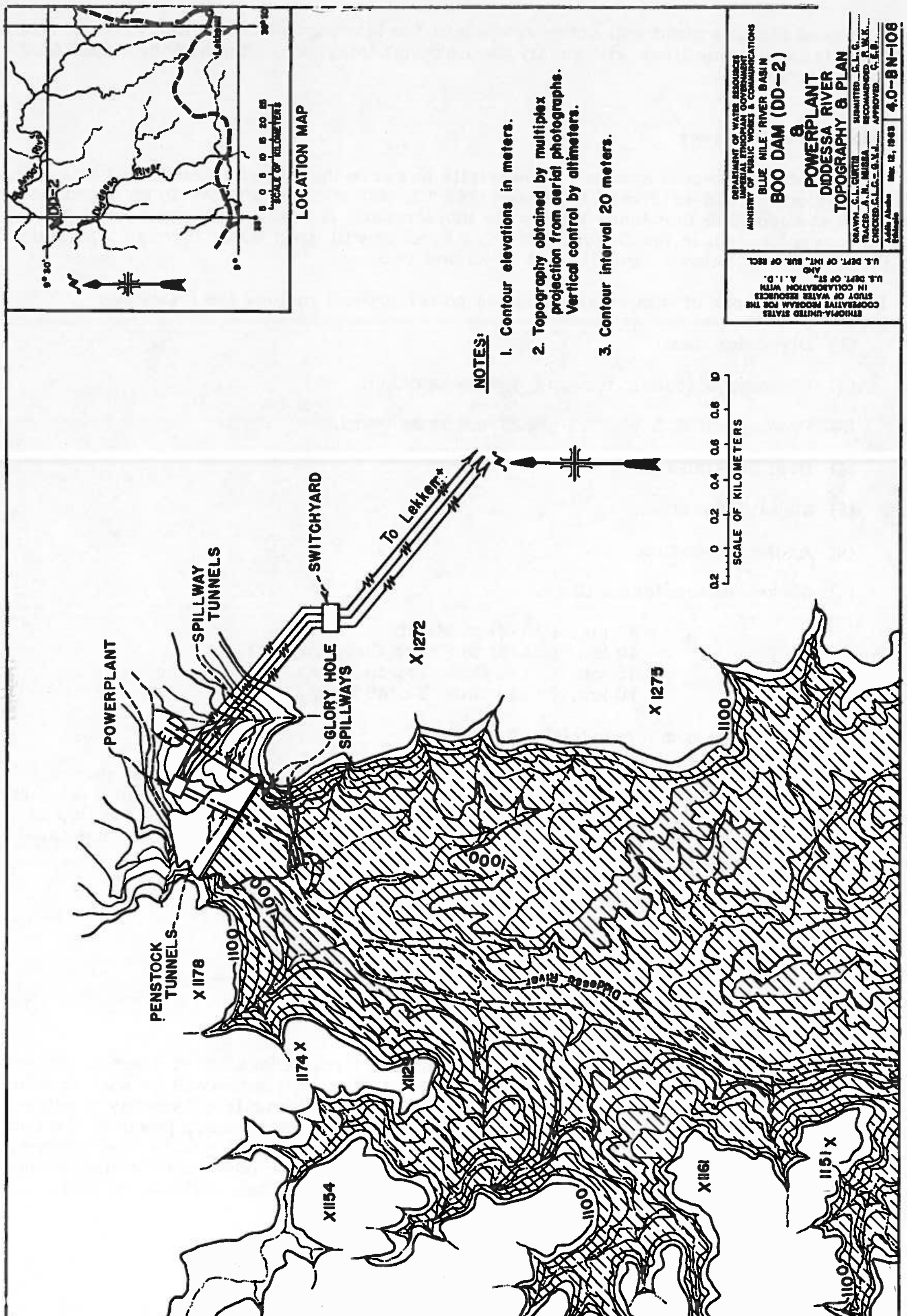


Figure V-54--Boo Dam (DD-2) and Powerplant--Topography and Plan

The need for this plant will not develop until the late part of this century, when three 230-kv. transmission lines will supply the Lekkemt interconnection and the Addis Ababa area with power.

Dabus Power Project

To provide a low-cost source of electricity to serve the Asosa, Mendi, and Begi areas (West Region) a "run-of-river" type powerplant installation may prove to be a satisfactory solution at such time that loads justify the investment. A 3,400-m. power canal from a small diversion dam in the Dabus River to a forebay will drop water through a penstock to the powerplant below. See Figures V-55 and V-62.

Briefly, features of this single-purpose power project include the following:

(1) Diversion dam.

(2) Waterways (canal, forebay, and penstocks).

(3) Powerplant (DA-8), 7.5 mw., and switchyard.

(4) Begi Substation.

(5) Mendi Substation.

(6) Asosa Substation.

(7) 45-kv. transmission lines:

30 km. (DA-8) to Mendi
40 km. (DA-8) to Chera Gude Tap
25 km. Chera Gude Tap to Asosa
70 km. Chera Gude Tap to Begi

(8) Access road and service facilities.

Powerplant capacity is based upon available water supplies in a minimum month of record, February 1914. The average water flow during that month was 11 m^3/sec.; and with the net head of about 89 meters, the "run-of-river" installation would develop in excess of 7,500 kw. The characteristics of these electrical facilities are as indicated by Figure V-62 and as summarized below:

Number of generators	2
Rating of each generator	3,750 kw. at 0.8 PF, 50-cycle
Plant installed capacity	9,375 kv.-a.
Turbines, each	5,290 hp. (English) Francis
Synchronous speed	600 r.p.m.
Design head	89 m.

If operated at 100 percent plant factor, the annual firm generation of electric power would be about 65,500,000 kw.-hr. However, load characteristics will be such that for the isolated system served, 38,511,000 kw.-hr. will be the maximum energy requirements for many years. The predominant lighting load will show sharp peaks at the early hours of the evening and drop off steeply thereafter. Load factors will be low. Hence, kilowatts, not kilowatt-hours will govern. The capacity of the powerplant could be doubled in future years if a plant factor of about 50 percent should prevail ultimately, and provisions could be made for peaking operation.

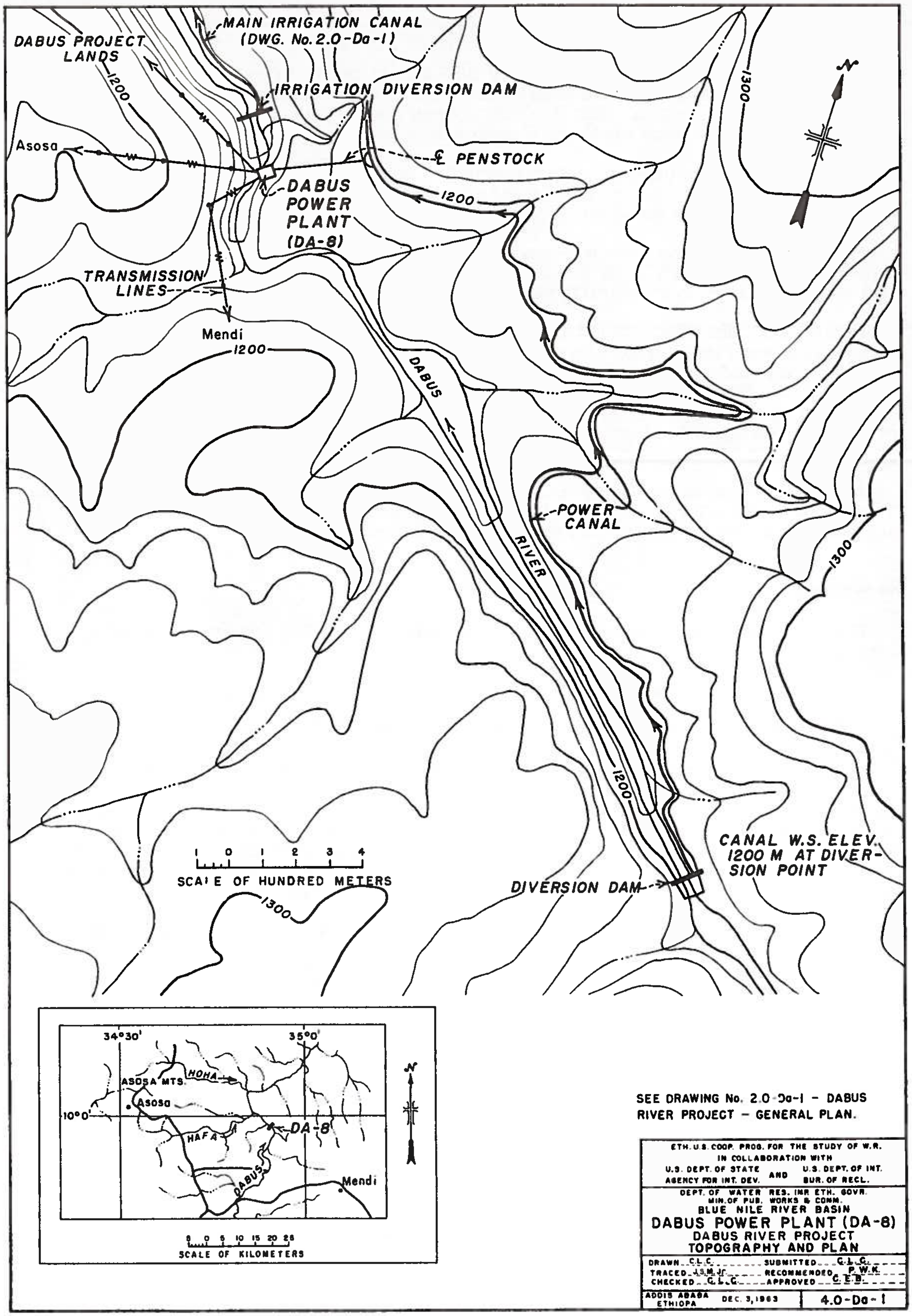


Figure V-55--Dabus Power Plant (DA-8)--Topography and Plan

Powerplant Installation Schedule

Tables V-108 and V-111 and Figure V-56 indicate 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 1963 through 1983 when interconnection with the South Region might develop.

Estimated peak generation requirements are based upon load estimates given earlier in this section wherein the maximum possible load growth was estimated considering many factors including goals set forth in the Second 5-year Development Plan.

For the North Region, use was made of the potential Gilgel Abbay Powerplants which were derated in capacity to be consistent with criteria used in establishing firm generator capability for other potential Blue Nile powerplants.

Figure V-57 and Table V-111 indicate 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.

Maximum possible load growth is also reflected by the installation schedules, Figure V-57, especially after 1982, when the target goal of establishing an industrial-agricultural economy is assumed to have been accomplished.

Reserves

There are different conceptions of the purpose of providing reserve generating capacity:

1. Provide for maintenance of equipment.
2. Provide for an unexpected increase in load.
3. Provide for loss of generator capacity due to unexpected failure of equipment.

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.

Overall national December averages of reserve margin in the United States were as follows from 1954 through 1961: 2/

Year	Percent reserve margins (December)
1954	20.6
1955	18.6
1956	19.7
1957	22.2
1958	27.1
1959	30.2
1960	31.5
1961	34.0

1/ Prior to formation of the National Grid, however, there will be generators installed in some plants which might be considered as "spares" during the early formative years of the regional systems.
2/ *Electrical World*, September 17, 1962.

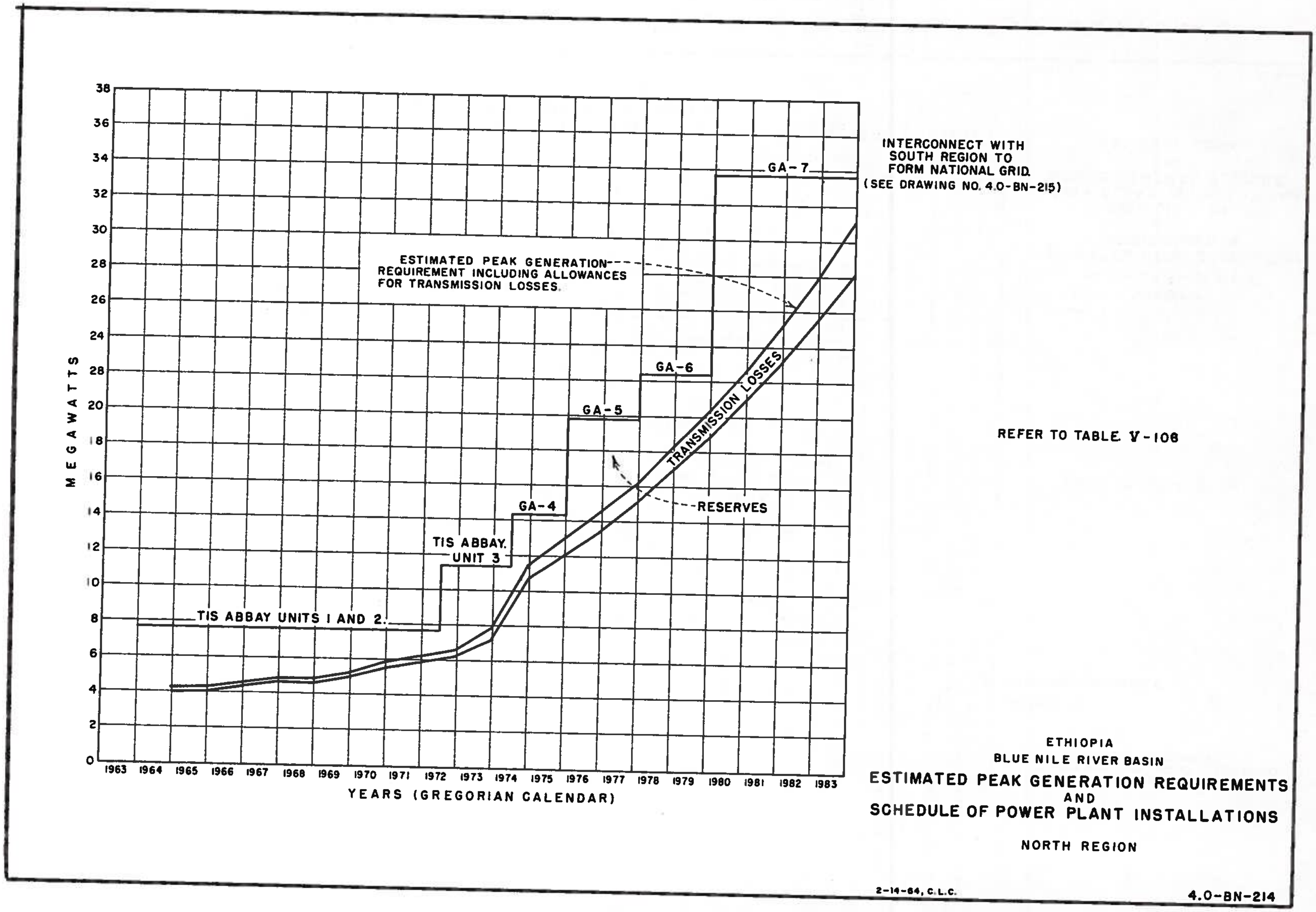


Figure V-56--Estimated Peak Generation Requirements and Schedule of Power Plant Installations--North Region

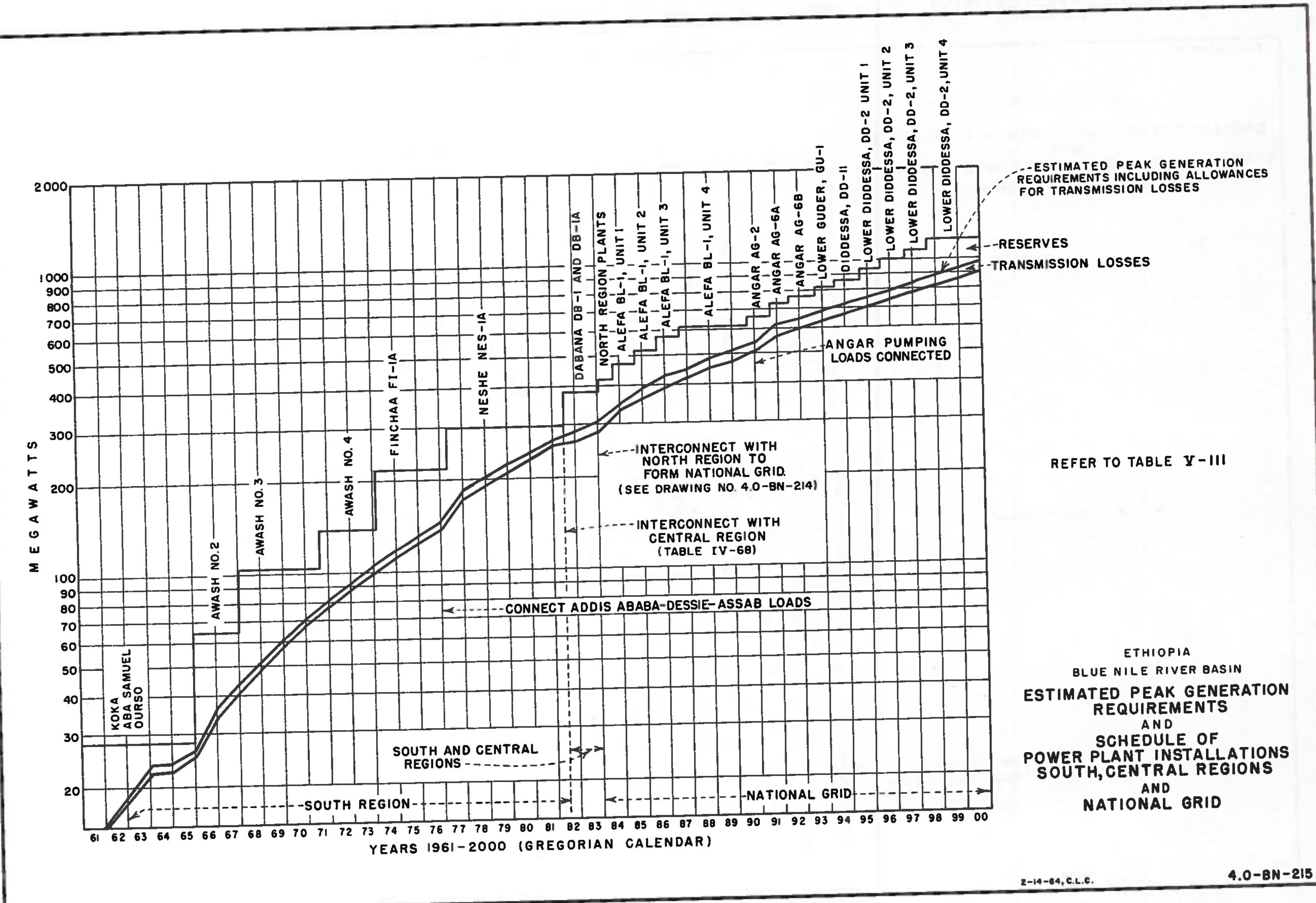


Figure V-57--Estimated Peak Generation Requirements and Schedule of Power Plant Installations--South, Central Regions, and National Grid

Some individual systems in the United States varied widely from the above.

In Ethiopia, reserve margins based upon December peaks are estimated as follows for the South, Central, and the ultimately combined regions forming the National Grid (Table V-111 and Figure V-57):

Year	Percent reserve margins (December)	
1964	15	
1965	29	(Includes Addis Steam and Alemaya Diesel, without which reserve margin would be 4 percent)
1966	44	
1967	33	
1968	49	
1969	39	
1970	29	
1971	40	
1972	32	
1973	28	
1974	47	
1975	40	
1976	33	
1977	39	
1978	32	
1979	26	
1980	18	
1981	9	
1982	26	
1983	19	
1984	24	
1985	24	
1986	25	
1987	26	
1988	21	
1989	16	
1990	16	
1991	16	
1992	16	
1993	16	
1994	15	
1995	19	
1996	21	
1997	23	
1998	24	
1999	20	
2000	15	

The large percentage of installed reserve capacity in the early years is to be expected on the theory that the reserve capacity should about equal the largest single unit in the system. A special situation exists in regard to the South Region interconnected system which is new, coming into existence in 1960 with one significant powerplant (Koka). The third unused turbine-generator unit at Koka is available as a "spare," and this term is used because it is believed that all three units will not normally be operated simultaneously;1/ and therefore, the third unit may not be considered as contributing toward a

1/Operating three units simultaneously probably would be avoided because of underregulated water supply and probably inability to use the additionally released water from the third unit downstream at the cascaded Powerplants 2, 3, and 4.

system reserve margin in the usual meaning of the term. The third unit may be considered available as a "spare" for meeting maintenance schedules for the other two units, but probably should be discounted as a long-range source of generation for reserve margins.

Initially, because of the South Region's widely separated Finchaa Sub-basin and Awash plants, located at the ends of long transmission lines with the Addis Ababa load located toward the center, each basin for an initial period might have its own reserves. This, however, would be rather costly, as the largest Awash and Finchaa units would be about 18.5 and 40 mw. respectively, or 58.5 mw. total.

Unusually large reserves, such as that indicated for 1966, 1968, and 1971, result from the completion of the full hydroelectric project all at once and avoid staggered generator schedules within a given plant. It would be too costly to bring in another contractor just to install the second generators and appurtenant facilities, for example, at Finchaa or Neshe, which would be required within a period of less than 2 years in any case, following operation of the first generator. While it represents a sizable investment, the second generator in each plant could be used initially as a "spare" during regular annual maintenance periods.

SECTION V--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 initial development in the next century. All are single-purpose power projects with the exception of (DI-7).

Project	Possible installed capacity, kw.	Possible firm annual generation, kw.-hr. 1/
Giamma (GI-1)	60,000	270,810,000
Muger Project,	26,000	2/121,600,000
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 (DI-7)	40,000	178,700,000
TOTALS	5,864,000	26,461,810,000

These projects are shown on the Frontispiece and on Plate I (in back pocket).

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.

By comparison with Table V-111, 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.

From the preceding tabulation, the facilities indicated were not substituted for projects in the "present century" category for these reasons:

Giamma (GI-1).--The high installed cost per kilowatt, accessibility, and high initial investment discourages early construction. See Figure V-58.

Muger Project (MU-1 and MU-4).--The installed cost per kw. is very reasonable but the long range municipal and industrial water requirements at Addis Ababa may ultimately favor the use of MU-4 Reservoir for nonpower generating purposes. See Figure V-59.

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

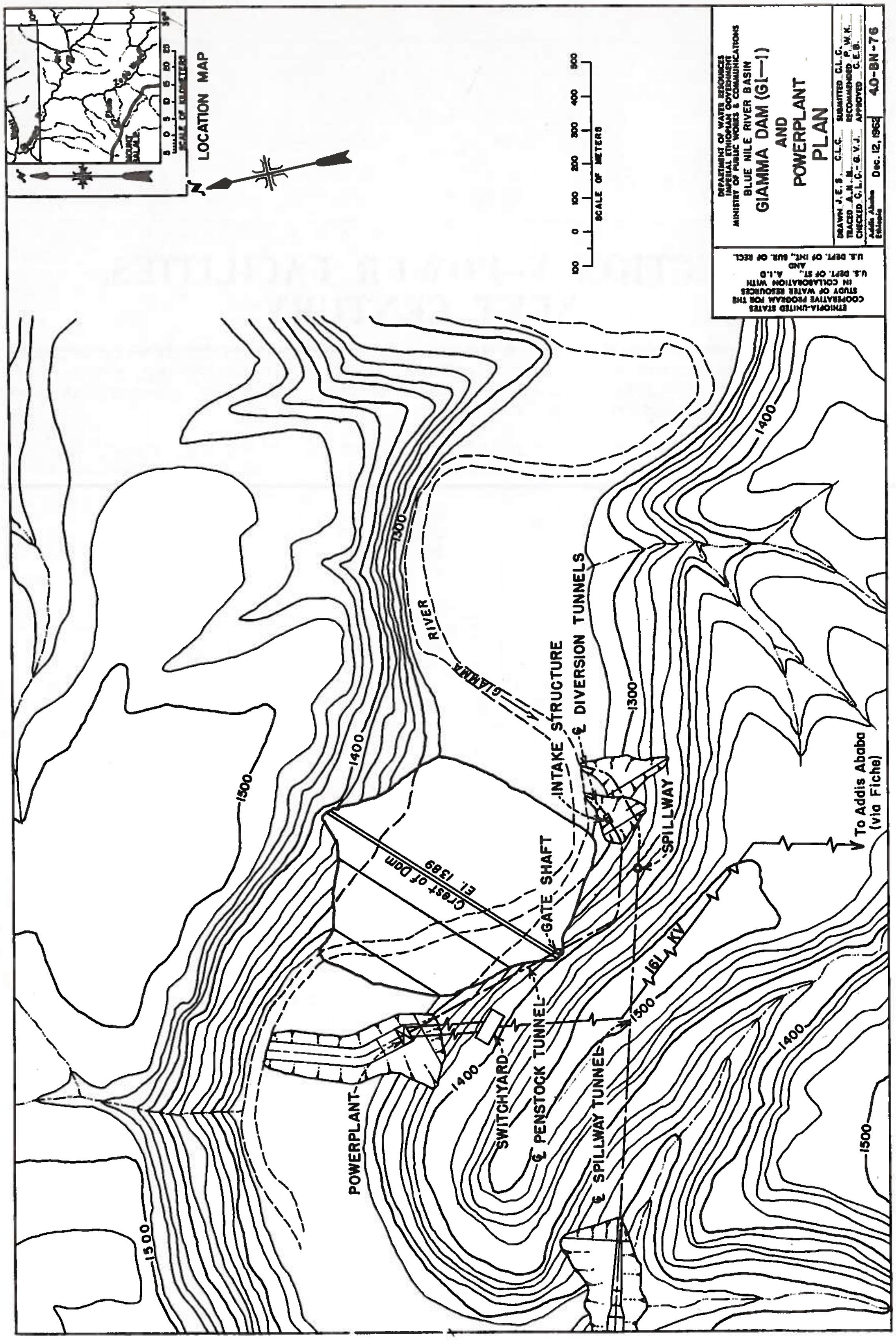


Figure V-58--Giamma Dam (GI-I) and Powerplant--Plan

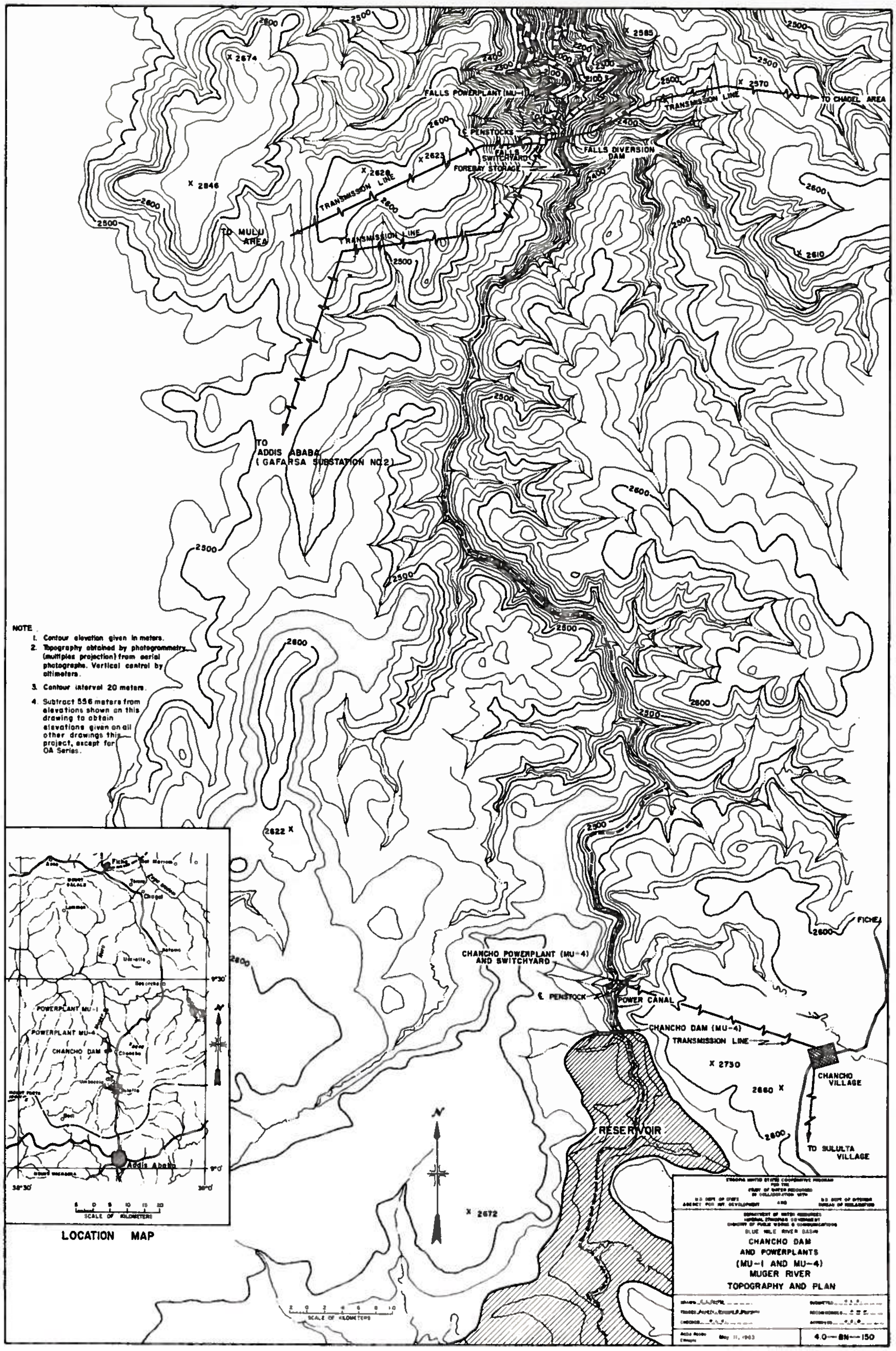


Figure V-59--Chancho Dam and Powerplants (MU-1 and MU-4)--Topography and Plan

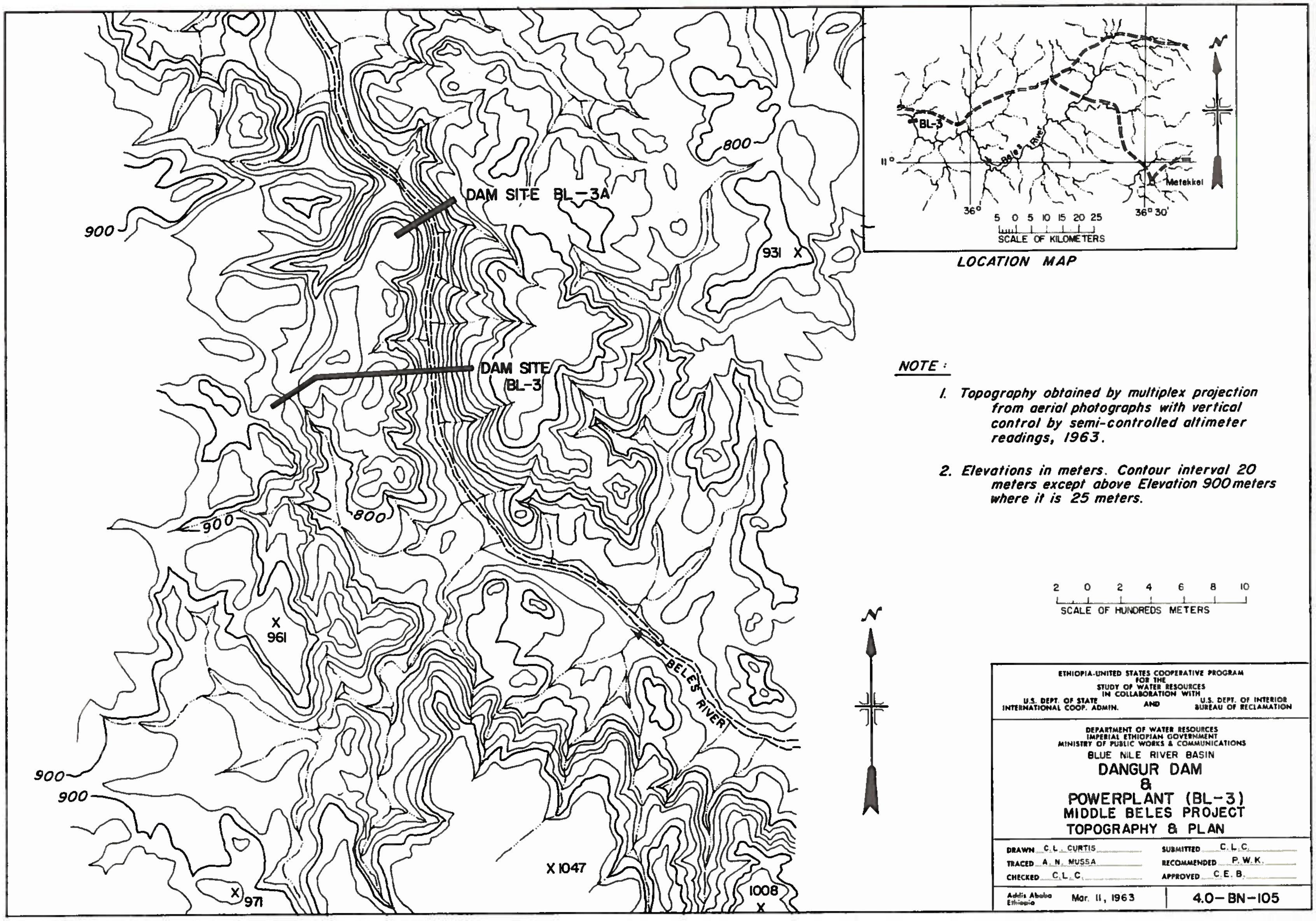


Figure V-60--Dangur Dam and Powerplant (BL-3)--Topography and Plan

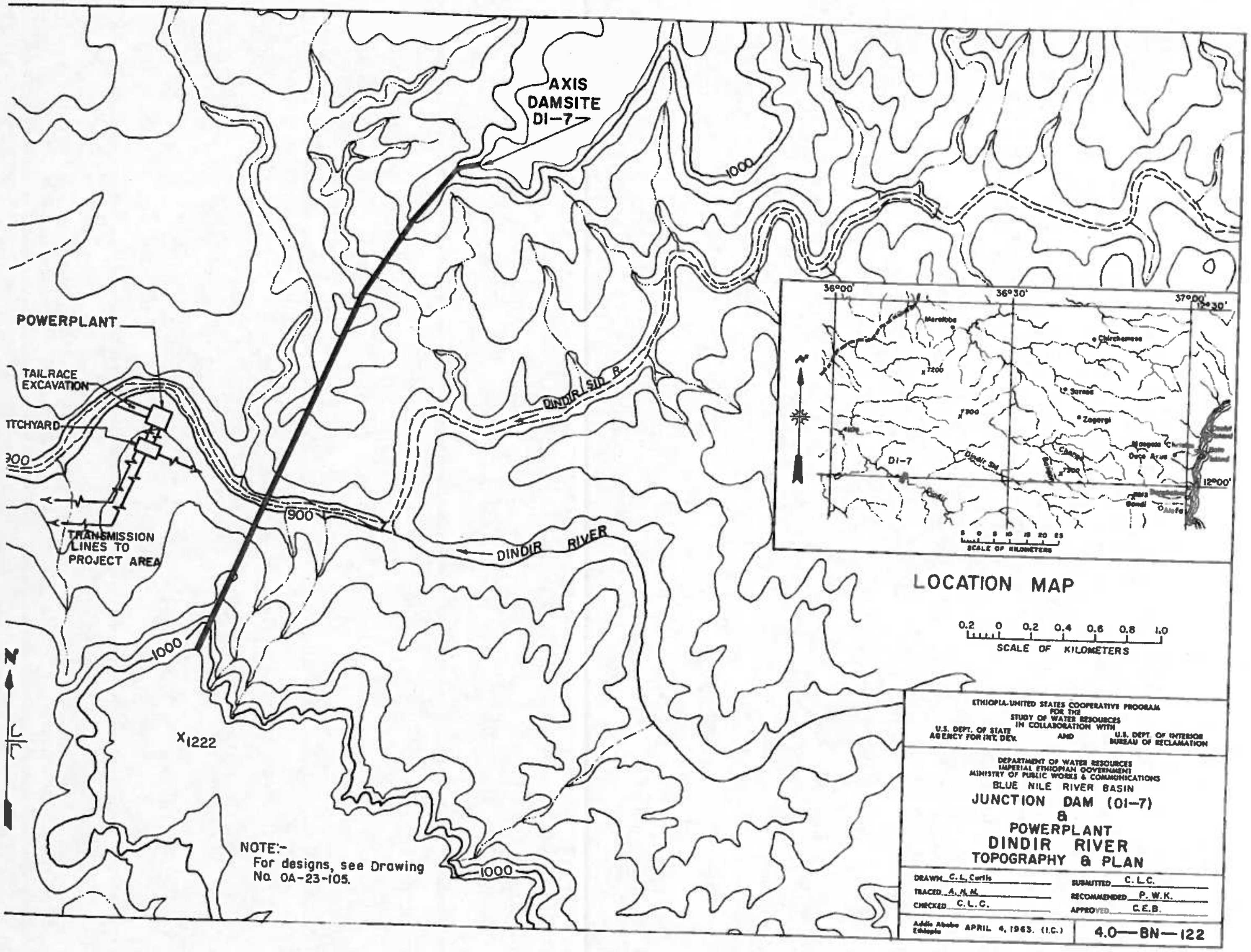


Figure V-61--Junction Dam (DI-7) and Powerplant--Topography and Plan

Karadobi (BN-3), Mabil (BN-19), Mendaia (BN-26A), and Border (BN-28).--The installed cost per kw. is very reasonable but the high initial investment and lack of a power market in the magnitude required for any one of these projects cannot justify construction in the present century. Karadobi (BN-3) may be justified early in the next century. This situation could easily change if international agreements with downstream countries resulted in an incentive for early construction.

Middle Beles (BL-3).--The full development of Alefa (BL-1) power facilities in the present century can only be justified with about one-half of its generation exported to the south region. There will be insufficient loads in the north region even by the year 2000 to utilize the full output from Alefa BL-1 powerplant unless exports become feasible to North Eritrea. Its distance from load centers discourages its early construction and therefore the need for it probably will not occur until the next century. See Figure V-60.

Junction (DI-7).--Power produced here will be a by-product of irrigation development, Dindir Project, and be used primarily for project purposes. Requirements will probably be established only after the initial irrigation development has been in operation for some time. It is not likely that this will occur in the present century. See Figure V-61.

The cost by projects of producing and delivering power and energy to load centers is discussed in Section IX.

Since it is impossible to forecast meaningful load requirements so far into the future, no specific time table of needs can be established for any of the powerplants in the preceding tabulation. Therefore, no technical studies for transmission plant facilities were made, although higher voltages than 230 kilovolts may be required in the future. For general costs of transmission plant facilities needed for transmission of full plant capacity away from the powerplants, some assumptions were made and the total costs are reflected in the project estimates, "Plans and Estimates," Appendix I. For engineering data concerning the four Blue Nile River Projects facilities refer to that Appendix.

Giamma Powerplant (GI-1)

Design head	90.4 m.
Number of generators	2
Rating of each generator	30,000 kw.
Total plant capacity	75,000 kv.-a.
Turbine rating (each)	42,330 hp.
Synchronous speed	230 r.p.m.
Type of turbines	Francis

Muger Project (MU-4 and MU-1)

Chancho Powerplant (MU-4)	
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)	1,415 hp.
Synchronous speed	750 r.p.m.
Type of turbines	Francis
Falls Powerplant (MU-1)	
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)	16,933 hp.
Synchronous speed	374 r.p.m.
Type of turbines	Impulse

Karadobi Project (BN-3)

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 (each)	158,800 hp.
Synchronous speed	200 r.p.m.
Type of turbines	Francis

Mabil Project (BN-19)

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 (each)	141,100 hp.
Synchronous speed	142 r.p.m.
Type of turbines	Francis

Mendaia Project (BN-26A)

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

Border Project (BN-28)

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

Middle Beles Project (BL-3) (Dangur)

Design head	87 m.
Number of generators	4
Rating of each generator	42,000 kw.
Total plant capacity	168,000 kw.
Turbine rating (each)	59,263 hp.
Synchronous speed	176.5 r.p.m.
Type of turbines	Francis

Dindir Project (DI-7) (Junction)

Design head	72.3 m.
Number of generators	4
Rating of each generator	10,000 kw.
Total plant capacity	40,000 kw.
Turbine rating (each)	14,110 hp.
Synchronous speed	333-1/3 r.p.m.
Type of turbines	Francis

SECTION VI-- TRANSMISSION PLANT, PRESENT CENTURY

The transmission plant that may exist by the end of the present century is represented in detail by the following regional system single-line diagrams:

Figure V-62 Reconnaissance System Diagram, West Region (4.0-BN-218)
Figure V-63 Reconnaissance System Diagram, North Region (4.0-BN-219)
Figure V-64 Reconnaissance System Diagram, South Region (Part) (4.0-BN-220)
Figure V-65 Reconnaissance System Diagram, South Region's, Addis Ababa-Assab Transmission Project (4.0-BN-221)
Figure V-66 Reconnaissance System Diagram, Central and South Region (Part) (4.0-BN-222)

Tables V-113 and V-114 provide suggested earliest possible in-service dates for the various transmission plant components.

On Table V-114 and the system diagrams, reference drawings are indicated that are mainly individual load center switching diagrams, all of which can be found in Annex "C" this Appendix. The more important individual switching diagrams show stage development as required to meet load growth demands with some in-service dates estimated. All individual switching diagrams identify which projects are represented, and derived project cost estimates in "Plans and Estimates," Appendix I, are on the basis of the diagrams.

Distribution lines generally have not been specifically identified. The 15-kilovolt lines have been identified only if they serve an outstanding function such as pumping plant motors.

ADDIS ABABA-ASSAB TRANSMISSION PROJECT

Essentially all of these transmission facilities are outside the Blue Nile River Basin Project area, but follow the east basin boundary for about 290 kilometers to the Dessie-Kembolcha area. From there the line route would be directly to Assab. This is a transmission plant project, and since it is not particularly identified with a specific Blue Nile River Basin power generation project due to location, no generation facilities are included. Sources of electric power and energy for these facilities can originate with the various interconnected Blue Nile power sources with the connection made at the East Substation on the outskirts of Addis Ababa. The rapid load growth at Dessie and Assab, together with the strategic importance of the latter, may eventually require outside sources of electricity.

These facilities are identified in Tables V-113 and V-114, and are shown on Figure V-67, "Addis Ababa-Assab Transmission Project." Briefly, they consist of the following features:

(1) 290 km. 230-kilovolt double-circuit steel tower transmission line from East Substation to Kembolcha

(2) 13 km. 132-kilovolt steel tower line from Kembolcha to Dessie

(3) 5 km. 132-kilovolt transmission line tie from East Substation Addis Ababa to Gafarsa No. 2 Substation

(4) 385 km. 230-kilovolt single-circuit steel tower transmission line from Kembolcha to Assab

(5) 110 km. 45-kilovolt steel tower transmission line from East Substation (Addis Ababa) to Debre Birhan

(6) 35 km. 45-kilovolt steel tower transmission line from Debre Birhan to Debre Sina

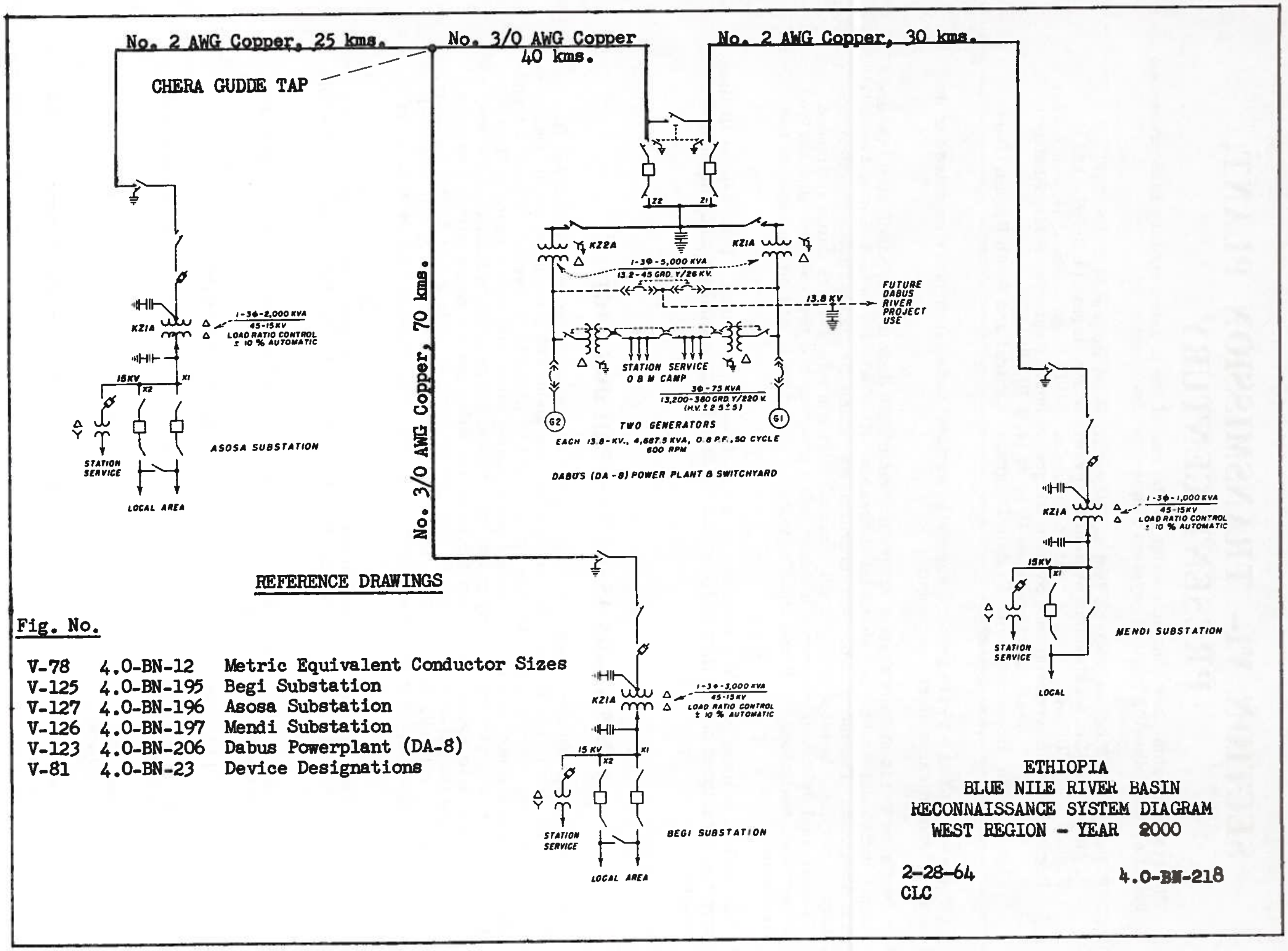
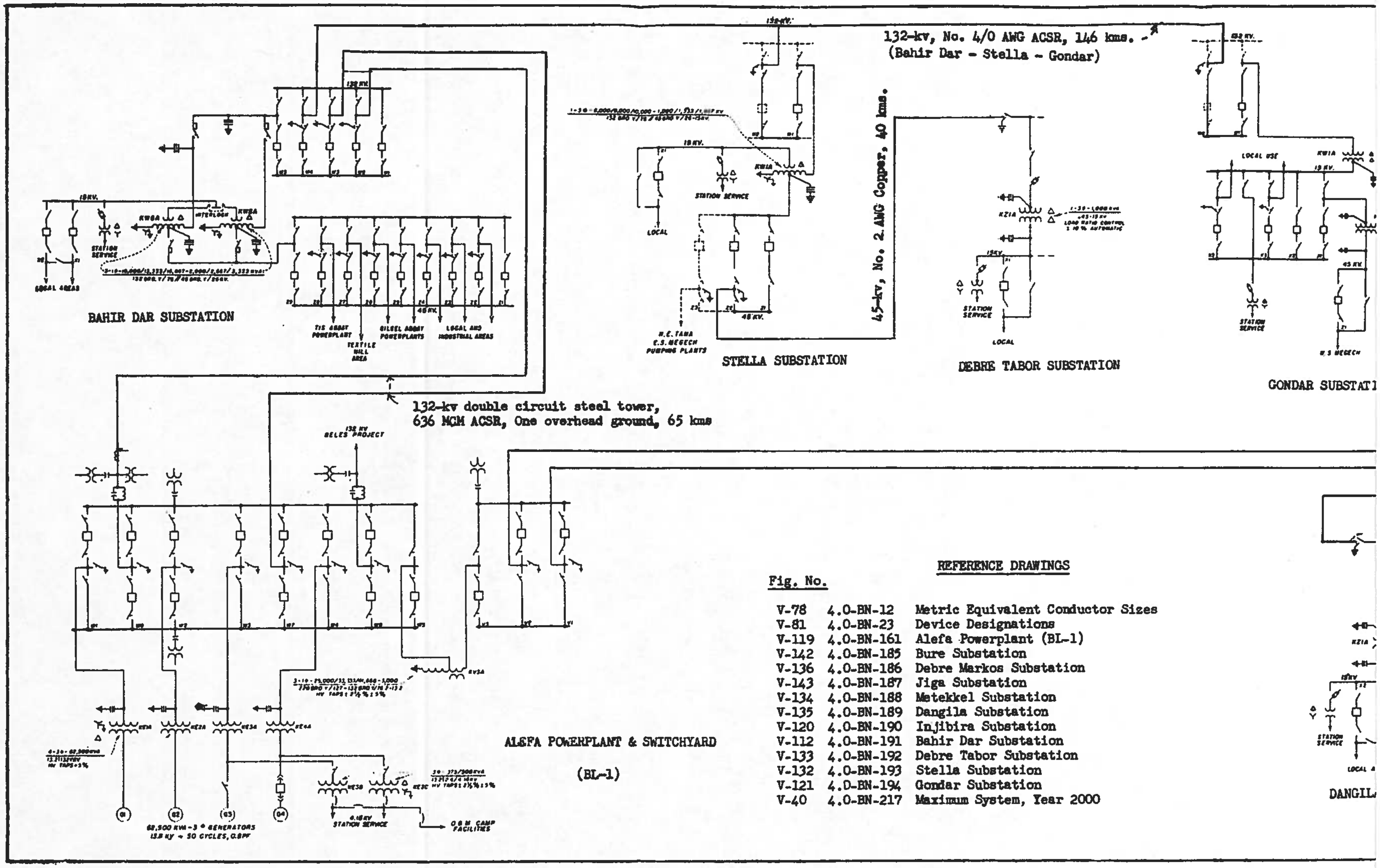


Figure V-62--Reconnaissance System Diagram--West Region--Year 2000



REFERENCE DRAWINGS

Fig. No.		
V-78	4.0-BN-12	Metric Equivalent Conductor Sizes
V-81	4.0-BN-23	Device Designations
V-119	4.0-BN-161	Alefa Powerplant (BL-1)
V-142	4.0-BN-185	Bure Substation
V-136	4.0-BN-186	Debre Markos Substation
V-143	4.0-BN-187	Jiga Substation
V-134	4.0-BN-188	Metekkel Substation
V-135	4.0-BN-189	Dangila Substation
V-120	4.0-BN-190	Injibira Substation
V-112	4.0-BN-191	Bahir Dar Substation
V-133	4.0-BN-192	Debre Tabor Substation
V-132	4.0-BN-193	Stella Substation
V-121	4.0-BN-194	Gondar Substation
V-40	4.0-BN-217	Maximum System, Year 2000

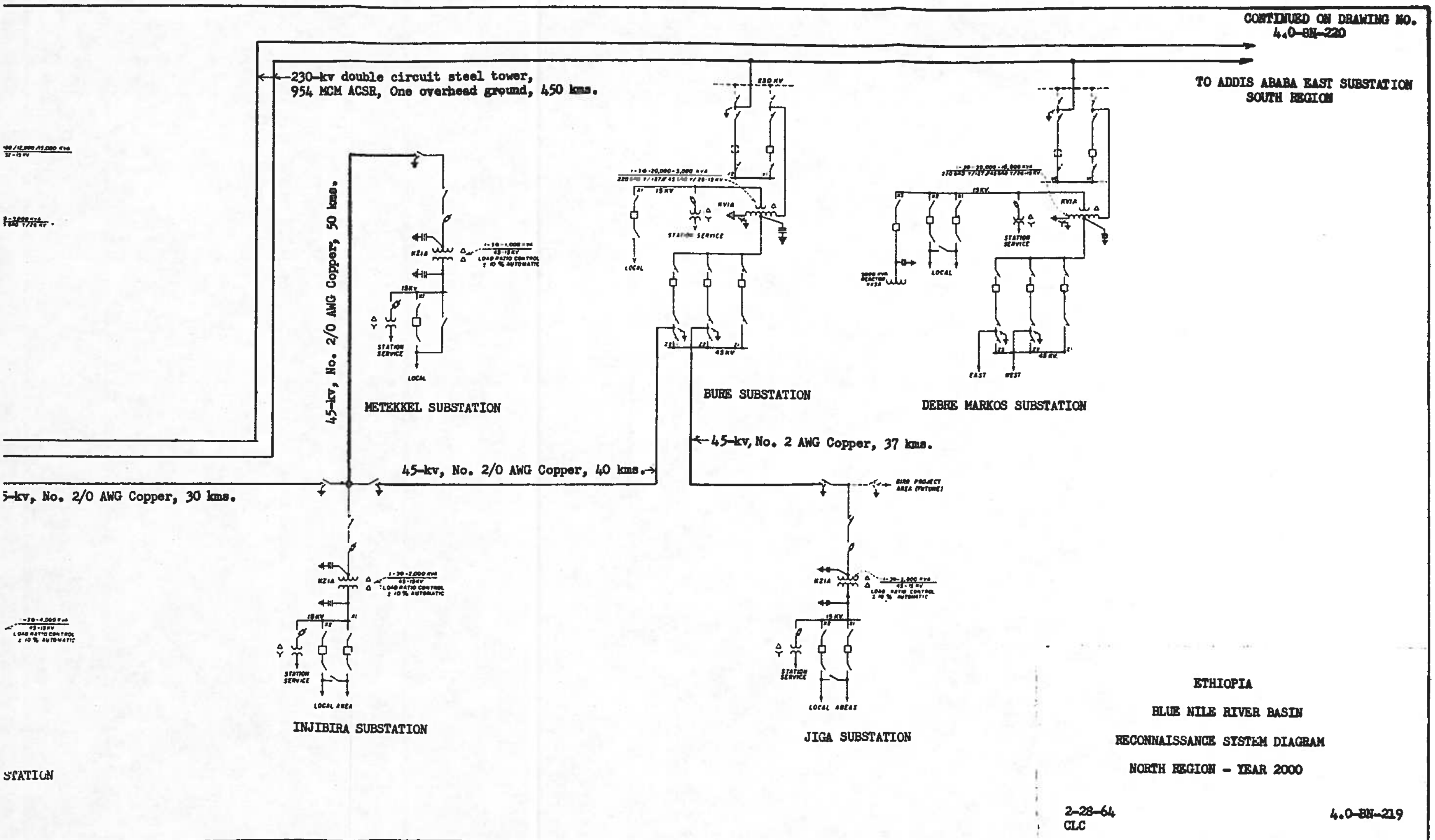
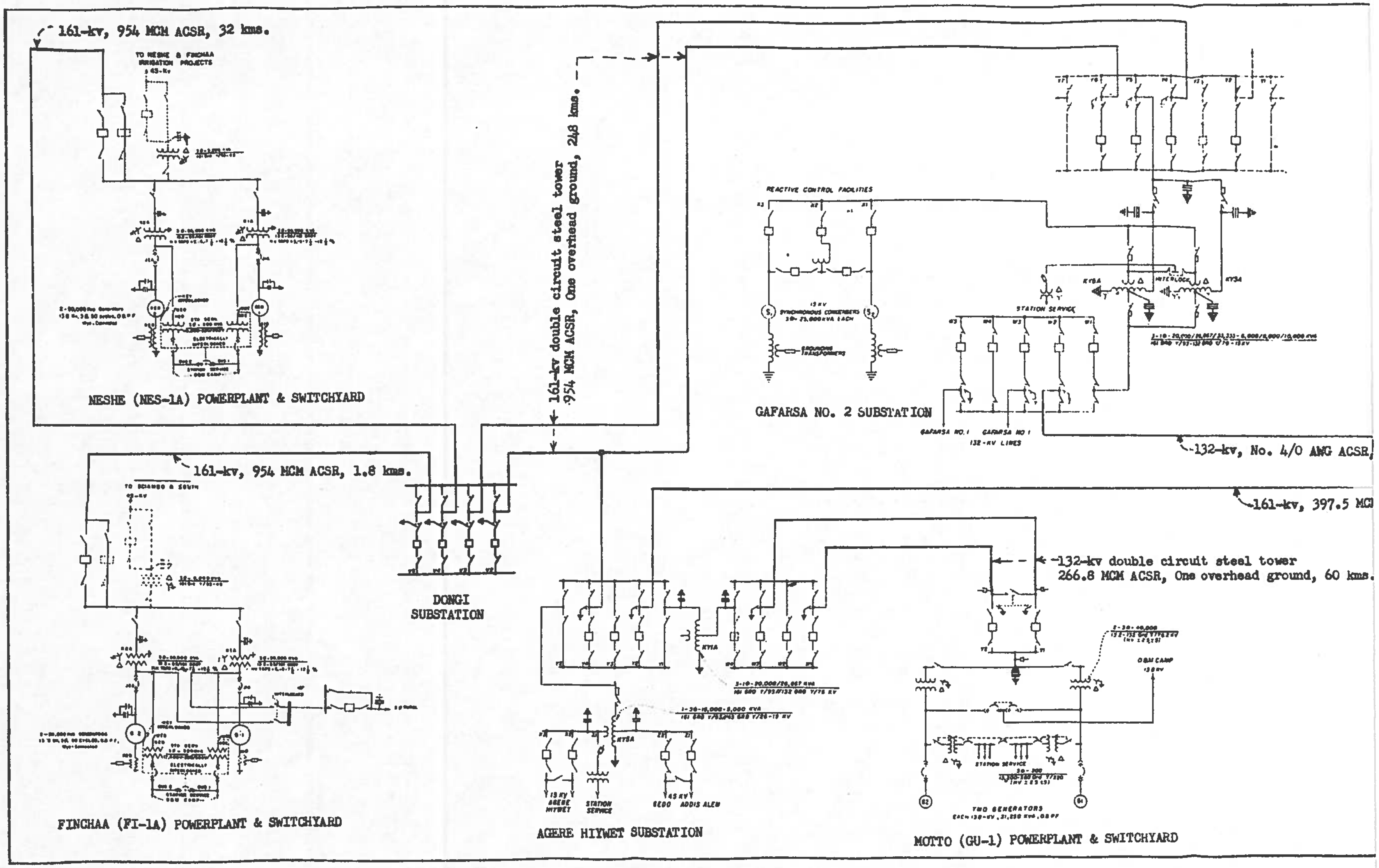


Figure V-63--Reconnaissance System Diagram--North Region--Year 2000


161-kv, 954 MCM ACSR, 32 kms.
TO NESHE & FINCHAA IRRIGATION PROJECTS
NESHE (NES-1A) POWERPLANT & SWITCHYARD
161-kv double circuit steel tower
954 MCM ACSR, One overhead ground, 248 kms.
161-kv, 954 MCM ACSR, 1.8 kms.
TO SCIANGO & SOUTH
DONGI SUBSTATION
FINCHAA (FI-1A) POWERPLANT & SWITCHYARD
REACTIVE CONTROL FACILITIES
13 KV SYNCHRONOUS CONDENSERS
GROUNDING TRANSFORMERS
STATION SERVICE
GAFARSA NO. 2 SUBSTATION
GAFARSA NO. 1
132-KV LINES
-132-kv, No. 4/0 AWG ACSR,
-161-kv, 397.5 MCM
-132-kv double circuit steel tower
266.8 MCM ACSR, One overhead ground, 60 kms.
OBM CAMP
STATION SERVICE
TWO GENERATORS
15 KV AGERE HIYWET
STATION SERVICE
45 KV GEDO ADDIS ALEM
AGERE HIYWET SUBSTATION
MOTTO (GU-1) POWERPLANT & SWITCHYARD

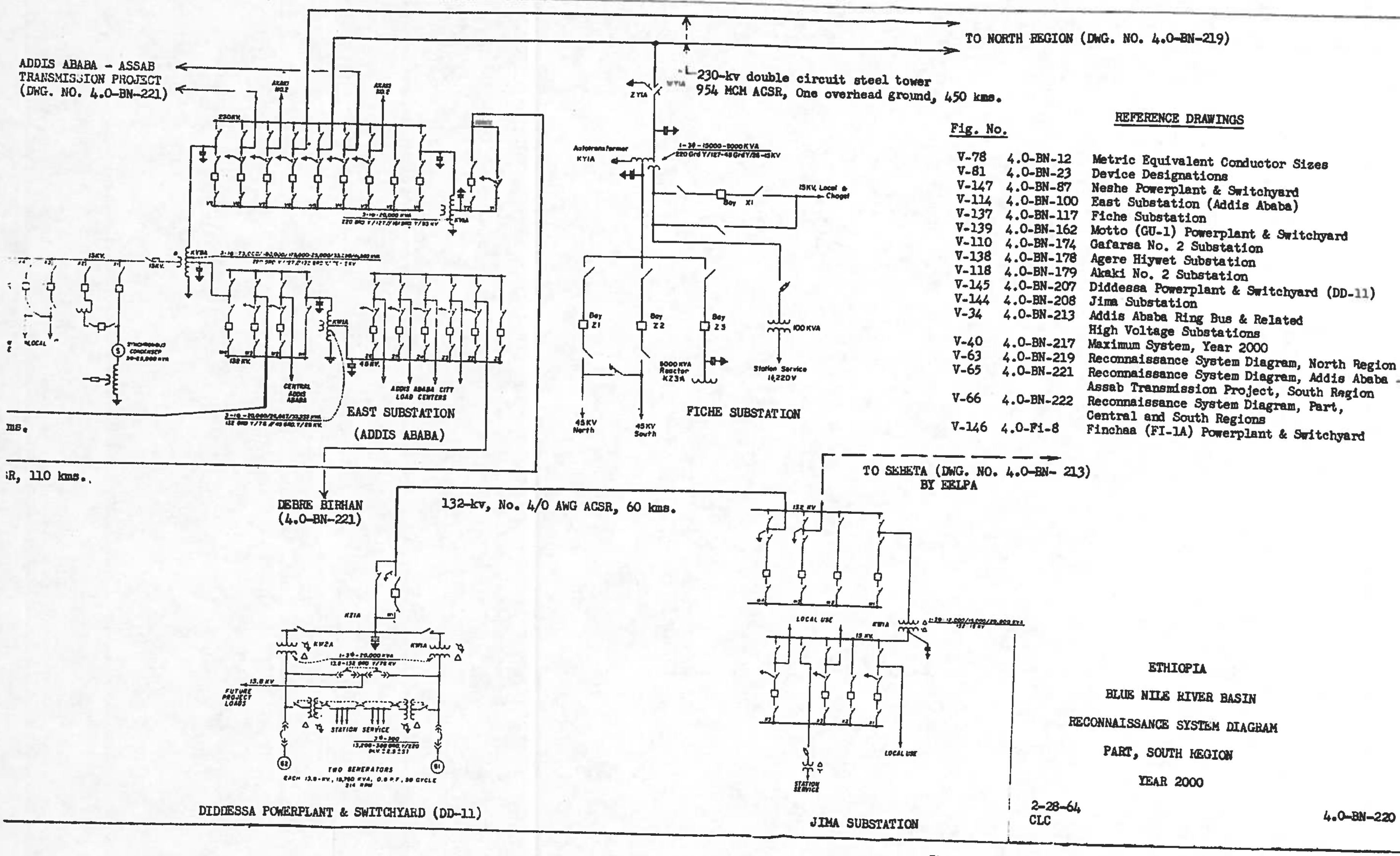
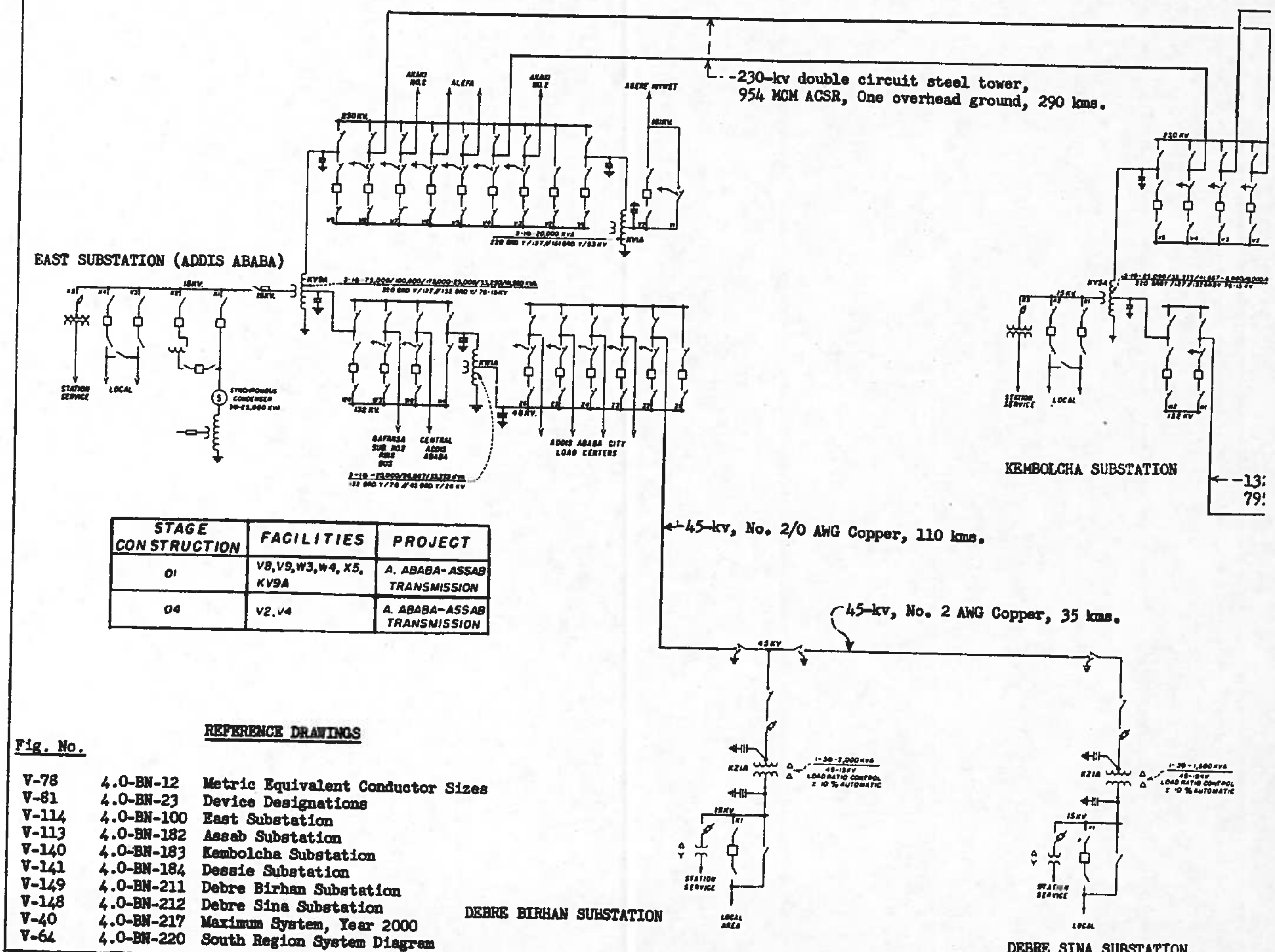


Figure V-64--Reconnaissance System Diagram--Part South Region--Year 2000



STAGE CONSTRUCTION	FACILITIES	PROJECT
01	V8, V9, W3, W4, X5, KV9A	A. ABABA-ASSAB TRANSMISSION
04	V2, V4	A. ABABA-ASSAB TRANSMISSION

REFERENCE DRAWINGS

Fig. No.		
V-78	4.0-BN-12	Metric Equivalent Conductor Sizes
V-81	4.0-BN-23	Device Designations
V-114	4.0-BN-100	East Substation
V-113	4.0-BN-182	Assab Substation
V-140	4.0-BN-183	Kembolcha Substation
V-141	4.0-BN-184	Dessie Substation
V-149	4.0-BN-211	Debre Birhan Substation
V-148	4.0-BN-212	Debre Sina Substation
V-40	4.0-BN-217	Maximum System, Year 2000
V-64	4.0-BN-220	South Region System Diagram

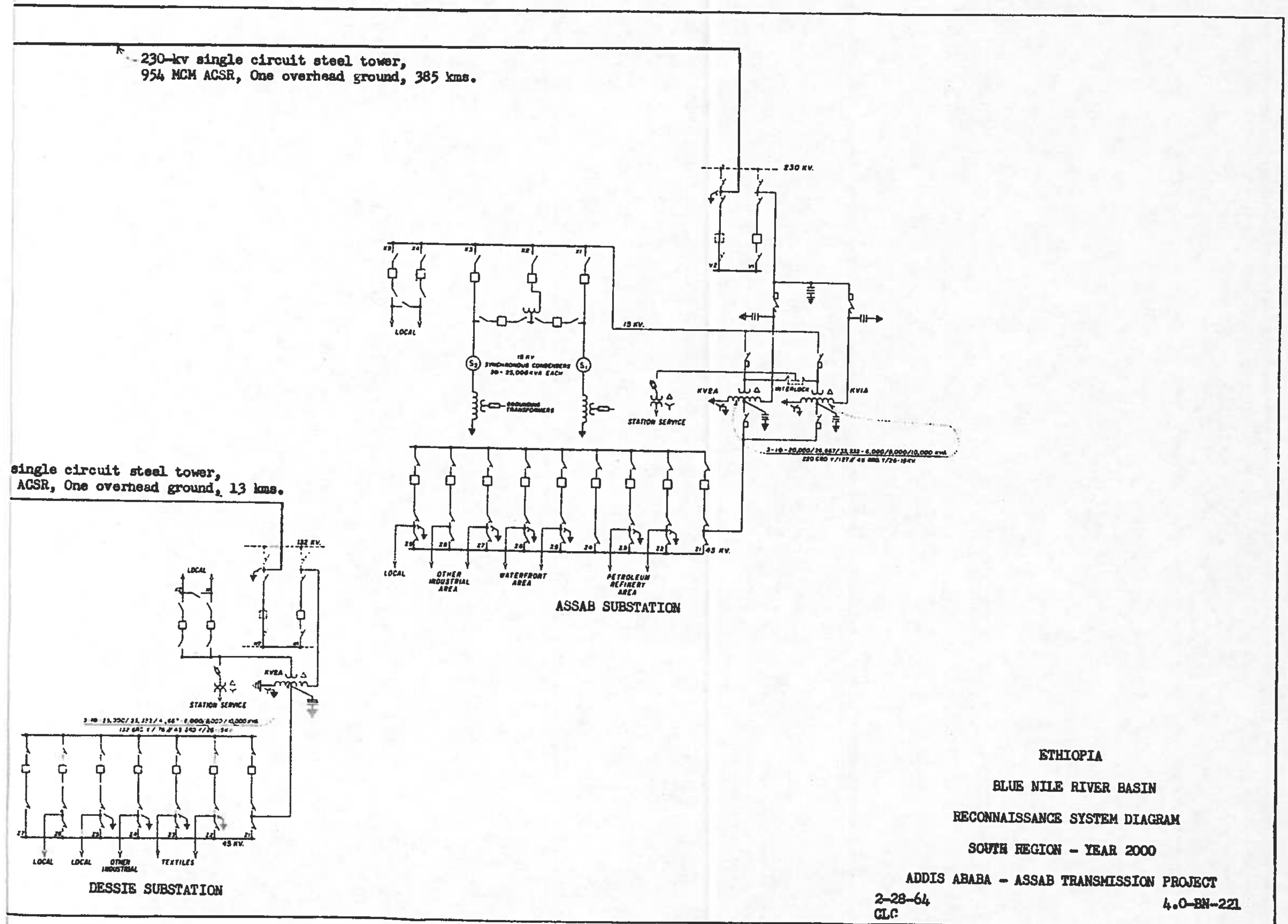
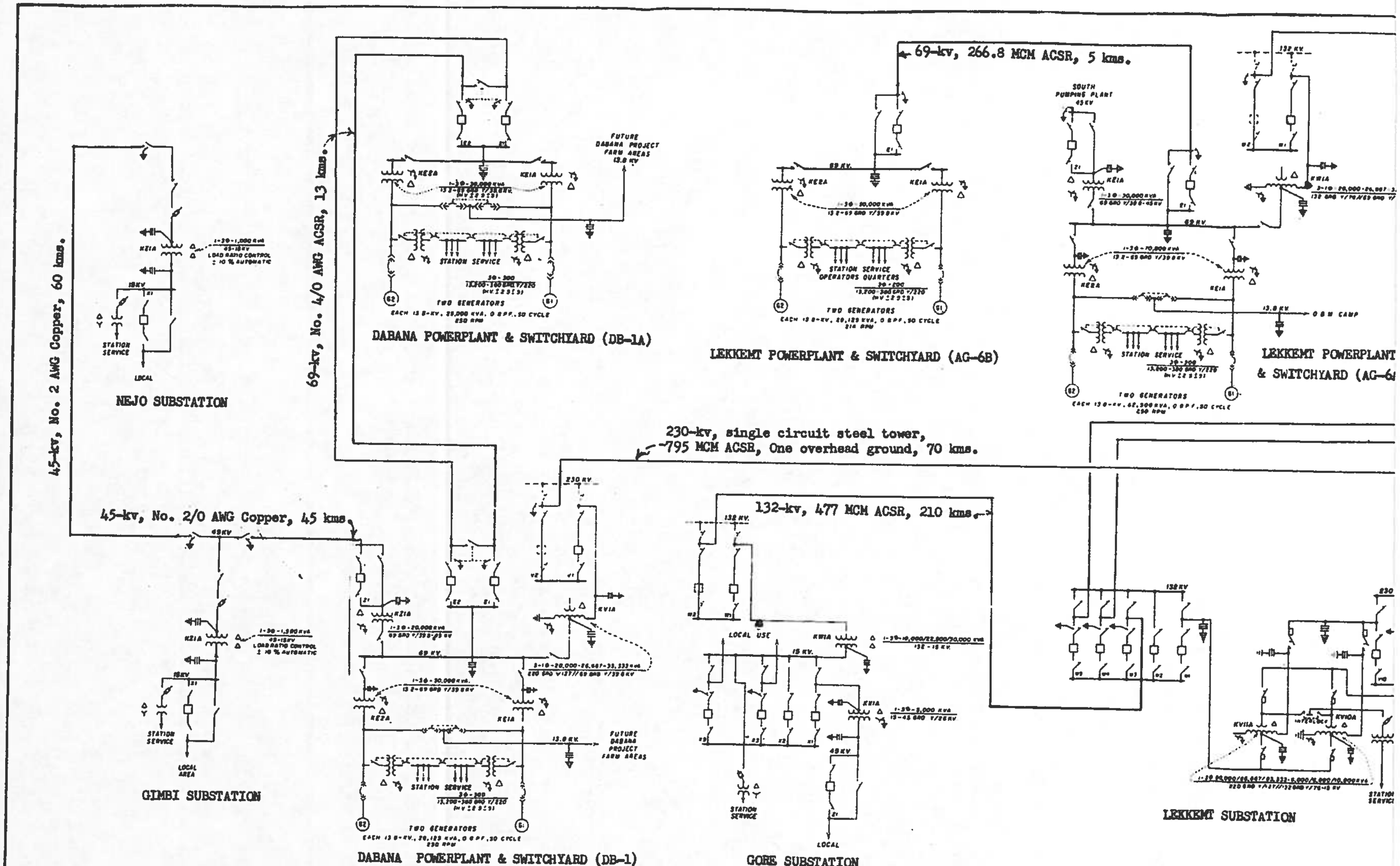


Figure V-65--Reconnaissance System Diagram--South Region--Year 2000



69-kv, 266.8 MCM ACSR, 5 kms.
SOUTH PUMPING PLANT 45 KV
FUTURE DABANA PROJECT FARM AREAS 13.8 KV
45-kv, No. 2 AWG Copper, 60 kms.
69-kv, No. 4/0 AWG ACSR, 13 kms.
NEJO SUBSTATION
DABANA POWERPLANT & SWITCHYARD (DB-1A)
LEKKEMT POWERPLANT & SWITCHYARD (AG-6B)
LEKKEMT POWERPLANT & SWITCHYARD (AG-6
TWO GENERATORS
STATION SERVICE
OPERATORS QUARTERS
O B M CAMP
230-kv, single circuit steel tower, 795 MCM ACSR, One overhead ground, 70 kms.
45-kv, No. 2/0 AWG Copper, 45 kms.
132-kv, 477 MCM ACSR, 210 kms.
LOCAL USE
FUTURE DABANA PROJECT FARM AREAS
GIMBI SUBSTATION
DABANA POWERPLANT & SWITCHYARD (DB-1)
GORE SUBSTATION
LEKKEMT SUBSTATION

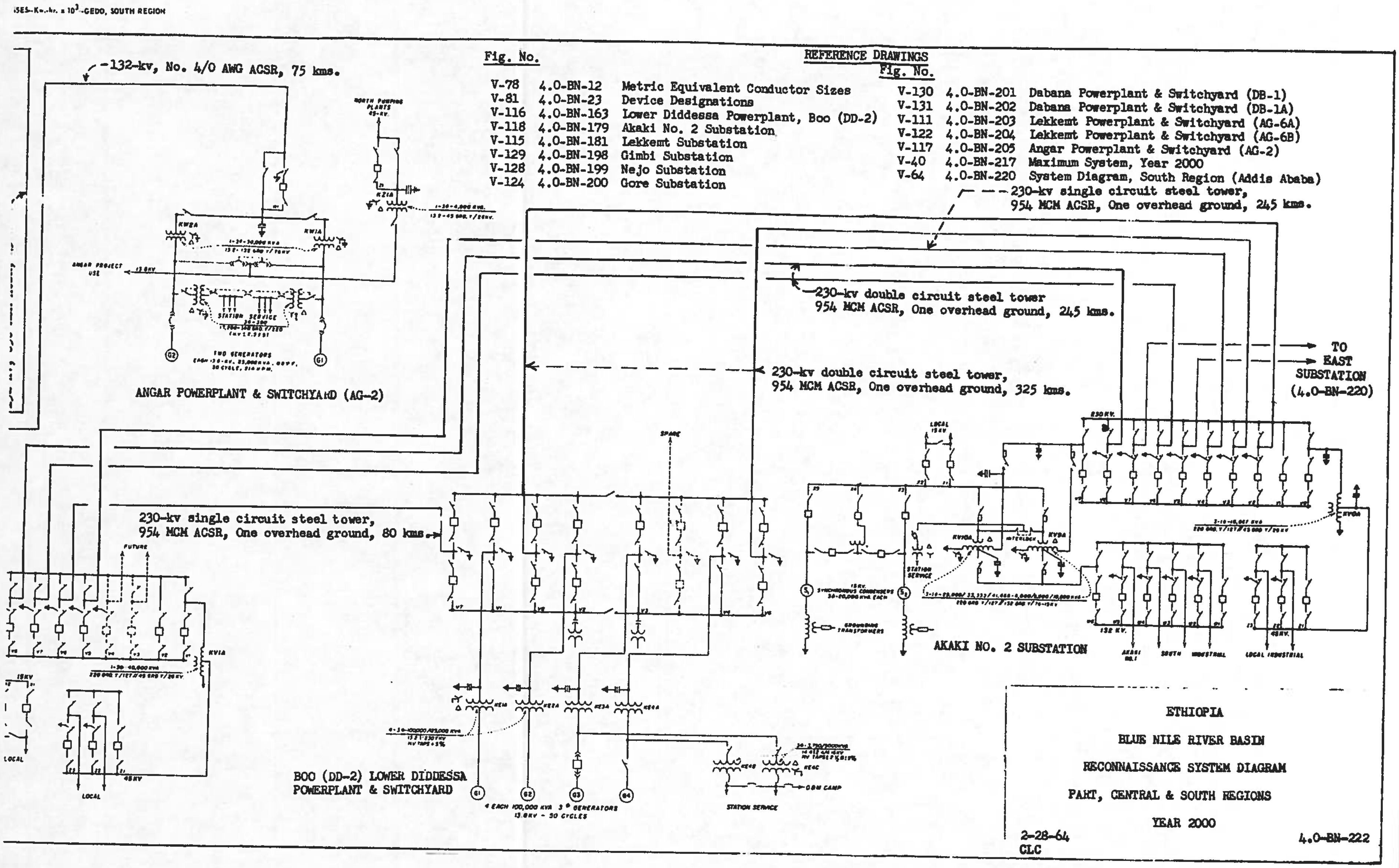


Figure V-66--Reconnaissance System Diagram--Part Central and South Regions

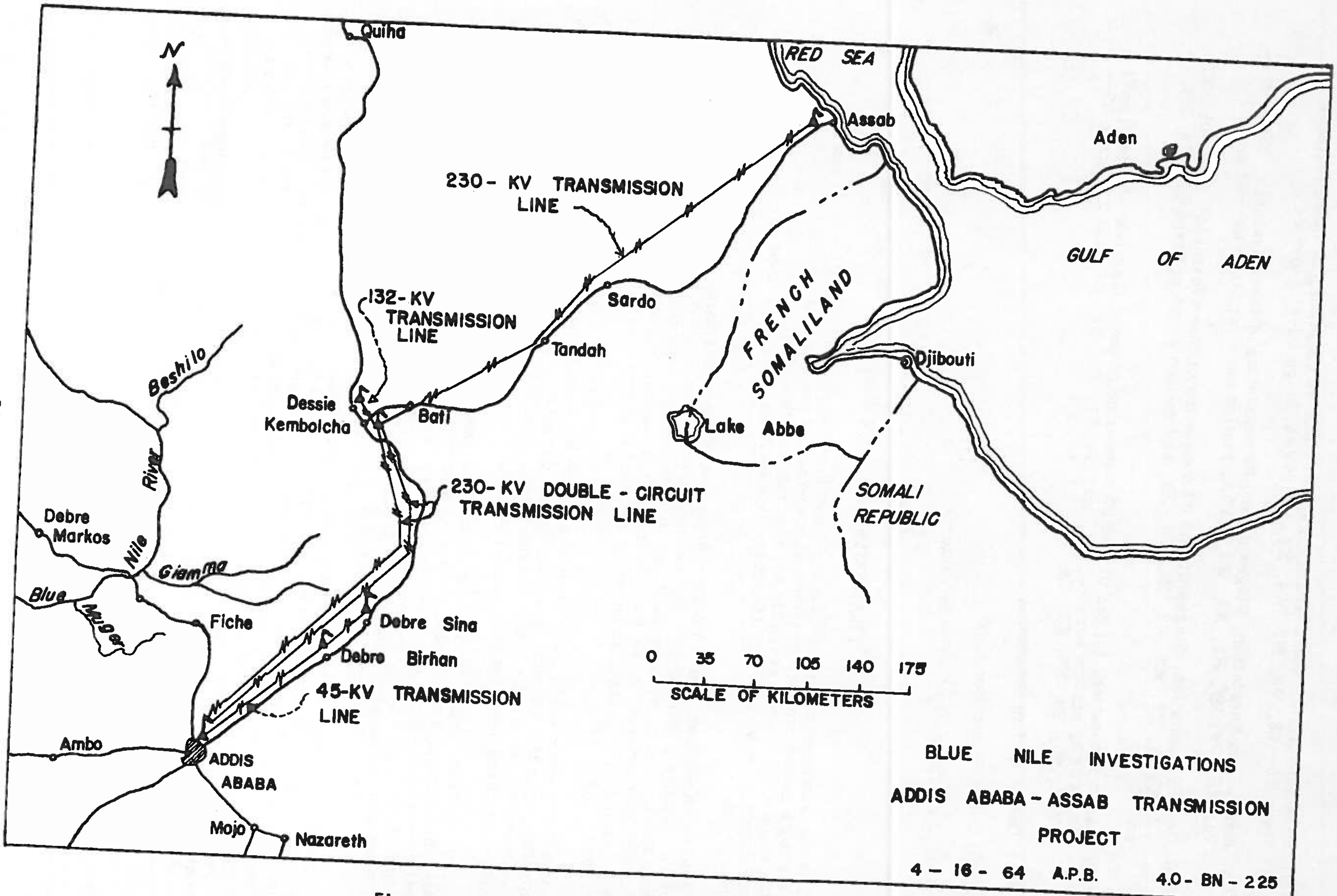


Figure V-67--Addis Ababa-Assab Transmission Project

(7) East Substation, Addis Ababa, Stages 01 and 04 consisting of these features: Stage 01--V8, V9, W3, W4, X5, and KV9A; Stage 02--V2 and V4

(8) Kembolcha Substation, Stages 01 and 02 consisting of these features: Stage 01--V1, V3, V5, V7, X1, X3, W2, KV5A, station service; Stage 02--V2 and X2

(9) Dessie Substation, Stages 01 and 02 consisting of these features: Stage 01--V1, V2, KV2A, Z1, Z2, Z3, Z5, Z7, X1, and station service; Stage 02--Z4, Z6, and X2

(10) Assab Substation, Stages 01 and 02 consisting of these features: Stage 01--V1, V2, KV1A, station service, X1, X2, X4, S1, Z1, Z2, Z4, and Z5; Stage 02--KV2A, S2, X3, X5, Z3, Z6, Z7, Z8, and Z9

(11) Debre Birhan Substation

(12) Debre Sina Substation

(13) Warehouses and service vehicles.

TRANSMISSION NETWORK

The reconnaissance nature of this report inventorying the basin's resources and evaluating a select number of potential projects did not warrant detailed studies of all of the many alternatives available for the transmission plant. Basically, the transmission network as envisioned by the end of this century will not be a complex system. See Figure V-40.

Studies based upon heavy load conditions were made assuming 0.90 lagging load power factors although generators were assumed to be designed for 0.8 power factor.1/ System power flows were based upon loads given in Section IV. At peak load conditions, line voltages and conductor sizes were based upon an acceptable voltage drop in percent of the receiving-end voltage; and upon an acceptable power loss in percent of the receiving-end load. System frequency was 50 cycles.

Overall transmission losses for peak heavy load conditions varied from 5 to 10 percent depending upon the location of the particular segment of the system and time period of development. In addition, distribution losses from the high-voltage side of the substation to the customers were factors to consider and were also given in Section IV.

Only limited studies were made concerning reactive powerflows, due to the reconnaissance nature of the report and the lack of this type information concerning the presently operated south region interconnected system (Koka). For special conditions where long high-voltage lines were involved, reactive power control facilities were indicated. Synchronous condenser installations at Assab and at Addis Ababa may be desirable, and are indicated on Figures V-63 and V-64.

The initial reactive control facilities at Addis Ababa, consisting essentially of two synchronous condensers, may not be required at the time the Neshe facilities are placed into operation, all depending upon the reactive support obtained from the Awash plants. However, with both plants delivering full output on peak to the Addis Ababa area, and receiving no reactive support at the receiving-end terminal, the synchronous condenser installation will be required. For light load conditions, either shunt reactors or synchronous condensers operated lagging may be needed. Synchronous condenser installations made early enough could provide for the light load requirements initially and also provide for the heavy load reactive support later. During the feasibility stage of investigations more data will be available regarding the Awash machine characteristics and load characteristics, including the reactive problem at principal load centers. For this study the added cost of the synchronous condensers are included.

1/Variable, 0.8 through unity, lag or lead, same as existing Koka Powerplant generators.

The phase shift angle between sending- and receiving-end voltages is within acceptable ranges.

Transformers also have an important part in regulating reactive powerflow depending upon tap settings. Although not so indicated on all switching diagrams, all transformers are assumed to be purchased with standard taps settings above and below normal ratings. Where tap changing under load (TCUL) is considered, it is specifically shown.

POWER SYSTEM STABILITY

Power system stability is defined as that ch-racteristic of a power system which insures that it will remain in operation through normal and certain abnormal conditions. Different types of stability problems exist, and can be broadly classified as steady state and transient. The steady state represents the stability of the system under conditions of gradual or slow changes in load. Transient stability refers to sudden changes such as short circuits or sudden changes in load that might occur and yet not cause instability. Steady state stability performance of synchronous generators can be specified by their short circuit ratio (SCR). High short-circuit ratio generators are more costly, but in the Blue Nile System, powerplants such as Alefa (BL-1) and Boo (DD-2) are likely to require higher short-circuit ratios, perhaps a ratio of at least 1.5 to 2.0. These higher short-circuit ratio generators have more line-charging capacity. The longer lines from (BL-1) to East Substation (Addis Ababa) and from the latter to Assab may create problems requiring suitable line-charging facilities. Stability limitations and line-charging requirements often occur simultaneously and the high SCR generator is one method of meeting both these requirements. Synchronous condensers shown at both terminals will offer a stabilizing influence. Nearly all lines in the Blue Nile system have inherent steady state margins for normal power transfer. Line resistance was kept on the low side to improve the stability limit and decrease the KVAR requirements. Detailed and complete analysis of the system will require network analyzer studies in the future as it develops, but such were beyond the scope of these reconnaissance studies.

COMPATIBILITY WITH EXISTING SOUTH REGION SYSTEM

In the Blue Nile system, autotransformers for the higher voltages were used and the 15-kilovolt tertiary windings were available to serve local loads. These windings are, of course, delta-connected, which are not compatible with the 15-kilovolt wye-connected Koka system. All other voltages are compatible. The 30° phase shift between the two 15-kilovolt systems should prove to be no problem, as interconnections between the north and south regions could never be made at 15 kilovolt, even if compatible. Ties between the various regional areas must be made at higher voltage as shown in Section IV.

Voltage Levels

Distribution voltages now in use and considered a standard in central Ethiopia are as follows:

15,000 volts (delta)

380/220 volts (wye)

In addition, a distribution voltage of 125 volts is in use in North Eritrea. Stepdown directly from 15,000 volts to 380/220 volts is accomplished without an intermediate voltage. The 380-volt connection is wye with the 380 volts measured line-to-line and the 220 volts obtained from line-to-neutral. The neutral wire is thus carried, making a four-wire system.

Transmission voltages which are accepted as standard in Ethiopia are:

45,000 volts
132,000 volts
50,000 volts1/

The above voltages adequately serve Ethiopia at present and probably will for several years. However, as transmission distance increases and as loads also increase in the future, the existing voltage standards will prove to be inadequate. These voltages have been used in the Blue Nile River Basin investigations:

15,000 volts
45,000 volts
69,000 volts
132,000 volts
161,000 volts
230,000 volts

Some savings with better system performance might result if an intermediate voltage between 15,000 volts and 380/220 volts were introduced in Addis Ababa where loads are becoming heavier. Greater flexibility in selection of transmission or distribution voltages will permit minimum power losses and less voltage fluctuation.

CONSTRUCTION

In 1960, distribution lines 380/220 volts were generally of untreated eucalyptus pole construction. All 15-, 45-, and 132-kilovolt construction utilized steel, no wood being used due to extremely short life because of rot and termites. In some instances wood poles had been reported as lasting only 6 months, hence the requirement and practice of using steel poles and lightweight steel towers for transmission lines 15 kilovolts and above. Recently, the EELPA obtained pole pressure-treating equipment in Addis Ababa. This plant permitted full-length treatment of poles which are being used for facilities up to and including 15-kilovolt lines. Treated poles will now be available, substantially reducing the cost of 15-kilovolt transmission line construction.

The 45-kilovolt construction utilizes steel poles or towers while 132-kilovolt lines use lightweight steel towers with single overhead ground wires. Lack of high winds, in some areas, and absence of frost, snow, and ice, as compared to other locations in the world, reduce the structural loading and hence permits economical steel construction with the ability to resist rot and termites and also withstand fires. Wood pole construction may be vulnerable in certain locations, but use of wood structures for voltages above 15 kilovolts should be developed. This has proven practical and economical in other countries and would also reduce dependence upon foreign imports of steel.

Nevertheless, in this particular report, all-steel transmission line construction has been assumed throughout, with the lines following existing roads or those routes expected to be developed in future highway programs. Transmission line costs are therefore high and considerable savings may result in future feasibility studies with use of wood pole construction and direct transmission routes. The comparative savings that might be expected along with the type of transmission construction used in this report are as indicated by these drawings:

Figure V-68--15-kv. Lines
Figure V-69--45-kv. Transmission Lines
Figure V-70--69-kv. Transmission Lines
Figure V-71--132-kv. Transmission Lines
Figure V-72--161-kv. Transmission Lines
Figure V-73--230-kv. Transmission Lines

1/North Eritrea only.

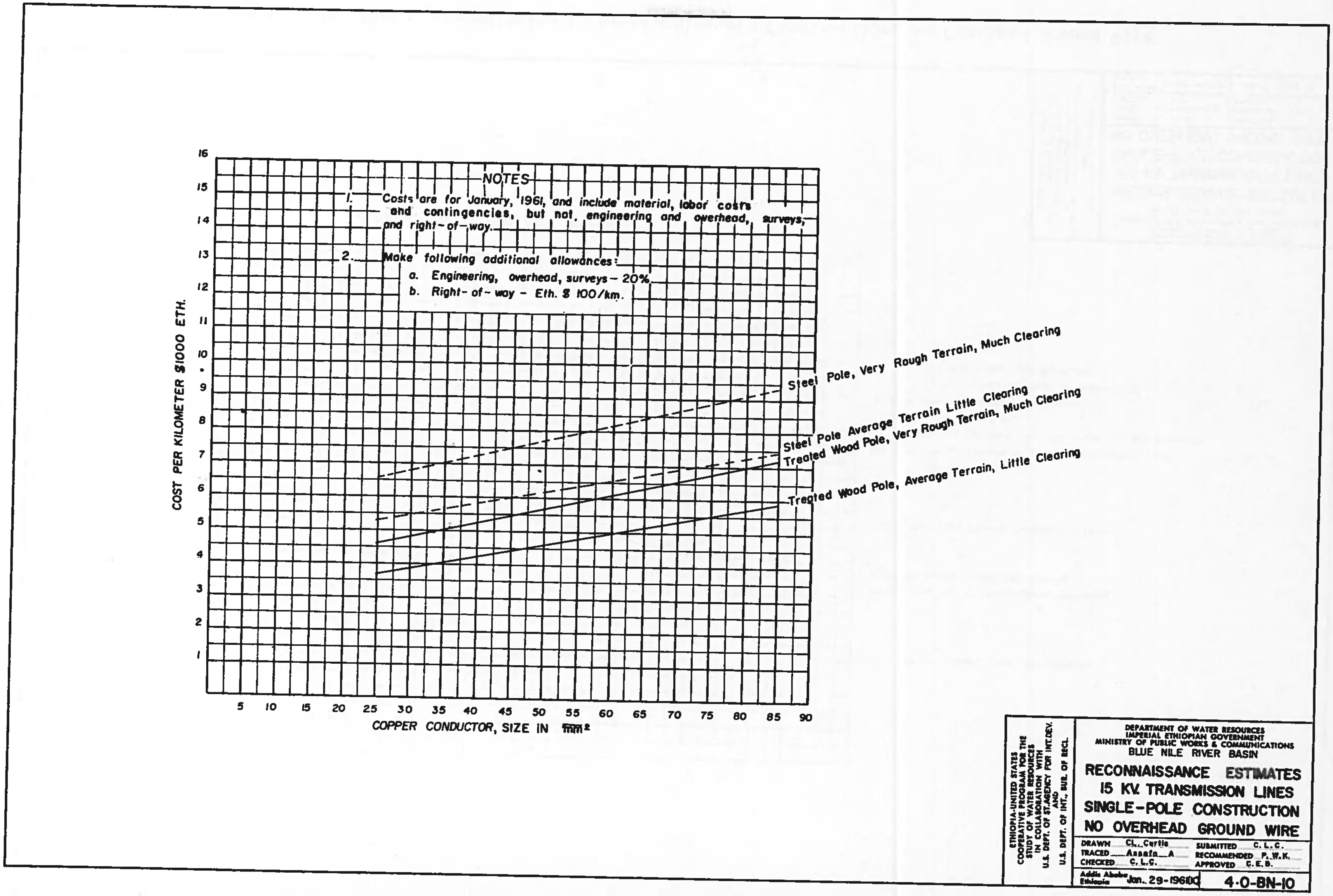
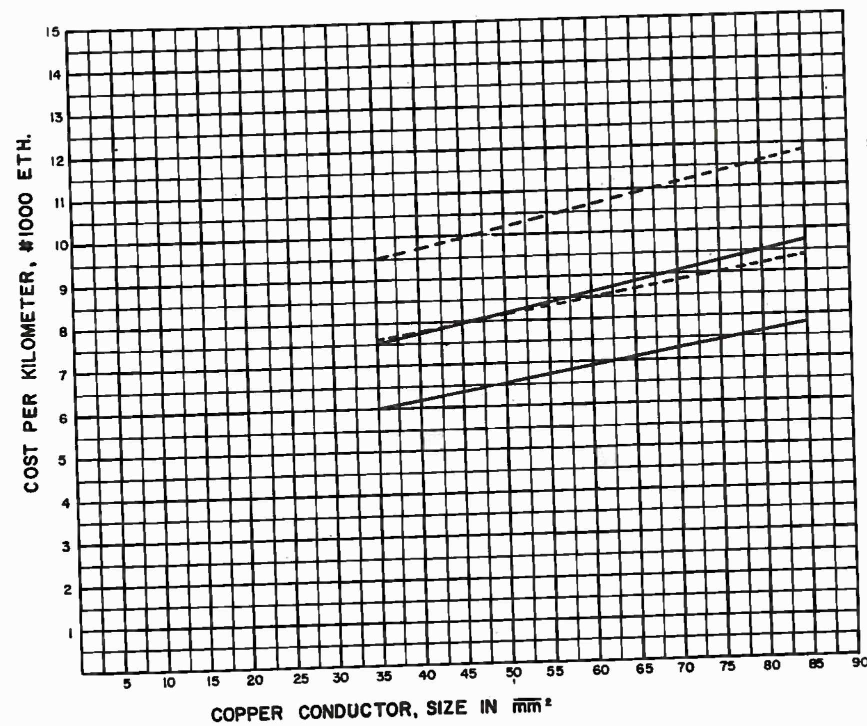


Figure V-68--15-kv. Transmission Lines--Single-pole Construction, No Overhead Ground Wire



NOTES

1 Costs are for January, 1961, and include material, labor, and contingencies but not engineering and overhead, surveys and right-of-way.

2 Make following additional allowances:
   a Engineering, overhead, surveys – 20%
   b Right-of-way - Eth. $ 200/km

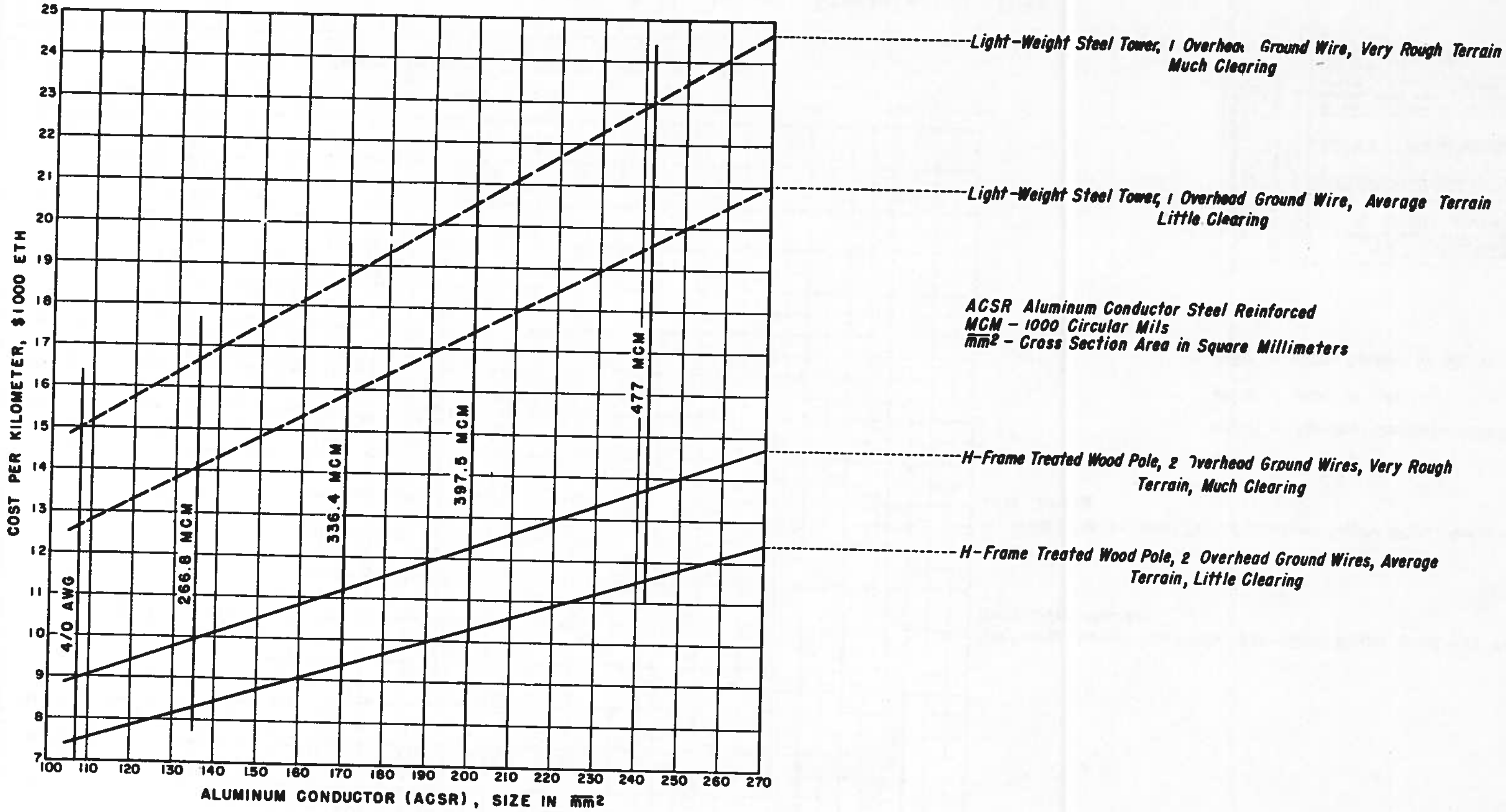
ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM FOR THE STUDY OF WATER RESOURCES IN COLLABORATION WITH U.S. DEPT. OF ST. AGENCY FOR INT. DEV. AND U.S. DEPT. OF INT. BUR. OF RECL.

DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS
BLUE NILE RIVER BASIN

RECONNAISSANCE ESTIMATES
45 KV. TRANSMISSION LINES
SINGLE-POLE CONSTRUCTION
NO OVERHEAD GROUND WIRE

DRAWN ... C.L. Curtis	SUBMITTED ... C.L.C.
TRACED ... Gabre Christos B.M.	RECOMMENDED P.W.K.
CHECKED ... C.L.C.	APPROVED ... C.E.B.
Addis Ababa Ethiopia Jan. 30-1962 (IC)	4-O-BN-11

Figure V-69--45-kv. Transmission Lines--Single-pole Construction, No Overhead Ground Wire



ACSR Aluminum Conductor Steel Reinforced
MCM - 1000 Circular Mils
mm² - Cross Section Area in Square Millimeters

NOTES

1. Costs are for January, 1961, and include material, labor and contingencies, but not engineering and overhead, surveys and right-of-way.
2. Make following additional allowances:
   a Engineering, overhead, surveys - 20 %
   b Right-of-way - Eth. $250/km.

ETHIOPIA
BLUE NILE RIVER BASIN
RECONNAISSANCE ESTIMATES
69-KV. TRANSMISSION LINES

1-6-64, C.L.C. 4.0-BN-180

Figure V-70--69-kv. Transmission Lines

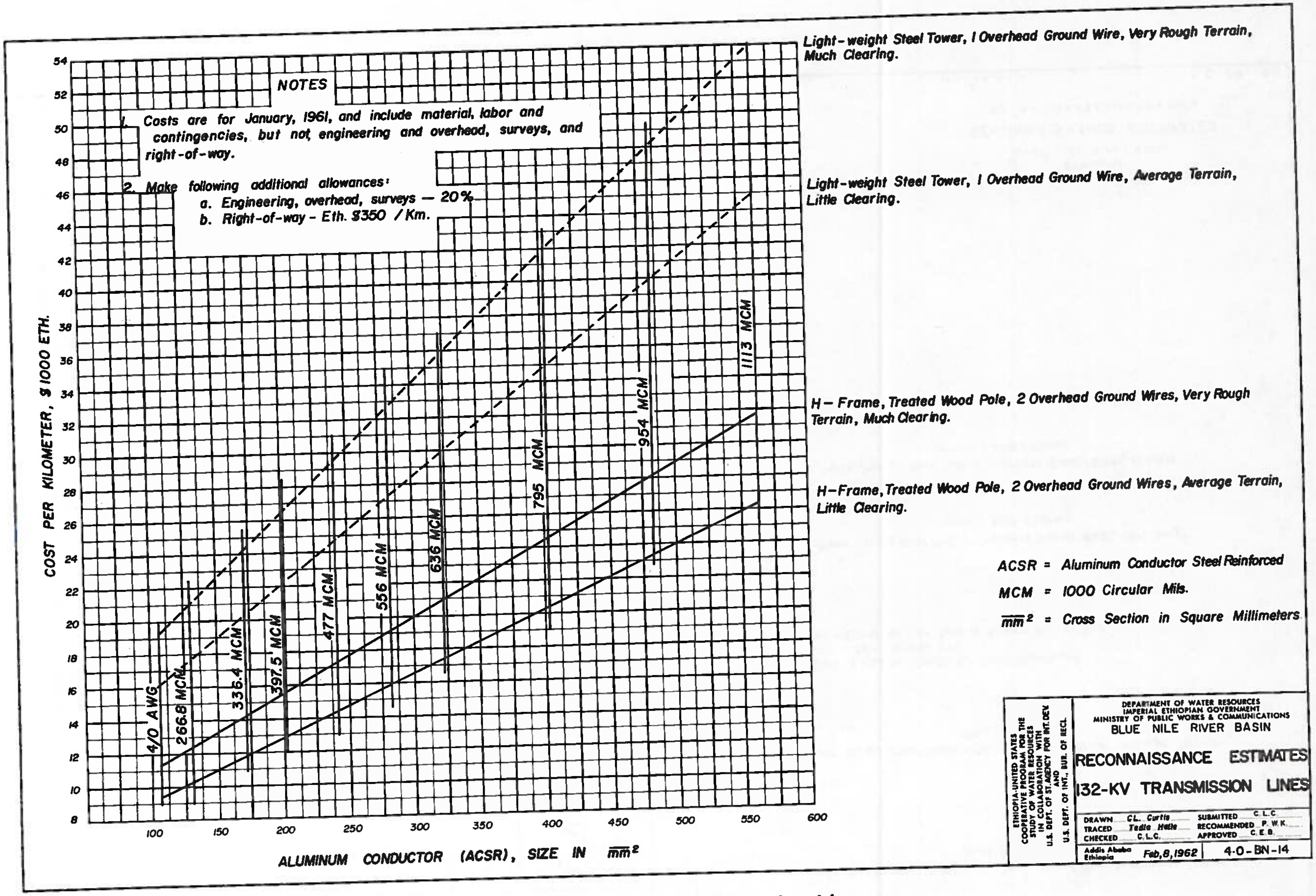
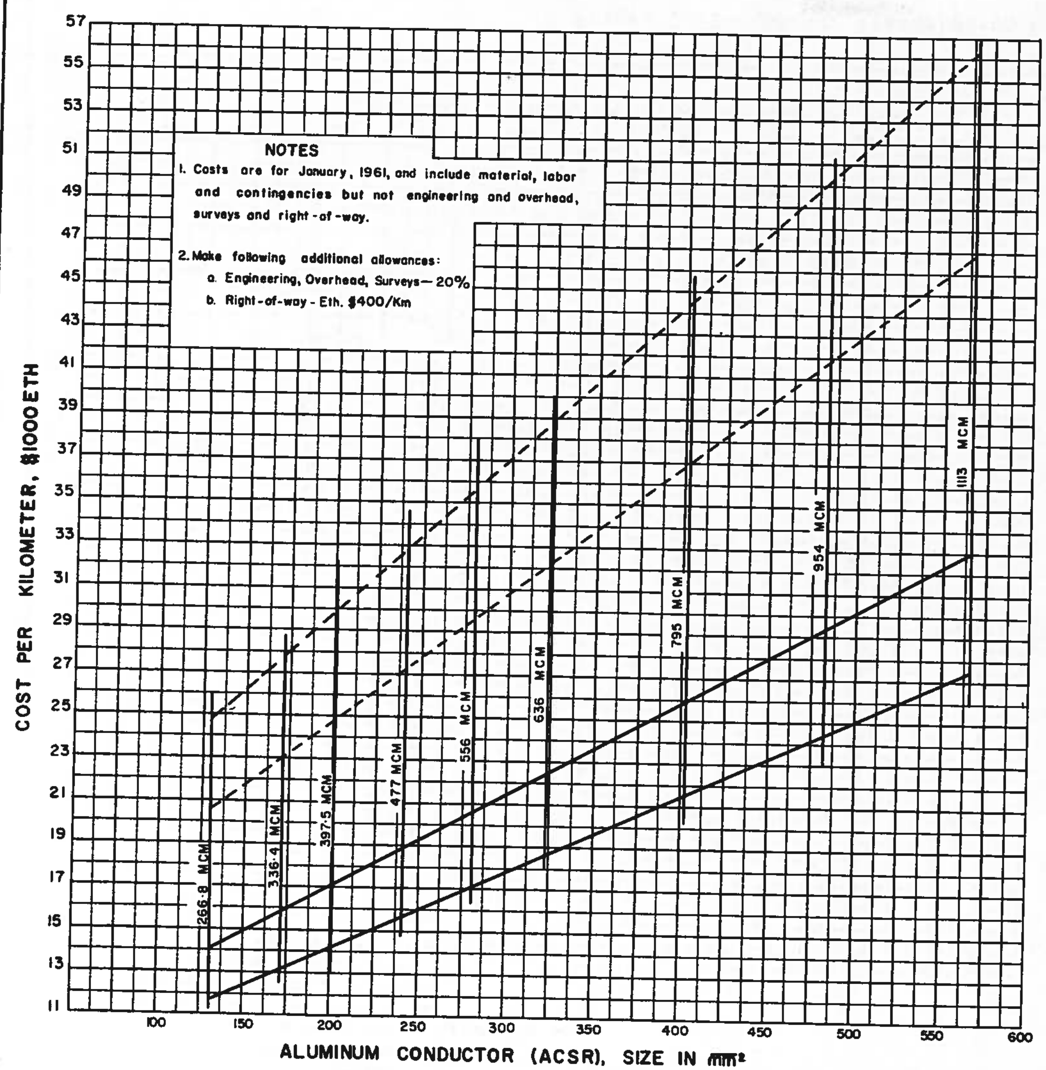


Figure V-71--132-kv. Transmission Lines



Light-weight Steel Tower, 1 Overhead Ground Wire, Very Rough Terrain, Much Clearing.

Light-weight Steel Tower, 1 Overhead Ground Wire, Average Terrain, Little Clearing.

ACSR - Aluminum Conductor Steel Reinforced
MCM - 1000 Circular Mils
mm² - Cross Section Area in Square Millimeters

H-frame, Treated Wood Pole, 2 Overhead Ground Wires, Very Rough Terrain, Much Clearing

H-frame, Treated Wood Pole, 2 Overhead Ground Wires, Average Terrain, Little Clearing

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 RECONNAISSANCE ESTIMATES 161-Kv. TRANSMISSION LINES
	DRAWN C.L. CURTIS — SUBMITTED C.L.C. TRACED Gabre christos G.M. — RECOMMENDED P.W.K. CHECKED C.L.C. — APPROVED C.E.B.
	Addis Ababa Ethiopia — Feb. 9-1962 — 4-O-BN-15

Figure V-72--161-kv. Transmission Lines

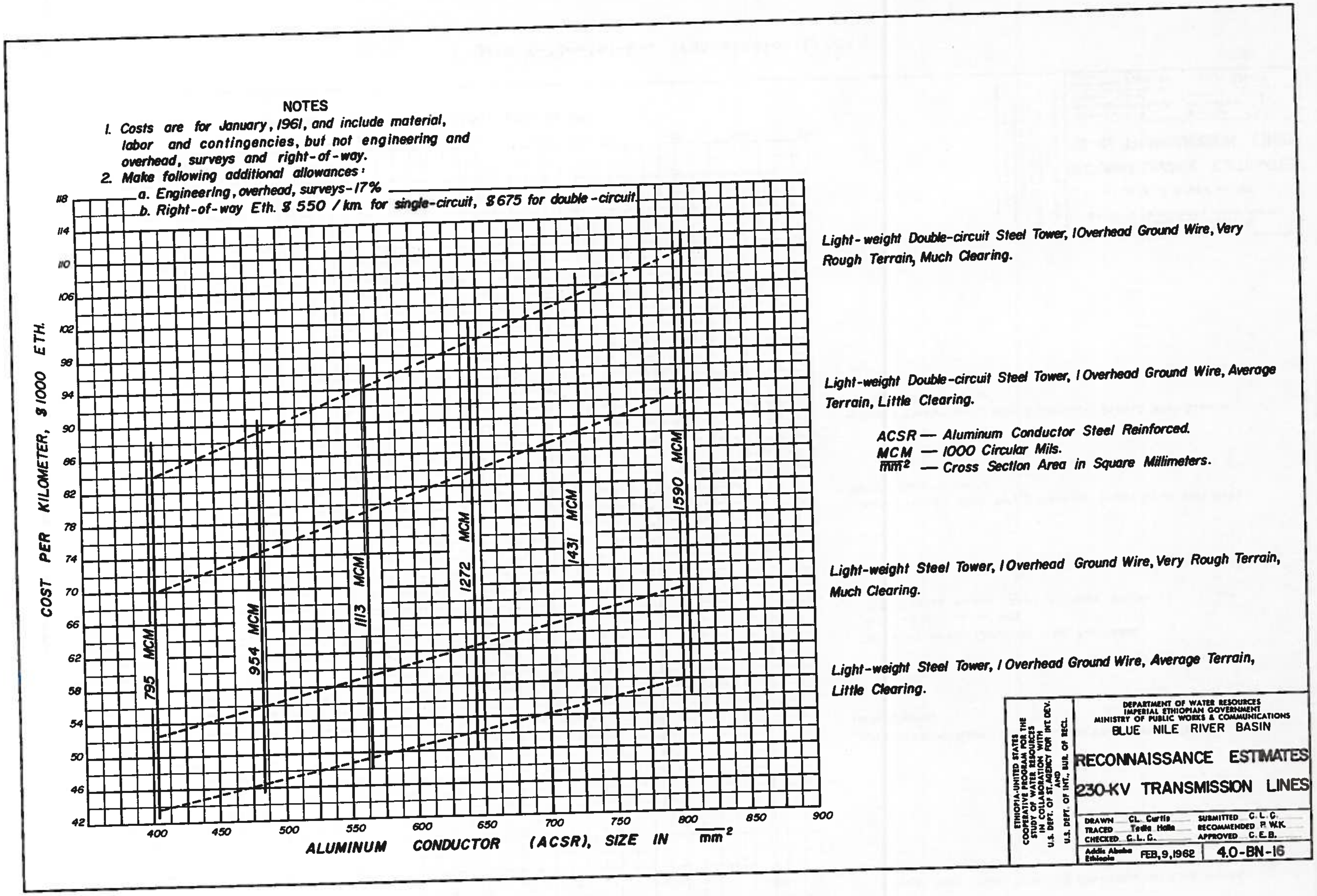


Figure V-73--230-kv. Transmission Lines

Design Standards

Generally, the standards of the International Electrotechnical Commission are used although in some northern areas Italian standards prevail (Associazione Elettrotecnica Italiana) and at times where these are less precise, German standards are then occasionally substituted. British Standard Institution specifications have also been referred to.

By comparison, the Ethiopian transmission line standards would generally compare with "light loading areas" used in the United States.

Tower footing resistance may prove to be inadequate in some soil areas especially during the dry periods of the year. For that reason an allowance has been made for buried counterpoise at each tower as was done for the existing Koka-Addis Ababa and Dire Dawa 132-kilovolt lines. Future feasibility studies will make separate determinations of soil resitivity for each transmission route and the need for buried counterpoise.

The wide range of elevations above mean sea level for various areas where future transmission plant facilities may be constructed will require variations in line-to-tower clearances. Elevations of 3000 meters above mean sea level may require steel tower designs having greater line-to-ground clearances than those constructed near sea level.

For design purposes, these conditions were specified for the existing 132-kilovolt lines:

Horizontal wind pressure on flat surface............	127kg/m^2
Horizontal wind pressure on diametral plane of round cylindrical surfaces....................	76kg/m^2
Horizontal wind pressure on tower structure re-coned on 1-1/2 times the projected area of one face	127kg/m^2

No ice loading. Minimum temperature was -5° C. Temperature rise in conductor above minimum was 55° C.

Climate and Isoceraunic Levels

Climatic conditions surrounding various load centers were given in Section IV.

Regarding isoceraunic levels, no data are available except for what was observed in 1961 and 1962. Rough estimates would place the number of thunderstorm days per year as follows:

Addis Ababa	35
Bahir Dar	25
Debre Tabor	40
Lekkemt	40
Asosa	20
Gore	50
Gondar	35
Dessie	35

This compares with an average number of storm days of about 30 per year for all of the United States east of the Rocky Mountains. Localized areas reach as high as 90. For the Blue Nile River Basin, about 75 lightning strokes to 100 kilometers of transmission line are estimated in an average year where the isoceraunic level is 35 to 40.

Figure V-74--Steel pole, 4-wire distribution line. Similar construction with modifications used at 15 and 45 kv., for Blue Nile River Basin studies.

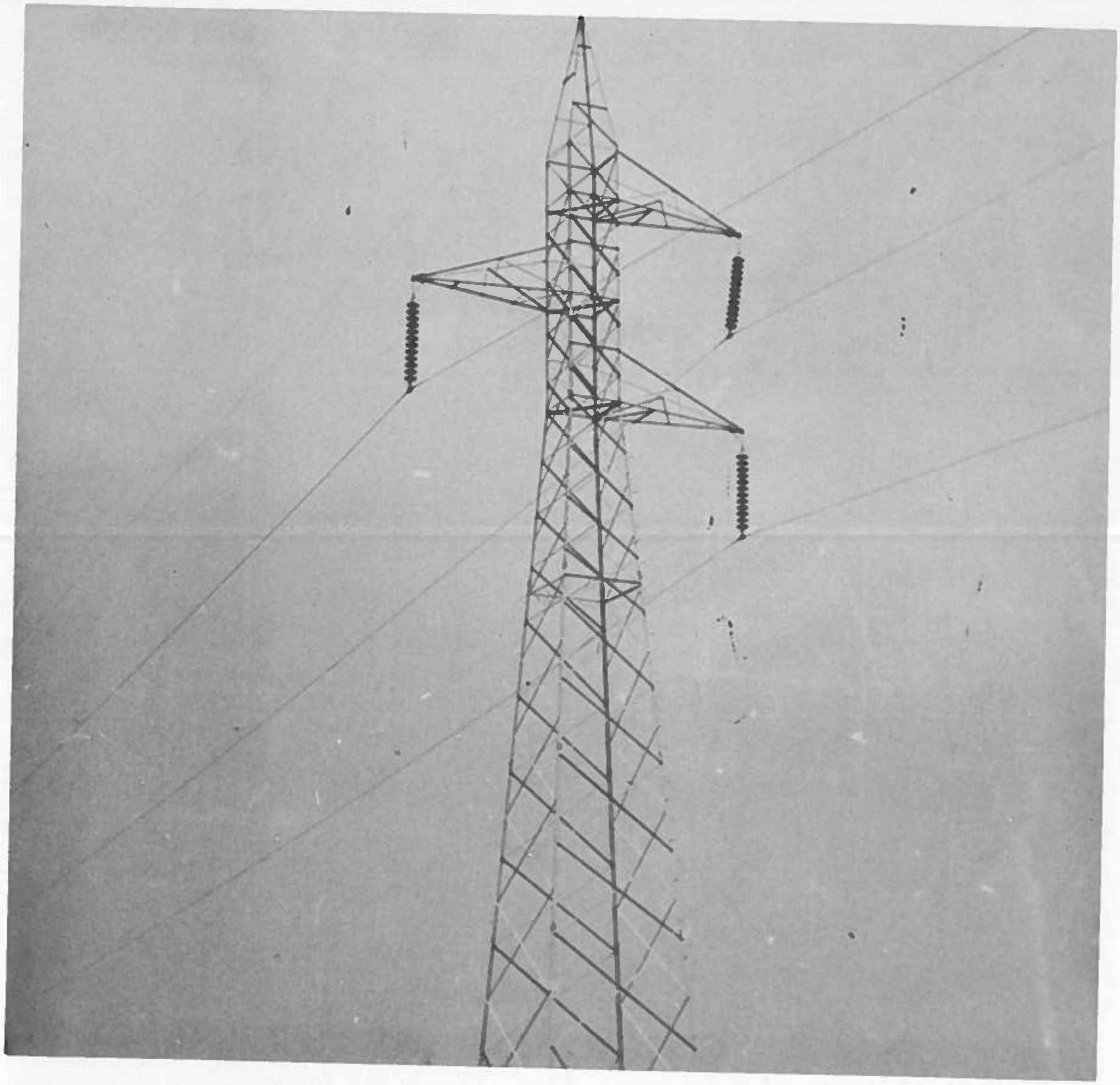


Figure V-75--Typical 132-kv. tangent steel tower structure with one overhead ground wire, Koka-Addis Ababa transmission line. This is the type of single-circuit construction considered for 132-, 161-, and 230-kv. transmission lines in the Blue Nile River Basin studies.

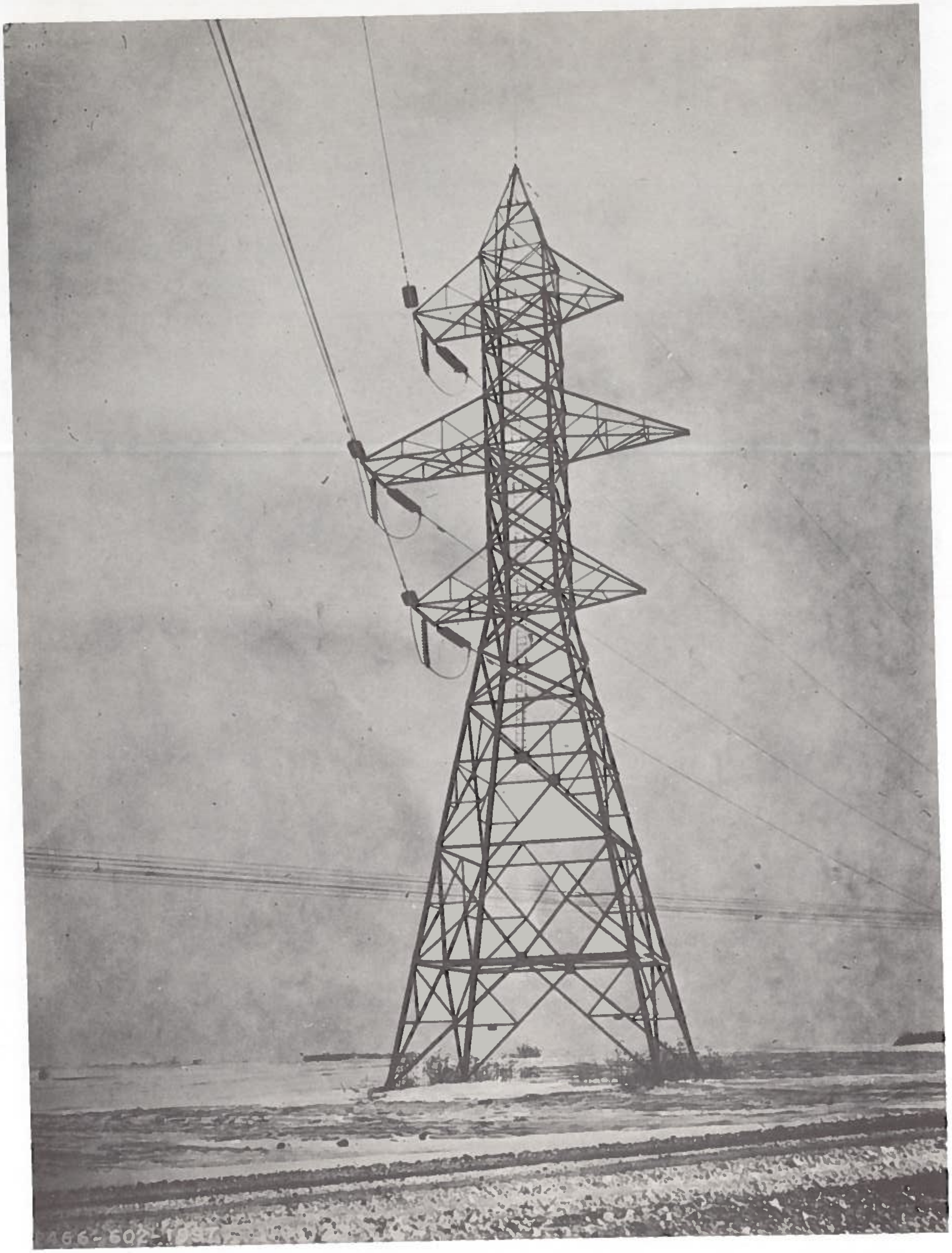


Figure V-76--230-kv. double circuit steel tower angle structure with one circuit installed initially. This is the type construction considered for 69-, 132-, and 161-kv. double circuit transmission lines in the Blue Nile River Basin studies.

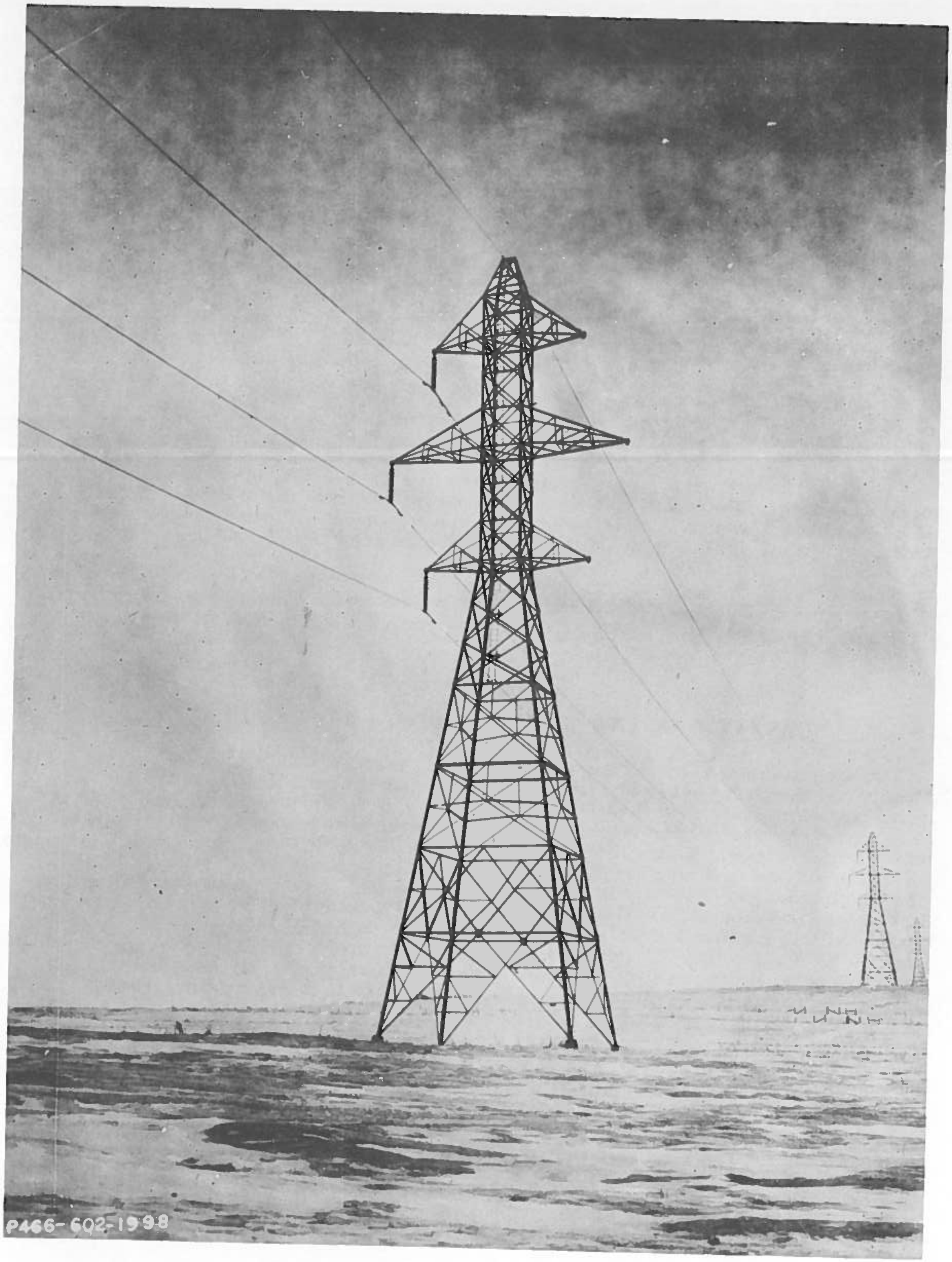


Figure V-77--230-kv. double circuit steel tower tangent structure with one circuit installed initially. This is the type construction considered for 69-, 132-, and 161-kv. double circuit transmission lines in the Blue Nile River Basin studies.

Nature of Terrain

The costs of transmission lines were based upon two very general terrain classifications--"very rough" and "average." Associated with these classifications was the degree of required clearing (cutting brush and trees and removing from the strip of land on which the line might be constructed). Generally, where the terrain was rough, more clearing seemed to be required than where the terrain was average. Selection of unit costs per kilometer was governed by the terrain and not by the amount of clearing. The nature of the terrain influences to a great extent the cost of constructing access roads along the route, which is included in the total transmission cost per kilometer.

"Average terrain" classification is similar to what was experienced for the existing Koka-Addis Ababa 132- and 45-kilovolt Tis Abbay-Bahir Dar Transmission Lines.

"Very rough terrain" is similar to that experienced in the construction of the Massawa-Asmara 50-kilovolt Line. This construction is characteristic of lines crossing escarpments.

Conductors

Tables V-112 and V-113 show all of the various types of conductors used in the transmission system. Where copper was used, it was at 45-kilovolt and below. Otherwise ACSR was used. Figure V-78 is a chart to convert square millimeter equivalents to the American circular mil system. Both measurements are shown on Figures V-68, V-69, V-70, V-71, V-72 and V-73.

Table V-113, "Summary of Transmission Lines, Present Century" summarizes all transmission line requirements with conductor type and sizes given for each line.

SUBSTATIONS AND SWITCHYARDS, PRESENT CENTURY

The substations will be of the outdoor type with controls and service equipment located indoors. One control house and one combination service building-warehouse will be necessary at most locations. A double-bus, single-breaker scheme with one transfer breaker per voltage section is generally used, but the latter breaker should be installed only when warranted. Connections are made according to American practice, which uses one main and one auxiliary bus whereas the European practice uses two main buses. Construction costs of both arrangements are about equal and both types have advantages. Since costs are about equal, the American practice is used here, as a major purpose of designs at this reconnaissance stage is to arrive at approximate estimates of cost. See Figures V-79 and V-80. Ultimately, when these facilities are investigated and designed for final construction, such designs may well follow European practice. These conditions also apply to powerplant switchyards. Standard A.S.A. electrical symbols, shown on Figure V-81, have been used.

For switchyards serving large powerplants (Alefa BL-1 and Boo DD-2) a double breaker installation per bay is used instead of the single breaker installation noted for substations.

Switching diagrams for each substation and switchyard can be found in Annex "C." Table V-114 summarizes the receiving-end substations and switchyards with capacities and stage construction throughout the period of review noted.

TABLE V-112--CONDUCTOR CHARACTERISTICS

Size			Weight	
MCM or AWG	sq. mm.	Type	kg./km.	Stranding
211.6 (4/0 AWG)	107.2	ACSR	420	1 steel--6 aluminum
266.8 MCM	135.1	ACSR	526	7 steel--26 aluminum
397.5 MCM	201.4	ACSR	787	7 steel--26 aluminum
477 MCM	241.7	ACSR	1,074	7 steel--26 aluminum
636 MCM	322.3	ACSR	1,259	7 steel--26 aluminum
795 MCM	402.8	ACSR	1,581	7 steel--26 aluminum
954 MCM	483.4	ACSR	1,767	7 steel--54 aluminum
4/0 AWG	107.2	Copper	941	19 strand copper
3/0 AWG	85.0	Copper	746	7 strand copper
2/0 AWG	67.4	Copper	592	7 strand copper
1 AWG	53.4	Copper	372	7 strand copper
2 AWG	33.6	Copper	295	7 strand copper

Notes:

Equivalent current carrying capacity:
4/0 AWG copper--336.4 MCM ACSR
3/0 AWG copper--266.8 MCM ACSR
2/0 AWG copper--211.6 MCM ACSR
1 AWG copper--2/0 AWG ACSR
2 AWG copper--1/0 AWG ACSR

ACSR = aluminum conductor steel reinforced (stranded steel core surrounded by stranded aluminum)

AWG = American wire gage

1 Mil = 0.001 inch

Circular Mils (CM) round wire = square of diameter in mils.;
Circular Mils (CM) = 1,973.5 multiplied by square millimeters ($mm.^2$)

MCM = 1,000 Circular Mils

TABLE V-113--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-Diddessa	132	Arjo-Diddessa 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

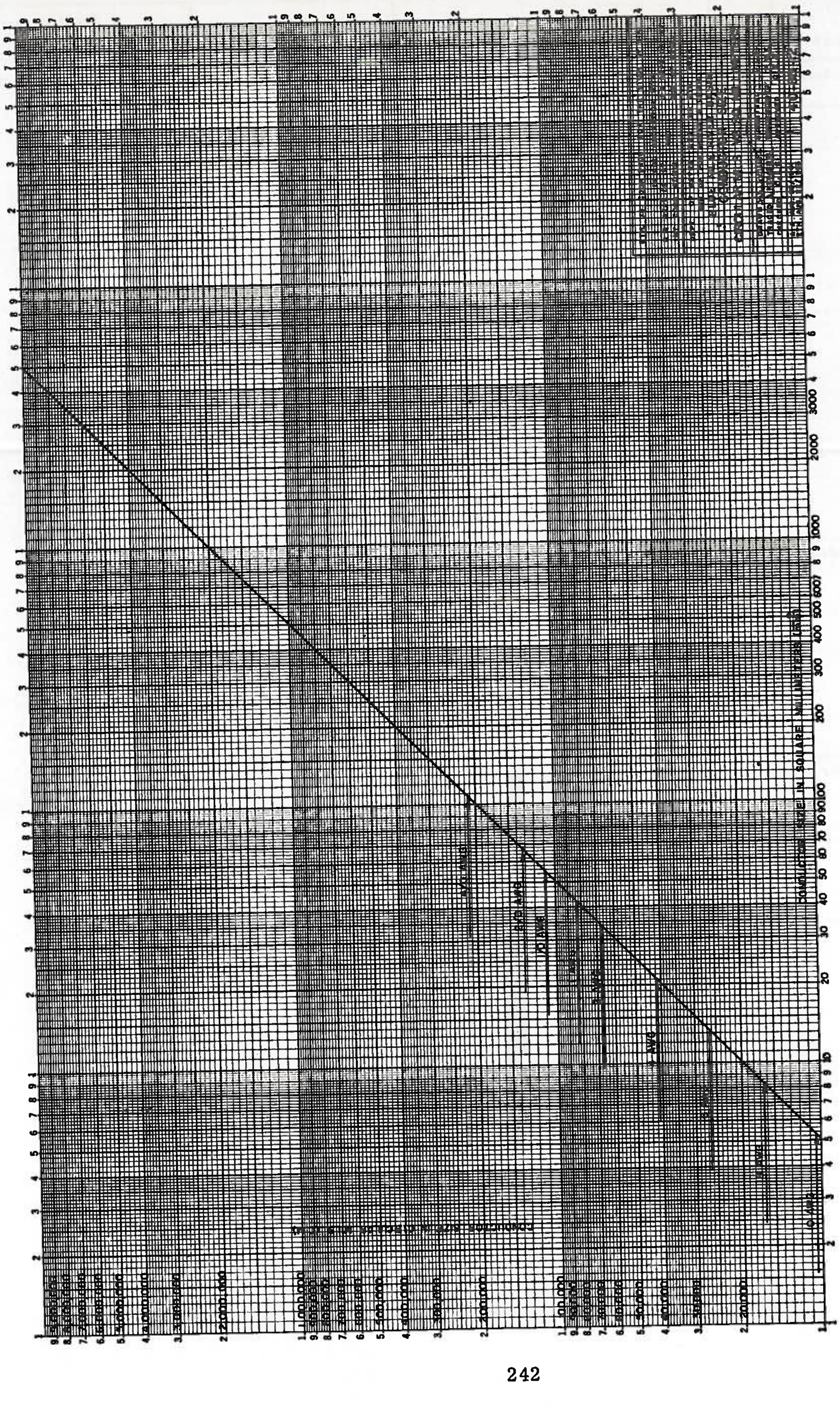
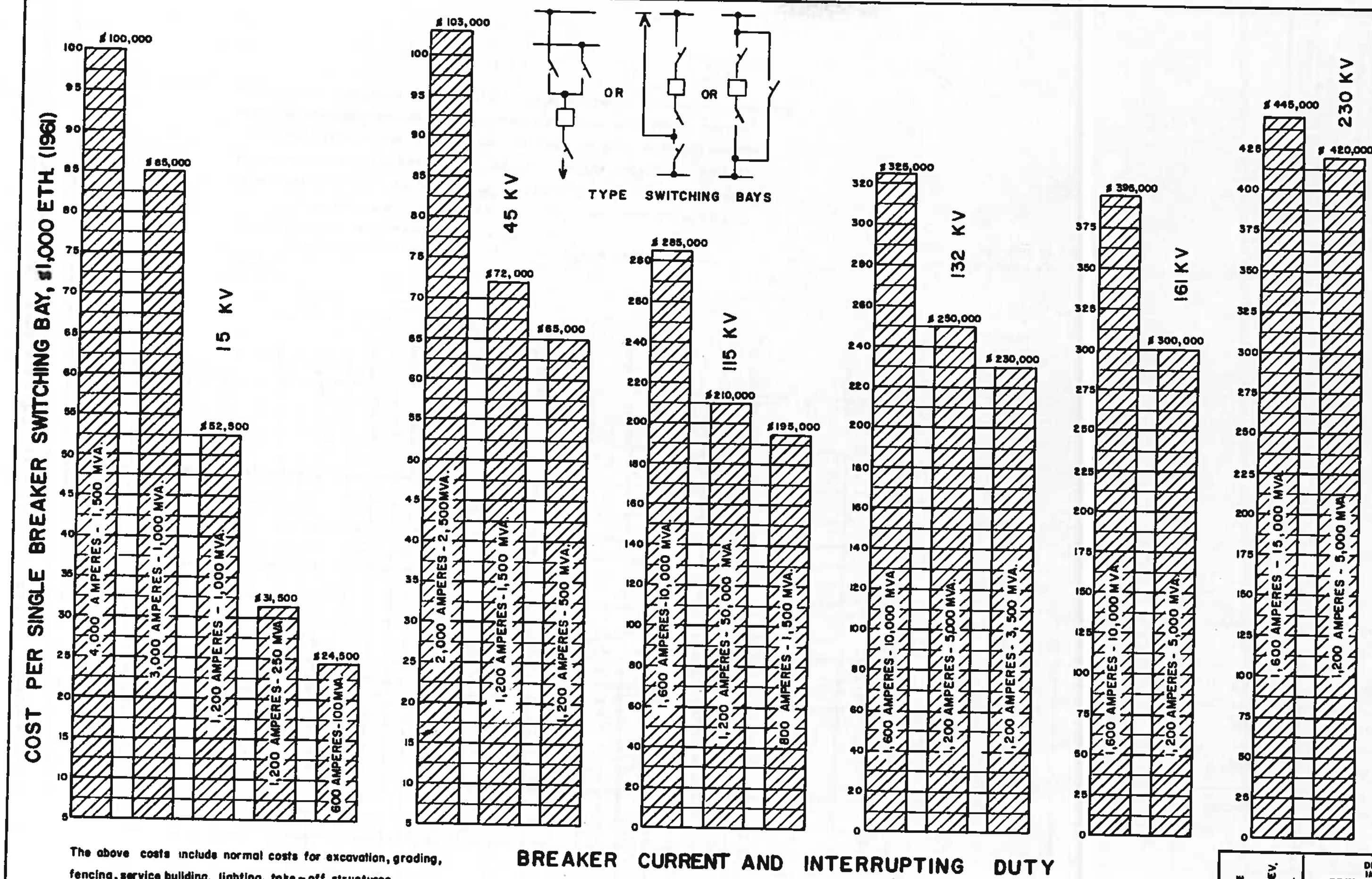


Figure V-78--Conductor Size-Circular Mils v. Sq. Millimeters



NOTES

If current and interrupting duty are not known use the following:

KV	AMPERES	MVA.
15	1,200	250
45	1,200	500
115	800	1, 500
132	1, 200	3, 500
161	1,200	5, 000
230	1, 600	15, 000

Eth. $1·00 = U.S. $0·40

Based upon European equipment and materials.

The above costs include normal costs for excavation, grading, fencing, service building, lighting, take-off structures, footings & foundations, conduit, bus and grounding copper, control cable, miscellaneous fittings, & contingencies.
Does not include costs for land and rights, relocations, high voltage circuits between powerplant and switchyard, engineering and general expenses.
Allow 25% for engineering and general expenses.

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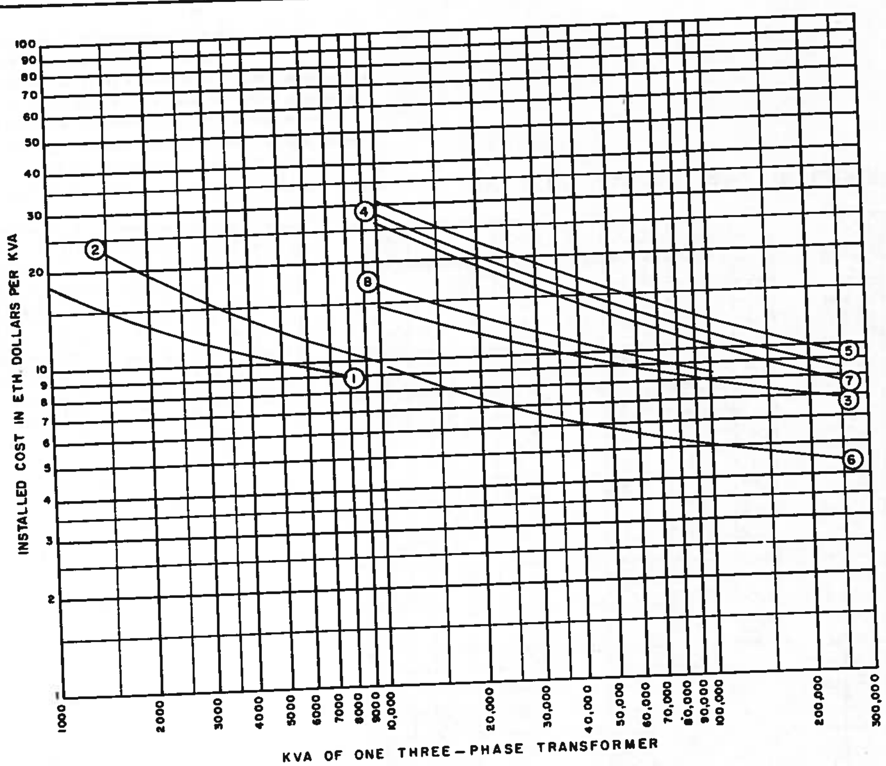
DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS
BLUE NILE RIVER BASIN

RECONNAISSANCE ESTIMATES
SWITCHYARDS & SUBSTATIONS
SINGLE BREAKER BAY

DRAWN CL Curtis — SUBMITTED C.L.C.
TRACED Gabrechristos — RECOMMENDED P.W.K.
CHECKED C.L.C. — APPROVED C.E.B.
Addis Ababa Ethiopia — Mar. 24-1962 — 4-O-BN-24

Figure V-79--Switchyard and Substations--Single Breaker Bay



Curve No.	High Voltage Kilovolts	Low Voltage Kilovolts	Transformer Type
1	15	2.4	Two-winding
2	45	15	Two-winding
3	115	15	Two-winding
4	230/196	15	Two-winding
5	230/196	45	Two-winding
6	115	15	Auto
7	230	115	Auto
8	132	45	Auto

NOTES

This drawing is to be used in conjunction with circuit breaker switching bay costs, Drawing No. 4.0-BN-24.

Costs are for self-cooled, 3 phase units and include 3 bushing type current transformers, lightning arresters, installation, labor and an allowance for contingencies. The costs do not include an amount for land and rights, relocations, foundations, and footings, bus take-off structures, high-voltage circuits between the power plant and switchyard, transfer tracks, untanking facilities, oil piping, etc., or allowance for engineering and general expenses. For the latter allow 25%.

Patterned after USBR Drawing No. 104-D-697, Adjusted to costs and practices in Ethiopia.

ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM FOR THE STUDY OF WATER RESOURCES IN COLLABORATION WITH U.S. DEPT. OF ST., AGENCY FOR IN. DE. 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

RECONNAISSANCE ESTIMATES

POWER TRANSFORMERS
INSTALLED COST PER KVA

DRAWN C.L. CURTIS — SUBMITTED C.L.C.
TRACED A. NEGASH M. — RECOMMENDED P.W.K.
CHECKED C.L.C. — APPROVED C.E.B.

Addis Ababa, Ethiopia — 23 MAR. 1962 — 4.0-BN-25

Figure V-80--Power Transformers--Installed Cost per Kv.-a.

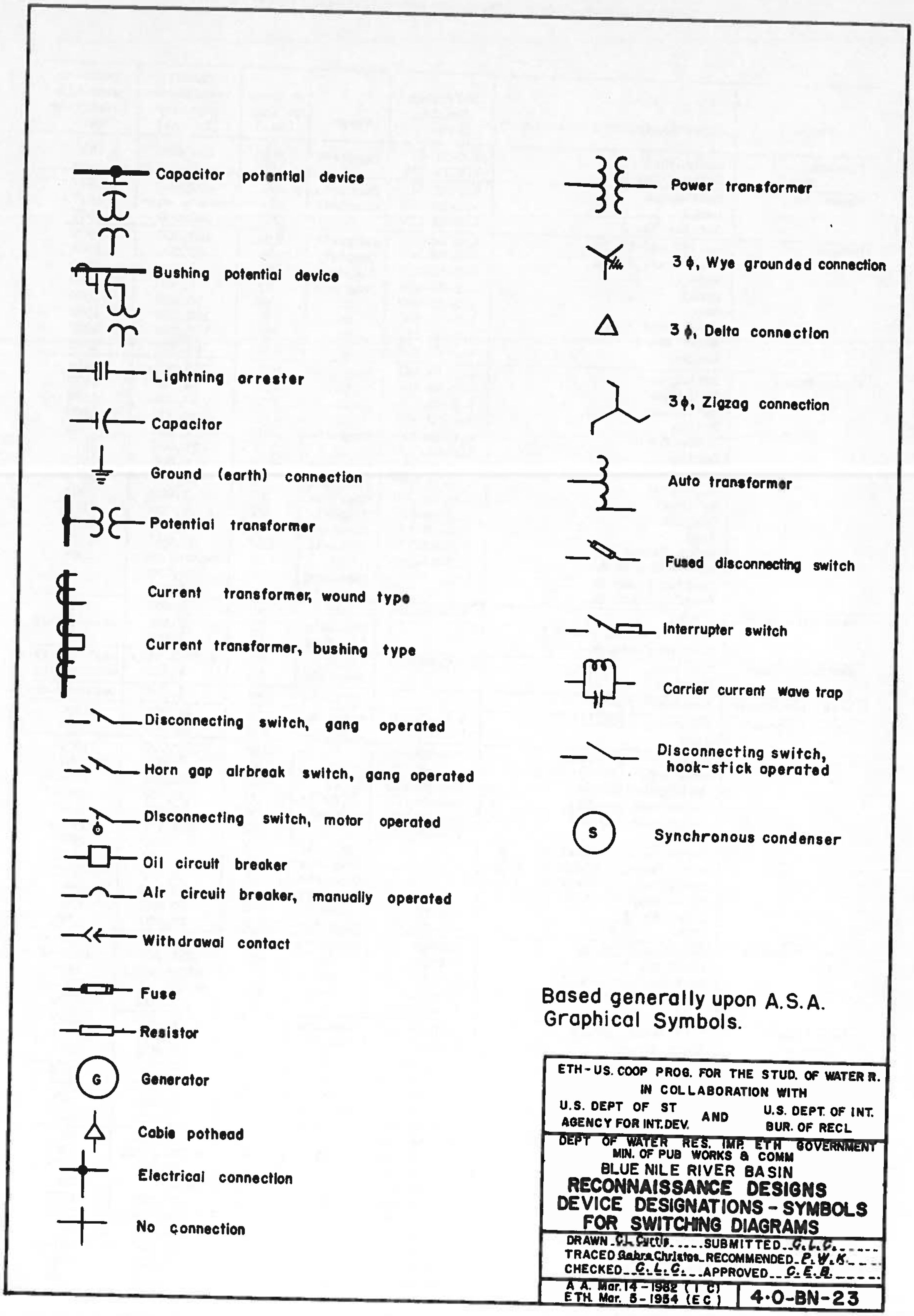


Figure V-81--Device Designations--Symbols for Switching Diagrams

TABLE V-114--SUMMARY OF H.V. SUBSTATION 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.

SECTION VII--COST OF POWER FACILITIES

OPERATION AND MAINTENANCE COSTS

A study of prevailing Ethiopian costs and practices was used in the development of annual operation and maintenance costs for the various electric power facilities as given by the following drawings:

Figure No.	Facilities
V-82	Hydroelectric powerplants
V-83	Steam electric powerplants
V-84	Welded steel pipe penstock
V-85	Substations and switchyards
V-86	15-kilovolt transmission lines
V-87	45-kilovolt transmission lines
V-88	69-kilovolt transmission lines
V-89	132-kilovolt transmission lines
V-90	161-kilovolt transmission lines
V-91	230-kilovolt transmission lines
V-92	Power canals
V-93	Power tunnels

Operation and maintenance expenses for each dam and reservoir were treated separately since they could not be consistently established on the basis of a fixed relationship with reservoir capacity due to so many variable factors between projects.

FIXED COSTS

As part of the development of project analysis, annual costs are made for comparison with anticipated benefits. Certain of these annual costs may be classified as fixed costs. Amortization, replacement, taxes, and insurance are among those principal elements of annual cost which may be classified in this category. All costs are reduced to an annual basis for comparison with annual benefits. The interest rate used is 5 percent.

Amortization

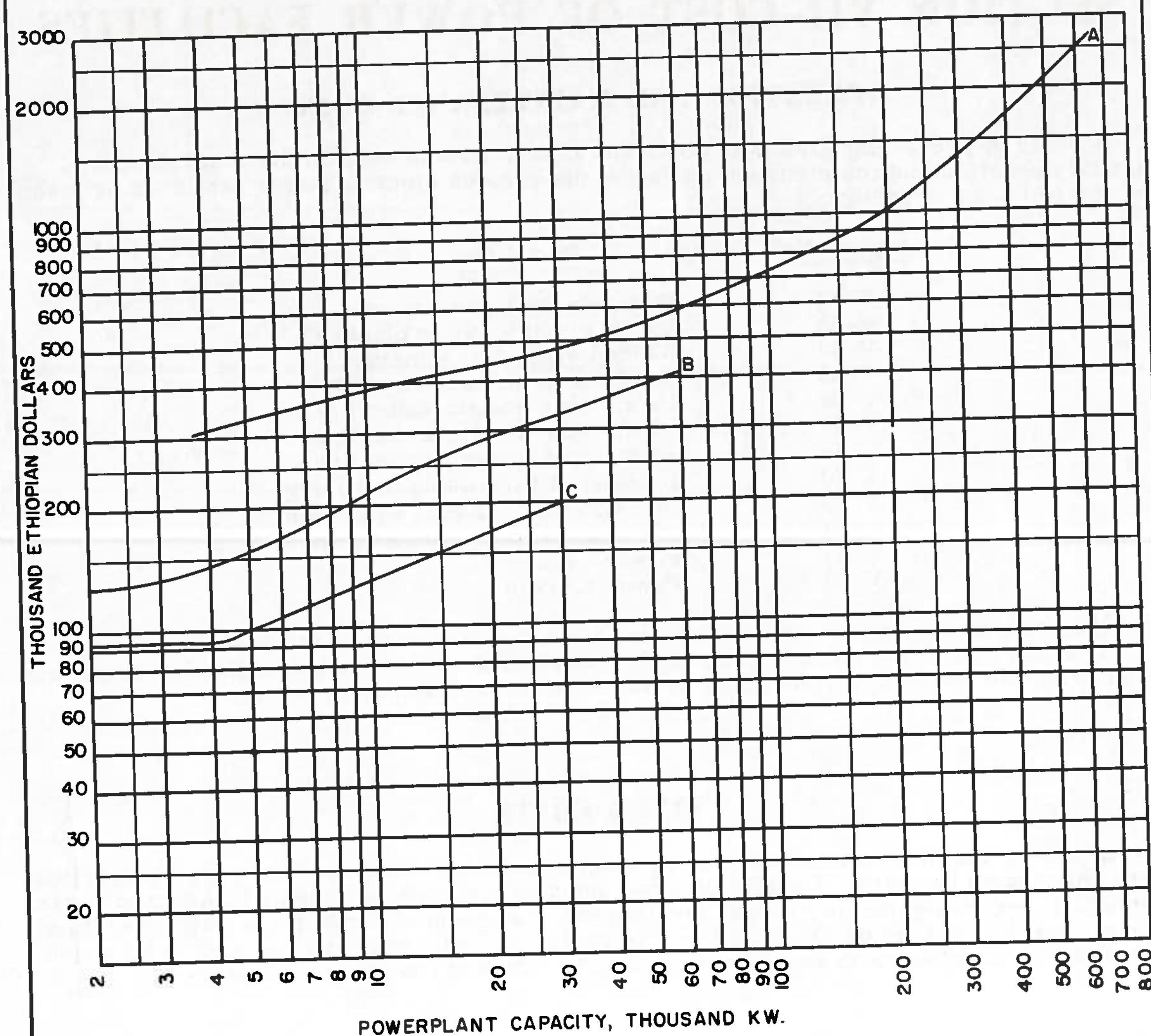
For this reconnaissance study of power facilities, interest during construction was calculated as follows:

$$\text{Interest during construction} = \begin{bmatrix}\text{Total} \\ \text{construction} \\ \text{cost}\end{bmatrix} \text{ multiplied by } 5\% \text{ multiplied by } \begin{bmatrix}\text{One-half of} \\ \text{construction} \\ \text{period}\end{bmatrix}$$

The capital cost of the power facilities of each project is then represented by the sum (1) of the construction cost and (2) the total monetary value of the interest during construction.

The period of amortization is 50 years and, at an interest rate of 5 percent, the factor of 0.054777 will provide the annual cost of amortizing the total project capital cost. 1/

1/Amortize: To provide for the gradual extinction of a future obligation in advance of maturity by periodic contributions to a sinking fund adequate to discharge a debt (capital cost).



A — Manual operation.
B — Semi-automatic, semi-attended operation.
C — Remote control, unattended operation.

Notes

1. Curves exclude reservoir, dams and waterway expense.
2. Curves include allowances for administrative and general expense.
3. Costs are for January, 1961
4. For Curve A, operation costs are about 57% of total O & M.
5. For Curve B, operation costs are about 44% of total O & M.

10-3-63 D- C.L.C.	MOVED CURVE A. DELETED NOTE 6.

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

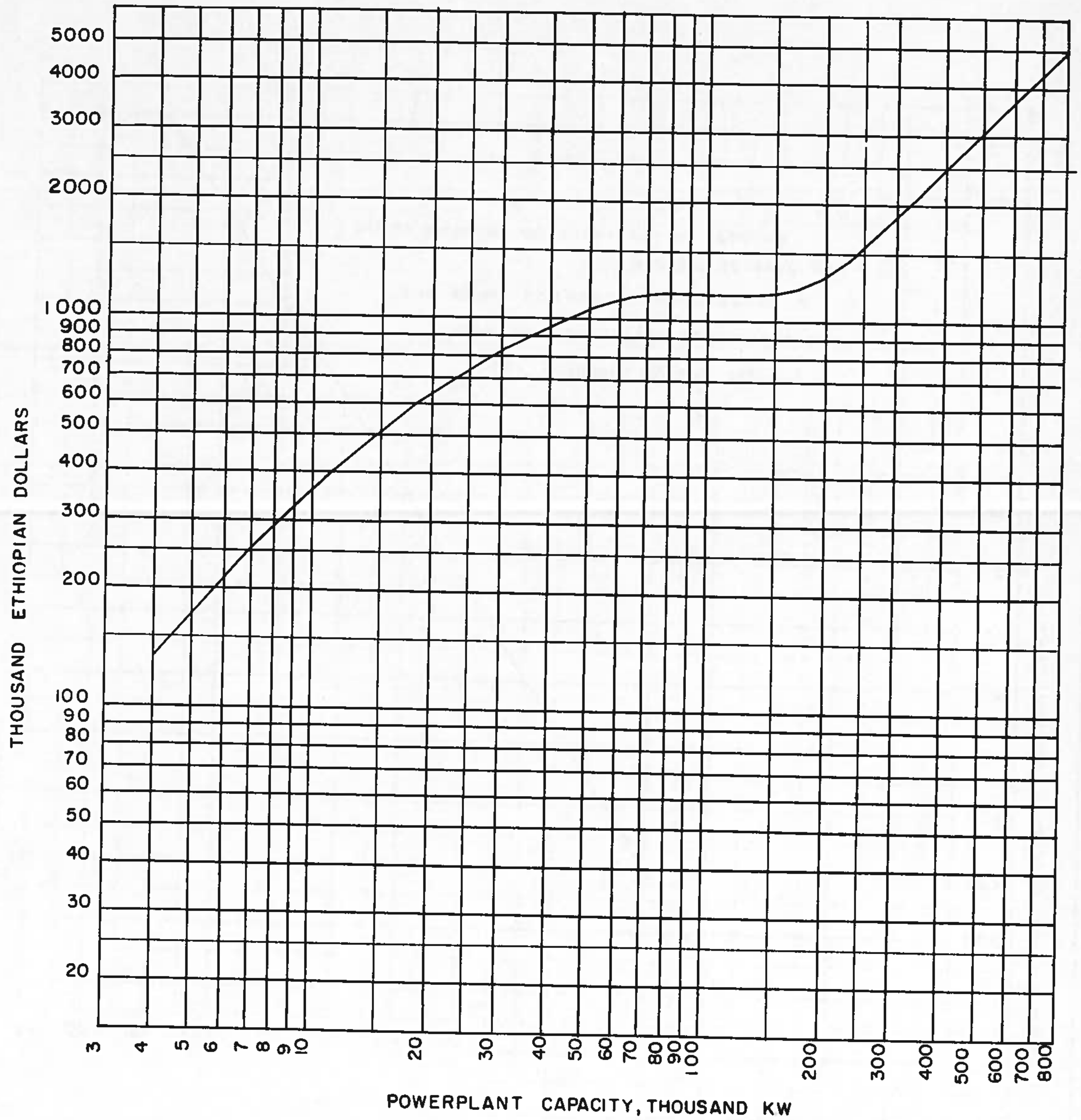
BLUE NILE RIVER BASIN

RECONNAISSANCE ESTIMATES
ANNUAL O&M EXPENSES
FOR
HYDROELECTRIC POWERPLANTS

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 OCT. 10, 1962 | 4.0-BN-58

Figure V-82--Annual O&M Expenses for Hydroelectric Powerplants



Notes:

1. Curve includes allowances for administrative and general expense.

2. Costs are for January, 1961

3. Based upon plant factor of about 65 %

4. Includes wages (with supervision), water, lubrication, supplies, maintenance and repair.

5. Does not include fuel costs.

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
RECONNAISSANCE ESTIMATES
ANNUAL O&M EXPENSE
FOR
STEAM ELECTRIC POWERPLANTS

DRAWN C.L. CURTIS	SUBMITTED C.L.C.
TRACED GIDEON	RECOMMENDED P.W.K.
CHECKED C.L.C.	APPROVED C.E.B.
Addis Ababa Ethiopia OCT 12, 1962	4 0-BN-59

Figure V-83--Annual O&M Expense for Steam Electric Powerplants

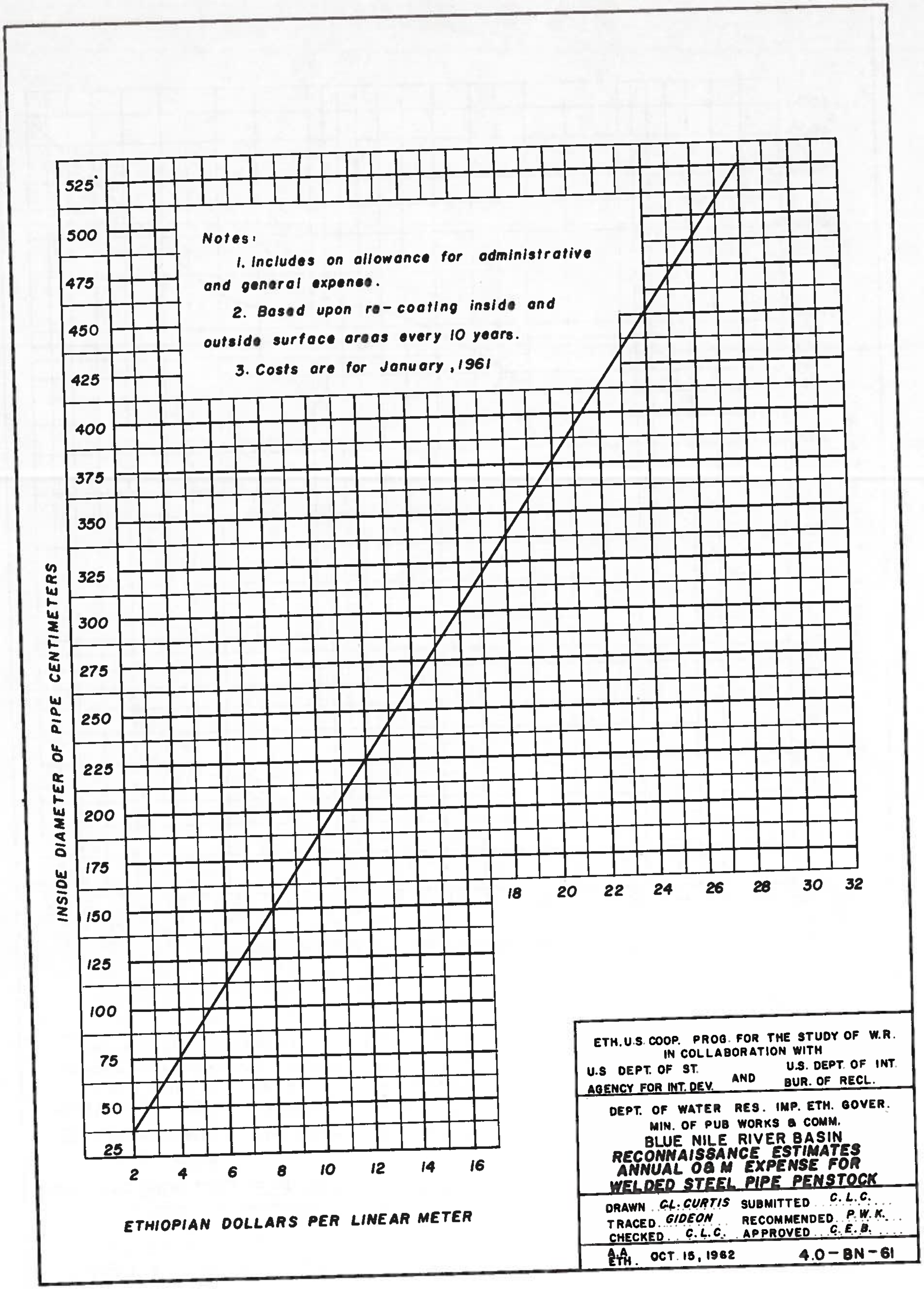


Figure V-84--Annual O&M Expense for Welded Steel Pipe Penstock

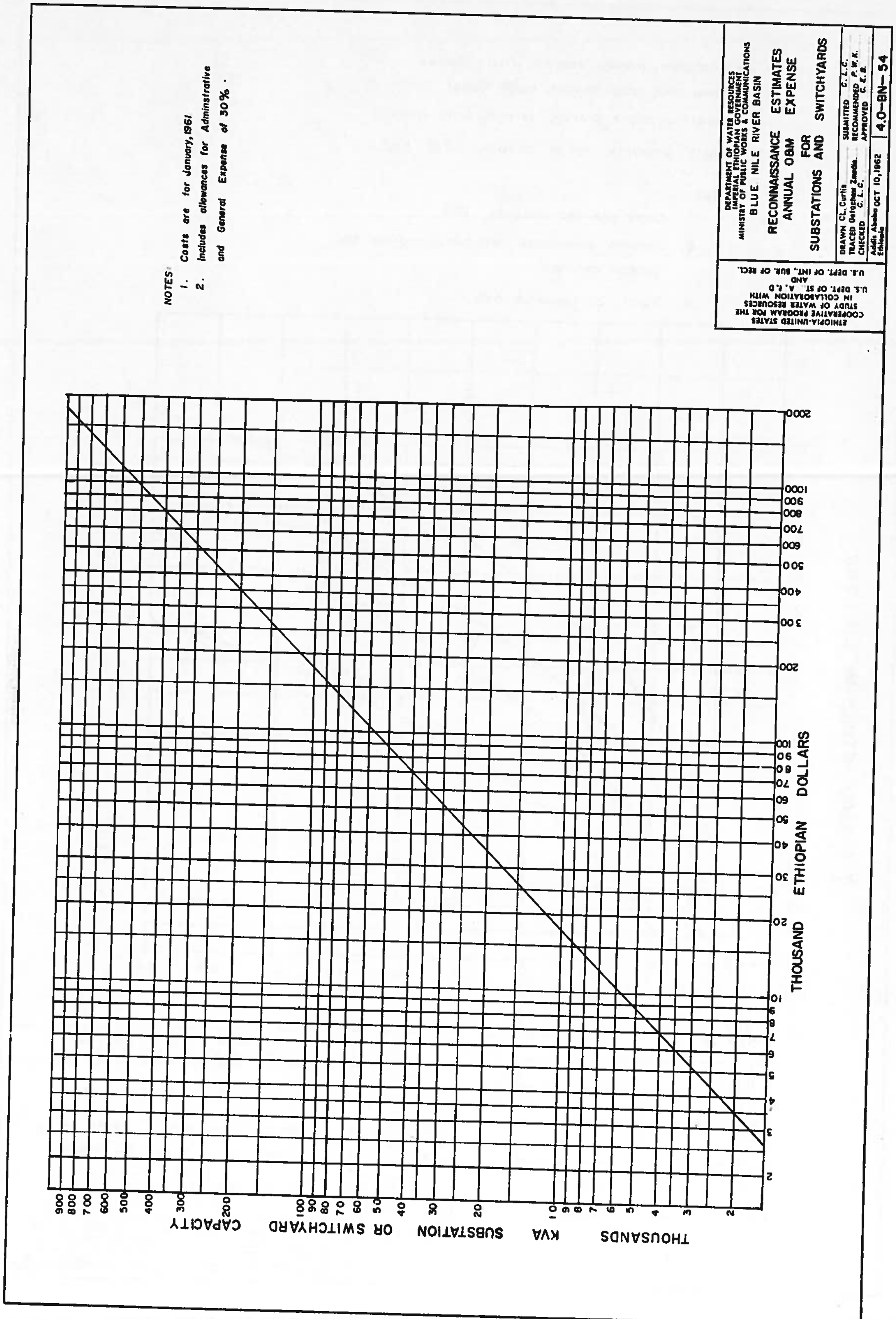


Figure V-85--Annual O&M Expense for Substations and Switchyards

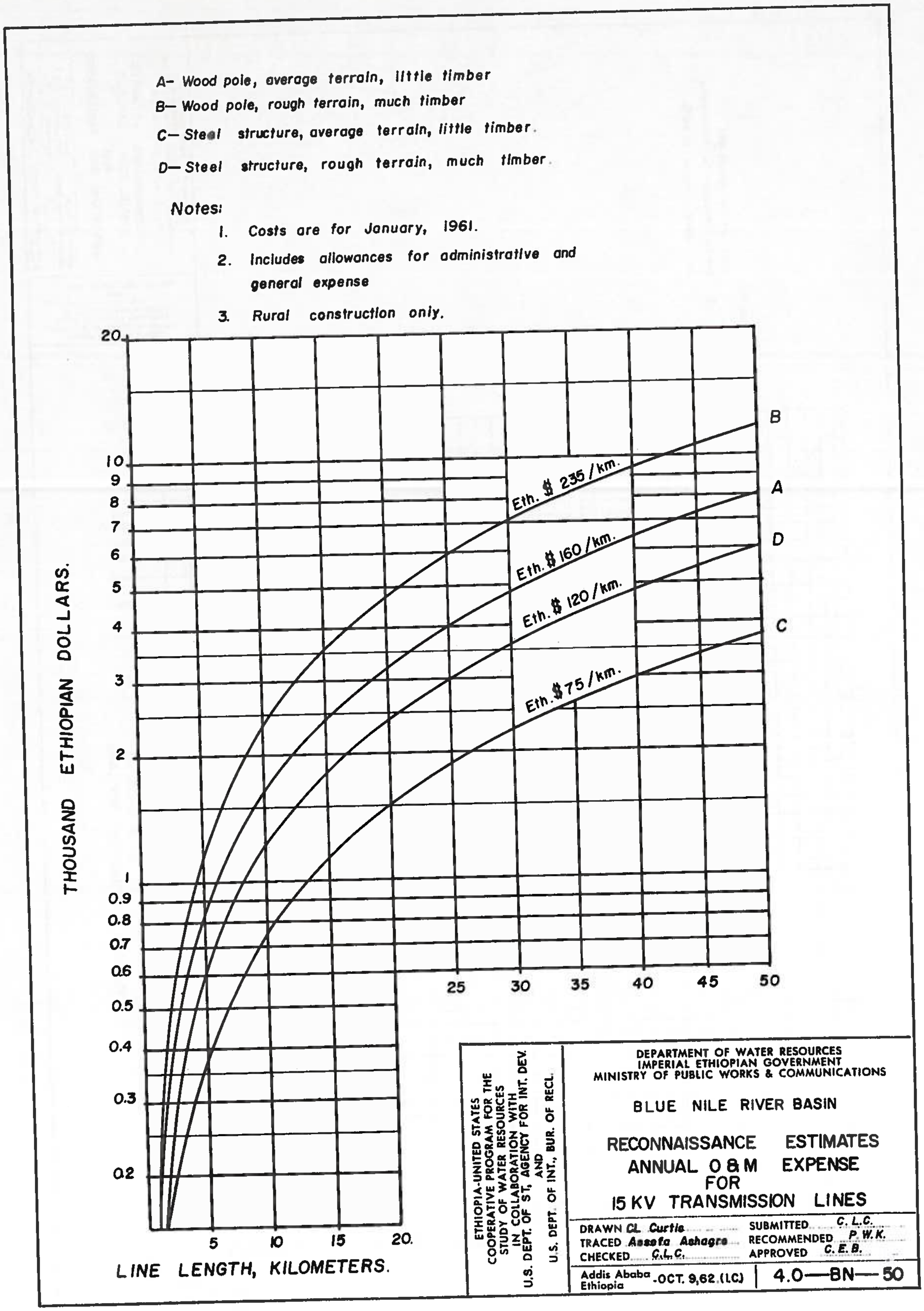


Figure V-86--Annual O&M Expense for 15-kv. Transmission Lines

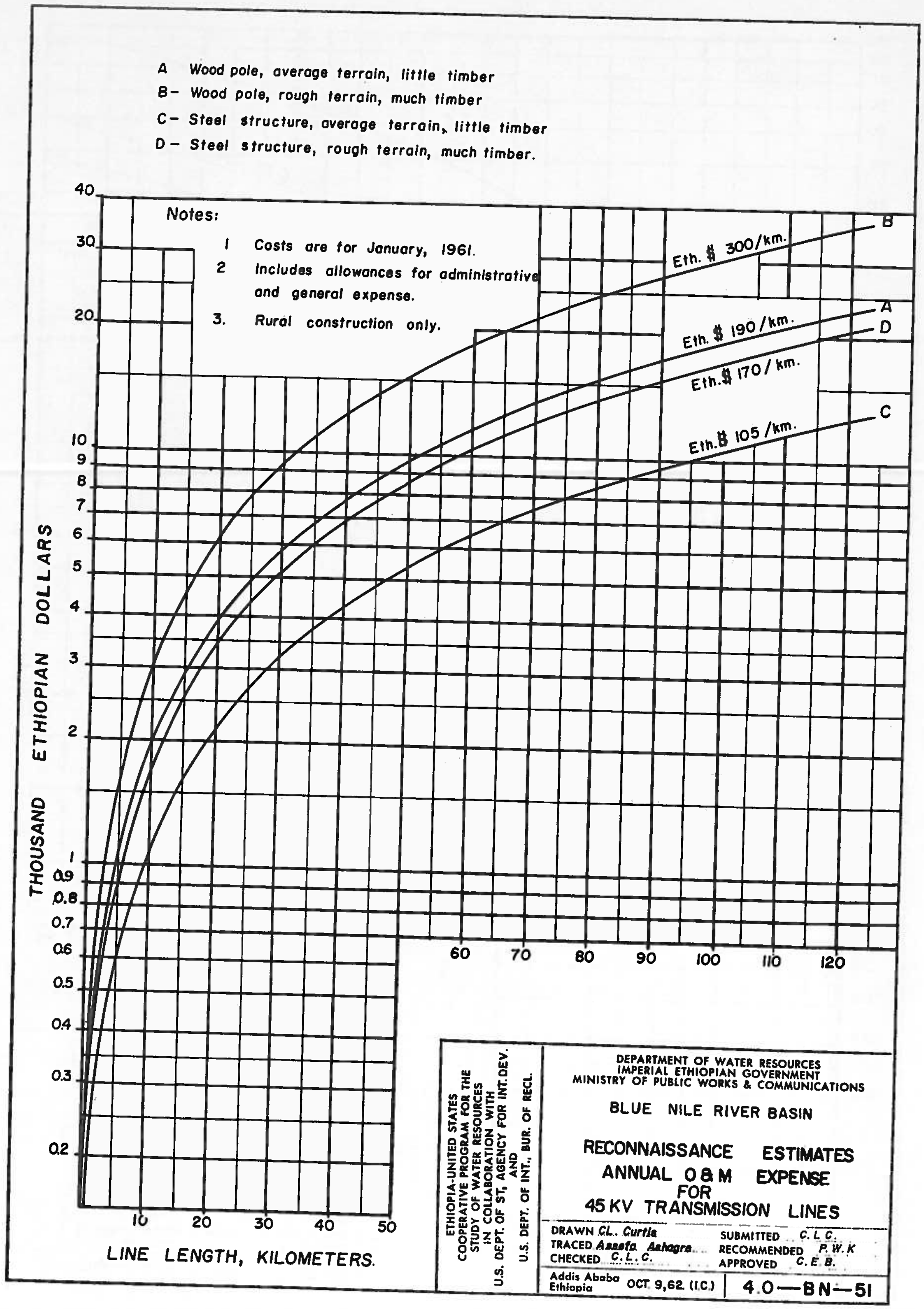


Figure V-87--Annual O&M Expense for 45-kv. Transmission Lines

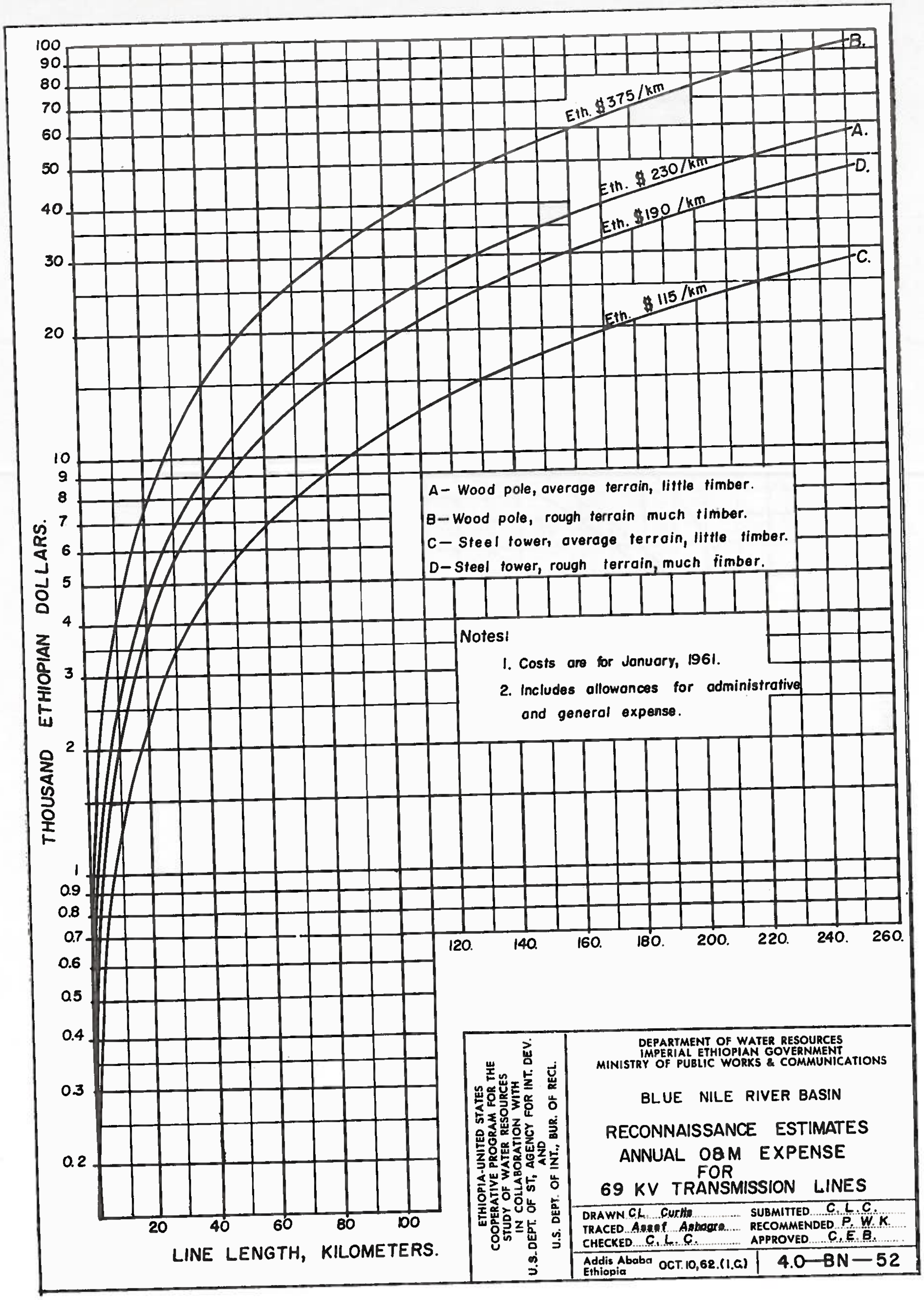
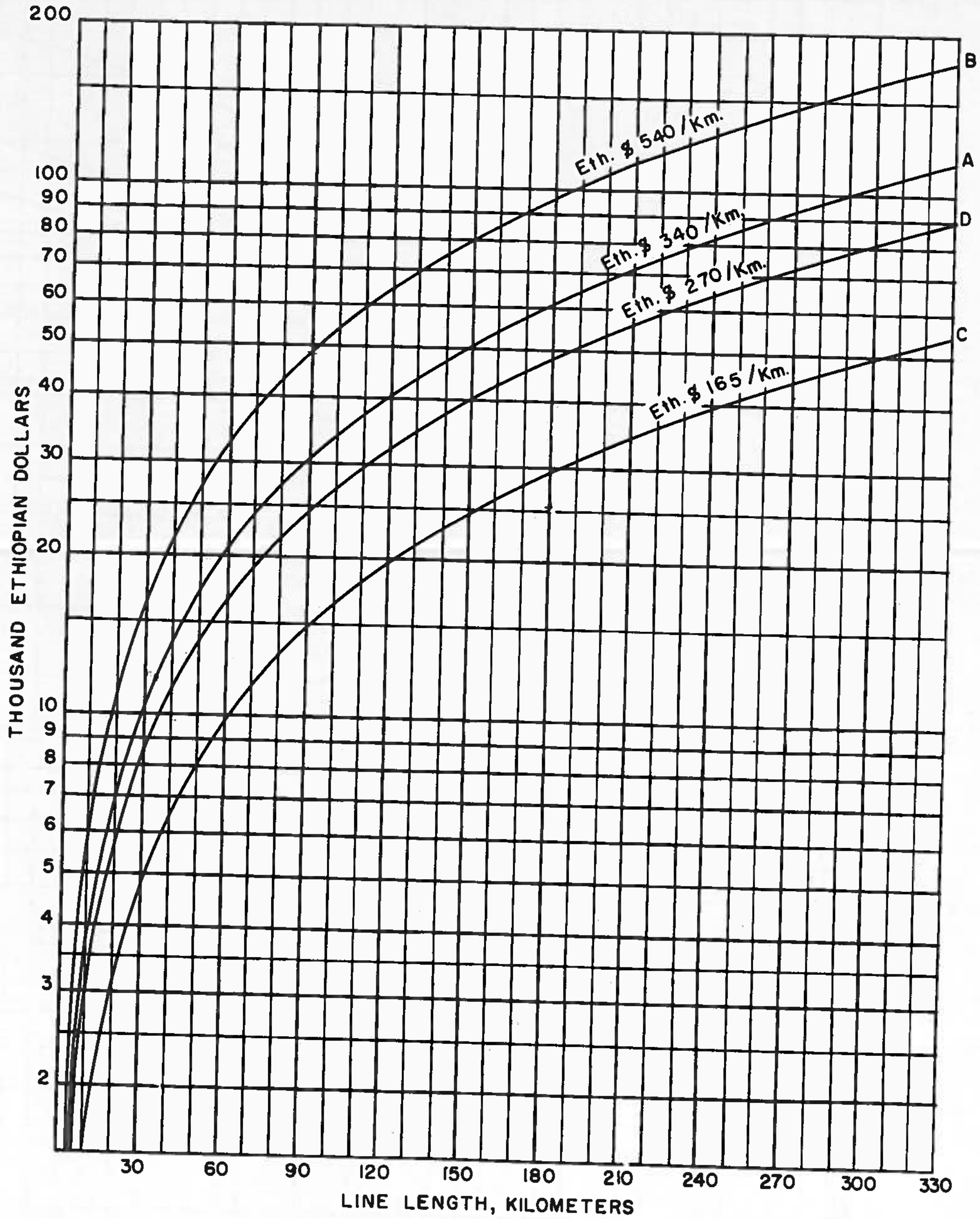


Figure V-88--Annual O&M Expense for 69-kv. Transmission Lines



A – Wood pole, average terrain, little timber.
B – Wood pole, rough terrain, much timber.
C – Steel tower, average terrain, little timber.
D Steel tower, rough terrain, much timber.

Notes

1. Costs are for January, 1961
2. Includes allowances for administrative and general expense.

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.

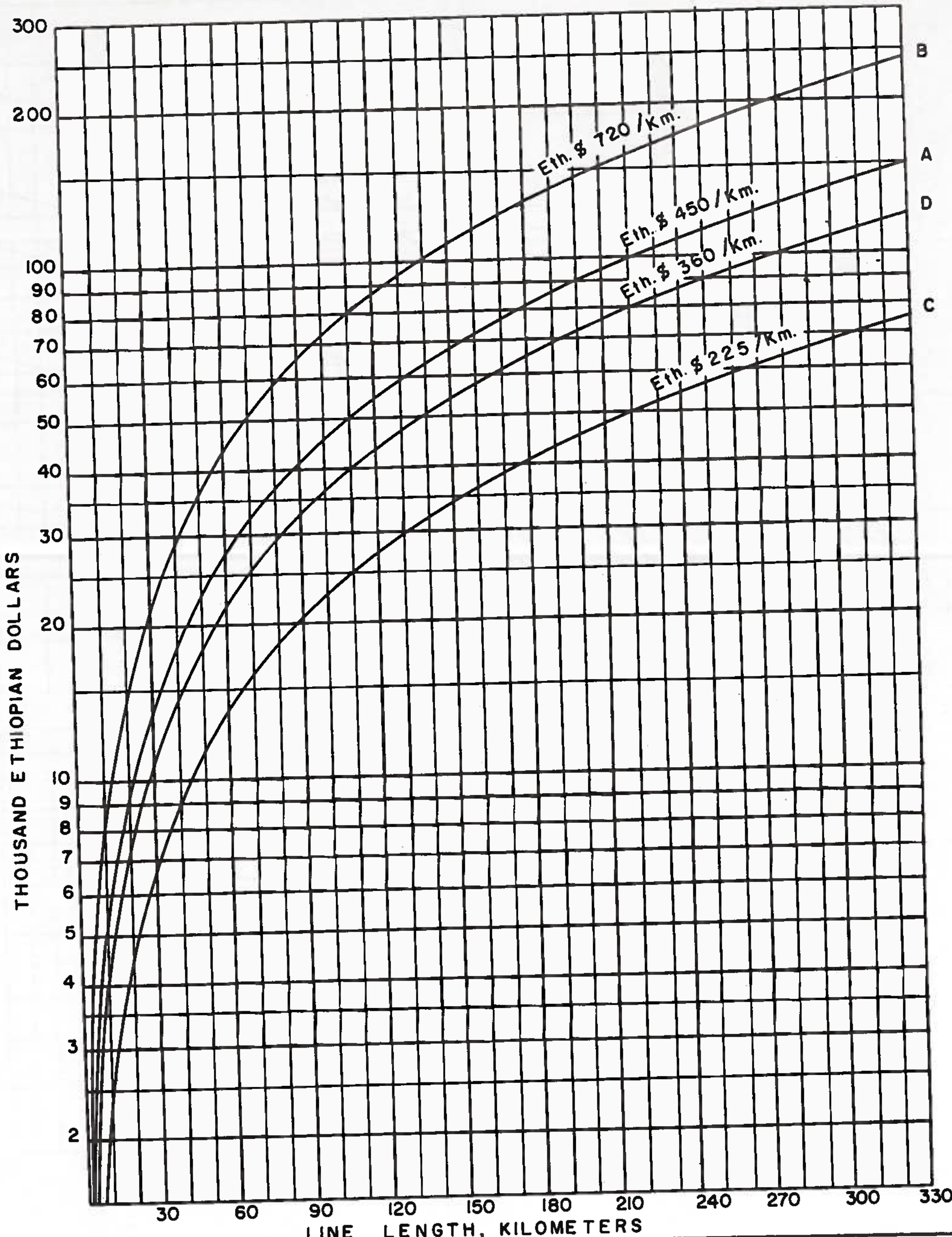
DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS

BLUE NILE RIVER BASIN
RECONNAISSANCE ESTIMATES
ANNUAL O&M EXPENSE
FOR
132-Kv. TRANSMISSION LINES

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 | Oct. 8, 1962 | 4.0-BN-55

Figure V-89--Annual O&M Expense for 132-kv. Transmission Lines



A – Wood pole, average terrain, little timber.
B – Wood pole, rough terrain, much timber.
C – Steel tower, average terrain, little timber.
D Steel tower, rough terrain, much timber

Notes

1. Costs are for January, 1961
2. Includes allowances for administrative and general expense

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
RECONNAISSANCE ESTIMATES

ANNUAL O&M EXPENSE
FOR
161-Kv TRANSMISSION LINES

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 — Oct. 8, 1962	4.0-BN-56

Figure V-90--Annual O&M Expense for 161-kv. Transmission Lines

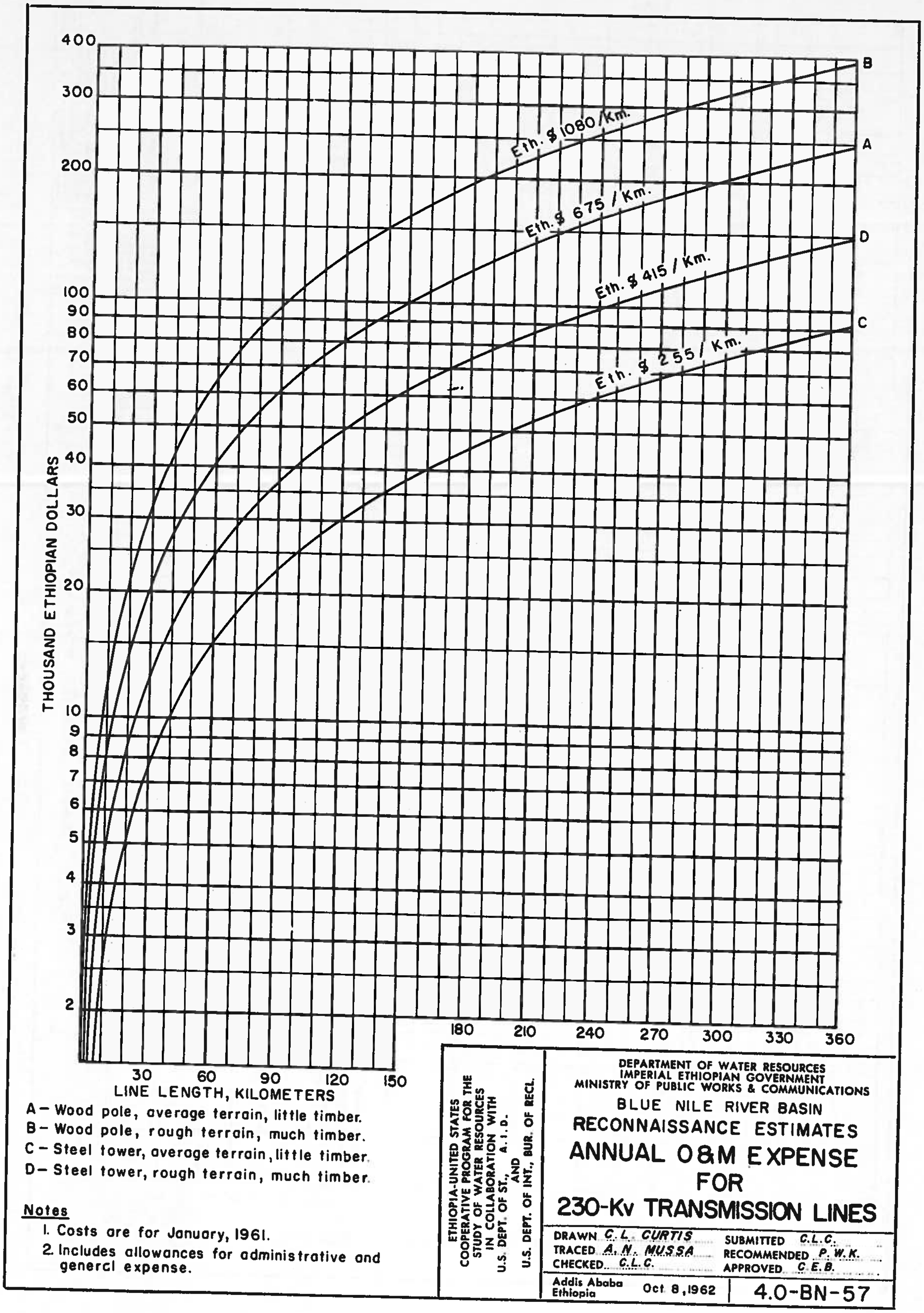


Figure V-91--Annual O&M Expense for 230-kv. Transmission Lines

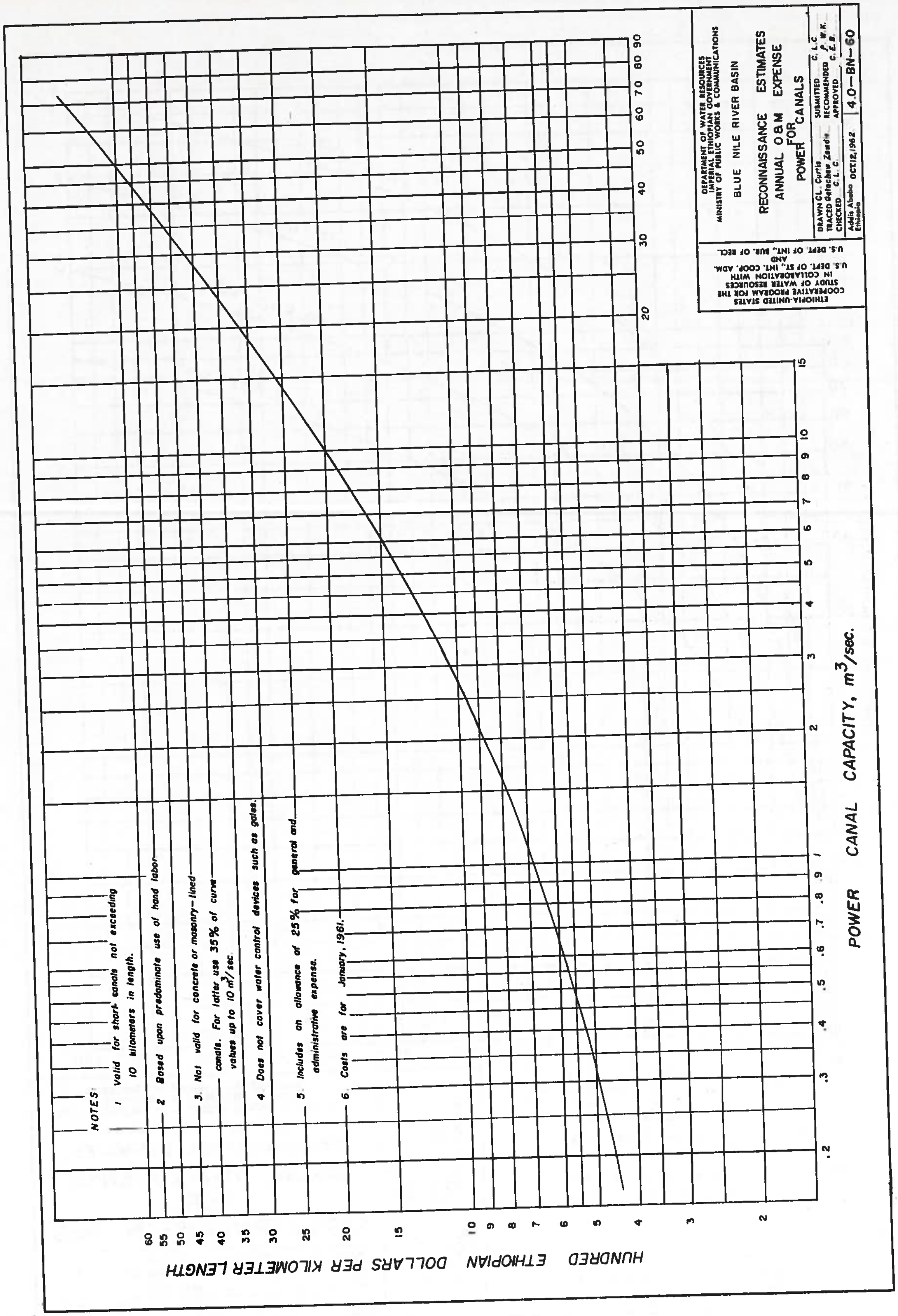


Figure V-92--Annual O&M Expense for Power Canals

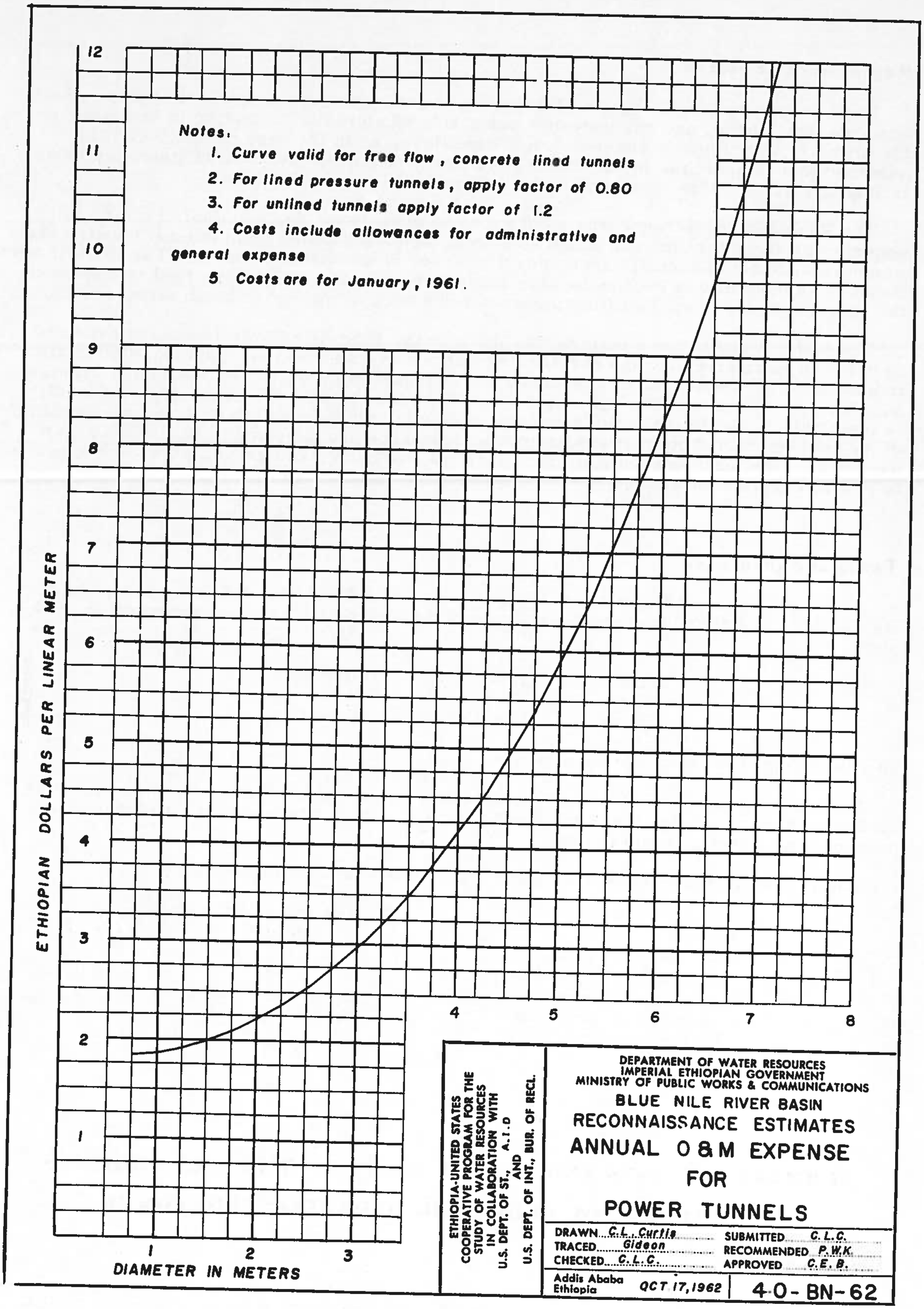


Figure V-93--Annual O&M Expense for Power Tunnels

Replacement Reserve

From the day the construction of a facility is completed, deterioration begins. Wear, use, physical decay, and obsolescense contribute to a gradual reduction in the value of the property as originally constructed. Sometimes, as in the case of EELPA, it is assumed that this decline in value is a linear or straight line function of time, the value falling to salvage value at the end of the estimated life of the facility.

The Replacement Reserve was established to provide for replacement of major components of a facility at the end of service lives as distinguished from normal repairs and minor replacements accomplished annually by use of maintenance funds. The Replacement Reserve as used in this reconnaissance study is based upon the sinking fund concept with the salvage values of all facilities assumed to be zero at the end of their service lives.

The components of the electrical facilities in the Blue Nile River Basin are expected to have the estimated average service lives shown in Table V-115. The same table also indicates the percent of each component that is replaceable during its estimated average service life. ("Service life" means the time between the date the plant, or component, is includible in electric plant in service, or electric plant leased to others, and the date of its retirement.) Note that insulators and hardware are assumed to be replaced as a part of the maintenance program, and overhead conductors and ground wires are expected to last through the 50-year period and are thus not listed.

Taxes and Insurance

Existing electric utilities are subject to taxation in Ethiopia. EELPA, according to its charter, is subject to normal taxation and the income tax rates on net profit in 1961 were:

First	Eth$75,000 -- 16 percent
Next	Eth$300,000 -- 26 percent
Above	Eth$375,000 -- 36 percent

In 1962, about Eth$660,000 was paid.

Insurance costs have not been a significant item for the two major utilities operating in Ethiopia, but as the value of the fixed assets in operation increases, insurance costs may become a factor in the future.

The following construction cost factors have been used in this report:

	Taxes and insurance percent
Hydroelectric plant facilities	0.15
Electrical transmission and substation facilities	0.15
Thermal electric plant facilities	0.35

SUMMARY OF COSTS AND ANNUAL COSTS BY SELECTED PROJECTS CAPABLE OF PRODUCING HYDROELECTRIC POWER

Present Century

Two types of projects are involved: single-purpose power and multiple-purpose (Irrigation and Power). During the present century, these projects may be of interest to IEG for possible development.

TABLE V-115--REPLACEMENT RESERVE FACTORS

Components 1/ (1)	Percent of component replaceable (2)	average service life (yr.) (3)	Replacement factors 5%, 50 yr. (4)	Approximate composite replacement reserve factors, 5%, 50 yr., for features, Col. 6 (5)	Features (6)
Hydraulic Production				0.00298	Hydroelectric powerplants
321 - Structures and improvements 2/	-	-	-		
322 - Reservoirs, dams, and waterways 3/	-	-	-		
323 - Turbines and generators	12.0	35	0.00207		
	5.5	40			
	6.0	50			
324 - Accessory electric equipment	2.0	15	0.00675		
	38.0	35			
	18.0	40			
	2.5	50			
325 - Miscellaneous equipment	8.25	25	0.00173		
Transmission Plant				0.00712	Switchyards and substations above 69 kv.
				0.00609	Switchyards and substations 69 kv. and below.
342 - Structures and improvements 3/	-	-	-		
343 - Station equipment					
High voltage 69 kv. and below 4/	18.9	35	0.00389		
	21.6	40			
High voltage above 69 kv.	29.0	35	0.00527		
	21.4	40			
	4.5	45			
344 - Towers and fixtures	5.0	50	0.000239	0.000239	Steel tower transmission lines
348 - Underground conductors and devices	100.0	25	0.0210		
General Plant					
371 - Structures and improvements 2/	-	-	-		
378 - Communications equipment	39.6	15	0.0222	0.0222	Communication facilities
	35.0	35			
Thermal Production					
Steam and diesel generation	100.0	25	-	0.0210 5/	Thermal-electric powerplants

1/ See Annex A for full description.
2/ Replacement costs directly estimated where possible.
3/ Considered as zero in these reconnaissance estimates.
4/ This applies to maximum voltage in the station. One factor is applied to all station equipment in an individual switchyard or substation, based on the maximum station voltage.
5/ Based upon 25-year average service life used by EELPA. One hundred percent replaceable this period. Diesel and steam have same factors--same average service life as used by EELPA.

Multiple-purpose	Single-purpose power
Finchaa	Lower Guder
Amarti-Neshe	Lower Diddessa
Dabana	Dabus Power
Upper Beles	
Angar	
Arjo-Diddessa	
Gilgel Abbay (West German Plan)*	

Table V-116 provides a summary of construction costs for the projects listed, and Table V-117 provides a summary of total annual costs chargeable to power. Tables V-118 and V-119 provide information supporting the OM&R costs for Transmission Plant features proposed for marketing of commercial power. Table V-120 provides a separate summary of total OM&R costs of electrical facilities used only for irrigation pumping purposes.

TABLE V-116--SUMMARY OF CONSTRUCTION COSTS--PRESENT CENTURY PROJECTS CAPABLE OF PRODUCING OR TRANSMITTING POWER

Project	Features			Total (Eth$)
	Irrigation (Eth$)	Power (Eth$)	Joint-use 1/ (Eth$)	
Finchaa (FI-1A)	16,112,000	65,177,000	4,838,000	86,127,000
Amarti-Neshe (NES-1A)	9,487,000	56,274,000	57,259,000	123,020,000
Dabana (DB-1; -1A)	13,096,000	89,542,000	255,730,000	358,368,000
Upper Beles (BL-1)	117,682,000	179,335,000	49,700,000	346,717,000
Angar (AG-2; -6A; -6B)	72,864,000	97,416,000	299,655,000	469,935,000
Lower Guder (GU-1)		126,848,000		126,848,000
Arjo-Diddessa (DD-11)	51,492,000	14,116,000	95,603,000	161,211,000
Lower Diddessa (DD-2)		404,885,000		404,885,000
Dabus Power		9,622,000		9,622,000
Addis Ababa-Assab Transmission		84,891,000		84,891,000

1/For cost allocation of these facilities to power and irrigation, see Appendix VI, "Agriculture and Economics."

Certain elements of annual costs developed in tabular form for various types of electrical facilities generally were not rounded until a total was reached for the total annual cost of a given project. The project total was then rounded.

Next Century

Section V listed the following inventoried projects capable of producing hydroelectric power which might be developed after the year 2000.

Multiple-purpose	Single-purpose power
Dindir (DI-7)	Giamma (GI-1)
	Muger (MU-1 and MU-4)
	Karadobi (BN-3)
	Mabil (BN-19)
	Mendaia (BN-26A)
	Middle Beles (BL-3)
	Border (BN-28)

Table V-121 provides a summary of construction costs for these projects and Table V-122 provides a summary of total annual costs chargeable to power.

*Data omitted from this volume.

TABLE V-117--SUMMARY OF ANNUAL COSTS--POWER--PRESENT CENTURY PROJECTS

Project	Purpose	Specific power features: Feature	Operation and maintenance (Eth$)	Replacement (Eth$)	Other 1/ (Eth$)	OM&R and other (rounded) (Eth$)	Summary by project: Additional annual costs 3/ (Eth$)	Total annual costs chargeable to power 3/ (Eth$)
Finchaa	Multiple-purpose	Power diversion dam	4,000					
		Power tunnel & penstocks	13,720					
		Powerplant (FI-1A)	653,000	32,825				
		Transmission plant (Tables V-116 & V-117)	376,000	46,412	98,000	1,224,000	4,143,000 2/	5,367,000
Amarti-Neshe	Multiple-purpose	Power canal	18,000					
		Power tunnel	830					
		Powerplant (NES-1A)	653,000	35,426				
		Penstocks	23,470					
		Transmission plant	370,840	58,521	84,000	1,244,000	6,097,000 2/	7,341,000
Dabana	Multiple-purpose	Power diversion dam	5,000					
		Powerplant (DB-1)	520,000	35,387				
		Penstocks (DB-1)	3,000					
		Powerplant (DB-1A)	500,000	92,279				
		Penstocks (DB-1A)	36,000					
		Power canal (DB-1A)	72,000					
		Forebay (DB-1A)	5,000					
		Transmission plant (Tables V-116 & V-117)	1,111,000	127,000	134,000	2,641,000	18,962,000 2/	21,603,000
Upper Beles	Multiple-purpose	Power canal	120,000					
		Forebay	5,000					
		Pressure tunnel & shaft	13,827					
		Penstock tunnels	17,598					
		Powerplant (BL-1)Alefa	1,000,000	52,150				
		Penstocks	67,200					
		Transmission plant (Tables V-116 & V-117)	1,193,000	165,634				
		Access road & service facilities	Included above--		265,000	2,900,000	12,837,000 2/	15,737,000
Angar	Multiple-purpose	Powerplant (AG-2)	500,000	35,760				
		Powerplant (AG-6A)	720,000	123,088				
		Powerplant (AG-6B)	530,000	62,338				
		Penstocks (AG-2)	6,000					
		Penstocks (AG-6A)	22,400					
		Penstocks (AG-6B)	12,000					
		Power canal (AG-6A)	120,000					
		Power canal (AG-6B)	39,000					
		Forebay (AG-6A)	5,000					
		Forebay (AG-6B)	5,000					
		Power diversion dam	5,000					
		Transmission plant (Tables V-116 & V-117)	729,000	102,000	146,000	3,163,000	19,699,000 2/	22,862,000
Lower Guder	Power only	Dam & reservoir (GU-1)	21,000					
		Powerplant (GU-1) Motto	550,000	42,036				
		Transmission plant (Tables V-116 & V-117)	431,500	47,500				
		Access roads & service facilities	Included above--		185,000	1,277,000	7,643,000 4/	8,920,000
Arjo-Diddessa	Multiple-purpose	Powerplant (DD-11)	500,000	29,800				
		Penstocks	5,000					
		Transmission plant	122,000	19,643	21,000	698,000	4,761,000 2/	5,459,000
Lower Diddessa	Power only	Dam & reservoir (DD-2)	100,000					
		Powerplant (DD-2) Boo	1,400,000	180,000				
		Penstocks	20,000					
		Transmission Plant	1,333,000	164,000				
		Access roads & service facilities	Included above--		599,000	3,796,000	26,060,000 4/	29,856,000
Addis Ababa-Assab Transmission	Power	Transmission plant (Tables V-116 & V-117)	1,309,000	156,000	127,000	1,592,000	9,331,000 4/	10,919,000
Dabus Power	Power	Diversion dam	2,000					
		Power canal	2,000					
		Forebay	500					
		Penstock	2,512					
		Powerplant	360,000	6,148				
		Transmission plant (Tables V-116 & V-117)	49,000	6,000				
		Access road						
		Service facilities	Included above		11,000	439,000	553,000 4/	992,000

1/ Taxes and insurance
2/ From cost allocations of joint-use facilities to power including amortization and additional OM&R
3/ See Appendix VI, "Agriculture and Economics"
4/ Amortization

TABLE V-118--ANNUAL OM&R COSTS FOR TRANSMISSION LINES--PRESENT CENTURY PROJECTS AND FEATURES (SPECIFICALLY POWER)

(FOR USE WITH TABLE V-115)

Voltage (kv.)	Description	Length (km.)	Project	Terrain	Annual cost O&M (Eth$)	Annual cost Replacement (Eth$)
161	Finchaa Switchyard-Dongi Sub.--steel tower, single circuit	1.8	Finchaa	Rough	56,000	3,582
161	Dongi Sub.-Gafarsa Sub. No. 2--double-circuit steel towers, one circuit needed initially	248		Average		
161	Neshe Switchyard-Dongi Sub.--steel tower single circuit	8 24	Amarti-Neshe	Rough Average	20,840	1,174
161	Dongi Sub.-Gafarsa Sub. No. 2--installation of second circuit on above Finchaa towers	248		Average		
69	Powerplant tie from DB-1 to DB-1A--steel tower	13	Dabana	Average	1,500	94
69	Second powerplant tie from DB-1 to DB-1A--steel tower	13		Average	1,500	
230	Powerplant DB-1 to Lekkemt Sub.--single-circuit steel tower	70		Average	17,000	861
230	Lekkemt Sub. to Akaki No. 2 Sub.--(double-circuit steel towers, one circuit installed initially)	245		Average	62,000	3,400
132	Lekkemt Sub. to Gore Sub.--steel tower	210		Average	34,000	1,475
132	Akaki No. 2 Sub. to Akaki No. 1 Sub.	12		Average	1,500	55
45	Powerplant DB-1 to Gimbi--steel	45		Average	5,000	111
45	Gimbi Sub. to Nejo Sub.--steel	60		Average	6,500	130
230	Akaki No. 2 Sub. to East Sub.--one circuit initially, double towers	10		Average	2,500	157
				Dabana totals Rounded	131,500 132,000	6,283 6,000
132	Alefa Powerplant (BL-1) to Bahir Dar Sub.--double circuit, steel	20 45	Upper Beles	Rough Average	7,200 7,000	591
230	Powerplant BL-1 to East Sub.--double-circuit, steel	110 340		Rough Average	32,400 104,400	9,868
45	Bure Sub. to Jiga Sub.--steel	37		Average	4,200	67
45	Bure Sub. to Injibira Sub. to Danglia Sub.--steel	70		Average	7,500	173
45	Injibira Sub. to Metekkel Sub.--steel	50		Rough	8,500	156
132	Bahir Dar Sub. to Stella Sub. to Gondar Sub.--steel tower	146		Average	24,000	670
45	Stella Sub. to Debre Tabor--steel	40		Rough	6,800	109
				Upper Beles totals	202,000	11,634
132	Powerplant AG-2 to Lekkemt Sub.--steel tower	75	Angar	Average	12,000	344
69	Powerplant AG-6B to Powerplant AG-6A intertie--steel tower	5		Rough	1,400	24
132	Powerplant AG-6A to Lekkemt Sub--steel tower	43		Average	6,800	431
230	Lekkemt Sub. to Akaki Sub. No. 2--install second circuit on existing steel towers. See Dabana Project	245		Average	18,000	
				Angar totals	38,200	799

(FOR USE WITH TABLE V-115)

Sheet 2 of 2

Voltage (kv.)	Description	Length (km.)	Project	Terrain	Annual cost O&M (Eth$)	Annual cost Replacement (Eth$)
161	Agere Hiywet Sub. to East Sub.--steel tower	110	Lower Guder	Average	25,000	1,358
132	Motto (GU-1) Powerplant to Agere Hiywet Substation--double circuit steel tower	20 40		Rough Average	15,000	
132	East Addis Ababa Sub. to Central A. Ababa Sub.--steel tower (Figure V-33)	5		Average	1,500	
			Lower Guder totals Rounded		41,500 41,500	1,358 1,500
132	Diddessa Powerplant (DD-11) to Jima Substation--steel tower	60	Arjo-Diddessa	Rough	17,000	335
230	Powerplant DD-2 to Akaki Sub. No. 2--double-circuit steel tower	25 300	Lower Diddessa	Rough Average	14,000 90,000	6,914
230	Akaki No. 2 Sub. to East Sub.--steel tower. Install on existing steel towers, second circuit. See Dabana Project	10		Average	1,000	01/
230	Powerplant Boo (DD-2) to Lekkemt Sub.--single circuit, steel tower	30 50		Rough Average	12,000 12,000	1,120
230	Lekkemt Sub. to Akaki Sub. No. 2--single circuit, steel tower	245		Average	62,000	3,185
			Lower Diddessa totals Rounded		191,000 191.000	11,219 11,000
230	East Sub. to Kembolcha--double circuit steel tower	75 215	Addis Ababa-Assab Transmission	Rough Average	36,000 66,000	6,375
132	Kembolcha Sub. to Dessie Sub.--steel tower	13		Rough	5,000	157
132	East Sub. to Gafarsa No. 2 Sub.--steel tower	5		Average	2,000	23
230	Kembolcha Sub. to Assab Sub.--steel tower, single circuit	85 300		Rough Average	35,000 78,000	8,407
45	East Sub. to Debre Birhan Sub.--steel	110		Average	12,000	271
45	Debre Birhan to Debre Sina Sub.--steel pole	35		Rough	6,000	95
			Addis Ababa-Assab Transmission totals Rounded		240,000 240,000	15,328 15,000
45	Powerplant DA-8 to Mendi--steel pole	30	Dabus Power 1/	Rough	5,000	1,000
45	Powerplant DA-8 to Chera Gudde--tap location, steel pole	40		Rough	7,000	
45	Chera Gudde Tap to Asosa--steel pole	25		Average	2,600	
45	Chera Gudde to Begi--steel pole	70		Average	7,400	
			Dabus Power totals		22,000	1,000

1/ Dabus Power Project is electrically isolated from all preceding projects.

TABLE V-119--ANNUAL OM&R COSTS FOR SUBSTATIONS AND SWITCHYARDS--PRESENT CENTURY PROJECTS AND FEATURES (SPECIFICALLY POWER)

(FOR USE WITH TABLE V-115)
Sheet 1 of 2

Switchyard or substation	Project	Stage	Maximum voltage (kv.)	Total transformer capacity (kv.-a.)	Annual cost O&M (Eth$)	Annual cost Replacement (Eth$)
Switchyard	Finchaa	complete	161	100,000	160,000	16,575
Gafarsa No. 2		01	161	100,000	160,000	26,255
				Finchaa totals	320,000	42,830
Switchyard	Amarti-Neshe	complete	161	100,000	160,000	16,296
Dongi		complete	161	switching only	30,000	10,680
Gafarsa No. 2		02	161	100,000	160,000	30,371
				Amarti-Neshe totals	350,000	57,347
Switchyard DB-1	Dabana	complete	230	162,000	275,000	28,095
Switchyard DB-1A		complete	69	60,000	100,000	7,058
Nejo		complete	45	1,000	1,500	706
Gimbi		complete	45	1,500	2,500	792
Gore		01	132	30,000	50,000	7,155
East		02	230	100,000	175,000	21,253
Akaki No. 2		01	230	125,000	225,000	29,235
Lekkemt		01	230	83,333	150,000	26,685
				Dabana totals	979,000	120,979
				Rounded	979,000	121,000
Switchyard	Upper Beles	complete	230	375,000	650,000	69,780
		01	132	50,000	175,000	29,900
Bahir Dar		02	132	50,000		
		01	132	10,000	17,000	5,169
Stella		complete	45	1,000	2,000	639
Debre Tabor		01	132	15,000	25,000	5,860
Gondar		complete	230	5,000	9,000	9,576
Bure		complete	45	2,000	3,500	1,065
Injibira		complete	45	1,000	2,000	639
Metekkel		complete	45	4,000	7,000	1,188
Dangila		complete	45	3,000	5,000	1,114
Jiga		complete	230	30,000	50,000	11,776
Debre Markas		03	230	switching only	48,500	17,294
East						
				Upper Beles totals	991,000	154,000
Switchyard (AG-2)	Angar	01	132	60,000	100,000	9,120
Switchyard (AG-6A)		01	132	100,000	175,000	29,412
Switchyard (AG-6B)		complete	69	60,000	100,000	7,141
Lekkemt		02	132	123,333	200,000	33,506
Akaki No. 2		02	230	50,000	90,000	15,750
Fiche		complete	230	15,000	26,000	5,640
				Angar totals	691,000	100,569
Switchyard (GU-1)	Lower Guder	complete	132	80,000	140,000	12,680
Agere Hiywet		complete	161	85,000	150,000	27,255
East		05	230	60,000	100,000	15,443
				Lower Guder totals	390,000	45,278
				Rounded	390,000	46,000
Switchyard (DD-11)	Arjo-Diddessa	complete	132	40,000	70,000	7,212
Jima		complete	132	20,000	35,000	12,096
				Arjo-Diddessa totals	105,000	19,308
Switchyard (DD-2)	Lower Diddessa	complete	230	500,000	900,000	85,740
Akaki No. 2		03	230	125,000	200,000	53,870
East		06	230	switching only	11,000	3,966
Lekkemt		03	230	switching only	22,000	7,917
Gore		02	45	5,000	9,000	1,507
				Lower Diddessa totals	1,142,000	153,000

(FOR USE WITH TABLE V-115)

Sheet 2 of 2

Switchyard or substation	Project	Stage	Maximum voltage (kv.)	Total transformer capacity (kv.-a.)	Annual cost O&M (Eth$)	Annual cost Replacement (Eth$)
East	Addis Ababa-Assab Transmission	01	230	125,000	225,000	21,000
		04	230	switching only	21,000	6,453
Kembolcha		01	230	125,000	225,000	33,210
		02	230	switching only	12,000	4,240
Dessie		01	132	125,000	225,000	18,362
		02	45	switching only	4,000	1,437
Assab		01	230	100,000	175,000	30,740
		02	230	100,000	175,000	23,643
Debre Birhan		complete	45	3,000	5,000	1,133
Debre Sina		complete	45	1,500	2,000	725
	Addis Ababa-Assab Transmission totals				1,069,000	140,943
				Rounded	1,069,000	141,000
DA-8 Switchyard	Dabus Power 1/	complete	45	10,000	17,000	2,223
Mendi Sub.		complete	45	1,000	1,500	640
Asosa Sub.		complete	45	2,000	3,500	1,041
Begi Sub.		complete	45	3,000	5,000	1,096
			Dabus Power totals		27,000	5,000

1/ Dabus Power Project is electrically isolated from all preceding projects.

TABLE V-120--ANNUAL OM&R COSTS OF ELECTRICAL FACILITIES USED FOR IRRIGATION PUMPING ONLY

Project	Description of facilities	Annual cost		
		O&M (Eth$)	Replacement (Eth$)	OM&R Totals (rounded) (Eth$)
West Megech	45-kv., 23-km., steel-pole transmission line. Gondar Substation to West Side Megech Relift Pumping Plant. Average terrain.	2,500	65	
	15-kv., 18-km., steel-pole transmission line. West Side Megech Relift Pumping Plant to Pumping Plant No. 1. Average terrain.	1,400	39	
	Gondar Substation, Stage 02, Figure V-120 (Annex "C").	8,800	1,267	
	Relift Pumping Plant Substation, complete. 45 kv. maximum voltage and 2,500 kv.-a.	4,500	688	
	Pumping Plant No. 1 Substation, complete. 15 kv. maximum voltage and 3,500 kv.-a.	6,000	755	
	West Side Megech totals	23,200	2,814	26,000
Northeast Tana	45-kv., 20-km., steel-pole transmission line. Stella Substation to Pumping Plant. Average terrain.	2,100	43	
	Stella Substation, Stage 02. Figure V-131 (Annex "C").	3,000	950	
	Pumping Plant Substation, complete. 45 kv., 4,500 kv.-a.	7,500	944	
	Northeast Tana totals	12,600	1,937	15,000
East Megech	45-kv., 13-km., steel-pole transmission line. Northeast Tana Pumping Plant to East Side Megech Pumping Plant. Average terrain.	1,500	28	
	Pumping Plant Substation, complete. 45 kv. and 7,500 kv.-a.	13,000	1,419	
	East Side Megech totals	14,500	1,447	16,000
Upper Beles	132-kv., 55-km., rough terrain, and 25-km., average terrain, steel-tower transmission line from Alefa Powerplant (BL-1) to Pumping Plant No. 2.	19,250	422	
	15-kv., 8-km., steel-pole line Pumping Plant No. 1 to Pumping Plant No. 2.	750	16	
	Pumping Plant No. 1 Substation. 15-kv. and 7,000 kv.-a.	12,000	937	
	Pumping Plant No. 2 Substation. 132 kv. and 10,000 kv.-a.	17,000	2,450	
	Upper Beles totals	49,000	3,825	53,000
Angar	15-kv., 7-km., steel-pole line. North Pumping Plant Substation No. 1 to North Pumping Plant Substation No. 2. Average terrain.	700	12	
	15-kv., 13-km., steel-pole line. North Pumping Plant Substation No. 2 to North Pumping Plant Substation No. 3. Average terrain.	1,000	28	
	45-kv., 15-km., steel-pole line. Powerplant Switchyard (AG-6A) to South Pumping Plant. Average terrain.	1,600	42	
	45-kv., 20-km., steel-pole line. Powerplant Switchyard (AG-2) to North Pumping Plant No. 1. Average terrain.	2,100	43	
	Switchyard (AG-2), Stage 02. Figure V-116 (Annex "C").	7,000	1,023	
	Switchyard (AG-6A), Stage 02. Figure V-110 (Annex "C").	50,000	3,830	
	North Pumping Plant No. 1 Substation. 45 kv. and 5,000 kv.-a.	9,000	1,559	
	North Pumping Plant No. 2 Substation. 15 kv. and 1,000 kv.-a.	1,500	445	
	North Pumping Plant No. 3 Substation. 15 kv. and 2,500 kv.-a.	4,200	579	
	South Pumping Plant Substation. 45 kv. and 33,000 kv.-a.	55,000	8,636	
	Angar totals	132,100	16,197	149,000
Dindir	105-km., 69-kv. transmission lines, steel tower, from DI-7 (Junction) Powerplant Switchyard to Pumping Plants. Average terrain.	12,000	488	
	Four each Pumping Plant Substations.	30,000	7,000	
	Dindir totals	42,000	7,488	50,000

TABLE V-121--SUMMARY OF CONSTRUCTION COSTS--NEXT CENTURY PROJECTS CAPABLE OF PRODUCING POWER

Project	Features			
	Irrigation (Eth$)	Power (Eth$)	Joint-use (Eth$)	Total (Eth$)
Dindir (DI-7)	161,730,000	18,990,000	267,752,000	448,472,000
Giamma (GI-1)		269,040,000		269,040,000
Muger (MU-1 & MU-4)		31,088,000		31,088,000
Karadobi (BN-3)		1,031,002,000		1,031,002,000
Mabil (BN-19)		851,079,000		851,079,000
Mendaia (BN-26A)		1,003,829,000		1,003,829,000
Middle Beles (BL-3)		213,737,000		213,737,000
Border (BN-28)		942,805,000		942,805,000

TABLE V-122.-SUMMARY OF ANNUAL COSTS.-NEXT CENTURY POWER PROJECTS

Project	Purpose	Specific power features: Feature	Operation and maintenance (Eth$)	Replacement (Eth$)	Other 1/ (Eth$)	Total OM&R and other (rounded) (Eth$)	Summary by project: Additional annual costs 3/ (Eth$)	Total annual costs chargeable to power 3/ (Eth$)
Dindir	Multiple-purpose	Powerplant (DI-7)	510,000	27,565	28,000	772,000	8,450,000 2/	9,222,000
		Penstocks	8,190					
		Transmission Plant	170,000	27,775				
Giamma	Power only	Dam & Reservoir	70,000		398,000	1,423,000	16,395,000 4/	17,818,000
		Powerplant	600,000	44,700				
		Communication	10,000	2,775				
		Penstocks	5,000					
		Transmission Plant	264,000	28,350				
		Access Road, Service Facilities	Included above					
Muger	Power only	Chancho Division			44,000	808,000	1,852,000 4/	2,660,000
		Chancho Dam & Reservoir	20,000					
		Canal	250					
		Forebay	3,000					
		Wasteway	50					
		Penstock	612					
		Powerplant MU-4	125,000	10,803				
		Transmission Plant	9,300	1,389				
		Falls Division						
		Diversion Dam	2,000					
		Penstock	3,718					
		Powerplant MU-1	450,000	16,762				
		Transmission Plant	109,250	11,884				
		Access Roads, Service Facilities	Included above					
Karadobi (BN-3)	Power only	Dam & Reservoir	400,000		1,514,000	15,897,000	66,746,000 4/	82,643,000
		Penstocks	15,600					
		Powerplant (BN-3)	6,210,000	372,500				
		Transmission Plant	6,555,000	830,055				
		Access Roads, Service Facilities	Included above					
Mabil (BN-19)	Power only	Dam & Reservoir	300,000		1,250,000	13,516,000	54,778,000 4/	68,294,000
		Penstocks	16,000					
		Powerplant (BN-19)	5,520,000	428,375				
		Transmission Plant	5,164,000	837,809				
		Access Roads, Service Facilities	Included above					
Mendaia (BN-26A)	Power only	Dam & Reservoir	320,000		1,474,000	17,905,000	65,297,000 4/	83,202,000
		Penstocks	30,000					
		Powerplant (BN-26A)	7,452,000	558,750				
		Transmission Plant	7,092,000	977,037				
		Access Roads, Service Facilities	Included above					
Border (BN-28)	Power only	Dam & Reservoir	280,000		1,387,000	17,249,000	58,100,000 4/	75,349,000
		Penstocks	25,000					
		Powerplant (BN-28)	6,440,000	596,000				
		Transmission Plant	7,594,000	927,002				
		Access Roads, Service Facilities	Included above					
Middle Beles (BL-3)	Power only	Dangur Dam & Reservoir	100,000		315,000	2,264,000	13,025,000 4/	15,289,000
		Powerplant (BL-3)	900,000	100,575				
		Penstocks	3,840					
		Transmission Plant	737,400	107,019				
		Access Road, Service Facilities	Included above					

1/Taxes and insurance
2/From cost allocations of joint-use facilities to power including amortization and additional OM&R
3/See Appendix VI, "Agriculture and Economics"
4/Amortization

SECTION VIII--POWER COSTS OF ALTERNATIVE SOURCES AND ANNUAL POWER BENEFITS

In the absence of any one of the previously discussed projects capable of producing electric power, alternative sources are presently limited to steam-electric generating plants for large load centers with diesel-electric considered for smaller load centers.

STEAM-ELECTRIC GENERATING STATIONS

Figures V-94 and V-95 were developed to compare cost estimates for various types of small- and medium-sized steam-electric generating stations in the Blue Nile River Basin. Figure V-96 provides a means for arriving at space requirements. Data for these curves came from various sources including the United States Federal Power Commission Publication S-149 for 1960, Electrical World, and the Ethiopian Electric Light and Power Authority.

Comparing the Nichols plant, Southwestern Public Service Company, Amarillo, Texas, with the cost of a similar facility in Addis Ababa would result in the Addis Ababa facility costing about 90 percent of the Texas facility. However, for areas remote from Addis Ababa, the costs will reach 110 percent of the United States price. This comparison assumes European equipment in Addis Ababa and American equipment for the United States plant.

For steam plants 100 mw. and above, construction costs of Eth$400 to Eth$500 per kw. of nameplate rating were used, the exact amount depending primarily upon capacity, accessibility, and problems at the selected construction sites. All plants are oil-fired Generally, two sites with suitable equivalent power transmission systems could be used to cover most conditions. One site is at the Aba Samuel Reservoir south of Addis Ababa (Figure V-97) and the other at Bahir Dar (Figure V-98).

By way of comparison, the average cost of steam electric generating stations in the United States in 1960 was US$152.50 (Eth$381) per installed kilowatt of capacity, 1/ exclusive of switchyard.

Fuel costs were based upon EELPA data for the existing Addis Ababa steamplant. Imported furnace oil cost Eth$128 per metric ton in Addis Ababa in 1961. An allowance was made for additional transportation costs at other locations with fuel cost reaching $140 or more per metric ton in some outlying areas. Furnace oil fuel cost in Asmara was taken at Eth$110 per metric ton based upon data obtained there. All fuel costs were assumed to be free of taxes.

Total station fuel costs were based upon these factors:

B.t.u. required per gross kw.-hr. generated	10,391
B.t.u. per kilogram of oil	40,700

Criteria for establishing other annual costs including OM&R, taxes, insurance, and amortization of the capital cost were covered in Section VII.

1/ Electrical World, 12th Steam Station Cost Survey, Oct. 2, 1961.

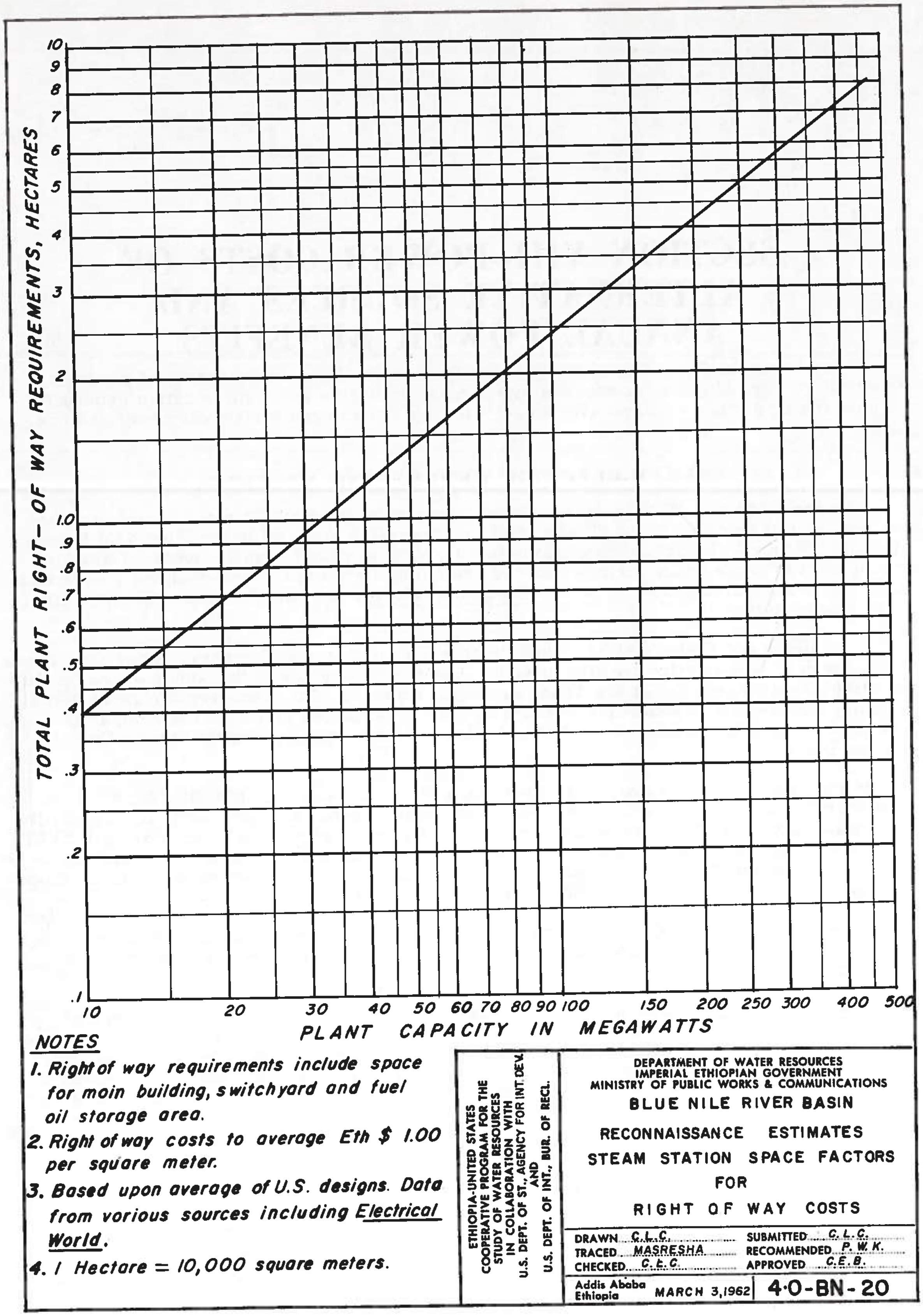
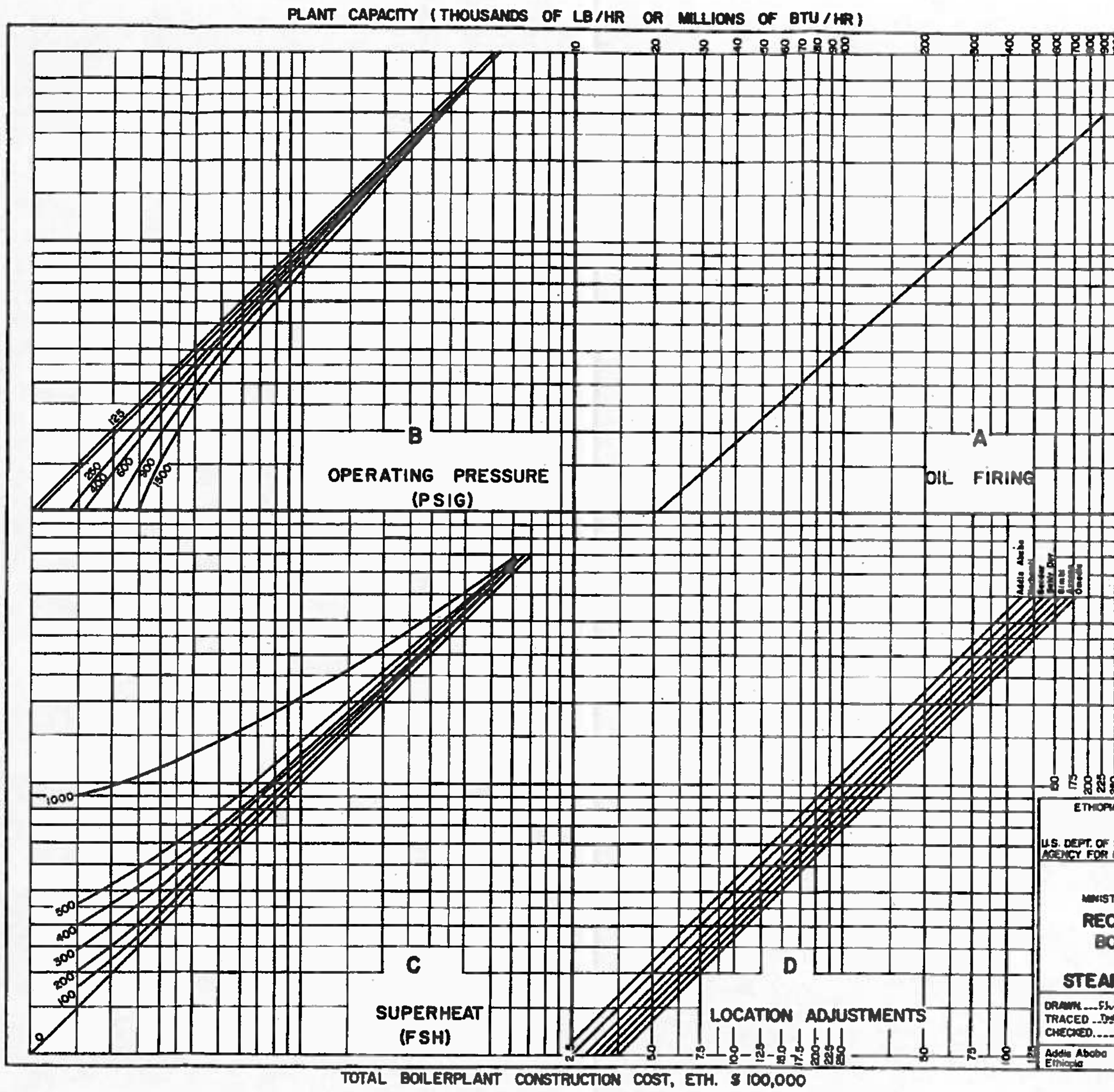


Figure V-94--Steam Station Space Factors for Right-of-Way Costs



CAUTION – To obtain total steam-electric powerplant costs add cost of boilerplant Drawing No. 4.0-BN-18 to cost of electric generating facilities, Drawing No. 4.0-BN-19.

TERMINOLOGY

P.S.I.G. - Pounds per square inch, gage.

F.S.H. - Fahrenheit, super heat.

NOTES

1. Costs include a total allowance of 25% for contingencies, engineering, and overhead. Right-of-way not included. Step-up electrical switchyard facilities not included.
2. To use curves, move vertically from scale on A to curve A, across to B, down to C, across to D, and vertically to scale on D.
3. Costs are for January 1961 and assume customs-free delivery of all items
4. For R.O.W. requirements see Drawing No. 4-0-BN-20.

Adapted to conditions and costs in Ethiopia from original curves by U.S. Bureau of Yards & Docks

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U.S. DEPT. OF ST. AGENCY FOR INT. DEV. — IN COLLABORATION WITH AND — U.S. DEPT. OF INT. BUR. OF RCL.

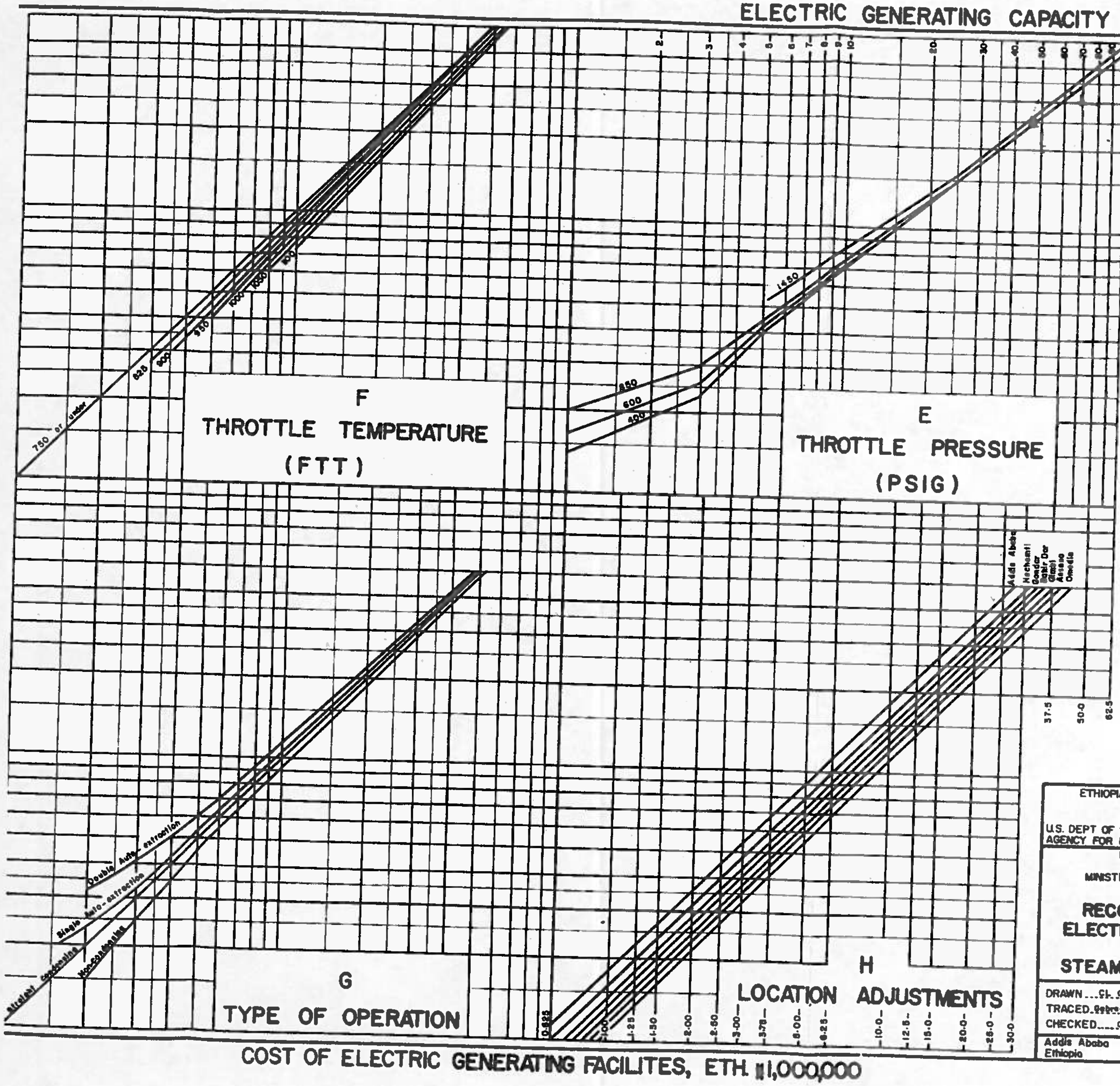
DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS

BLUE NILE RIVER BASIN

RECONNAISSANCE ESTIMATES
BOILERPLANT COMPONENT
OF
STEAM-ELECTRIC POWERPLANT

DRAWN ...	SUBMITTED ... G.L.G.
TRACED ...	RECOMMENDED ... P.W.K.
CHECKED ... G.L.G.	APPROVED ... G.E.B.
Addis Ababa, Ethiopia — March 1, 1962 (IC)	4.0-BN-18

Figure V-95--Boiler Plant Component of Steam-Electric Powerplant



CAUTION – To obtain total steam – electric powerplant costs add cost of boilerplant, Drawing No. 4-O-BN-18 to cost of electric generating facilites Drawing No. 4-O-BN 19

TERMINOLOGY

PSIG Pounds per square inch, gage
FTT- Fahrenheit, throttle temp.

NOTES

1 Costs include a total allowance of 25% for contingencies, engineering, and over head. Right-of-way not included. Step-up electrical switchyard facilities not included

2 To use curves, move vertically from scale on E to curve E across to F, down to G across to H and vertically to scale on H.

3 Costs are for January 1961 and assumes customs - free delivery of all items

4 For R O W requirements, see Drawing No. 4-O-BN-20

Adapted to conditions and costs in Ethiopia from original curves by U.S. Bureau of Yards & Docks.

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 RCL.

DEPARTMENT OF WATER RESOURCES
IMPERIAL ETIOPIAN GOVERNMENTS
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS
BLUE NILE RIVER BASIN

RECONNAISSANCE ESTIMATES ELECTRIC GENERATING FACILITY COMPONENT OF STEAM-ELECTRIC POWERPLANT

DRAWN ... Cl. Certis	SUBMITTED ... C.L.C.
TRACED ... Gebrekristos G.M.	RECOMMENDED ... P.W.K.
CHECKED ... C.L.C.	APPROVED ... C.E.B.
Addis Ababa Ethiopia March 19-1962 (I.C.)	4-O-BN-19

Figure V-96--Electric Generating Component of Steam-Electric Powerplant

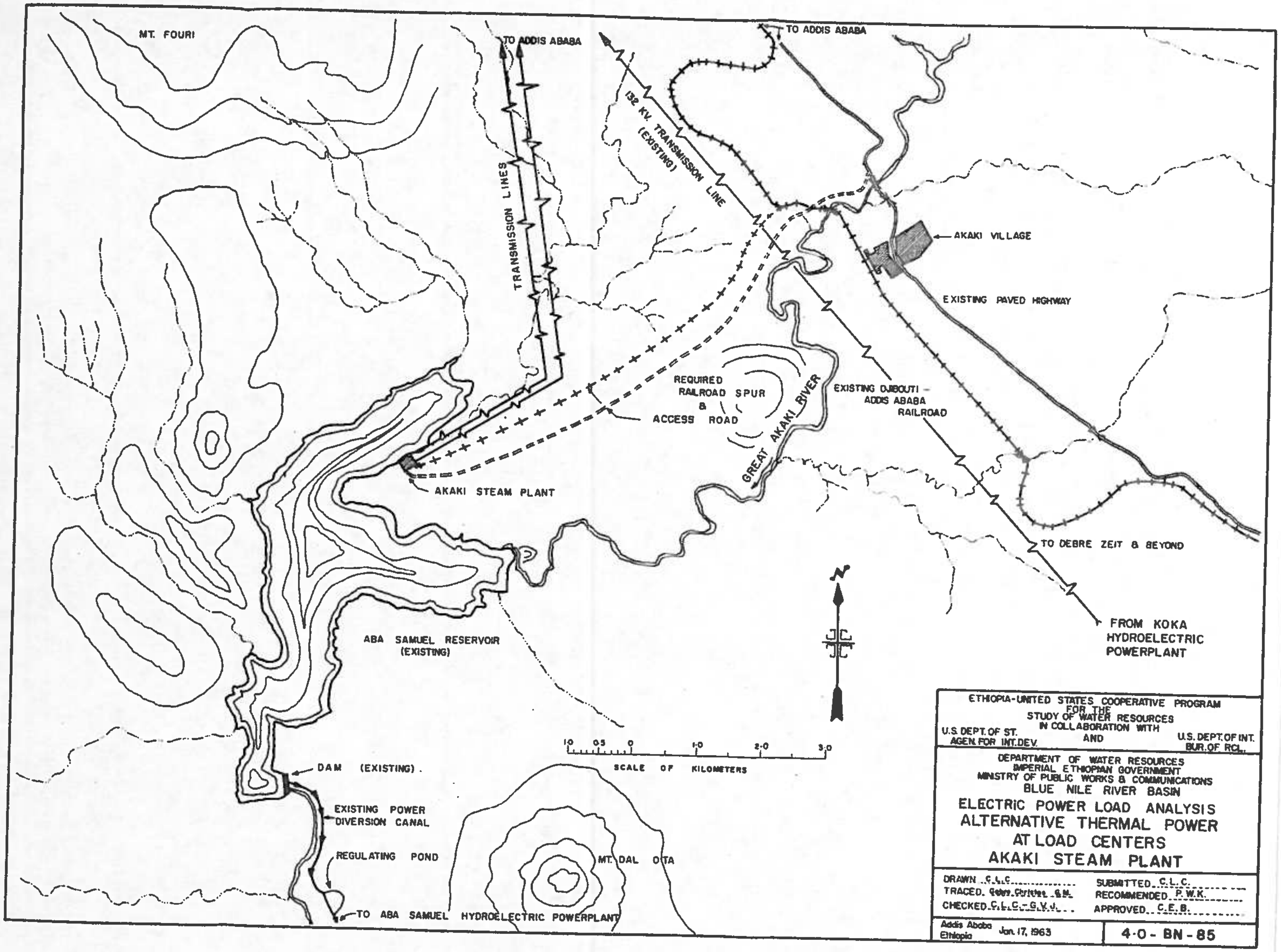


Figure V-97--Alternative Thermal Power at Load Centers--Akaki Steam Plant

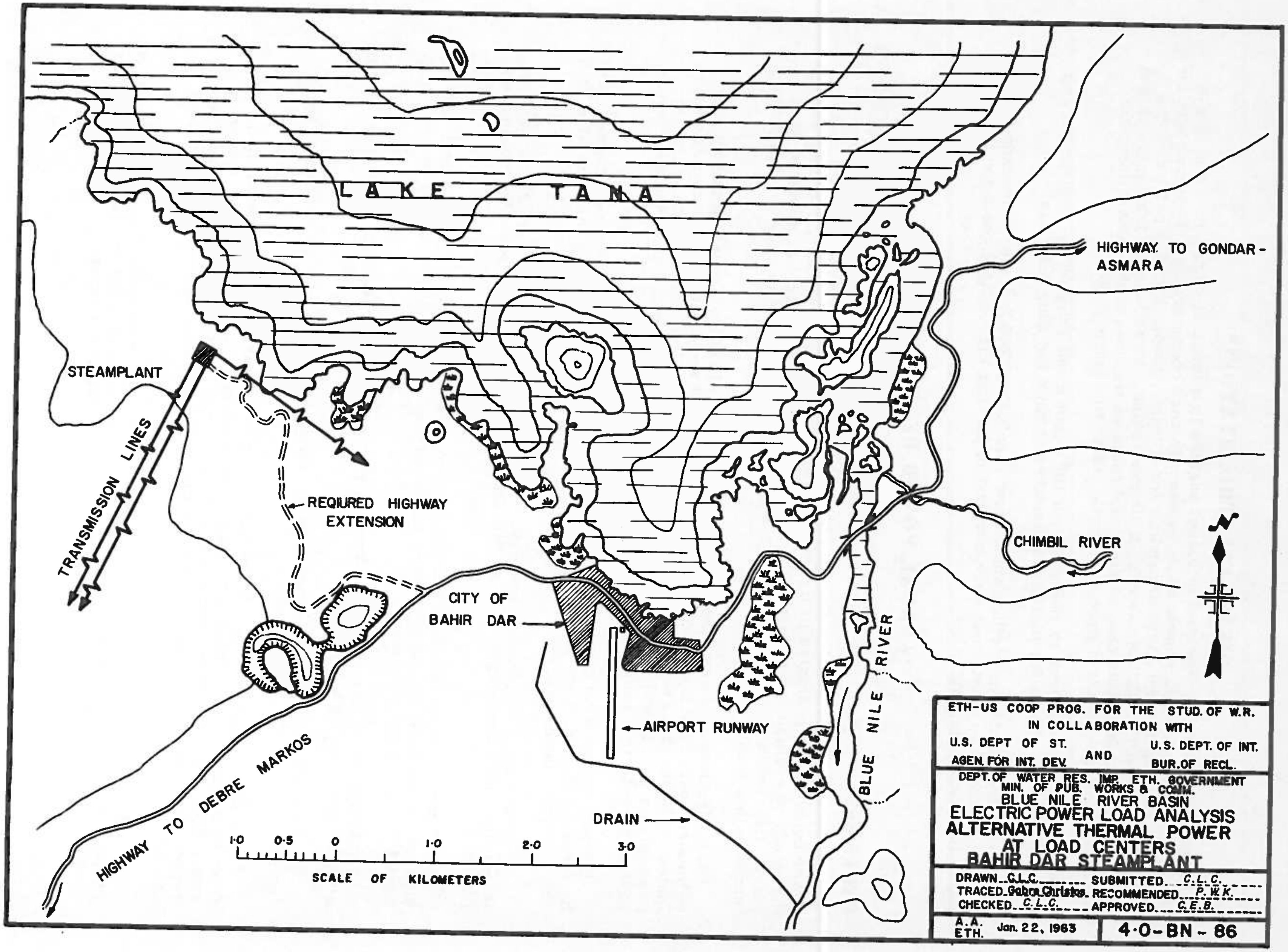


Figure V-98--Alternative Thermal Power at Load Centers--Bahir Dar Steam Plant

DIESEL-ELECTRIC STATIONS

Among other factors, the cost of diesel engines is a function of r.p.m., and due to this, prices at various European sources seem to vary considerably. Typical costs for diesel plants ranged from Eth$650 per kw. for a 1-mw. plant, Eth$475 per kw. for a 5-mw. plant, and Eth$425 per kw. for a 10-mw. plant. Investment in transmission and distribution plant facilities may be about the same as the cost of the generating plant. For smaller diesel-electric generating sets, refer to Figure V-99.

Diesel fuel oil delivered to Bahir Dar in 1961 cost about Eth$308 per metric ton and this was used as a basis for fuel costs elsewhere within the Blue Nile Basin.

Criteria for establishing other annual costs including OM&R, taxes, insurance, and amortization of the capital cost were covered in Section VII. OM&R costs for thermal plants include lubricating oil.

ANNUAL POWER BENEFITS

Definitions

Two broad categories of power benefits are used: direct, and indirect. Direct power benefits are evaluated in monetary terms and comprise the only category used in this study to evaluate benefits when comparing with costs to arrive at a benefit-cost ratio. Indirect benefits, although very important, have not been evaluated in monetary terms in this study.

Direct (primary) power benefits from projects in this study are measured by the estimated cost of the most likely alternative source of the same amount of power anticipated in the market area in the absence of the project. For this analysis, thermal powerplants (steam and diesel-driven) within the market area are assumed as alternatives to the hydroelectric source.

Indirect (secondary) power benefits, although not measured in monetary terms, occur by virtue of the existence and operation of the project features. For the Blue Nile Projects, indirect benefits are:

1. Effectuation of greater dependability and continuity of power service through the integration and coordination of Blue Nile River Basin powerplants with the Awash powerplants.

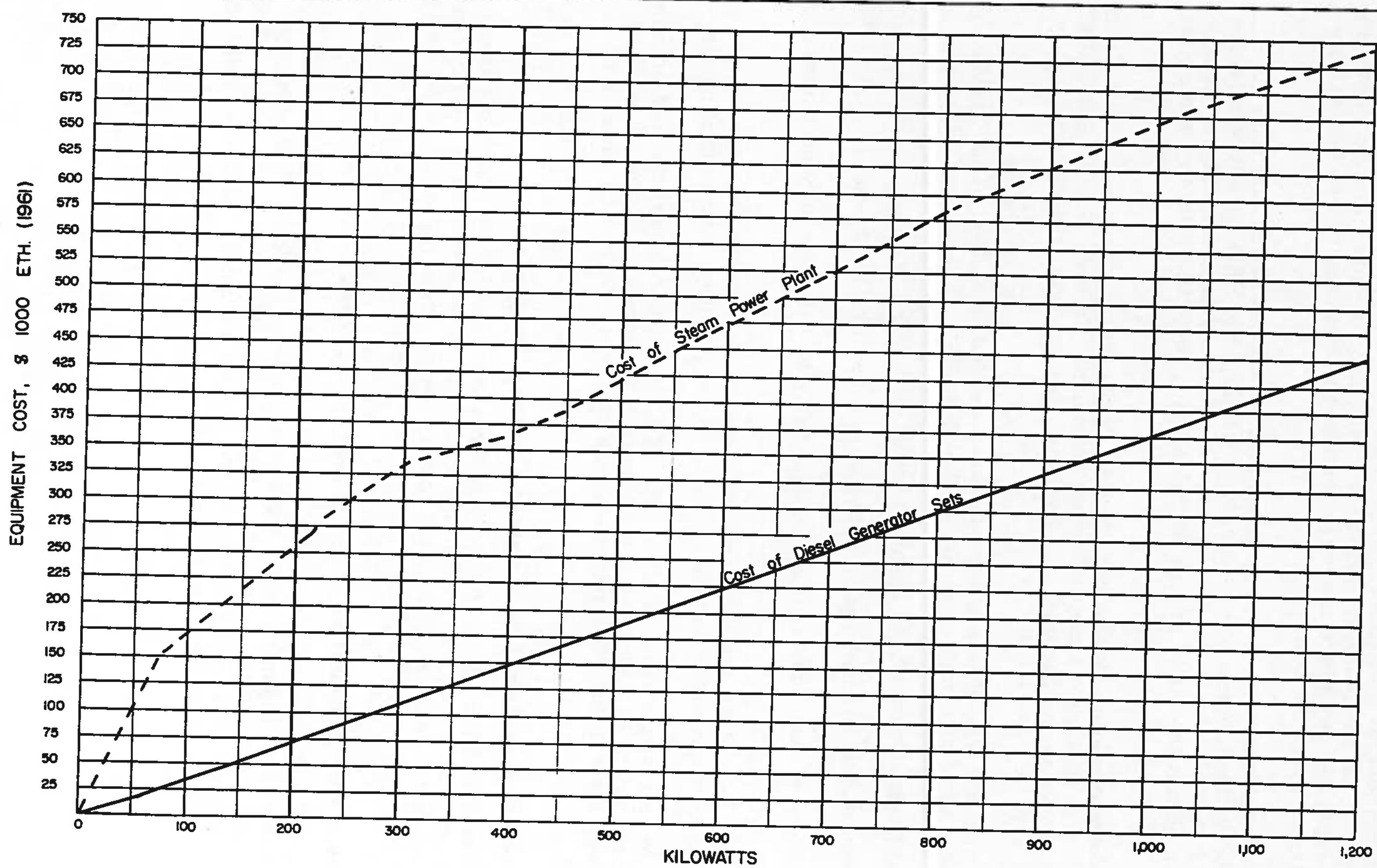
2. Contribution to effective industrial, commercial, and urban development to help achieve the national goal of transforming the present agricultural economy to an agricultural-industrial economy by 1982.

3. Making available of larger blocks of power useful in a national emergency, and so contributing to national security.

4. Conservation of foreign exchange by reducing the need for importation of fossil fuels.

5. Sedimentation control. In the future, as reservoirs are constructed in sequence from upstream to downstream as established previously in this study, the upstream reservoirs will contribute toward the prolongation of the useful lives of downstream reservoirs, resulting in the extension of the power and other benefits that they may provide.

6. Fish and wildlife conservation. Ultimately, the reservoirs, when planted with the proper species, may provide a good source of fish to supplement the diets of the local people or even produce enough to warrant commercial development.



NOTES

1. Costs are approximate only and are F.O.B. Djibouti or Assab.
2. For steam power plant, costs are based on average or adjusted prices which will vary for different types of boiler plant design and characteristics of power generated (Voltage etc.) Costs include boiler, accessories, engine and generator but not switchboard, building or construction.
3. When more than 200 KW. diesel generated power called for, multiple units are installed. Costs are for diesel generator sets only. Multiply by factor of 1.75 to obtain total installed cost in central Ethiopia. Does not include electrical distribution system.

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DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS
BLUE NILE RIVER BASIN

COMPARATIVE COST OF DIESEL GENERATOR SETS AND STEAM POWER PLANT EQUIPMENT

DRAWN C.L. Curtis SUBMITTED C. L. C.
TRACED Tadla Haile RECOMMENDED P. W.K.
CHECKED C. L. C. APPROVED C. E. B.
Addis Ababa Ethiopia FEB 21, 1962 4.0-BN-17

Figure V-99--Comparative Costs of Diesel Generator Sets and Steam Power Plant Equipment

Of the indirect benefits, the contribution of the projects toward developing the industrial, commercial, and urban segments of the economy may be considered the most important. In a country which has no local supply of oil, coal, or other economical source of energy in commercial quantities, the necessity to import large quantities of fuel proves a deterrent to large-scale development. Not only is imported fuel costly to use, but the import expenses can place a severe load on the economy which has to provide sufficient exports to meet the bill.

Ethiopia, with the establishment of the Awash River power facilities and with continued additions to the hydroelectric power supply, including the Blue Nile River facilities, will solve the industrial fuel problem by providing for its own domestic source of power. It has or can obtain the other means of industrial production--labor, materials, and enterprise.

Diversification of the economy by placing greater emphasis on industrialization, can form a basis for permanent improvement of living standards, in turn resulting in better health, education, and per capita income. The stimuli to industrialization provided by ample hydroelectric supplies are three:

1. Reduction of initial costs of power installations and the total cost of providing power during the lifetime of any particular industrial concern;

2. Sufficient quantities of power, as and when required; and

3. Flexibility provided by electricity as opposed to other forms of power.

The beneficial effects of industrialization as they apply to Ethiopia may be summarized as follows:

1. Greater use is made of Ethiopia's own resources so that a higher proportion of the final value of the country's products can be retained in the country, reducing imports.

2. A new class of artisans will be created who will, in turn, necessitate and bring about a gradual improvement in educational standards. The new conditions of working and earning encourage the raising of living standards by giving the people incentives to own material things.

Evaluation of Direct Power Benefits, Present Century Projects

Table V-123 summarizes the annual costs of alternative thermal installations for the projects capable of producing electric power that might be developed during the present century. The figures in the last column, total annual costs, are a measure of the anticipated total direct annual power benefits.

Evaluation of Direct Power Benefits, Next Century Projects

Load projections were carried in some detail to the year 2000, but after that year, rough approximations of load magnitude and load centers were made, and used only to arrive at approximate annual costs. Some international exports were considered. For the purposes of this report, this procedure was considered adequate, with the resulting direct annual power benefits indicated by Table V-124.

TABLE V-123--SUMMARY OF ANNUAL COSTS--ALTERNATIVE SOURCES IN MARKET AREA--PRESENT CENTURY PROJECTS

Hydro project	Description of alternative thermal project	OM&R amortization other 1/ (Eth$)	Fuel (Eth$)	Total annual cost (rounded) (Eth$)
Finchaa (FI-1A)	83.4-mw. steamplant at Aba Samuel Reservoir south of Addis Ababa near Akaki with transmission lines to Addis Ababa and terminal facilities.	4,462,759	11,941,376	16,400,000
Amarti-Neshe (NES-1A)	87.5-mw. steamplant at Aba Samuel Reservoir south of Addis Ababa near Akaki with transmission lines to Addis Ababa and terminal facilities.	4,572,939	12,538,500	17,110,000
Dabana (DB-1, -1A)	90-mw. steamplant at Aba Samuel Reservoir and transmission plant performing equivalent function of transmission plant of hydro project.	7,373,000	12,800,000	20,173,000
Upper Beles (BL-1)	96-mw. steamplant at Bahir Dar and 135-mw. steamplant at Aba Samuel Reservoir. Not interconnected, but with transmission plants performing equivalent function of transmission plant of hydro project.	15,372,000	41,226,000	56,598,000
Angar (AG-2, -6A, -6B)	153-mw. steamplant at Aba Samuel Reservoir and transmission plant performing equivalent function of transmission plant of hydro project.	14,739,000	42,140,000 2/	56,879,000
Lower Guder (GU-1)	49-mw. steamplant at Aba Samuel Reservoir and transmission plant performing equivalent function of transmission plant of hydro project.	3,141,000	7,652,000	10,793,000
Arjo-Diddessa (DD-11)	28.8-mw. diesel electric plants at Jima. Unsuitable location for steam electric powerplant.	2,170,000	12,738,000	14,908,000
Lower Diddessa (DD-2)	316-mw. steamplant at Aba Samuel Reservoir and transmission plant performing equivalent function of transmission plant of hydro project.	14,786,000	47,488,000	62,274,000
Dabus Power (DA-8)	8.2-mw. diesel electric plants, total capacity, located at Asosa, Mendi, and Begi.	895,000	3,282,000	4,177,000 3/

1/ Taxes and insurance
2/ Base operation favored for hydro. Plant factor is high, reflecting equivalent situation in Hydro System, which has long canals reducing capability to peak under certain conditions but with little effect on the total high annual energy production.
3/ Thirty-year lag period before full development. Total annual equivalent is therefore reduced to Eth$2,059,700.

TABLE V-124--SUMMARY OF ANNUAL COSTS--ALTERNATIVE POWER SOURCES IN MARKET AREA--NEXT CENTURY PROJECTS

Hydro project	Alternative thermal projects	Annual cost thermal projects 1/ (Eth$)
Dindir (DI-7)	42-mw. steamplant at Galegu with transmission plant performing equivalent function of transmission plant of hydro project.	10,870,000
Giamma (GI-1)	59-mw. steamplant at Aba Samuel Reservoir south of Addis Ababa with transmission plant.	12,864,000
Muger (MU-1 & MU-4)	28-mw. steamplant at Aba Samuel Reservoir south of Addis Ababa with transmission plant.	6,429,000
Karadobi (BN-3)	1,260-mw., total capacity for steamplants located at Debre Markos on Chemoga River and at Aba Samuel Reservoir with required transmission plant.	260,964,000
Mabil (BN-19)	1,146-mw., total capacity for steamplants located at Bure on Selale River and near Lekkemt on the Negeso River near site NE-4, including required transmission plant.	249,148,000
Mendaia (BN-26A)	1,550-mw., total capacity for steamplants located at Dabus River-Asosa highway crossing and south of Lekkemt on the Negeso River near site NE-4, including required transmission plant.	361,909,000
Border (BN-28)	1,361-mw., total capacity for three steamplants: (1) near Asosa on Dabus River-Highway Crossing; (2) near Asmara, Belesa Reservoir; and (3) at Bahir Dar with required transmission plant.	281,761,000
Middle Beles (BL-3)	172-mw. steamplant at Metekkel on Dura River with required transmission plant	39,377,000

1/ OM&R, Fuel, Taxes & Insurance, Amortization

SECTION IX--EFFECT OF BLUE NILE PROJECTS ON ELECTRIC RATES (TARIFF)

Neglecting the effects of the annual costs of electrical facilities external to the Blue Nile River Basin (Awash River Basin particularly), and taking into account only the power share of joint-use features where multiple-purpose projects are involved, costs per kw.-hr. including terminal facilities, except for the West Region, as indicated by system diagrams are as shown by Table V-125.

The Dabana Project has a benefit-cost ratio of less than 1.0 to 1.0 and has a comparatively high cost of 5.9 Eth¢ per kw.-hr. It was included in the project sequence of development because of its multiple-purpose possibilities and generally easy accessibility from present roads. Also, future feasibility studies may improve the economic prospects for this project.

The cost per kw.-hr. of energy delivered from the existing Koka hydroelectric installation to load centers was about 2.15 Eth¢, provided an average of about 110 million kw.-hr. were delivered per year. This is not entirely comparable with Blue Nile Projects as different bases for cost estimates and determination of annual costs were probably used. From Table V-125, most of the projects occurring in the present century category show costs less than 2.15 Eth¢.

Regarding the isolated West Region (Figure V-62), the following information is of interest:

Project: Dabus Power (DA-8)

Type: Power only

Capacity: 7.5 mw.

Annual Benefits: Eth$2,059,700

Annual Costs: Eth$992,000

Benefit-Cost Ratio: 2.08 to 1

Cost per kw.-hr. at Load Centers: 2.6 Eth¢

Table V-125 must be used with caution for multiple-purpose projects, as each purposed served (power or irrigation) has a different ratio of benefits to allocated costs within a multiple-purpose project than it would if constructed as a single-purpose project.

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, 433,000 hectares, will represent about 7 percent of the total project lands listed for possible irrigation development.)

A more rigorous analysis that may be made in the future when feasibility studies are made, including repayment analysis, 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 V-125--APPROXIMATE EFFECT OF BLUE NILE RIVER PROJECTS ON ELECTRIC RATES FOR NORTH, SOUTH, AND CENTRAL REGIONS-POWER ONLY--NATIONAL GRID 1/

Project	Type	Mega-watts 2/	Project annual benefits 3/ (Eth$)	Project annual costs 4/ (Eth$)	Project benefit-cost ratio	Project cost per kw.-hr. 5/ (Eth¢)	Approximate system benefit-cost ratio	Approximate system cost per kw.-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-Didessa (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 Didessa (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.

SECTION X--ORGANIZATION AND OPERATION

NATIONAL ORGANIZATION

Administrative organizations responsible for the development of natural resources vary between nations, depending upon the objectives, laws, governmental policies, and availability of skills and financial supports. Responsibilities are frequently divided among several agencies. The need for a central organization 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 governmental organization, and many agencies of government will share an interest, some to a greater extent than others. Therefore, the agency that must administer the program should be so constituted as to recognize and consider the requirements and the responsibilities of other agencies of government.

Initially, the Water Resources Department, an established agency under the direction of the Ministry of Public Works and Communication, could become the agency to administer the program. It could probably better serve the needs of the Nation if it were an autonomous agency operating under the broad direction of a board consisting of representatives from the ministries and agencies of the Government sharing major interest in this field. The primary purposes of the Water Resources Department or any succeeding agency should be to conserve and safeguard the land and water resources, promote orderly economic development of these resources, protect existing rights, provide for equitable distribution and allocation of water between the various uses, and guide the development of projects to the greatest beneficial use for the enjoyment of the people of the Nation.

Since the role to be played by the Water Resources Department in the development of land and water resources projects has not as yet been clearly defined and since no determination has been made regarding the methods of financing projects or of repaying the costs of construction, it would seem desirable for the Imperial Ethiopian Government initially to appoint an expert committee on resource development. The committee should consist of representatives of the various ministries and agencies, including representation from the Water Resources Department, supported by experienced consultants if required. It would review and study existing legislation and customs relating to the utilization of land and water resources and the responsibilities of the various governmental agencies in this field. This committee should recommend legislation as required to provide the authority for a centralized agency for the development of the Nation's land and water resources through the construction, operation, and maintenance of hydroelectric, irrigation, and related projects.

The committee could recommend:

1. A charter for the centralized agency, setting forth the objectives, authority, and responsibility.

2. A water code insuring adequate control and regulation of the use of water for power, agriculture, industry, and municipal and domestic supply.

3. A plan to consolidate and/or coordinate the activities of the various agencies now operating in this field.

4. A plan for financing the costs of projects and retirement of obligations.

The development of the basic organizational principles would then support the gradual development of an organizational structure for the agency and for specific projects similar to that discussed and illustrated in subsequent paragraphs.

Consideration should be given to the possible advantages of consolidating or merging existing agencies whose functions may overlap as the program for resource development gains momentum. The Surveys and Mapping Division of the Water Resources Department and the Mapping and Geography Institute might well be consolidated into one Geodetic Survey and Mapping Agency. The Ethiopian Electric Light and Power Authority and the Water Resources Department have a common purpose, except that the Water Resources Department must consider multiple-purpose projects. The two could be consolidated under a common board of directors with the former becoming the Power Division of the new organization. The existing Water Resources Department organization could become the Engineering, Irrigation, and Development Divisions, and the Administrative Divisions of the two agencies could combine under the new central organization. These consolidations would reduce the cost of administration; recognize the value of an existing, well-trained, and successfully operating power unit; and provide for more efficient management as the organization grows to meet the expanding needs of multiple-purpose projects.

ELECTRIC POWER OPERATIONS

The present Ethiopian Electric Light and Power Authority is a well established and operated organization, and its charter states:

> "The purpose of the Authority is to engage in the business of producing, transmitting, distributing and selling electrical energy to the public in Ethiopia and to carry on any other lawful business incidental or appropriate hereto which is calculated directly or indirectly to promote the interest of the Authority to enhance the value of its properties."1/

Paragraph 4 of the same charter also states:

> "...the Authority shall have the powers: (f) to establish rates, charges, rules and regulations for the sale of its services and electrical energy."1/

The charter thus implies that EELPA is a major agency in producing, transmitting, and marketing electrical energy in Ethiopia (excluding existing concession areas in Eritrea), and therefore any discussion of the future role that the Water Resources Department or any succeeding agency may have in this field would have to recognize this already established fact. A developing country cannot initially afford two separate governmental organizations competitively engaged in the public utility business, requiring some duplication of engineers, other specialists, and resultant costs, where such qualified personnel are in very short supply.

The present EELPA organization chart is shown by Figure V-100. While the desirable objective may be in having only one autonomous governmental agency involved in the power generation, transmission, and marketing field, this can still be accomplished by having EELPA (or private utility) and the Water Resources Department operate initially under a special interim agreement.

Enacting laws as recommended by the Government Committee could establish the concept of multiple-purpose projects requiring that a part of power revenues returned to the Ministry of Finance be used in financing or retiring indebtedness incurred in the construction of multiple-purpose projects. At the same time, a reasonable return must be allowed the power operating agency.

The present charter for EELPA specifies, regarding taxation:

> "9. Taxation--The Authority shall be subject to all taxes and custom duties levied by the Imperial Ethiopian Government including Federal Taxes, and such local and municipal taxes as shall be approved by the Imperial Ethiopian Government."1/

If the taxation obligation remains in its present form, then this will have a definite effect upon the rate of return required for any power operating agency from operation of

1/General Notice No. 213 of 1956, Charter.

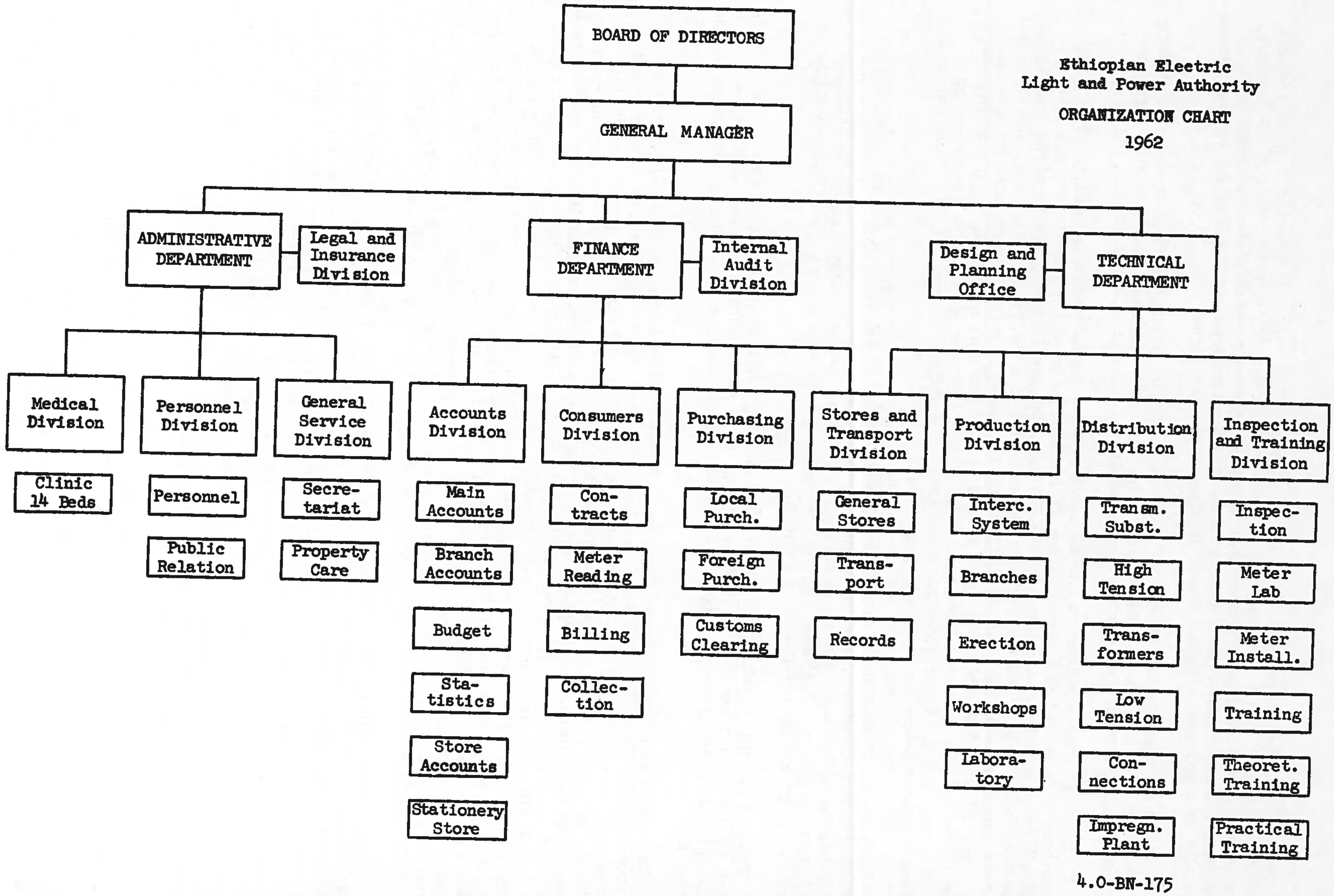

Figure V-100--Organization Chart, Ethiopian Electric Light and Power Authority the power facilities of multiple-purpose projects. The over-all effect will be to require higher rates than would otherwise be necessary. A reduction in tax obligations only on power generated from government-owned water resource, multiple-purpose projects, resulting in lower cost power may provide an added inducement for EELPA to participate initially as a partner with the Water Resources Department.

While it is possible for these operations to continue indefinitely, a final step resulting in complete consolidation of the two agencies would be most desirable to afford greater economy and efficiency as has been the result in a number of other developing countries.

Ultimately, both agencies would be combined as one autonomous agency. For convenience, it is referred to here as the Ethiopian Power and Water Resources Agency (EP&WRA). In effect, the former EELPA becomes the Power Division of the new agency and the Water Resources Department becomes the Engineering, Irrigation, and Development Divisions, with the Administrative Division made up from the combined agencies. The new EP&WRA would be under a Board of Directors as shown on Figure V-101 but administered by a General Manager. The Power Division would have four branches--Marketing, R & D, Operation and Maintenance, and System Operations. The functions of each branch would be as described below.

Marketing: This branch would be responsible for negotiating power sales contracts, reading meters, billing, and collection. It would also 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. Such data would be available for use by the Planning Branch.

Resources and Development: General planning, including load forecasting, feasibility studies for system additions, rate and repayment studies for the power aspects of multiple-purpose development, and technical power studies, are among the duties of this branch.

Operation and Maintenance: This branch might have three sections--Production, Transmission-Distribution Plant, and Inspection and Training. On multiple-purpose projects, technical guidance (operation and maintenance) would be given the Project Power Branch, but the latter is administratively under the Project Director for the project. The Transmission-Distribution Plant Section would be responsible for maintenance of all transmission and distribution lines as well as substations 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 teach linemen, powerplant operators, meter installers, laboratory technicians (transformer oil breakdown tests, meter testing, etc.), electricians, and inspectors. The latter would be for inspection of customers' premises as well as the agency's own facilities. This section would also be responsible for maintaining an adequate electrical wiring code and enforcing its provisions as well as providing maintenance for all communication facilities.

System Operations: This branch might also have three sections--Dispatching, Power Scheduling, and Technical Analysis. Initially, this branch's activities would be limited because of the simple nature of the system, but it would become more active as more generating stations and loads are added. In any event, its activities would be limited to the Interconnected System. The Dispatching Section would be responsible for meeting load requirements and schedules as well as for controlling all switching and clearances. 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 (relays, etc.) would be the responsibility of this section.

Close liaison between the System Operations Branch and the Hydrology Branch under the Development Division would be required regarding reservoir operations.

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

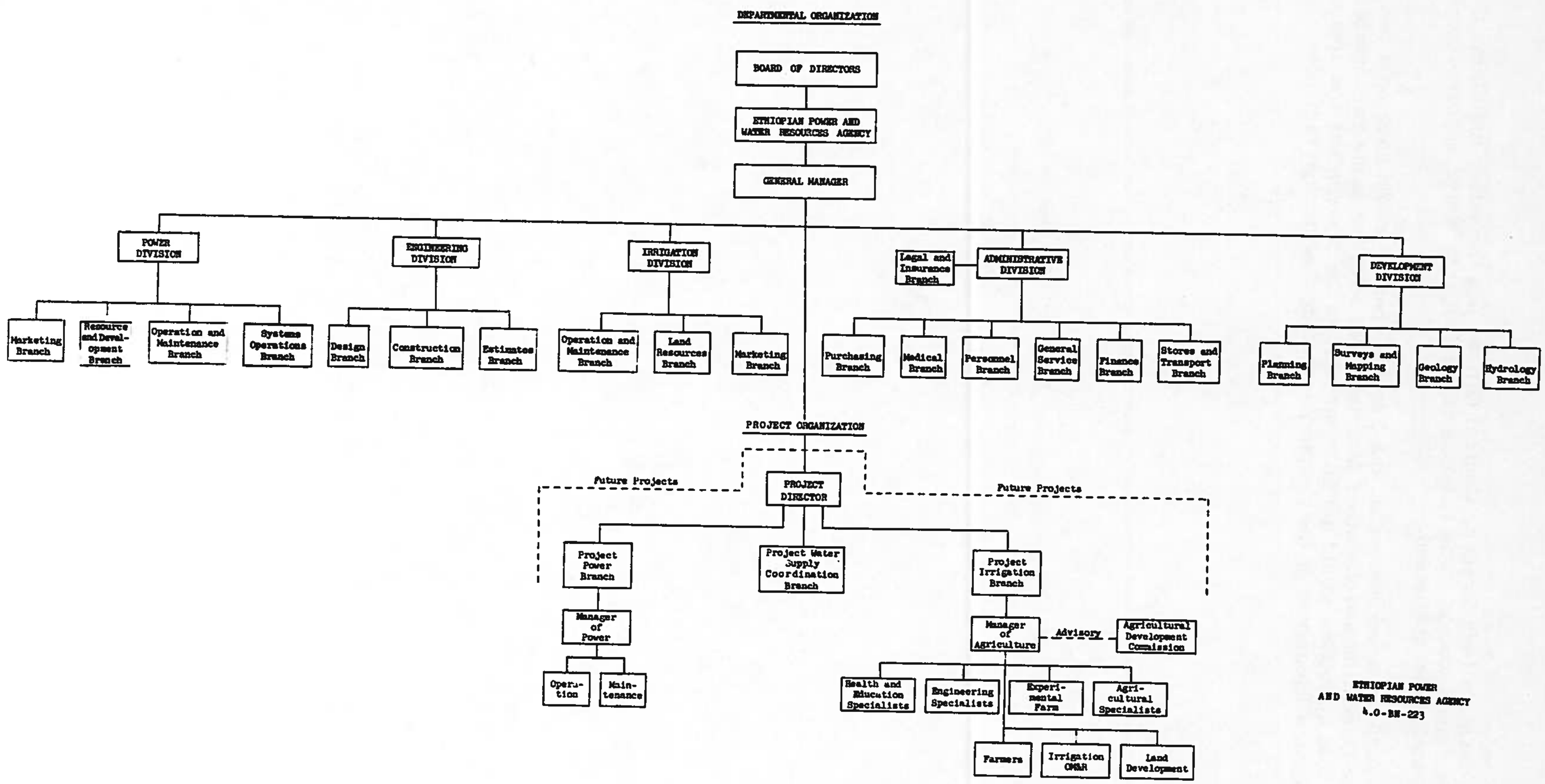

Figure V-101--Organization Chart, Ethiopian Power and Water Resources Agency from the System Operations Branch, Central Office, and the latter maintains the powerplants and appurtenant works. The function of the Projects Water Supply Coordination Branch has already been discussed.

For single-purpose power projects, the Power Director would have only two groups under him, one Operation 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.

ANNEX "A"

DEFINITIONS OF ELECTRIC PLANT COMPONENTS USED IN BLUE NILE RIVER BASIN STUDIES

INTRODUCTION

Cost estimates of electrical facilities developed in these studies were on the basis of electric plant components. For example, Figures V-102, V-103, and V-104 were developed along this basis. Also, some of the annual fixed cost factors (Replacement Reserve) were on the basis of electric plant components. A minimum number of features under Production, Transmission, and General Plants were used, due to the reconnaissance nature of the study, and these are subsequently identified in this Annex.

PRODUCTION PLANT - HYDRAULIC PRODUCTION

Structures and Improvements

This includes structures and improvements used in connection with hydraulic power generation.

Reservoirs, Dams and Waterways

This includes facilities used for impounding, collecting, storage, diversion, regulation, and delivery of water used primarily for generating electricity.

Items

1. Bridges and culverts (when not a part of roads or railroads).

2. Clearing and preparing land.

3. Dams, including wasteways, spillways, flashboards, spillway gates with operating and control mechanisms, tunnels, gate houses, and fish ladders.

4. Dikes and embankments.

5. Electric system, including conductors, control system, transformers, lighting fixtures, etc.

6. Excavation, including shoring, bracing, bridging, refill, and disposal of excess excavated materials.

7. Foundations and settings specially constructed for and not expected to outlast the apparatus for which provided.

8. Intakes, including trash racks, rack cleaners, control gates and valves with operating mechanisms, and intake house when not a part of station structure.

9. Platforms, railings, steps, gratings, etc., appurtenant to structures listed herein.

SECTION XI--CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. Regardless of the extent of system interconnections that would be possible by the year 1980, the Finchaa power facilities are required to be in service during the year 1974 The Neshe power facilities will be required in 1977 or 1978, with the output of both powerplants plus the four Awash plants providing for the needs of the South Region Interconnecte System through 1980 or 1981.

2. There are no lakes on the Blue Nile River but Lake Tana.

3. There are no falls except for Tis Isat in the Blue Nile River.

4. There are many potential storage sites along the course of the Blue Nile River.

5. There are no lands along the Blue Nile River that can be irrigated; its future potential in Ethiopia is limited to hydroelectric power production.

6. Greater power production can be obtained by diverting Lake Tana water to the headwaters of the Rahad River, but the water is not required for irrigation purposes downstream and the water will not return to the Blue Nile River in Ethiopia. Diversion to the headwaters of the Beles River permits substantial power production and at the same time provides water for irrigation. The Beles River joins the Blue Nile River in Ethiopia.

RECOMMENDATIONS

1. Awash Powerplant No. 4 should not be constructed immediately following Awash No. 3, if at all possible; and, with this in mind, every effort should be made to expedite the engineering and economic feasibility studies for the Finchaa Project with the objective of having the power facilities in operation by the end of 1971. By that time, enough operating experience with the Koka Reservoir and Awash River should have been accumulated to determine whether Awash No. 4 should be constructed. If construction of Awash No. 4 is justified, this could be done after the Finchaa or Neshe project development, because by then the hydroelectric powerplants will not all be in one river basin.

2. Nongovernmentally owned utilities providing electric supplies to the public are principally located in northern Eritrea and operate by virtue of concessions granted by the former Italian government. Privately owned and operated electric utilities generally do not exist in the other 13 provinces. Exceptions are small isolated plants serving commercial establishments, small missionary outposts, or parts of villages. The latter category is confined to perhaps one or two small towns.

The development of privately owned public utilities is to be encouraged for many reasons, although it is recognized that this may be a long-range goal. Improvement of the investment climate, utility taxation laws, and many facets of related problems are an initial requirement.

3. Plans should be made to investigate the geothermal potential in the Empire, including the Blue Nile Basin.

4. Electrical equipment standards should be established in cooperation with other African countries so that future exchanges of power through interconnecting high-voltage transmission lines will not be precluded.

5. Statistical information as to classes of power and energy sold should be collected as recommended in this volume. Standardization throughout Africa would be desirable.

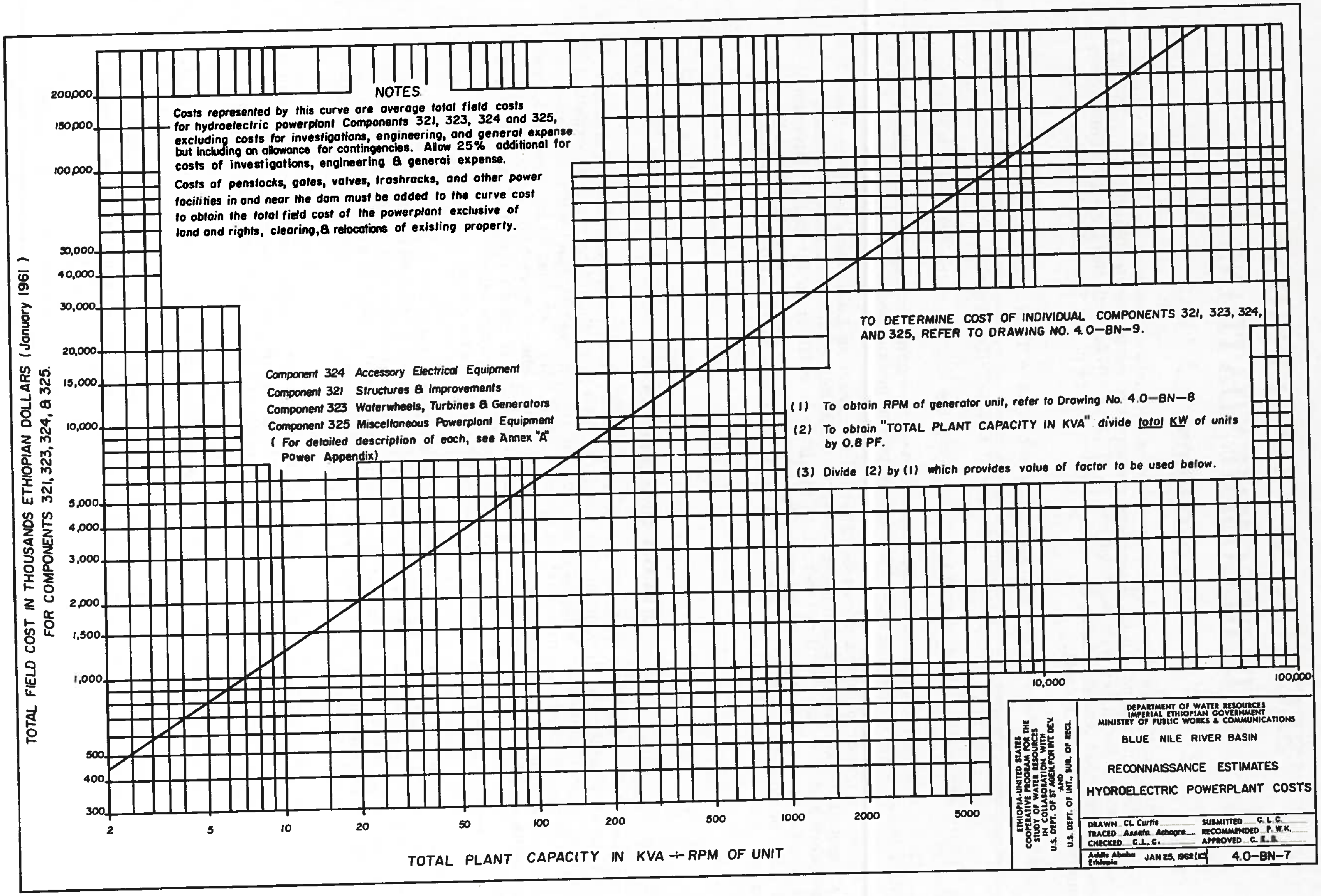

Figure V-102--Hydroelectric Powerplant Costs

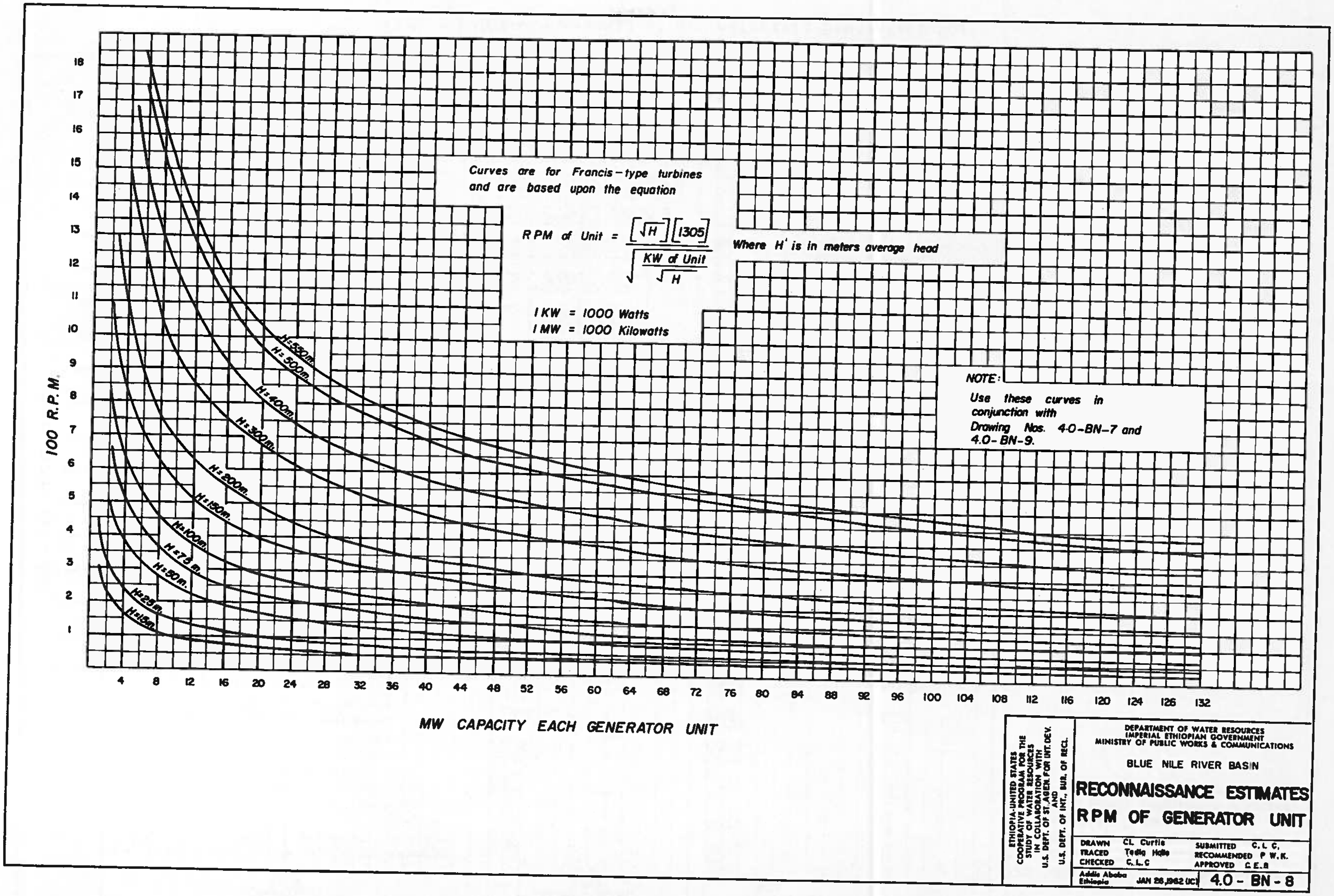

Figure V-103--R.P.M. of Generator Unit

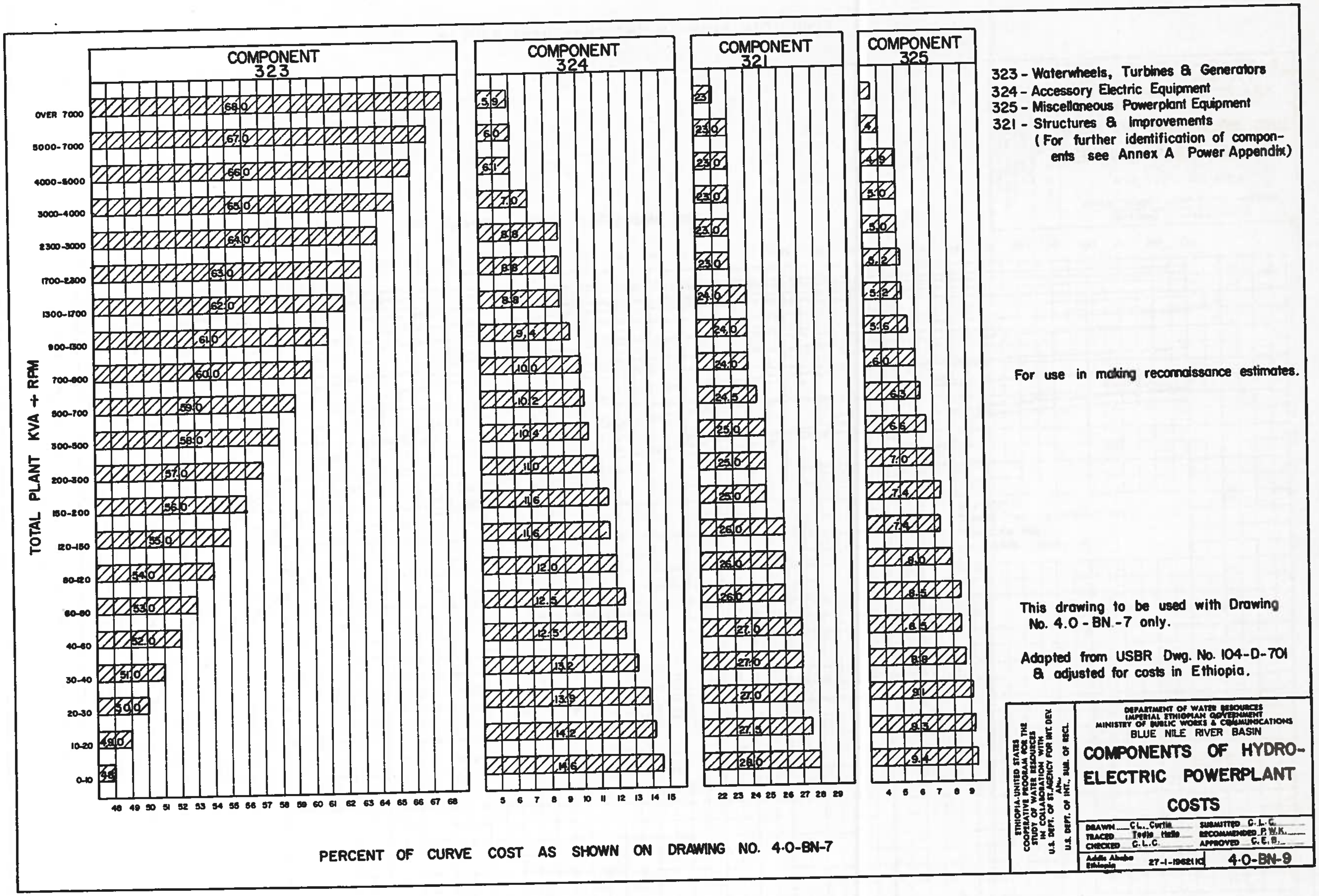

Figure V-104--Components of Hydroelectric Powerplant Costs

10. Power lines wholly identified with items included herein.

11. Retaining walls.

12. Water conductors and accessories, including canals, tunnels, flumes, penstocks, pipe conductors, forebays, tailraces, navigation locks and operating mechanisms, water-hammer and surge tanks, and supporting trestles and structures.

13. Water storage reservoirs, including dams, flashboards, spillway gates and operating mechanisms, inlet and outlet tunnels, regulating valves and valve towers, silt and mud sluicing tunnels with valve or gate towers, and all other structures wholly identified with any of the foregoing items.

Water Wheels, Turbines and Generators

This includes water wheels and hydraulic turbines (from connection with penstock or flume to tail-race) and generators driven thereby devoted to the production of electricity by water power or for the production of power for industrial or other purposes, if the equipment used for such purposes is a part of the hydraulic powerplant works.

Items

1. Exciter water wheels and turbines, including runners, gates, governors, pressure regulators, oil pumps, operating mechanisms, scroll cases, draft tubes, and draft-tube supports.

2. Fire-extinguishing equipment.

3. Foundations and settings specially constructed for and not expected to outlast the apparatus for which provided.

4. Generator cooling system, including air cooling and washing apparatus, air fans and accessories, air ducts, etc.

5. Generators--main, a.c., or d.c.--including field rheostats and connections for self-excited units and excitation system when identified with the generating unit.

6. Lighting systems.

7. Lubricating systems, including gages, filters, tanks, pumps, piping, etc.

8. Main penstock valves and appurtenances, including main valves, control equipment, bypass valves and fittings, and other accessories.

9. Main turbines and water wheels, including runners, gates, governors, pressure regulators, oil pumps, operating mechanisms, scroll cases, draft tubes, and draft-tube supports.

10. Mechanical meters and recording instruments.

11. Miscellaneous water-wheel equipment, including gages, thermometers, meters, and other instruments.

12. Platforms, railings, steps, gratings, etc., appurtenant to apparatus listed herein.

13. Scroll case filling and drain system, including gates, pipe, valves, fittings, etc.

14. Water-actuated pressure-regulator system, including tanks and housings, pipes, valves, fittings and insulations, piers and anchorage, and excavation and backfill.

Accessory Electric Equipment

This includes auxiliary generating apparatus, conversion equipment, and equipment used primarily in connection with the control and switching of electric energy produced by hydraulic power and the protection of electric circuits and equipment, except electric motors used to drive equipment included in the component in which the equipment with which they are associated is included.

Items

1. Auxiliary generators, including boards, compartments, switching equipment, control equipment, and connections to auxiliary power bus.

2. Excitation system, including motor, turbine, and dual-drive exciter sets and rheostats, storage batteries and charging equipment, circuit breakers, panels and accessories, knife switches and accessories, surge arresters, instrument shunts, conductors and conduit, special supports for conduit generator field and exciter switch panels, exciter bus tie panels, generator and exciter rheostats, etc., special housing, protective screens, etc.

3. Generator main connections, including oil circuit breakers and accessories, disconnecting switches and accessories, disconnecting switches and interlocks, current transformers, potential transformers, protective relays, isolated panels and equipment, conductors and conduit, special supports for generator main leads, grounding switch, etc., special housings, protective screens, etc.

4. Station buses, including main, auxiliary, transfer, synchronizing, and fault ground buses, including oil circuit breakers and accessories, disconnecting switches and accessories, operating mechanisms and interlocks, reactors and accessories, voltage regulators and accessories, compensators, resistors, starting transformers, current transformers, potential transformers, protective relays, storage batteries and charging equipment, isolated panels and equipment, conductors and conduit, special supports, special fire-extinguishing system, and test equipment.

5. Station control system, including station switchboards with panel wiring, panels with instruments and control equipment only, panels with switching equipment mounted or mechanically connected, truck type boards complete, cubicles, station supervisory control devices, frequency control equipment, master clocks, watt-hour meter, station totalizing watt-meter, storage batteries, panels and charging sets, instrument transformers for supervisory metering, conductors and conduit, special supports for conduit, switchboards, batteries, special housings for batteries, protective screens, doors, etc.

Miscellaneous Powerplant Equipment

This includes miscellaneous equipment in and about the hydroelectric generating plant which is devoted to general station use and is not properly includible in other hydraulic production components.

Items

1. Compressed air and vacuum cleaning systems, including tanks, compressors, exhausters, air filters, piping, etc.

2. Cranes and hoisting equipment, including cranes, cars, crane rails, monorails, hoists, etc., with electric and mechanical connections.

3. Fire-extinguishing equipment for general station use.

4. Foundations and settings specially constructed for and not expected to outlast the apparatus for which provided.

5. Locomotive cranes not includible elsewhere.

6. Locomotives not includible elsewhere.

7. Marine equipment, including boats, barges, etc.

8. Miscellaneous belts, pulleys, countershafts, etc.

9. Miscellaneous equipment, including atmospheric and weather indicating devices, intrasite communication equipment, laboratory equipment, insect control equipment, signal system, callophones, emergency whistles and sirens, fire alarms, and other similar equipment.

10. Railway cars not includible elsewhere.

11. Refrigerating system, including compressors, pumps, cooling coils, etc.

12. Station maintenance equipment, including lathes, shapers, planers, drill presses, hydraulic presses, grinders, etc., with motors, shafting, hangers, pulleys, etc.

13. Ventilating equipment, including items wholly identified with apparatus listed herein.

TRANSMISSION PLANT

Structures and Improvements

This includes structures and improvements used in connection with transmission operations.

Station Equipment

This includes transforming, conversion, and switching equipment used for the purpose of changing the characteristics of electricity in connection with its transmission or for controlling transmission circuits.

Items

1. Bus compartments, concrete, brick and structural steel, including items permanently attached thereto.

2. Conduit, including concrete and iron duct runs not part of a building.

3. Conversion equipment, including transformers, indoor and outdoor, frequency changers, motor generator sets, rectifiers, synchronous converters, motors, cooling equipment, and associated connections.

4. Fences.

5. Fixed and synchronous condensers, including transformers, switching equipment, blowers, motors, and connections.

6. Foundations and settings specially constructed for and not expected to outlast the apparatus for which provided.

7. General station equipment, including air compressors, motors, hoists, cranes, test equipment, ventilating equipment, etc.

8. Platforms, railings, steps, gratings, etc., appurtenant to apparatus listed herein.

9. Primary and secondary voltage connections, including bus runs and supports, insulators, potheads, lightning arresters, cable and wire runs from and to outdoor connections or to manholes and the associated regulators, reactors, resistors, surge arresters, and accessory equipment.

10. Switchboards, including meters, relays, control wiring, etc.

11. Switching equipment, indoor and outdoor, including oil circuit breakers and operating mechanisms, truck switches, and disconnect switches.

12. Tools and appliances.

Towers and Fixtures

This includes towers and appurtenant fixtures used for supporting overhead transmission conductors.

Items

1. Anchors, guys, braces.
2. Brackets.
3. Crossarms, including braces.
4. Excavation, backfill, and disposal of excess excavated material.
5. Foundations.
6. Guards.
7. Insulator pins and suspension bolts.
8. Ladders and steps.
9. Railings, etc.
10. Towers.

GENERAL PLANT

Structures and Improvements

This includes structures and improvements used for utility purposes, the cost of which is not properly includible in other structures and improvements.

Communication Equipment

This includes telephone, telegraph, and wireless equipment for general use in connection with utility operations.

Items

1. Antennae.
2. Booths.

3. Cables.

4. Distributing boards.

5. Extension cords.

6. Gongs.

7. Hand sets, manual and dial.

8. Insulators.

9. Intercommunicating sets.

10. Loading coils.

11. Operators' desks.

12. Poles and fixtures used wholly for telephone or telegraph wire.

13. Radio transmitting and receiving sets.

14. Remote control equipment and lines.

15. Sending keys.

16. Storage batteries.

17. Switchboards.

18. Telautograph circuit connections.

19. Telegraph receiving sets.

20. Telephone and telegraph circuits.

21. Testing instruments.

22. Towers.

23. Underground conduit used wholly for telephone or telegraph wires and cable wires.

ANNEX "B"

NORTH ERITREA REGIONAL LOAD CENTERS AS POTENTIAL OUTLET FOR FUTURE BLUE NILE RIVER BASIN HYDROELECTRIC POWER

INTRODUCTION

Whether in the future it will be economically feasible to generate hydroelectric power somewhere in the 13 provinces where an abundant water supply is available (such as in the Blue Nile River Basin) and construct high-voltage transmission lines to Eritrea is a matter of conjecture at this time (1962). However, with local Eritrean power supplies primarily dependent upon thermal plants using imported petroleum products, the future possibility of making hydroelectric power available cannot be overlooked. Also, any study of Ethiopia's power needs would not be complete without considering Eritrea, which is a part of the Empire of Ethiopia.

Based upon the criteria used, it appears that it may be economically feasible to import hydroelectric power by means of high-voltage lines by 1985, the date that hydroelectric power will show an economic advantage over locally generated thermal power. It is during the 1980's that a deficiency in power supply will begin to manifest itself and can be met either by thermal power or by imported hydroelectric power. Whether importation would come from future Takazze River Plants or from the Blue Nile is unknown, pending completion of future studies of the Takazze River potential. In the event that Takazze power development proves nonfeasible, then reliance upon Blue Nile production facilities may be the result.

The present study shows no economic justification for a transmission tie between Assab and Asmara in the foreseeable future. This study also records present power sources, their characteristics, and loads served. Some of the thermal plants serving villages are very small and are listed if electricity is generally available to those who desire it. Some villages have an occasional private plant which limits its service to one or two business establishments. These are not listed.

The report and study given in the following pages can be more fully appreciated when it is understood that one of the largest businesses in Eritrea, in terms of sales, is the electric utility industry. The largest of the various electric utility companies operating in Eritrea reported annual sales of Eth$3,000,000 in fiscal year 1959-1960 (July 1, 1959 through June 30, 1960). The powerplants, basically, are those installed before World War II during the Italian Administration in Eritrea.

Data contained in this Annex were obtained from numerous sources including verbal contact through interpreters with Italian utility officials. Occasionally, electrical terms used in American English had no similar Italian meaning and it was with some difficulty that the meaning was made clear. One term, "wholesale rates," had no meaning.

Therefore, some of the historical and statistical data may not be completely accurate, but the inaccuracies involved, if any, should be minor.

LOAD CENTERS

There is at present only one major load area in the North Eritrea region and that is the one served by Societá Elettrica Dell' Africa Orientale (SEDAO) which serves the Massawa-Asmara area. The only transmission line (50 kilovolts) in Eritrea extends from Massawa to Asmara, 62 km.

Compagia Imprese Elettriche Dell'Eritrea (CONIEL) serves isolated towns with small plants not interconnected. It owns and operates small thermal plants in the following towns:

Decamere
Keren (Cheren)*
Adi Ugri
Adi Caieh
Adi Quala

In addition, the Department of Public Works and Mines, Government of Eritrea, owns small thermal plants at these locations:

Saganeiti
Senafe
Barentu
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 OmHager and Maraba, and at Godofellasi, the latter for pumping municipal water. The Department of Public Works controls OmHager and Godofellasi, whereas CONIEL operates Maraba.

POWER SUPPLY FACILITIES

SEDAO--This organization was incorporated in Italy with a share capital of Eth$5,600,000 (US$2,240,000). In 1936, the former Italian Government granted a concession to SEDAO to operate the powerplants that the Government owned at Massawa, Asmara, and Dorfu Valley. This concession was renewed in 1953 by the Eritrean Government. These plants were to become the sole property of the Eritrean Government at the expiration of the year 1996 and any plants that might be constructed by SEDAO in the period 1986 to 1996 were to have been paid for by the Eritrean Government. In the event of termination of the concession the Government of Eritrea was to pay for any property installed by SEDAO which had not already been fully amortized.

SEDAO generates electricity for Asmara, Massawa, and the towns between, including Nefacit, Mai Haber, Embatkalla, Ghinda, Dongollo, etc. The firm employs approximately 130 Italians and Ethiopians. In May 1961, the installed generating capacity was 15,180 hp. rated at 11,935 kv.-a.

The single-line diagram, Figure V-105, indicates the extent of SEDAO's system, and gives a listing of all generator units, hydro or thermal. The only high-voltage transmission line in Eritrea is the line from Massawa to Asmara which is 50,000 volts and has aluminum conductor (an alloy), 35 mm.^{2} but does not have an overhead ground wire.

*Alternate spelling.

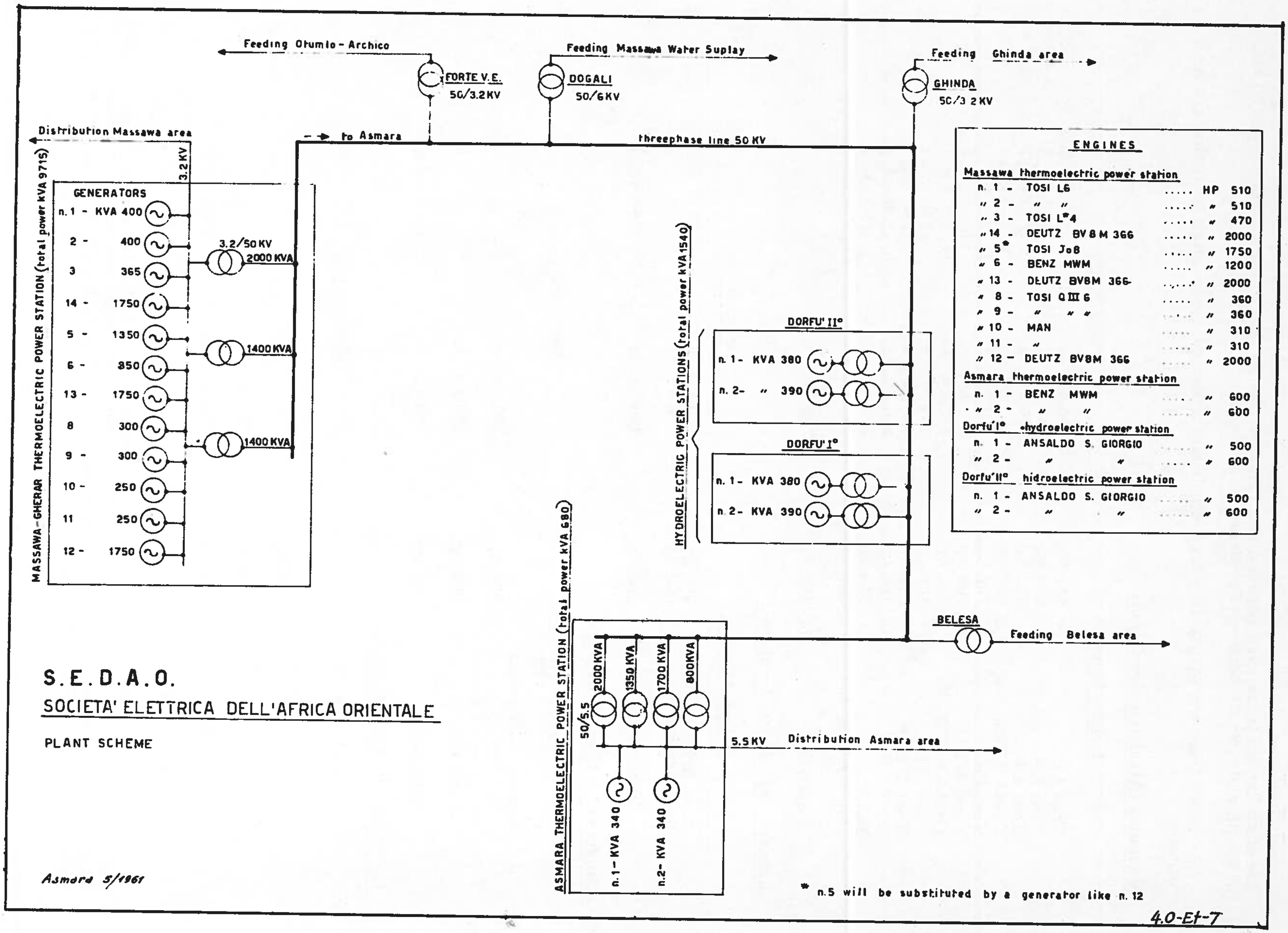

Figure V-105--SEDAO Plant Scheme

The distribution lines used between and within towns on this system total about 190 km. in length and operate between 5,540 and 3,200 volts.

As noted from the single-line diagram (Plant Scheme), generation facilities are as follows:

Massawa (All thermal--diesel)

Prime Movers		Generators	
Tosi L6	510 hp.	400 kv.-a.	(320 kw.)
Tosi L6	510 hp.	400 kv.-a.	(320 kw.)
Tosi L4	470 hp.	365 kv.-a.	(290 kw.)
Deutz BV8M 366	2,000 hp.	1,750 kv.-a.	(1,400 kw.)
Tosi J8	1,750 hp.	1,350 kv.-a.	(1,070 kw.)
Benz MWM	1,200 hp.	850 kv.-a.	(680 kw.)
Deutz BV8M 366	2,000 hp.	1,750 kv.-a.	(1,400 kw.)
Tosi Q III 6	360 hp.	300 kv.-a.	(240 kw.)
Tosi Q III 6	360 hp.	300 kv.-a.	(240 kw.)
MAN	310 hp.	250 kv.-a.	(200 kw.)
MAN	310 hp.	250 kv.-a.	(200 kw.)
Deutz BV8M 366	2,000 hp.	1,750 kv.-a.	(1,400 kw.)
Subtotals	11,780 hp.	9,715 kv.-a.	

Asmara (All thermal--diesel)

Prime Movers		Generators	
Benz MWM	600 hp.	340 kv.-a.	
Benz MWM	600 hp.	340 kv.-a.	
Subtotals	1,200 hp.	680 kv.-a.	(544 kw.)

Dorfu No. I (Hydroelectric)

Prime Movers		Generators	
Ansaldo S. Giorgio Turbine	500 hp.	380 kv.-a.	
Ansaldo S. Giorgio Turbine	600 hp.	390 kv.-a.	
Subtotals	1,100 hp.	770 kv.-a.	(616 kw.)

Dorfu No. II (Hydroelectric)

Prime Movers		Generators	
Ansaldo S. Giorgio Turbine	500 hp.	380 kv.-a.	
Ansaldo S. Giorgio Turbine	600 hp.	390 kv.-a.	
Subtotals	1,100 hp.	770 kv.-a.	(616 kw.)
Totals (SEDAO)	15,180 hp.	11,935 kv.-a.	(9,536 kw.)

Dorfu Plant I utilizes a head of about 420 meters and an average flow through the turbine of 110 liters per second from a 250-mm. diameter penstock, and Dorfu Plant II utilizes a head of 395 meters. The peak load is reached during the evening hours with a maximum discharge of 150 liters per second.

CONIEL--This organization is a privately owned corporation (company) and was granted its concession for 30 years by the former Italian Government in 1936 for the supply of electricity to Decamere, Keren, Adi Ugri, Adi Quala, and Adi Caieh. (The Government has no shares in it.) It was understood that at the expiration of the concession, if the company had paid back its capital and made a profit of about 12 percent per year, the plants would have become the property of the Government; otherwise, the concession would have been extended. At the present rate of return, the concession will be eligible for renewal in 1966. No foreign firms participate in the company's capital and profits. In 1955 the total employed was 54. No data was furnished in 1962 on this but the company indicated that there has been little change in load growth and no change in plant capacities.

CONIEL is the only source of electricity in the various towns mentioned above and small industries must depend on these plants for their power requirements. With the exception of Decamere where the large cereal mills (Tosca Mills) are located, there are no large industries in these five towns.

The powerplants operated by CONIEL are small, having these characteristics:

Decamere (diesel)

Prime Movers

500 hp.	one each
500 hp.	one each
300 hp.	one each
150 hp.	one each

1,450 hp. available for driving generators totaling 1,140 kw.

Keren (diesel)

Prime Movers

150 hp.	one each
400 hp.	one each

550 hp. available for driving generators totaling 380 kw.

Adi Ugri (diesel)

Prime Movers

300 hp.	one each
150 hp.	two each
50 hp.	one each

650 hp. available for driving generators totaling 490 kw.

Adi Quala (diesel)

Prime Movers

70 hp.	one each
50 hp.	one each

120 hp. available for driving generators totaling 95 kw.

Adi Caieh (diesel electric)

Prime Mover

50 hp.	two each

100 hp. available for driving generators totaling 70 kw.

The CONIEL installed generating capacity in June 1962 was made up of diesel prime movers having about 2,870 total rated horsepower available for driving generators totaling about 2,155-kw. capacity. However, many of these units have been in operation for over 20 years and it appears that in some plants one-half of the units or more are idle during periods of generation which is usually for only 6 hours (6 p.m. to 12 midnight) per day.

There are no interconnecting transmission or distribution lines between plants. The total length of distribution lines (3,000 volts) including low-voltage drops to buildings (220/127 volts) is about 76 km.

Department of Public Works--This department (1962) of the Eritrean Government-owned plants that have these characteristics:

Saganeiti (diesel)

25 hp.	one each
25 hp.	one each (new)

Senafe (diesel)

40 hp.	one each
60 hp.	one each (standby)
12 hp.	two each (for water supply)

Barentu (diesel)1/

50 hp.	one each

Nacfa (diesel)

10 hp.	one each2/

Total, 210 hp. available for driving generators totaling 125 kw.

Others--These individually owned small plants have these characteristics:

Societa Anonimo Industriale Dell'Bassopiano Oriental (SAIBO)

Agordat (diesel)

60 hp.	one each
120 hp.	one each
60 hp.	one each3/
50 hp.	one each3/
60 hp.	one each4/
24 hp.	one each4/

Total, 290 hp. available for driving generators totaling about 175 kw.

Societa Anonimo Electrica Tessenei (SAET)

Tessenei

100 hp.	one each
62 hp.	one each3/
60 hp.	one each3/
24 hp.	two each4/
18 hp.	one each4/

Total, 222 hp. available for driving generators, totaling about 135 kw.

1/Negotiations underway to lease to contractor for operation. If leased, contractor will install new plant and new line. Present lines are telephone wires.
2/25 horsepower to have been installed if approval from Eritrean Government received.
3/Standby units.
4/For pumping municipal water only.

Miscellaneous

Maraba

12 hp.	one each, operated by CONIEL to drive about a 7-1/2-kw. generator

OmHager

9 hp.	operated by Government to drive about a 5-kw. generator

PAST AND PRESENT POWER PRODUCTION

SEDAO--The annual production in kw.-hr. from 1936 through 1960 is summarized as follows:

Year	Production (kw.-hr.)	Percent growth
1936	4,300,000	--
1937	8,000,000	86
1938	11,600,000	45
1939	14,900,000	28
1940	13,100,000	-13
1941	14,900,000	28
1942	17,850,000	20
1943	15,800,000	-13
1944	18,250,000	16
1945	20,300,000	11
1946	20,260,000	--
1947	18,660,000	- 9
1948	17,970,000	- 4
1949	17,700,000	- 2
1950	16,945,000	- 4
1951	18,080,000	7
1952	18,865,000	4
1953	17,284,000	- 9
1954	17,677,000	2
1955	18,225,000	3
1956	18,600,000	2
1957	21,100,000	13
1958	22,000,000	4
1959	22,850,000	4
1960	25,969,642	14
1961	29,944,578	15

CONIEL--In June 1962, officials of CONIEL stated there had been no substantial change in the production of electricity from the 1953 production figures for five plants. These production figures as well as sales figures were as follows:

Plant	1953 production, kw.-hr.	1953 sales, kw.-hr.
Decamere	651,810	428,431
Keren	278,150	186,681
Adi Ugri	181,067	147,394
Adi Quala	23,697	18,967
Adi Caieh	38,996	44,318
Total	1,173,720	825,791

The reason given for the lack of load growth is that no new industries are being developed in these towns, and there is a constant inflow and outflow of residents, the inflow about balancing the outflow. Consequently, there are no plans for increasing the capacity of existing plants. This situation may in part be due to the moderately high cost of electricity.

Department of Public Works--During June 1962, it was indicated that there had been no substantial load growth since 1952, although as far as could be determined no accurate production records were kept. On this basis, annual production during the past few years would have been as follows per year:

Saganeiti	21,000 kw.-hr.
Senafe	60,000 kw.-hr.
Barentu	46,000 kw.-hr.
Nacfa	9,200 kw.-hr.
Total	136,200 kw.-hr.

Saganeiti, Barentu and Nacfa serve lighting loads only. All four plants operate about 6 hours per day, 1800 hours to midnight. The distribution lines belong to the contracting utility (operators) except for Saganeiti and Senafe.

Others--

SAIBO (1961)

Agordat	92,000 kw.-hr.

This plant operates all night, but not during the daytime. The above figure is for 1953, with 1961 the same. Although no new data were available, the consensus of opinion was that little growth, if any, had occurred.

SAET (1961)

Tessenei	81,000 kw.-hr.

This plant operates 6 hours per night but may go to all-night operation soon. This production figure is actually for 1953 with little change since then, and 1961 would be the same.

Miscellaneous

Maraba	15,000 kw.-hr.1/
OmHager	11,000 kw.-hr.1/

These are the 1953 and 1959 production figures, although under the new management (EELPA), some recent changes may have occurred, the nature of which was not obtained.

Summary of North Eritrea Production by Sources for 1961

Source	Kw.-hr.	Percent of total
SEDAO	29,944,578	95.2
CONIEL2/	1,173,720	3.7
Dept. Public Works2/	136,200	0.4
SAIBO2/	92,000	0.3
SAET2/	81,000	0.3
Miscellaneous2/	26,000	0.1
Totals	31,453,498	100.0

1/Estimated, based upon 6 hours operation per night at 7 kw., for 1961.
2/The total of all other production exclusive of SEDAO will range from about 1,500,000 kw.-hr. to 2,700,000 kw.-hr. during the period 1954-1962.

PRESENT LOAD CHARACTERISTICS

SEDAO--The data supplied by the Company was interpreted to indicate the following annual load factor:

$$\text{for 1960, A.L.F.} = \frac{25,969,642 \div 8,760}{5,020 \text{ kw.}} = 0.59$$

Figure V-106 indicates typical load diagrams for a heavy and light load day that occurred in 1962. Power factors are about 0.8 lagging.

ALL OTHERS--The remainder of the installations are small and not interconnected, serving individual towns, and all operate for a part or all of the night, but not during the daylight hours. Load characteristics are variable and do not have much meaning, so are not covered here. These include CONIEL, Department of Public Works, SAIBO, SAET and miscellaneous.

PRESENT POWER PRODUCTION COSTS

Data on the direct production cost per kw.-hr. could not be obtained although some data were obtained regarding fuel costs, cost of wages, and plant investments. Lacking were the cost of amortization interest rates and OM&R so the cost of production per kw.-hr. to the utilities could only be estimated.

Retail rates reflect the high cost of production (all thermal--diesel) and at Tessenei, for example, the rate is Eth¢55/kw.-hr. for power and Eth¢44 for lights. It was stated by Public Works officials that in some localities, even with these rates, it is difficult to install a small plant and insure sufficient return on the investment to justify operation.

TRANSMISSION AND DISTRIBUTION VOLTAGES

The one transmission line, Massawa-Asmara operates at 50,000 volts. Distribution voltages within urban settlements range around 3,000 and 5,000 volts. Distribution feeder drops to residences provide 127 volts for lighting and 220 volts for house circuits serving hot water heaters and other appliance-type nonlighting loads. Thus each house has two separate meters--one (127 volts) for lighting loads and one (220 volts) for nonlighting loads (called "power"). The single-line diagram, Figure V-105, provides more details on voltages used on the SEDAO system.

PAST TREND IN USAGE

No attempt is made by the utility companies to classify power usage other than what is recorded from metering installations which separate lighting loads from nonlighting loads (power). Estimates were once obtained for a percentage breakdown in 1955, and in the case of CONIEL were updated to 1960-1962. In the latter case, officials supplied revised estimates in June 1962.

SEDAO

The breakdown is between "light" and "power" only with totals shown, and is summarized below:

S.E.D.A.O. SOCIETA ELETTRICA DELL'AFRICA ORIENTALE-ASMARA

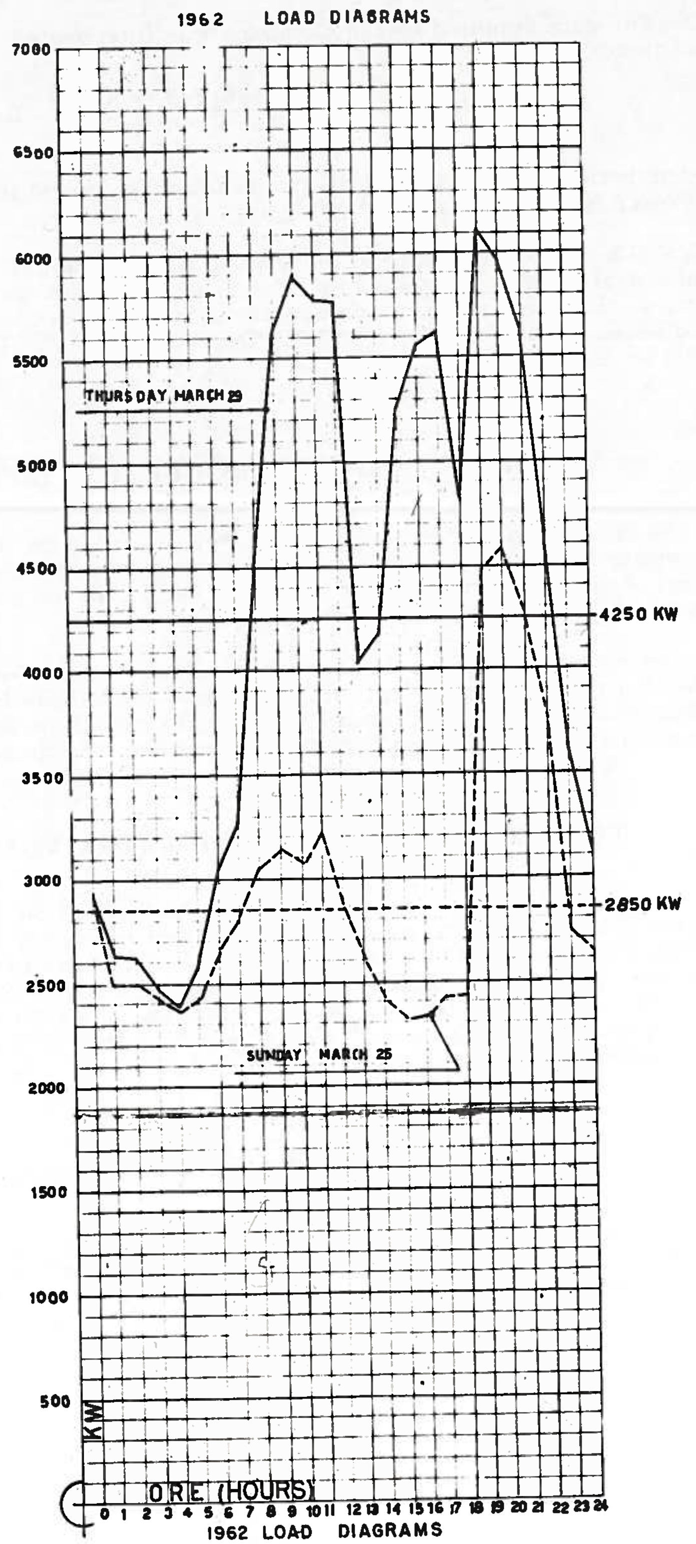

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Figure V-106--SEDAO Load Diagrams

Classification of Electrical Energy Sold
(Millions kw.-hr.)

	1953	1954	1955	1956	1957	1958	1959	1960
Light	4.9	4.7	4.8	5.0	4.8	4.7	5.1	5.3
Power	8.3	8.7	9.1	9.8	12.3	13.0	13.2	15.8
Total	13.2	13.4	13.9	14.8	17.1	17.7	18.3	21.1

In 1955 SEDAO supplied an estimate of usage which it classified as follows:

Private homes	23%
Bars and restaurants	4%
Commercial stores	4%
Theaters	1%
Industry	39%
Professional people	1%
Municipal water supply	5%
Street lights	3%
Government buildings	20%
	100%

This can be summarized as follows:

Domestic including lighting	46%
Commercial & industrial including municipal water pumping	54%
	100%

For 1960 this is estimated to be about the same with this variation:

Domestic including lighting	47%
Commercial & industrial including municipal water pumping	53%
	100%

CONIEL

These estimates were given for 1955 regarding classification of energy sold.

	Decamere	Keren	Adi Ugri	Adi Quala	Adi Caieh
Private homes	12%	39%	27%	45%	22%
Bars, restaurants, commercial stores, theaters, and industry	77	27	6		
Municipal water	4	6	27		
Street lights	4	17	35	18	38
Government buildings	3	11	5	37*	40**

*Prison.
**Police school.

CONIEL's share of the total Eritrean electrical energy sold in 1955, however, was less than 7 percent, so the influence of its market pattern on the total Eritrean pattern is small.

In June 1962, CONIEL affirmed the correctness of the above classification for 1961 except for Keren which had 45 percent for private homes and zero for municipal water pumping.

Data for other small plants are not given since their influence on the total market pattern is very small.

In the North Eritrea Region the trend in production and sales beginning with 1954 was about as follows:

Year	Production kw.-hr.	Sales kw.-hr.	(a) Public consumption and illumination kw.-hr.	(b) National economy kw.-hr.
1954	19,025,000	14,508,000	6,673,680	7,834,320
1955	19,573,000	15,040,000	6,918,400	8,122,000
1956	19,948,000	15,940,000	7,412,000	8,528,000
1957	22,448,000	18,240,000	8,572,800	9,667,200
1958	23,348,000	18,840,000	8,666,400	10,173,600
1959	24,197,975	19,440,000	9,136,800	10,303,200
1960	27,995,582	22,240,000	11,787,000	10,453,000
1961	31,970,518	25,398,000	11,937,000	13,461,000

No electrical energy of significance was used for irrigation pumping or for traction. The railroad from Massawa to Asmara and from Asmara north and west is not electrified. Diesel buses are used in the principal city, Asmara. Several years ago an aerial tramway (ropeway) operated between Massawa and Asmara but was discontinued in the mid 1940's. It was operated by electric motors.

Losses

The principal utility, SEDAO, had these losses for the years indicated:

Year	Production kw.-hr.	Sales kw.-hr.	Percent losses
1953	17,284,000	13,200,000	23.6
1954	17,677,000	13,400,000	24.2
1955	18,225,000	13,900,000	23.7
1956	18,600,000	14,800,000	20.4
1957	21,100,000	17,100,000	19.0
1958	22,000,000	17,700,000	19.5
1959	22,850,000	18,300,000	19.9
1960	25,969,642	21,100,000	18.7

Losses for North Eritrea should follow closely and were as follows:

Year	Percent losses
1953	-- -
1954	23.7
1955	23.2
1956	20.1
1957	18.8
1958	19.3
1959	19.7
1960	20.6

As existing systems are modernized and transmission and distribution losses are reduced, a gradual improvement is to be expected. Present losses of around 24 percent can be reduced to 11 or 12 percent in the future. This is summarized by years in a subsequent section. For example, reconductoring the Massawa-Asmara line would help, as it is understood that on peak load these transmission line losses are about 13 percent, which is high. Placing a new source of generation closer to the Asmara load center will also reduce the line losses considerably. Such a development should take place within 3 years if present plans materialize.

ELECTRIC POWER RATES

Rates are very high due to small isolated plants (thermal) serving small towns, high distribution losses in some areas, 1/ and the heavy loss in efficiency in diesel units operating at 6,000 to 7,000 feet (2,000 meters) above sea level. Losses in efficiency due to altitude alone range from 20-35 percent. All equipment, materials, fuel oils, and lubricants are imported. Transportation costs from Massawa up over the escarpment to points inland are high. See Section III for tariff structure of various towns.

POTENTIAL DEMAND FOR ELECTRICITY

National Economy, Commerce and Industry

No accurate figures are available as to what proportion of total energy sold in recent years is used by commerce and industry, although an estimate based upon earlier data is given in the preceding section.

Increases per year since 1954 are as follows:

Year	Percent increase over preceding year
1954	-- -
1955	3.7
1956	5.0
1957	13.4
1958	5.2
1959	1.2
1960	1.5
1961	28.8

The average annual increase over this period was about 700,000 kw.-hr., representing an 8 or 9 percent average increase per year for this sector alone since 1954.

The principal areas of activity in this sector are food processing, beverages, and textiles. Food processing and textiles have shown sharp increases since 1957, while beverages had a slight drop beginning in 1958. This was due to the drop in the production of beer.

The principal smaller industries are those concerned with tobacco, cement and bricks, and footwear and leather. The first two have shown a slight decline in productivity since 1957.

In general, the total gross industrial production for Eritrea has shown a gradual, steady increase since 1957 (data not available prior to then), and there is no reason to expect that this trend will not continue in the future.

Specifically, the following new industries may be established during the next 10 years in North Eritrea:

There is an abundance of fish in the Red Sea, and this industry could be developed to a greater degree. Some thought has been given toward establishing a fish processing plant at Massawa. The investment for such a plant would be on the order of Eth$2,000,000.

1/One small town is wired with telephone cable which is very small. Distribution loss and voltage drop are abnormally high as a result.

A one-shift operation would require 234,000 kw.-hr. annually. Eventually three-shift operation would be possible, requiring about 700,000 kw.-hr. annually (maximum demand 80 kw.).

A ship repair plant at either Massawa or Assab is likely with the gradual development of the Ethiopian Navy. An estimate of annual energy requirements is about 470,000 kw.-hr. with a maximum demand of 225 kw. using a one-shift-per-day operation.

Near Massawa in 1936 there was an old cement factory in operation which was later dismantled by occupation authorities. A new cement factory, to be completed in 1965, is to be constructed having an annual capacity of 150,000 tons. This may cost Eth$15,000,000, employ 350 people, and have an annual energy requirement of 20,000,000 kw.-hr. with a maximum demand of 2,500 kw. (SEDAO thought the energy requirement would be near 15,000,000 kw.-hr.)

At Agametta, 30 kilometers southwest of Massawa, a substantial iron ore deposit exists (60 percent hematite and magnetite). A barter deal with Krupp Industries may result in the development of this deposit with as much as 300,000 tons exported annually. An open pit operation may not require much electrical energy although it may be close enough to the SEDAO concession area that this utility might be interested and able to serve.

A cotton mill now in operation in the SEDAO area started at 200 kw. demand but has increased to 500 kw. demand with 24-hour operation.

An Agava plant fiber mill is now in operation which produces rope and bags. Operation is 8-10 hours per day with a demand of 200 kw. Location is Asmara. This operation should expand in the future.

The new airport at Asmara was completed in 1963. New runway, taxi strip, and new terminal building will increase the demand from 100 to 400 kw.

The Asmara glass factory has been completely automated with an increase in demand to 200 kw., which is not as much as was expected.

Other loads which have increased with a good prospect for further increase in the future are the Melotti Brewery, Asmara, and a salt plant at Massawa.

The naval base at Massawa has a 600 kw. demand and the other harbour facilities require 200 kw. with prospects for increases.

The Kagnew Station (US Forces) at Asmara is reported to require 10,000 kw. which was all supplied by its own generation in 1962, except for about 100-200 kw. supplied to some dwelling units by the local utility, SEDAO.

In a recent year (probably 1960), the following minerals were produced in this section of Eritrea:

China clay (Kaolin)	20,000 quintals
Feldspar	15,000 quintals
Refined gold	165 kilograms

Pumice is very abundant but is little used to date. Kaolin is useful for porcelain and a firm in Asmara produces procelain, mosaics, and refractories.

For the immediate future, the cost of electricity developed primarily by thermal means may remain high. Electrification of the railroad, for example, will not be a feasible undertaking even for the future, unless the annual tonnage transported increases tremendously and the cost of electricity is reduced substantially. Likewise, converting the public transport system, now diesel buses, in Asmara to electric trolley operation does not appear feasible, because of the cost of electricity, high initial investment, and low return on the investment. Irrigation pumping by electric motors probably will not develop to any extent. Surface water during most of the year is very limited. Pumping from wells for large-scale farming operations will not be feasible, except in special circumstances, for several years even if areas having suitable acquifer are found. The cost of electricity, cost of installation and preparation of land, and market value of most agricultural items are the limiting factors.

Municipal water pumping, however, will continue to develop as rapidly as electricity becomes available to the village and towns. Loads will be comparatively small for the average village.

Production of electricity by industrial plants for their own use in North Eritrea has been and still is negligible (between 100,000 and 200,000 kw.-hr. per year at most). 1/

Public Consumption and Illumination, Residential and Government

Earlier estimates are available as to the proportion of the total electrical energy sold that was used for these purposes. No accurate records are kept except as noted before; i.e. "light" and "power" loads. Increases per year since 1954 are estimated as follows:

Year	Percent increase over preceding year
1954	-- -
1955	3.6
1956	7.1
1957	15.6
1958	1.0
1959	5.4
1960	29.0
1961	12.7

The average annual increase during this period was about 650,000 kw.-hr., representing a 9 or 10 percent average annual increase per year for this sector since 1954.

There have been no sales to farms. All sales have been in urban areas with the greatest share of the sales going to residential customers in the last 2 or 3 years. Earlier, sales to Government and to residences were nearly balanced.

The main population centers are Asmara and Massawa, with various estimates ranging around 100,000 for Asmara and 25,000 for Massawa. Some estimates placed the total population for Eritrea at 2.5 million which is obviously too high if estimates including that of the United Nations are followed. If the 1940 boundary line were used, the 2.5 million would be closer to being correct. However, the present boundary line would limit the population to less than 1.5 million, it is believed. Allowing 150,000 for urban dwellers leaves 1.35 million rural dwellers all divided between farm and nomads who migrate yearly with their livestock from place to place. The latter group will offer little potential load source even in the future. None of the farms or nomad groups are served with electricity.

If the standard of living is raised and the cost of electricity reduced it may become profitable to expand electrical service in the future to serve more rural areas.

It is believed that the overall average rate of increase per year will be about 10 percent in this sector, confined mainly to residential and Government loads, but starting out around 14 percent and diminishing to around 9 percent in the future.

A summary of future load requirements by sectors is given by Table V-126.

SUMMARY OF ESTIMATED FUTURE REQUIREMENTS

SEDAO, the supplier of 95 percent of the present total North Eritrea load, forecast a "good load increase during the next few years of 10 percent."

As indicated elsewhere, generation by industrial firms for their own use is small in comparison to the total and is not separated. These estimates of future loads may seem optimistic; however, considering the trend in recent years by SEDAO and considering the world average over the past few years, the estimates given are possible of attainment and should develop barring some unforeseen condition.

1/US Armed Forces KAGNEW Station generation specifically omitted.

TABLE V-126—SUMMARY OF ESTIMATED FUTURE REQUIREMENTS

Year (1)	Percent (2)	Production (kw.-hr.) (3)	All loss (incl. plant use) percent (4)	Losses (kw.-hr.) (5)	Sales (kw.-hr.) (6)	Public consumption and illumination 1/ Percent (7)	Public consumption and illumination 1/ (kw.-hr.) (8)	National economy 2/ Percent (9)	National economy 2/ (kw.-hr.) (10)
1954	2	19,025,000 3/	23.7	4,517,000	14,508,000 3/	46	6,673,680	54	7,834,320
1955	3	19,573,000 3/	23.7	4,533,000	15,040,000 3/	46	6,918,400	54	8,122,000
1956	2	19,948,000 3/	23.2	4,008,000	15,940,000 3/	46	7,412,100	54	8,528,000
1957	13	22,448,000 3/	20.1	4,208,000	18,240,000 3/	47	8,572,800	53	9,667,200
1958	4	23,348,000 3/	18.8	4,508,000	18,840,000 3/	46	8,666,400	54	10,173,600
1959	4	24,197,975 3/	19.3	4,757,975	19,440,000 3/	47	9,136,800	53	10,303,200
1960	16	27,995,582 3/	19.7	5,755,582	22,240,000 3/	47	11,787,000	53	10,453,000
1961	14	31,970,518 3/	20.6	6,572,518	25,398,000	47	11,937,000	53	13,461,000
1962	12	35,800,000	20.0	7,160,000	28,640,000	46	13,174,000	54	15,466,000
1963	10	39,380,000	20.0	7,876,000	31,504,000	46	14,491,000	54	17,013,000
1964	10	43,318,000	20.0	8,663,000	34,655,000	46	15,941,000	54	18,714,000
1965	10	47,650,000	20.0	9,530,000	38,120,000	45	17,154,000	55	20,966,000
1966	10	52,415,000	19.5	10,221,000	42,194,000	45	18,987,000	55	23,207,000
1967	10	57,657,000	19.0	10,955,000	46,702,000	44	20,549,000	56	26,153,000
1968	10	63,423,000	19.0	12,050,000	51,373,000	44	22,600,000	56	28,773,000
1969	10	69,765,000	19.0	13,255,000	56,510,000	44	24,860,000	56	31,650,000
1970	10	76,741,000	19.0	14,581,000	62,160,000	44	27,350,000	56	34,810,000
1971	10	84,415,000	18.5	15,617,000	68,798,000	44	30,270,000	56	38,528,000
1972	9	92,000,000	18.0	16,560,000	75,440,000	43	32,439,000	57	43,001,000
1973	9	100,200,000	18.0	18,036,000	82,164,000	43	35,330,000	57	46,834,000
1974	9	109,000,000	18.0	19,620,000	89,380,000	43	38,433,000	57	50,947,000
1975	9	118,800,000	17.5	20,790,000	98,010,000	43	42,144,000	57	55,866,000
1976	9	129,500,000	17.0	22,015,000	107,485,000	43	46,219,000	57	61,266,000
1977	9	141,155,000	17.0	23,996,000	117,159,000	43	50,378,000	57	66,781,000
1978	9	153,850,000	17.0	26,155,000	127,695,000	43	54,908,000	57	72,787,000
1979	9	167,700,000	16.5	27,671,000	140,030,000	42	58,813,000	58	81,217,000
1980	9	182,700,000	16.0	29,232,000	153,468,000	41	62,922,000	59	90,546,000
1981	8	197,300,000	16.0	31,568,000	165,732,000	41	67,950,000	59	97,782,000
1982	8	213,000,000	16.0	34,080,000	178,920,000	41	73,357,000	59	105,563,000
1983	8	230,000,000	15.5	35,650,000	194,350,000	40	77,740,000	60	116,610,000
1984	8	248,000,000	15.0	37,200,000	210,800,000	40	84,320,000	60	126,480,000
1985	8	268,000,000	15.0	40,200,000	227,800,000	40	91,120,000	60	136,680,000
1986	8	289,000,000	14.5	41,905,000	247,095,000	40	98,838,000	60	148,257,000
1987	8	312,000,000	14.0	43,680,000	268,320,000	39	104,645,000	61	163,674,000
1988	8	337,000,000	14.0	47,180,000	289,820,000	39	113,030,000	61	176,790,000
1989	8	363,000,000	13.0	47,190,000	315,810,000	38	120,000,000	62	195,810,000
1990	7	392,000,000	13.0	50,960,000	341,040,000	38	129,595,000	62	211,445,000
1991	7	419,000,000	13.0	54,470,000	364,530,000	38	138,520,000	62	226,010,000
1992	7	448,000,000	13.0	58,240,000	389,760,000	38	148,100,000	62	241,660,000
1993	7	479,000,000	12.5	59,875,000	419,125,000	37	155,076,000	63	264,049,000
1994	7	512,000,000	12.0	61,440,000	450,560,000	37	166,700,000	63	283,860,000
1995	7	548,000,000	12.0	65,760,000	482,224,000	36	173,600,000	64	308,624,000
1996	7	586,000,000	12.0	70,320,000	515,680,000	36	185,645,000	64	330,035,000
1997	7	627,000,000	11.5	72,105,000	554,895,000	36	199,760,000	64	355,135,000
1998	7	670,000,000	11.0	73,700,000	596,300,000	36	214,670,000	64	381,630,000
1999	7	717,000,000	11.0	78,870,000	638,130,000	36	229,727,000	64	408,403,000
2000	7	767,000,000	11.0	84,370,000	682,630,000	34	232,094,000	65	450,536,000

1/ Largely urban, residential and Government
2/ Largely commercial and industrial
3/ Historical

Eritrea has had a serious trade deficit during its history. The deficit was made up by the former Italian Government and this was due mainly to the importation of essential items such as food and clothing from Italy by Italian residents. Some basic food staples were imported from Ethiopia at that time.

During and following World War II, the port facilities of Massawa were largely dismantled. Since Federation with Ethiopia in 1953, port facilities have been gradually restored and the self-sufficiency of this part of Eritrea has improved, with some small industries being started. Power loads have shown a gradual increase since then. On the other hand, this part of Eritrea has lost population, with many Italian residents leaving and with many Eritreans moving into Ethiopia where economic conditions were better. Even with this loss of population, power loads have increased as noted. With the stabilization that is gradually being felt, a good climate for economic growth is being developed as proven by the increases in power loads since 1953. Part of the economic stabilization is due to the presence of the American KAGNEW Station near Asmara.

However, SEDAO, the main supplier, estimated 10 percent growth for the future, and the overall rate of growth used is slightly over 8 percent. See Table V-126 and Figure V-107.

FUTURE CAPACITY REQUIREMENTS

The isolated independent plants have no immediate bearing on this problem and in the future, perhaps in 20 years or less, some of these will be integrated into the major interconnected systems group which may consist principally of CONIEL and SEDAO. Therefore, early interest is largely centered on the SEDAO System, the principal supplier (95 percent), which operates an interconnected system now having powerplants at three separate general locations (Dorfu, Asmara--later Belesa, and Massawa).

Capability will have to grow as fast as peaks in order to keep an adequate margin between peaks and generating capability to cover outages and maintenance. Considering this, future capacity requirements are estimated as shown in Table V-127.

Figure V-108 indicates the required generating capability and the maximum demand in kilowatts expected to the year 2000. A reserve margin of about 20 percent between maximum yearly demand and generating capability has been allowed. The 20 percent is considered the minimum needed to meet maintenance schedules and outages and is low for the earlier years.

POWER FACILITIES UNDER CONSTRUCTION OR PLANNED

In 1962, SEDAO had an application for loan pending to finance the construction of a steam-driven generating station at Belesa, using available impounded water (1 million cubic meters) for cooling and makeup purposes. The Belesa station will use imported oil as a fuel and will eventually have an ultimate capacity of three units, each rated 5,000 kw. One 5,000-kw. unit will be installed initially and will be placed in operation in 1963. When placed in operation, it will operate during the nighttime heavy-load period with the day-time lighter load shifted to the Massawa units. The older, less economical Asmara diesel units will be retired.

The present 50-kilovolt tubular steel supported transmission line from Massawa has small conductor, 35 mm^2 aluminum. A new 50-kilovolt line will be constructed paralleling the existing one from Belesa to Asmara.

The management of SEDAO decided upon the steamplant because rainfall has been undependable, resulting in an unsatisfactory hydrological situation in its concession area. A few years ago (December 12, 1953), SEDAO and the Eritrean Government signed a contract for the exploitation of the water resources for hydroelectric power development. SEDAO considered developing a project for the construction of three new hydroelectric

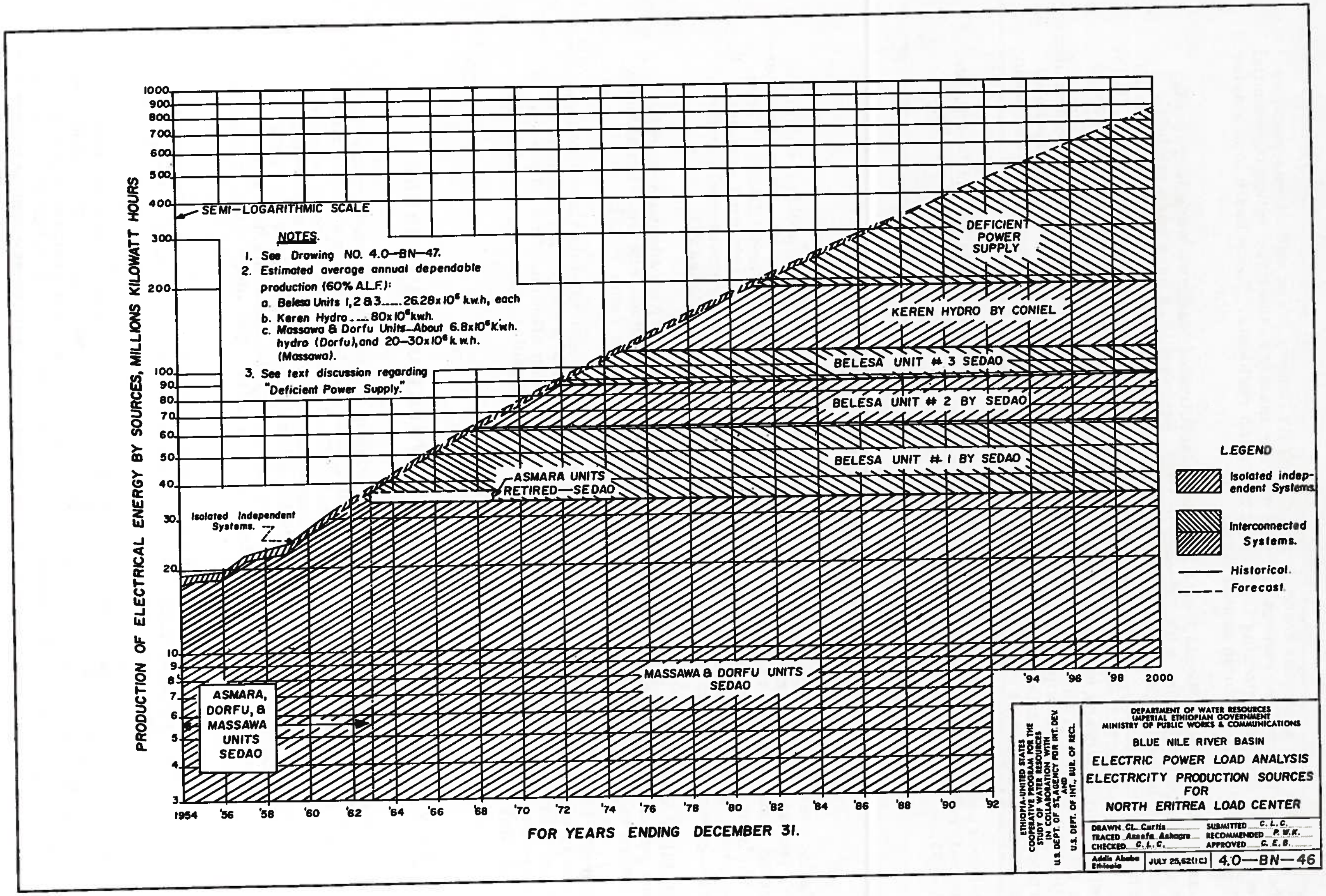


Figure V-107--Electricity Production Sources for North Eritrea Load Center

TABLE V-127 -NORTH ERITREA INTERCONNECTED SYSTEM

Year	Production requirement (kw.-hr.)	Annual load factor	Maximum demand (kw.)	Minimum required generating capability (kw.)	Production sources
1954	17,677,0001/				Dorfu Hydro Asmara Thermal Massawa Thermal
1955	18,225,0001/				Dorfu Hydro Asmara Thermal Massawa Thermal
1956	18,600,0001/				Dorfu Hydro Asmara Thermal Massawa Thermal
1957	21,100,0001/				Dorfu Hydro Asmara Thermal Massawa Thermal
1958	22,000,0001/				Dorfu Hydro Asmara Thermal Massawa Thermal
1959	22,850,0001/				Dorfu Hydro Asmara Thermal Massawa Thermal
1960	25,969,6421/	0.591/	5,0201/	6,025	Dorfu Hydro Asmara Thermal Massawa Thermal
1961	29,944,5781/	0.59	6,100	7,320	Dorfu Hydro Asmara Thermal Massawa Thermal
1962	33,000,000	0.59	6,400	7,700	Dorfu Hydro Asmara Thermal Massawa Thermal
1963	37,000,000	0.59	7,180	8,600	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1
1964	42,000,000	0.59	8,100	9,700	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1
1965	46,000,000	0.59	8,900	10,600	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1
1966	50,000,000	0.59	9,650	11,600	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1
1967	56,000,000	0.59	10,800	13,000	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1
1968	62,000,000	0.60	11,800	14,200	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2
1969	67,000,000	0.60	12,750	15,400	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2
1970	74,000,000	0.60	14,100	17,000	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2
1971	80,000,000	0.60	15,200	18,200	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2
1972	86,000,000	0.61	16,100	19,300	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal No. 3
1973	96,000,000	0.61	17,965	21,558	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal No. 3

1/ Historical

TABLE V-127--NORTH ERITREA INTERCONNECTED SYSTEM

Year	Production requirement (kw.-hr.)	Annual load factor	Maximum demand (kw.)	Minimum required generating capability (kw.)	Production sources
1974	105,000,000	0.61	19,650	23,580	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal No. 3
1975	112,000,000	0.62	20,622	24,746	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal No. 3
1976	124,000,000	0.62	22,830	27,396	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal No. 3 Keren Hydro
1977	138,000,000	0.63	25,005	30,006	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal N . 3 Keren Hydro
1978	146,000,000	0.63	26,455	31,746	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal No. 3 Keren Hydro
1979	160,000,000	0.63	28,992	34,790	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal No. 3 Keren Hydro
1980	172,000,000	0.64	30,679	36,815	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal No. 3 Keren Hydro
1981 2/	190,000,000	0.64	33,890	40,668	Dorfu Hydro Massawa Thermal Belesa Thermal No. 1 Belesa Thermal No. 2 Belesa Thermal No. 3 Keren Hydro
1982	200,000,000	0.64	35,673	42,808	
1983	225,000,000	0.64	40,132	48,150	
1984	240,000,000	0.64	42,808	51,375	
1985	260,000,000	0.64	46,375	55,650	
1986	280,000,000	0.64	49,944	59,933	
1987	310,000,000	0.65	54,431	65,317	
1988	330,000,000	0.65	57,955	69,546	
1989	352,000,000	0.66	60,881	73,057	
1990	390,000,000	0.66	67,455	84,546	
1991	419,000,000	0.66	72,471	86,965	
1992	448,000,000	0.66	77,485	92,982	
1993	479,000,000	0.66	82,848	99,418	
1994	512,000,000	0.67	87,234	104,681	
1995	548,000,000	0.67	93,369	112,043	
1996	586,000,000	0.67	99,843	116,000	
1997	627,000,000	0.67	106,832	128,198	
1998	670,000,000	0.67	114,155	136,986	
1999	717,000,000	0.67	122,163	146,596	
2000	767,000,000	0.67	130,000	156,000	

2/Add new thermal generation as required from now on or import from other sources; otherwise deficiency will result.

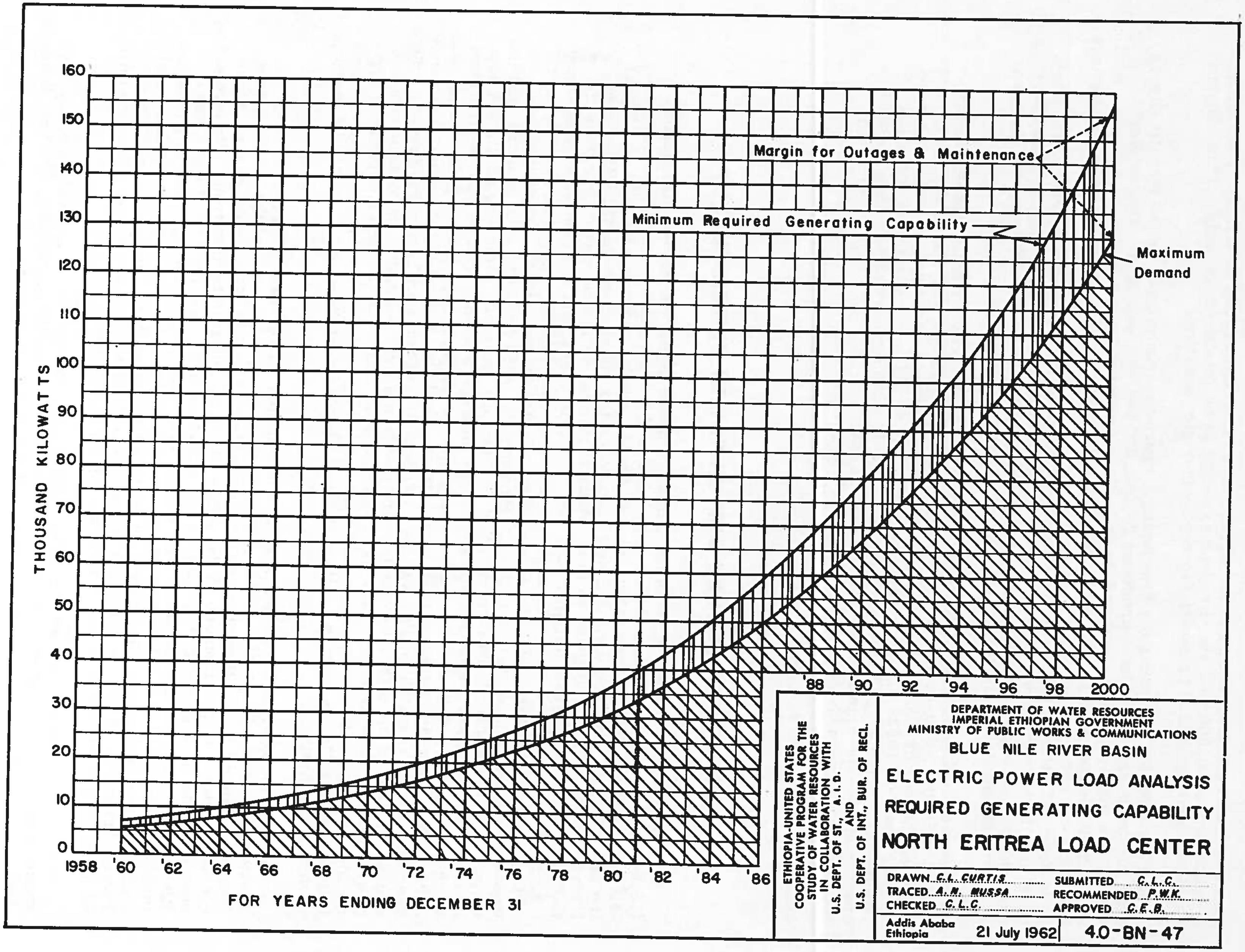


Figure V-108--Required Generating Capability--North Eritrea Load Center plants in the Dorfu and Ghinda River valleys at an average cost of Eth$10,000,000 each. A maximum of 10,000,000 kw.-hr. was expected to be produced annually. This scheme was later abandoned due to unsatisfactory hydrologic conditions.

In 1940 CONIEL had plans for developing a hydroelectric project on the Nehafit River near Himberti and would have produced 20,000,000 kw.-hr. annually. Due to World War II this project was shelved and there is little prospect for its revival. Actually, it was a multiple-purpose project with the main function to supply municipal water to Asmara.

In June 1962 the CONIEL representative did not discuss the Keren hydroelectric proposal but the Government representatives indicated CONIEL was interested in a hydroelectric project near Keren (Cheren), which could produce 80,000,000 kw.-hr. per year at a very attractive production cost. Details were not furnished.

Beginning in 1899, some studies were made for developing a multipurpose project using the Damas, Jangus, and Agbalo Rivers between Asmara and Massawa. A total of 20,000,000 kw.-hr. could be developed in an average year according to estimates prepared as late as 1952. The regulated water supply would serve municipal purposes (Massawa), irrigate 1,000 hectares of land, and develop hydroelectric energy from five small plants. The existing SEDAO Massawa-Asmara 50-kv line roughly parallels the northern edge of these drainage areas. This project has never been constructed and it is possible that this may be due to unsatisfactory hydrologic conditions. Rainfall is sparse in some years.

ESTIMATED FUTURE DEFICIENCY IN POWER SUPPLY

At a very modest rate of growth the output from the complete Belesa steamplant (15,000 kw.), and the Dorfu and Massawa units will be fully utilized by 1975 with little left for reserve. Therefore, other sources should reach production by 1974 or 1975 at the latest. This would be a good time to introduce the output from the CONIEL Keren Hydroelectric plant. But prior to this, plans should be well underway to integrate the CONIEL and SEDAO systems, provided the economic conditions warrant such investments. Or, perhaps a special arrangement can be made so that SEDAO can contract for a part of the output of the Keren Hydroelectric plant. By this time CONIEL may have also expanded its service to other locations. Beginning in 1980 or 1981, it is possible that the output from the Keren Hydroelectric plant will be fully utilized, requiring additional new sources of generation. Perhaps some of those discussed earlier can be revived but even so these would prove to be inadequate to meet the needs that may develop prior to the year 2000. Thus, beginning around 1980 it may come about that a cumulative annual deficiency reaching a level from 10 million kw.-hr. to about 30 million kw.-hr. might develop. This could be provided for either by constructing additional thermal plants or by importing power from outside Eritrea. This assumes that good hydroelectric sites capable of producing large quantities of energy would have been fully developed. Due to the scanty rainfall few, if any, large ones in addition to those already mentioned are likely to be feasible to develop in Eritrea.

The future choice in the 1980's will then depend primarily upon the economics of choosing between additional thermal plants or imports from outside of the North Eritrea Region. Hence the question of importing power from the Blue Nile River Basin Hydroelectric network if development on the latter has been initiated by that time. Hydroelectric developments in Begemidir Province on the Takazze River, a tributary of the Atbara River which empties into the main Nile River, may also be a possibility and might be the most economical choice. Because of this unknown potential, Blue Nile powerplants and transmission facilities to North Eritrea were not included in the main section of this Power Appendix. When the potential of the Takazze River becomes known, the possibility of using Blue Nile power in North Eritrea will be determined.

Unless the loads in the North Eritrea Region and those at Assab increase greatly over those indicated in this study, there will be no economic justification for a 500-km. Asmara-Assab transmission tieline during the period covered by this study.

FEASIBILITY OF USING BLUE NILE HYDROELECTRIC POWER TO MEET FUTURE DEFICIENCIES

The transmission line distance from Gondar to Asmara is about 420 km. Power delivered to the North Eritrea Region from the Blue Nile System may become competitive with power from local thermal plants when the net load requirements of approximately 300,000,000 kw.-hr. per year develop. This may occur in the 1980's.

In the preceding section it was observed that deficiency in the North Eritrea Region may also occur in the 1980's. That deficiency could be alleviated by constructing a large thermal plant or by importing power from the Blue Nile network.1/ The Blue Nile facilities may be capable of providing for the deficiency beginning about that time.

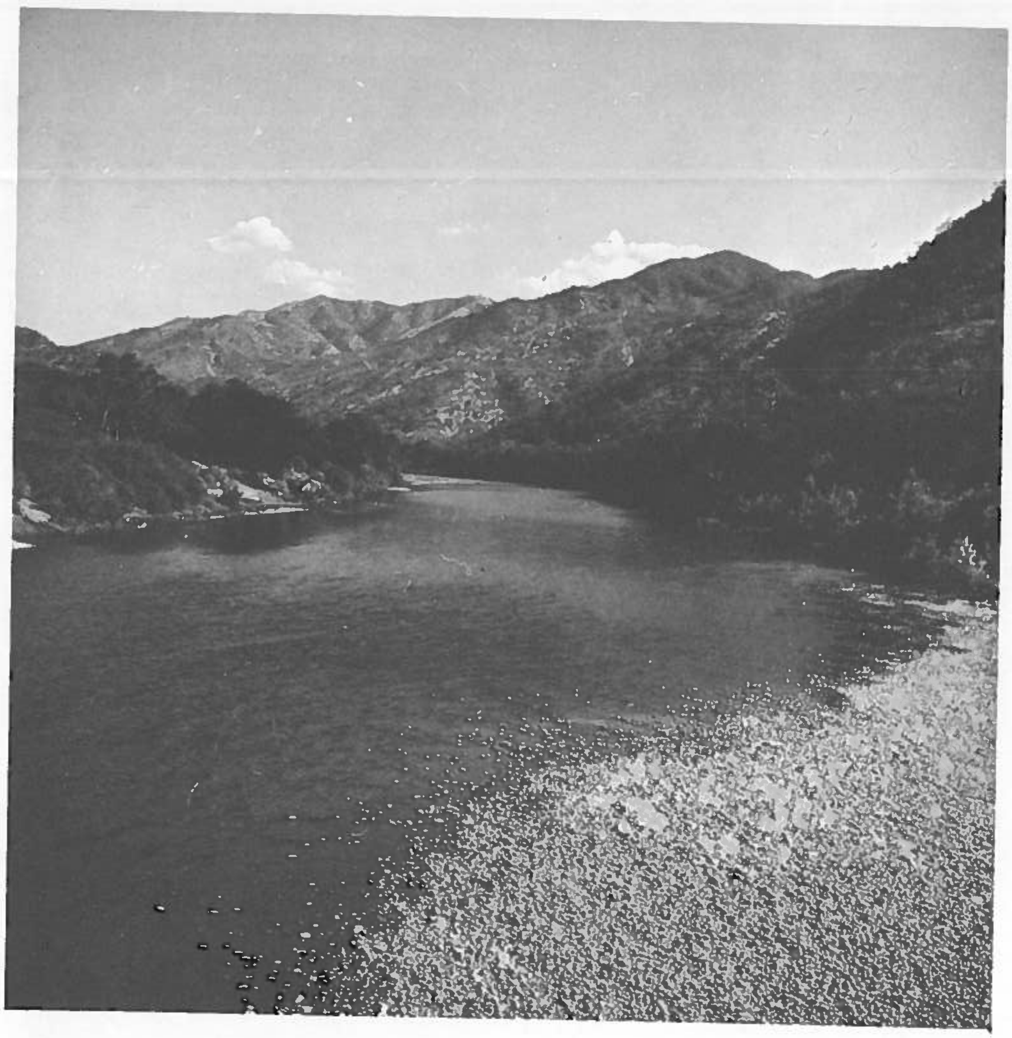


Figure V-109--The Takazze River during low water. Before the feasibility of exporting Blue Nile Basin power to North Eritrea can be determined, the hydroelectric potential of this river must be determined.

1/Only if studies made by that time indicate that the Takazze River potential is less favorable than Blue Nile importation.

ANNEX "C"

RECONNAISSANCE ELECTRIC POWER SWITCHING DIAGRAMS

Individual electrical switching diagrams of powerplants and substations on the following pages provide additional information not available on the System Diagrams given in Section VI:

Approximate elevation of substations in meters above mean sea level
Identification of facilities by stage of construction
Project identification
Approximate in-service dates of identified facilities

Cost estimates were derived from these basic diagrams.

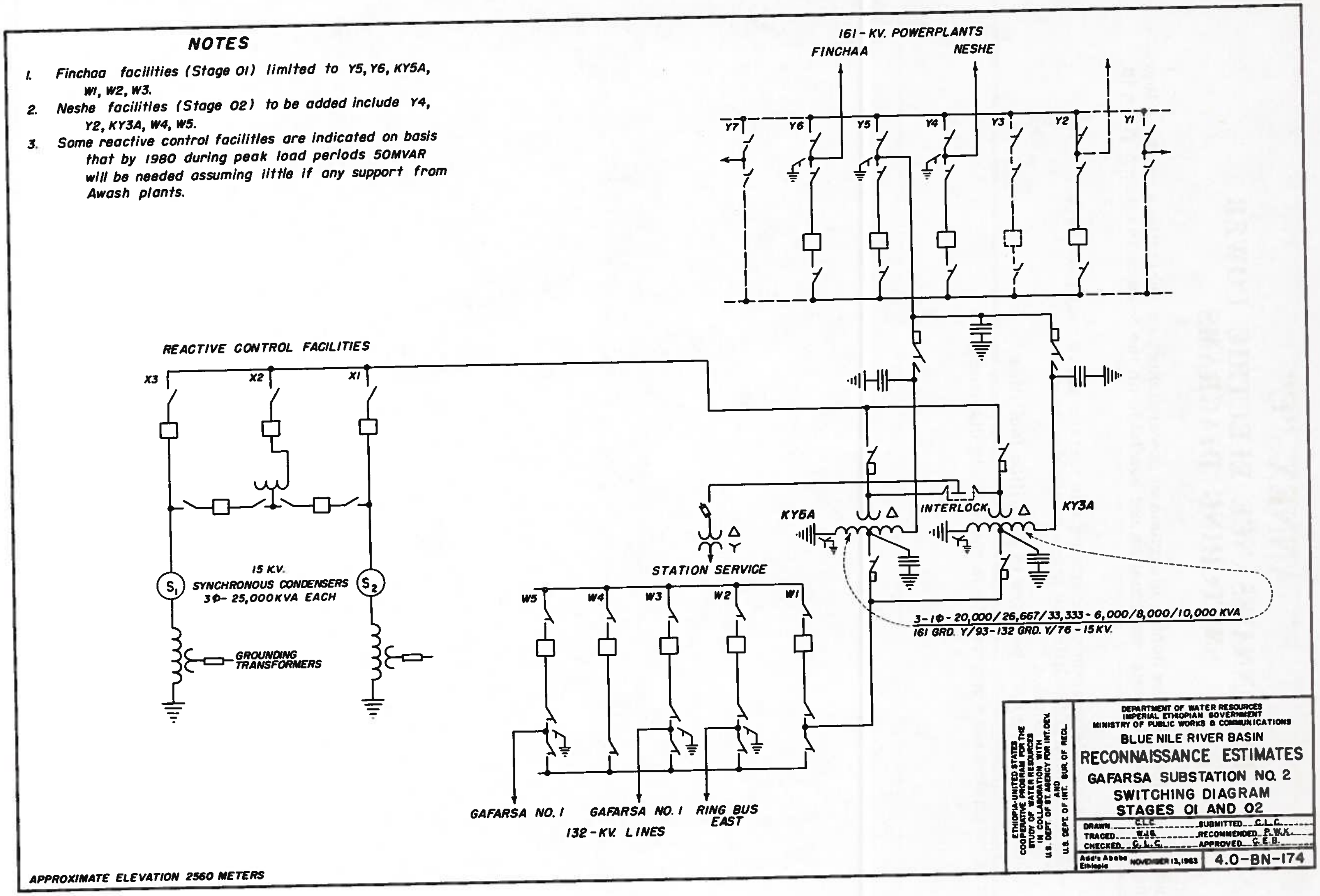
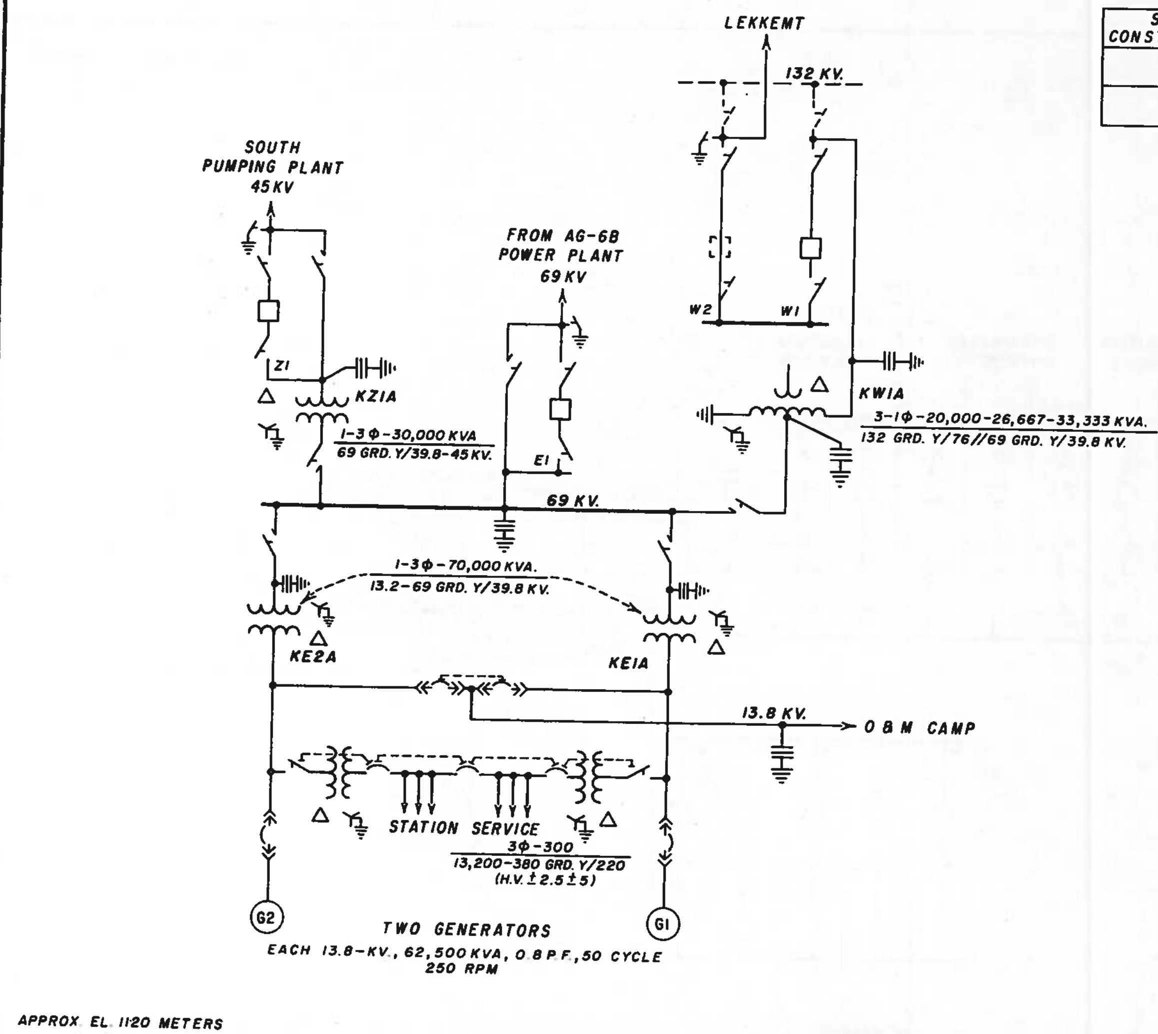


Figure V-110--Gafarsa Substation No. 2--Switching Diagram, Stages 01 and 02

STAGE CONSTRUCTION	FACILITIES	PROJECT
01	G1, G2, KE1A, KE2A, E1, KW1A, W1, W2, STA. SERV.	ANGAR (POWER)
02	Z1, KZ1A	ANGAR (IRRIGATION)

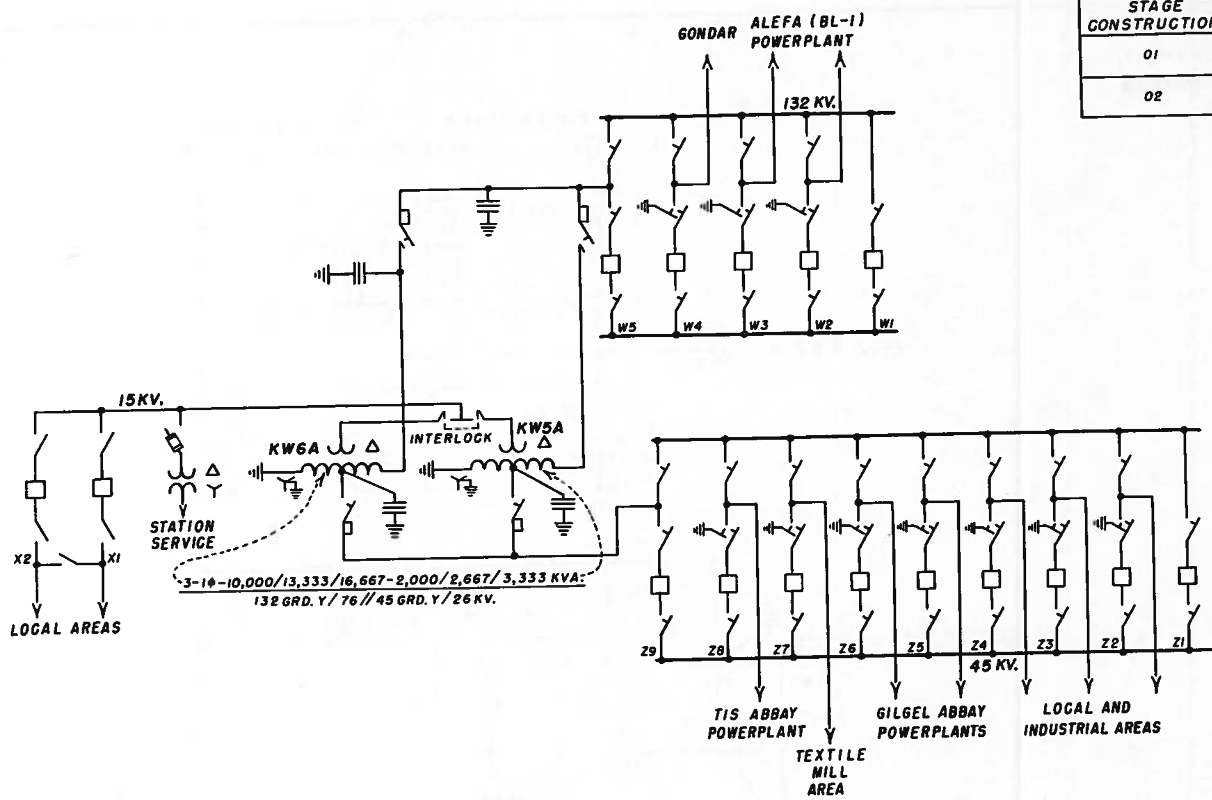


ETHIOPIA
BLUE NILE RIVER BASIN
RECONNAISSANCE SWITCHING DIAGRAM
LEKKEMT (AG-6A) POWERPLANT & SWITCHYARD

1-14-64, C.L.C.   4.0-BN-203

Figure V-111--Lekkemt (AG-6A) Powerplant and Switchyard--Switching Diagram

UPPER BELES PROJECT		
STAGE CONSTRUCTION	FACILITIES	IN SERVICE DATE*
01	W4, W5, X1, Z7, Z8, Z9 STA. SERVICE, KW5A	1972-1974
02	W1, W2, W3, X2, Z1, Z2, Z3, Z4, Z5, Z6, KW6A	1984-1987



* SEE TEXT

APPROX. EL. 1800 METERS

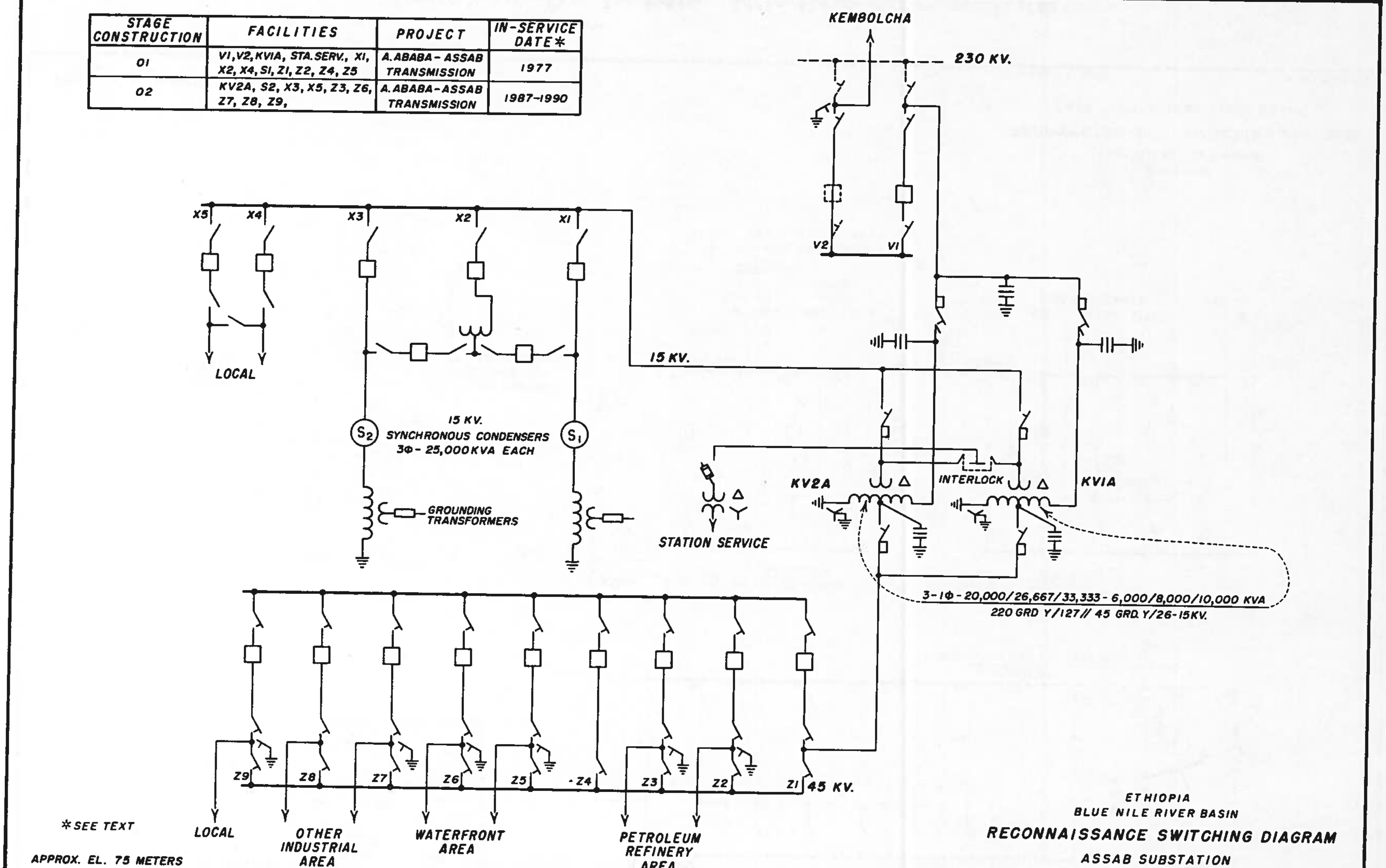
ETHIOPIA
BLUE NILE RIVER BASIN
RECONNAISSANCE SWITCHING DIAGRAM
BAHIR DAR SUBSTATION

1-9-64, C.L.C.

4.0-BN-191

Figure V-112--Bahir Dar Substation--Switching Diagram

STAGE CONSTRUCTION	FACILITIES	PROJECT	IN-SERVICE DATE*
01	V1, V2, KV1A, STA. SERV., X1, X2, X4, S1, Z1, Z2, Z4, Z5	A. ABABA - ASSAB TRANSMISSION	1977
02	KV2A, S2, X3, X5, Z3, Z6, Z7, Z8, Z9,	A. ABABA - ASSAB TRANSMISSION	1987-1990



*SEE TEXT

APPROX. EL. 75 METERS

ETHIOPIA
BLUE NILE RIVER BASIN

RECONNAISSANCE SWITCHING DIAGRAM

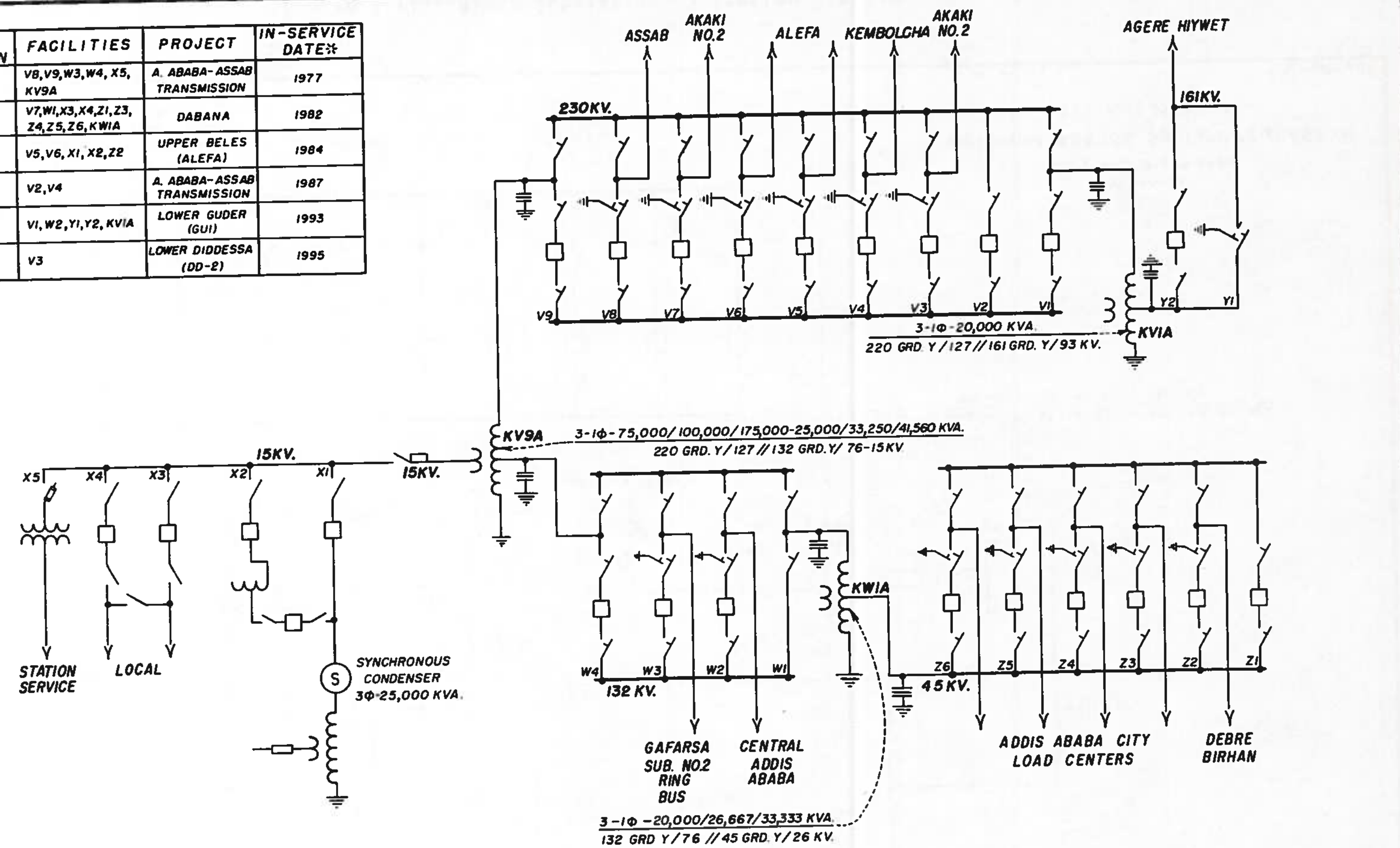
ASSAB SUBSTATION

1-6-64, C.L.C.

4.0-BN-182

Figure V-113--Assab Substation--Switching Diagram

STAGE CONSTRUCTION	FACILITIES	PROJECT	IN-SERVICE DATE*
01	V8, V9, W3, W4, X5, KV9A	A. ABABA-ASSAB TRANSMISSION	1977
02	V7, W1, X3, X4, Z1, Z3, Z4, Z5, Z6, KW1A	DABANA	1982
03	V5, V6, X1, X2, Z2	UPPER BELES (ALEFA)	1984
04	V2, V4	A. ABABA-ASSAB TRANSMISSION	1987
05	V1, W2, Y1, Y2, KV1A	LOWER GUDER (GUI)	1993
06	V3	LOWER DIDDESSA (DD-2)	1995



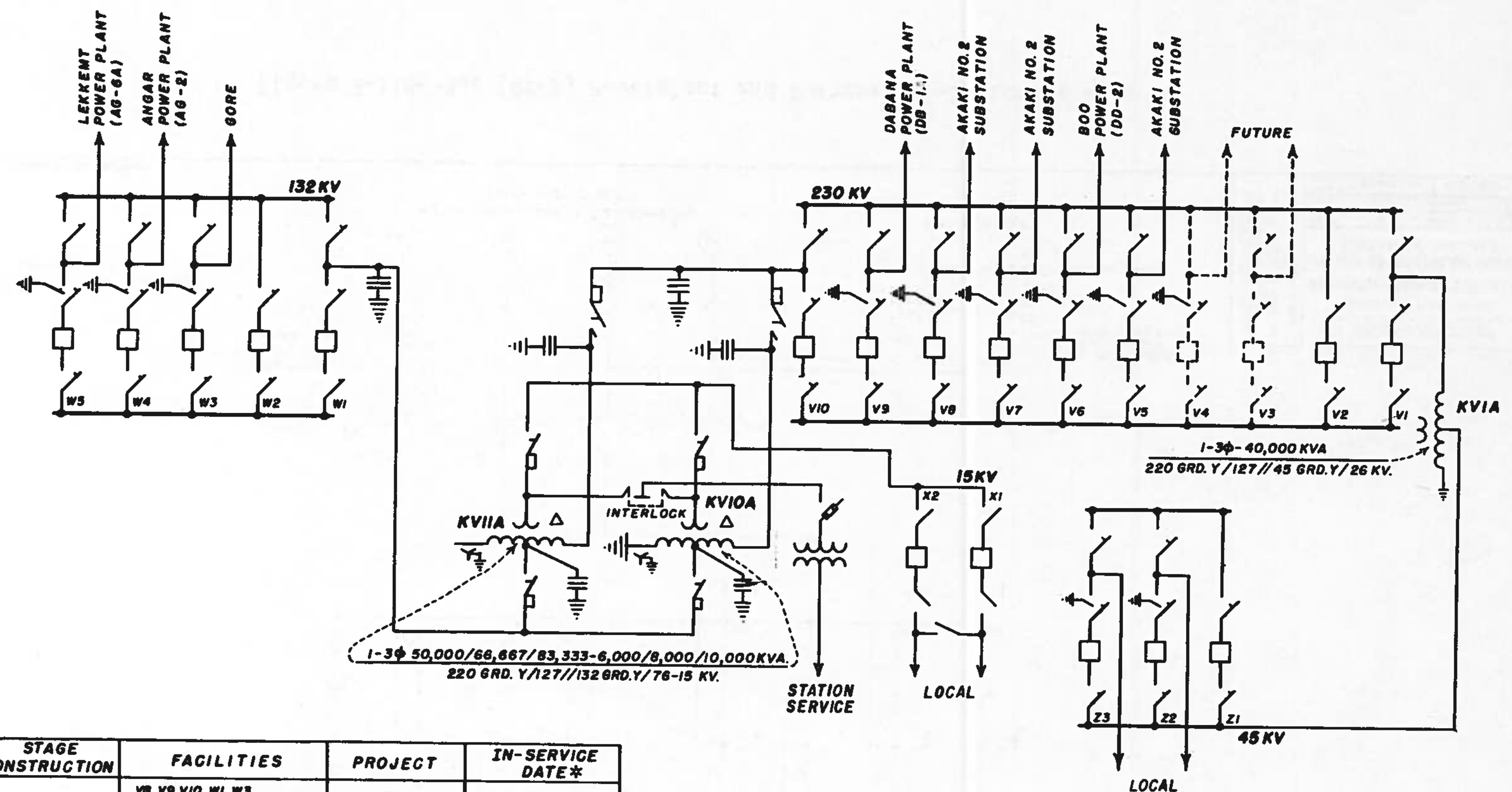
*SEE TEXT

APPROX. EL 2700 METERS

ETHIOPIA
BLUE NILE RIVER BASIN
RECONNAISSANCE SWITCHING DIAGRAM
EAST SUBSTATION - ADDIS ABABA

4 O-BN-100

Figure V-114--East Substation, Addis Ababa--Switching Diagram



STAGE CONSTRUCTION	FACILITIES	PROJECT	IN-SERVICE DATE*
01	V8, V9, V10, W1, W3, X1, X2, KV10A, STA. SERV.	DABANA	1982
02	V1, V2, V7, W2, W4, W5, Z1, Z2, Z3, KV1A, KV11A	ANGAR	1990 - 91
03	V5, V6	BOO (DD-2)	1995 - 98

*SEE TEXT

APPROX. EL. 1830 METERS

ETHIOPIA
BLUE NILE RIVER BASIN
RECONNAISSANCE SWITCHING DIAGRAM
LEKKEMT SUBSTATION

1-6-64, C.L.C. 4.0-BN-181

Figure V-115--Lekkemt Substation--Switching Diagram

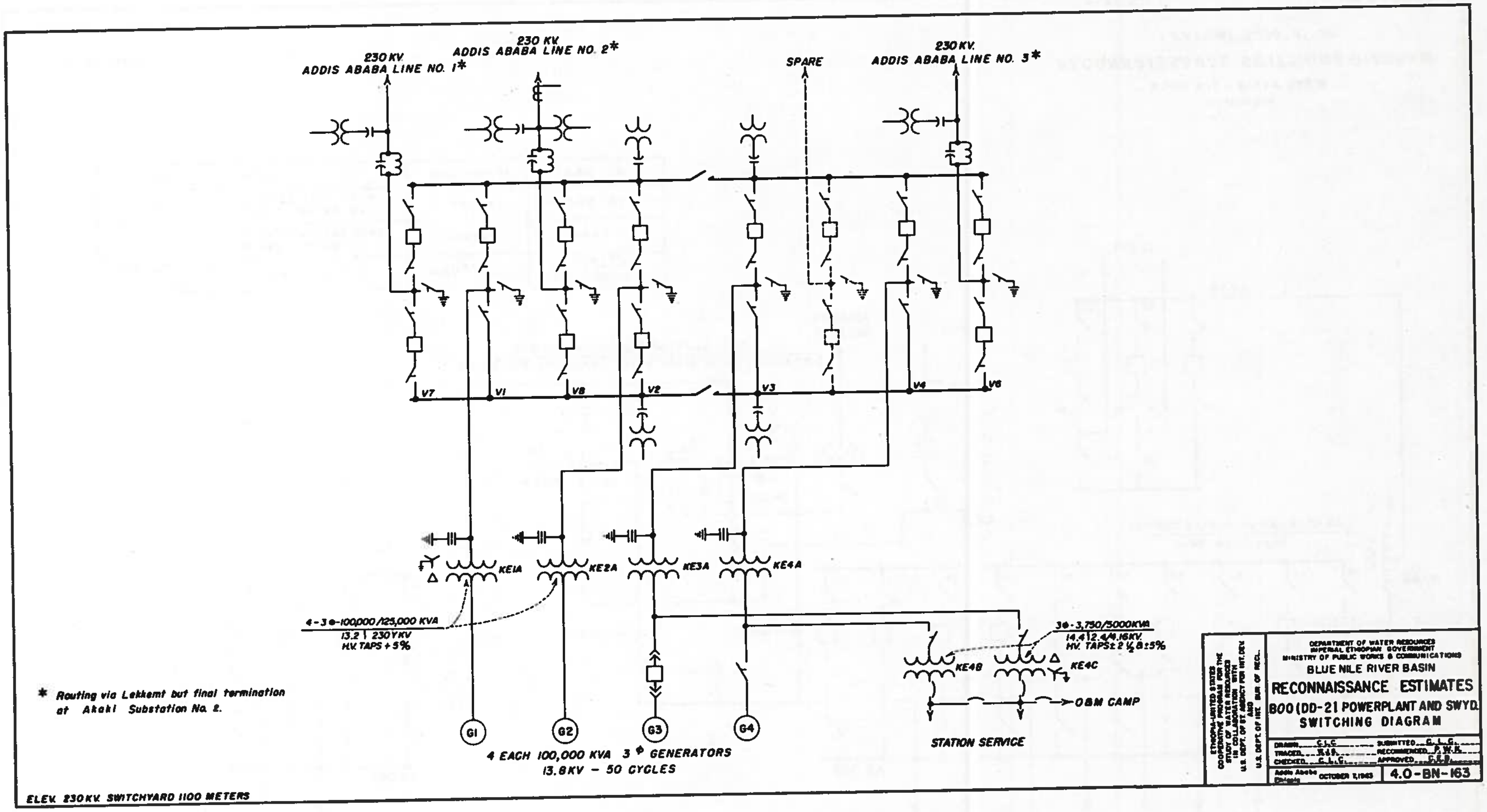
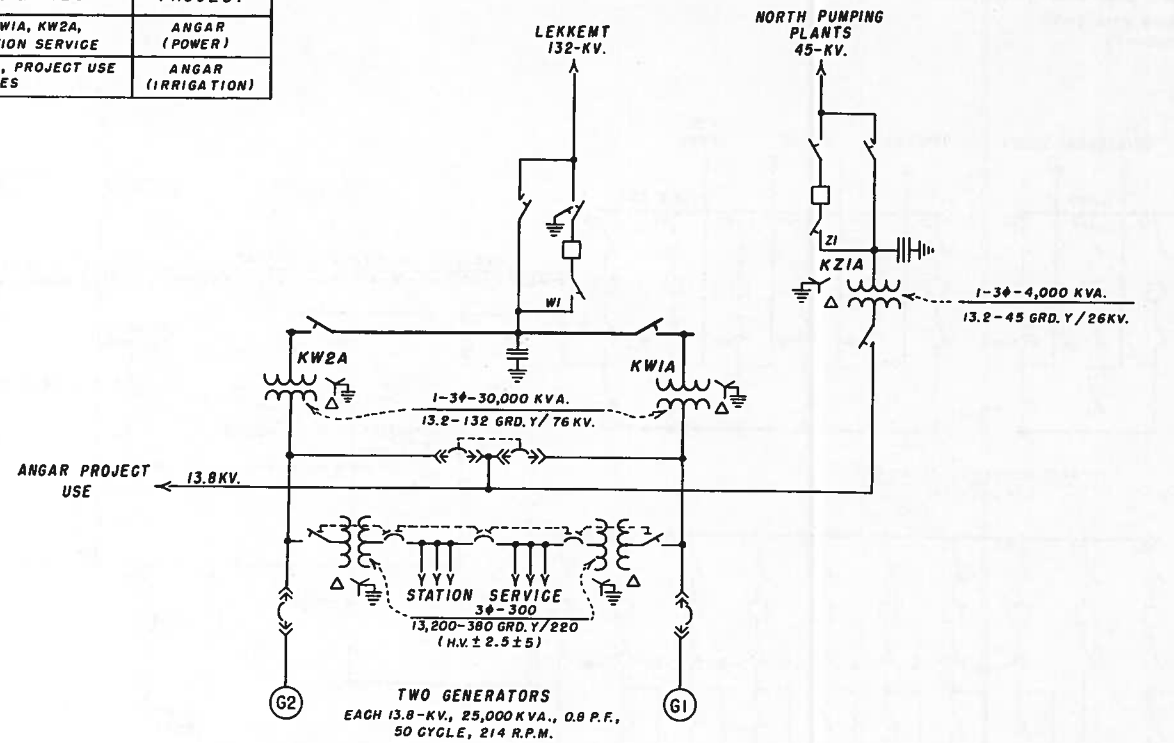


Figure V-116--Boo (DD-2) Powerplant and Switchyard--Switching Diagram

STAGE CONSTRUCTION	FACILITIES	PROJECT
01	G1, G2, KW1A, KW2A, W1, STATION SERVICE	ANGAR (POWER)
02	KZ1A, Z1, PROJECT USE FACILITIES	ANGAR (IRRIGATION)



APPROX. EL. 1460 METERS

ETHIOPIA
BLUE NILE RIVER BASIN

RECONNAISSANCE SWITCHING DIAGRAM

ANGAR (AG-2) POWER PLANT & SWITCHYARD

1-15-64, C.L.C. 4.0-BN-205

Figure V-117--Angar (AG-2) Powerplant and Switchyard--Switching Diagram

STAGE CONSTRUCTION	FACILITIES	PROJECT	YEAR
01	V7, V8, V9, W5, W6, STA. SERV. KV9A	DABANA	1982
02	V0, V6, KV0A, Z1, Z2, Z3	ANGAR	1990
03	V1, V2, V3, V4, V5, W1, W2, W3, W4, X1, X2, X3, X4, X5, S1, S2, KV10A	LOWER DIDDESSA (DD-2)	1995-1998

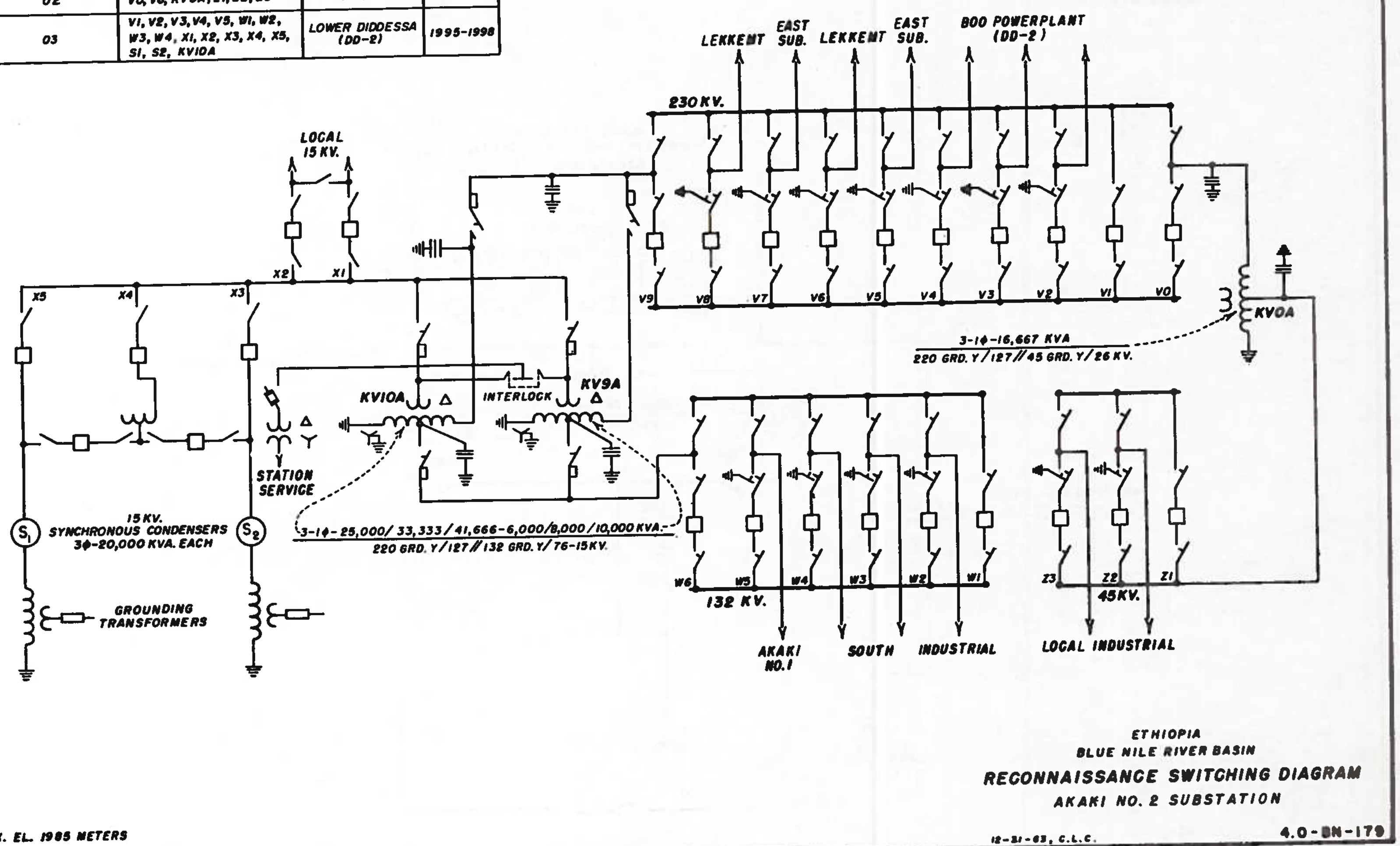


Figure V-118--Akaki No. 2 Substation--Switching Diagram

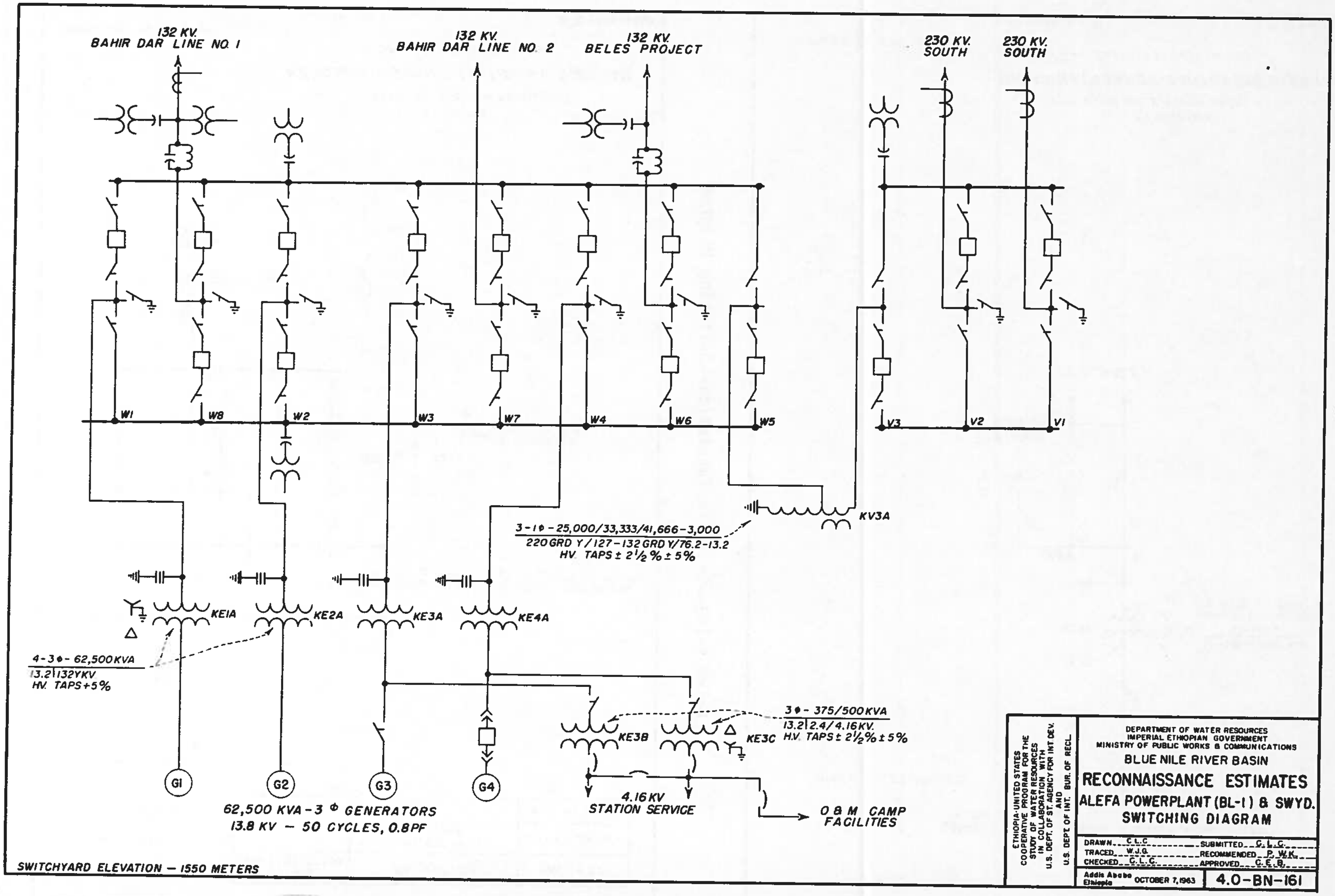


Figure V-119--Alefa Powerplant (BL-1) and Switchyard--Switching Diagram

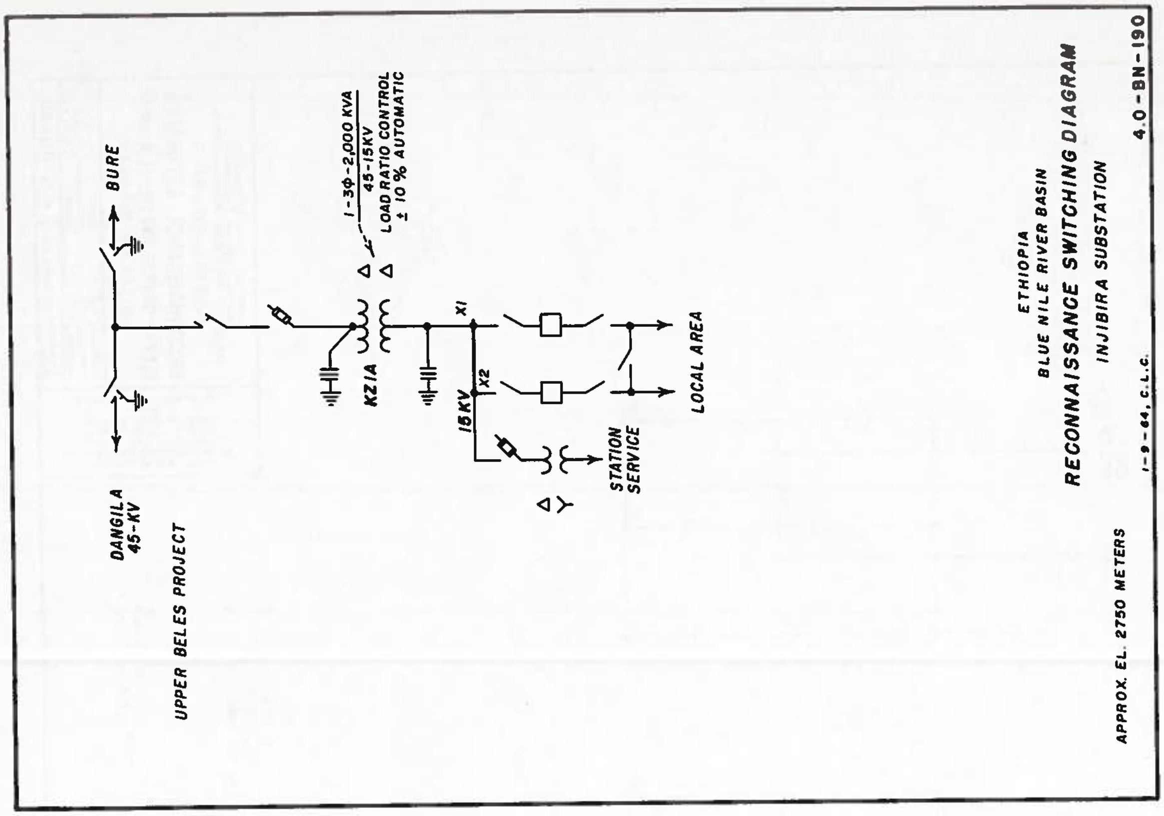


Figure V-120--Injibira Substation--Switching Diagram

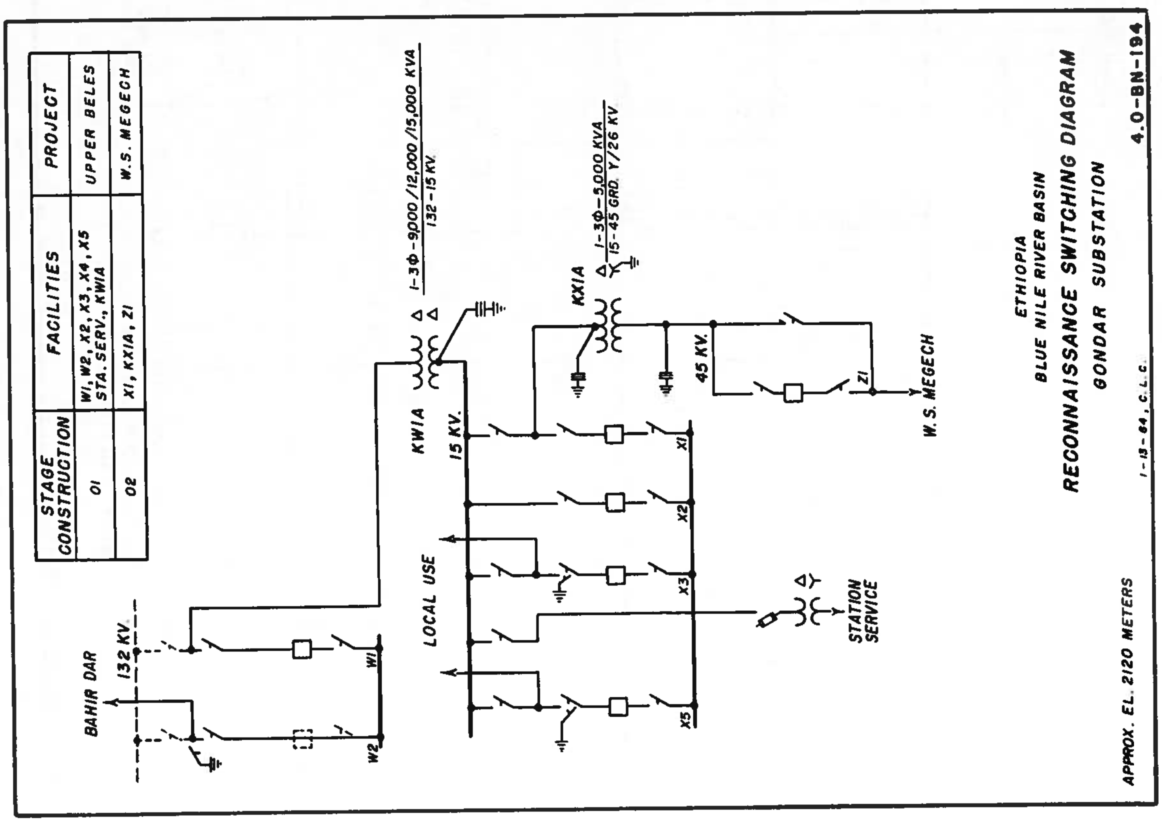


Figure V-121--Gondar Substation--Switching Diagram

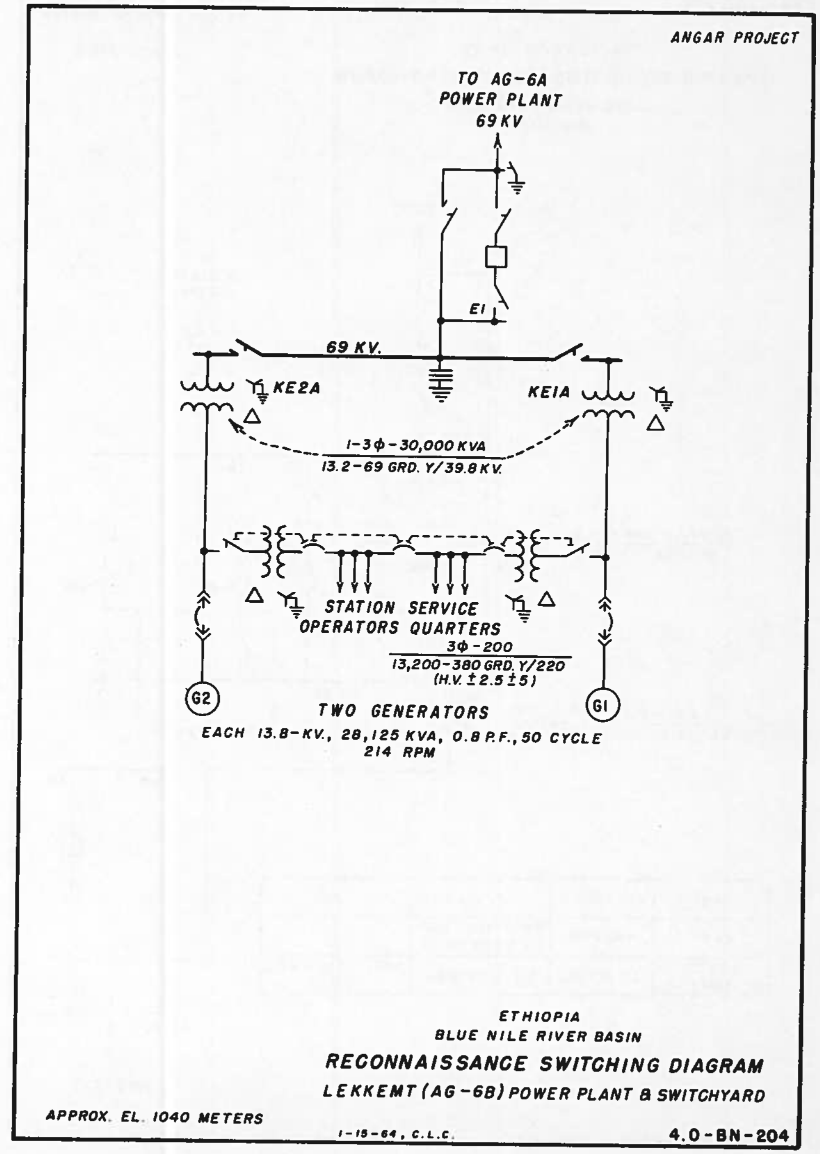


Figure V-122--Lekkemt (AG-6B) Powerplant and Switchyard--Switching Diagram

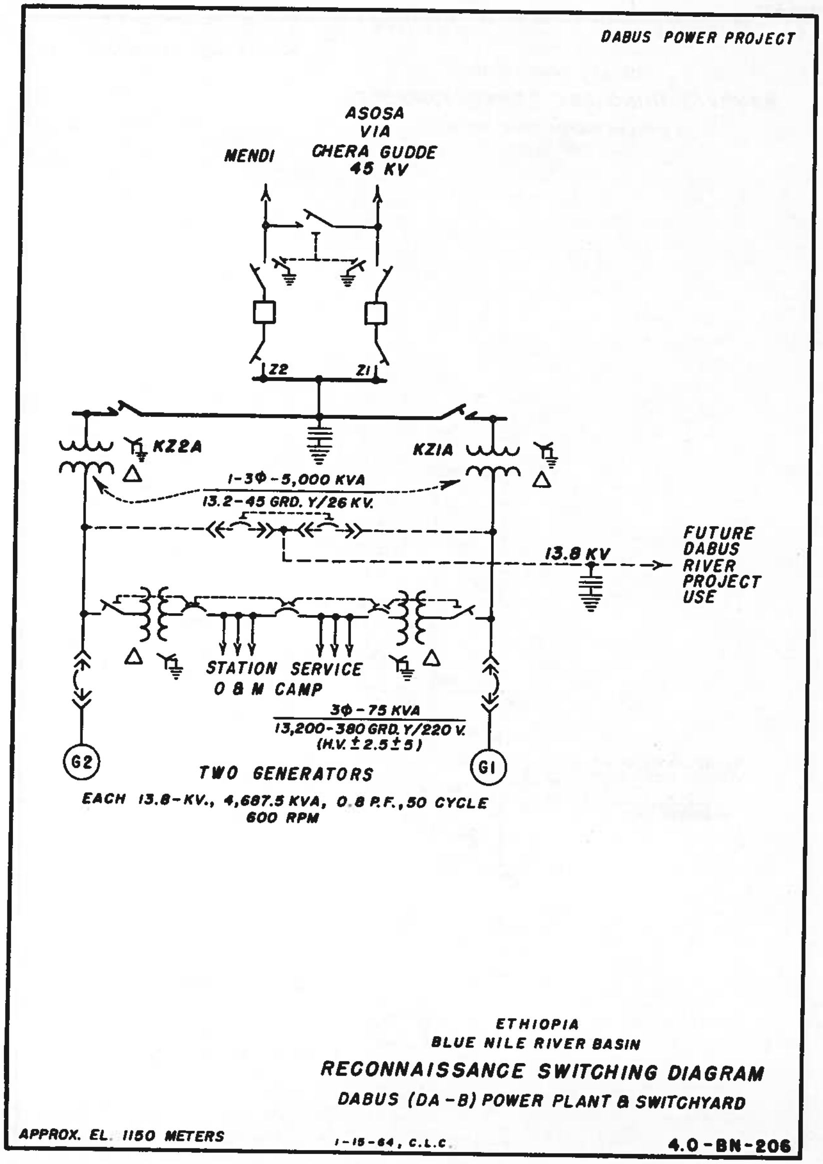


Figure V-123--Dabus (DA-8) Powerplant and Switchyard--Switching Diagram

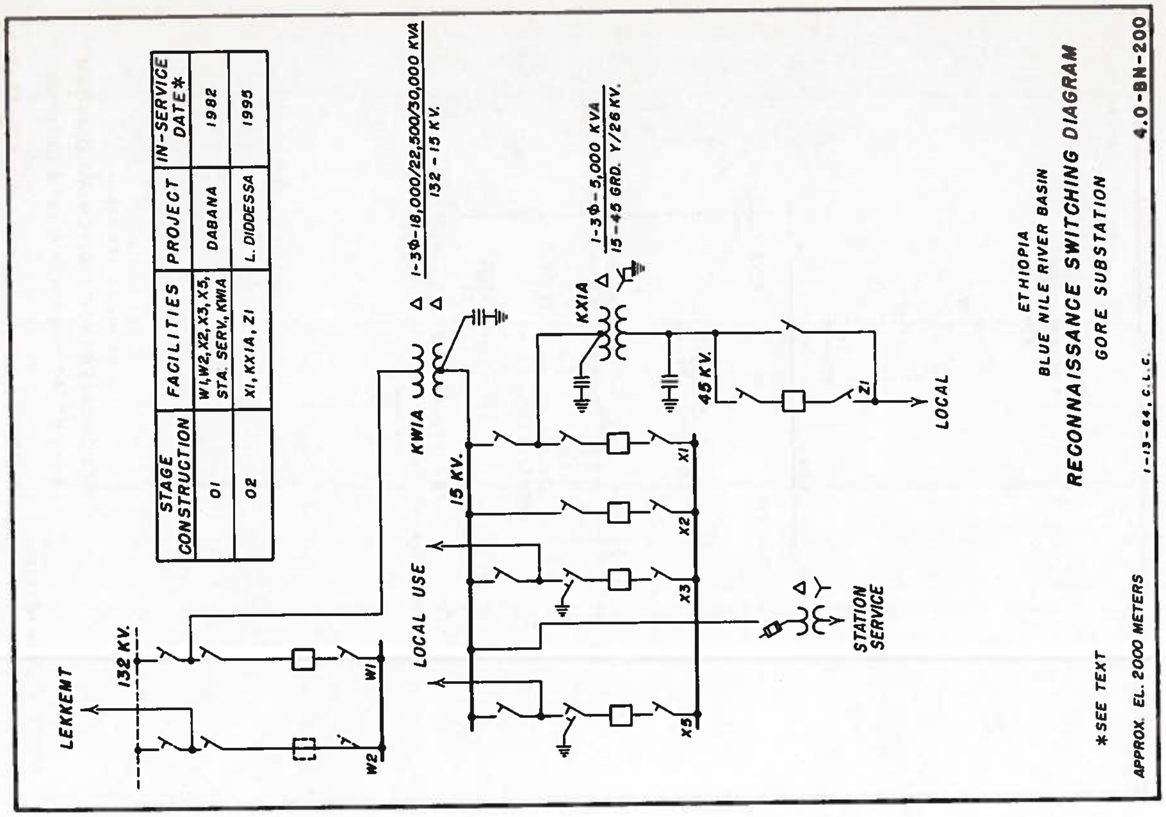


Figure V-124--Gore Substation--Switching Diagram

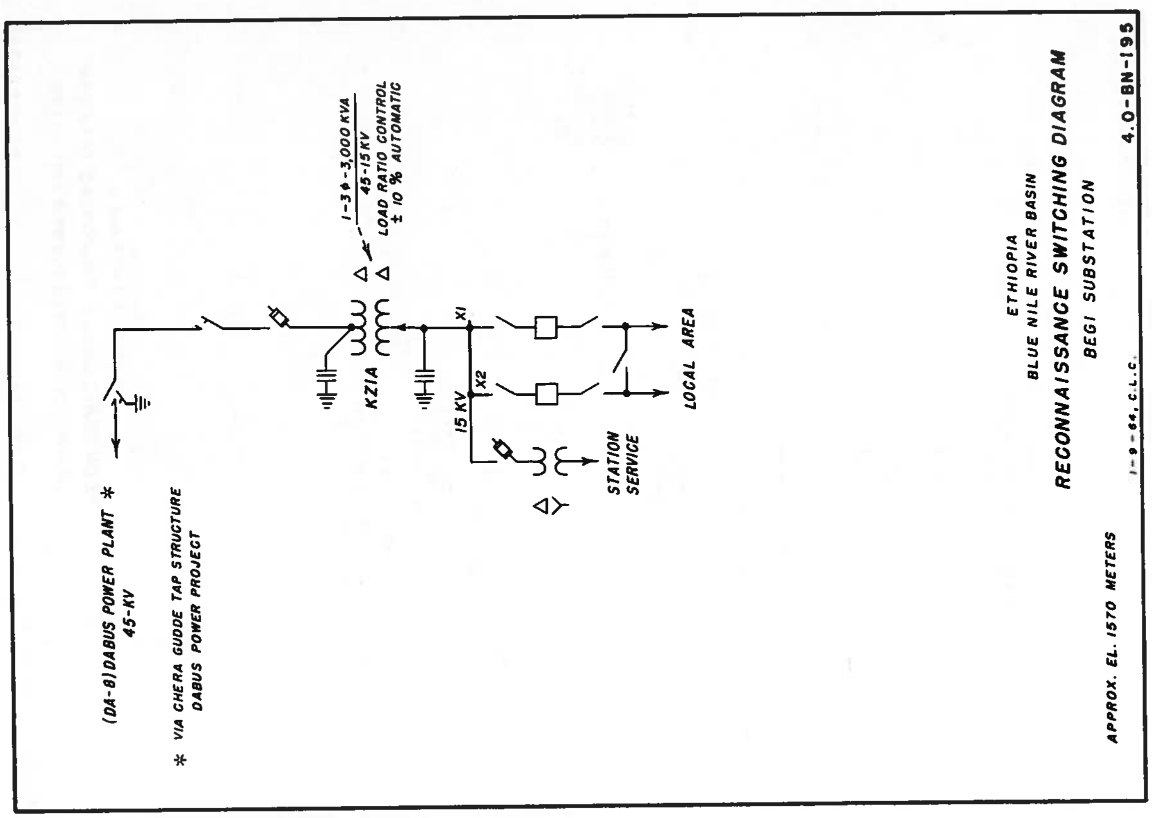


Figure V-125--Begi Substation--Switching Diagram

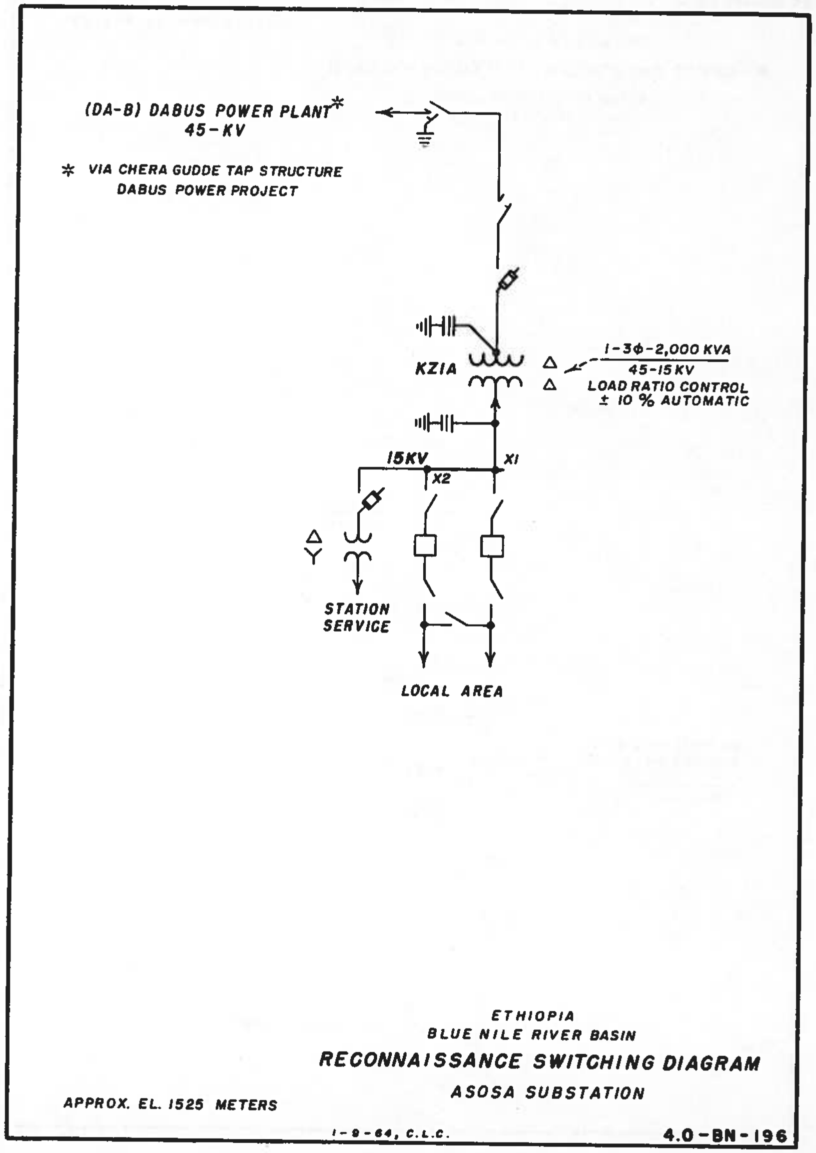


Figure V-127--Asosa Substation--Switching Diagram

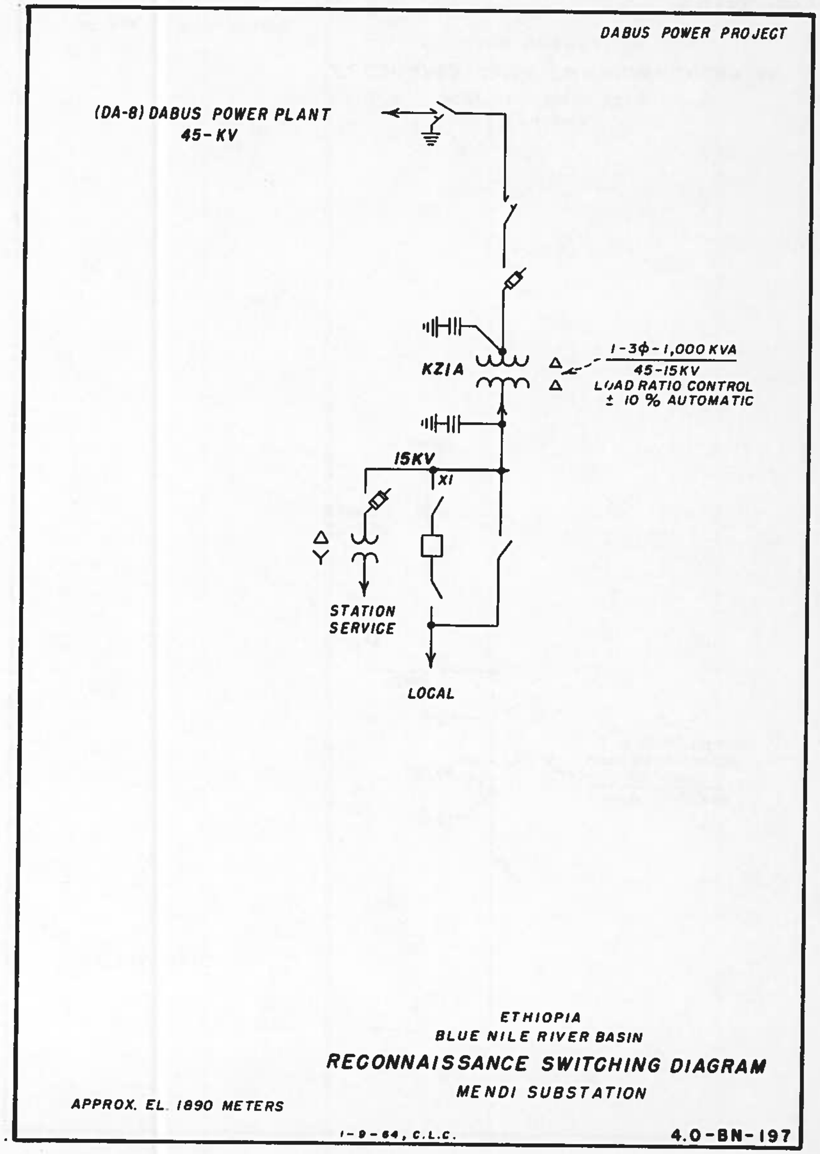


Figure V-126--Mendi Substation--Switching Diagram

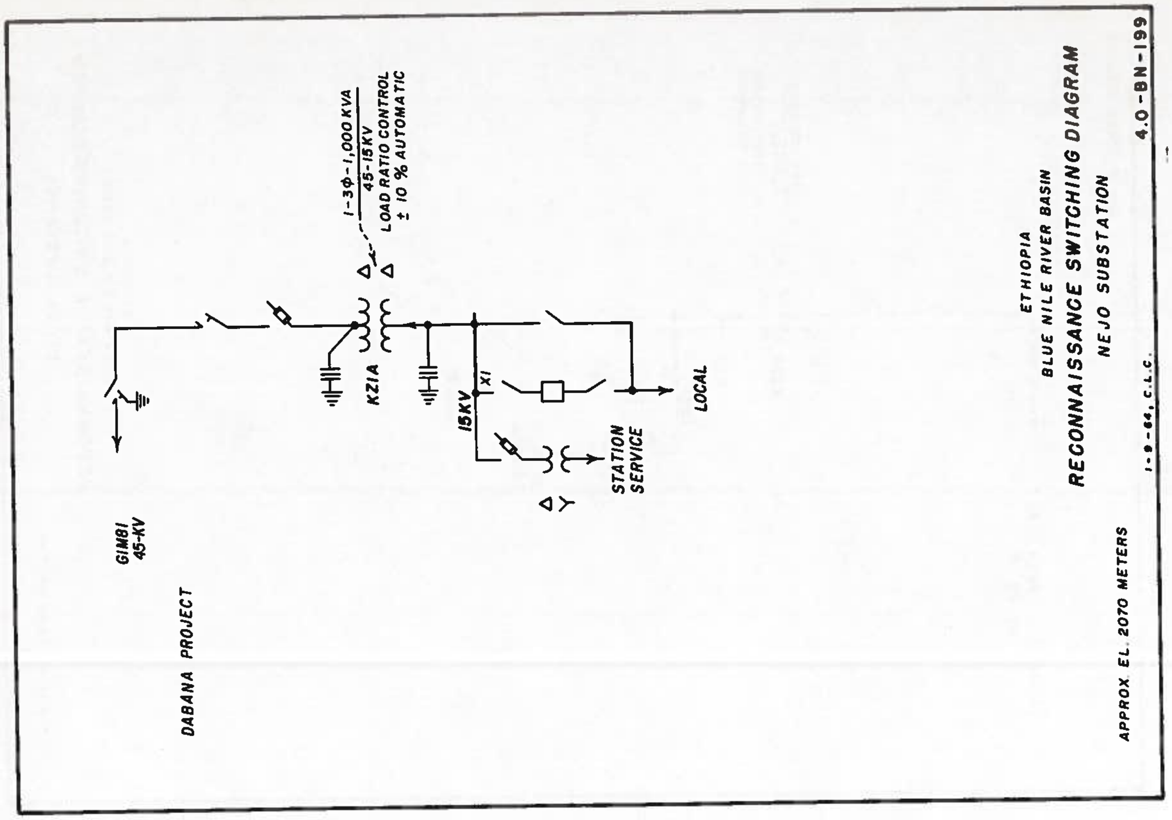


Figure V-128--Nejo Substation--Switching Diagram

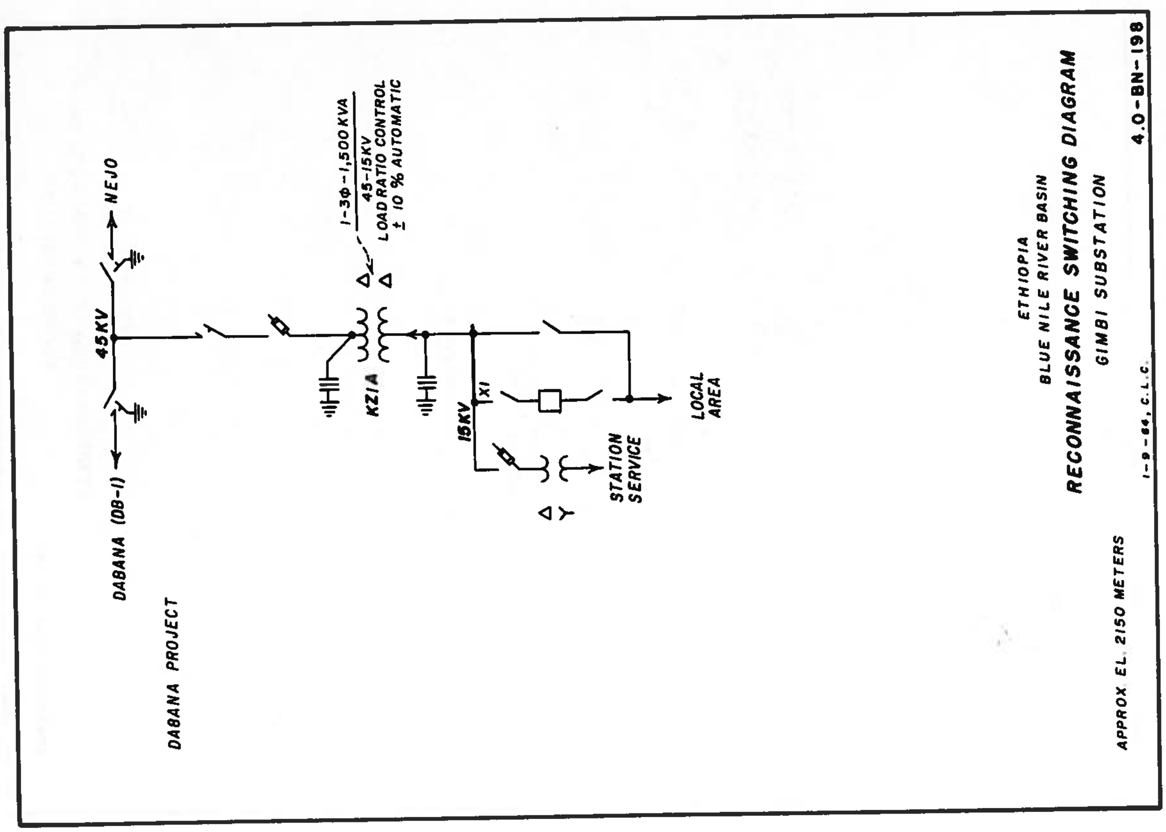


Figure V-129--Gimbi Substation--Switching Diagram

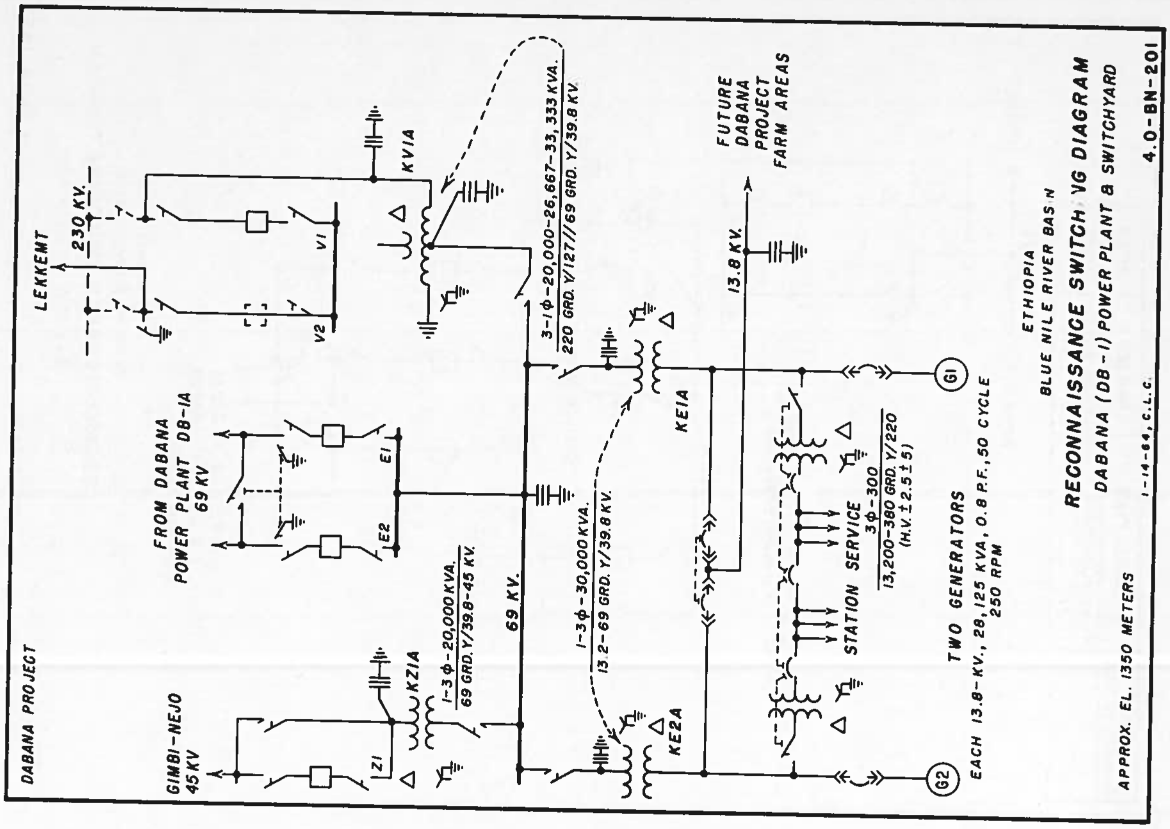


Figure V-130--Dabana (DB-I) Powerplant and Switchyard--Switching Diagram

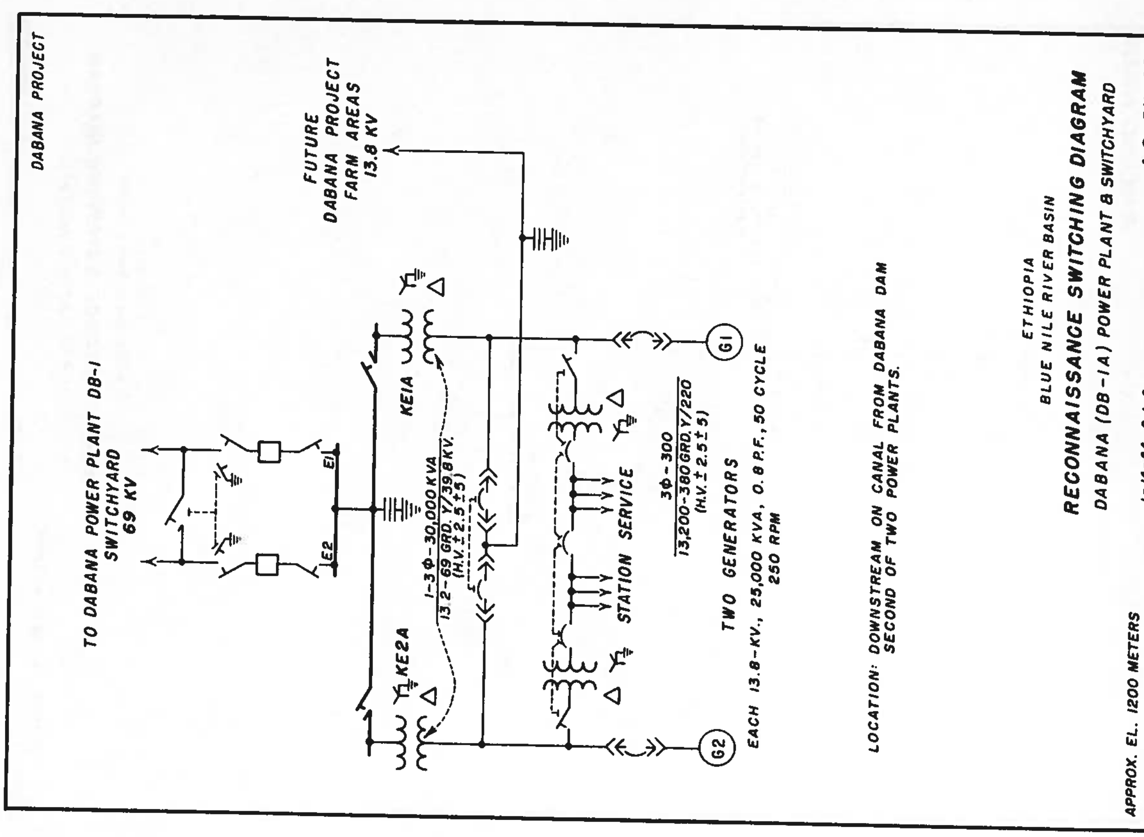


Figure V-131--Dabana (DB-IA) Powerplant and Switchyard--Switching Didgram

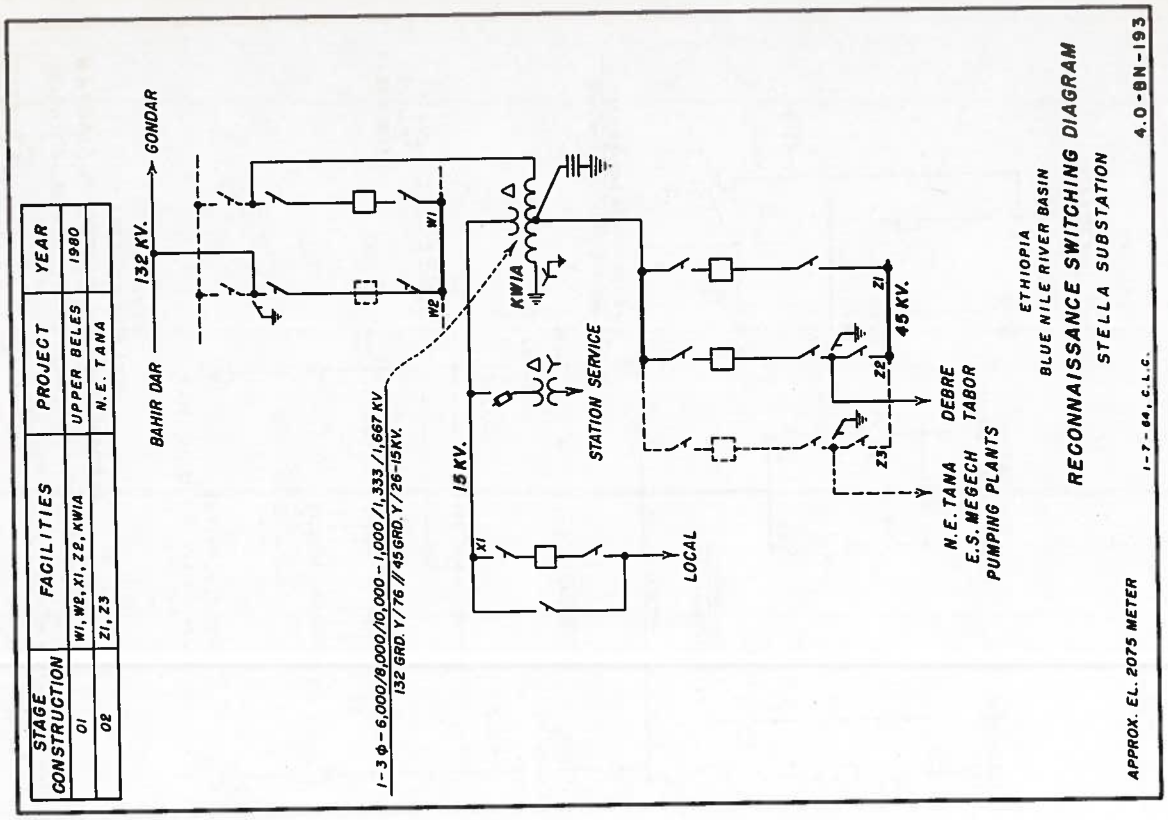


Figure V-132--Stella Substation--Switching Diagram

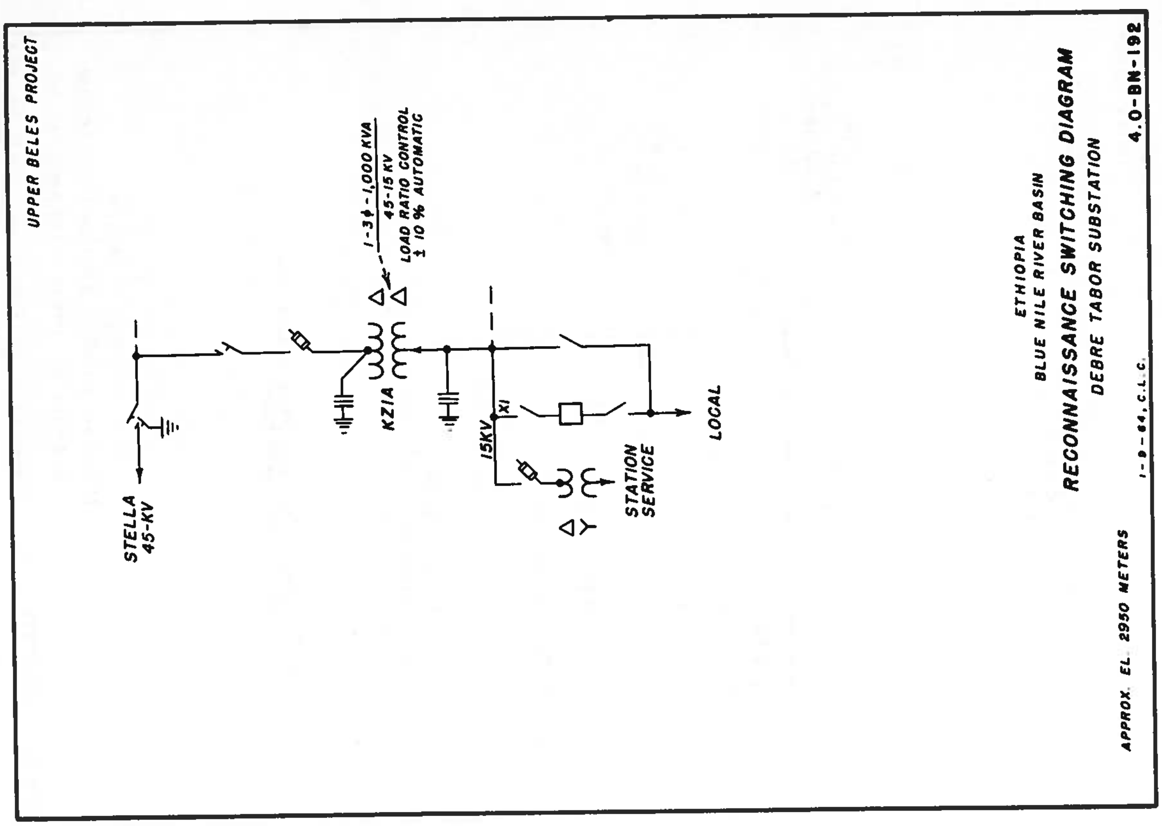


Figure V-133--Debre Tabor Substation--Switching Diagram

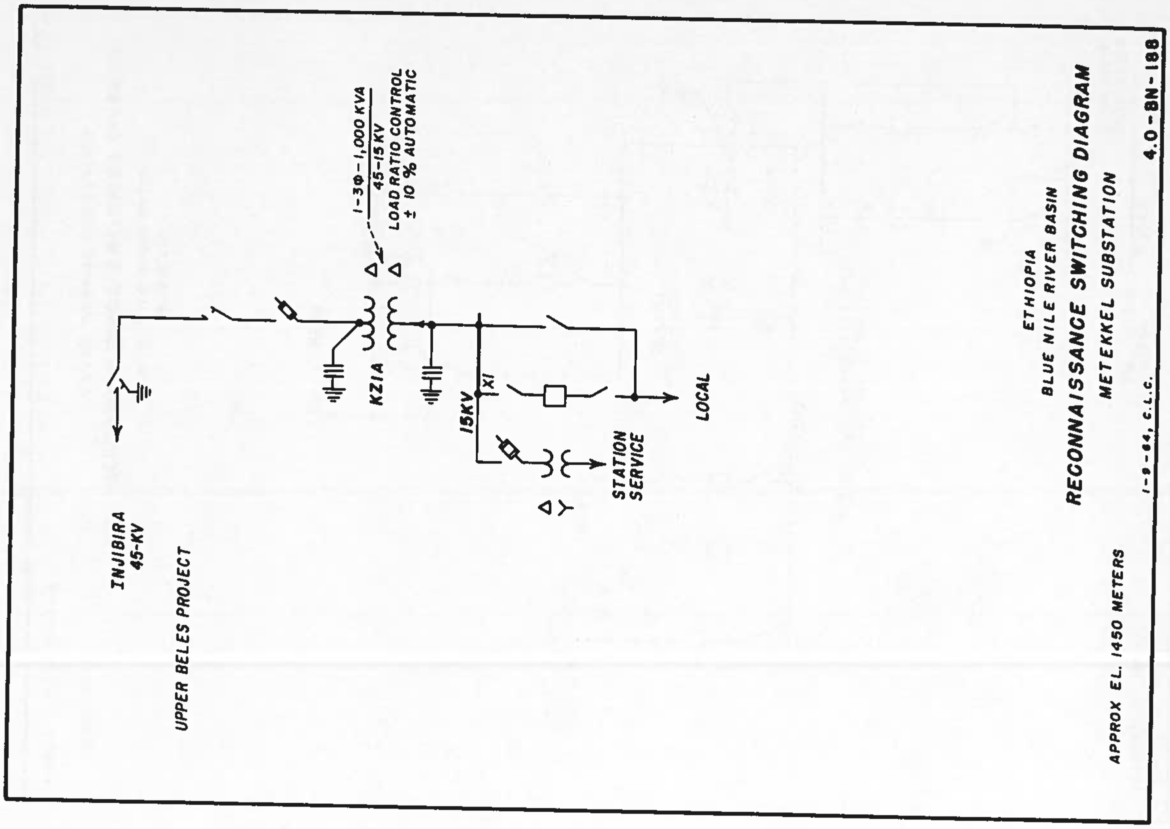


Figure V-134--Metekkel Substation--Switching Diagram

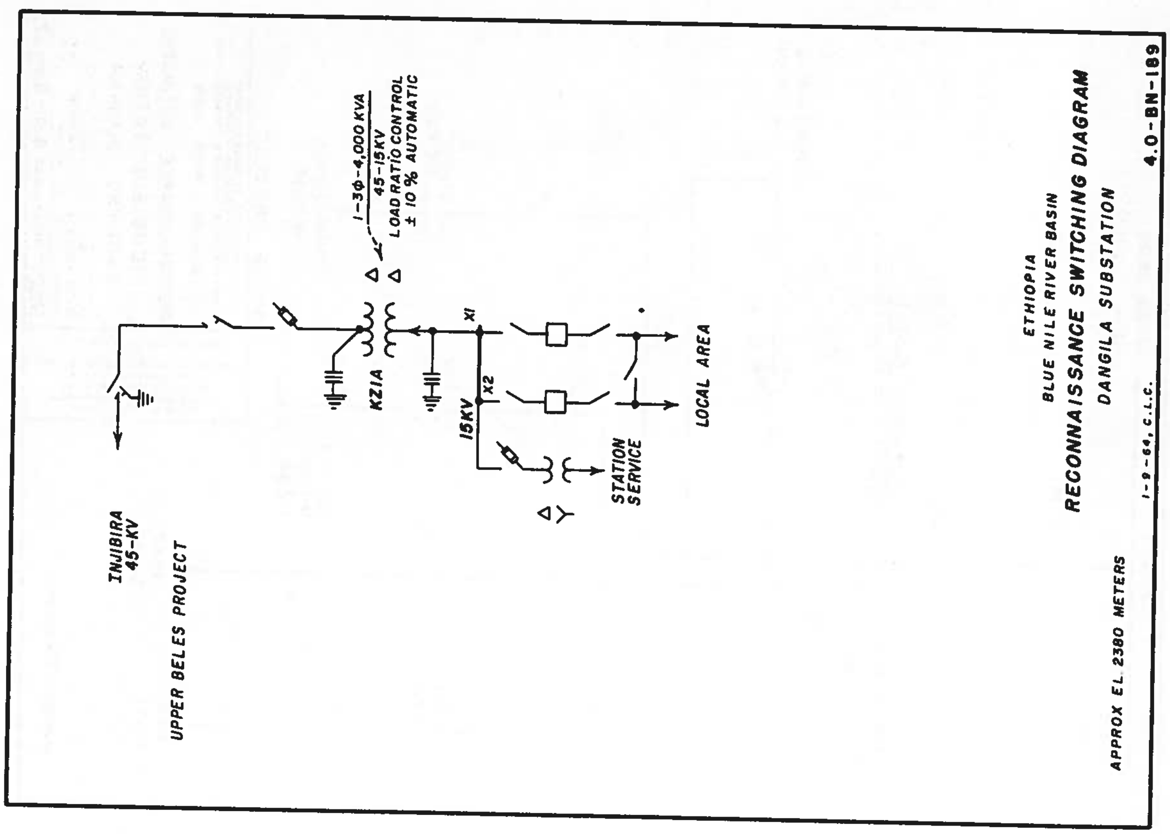


Figure V-135--Dangila Substation--Switching Diagram

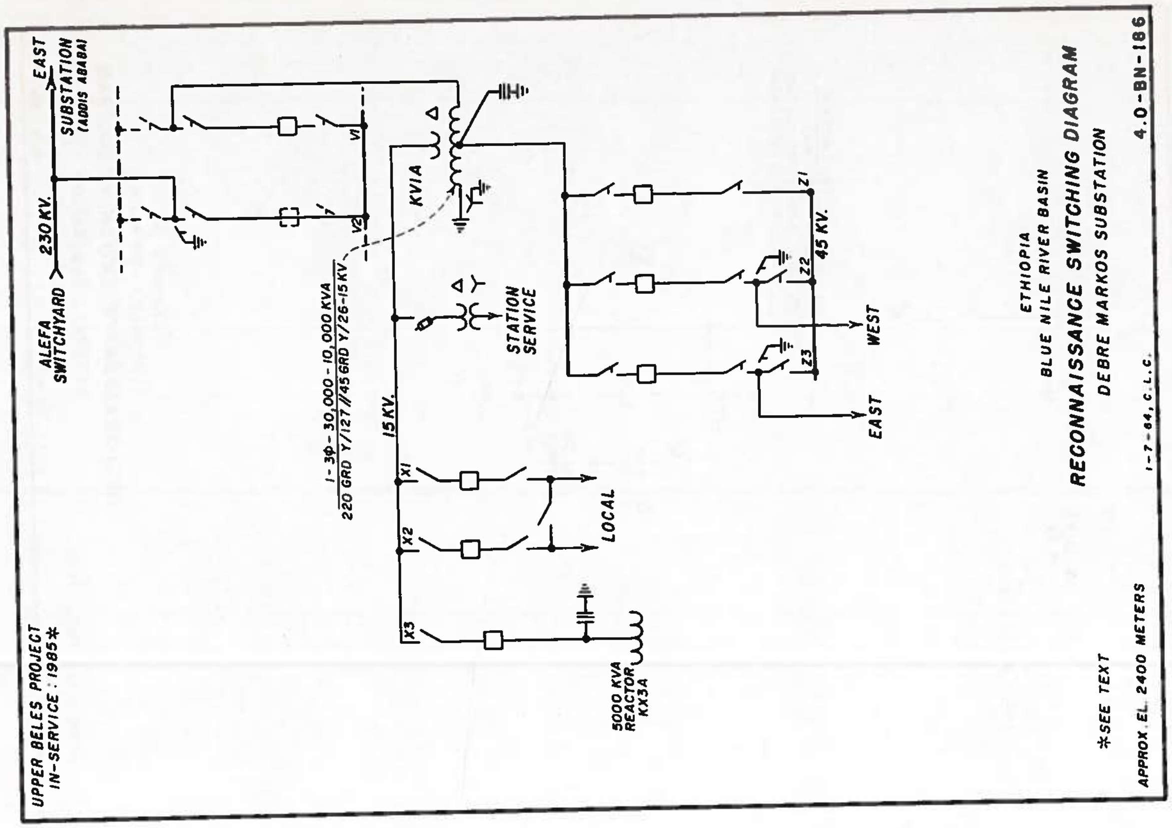


Figure V-136--Debre Marko's Substation--Switching Diagram

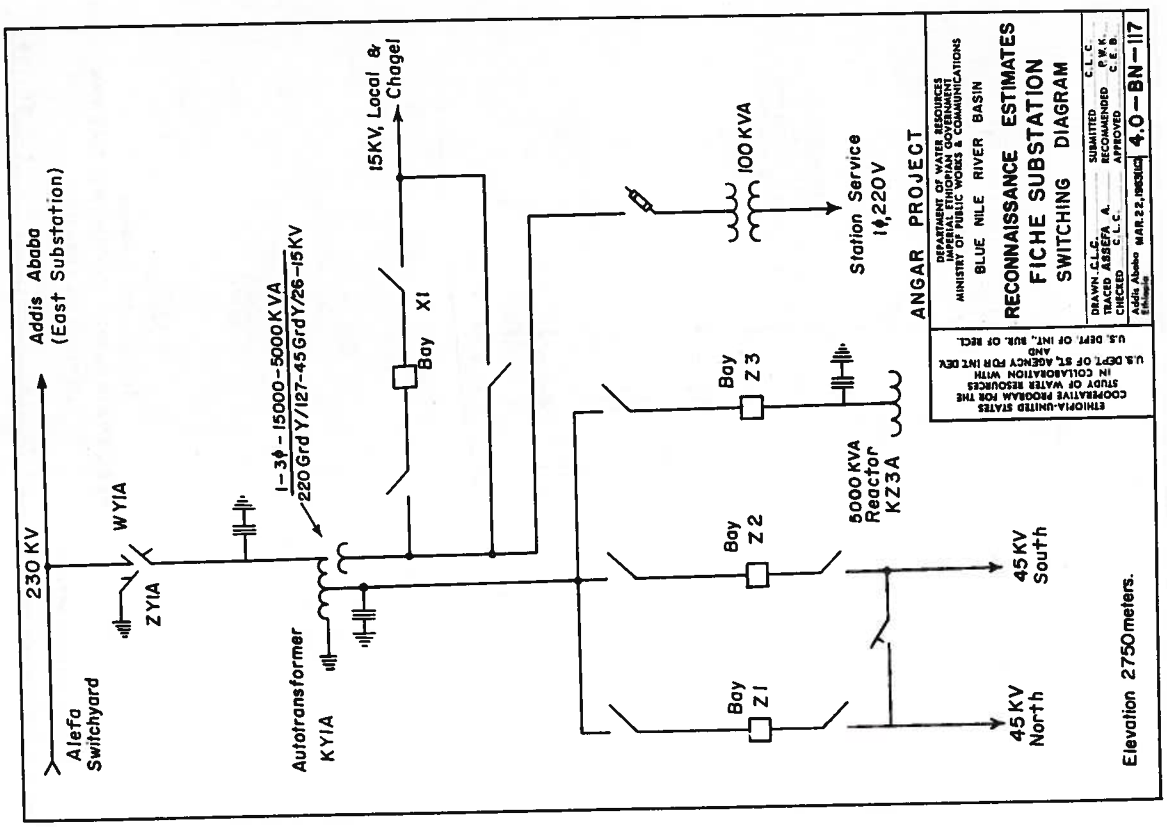


Figure V-137--Fiche Substation--Switching Diagram

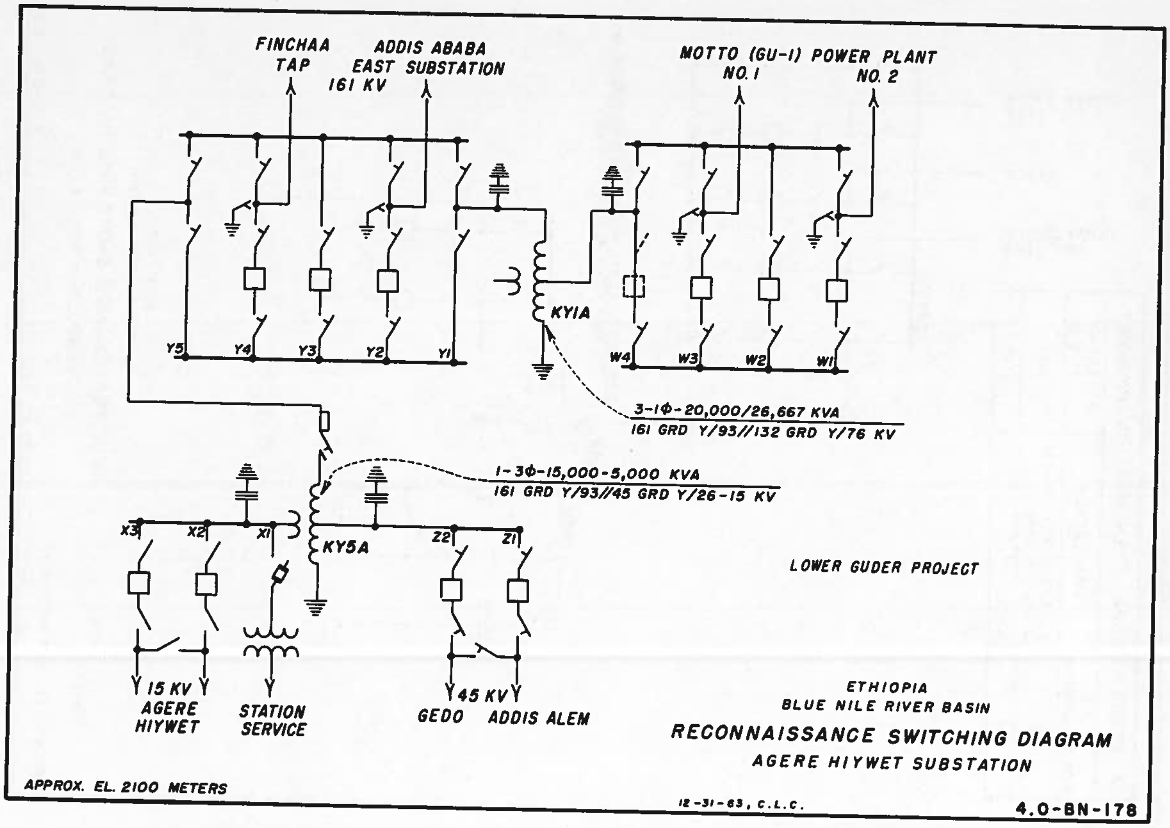


Figure V-138--Agere Hiywet Substation--Switching Diagram

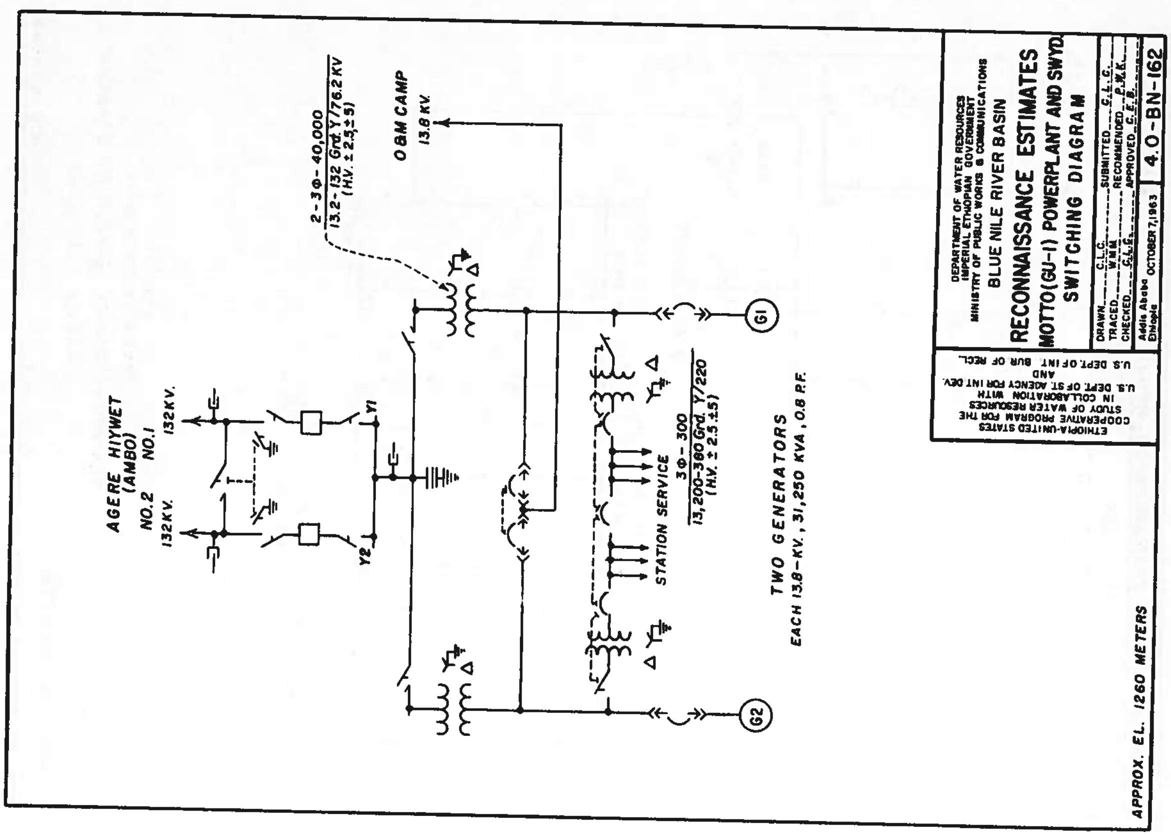


Figure V-139--Motto (GU-I) Powerplant and Switchyard--Switching Diagram

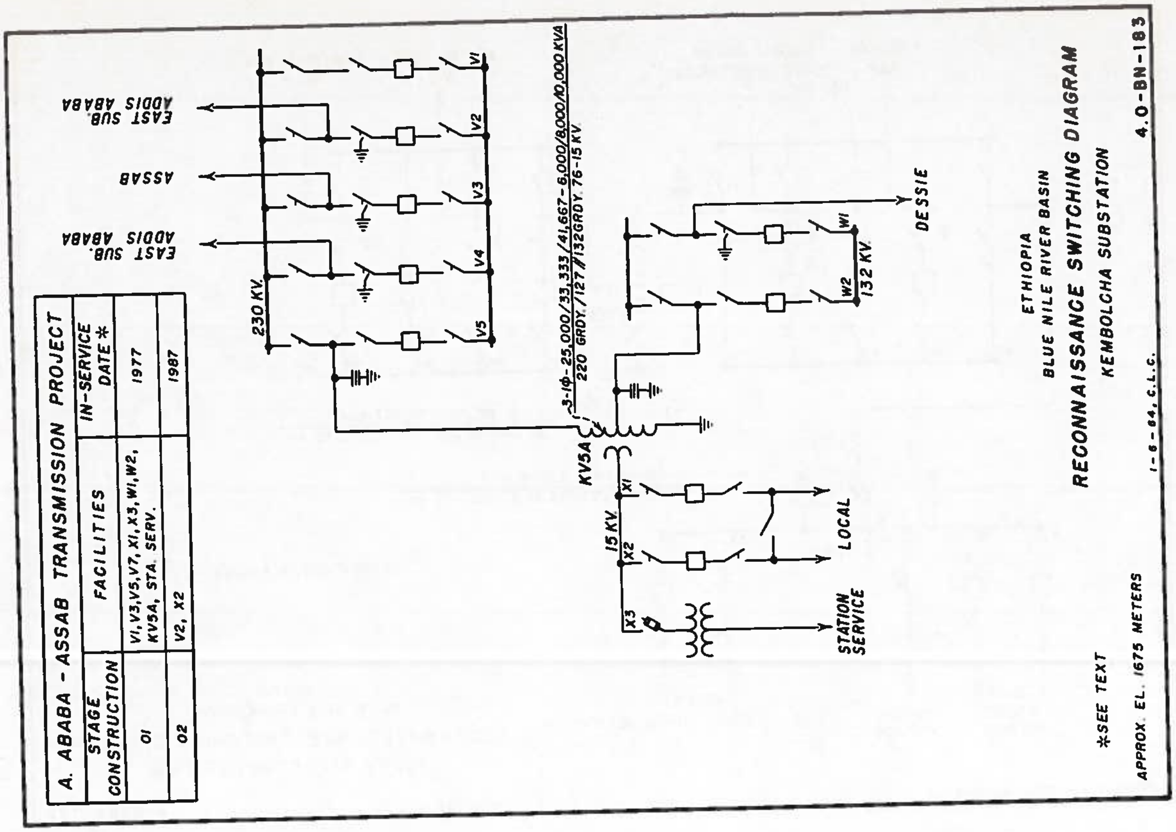


Figure V-140--Kembolcha Substation--Switching Diagram

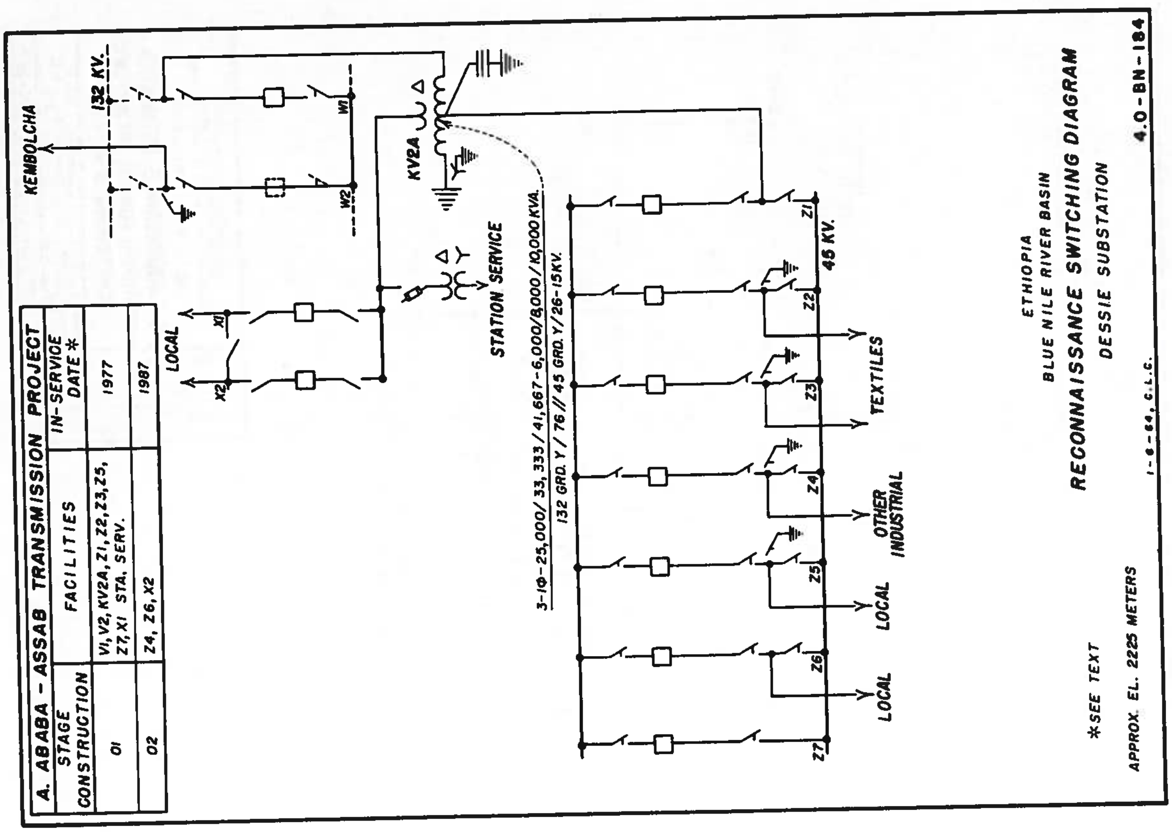


Figure V-141--Dessie Substation--Switching Diagram

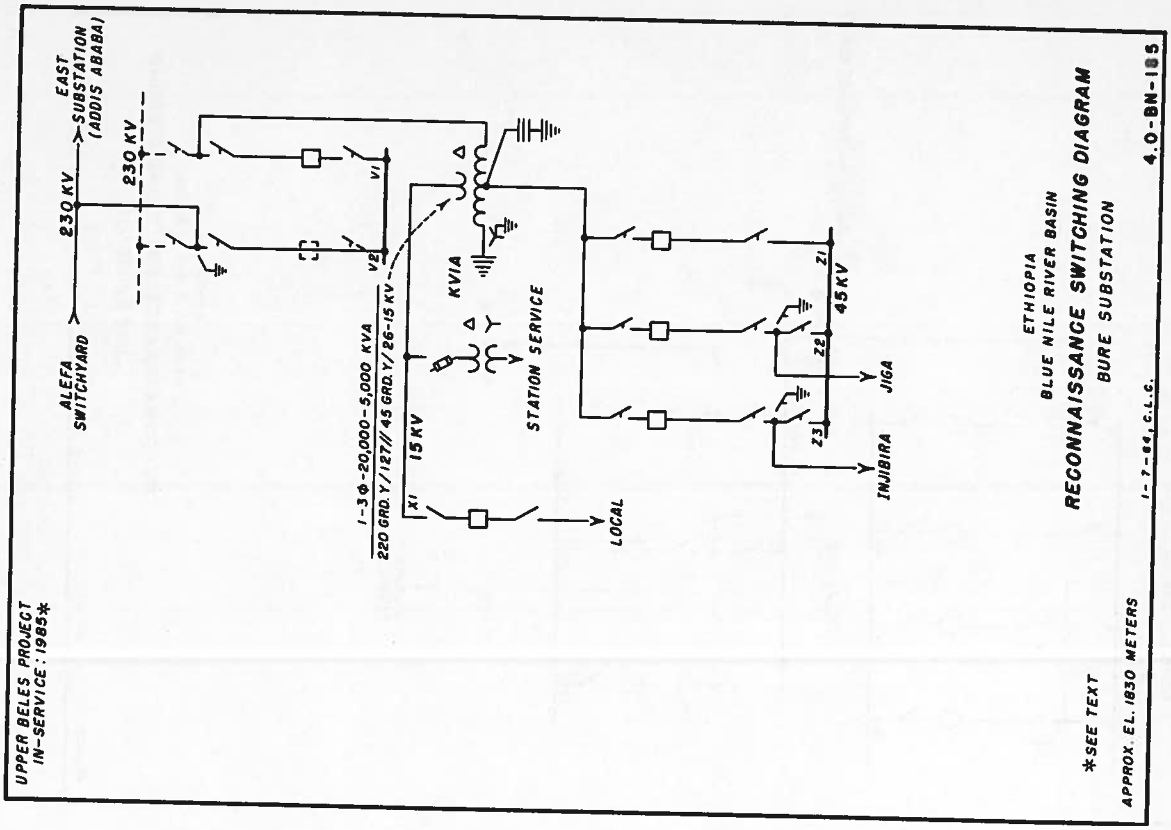


Figure V-142--Bure Substation--Switching Diagram

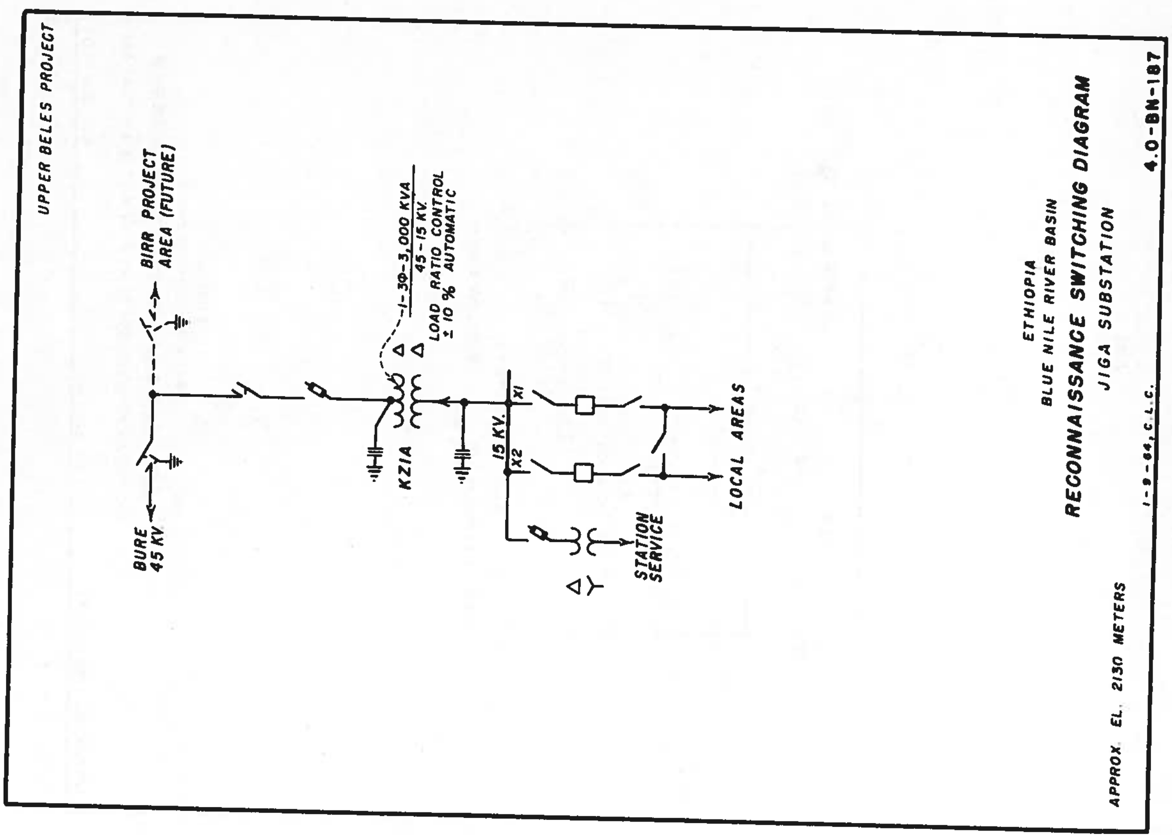


Figure V-143--Jiga Substation--Switching Diagram

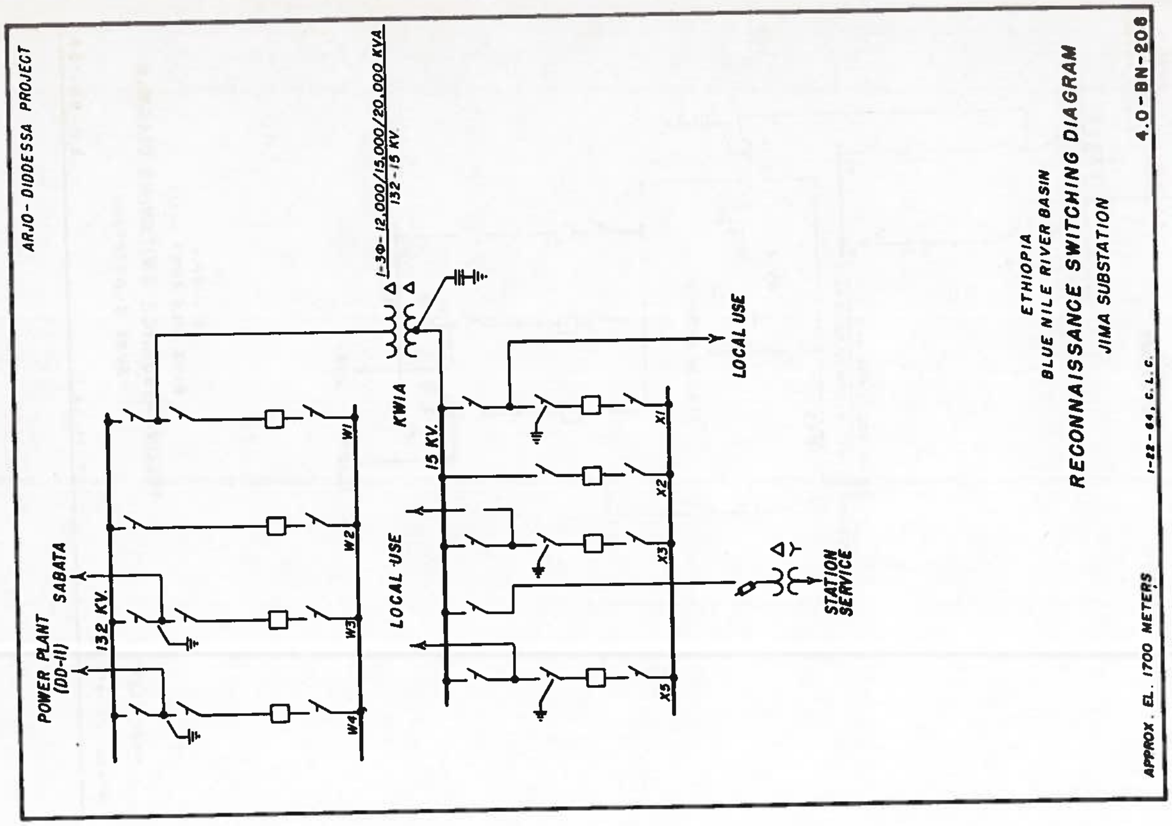


Figure V-144--Jima Substation--Switching Diagram

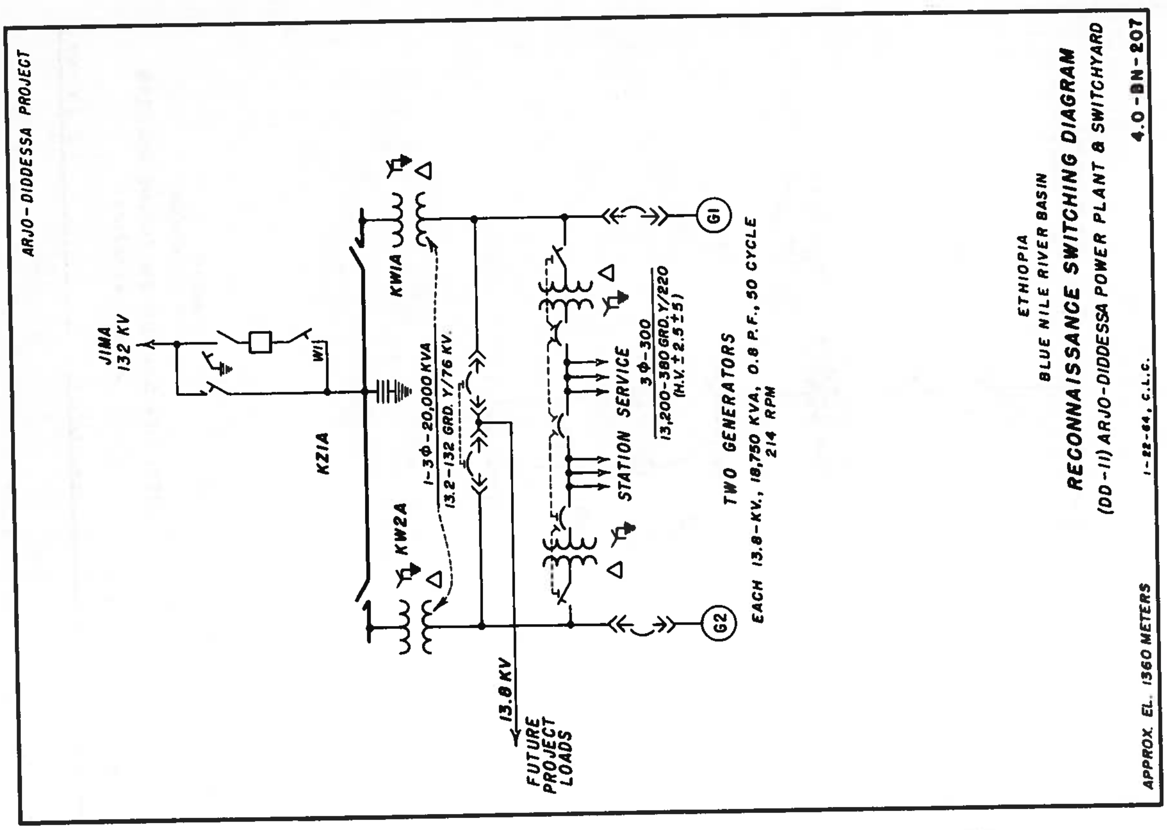


Figure V-145--(DD-II) Arjo-Diddessa Powerplant and Switchyard--Switching Diagram

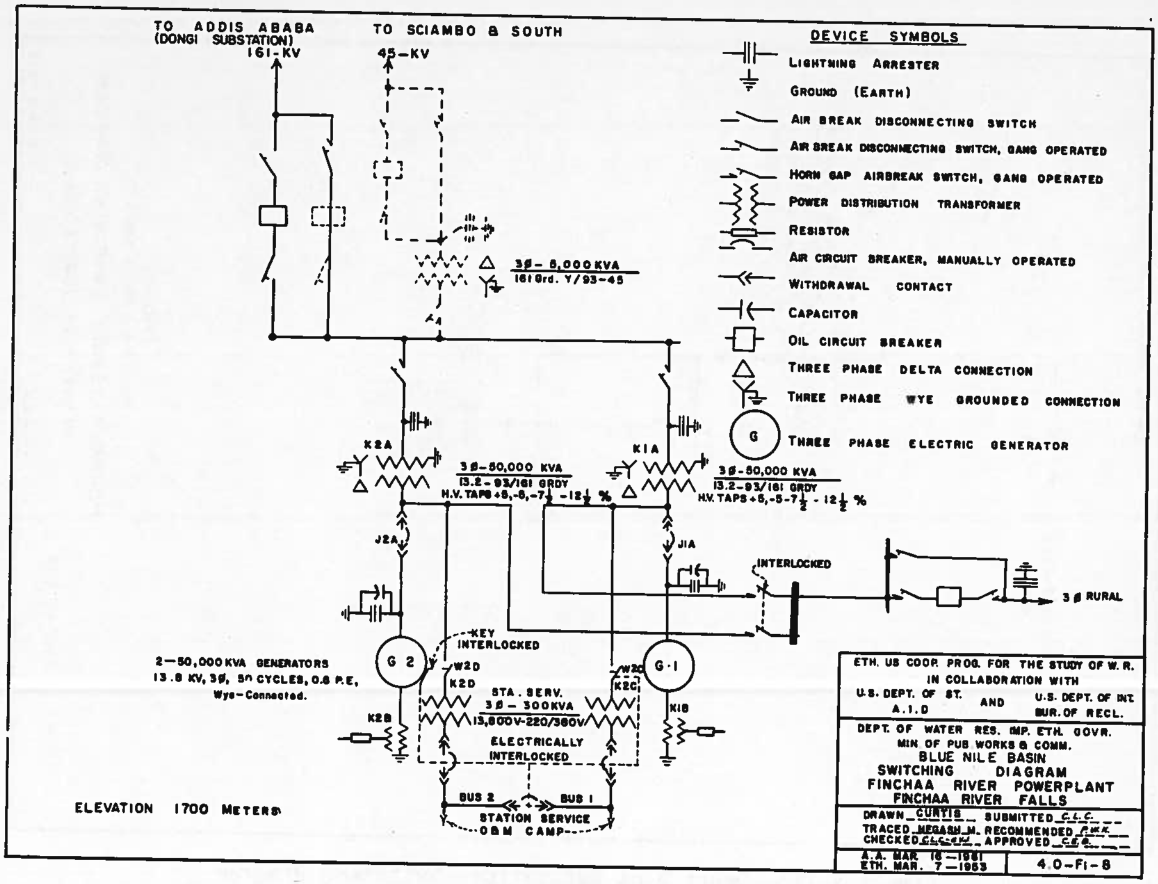


Figure V-146--Finchaa Powerplant--Switching Diagram

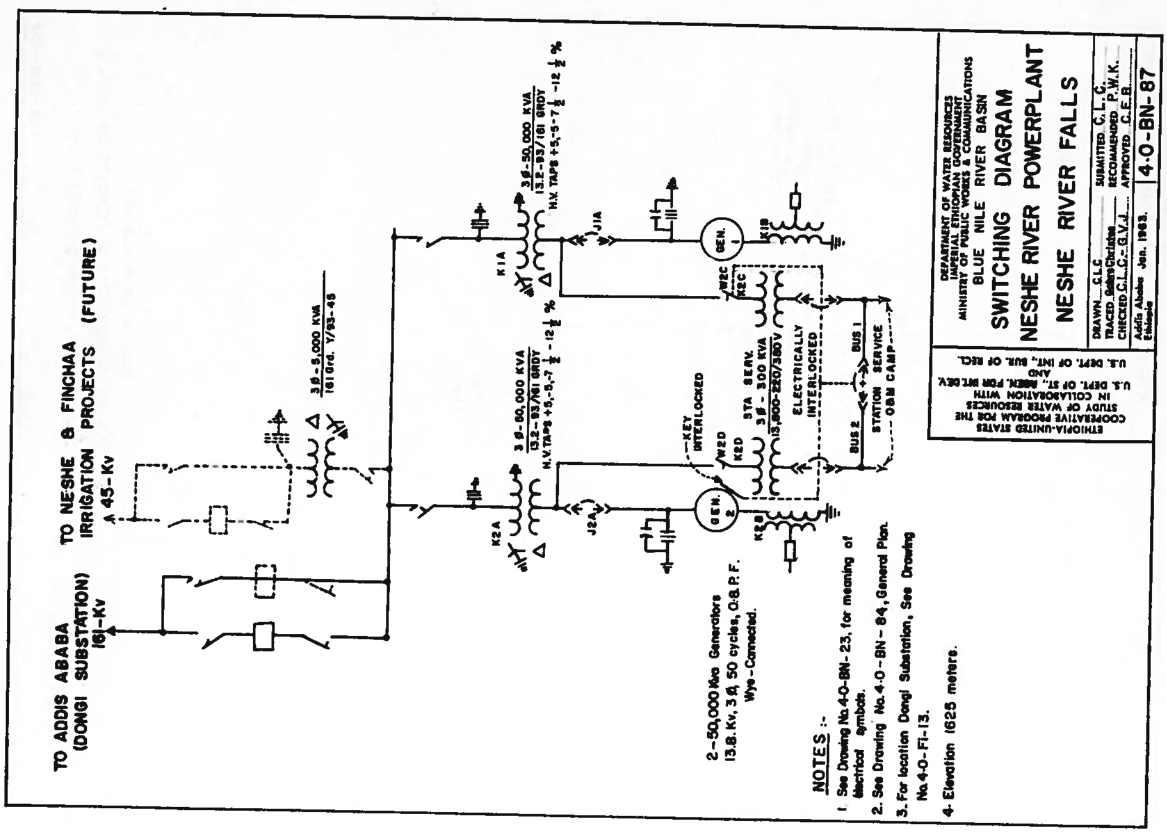


Figure V-147--Neshe Powerplant--Switching Diagram

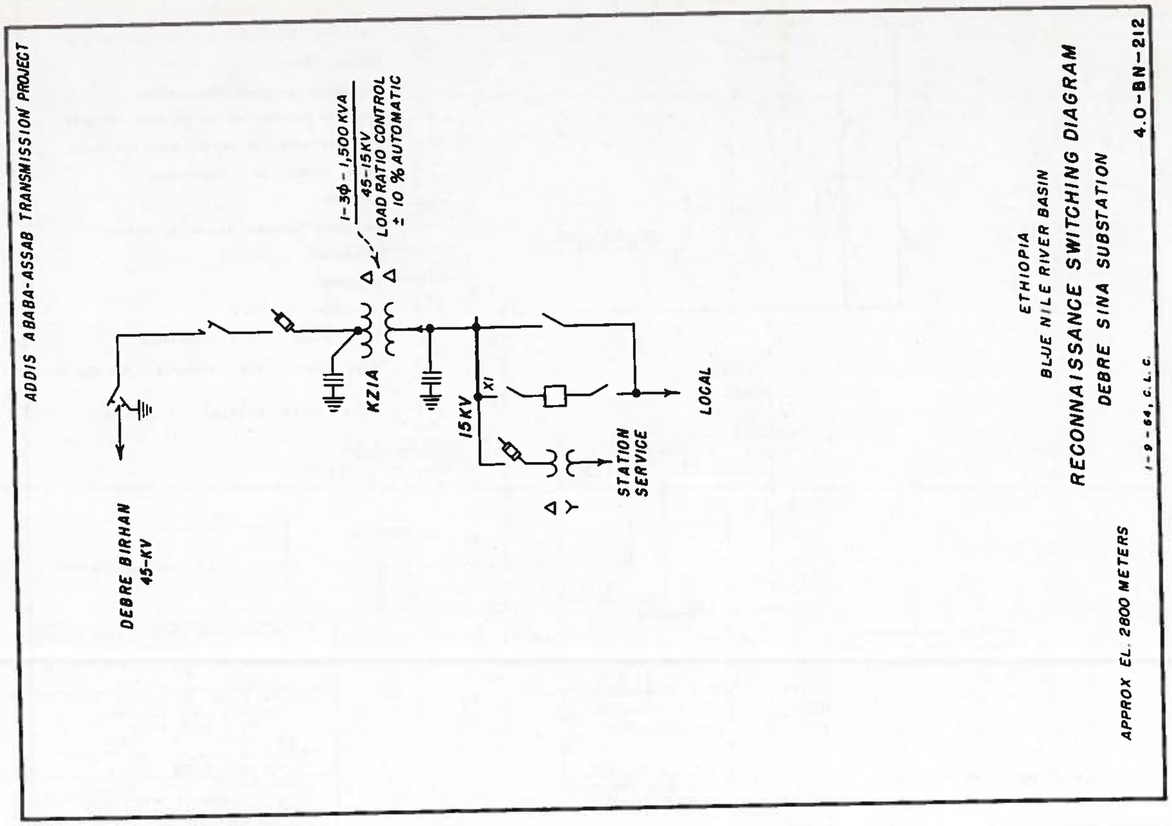


Figure V-148--Debre Sina Substation--Switching Diagram

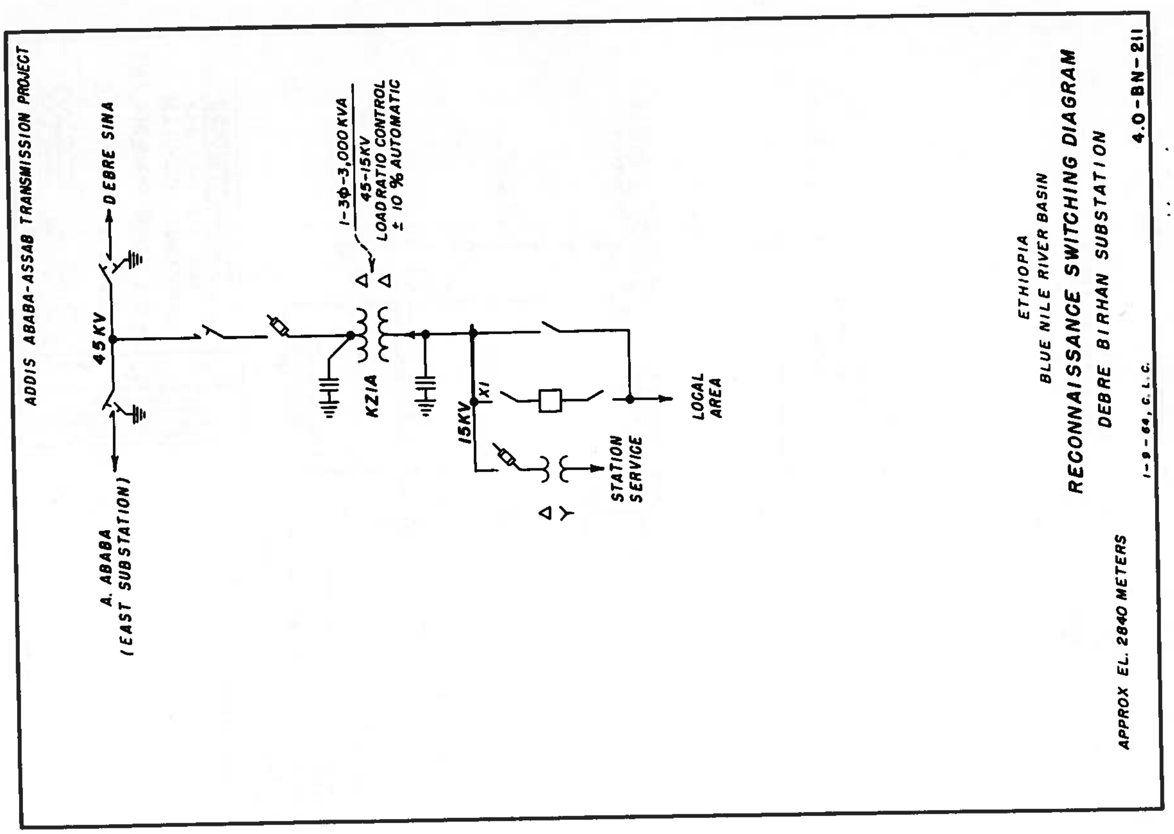


Figure V-149--Debre Birhan Substation--Switching Diagram

ANNEX "D"

EXAMPLE OF A SMALL HYDROELECTRIC INSTALLATION FOR VILLAGE USE

INTRODUCTION

The first all-Africa power conference was held in Addis Ababa, Ethiopia, in 1963 under the auspices of the United Nations Economic Commission for Africa. One of the subjects evoking considerable interest was electric power sources for small villages, and these included discussions of micro sets--small hydroelectric powerplants, and small diesel installations. Particularly, the Conference requested the United Nations Secretariat to undertake an exhaustive study of the possibilities of producing electric power by small scale hydro-power plants.

The development of electricity supplies for African villages will be very slow, and initially will be on the basis of utilizing either the small hydro or thermal facilities.

Generally, the disadvantages of small micro hydro sets favor small diesel installations. Capital costs per kw. of small hydro sets generally exceed that of small thermal units. The annual costs of the latter are usually higher.

Capital costs of small hydro installations can be held to a minimum if there is a concerted effort on the part of villagers to provide volunteer labor using locally available materials.

Few of the villages within Ethiopia have electricity, even though many are located within a reasonable distance of a suitable water supply with sufficient capacity to provide a minimum power supply.

To illustrate the point that a small hydroelectric power system can be developed to meet minimum village requirements, one such site was selected at random and minimum data obtained for preparing designs and estimates for such a power supply. The one selected was Dembecha, a village of about 2,500 population (500 families) located near the Timochia River northwest of Debre Markos. The power site selected at random is somewhat typical in that the river is deeply entrenched with steep banks and with a steep hydraulic gradient. The design was based upon the minimum observed flow of the river with no provision made for regulation in the initial stage of development. The system is capable of future expansion.

The village of Dembecha is on the main highway from Debre Markos to Bahir Dar, about 45-km. from Debre Markos. The Timochia River passes generally from the east to west about 4-km. south of Dembecha, in a rather narrow canyon. Figure V-150 provides specific information.

Typical of streams in Ethiopia, the Timochia River is deeply entrenched, has a steep hydraulic gradient, and is a virtual torrent during the annual rains (June through September), with very low flows during the period immediately preceding the rains. The low flows observed were 0.30 cubic meters per second and powerplant designs were based upon this although the lowest average monthly flow occurred in March and was 1.3 cubic meters per second. 1/

The initial stage of development would consist of a river diversion weir to divert water into a power diversion channel and then into a penstock intake structure some 1,500 meters downstream. A 54-meter long penstock would drop the water about 25 meters into a small horizontal Francis-type turbine which develops nearly 90 horsepower. The turbine drives

1/Subsequent data revised these water supply figures but has no effect upon the objectives of this analysis.

a 75 kv.-a. 3-phase generator which is insulated for 2,400 volts and supplies a 4.7-km., 2,400-volt line terminating in Dembecha. A stepdown substation, two-pole structure, constructed of treated eucalyptus poles is provided, transforming the 2,400 volts to 380 volts line-to-line or 220 volts, line-to-neutral. About 3 km. of distribution line would be needed initially.

PROJECT WORKS

Diversion Works

A masonry-type diversion weir 5 meters high with uncontrolled overflow ogee crest is contemplated. The maximum crest length of the weir would be about 28 meters. Diversion into a canal headworks located on the right abutment is contemplated, with water level controlled by a means of an inexpensive slide gate arrangement. The intake structure would be of heavy masonry and would extend above the maximum high water level. Figure V-151 illustrates details. The river channel rests on exposed bedrock, so little overburden need be removed except near and including the abutments. A cut-off trench will need to be excavated in the rock foundation. Availability of rock is no problem as it is plentiful all along the river, but it will have to be quarried. Ethiopians excel in masonry-type construction of all kinds so this is not considered a problem. The rock available is fractured basalt and should weigh about 2,400 kg. per cubic meter. The upstream face near the crest was given more curvature than usual to accommodate the heavy debris that occasionally travels down the river when it rises rapidly at the beginning of the annual rains. Also the base width of the structure and hence the volume is little more than normally required.

Power Diversion Channel

This channel will follow the right bank of the river for a distance of about 1,500 meters. Part of it will be of masonry construction with a covered top, in some stretches. Where possible, an open-type earth canal, trapezoidal section, will be constructed on the flatter slopes. The red clay slopes, when covered with grass, have been observed to be stable, even from erosion, so instability of the slopes may not be a problem. (It has been observed that hand-excavated water wells for domestic water purposes in red clay soil areas having a diameter of about 2 meters and depth of 15 meters or more endure without curbing of any kind, so the soil is stable.) Also, the red clay soils if properly compacted should form a relatively tight canal. Losses due to seepage were estimated to be less than 0.028 m^3/sec. (1/10 cubic foot per sec.) out of a delivered quantity of about 0.3 m^3/sec. (11 cubic feet per sec.) to the canal headworks. The canal will terminate at a penstock intake structure with any momentary excess water above power generation requirements spilling over a small weir into a masonry-lined wasteway back into the river. The velocity of the water will be about 0.61 meters per sec. (2 feet per sec.) and in its entire length of about 1,500 meters will drop around 1.535 meters.

Penstock

A single steel penstock 50 cm. in diameter with about 3 mm. thick walls should be sufficient. The 57-meter length will be exposed except for a section near the powerhouse. Anchors will be required. The most economical diameter was arrived at by taking into consideration the value of electrical power, cost of the penstock per unit weight, and the annual fixed costs. A removable trashrack located in a small concrete inlet structure is to be provided.

Powerplant

The powerhouse will consist of a small 5- by 6-meter structure with the walls above the main floor level consisting of masonry and the substructure including the floor to be

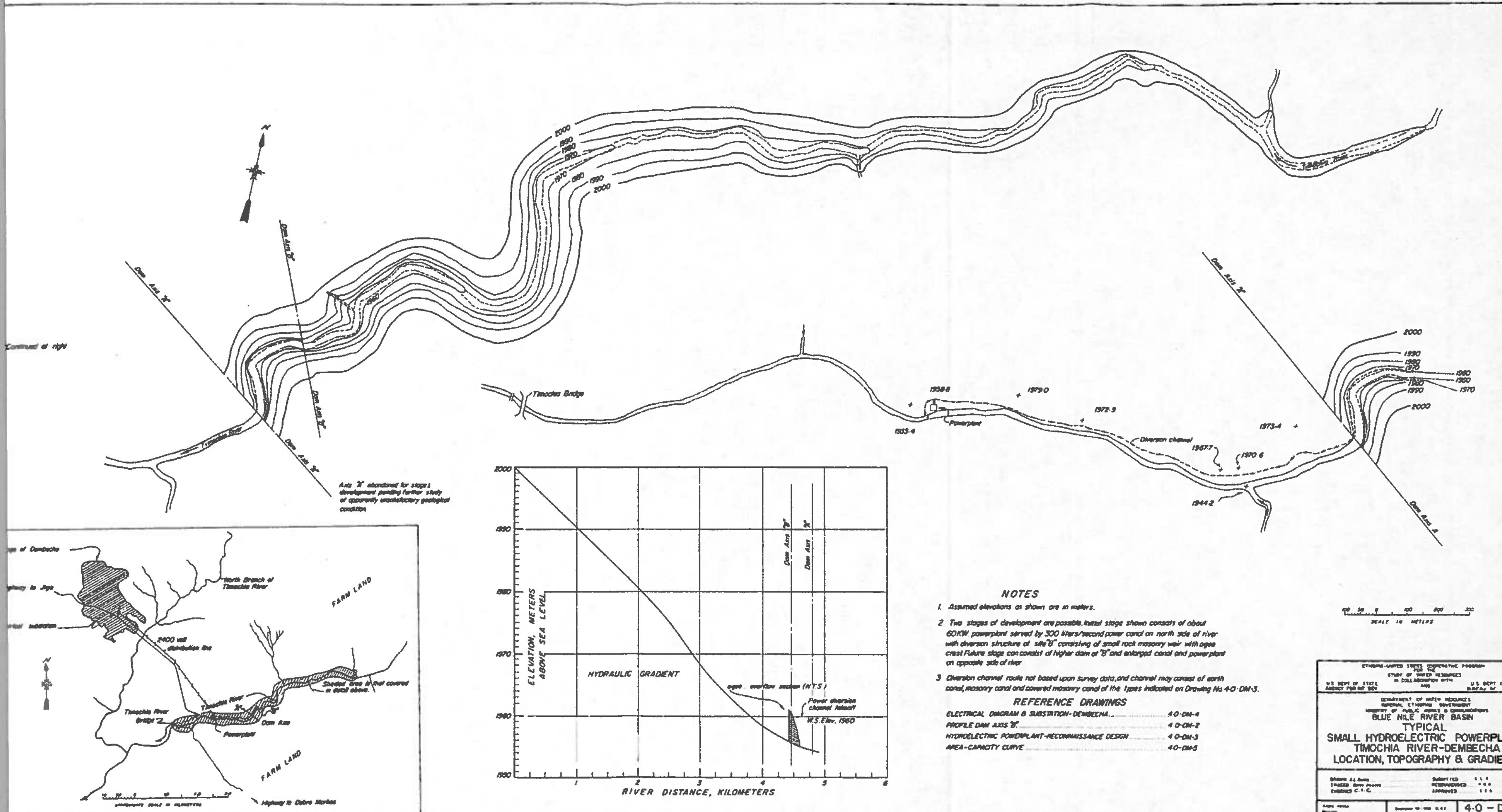


Figure V-150--Typical Small Hydroelectric Powerplant--Timochia River--Dembecha--Location, Topography, and Gra

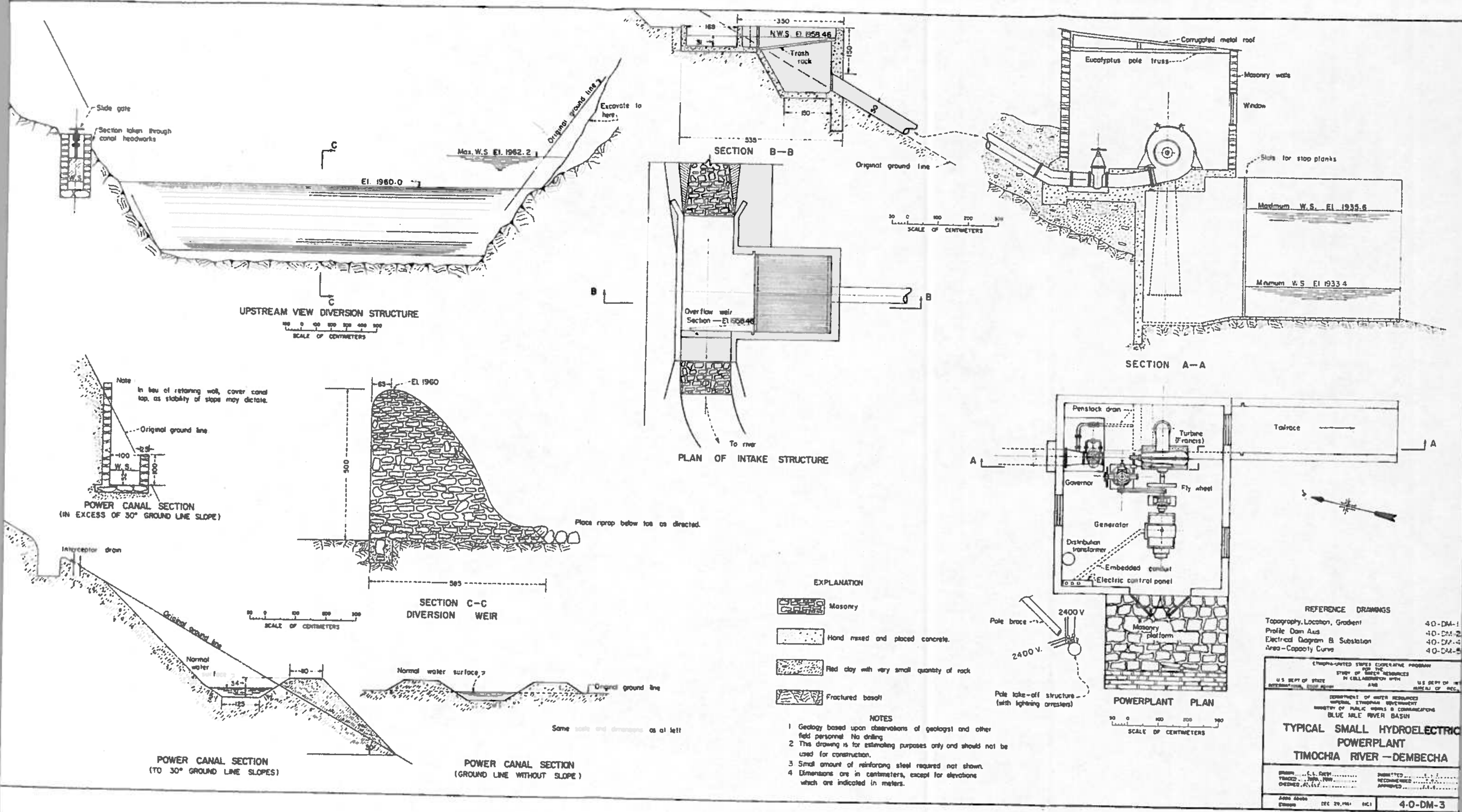


Figure V-151--Typical Small Hydroelectric Powerplant--Timochia River--Dembe of reinforced concrete. A rock masonry platform at the entrance (double door) will serve as an unloading area with steps leading to the ground level. A small penstock drain with valve is provided, as well as a main penstock shutoff valve and valve by-pass assembly. The structure will house a horizontal-type Francis turbine having 90 h. p. and a synchronous speed of 1,500 r.p.m. A belt-driven governor is to be provided. The generator will consist of a 4-pole horizontal machine rated 75 kv.-a., 3 phase, 50 cycles, with generation at 2,400 volts. Normally there is no additional charge for voltages up to this value, but for higher voltages the cost increases as much as 40 percent for 13.8-kv. in the 0-1,100 kv.-a. capacity class. The use of 2,400 volts obviates the need for step-up transformers at the powerplant as 2,400 volts is the correct transmission voltage (distribution class). A small 3-phase 5 kv.-a. station service transformer is provided. A simple isolated radial system is energized by the generator. System protection is simple and is no problem.

Figures V-152 and V-153 have been developed to provide cost and other basic data for small turbines and generators.

Electrical Distribution System

A 4.5-km. 2,400-volt line from the powerplant to Dembecha will be required. This will be a wood-pole line using single poles (treated full-length) with U irons and insulators (no crossarm construction). Three conductors, each 20 mm^2 bare line conductor, span the distance from the bracket to the takeoff pole. Insulators are set on the metal bracket.

The 2,400-380/220-volt stepdown substation at Dembecha will consist of a two-pole structure supporting three single-phase transformers (crossarm mounted) as shown on Figure V-154. Disconnecting fuses, lightning arresters, and insulator assemblies are provided for. All crossarms are of selected and treated eucalyptus poles firmly bolted in place. The heavy steel bracket at the base of the two poles is designed to provide special support and prevent sudden structure failure as the poles deteriorate at the ground line. The concrete and steel are to be placed so that a pole can be removed and replaced without too much difficulty. All spans to the substation are to be slack spans. If tension spans, additional simple bracing will be required here in lieu of the bracing at the adjacent dead end structure.

An allowance of about 3 km. of 380/220-volt distribution line in Dembecha was made. No allowance for kw.-hr. meters was made as many loads may entirely consist of lights and the total lighting load may not exceed 100 watts for many families. Hence, the cost of kw.-hr. meters in these cases is not justified and billing would be done on an equivalent flat rate per month.

DESIGN AND CONSTRUCTION

The average small hydroelectric power development for village or town use is comparatively simple to design and construct. Nearly all of the construction can be accomplished by local hand labor with the exception of transportation to the power site of heavy pieces of machinery such as the turbine and generator. One qualified engineer can design, prepare specifications, and provide general supervision of construction. All materials are available locally, except for cement which is manufactured in Ethiopia and has to be transported to the site. Hydraulic and electrical machinery must be imported as well as the steel penstock and other metal items.

At Dembecha, rock (basalt) can be quarried anywhere along the Timochia River although in places it is estimated that the red clay overburden may be as much as 4 meters in depth. Sand and gravel are not available so must be crushed from the basalt. This can be done by hand labor or by a commercial power driven portable crusher which is generally available in Ethiopia. Hand labor can be used to strip the dam foundation and abutment as well as construct the canal. The work on the dam (diversion structure) foundation

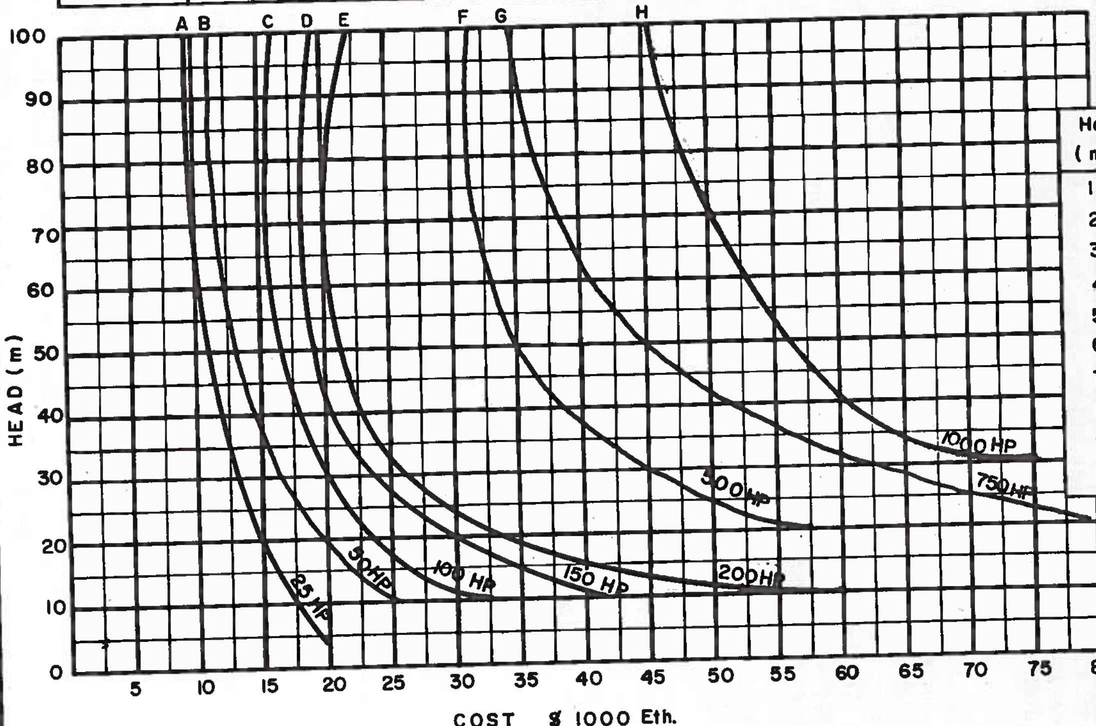
Head (m)	Weight, Kg.							
	25 hp.	50 hp	100hp	150 hp	200hp	500hp	750hp	1000hp
10	3255	5080	8830	10820	12440			
20	1850	3260	4540	4945	8030	14080	21610	
30	1590	2060	3170	3620	5195	11570	17230	21605
40	1625	2090	2585	2960	4115	8820	13475	15220
50	1820	2030	2640	2420	3895	7830	11710	13800
60	1920	2435	2415	2915	3255	6900	8800	13615
70	1700	2280	2440	2970	3470	6570	7780	11260
80	1655	2010	3365	3090	3590	6170	7570	11240
90	1405	1830	2750	3450	4260	5730	6920	10550
100	1375	1920	2875	3185	4070	5780	6620	10455

Curve	Q (Liters/sec.) Range
A	232 – 23
B	469 – 46
C	915 – 92
D	1370 – 139
E	1830 – 184
F	2240 – 452
G	3410 – 674
H	3010 – 888

28.3 Liters/sec. = 1 ft.^{3}/sec.
1 m = 3.28 ft.

Prices are approximate as of January, 1961 delivered at Djibouti or Assab. Includes horizontal turbine with shaft, external bearing and flexible coupling, draft tube of steel plate, intake tube, stop valve and reducing pipe, automatic oil pressure speed governor, flywheel, measuring instrument, trashrack, intake and outlet gate.

Impulse turbines below steps
Francis above steps



Head (m)	R P M							
	25 hp	50 hp	100 hp	150 hp	200 hp	500hp	750 hp	1000hp
10	750	750	750	600	500			
20	1500	1000	1000	1000	750	750	500	
30	1500	1500	1500	1500	1000	750	600	600
40	1500	1500	1500	1500	1000	1000	1000	750
50	1000	1500	1500	1500	1000	1000	1000	750
60	1000	1000	1500	1500	1500	1000	1500	750
70	1000	1000	1500	1500	1500	1000	1500	1000
80	1000	1000	1000	1500	1500	1500	1500	1000
90	1500	1000	1000	1000	1500	1500	1500	1000
100	1500	1000	1000	1000	1000	1500	1500	1000

ETH. US COOP. PROG. FOR THE STUDY OF W. R.
IN COLLABORATION WITH
U.S. DEPT. OF ST. INT. COOP. ADMIN. AND U.S. DEPT. OF INT. BUR. OF RECL.

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

COST ESTIMATES
SMALL HYDRAULIC TURBINES

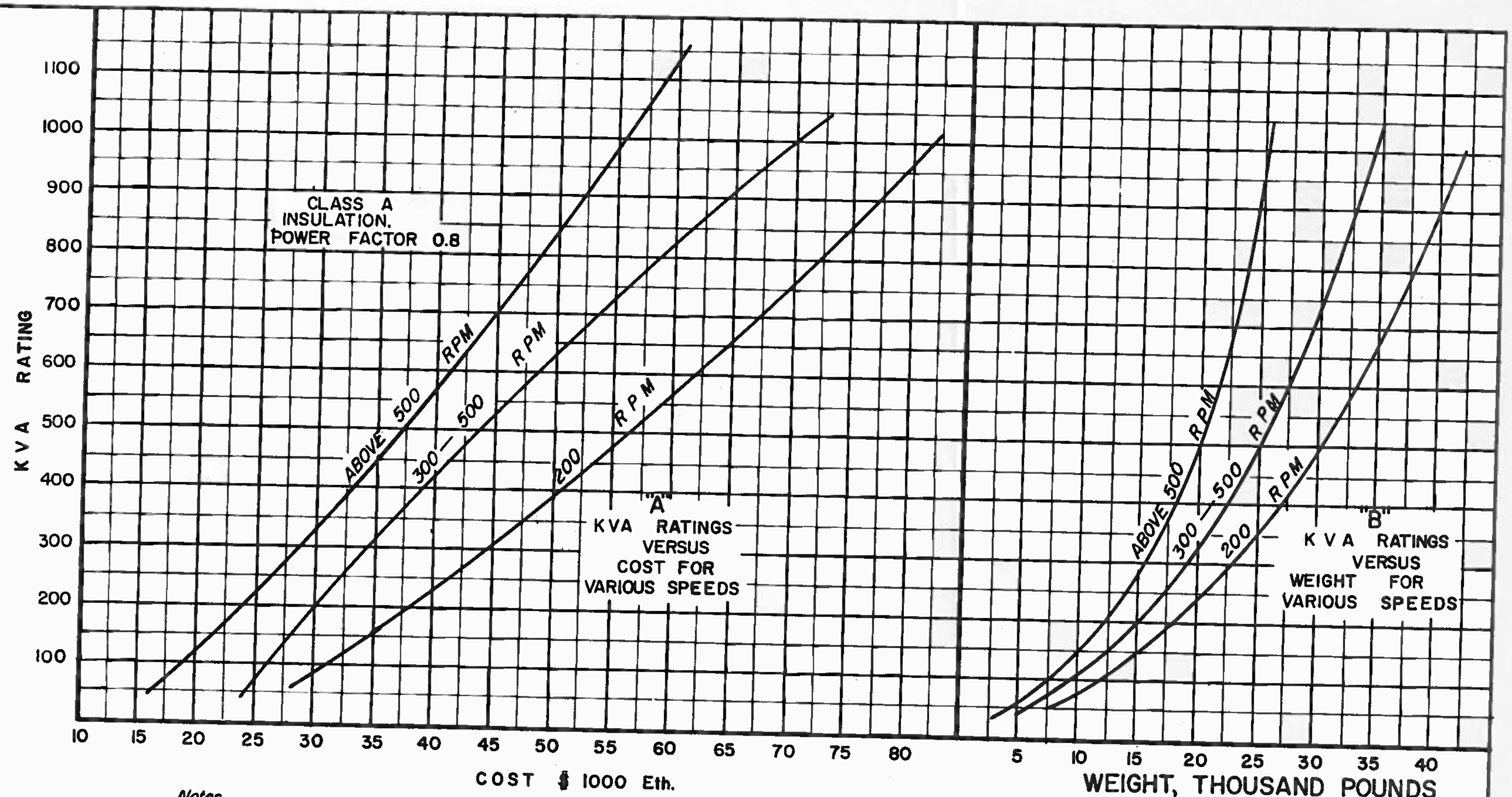
DRAWN C.L.CURTIS SUBMITTED C.L.C.
TRACED NEGASH MU. RECOMMENDED P.W.K.
CHECKED CLC-BJC APPROVED C.E.B.

A.A. JAN. 12/1961(IC)
ETH. JAN. 4/1953(EC)

4.0–BN–2

Rev. Jan. 1962 CLC

Figure V-152--Cost Estimates, Small Hydraulic Turbine



Notes

1. Curves include generator and exciter
2. Add 10% to get costs fob Assab, Djibouti.
3. Curves are for vertical machines. Horizontal, including base, straight shaft (less couplings) and manually operated generator—field rheostat arrived at by adjusting curves as follows:

KVA	R P M	Cost Reduction
500 & below	500 & above	30 %
500 & below	Below 500	20 %
Above 500	All Speeds	15 %

4. Curves based upon 2400 volts maximum. For higher voltages increase as follows: (Curve "B" will not apply.)

4,800 ____ 5 %
6,900 ____ 15 %
11,500 ____ 30 %
13,800 ____ 40 %

Rev. Jan. 1962
C. L. C.

ETH. US COOP. PROG FOR THE STUDY OF W.R.
IN COLLABORATION WITH
U.S. DEPT. OF ST. INT. COOP. ADMIN. AND U.S. DEPT. OF INT. BUR. OF RECL.

DEPT. OF WATER RES. IMP. ETH. GOVR.
MIN OF PUB. WORKS & COMM.
WEIGHTS & COST ESTIMATES
SMALL GENERATORS
(HYDRAULIC TURBINE DRIVE)

DRAWN C.L. CURTIS — SUBMITTED C. L. C.
TRACED Y.S. — RECOMMENDED P. W. K.
CHECKED C.C.–J.C. — APPROVED C. E. B.
A. A. JULY 29—1961 (IC)
ETH. JULY 22—1953 (EC)
4.0-BN-4

Figure V-153--Weights and Cost Estimates, Small Generators

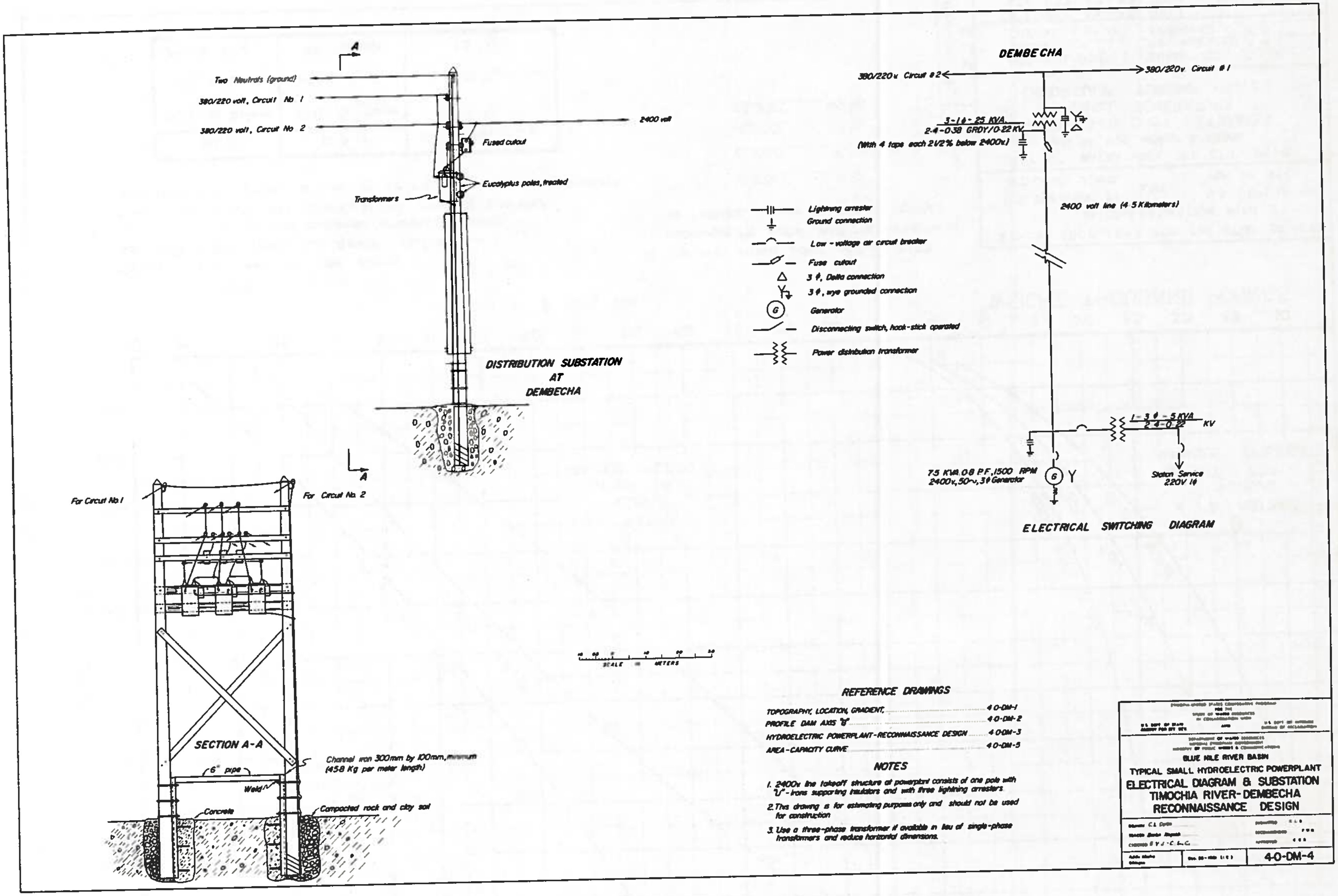


Figure V-154--Electrical Diagram and Substation should be initiated in the dry season with a small clay cofferdam built to dewater about one-half the foundation area at a time. The water level should not exceed 1-meter in depth and may be slightly less during the period of minimum flow. Cutoff trench excavation in the fractured basalt can continue in the dewatered area as well as hand excavation of the abutment areas. A 1-meter diameter opening at streambed level should be allowed during construction of the diversion structure to care for the river during the dry season while work progresses. This would be plugged upon completion of the work. Whether the diversion structure is completed in one dry season is immaterial, as construction can be left in such a manner that the partially completed structure can be overtopped during the rains without damage.

Hand mixed and placed concrete in the penstock intake structure and powerhouse structure can be accomplished in one dry season. Two stages of concrete will not be required as the draft tube and penstock sections should be on hand when concrete operations start. Preceding the concrete work, hand excavation can start toward the end of the rains although final rock excavation in the small tailrace area must await low water level.

Work on the power diversion channel can proceed at a slower pace during the rains with maximum effort directed toward construction during the dry season.

Estimates were prepared on the basis of employing a construction contractor with the nature of the job calling for hand labor, primarily.

A small dry-season one-vehicle-wide access road from the area above the canyon down the side of the north bank of the river to the powerplant is required for transportation of heavy machinery and cement. Although the generator and accessories may weigh 2,700 kg. and the turbine weigh nearly 3,000 kg., there is no need to provide for crane handling facilities in the powerplant as these items can be unloaded onto the masonry platform (equal to truck bed height) and moved on rollers into position in the powerplant.

COST ESTIMATES

Construction costs were estimated as follows:

Timochia Diversion Dam	Eth$ 30,100
Power Canal	39,090
Powerplant	86,150
2,400-volt distribution line	18,225
Substation	6,025
Distribution facilities in village	10,450
	Eth$190,040

ANNUAL COSTS AND COST OF POWER

Total annual costs including OM&R, amortization, Replacement Reserve, taxes, and insurance were estimated at about Eth$18,000.

The maximum theoretical production, if all were salable, would be around 500,000 kw.-hr. At 500,000 kw.-hr., the production and distribution cost would be around Eth¢3-1/2, but at 100,000 kw.-hr., the cost would be around Eth¢17.

Plant cost operation, including transmission and partial distribution, will be slightly over Eth$2.00 per hour.

COMPARISON OF COSTS, HYDRO VERSUS THERMAL

Complete cost data for the Bahir Dar diesel-electric powerplant was supplied by the Ethiopian Electric Light and Power Authority. The plant has a total capacity of 96 kw. at site compared to 60 kw. for the Dembecha Hydroelectric plant. However, the costs at Dembecha include transmission and distribution, whereas the costs used and plotted on Figure V-155 for the Bahir Dar plant include only production. Thus, in the one case the curve is for a slightly larger plant without any distribution costs, while on the other hand, the second is for a smaller plant but does include transmission and distribution costs. Costs are thus not strictly comparable but are close.

A comparison of plant capital costs is as follows:

Bahir Dar Diesel-Electric Plant	Eth$ 57,100
Dembecha Hydroelectric Plant	190,040

The cost of energy at 300,000 kw.-hr. annual production for each is as follows (see Figure V-155:

Bahir Dar	Eth$0.40/kw.-hr.
Dembecha	0.06/kw.-hr.

Hence the reaffirmation of the preconclusions generally reached by engineers seeking solutions for serving small isolated electrical loads:

1. Small thermal units may generally require lower initial investment than comparable hydro.

2. Comparable hydro units can generally provide lower cost energy than can thermal where costs of fuel and oil are high.

3. Thermal units have greater flexibility as they can be moved and shifted about as required.

POWER LOADS AND RATES (TARIFF)

Aerial photograph interpretation reveals about 420 houses in 1956, and 500 houses were assumed for 1961 with 5 inhabitants per house. If each family (or house) were to have an average connected load of 100 watts (lights, primarily) for 5 hours per day, the peak load would be in the evening and would reach 50 kw. (plant capacity about 60 kw.) Loads during the day would be less initially but a mill load of 15 kw. and other smaller miscellaneous loads (motors, primarily) would develop. Also, a small pipeline from the river near the tailrace area to a storage reservoir in the village using electric power during off-peak hours for pumping (time 1,300 to 1,700 hours) is possible and desirable. The plant operators can control pumping and practically no electrical distribution facilities would be required. A small 3-conductor signal line from a float-operated switch in the village reservoir would tell the plant operator when the reservoir was full or empty, or for little more in investment, the actual water level in the reservoir, and thus he can control pumping accordingly during off-peak hours. The signal circuit can be placed on the same poles that are a part of the 2,400-volt line from the powerplant to Dembecha.

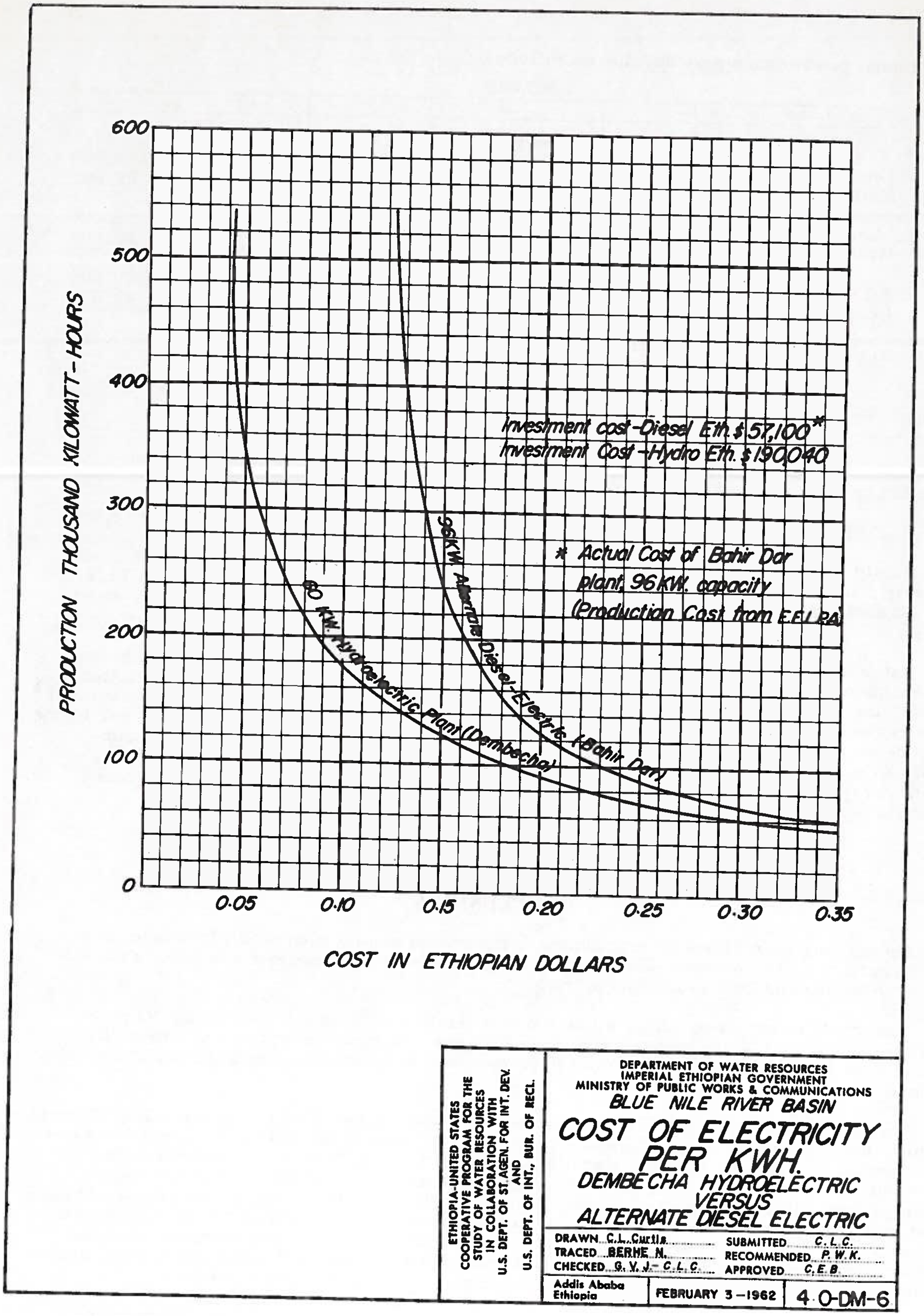


Figure V-155--Cost of Electricity per Kw.-hr.--Dembecha Hydroelectric v. Alternate Diesel-Electric

Annual power loads may develop as follows:

Load	YEARS 1	5	10	15	25
		(kilowatt-hours)			
Lighting	31,000	56,000	110,000	145,000	145,000
Mills	19,000	19,000	25,000	38,000	62,000
Small motors & heating	10,000	12,000	30,000	62,000	62,000
Water pumping	--	7,500	11,000	15,000	20,000
Subtotal	60,000	94,500	176,000	260,000	289,000
Losses	9,000	14,000	26,000	39,000	43,000
Totals	69,000	108,500	202,000	299,000	332,000
Maximum demand, kw.	13	36	55	60	60

The corresponding production, transmission, and distribution cost per revenue-producing kw.-hr. will be as follows (see Figure V-155):

Eth$:	0.29	0.20	0.10	0.065	0.06

If sold at cost initially (29 cents per kw.-hr.), a family could have a 25-watt bulb for nearly 5 hours per night (time 1,800-2,300 hours) for every day of the month for Eth$1.00. At 10 cents per kw.-hr., an average of about 70 watts would be available for this same cost.

Rates can be set on the basis of the cost curve, Figure V-155, or a fixed charge in accordance with the existing EELPA "postage stamp" rate can be levied. In the latter case, the plant would operate at a loss as it costs $2.00 per hour to operate the plant and the revenue, in the first and fifth years, respectively, would be $1.03 and $1.61 per hour (15 cents per kw.-hr. per first 100 kw. per month). This loss would have to be subsidized by profits from larger plants where production and established loads are large with corresponding economical costs per kw.-hr. This is also the situation for small thermal units now serving small villages.

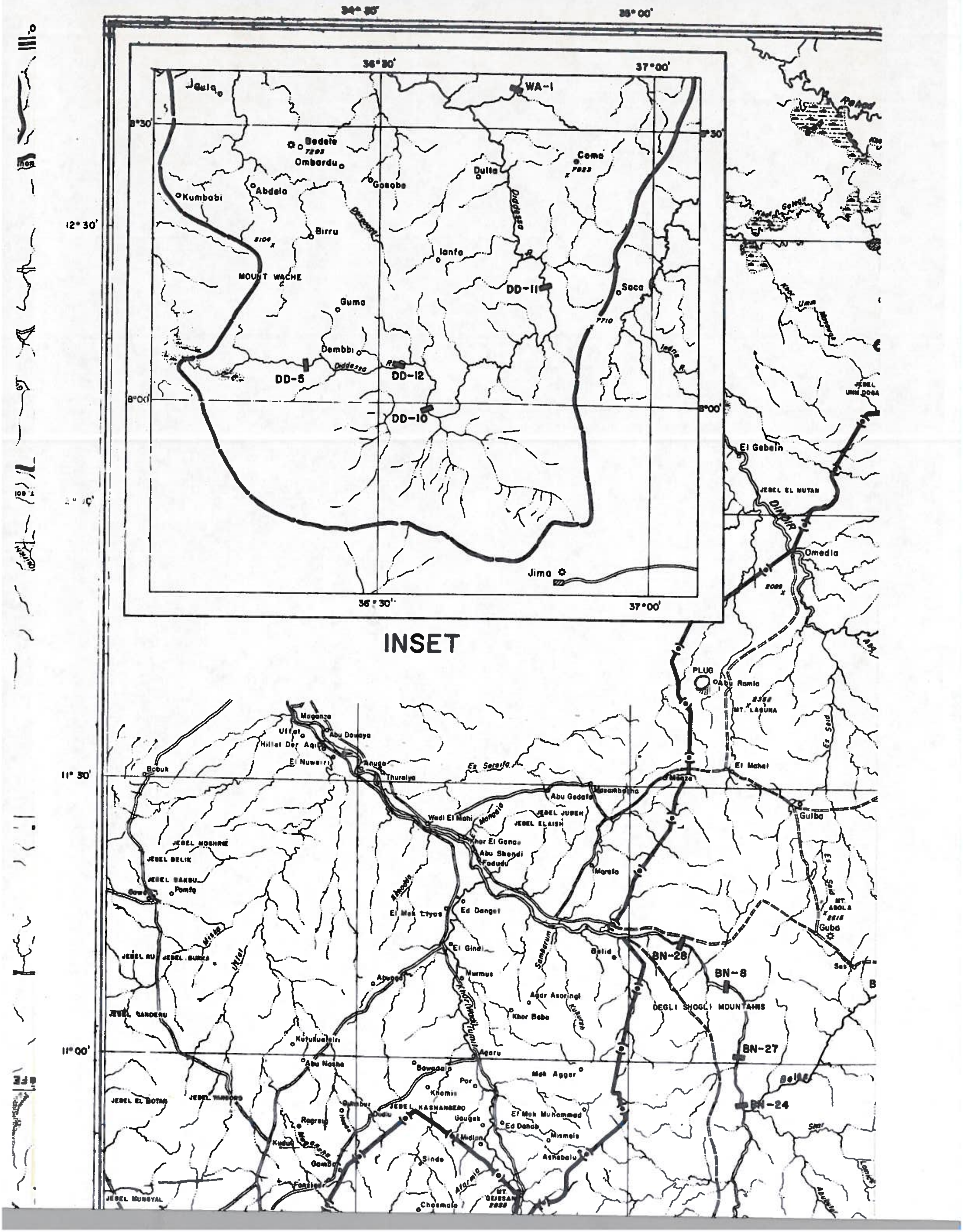
CONCLUSIONS

Developing countries with abundant water supplies can develop small hydroelectric powerplants to serve towns and villages using mainly local materials and labor except for the electrical and hydraulic machinery.

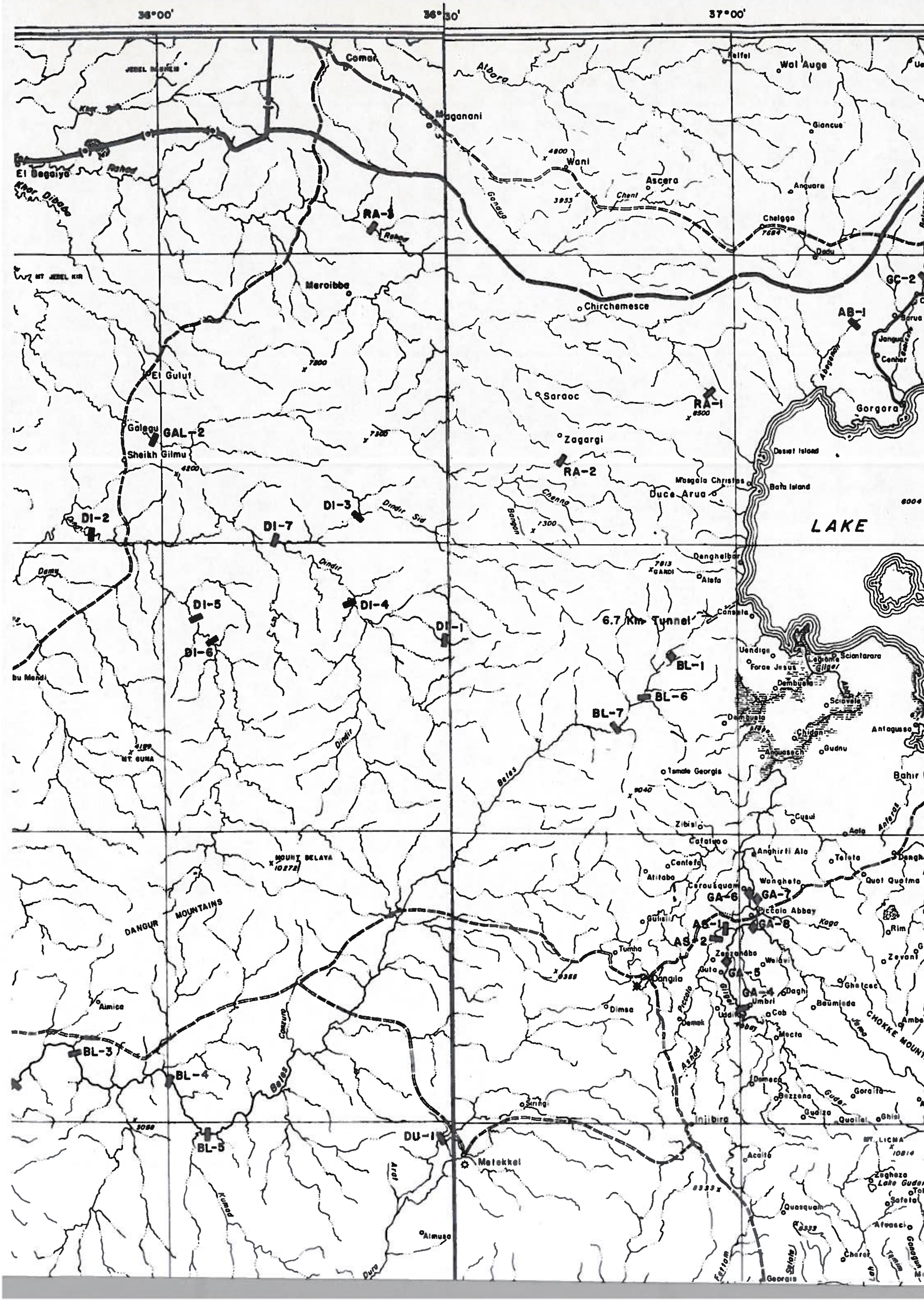
The study of any river basin would not be complete without acknowledging the possibility of this first-stage development near villages. Several villages exist within the Blue Nile Basin that might be served by very small hydroelectric units located reasonably close to the villages or towns.

Initial capital investment will usually be somewhat higher than a corresponding thermal unit. Cost of energy from a hydroelectric unit will usually be lower. Thermal units are somewhat portable while hydro installations are not, except, in some instances, for the machinery. Hydro units require no foreign purchases for operation and maintenance except for replacement parts. Thermal units in Ethiopia, for example, do require importation of fuel oil and lube oils which are costly and require a drain on the foreign exchange. Hydro units save this cost if strategically located with respect to the towns or villages. Hydro units require less specialized maintenance than do thermal units. Hydro installations are not readily expandable whereas thermal units can be easily added.

In the case of Dembecha, a future stage of development is possible by constructing a storage dam and providing regulation. No attempt has been made to study the economics of this approach.



34° 30'
35° 00'
36° 30'
37° 00'
Gula
8° 30'
WA-1
Bedele
7293
Omberdu
Gosobe
Coma
7823
Dulle
Didessa
Kumbabi
Abdela
Birru
Dencoru
8106
Ianfa
MOUNT WACHE
DD-11
Saca
7710
Guma
Dembbi
Dedessa R.
Iedna R.
DD-12
DD-5
8° 00'
DD-10
Jima
36° 30'
37° 00'
INSET
Rahad
Khor Galegu
Khor Umm
JEBEL UMM DOSA
El Gebein
JEBEL EL MUTAN
DINDIR
Omedla
2066
PLUG
Abu Ramla
2358
MT. LAGUNA
Es Seid
12° 30'
11° 30'
11° 00'
Maganza
Utfat
Abu Daweya
Hillet Der Aqiq
El Nuwerri
Anugo
Thuraiya
Es Seraifa
El Mahal
Bobuk
Abu Gedafe
Masambaha
Gulba
Wadi El Mahi
JEBEL JUBEK
JEBEL ELAISH
Khor El Gona
Abu Shendi
Fadudu
JEBEL MOSHRIE
JEBEL BELIK
JEBEL SAKBU
Pomia
Morela
Ed Dangel
El Mek Liyas
MT. ABOLA
2618
Guba
BN-28
BN-8
Belid
El Gindi
JEBEL RU
JEBEL BURKA
Atugo
Murmus
Sambarum
Agar Asoringi
Khor Baba
DEGLI SHOGLI MOUNTAINS
JEBEL GANDERU
Kutukuateiri
BN-27
Agaru
Abu Nasha
Bawadaia
Mek Aggar
Por
Khamis
Belle
JEBEL EL BOTAR
JEBEL TARBOGO
Gumbur
JEBEL KASHANGERO
Gauges
El Mek Muhammad
Ed Dahab
BN-24
Rograir
Kudub
Midjon
Mismeis
Gembo
Sindo
Ashabalu
Afarmia
Fonsier
MT. GEISAN
2935
JEBEL MUNGYAL
Chosmaio



36°00'
36°30'
37°00'
Comar
Maganani
Albora
Wal Auge
Giancue
Wani
Ascera
Anguara
Chelgga
Dadu
El Begaiya
Khor Dibaba
Rahad
RA-3
Gonaug
Chent
Meraibba
Chirchemesce
GC-2
AB-1
Barua
Cenher
Gorgora
El Gulut
Saraoc
RA-1
Galagu
GAL-2
Sheikh Gilmu
Zagargi
RA-2
Dasiet Island
Masgala Christos
Bata Island
Duce Arua
DI-3
Dindir
DI-2
DI-7
Chenna
LAKE
Denghelbar
Alefa
DI-5
DI-4
DI-1
DI-6
6.7 Km Tunnel
Consela
Uendige
Forae Jesus
Sciantarara
BL-1
Dembuela
Sciavela
BL-6
BL-7
Chigan
Antagusso
Gudnu
MT. GUNA
Beles
Tamale Georgis
Bahir
Zibisi
Cusul
Cofatu
Anghirti Ala
Teleta
MOUNT BELAYA
Centefo
Atitaba
Cerousquam
Wongheta
Quot Quatma
DANGUR MOUNTAINS
GA-6
GA-7
Piccolo Abbay
AS-1
GA-8
AS-2
Tumha
Zenzenaba
Weidevi
Zevani
Dangila
Guta
GA-5
GA-4
Ghetcec
Aimica
Dimsa
Umbri
Baumieda
Demek
Cob
CHOKKE MOUNT
BL-3
BL-4
Mecta
Beles
Dameca
Bezzena
Guder
Goraita
Siringi
Injibira
Guaiza
Quailet
Ghisi
BL-5
DU-1
Metekkel
MT. LICMA
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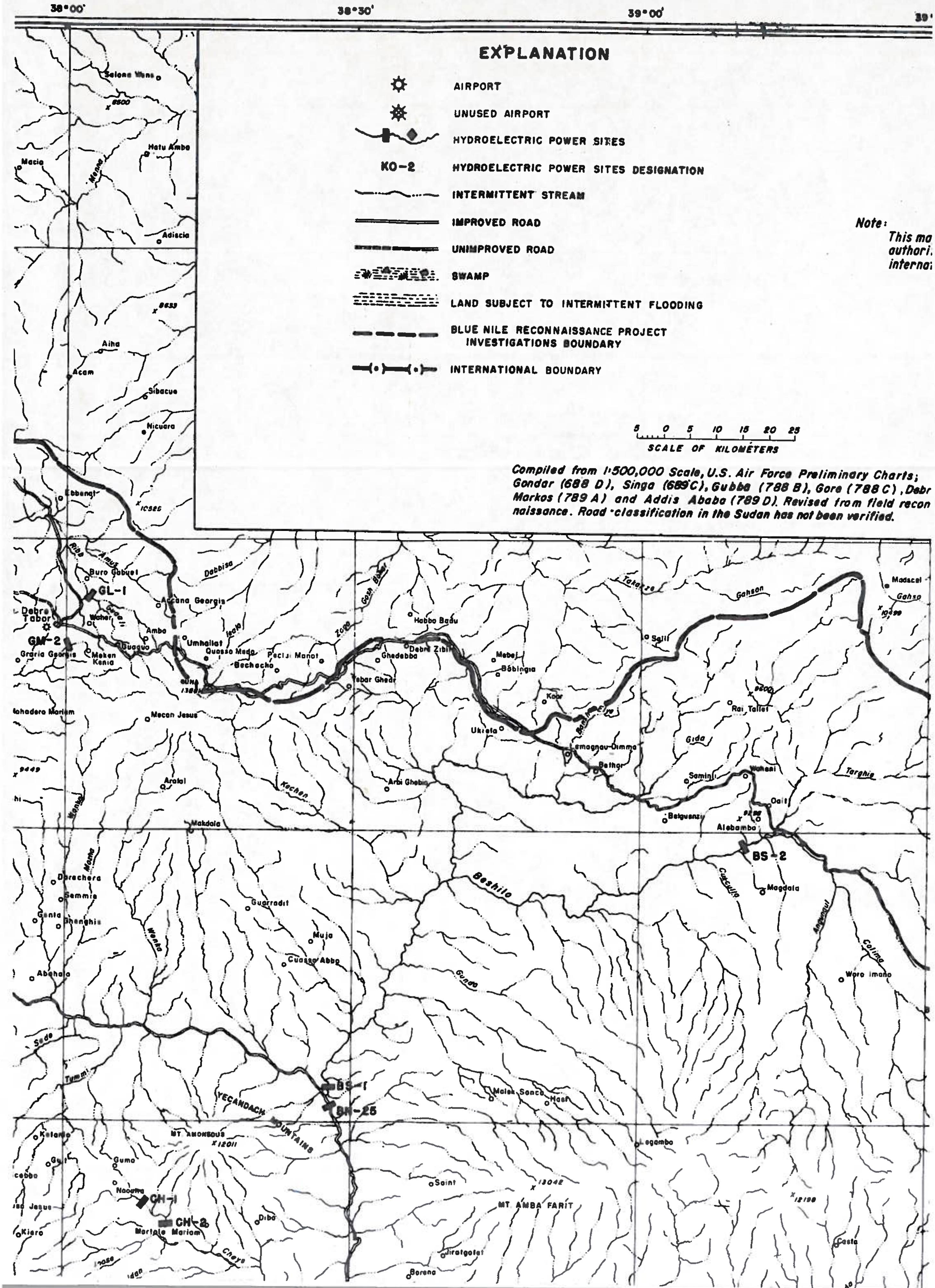
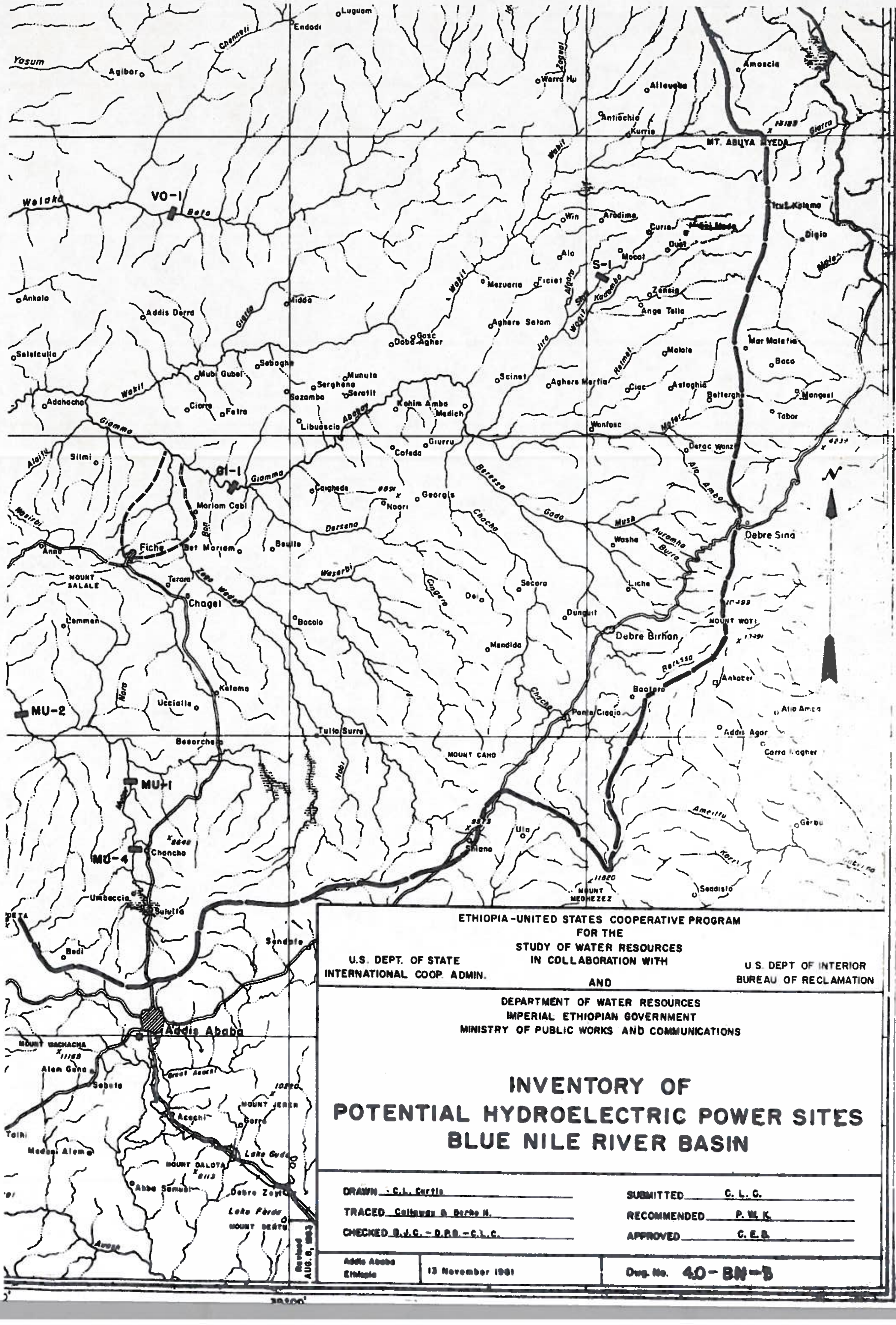
Zeghaza
Lake Guder
Sofeta
Quasquam
Afeasci
Almusa
Dura
Kumad
Cherer
Georgis



38°00'
38°30'
39°00'
EXPLANATION
AIRPORT
UNUSED AIRPORT
HYDROELECTRIC POWER SITES
KO-2
HYDROELECTRIC POWER SITES DESIGNATION
INTERMITTENT STREAM
IMPROVED ROAD
UNIMPROVED ROAD
SWAMP
LAND SUBJECT TO INTERMITTENT FLOODING
BLUE NILE RECONNAISSANCE PROJECT INVESTIGATIONS BOUNDARY
INTERNATIONAL BOUNDARY
5 0 5 10 15 20 25
SCALE OF KILOMETERS
Compiled from 1:500,000 Scale, U.S. Air Force Preliminary Charts; Gondar (688 D), Singa (689 C), Gubba (788 B), Gore (788 C), Debr Markos (789 A) and Addis Ababa (789 D). Revised from field recon naissance. Road classification in the Sudan has not been verified.
Note:
This ma
authori
interna
Hatu Ambo
Adiscia
Aiha
Acam
Sibacue
Nicuara
GL-1
GM-2
Debre Tabor
Buro Gabuet
Ambo
Umhaliat
Quasso Mado
Bechacho
Ghedebba
Debre Zibit
Mebej
Bobingia
Tebar Ghedr
Mecan Jesus
Takazze
Gahson
Salli
Rai Tallet
Gida
Ukiela
Bethor
Samini
Wahani
Oait
Belguenzi
Alebamba
BS-2
Magdala
Beshilo
Arbi Ghebia
Aralal
Kechen
Makdala
Dorechera
Semmia
Genta
Ghenghis
Guarradit
Muja
Abahala
Woro Imano
Colima
Sede
Tummi
BS-1
BN-25
YECANDACH MOUNTAINS
MT AMONSOUS
x12011
Molen Sonce
Haat
Legambo
Kelanio
Gult
Gumo
Nacotta
CH-1
CH-2
Mortale Mariam
Chaye
Kiero
Dibo
Saint
x13042
MT AMBA FARIT
x12198
Jiratgolat
Boreno
Casta



ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM
FOR THE
STUDY OF WATER RESOURCES
IN COLLABORATION WITH

U.S. DEPT. OF STATE
INTERNATIONAL COOP. ADMIN.

AND

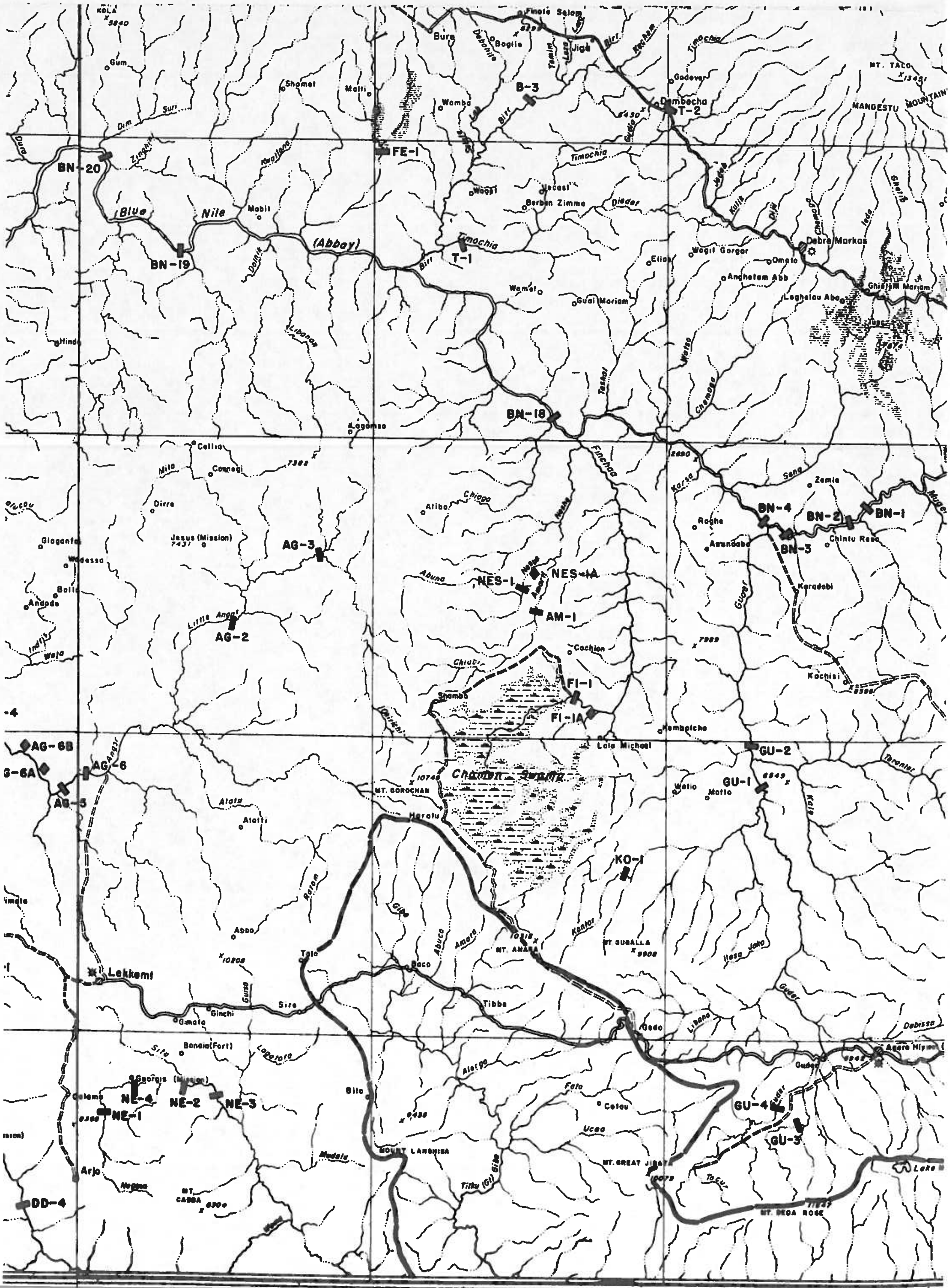
U.S. DEPT OF INTERIOR
BUREAU OF RECLAMATION

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

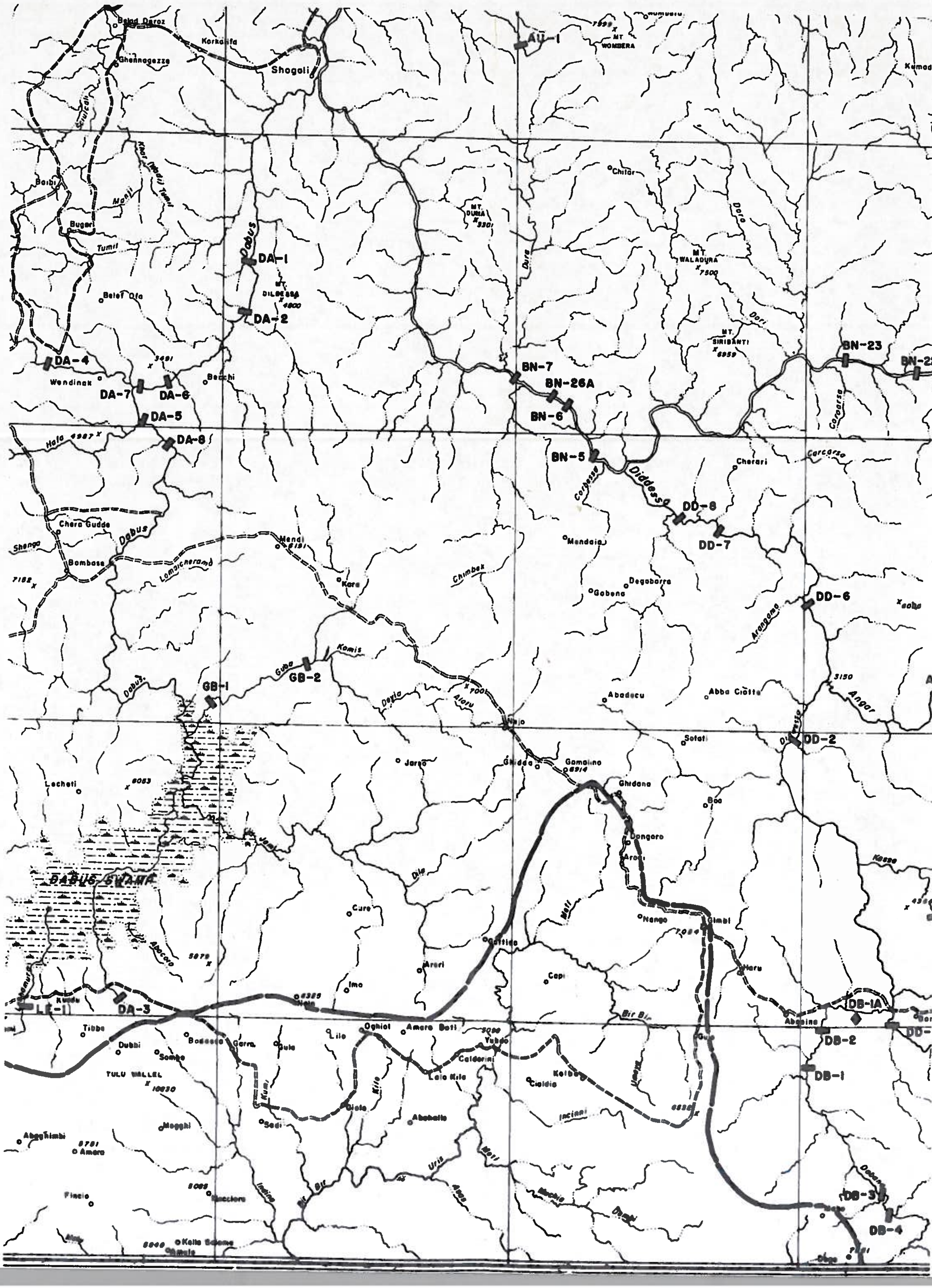
INVENTORY OF POTENTIAL HYDROELECTRIC POWER SITES BLUE NILE RIVER BASIN

DRAWN - C.L. Curtis	SUBMITTED C. L. C.
TRACED Callaway & Berhe H.	RECOMMENDED P. W. K.
CHECKED B.J.C. - D.P.B. - C.L.C.	APPROVED C. E. B.

Addis Ababa Ethiopia	13 November 1961	Dwg. No. 40-BN-B



Blue Nile (Abbay)
BN-20
BN-19
BN-18
BN-4
BN-3
BN-2
BN-1
FE-1
B-3
T-2
T-1
Dembecha
Debre Markos
MANGESTU MOUNTAIN
MT. TALO
Finote Selam
Jigé
Bure
Timochia
Fincha
AG-3
AG-2
AG-6B
AG-6
AG-5
NES-1
NES-1A
AM-1
FI-1
FI-1A
Chomen Swamp
GU-1
GU-2
GU-3
GU-4
KO-1
Lekkemt
NE-1
NE-2
NE-3
NE-4
DD-4
Arjo
Gedo
Guder
Ageré Hiywet
MT. GREAT JIBAT
MT. DEDA ROSE
MOUNT LANGHISA
MT. SOROCHAN
MT. AMARA
MT. GUSALLA
Little Angar
Guder
Gibe
Jesus (Mission)
Bonaia(Fort)
Georgis (Mission)
Kachisi
Karadobi
Lata Michael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Korkadifa
Ghennogezze
Shogoli
AU-1
MT WOMBERA
Kemad
Bolbi
Buger
Tumii
Chilar
MT DURA 8301
Dura
Dora
MT WALADURA 7500
Dabus
DA-1
MT DILBESSA 4800
DA-2
Belet Ofa
DA-4
Wendinak
DA-7
DA-6
DA-5
DA-8
Becchi
BN-7
BN-26A
BN-6
BN-5
MT SIRIBANTI 6959
Dori
BN-23
BN-22
Corcorsa
Cherari
Diddessa
DD-8
DD-7
Mendaia
Chera Gudde
Shenga
Bombase
Lomaicheramo
Mendi 6191
Kora
Chimbek
Degabarra
Gobena
DD-6
Arangamo
Komis
Guba
GB-1
GB-2
Abadecu
Abba Ciotta
Angar
Najo
DD-2
Sofati
Jarso
Ghidda
Gamolino 6914
Ghidana
Boo
Lecheti
Dangoro
DABUS SWAMP
Cure
Nango
Gimbi
Haru
Capi
Arori
Imo
DA-3
LE-1
DB-1A
DB-2
DB-1
Tibbe
Dubbi
Sombo
Bodessa
Garra
Gulo
Lile
Oghiol
Amaro Beti
Yubdo
Calderini
Lolo Kile
Cioldio
TULU WALLEL 10830
Mogghi
Sedi
Ababallo
Incinni
Ciolo
Uria
Bir Bir
Abagghimbi
Amaro
Fincio
Bacciaro
Kello Salome
DB-3
DB-4
Kasso