Land and Water Resources of the Blue Nile Basin

Ethiopia

APPENDIX III - HYDROLOGY

Prepared for the Department of State
Agency for International Development

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

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ABBREVIATIONS, CONVERSION FACTORS, AND ETHIOPIAN MONETARY AND CALENDAR EQUIVALENTS

Abbreviations:

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

Conversion Factors: Metric-English Systems

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

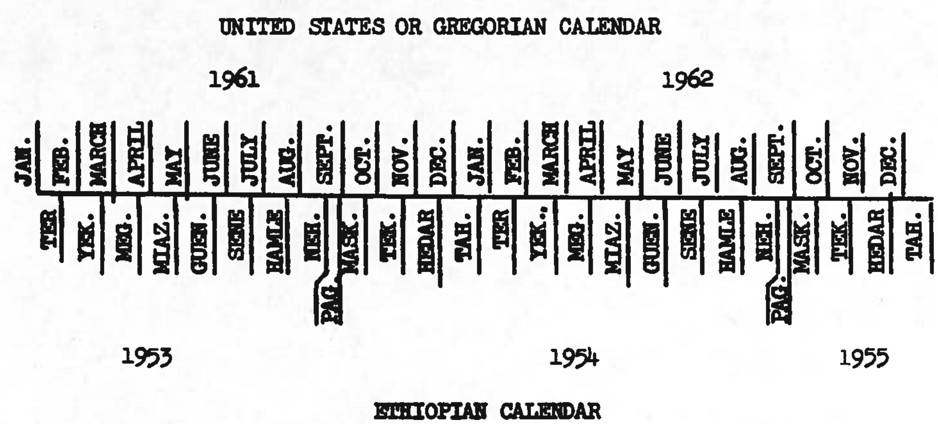
Temperature Conversion:

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

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

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

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



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.

PREFACE

The hydrologic appendix to the Blue Nile Basin Report is presented here in four sections. Section I is a general chapter on climate, quality of water, sedimentation, and irrigation requirements. Section II presents the streamflow data, both historical and estimated. Section III is flood flows, and Section IV is water use studies.

SECTION I--GENERAL

Hydrology Personnel and Training

When the present investigation was initiated in 1958, two United States engineers were assigned to the Hydrology Branch. This number was expanded as the investigation proceeded to a maximum of six. They were engaged in the planning, supervision, and actual collection of hydrologic data and the subsequent use of the data in planning potential projects.

One to four Ethiopian engineers were assigned to the Hydrology Branch during the course of the investigation. These engineers were given on-the-job training, often in counterpart positions, at first to enable them to assume responsibility for portions of the program, and finally in 1963, with the departure of the last U.S. engineer, to assume complete responsibility for the continuation of the hydrology program of the Water Resources Department throughout Ethiopia.

In addition to the professional engineers, 32 Ethiopians, generally with secondary school educations, were trained to perform the many and various duties of hydrology technicians including construction and installation of staff gages and recorders and the complete maintenance of the gaging stations; taking stream measurements from cableways, boats, and bridges as well as by wading; collection of sediment and water quality samples; collection of climatic data such as temperature, precipitation, wind, evaporation and humidity; compilation of climatic and streamflow data; developing rating curves for gaging stations and their use in computing runoff; performing reservoir operation studies; and routing floods through reservoirs. One technician was given special training in the installation of climatic stations as well as the collection of data from them and the summarization and utilization of the data. He acted as a liaison between the Water Resources Department and the Climatic Institute which has the primary responsibility for the collection and publication of climatic data throughout the Empire.

During the June to September rainy season, additional college and secondary students were employed to help the regular technicians in obtaining field data.

Local residents, generally primary school students, were employed to record gage heights of streams at gaging stations twice daily.

The major stream gage station construction was performed at first by contract and later by the same personnel on the project payroll. There were normally 4 crews all under the management of an Italian supervisor. Each crew consisted of 1 Italian foreman, 2 Ethiopian skilled laborers, 1 Ethiopian semiskilled laborer (all from Addis Ababa on monthly salaries) and from 4 to 20 day laborers (hired at the site).

Climate

DESCRIPTION

The climate of the Blue Nile Basin in Ethiopia results from its location (7°44' to 12°46' north of the equator) and elevation (490 to 4230 meters, or 1610 to 13,900 feet). It can generally be described as temperate at the higher elevations and tropical at the lower elevations. However, due to the distinctive aspects of the highland climate, it is perhaps better to describe it using the local climatic zones which have been established with elevation (and resultant temperatures) as controlling factors.

The K'olla zone lies below 1800 meters (5905 feet) and has average annual temperatures ranging from 20° to 28° C (68° to 82° F). The Woina Dega zone lies between 1800 and 2400 meters (5905 and 7874 feet), and has average annual temperatures ranging from 16° to 20° C (61° to 68° F). The Dega zone, above 2400 meters (7874 feet) has average annual temperatures ranging from 10° to 16° C (50° to 61° F). The approximate extent of these zones within the basin are shown on Figure III-1. The great bulk of the population inhabit the more climatically pleasant and healthful upper two zones, leaving the lowest (K'olla) zone very sparsely populated.

The low latitude (with daily sunlight hours only varying from 11-1/2 to 12-1/2 hours per day) produces monthly temperature averages that only vary 3° to 7° C throughout the year. The mean daily range in temperature varies from 6° to 20° C, with the smaller range occurring during the rainy season due to the cloud cover and greater amount of moisture in the air.

The moisture for the precipitation comes primarily from the South Atlantic Ocean and to a lesser extent from the Indian Ocean. The rainfall belt across tropical Africa has an annual oscillation northwards and southwards, following the sun's declination with about a 2-month's lag and an amplitude of motion about half that of the sun. This places the center of gravity of rainfall distribution at its northernmost latitude of 9° north in August. Most of the precipitation in the Blue Nile Basin is concentrated in the June through September period with virtual drought from November through February. Annual totals average from less than 100 centimeters (25 inches) to more than 200 centimeters (50 inches). The variations in average annual totals within the basin are primarily due to elevation differences, with a general increase in precipitation with an increase in elevation. The secondary factors influencing the precipitation totals include: latitude (slightly less precipitation with increase in latitude), location (the southwest portion receives more precipitation than can be accounted for by elevation and latitude alone, perhaps due to the aforementioned center of gravity of rainfall distribution having a southeast to northwest and return motion located southwest of the basin), and local orography. The annual precipitation totals are quite uniform from year to year as evidenced by the record at Addis Ababa (just out of the basin to the southeast). There the average annual variation from the 47-year average of 123.4 centimeters is only 15 percent and the extremes are 91.6 centimeters (26 percent less than normal) and 193.7 centimeters (56 percent more than normal).

Data

Climatic data have been recorded at some 80 stations (locations shown on Figure III-2) in or near the Abbay Basin. Most of this is of a few months or years duration only and consists of daily maximum and minimum temperatures and daily precipitation totals.

A summary of these data from 22 stations with the longest records is shown on Table III-1. This summary was prepared primarily from the Abbay Basin Hydrologic Summary 1962, which tabulated temperature averages for all months of record as well as precipitation totals by month. The data from the stations in the Sudan were obtained from Climate and Man, USDA, 1941 yearbook; Agriculture in the Sudan, 1948; and from Nile Basin Reports, Ministry of Public Works, Egypt.

TABLE III-1--TEMPERATURE AND PRECIPITATION AT CLIMATIC STATIONS

Station	Elevation (meters)	Average precipitation			Average temperature		
		Annual (mm.)	Maximum month (mm.)	Minimum month (mm.)	Annual (° C.)	Maximum month (° C.)	Minimum month (° C.)
Dega zone							
Debre Tabor	2945	1,715	518 Jul	7 Jan	16.5	18.8 May	14.8 Aug
Debre Birhan	2840	925	323 Jul	6 Dec	16.8	20.0 Jun	13.4 Dec
Fiche	2820	1,398	497 Jul	7 Nov	12.9	15.1 Jun	10.8 Nov
Arjo	2565	1,756	322 Jul	14 Jan	-	-	-
Addis Ababa*	2408	1,243	290 Aug	8 Dec	16.2	18.0 May	15.1 Nov
Woina Dega zone							
Debre Markos	2313	1,499	403 Jul	16 Dec	15.3	17.4 Mar	13.8 Jul
Ambo	2130	1,075	247 Jul	5 Nov	18.4	20.1 Mar	16.7 Jul
Gondar	2121	1,213	337 Aug	3 Jan	19.2	21.6 Mar	17.2 Aug
Dangila	2107	1,472	371 Jul	1 Jan	17.3	18.7 May	15.2 Jan
Lekkemt	2005	1,996	373 Jun	16 Jan	18.3	20.7 Dec	15.2 Jul
Gimbi*	1988	2,152	431 Sep	0 Feb	21.2	23.8 Feb	18.4 Jul
Kembolcha*	1903	1,097	283 Jul	16 Dec	19.1	22.6 Jun	16.2 Dec
Nejo	1900	1,882	355 Aug	3 Jan	18.9	21.4 Mar	16.6 Jul
Bahir Dar	1802	1,178	382 Jul	0 Jan	18.5	20.6 Mar	16.8 Dec
K'olla zone							
Mendi	1767	1,775	346 Sep	4 Feb	19.9	22.5 Mar	18.0 Jul
Jima*	1701	1,559	239 Aug	28 Jan	18.2	19.6 Mar	16.9 Nov
Asosa	1665	1,303	251 Aug	0 Jan	20.9	22.9 Mar	18.3 Jul
Wonji*	1580	823	214 Jul	2 Nov	20.8	23.1 Jun	18.6 Jan
Galabat**	765	907	252 Aug	0 Jan	26.6	30.6 Apr	23.8 Aug
Kurmuk**	702	924	199 Aug	0 Jan	-	-	-
Roseires**	467	786	216 Aug	0 Jan	28.1	31.6 Apr	26.2 Jan
Gambela*	450	1,284	261 Aug	6 Jan	27.2	29.9 Mar	25.6 Aug

* Station is in Ethiopia, outside the Blue Nile Basin.
** Station is in the Sudan.

From these limited data, a basin map, Figure III-3, was prepared showing isotherms (lines along which average annual temperature is constant) at intervals of 2° C and Figure III-4 was prepared showing isohyetals (lines along which average annual precipitation is constant) at 50-cm. intervals.

The basin precipitation drawing, besides reflecting the marked precipitation increase with higher elevation, also shows that the Diddessa and Dabus Sub-basins in the southwest receive heavier annual quantities than the basin as a whole. Examination of the rainfall records from this area shows that this is due to a longer (May through October) rainy season rather than heavier maximum monthly quantities.

The average precipitation and temperature data by months for selected stations at elevations from 467 meters to 2945 meters are shown graphically on Figures III-5 and III-6. The precipitation graph shows the concentration of 80 percent of the precipitation during the 4-month June-through-September period and drought (only 3 percent) during the 4-month November-through-February period. This graph also shows the marked increase in precipitation with increase in elevation. The temperature graph, conversely, shows the marked decrease in temperature with increase in elevation. The temperature graph also shows the mean daily range varying from 6° C in the rainy period to 20° C in the dry season.

Some rainy season precipitation records were collected by project personnel at isolated hydrographic camps in areas not covered by the regular station records. These are presented in Table III-2.

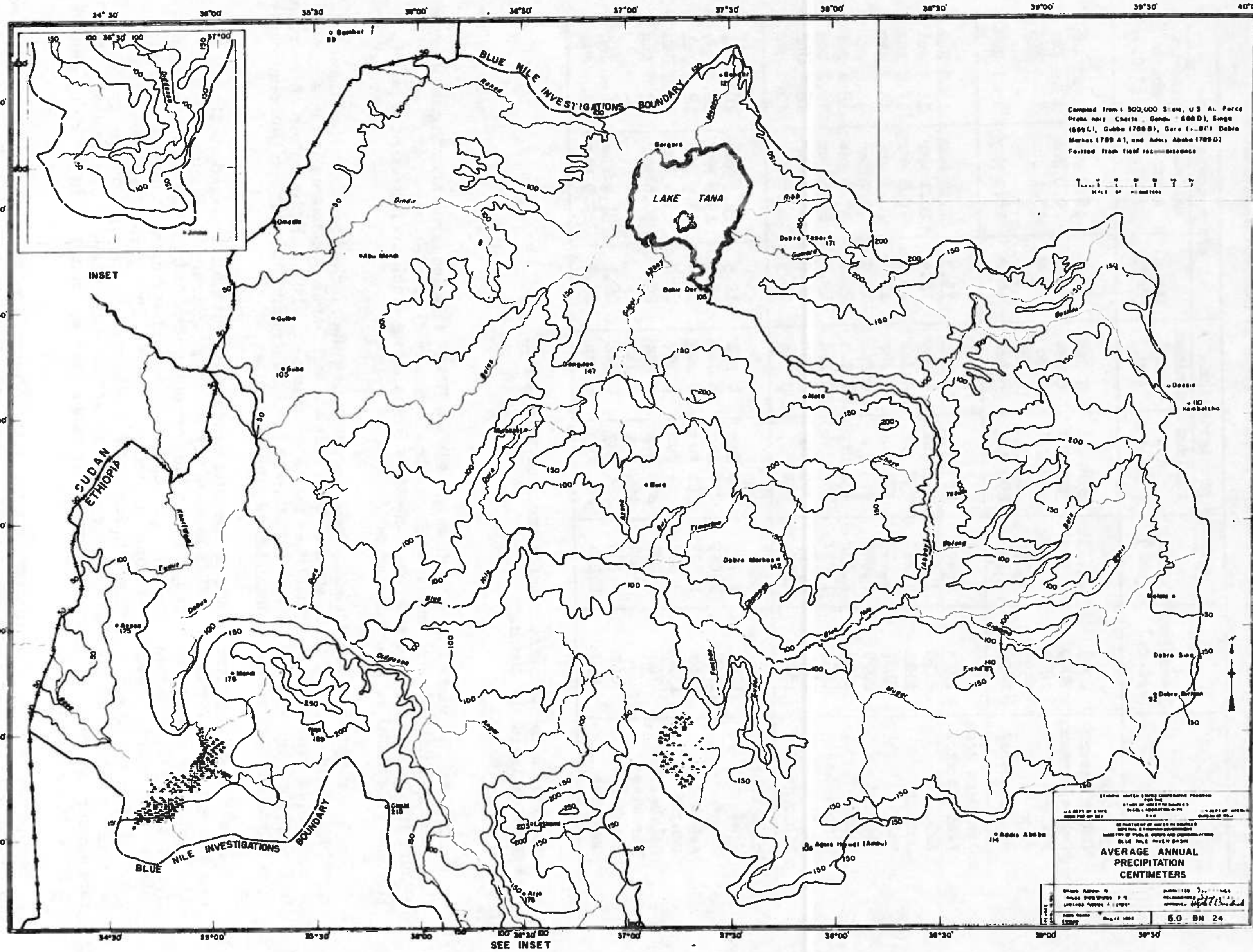


Figure III-4--Average Annual Precipitation, Centimeters

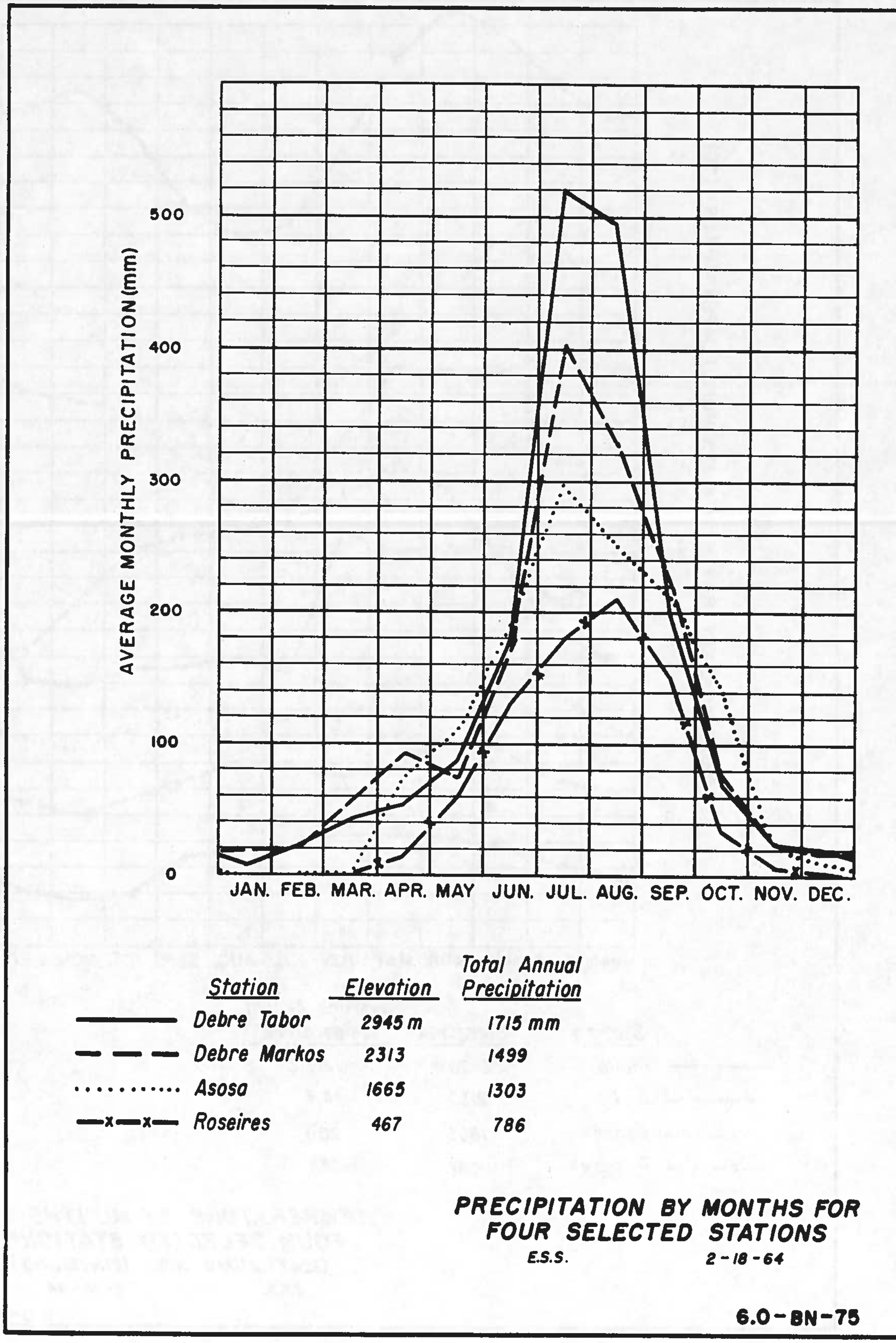


Figure III-5--Precipitation by Months for Four Selected Stations

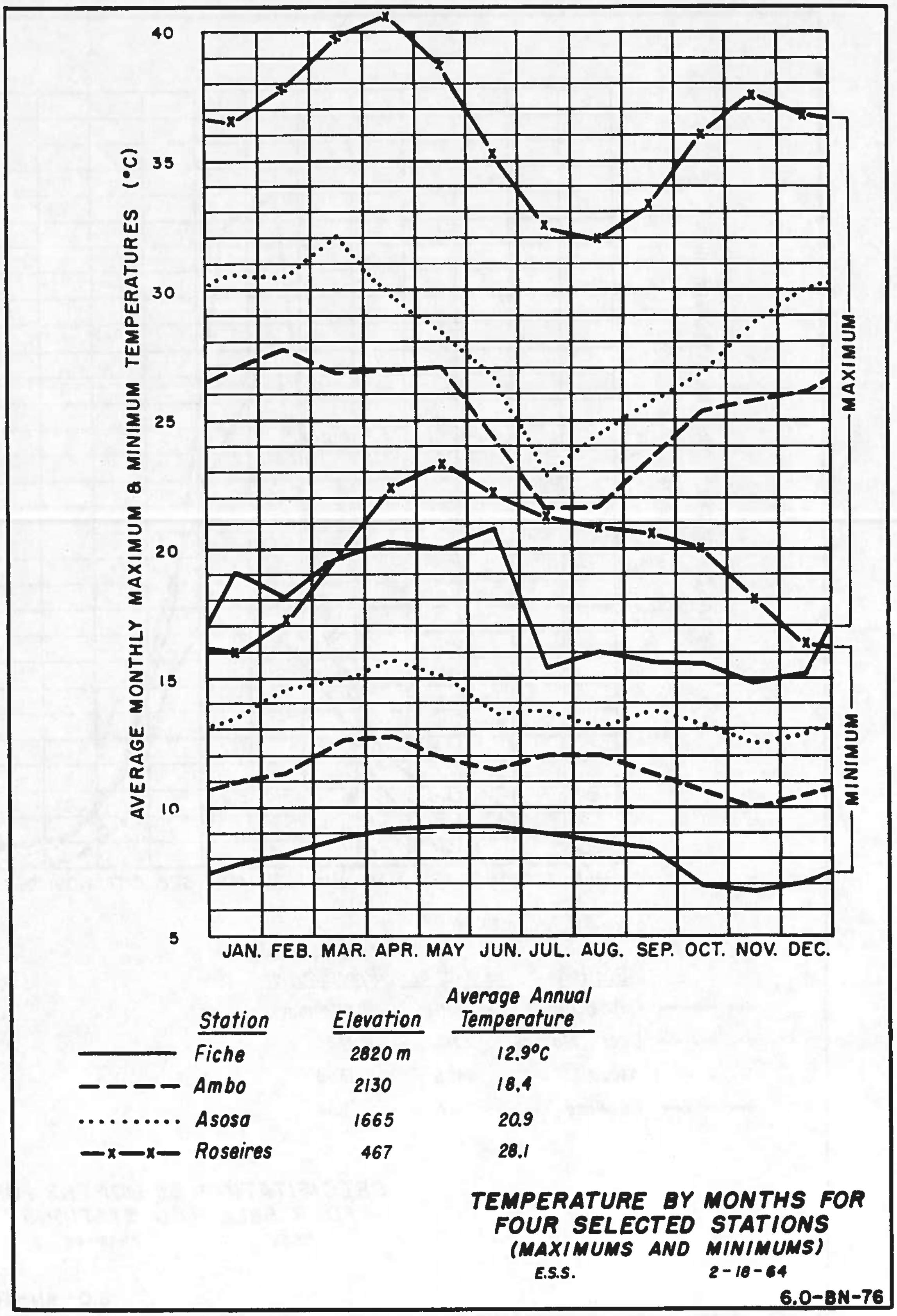


Figure III-6--Temperature by Months for Four Selected Stations

TABLE III-2--RAINY SEASON PRECIPITATION AT ISOLATED CAMPS

Camp	Year	Precipitation in centimeters								
		May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Total
Metemma	1961	4.4	12.3	20.0	13.6	6.3	6.4	-	-	63.0
	1962	-	10.2	23.6	12.3	9.3	1.7	-	-	57.1
Guba	1961	0.4	4.0	6.5	23.2	25.4	14.7	-	-	74.2
	1962	3.0	21.0	14.3	25.3	24.4	12.2	0.1	-	100.3
Beles	1962	-	17.5	18.6	24.3	10.3	-	-	-	70.7
Dindir	1962	-	-	15.1	30.6	15.9	-	-	-	61.6
Guder at mouth	1962	-	6.9	23.5	18.3	6.1	-	-	-	54.8
Sudan border	1962	-	-	1.8	2.3	2.4	-	-	-	6.5
Rahad	1962	-	-	11.4	33.8	24.6	15.5	-	-	85.3

Evaporation data from the few stations with such records are tabulated in Table III-3. Evaporation (as with temperature) decreases with elevation.

Average annual temperature, precipitation, and evaporation at the stations of longest record are plotted against elevation on Figure III-7. This drawing was used in the preparation of the aforementioned temperature and precipitation basin maps.

Quality of Water

The quality of water for irrigation purposes in streams is generally very good in the basin. Samples were taken at the stations shown on Figure III-8 and were subsequently analyzed by the Pasteur Institute of Addis Ababa to determine:

1. pH
2. Specific conductance (EC x 10^6 at 25° C) in micromhos/cm.
3. Total dissolved solids (T.D.S.) in parts per million
4. Cations--in parts per million (p.p.m.), equivalents per million (e.p.m.), or milliequivalents per liter (m.e.l.)
    a. Calcium (Ca)
    b. Magnesium (Mg)
    c. Sodium (Na)
    d. Potassium (K)
    e. Iron (Fe)
5. Anions--in p.p.m., or m.e.l. of
    a. Carbonate (CO_3)
    b. Bicarbonate (HCO_3)

TABLE III-3--EVAPORATION AT CLIMATIC STATIONS

Year	Evaporation in centimeters													
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Average
ADDIS ABABA, ETHIOPIA														
1959	13.6	13.7	18.8	17.2	15.7	13.0	12.3	11.0	16.3	13.2	13.5	14.0	172.3	14.4
1960	14.0	18.4	15.3	16.6	16.5	15.2	12.9	10.4	17.4	12.3	15.7	15.3	180.0	15.0
1961	17.0	16.8	15.8	15.7	17.1	14.2	12.6	10.7	15.4	16.1	16.7	17.3	185.4	15.4
Average	14.9	16.3	16.6	16.5	16.4	14.1	12.6	10.7	16.4	13.9	15.3	15.5	179.2	-
ASOSA, ETHIOPIA														
1960									19.3		19.5	14.3		
1961	25.2	20.8	26.8						17.6	19.8	11.4			
1962				21.3	21.6	16.6	14.5				12.1	17.4		
1963	20.9	20.0	25.8	17.2	14.2	15.6	14.2	11.8	14.0	12.8				
Average	23.0	20.4	26.3	19.2	17.9	16.1	14.4	11.8	17.0	16.3	14.3	15.8	212.5	-
BAHIR DAR, ETHIOPIA														
1960	14.8	16.0			20.4	10.8	21.9*	34.2*	17.3					
1961	15.1	14.0	21.4	24.9	21.9	10.8	33.5*	26.4*	14.6	18.1	15.1	13.3	229.1	
1962			22.0	24.7	21.8									
1963	13.7	16.0	21.4	19.9	18.3	10.8	14.1							
Average	14.5	15.3	21.6	23.2	20.6	10.8	23.2	30.3	16.0	18.1	15.1	13.3	222.0	-
WAD MEDANI, SUDAN														
1959	29.4	32.3	43.7	47.0	50.2	45.6	31.0	25.9	18.9	26.0	29.4	25.4	404.8	33.7
1960	27.6	30.2	40.0	45.4	50.8	47.1	33.5	24.1	29.4	29.4	33.0	28.2	418.7	34.9
Average	28.5	31.2	41.8	46.2	50.5	46.4	32.2	25.0	24.2	27.7	31.2	26.8	411.7	-
WONJI SUGAR PLANTATION, ETHIOPIA														
1959	22.5	22.4	28.6	32.2	29.8	26.9	20.0	17.0	15.9	22.2	24.6	22.2	284.3	23.7
1960	24.3	27.9	21.0	24.8	23.9	27.8	18.8	17.4	16.0	23.9	23.6	24.5	273.9	22.8
1961	25.0	26.6	27.8	23.7	28.6	24.8	18.9	15.2	17.2	20.3	17.8	15.2	261.1	21.8
1962	22.4	23.6	24.1	25.9	27.2	23.9	19.3	17.6	17.8	23.6	22.0	24.3	271.7	22.6
1963	23.7	25.6	31.1	18.4	19.6	21.2	17.5							
Average	23.5	25.2	26.5	25.0	25.8	24.9	18.9	16.8	16.7	22.5	22.0	21.6	269.4	-

* observations doubtful

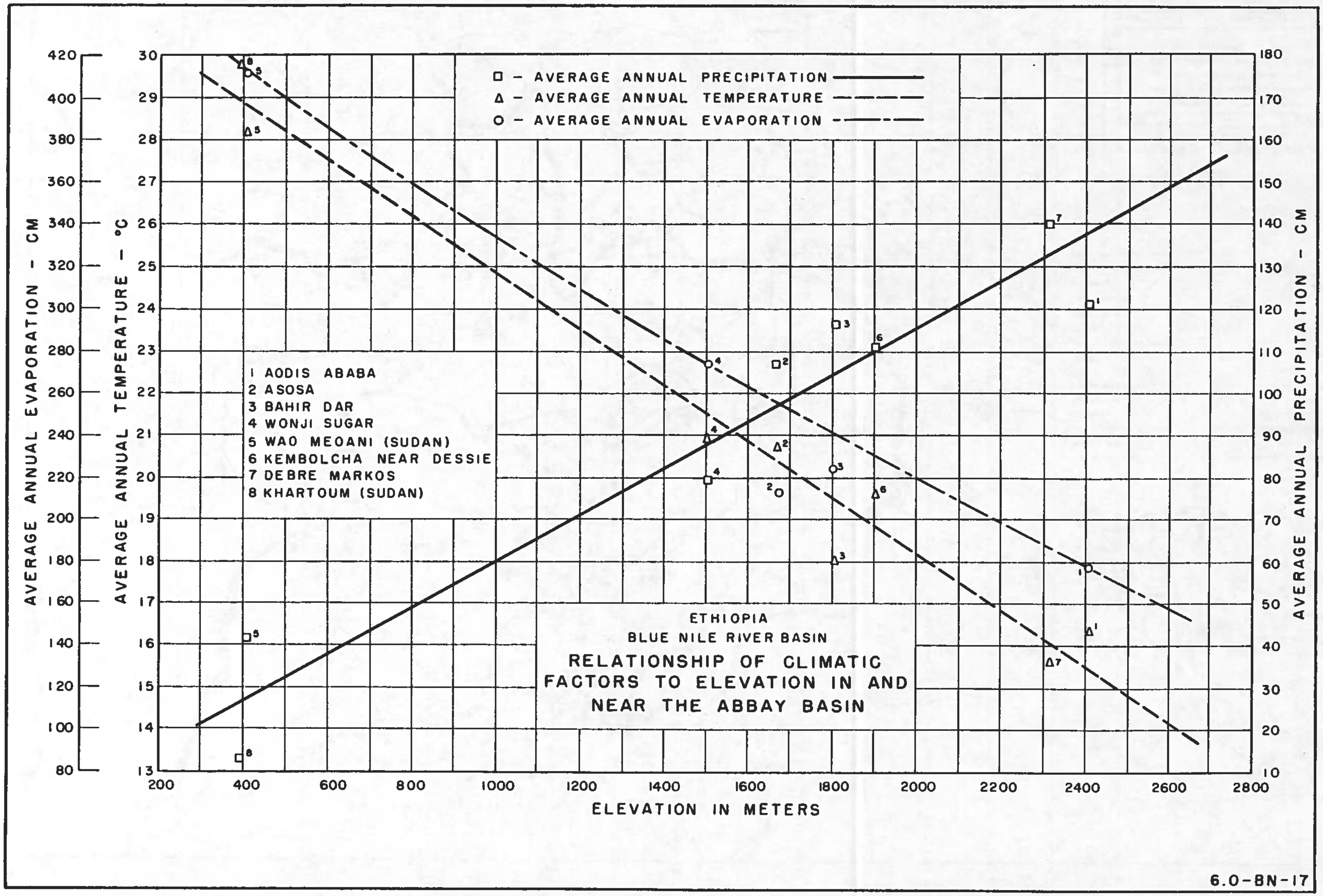


Figure III-7--Relationship of Climate Factors to Elevation and near the Abbay Basin

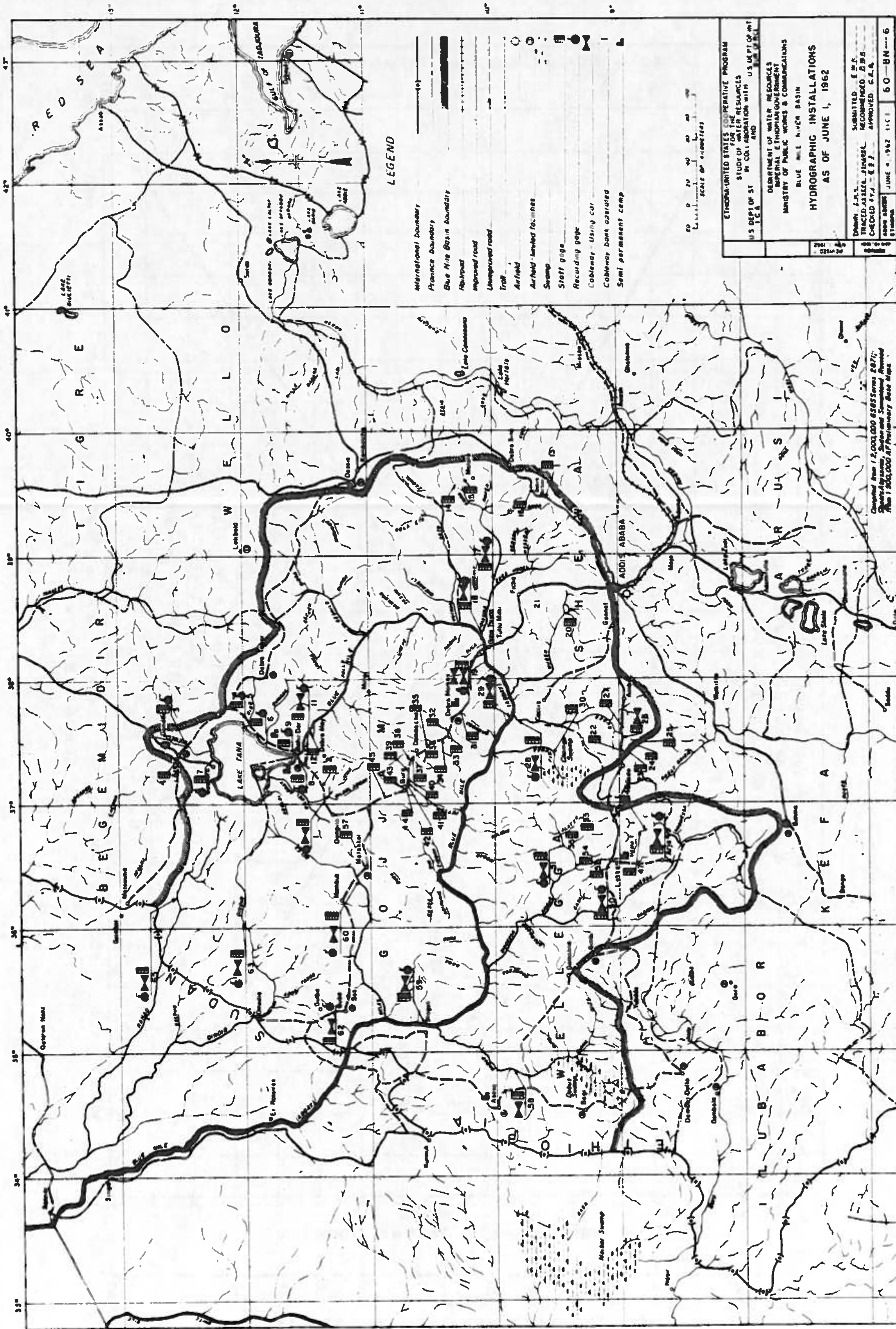


Figure III-8--Hydrographic Installations as of June 1, 1962

c. Sulfate (SO_4)

d. Chloride (Cl)

e. Nitrate (NO_3)

f. Fluoride (F)

6. Boron (B) in p.p.m.

Results of the analyses are shown in Table III-4 and are illustrated by Figure III-9.

Each of the samples shows a very low (negligible) sodium (alkali) hazard; and most show low to medium salinity hazard. Samples contained from none to a maximum of 0.2 p.p.m. of boron, which would be tolerated by the most sensitive crops.

The samples showing the highest salinity were taken from the Muger (Station 21) and Dindir (Station 63) Rivers. Sampling on the Muger was initiated when project geologists advised that, due to the presence of shale and gypsum, adverse samples would be found there if any were to be obtained in significant flows in the Abbay Basin. The Dindir sample showing high salinity hazard is not considered representative as it was taken from a pothole at zero flow. A subsequent sample taken at moderate flow (40 cu.m. per sec., July 15, 1962) had a conductivity of 167 micromhos (low salinity hazard), contained only 114 p.p.m. of dissolved solids, and had a sodium-absorption ratio of 0.135. All significant flows in the Dindir are expected to reflect the excellent quality of this 1962 sample.

Sedimentation

A high percentage of the sediment transported by a stream is retained in any storage reservoir through which the flow must pass. During the life of a project, this sediment often fills a considerable portion of a reservoir, and the loss of capacity must be taken into account when planning capacities and resultant yields from the reservoir. Since the period of analysis for irrigation projects in this investigation is 50 years, the amount of sediment deposited in each reservoir during a 50-year period has been estimated and then deducted from the original reservoir capacity to obtain the capacity used in operation studies. Therefore, yields shown in the studies can be maintained to the end of the 50-year period.

Sediment is transported by streams primarily in suspension and secondarily by traction (being rolled or pushed along the bed of the stream). The sediment in suspension was sampled, using sediment samplers that procure approximately 400 ml. of water and sediment in a bottle while being lowered from the surface to the bottom and then raised back to the surface again.1/ Normally, sampling was done in the center of a stream and at the two quarter points. The contents of the three bottles were then composited and analyzed by the Imperial Ethiopian Government Highway Authority Laboratory to determine the percentage of sediment and its gradation. Approximately 56 of these composite suspended sediment samples from 20 gaging stations were obtained and analyzed during 1960 and 1961. The analyses for size gradation were made by the hydrometric method, although materials were generally too fine for proper use of the method. The bottom withdrawal method of analysis would have been preferable, but equipment was not available. Results of each analysis were included in the Abbay Basin Hydrologic Summary 1961, Ethiopia-United States Cooperative Program for Water Resources.

The traction (bedload) sediment is much more difficult and expensive to sample directly, and such sampling was not done during this reconnaissance investigation. Instead, data

1/Recommended Procedures for Sediment Observations, Sedimentation Section, Hydrology Branch, Project Planning Division, Bureau of Reclamation, Denver, Colorado, January 1952. The samplers used were: United States 'D-47' 100-pound depth-integrating sampler, adapted for use in streams up to 39 feet in depth and with high velocities; and United States 'HD-48' 15-pound depth-integrating wading sampler, adapted for use in shallow streams which can be waded.

TABLE III-4--SUMMARY OF REPORTS ON QUALITY OF WATER ANALYSES

Date da/mo/yr	Station location	Sta. No.	Gage height (m.)	Conductance EC(10)⁶ at 25° C.	pH	SAR a/	TDS	B	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	SiO_2
18/2/60	Abbay nr Kese	19	1.30	125 f/	7.4	0.388	126	0	26	5	8	T	-	100	0	T	0	-
26/7/61	Abbay nr Kese	19	-	200 f/	7.9	0.137	194	T	21.2	9	3	1.3	0	122	T	3.55	1.72	T
4/8/61	Abbay nr Kese	19	-	242 f/	8.2	0.190	118	T	28	3.5	4	1.8	0	110	0	3.55	0.57	T
19/2/60	Muger nr Chancho	20	0.43	175 f/	7.3	0.43	192	0	25	5	9	T	-	105	0	T	0	-
3/8/60	Muger at Corra Corri-Manare crossing	21	-	460 e/	7.7	0.20	300	0	44	T	7	2	-	200	0	T	0	-
6/10/60	Muger at Corra Corri-Manare crossing	21	-	320 e/	7.15	0.164	208	0	30	2.43	5	T	-	170	0	T	0	10
28/12/60	Muger at Corra Corri-Manare crossing	21	-	800 e/	7.8	0.275	519	0.2	100.8	26.24	12	2.5	-	152	235	T	0	-
14/1/60	Jibat nr Guder	22	0.43	101	7.7	0	32	0.2	13	3	T	2	-	34	0	0	0	20
14/1/60	Bello nr Guder	23	0.64	82	7.7	0	36	0	15	4	T	2.5	-	45	0	0	0	20
14/1/60	Fato nr Guder	24	0.40	101	7.6	0	88	0	1.5	3	T	3.5	-	35	0	0	0	20
14/1/60	Melke nr Guder	25	0.35	104	7.7	0	64	0.1	15	4	T	4	-	36	0	0	0	24
16/2/60	Guder at Guder	26	0.55	105 f/	7.15	0.457	126	0	25	5	10	45	-	80	0	T	0	-
15/9/61	Diddessa nr Arjo	49	-	88 f/	6.9	0.163	112	0.05	5.2	3.16	1.9	1.0	0	54.9	0	T	0	-
20/3/61	Beles nr Metekkel	60	-	369 e/	8.2	0.302	240	0.1	40	21	9.5	2	0	305	0	T	0	-
20/3/61	Dindir nr Abu Mendi	63	-	846 e/	8.7	1.36	550	0	28	58.32	55	4.2	60	366	0	0	0	-
25/2/61	Spring nr Finote Selam	410	-	166 e/	7.0	0.377	108	0.2	14	7.29	7	2.66	0	122	0	T	0	-
11/2/61	Spring nr Jiga	371	-	311 e/	7.6	0.231	202	0.3	26.8	14.82	6	1.33	0	183	0	0	0	-
20/2/61	Spring nr Jiga	371	-	311 e/	7.2	0.225	202	0.2	28.8	15.3	6	1.33	0	183	0	T	0	-
21/12/61	Lake Tana nr Zege Peninsula	LT-2	-	145	8.4	0.439	94	0	16	6.32	8.2	17.6	6	134.2	0	T	0	0
21/12/61	Lake Tana at south end Kibran Island	LT-1	-	163	8.5	0.483	106	0	15.2	6.56	8.6	18.4	6	97.6	0	T	0	0
15/7/62	Dindir nr Abu Mendi	63	1.0	167		0.135	114	-	-	-	-	-	-	-	-	-	-	-

a/ Sodium-absorption ratio = $\dfrac{\text{epm Na}}{\sqrt{\dfrac{\text{epm (Ca + Mg)}}{2}}}$ See USGS W.S.P. 1454, page 80 and page 265.

e/ Conductance estimated as $\dfrac{\text{T. D. S.}}{0.65}$

f/ Measured conductance adjusted upward 2 percent (2%) for each degree temperature at time of analysis fell below 25° C.

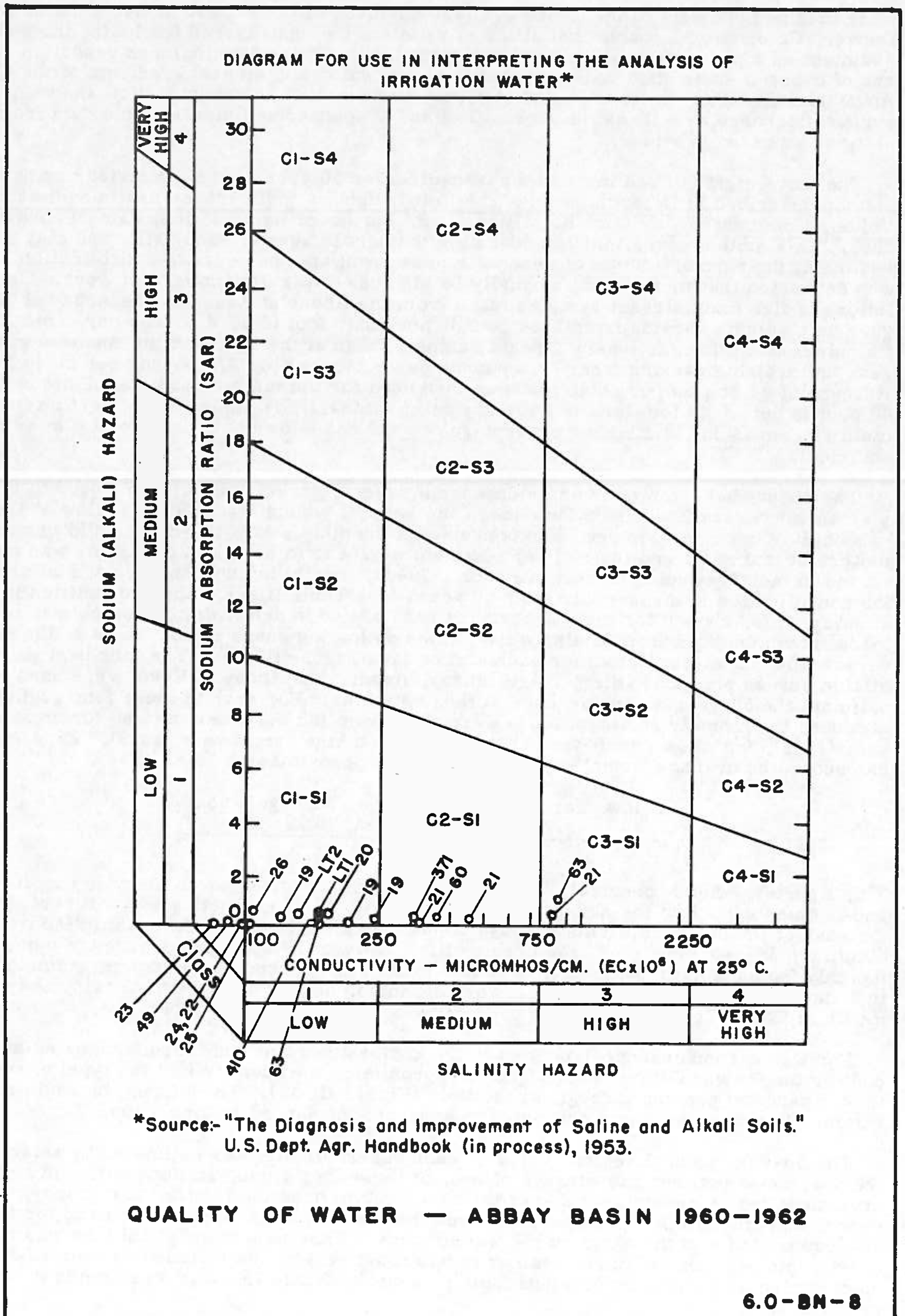


Figure III-9--Quality of Water--Abbay Basin were obtained and sent to the Office of Chief Engineer of the Bureau of Reclamation in Denver, Colorado, to enable that office to estimate the unmeasured (including the bedload) sediment as a percentage of the total sediment load. These data included gradation analyses of exposed streambed sediments taken at low water and stream gradients at the Gilgel Abbay and the Abbay at Kese gaging stations. Information on cross section and velocity versus discharge as well as the streamflow and suspended sediment sample data from these stations was also provided.

The unit weights of sediment in a reservoir after 50 years were estimated, using the method described in Determination of the Unit Weight of Sediment for use in Sediment Volume Computations by Carl R. Miller, U.S. Bureau of Reclamation, dated February 17, 1953. This method takes into consideration the percentages of sand, silt, and clay in the sediment; the normal amount of reservoir drawdown; and the years of consolidation. It was estimated that there would normally be high reservoir drawdown each year. Calculations of five main stream samples taken from the Abbay at Kese and the Abbay at Shogali gave unit weights varying from 81.6 pounds per cubic foot to 86.4 pounds per cubic foot. Calculations on three tributary stream samples taken at the Birr and the Andassa gages gave unit weights varying from 76.5 pounds per cubic foot to 83.0 pounds per cubic foot. A figure of 84 pounds per cubic foot was then used for the main stream calculations and 80 pounds per cubic foot for the tributary calculations. The higher unit weight on the main stream is due to a higher percentage of sand and a lower percentage of clay in the sediment.

The suspended sediment sample data from several gaging stations were used to prepare a sediment versus flow curve for each of the several gaging stations. The flow at the time of sampling in cu.m. per sec. was converted to monthly runoff (30-day month) in cubic meters at that rate, and the ratio of sediment weight to total weight of sample was converted to monthly sediment load (also for a 30-day month) in cubic meters and adjusted for consolidation in a reservoir after 50 years (see Table III-5). These quantities in monthly units, chosen for their subsequent ease of use in determining monthly sediment loads from monthly runoff totals, were plotted on log log graph paper, and a sediment versus flow curve was drawn for each station (see Figure III-10). The four best gaging station curves produced (Birr, Gilgel Abbay, Angar, and Abbay at Kese) were used to estimate the 50-year sediment loads at these stations. For each of these four gaging stations, the monthly sediment loads were read from the curve and totaled for an average year (1932), for a low runoff year (1913), and for a high runoff year (1929). Experience has shown the average annual sediment load will approximate:

$$\frac{1\text{ (low year load)} + 2\text{ (average runoff year load)} + 1\text{ (high year load)}}{4}$$

This figure is often appreciably higher than the sediment load for an average runoff year and is close enough to the actual average figure to obviate computing the sediment totals for each of the 50 years. This average annual sediment load was then multiplied by 50 to obtain the 50-year sediment load (Tables III-6 through III-9). The adequacy of using monthly increments in computing sediment loads was checked by computing sediment loads in 5-day increments for an extremely erratic month of flow and a normal rainy season month of flow. The difference (±3 percent) was judged to be negligible.

For this reconnaissance-type survey the unmeasured sediment load (estimated at 3 percent by the Denver Office) was judged to approximate the quantity (not the type) of sediment (2 to 6 percent) passing through a reservoir (Figure III-11). Therefore, the sediment retained in a reservoir was estimated to equal the suspended sediment load.

The 50-year natural sediment flow at each reservoir site was estimated by selecting the one, or sometimes the average of two, of these four gaging stations with a drainage area most nearly resembling that of the reservoir in question in size, topography, vegetation, and elevation. It was assumed then that the sediment versus flow ratio for the 50-year period was the same on the two streams. This natural sediment flow was modified to take into account sediment retained in upstream reservoirs included in the initial development plan as well as any downstream "pick-up." (Table III-10 is an example of this procedure.)

TABLE III-5.--COMPUTATION OF RELATION OF VOLUME OF DEPOSITED SEDIMENT TO VOLUME OF FLOW BY GAGING STATION AND DATE OF SAMPLING

River	Date (da/mo/yr)	Weight of sediment (gm.)	Sedi-ment by weight (percent)	Total weight of sample (gm.)	Gage height (m.)	Flow (cu. m. per sec.)	Monthly[1/] runoff at flow sampled (million cu. m.)	Unit weight at 50 yr. (lbs. per cu. ft.)	Monthly[1/] sed. load at flow sampled (million cu. m.)
Birr	13/9/60	0.519	-	1,225.39	-	40.0	105	80	0.0346
	30/6/61	8.5442	-	842.18	-	7.21	18.7	80	0.149
	28/7/61	1.4321	-	789.72	-	133.3	345	80	0.493
	30/9/61	0.4976	-	918.70	-	18.15	47.0	80	0.0204
Gilgel Abbay	9/5/61	0.10	-	648.15	-	1.77	4.58	80	0.000557
	5/7/61	0.5018	-	1,185.28	-	42.1	109	80	0.0364
	12/8/61	1.5834	-	916.92	-	180.2	467	80	0.635
	23/9/61	0.9518	-	1,071.25	-	159.1	412	80	0.289
	7/10/61	0.80	-	1,153.98	-	94.0	243	80	0.133
	8/11/61	0.25	-	1,123.98	-	21.1	54.6	80	0.00957
Abbay (Kese)	17/6/60	1.3462	-	1,213.09	0.65	33.0	85.5	84	0.0711
	13/7/60	8.1931	-	1,260.45	2.00	276	715	84	3.48
	2/8/60	5.7488	-	1,348.02	-	1,587	4,110	84	13.13
	30/8/60	3.7027	-	1,039.21	-	2,013	5,220	84	13.9
	30/9/60	0.4160	-	1,012.35	-	767	1,990	84	0.611
	4/4/61	4.5280	-	976.62	-	112	290	84	1.07
	11/7/61	17.0887	-	915.95	4.0	1,100	2,850	84	39.7
Abbay (Sudan border)	28/3/61	0.235	-	919.30	-	230	596	84	0.114
	29/6/61	8.05	-	1,238.24	-	1,359	3,540	84	17.1
	27/7/61	19.85	-	1,079.64	8.10	6,340	16,400	84	226
	29/8/61	12.40	-	1,128.72	9.18	7,661	19,800	84	163
	28/9/61	6.60	-	1,088.67	-	4,348	11,300	84	51.1
Andassa	13/7/61	17.1554	-	1,143.5	1.68	21.94	56.8	80	0.672
	7/8/61	3.5688	-	1,134.31	2.00	36.60	94.8	80	0.235
	27/10/61	0.30	-	1,078.40	1.00	6.37	16.5	80	0.00362
	6/12/61	0.40	-	1,098.35	1.10	6.37	16.5	80	0.00473
Angar	8/6/60	-	0.0089	-	-	13.3	34.5	80	0.00242
	8/7/60	-	0.046	-	-	75.4	195	80	0.0707
	20/8/60	-	0.0304	-	-	223	578	80	0.138
	25/11/60	-	0.0313	-	-	32.9	85.2	80	0.0210
	1/7/61	-	0.0282	-	-	92.4	239	80	0.0532
	27/7/61	-	0.162	-	-	221	572	80	0.730
	2/10/61	-	0.0587	-	-	330	855	80	0.395

1/ One cu. m. per sec. will produce 60 x 60 x 24 x 30 = 2.59 million cu. m. in a 30-day month. Each percent of sediment in the total flow by weight will produce 20,400 cu. m. in a 30-day month at a constant flow of 1 cu. m. per sec. (assuming 80 lbs. per cu. ft. in place) or 19,400 cu. m. (84 lbs. per cu. ft. in place).

If the flow has 2% sediment by weight (near the upper limit) the Sp.G. of the total flow approximates 1.01--close enough to 1.00 to obviate making a correction for Sp.G.

TABLE III-6 - SEDIMENT COMPUTATIONS - ABBAY (KESE) AT GAGE

Year	All quantities in million cubic meters							7-month total
	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	
1929 (High)								
Flow at gage	1,150	3,048	9,700	6,110	2,735	895	527	
Sediment at gage	3	18	135	61	15	2	1	235
1932 (Average)								
Flow at gage	425	1,240	5,480	5,040	1,980	624	345	
Sediment at gage	1	4	50	44	9	1	0	109
1913 (Low)								
Flow at gage	120	645	1,835	1,690	600	205	95	
Sediment at gage	0	1	8	7	1	0	0	17

$$\text{Average yearly sediment flow} = \frac{235 + 2\,(109) + 17}{4}$$

$$= 118 \text{ million cu. m.}$$

Average yearly runoff (water and sediment) = 15,900 million cu. m.

Percentage of sediment = 0.74 percent

50-year sediment load = 5,900 million cu. m.

TABLE III-7 - SEDIMENT COMPUTATIONS - GILGEL ABBAY AT GAGE

Year	All quantities in million cubic meters							6-month total
	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	
1929 (High)								
Flow and gage	122	324	1,030	650	290	95	-	
Sediment at gage	0.05	0.20	1.13	0.56	0.18	0.03	-	2.15
1932 (Average)								
Flow at gage	45	132	582	537	210	66	-	
Sediment at gage	0.01	0.06	0.48	0.43	0.19	0.03	-	1.20
1913 (Low)								
Flow at gage	13	69	195	179	64	22	-	
Sediment at gage	0	0.02	0.10	0.09	0.02	0	-	0.23

$$\text{Average yearly sediment flow} = \frac{2.15 + 2\,(1.20) + 0.23}{4}$$

$$= 1.19 \text{ million cu. m.}$$

Average yearly runoff (water and sediment) = 1,496 million cu. m.

Percentage of sediment = 0.080 percent

50-year sediment load = 59.5 million cu. m.

TABLE III-8--SEDIMENT COMPUTATIONS--BIRR AT GAGE

Year	All quantities in million cubic meters							4-month total
	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	
1929 (High)								
Flow at gage	-	80	484	241	67	-	-	
Sediment at gage	-	0.035	1.15	0.30	0.025	-	-	1.510
1932 (Average)								
Flow at gage	-	19	203	178	40	-	-	
Sediment at gage	-	0.002	0.21	0.165	0.009	-	-	0.386
1913 (Low)								
Flow at gage	-	6	35	31	6	-	-	
Sediment at gage	-	0.001	0.007	0.006	0.001	-	-	0.015

Average yearly sediment flow $= \frac{1.510 + 2\ (0.386) + 0.015}{4}$

= 0.574 million cu. m.

Average yearly runoff (water and sediment) = 486.6 million cu. m.

Percentage of sediment = 0.12 percent

50-year sediment load = 28.7 million cu. m.

TABLE III-9--SEDIMENT COMPUTATIONS--ANGAR AT GAGE

Year	All quantities in million cubic meters							7-month total
	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	
1929 (High)								
Flow at gage	207	543	950	817	489	163	98	
Sediment at gage	0.07	0.32	0.77	0.63	0.27	0.05	0.02	2.13
1932 (Average)								
Flow at gage	79	311	788	763	354	115	64	
Sediment at gage	0.02	0.13	0.57	0.55	0.16	0.03	0.01	1.47
1913 (Low)								
Flow at gage	25	118	329	303	110	41	21	
Sediment at gage	0	0.03	0.14	0.13	0.03	0.01	0	0.34

Average yearly sediment flow $= \frac{2.13 + 2\ (1.47) + 0.34}{4}$

= 1.35 million cu. m.

Average yearly runoff (water and sediment) = 2,452 million cu. m.

Percentage of sediment = 0.055 percent

50-year sediment load = 67.5 million cu. m.

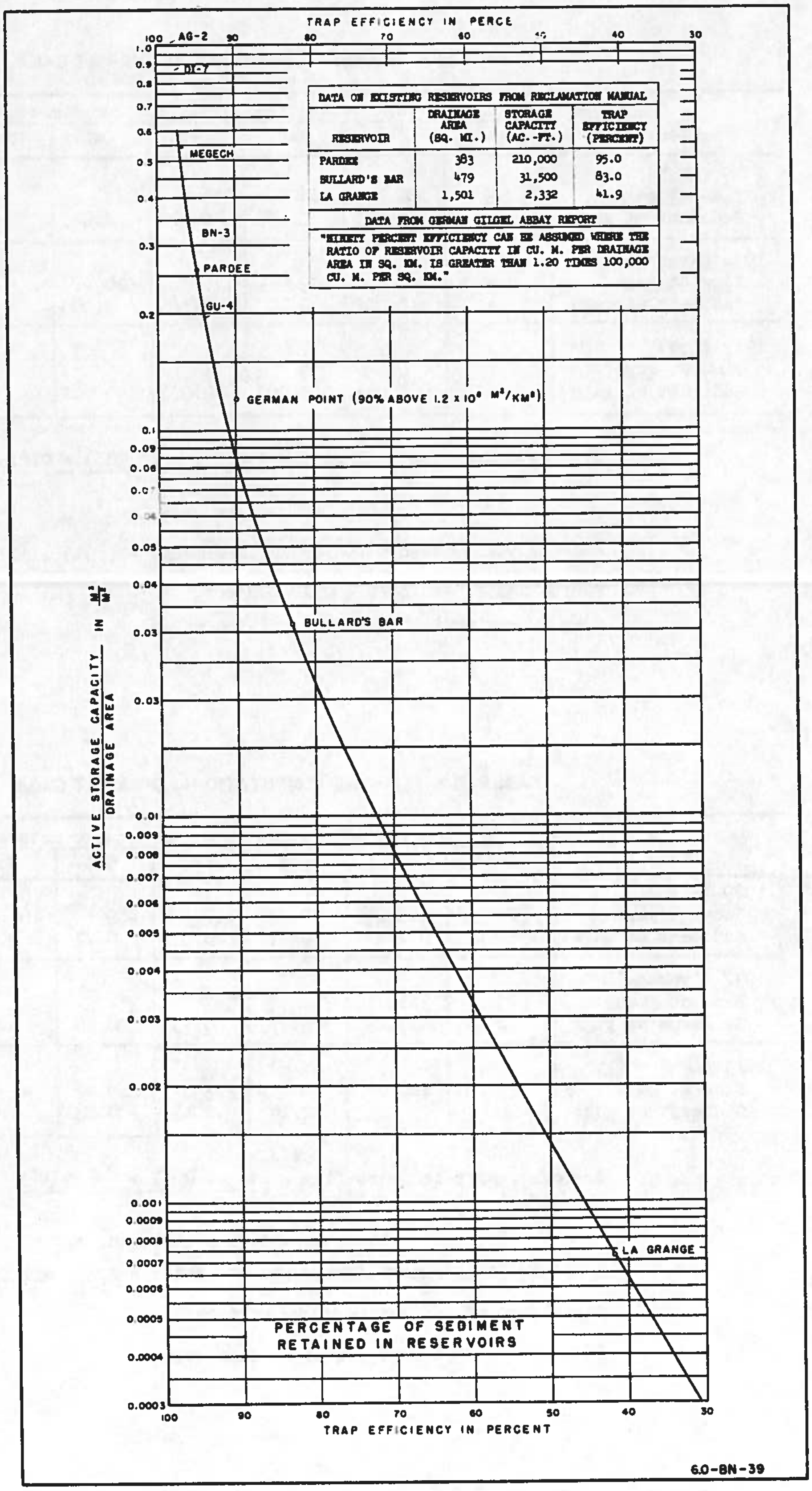


Figure III-11--Percentage of Sediment Retained in Reservoirs

TABLE III-10--SEDIMENT ESTIMATE--DINDIR (DI-2) RESERVOIR

Assumptions

1. The natural 50-year sediment inflow to DI-2 will have a sediment-to-flow ratio between that of the Gilgel Abbay at the gage and that of the Abbay at Kese.

2. The natural sediment inflow will be modified by the amount retained by the DI-7 reservoir upstream.

50-year sediment inflow

Gilgel Abbay at gage	= 59.5 million cu. m.
Abbay at Kese	= 5,900 million cu. m.
Dindir at DI-7	= 243 million cu. m.

Average yearly discharge, water

Gilgel Abbay at gage	= 1,496 million cu. m.
Abbay at Kese	= 15,900 million cu. m.
Dindir at DI-2	= 1,986 million cu. m.

50-year natural sediment inflow at DI-2

$$= \frac{1{,}986 \times 10^6}{2}\left(\frac{59.5 \times 10^6}{1{,}496} + \frac{5{,}900 \times 10^6}{15{,}900}\right)$$

= 408 million cu. m.

minus 50-year DI-7 sediment -243 million cu. m.

50-year modified sediment inflow at DI-2 = 165 million cu. m.

The operation studies on many of the upstream reservoirs were performed assuming the 50-year sediment quantity in the bottom of the reservoir. In others (including the four main stem reservoirs), the 50-year modified sediment quantities were distributed and the 100-year sediment elevation at the dam was determined before the operation studies were performed. In all cases before making project feature layouts, sediment distribution was estimated according to the Revision of the Procedure to Compute Sediment Distribution in Large Reservoirs by the Sediment Section, Hydrology Branch, Chief Engineer's Office, U.S. Bureau of Reclamation, dated May 1962.

The procedure consisted of (1) determining the reservoir type, (2) determining the depth of sediment deposited at the dam after 50 and 100 years, (3) distributing the 50-year sediment quantity, and (4) adding the 50-year area and capacity curves to the original area-capacity curve figures.

The sediment samples obtained at the relatively few locations in the Blue Nile Basin show that the sediment versus flow ratio varies between wide limits. Because the sediment load will materially influence the size of reservoirs required to produce a given annual yield, it will be very important to obtain sediment samples throughout at least 1 year at each damsite before final planning and design are done.

Table III-11 lists the 50-year sediment quantities and 100-year sediment elevations at the dam for the reservoirs included in the initial development plan.

TABLE III-11--SUMMARY OF RESERVOIR SEDIMENTATION

Reservoir	Key sediment station correlated with	50-year natural sediment quantity ($m^3 \times 10^6$)	50-year modified sediment quantity ($m^3 \times 10^6$)	100-year sediment elevation at dam (meters)
Amarti-Neshe	Birr	21	Unmodified	2184.3*
Angar	Angar	46	Unmodified	1350.8
Bello	Birr	11.2	Unmodified	2419.4
Boo	Angar, Kese	900	781	999.6
Border	Kese	19,270	4,671	562.5
Chancho	Birr	8.9	Unmodified	2538.5
Dabana	Gilgel	59	Unmodified	1294.8
Dangur	Gilgel, Kese	449	Unmodified	767.7
Debohila	Birr	1.1	Unmodified	1975.6
Diddessa	Gilgel	60	Unmodified	1359.0
Dindir	Gilgel, Kese	408	165	731.0
Finchaa	Birr	33	Unmodified	2208.8
Galegu	Gilgel, Kese	51	Unmodified	748.2
Giamma	Kese	521	Unmodified	1303.7
Gumara	Gilgel	9.4	Unmodified	1895.2
Junction	Gilgel, Kese	243	Unmodified	923.0
Karadobi	Kese	6,570	6,040	1034.5
Lake Tana	Gilgel	204	124	**
Lekkemt	Angar	70	28	1278.8
Mabil	Kese	9,900	2,729	839.4
Megech	Gilgel	3.2	Unmodified	1875.0
Mendaia	Kese	15,722	4,772	685.2
Motto	Kese	548	537	1317.1
Rahad	Gilgel, Kese	302	Unmodified	843.9
Ribb	Gilgel	10.6	Unmodified	1869.3
Upper Birr	Birr	18.5	Unmodified	1883.8

* One hundred-year sediment elevation in table is for Neshe side of reservoir, elevation at Amarti dam will be 2228.6 meters.

** Sediment will not reach dam.

Irrigation Requirement

CONSUMPTIVE USE

The consumptive use of crops was estimated employing the Blaney-Criddle procedure and formula. The formula is U = k(tp),

where U = monthly consumptive use (evaporatranspiration)
k = empirical coefficient for crop
t = mean monthly temperature
p = monthly percentage of daylight hours of the year for latitude in which crop is grown.

In a 4-day conference in Nairobi, Kenya, in 1961, between Wayne D. Criddle (coauthor of the Blaney-Criddle formula) and Ronald R. Pannell, Civil Engineering Advisor, USAID, Ethiopia, the probability that all known factors in the formula would be obtainable was established.

The Scott's Laboratory, which has been doing agriculture research for the past 15 years, has through laboratory and field tests confirmed that the Blaney-Criddle formula is as accurate as any of the various methods for calculating consumptive use they have found. It has been found that the formula is conservative and the engineer is on the safe side when he uses this method for determining diversion requirements. Scotts maintain an experimental farm at Thompson's Falls, Kenya, approximately 4 miles north of the equator. During the past 10 years they have experimented with consumptive use factors. Table III-12 shows the normal consumptive coefficient for crops grown on the experimental farm. Elevation of the farm is approximately 1830 meters. The emphasis placed on adequate cropping patterns by the laboratory is essential where effective use of rainfall is to be considered.

From the Thompson's Falls data, Mr. Criddle estimated k factors in the Blue Nile Basin as follows:

Area	Crop	k factor
Ambo	Grapes	0.50
	Fruit trees	0.65
	Cereals and grasses	0.75
	Oil seeds	0.70
Lekkemt	Coffee	0.75
	Citrus fruit	0.60
	Tobacco	0.75
	Peanuts	0.75
Dangila	Cereals	0.75
	Forage crops	0.85
	Oil seeds	0.70
Galabat	Cotton	0.70
	Vegetables	0.65
	Cereals	0.75
	Sugar cane	0.90
	Sorghum	0.70
	Safflower	0.70

Considering the amount of water to be allowed for waste and losses, and considering the degree to which the crops and cropping patterns to be grown on contemplated projects is unknown, an average k factor of 0.715 and an irrigation season of October 1 through May 31, were adopted for all projects. This k factor was derived from application of k factors to crops expected to be grown in Guder and Birr Project service areas as follows:

TABLE III-12.-NORMAL CONSUMPTIVE USE COEFFICIENTS FOR THE MORE IMPORTANT IRRIGATED CROPS

Crop	Length of growing season	k factor
Alfalfa	Frost-free	0.85
Beans	3 months	0.65
Corn	4 months	0.75
Coffee	All year	0.75
Cotton	7 months	0.70
Citrus orchards	All year	0.55 - 0.60
Deciduous orchards	All year	0.65
Grapes	Frost-free	0.50 - 0.55
Pasture--grass, hay, annuals	Frost-free	0.75
Potatoes	3 months	0.70
Rice	3 - 4 months	1.00 - 1.10
Sisal	All year	0.70
Small grains	3 months	0.75
Sorghum	5 months	0.70
Sugar beets	5-1/2 months	0.70
Sugar cane	All year	0.90
Tobacco	4 months	0.75
Oil seeds	3 - 4-1/2 months	0.65 - 0.75
Onions	4 months	0.80

(Taken from data from experimental farm, Scott's Laboratory, Thompson's Falls, Kenya.)

Area	Crop	Percent net irrigated	k factor	Percent x k
Ambo	Noog	10	0.70	7.00
	Corn	15	0.75	11.25
	Sorghum	20	0.70	14.00
	Barley	10	0.75	7.50
	Wheat	10	0.75	7.50
	Castor beans	15	0.70	10.50
	Sunflowers	15	0.70	10.50
	(Fallow	5)		
				68.25 ÷ 95 = 0.718 (Ave. k)
Birr	Barley	10	0.75	7.50
	Noog	15	0.70	10.50
	Corn	20	0.75	15.00
	Peppers	15	0.65	9.75
	Castor beans	15	0.70	10.50
	Sunflowers	10	0.70	7.00
	Coffee	10	0.75	7.50
	(Fallow	5)		
				67.75 ÷ 95 = 0.713 (Ave. k)

Some crops will not require the long (October through May) growing season, but it is anticipated that, since temperatures are almost constant from month to month, new crops may be planted as soon as one is harvested. Present practice in Ethiopia is to utilize the June through September rains as fully as possible by planting a crop as soon as the "little" rains of April and May make the soil sufficiently moist. On some of the dark clay soils, it may be desirable to stay off the land during the rainy season, after project irrigation water is made available. However, from a water supply standpoint, it was unnecessary to decide whether there would or would not be cropping during the rainy season. During the June through September period, rainfall is everywhere adequate to meet the requirements, if cropping is continued. It therefore will not require any additional water to continue the cropping--only the economic budgets will be affected.

A monthly percent of daytime chart for latitude 0° to 22° north is contained in Table III-13.

FARM EFFICIENCY AND OPERATIONAL WASTES

To help estimate farm efficiency and operational waste as well as to obtain general information on irrigation practices and procedures, three existing irrigation projects were visited by Blue Nile Project personnel and are discussed below. Because of the high cost of storing water on the service areas, as discussed under canal design, a decision was reached early in the survey that studies should assume 24-hour irrigation operations. It is not known how such a change from present practices of irrigation only during daylight hours would affect farm losses or canal operational wastes on the existing projects where reported deliveries are available. The following information from these projects, therefore, provides only a rough check on applicability of the accompanying Blaney-Criddle estimates of diversion requirement to the project areas.

Wonji Estate

The Wonji Estate is a sugarcane plantation located in the Awash River Basin 90 kilometers southeast of Addis Ababa at an elevation of 1580 meters.

TABLE III-13--MONTHLY PERCENTAGES OF DAYTIME HOURS OF THE YEAR FOR LATITUDES 0° TO 22° NORTH OF THE EQUATOR

Lat. (°N)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
22	7.76	7.22	8.41	8.57	9.22	9.12	9.31	9.00	8.30	8.13	7.50	7.56
20	7.83	7.26	8.20	8.52	9.14	9.02	9.25	8.95	8.30	8.19	7.58	7.88
18	7.88	7.26	8.40	8.46	9.06	8.99	9.20	8.81	8.29	8.24	7.67	7.89
16	7.94	7.30	8.42	8.45	8.98	8.98	9.07	8.80	8.28	8.24	7.72	7.90
14	8.03	7.39	8.43	8.44	8.90	8.73	8.99	8.79	8.28	6.28	7.85	8.04
12	8.08	7.40	8.44	8.43	8.84	8.64	8.90	8.78	8.27	8.28	7.85	8.05
10	8.11	7.40	8.41	8.43	8.81	8.57	8.84	8.74	8.26	8.29	7.89	8.08
8	8.13	7.41	8.45	8.39	8.75	8.51	8.77	8.70	8.25	8.31	7.89	8.11
6	8.19	7.49	8.45	8.39	8.73	8.45	8.75	8.69	8.25	8.41	7.95	8.19
4	8.20	7.58	8.46	8.33	8.65	8.40	8.67	8.63	8.21	8.43	7.95	8.20
2	8.43	7.62	8.47	8.22	8.51	8.25	8.52	8.50	8.20	8.45	8.16	8.42
0	8.49	7.67	8.49	8.22	8.49	8.22	8.49	8.49	8.19	8.49	8.22	8.49

*Taken from Smithsonion Meteorological Tables, Table 171, 1951.

System of Irrigation. Irrigation was initially carried out on a 24-hour basis. The results were so disappointing in terms of water wastage, inefficient application, over-irrigation, and breaking or overtopping of sections of ditches and field boundaries that night irrigation was abandoned. Wonji has converted to daylight irrigation, and by establishing two internal storage lakes of 12- and 25-hectare size, they are able to begin daily turnout of water about 6 a.m. each day. The larger storage lake has an average depth of about 1 meter. Use of this system permits a full day's irrigation, whereas in previous times as much as 4 hours were involved in filling the canals and getting water to remote areas of the estate.

Row irrigation is used almost exclusively, although some tests have been made on basin-type irrigation. Length of irrigation run varies from 10 to 30 meters with most of the older cane rows and the majority of the new ones being of 10-meter length. Water is turned into these short runs 8 rows at a time. It may take as long as a half hour to fill up the 8 rows in brown soil. This is for new plantings. The rows are then plugged and another set is made. Supervisors expect eventually to extend the length of run to 50 meters, but they are not hopeful of achieving this for some years. In older cane plantings, as many as 14 rows may be served at one time. Since their growth is extremely dense, water is turned into the row and when it reaches the end of the row another set is made. There is no definite assurance in these older plantings that distribution of irrigation water is uniform throughout the set. In either case the quantity is about 25 to 30 liters per second, for the 8 to 14 rows served. Cane rows are 130 cm. from center to center.

Rate Frequency and Depth of Application. Immediately after planting and until the time plants are 3 months old, the frequency of irrigation on black soils is 18 days, and on brown soils from 10 to 14 days. For older cane, brown soils are irrigated every 20 days and black soils every 30 days. There is usually a latitude of several days on most irrigations. For mature cane, applications of 12 to 15 cm. (water depth) are made at each irrigation. On brown soils it may take as long as 1 hour for the irrigation water to reach a depth of 70 cm. On black soils which are deeply cracked, it may take only 2 to 3 minutes for the water to penetrate to a depth of 70 cm. Water fills the cracks and later the moisture is absorbed by the soil clumps. Cracking in the black soils begins at about 50 to 52 percent available moisture. The level of available moisture at the deep cracking stage might well be in the range of plant wilting point. Attempts to determine effect of relative humidity indicate that in the range of a variation from 30 to 50 percent, relative humidity does not permit more than 3 days' decrease in irrigation period.

The gross water requirements for the estate were given as 2,700 liters per second on a 24-hour basis for the 8 dry months and for the 3,500 hectares in the estate. On a hectare basis the requirement for the same period and for 24-hour-per-day operation of the pumping plant, excluding rainfall, was 0.8 liter per second. On black soils the annual requirement is based on one application per month during the 8 nonrainy months (8 x 150 mm. per application equals 1,200 mm. total for the season).

Miscellaneous Data. Early experience involved overirrigation on heavy soils. Experiments are being conducted which tend to indicate that delay of irrigation until moisture levels read one-third of readily available moisture will give higher yields than if moisture levels are kept higher. There is a need to watch against too much water on brown soils and especially on black soils which will bring about poor soil aeration and increasing salt levels.

The estate is divided into divisions of 350 to 400 hectares each. Divisions are divided into blocks of 500 meters by 500 meters (25 hectares). These blocks are further divided into five strips of 5 hectares each and each strip has rows of 10 to 30 meters in length. Short runs are indicated because of slopes ranging from zero to one-half percent. Every 100 meters throughout the block there is a parallel supply ditch and a collection drain. For a block of 25 hectares a minimum of 6 men is required for irrigation--sometimes as many as 10 men will be used. There is a village situated adjacent to each block of land. Generally, 250 to 300 male inhabitants work in this particular block.

Training of irrigators has been slow because of the workers' complete lack of previous experience in even remotely similar work. At the beginning of each irrigation season the irrigators who have been there as long as 5 years must again be trained for their work. Instructions for building dams in field ditches and number of rows to irrigate have often not been heeded.

One pump has been kept in reserve, and therefore delivery rate has not been limited because of lack of capacity.

Irrigation System. Laterals in most cases were constructed by hand labor. Many control structures were provided. Combination of concrete and rubble masonry (especially on transitions) was used. Advantage is taken of the rainy season to clean out the weeds in the canal by hand labor.

Measuring devices were limited to diversion structures and slidegates and stoplogs were used to control flow.

Summary. Concern was expressed during our visit that the heavy soils would give trouble if irrigation frequency was much greater than once ever 3 to 4 weeks. The trouble would arise from waterlogging of the soils and the reduction of crop yields. Further trouble would arise eventually from the accumulation of salts which could not be easily leached, if at all, from the heavy textured soils.

Daylight to dark irrigation, augmented by night storage of water in reservoirs, has replaced the 24-hour type of irrigation.

Extreme short lengths of irrigation runs, used for control of water and to reduce the possibility of waterlogging the soils, implies problems which could and probably would arise in heavy soil areas in the Abbay Basin.

The village system for housing workers may be a planning requirement on large projects in the Abbay Basin. Wonji experience provides a basis for assuming that large amounts of housing for laborers, in order that they be immediately available for work within short walking distances of their assigned blocks, should be considered in the plans for project development.

Computations of farm waste and deep percolation losses follow. In these computations, the Blaney-Criddle factors and the description of deliveries as obtained from the operators are adopted, and the consequent estimates of farm waste and deep percolation then become available.

From Blaney-Criddle,

$U = k\ (tp)$
U = consumptive use in inches
k = empirical coefficient for crop
t = mean monthly temperature in degrees Fahrenheit
p = monthly percentage of daylight hours of the year
k = 0.90 for sugarcane

Irrigation efficiency for different soil conditions and irrigation distribution systems range from 40 to 70 percent.

Month	k	t	8° Lat p	U	R 80% of ppt in inches	U-R inches
Oct.	0.9	67	0.0831	5.0	1.2	3.8
Nov.	0.9	65	0.0789	4.6	.0	4.6
Dec.	0.9	65	0.0811	4.7	0.3	4.4
Jan.	0.9	65	0.0813	4.8	0.3	4.5
Feb.	0.9	68	0.0741	4.5	0.7	3.8
Mar.	0.9	73	0.0845	5.6	1.5	4.1
Apr.	0.9	73	0.0839	5.5	2.4	3.1
May	0.9	74	0.0975	5.8	1.0	4.8
						33.1 inches = 841 mm.

$$\text{Irrigation Efficiency (apparent)} = \frac{841}{1,200} = 70\%$$

Gezira Project

The Gezira Project is a Sudan Government project along the west bank of the Blue Nile at an average elevation of 400 meters.

It is reported that the Gezira soils will take water at about one 100th of an inch per hour, or less, once the cracks have been filled.

The Gezira water operations differ from those employed on Bureau of Reclamation projects in many respects. Approximately one-half of the project is completely fallow throughout each year. This permits some accumulation of nitrogen in the soil through the cracks and may improve tilth in such a way as to facilitate absorption of water during future irrigations. It may permit capillary movement of salts to the surface following light rains, and subsequent removal of these salts by surface runoff during such heavy rains as occur when the cracks are swollen shut.

Main laterals have been constructed with excess freeboard for the purpose of storing nighttime deliveries from the main canals. There are occasional weirs for spilling water from one block of the lateral to the next during the night so as to use the storage capacity provided by excess freeboard first in the upper part and then in the lower part of each lateral. This excess capacity and the occasional weirs have been constructed at considerable cost to the project. Aside from avoiding inconveniences of nighttime irrigation the procedure may be essential because of the difficulty of making precise deliveries during the night. An excess delivery upon this soil might cause sufficient ponding to scald the crop before the excess water could be removed through surface drains.

The project is firmly managed by the central office; no tenant has any control over the water deliveries. The tenant is assigned different land from year to year in order to accomplish rotation between cotton, dura (similar to popcorn), and vegetables, with one-half the land fallow. The areas in any one crop are in blocks of 90 feddans (38 hectares), including 9 "allotments" of 10 feddans each. Most farmers have 40 feddans but not in contiguous 10-feddan units. None of the land is fenced, which means that there are few cattle, and possibly because of the strong inclination of the farmers to market their produce, table gardens are not extensive. By deliveries of water to 90-feddan blocks, the project management is able to carefully measure the amounts delivered. Delivery is approximately 4 inches (10 cm.) at each irrigation, which is just enough to fill the cracks and subsequently allow lateral movement of water into the adjacent soil. In the absence of such strict supervision of deliveries, an excess would probably be delivered with consequent ponding of water, scalding of crops, and aggravation of salt problems.

Project officials, while they agree that some changes in procedure might be possible, are agreed that no changes should be made without first testing the proposals on an experimental basis, over a considerable period. This appears to be a sound position. It is doubtful that anyone has sufficient knowledge of the total complexities to predict with reasonable certainty how a successful change could be made.

Project officials (or at least many of them) are convinced that no water passes vertically through the soil profile to the ground-water table, although they have not constructed any observation wells for the purpose of supporting this opinion. It would seem desirable to construct such wells because of the fact that ground-water gains frequently occur on other irrigation projects. If there is some movement to the ground-water table this would be a possible explanation of the fact that salt (delivered with the irrigation supply) has not accumulated in the soil profile. Knowledge of the salt balance in the project would be considerably improved at little cost. Should there be a continuing rise in the ground-water table, however slight, it certainly could not be relieved by construction of drains, unless there are strata more permeable than the soil from which the drains could pull the ground water.

Crops are grown during the periods indicated below and receive the indicated number of deliveries, approximately equally spaced over their growing season:

Crop	Planted	Interval between Irrigation days: Oct.	Interval between Irrigation days: Later	Irrigations	M^3 per feddan	Cropped
Cotton	a/August	10-12	b/14-16	14	6500	Dec.-April
Dura	July			3-4		Oct.-Nov.
Lubia	September			7		Jan.-Feb.
Wheat	November					March

Computations of farm waste and deep percolation losses follow. These were computed in the same manner as in the preceding Wonji section with this additional information:

100 mm. x 14 = 1,400 mm. total application for the season

8-month cotton irrigation season

k = 0.70 for cotton

From Wad Medani weather records:

a/One irrigation before sowing in north part of project.
b/Irrigation ends in March
Source: Gezira Soil Bulletin 12, 1955.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
Ppt (inches)	0	0	0	0.2	0.4	1.4	5.3	5.6	2.3	0.5	0	0
Temp (° F)	76	77	81	88	90	89	84	82	84	86	82	77

Month	k	t	14° Lat p	U	R 80% of ppt in inches	U-R inches
Oct.	0.7	86	0.0828	5.0	0.4	4.6
Nov.	0.7	82	0.0785	4.5	0	4.5
Dec.	0.7	77	0.0804	4.3	0	4.3
Jan.	0.7	76	0.0803	4.3	0	4.3
Feb.	0.7	77	0.0739	4.0	0	4.0
Mar.	0.7	81	0.0843	4.8	0	4.8
Apr.	0.7	88	0.0844	5.2	0.2	5.0
May	0.7	90	0.0890	5.6	0.3	5.3
						36.8 inches = 935 mm.

$$\text{Irrigation Efficiency (apparent)} = \frac{935}{1,400} = 67 \text{ percent}$$

It should be recognized that the Gezira officials do not believe that they have a 33-percent farm waste and deep percolation, as the above application of Blaney-Criddle factors would suggest. If farm waste and deep percolation are as much as 33 percent, then most of this must be to deep percolation. And since the water table has not come to the surface, such deep percolation, if it occurs, must be carried away through permeable strata which have not yet been discovered. By making deliveries to 90 feddans as a minimum, losses to surrounding fallow areas appear to have been kept very low, and a farm waste in excess of 10 percent, on the basis of field observation, would appear to be improbable.

Alazar-Tolde Farm

The Alazar-Tolde Farm is on the shore of Lake Tana near Bahir Dar at an elevation of 1790 meters. Approximately 3 hectares were irrigated during the 1961-1962 dry season by pumping water from Lake Tana. Project personnel made a daily record of the rates and times of water delivered and the area irrigated. The major crop grown was coffee but several other crops were intermixed in the area served by the three laterals as follows:

Lateral No. 1: Coffee, tomato, potato, onion, pineapple, and seedling vegetables. Partly poor and shallow light soil.

Lateral No. 2: Coffee, tomato, garden beans, some orchard trees, and carrots. Medium light and shallow profile soils.

Lateral No. 3: Coffee, tomato, cabbage, carrots, onions, papaya, beans, spinach, lettuce, pepper, radish, cucumber, Swiss chard, eggplant, banana, potato, celery, and cauliflower. Deep light soil and partly medium to shallow rock subsoil.

The following summarizes by months the areas receiving one or more irrigations served by each lateral.

Lateral No.	Square meters receiving water								Considered irrigated through season (sq. m.)
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	
One	0	0	1,568	1,713	1,753	1,674	1,688	1,569	1,700
Two	767	3,380	10,154	10,473	10,764	10,498	10,630	8,807	10,500
Three	8,301	10,350	16,573	17,259	16,865	16,786	15,353	14,161	17,000
Total	9,068	13,730	28,295	29,445	29,382	28,958	26,671	24,537	29,200

Assuming accuracy of the above-described measurements, and assuming that 25 percent of the water was lost to surface waste and deep percolation, that 80 percent of the rainfall was effective in meeting crop requirements, and that the crops got neither more nor less water than desired for maximum yield, the study shows consumptive use requirement to be as indicated in Table III-14.

By accepting the boundary of area irrigated, the rate of delivery, and starting time and stopping time as reported, it was possible to prepare Table III-15 descriptive of the irrigation season on the Alazar-Tolde farm. Wide deviations between the maxima and the minima probably reflect poor control and inefficiency of irrigation or errors in measurement of irrigation delivery.

A theoretical average period between irrigations may be derived from the preceding tabulations. Average depth of delivery per irrigation divided into depth of delivery for the season gives number of irrigations; and this, divided into length of the season, gives average period between irrigations. Length of the October 16 to May 11 season is 208 days.

Lateral No. (Col. 1)	Average depth per irrigation (mm.) (Col. 2)	Total delivered in season (mm.) (Col. 3)	Number of irrigations (Col. 4) = (Col. 3) ÷ (Col. 2)	Average number of days between irrigations (Col. 5) = 208 ÷ (Col. 4)
1	54	585	10.8	19.3
2	49	490	10.0	20.8
3	72	720	10.0	20.8
Average	58	600	10.3	20.3

This computation is probably a more detailed analysis than could be justified using the existing data. However, it should be of value as an indication of how a similar study could be made of other irrigated areas in Ethiopia should the Imperial Ethiopian Water Resources Department plan a further field study of irrigation deliveries.

Canal Seepage

Figure III-12, for estimation of canal seepage losses, was prepared by use of the Moritz formula. However, where the curve would produce an estimated seepage loss of less than 5 percent, a 5 percent loss was provided for. Soils fall so consistently in the red-friable and black-grumusol groups that no others were considered.

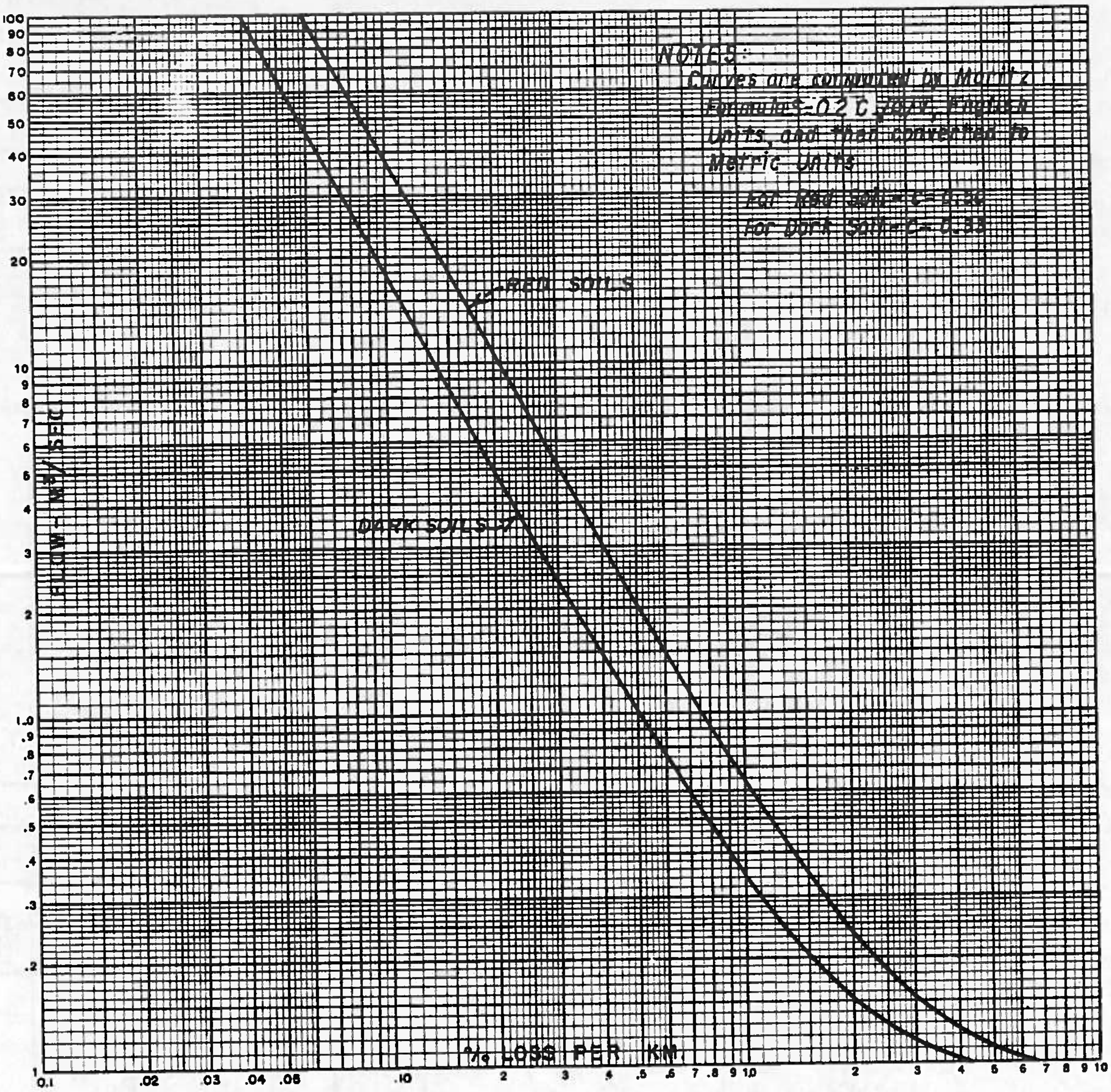
TABLE III-14--ALAZAR-TOLDE FARM--CONSUMPTIVE USE REQUIREMENT

Month	Depth of water in millimeters				
	Measured delivery	Farm losses 25%	Irrigation consumptive use	80% of precipi-tation	Consump-tive use
Lateral One					
Oct (16-31)	0	0	0	28	28
Nov	0	0	0	68	68
Dec	89	22	67	15	82
Jan	94	24	70	0	70
Feb	117	29	88	0	88
Mar	120	30	90	0	90
Apr	111	28	83	4	87
May (1-11)	54	13	41	12	53
Season	585	146	439	127	566
Lateral Two					
Oct (16-31)	6	2	4	28	32
Nov	21	5	16	68	84
Dec	97	24	73	15	88
Jan	78	20	58	0	58
Feb	125	31	94	0	94
Mar	45	11	34	0	34
Apr	83	21	62	4	66
May (1-11)	35	9	26	12	38
Season	490	123	367	127	494
Lateral Three					
Oct (16-31)	46	12	34	28	62
Nov	49	12	37	68	105
Dec	136	34	102	15	117
Jan	142	35	107	0	107
Feb	126	31	95	0	95
Mar	90	22	68	0	68
Apr	80	20	60	4	64
May (1-11)	51	13	38	12	50
Season	720	179	541	127	668

TABLE III-15--ALAZAR-TOLDE FARM--DELIVERIES AND DELIVERY RATES

Month	Delivery per irrigation in millimeters by lateral								
	Lateral One			Lateral Two			Lateral Three		
	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.
Oct.	0	0	0	45	41	37	77	58	21
Nov.	0	0	0	64	54	40	662	136	24
Dec.	84	49	15	109	72	27	210	76	34
Jan.	58	48	39	73	54	30	112	54	39
Feb.	74	56	38	62	41	26	90	48	20
Mar.	52	51	50	38	34	30	83	47	28
Apr.	62	53	18	86	51	32	73	49	32
May	98	75	52	86	51	32	73	49	32
Season	98	54	15	109	49	18	662	72	20

Month	Delivery rate in millimeters per hour by lateral								
	Lateral One			Lateral Two			Lateral Three		
	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.
Oct.	0	0	0	75	64	56	80	35	14
Nov.	0	0	0	79	52	26	615	124	17
Dec.	32	31	30	98	49	13	185	41	12
Jan.	33	28	23	187	53	14	294	34	5
Feb.	23	22	21	84	26	7	40	17	8
Mar.	57	34	21	12	11	8	56	22	7
Apr.	41	30	20	52	21	7	464	60	4
May	391	207	23	33	23	8	36	19	9
Season	391	59	20	187	37	7	615	44	4



BLUE NILE RIVER BASIN

CANAL SEEPAGE LOSSES

6.0-BN-22

Figure III-12--Canal Seepage Losses

TABLE III-16--COMPUTATION OF FARM DELIVERY REQUIREMENTS

Sheet 1 of 2

Project	Elev. (m.)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total (mm.)
		Average Monthly Data--Millimeters								
Angar	1340									
Consumptive use		98.0	95.0	101.0	99.5	92.0	110.5	111.0	113.5	820.5
Utilized rain (80%)		56.0	6.4	5.6	4.8	7.2	28.0	32.0	60.0	200.0
Net consumptive use		42.0	88.6	95.4	94.7	84.8	82.5	79.0	53.5	620.5
Farm irrig. efficiency		.6	.6	.6	.6	.6	.6	.6	.6	.6
Water requirement		70.0	147.7	159.0	157.8	141.3	137.5	131.7	89.2	1,034.2
Arjo	1340									
Consumptive use		99.0	96.0	102.0	101.0	93.0	111.0	111.0	115.0	828.0
Utilized rain (80%)		52.0	10.0	17.0	13.0	22.0	45.0	76.0	89.0	324.0
Net consumptive use		47.0	86.0	85.0	88.0	71.0	66.0	35.0	26.0	504.0
Farm irrig. efficiency		.7	.7	.7	.7	.7	.7	.7	.7	.7
Water requirement		67.0	123.0	122.0	126.0	101.0	94.0	50.0	37.0	720.0
Beles	1100									
Consumptive use		104.0	101.0	104.0	103.0	95.0	114.0	117.0	120.0	858.0
Utilized rain (80%)		60.0	6.0	3.0	1.0	2.0	3.0	17.0	51.0	143.0
Net consumptive use		44.0	95.0	101.0	102.0	93.0	111.0	100.0	69.0	715.0
Farm irrig. efficiency		.7	.7	.7	.7	.7	.7	.7	.7	.7
Water requirement		63.0	136.0	144.0	146.0	133.0	158.0	143.0	99.0	1,022.0
Birr, Lower	1450									
Consumptive use		97.0	93.4	100.2	99.4	91.8	109.5	109.3	112.5	813.1
Utilized rain (80%)		47.4	7.4	6.4	7.4	5.9	19.3	30.1	38.5	162.4
Net consumptive use		49.6	86.0	93.8	92.0	85.9	90.2	79.2	74.0	650.7
Farm irrig. efficiency		.7	.7	.7	.7	.7	.7	.7	.7	.7
Water requirement		70.9	122.9	134.0	131.4	122.7	128.9	113.1	105.7	929.6
Birr, Upper	1820	(Used for Upper Birr and Debohila service areas)								
Consumptive use		93.0	87.0	95.0	93.0	86.0	103.0	102.0	105.5	764.5
Utilized rain (80%)		40.0	6.4	3.2	1.6	3.2	22.4	26.4	60.0	163.2
Net consumptive use		53.0	80.6	91.8	91.4	82.8	80.6	75.6	45.5	601.3
Farm irrig. efficiency		.7	.7	.7	.7	.7	.7	.7	.7	.7
Water requirement		75.7	115.2	131.1	130.6	118.3	115.1	108.0	65.0	859.0
Dabana	1240									
Consumptive use		101.0	98.0	103.0	101.0	94.0	112.0	114.0	117.0	840.0
Utilized rain (80%)		45.0	11.0	7.0	14.0	6.0	11.0	43.0	113.0	250.0
Net consumptive use		56.0	87.0	96.0	87.0	88.0	101.0	71.0	4.0	590.0
Farm irrig. efficiency		.6	.6	.6	.6	.6	.6	.6	.6	.6
Water requirement		93.0	145.0	160.0	145.0	147.0	168.0	118.0	7.0	983.0
Dabus	1160									
Consumptive use		101.0	98.5	103.0	101.0	93.5	113.0	114.0	117.0	841.0
Utilized rain (80%)		56.0	6.4	5.6	4.8	5.6	9.6	30.4	108.0	226.4
Net consumptive use		45.0	92.1	97.4	96.2	87.9	103.4	83.6	9.0	614.6
Farm irrig. efficiency		.6	.6	.6	.6	.6	.6	.6	.6	.6
Water requirement		75.0	153.5	162.4	160.3	146.5	172.3	139.3	15.0	1,024.3
Diddessa	1420									
Consumptive use		98.0	95.0	101.0	99.5	92.0	110.5	111.0	113.5	820.5
Utilized rain (80%)		32.0	7.2	7.2	7.2	8.0	72.0	92.0	120.0	345.6
Net consumptive use		66.0	87.8	93.8	92.3	84.0	38.5	19.0	0	481.14
Farm irrig. efficiency		.7	.7	.7	.7	.7	.7	.7	.7	.7
Water requirement		94.3	125.4	134.0	131.9	120.0	55.0	27.1	0	687.7

TABLE III - 16 COMPUTATION OF FARM DELIVERY REQUIREMENTS

Sheet 2 of 2

Project	Elev. (m.)	Average Monthly Data--Millimeters								Total (mm.)
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	
Dindir-Rahad	610									
Consumptive use		118.0	107.0	109.0	105.0	98.0	118.0	125.0	131.0	911.0
Utilized rain (80%)		36.0	4.0	2.0	0	1.0	1.0	10.0	32.0	86.0
Net consumptive use		82.0	103.0	107.0	105.0	97.0	117.0	115.0	99.0	825.0
Farm irrig. efficiency		.6	.6	.6	.6	.6	.6	.6	.6	.6
Water requirement		137.0	171.0	178.0	175.0	162.0	195.0	192.0	165.0	1,375.0
Finchaa	1450	(Used also for the Amarti-Neshe service areas)								
Consumptive use		98.0	96.0	101.0	100.0	92.0	111.0	111.0	114.0	823.0
Utilized rain (80%)		32.0	6.4	5.6	4.8	6.4	32.0	29.6	38.4	155.2
Net consumptive use		66.0	89.6	95.4	95.2	85.6	79.0	81.4	75.6	667.8
Farm irrig. efficiency		.7	.7	.7	.7	.7	.7	.7	.7	.7
Water requirement		94.3	128.0	136.3	136.0	122.3	112.8	116.3	108.0	954.0
Gilgel Abbay	1981									
Consumptive use		92.0	85.0	92.0	90.0	84.0	99.0	99.5	103.0	744.5
Utilized rain (80%)		52.0	7.2	5.6	2.4	5.6	20.0	32.0	72.0	196.8
Net consumptive use		40.0	77.8	86.4	87.6	78.4	79.0	67.5	31.0	547.7
Farm irrig. efficiency		.7	.7	.7	.7	.7	.7	.7	.7	.7
Water requirement		57.2	111.2	123.4	125.1	112.0	112.8	96.4	44.3	782.4
Guder, Upper	2200									
Consumptive use		89.0	82.0	83.0	85.0	81.0	91.5	94.0	99.0	704.5
Utilized rain (80%)		23.0	5.4	27.2	11.4	23.8	68.0	63.8	62.7	285.3
Net consumptive use		66.0	76.6	55.8	73.6	57.2	23.5	30.2	36.3	419.2
Farm irrig. efficiency		.6	.6	.6	.6	.6	.6	.6	.6	.6
Water requirement		110.1	127.8	93.0	122.7	95.4	39.2	50.4	60.5	699.1
Gumara	1840									
Consumptive use		93.0	87.0	95.0	93.0	86.0	103.0	102.0	105.5	764.5
Utilized rain (80%)		44.8	14.4	20.8	1.6	8.8	28.0	48.0	67.2	233.6
Net consumptive use		48.2	72.6	74.2	91.4	77.2	75.0	54.0	38.3	530.9
Farm irrig. efficiency		.6	.6	.6	.6	.6	.6	.6	.6	.6
Water requirement		80.3	121.0	123.7	152.3	128.7	125.0	90.0	63.8	884.8
Megech	1830									
Consumptive use		93.0	87.0	95.0	93.0	86.0	103.0	102.0	105.5	764.5
Utilized rain (80%)		36.8	22.4	16.0	1.6	12.0	12.8	44.0	56.0	201.6
Net consumptive use		56.2	64.6	79.0	91.4	74.0	90.2	58.0	49.5	562.9
Farm irrig. efficiency		.6	.6	.6	.6	.6	.6	.6	.6	.6
Water requirement		93.7	107.7	131.7	152.3	123.3	150.3	96.7	82.5	938.2
Ribb	1840									
Consumptive use		92.5	86.0	93.5	92.0	85.0	101.0	100.5	104.5	755.0
Utilized rain (80%)		40.8	18.4	18.4	1.6	10.4	24.0	45.6	62.4	221.6
Net consumptive use		51.7	67.6	75.1	90.4	74.6	77.0	54.9	42.1	533.4
Farm irrig. efficiency		.6	.6	.6	.6	.6	.6	.6	.6	.6
Water requirement		86.2	112.6	125.2	150.7	124.3	128.3	91.5	70.2	889.0

FARM DELIVERY REQUIREMENTS

The estimated farm delivery requirements for the several project areas are shown in Table III-16 (two sheets). In preparing these estimates, effective precipitation was assumed to be limited to the consumptive use requirement in any month, or 80 percent of the actual precipitation, whichever was the lesser. Figure III-7 and records at the nearest station were examined for purposes of estimating temperature, used in the Blaney-Criddle formula, and for estimating precipitation. Farm irrigation losses were estimated to vary from 40 to 30 percent, depending upon topography.

SECTION II--STREAMFLOW

Measuring System

OUTSIDE THE BASIN

Since there are no streamflow records of 10 years' duration within the Blue Nile Basin in Ethiopia, longer records in adjacent areas were obtained and utilized to estimate long-time averages and drought period flows within the Basin. These records, in 10-day runoff increments, were all collected by Government agencies in Sudan. The source of data through 1942 was "The Nile Basin" by H. E. Hurst and P. Phillips, Government Press, Ministry of Public Works, Cairo, Egypt, published in various volumes between 1933 and 1945. Data subsequent to 1942 were obtained from the Sudan Government.

The monthly runoff totals for the Blue Nile River at Roseires (100 kilometers downstream from the Ethiopian border) for 1912 through 1962, the Dindir River at Hillet Idris (300 kilometers downstream from the Ethiopian border) for 1907 through 1951, and the Rahad River at Abu Haraz (300 kilometers downstream from the Ethiopian border) for 1908 through 1951 are tabulated on Tables III-17, III-18, and III-19. Some use was also made of records of the Blue Nile River at Sennar (200 kilometers downstream from Roseires) and the Baro River at Gamela (immediately south of the Dabus Sub-basin portion of the Blue Nile Basin). Other station records were examined to evaluate the reliability of the above records.

WITHIN THE BASIN PRIOR TO 1958

The outflow of the Abbay from Lake Tana was recorded from August 1920 through February 1926 and again from January 1928 through December 1932. These records, which are summarized by months in Table III-29, were published in 10-day runoff increments in "The Nile Basin." Some additional data on maximum and minimum Lake Tana water surface levels were recorded in these years plus 1902, 1915, and 1933. The data are tabulated in Section III, where it was utilized in a flood frequency study.

A staff gage was installed on the Abbay near Kese during the 1935-1941 Italian occupation but no records were available for that period. A new staff gage was installed at this site in July 1953 and runoff records are available from July 1953 through September 1954. There is a gap in the records until 1956, when a recorder was installed, but from January 1956 until the present time the record is complete. The daily flows through 1962 were published in the 1961 and 1962 Abbay Basin Hydrologic Summary and are summarized by months on Table III-57.

TABLE III-17--HISTORICAL HYDROGRAPHIC DISCHARGE DATA, BLUE NILE AT ROSEIRES, SUDAN

Runoff of BLUE NILE at Roseires, Sudan

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
*1911	740	420	290	180	540	1,040	5,040	15,120	13,790	6,520	3,240	1,640	48,560
1912	860	570	360	240	250	1,450	5,930	14,200	8,690	3,440	1,620	870	38,480
1913	580	350	270	260	600	400	2,320	6,620	6,090	2,140	740	320	20,690
1914	190	140	150	230	190	980	5,660	16,900	11,400	8,850	4,610	1,740	51,040
1915	870	470	340	230	560	1,250	3,640	8,190	11,100	6,940	2,960	1,350	37,900
1916	730	410	240	220	490	1,390	7,450	19,400	16,800	10,900	4,500	2,210	64,740
1917	1,190	670	500	370	630	1,760	8,210	18,400	21,100	10,900	3,910	2,030	69,670
1918	1,160	750	650	540	950	1,980	5,850	12,600	8,670	3,860	1,720	880	39,610
1919	700	460	320	160	500	1,600	7,200	15,100	13,100	4,280	1,800	940	46,160
1920	620	390	400	230	880	2,210	7,230	12,700	9,910	7,350	2,860	1,320	46,100
1921	780	470	310	200	430	1,290	4,330	15,000	12,300	5,690	2,190	1,100	44,090
1922	640	380	270	180	370	1,460	5,510	14,200	12,200	6,850	2,330	1,220	45,610
1923	710	430	410	420	1,080	1,930	6,890	18,000	13,100	5,160	2,380	1,530	52,040
1924	800	540	380	530	560	1,830	6,960	15,100	13,900	5,930	3,540	1,630	51,700
1925	920	520	400	290	700	2,030	4,890	12,900	9,900	5,280	2,380	1,160	41,370
1926	720	430	400	350	1,850	1,990	7,320	17,300	14,000	7,060	2,670	1,550	55,640
1927	800	440	400	240	270	1,850	6,130	12,500	9,080	5,220	1,840	990	39,760
1928	570	320	250	410	1,540	2,250	8,900	17,600	11,900	5,760	2,560	1,330	53,390
1929	750	470	330	370	1,880	4,130	11,000	19,300	16,600	9,890	3,230	1,890	69,840
1930	1,070	620	460	530	610	1,610	7,090	14,300	11,300	4,280	2,020	1,080	44,970
1931	630	340	260	190	220	1,450	4,890	15,300	12,700	7,520	2,570	1,200	47,270
1932	675	383	259	203	747	1,520	6,260	16,000	15,500	7,140	2,240	1,210	52,137
1933	707	419	327	248	512	1,210	4,510	13,300	13,400	7,130	2,900	1,510	46,173
1934	805	452	317	280	452	1,700	7,620	17,900	12,700	7,390	2,750	1,590	53,956
1935	878	484	362	379	1,095	2,587	10,876	18,881	16,740	8,090	2,838	1,594	64,804
1936	1,000	745	471	445	535	1,512	8,423	16,410	14,660	5,762	2,327	1,360	53,650
1937	825	479	371	237	597	1,371	7,360	17,028	13,100	4,804	2,279	1,264	49,715
1938	696	382	385	218	371	1,663	9,122	18,969	16,510	10,032	3,237	1,610	63,195
1939	933	541	405	364	649	1,625	5,622	11,787	10,830	6,490	2,917	1,389	43,552
1940	792	471	333	243	344	1,088	3,944	15,073	10,250	3,872	1,576	816	38,802
1941	475	289	209	127	734	2,348	6,169	12,214	10,080	7,040	3,076	1,353	44,114
1942	662	370	715	288	656	1,424	8,070	16,633	12,880	6,879	2,209	1,216	52,002
1943	764	419	289	222	419	864	5,079	14,828	13,790	5,931	2,405	1,230	46,240
1944	683	402	280	248	764	1,580	6,380	14,448	11,030	4,186	1,896	1,044	42,941
1945	616	344	226	181	756	1,386	5,665	12,696	13,750	8,489	3,530	1,694	49,333
1946	947	502	326	293	334	1,824	9,484	25,174	15,230	7,216	3,029	1,583	65,942
1947	905	517	462	688	416	1,041	4,903	17,163	14,910	6,580	2,253	1,379	51,217
1948	734	501	437	219	348	2,584	7,733	14,513	13,950	10,160	3,526	1,594	56,299
1949	894	500	419	354	438	2,072	7,731	15,963	13,940	6,603	2,498	1,677	53,089
1950	938	475	359	508	802	1,777	5,935	15,130	13,860	5,573	2,088	1,193	48,638
1951	720	405	350	243	382	1,167	4,546	15,486	9,620	7,443	3,154	1,542	45,058
1952	764	425	321	244	360	1,145	6,032	15,332	11,530	6,513	2,170	1,110	45,946
1953	615	336	281	248	568	869	6,846	17,668	11,250	5,835	2,325	1,290	48,131
1954	768	430	319	252	304	1,634	8,695	18,090	15,030	8,571	3,043	1,624	58,760
1955	1,103	599	380	459	670	1,499	7,503	16,775	15,260	8,753	3,053	1,641	57,695
1956	911	513	383	467	440	2,335	7,157	15,037	11,970	14,119	4,315	1,945	59,592
1957	1,091	606	1,100	1,294	707	1,784	5,662	17,166	10,500	3,724	1,720	1,004	46,358
1958	591	398	257	320	382	1,870	7,784	19,005	13,790	9,674	3,407	1,696	59,174
1959	1,053	643	456	283	610	1,102	5,383	16,180	16,070	9,289	3,850	1,976	56,895
1960	1,240	725	543	405	543	1,260	6,975	16,430	13,800	6,975	2,880	1,674	53,450
1961	787	525	368	536	372	1,483	9,241	16,899	16,537	10,989	3,613	2,235	63,585
1962	1,140	602	494	282	524	1,720	5,130	15,423	14,298	9,044	2,502	E1,300	E52,459
1911-62	41,742	24,472	19,594	17,148	31,931	84,924	344,280	814,331	674,395	364,116	141,276	73,323	2,631,532

* 1911 (only) correlated with Blue Nile at Sennar (Drawing No. 6.0-BN-72).

Average 1911-62 = 50,610 million cubic meters.

E = Estimate

TABLE III-18--HISTORICAL HYDROGRAPHIC DISCHARGE DATA, DINDIR RIVER AT HILLET IDRIS, SUDAN

Runoff of DINDIR RIVER at Hillet Idris, Sudan

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1907						35	373	389	475	72			1,340
1908						41	303	1,530	1,530	421	56		3,890
1909						235	389	1,320	1,330	443	0	0	3,710
1910							377	946	1,230	855	139	9	3,560
1911						20	132	961	1,270	399	73	-	2,850
1912							381	1,380	718	122	22		2,620
1913							231	678	466	49	0	0	1,420
1914							330	1,010	951	392	52	-	2,740
1915						36	254	487	906	304	17		2,000
1916						44	623	1,460	2,060	1,220	185	58	5,650
1917						16	409	1,010	1,430	754	82	6	3,710
1918							363	859	622	111	7	-	1,960
1919						35	334	645	614	85	-	-	1,710
1920						52	748	1,460	1,220	607	72	-	4,160
1921							155	702	908	313	-	-	2,080
1922							221	648	883	530	27	-	2,310
1923							437	1,400	1,340	426	71		3,670
1924							197	870	1,080	181	34		2,360
1925						2	283	880	670	211	17		2,060
1926						20	304	1,380	1,210	300	43		3,260
1927							221	1,130	846	206	7		2,410
1928						0	401	953	740	247	21.9	0	2,360
1929						153	827	1,230	1,720	564	92.5	0	4,590
1930						40	354	987	773	147	10.8	0	2,310
1931						0	202	1,080	1,280	486	87.3	0	3,140
1932						0	222	1,090	1,170	302	30.7	0	2,820
1933							205	947	1,380	501	79.3	19.5	3,130
1934						98.2	675	1,700	1,510	427	97.7	44.2	4,540
1935						22.6	457	1,030	1,220	359	38.0	4.8	3,150
1936						0	598	1,140	1,680	1,110	75.2	0	4,600
1937						10.1	368	1,520	1,130	209	29.5	9.6	3,270
1938						0	319	1,150	1,560	722	88.4	14.3	3,860
1939						0	310	1,060	967	369	41.9	9.2	2,760
1940						0	201	949	1,010	128	18.9	2.9	2,310
1941						0	122	338	517	188	66.7	7.3	1,240
1942						0	400	1,290	1,020	385	23.8	5.1	3,120
1943							359	966	1,135	346	61	9	2,880
1944							212	684	973	214	25	11	2,120
1945							205	835	1,144	574	98	E34	2,890
1946							491	1,303	1,492	424	84	19	3,810
1947							247	1,253	1,458	503	80	31	3,570
1948						62	532	992	769	422	72	28	2,880
1949							292	1,110	1,090	365	79	17	2,950
1950							230	1,190	1,390	414	83	14	3,320
1951							180	1,040	550	352	187	41	2,350
1907-51													133,440

45-year average 2,970

E = estimate

TABLE III-19--HISTORICAL HYDROGRAPHIC DISCHARGE DATA, RAHAD RIVER AT ABU HARAZ, SUDAN

Runoff of RAHAD R. at Abu Haraz, Sudan

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1908							130	499	652	412	54	17	1,760
1909						54	257	555	635	369	77	13	1,960
1910							119	476	602	538	69	22	1,830
1911							23	-	-	91	17		E 900
1912							127	553	429	34			1,140
1913							71	340	361	4			776
1914							78	458	534	282	41	4	1,400
1915						29	43	339	453	138			1,000
1916							178	461	594	510	28		1,770
1917							113	272	504	269			1,160
1918							86	379	228	26			719
1919							← Observations rejected →						E 1,000
1920						6	243	428	479	245	34		1,430
1921							123	343	410	147	13		1,040
1922							78	360	415	327	16		1,200
1923							46	379	435	284			1,140
1924						18	166	316	336	210	10		1,060
1925							101	366	382	207	8		1,060
1926							105	356	378	241	23		1,100
1927							97	344	420	287	7		1,160
1928						0	93.1	298	337	136	12.5	0	877
1929						3.5	198	413	480	411	31.4	0	1,540
1930						0	191	355	373	137	0	0	1,060
1931							44.0	330	393	324	20.7		1,110
1932							82.3	351	380	273	11.2		1,100
1933							55.7	296	391	267	27.5		1,040
1934							180	374	428	306	8.8		1,300
1935							183	353	371	298	9.1		1,210
1936							69	270	349	267	12.7		968
1937							122	353	375	179	11.7		1,040
1938							102	335	348	356	77.8	5.5	1,220
1939							90.5	281	336	209	29.5	1.8	948
1940							54.7	325	320	95.6	13.1	1.4	810
1941							20.2	129	226	110	42.2	4.2	532
1942							78.0	251	326	225	39.4	2.3	922
1943							56	288	324	296	51	5	1,020
1944							101	311	340	186	19	1	958
1945							58	297	326	335	61	5	1,080
1946							145	230	343	288	88	17	1,110
1947							50	262	387	269	35	2	1,010
1948							131	286	326	297	85	6	1,130
1949							102	405	414	360	80	2	1,360
1950							79	383	391	274	41	3	1,170
1951							46	324	335	251	82	5	1,040

E = estimate

PRESENT INVESTIGATION WITHIN THE BASIN

Plan of the Network

When the present investigation was initiated in 1958, a comprehensive network of stream-gaging stations was planned because of the extreme paucity of runoff data within the basin. In planning this network, consideration was given to potential damsite locations, an overall inventory of the basin runoff, and ease of access for construction and operation.

Between 1958 and 1963 a total of 59 gaging stations were established, including 14 stations with both automatic stage recorders and cableways from which to obtain measurements and ranging down to simple staff gages read visually. In addition, occasional measurements and stage readings were taken at other locations. These stations and locations are shown by type on Figure III-8. A detailed description of each station including the location, extent of the installation, and the history of its establishment was given in Manual of Data for Operations and Maintenance of Hydrological Stations within the Blue Nile (Abbay) River Basin, dated May 3, 1963. The stations are listed alphabetically on Table III-20.

Construction and Installation

Construction and installation of the various stations was accomplished as early as possible in the investigation period. This was done on the simpler and more easily accessible stations first, while concurrently the survey, design, procurement, and fabrication of material for the stations on the large tributaries and Abbay proper went forward. The first new cableway was not completed until October 1960 due to the long time required to procure and fabricate materials.

The simpler staff gage stations and some of the automatic recorders in corrugated pipe stilling wells were installed by project hydrologists and hydrographers. All of the cableways and most of the recorder installations were prepared by special construction crews; first by contract and later by the same crews on the project payroll.

The design and construction of the gaging stations were described in Report of Construction of Hydrologic Stations within the Blue Nile Basin, 1961, and Stream Gaging Station Construction, Abbay Basin, February 9, 1961 to May 15, 1962.

Collection of Field Data

As gaging stations were established, the records of the stage were obtained from the automatic recorder charts or from entries in gage height books made twice daily by locally hired gage readers. Measurements were made on a schedule calling for at least one per month per station during the dry season and more during the rainy season. To accomplish this, four field offices were established (at Lekkemt, Asosa, Debre Markos, and Bahir Dar) and operated continuously throughout the investigation period. Hydrographers from these offices and Addis Ababa took periodic measurements, serviced the automatic recorders, and collected gage height books from the local gage readers. Temporary camps with hydrographers were maintained at remote gaging stations during the rainy season when access overland was very difficult if not impossible.

Miscellaneous measurements and stage readings were taken at various gage sites prior to their construction as well as at other locations where gaging stations were never established.

TABLE III-20--HYDROGRAPHIC INSTALLATIONS

Stream	Sta. No.	Location	Installation includes: Staff	Cable-way	Recorder: in well	Recorder: bubble activated
Abbay	9	nr Bahir Dar	x		x	
Abbay	19	nr Kese	x	x	x	
Abbay	29	below Guder River	x	x		x
Abbay	59	at Shogali	x	x	x	
Abbay	62	nr Sudan border	x	x		x
Amarti		nr Cochion	x			
Andassa	11	nr Bahir Dar	x		x	
Angar	51	north of Lekkemt	x	x	x	
Arera	42	nr Finote Selam	x			
Beles	60	nr Metekkel	x	x	x	
Bello	23	nr Guder	x			
Beressa	16	nr Debre Birhan	x			
Birr	38	nr Jiga	x			
Chacha	13	nr Debre Markos	x			
Chemoga	31	nr Debre Markos	x			
Dabana	50	nr mouth	x	x	x	
Dabus	58	nr Asosa	x	x	x	
Debeli	52	nr Lekkemt	x			
Debohila	43	nr Bure	x			
Diddessa	49	nr Arjo	x	x	x	
Dijil	32	nr Debre Markos	x			
Dindir	63	nr Abu Mendi-Metemma road	x	x	x	
Dura	57	nr Metekkel	x			
Fato	24	nr Guder	x			
Fettam	45	at Teltelle	x			
Finchaa	30	nr Cochion	x			
Giamma	17	nr Insaro	x	x	x	
Giamma	18	nr mouth	x	x	x	
Gilgel Abbay	1	at Dangila-Bahir Dar road	x	x	x	
Guder	26	at Guder	x	x		
Guder	28	at mouth	x	x		x
Gudla	36	nr Dembecha	x			
Gumara	6	nr Bahir Dar	x		x	
Indris	27	nr Guder	x			
Jedeb	34	nr Amanuel	x			
Jibat	22	nr Guder	x			
Kechem	37	nr Jiga	x			
Koga	2	nr Bahir Dar	x			
Kulich	33	nr Debre Markos	x			
Lah	41	nr Finote Selam	x			
Leza	39	nr Jiga	x			
Mari	55	nr Lekkemt	x			
Megech	3	nr Azozo	x		x	
Melke	25	nr Guder	x			
Muger	20	nr Chancho	x	x 1/		
Neshe		nr Cochion	x			
Rahad	65	nr Metemma	x	x	x	
Ribb	5	nr Addis Zemin	x		x	
Roba	54	nr Lekkemt	x			
Selale	44	nr Bure	x			
Shye	14	at Tsehai Senna	x			
Sifa	47	nr Lekkemt	x	x 1/		
Tana, Lake	8	at Bahir Dar	x		x	
Tana, Lake	7	at Gorgora	x		x	
Timochia	35	nr Dembecha	x			
Temim	40	nr Finote Selam	x			
Wama	48	nr Lekkemt	x	x 1/		
Wizer	15	at Mehal Meda	x			
Wuke	53	nr Lekkemt	x			

1/ Bank operated.

Compilation of Historical Runoff Records

Methods Used. The field data were assembled in Addis Ababa and checked for accuracy where possible. The average daily gage heights were entered on yearly gage height-discharge sheets. The measurements were plotted on log log paper with discharge plotted versus gage height. A discharge versus gage height rating curve was drawn (one curve was usually sufficient, but if the control was shifting or backwater effects were present, more were needed) and from the curve a rating table was prepared. Then the average daily rate of discharge was entered on the yearly gage height-discharge sheets. Usually if less than a third of a month's record was missing the remainder was estimated to enable the monthly total to be entered. Judgment was used, however, to decide whether or not to estimate missing parts of the record considering uniformity in flow and probable rise or fall during the period of the missing record. These daily gage heights and discharges were included in the Abbay Basin Hydrologic Summaries for 1961 and 1962. The monthly runoff totals for each station are tabulated on Tables III-24 through III-59.

Reliability. The records vary in reliability according to the nature of the control section, the measuring section, and the gage height record. Most could be called fair to good.

RECOMMENDATIONS FOR THE FUTURE

The importance of continuing the collection of streamflow data within the basin cannot be overemphasized. The expense of gathering the data will be returned manyfold when potential projects are designed, constructed, and operated.

The complete existing network of stations should be maintained for the next 5 years. At the end of that period the records collected should be analyzed and considered in respect to potential developments within and near the basin to determine if some stations can be dropped from the continuous record network. Even at stations that are discontinued, records of extreme flood stages and minimum flows should be made when possible.

Table III-21 has been prepared as a guide in the future operation of a basin streamflow gaging program. The stations are placed in priority groups according to their estimated importance at this time. Group A consists of 9 key stations forming a minimum network to provide data for future water studies. Group B consists of an additional 12 stations that have a high priority due to project potential or overall basin inventory requirements. Group C consists of 5 more stations with only a slightly lower priority than Group B.

At existing stations, in the future the emphasis should be placed on continuing a record of the stage. Only occasional measurements should be necessary except where the rating curve has not been well defined or the control is changing.

The collection and analysis of periodic sediment and water quality samples would also be desirable.

Runoff Estimates

SELECTION OF STUDY PERIODS

A plan for initial development of dams, reservoirs, powerplants, canals, and irrigated areas was selected so that operation studies with allowance for upstream depletions could be performed. At each of the damsites it was necessary to develop a critical drought-period flow for use in estimating firm yield available and storage required for a project. There was no severe drought during the short period of record within the basin in Ethiopia. Therefore, the records of the Blue Nile at Roseires, the Dindir River at Hillet Idris, and the Rahad River at Abu Haraz (all in Sudan) were analyzed.

TABLE III-21--GAGING STATION PRIORITY LIST

Group	Stream	Station	Prime use
A	Abbay	Bahir Dar	Beles Project
	Abbay	Kese	Basin inventory
	Abbay	Sudan Border	International
	Amarti	Cochion	Amarti-Neshe Project
	Dabana	Mouth	Dabana Project
	Finchaa	Cochion	Finchaa Project
	Gilgel Abbay	Bahir Dar	Basin inventory
	Neshe	Cochion	Amarti-Neshe Project
	Tana, Lake	Bahir Dar	Beles Project
B	Angar	Lekkemt	
	Beles	Metekkel	
	Birr	Jiga	
	Dabus	Asosa	
	Debohila	Bure	
	Dindir	Abu Mendi	
	Guder	Guder	
	Gumara	Bahir Dar	
	Megech	Azozo	
	Muger	Chancho	
	Rahad	Metemma	
	Ribb	Addis Zemin	
C	Bello	Guder	
	Diddessa	Arjo	
	Guder	Mouth	
	Sifa	Lekkemt	
	Wama	Lekkemt	

A mass diagram of annual runoffs of the Blue Nile at Roseires from 1912 through 1961 (Figure III-13) indicated a critical drought period occurred there in the first few years of record, primarily because the 1913 runoff was approximately 40 percent of normal. This low runoff in 1913 produced the lowest Nile flood in the last 200 years and only three other floods as low have occurred in the 960 years for which flood records have been kept in Egypt. Analysis of the Blue Nile runoff records at Sennar and Khartoum (which predate the start of the Roseires record) indicates that the reservoirs should be full after the supranormal runoff in 1911. The Roseires mass diagram shows that the reservoirs should refill from the supranormal runoff in 1917. Therefore, the 6-year period from October 1, 1911 to October 1, 1917, was used as the critical period for determining yields and storage requirements for projects throughout the basin except for the Dindir-Rahad Sub-basin.

The Dindir River at Hillet Idris mass diagram of annual runoff from 1907 through 1951 (Figure III-14) indicates a critical drought period between 1917 and 1938. Therefore the 21-year period from October 1, 1917 to October 1, 1938 was selected as the critical study period for the Dindir River Projects, including the Galegu River, a tributary.

The Rahad River at Abu Haraz mass diagram of annual runoff from 1908 through 1951 (Figure III-15) indicates a critical drought period between 1938 and 1950. Therefore, the 12-year period from October 1, 1938 to October 1, 1950 was selected as the critical study period for the Rahad Project.

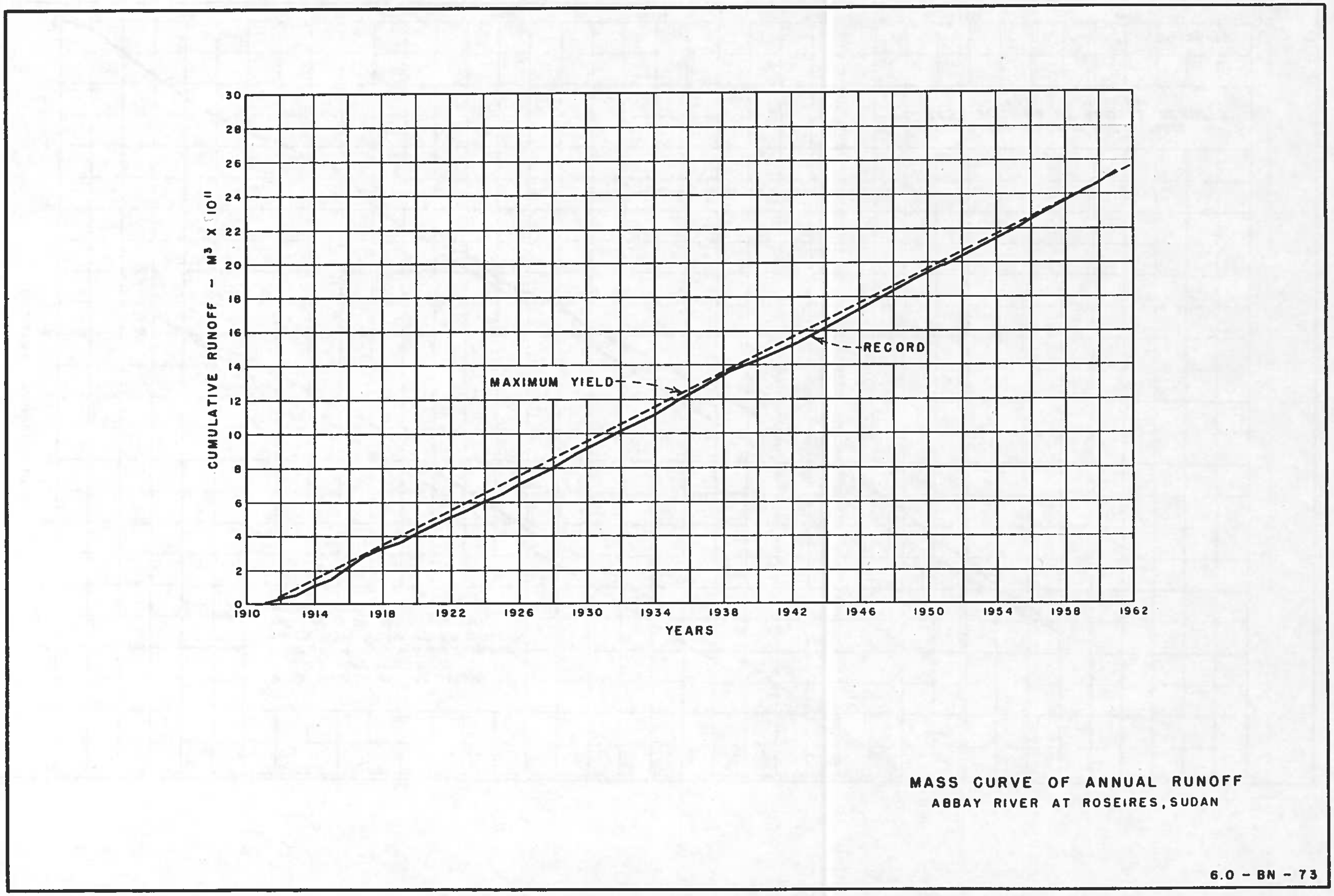


Figure III-13--Mass Curve of Annual Runoff, Abbay River at Roseires, Sudan

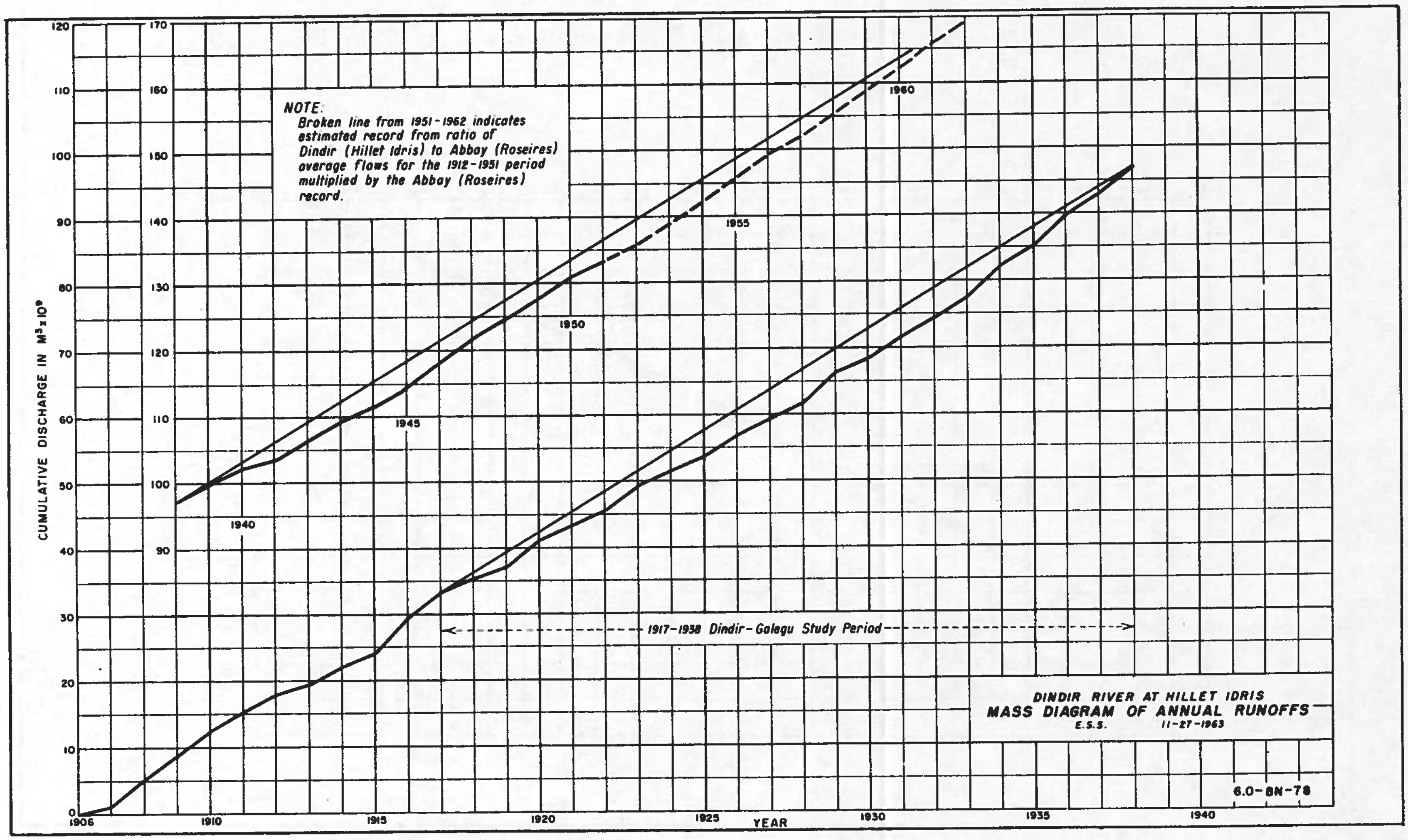


Figure III-14--Mass Diagram of Annual Runoffs, Dindir River at Hillet Idris, Sudan

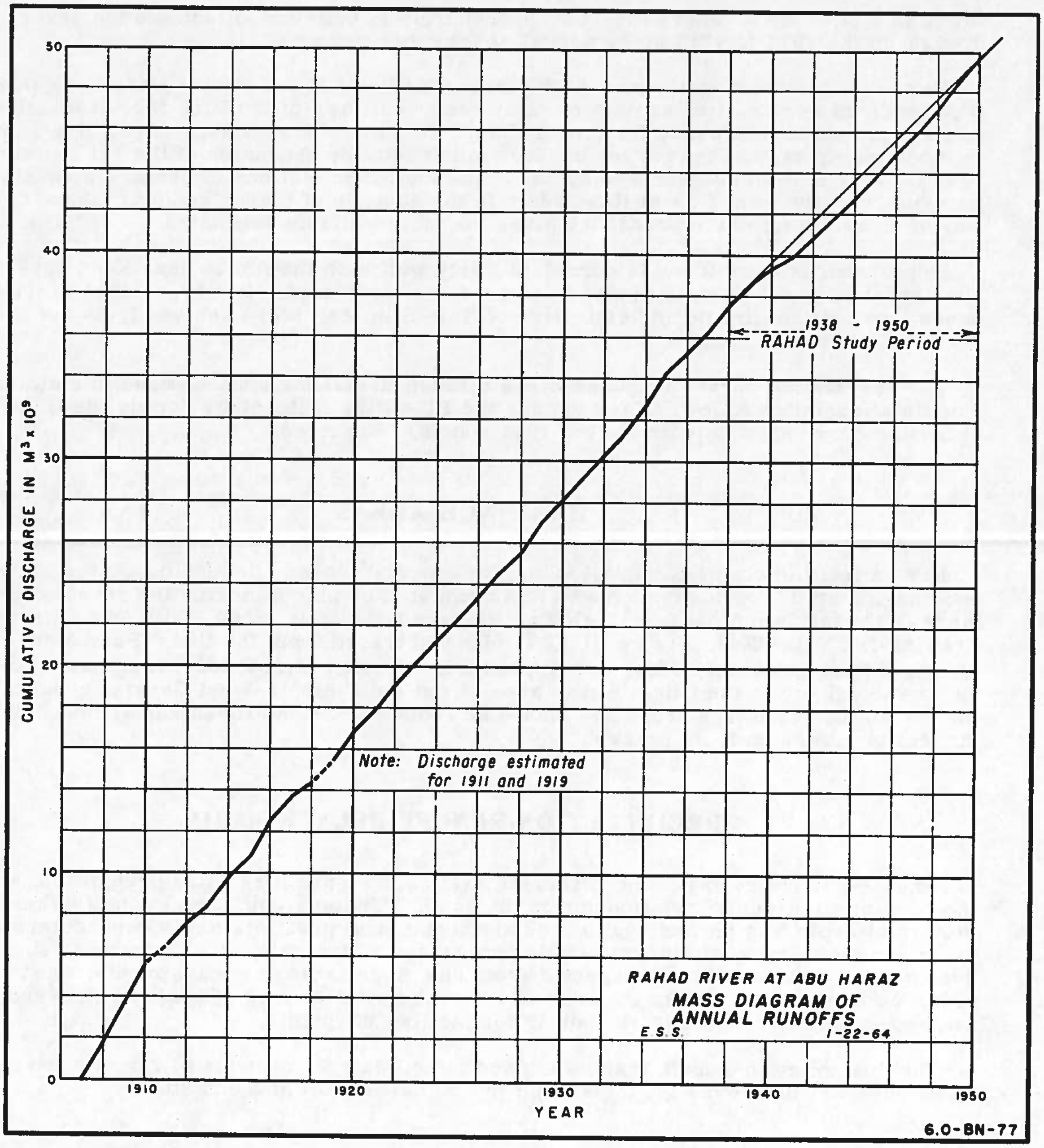


Figure III-15--Mass Diagram of Annual Runoffs, Rahad River at Abu Haraz, Sudan

CORRELATION METHODS

Because of the pronounced concentration of the rains in the June through September period, hydrographs of Abbay tributaries have much the same shape, regardless of what tributary or what year is under consideration. Had there been records over 5 or 10 years of flow available at the stations where drought-period estimates were required, a correlation of annual totals with annual totals of the Blue Nile at Roseires would have been preferable to a correlation of monthly totals. Estimated totals could then have been distributed to the months by ratios derived from the local record. This procedure was followed in a few cases, where the usual procedure was believed to indicate too severe a drought in the 1911 to 1917 study period or for other reasons.

However, for most stations, monthly recorded flows at the station where an estimate was required were plotted against monthly recorded flows of the Blue Nile at Roseires, with or without an allowance for travel time. This had the advantage of defining a curve in most instances, but the curves produce much smaller estimates of the 1913 minimum year flows than would be secured by assuming the upper stations to produce a constant percentage of the total flow at Roseires. In the absence of longer records, there is no way of determining which procedure gives the more reliable estimates.

Some records were found to correlate fairly well with the Abbay near Kese 1956 through 1962 records or other stations and in some cases were used. However, even in these cases, the critical dry period estimates of flow ultimately were derived from the Blue Nile at Roseires record.

The correlation curves (Figures III-16 through III-42) for stations used to estimate runoffs at damsites follow. They include the Blue Nile at Roseires versus the Blue Nile at Sennar curve used to estimate the 1911 runoff at Roseires.

DRAINAGE AREAS

For estimating runoff at damsites and for other purposes, the drainage area above each gaging station and each damsite was estimated by planimetering the areas on one or more of the following maps; a USAF Preliminary Base Map (1:500, 000), project map Drawing No. 4. 0-BN-3, Figure III-62 (1:500, 000 traced from the USAF Base Maps), a Geologic Reconnaissance Map, see Appendix II, Geology (1:500, 000 $\pm$ from unrectified flight sheets), or in the Gilgel Abbay area, from the Ethiopia-West German cooperative survey maps. Drainage areas are shown in Tables III-22 and III-23 and are probably subject to errors up to 30 percent.

PRECIPITATION-RUNOFF RELATIONSHIP

When sufficient runoff records became available Figure III-43 was prepared to show the precipitation-runoff relationship in the basin. The average annual runoff in centimeters of depth was plotted against the average annual precipitation in centimeters of depth for each gaging station on semilog paper and a straight line was drawn to show the average depth of runoff to be expected from any given average annual precipitation. Besides the runoff data, drainage areas and the precipitation map, Figure III-4, were utilized to obtain the necessary figures for plotting the points.

The precipitation-runoff graph was used to estimate increments of runoff when moving up or downstream from a gaging station to estimate runoff at a damsite.

ESTIMATES BY MONTHS

At Gaging Stations

The historical runoff in cubic meters by months for each of the gaging stations within the Blue Nile Basin in Ethiopia is given on Tables III-24 through III-59, which are arranged starting at the upper end of the basin and working downstream with the main stem stations from Abbay near Kese through Abbay near Sudan border placed last. If the station is also at a damsite it is so indicated and if the station was used to obtain estimated flow through the critical study period for one or more damsites the estimated correlated natural flows for that period at the station (with the method or correlation curve used noted) are entered on the same sheet with the historical runoff.

At Damsites

The estimated critical study period natural flow by months at each damsite (not at a gaging station site tabulated previously) is given on Tables III-60 through III-78, which are arranged in an order similar to the gaging stations, starting at the upper end of the basin. The method of estimating the flow is given on each sheet (generally moving up or down a stream from a gaging station by straight or square root proportion of the drainage areas or by precipitation-runoff relationship for the drainage area increment or decrement). The flows as modified by contemplated upstream development are given on the operation study tables in Section IV.

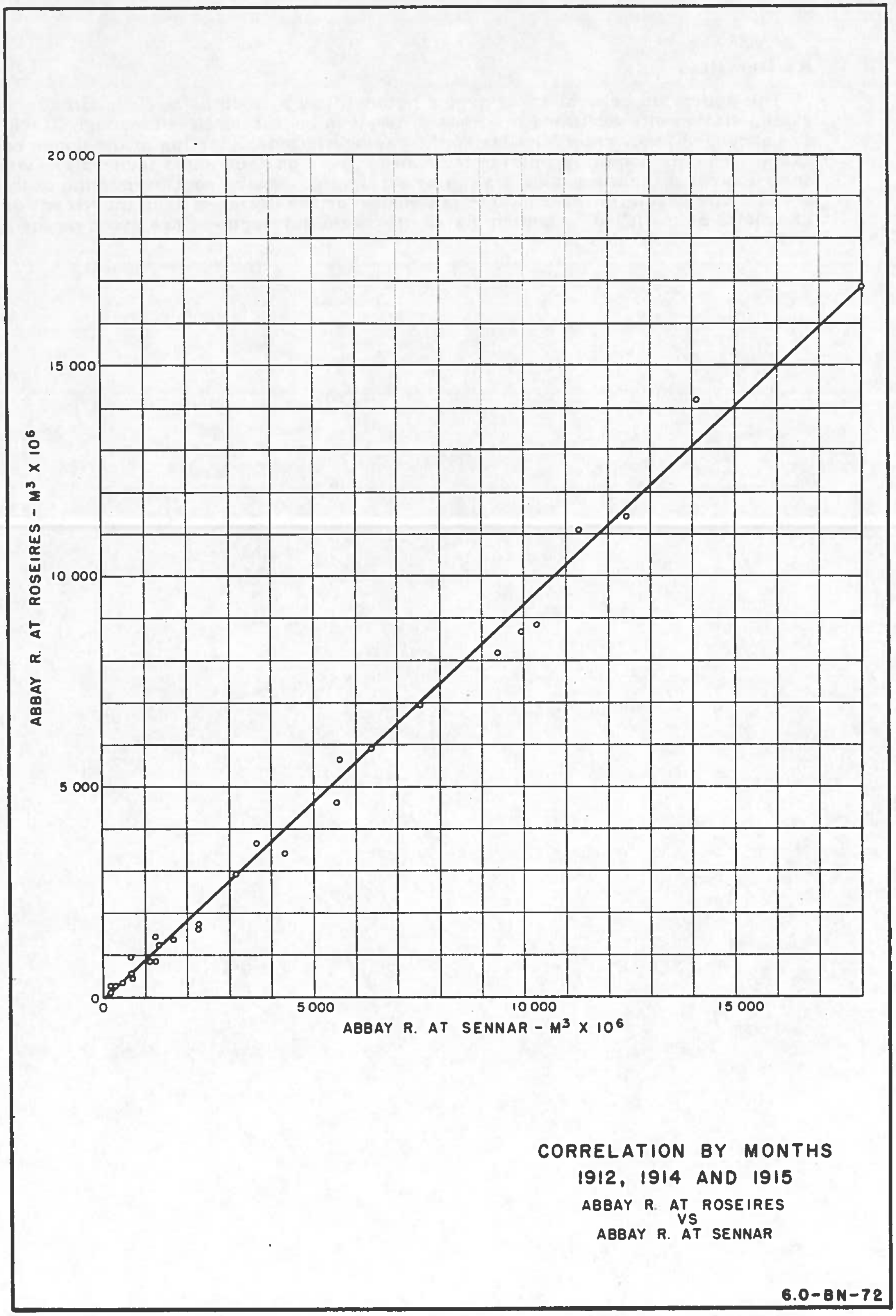


Figure III-16--Correlation by Months, 1912, 1914, and 1915-Abbay River at Roseires v. Abbay River at Sennar

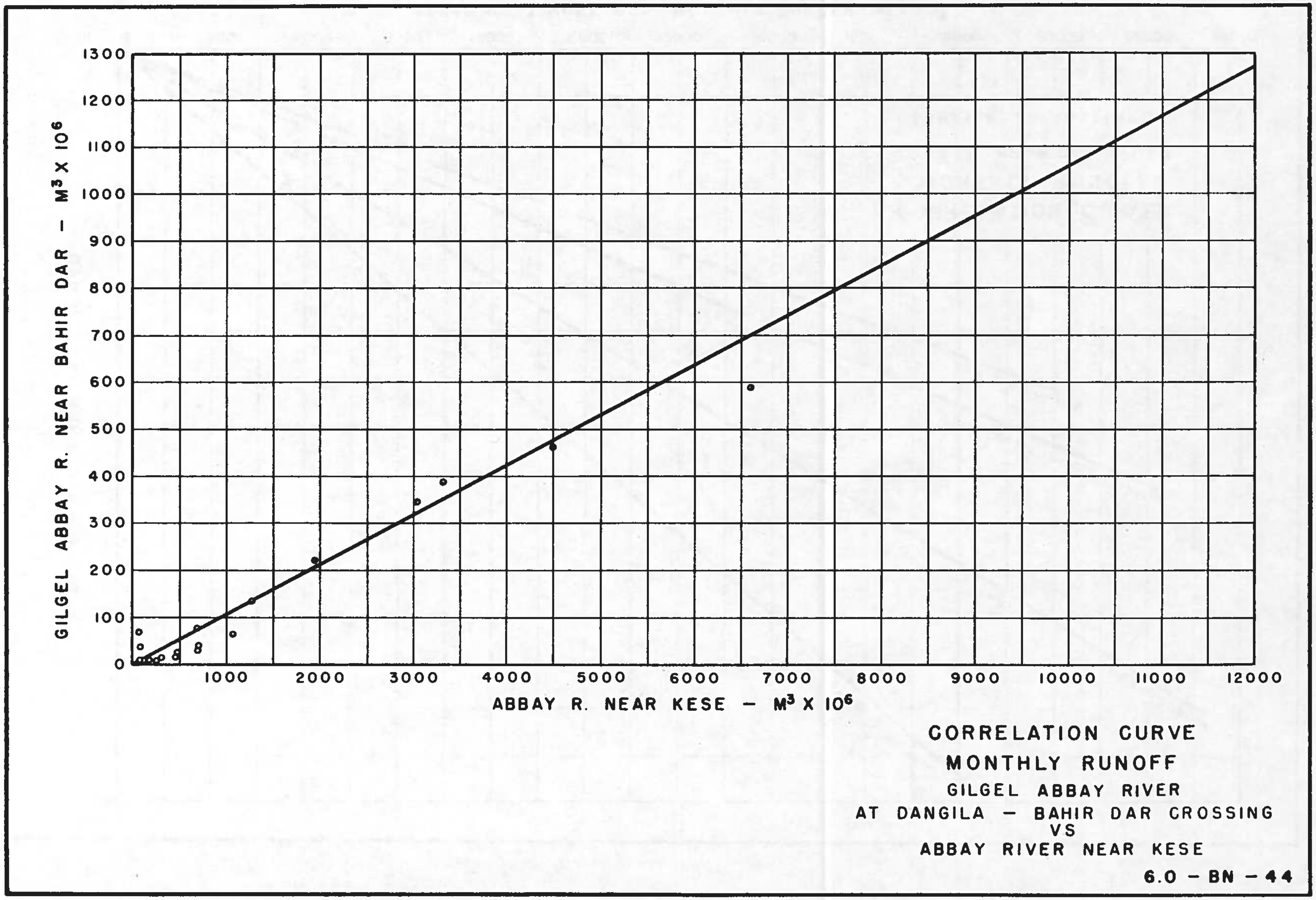


Figure III-17--Correlation Curve, Monthly Runoff--Gilgel Abbay River at Dangila v. Abbay River near Kese

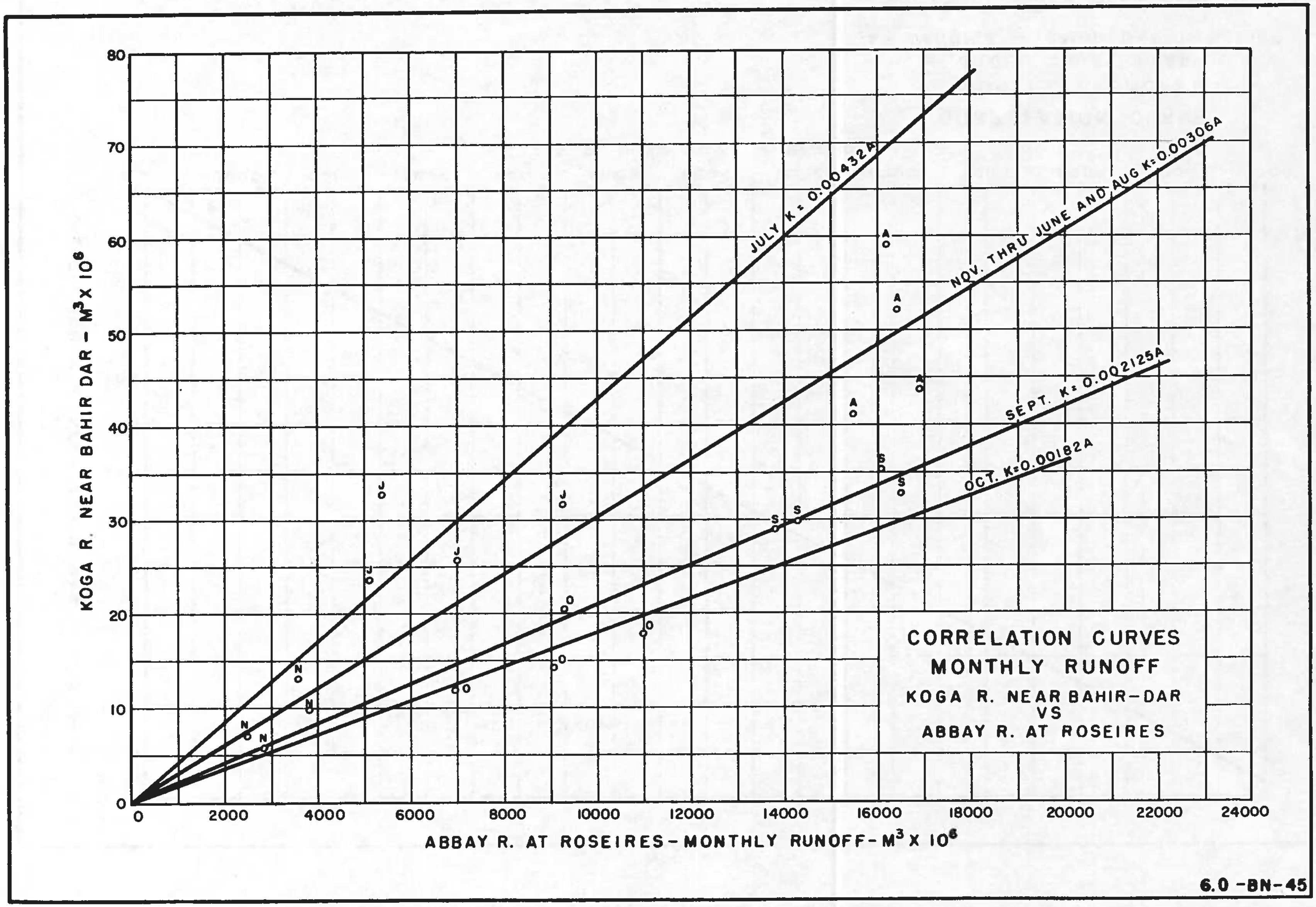


Figure III-18--Correlation Curves, Monthly Runoff--Koga R. near Bahir Dar v. Abbay R. at Roseires

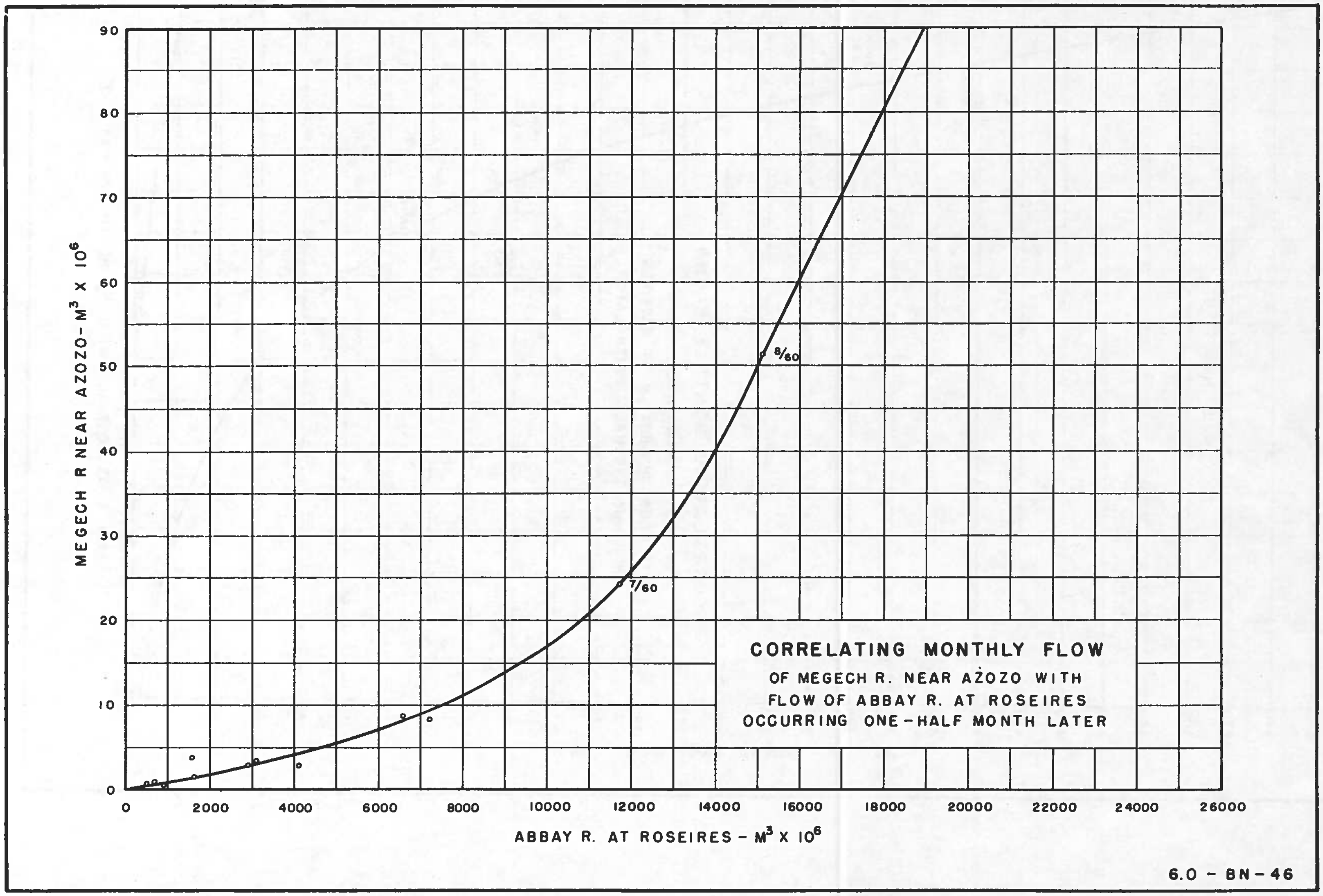


Figure III-19--Correlating Monthly Flow--Megech R. near Azozo v. Abbay R. at Roseires

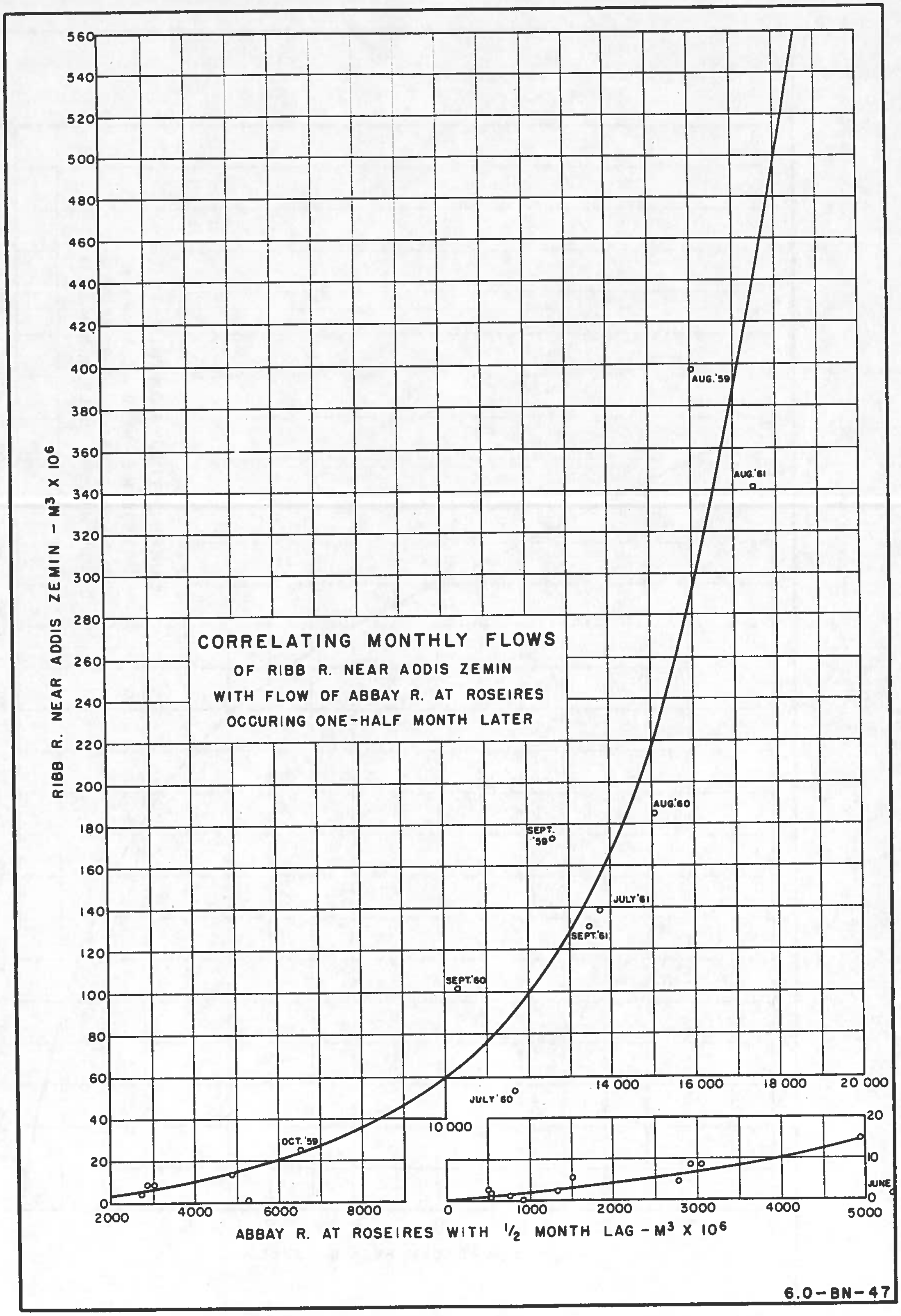


Figure III-20--Correlating Monthly Flows--Ribb R. near Addis Zemin v. Abbay R. at Roseires

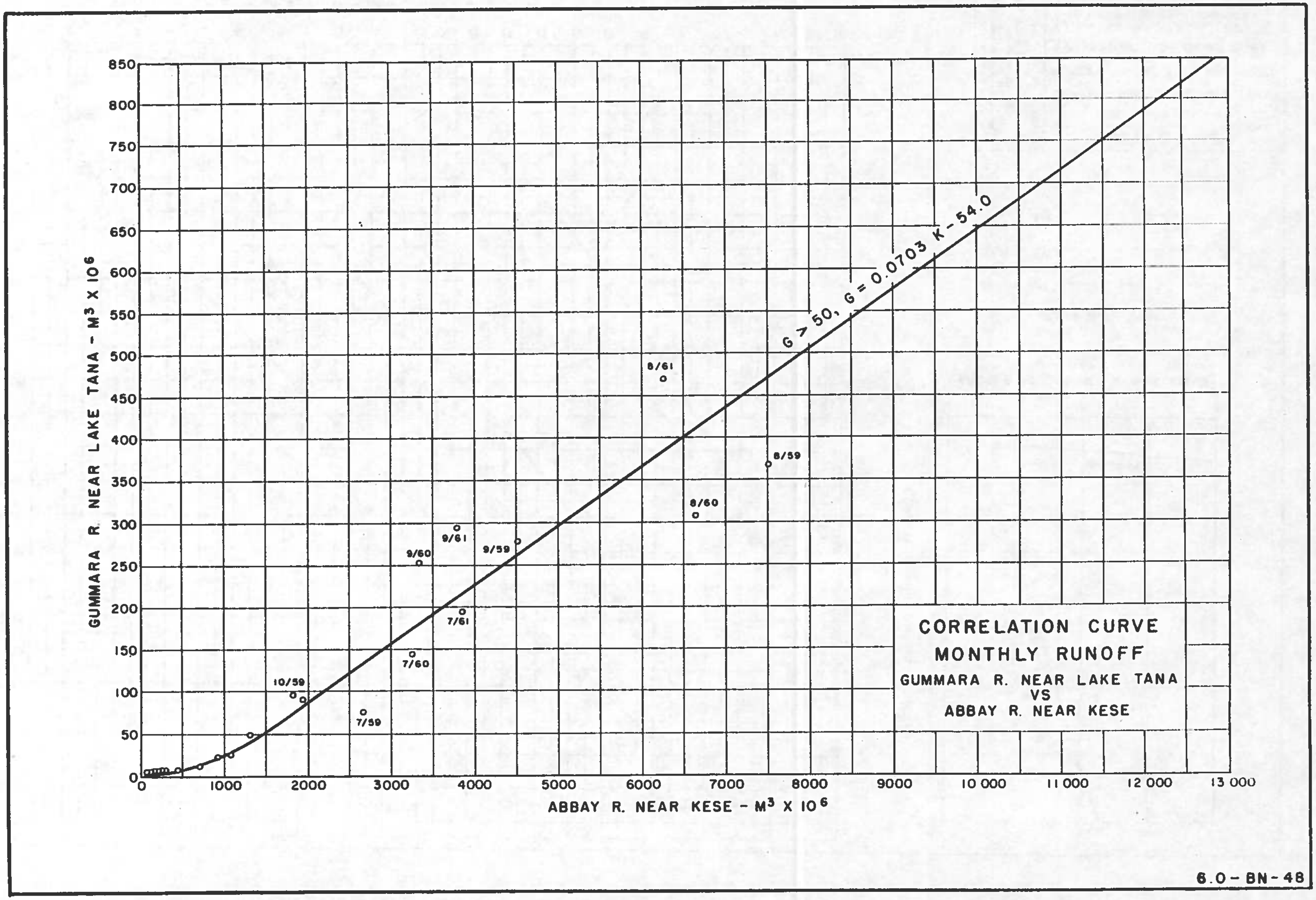


Figure III-21--Correlation Curve, Monthly Runoff--Gumara R. near Lake Tana v. Abbay R. near Kese

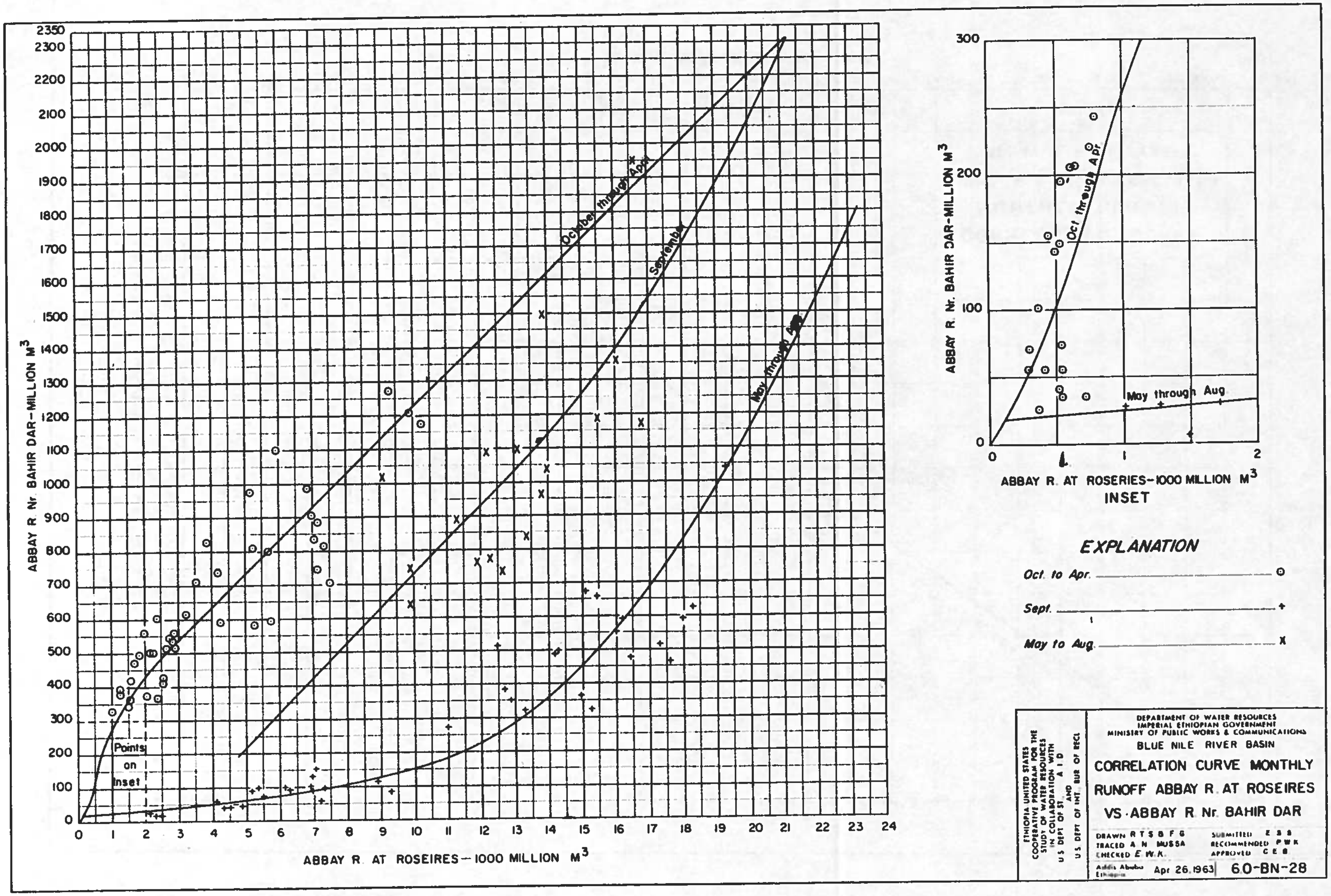


Figure III-22--Correlation Curve, Monthly Runoff--Abbay R. near Bahir Dar v. Abbay R. at Roseires

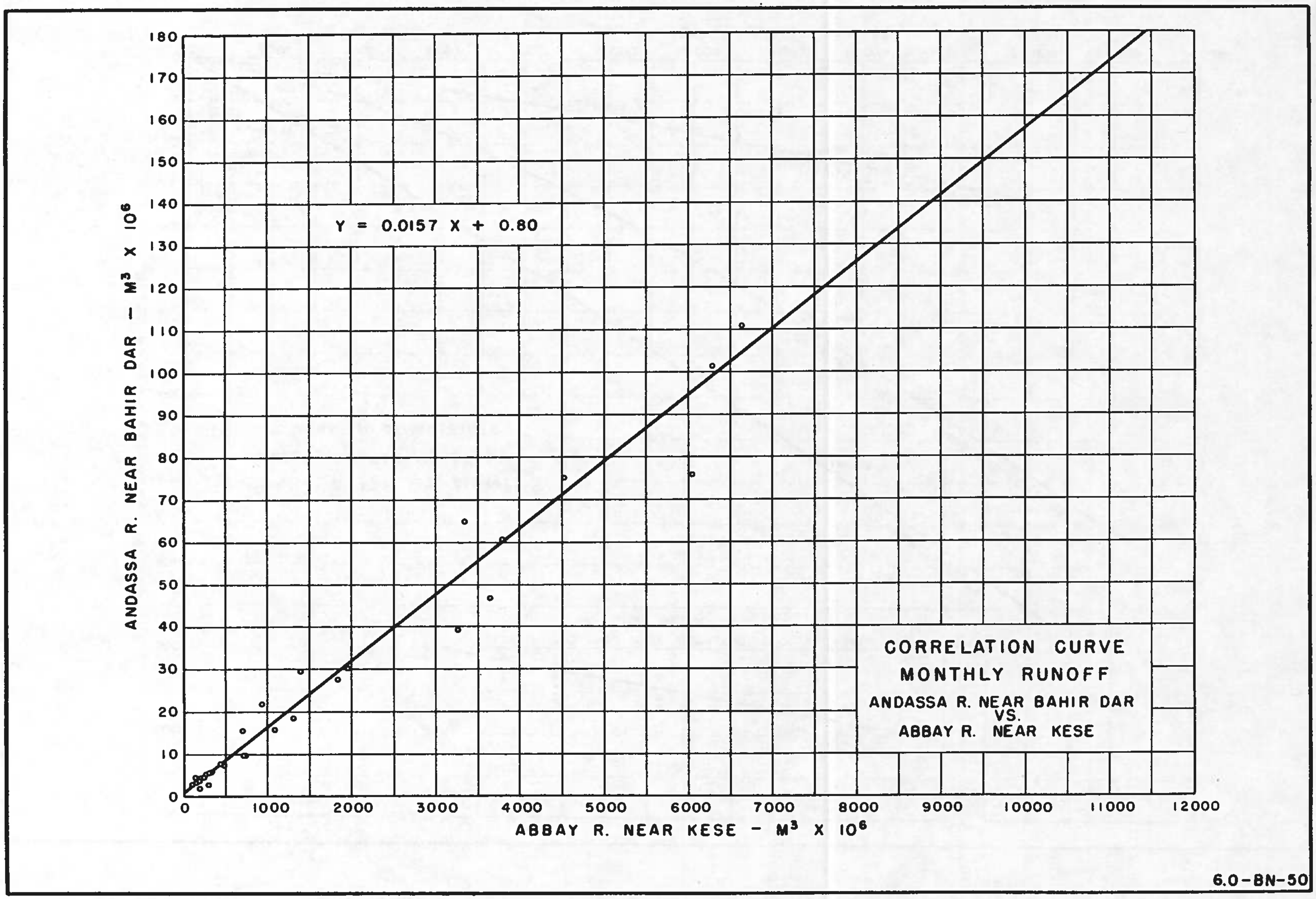


Figure III-23--Correlation Curve, Monthly Runoff--Andassa R. near Bahir Dar v. Abbay R. near Kese

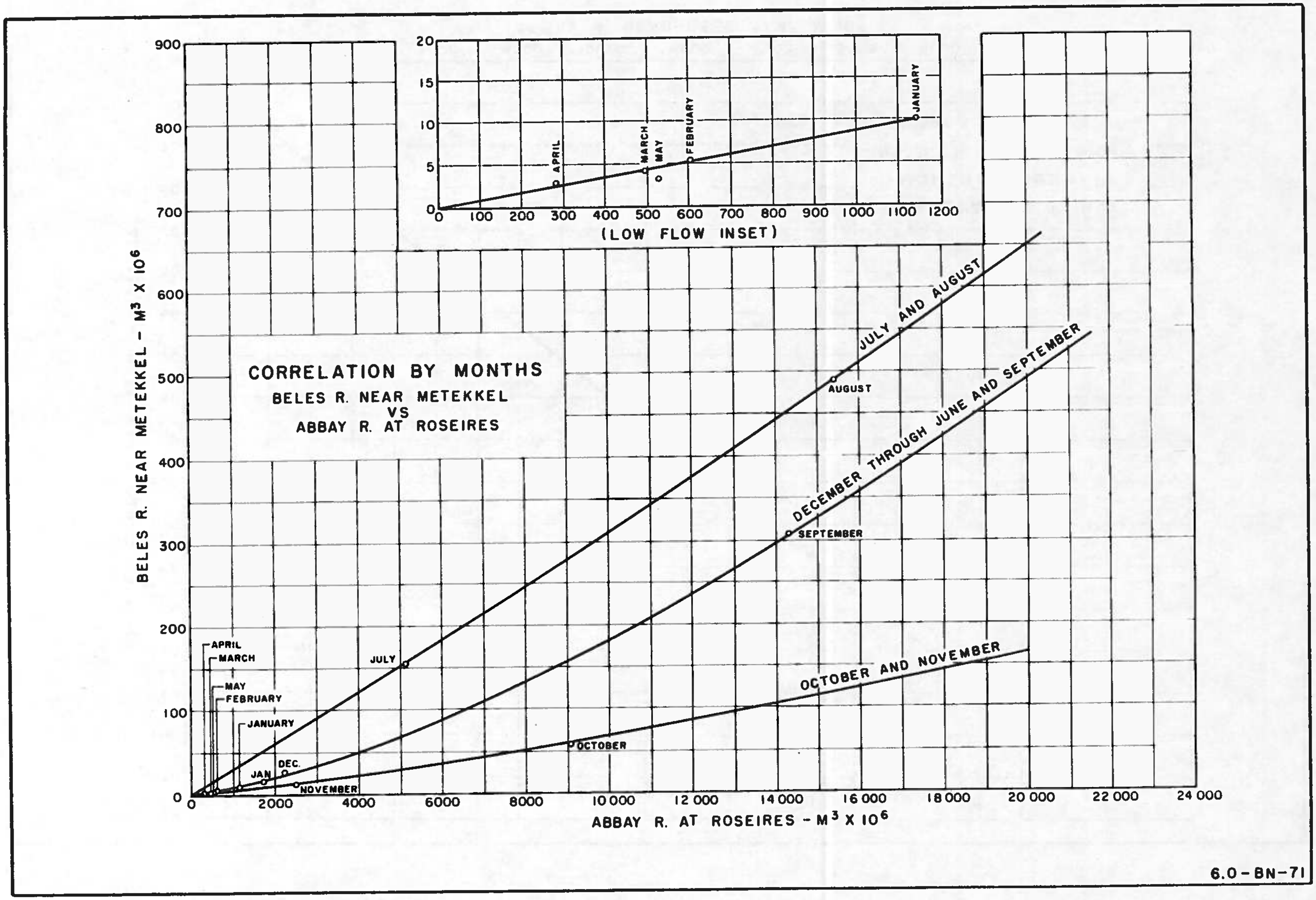


Figure III-24--Correlation by Months--Beles R. near Metekkel v. Abbay R. at Roseires

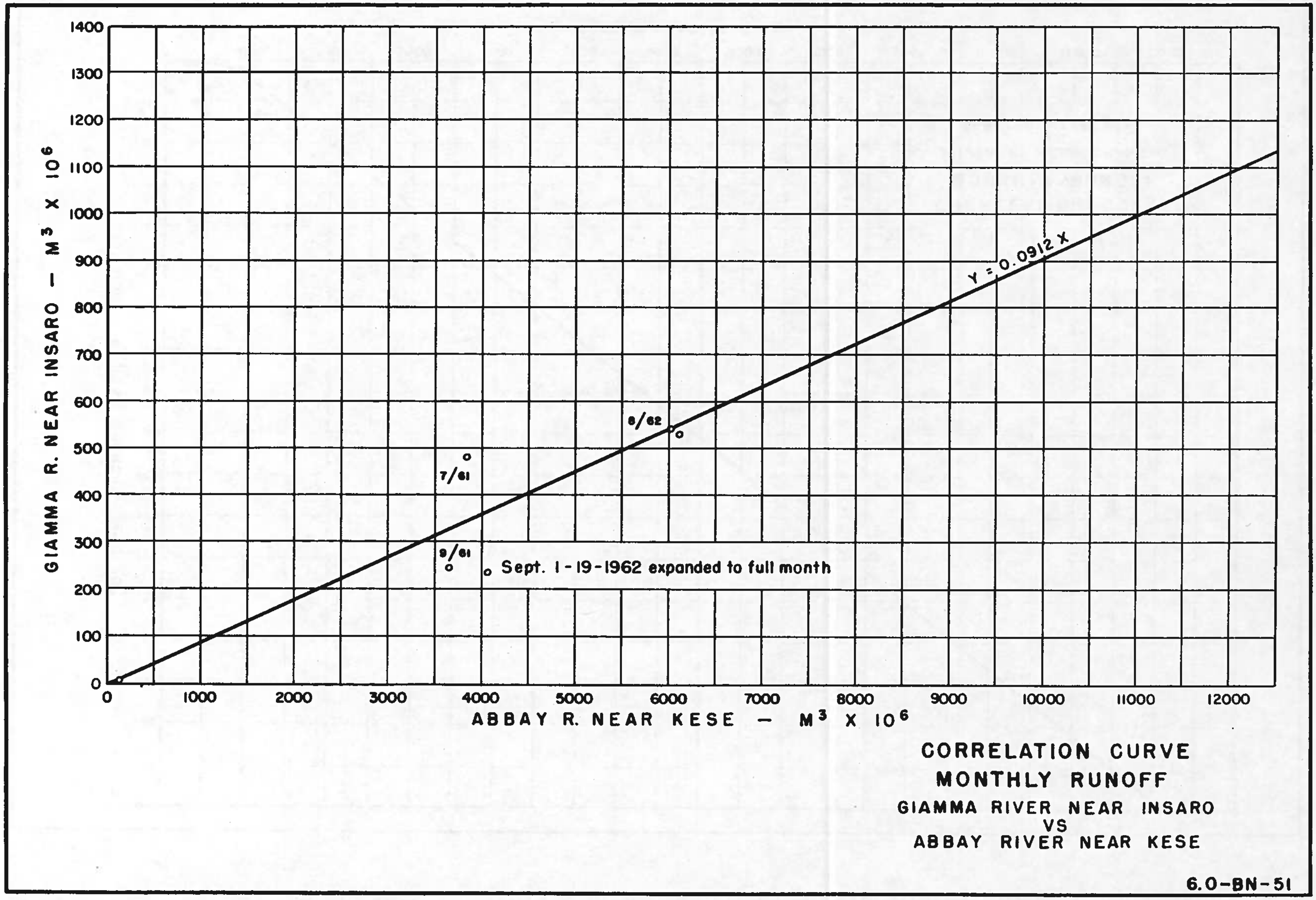


Figure III-25--Correlation Curve, Monthly Runoff--Giamma R. near Insaro v. Abbay R. near Kese

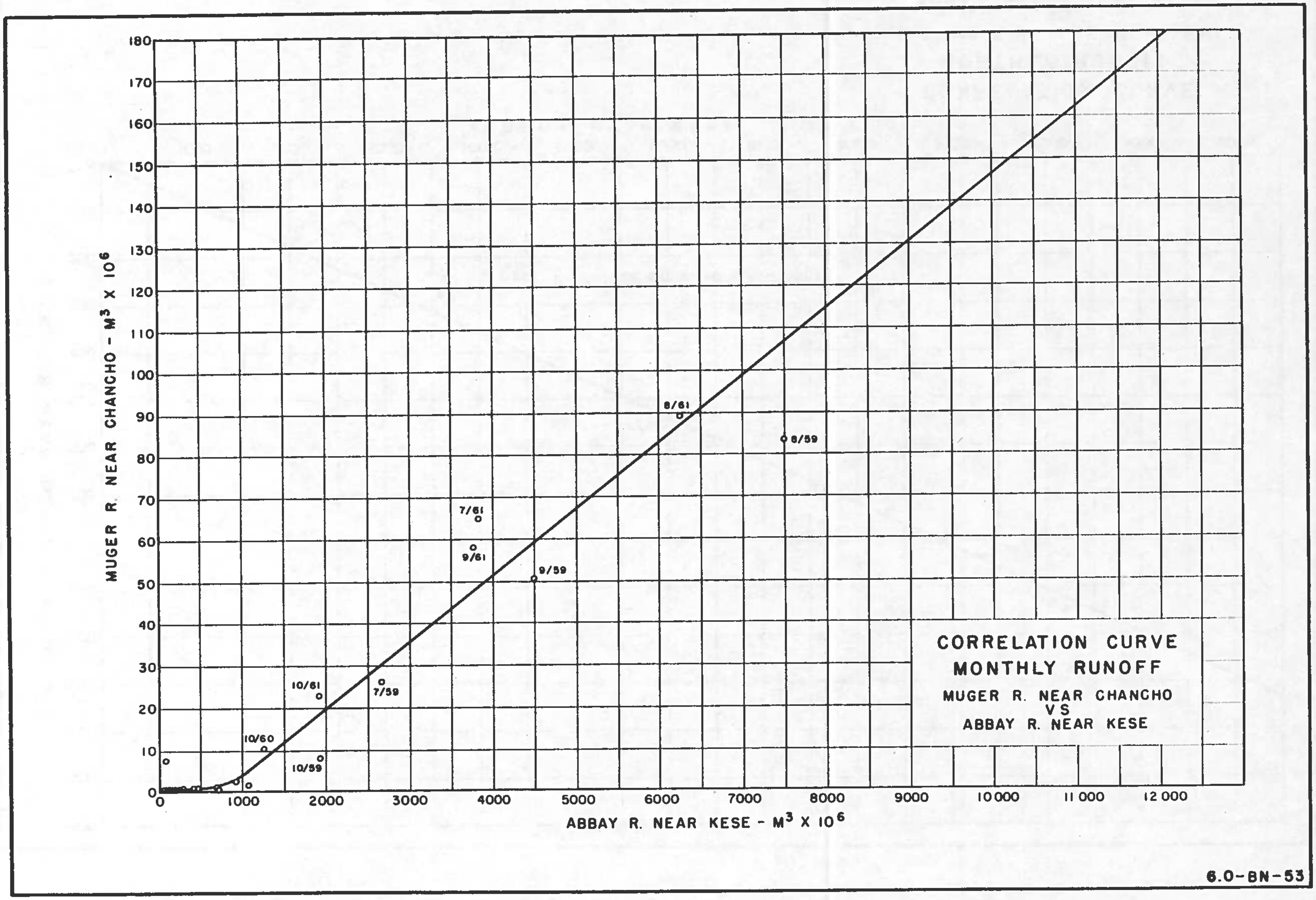


Figure III-26--Correlation Curve, Monthly Runoff--Muger R. near Chancho v. Abbay R. near Kese

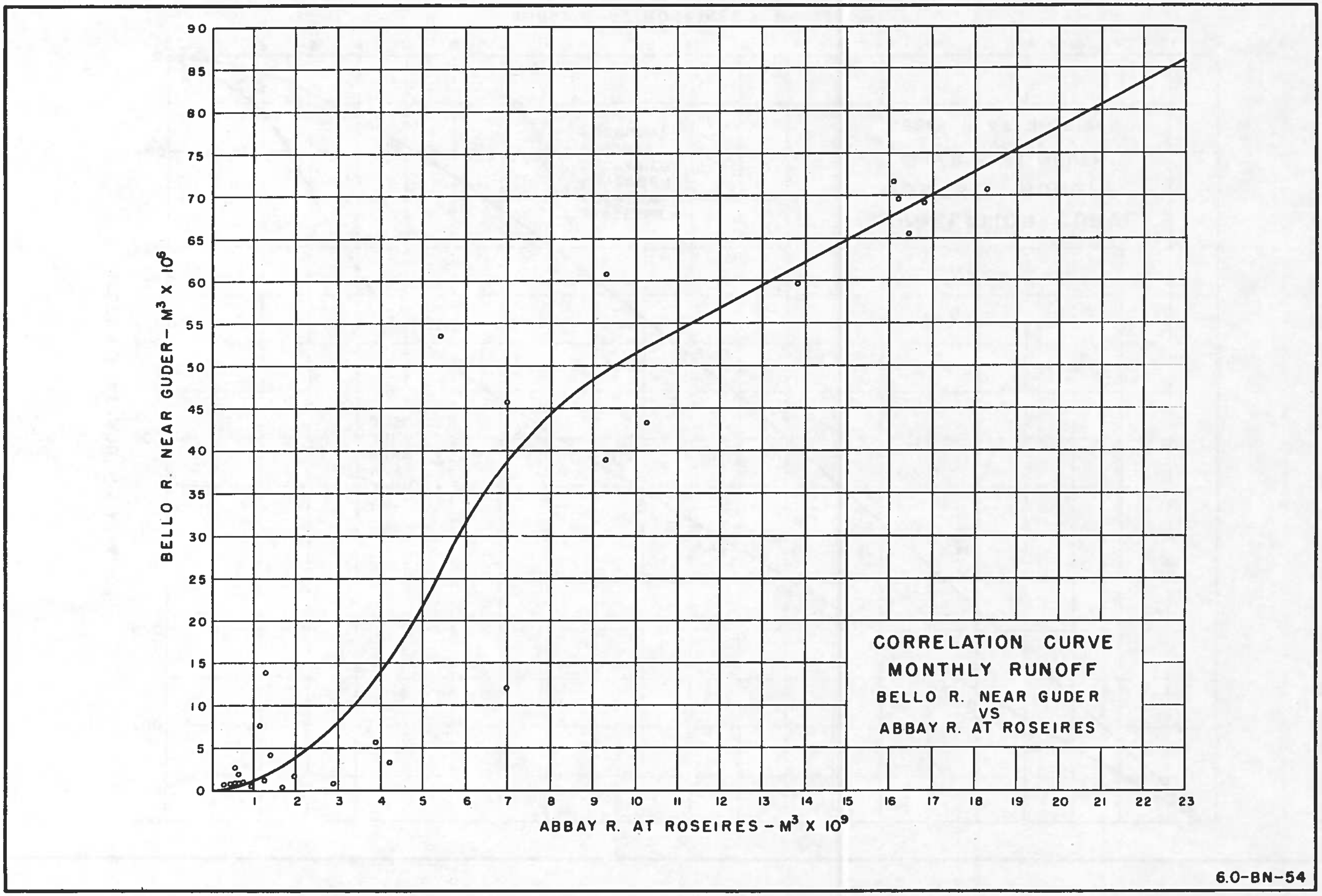


Figure III-27--Correlation Curve, Monthly Runoff--Bello R. near Guder v. Abbay R. at Roseires

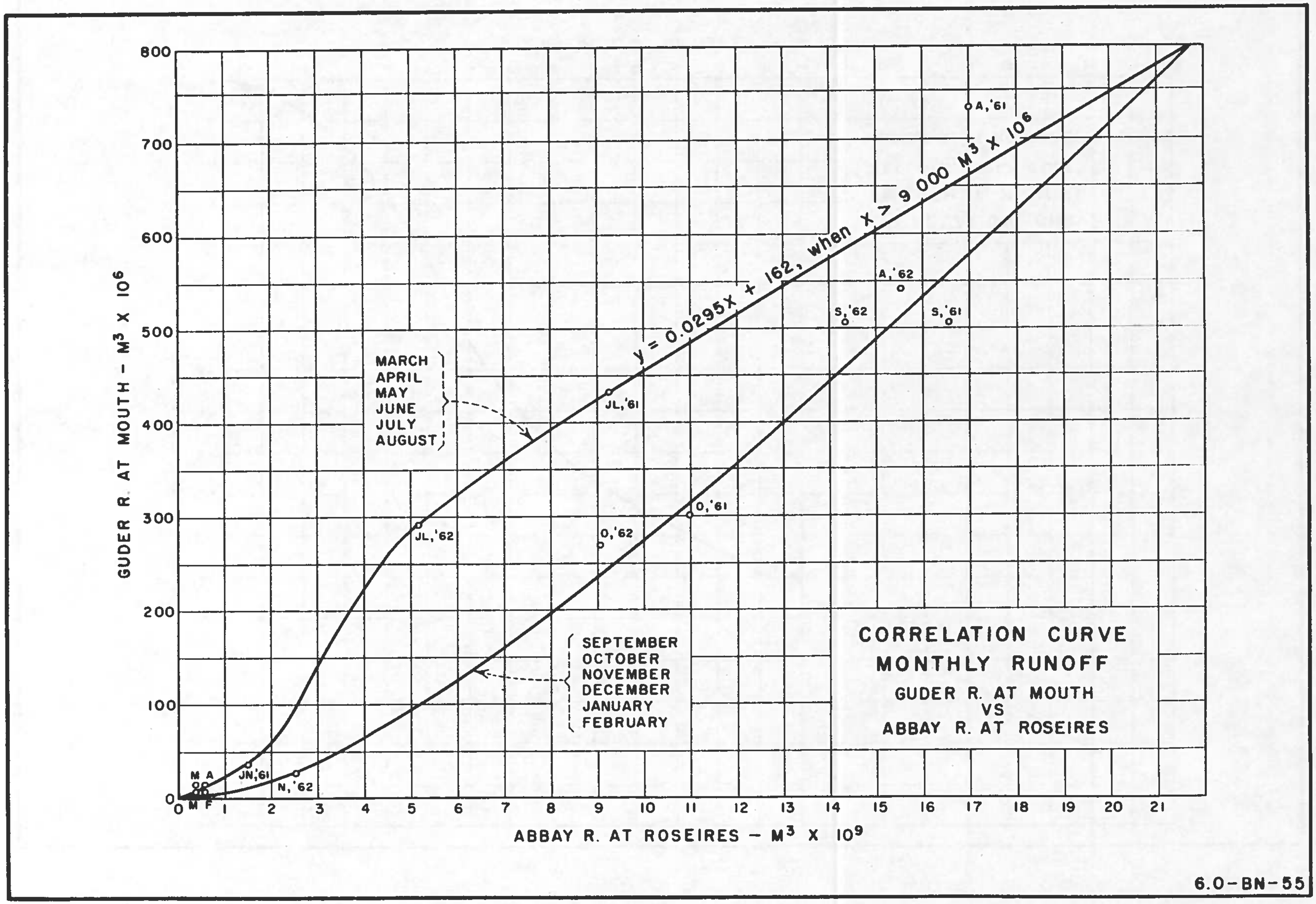


Figure III-28--Correlation Curve, Monthly Runoff--Guder R. at Mouth v. Abbay R. at Roseires

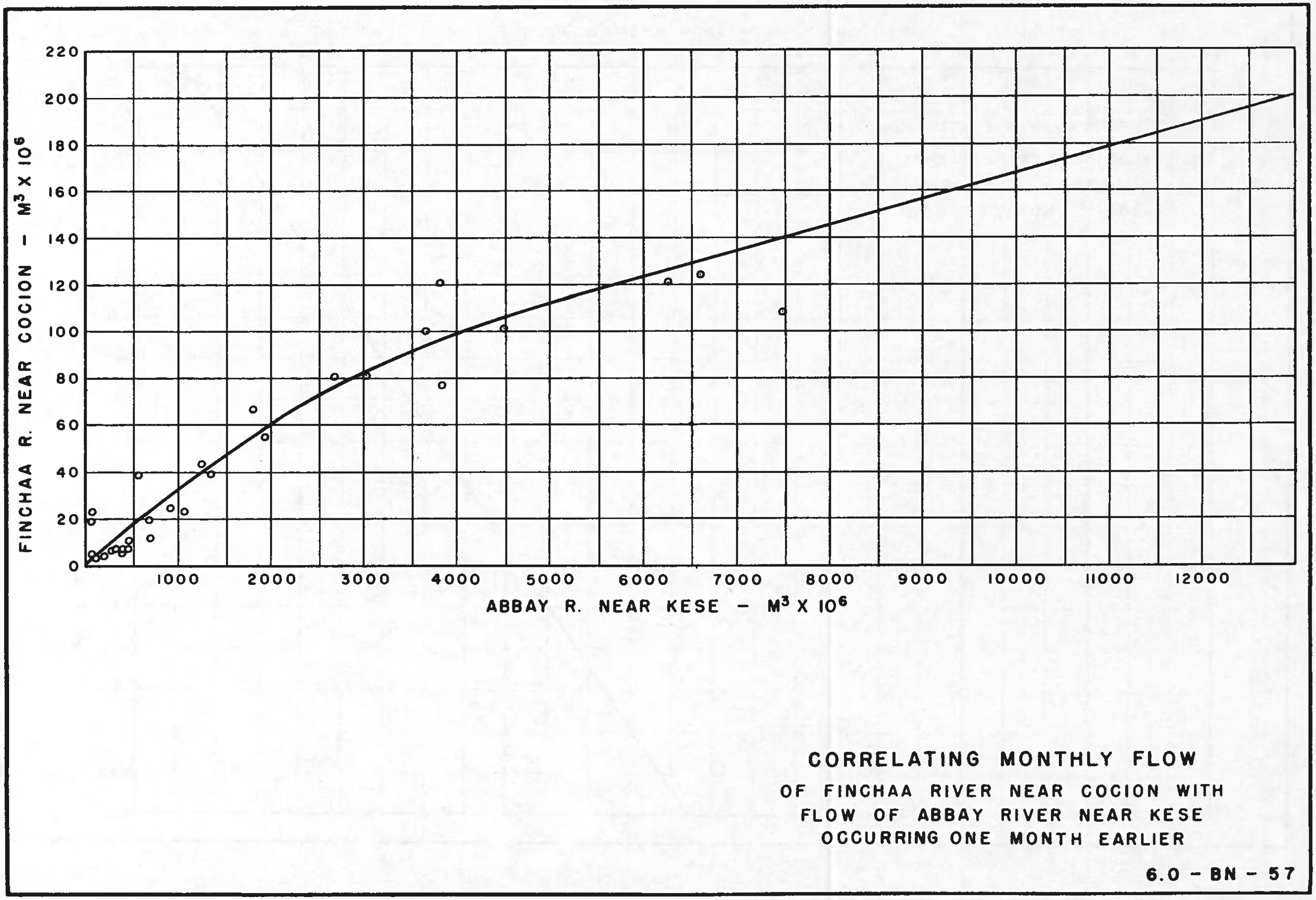


Figure III-29--Correlating Monthly Flow--Finchaa R. near Cochion v. Abbay R. near Kese

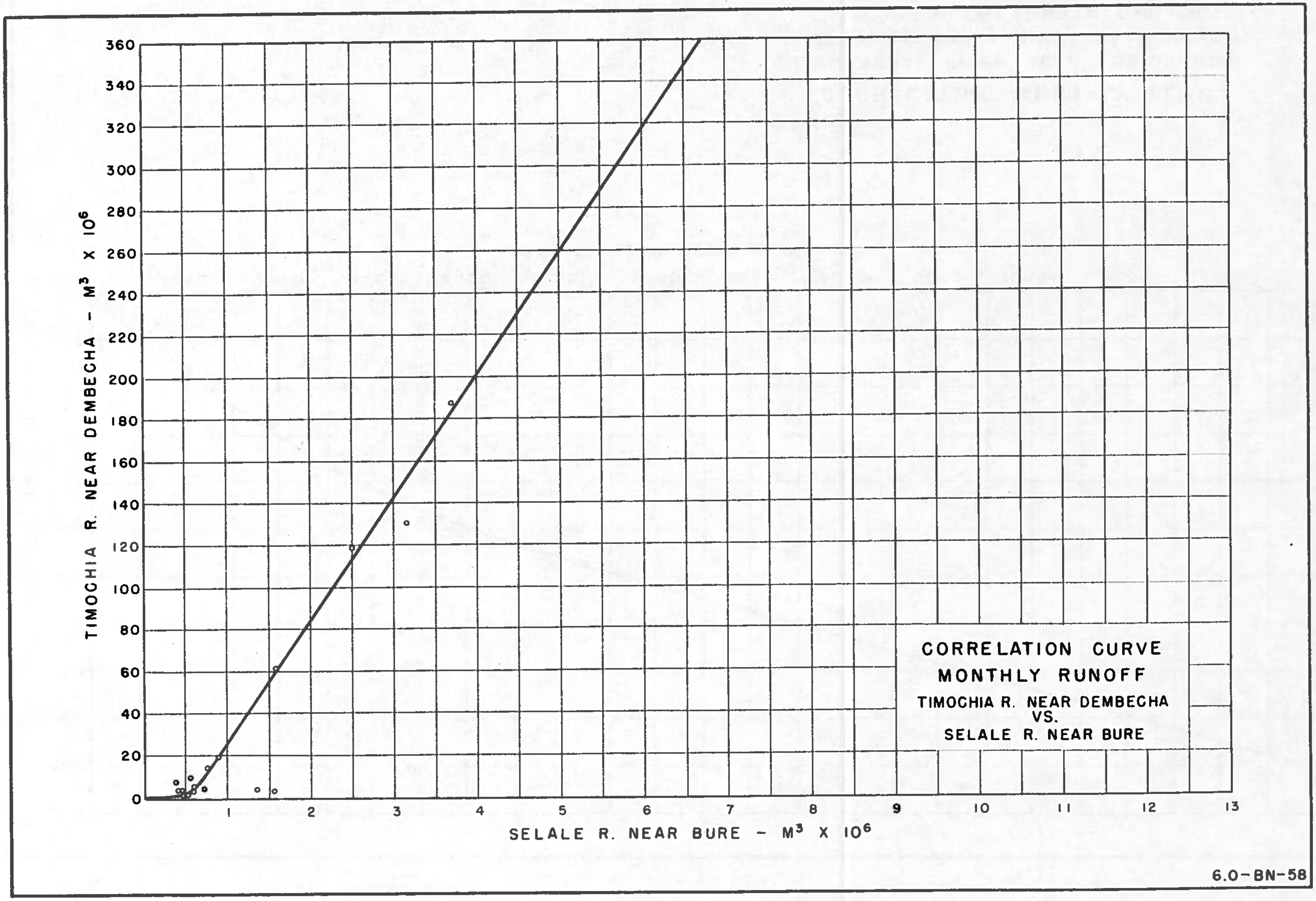


Figure III-30--Correlation Curve, Monthly Runoff--Timochia R. near Dembecha v. Selale R. near Bure

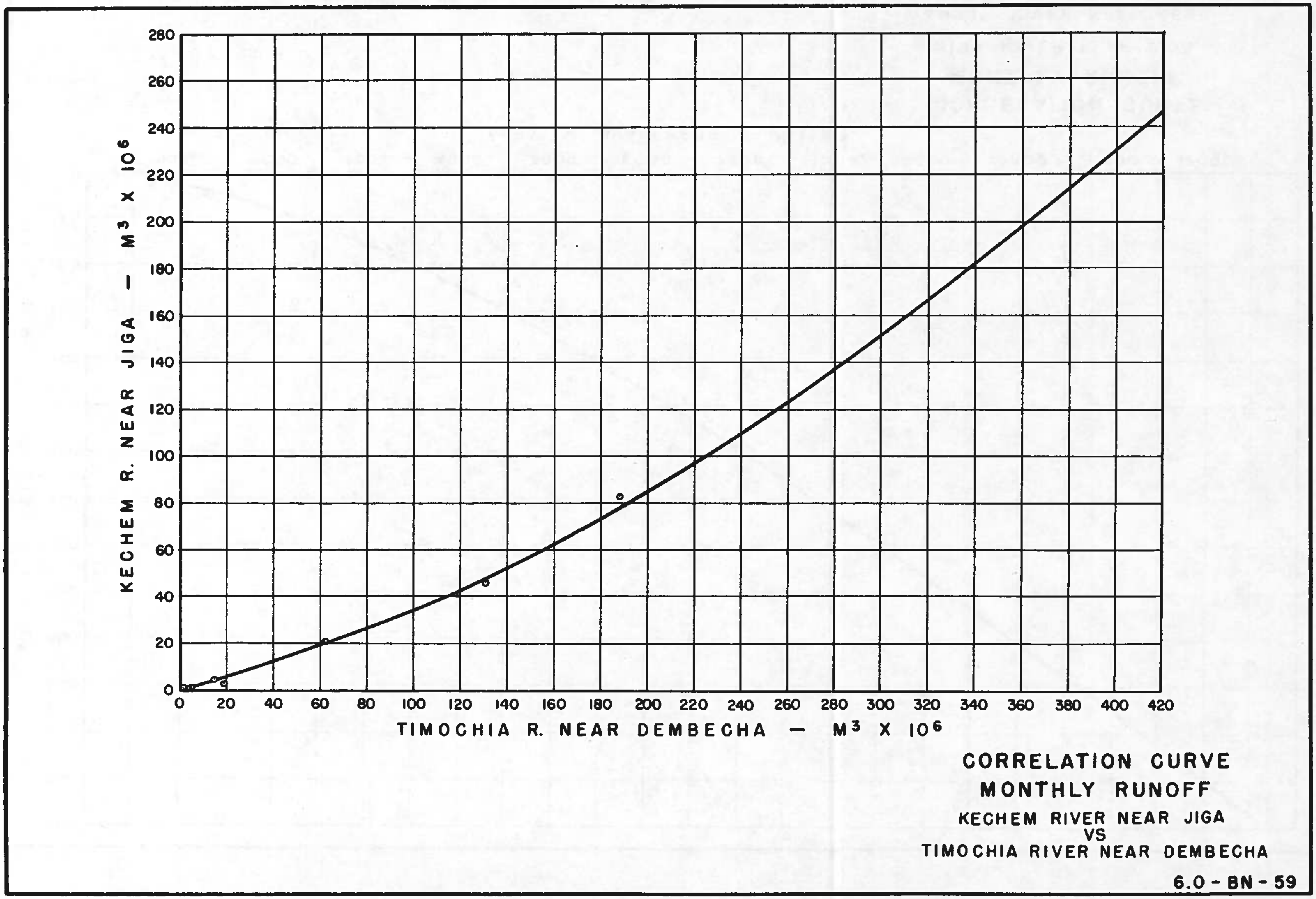


Figure III-31--Correlation Curve, Monthly Runoff--Kechem R. near Jiga v. Timochia R. near Dembecha

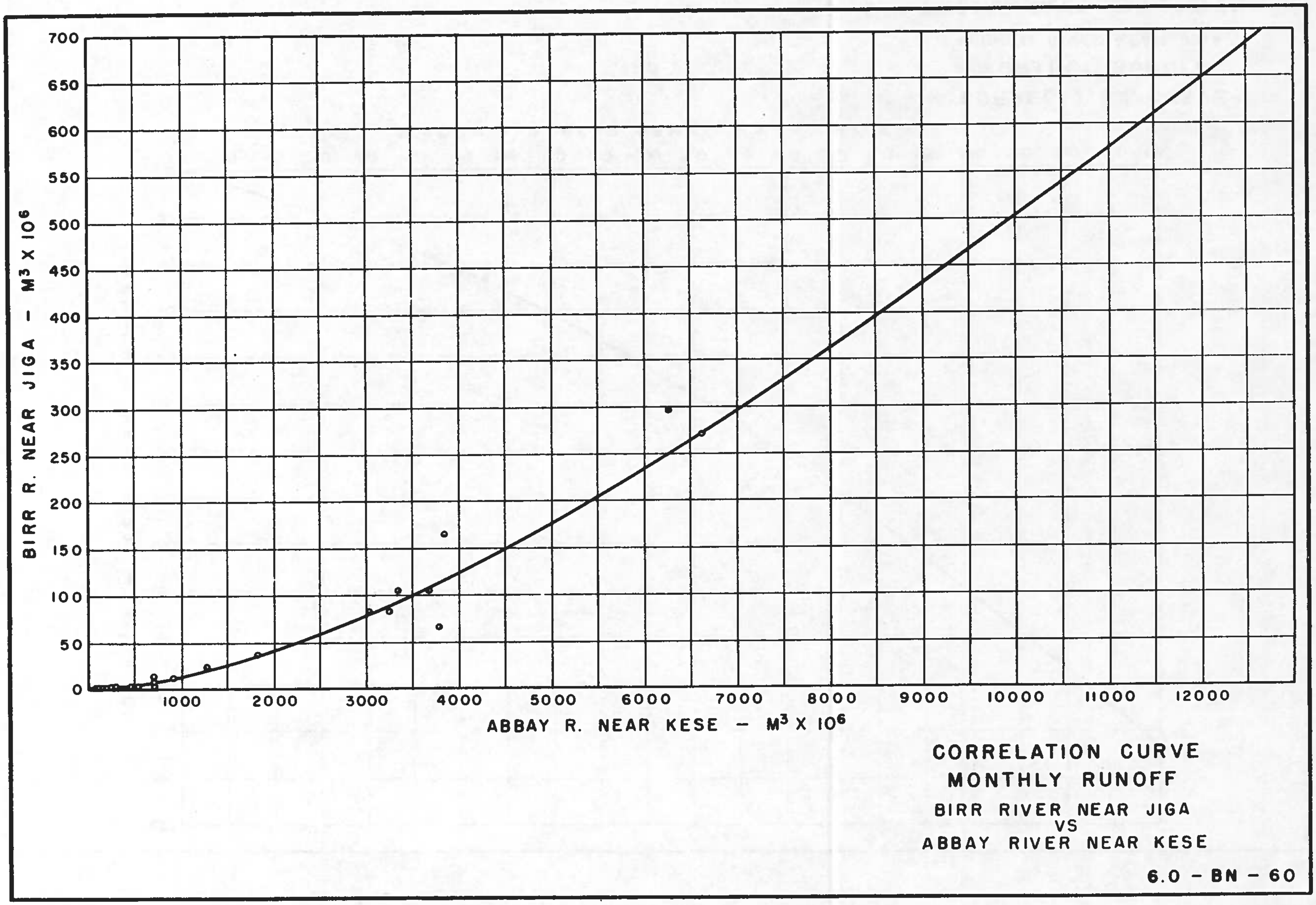


Figure III-32--Correlation Curve, Monthly Runoff--Birr R. near Jiga v. Abbay R. near Kese

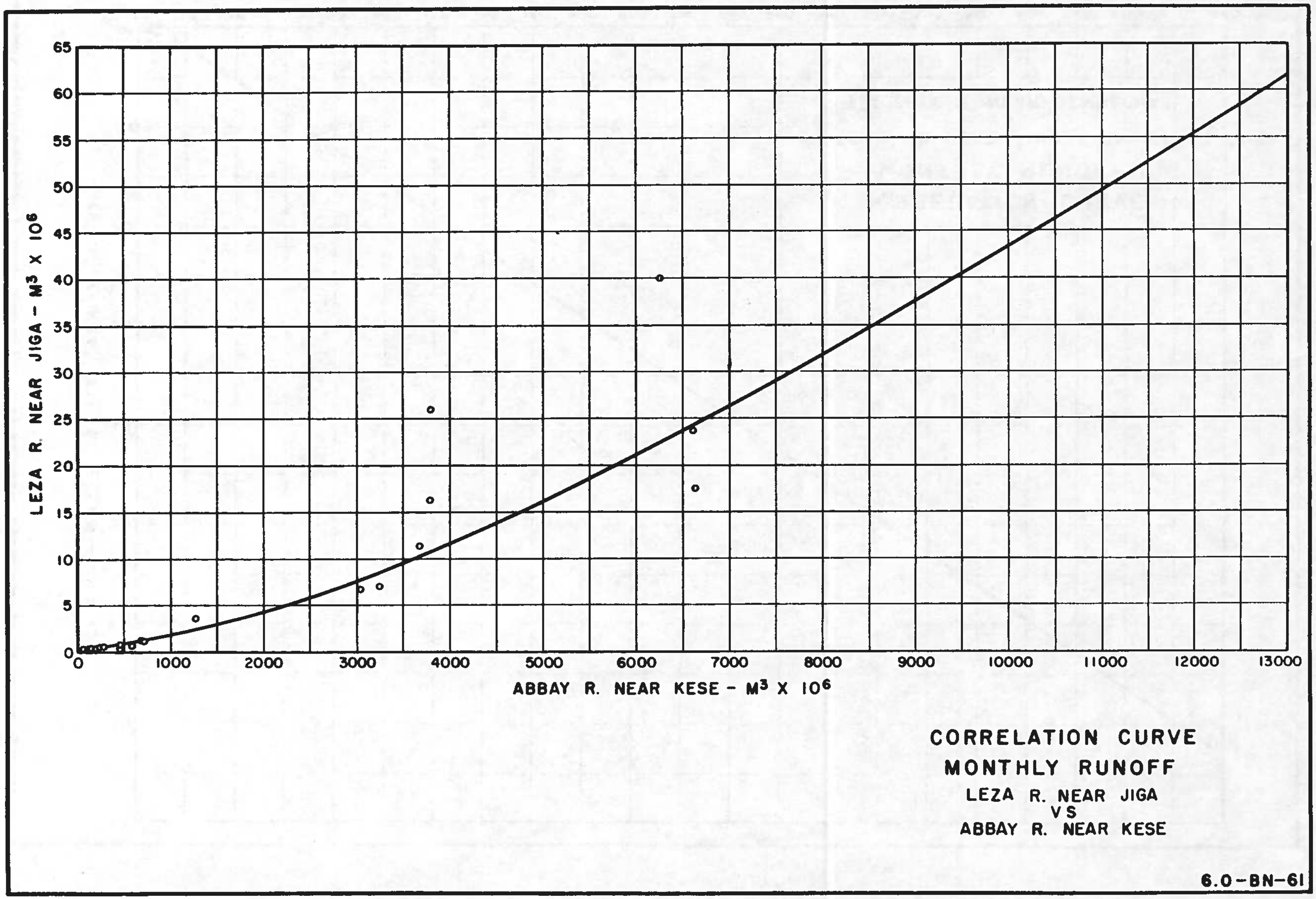


Figure III-33--Correlation Curve, Monthly Runoff--Leza R. near Jiga v. Abbay R. near Kese

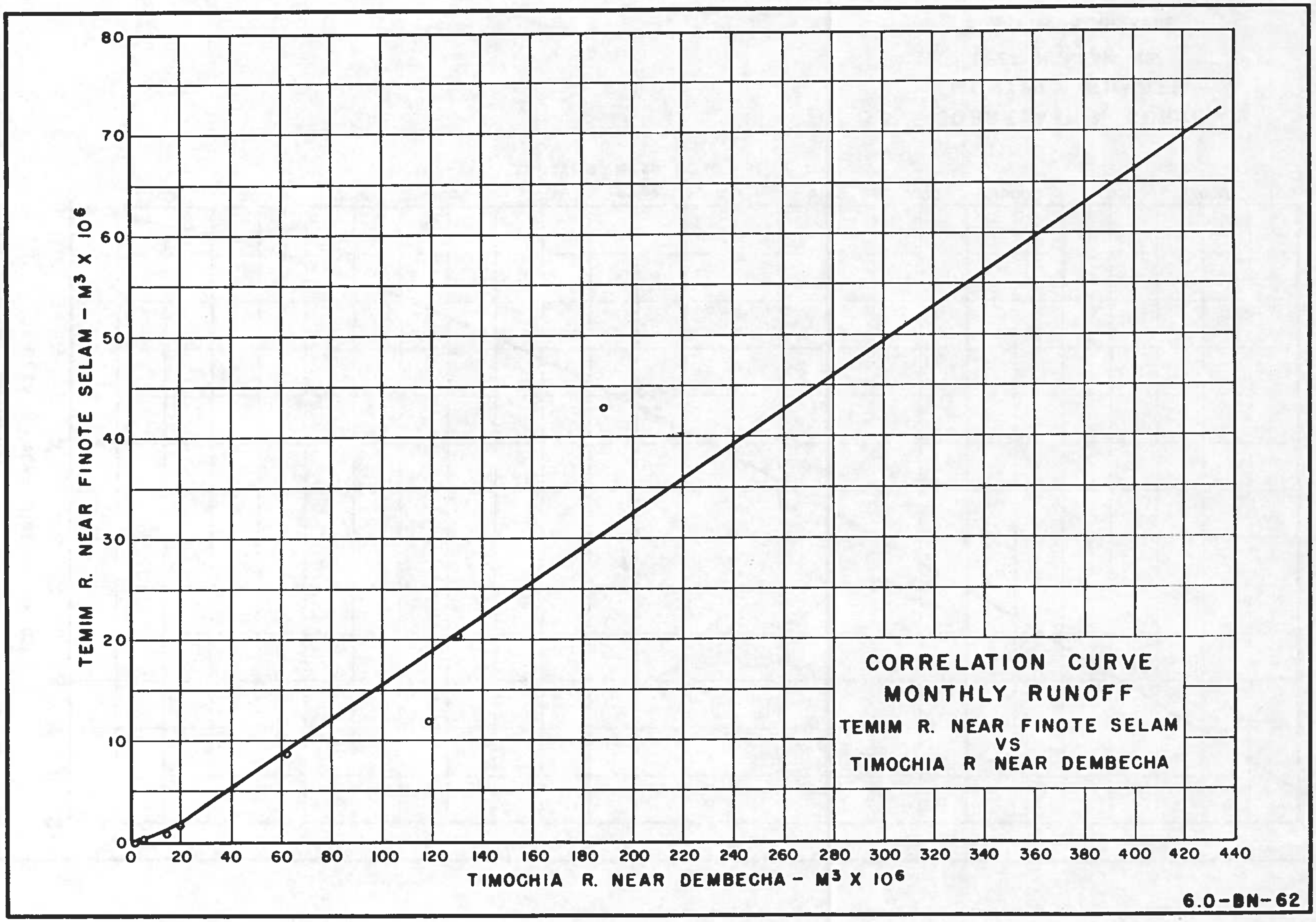


Figure III-34--Correlation Curve, Monthly Runoff--Temim R. near Finote Selam v. Timochia R. near Dembecha

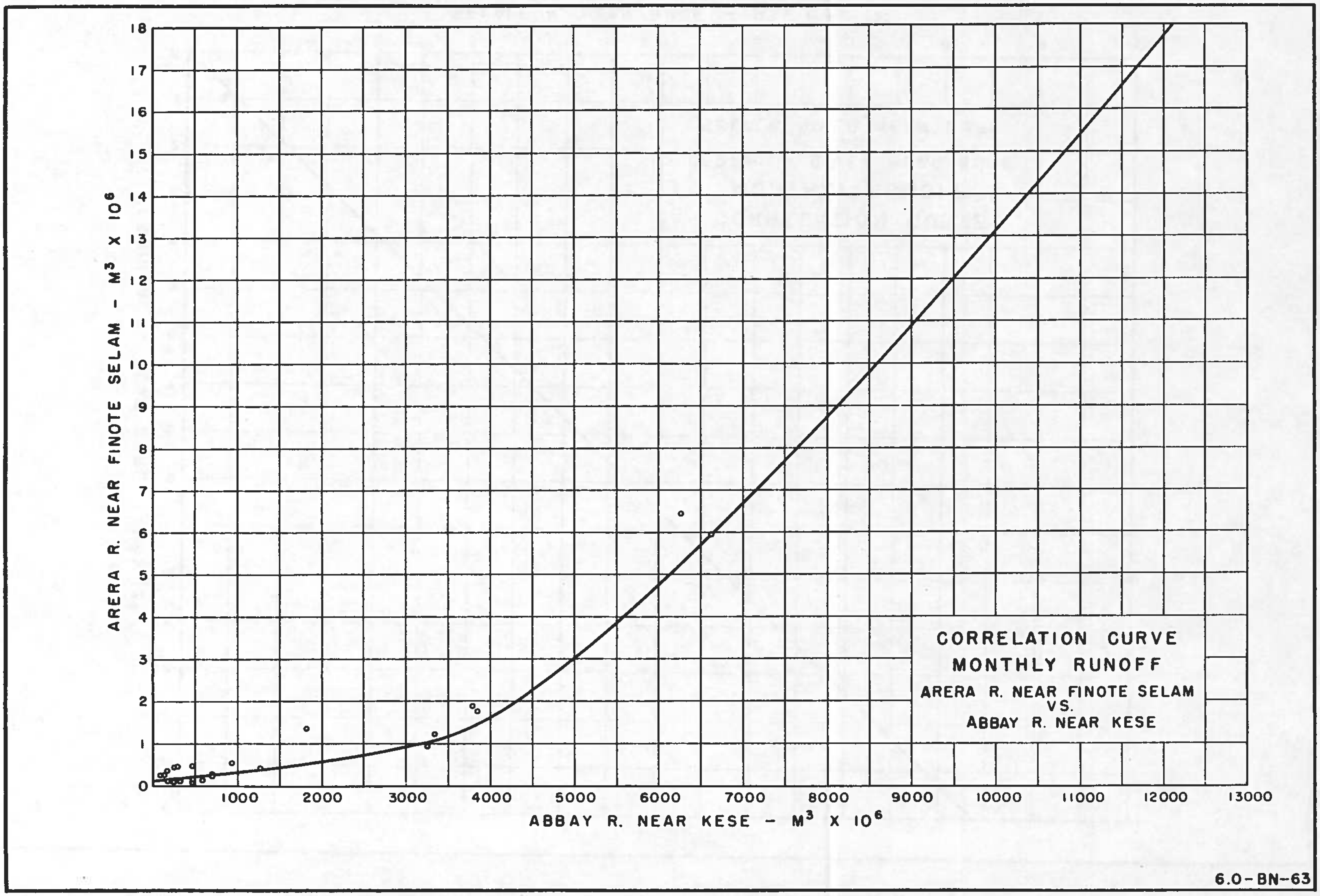


Figure III-35--Correlation Curve, Monthly Runoff--Arera R. near Finote Selam v. Abbay R. near Kese

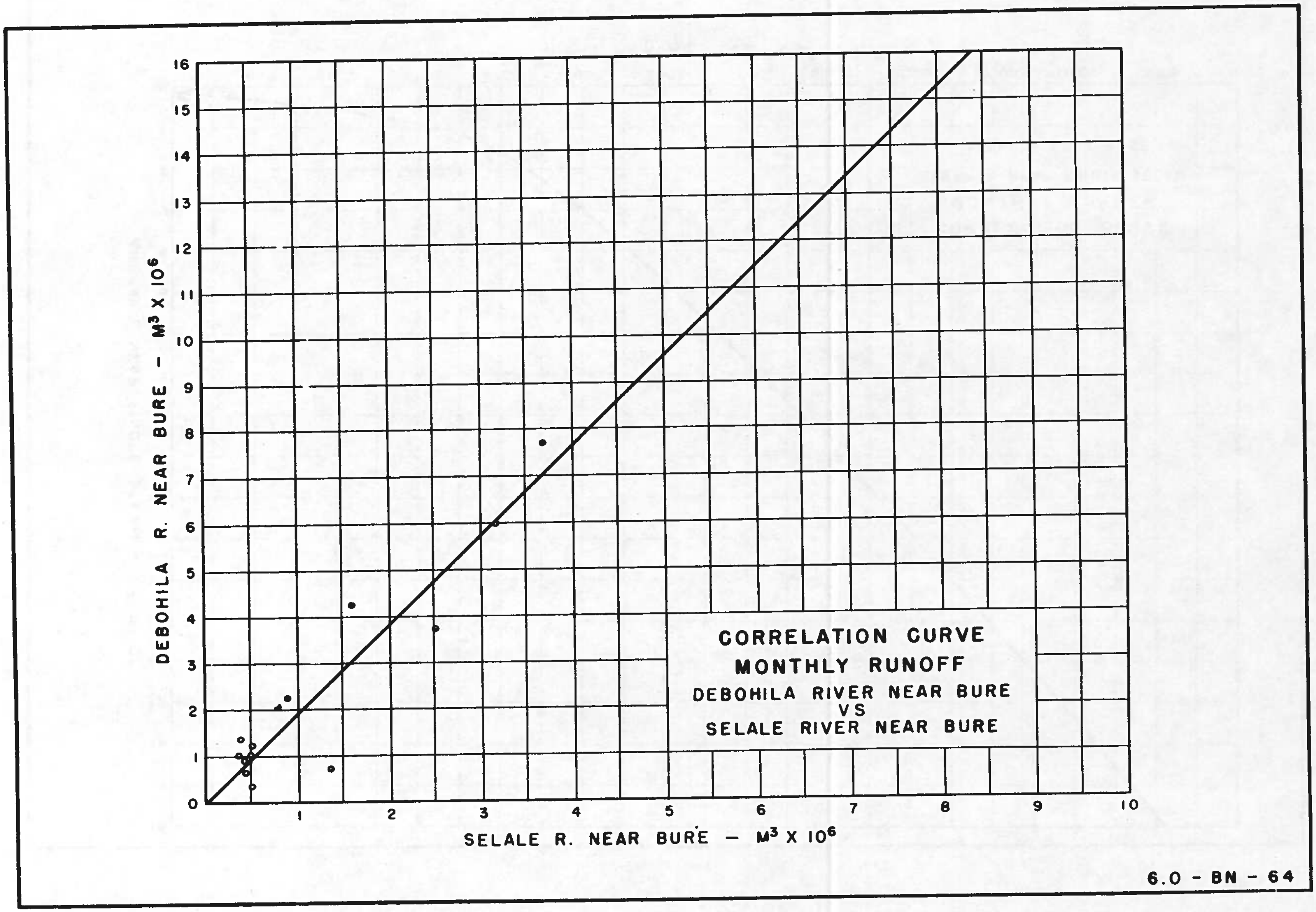


Figure III-36--Correlation Curve, Monthly Runoff--Debohila R. near Bure v. Selale R. near Bure

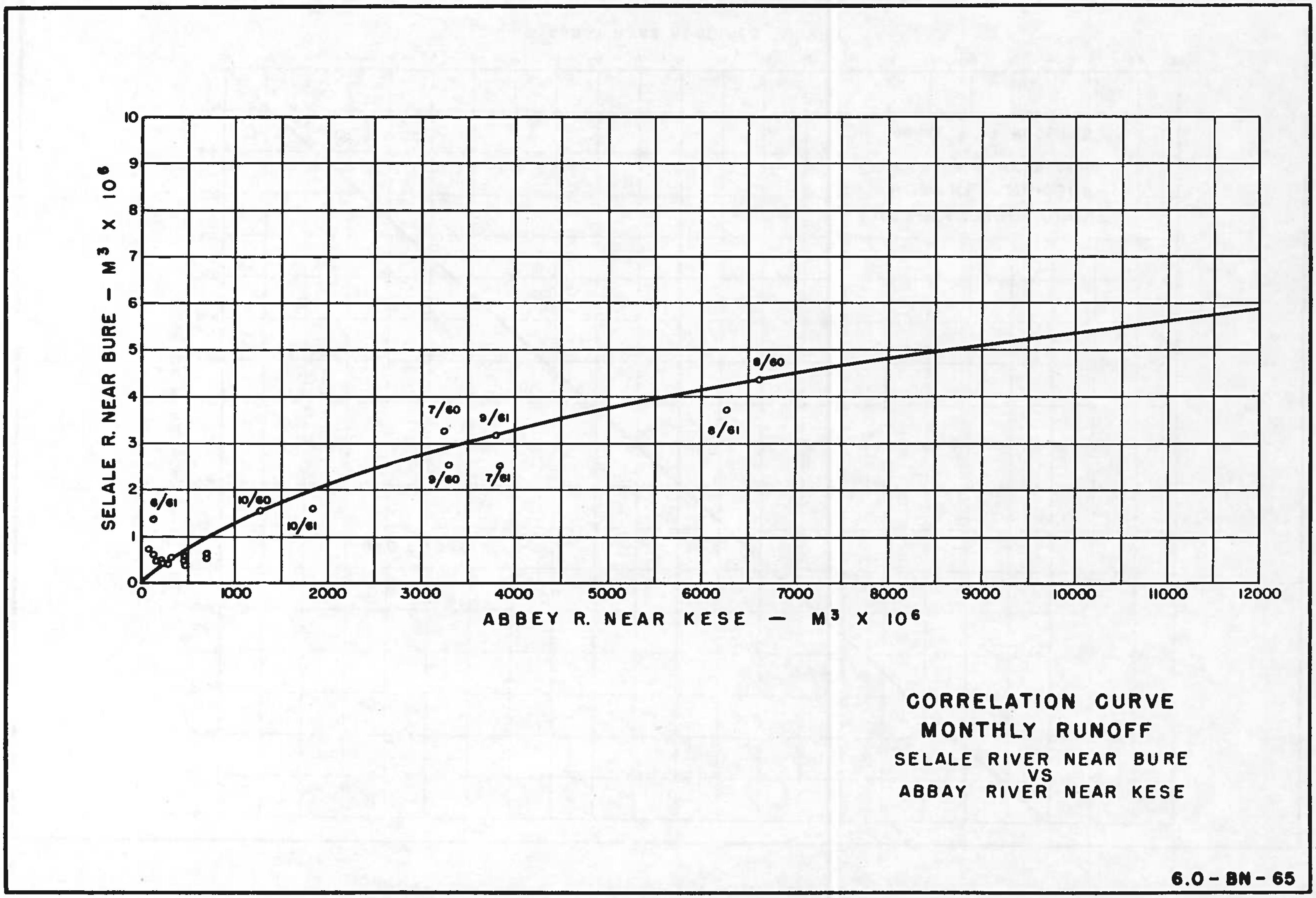


Figure III-37--Correlation Curve, Monthly Runoff--Selale R. near Bure v. Abbay R. near Kese

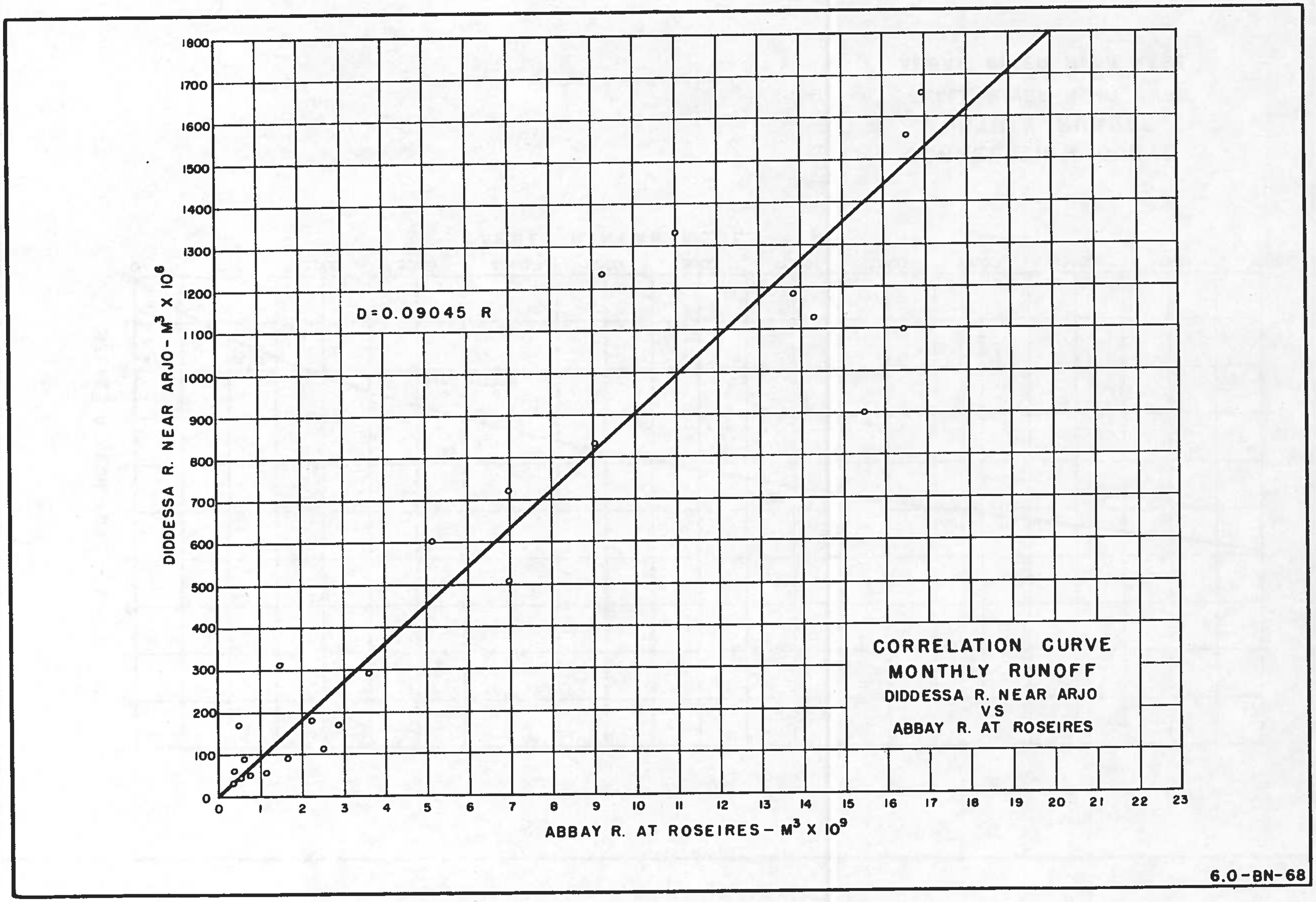


Figure III-38--Correlation Curve, Monthly Runoff--Diddessa R. near Arjo v. Abbay R. at Roseires

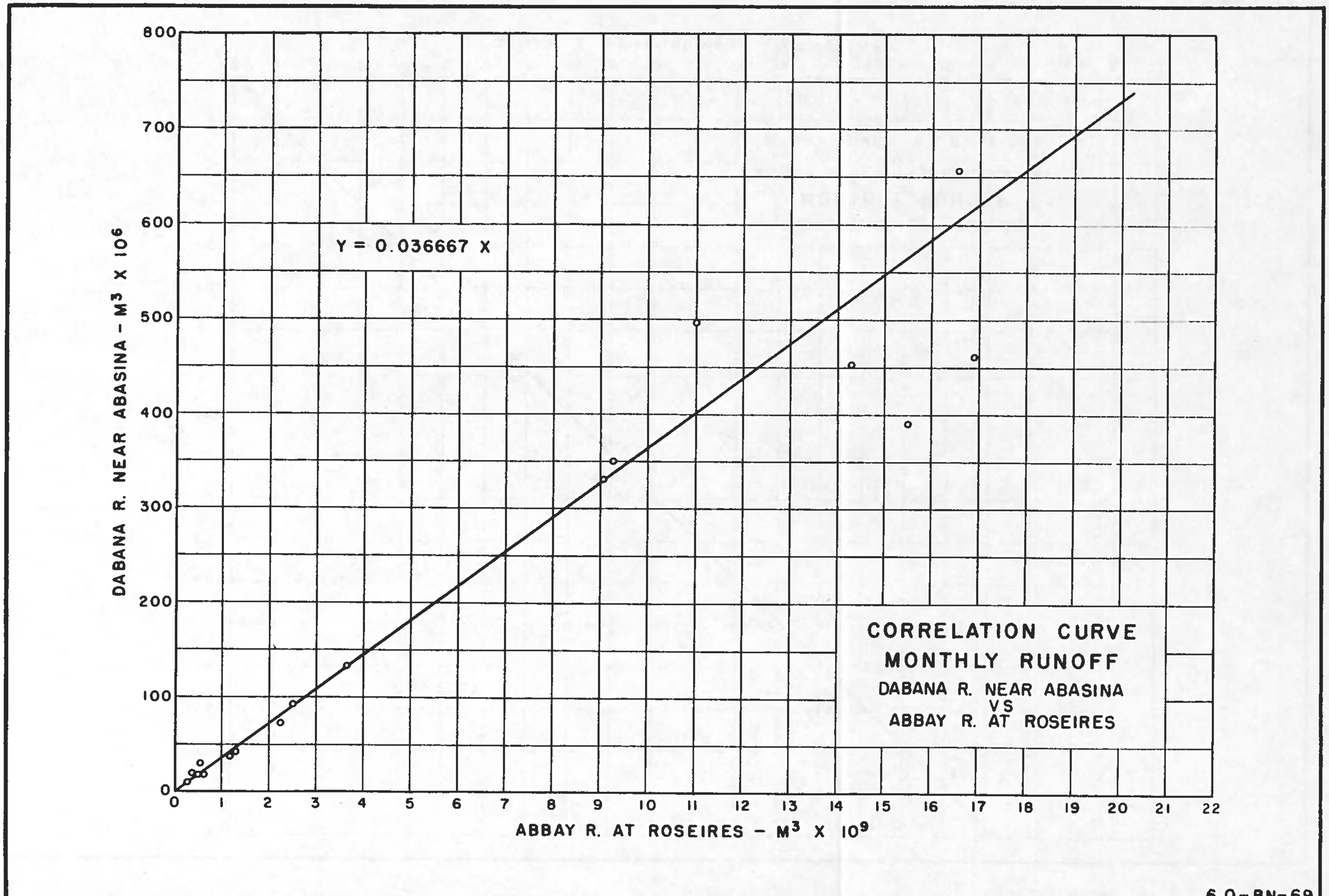


Figure III-39--Correlation Curve, Monthly Runoff--Dabana R. near Abasina v. Abbay R. at Roseires

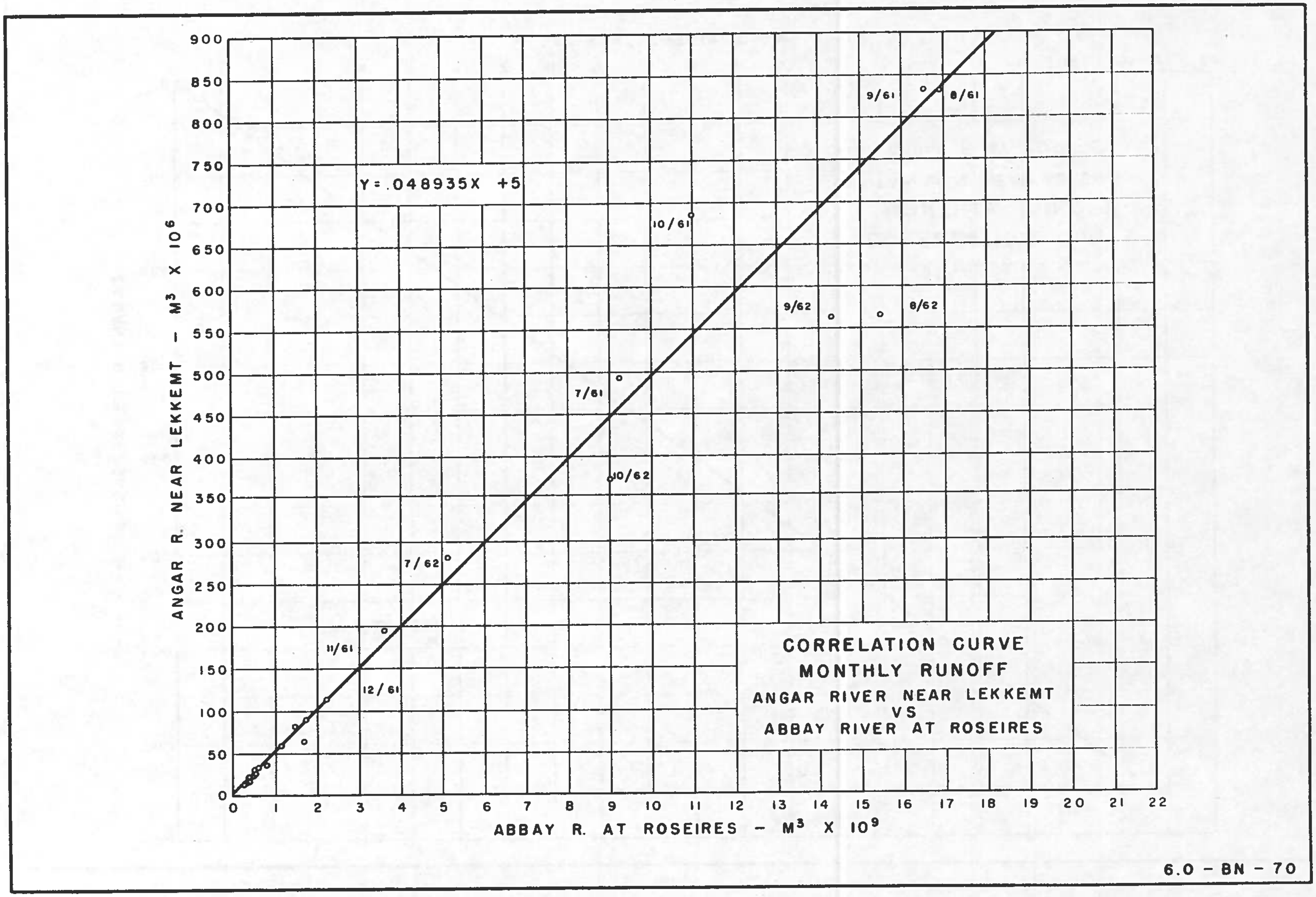


Figure III-40--Correlation Curve, Monthly Runoff--Angar R. near Lekkemt v. Abbay R. at Roseires

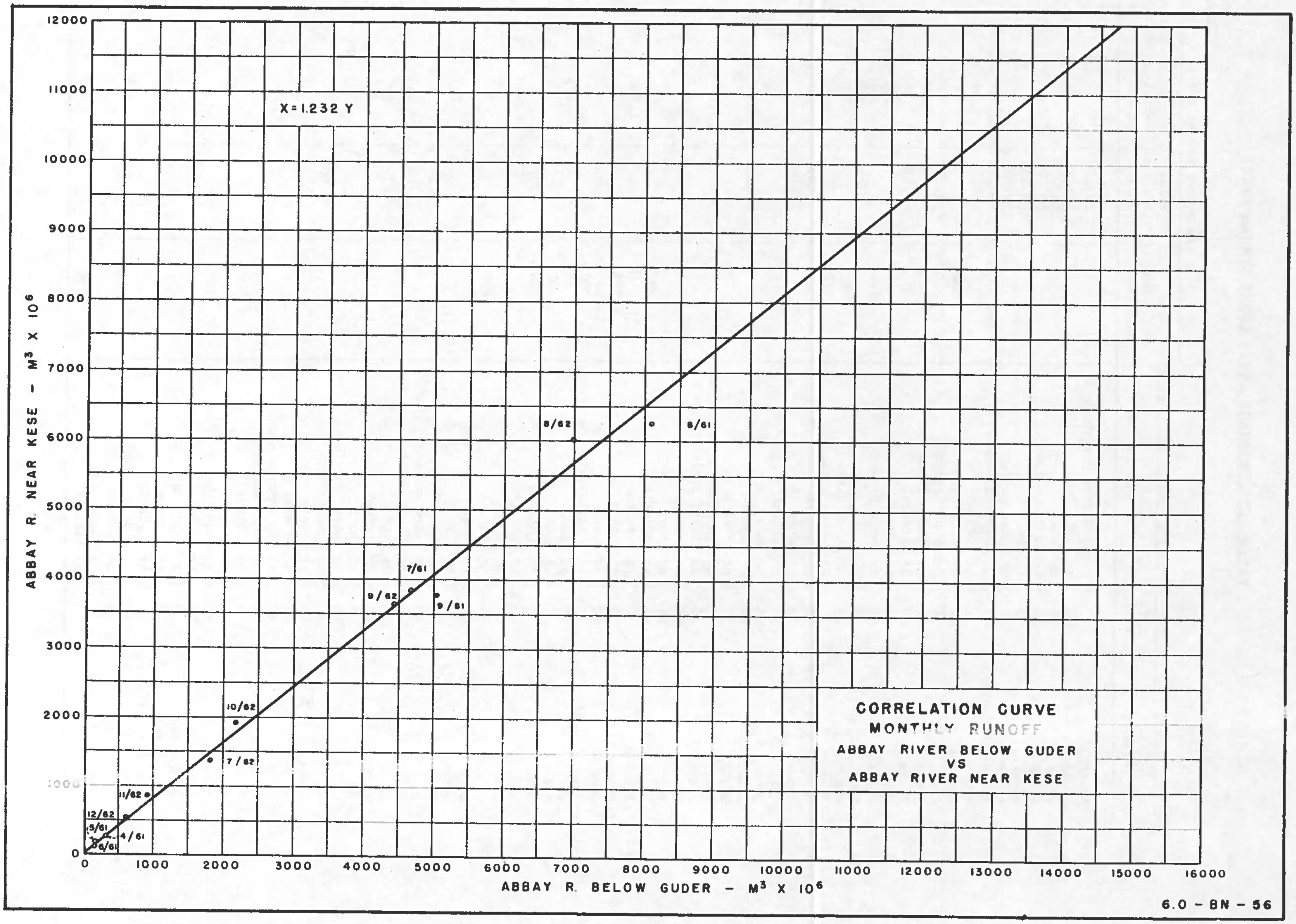


Figure III-42--Correlation Curve, Monthly Runoff--Abbay R. below Guder v. Abbay R. near Kese

TABLE III-22--DRAINAGE AREAS ABOVE STREAM GAGES

Stream gages			In square kilometers			
Stream	Sta. no.	Location	USAF preliminary base map	Drawing No. 4.0-BN-3	Aerial photos	Ethiopia-West Germany map
Abbay		Outflow from Lake Tana		15,165		
Abbay	9	nr Bahir Dar		15,240		
Abbay	19	nr Kese		65,000		
Abbay	29	below Guder River		82,220		
Abbay	59	at Shogali		158,800		
Abbay	62	nr Sudan border		174.600		
Abbay (Blue Nile)	68	at Roseires, Sudan	195,000 from Roseires Dam flood report			
Amarti		nr Cochion			245	
Andassa	11	nr Bahir Dar	660			
Angar	51	north of Lekkemt		4,350		
Arera	42	nr Finote Selam			31	
Beles	60	nr Metekkel		3,520		
Bello	23	nr Guder			244	
Beressa	16	nr Debre Birhan	220			
Birr	38	nr Jiga			813	
Chacha	13	nr Debre Birhan	400			
Chemoga	31	nr Debre Markos	320			
Dabana	50	nr Abasina		3,080		
Dabus	58	nr Asosa		10,100		
Debel	52	nr Lekkemt	10			
Debohila	43	nr Bure			74.7	
Didessa	49	nr Arjo		9,486		
Dijil	32	nr Debre Markos	70			
Dindir	63	nr Abu Mendi-Metemma road			3,110	
Dindir	66	nr Hillet Idris, Sudan				
Dura	57	nr Metekkel	550			
Fato	24	nr Guder			98	
Fettam	45	at Teltelle	200			
Finchaa	30	nr Cochion			1,390	
Giamma	17	nr Insaro	6,320			
Giamma	18	nr mouth	15,500			
Gilgel Abbay	1	at Dangila-Bahir Dar road	1,600			
Guder	26	at Guder			499	
Guder	28	at mouth	6,690			
Gudla	36	nr Dembecha	360			
Gumara	6	nr Lake Tana			1,239	
Indris	27	nr Guder			76	
Jedeb	34	nr Amanuel	250			
Jibat	22	nr Guder	143			
Kechem	37	nr Jiga			183	
Koga	2	nr Bahir Dar				266
Kulich	33	nr Debre Markos	50			
Lah	41	nr Finote Selam			273	
Leza	39	nr Jiga			159	
Mari	55	nr Lekkemt	10			
Megech	3	nr Azozo	519			
Melke	25	nr Guder			80	
Muger	20	nr Chancho		606		
Neshe		nr Cochion			309	
Rahad	65	nr Metemma			4,035	
Rahad	67	at Abu Haraz, Sudan				
Ribb	5	nr Addis Zemin	1,497			
Roba	54	nr Lekkemt	20			
Selale	44	nr Bure			26	
Shye	14	at Tsehai Senna	100			
Sifa	47	nr Lekkemt		978		
Tana, Lake	8	at Bahir Dar				
Tana, Lake	7	at Gorgora				
Timochia	35	nr Dembecha	350			
Temia	40	nr Finote Selam			108	
Wama	48	nr Lekkemt		764		
Wizer	15	at Mehal Meda	60			
Wuke	53	nr Lekkemt	170			

TABLE III-23--DRAINAGE AREAS ABOVE DAMSITE

Project (river)	Damsite No.	Damsite Name	In square kilometers: USAF preliminary base map	Drawing No. 4.0-BN-3	Aerial photos	Ethiopia-West Germany map
Abbay	10	Tis Isat	16,420			
	3	Karadobi		75,500		
	19	Mabil		100,300		
	26A	Mendaia		139,000		
	28	Border		173,300		
Angar	2	Angar		1,780		
	6	Lekkemt		4,523		
	6B	Power Diversion Dam		5,220		
Beles		Tana		15,165		
		Irrigation Diversion Dam			845	
	3	Dangur		9,070		
Birr		Selale			23.4	
		Adefita			6.2	
		Ghussa			20.2	
	3	Debohila			77.4	
	5	Upper Birr			591	
	3	Lower Birr			1,378.4	
Dabana	1	Dabana		2,654		
Dabus		Power Diversion Dam		10,360		
		Irrigation Diversion Dam		10,440		
Diddessa	11	Diddessa		3,360		
	2	Boo		16,700		
Dindir	7	Junction			2,690	
	2	Dindir			4,900	
	2	Galegu			543	
Finchaa	1	Finchaa			1,391	
		Power Diversion Dam			1,422	
		Irrigation Diversion Dam			1,586	
Guder	4	Bello			244	
	1	Motto	3,670			
Giamma	1	Giamma			6,140	
Gumara	6	Gumara			370	
		Diversion Dam			1,073	
Gilgel Abbay (German Scheme)		Sawessa Mariam				216
		Koga Tank				160
		Umbri Mariam				600
		Debekan Mariam				1,170
		Ker Quosquam				2,000
Megech	2	Megech	417			
		Diversion Dam	545			
Muger	4	Chancho		499		
	1	Falls		652		
Neshe	1	Amarti			245	
	2	Neshe			309	
		Irrigation Diversion Dam			331	
Rahad	3	Rahad			3,800	
		Diversion Dam			4,035	
Ribb	2	Ribb	676			
		Diversion Dam			950	

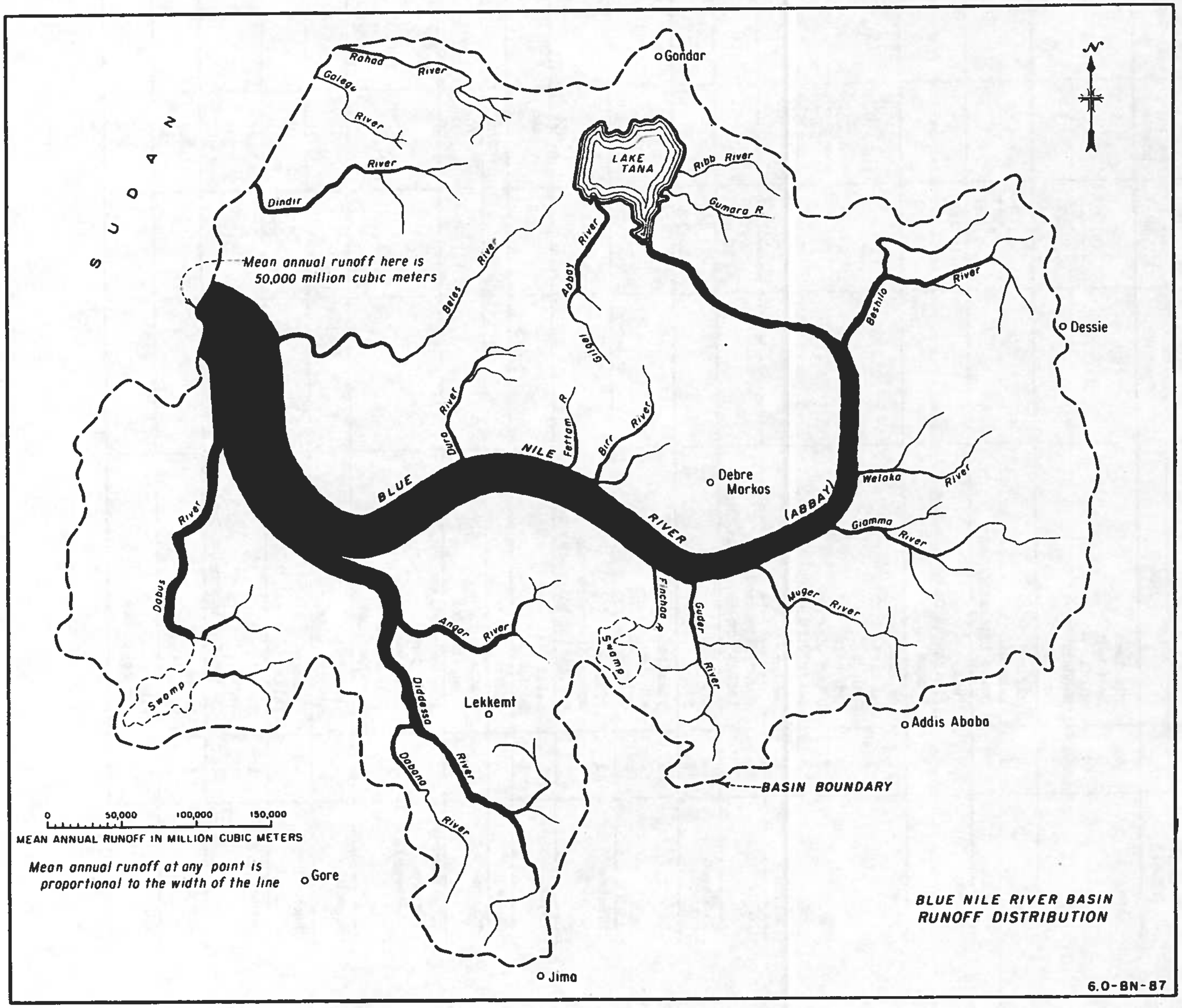
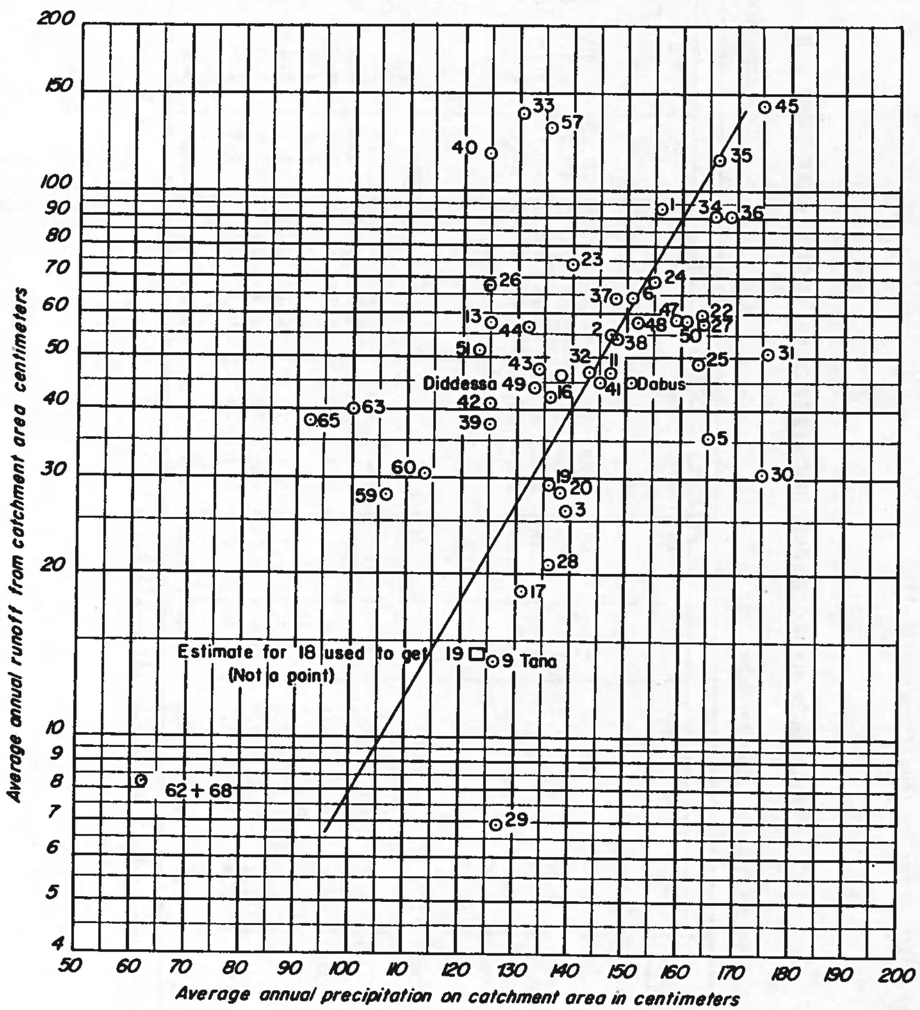


Figure III-43--Runoff Distribution



NOTES

Reasons for dispersion of points:

1. *Errors in rainfall data and their interpretation on map.*
2. *Areas of smaller drainage basins are known only to ± 50 percent.*
3. *Average annual flows are estimated from less than one year of record in some instances. Average record is about 1.5 years.*
4. *More Oct. to May rainfall in southwest produces higher percentage use there.*

REVISED MAY 3, 1963	
ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM FOR THE STUDY OF WATER RESOURCES IN COLLABORATION WITH U.S. DEPT. OF ST. AND A.I.D. U.S. DEPT. OF INT., BUR. OF RECL.	DEPARTMENT OF WATER RESOURCES IMPERIAL ETHIOPIAN GOVERNMENT MINISTRY OF PUBLIC WORKS & COMMUNICATIONS BLUE NILE RIVER BASIN RAINFALL—RUNOFF RELATIONSHIP IN BLUE NILE BASIN
DRAWN KRAMER TRACED A. N. MUSSA CHECKED Admasu M. Addis Ababa Ethiopia	SUBMITTED RECOMMENDED APPROVED MAR 15, 1963 6.0-BN-27

Figure III-44--Rainfall-Runoff Relationship in Blue Nile Basin (6.0-BN-27)

TABLE III-24--HYDROGRAPHIC DISCHARGE DATA, GILGEL ABBAY R. NEAR BAHIR DAR

Runoff at GILGEL ABBAY R. gage nr Bahir Dar — Drainage area 1,600 sq km

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
HISTORICAL													
1959				8.17	11.42	74.36			465.41	224.84	65.94	32.76	
1960	19.71	13.45	9.99	7.07	8.82	37.87	348.44	590.12	388.42	134.85	40.25	24.69	1,623.68
1961	15.01	12.58	11.94	9.66	5.28	37.69	285.80	449.34	449.49	189.09	87.44	71.40	1,624.72
1962	27.12	13.27	11.25	7.71	10.80	55.48	393.45	556.00	391.32	178.94	43.05	23.13	1,711.52
1963	12.60	7.27	5.96										
CORRELATED 1/													
1911	22	13	10	5	16	31	149	504	426	191	96	48	1,511
1912	26	17	11	7	8	43	175	448	255	101	48	27	1,166
1913	18	11	9	8	19	13	69	195	179	64	22	10	617
1914	6	5	5	7	6	29	168	685	335	260	136	52	1,694
1915	27	15	11	7	17	37	107	240	326	203	87	40	1,117
1916	22	12	7	7	15	41	218	1,046	672	320	133	65	2,558
1917	35	20	15	12	19	53	242	892	1,327	320	116	60	3,111
1929	22	15	10	11	56	122	324	1,030	650	290	95	56	2,681
1932	21	12	8	7	22	45	132	582	537	210	66	37	1,679

1/ With Abbay nr Kese (Figure III-17).

TABLE III-25--HYDROGRAPHIC DISCHARGE DATA, KOGA R. NEAR BAHIR DAR

Runoff at KOGA R. gage nr Bahir Dar — Drainage area 266 sq km

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
HISTORICAL													
1959				1.61	1.62	2.48	30.30	59.66	38.16	20.69	9.89	5.71	
1960	4.22	3.23	2.39	1.66	1.65	2.28	25.87	52.68	29.30	12.21	5.97	4.41	145.87
1961	3.18	2.65	2.15	1.88	1.38	2.36	31.87	44.12	33.17	17.67	13.36	10.46	164.25
1962	3.94	2.44	2.15	1.32	1.59	2.26	23.89	41.63	30.08	14.48	7.15	4.60	135.53
1963	3.23	2.17	1.99										
CORRELATED 1/													
1911	2.3	1.3	0.9	0.6	1.7	3.2	21.8	46.3	29.3	11.9	9.9	5.0	134.2
1912	2.6	1.7	1.1	0.7	0.8	4.4	25.6	43.4	18.5	6.3	5.0	2.7	112.8
1913	1.8	1.1	0.8	0.8	1.8	1.2	10.0	20.3	12.9	3.9	2.3	1.0	57.9
1914	0.6	0.4	0.5	0.7	0.6	3.0	24.4	51.7	24.2	16.1	14.1	5.3	141.6
1915	2.7	1.4	1.0	0.7	1.7	3.8	15.7	25.1	23.6	12.6	9.1	4.1	101.5
1916	2.2	1.3	0.7	0.7	1.5	4.3	32.2	59.4	35.7	19.8	13.8	6.8	178.4
1917	2.6	2.0	1.5	1.1	1.9	5.4	35.5	56.3	44.8	19.8	12.0	6.2	189.1
1932	2.1	1.2	0.8	0.6	2.3	4.6	27.0	49.0	32.9	13.0	6.9	3.7	144.1

1/ With Abbay at Roseires (Figure III-18).

TABLE III-26--HYDROGRAPHIC DISCHARGE DATA, MEGECH R. NEAR AZOZO

Runoff at MEGECH R. gage nr Azozo — Drainage area 519 sq km

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
HISTORICAL													
1959											2.98	1.61	
1960	0.99	0.76	0.50	0.41	0.56	2.80	24.21	51.43					
1961			0.31	0.39	0.25					8.28	3.30	3.81	
1962	0.76	1.17	1.29	0.51	0.68	1.15							
CORRELATED 1/													
1911	0.5	0.3	0.2	0.3	0.6	2.9	17.1	44.7	17.3	5.2	2.2	1.0	92.3
1912	0.6	0.4	0.2	0.2	0.7	3.7	17.1	22.9	7.1	2.4	1.0	0.6	56.9
1913	0.4	0.2	0.2	0.3	0.4	1.1	4.7	7.6	4.2	1.2	0.4	0.2	20.9
1914	0.1	0.1	0.2	0.2	0.5	3.2	22.0	41.9	17.3	8.3	3.1	1.1	98.0
1915	0.5	0.3	0.2	0.3	0.8	2.2	7.7	15.8	13.9	4.6	1.9	0.9	49.1
1916	0.5	0.3	0.2	0.3	0.8	4.6	35.8	81.5	39.3	10.5	3.3	1.5	178.6
1917	0.8	0.5	0.3	0.4	1.0	5.4	34.9	99.2	60.2	9.7	2.8	1.4	216.6
1932	0.4	0.2	0.2	0.3	1.0	3.9	21.3	57.5	22.3	5.0	1.5	0.8	114.4

1/ With Abbay at Roseires (Figure III-19).

TABLE III-27--HYDROGRAPHIC DISCHARGE DATA, RIBB R. NEAR ADDIS ZEMIN

Runoff at RIBB R. gage nr Addis Zemin — Drainage area 1,497 sq km

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
HISTORICAL													
1959								396.80	173.34	24.93	8.86		
1960							52.88	185.53	101.16	14.10	4.94	2.09	
1961	1.18	2.98	1.51	2.18	0.37	1.62	138.56	341.91	131.36		8.45	5.69	
1962	2.33	1.42	1.01	0.58	1.52	2.82				41.13	7.93	4.20	
CORRELATED 1/													
1911	1.0	0.5	0.3	0.5	1.2	7.0	59.5	183.0	61.0	14.0	5.1	2.3	335.4
1912	1.1	0.7	0.4	0.3	1.4	9.0	59.5	85.0	21.0	5.4	2.3	1.1	187.2
1913	0.8	0.4	0.3	0.7	0.8	2.6	12.2	22.5	10.7	2.7	0.9	0.3	54.9
1914	0.2	0.2	0.2	0.3	1.0	7.8	81.0	169.0	60.5	25.0	7.3	2.4	354.9
1915	1.1	0.6	0.3	0.5	1.6	5.2	23.0	53.5	45.5	12.1	4.5	1.8	149.7
1916	1.0	0.4	0.3	0.5	1.6	12.0	140.0	503.0	156.5	32.5	7.9	3.3	859.0
1917	1.6	1.0	0.7	0.8	2.2	14.7	136.0	681.0	284.0	30.5	5.7	3.1	1,161.3
1932	0.9	0.4	0.3	0.8	2.0	9.8	78.0	264.0	82.0	13.1	3.4	1.7	456.4

1/ With Abbay at Roseires (Figure III-20).

TABLE III-28--HYDROGRAPHIC DISCHARGE DATA, GUMARA R. NEAR LAKE TANA

Runoff at GUMARA R. gage nr Lake Tana | Drainage area 1,239 sq km

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
HISTORICAL													
1959						5.59	75.98	368.25	279.08	90.18	26.06	11.38	
1960	7.20	6.32	6.52	5.08	5.20	7.14	144.67	307.47	254.03	48.27			
1961	5.67	6.44	6.90	6.29	5.42	6.81	194.07	471.16	295.32	97.20	22.24	13.51	1,131.03
1962	7.11	5.35	6.36	5.10			87.26	383.86	241.52	102.33	20.76	9.31	
CORRELATED 1/													
1911	2.7	2.5	2.4	2.0	2.5	4.0	45.3	279.8	227.8	72.5	21.0	6.8	669.3
1912	2.9	2.5	2.4	2.4	2.4	6.0	62.0	242.5	114.7	23.0	6.8	3.0	470.6
1913	2.5	2.4	2.4	2.4	2.5	2.5	11.8	75.0	64.7	10.1	2.7	2.4	181.4
1914	2.1	2.0	2.0	2.3	2.1	3.5	56.6	399.6	167.3	118.1	39.0	7.5	802.1
1915	3.0	2.5	2.4	2.3	2.5	4.7	25.0	105.1	161.7	80.5	17.7	5.2	412.6
1916	2.7	2.4	2.4	2.3	2.5	5.3	90.4	638.3	391.0	157.9	37.4	10.2	1,342.8
1917	4.9	2.6	2.5	2.4	2.5	7.5	105.9	536.0	824.2	157.9	29.0	9.6	1,685.0
1932	2.6	2.4	2.4	2.3	2.8	6.3	36.8	331.0	300.1	85.1	10.7	4.6	787.1

1/ With Abbay nr Kese (Figure III-21).

TABLE III-29--HISTORICAL HYDROGRAPHIC DISCHARGE DATA, ABBAY R. FROM LAKE TANA

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
ABBAY R. outflow from Lake Tana														15,165
1920								385	748	814	538	353		
1921	227	133	95	44	21	12	38	365	774	800	500	330	3,340	
1922	206	122	75	35	22	13	71	490	1,090	987	600	374	4,080	
1923	240	140	97	51	34	33	100	593	1,150	979	604	415	4,440	
1924	266	161	103	69	33	25	129	678	1,450	1,060	712	472	5,160	
1925	285	165	115	60	34	20	42	354	640	582	369	248	2,910	
1926	163	87												
1927														
1928	199	115	52	26	24	19	112	463	764	595	428	260	3,060	
1929	149	95	62	30	31	59	273	1,040	1,950	1,210	613	407	5,920	
1930	216	143	109	54	29	42	15	499	890	592	375	235	3,340	
1931	143	93	55	25	20	16	37	321	745	706	411	255	2,830	
1932	164	107	61	28	22	17	90	557	1,190	889	502	390	4,020	

TABLE III-30--HYDROGRAPHIC DISCHARGE DATA, ABBAY R. NEAR BAHIR DAR

Runoff at ABBAY R. gage nr Bahir Dar — Drainage area 15,240 sq km

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
HISTORICAL													
1959						27.49	95.19	596.24	1,425.94	1,323.79	841.83	567.53	
1960	365.36	221.58				29.68	86.58	480.16	1,019.55	930.41	561.80	376.59	
1961	243.16	147.77	101.40	54.45	25.50	10.17	84.53	631.85	1,410.00	1,212.90	741.74	540.99	5,204.46
1962	347.92	206.23	143.11	74.72	41.65	30.30	90.01	667.77	1,334.33	1,195.07	735.99	54.57	4.921.67
CORRELATED 1/													
1911	205	85	45	25	20	22	60	465	1,118	880	559	378	3,862
1912	236	148	60	38	18	25	72	379	593	579	376	237	2,761
1913	150	57	40	40	20	19	31	82	328	447	205	50	1,469
1914	28	19	20	35	17	22	69	672	871	1,110	694	392	3.949
1915	237	98	59	35	20	24	44	109	840	922	530	332	3,250
1916	202	84	38	32	20	25	96	1,050	1,512	1,312	682	456	5,509
1917	303	181	109	62	20	27	110	888	2,300	1,312	626	434	6,372
1932	185	72	40	29	21	26	77	560	1,323	941	454	309	4,037

1/ With Abbay at Roseires (Figure III-22).

TABLE III-31--HYDROGRAPHIC DISCHARGE DATA, BELES R. NEAR METEKKEL

Runoff at BELES R. gage nr Metekkel — Drainage area 3,520 sq km

Year	In millions of cubic meters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
HISTORICAL													
1962	10.14	5.51	4.23	2.54	3.34	17.23	157.22	492.11	308.75	60.10	14.22	27.65	
CORRELATED 1/													
1911	6	3	2	1	4	9	153	482	292	41	19	15	1,027
1912	8	5	3	2	2	13	182	450	149	20	9	8	851
1913	5	3	2	2	5	3	70	207	90	12	4	3	406
1914	2	1	1	2	2	9	170	548	221	59	28	17	1,060
1915	8	4	3	2	5	11	110	254	212	44	17	12	682
1916	6	4	2	2	4	13	230	630	388	76	27	23	1,405
1917	10	6	4	3	6	17	255	596	527	76	23	21	1,544
1932	5	3	2	2	6	15	192	512	347	46	13	11	1,154

1/ With Abbay at Roseires (Figure III-24).

TABLE III-32--HYDROGRAPHIC DISCHARGE DATA, ANDASSA R. NEAR BAHIR DAR

Runoff at ANDASSA R. gage nr Bahir Dar — Drainage area 660 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1959									75.00	30.11	15.76	9.86	
1960	7.14	5.09	4.26	3.19	3.31	2.65	39.40	110.91	64.84	18.46	9.74	7.32	276.31
1961	5.57	4.45	3.83	2.81	1.93			101.11	60.45	27.45	21.92	15.61	
1962	7.86	5.12	4.69	3.15	3.23	4.42	29.66	75.76	46.88	25.81	9.16	6.15	221.89
CORRELATED 1/													
1911	4.02	2.76	2.21	1.59	3.16	5.35	22.78	75.37	63.76	29.06	14.93	7.86	232.85
1912	4.57	3.31	2.37	1.90	1.98	7.08	26.71	67.05	38.48	15.72	7.86	4.72	181.75
1913	3.39	2.37	2.13	2.01	3.55	2.68	10.93	29.61	27.33	10.22	4.02	2.29	100.53
1914	1.62	1.57	1.58	1.82	1.62	5.12	25.53	102.07	50.25	39.27	20.97	8.49	259.91
1915	4.72	3.00	2.37	1.82	3.31	6.29	16.58	36.36	49.00	30.87	13.67	6.77	174.76
1916	4.01	2.61	1.90	1.79	3.08	6.92	33.06	155.44	100.18	48.13	20.42	10.46	388.00
1917	5.98	3.78	3.06	2.53	3.59	8.65	36.52	132.60	197.05	48.14	17.91	9.67	469.48
1932	3.86	2.53	2.01	1.77	4.10	7.47	20.27	86.83	79.93	31.88	10.60	6.22	257.47

1/ With Abbay at Kese (Figure III-23).

TABLE III-33--HISTORICAL HYDROGRAPHIC DISCHARGE DATA, SHYE, WIZER, BERESSA, CHACHA, AND GIAMMA RIVERS

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
SHYE R. at Tsehai Senna														100
1961	0.16	0.16	0.19	1.06	0.73	0.16				0.76	0.47	0.38		
WIZER R. at Mehal Meda														60
1961	0.01	0.01	0.13	1.07	0.67	0.10	8.56	7.28	3.12	0.28	0.07	0.05	21.35	
1962	0.04	0.03	0.04	0.16	0.05									
BERESSA R. at Debre Birhan														220
1961			0.50	3.64	1.87	1.01	52.79	48.35	17.45	2.21	0.92	0.68		
1962	0.32	0.27	0.50	0.55	0.60	0.91	22.79	45.63	19.36	1.73	1.30	0.75	94.71	
1963	0.43	0.28												
CHACHA R. nr Debre Birhan														400
1962			0.53	0.41	0.31			63.67	30.21	2.16	0.35	0.14		
1963	0.18	0.18												
GIAMMA R. nr mouth														15,500
1959											37.83	31.27		
1960	25.35	19.75	28.17	25.34	21.56	16.19						19.69		
1961	14.29	11.68	14.04	39.36	23.70	12.00				118.73	42.91	33.11		
1962	26.61	17.05	24.17					2,049.04	542.72	76.94	26.66	19.43		
1963	16.05	10.73												

TABLE III-34--HYDROGRAPHIC DISCHARGE DATA, GIAMMA R. NEAR INSARO

Runoff at GIAMMA R. gage nr Insaro | Drainage area 6,320 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1961						5.15	480.56		247.99				
1962							546.88						
CORRELATED 1/													
1911	18	9	5	2	11	23	126	431	364	162	80	39	1,270
1912	20	12	6	4	4	35	149	383	217	84	39	20	973
1913	13	6	5	4	13	8	57	164	151	52	18	6	497
1914	2	2	2	3	2	23	141	586	285	222	114	41	1,423
1915	20	10	6	3	12	30	90	203	279	172	72	32	929
1916	18	7	4	3	10	32	186	897	575	273	111	53	2,169
1917	28	14	10	7	13	43	205	763	1,140	273	98	50	2,644
1932	15	7	4	3	18	37	110	499	458	179	54	29	1,413

1/ With Abbay nr Kese (Figure III-25).

TABLE III-35--HYDROGRAPHIC DISCHARGE DATA, MUGER R. NEAR CHANCHO

Runoff at MUGER R. gage nr Chancho | Drainage area 606 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1958												1.17	
1959	0.94	0.69	0.58	0.64	0.74	0.74	26.22	83.55	50.50	8.09	1.72	0.82	175.23
1960	0.52	0.56	0.67	0.76	0.94	7.73				10.31	1.15	0.36	
1961	0.36	0.22	0.31	0.60	0.37	0.98	65.12	89.39	58.42	22.96	2.48	1.06	242.27
1962	0.62	0.40	0.53	0.44	0.76	1.26	8.60	37.31	51.02	11.02	2.24	1.38	115.58
1963	1.68	1.42											
CORRELATED 1/													
1911	0.3	0.2	0.1	0.1	0.2	0.4	9.9	63.1	51.3	16.2	2.6	0.7	145.1
1912	0.3	0.2	0.1	0.1	0.1	0.5	14.0	54.7	25.9	3.0	0.7	0.3	99.9
1913	0.2	0.1	0.1	0.1	0.2	0.2	1.0	16.9	14.6	1.0	0.3	0.1	34.8
1914	0.1	0.1	0.1	0.1	0.1	0.4	12.7	89.9	37.8	26.6	8.0	0.8	176.7
1915	0.4	0.2	0.1	0.1	0.2	0.5	3.6	23.7	36.5	18.1	2.1	0.5	86.0
1916	0.3	0.2	0.1	0.1	0.2	0.5	20.2	143.6	88.0	35.5	7.4	1.0	297.1
1917	0.5	0.3	0.2	0.1	0.2	0.8	23.8	120.7	185.2	35.5	5.0	1.0	373.3
1932	0.2	0.1	0.1	0.1	0.3	0.6	7.2	74.7	67.7	19.1	1.0	0.6	171.7

1/ With Abbay nr Kese (Figure III-26).

TABLE III-36--HISTORICAL HYDROGRAPHIC DISCHARGE DATA, JIBAT, FATO, MELKE, GUDER, AND INDRIS RIVERS

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
JIBAT R. nr Guder														143
1959				0.36	1.75	6.42	22.51	24.04	23.70	17.50	2.75	0.86		
1960	0.56	0.48	0.51	0.44	2.28	10.19	17.88	24.36	21.97	5.51	0.78	0.60	86.06	
1961	0.39													
FATO R. nr Guder														98
1959			0.28	0.23	0.43	2.40	21.21	21.37	19.80	9.24	1.07	0.46		
1960	0.35	0.29	0.37	0.25	0.40	1.90				3.11	0.49	0.37		
1961	0.24	0.18	0.21	0.29	0.20	1.01	14.33	16.96	15.76	9.89	0.82	0.41	60.30	
1962	0.26	0.22	0.27	0.21	0.48	0.73	9.94	19.07	20.34	7.36	0.62	0.39	59.89	
1963	0.40	0.30	0.28	0.57										
MELKE R. nr Guder														80
1959			0.24	0.19	0.27	0.77	11.26	13.38	10.70	2.73	0.46	0.31		
1960	0.27	0.22	0.26	0.22	0.60	1.18				1.02	0.35	0.32		
1961	0.27	0.24												
GUDER R. nr Guder														499
1959			1.50	1.17	2.73	12.21	119.97	158,89	142.87	72.60	8.00	2.70		
1960	1.93	1.68	1.74	1.51	4.37	21.75	97.65	143.41	125.93	22.52	2.65	2.09	427.23	
1961	1.41	1.17	1.25	1.77	1.57	5.36	106.09	114.28	123.41	78.28	5.10	2.87	442.56	
1962	1.74	1.17	1.45	0.91	2.11	6.59	47.57	89.64	114.70	46.43	3.35	2.16	317.82	
1963														
INDRIS R. nr Guder														76
1959			0.95	0.72	0.92	1.49	12.84	19.31	21.10	6.28	1.55	1.02		
1960	0.87	0.83	0.89	0.96	1.27	2.23	9.41	28.14	14.04	3.85	1.45	1.25	64.63	
1961	0.99	0.81	0.92	1.09	1.17	4.58	14.59	17.79	14.62	11.20	2.29	1.47	71.52	
1962	0.85	0.51	0.69	0.50	0.88	1.62	9.29	17.86	18.79	7.32	1.52	1.06	60.89	
1963	0.97	0.65	0.55	0.90										

TABLE III-37--HYDROGRAPHIC DISCHARGE DATA, BELLO R. NEAR GUDER

Runoff at BELLO R. gage nr Guder (Bello damsite) — Drainage area 244 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1959				0.64	1.95	7.78	53.58	69.84	71.80	39.01	5.09	1.51	
1960	1.07	0.99	0.93	0.87	2.72	13.90	45.76	65.58	59.80	12.17	0.93	0.44	205.16
1961	0.53	0.53	0.51	0.97	0.83	4.34	60.79	70.97	69.40	43.37	3.30	1.60	257.14
1962	0.90	0.60	0.84	0.64		7.57	59.78	67.20					
CORRELATED 1/													
1911	0.75	0.35	0.15	0.05	0.45	1.40	22.50	65.40	61.85	35.80	9.50	2.85	201.05
1912	1.00	0.49	0.25	0.08	0.08	2.35	31.20	62.90	47.40	10.65	2.85	1.01	160.26
1913	0.50	0.23	0.14	0.12	0.60	0.30	5.25	36.60	32.40	4.50	0.75	0.20	81.59
1914	0.05	0.02	0.03	0.07	0.05	1.24	28.40	70.15	55.55	47.98	18.70	3.15	225.39
1915	1.05	0.40	0.22	0.07	0.50	1.85	11.80	45.40	54.75	38.75	7.60	2.02	164.41
1916	0.74	0.32	0.08	0.07	0.41	2.20	41.75	76.80	69.80	54.20	17.75	4.70	268.82
1917	1.65	0.68	0.41	0.24	0.62	3.20	45.60	74.15	81.28	54.20	13.45	4.15	279.63
1932	0.70	0.24	0.12	0.06	0.80	2.50	33.75	67.72	66.40	39.95	4.90	1.76	218.90

1/ With Abbay at Roseires (Figure III-27).

TABLE III-38--HYDROGRAPHIC DISCHARGE DATA, GUDER R. AT MOUTH

Runoff at GUDER R. gage at mouth — Drainage area 6,690 sq km

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	In millions of cubic meters												
HISTORICAL													
1961		7.04	7.22	15.06	16.35	39.81	434.63	736.47	506.65	303.07			
1962							293.72	540.35	517.19	270.21	28.72	19.03	
1963	15.8	9.2											
CORRELATED 1/													
1911	4	2	6	4	12	25	289	607	434	144	45	12	1,584
1912	5	2	8	5	5	38	324	580	222	50	12	5	1,256
1913	2	1	6	5	13	9	80	349	130	20	3	1	619
1914	1	1	3	5	4	23	314	659	331	228	84	14	1,667
1915	5	2	7	5	12	32	199	401	319	158	39	9	1,188
1916	3	2	5	5	11	36	378	733	571	310	81	21	2,156
1917	7	3	11	9	14	50	401	703	772	310	63	19	2,362
1932	2	1	5	4	17	40	336	633	511	165	22	8	1,744

1/ With Abbay at Roseires (Figure III-28).

TABLE III-39--HYDROGRAPHIC DISCHARGE DATA, FINCHAA R. NEAR COCHION

Runoff at FINCHAA R. gage nr Cochion (also Finchaa Damsite) — Drainage area 1,390 sq km

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	In millions of cubic meters												
HISTORICAL													
1959						4.98	19.14	80.59	107.93	100.88	54.72	23.15	
1960	12.03	7.59	6.51	5.30	5.42	5.96	22.92	81.54	123.85	100.08	43.78	19.07	434.05
1961	10.78	6.87	6.02	5.65	5.06	5.58	39.03	76.78	120.42	120.60	67.17	24.61	488.57
1962	11.28	6.90	6.23	4.82	4.36	4.98	38.10	80.36	107.65	118.15	54.47	17.67	454.97
1963	9.80	7.12	5.89										
CORRELATED 1/													
1911	12.0	7.0	4.5	3.8	2.3	5.0	10.2	44.0	103.0	99.0	54.7	29.5	381.0
1912	15.3	8.8	5.2	4.0	2.9	2.5	13.9	50.7	102.0	70.0	31.0	15.3	321.6
1913	9.0	5.2	4.0	3.8	3.0	5.8	4.3	21.9	55.5	52.0	20.0	7.0	191.5
1914	3.9	2.3	2.1	2.3	2.4	2.3	6.0	49.0	128.0	85.3	71.0	40.9	395.5
1915	16.3	9.0	5.0	4.0	2.4	5.2	12.0	32.3	66.3	84.0	57.5	26.3	320.3
1916	13.5	7.0	4.0	2.9	2.4	5.0	13.7	61.0	165.5	126.5	82.7	39.4	523.6
1917	20.2	11.0	6.9	5.0	4.0	6.0	16.7	67.0	149.5	194.3	82.7	35.0	598.3
1932	11.9	6.5	4.2	3.0	2.4	7.1	14.5	39.2	117.5	112.2	59.9	21.0	399.4

1/ With Abbay nr Kese (Figure III-29).

TABLE III-40--HISTORICAL HYDROGRAPHIC DISCHARGE DATA, CHENIOGA, DIJIT, KULICH, AND JEDEB RIVERS

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
CHEMOCA R. nr Debre Markos														320
1960							53.45	89.66	36.39	5.55	1.73	1.45		
1961	0.63	0.53	0.59	3.58	2.44	3.45	69.47	94.32	49.35	33.42	4.33	2.70	264.91	
1962	1.46	0.82	1.66	1.29	1.47	1.45	25.30	83.50	54.35	19.24	1.98	1.38	193.90	
1963	1.20	0.86	0.74											
DIJIL R. nr Debre Markos														70
1959												0.38		
1960	0.31	0.30	0.26	0.20	0.23	0.35	7.99	15.22	11.08	2.29	0.56	0.44	39.23	
1961	0.33	0.31	0.30	0.35	0.32	0.48	7.61	13.01	9.62	5.64	0.79	0.51	39.27	
1962	0.39	0.28	0.20	0.13	0.14	0.18	2.42	6.50	7.26	3.74	0.50	0.17	21.91	
KULICH R. nr Debre Markos														50
1959												0.65		
1960	0.40	0.30	0.27	0.22	0.26	0.31	6.98	16.83	15.93	3.19	1.18	0.70	46.57	
1961	0.53	0.52	0.46	0.73	0.41	1.08					1.98	1.58		
1962	1.25	0.88	0.94	0.53	0.77	1.08	8.34	28.74	19.70	4.12	1.64	1.22	69.21	
JEDEB R. nr Amanuel														250
1959												5.56		
1960	3.79	3.57	3.41	2.08	2.52	4.20	50.71	78.45	41.83	14.69	3.71	2.55	211.51	
1961	1.40	1.16	1.00	2.38	1.38	3.29	93.89	129.46	78.35	47.60	7.06	4.77	371.74	
1962	2.52	1.46	1.70	0.96	1.66	3.50	44.86	90.00	59.89	28.91	4.04	2.42	241.92	

TABLE III-41--HYDROGRAPHIC DISCHARGE DATA, TIMOCHIA R. AT DEMBECHA

Runoff at TIMOCHIA R. gage at Dembecha — **Drainage area 350 sq km**

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1959												9.77	
1960	7.21	3.77	3.28	1.62	4.82	4.23				2.65	4.91	3.66	
1961	1.98	1.73	1.91	4.03	1.77	4.16	118.38	188.01	130.23	62.10	19.51	14.32	548.13
1962	2.25	0.86	2.52	1.27	5.60	15.87	75.74	116.92	82.16	38.98	8.32	5.07	355.56
1963	2.97	1.72	1.71										
CORRELATED 1/													
1911	0.8	0.5	0.4	0.2	0.6	2.0	62.0	178.9	159.8	81.2	37.0	8.7	532.1
1912	1.0	0.6	0.4	0.3	0.3	5.3	72.8	164.9	107.1	38.6	8.7	0.8	400.8
1913	0.6	0.4	0.4	0.4	0.7	0.4	20.5	81.2	75.3	17.2	0.8	0.4	198.3
1914	0.3	0.3	0.3	0.3	0.3	1.8	71.6	219.0	131.2	107.3	56.1	8.9	597.4
1915	1.0	0.6	0.4	0.3	0.6	3.4	42.8	101.0	130.1	84.9	31.1	5.0	401.2
1916	0.8	0.4	0.3	0.3	0.6	5.1	91.2	277.3	215.0	124.6	55.0	19.0	789.6
1917	2.9	0.7	0.6	0.4	0.7	4.2	101.5	254.0	316.8	124.6	46.2	15.3	874.9
1932	0.7	0.4	0.4	0.3	0.9	6.7	54.0	196.8	186.6	87.6	20.0	4.2	558.6

1/ With Selale nr Bure (Figure III-30).

TABLE III-42--HISTORICAL HYDROGRAPHIC DISCHARGE DATA, FETTARU, SIFA, AND WAMA RIVERS

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
FETTAM R. nr Teltelle														200
1959												3.73		
1960	2.79	2.12	2.02	1.69	2.69	25.10	135.21	119.46	59.60	23.18	4.56	3.36	381.78	
1961	2.07	1.77	2.08	2.15	1.40	21.91	68.13	87.14	85.00	32.02	8.88	9.40	321.95	
1962	2.73	1.76	1.60	1.46	3.22	9.19	88.29	91.93	94.98	29.07	4.45	2.93	331.61	
1963	2.18	1.59	1.62											
SIFA R. nr Lekkemt														978
1960										62.1	17.5	10.1		
1961	4.5	3.5	3.5	4.4	6.9	64.5	148.2	174.0	161.4	115.3	34.9	16.4	737.5	
1962	6.8	4.5	3.0	1.5	6.5	29.0			128.9	89.1	17.9	9.3		
1963	5.8	3.6												
WAMA R. nr Lekkemt														764
1960										11.1	7.6	6.1		
1961	3.5	2.2	2.2	3.9	3.4	17.3	119.4	148.9	108.7	113.2	19.3	13.4	555.4	
1962	7.7	3.7	3.4	2.0	4.7	14.9			55.0	54.4	12.1	7.2		
1963	4.6	1.8												

TABLE III-43--HYDROGRAPHIC DISCHARGE DATA, KECHEM R. NEAR JIGA

Runoff at KECHEM R. gage nr Jiga — Drainage area 183 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1960												1.22	
1961	0.54	0.41	0.44	0.38	0.17	0.57	40.37	83.37	46.28	21.53	3.93	4.65	202.72
1962	1.14	0.38	0.28				26.59	62.86	44.70	12.23	1.88	0.89	
1963	0.46	0.19	0.15										
CORRELATED 1/													
1911	0.35	0.30	0.20	0.10	0.30	0.80	20.00	73.20	63.20	27.00	11.30	2.95	199.70
1912	0.50	0.30	0.20	0.12	0.12	2.00	24.00	65.65	37.90	11.85	2.95	0.35	145.94
1913	0.30	0.20	0.20	0.20	0.35	0.20	6.00	27.00	24.85	5.20	0.35	0.20	65.05
1914	0.12	0.12	0.12	0.12	0.12	0.80	23.20	96.90	48.50	37.92	17.60	2.95	228.47
1915	0.50	0.30	0.20	0.12	0.30	1.23	13.15	35.30	48.00	28.65	9.30	1.95	139.00
1916	0.35	0.20	0.12	0.12	0.30	1.96	31.00	135.20	94.31	45.89	17.00	5.80	332.25
1917	1.20	0.35	0.30	0.20	0.35	3.10	35.40	119.50	164.30	45.89	14.00	4.40	388.99
1932	0.35	0.20	0.20	0.12	0.40	2.08	16.80	83.75	77.80	29.50	6.00	1.50	218.70

1/ With Timochia nr Dembecha (Figure III-31).

TABLE III-44--HYDROGRAPHIC DISCHARGE DATA, BIRR R. NEAR JIGA

Runoff at BIRR R. gage nr Jiga — Drainage area 813 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1959												5.78	
1960	2.80	1.50	0.81	0.24	0.82	1.81	82.90	273.02	105.09	24.91	4.52	2.58	500.98
1961	1.07	0.80	0.85	0.80	0.25	2.43	165.47	295.96	65.12	36.46	11.42	13.50	594.13
1962	3.18	1.06	0.69	0.19	0.58	4.69	80.35	276.24	120.63	32.97	5.58	2.68	528.84
1963	1.29	0.48	0.31										
CORRELATED 1/													
1911	2	2	1	1	2	2	23	163	125	35	10	4	370
1912	2	2	1	1	1	3	30	135	55	12	4	2	248
1913	2	1	1	1	2	2	6	35	31	6	2	1	90
1914	1	1	1	1	1	2	28	262	85	58	20	4	464
1915	2	2	1	1	2	2	13	51	81	38	9	3	205
1916	2	2	1	1	2	3	43	495	253	79	19	6	906
1917	3	2	2	1	2	4	51	390	689	79	15	6	1,244
1929	2	2	1	1	5	16	80	484	241	67	10	5	914
1932	2	1	1	1	2	3	19	203	178	40	6	3	459

1/ With Abbay nr Kese (Figure III-32).

TABLE III-45--HYDROGRAPHIC DISCHARGE DATA, LEZA R. NEAR JIGA

Runoff at LEZA R. gage nr Jiga — Drainage area 159 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1959												1.37	
1960	0.79	0.60	0.52	0.47	0.47	0.50	6.41	17.61	10.50	3.65	1.32	0.94	43.78
1961	0.70	0.52	0.51	0.52	0.39	0.68	26.30	40.20	16.56	8.28	2.83	2.10	99.59
1962	1.00	0.56	0.49	0.34	0.45	0.85	10.19	24.12	15.50			1.20	
CORRELATED 1/													
1911	0.34	0.16	0.13	0.08	0.25	0.46	2.75	14.99	11.57	3.82	1.55	0.76	36.86
1912	0.40	0.26	0.17	0.10	0.10	0.65	3.43	12.50	5.50	1.72	0.76	0.46	26.05
1913	0.26	0.17	0.12	0.11	0.28	0.18	1.01	3.85	3.50	1.00	0.34	0.13	10.95
1914	0.08	0.08	0.08	0.09	0.08	0.47	3.20	23.30	8.15	5.65	2.50	0.82	44.50
1915	0.46	0.24	0.17	0.09	0.26	0.56	1.82	5.09	7.80	4.06	1.50	0.67	22.72
1916	0.34	0.18	0.10	0.09	0.25	0.63	4.50	42.40	22.65	7.58	2.44	1.03	82.19
1917	0.50	0.30	0.24	0.18	0.28	0.86	5.12	34.00	58.49	7.58	2.00	0.96	110.51
1932	0.34	0.18	0.10	0.09	0.38	0.73	2.42	18.40	16.30	4.20	1.04	0.55	44.73

1/ With Abbay nr Kese (Figure III-33).

TABLE III-46--HYDROGRAPHIC DISCHARGE DATA, TEMIM R. NEAR FINOTE SELAM

Runoff at TEMIM R. gage nr Finote Selam | Drainage area 108 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1960												0.19	
1961	0.11	0.07	0.04	0.05	0.03	0.03	11.92	42.84	21.70	9.87	1.92	0.78	89.36
1962				0.01	0.02	0.02	8.38	33.99	19.87	8.89	0.41	0.25	
1963	0.007	0.004											
CORRELATED 1/													
1911	0.12	0.10	0.09	0.05	0.10	0.18	9.00	28.75	25.60	12.25	4.80	0.62	81.66
1912	0.13	0.10	0.09	0.07	0.07	0.35	10.75	26.40	16.67	5.00	0.62	0.12	60.37
1913	0.10	0.09	0.09	0.09	0.11	0.09	2.00	12.25	11.20	1.50	0.12	0.09	27.73
1914	0.07	0.07	0.07	0.07	0.07	0.18	10.50	35.50	20.66	16.67	7.93	0.62	92.41
1915	0.13	0.10	0.09	0.07	0.10	0.25	5.75	15.60	20.45	12.85	3.70	0.35	59.44
1916	0.12	0.09	0.07	0.07	0.10	0.35	13.85	45.25	34.80	19.50	7.80	1.80	123.80
1917	0.22	0.11	0.10	0.09	0.11	0.80	15.63	42.30	51.80	19.50	6.25	1.35	138.26
1932	0.11	0.09	0.09	0.07	0.12	0.46	7.60	32.70	30.00	13.20	1.95	0.27	86.66

1/ With Timochia nr Dembecha (Figure III-34).

TABLE III-47--HYDROGRAPHIC DISCHARGE DATA, ARERA R. NEAR FINOTE SELAM

Runoff at ARERA R. gage nr Finote Selam | Drainage area 31 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1959												0.30	
1960	0.47	0.47	0.47	0.39	0.28	0.28	0.92	5.95		0.43	0.21	0.17	
1961	0.13	0.11	0.11	0.11	0.09	0.11	1.77	6.45	1.89	1.37	0.52	0.36	13.02
1962	0.23	0.20	0.21	0.23	0.27	0.76	6.94	3.98	2.06	0.97	0.41	0.33	16.59
CORRELATED 1/													
1911	0.17	0.13	0.12	0.11	0.13	0.19	0.41	2.61	1.60	0.50	0.30	0.20	6.47
1912	0.18	0.15	0.12	0.12	0.12	0.20	0.49	1.85	0.70	0.30	0.20	0.18	4.61
1913	0.15	0.12	0.12	0.12	0.15	0.12	0.23	0.52	0.49	0.22	0.17	0.12	2.53
1914	0.11	0.11	0.11	0.11	0.11	0.18	0.45	5.59	1.00	0.71	0.39	0.20	9.07
1915	0.18	0.13	0.12	0.11	0.15	0.19	0.31	0.67	0.98	0.55	0.28	0.19	3.86
1916	0.17	0.12	0.12	0.11	0.13	0.19	0.60	12.71	5.36	0.93	0.39	0.22	21.05
1917	0.19	0.17	0.13	0.12	0.15	0.20	0.68	9.50	18.91	0.93	0.34	0.21	31.53
1932	0.17	0.12	0.12	0.11	0.17	0.20	0.39	3.78	3.03	0.58	0.23	0.19	9.09

1/ With Abbay nr Kese (Figure III-35).

TABLE III-48--HYDROGRAPHIC DISCHARGE DATA, DEBOHILA R. NEAR BURE

Runoff at DEBOHILA R. gage nr Bure — Drainage area 74.7 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1960												1.52	
1961	1.21	0.92	1.03	0.67	0.35	0.74	3.74	7.72	5.97	4.26	2.27	2.09	30.97
1962	1.39	1.02	1.02	0.96	1.19	2.30	16.57	10.61	6.05	3.88	1.59	1.38	47.96
1963	1.30												
CORRELATED 1/													
1911	0.66	0.44	0.35	0.20	0.52	0.88	3.11	6.92	6.30	3.73	2.30	1.34	26.75
1912	0.76	0.57	0.39	0.29	0.29	1.18	3.47	6.45	4.59	2.34	1.34	0.76	22.43
1913	0.58	0.39	0.34	0.30	0.59	0.43	1.76	3.73	3.55	1.64	0.66	0.39	14.36
1914	0.22	0.22	0.22	0.28	0.22	0.87	3.41	8.22	5.38	4.60	2.91	1.35	27.90
1915	0.76	0.50	0.39	0.28	0.57	1.05	2.48	4.39	5.36	3.84	2.10	1.15	22.87
1916	0.65	0.40	0.29	0.28	0.49	1.16	4.04	10.12	8.10	5.21	2.88	1.70	35.32
1917	1.06	0.60	0.49	0.40	0.59	1.45	4.40	9.39	11.43	5.21	2.60	1.56	39.18
1932	0.61	0.40	0.30	0.22	0.68	1.25	2.85	7.50	7.18	3.93	1.75	1.10	27.77

1/ With Selale nr Bure (Figure III-36).

TABLE III-49--HYDROGRAPHIC DISCHARGE DATA, SELALE R. NEAR BURE

Runoff at SELALE R. gage nr Bure — Drainage area 26 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1959												0.55	
1960	0.39	0.40	0.42	0.48	0.60	0.71	3.25	4.38	2.58	1.56	0.60	0.58	15.95
1961	0.51	0.42	0.49	0.43	0.49	1.35	2.50	3.68	3.15	1.57	0.89	0.78	16.26
1962	0.38	0.35	0.61	0.32	0.43	0.75	3.43	4.97	3.33	1.60	0.36	0.38	16.91
1963	0.34	0.24	0.30										
CORRELATED 1/													
1911	0.35	0.23	0.18	0.11	0.27	0.46	1.62	3.62	3.29	1.95	1.19	0.70	13.97
1912	0.40	0.28	0.20	0.15	0.15	0.62	1.81	3.38	2.39	1.22	0.70	0.40	11.70
1913	0.29	0.20	0.17	0.16	0.30	0.22	0.91	1.95	1.85	0.85	0.35	0.20	7.45
1914	0.12	0.12	0.12	0.14	0.12	0.45	1.78	4.30	2.81	2.40	1.52	0.73	14.61
1915	0.40	0.26	0.20	0.14	0.28	0.55	1.29	2.29	2.79	2.01	1.10	0.60	11.91
1916	0.34	0.21	0.15	0.14	0.25	0.61	2.12	5.30	4.23	2.72	1.50	0.88	18.45
1917	0.53	0.31	0.25	0.21	0.30	0.75	2.30	4.90	5.97	2.72	1.35	0.82	20.41
1932	0.32	0.21	0.16	0.12	0.36	0.65	1.48	3.92	3.75	2.06	0.90	0.57	14.50

1/ With Abbay nr Kese (Figure III-37).

TABLE III-50--HISTORICAL HYDROGRAPHIC DISCHARGE DATA, DURA, ABBAY (NR. SUDAN BORDER), LAH, AND GUDLA RIVERS

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
DURA R. nr Metekkel														550
1961	5.8	4.5	3.6	2.6	1.9	5.1	74.1	243.7	346.6	178.5	37.1	23.1	926.6	
1962	7.6	4.2	3.3	2.2	3.2	6.8	66.0	271.4	235.4	96.9	20.8	9.0	717.7	
1963	5.0	2.8	2.7	2.4										
ABBAY nr Sudan Border														174,600
1961							9,182	17,407	15,744	10,030				
1962						1,732	6,287	16,870	14,483	8,503	2,558	1,423		
1963	868	455	345											
LAH R. nr Finote Selam														273
1959												2.86		
1960	1.23	1.11	0.98	1.10	1.10	6.30	44.96	73.53	38.21	16.46	3.37	2.27	190.62	
1961	1.08	0.92	0.97	1.15	1.05	5.69	42.68	73.75	36.23	28.96	7.40	8.25	208.13	
1962	2.26	0.85	1.01	0.96	1.94	7.87	64.20	70.43	52.79	20.36	4.26	2:15	229.08	
GUDLA R. nr Dembecha														360
1959												4.36		
1960	2.93	1.36	0.99	0.61	1.99	2.45	74.37	83.24	54.71	12.03	3.02	1.59	239.29	
1961	0.78	0.66	0.64	0.94	0.51	1.38	83.70		87.21	34.12	5.54	5.26		
1962	1.33	0.49	0.68	0.39	1.01	14.71	90.79	117.27	89.32	25.47	4.24	2.21	347.91	

TABLE III-51--HYDROGRAPHIC DISCHARGE DATA, DIDDESSA R. NEAR ARJO

Runoff at DIDDESSA R. nr Arjo — Drainage area 9,486 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1960								1,097.63	1,185.49	509.69	175.54	91.48	
1961	51.04	43.76	37.16	94.64	65.18	301.68	1,236.30	1,660.44	1,559.26	1,330.82	296.40	183.55	6,860.23
1962	59.61	27.50	25.12				606.79	900.29	1,129.25	830.75	112.43	56.99	
1963	36.30	15.57	13.52	41.97									
CORRELATED 1/													
1911	67	38	26	16	49	94	456	1,368	1,247	590	293	148	4,392
1912	78	52	33	22	23	131	536	1,284	786	311	146	79	3,481
1913	52	32	24	23	54	36	210	599	551	194	67	29	1,871
1914	17	13	14	21	17	89	512	1,529	1,031	800	417	157	4,617
1915	79	42	31	21	50	113	329	741	1,004	628	268	122	3,428
1916	66	37	22	20	44	126	674	1,755	1,519	986	407	200	5,856
1917	108	61	45	33	57	159	743	1,664	1,908	986	354	184	6,302
1932	62	34	24	18	68	137	566	1,447	1,402	646	203	109	4,716

1/ With Abbay at Roseires (Figure III-38).

TABLE III-52--HYDROGRAPHIC DISCHARGE DATA, DABANA R. NEAR ABASINA

Runoff at DABANA R. gage nr Abasina — Drainage area 3,080 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1961					19.65		350.40	461.48	657.20	495.31	132.94	73.54	
1962	37.83	17.80	16.30	8.05	28.57			389.09	451.34	331.54	91.47	44.11	
1963	27.8	13.4	11.0	23.8									
CORRELATED 1/													
1911	27	15	11	7	20	38	185	554	506	239	119	60	1,781
1912	32	21	13	9	9	53	217	521	319	126	59	32	1,411
1913	21	13	10	10	22	15	85	243	223	78	27	12	759
1914	7	5	6	8	7	36	208	620	418	325	169	64	1,873
1915	32	17	12	8	21	46	133	300	407	254	109	50	1,389
1916	27	15	9	8	18	51	273	711	616	400	165	81	2,374
1917	44	25	18	14	23	65	301	675	774	400	143	74	2,556
1932	25	14	10	7	28	56	230	587	568	262	82	44	1,913

1/ With Abbay at Roseires (Figure III-39).

TABLE III-53--HYDROGRAPHIC DISCHARGE DATA, ANGAR R. NEAR LEKKEMT

Runoff at ANGAR R. gage nr Lekkemt — Drainage area 4,350 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1960												64.90	
1961	36.68	26.63	21.69	23.68	15.67	82.51	492.94	832.12	833.41	684.63	194.83	111.76	3,356.55
1962	58.94	30.26	23.77	13.01	24.24	88.17	281.01	566.18	563.59	372.98			
1963	33.31	16.95	13.13	18.93									
CORRELATED 1/													
1911	41	26	19	14	31	56	252	745	680	324	163	85	2,436
1912	47	33	23	17	17	76	295	700	430	173	84	48	1,943
1913	33	22	18	18	34	25	118	329	303	110	41	21	1,072
1914	14	12	13	16	14	53	282	832	563	438	231	90	2,558
1915	48	28	22	16	32	66	183	406	548	345	150	71	1,915
1916	41	25	17	16	29	73	370	954	827	538	225	113	3,228
1917	63	38	30	23	36	91	407	905	1,038	538	196	104	3,469
1929	42	28	21	23	97	207	543	950	817	489	163	98	3,478
1932	38	24	18	15	42	79	311	788	763	354	115	64	2,611

1/ With Abbay at Roseires (Figure III-40).

TABLE III-54--HYDROGRAPHIC DISCHARGE DATA, DABUS R. NEAR ASOSA

Runoff at DABUS R. gage nr Asosa — Drainage area 10,100 sq km

Year	In millions of cubic meters												Total	Historical annual runoff of Baro River at Gambela
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
HISTORICAL														
1962		100	97	76	47	209	450	702	1,105	1,050	475	231		
1963	126													
CORRELATED 1/														
1911	104	77	50	50	212	452	687	1,034	998	465	248	140	4,517	12,534
1912	75	55	36	36	73	326	496	747	800	336	179	101	3,260	9,046
1913	71	52	34	34	145	107	467	704	879	317	169	95	3,074	8,530
1914	51	27	43	43	86	395	600	904	1,052	407	217	122	3,947	10,953
1915	103	76	49	49	210	447	680	1,024	988	460	246	139	4,471	12,407
1916	116	85	55	55	136	502	763	1,150	1,209	517	276	156	5,020	13,930
1917	121	121	90	58	248	527	801	1,206	1,164	543	290	163	5,269	14,620
1932	126	100	97	76	47	208	449	701	1,103	1,048	474	230	4,659	12,927

1/ With Baro at Gambela for yearly runoff (0.3604 x Baro at Gambela).

$$0.3604 = \frac{4{,}668 \text{ (Dabus nr Asosa (1962))}}{52{,}459 \text{ (Abbay at Roseires (1962))}} \times \frac{50{,}600 \text{ (Abbay at Roseires Mean)}}{12{,}493 \text{ (Baro at Gambela Mean)}}$$

Distributed by months as Dabus nr Asosa, February 1962 through January 1963 flow, except 80 taken out of May 1912, 200 out of June 1913, 40 out of January 1914, 40 out of February 1914, 100 out of May 1914, and 100 out May 1916 and added to the September runoff of those years. The Baro at Gambela runoff was unusually low during these months where the runoff was decreased.

TABLE III-55--HYDROGRAPHIC DISCHARGE DATA, DINDIR R. NEAR ABU MENDI

Runoff at DINDIR R. gage nr Abu Mendi — Drainage area 3,110 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1962			0	0	0.21	30.42	168.55	538.60	513.14	87.96	5.87	0.75	
CORRELATED 1/													
1917	0	0	0	0	0	69	203	535	633	159	17	0	1,616
1918	0	0	0	0	0	68	197	392	172	26	0	0	855
1919	0	0	0	0	0	23	269	244	196	14	0	0	746
1920	0	0	0	0	0	72	408	677	493	151	10	0	1,811
1921	0	0	0	0	0	10	109	395	325	66	0	0	905
1922	0	0	0	0	0	23	150	330	409	92	4	0	1,008
1923	0	0	0	0	0	18	337	635	497	103	12	0	1,602
1924	0	0	0	0	0	27	100	557	313	29	7	0	1,033
1925	0	0	0	0	0	20	179	428	223	48	1	0	899
1926	0	0	0	0	0	39	267	648	387	74	7	0	1,422
1927	0	0	0	0	0	23	191	541	261	37	0	0	1,053
1928	0	0	0	0	0	5	255	488	211	69	1	0	1,029
1929	0	0	0	0	9	127	418	659	619	156	12	0	2,000
1930	0	0	0	0	0	40	306	408	226	28	2	0	1,010
1931	0	0	0	0	0	6	190	542	455	161	13	0	1,367
1932	0	0	0	0	0	0	208	547	407	59	6	0	1,227
1933	0	0	0	0	0	4	175	562	459	139	20	4	1,363
1934	0	0	0	0	0	71	441	838	494	95	32	17	1,988
1935	1	0	0	0	0	58	261	528	432	77	9	1	1,367
1936	0	0	0	0	0	38	315	622	764	264	3	0	2,006
1937	0	0	0	0	0	23	281	760	300	55	7	2	1,428
1938	0	0	0	0	0	0	267	613	614	164	20	3	1,681
1939	0	0	0	0	0	30	209	535	328	90	9	2	1,203
1940	0	0	0	0	0	2	196	524	249	31	5	0	1,007
1941	0	0	0	0	0	0	97	215	150	59	18	1	540
1942	0	0	0	0	0	18	296	580	397	60	7	1	1,359
1943	0	0	0	0	0	52	245	446	380	109	19	3	1,254

1/ With Dindir at Hillet Idris using a factor of 0.436 and a 10-day lag at Dindir at Hillet Idris.

$$0.436 = \frac{\overset{\text{Abbay (Roseires) Mean}}{50,648}}{\underset{\text{Dindir (Hillet Idris) Mean}}{2,970}} \times \frac{\overset{\text{Dindir (Abu Mendi) 1962 (Preliminary estimate)}}{1,344}}{\underset{\text{Abbay (Roseires) 1962 (Preliminary estimate)}}{52,529}}$$

TABLE III-56--HYDROGRAPHIC DISCHARGE DATA, RAHAD R. NEAR METEMMA

Runoff at RAHAD R. gage nr Metemma (also diversion damsite) — Drainage area 4,035 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1962				0	0	22.43	151.83	687.14	609.29	87.19	6.81	1.70	
CORRELATED 1/													
1938	0	0	0	0	0	0	284	461	483	379	48	1	1,656
1939	0	0	0	0	0	18	205	432	445	169	14	0	1,283
1940	0	0	0	0	0	0	213	446	356	69	12	0	1,096
1941	0	0	0	0	0	0	82	239	246	123	29	1	720
1942	0	0	0	0	0	0	198	392	445	187	25	0	1,247
1943	0	0	0	0	0	0	187	414	459	283	36	1	1,380
1944	0	0	0	0	0	0	269	441	427	147	12	0	1,296
1945	0	0	0	0	0	0	192	427	464	336	44	1	1,464
1946	0	0	0	0	0	19	325	283	515	281	73	7	1,503
1947	0	0	0	0	0	0	147	441	526	224	22	0	1,360
1948	0	0	0	0	0	36	247	422	440	329	52	4	1,530
1949	0	0	0	0	0	0	295	576	560	377	36	0	1,844
1950	0	0	0	0	0	0	254	542	531	226	31	0	1,584

1/ With Rahad at Abu Haraz using a factor of 1.353 and a 10-day lag at Rahad at Abu Haraz.

$$1.353 = \frac{49{,}610}{1{,}095} \times \frac{1{,}567}{52{,}459}$$

where 49,610 = Abbay (Roseires) Mean (1912-1951, except 1919); 1,095 = Rahad (Abu Haraz) Mean (1912-1951, except 1919); 1,567 = Rahad (Metemma) (1962); 52,459 = Abbay Roseires (1962).

TABLE III-57--HYDROGRAPHIC DISCHARGE DATA, ABBAY R. NEAR KESE

Runoff at ABBAY R. gage nr Kese — Drainage area 65,000 sq km

Year	In millions of cubic meters												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
HISTORICAL													
1953							4,407	8,677		1,288	787	518	
1954	299	168	160	89	37	126	4,050	9,216	5,419				
1955													
1956	312	190	141	225	87	90	2,545	5,239	2,375	2,327	987	618	15,136
1957	395	228	638	525	174	212	1,531	5,472	2,055	841	495	348	12,914
1958	227	158	106	88	38	143	3,205	7,766	3,110	1,914	1,015	640	18,410
1959	424	266	205	123	77	61	2,672	7,502	4,507	1,944	1,075	709	19,565
1960	469	289	245	157	128	86	3,253	6,619	3,334	1,298	722	460	17,060
1961	314	201	177	281	171	107	3,840	6,263	3,782	1,826	921	697	18,580
1962	436	254	226	134	117	131	1,378	6,018	3,628	1,928	851	536	15,637
1963													
CORRELATED 1/													
1911	205	125	90	50	150	290	1,400	4,750	4,010	1,800	900	450	14,220
1912	240	160	100	70	75	400	1,650	4,220	2,400	950	450	250	10,965
1913	165	100	85	77	175	120	645	1,835	1,690	600	205	95	5,792
1914	52	49	50	65	52	275	1,575	6,450	3,150	2,450	1,285	490	15,943
1915	250	140	100	65	160	350	1,005	2,265	3,070	1,915	820	380	10,520
1916	204	115	70	63	145	390	2,055	9,850	6,330	3,015	1,250	615	24,102
1917	330	190	144	110	178	500	2,275	8,395	12,500	3,015	1,090	565	29,292
1929	210	140	97	105	525	1,150	3,048	9,700	6,110	2,735	895	527	25,242
1932	195	110	77	62	210	425	1,240	5,480	5,040	1,980	624	345	15,788

1/ With Abbay at Roseires (Figure III-41).

TABLE III-58--HYDROGRAPHIC DISCHARGE DATA, ABBAY R. BELOW GUDER R.

Runoff at ABBAY R. gage below Guder R. Drainage area 82,220 sq km

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	In millions of cubic meters												
HISTORICAL													
1961				328	172	153	4,668	8,088	5,048				
1962							1,827	6,983	4,439	2,196	926	619	
1963	408	242											
CORRELATED 1/													
1911	252	154	111	62	185	357	1,725	5,852	4,940	2,218	1,109	554	17,519
1912	296	197	123	86	93	493	2,033	5,199	2,957	1,170	554	308	13,509
1913	203	123	105	95	216	148	795	2,261	2,082	739	252	117	7,136
1914	64	60	62	80	64	339	1,940	7,947	3,881	3,018	1,583	604	19,642
1915	308	173	123	80	197	431	1,238	2,791	3,782	2,359	1,010	468	12,960
1916	251	142	86	78	179	480	2,532	12,135	7,799	3,714	1,540	758	29,694
1917	407	234	177	136	219	616	2,803	10,343	15,400	3,714	1,343	696	36,088
1932	240	136	95	76	259	524	1,528	6,751	6,209	2,439	769	425	19,451

1/ With Abbay nr Kese (Figure III-42).

TABLE III-59--HYDROGRAPHIC DISCHARGE DATA, ABBAY R. AT SHOGALI

Runoff at ABBAY R. gage at Shogali Drainage area 158,800 sq km

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	In millions of cubic meters												
HISTORICAL													
1959					588	1,116	5,868	15,139	14,598	8,732	3,796		
1960							7,335	15,155					
1961			353	533		1,452	8,329	16,311	14,652	9,787	3,720	2,349	
1962						1,585	5,454	13,771	12,199				
CORRELATED 1/													
1911	722	410	283	176	526	1,014	4,622	13,865	12,645	6,357	3,159	1,599	45,378
1912	838	556	351	234	244	1,414	5,438	13,021	7,969	3,354	1,580	848	35,847
1913	566	341	263	254	585	390	2,127	6,070	5,584	2,086	722	312	19,300
1914	185	136	146	224	185	956	5,190	15,497	10,454	8,629	4,495	1,696	47,793
1915	848	458	332	224	546	1,219	3,338	7,510	10,179	6,766	2,886	1,316	35,622
1916	712	400	234	214	478	1,355	6,832	17,790	15,406	10,628	4,388	2,155	60,592
1917	1,160	653	488	361	614	1,716	7,528	16,873	19,349	10,628	3,812	1,979	65,161
1932	663	370	254	195	731	1,482	5,740	14,672	14,214	6,962	2,184	1,180	48,647

1/ 0.917 x Abbay (Roseires) for July, August, and September
0.975 x Abbay (Roseires) for October through June.

TABLE III-60--COMPUTED HYDROGRAPHIC DISCHARGE DATA, MEGECH STORAGE AND DIVERSION

Year	In millions of cubic meters													Square kilometers
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
MEGECH R. at storage dam = 0.8035 x Megech R. at gage nr Azozo $(0.8035 = \frac{417}{519})$														417
1911	0.4	0.2	0.2	0.2	0.5	2.3	13.7	35.9	13.9	4.2	1.8	0.8	74.1	
1912	0.5	0.3	0.2	0.2	0.6	3.0	13.7	18.4	5.7	1.9	0.8	0.5	45.8	
1913	0.3	0.2	0.2	0.2	0.3	0.9	3.8	6.1	3.4	1.0	0.3	0.2	16.9	
1914	0.1	0.1	0.2	0.2	0.4	2.6	17.7	33.7	13.9	6.7	2.5	0.9	79.0	
1915	0.4	0.2	0.2	0.2	0.6	1.8	6.2	12.7	11.2	3.7	1.5	0.7	39.4	
1916	0.4	0.2	0.2	0.2	0.6	3.7	28.8	65.5	31.6	8.4	2.7	1.2	143.5	
1917	0.6	0.4	0.2	0.3	0.8	4.3	28.0	79.7	48.4	7.8	2.2	1.1	173.8	
1932	0.3	0.2	0.2	0.2	0.8	3.1	17.1	46.2	17.9	4.0	1.2	0.6	91.8	
MEGECH R. at diversion dam = 1.026 x Megech R. at gage nr Azozo $(1.026 = \sqrt{\frac{546}{519}})$														546
1911	0.5	0.3	0.2	0.3	0.6	3.0	17.5	45.9	17.7	5.3	2.3	1.0	94.6	
1912	0.6	0.4	0.2	0.2	0.7	3.8	17.5	23.5	7.3	2.5	1.0	0.6	58.3	
1913	0.4	0.2	0.2	0.3	0.4	1.1	4.8	7.8	4.3	1.2	0.4	0.2	21.3	
1914	0.1	0.1	0.2	0.2	0.5	3.3	22.6	43.0	17.7	8.5	3.2	1.1	100.5	
1915	0.5	0.3	0.2	0.3	0.8	2.3	7.9	16.2	14.3	4.7	1.9	0.9	50.3	
1916	0.5	0.3	0.2	0.3	0.8	4.7	36.7	83.6	40.3	10.8	3.4	1.5	183.1	
1917	0.8	0.5	0.3	0.4	1.0	5.5	35.8	101.8	61.8	10.0	2.9	1.4	222.2	

TABLE III-61--COMPUTED HYDROGRAPHIC DISCHARGE DATA, RIBB STORAGE AND DIVERSION

Year	In millions of cubic meters													Square kilometers
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
RIBB R. at storage dam = 0.672 x Ribb R. at gage nr Addis Zemin $(0.672 = \sqrt{\frac{676}{1,497}})$														676
1911	0.7	0.3	0.2	0.3	0.8	4.7	40.0	123.0	41.0	9.4	3.4	1.5	225.3	
1912	0.7	0.5	0.3	0.2	0.9	6.0	40.0	57.0	14.0	3.6	1.5	0.7	125.4	
1913	0.5	0.3	0.2	0.5	0.5	1.7	8.2	15.0	7.2	1.8	0.6	0.2	36.7	
1914	0.1	0.1	0.1	0.2	0.7	5.2	54.5	113.5	40.5	17.0	4.9	1.6	238.4	
1915	0.7	0.4	0.2	0.3	1.1	3.5	15.5	36.0	30.5	8.1	3.0	1.2	100.5	
1916	0.7	0.3	0.2	0.3	1.1	8.1	94.0	338.0	105.0	22.0	5.3	2.2	577.2	
1917	1.1	0.7	0.5	0.5	1.5	9.9	91.5	457.5	191.0	20.5	3.8	2.1	780.6	
1932	0.6	0.3	0.2	0.5	1.3	6.6	52.5	177.5	55.0	8.8	2.3	1.1	306.7	
RIBB R. at diversion dam = 0.797 x Ribb R. at gage nr Addis Zemin $(0.797 = \sqrt{\frac{950}{1,497}})$														950
1911	0.8	0.4	0.2	0.4	1.0	5.6	47.5	146.0	48.5	11.2	4.1	1.8	267.5	
1912	0.9	0.6	0.3	0.2	1.1	7.2	47.5	68.0	16.5	4.3	1.8	0.9	149.3	
1913	0.6	0.3	0.2	0.6	0.6	2.1	9.7	18.0	8.5	2.2	0.7	0.2	43.7	
1914	0.2	0.2	0.2	0.2	0.8	6.2	64.5	134.5	48.0	20.0	5.8	1.9	282.5	
1915	0.9	0.5	0.2	0.4	1.3	4.1	18.5	42.5	36.5	9.6	3.6	1.4	119.5	
1916	0.8	0.3	0.2	0.4	1.3	9.6	111.5	401.0	125.0	26.0	6.3	2.6	685.0	
1917	1.3	0.8	0.6	0.6	1.8	11.7	108.5	543.0	226.5	24.5	4.5	2.5	926.3	

TABLE III-62--COMPUTED HYDROGRAPHIC DISCHARGE DATA, GUMARA STORAGE AND DIVERSION

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
GUMARA R. at storage dam = 0.344 x Gumara R. at diversion dam (0.344 = $\sqrt{\frac{370}{1,073}}$)														370
1911	0.9	0.8	0.7	0.7	0.8	1.3	14.5	89.6	72.9	23.2	6.7	2.2	214.3	
1912	0.9	0.8	0.8	0.8	0.8	1.9	19.8	77.7	36.7	7.3	2.2	1.0	150.7	
1913	0.8	0.8	0.8	0.8	0.8	0.8	3.8	24.0	20.7	3.2	0.8	0.8	58.1	
1914	0.7	0.7	0.7	0.7	0.7	1.1	18.1	128.0	53.5	37.8	12.5	2.4	256.9	
1915	1.0	0.8	0.7	0.7	0.8	1.5	8.0	33.7	51.8	25.8	5.7	1.6	132.1	
1916	0.9	0.8	0.7	0.7	0.8	1.7	29.0	204.4	125.2	50.5	12.0	3.3	430.0	
1917	1.6	0.8	0.8	0.7	0.8	2.4	33.9	171.6	264.0	50.6	9.3	3.1	539.6	
1932	0.8	0.8	0.8	0.7	0.9	2.0	11.8	106.0	96.1	27.3	3.4	1.5	252.1	
GUMARA R. at diversion dam = 0.931 x Gumara R. at gage nr Lake Tana (0.931 = $\sqrt{\frac{1,073}{1,239}}$)														1,073
1911	2.5	2.3	2.2	1.9	2.3	3.7	42.2	260.5	212.1	67.5	19.6	6.3	623.1	
1912	2.7	2.3	2.2	2.2	2.2	5.6	57.7	225.8	106.8	21.4	6.4	2.8	438.1	
1913	2.3	2.3	2.3	2.3	2.3	2.3	11.0	69.8	60.2	9.4	2.5	2.2	168.9	
1914	2.0	1.9	1.9	2.1	2.0	3.2	52.7	372.0	155.7	110.0	36.3	7.0	746.8	
1915	2.8	2.3	2.2	2.1	2.3	4.4	23.3	97.9	150.6	74.9	16.5	4.8	384.1	
1916	2.5	2.2	2.2	2.1	2.3	5.0	84.2	594.3	364.0	147.0	34.8	9.5	1,250.1	
1917	4.6	2.4	2.3	2.2	2.3	7.0	98.6	499.0	767.3	147.0	27.0	9.0	1,568.7	

TABLE III-63--COMPUTED HYDROGRAPHIC DISCHARGE DATA, LAKE TANA INFLOW AND OUTFLOW

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
ABBAY Outflow from Lake Tana 1/														15,165
1911										879	559	378		
1912	235	148	60	38	18	24	70	373	590	579	376	237	2,748	
1913	150	57	40	40	20	19	30	79	326	447	205	50	1,463	
1914	28	19	20	35	17	22	67	663	868	1,108	693	392	3,932	
1915	237	98	59	35	20	24	43	106	837	920	529	332	3,240	
1916	202	84	38	32	19	25	93	1,036	1,504	1,310	682	456	5,481	
1917	303	181	109	62	20	26	107	877	2,284					
LAKE TANA Inflow (exclusive of precipitation on lake) 2/														12,000±
1911										473	194	86		
1912	43	32	20	16	32	162	890	1,732	692	205	83	47	3,954	
1913	33	21	19	22	34	59	268	646	448	113	36	19	1,718	
1914	16	16	16	16	32	151	1,233	3,587	1,503	906	358	119	7,953	
1915	59	34	29	24	59	151	570	1,398	1,549	672	229	98	4,872	
1916	31	15	16	16	23	117	1,004	3,745	1,861	662	210	86	7,786	
1917	40	24	16	16	24	121	848	3,329	2,909					

1/ Abbay nr Bahir Dar - 0.0018 (Abbay nr Kese - Abbay nr Bahir Dar - Andassa nr Bahir Dar - Giamma nr Insaro).

Abbay Outflow from Lake Tana = 15,165 km²
Abbay nr Bahir Dar = 15,240
Andassa nr Bahir Dar = 660
Abbay nr Kese = 65,000
Giamma nr Insaro = 6,320

$$\frac{15,240 - 15,165}{65,000 - 15,240 - 660 - 6,320} = 0.0018$$

2/ The yearly totals were estimated from the outflow estimate, change in storage and estimated precipitation and evaporation on the lake surface. Each yearly total was then distributed by months with the same monthly percentages as for the average estimated flows on the Gilgel Abbay, Megech, Ribb, and Gumara for the corresponding year.

TABLE III-64--COMPUTED HYDROGRAPHIC DISCHARGE DATA, ABBAY AT TIS ISAT FALLS, BELES AT DANGUR

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
ABBAY R. at Tis Isat Falls (BN-10) 1/														16,420
1911										918	577	386		
1912	240	151	63	40	21	36	116	487	650	598	384	242		
1913	153	60	43	42	25	23	49	130	370	458	209	53		
1914	30	21	22	37	19	30	111	836	945	1,162	720	401		
1915	242	101	62	37	25	34	71	169	912	962	546	339		
1916	206	87	40	34	24	36	150	1,299	1,662	1,377	708	468		
1917	309	185	112	65	25	41	170	1,101	2,604					
BELES R. at Dangur (BL-3) Dam = 2.094 x Beles R. at gage nr Metekkel ($2.094 = \frac{2,186}{1,044}$)														9,070
2,186 = Beles at Dangur Dam average annual runoff.														
1,044 = Beles nr Metekkel average annual runoff.														
1911	13	6	4	2	8	19	320	1,010	611	86	40	31	2,150	
1912	17	10	6	4	4	27	381	942	312	42	19	17	1,781	
1913	10	6	4	4	10	6	147	434	188	25	8	6	848	
1914	4	2	2	4	4	19	356	1,148	463	124	59	36	2,221	
1915	17	8	6	4	10	23	230	532	444	92	36	25	1,427	
1916	13	8	4	4	8	27	482	1,319	812	159	57	48	2,941	
1917	21	13	8	6	13	36	534	1,248	1,104	159	48	44	3,234	
1932	10	6	4	4	13	31	402	1,072	727	96	27	23	2,415	

1/ Abbay nr Bahir Dar + Andassa nr Bahir Dar + 0.0121 (Abbay nr Kese - Abbay nr Bahir Dar - Andassa nr Bahir Dar - Giamma nr Insaro).

Abbay at Tis Isat = 16,420 km^2
Abbay nr Bahir Dar = 15,240
Andassa nr Bahir Dar = 660
Abbay nr Kese = 65,000
Giamma nr Insaro = 6,320

$$\frac{16,420 - 15,240 - 660}{65,000 - 15,240 - 660 - 6,320} = 0.0121$$

TABLE III-65--COMPUTED HYDROGRAPHIC DISCHARGE DATA, GIAMMA AND MOTTO

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
GIAMMA R. at Giamma Dam = 0.986 x Giamma R. at gage nr Insaro ($0.986 = \sqrt{\frac{6,140}{6,320}}$)														6,140
1911	18	9	5	2	11	22	124	425	359	160	79	38	1,252	
1912	20	12	6	4	4	34	147	377	214	83	38	20	959	
1913	13	6	5	4	13	8	56	161	149	51	18	6	490	
1914	2	2	2	3	2	23	139	578	281	219	112	40	1,403	
1915	20	10	6	3	12	29	89	200	275	169	71	32	916	
1916	18	7	4	3	10	32	183	885	567	269	109	52	2,139	
1917	28	14	10	7	13	42	202	752	1,124	269	97	49	2,607	
1932	15	7	4	3	18	36	108	492	452	176	53	29	1,393	
GUDER R. at Motto (GU-1) Dam = 0.841 x Guder R. at gage nr mouth														3,670
1911	3.4	1.7	5.0	3.4	10.1	21.0	243.0	510.5	365.0	121.1	37.8	10.1	1,332.1	
1912	4.2	1.7	6.7	4.2	4.2	32.0	272.5	487.8	186.7	42.0	10.1	4.2	1,056.3	
1913	1.7	0.8	5.1	4.2	10.9	7.6	67.3	293.5	109.3	16.8	2.5	0.9	520.6	
1914	0.8	0.8	2.5	4.2	3.4	19.3	264.1	554.2	278.4	191.8	70.6	11.8	1,401.9	
1915	4.2	1.7	5.9	4.2	10.1	26.9	167.3	337.2	268.3	132.9	32.8	7.6	999.1	
1916	2.5	1.7	4.2	4.2	9.2	30.3	317.9	616.5	480.2	260.7	68.1	17.7	1,813.2	
1917	5.9	2.5	9.3	7.6	11.8	42.0	337.2	591.2	649.2	260.7	53.0	16.0	1,986.4	
1932	1.7	0.8	4.2	3.4	14.3	33.6	282.6	532.4	429.7	138.8	18.5	6.7	1,466.7	

$$0.841 = (1,744 - \frac{52,140}{50,600} \times 3,020 \times 0.0891) \div 1,744$$

1,744 = 1932 runoff of Guder R. at mouth
52,140 = 1932 runoff of Abbay R. at Roseires
50,600 = Average annual runoff of Abbay R. at Roseires
3,020 = Area in square kilometers between GU-1 and Guder mouth
0.0891 = Average annual depth runoff in meters between GU-1 and Guder mouth

TABLE III-66--COMPUTED HYDROGRAPHIC DISCHARGE DATA, CHANCHO AND FALLS

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
MUGER R. at Chancho (MU-4) Dam = 0.907 x Muger R. at gage nr Chancho ($0.907 = \sqrt{\frac{499}{606}}$)														499
1911	0.27	0.18	0.09	0.09	0.18	0.36	8.98	57.23	46.53	14.69	2.36	0.64	131.60	
1912	0.27	0.18	0.09	0.09	0.09	0.46	12.70	49.61	23.49	2.72	0.64	0.27	90.61	
1913	0.18	0.09	0.09	0.09	0.18	0.18	0.91	15.33	13.24	0.91	0.27	0.09	31.56	
1914	0.09	0.09	0.09	0.09	0.09	0.36	11.52	81.54	34.28	24.13	7.26	0.73	160.27	
1915	0.36	0.18	0.09	0.09	0.18	0.46	3.26	21.50	33.10	16.42	1.91	0.45	78.00	
1916	0.27	0.18	0.09	0.09	0.18	0.45	18.32	130.25	79.82	32.20	6.71	0.91	269.47	
1917	0.45	0.27	0.18	0.09	0.18	0.73	21.59	108.47	167.98	32.20	4.53	0.91	338.58	
1932	0.18	0.09	0.09	0.09	0.27	0.55	6.53	67.75	61.41	17.32	0.91	0.54	155.73	
MUGER R. at Falls (MU-1) Diversion Dam = 1.037 x Muger R. at gage nr Chancho ($1.037 = \sqrt{\frac{652}{606}}$)														652
1911	0.31	0.21	0.10	0.10	0.21	0.41	10.27	65.44	53.20	16.80	2.70	0.72	150.47	
1912	0.31	0.21	0.10	0.10	0.10	0.52	14.52	56.73	26.86	3.11	0.73	0.31	103.60	
1913	0.21	0.10	0.10	0.10	0.21	0.21	1.04	17.53	15.14	1.04	0.31	0.10	36.09	
1914	0.10	0.10	0.10	0.10	0.11	0.42	13.17	93.23	39.20	27.58	8.30	0.83	183.24	
1915	0.41	0.21	0.10	0.10	0.21	0.52	3.73	24.58	37.85	18.77	2.18	0.52	89.18	
1916	0.31	0.21	0.10	0.10	0.21	0.52	20.95	148.91	91.26	36.81	7.67	1.04	308.09	
1917	0.52	0.31	0.21	0.10	0.21	0.83	24.68	125.17	192.05	36.81	5.18	1.04	387.11	
1932	0.21	0.10	0.10	0.10	0.31	0.62	7.47	77.46	70.21	19.81	1.04	0.62	178.05	

TABLE III-67--COMPUTED HYDROGRAPHIC DISCHARGE DATA, NESHE OR AMARTI RIVERS

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
NESHE R. or AMARTI R. at damsites 1/														Neshe 309 Amarti 245
1911	0	0	0	0	0	4	14	35	67	27	4	0	151	
1912	0	0	0	0	0	3	10	27	52	21	3	0	116	
1913	0	0	0	0	0	2	6	14	27	11	1	0	61	
1914	0	0	0	0	0	5	15	39	76	30	4	0	169	
1915	0	0	0	0	0	3	10	26	50	20	3	0	112	
1916	0	0	0	0	0	8	23	59	114	46	6	0	256	
1917	0	0	0	0	0	9	28	72	139	55	7	0	310	
1932	0	0	0	0	0	5	15	39	74	30	4	0	167	

1/ From six measurements taken in 1962 on the Amarti and Neshe Rivers near the damsites, hydrographs were drawn. They were similar in shape and size so the mean of the two was used to estimate the runoff by months for each river. The estimated quantities by months in millions of cubic meters are as follows: June = 5, July = 15, August = 39, September = 75, October = 30, and November = 4. Runoff in the other 6 months was considered to be negligible, so the estimated total for 1962 for either river is 168 million cubic meters. The annual runoff for the years 1911 through 1917 and 1932 was computed as the 1962 runoff multiplied by the ratio of annual runoffs for the Abbay nr Kese for each year to the 1962 Abbay nr Kese runoff. The annual runoffs so computed were then proportioned by months in the same percentages as the 1962 runoff estimate for the Amarti or Neshe River.

TABLE III-68--COMPUTED HYDROGRAPHIC DISCHARGE DATA, UPPER BIRR. DEBOHILA, LOWER BIRR

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
BIRR R. at Upper Birr (B-5) Dam = 0.7785 x Birr R. gage nr Jiga ($0.7785 = \frac{678}{813}\sqrt{\frac{591}{678}}$)														591
1911	1.56	1.56	0.78	0.78	1.56	1.56	17.90	126.89	97.31	27.24	7.78	3.12	288.04	
1912	1.56	1.56	0.78	0.78	0.78	2.33	23.35	105.09	42.81	9.34	3.12	1.56	193.06	
1913	1.56	0.78	0.78	0.78	1.56	1.56	4.68	27.24	24.12	4.67	1.56	0.78	70.07	
1914	0.78	0.78	0.78	0.78	0.78	1.56	21.79	203.96	66.17	45.14	15.57	3.12	361.21	
1915	1.56	1.56	0.78	0.78	1.56	1.56	10.12	39.69	63.06	29.58	7.01	2.33	159.59	
1916	1.56	1.56	0.78	0.78	1.56	2.33	33.47	385.34	196.95	61.50	14.79	4.67	705.29	
1917	2.33	1.56	1.56	0.78	1.56	3.12	39.69	303.61	536.37	61.50	11.68	4.67	968.43	
1932	1.56	0.78	0.78	0.78	1.56	2.33	14.80	158.03	138.56	31.14	4.67	2.33	357.32	
DEBOHILA R. at storage dam = 1.018 x Debohila at gage nr Bure ($1.018 = \sqrt{\frac{77.4}{74.7}}$)														77.4
1911	0.67	0.45	0.36	0.20	0.53	0.90	3.17	7.04	6.41	3.80	2.34	1.36	27.23	
1912	0.77	0.58	0.40	0.30	0.30	1.20	3.53	6.57	4.67	2.38	1.36	0.77	22.83	
1913	0.59	0.40	0.35	0.30	0.60	0.44	1.79	3.80	3.61	1.67	0.67	0.40	14.62	
1914	0.22	0.22	0.22	0.29	0.22	0.89	3.47	8.37	5.48	4.68	2.96	1.38	28.40	
1915	0.77	0.51	0.40	0.29	0.58	1.07	2.52	4.47	5.45	3.91	2.14	1.17	23.28	
1916	0.66	0.41	0.30	0.29	0.50	1.18	4.11	10.30	8.25	5.30	2.93	1.73	35.96	
1917	1.08	0.61	0.50	0.41	0.60	1.48	4.48	9.56	11.63	5.30	2.65	1.59	39.89	
1932	0.62	0.41	0.31	0.22	0.69	1.27	2.90	7.64	7.31	4.00	1.78	1.12	28.27	
BIRR R. at Lower Birr (B-3) Dam 1/														1,378.4
1911	3.07	2.79	1.55	1.34	2.89	3.75	59.75	305.50	245.95	85.20	30.17	9.09	751.05	
1912	3.31	2.90	1.59	1.41	1.41	6.55	74.40	261.42	125.58	33.36	9.09	3.20	524.22	
1913	2.90	1.59	1.54	1.53	2.99	2.70	16.38	85.23	76.99	14.95	3.07	1.55	211.42	
1914	1.39	1.39	1.39	1.40	1.39	3.76	70.82	455.83	177.13	129.03	52.41	9.16	905.10	
1915	3.37	2.88	1.59	1.40	2.90	4.41	36.80	116.76	171.61	91.19	25.64	6.52	465.07	
1916	3.07	2.70	1.41	1.40	2.89	6.48	100.78	783.39	441.71	165.84	50.46	15.97	1,576.10	
1917	5.37	3.01	2.88	1.61	2.99	9.56	116.93	639.28	1,051.57	165.84	40.65	13.87	2,053.56	
1932	3.06	1.61	1.52	1.40	3.16	6.84	50.00	368.70	329.68	94.83	16.36	5.80	882.96	

1/ Sum of flows at Leza, Temim, Birr, and Kechem gages plus inflow below these gages which is taken to equal $\frac{115.4}{1,263}$ or 0.0913 x their combined flows.

TABLE III-69--COMPUTED HYDROGRAPHIC DISCHARGE DATA, SELALE, ADEFITA, GHUSSA

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
SELALE R. at diversion dam = 0.942 x Selale R. gage nr Bure ($0.942 = \sqrt{\frac{23.37}{26.33}}$)														23.37
1911	0.33	0.22	0.17	0.10	0.25	0.43	1.53	3.41	3.10	1.84	1.12	0.66	13.16	
1912	0.38	0.26	0.19	0.14	0.14	0.58	1.71	3.18	2.25	1.15	0.66	0.38	11.02	
1913	0.27	0.19	0.16	0.15	0.28	0.21	0.86	1.84	1.74	0.80	0.33	0.19	7.02	
1914	0.11	0.11	0.11	0.13	0.11	0.43	1.68	4.05	2.65	2.26	1.43	0.69	13.76	
1915	0.38	0.24	0.19	0.13	0.26	0.52	1.22	2.16	2.63	1.89	1.04	0.56	11.22	
1916	0.32	0.20	0.14	0.13	0.24	0.57	2.00	4.99	3.99	2.56	1.41	0.83	17.38	
1917	0.50	0.29	0.24	0.20	0.28	0.71	2.17	4.62	5.62	2.56	1.27	0.77	19.23	
ADEFITA R. at diversion dam = 0.312 x Arera R. gage nr Finote Selam ($0.312 = \frac{6.15}{12.47} \times \sqrt{\frac{12.47}{31.12}}$)														6.15
1911	0.05	0.04	0.04	0.04	0.04	0.06	0.13	0.81	0.50	0.16	0.09	0.06	2.02	
1912	0.05	0.05	0.04	0.04	0.04	0.06	0.15	0.58	0.22	0.10	0.06	0.05	1.44	
1913	0.04	0.04	0.04	0.04	0.04	0.04	0.07	0.16	0.15	0.07	0.06	0.04	0.79	
1914	0.04	0.04	0.04	0.04	0.03	0.05	0.14	1.74	0.31	0.22	0.12	0.06	2.83	
1915	0.05	0.04	0.04	0.03	0.04	0.06	0.10	0.21	0.31	0.17	0.09	0.06	1.20	
1916	0.05	0.03	0.04	0.04	0.04	0.06	0.19	3.97	1.67	0.29	0.12	0.07	6.57	
1917	0.06	0.06	0.04	0.04	0.05	0.06	0.21	2.96	5.90	0.29	0.11	0.06	9.84	
GHUSSA R. at diversion dam = 0.864 x Selale R. at diversion dam ($0.864 = \frac{20.20}{23.37}$)														20.20
1911	0.28	0.19	0.15	0.09	0.22	0.37	1.32	2.94	2.68	1.59	0.97	0.57	11.37	
1912	0.33	0.23	0.16	0.12	0.12	0.50	1.48	2.75	1.94	0.99	0.57	0.33	9.52	
1913	0.23	0.17	0.14	0.13	0.24	0.18	0.74	1.59	1.50	0.69	0.29	0.17	6.07	
1914	0.10	0.10	0.09	0.11	0.10	0.37	1.45	3.50	2.29	1.95	1.23	0.60	11.89	
1915	0.33	0.21	0.17	0.11	0.22	0.45	1.05	1.87	2.27	1.63	0.90	0.48	9.69	
1916	0.28	0.17	0.12	0.11	0.21	0.49	1.73	4.31	3.45	2.21	1.22	0.72	15.02	
1917	0.43	0.25	0.21	0.17	0.24	0.61	1.88	3.99	4.86	2.21	1.10	0.67	16.62	

TABLE III-70--COMPUTED HYDROGRAPHIC DISCHARGE DATA, DIDDESSA AND DABANA

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
DIDDESSA R. at Diddessa (DD-11) Dam = 0.354 x Diddessa R. gage nr Arjo (0.354 = $\frac{3,360}{9,486}$)														3,360
1911	24	13	9	6	17	33	162	484	442	209	104	52	1,555	
1912	28	18	12	8	8	46	190	454	278	110	52	28	1,232	
1913	18	11	9	8	19	13	74	212	195	69	24	10	662	
1914	6	5	5	7	6	31	181	541	365	283	148	56	1,634	
1915	28	15	11	7	18	40	117	262	356	222	95	43	1,214	
1916	23	13	8	7	15	45	239	621	538	349	144	71	2,073	
1917	38	22	16	12	20	56	263	589	676	349	125	65	2,231	
1932	22	12	9	6	24	48	200	512	496	229	72	39	1,669	
DABANA R. at Dabana Storage Dam = 0.862 x Dabana R. gage nr Abasina (0.862 = $\frac{2,654}{3,080}$)														2,654
1911	23	13	9	6	17	33	160	478	436	206	103	52	1,536	
1912	28	18	11	8	8	46	187	449	275	109	51	28	1,218	
1913	18	11	9	9	19	13	73	210	192	67	23	10	654	
1914	6	4	5	7	6	31	179	535	361	280	146	55	1,615	
1915	28	15	10	7	18	40	115	259	351	219	94	43	1,199	
1916	23	13	8	7	16	44	235	613	531	345	142	70	2,047	
1917	38	22	16	12	20	56	260	582	668	345	123	64	2,206	
1932	22	12	9	6	24	48	198	506	490	226	71	38	1,650	

TABLE III-71--COMPUTED HYDROGRAPHIC DISCHARGE DATA, BOO AND RAHAD

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
DIDDESSA R. at Boo (DD-2) Dam 1/														16,700
1911	130	73	51	32	95	182	886	2,658	2,424	1,146	570	288	8,535	
1912	152	101	64	43	44	254	1,041	2,496	1,528	604	283	153	6,765	
1913	101	62	47	45	105	70	408	1,164	1,070	376	130	57	3,635	
1914	33	25	28	40	33	173	995	2,971	2,004	1,555	810	305	8,972	
1915	153	82	60	40	98	220	639	1,440	1,951	1,220	521	238	6,662	
1916	100	56	34	30	67	187	996	2,614	2,270	1,450	604	301	8,709	
1917	159	90	66	49	85	234	1,093	2,487	2,817	1,450	529	278	9,337	
1932	120	66	47	35	132	269	1,100	2,812	2,724	1,256	394	212	9,167	
RAHAD R. at storage dam = 0.970 x Rahad R. at gage nr Metemma (0.970 = $\frac{1,469 \text{ storage dam average annual runoff}}{1,514 \text{ Rahad gage average annual runoff}}$)														3,800
1938	0	0	0	0	0	0	275	447	468	368	47	1	1,606	
1939	0	0	0	0	0	17	199	419	432	164	14	0	1,245	
1940	0	0	0	0	0	0	207	433	345	67	11	0	1,063	
1941	0	0	0	0	0	0	79	232	239	119	28	1	698	
1942	0	0	0	0	0	0	192	380	432	182	24	0	1,210	
1943	0	0	0	0	0	0	181	402	445	275	35	1	1,339	
1944	0	0	0	0	0	0	261	428	414	142	12	0	1,257	
1945	0	0	0	0	0	0	186	414	450	326	43	1	1,420	
1946	0	0	0	0	0	18	315	274	500	273	71	7	1,458	
1947	0	0	0	0	0	0	143	428	510	217	21	0	1,319	
1948	0	0	0	0	0	35	240	409	427	319	50	4	1,484	
1949	0	0	0	0	0	0	286	559	543	366	35	0	1,789	
1950	0	0	0	0	0	0	246	526	515	219	30	0	1,536	

1/ For 1911-1915, 1932 Runoff = Dabana at gage + Diddessa nr Arjo gage + 0.538 x Diddessa nr Arjo gage (From ppt.-runoff). For 1916 and 1917 Runoff = Dabana at gage + Diddessa nr Arjo gage + 476.3 (With Abbay at Roseires distribution).

TABLE III-72--COMPUTED HYDROGRAPHIC DISCHARGE DATA, ANGAR AND LEKKEMT

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
ANGAR R. at Angar (AG-2) Dam = 0.409 x Angar R. at gage nr Lekkemt ($0.409 = \frac{1,780}{4,350}$)														1,780
1911	17	11	8	6	13	23	103	304	278	132	66	35	996	
1912	19	14	9	7	7	31	121	286	176	71	34	20	795	
1913	13	9	7	7	14	10	48	135	124	45	17	9	438	
1914	6	5	5	7	6	22	115	340	230	179	94	37	1,046	
1915	20	11	9	7	13	27	75	166	224	141	61	29	783	
1916	17	10	7	7	12	30	151	390	338	220	92	46	1,320	
1917	26	16	12	9	15	37	166	370	425	220	80	43	1,419	
1932	16	10	7	6	17	33	127	322	312	145	47	26	1,068	
ANGAR R. at Lekkemt (AG-6) Dam = 1.040 x Angar R. at gage nr Lekkemt ($1.040 = \frac{4,523}{4,350}$)														4,523
1911	43	27	20	15	32	58	262	775	707	337	170	88	2,534	
1912	49	34	24	18	18	79	307	728	447	180	87	50	2,021	
1913	34	23	19	19	35	26	123	342	315	114	43	22	1,115	
1914	15	12	14	17	15	55	293	865	586	456	240	94	2,662	
1915	50	29	23	17	33	69	190	422	570	359	156	74	1,992	
1916	43	26	18	17	30	76	385	992	860	560	234	118	3,359	
1917	66	40	31	24	37	95	423	941	1,080	560	204	108	3,609	
1932	40	25	19	16	44	82	323	820	794	368	120	67	2,718	

TABLE III-73--COMPUTED HYDROGRAPHIC DISCHARGE DATA, JUNCTION

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
DINDIR R. at Junction (DI-7) Dam = 0.909 x Dindir R. gage nr Abu Mendi ($0.909 = \frac{1,182 \text{ Junction average annual runoff}}{1,300 \text{ Abu Mendi average annual runoff}}$)														2,690
1917	0	0	0	0	0	63	184	486	575	144	15	0	1,467	
1918	0	0	0	0	0	62	179	356	156	24	0	0	777	
1919	0	0	0	0	0	21	244	222	178	13	0	0	678	
1920	0	0	0	0	0	64	371	615	448	137	9	0	1,644	
1921	0	0	0	0	0	9	99	359	294	60	0	0	821	
1922	0	0	0	0	0	21	136	300	372	84	4	0	917	
1923	0	0	0	0	0	16	306	577	452	94	11	0	1,458	
1924	0	0	0	0	0	24	91	506	284	26	6	0	937	
1925	0	0	0	0	0	18	162	389	203	44	1	0	817	
1926	0	0	0	0	0	35	243	589	352	67	6	0	1,292	
1927	0	0	0	0	0	21	171	492	237	34	0	0	955	
1928	0	0	0	0	0	4	232	444	192	63	1	0	936	
1929	0	0	0	0	8	115	380	599	563	142	11	0	1,818	
1930	0	0	0	0	0	36	278	371	205	25	2	0	917	
1931	0	0	0	0	0	5	173	493	414	146	12	0	1,243	
1932	0	0	0	0	0	0	189	497	370	54	5	0	1,115	
1933	0	0	0	0	0	4	159	511	417	126	18	4	1,239	
1934	0	0	0	0	0	64	401	762	449	86	29	15	1,806	
1935	1	0	0	0	0	53	237	480	393	70	8	1	1,243	
1936	0	0	0	0	0	34	286	565	694	240	3	0	1,822	
1937	0	0	0	0	0	21	255	691	273	50	6	2	1,298	
1938	0	0	0	0	0	0	243	557	558	149	18	3	1,528	
1939	0	0	0	0	0	27	190	486	298	82	8	2	1,093	
1940	0	0	0	0	0	2	178	476	226	28	5	0	915	
1941	0	0	0	0	0	0	88	195	136	54	16	1	490	
1942	0	0	0	0	0	16	269	527	361	55	6	1	1,235	
1943	0	0	0	0	0	47	223	405	345	99	17	3	1,139	

TABLE III-74--COMPUTED HYDROGRAPHIC DISCHARGE DATA, DINDIR

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
DINDIR R. at Dindir (DI-2) Dam = 1.528 x Dindir R. at gage nr Abu Mendi														4,900
$\left(1.528 = \frac{1,986 \text{ Dindir Dam average annual runoff}}{1,300 \text{ Abu Mendi average annual runoff}}\right)$														
1917	0	0	0	0	0	105	310	817	967	243	26	0	2,468	
1918	0	0	0	0	0	104	301	599	263	40	0	0	1,307	
1919	0	0	0	0	0	35	411	373	299	21	0	0	1,139	
1920	0	0	0	0	0	110	623	1,034	753	231	15	0	2,766	
1921	0	0	0	0	0	15	166	604	497	101	0	0	1,383	
1922	0	0	0	0	0	35	229	504	625	140	6	0	1,539	
1923	0	0	0	0	0	28	515	970	759	157	18	0	2,447	
1924	0	0	0	0	0	41	153	851	478	44	11	0	1,578	
1925	0	0	0	0	0	30	274	654	341	73	2	0	1,374	
1926	0	0	0	0	0	60	408	990	591	113	10	0	2,172	
1927	0	0	0	0	0	35	292	827	399	56	0	0	1,609	
1928	0	0	0	0	0	8	390	746	322	105	2	0	1,573	
1929	0	0	0	0	14	194	639	1,007	946	238	18	0	3,056	
1930	0	0	0	0	0	61	467	623	345	43	3	0	1,542	
1931	0	0	0	0	0	9	290	828	695	246	20	0	2,088	
1932	0	0	0	0	0	0	318	836	622	90	9	0	1,875	
1933	0	0	0	0	0	6	267	859	701	212	31	6	2,082	
1934	0	0	0	0	0	108	674	1,280	755	145	49	26	3,037	
1935	2	0	0	0	0	89	399	807	660	118	14	2	2,091	
1936	0	0	0	0	0	58	481	950	1,167	403	5	0	3,064	
1937	0	0	0	0	0	35	429	1,161	458	84	11	3	2,181	
1938	0	0	0	0	0	0	408	937	938	251	31	5	2,570	
1939	0	0	0	0	0	46	319	817	501	137	14	3	1,837	
1940	0	0	0	0	0	3	299	800	380	47	8	0	1,537	
1941	0	0	0	0	0	0	148	328	229	90	28	2	825	
1942	0	0	0	0	0	28	452	886	606	92	11	2	2,077	
1943	0	0	0	0	0	79	374	681	581	167	29	5	1,916	

TABLE III-75--COMPUTED HYDROGRAPHIC DISCHARGE DATA, GALEGU

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
GALEGU R. at Galegu Dam = 0.192 x Dindir R. at gage nr Abu Mendi $\left(0.192 = \frac{656}{3,110}\sqrt{\frac{543}{656}}\right)$														543
1917	0	0	0	0	0	13.3	38.9	102.6	121.5	30.6	3.3	0	310.2	
1918	0	0	0	0	0	13.1	37.9	75.2	33.1	4.9	0	0	164.2	
1919	0	0	0	0	0	4.5	51.7	46.9	37.6	2.7	0	0	143.4	
1920	0	0	0	0	0	13.9	78.4	130.0	94.7	28.9	2.0	0	347.9	
1921	0	0	0	0	0	2.0	21.0	75.8	62.4	12.6	0	0	173.8	
1922	0	0	0	0	0	4.5	28.7	63.3	78.6	17.7	0.7	0	193.5	
1923	0	0	0	0	0	3.4	64.6	121.9	95.5	19.7	2.3	0	307.4	
1924	0	0	0	0	0	5.2	19.1	106.9	60.0	5.6	1.3	0	198.1	
1925	0	0	0	0	0	3.9	34.4	82.2	42.8	9.3	0.2	0	172.8	
1926	0	0	0	0	0	7.4	51.2	124.5	74.2	14.2	1.4	0	272.9	
1927	0	0	0	0	0	4.4	36.6	103.9	50.1	7.1	0	0	202.1	
1928	0	0	0	0	0	1.0	48.9	93.7	40.5	13.2	0.2	0	197.5	
1929	0	0	0	0	1.8	24.4	80.2	126.6	118.8	29.9	2.3	0	384.0	
1930	0	0	0	0	0	7.7	58.7	78.2	43.4	5.4	0.3	0	193.7	
1931	0	0	0	0	0	1.2	36.5	104.0	87.3	31.0	2.5	0	262.5	
1932	0	0	0	0	0	0	40.0	105.0	78.1	11.4	1.1	0	235.6	
1933	0	0	0	0	0	0.8	33.6	107.9	88.2	26.6	3.9	0.8	261.8	
1934	0	0	0	0	0	13.6	84.6	160.9	94.8	18.2	6.2	3.2	381.5	
1935	0.2	0	0	0	0	11.1	50.1	101.5	83.0	14.8	1.7	0.1	262.5	
1936	0	0	0	0	0	7.2	60.5	119.5	146.8	50.6	0.5	0	385.1	
1937	0	0	0	0	0	4.4	53.9	145.9	57.5	10.5	1.4	0.4	274.0	
1938	0	0	0	0	0	0	51.2	117.6	117.8	31.6	3.8	0.6	322.6	

TABLE III 76--COMPUTED HYDROGRAPHIC DISCHARGE DATA, KARADOBI

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
ABBAY at Karadobi (BN-3) Dam 1/														75,500
1911	248	152	105	58	173	332	1,426	5,178	4,452	2,056	1,060	541	15,781	
1912	291	195	115	81	88	454	1,694	4,561	2,707	1,116	541	303	12,146	
1913	201	122	99	90	203	139	714	1,894	1,936	717	248	116	6,479	
1914	63	59	59	75	60	315	1,613	7,193	3,510	2,761	1,490	589	17,787	
1915	303	171	116	75	185	399	1,035	2,365	3,424	2,181	968	458	11,680	
1916	248	140	81	73	168	443	2,133	11,249	7,135	3,366	1,450	735	27,221	
1917	399	231	166	127	205	565	2,377	9,512	14,430	3,366	1,274	675	33,327	
1932	238	135	90	72	242	483	1,240	6,038	5,626	2,253	746	416	17,579	

1/ Abbay nr Kese + 0.997 (Abbay below Guder - Guder at mouth - Muger at MU-1 - Abbay nr Kese).

$$0.997 = \frac{\underset{\text{BN-3}}{75{,}500} - \underset{\text{Abbay (Kese)}}{65{,}000} - \underset{\text{MU-1}}{652}}{\underset{\text{Abbay (Guder)}}{82{,}220} - \underset{\text{Abbay (Kese)}}{65{,}000} - \underset{\text{MU-1}}{652} - \underset{\text{Guder (mouth)}}{6{,}690}}$$

TABLE III-77--COMPUTED HYDROGRAPHIC DISCHARGE DATA, MABIL

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
ABBAY at Mabil (BN-19) Dam 1/														100,300
1911	327	200	141	83	236	457	2,316	8,009	6,948	3,110	1,503	733	24,063	
1912	384	257	159	112	118	628	2,730	7,146	4,185	1,637	738	397	18,491	
1913	264	159	134	123	272	195	1,032	3,059	2,874	1,017	337	152	9,618	
1914	86	76	79	103	84	434	2,609	10,707	5,540	4,208	2,162	801	26,889	
1915	398	225	158	105	249	547	1,650	3,834	3,588	3,272	1,370	613	17,709	
1916	358	204	122	110	246	681	3,756	13,453	11,470	5,690	2,306	1,100	39,496	
1917	571	326	246	186	299	857	4,109	14,467	16,202	5,688	1,982	990	45,923	
1932	311	175	123	98	326	674	2,185	9,169	8,621	3,428	1,052	553	26,715	

1/ 1911-1915, and 1932 = Abbay (below Guder) + Finchaa + Amarti + Neshe + 3.045 Lower Birr + 0.07365 Abbay (Roseires).
1916 and 1917 = Abbay (below Guder) + Finchaa + Amarti + Neshe + 3.045 Lower Birr + 744.5 (with Abbay Roseires distribution).

Except: Arbitrarily lowered August 1916 and September 1917 runoff to keep it lower than BN-26A runoff. Made incremental increase between BN-4 and BN-19, 30 percent of increase between BN-4 and BN-26A for these 2 months.

TABLE III-78--COMPUTED HYDROGRAPHIC DISCHARGE DATA, MENDAIA AND BORDER

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
ABBAY at Mendaia (BN-26A) Dam 1/														139,000
1911	591	318	222	119	294	524	3,750	12,275	11,140	5,652	2,792	1,399	39,076	
1912	731	480	302	189	162	1,035	4,724	11,752	6,849	2,892	1,341	715	31,172	
1913	474	276	219	210	418	268	1,575	5,123	4,481	1,690	526	205	15,465	
1914	127	104	97	173	92	525	4,382	13,972	8,983	7,897	4,108	1,510	41,970	
1915	713	365	271	167	315	726	2,524	6,185	8,783	6,051	2,531	1,127	29,758	
1916	592	313	178	158	339	845	6,026	16,529	14,101	10,048	4,086	1,986	55,201	
1917	1,033	559	427	301	363	1,180	6,683	15,569	18,073	10,027	3,501	1,805	59,521	
1932								13,383					42,071	
ABBAY at Border (BN-28) Dam 2/														173,300
1911	740	420	290	180	540	1,040	4,970	14,920	13,610	6,430	3,240	1,640	48,020	
1912	860	570	360	240	250	1,450	5,870	14,010	8,570	3,390	1,620	870	38,060	
1913	580	350	270	260	600	400	2,290	6,530	6,010	2,110	740	320	20,450	
1914	190	140	150	230	190	980	5,580	16,680	11,250	8,730	4,610	1,740	50,470	
1915	870	470	340	230	560	1,250	3,590	8,080	10,950	6,850	2,960	1,350	37,500	
1916	730	410	240	220	490	1,390	7,350	19,150	16,580	10,760	4,500	2,210	64,030	
1917	1,190	670	500	370	630	1,760	8,100	18,160	20,820	10,760	3,910	2,030	68,880	
1932	680	380	260	200	750	1,520	6,180	15,800	15,300	7,050	2,240	1,210	51,570	

1/ 1911-1915, and 1932 = Abbay at Shogali - Dabus nr Asosa - 0.03677 Abbay at Roseires
1916 and 1917 = Abbay at Shogali - Dabus nr Asosa - 371.6 (with Abbay at Roseires distribution)

2/ Annual runoff = 0.989 x Abbay at Roseires

$$\left(0.989 = \frac{50{,}014 \text{ Border average annual runoff}}{50{,}600 \text{ Roseires average annual runoff}}\right)$$

July through October = 0.987 x Abbay at Roseires
November through June = 1.000 x Abbay at Roseires

SECTION III--FLOOD FLOWS

Introduction

The Blue Nile Basin has three characteristics, climate, topography, and geology, that cause the floods to be relatively uniform from year to year in size and time of occurrence. Because of this uniformity, it was possible to make studies with the use of a meager amount of data.

CLIMATE

A more complete presentation of the climate is made in Section I and only characteristics specifically influencing floods are mentioned here. The source of floods is almost entirely from the "big" rains during June through September. The time of their occurrence and the total annual rainfall are quite uniform from year to year with the annual rainfall extremes in 47 years of record at Addis Ababa being 74 and 156 percent of normal.

During July and August the rains are intense and frequent enough to maintain flood conditions until September. In September or early October the rains decline to isolated storms of short duration. In some rivers the flood peak may be as late as October 1, but by the end of October all streams in the basin will show a sharp decrease in flow.

TOPOGRAPHY

The Blue Nile Basin is predominantly a high plateau deeply eroded by the Abbay River and its tributaries. The drainage system is well defined, and the gradient on most streams is steep. Floodwaters quickly collect in the drainage channels, and the loss by overflowing on flood plains or to evaporation is small.

There are three areas that are exceptions to the rule of rapid flow and quick concentration of floodwater. (1) Lake Tana is so large in proportion to the contributing drainage area that it stores most of the floodwater during the rainy season--July through September--and approximately 50 percent is lost to evaporation. The area of the lake is about 3,000 square kilometers. (2) Chomen Swamp on the Finchaa River also retards floodwater, and the losses by evaporation are high. The area of the swamp is probably more than 500 square kilometers. (3) The third area is Dabus Swamp on the Dabus River, and again it is a large swamp that smooths out flood flows. Losses by evaporation are high. The area of this swamp is probably more than 900 square kilometers.

GEOLOGY

Geologically, the Blue Nile Basin is a high plateau of volcanic, sedimentary, and metamorphic rocks. This plateau was eroded by the Blue Nile drainage system into deep canyons that cut through the volcanic and sedimentary rocks into the Precambrian metamorphic rocks.

The soils are primarily a red clay and a black clay that absorb water slowly when saturated. Because of the sparse growth of trees, the shallow soil, and the rock, runoff is rapid and a relatively small amount of the rainfall is retained by deep percolation or absorption.

Design Rain

DAILY VARIATIONS

Introduction

A set of precipitation curves was drawn to represent the maximum probable rain in the Blue Nile Basin for periods of 1, 2, 5, 10, and 15 days. The maximized rain data for each of these curves were plotted against drainage area, so for any size basin it was possible to read off a design rain. No rainfall records are available in most areas and a generalized curve was necessary to obtain a design rain. For future, more detailed studies, it will be necessary to accumulate more records and to follow a similar procedure over smaller areas near the proposed reservoirs.

The rainfall records for all precipitation stations in the Blue Nile Basin were reviewed and maximum 1-, 2-, 5-, 10-, and 15-day accumulated rainfall amounts tabulated for six stations that had the highest amounts of rain (Table III-79). Of these stations, Lekkemt had the maximum 1-, 2-, and 5-day amounts and Fiche the maximum 10- and 15-day amounts. The point rainfall data at these two stations were adjusted to obtain maximum probable point rainfall, and were adjusted somewhat differently to obtain maximum rainfall for an area of 195,000 square kilometers. Factors for adjusting the rainfall were estimated by reference to "Studies of the Probable Maximum Flood for the Roseires Dam Project, Blue Nile Catchment," by a group of consulting engineers including Franklin P. Snyder of the United States Corps of Engineers. Examination of records which have become available subsequent to the preparation of the Roseires Project Report revealed that higher recorded rainfall (as shown on the top line of Table III-80) should be substituted for rainfall estimates assigned to small areas in the Roseires Report, which was primarily concerned with developing a flood for the 195,000-square-kilometer Roseires drainage area.

Adjustment of Observed Data

Two types of upward adjustment were used with respect to the data that were obtained by experience. The simplest of these adjustments allows for the possibility that a storm might enter the area with 40 percent more precipitable water in the clouds than usually comes in over a 40- or 50-year period (this is called the dewpoint adjustment, since temperature at which dew is precipitated is a measure of precipitable water in the air). The dewpoint adjustment is made regardless of size of storm and area under consideration. The other adjustments differ as between point rainfall adjustment and storm area adjustment.

In addition to dewpoint adjustment, there is an upward adjustment of point rainfall to allow for the fact that the records here in use are even shorter and, therefore, probably contain smaller storms than would be apt to occur over the period of about 50 years of record, to which the dewpoint adjustment is usually applied, and to allow for conversion from a 24-hour calendar day observation to the larger item which could have been observed over a 24-hour noncalendar period. Rain observed in the basin (Table III-79), rain observed near the basin in Ethiopia (Table III-81), and regularity of the runoff (see Figure III-13) were all considered in placing this factor at 1.43 to obtain an overall multiplier of 2.0 for securing maximum probable point rainfall from the maximum recorded rainfall, i.e., 1.4 for dewpoint multiplied by 1.43 gives 2.0. There is a strong possibility that this factor produces something less than the maximum probable point rainfall. Before spillways are built, nearby rainfall records should be obtained over a number of years to form a basis of verification, or modification, before a factor is adopted for fixing the size of spillway. This will be particularly important in the case of spillways below small drainage areas where amount of point rainfall is a most important consideration. Before applying this factor to the observed data on the first line of

TABLE III-79--MAXIMUM RECORDED RAINFALL

Station and year	1-day mm.	1-day mo./day	2-day mm.	2-day mo./day	5-day mm.	5-day mo./day	10-day mm.	10-day mo./day	15-day mm.	15-day mo./day
Ambo										
1951	30	6/17	52	6/16-17	91	6/15-19	128	6/10-19		
1952	39	6/26	57	6/26-27	97	6/22-26	126	7/20-29		
1954	42	8/5	57	8/5-6	118	8/5-9	169	8/3-12	188	7/30-8/13
1955	43	7/26	71	7/26-27	94	7/24-28	126	7/19-28		
1956	68	10/16	71	10/16-17	112	10/16-20	146	8/4-13	197	8/3-17
1957	42	8/8	53	7/15-16	85	8/12-16	129	8/7-16		
1958	65	3/29	79	3/29-30	84	7/9-13	134	7/4-13		
1959	38	8/31	56	8/15-16	89	8/31-9/4	138	8/14-23	169	8/7-21
1960	48	7/3	50	7/24-25	80	7/24-28				
Arjo										
1954	66	4/10	90	9/23-24	163	9/1-5	247	8/27-9/5	331	9/11-25
1955	56	7/1	96	7/1-2	123	7/28-8/1	217	7/28-8/6	266	6/19-7/2
1956	56	10/19	100	10/18-19	134	10/15-19	170	10/10-19		
1957	52	8/13	76	8/8-9	129	3/26-30	170	8/16-25		
1958	51	4/11	72	9/26-27	95	7/18-22	181	7/17-26		
1959	34	8/30	48	8/3-4	86	8/30-9/3	159	8/3-12		
Asosa										
1961	113	9/4								
Fiche										
1954	43	7/18	78	7/17-18	188	7/14-18	294	7/10-19	353	7/4-18
1955	58	7/24	111	7/23-24	211	7/21-25	357	7/19-28	454	7/16-30
1956	50	8/7	75	8/7-8	151	8/5-9	200	7/31-8/9		
1957	50	7/24	92	7/23-24	136	7/20-24	194	7/24-8/2		
1958	45	7/10	79	7/10-11	171	7/10-14	262	7/10-19	336	7/10-24
1959	82	7/31	97	8/27-28	136	8/24-28	250	8/20-29	313	8/14-28
Guder										
1954	43	9/10	50	7/1-2						
1956	33	8/10	55	8/9-10	85	8/9-13				
1957	46	3/21								
1958	43	8/9	50	7/11-12	115	7/12-16	152	7/11-19	209	7/11-25
1959	34	4/25	50	7/12-13	97	7/12-16	129	7/12-21		
1960	46	8/15	71	8/14-15	99	7/26-30	110	7/26-8/4		
Lekkemt										
1952	65	6/24	78	6/24-25						
1953	62	5/16	99	5/15-16						
1955	124	6/12	175	6/12-13	226	8/10-14	264	6/10-19	357	6/10-24
1956	81	6/9	105	6/9-10	155	6/9-13	255	6/9-18	355	6/9-23
1960	67	9/4	90	9/4-5	115	8/22-26	195	8/26-9/4		
1961	80	7/18			171	7/17-21	298	7/17-26		

TABLE III-80--MAXIMUM DESIGN RAIN FOR THE BLUE NILE BASIN

	1-day	2-day	5-day	10-day	15-day
Line 1	6/12/55 (Lekkemt) 124	6/12-13/55 (Lekkemt) 175	8/10-14/55 (Lekkemt) 226	7/19-28/55 (Fiche) 357	7/16-30/55 (Fiche) 454
	Point rainfall - factor = 1.0 (rounded)				
Line 2	125	175	260	360	450
	195,000 sq. km. - factor = 0.42 (Roseires report)				
Line 3	52	74	109	151	189
	Maximized precipitation point rainfall - factor = 2.0				
Line 4	250	350	520	720	900
	195,000 sq. km. - factor = 1.70				
Line 5	87	126	185	257	321

TABLE III-81--MAXIMUM RECORDED PRECIPITATION IN 24 HOURS

Station	Period of record From	To	Years	Inches	Remarks
Addis Ababa			37	3.1	--
Bahir Dar	1920	1924	5	3.3	This station is only one on this table in Blue Nile Basin, Ethiopia.
Dessie	1908 1937	1915 1939	9	3.2	--
Gambela	1905	1937	30	5.1	In higher rainfall area southwest of basin.
Harar	1908	1918	11	3.6	--
Jima	1937	1940	4	3.9	--
Negelli	1936	1939	1	2.0	--
Roseires (Sudan)	1915	1950	25	2.8	--

1/ From Tables of temperature, relative humidity, and precipitation for the World, Her Majesty's Stationery Office, London, 1958.

Table III-80 to get the adjusted values on the fourth line, a curve was drawn through a plot against time of the observed value (line 1) and the 5-day value for Lekkemt was increased as shown on line 2 in order to secure a smooth curve.

In addition to the dewpoint adjustment and the adjustment as described above the point rainfall, it was necessary to make an adjustment from the point rainfall data to rainfall expected over the larger areas above spillway sites. The Roseires report gave point observed rainfall for Fiche, as indicated on line A of Table III-82, and average rainfall over 195,000 square kilometers (the drainage area above Roseires Dam) as indicated by line B of Table III-82. Dividing the items on line B by items on line A gave ratios of large area rainfall to point rainfall as indicated on line C. The variation between these ratios was considered insignificant, and the smaller ratio of 0.42 was adopted as most probably representing the Blue Nile conditions where there is a minimum of variation from the normal as discussed above. Line D of Table III-82 shows maximum probable rainfall for 195,000 square kilometers, as developed in the Roseires report. Dividing these values by the values on line B gave line E, the ratio of maximum probable rainfall to recorded rainfall over 195,000 square kilometers, as used in Roseires report. Here again, variation between these values was considered insignificant, and the lower value of 1.72 was rounded to 1.7 and adopted as probably most representative of the minor variations believed to occur in the Blue Nile Basin.

These multipliers, developed from Roseires report data in Table III-82, were utilized against observed rainfall as indicated in Table III-80. Items on line 2 of Table III-80, when multiplied by 1.42, give average rainfall over 195,000 square kilometers for a comparable storm as shown on line 3; and items on line 3, when multiplied by 1.7, give maximum probable depth of average rainfall over 195,000 square kilometers, as shown on line 5. Here again, the process followed is not reliable. Additional stations should be established and longer records should be obtained in order to form a basis for confirming the multipliers, or for revising them, before spillways are constructed on this basis. In the preparation of Figure III-45, an area of 60 square kilometers was arbitrarily selected to represent point rainfall. This value could have been selected as 10 or 100 square kilometers without much effect on the final result.

Design Rainfall Curve

The maximum rainfall values for 60 and 195,000 square kilometers were plotted on semilogarithmic paper (Figure III-45) and curves were then drawn for the 1-, 2-, 5-, 10-, and 15-day rainfall amounts.

VARIATIONS WITHIN THE DAY

A few tabulations of rainfall data from an hourly recording precipitation gage at Bahir Dar (southern tip of Lake Tana) were available. Nineteen events in which rainfall equalled or exceeded 1.27 centimeters showed rainfall durations of from less than 1 hour to 10 hours with a mean duration time of 5.7 hours. Fourteen events occurred between the hours of 6 p.m. and 6 a.m. the following day. Two events extended to 7 a.m., one to 8 a.m., and one to 9 a.m. One event occurred between 6 a.m. and 1 p.m. A notation of intense rainfall at Asosa (in the Dabus drainage near the western edge of the Blue Nile Basin) listed an observed rainfall of 11.3 centimeters in 4 hours, 9 a.m. to 1 p.m., September 4, 1961. These data seem indicative that most daily rainfall amounts occur within a period of from 4 to 8 hours and that greatest rainfall would most likely occur in the 12-hour period between 6 p.m. and 6 a.m., with perhaps additional rain for another 6 hours. The effect of runoff of burst-type rainfall is clearly shown by a water-stage recorder hydrograph for the Gumara River near Lake Tana for the period August 18-23, 1960. For 5 successive days there are distinct sharp rises and recessions of the hydrograph. Burst-type rainfall coupled with rapid runoff characteristics makes the short intense bursts of rainfall within a period of 1 or 2 days the most critical storm situation at most of the damsite locations. Only at sites on the lower reaches of the Blue Nile itself would storms of longer duration be significant for flood computations. Even in these instances, storms of longer duration would be more significant in respect to peak discharge because of random distribution of storm centers over upstream tributaries having rapid runoff characteristics.

TABLE III-82--ADJUSTMENT FACTORS FOR CONVERTING OBSERVED POINT RAINFALL TO RAINFALL OVER 195,000 SQ. KM.

		Days		
		5	10	15
Line A	Point rainfall (Fiche)	180	300	400
Line B	Average recorded over 195,000 square kilometers	75	130	180
Line C	B/A	0.42	0.43	0.45
	Use 42% to change point rainfall to average rainfall over 195,000 sq kms (factor 0.42).			
Line D	Maximum probable over 195,000 square kilometers	150	240	310
Line E	D/B	2.00	1.85	1.72
	Use factor of 1.7 to increase recorded rainfall to maximum rainfall over 195,000 square kilometers.			

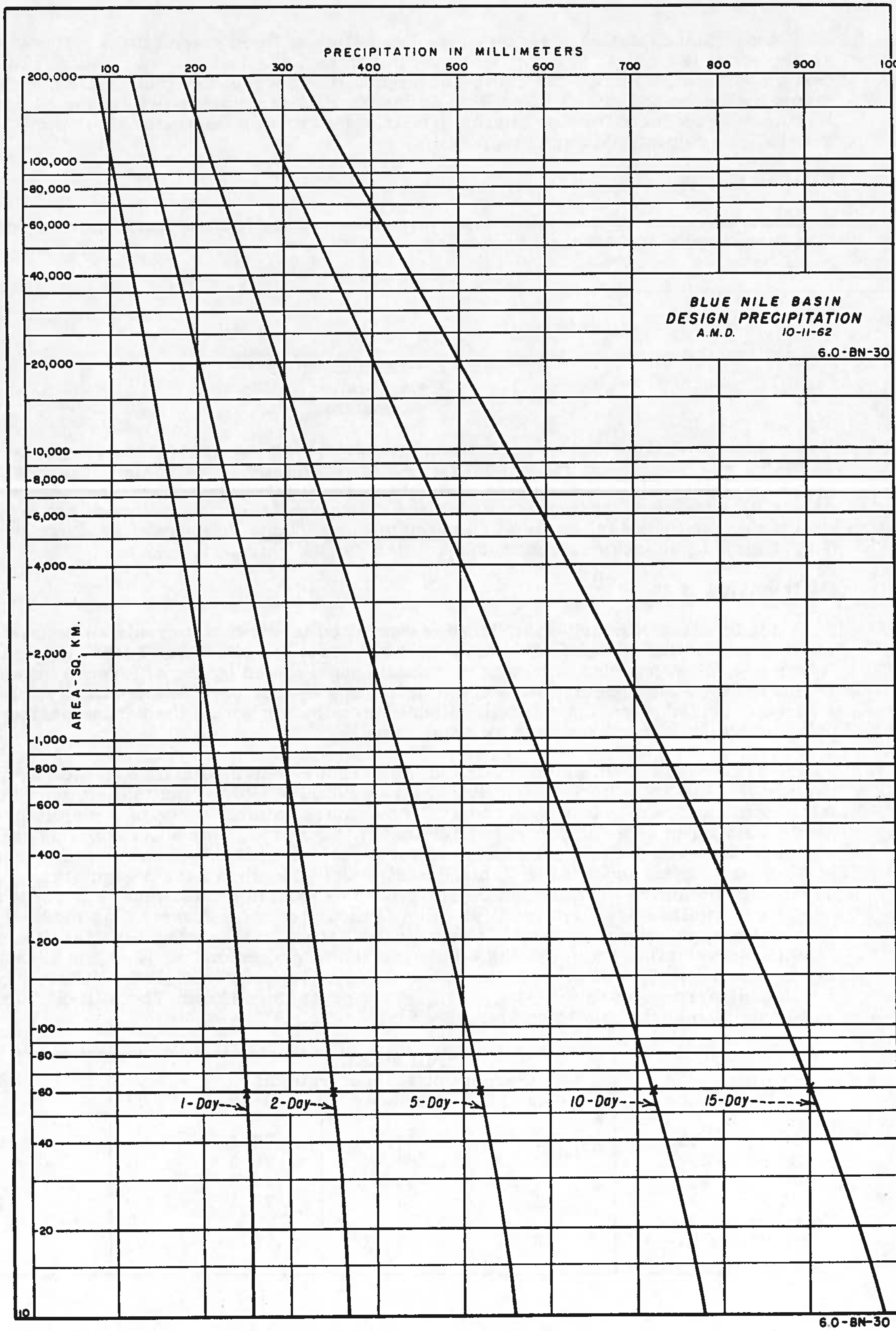


Figure III-45--Design Precipitation

Hourly rainfall data are required for evaluation of flood potential for watersheds having short lag times. To fulfill this requirement, the 1- and 2-day design precipitation amounts indicated by the curves on Figure III-45 were distributed into hourly increments by two approaches (A and B). As hourly data for stations within the Blue Nile Basin are inadequate for this purpose, hourly distribution was estimated on the basis of generalized rainfall data and judgment.

Distribution A

It has been found that rainfall depth-duration values for many major storms can be closely approximated by the equation

$$Y = bX^{.5}$$

where

Y = rainfall depth
X = rainfall duration
b = constant

Depth-duration values for a 24-hour design rainfall for the watersheds above the three damsites were computed by the above equation, using the 1-day design precipitation curve on Figure III-45. Hourly increments were obtained from the curve and given a design arrangement; increments within the maximum 6-hour period were arranged in the order given in Step 3 (c), page 50, Design of Small Dams, Bureau of Reclamation, 1961. This distribution assumes continuous rainfall for 24 hours.

Distribution B

A combination of hourly distributions was fitted together to provide an estimate of varying intensities of rainfall within a 30-hour period to simulate "burst" type rainfall. It was reasoned that the increment of rainfall represented by the difference between 1- and 2-day design precipitation could occur in a 6-hour period immediately following a 24-hour period of design rainfall. Hourly distribution within the 6-hour period was obtained by the same procedure as cited above.

It was believed permissible to divide the 24-hour design rainfall into two parts as proportioned by substituting 12 hours in the equation $Y = bX^{.5}$ and to distribute the rain fall within each part proportional to a 10-hour mass rainfall curve of a major thunderstorm rainfall in eastern Colorado (Burlington, Colorado, May 30, 1935). These assumptions were put into mathematical form for use as hourly incremental percentages of 30-hour rainfall as listed in Table III-83, which also shows the design arrangement used. Accumulative percentages in Table III-83 show, in effect, that 79 percent of 48-hour rainfall is assumed to occur in an 18-hour period. A check was made of convective-type rainfall in the Gulf area of the United States--storm of May 30-June 4, 1909 (Mississippi). The following tabulation shows maximum 6-, 12-, and 18-hour depth-duration values expressed as percentages of 48-hour rainfall for different size areas and corresponding 6-, 12-, and 18-hour percentages from Table III-83, which were assumed applicable to any size area.

Area		Gulf storm Percent of 48-hour rainfall			48-hour rainfall
sq. mi.	sq. km.	6-hour	12-hour	18-hour	
10	25.9	61.5	68.7	79.2	24.4
100	259	61.7	69.1	79.8	23.9
500	1,295	55.2	63.2	77.0	22.1
1,000	2,590	45.7	54.3	74.1	20.6
Compare maxima from Table III-83		36.55	56.03	78.99	

TABLE III-83.-BURST-TYPE RAINFALL DISTRIBUTION

Time hours	Incremental percent of total	Accumulative percentage
0	0	0
1	0.23	0.23
2	0.94	1.17
3	2.34	3.51
4	2.58	6.09
5	2.89	8.98
6	2.03	11.01
7	0.23	11.24
8	0.94	12.18
9	5.55	17.73
10	3.28	21.01
11	0	21.01
12	0	21.01
13	0.70	21.71
14	2.26	23.97
15	5.70	29.67
16	6.33	36.00
17	7.19	43.19
18	4.92	48.11
19	0.62	48.73
20	2.26	50.99
21	13.59	64.58
22	7.97	72.55
23	0	72.55
24	0	72.55
25	2.50	75.05
26	2.74	77.79
27	2.98	80.77
28	11.26	92.03
29	4.68	96.71
30	3.29	100.00

TABLE III-84.-BELLO UNIT HYDROGRAPH ANALYSIS

Derivation of dimensionless or applied unitgraph for 1 inch of rainfall excess in 1 hour (i.e., D on Figure III-51 = 1 hour). Lag = 3.8 hours (from Figure III-49 when L = 21.7 miles, L_{ca} = 10.85 miles and S = 140 feet per mile). $t_s = \text{lag} + \frac{D}{2} = 4.3$ hours.

Drainage area = 94.2 square miles.

DSF* for 1 inch = $\frac{(5,280)^2}{24 \times 60 \times 60 \times 12}$ x area = 26.89 x 94.2 = 2,533.

Hours	Percent t_s $(\frac{100}{t_s} = 23.26)$	Dimensionless ordinate $Q \frac{t_s}{DSF}$	Q cfs
1	23.26	2.6	1,530
2	46.5	11.0	6,479
3	69.8	19.0	11,191
4	93.0	20.8	12,251
5	116.3	16.8	9,895
6	139.5	11.3	6,656
7	162.8	7.6	4,476
8	186.0	5.2	3,063
9	209.3	3.5	2,062
10	232.6	2.3	1,355
11	255.8	1.52	895
12	279.0	1.03	607
13	302.3	0.71	418
14	325.6	0.58	342
15	348.8	0.33	194
16	372.1	0.22	129
17	395.3	0.15	88
18	418.6	0.10	59
(1)	(2)	(3)	(4)
Source	Col. (1) x 23.26	Col. (2) and Figure III-51	Col. (3) x $\frac{DSF}{t_s}$ = Col. (3) x 589

* 1 DSF is a volume equal to 1 cubic foot per second flowing for 1 day.

Each distribution gave maximum hourly rainfall amounts that agreed within less than 2.5 millimeters. Evaluation of the two distributions in regard to flood peak potential and flood runoff volume as discussed later led to selection of Distribution B, the burst-type distribution (Table III-83), for use for estimating design flood volumes.

RETENTION RATE

A constant retention rate of 5 millimeters per hour was selected by judgment as an average value applicable to all watersheds.

TRIAL DESIGN FLOODS

Design (maximum probable) floods for each of the three damsites were computed by procedures outlined on Table III-84. A constant retention rate of 5 millimeters per hour was applied to each design storm distribution and the excess precipitation increments applied to respective unitgraphs. Results are tabulated below.

Damsite	Area (sq. km.)	Design Flood Values			
		Storm Distribution A		Storm Distribution B	
		Peak discharge (cu. m. per sec.)	Volume (million cu. m.)	Peak discharge (cu. m. per sec.)	Volume (million cu. m.)
Bello	244	1,031	27.8	998	52.4
Upper Birr	591	2,237	58.5	2,220	114.1
Diddessa	3,360	4,078	240.6	5,891	492.4

Computed hydrographs for the small areas exhibited rise and fall directly reflecting variations in rainfall intensities estimated for the burst-type rainfall. As maximum intensities in each distribution for a few hours duration were about equal, the peak discharges computed from each distribution agreed closely. The burst-type distribution gave much larger volume of runoff. For the large area, the longer lag time for the watershed "dampened out" the effect of variation in rainfall intensities. The burst-type distribution which gave the larger volume of runoff also gave the larger peak discharge.

Flood Development

SUMMARY

It was necessary to provide maximum probable inflow design flood hydrographs for more than 25 damsites in the Blue Nile Basin. Drainage areas above individual damsites range from 77 to 173,000 square kilometers. Streamflow data and rainfall data are so meager that they offer only rough guides as to extreme flood characteristics. Studies of rain-produced floods have shown that a "Creager" type curve1/ where n varies with area represents a better relationship of observed discharges for wide ranges in area than does a curve where n is a constant, such as 0.5.

1/Engineering for Dams, Creager, Justin, and Hinds, 1945 Edition, Vol. 1, Chapter 5, p. 125.

Creager's formula, in	
English units	Metric units
$Q = 46\ CA^n$	$Q = \frac{1,302CA^n}{2.59^n}$
= cubic feet per second	= cubic meters per second
C = a constant, usually 100	C = a dimensionless constant, usually 100
A = drainage area in square miles	A = drainage area in square kilometers
$n = \frac{0.894}{A^{0.048}}$	$n = \frac{0.936}{A^{0.048}}$

The highest flows recorded in the basin were those of July 31, 1963. Although information on discharges for this flood are tentative, it appears that discharges for at least two stations approached maximum probable flood curve values (40-year and 100-year plus floods).

Station	Drainage area (sq. km.)	Flow in cu. m. per sec. July 31, 1963 peak	Max. probable flood
Abbay nr Kese	50,000*	8,500	13,300
Abbay below Guder	67,200*	10,900	14,600

*Exclusive of Lake Tana.

Inflow design floods were computed for three damsites with drainage areas of 244, 591, and 3,360 square kilometers, respectively, using unitgraph procedure, an estimate of lag, a design storm estimate, and a constant retention rate. The computed design peak discharges were plotted on log-log paper, discharge versus area; and, using the points as guides, a "Creager" type curve was drawn from a point representing the design inflow at Roseires, 18,800 cubic meters per second for an area of 180,000 square kilometers (excluding 15,200 square kilometers of Lake Tana drainage area) to 2,590 square kilometers (1,000 square miles). The values for discharge and area for Roseires are from the Roseires report. The curve was then steepened and drawn down to the smallest required drainage area of 77 square kilometers, passing it through the maximum design flood for the 244-square kilometer Bello drainage area. This curve, shown on Figure III-46, was adopted for obtaining maximum probable inflow design flood peak discharges for areas in the Blue Nile Basin, excluding drainage areas which contain large swamps or lakes. One of the unitgraphs and the lag curve used in its development will be described later.

The 2-day design rainfall versus area is shown on Figure III-45. A curve of runoff versus 2-day design precipitation was developed and is shown on Figure III-47. To facilitate the computations, Figure III-48, showing runoff as a function of drainage area, has been developed for use in place of Figures III-45 and III-47. An equation relating time to peak, area, and volume of runoff was developed for computing flood hydrographs and the following procedure was used for deriving a reconnaissance-type inflow design flood for any area in the Blue Nile Basin, excluding drainage areas containing large swamps or lakes.

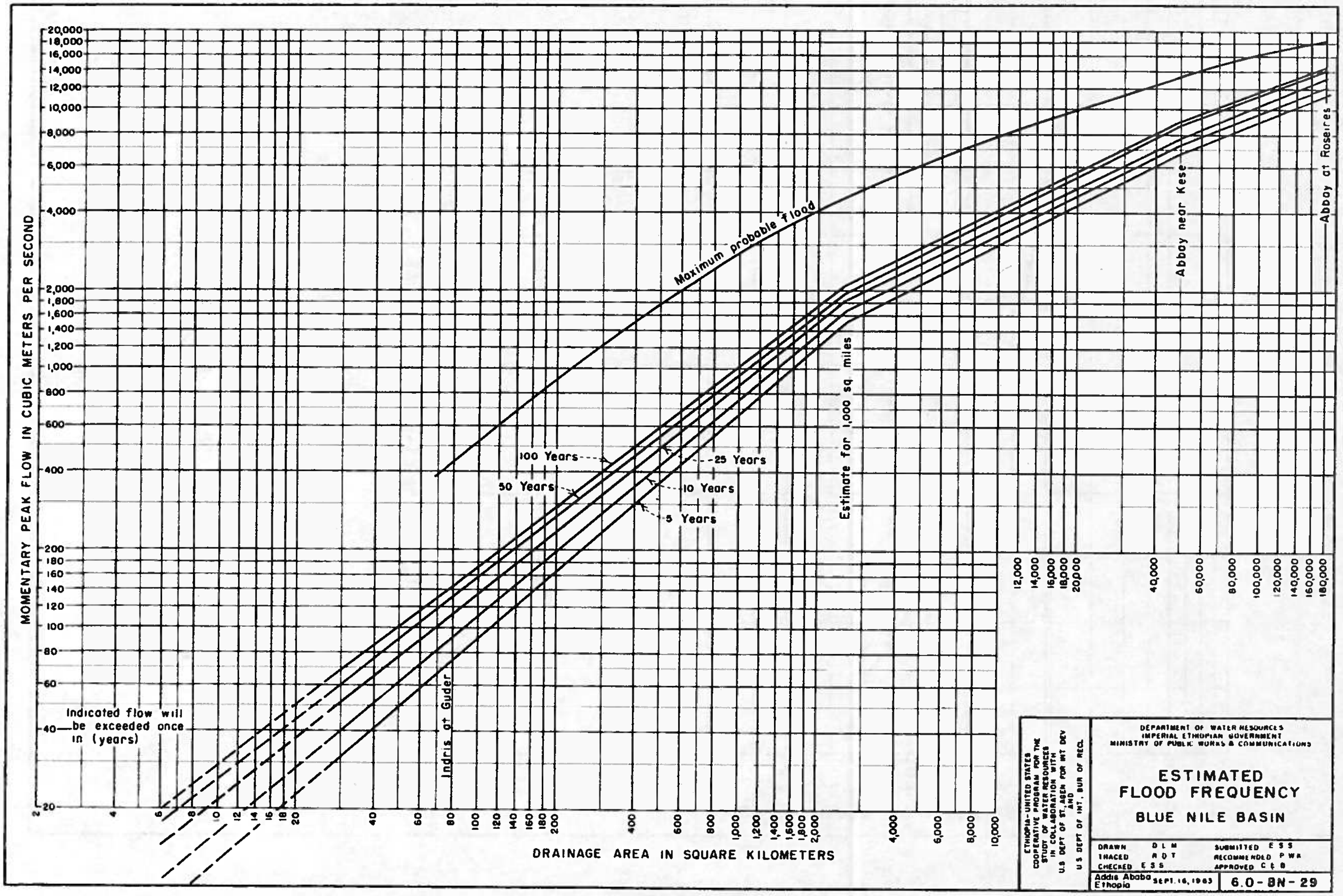


Figure III-46--Estimated Flood Frequency

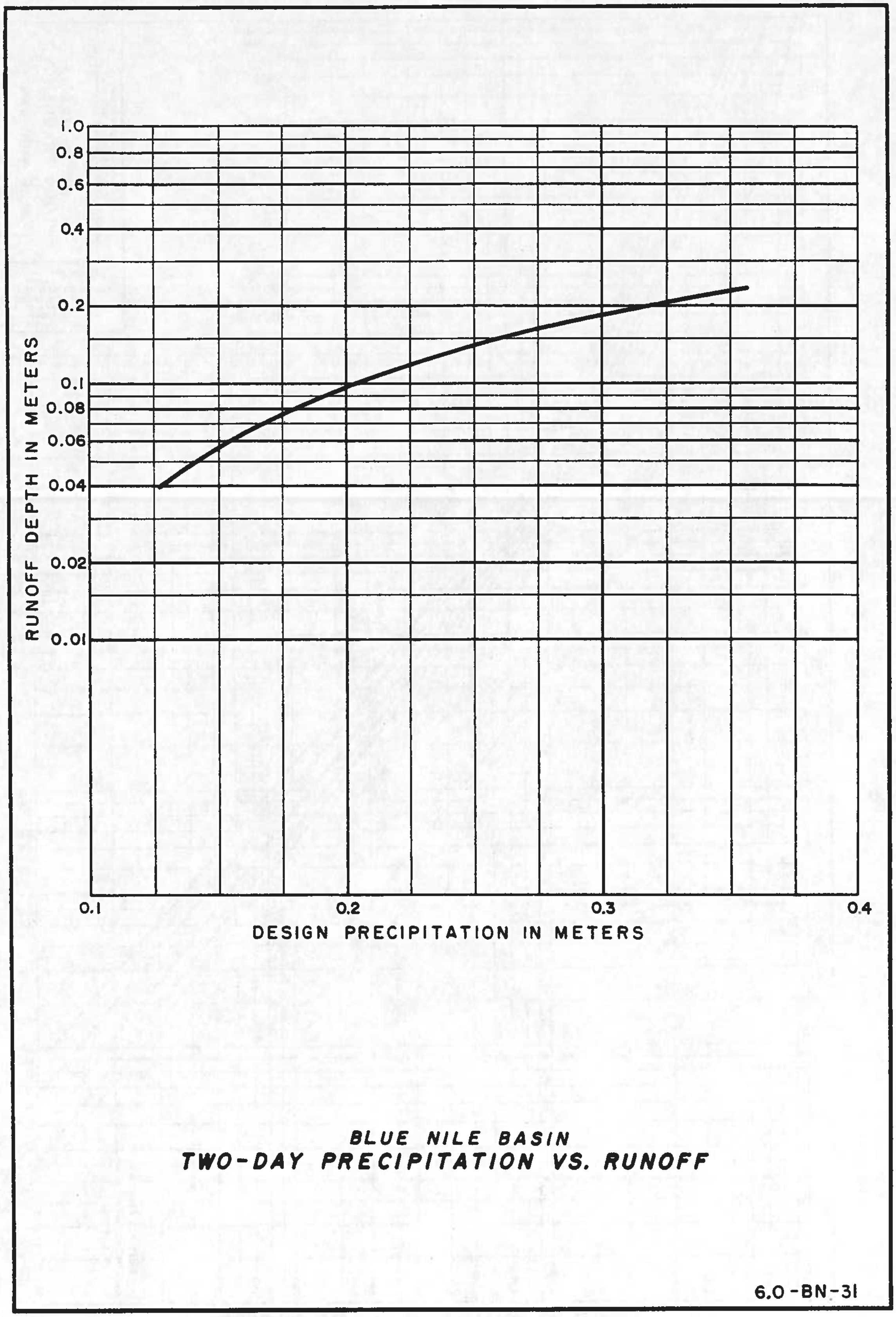


Figure III-47--Two-day Precipitation v. Runoff

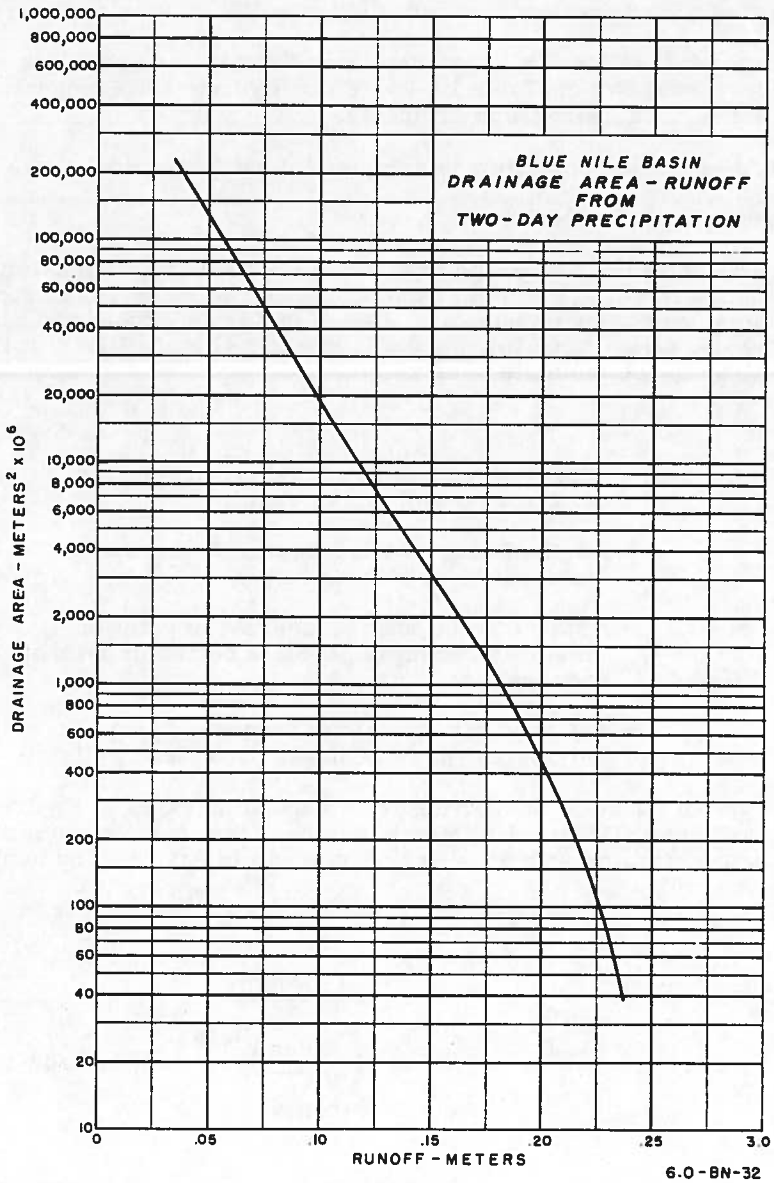


Figure III-48--Drainage Area v. Runoff--from Two-day Precipitation

1. Determine drainage area above damsite in square kilometers. (The 15,200 square kilometers above Lake Tana outlet were deducted from downstream damsite drainage areas, but no other deductions of areas for proposed upstream developments were made.)

2. Enter maximum probable flood curve (Figure III-46) with area; read maximum probable flood.

3. Enter area versus runoff curve (Figure III-48) with area; read depth of runoff.

4. Using values for drainage area, runoff depth, and peak discharge, substitute in equation shown on Table III-85, Flood Hydrograph Computation Form, to compute design flood hydrograph ordinates.

5. Add estimated base flow to computed flood to get total flow.

Unit Hydrograph Analysis

As was mentioned, unitgraph analyses were basic to the maximum probable flood curve (Figure III-46). The unitgraph procedure is described in some detail in Design of Small Dams, beginning on page 39. Use of unitgraph procedure requires adoption of a lag curve; and a lag curve for mountain streams (Figure III-49 in English units or Figure III-50 in metric units) was selected,

where

Lag = time from center of period of excess rain to center of volume of runoff

L = length of longest watercourse from point of interest to watershed divide

L_{ca} = distance from point of interest to point on main watercourse opposite center of area of watershed

S = difference in elevation between watershed divide and point of interest, divided by L

This type of curve is further described and illustrated in Figure 11B, pages 41 and 42 in Design of Small Dams. Lag times obtained from it have been found applicable to foothill mountain streams and large drainage areas in Arizona and southern California.

The following formulas give the same results as readings from the lag curves.

Item defined above	English units	Metric units
Lag	$1.2 \left(\frac{L\ L_{ca}}{\sqrt{S}}\right)^{0.38}$ (hours)	$3.0978 \left(\frac{L\ L_{ca}}{\sqrt{S}}\right)^{0.38}$ (seconds)
L	miles	meters
L_{ca}	miles	meters
S	feet per mile	meters per meter

TABLE III-85--FLOOD HYDROGRAPH COMPUTATION FORM

(Date)

$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{\quad x\ 10^6\ x \quad}{\quad} = \quad$ seconds

a = drainage area in square meters = x 10^6

d = depth of runoff in meters =

q_p = flood peak in cubic meters per second =

Base flow assumed to be August 1932 average = $\frac{\quad \text{cu. m.}}{2,678,400 \text{ sec.}}$ = cu. m. per sec.

Basic ratios $\frac{T}{T_p}$	Basic ratios $\frac{q}{q_p}$	Time in thousand seconds	Design flood in Hydrograph	Design flood in Base flow	Design flood in Total
0	0				
0.1	0.015				
0.2	0.075				
0.3	0.16				
0.4	0.28				
0.5	0.43				
0.6	0.60				
0.7	0.77				
0.8	0.89				
0.9	0.97				
1.0	1.00				
1.1	0.98				
1.2	0.92				
1.3	0.84				
1.4	0.75				
1.5	0.66				
1.6	0.56				
1.8	0.42				
2.0	0.32				
2.2	0.24				
2.4	0.18				
2.6	0.13				
2.8	0.098				
3.0	0.075				
3.5	0.036				
4.0	0.018				
4.5	0.009				
5.0	0.004				

Flood total million cubic meters in days

say million cubic meters in days

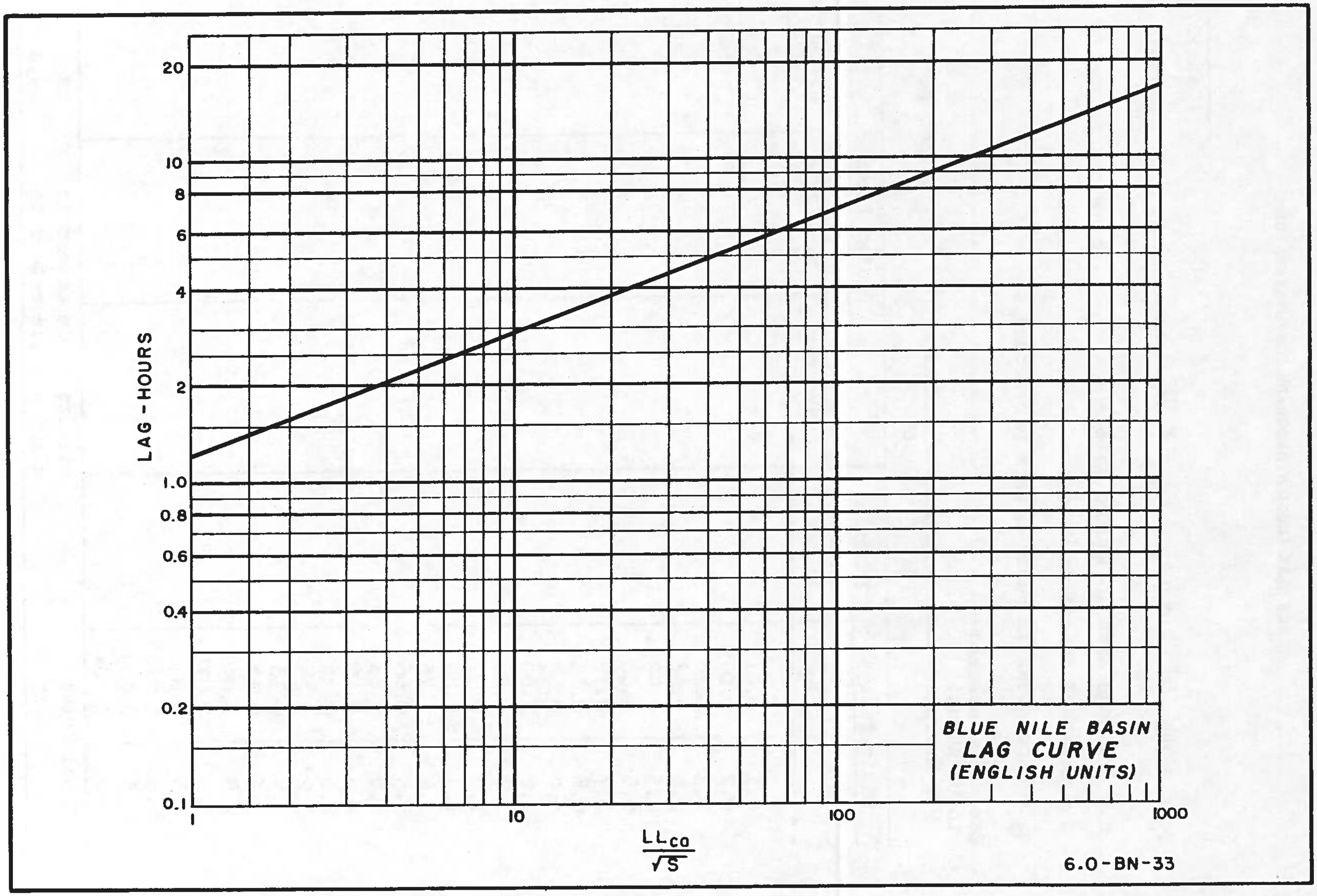


Figure III-49--Lag Curve (English units)

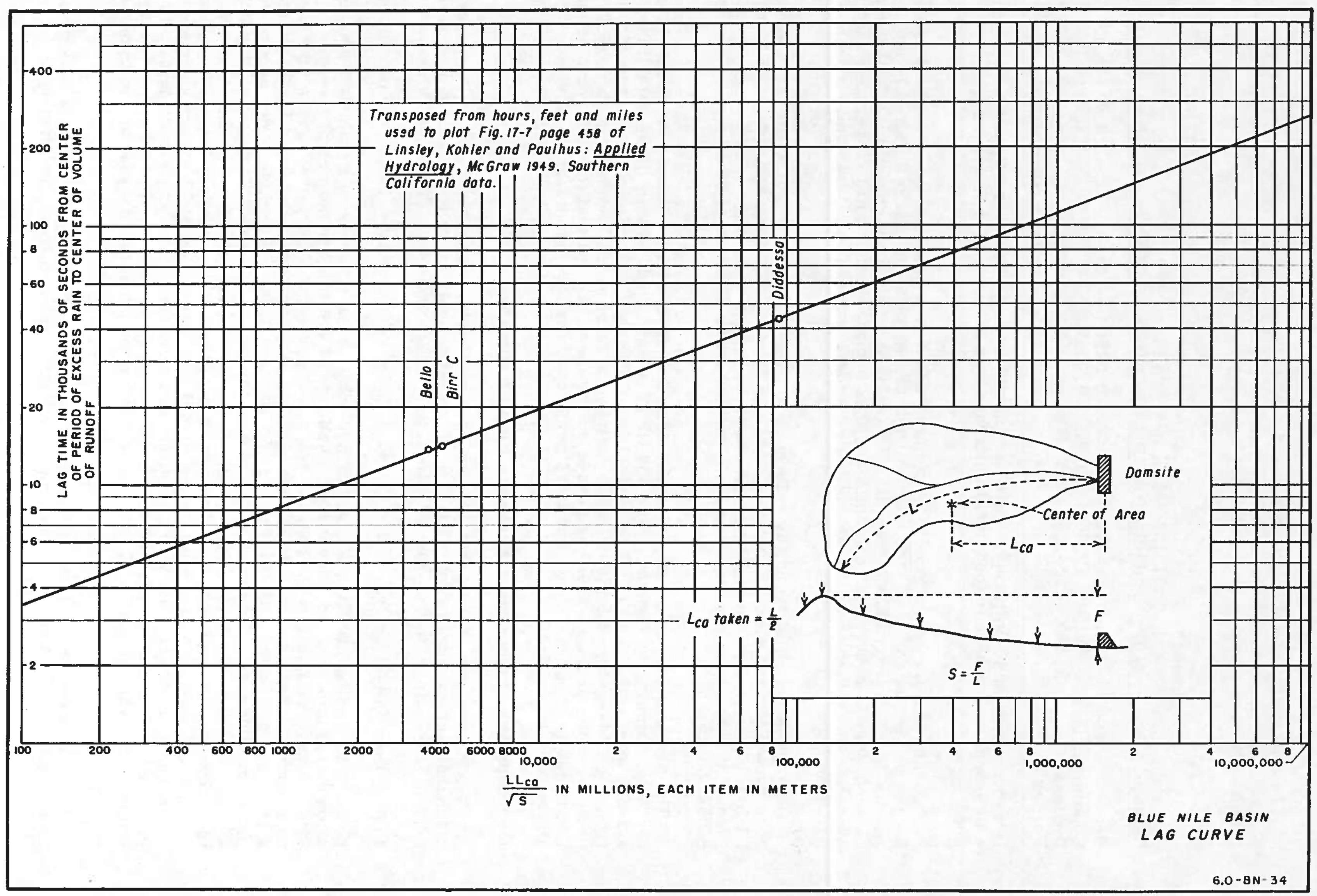


Figure III-50--Lag Curve (Metric units)

The following table shows factors used for obtaining the lag times used for unitgraph derivation. As an expedient each L_{ca} was taken as one-half L. Experience has shown that L_{ca} is very close to one-half L for most watersheds.

Damsite	Drainage area in $m^2(10)^6$	L in $m(10)^3$	Lca in $m(10)^3$	S in m/m	$\sqrt{s}$	$\frac{LL_{ca}}{\sqrt{s}}$ in millions	Lag in thousands of seconds
Bello	244	34.91	17.46	0.0266	0.163	3,739	13.68
Upper Birr	591	39.90	19.95	0.0357	0.189	4,211	14.04
Diddessa	3,360	124.86	62.43	0.0083	0.091	85,659	43.92
Border	159,400	887	444	0.001443	0.038	10,363,895	273.434

One-hour (one-inch) unitgraphs were computed for Bello River and Upper Birr River watersheds. A two-hour (one-inch) unitgraph was computed for Diddessa watershed.

In order that Design of Small Dams may suffice as a principal source of explanation for the procedure followed, the unit hydrograph analysis for the Bello site (Table III-84) and the Ideal Hydrograph (Figure III-51) have been left in English units. It will therefore be necessary to convert to such units and then back to metric units, if persons working in metric units wish to follow or duplicate the derivation of the Maximum Probable Flood curve on Figure III-46.

Having estimated lag time (by reference to Figure III-49), a unit hydrograph can be constructed for any watershed by reference to the dimensionless hydrograph (Figure III-51). This is the curvilinear graph shown in Figure 14A, page 48 of Design of Small Dams but it has been converted to the idealized form, illustrated by Figure 10B on page 40 of that book.

The procedure to be employed is illustrated on Table III-84, where the points plotted for Bello damsite on Figures III-46 and III-47 are derived. Table III-84 establishes that a 2-day storm of 325 mm. (12.8 inches) from Figure III-45 will produce a runoff volume from the 244-square-kilometer Bello drainage area of 52 million cubic meters (0.21 meter depth over the drainage area) as plotted on Figure III-47 and that the maximum probable flood peak is about 1,000 cubic meters per second for the 244 square kilometers, as shown on Figure III-46.

Development of Maximum Probable Flood Estimates

Peak discharges of the computed trial design floods were plotted on log-log paper, discharge versus area (Figure III-46). The design peak inflow for Roseires was also plotted, excluding the area above Lake Tana. By inspection, a "Creager" type curve of equation $Q = 1.302C(\frac{A}{2.59})n$ where $C = 42.1$ and $n = (0.932/A^{.048})$ was drawn from the point representing Roseires inflow (18,800 cubic meters per second from 180,000 square kilometers) to a point representing a discharge of 4,620 cubic meters per second for 2,590 square kilometers (or 163,000 cubic feet per second for 1,000 square miles). The trial curve indicated a peak discharge of 5,240 cubic meters per second for 3,370 square kilometers compared with flood peaks of 5,890 and 4,080 cubic meters per second computed for Diddessa. Extension of a curve of this equation to small areas would indicate a peak discharge for Bello River about 145 percent of the trial flood peaks. Therefore, the curve was steepened to pass through an approximate mean of the Bello River computed discharges. This curve (Figure III-46) was terminated at 77 square kilometers drainage area because that is the smallest drainage area for which a storage dam is proposed. This curve indicated 1,870 cubic meters per second discharge for 591 square kilometers, which is about 17 percent below the computed discharges for the Upper Birr damsite.

It was determined by trial that an acceptable hydrograph representing a peak discharge from the curve (Figure III-46) and runoff volume computed from the burst-type

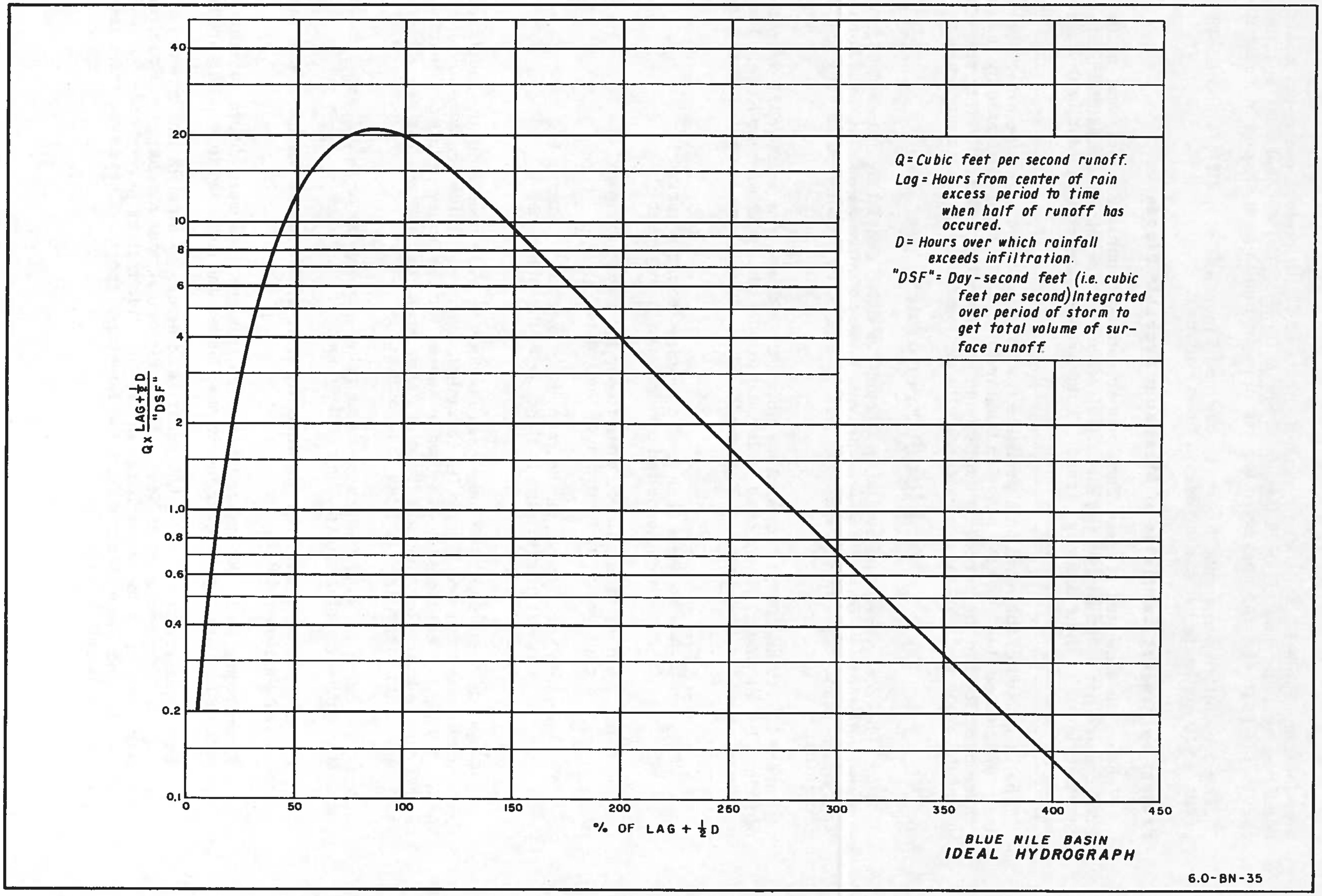


Figure III-51--Ideal Hydrograph

distribution, Table III-83, using a retention rate of 5 millimeters per hour, could be computed by using data given in Design of Small Dams. The general peak equation, Figure 12, page 45, was converted for use in metric units as indicated in Table III-86.

The precipitation and runoff curves shown on Figures III-45, III-47, and III-48 were prepared to facilitate estimating design flood volumes.

Project by Project Estimates of Maximum Probable Floods

Floods to be expected at Lake Tana proper, on the Finchaa Project, and on the Dabus Projects are not estimated by the method given in the foregoing discussion because of characteristics of their drainage areas. They are considered individually in a later section, "Special Problem Areas."

The estimates of the maximum probable floods to be expected on the other projects are presented on the following pages in tabular form. They are estimated by the procedure described in the preceding section and are placed in order, starting at the upper end of the basin and working downstream with the main stem projects placed last.

Flood Frequency

It must be recognized that available streamflow data, consisting of one record of 9 years and other records of 4 years, provide a very limited sample of flood occurrences. Therefore, frequency curves based on these data must be considered as very tentative estimates.

Tables III-112 and III-113 present maximum peak flows, one each year, over periods of record for the Indris River near Guder and for the Abbay River near Kese. Plotting positions, used for such flows on Figures III-52 and III-53, are computed by the formula:

$F = \frac{(2m-1)}{2n}$ = Percent chance of a reading from the curve being equalled or exceeded in any year

m = Number of any flood, when floods have been arrayed, one each year, in the order of their size

n = Number of years in the record of flows (i.e., four in the case of Indris, nine in the case of the Abbay near Kese record)

Five 10-, 25-, 50-, and 100-year peak discharges were read from the Indris and Kese curves and plotted on Figure III-46 against their respective drainage areas of 76 and 50,000 square kilometers. The latter figure, for the Abbay near Kese, excludes 15,000 square kilometers of Lake Tana drainage area, because storms are not so great as to cause sharp increases in Lake Tana outflow.

Using the curve for reconnaissance design peaks as a general guide, generalized frequency curves were drawn on Figure III-46 as follows:

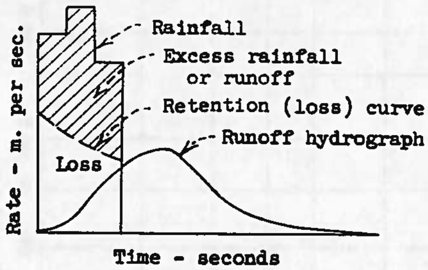
1. From the Kese points, curves were drawn to 2,590 square kilometers as straight lines having a slope of 0.5.

2. From points at 2,590 square kilometers straight lines were drawn passing through respective frequency points for Indris near Guder and extended to smaller areas.

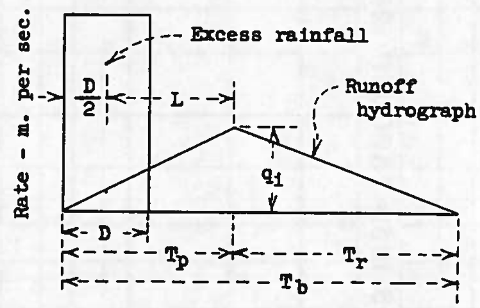
3. For areas greater than 50,000 square kilometers, a straight line was drawn connecting the 100-year point at Kese with the historical peak discharge at Roseires. (Roseires historical peak discharge of 15,000 cubic meters per second--530,000 cubic feet per second--was obtained from the Roseires report). Curves for other frequencies were drawn parallel to this line.

TABLE III-86--FLOOD ORDINATE COMPUTATIONS

Derived from hydrograph representing peak discharge, found on page 45 in Design of Small Dams in English units. The following conversion states the equation in metric units.



Typical Unitgraph



Schematic Representation of Unitgraph

Approximating curvilinear graph by triangle having equal total runoff, peak rate, and time to peak.

Explanation

q_p = Peak rate, cubic meters per second

Q = Depth runoff in meters (total)

q_i = Peak rate, meters per second, depth

T_p = Time in seconds from start of rise to peak rate

T_r = Time in seconds from peak rate to end of triangle

D = Rainfall excess period, seconds

L = Lag, time from center of excess rainfall to time of peak, seconds

T_c = Time of concentration--travel time of water from hydraulically most distant point to point of interest, seconds

T_b = Time base of hydrograph, seconds

Empirical relationship for lag $L = 0.6\ T_c$

Peak Equation Development

Using triangle from schematic above,

$$Q = \frac{q_i\ T_p}{2} + \frac{q_i\ T_r}{2} \qquad 2Q = q_i\ (T_p + T_r) \qquad q_i = \frac{2Q}{T_p + T_r}$$

Let $T_r = HT_p$, where H is a constant to be determined for a particular watershed.

$$q_i = \frac{2Q}{T_p + HT_p} \qquad q_i = \frac{2Q}{T_p\ (1 + H)} \qquad q_i = \frac{2}{(1 + H)}\ \frac{Q}{T_p}$$

Introduce drainage area, A in square meters.

$$q_p = \frac{2}{(1 + H)}\ \frac{AQ}{T_p} \quad \text{or} \quad q_p = \frac{KAQ}{T_p} \quad \text{where } K = \frac{2}{1 + H}$$

Value H for a particular stream may be computed from recorded hydrographs. Analyses by the Soil Conservation Service have resulted in their adoption of $H = 1.67$ as a general average value for ungaged watersheds.

General Peak Equation

$$K = \frac{2}{1 + 1.67} = \frac{2}{2.67} = 0.749$$

$$q_p = \frac{0.749\ AQ}{T_p} \qquad \text{For } H = 1.67 \qquad T_b = 2.67\ T_p$$

or using $L = 0.6\ T_c$ $\qquad q_p = \dfrac{0.749\ AQ}{D/2 + 0.6\ T_c}$ $\qquad$ since $T_p = \dfrac{D}{2} + 0.6\ T_c$

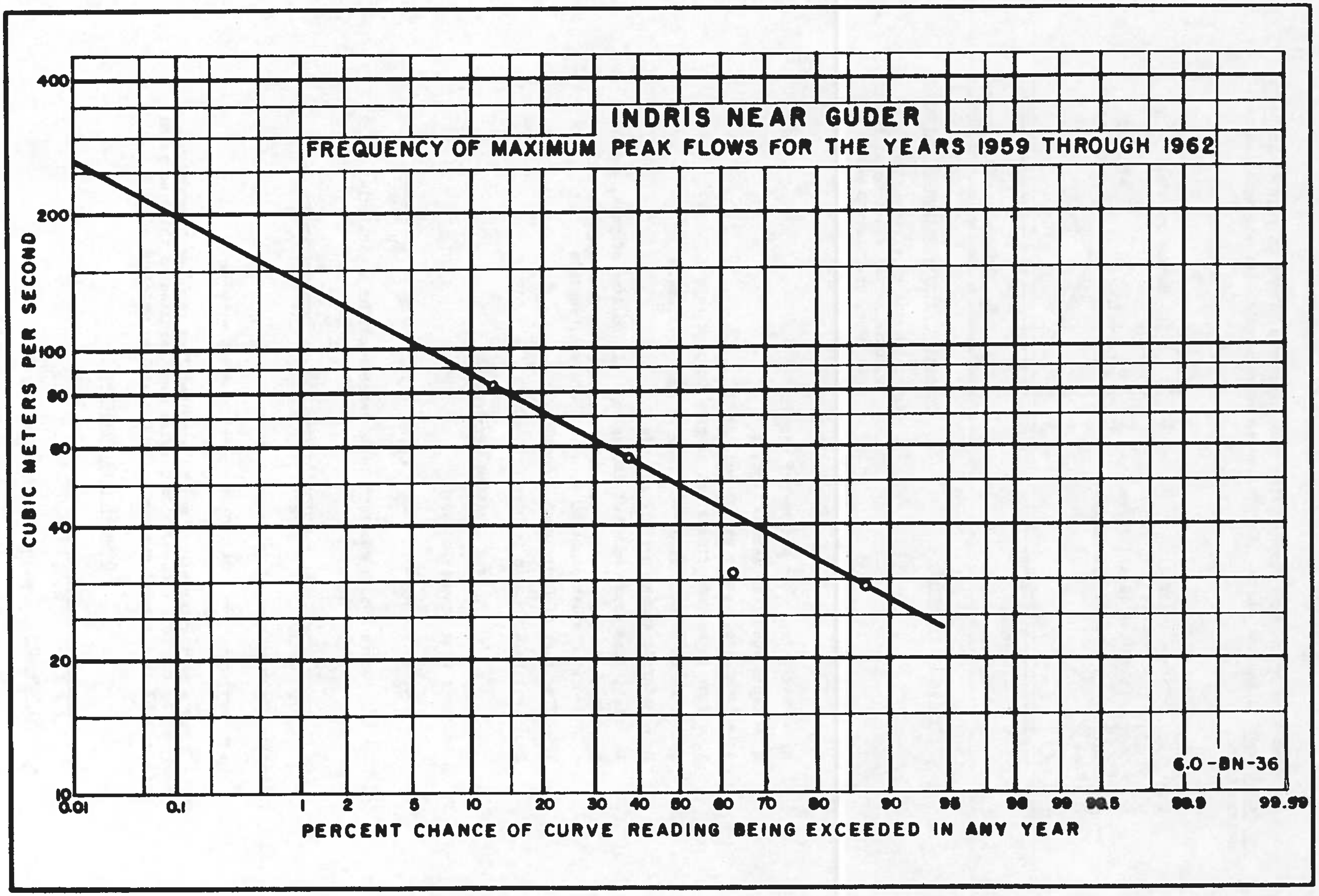


Figure III-52--Indris near Guder--Frequency of Maximum Peak Flows for the Years 1959 through 1962

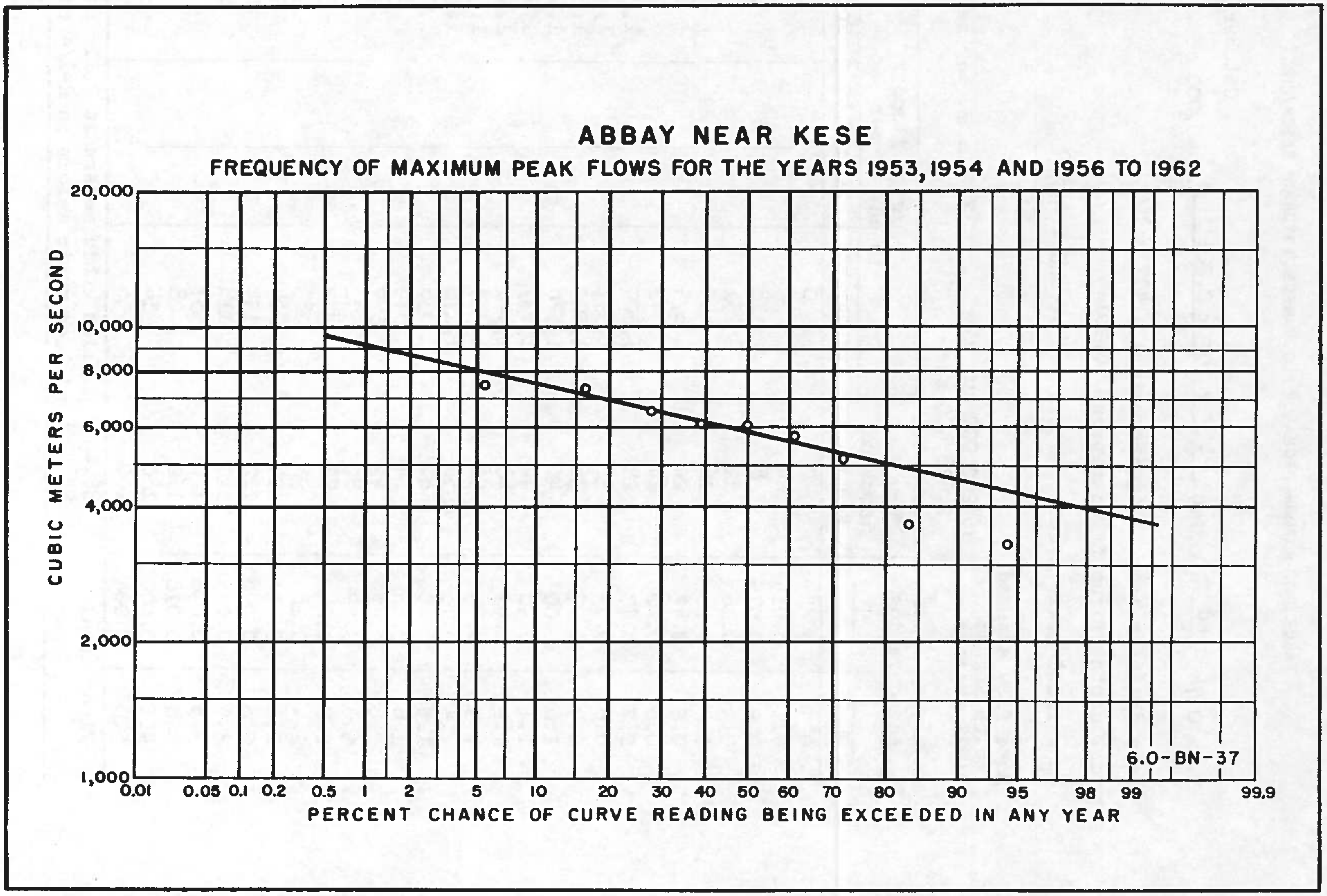


Figure III-53--Abbay near Kese--Frequency of Maximum Peak Flows for the Years 1953, 1954, and 1956 to 1962

TABLE III-87--MAXIMUM PROBABLE FLOOD--MEGECH STORAGE RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{417 \times 10^6 \times 0.201}{1,570} = 40,000 \text{ sec.}$$

a = drainage area in square meters = 417×10^6

d = depth of runoff in meters = 0.201

q_p = flood peak in cubic meters per second = 1,570

Base flow assumed to be August 1932 average = $\frac{46,200,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 17 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in cu. m. per sec.		
$\frac{T}{T_p}$	$\frac{q}{q_p}$		Hydrograph	Base flow	Total
0	0	0	0	17	17
0.1	0.015	4	24		41
0.2	0.075	8	118		135
0.3	0.16	12	251		268
0.4	0.28	16	440		457
0.5	0.43	20	675		692
0.6	0.60	24	942		959
0.7	0.77	28	1,209		1,226
0.8	0.89	32	1,397		1,414
0.9	0.97	36	1,523		1,540
1.0	1.00	40	1,570		1,587
1.1	0.98	44	1,539		1,556
1.2	0.92	48	1,444		1,461
1.3	0.84	52	1,319		1,336
1.4	0.75	56	1,178		1,195
1.5	0.66	60	1,036		1,053
1.6	0.56	64	879		896
1.8	0.42	72	659		676
2.0	0.32	80	502		519
2.2	0.24	88	377		394
2.4	0.18	96	283		300
2.6	0.13	104	204		221
2.8	0.098	112	154		171
3.0	0.075	120	118		135
3.5	0.036	140	57		74
4.0	0.018	160	28		45
4.5	0.009	180	14		31
5.0	0.004	200	6	17	23
Flood total		88.45	million cubic meters in 2.31 days		
say		88	million cubic meters in 2-1/4 days		

TABLE III-88--MAXIMUM PROBABLE FLOOD--RIBB STORAGE RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{676 \times 10^6 \times 0.190}{2,180} = 44,150 \text{ sec.}$$

a = drainage area in square meters = 676×10^6

d = depth of runoff in meters = 0.190

q_p = flood peak in cubic meters per second = 2,180

$$\text{Base flow assumed to be August 1932 average} = \frac{177,500,000 \text{ cu. m.}}{2,678,400 \text{ sec.}} = 66 \text{ cu. m. per sec.}$$

Basic ratios		Time in thousand seconds	Design flood in cu. m. per sec.		
$\frac{T}{T_p}$	$\frac{q}{q_p}$		Hydrograph	Base flow	Total
0	0	0	0	66	66
0.1	0.015	4	33		99
0.2	0.075	9	164		230
0.3	0.16	13	349		415
0.4	0.28	18	610		676
0.5	0.43	22	937		1,003
0.6	0.60	26	1,308		1,374
0.7	0.77	31	1,679		1,745
0.8	0.89	35	1,940		2,006
0.9	0.97	40	2,115		2,181
1.0	1.00	44	2,180		2,246
1.1	0.98	49	2,136		2,202
1.2	0.92	53	2,006		2,072
1.3	0.84	57	1,831		1,897
1.4	0.75	62	1,635		1,701
1.5	0.66	66	1,439		1,505
1.6	0.56	71	1,221		1,287
1.8	0.42	79	916		982
2.0	0.32	88	698		764
2.2	0.24	97	523		589
2.4	0.18	106	392		458
2.6	0.13	115	283		349
2.8	0.098	124	214		280
3.0	0.075	132	164		230
3.5	0.036	155	78		144
4.0	0.018	177	39		105
4.5	0.009	199	20		86
5.0	0.004	221	9	66	75
Flood total		145.04	million cubic meters in 2.56 days		
say		145	million cubic meters in 2-1/2 days		

TABLE III-89--MAXIMUM PROBABLE FLOOD--GUMARA STORAGE RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{370 \times 10^6 \times 0.203}{1,450} = 38,800 \text{ sec.}$$

a = drainage area in square meters = 370×10^6

d = depth of runoff in meters = 0.203

q_p = flood peak in cubic meters per second = 1,450

Base flow assumed to be August 1932 average = $\frac{106,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 40 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in cu. m. per sec.		
$\frac{T}{T_p}$	$\frac{q}{q_p}$		Hydrograph	Base flow	Total
0	0	0	0	40	40
0.1	0.015	4	22		62
0.2	0.075	8	109		149
0.3	0.16	12	232		272
0.4	0.28	16	406		446
0.5	0.43	19	624		664
0.6	0.60	23	870		910
0.7	0.77	27	1,116		1,156
0.8	0.89	31	1,290		1,330
0.9	0.97	35	1,406		1,446
1.0	1.00	39	1,450		1,490
1.1	0.98	43	1,421		1,461
1.2	0.92	47	1,334		1,374
1.3	0.84	50	1,218		1,258
1.4	0.75	54	1,088		1,128
1.5	0.66	58	957		997
1.6	0.56	62	812		852
1.8	0.42	70	609		649
2.0	0.32	78	464		504
2.2	0.24	85	348		388
2.4	0.18	93	261		301
2.6	0.13	101	188		228
2.8	0.098	109	142		182
3.0	0.075	116	109		149
3.5	0.036	136	52		92
4.0	0.018	155	26		66
4.5	0.009	175	13		53
5.0	0.004	194	6	40	46
Flood total		83.79	million cubic meters in 2.25 days		
say		84	million cubic meters in 2-1/4 days		

TABLE III-90--MAXIMUM PROBABLE FLOOD--DANGUR (BL-3) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{9{,}070 \times 10^6 \times 0.119}{7{,}630} = 106{,}000 \text{ sec.}$$

a = drainage area in square meters = $9{,}070 \times 10^6$

d = depth of runoff in meters = 0.119

q_p = flood peak in cubic meters per second = 7,630

Base flow assumed to be August 1932 average = $\frac{1{,}072{,}000{,}000 \text{ cu. m.}}{2{,}678{,}400 \text{ sec.}}$ = 400 cu. m. per sec.

Basic ratios T/T_p	Basic ratios q/q_p	Time in thousand seconds	Design flood in thousand cu. m. per sec. Hydrograph	Base flow	Total
0	0	0	0	0.40	0.40
0.1	0.015	11	0.11		0.51
0.2	0.075	21	0.57		0.97
0.3	0.16	32	1.22		1.62
0.4	0.28	42	2.14		2.54
0.5	0.43	53	3.28		3.68
0.6	0.60	64	4.58		4.98
0.7	0.77	74	5.88		6.28
0.8	0.89	85	6.79		7.19
0.9	0.97	95	7.40		7.80
1.0	1.00	106	7.63		8.03
1.1	0.98	117	7.48		7.88
1.2	0.92	127	7.02		7.42
1.3	0.84	138	6.41		6.81
1.4	0.75	148	5.72		6.12
1.5	0.66	159	5.04		5.44
1.6	0.56	170	4.27		4.67
1.8	0.42	191	3.20		3.60
2.0	0.32	212	2.44		2.84
2.2	0.24	233	1.83		2.23
2.4	0.18	254	1.37		1.77
2.6	0.13	276	0.99		1.39
2.8	0.098	297	0.75		1.15
3.0	0.075	318	0.57		0.97
3.5	0.036	371	0.27		0.67
4.0	0.018	424	0.14		0.54
4.5	0.009	477	0.07		0.47
5.0	0.004	530	0.03	0.40	0.43
Flood total		1,308	million cubic meters in 6.13 days		
	say	1,300	million cubic meters in 6 days		

TABLE III-91--MAXIMUM PROBABLE FLOOD--GIAMMA STORAGE RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{6,140 \times 10^6 \times 0.130}{6,640} = 90,000 \text{ sec.}$$

a = drainage area in square meters = $6,140 \times 10^6$

d = depth of runoff in meters = 0.130

q_p = flood peak in cubic meters per second = 6,640

$$\text{Base flow assumed to be August 1932 average} = \frac{492,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}} = 184 \text{ cu. m. per sec.}$$

Basic ratios		Time in thousand seconds	Design flood in thousand cu. m. per sec.		
T/T_p	q/q_p		Hydrograph	Base flow	Total
0	0	0	0	0.18	0.18
0.1	0.015	9	0.10		0.28
0.2	0.075	18	0.50		0.68
0.3	0.16	27	1.06		1.24
0.4	0.28	36	1.86		2.04
0.5	0.43	45	2.86		3.04
0.6	0.60	54	3.98		4.16
0.7	0.77	63	5.11		5.29
0.8	0.89	72	5.91		6.09
0.9	0.97	81	6.44		6.62
1.0	1.00	90	6.64		6.82
1.1	0.98	99	6.51		6.69
1.2	0.92	108	6.11		6.29
1.3	0.84	117	5.58		5.76
1.4	0.75	126	4.98		5.16
1.5	0.66	135	4.38		4.56
1.6	0.56	144	3.72		3.90
1.8	0.42	162	2.79		2.97
2.0	0.32	180	2.12		2.30
2.2	0.24	198	1.59		1.77
2.4	0.18	216	1.20		1.38
2.6	0.13	234	0.86		1.04
2.8	0.098	252	0.65		0.83
3.0	0.075	270	0.50		0.68
3.5	0.036	315	0.24		0.42
4.0	0.018	360	0.12		0.30
4.5	0.009	405	0.06		0.24
5.0	0.004	450	0.03	0.18	0.21
Flood total		890	million cubic meters in 5.21		days
	say	885	million cubic meters in 5		days

TABLE III-92--MAXIMUM PROBABLE FLOOD--CHANCHO (MU-4) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{499 \times 10^6 \times 0.197}{1,780} = 41,400 \text{ sec.}$$

a = drainage area in square meters = 499×10^6

d = depth of runoff in meters = 0.197

q_p = flood peak in cubic meters per second = 1,780

Base flow assumed to be August 1932 average = $\frac{67,750,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 25 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in cu. m. per sec.		
$\frac{T}{T_p}$	$\frac{q}{q_p}$		Hydrograph	Base flow	Total
0	0	0	0	25	25
0.1	0.015	4	27		52
0.2	0.075	8	134		159
0.3	0.16	12	285		310
0.4	0.28	17	498		523
0.5	0.43	21	765		790
0.6	0.60	25	1,068		1,093
0.7	0.77	29	1,371		1,396
0.8	0.89	33	1,584		1,609
0.9	0.97	37	1,727		1,752
1.0	1.00	41	1,780		1,805
1.1	0.98	46	1,744		1,769
1.2	0.92	50	1,638		1,663
1.3	0.84	54	1,495		1,520
1.4	0.75	58	1,335		1,360
1.5	0.66	62	1,175		1,200
1.6	0.56	66	997		1,022
1.8	0.42	75	748		773
2.0	0.32	83	570		595
2.2	0.24	91	427		452
2.4	0.18	99	320		345
2.6	0.13	108	231		256
2.8	0.098	116	174		199
3.0	0.075	124	134		159
3.5	0.036	145	64		89
4.0	0.018	166	32		57
4.5	0.009	186	16		41
5.0	0.004	207	7	25	32
Flood total		104.75	million cubic meters in 2.40 days		
	say	105	million cubic meters in 2-1/2 days		

TABLE III-93--MAXIMUM PROBABLE FLOOD--BELLO (GU-4) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{244 \times 10^6 \times 0.212}{1{,}060} = 36{,}550 \text{ sec.}$$

a = drainage area in square meters = 244×10^6

d = depth of runoff in meters = 0.212

q_p = flood peak in cubic meters per second = 1,060

Base flow assumed to be August 1932 average = $\frac{67{,}720{,}000 \text{ cu. m.}}{2{,}678{,}400 \text{ sec.}}$ = 25 cu. m. per sec.

Basic ratios T/T_p	Basic ratios q/q_p	Time in thousand seconds	Design flood in cu. m. per sec.: Hydrograph	Base flow	Total
0	0	0	0	25	25
0.1	0.015	4	16		41
0.2	0.075	7	80		105
0.3	0.16	11	170		195
0.4	0.28	15	297		322
0.5	0.43	18	456		481
0.6	0.60	22	636		661
0.7	0.77	26	816		841
0.8	0.89	29	943		968
0.9	0.97	33	1,028		1,053
1.0	1.00	37	1,060		1,085
1.1	0.98	40	1,039		1,064
1.2	0.92	44	975		1,000
1.3	0.84	48	890		915
1.4	0.75	51	795		820
1.5	0.66	55	700		725
1.6	0.56	58	594		619
1.8	0.42	66	445		470
2.0	0.32	73	339		364
2.2	0.24	80	254		279
2.4	0.18	88	191		216
2.6	0.13	95	138		163
2.8	0.098	102	104		129
3.0	0.075	110	80		105
3.5	0.036	128	38		63
4.0	0.018	146	19		44
4.5	0.009	164	10		35
5.0	0.004	183	4	25	29
Flood total		57.06	million cubic meters in 2.12 days		
say		57	million cubic meters in 2 days		

TABLE III-94--MAXIMUM PROBABLE FLOOD--MOTTO (GU-1) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{3,670 \times 10^6 \times 0.1435}{5,400} = 73,050 \text{ sec.}$$

a = drainage area in square meters = $3,670 \times 10^6$

d = depth of runoff in meters = 0.1435

q_p = flood peak in cubic meters per second = 5,400

Base flow assumed to be August 1932 average = $\frac{532,400,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 199 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in thousand cu. m. per sec.		
T/T_p	q/q_p		Hydrograph	Base flow	Total
0	0	0	0	0.20	0.20
0.1	0.015	7	0.08		0.28
0.2	0.075	15	0.40		0.60
0.3	0.16	22	0.86		1.06
0.4	0.28	29	1.51		1.71
0.5	0.43	37	2.32		2.52
0.6	0.60	44	3.24		3.44
0.7	0.77	51	4.16		4.36
0.8	0.89	58	4.81		5.01
0.9	0.97	66	5.24		5.44
1.0	1.00	73	5.40		5.60
1.1	0.98	80	5.29		5.49
1.2	0.92	88	4.97		5.17
1.3	0.84	95	4.54		4.74
1.4	0.75	102	4.05		4.25
1.5	0.66	110	3.56		3.76
1.6	0.56	117	3.02		3.22
1.8	0.42	131	2.27		2.47
2.0	0.32	146	1.73		1.93
2.2	0.24	161	1.30		1.50
2.4	0.18	175	0.97		1.17
2.6	0.13	190	0.70		0.90
2.8	0.098	205	0.53		0.73
3.0	0.075	219	0.41		0.61
3.5	0.036	256	0.19		0.39
4.0	0.018	292	0.10		0.30
4.5	0.009	329	0.05		0.25
5.0	0.004	365	0.02	0.20	0.22
Flood total		594.9	million cubic meters in	4.22	days
	say	590	million cubic meters in	4	days

TABLE III-95--MAXIMUM PROBABLE FLOOD--NESHE (W/O AMARTI) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{309 \times 10^6 \times 0.207}{1,240} = 38,650 \text{ sec.}$$

a = drainage area in square meters = 309×10^6

d = depth of runoff in meters = 0.207

q_p = flood peak in cubic meters per second = 1,240

Base flow assumed to be August 1932 average = $\frac{39,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 15 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in cu. m. per sec.		
$\frac{T}{T_p}$	$\frac{q}{q_p}$		Hydrograph	Base flow	Total
0	0	0	0	15	15
0.1	0.015	4	19		34
0.2	0.075	8	93		108
0.3	0.16	12	198		213
0.4	0.28	15	347		362
0.5	0.43	19	533		548
0.6	0.60	23	744		759
0.7	0.77	27	955		970
0.8	0.89	31	1,104		1,119
0.9	0.97	35	1,203		1,218
1.0	1.00	39	1,240		1,255
1.1	0.98	42	1,215		1,230
1.2	0.92	46	1,141		1,156
1.3	0.84	50	1,042		1,057
1.4	0.75	54	930		945
1.5	0.66	58	818		833
1.6	0.56	62	694		709
1.8	0.42	70	521		536
2.0	0.32	77	397		412
2.2	0.24	85	298		313
2.4	0.18	93	223		238
2.6	0.13	101	161		176
2.8	0.098	108	122		137
3.0	0.075	116	93		108
3.5	0.036	135	45		60
4.0	0.018	155	22		37
4.5	0.009	174	11		26
5.0	0.004	193	5	15	20

TABLE III-96--MAXIMUM PROBABLE FLOOD--AMARTI-NESHE RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{554 \times 10^6 \times 0.195}{1,910} = 42,400 \text{ sec.}$$

a = drainage area in square meters = 554×10^6

d = depth of runoff in meters = 0.195

q_p = flood peak in cubic meters per second = 1,910

Base flow assumed to be August 1932 average = $\frac{78,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 29 cu. m. per sec.

Basic ratios $\frac{T}{T_p}$	Basic ratios $\frac{q}{q_p}$	Time in thousand seconds	Design flood in cu. m. per sec. Hydrograph	Base flow	Total
0	0	0	0	29	29
0.1	0.015	4	29		58
0.2	0.075	8	143		172
0.3	0.16	13	306		335
0.4	0.28	17	535		564
0.5	0.43	21	821		850
0.6	0.60	25	1,146		1,175
0.7	0.77	30	1,471		1,500
0.8	0.89	34	1,700		1,729
0.9	0.97	38	1,853		1,882
1.0	1.00	42	1,910		1,939
1.1	0.98	47	1,872		1,901
1.2	0.92	51	1,757		1,786
1.3	0.84	55	1,604		1,633
1.4	0.75	59	1,432		1,461
1.5	0.66	64	1,261		1,290
1.6	0.56	68	1,070		1,099
1.8	0.42	76	802		831
2.0	0.32	85	611		640
2.2	0.24	93	458		487
2.4	0.18	102	344		373
2.6	0.13	110	248		277
2.8	0.098	119	187		216
3.0	0.075	127	143		172
3.5	0.036	148	69		98
4.0	0.018	170	34		63
4.5	0.009	191	17		46
5.0	0.004	212	8	29	37
Flood total		115.83	million cubic meters in 2.45 days		
	say	116	million cubic meters in 2-1/2 days		

TABLE III-97--MAXIMUM PROBABLE FLOOD--UPPER BIRR (B-5) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{591 \times 10^6 \times 0.193}{2,000} = 42,720$$

a = drainage area in square meters = 591×10^6

d = depth of runoff in meters = 0.193

q_p = flood peak in cubic meters per second = 2,000

Base flow assumed to be August 1932 average = $\frac{158,030,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 59 cu. m. per sec.

Basic ratios T/T_p	Basic ratios q/q_p	Time in thousand seconds	Design flood in cu. m. per sec. Hydrograph	Base flow	Total
0	0	0	0	59	59
0.1	0.015	4	30		89
0.2	0.075	9	150		209
0.3	0.16	13	320		379
0.4	0.28	17	560		619
0.5	0.43	21	860		919
0.6	0.60	26	1,200		1,259
0.7	0.77	30	1,540		1,599
0.8	0.89	34	1,780		1,839
0.9	0.97	38	1,940		1,999
1.0	1.00	43	2,000		2,059
1.1	0.98	47	1,960		2,019
1.2	0.92	51	1,840		1,899
1.3	0.84	56	1,680		1,739
1.4	0.75	60	1,500		1,559
1.5	0.66	64	1,320		1,379
1.6	0.56	68	1,120		1,179
1.8	0.42	77	840		899
2.0	0.32	85	640		699
2.2	0.24	94	480		539
2.4	0.18	103	360		419
2.6	0.13	111	260		319
2.8	0.098	120	196		255
3.0	0.075	128	150		209
3.5	0.036	150	72		131
4.0	0.018	171	36		95
4.5	0.009	192	18		77
5.0	0.004	214	8	59	67
Flood total		128.34	million cubic meters in 2.48 days		
	say	129	million cubic meters in 2-1/2 days		

TABLE III-98--MAXIMUM PROBABLE FLOOD--DEBOHILA STORAGE RESERVOIR

September 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{77.4 \times 10^6 \times 0.229}{425} = 31{,}240 \text{ sec.}$$

a = drainage area in square meters = 77.4×10^6

d = depth of runoff in meters = 0.229

q_p = flood peak in cubic meters per second = 425

Base flow assumed to be August 1932 average = $\frac{7{,}640{,}000 \text{ cu. m.}}{2{,}678{,}400 \text{ sec.}}$ = 2.9 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in cu. m. per sec.		
T/T_p	q/q_p		Hydrograph	Base flow	Total
0	0	0	0	2.9	2.9
0.1	0.015	3	6.4		9.3
0.2	0.075	6	31.9		34.8
0.3	0.16	9	68.0		70.9
0.4	0.28	12	119.0		121.9
0.5	0.43	16	182.8		185.7
0.6	0.60	19	255.0		257.9
0.7	0.77	22	327.3		330.2
0.8	0.89	25	378.3		381.2
0.9	0.97	28	412.3		415.2
1.0	1.00	31	425.0		427.9
1.1	0.98	34	416.5		419.4
1.2	0.92	38	391.0		393.9
1.3	0.84	41	357.0		359.9
1.4	0.75	44	318.8		321.7
1.5	0.66	47	280.5		283.4
1.6	0.56	50	238.0		240.9
1.8	0.42	56	178.5		181.4
2.0	0.32	62	136.0		138.9
2.2	0.24	69	102.0		104.9
2.4	0.18	75	76.5		79.4
2.6	0.13	81	55.3		58.2
2.8	0.098	87	41.7		44.6
3.0	0.075	94	31.9		34.8
3.5	0.036	109	15.3		18.2
4.0	0.018	125	7.7		10.6
4.5	0.009	141	3.8		6.7
5.0	0.004	156	1.7	2.9	4.6

Flood total 18.44 million cubic meters in 1.81 days
say 18.4 million cubic meters in 1-3/4 days

TABLE III-99--MAXIMUM PROBABLE FLOOD--DIDDESSA (DD-11) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{3,360 \times 10^6 \times 0.147}{5,200} = 71,100 \text{ sec.}$$

a = drainage area in square meters = $3,360 \times 10^6$

d = depth of runoff in meters = 0.147

q_p = flood peak in cubic meters per second = 5,200

Base flow assumed to be August 1932 average = $\frac{512,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 191 cu. m. per sec.

Basic ratios T/T_p	Basic ratios q/q_p	Time in thousand seconds	Design flood in thousand cu. m. per sec. Hydrograph	Base flow	Total
0	0	0	0	0.19	0.19
0.1	0.015	7	0.08		0.27
0.2	0.075	14	0.39		0.58
0.3	0.16	21	0.83		1.02
0.4	0.28	28	1.46		1.65
0.5	0.43	36	2.24		2.43
0.6	0.60	43	3.12		3.31
0.7	0.77	50	4.00		4.19
0.8	0.89	57	4.63		4.82
0.9	0.97	64	5.04		5.23
1.0	1.00	71	5.20		5.39
1.1	0.98	78	5.10		5.29
1.2	0.92	85	4.78		4.97
1.3	0.84	92	4.37		4.56
1.4	0.75	100	3.90		4.09
1.5	0.66	107	3.43		3.62
1.6	0.56	114	2.91		3.10
1.8	0.42	128	2.18		2.37
2.0	0.32	142	1.66		1.85
2.2	0.24	156	1.25		1.44
2.4	0.18	171	0.94		1.13
2.6	0.13	185	0.68		0.87
2.8	0.098	199	0.51		0.70
3.0	0.075	213	0.39		0.58
3.5	0.036	249	0.19		0.38
4.0	0.018	284	0.09		0.28
4.5	0.009	320	0.05		0.24
5.0	0.004	356	0.02	0.19	0.21
Flood total		568.4	million cubic meters in	4.12	days
	say	565	million cubic meters in	4	days

TABLE III-100--MAXIMUM PROBABLE FLOOD--DABANA STORAGE RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{2,654 \times 10^6 \times 0.154}{4,670} = 65,600 \text{ sec.}$$

a = drainage area in square meters = $2,654 \times 10^6$

d = depth of runoff in meters = 0.154

q_p = flood peak in cubic meters per second = 4,670

Base flow assumed to be August 1932 average = $\frac{506,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 189 cu. m. per sec.

Basic ratios T/T_p	Basic ratios q/q_p	Time in thousand seconds	Design flood in thousand cu. m. per sec. Hydrograph	Base flow	Total
0	0	0	0	0.19	0.19
0.1	0.015	7	0.07		0.26
0.2	0.075	13	0.35		0.54
0.3	0.16	20	0.75		0.94
0.4	0.28	26	1.31		1.50
0.5	0.43	33	2.01		2.20
0.6	0.60	39	2.80		2.99
0.7	0.77	46	3.60		3.79
0.8	0.89	52	4.16		4.35
0.9	0.97	59	4.53		4.72
1.0	1.00	66	4.67		4.86
1.1	0.98	72	4.58		4.77
1.2	0.92	79	4.30		4.49
1.3	0.84	85	3.92		4.11
1.4	0.75	92	3.50		3.69
1.5	0.66	98	3.08		3.27
1.6	0.56	105	2.62		2.81
1.8	0.42	118	1.96		2.15
2.0	0.32	131	1.49		1.68
2.2	0.24	144	1.12		1.31
2.4	0.18	157	0.84		1.03
2.6	0.13	171	0.61		0.80
2.8	0.098	184	0.46		0.65
3.0	0.075	197	0.35		0.54
3.5	0.036	230	0.17		0.36
4.0	0.018	262	0.08		0.27
4.5	0.009	295	0.04		0.23
5.0	0.004	328	0.02	0.19	0.21
Flood total		477.3	million cubic meters in	3.80	days
	say	480	million cubic meters in	4	days

TABLE III-101--MAXIMUM PROBABLE FLOOD--BOO (DD-2) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{16,700 \times 10^6 \times 0.102}{9,450} = 135,000 \text{ sec.}$$

a = drainage area in square meters = $16,700 \times 10^6$

d = depth of runoff in meters = 0.102

q_p = flood peak in cubic meters per second = 9,450

$$\text{Base flow assumed to be August 1932 average} = \frac{2,812,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}} = 1,050 \text{ cu. m. per sec.}$$

Basic ratios		Time in thousand seconds	Design flood in thousand cu. m. per sec.		
T/T_p	q/q_p		Hydrograph	Base flow	Total
0	0	0	0	1.05	1.05
0.1	0.015	14	0.14		1.19
0.2	0.075	27	0.71		1.76
0.3	0.16	40	1.51		2.56
0.4	0.28	54	2.65		3.70
0.5	0.43	68	4.06		5.11
0.6	0.60	81	5.67		6.72
0.7	0.77	94	7.28		8.33
0.8	0.89	108	8.41		9.46
0.9	0.97	122	9.17		10.22
1.0	1.00	135	9.45		10.50
1.1	0.98	148	9.26		10.31
1.2	0.92	162	8.69		9.74
1.3	0.84	176	7.94		8.99
1.4	0.75	189	7.09		8.14
1.5	0.66	202	6.24		7.29
1.6	0.56	216	5.29		6.34
1.8	0.42	243	3.97		5.02
2.0	0.32	270	3.02		4.07
2.2	0.24	297	2.27		3.32
2.4	0.18	324	1.70		2.75
2.6	0.13	351	1.23		2.28
2.8	0.098	378	0.93		1.98
3.0	0.075	405	0.71		1.76
3.5	0.036	472	0.34		1.39
4.0	0.018	540	0.17		1.22
4.5	0.009	608	0.09		1.14
5.0	0.004	675	0.04	1.05	1.09
Flood total		2,437	million cubic meters in	7.81	days
	say	2,450	million cubic meters in	8	days

TABLE III-102--MAXIMUM PROBABLE FLOOD--ANGAR (AG-2) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{1,780 \times 10^6 \times 0.166}{3,850} = 57,500 \text{ sec.}$$

a = drainage area in square meters = $1,780 \times 10^6$

d = depth of runoff in meters = 0.166

q_p = flood peak in cubic meters per second = 3,850

Base flow assumed to be August 1932 average = $\frac{322,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 120 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in thousand cu. m. per sec.		
T/T_p	q/q_p		Hydrograph	Base flow	Total
0	0	0	0	0.12	0.12
0.1	0.015	6	0.06		0.18
0.2	0.075	12	0.29		0.41
0.3	0.16	17	0.62		0.74
0.4	0.28	23	1.08		1.20
0.5	0.43	29	1.66		1.78
0.6	0.60	34	2.31		2.43
0.7	0.77	40	2.96		3.08
0.8	0.89	46	3.43		3.55
0.9	0.97	52	3.73		3.85
1.0	1.00	58	3.85		3.97
1.1	0.98	63	3.77		3.89
1.2	0.92	69	3.54		3.66
1.3	0.84	75	3.23		3.35
1.4	0.75	80	2.89		3.01
1.5	0.66	86	2.54		2.66
1.6	0.56	92	2.16		2.28
1.8	0.42	104	1.62		1.74
2.0	0.32	115	1.23		1.35
2.2	0.24	126	0.92		1.04
2.4	0.18	138	0.69		0.81
2.6	0.13	150	0.50		0.62
2.8	0.098	161	0.38		0.50
3.0	0.075	172	0.29		0.41
3.5	0.036	201	0.14		0.26
4.0	0.018	230	0.07		0.19
4.5	0.009	259	0.03		0.15
5.0	0.004	288	0.02	0.12	0.14
Flood total		334.1	million cubic meters in 3.33 days		
	say	340	million cubic meters in 3-1/2 days		

TABLE III-103--MAXIMUM PROBABLE FLOOD--LEKKEMT (AG-6) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{4,523 \times 10^6 \times 0.138}{5,870} = 79,600 \text{ sec.}$$

a = drainage area in square meters = $4,523 \times 10^6$

d = depth of runoff in meters = 0.138

q_p = flood peak in cubic meters per second = 5,870

Base flow assumed to be August 1932 average = $\frac{820,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 306 cu. m. per sec.

Basic ratios T/T_p	Basic ratios q/q_p	Time in thousand seconds	Design flood in thousand cu. m. per sec.: Hydrograph	Base flow	Total
0	0	0	0	0.31	0.31
0.1	0.015	8	0.09		0.40
0.2	0.075	16	0.44		0.75
0.3	0.16	24	0.94		1.25
0.4	0.28	32	1.64		1.95
0.5	0.43	40	2.52		2.83
0.6	0.60	48	3.52		3.83
0.7	0.77	56	4.52		4.83
0.8	0.89	64	5.22		5.53
0.9	0.97	72	5.69		6.00
1.0	1.00	80	5.87		6.18
1.1	0.98	88	5.75		6.06
1.2	0.92	96	5.40		5.71
1.3	0.84	103	4.93		5.24
1.4	0.75	111	4.40		4.71
1.5	0.66	119	3.87		4.18
1.6	0.56	127	3.29		3.60
1.8	0.42	143	2.47		2.78
2.0	0.32	159	1.88		2.19
2.2	0.24	175	1.41		1.72
2.4	0.18	191	1.06		1.37
2.6	0.13	207	0.76		1.07
2.8	0.098	223	0.58		0.89
3.0	0.075	239	0.44		0.75
3.5	0.036	279	0.21		0.52
4.0	0.018	318	0.11		0.42
4.5	0.009	358	0.05		0.36
5.0	0.004	398	0.02	0.31	0.33
Flood total		733.2	million cubic meters in 4.61		days
say		740	million cubic meters in 5		days

TABLE III-104--MAXIMUM PROBABLE FLOOD--JUNCTION (DI-7) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{2,690 \times 10^6 \times 0.153}{4,700} = 65,600 \text{ sec.}$$

a = drainage area in square meters = $2,690 \times 10^6$

d = depth of runoff in meters = 0.153

q_p = flood peak in cubic meters per second = 4,700

Base flow assumed to be August 1932 average = $\frac{497,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 186 cu. m. per sec.

Basic ratios $\frac{T}{T_p}$	Basic ratios $\frac{q}{q_p}$	Time in thousand seconds	Design flood in thousand cu. m. per sec. Hydrograph	Base flow	Total
0	0	0	0	0.19	0.19
0.1	0.015	7	0.07		0.26
0.2	0.075	13	0.35		0.54
0.3	0.16	20	0.75		0.94
0.4	0.28	26	1.32		1.51
0.5	0.43	33	2.02		2.21
0.6	0.60	39	2.82		3.01
0.7	0.77	46	3.62		3.81
0.8	0.89	52	4.18		4.37
0.9	0.97	59	4.56		4.75
1.0	1.00	66	4.70		4.89
1.1	0.98	72	4.61		4.80
1.2	0.92	79	4.32		4.51
1.3	0.84	85	3.95		4.14
1.4	0.75	92	3.52		3.71
1.5	0.66	98	3.10		3.29
1.6	0.56	105	2.63		2.82
1.8	0.42	118	1.97		2.16
2.0	0.32	131	1.50		1.69
2.2	0.24	144	1.13		1.32
2.4	0.18	157	0.85		1.04
2.6	0.13	171	0.61		0.80
2.8	0.098	184	0.46		0.65
3.0	0.075	197	0.35		0.54
3.5	0.036	230	0.17		0.36
4.0	0.018	262	0.08		0.27
4.5	0.009	295	0.04		0.23
5.0	0.004	328	0.02	0.19	0.21
Flood total		479.6	million cubic meters in	3.80	days
say		480	million cubic meters in	4	days

TABLE III-105--MAXIMUM PROBABLE FLOOD--DINDIR (DI-2) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{4{,}900 \times 10^6 \times 0.137}{6{,}060} = 82{,}970 \text{ sec.}$$

a = drainage area in square meters = $4{,}900 \times 10^6$

d = depth of runoff in meters = 0.137

q_p = flood peak in cubic meters per second = 6,060

Base flow assumed to be August 1932 average = $\frac{836{,}000{,}000 \text{ cu. m.}}{2{,}678{,}400 \text{ sec.}}$ = 312 cu. m. per sec.

Basic ratios T/T_p	Basic ratios q/q_p	Time in thousand seconds	Design flood in thousand cu. m. per sec. Hydrograph	Base flow	Total
0	0	0	0	0.31	0.31
0.1	0.015	8	0.09		0.40
0.2	0.075	17	0.45		0.76
0.3	0.16	25	0.97		1.28
0.4	0.28	33	1.70		2.01
0.5	0.43	41	2.61		2.92
0.6	0.60	50	3.64		3.95
0.7	0.77	58	4.67		4.98
0.8	0.89	66	5.39		5.70
0.9	0.97	75	5.88		6.19
1.0	1.00	83	6.06		6.37
1.1	0.98	91	5.94		6.25
1.2	0.92	100	5.58		5.89
1.3	0.84	108	5.09		5.40
1.4	0.75	116	4.54		4.85
1.5	0.66	124	4.00		4.31
1.6	0.56	133	3.39		3.70
1.8	0.42	149	2.55		2.86
2.0	0.32	166	1.94		2.25
2.2	0.24	183	1.45		1.76
2.4	0.18	199	1.09		1.40
2.6	0.13	216	0.79		1.10
2.8	0.098	232	0.59		0.90
3.0	0.075	249	0.45		0.76
3.5	0.036	290	0.22		0.53
4.0	0.018	332	0.11		0.42
4.5	0.009	373	0.05		0.36
5.0	0.004	415	0.02	0.31	0.33
Flood total		809.4	million cubic meters in	4.80	days
	say	815	million cubic meters in	5	days

TABLE III-106--MAXIMUM PROBABLE FLOOD--GALEGU STORAGE RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{543 \times 10^6 \times 0.195}{1,880} = 42,200 \text{ sec.}$$

a = drainage area in square meters = 543×10^6

d = depth of runoff in meters = 0.195

q_p = flood peak in cubic meters per second = 1,880

Base flow assumed to be August 1932 average = $\frac{105,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 39 cu. m. per sec.

Basic ratios T/T_p	Basic ratios q/q_p	Time in thousand seconds	Design flood in cu. m. per sec. Hydrograph	Base flow	Total
0	0	0	0	39	39
0.1	0.015	4	28		67
0.2	0.075	8	141		180
0.3	0.16	13	301		340
0.4	0.28	17	526		565
0.5	0.43	21	808		847
0.6	0.60	25	1,128		1,167
0.7	0.77	30	1,448		1,487
0.8	0.89	34	1,673		1,712
0.9	0.97	38	1,824		1,863
1.0	1.00	42	1,880		1,919
1.1	0.98	46	1,842		1,881
1.2	0.92	51	1,730		1,769
1.3	0.84	55	1,579		1,618
1.4	0.75	59	1,410		1,449
1.5	0.66	63	1,241		1,280
1.6	0.56	68	1,053		1,092
1.8	0.42	76	790		829
2.0	0.32	84	602		641
2.2	0.24	93	451		490
2.4	0.18	101	338		377
2.6	0.13	110	244		283
2.8	0.098	118	184		223
3.0	0.075	127	141		180
3.5	0.036	148	68		107
4.0	0.018	169	34		73
4.5	0.009	190	17		56
5.0	0.004	211	8	39	47
Flood total		116.19	million cubic meters in 2.44 days		
say		116	million cubic meters in 2-1/2 days		

TABLE III-107--MAXIMUM PROBABLE FLOOD--RAHAD STORAGE RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{3,800 \times 10^6 \times 0.144}{5,460} = 75,100 \text{ sec.}$$

a = drainage area in square meters = $3,800 \times 10^6$

d = depth of runoff in meters = 0.144

q_p = flood peak in cubic meters per second = 5,460

Base flow assumed to be September 1946 average = $\frac{500,000,000 \text{ cu. m.}}{2,592,000 \text{ sec.}}$ = 193 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in thousand cu. m. per sec.		
$\frac{T}{T_p}$	$\frac{q}{q_p}$		Hydrograph	Base flow	Total
0	0	0	0	0.19	0.19
0.1	0.015	8	0.08		0.27
0.2	0.075	15	0.41		0.60
0.3	0.16	23	0.87		1.06
0.4	0.28	30	1.53		1.72
0.5	0.43	38	2.35		2.54
0.6	0.60	45	3.28		3.47
0.7	0.77	53	4.20		4.39
0.8	0.89	60	4.86		5.05
0.9	0.97	68	5.30		5.49
1.0	1.00	75	5.46		5.65
1.1	0.98	83	5.35		5.54
1.2	0.92	90	5.02		5.21
1.3	0.84	98	4.59		4.78
1.4	0.75	105	4.10		4.29
1.5	0.66	113	3.60		3.79
1.6	0.56	120	3.06		3.25
1.8	0.42	135	2.29		2.48
2.0	0.32	150	1.75		1.94
2.2	0.24	165	1.31		1.50
2.4	0.18	180	0.98		1.17
2.6	0.13	195	0.71		0.90
2.8	0.098	210	0.54		0.73
3.0	0.075	225	0.41		0.60
3.5	0.036	263	0.20		0.39
4.0	0.018	300	0.10		0.29
4.5	0.009	338	0.05		0.24
5.0	0.004	376	0.02	0.19	0.21
Flood total		626.4	million cubic meters in 4.35 days		
	say	630	million cubic meters in 4-1/2 days		

TABLE III-108--MAXIMUM PROBABLE FLOOD--KARADOBI (BN-3) RESERVOIR

September 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{60,300 \times 10^6 \times 0.068}{14,100} = 217,800 \text{ sec.}$$

a = drainage area in square meters = $60,300 \times 10^6$

d = depth of runoff in meters = 0.068

q_p = flood peak in cubic meters per second = 14,100

Base flow assumed to be August 1932 average = $\frac{6,038,000,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 2,254 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in thousand cu. m. per sec.		
$\frac{T}{T_p}$	$\frac{q}{q_p}$		Hydrograph	Base flow	Total
0	0	0	0	2.3	2.3
0.1	0.015	22	0.2		2.5
0.2	0.075	44	1.1		3.4
0.3	0.16	65	2.3		4.6
0.4	0.28	87	3.9		6.2
0.5	0.43	109	6.1		8.4
0.6	0.60	131	8.5		10.8
0.7	0.77	152	10.9		13.2
0.8	0.89	174	12.5		14.8
0.9	0.97	196	13.7		16.0
1.0	1.00	218	14.1		16.4
1.1	0.98	240	13.8		16.1
1.2	0.92	261	13.0		15.3
1.3	0.84	283	11.8		14.1
1.4	0.75	305	10.6		12.9
1.5	0.66	327	9.3		11.6
1.6	0.56	349	7.9		10.2
1.8	0.42	392	5.9		8.2
2.0	0.32	436	4.5		6.8
2.2	0.24	479	3.4		5.7
2.4	0.18	523	2.5		4.8
2.6	0.13	566	1.8		4.1
2.8	0.098	610	1.4		3.7
3.0	0.075	653	1.1		3.4
3.5	0.036	762	0.5		2.8
4.0	0.018	871	0.3		2.6
4.5	0.009	980	0.1		2.4
5.0	0.004	1,089	0.1	2.3	2.4
Flood total		6,673	million cubic meters in 12.61 days		
say		6,750	million cubic meters in 13 days		

TABLE III-109--MAXIMUM PROBABLE FLOOD--MABIL (BN-19) RESERVOIR

September 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{85,100 \times 10^6 \times 0.060}{15,600} = 245,000 \text{ sec.}$$

a = drainage area in square meters = $85,100 \times 10^6$

d = depth of runoff in meters = 0.060

q_p = flood peak in cubic meters per second = 15,600

Base flow assumed to be August 1932 average = $\frac{9,169,000 \text{ cu. m.}}{2,678,400 \text{ sec.}}$ = 3,423 cu. m. per sec.

Basic ratios $\frac{T}{T_p}$	Basic ratios $\frac{q}{q_p}$	Time in thousand seconds	Design flood in thousand cu. m. per sec. Hydrograph	Base flow	Total
0	0	0	0	3.4	3.4
0.1	0.015	24	0.2		3.6
0.2	0.075	49	1.2		4.6
0.3	0.16	73	2.5		5.9
0.4	0.28	98	4.4		7.8
0.5	0.43	122	6.7		10.1
0.6	0.60	147	9.4		12.8
0.7	0.77	171	12.0		15.4
0.8	0.89	196	13.9		17.3
0.9	0.97	220	15.1		18.5
1.0	1.00	245	15.6		19.0
1.1	0.98	269	15.3		18.7
1.2	0.92	294	14.4		17.8
1.3	0.84	318	13.1		16.5
1.4	0.75	343	11.7		15.1
1.5	0.66	367	10.3		13.7
1.6	0.56	392	8.7		12.1
1.8	0.42	441	6.6		10.0
2.0	0.32	490	5.0		8.4
2.2	0.24	539	3.7		7.1
2.4	0.18	588	2.8		6.2
2.6	0.13	637	2.0		5.4
2.8	0.098	686	1.5		4.9
3.0	0.075	735	1.2		4.6
3.5	0.036	858	0.6		4.0
4.0	0.018	980	0.3		3.7
4.5	0.009	1,103	0.1		3.5
5.0	0.004	1,225	0.1	3.4	3.5
Flood total		9,260	million cubic meters in	14.18	days
	say	9,200	million cubic meters in	14	days

TABLE III-110--MAXIMUM PROBABLE FLOOD--MENDAIA (BN-26A) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{123{,}800 \times 10^6 \times 0.0505}{17{,}100} = 273{,}800 \text{ sec.}$$

a = drainage area in square meters = $123{,}800 \times 10^6$

d = depth of runoff in meters = 0.0505

q_p = flood peak in cubic meters per second = 17,100

Base flow assumed to be August 1932 average = $\frac{13{,}383{,}000{,}000 \text{ cu. m.}}{2{,}678{,}400 \text{ sec.}}$ = 4,997 cu. m. per sec.

Basic ratios T/T_p	Basic ratios q/q_p	Time in thousand seconds	Design flood in thousand cu. m. per sec.: Hydrograph	Base flow	Total
0	0	0	0	5.0	5.0
0.1	0.015	27	0.3		5.3
0.2	0.075	55	1.3		6.3
0.3	0.16	82	2.7		7.7
0.4	0.28	110	4.8		9.8
0.5	0.43	137	7.4		12.4
0.6	0.60	164	10.3		15.3
0.7	0.77	192	13.2		18.2
0.8	0.89	219	15.2		20.2
0.9	0.97	246	16.6		21.6
1.0	1.00	274	17.1		22.1
1.1	0.98	301	16.8		21.8
1.2	0.92	329	15.7		20.7
1.3	0.84	356	14.4		19.4
1.4	0.75	383	12.8		17.8
1.5	0.66	411	11.3		16.3
1.6	0.56	438	9.6		14.6
1.8	0.42	493	7.2		12.2
2.0	0.32	548	5.5		10.5
2.2	0.24	602	4.1		9.1
2.4	0.18	657	3.1		8.1
2.6	0.13	712	2.2		7.2
2.8	0.098	767	1.7		6.7
3.0	0.075	821	1.3		6.3
3.5	0.036	958	0.6		5.6
4.0	0.018	1,095	0.3		5.3
4.5	0.009	1,232	0.2		5.2
5.0	0.004	1,369	0.1	5.0	5.1
Flood total		13,210	million cubic meters in 15.85 days		
say		13,300	million cubic meters in 16 days		

TABLE III-111--MAXIMUM PROBABLE FLOOD--BORDER (BN-28) RESERVOIR

October 1963

$$T_p = 0.749 \frac{ad}{q_p} = 0.749 \frac{158{,}100 \times 10^6 \times 0.044}{18{,}000} = 289{,}500 \text{ sec.}$$

a = drainage area in square meters = $158{,}100 \times 10^6$

d = depth of runoff in meters = 0.044

q_p = flood peak in cubic meters per second = 18,000

Base flow assumed to be August 1932 average = $\frac{15{,}800{,}000{,}000 \text{ cu. m.}}{2{,}678{,}400 \text{ sec.}}$ = 5,899 cu. m. per sec.

Basic ratios		Time in thousand seconds	Design flood in thousand cu. m. per sec.		
$\frac{T}{T_p}$	$\frac{q}{q_p}$		Hydrograph	Base flow	Total
0	0	0	0	5.9	5.9
0.1	0.015	29	0.3		6.2
0.2	0.075	58	1.4		7.3
0.3	0.16	87	2.9		8.8
0.4	0.28	116	5.0		10.9
0.5	0.43	145	7.7		13.6
0.6	0.60	174	10.8		16.7
0.7	0.77	203	13.9		19.8
0.8	0.89	232	16.0		21.9
0.9	0.97	261	17.5		23.4
1.0	1.00	290	18.0		23.9
1.1	0.98	318	17.6		23.5
1.2	0.92	347	16.6		22.5
1.3	0.84	376	15.1		21.0
1.4	0.75	405	13.5		19.4
1.5	0.66	434	11.9		17.8
1.6	0.56	463	10.1		16.0
1.8	0.42	521	7.6		13.5
2.0	0.32	579	5.8		11.7
2.2	0.24	637	4.3		10.2
2.4	0.18	695	3.2		9.1
2.6	0.13	753	2.3		8.2
2.8	0.098	811	1.8		7.7
3.0	0.075	868	1.4		7.3
3.5	0.036	1,013	0.6		6.5
4.0	0.018	1,158	0.3		6.2
4.5	0.009	1,303	0.2		6.1
5.0	0.004	1,448	0.1	5.9	6.0
Flood total		15,293	million cubic meters in 16.76 days		
	say	15,400	million cubic meters in 17 days		

TABLE III-112--FLOOD FREQUENCY--INDRIS RIVER NEAR GUDER

Year	Mo./day	Flow cu. m./sec.	In order of magnitude	m.	F.
1959	9/12	57	82	1	12.5
1960	8/21	82	57	2	37.5
1961	8/11	31	31	3	62.5
1962	9/26	29	29	4	87.5

TABLE III-113--FLOOD FREQUENCY--ABBAY RIVER NEAR KESE

Year	Mo./day	Abbay nr Kese flow cu. m./sec.	Abbay nr Bahir Dar flow cu. m./sec.	Net flow cu. m./sec.	In order of magnitude	m.	F.
1953	8/7	7,548	200 E	7,348	7,516	1	5.6
1954	8/12	6,683	200 E	6,483	7,348	2	16.7
1955		No data					
1956	8/7	5,310	200 E	5,110	6,483	3	27.8
1957	8/9	3,855	200 E	3,655	6,094	4	38.9
1958	8/12	5,992	200 E	5,792	6,056	5	50.0
1959	8/29	7,900	384	7,516	5,792	6	61.1
1960	8/22	6,208	214	6,094	5,110	7	72.2
1961	8/8	6,200 E	144	6,056	3,655	8	83.3
1962	9/1	3,616	308	3,308	3,308	9	94.4

E means estimated.

The 5-, 10-, 25-, 50-, and 100-year peak discharges (taken from the curves) to be expected at the storage and diversion damsites (except those presented later as "special problem areas") are tabulated in Table III-114. As in the case of the maximum design flood estimates, no adjustments were made for proposed upstream developments except for the Neshe irrigation diversion dam, where flood flows will be routed over the Amarti spillway, and for the Beles irrigation diversion dam, where power diversion flow from Lake Tana was included.

Special Problem Areas

As mentioned in preceding sections, Lake Tana, Chomen Swamp, and Dabus Swamp greatly affect flood peaks on their streams, so the generalized procedures for estimating maximum probable floods and flood frequency values are not applicable. These three areas are considered here individually.

LAKE TANA

General Description of Lake Tana

The generalized procedure is applicable for computing reconnaissance design floods for damsites on streams tributary to Lake Tana. However, design criteria for a structure controlling outflow from Lake Tana present special problems.

The lake covers approximately 3,000 square kilometers of the total drainage area of 15,165 square kilometers above the lake outlet (Frontispiece). Therefore, the lake has a great effect on the outflow, both in quantity of annual discharge and in the peak discharge each year. The lake level fluctuates an average of 1.6 meters in the annual cycle, reaching a low each year near the end of June and a high near the end of September. The recorded historical extremes from 14 and 18 years of record, respectively, are a low at elevation 1785.34 in June 1961, and a high at elevation 1787.57 in September 1929, a range of 2.23 meters (Table III-115). It is estimated that approximately 50 percent of the annual inflow is lost in evaporation from the lake.

Seiche and wave action can, for a short while, raise parts of the water surface above the general water surface. (Seiche is a harmonic motion of water back and forth across the lake, which is activated by wind). High winds can occur at any time in the March-through-October period. Recorder charts show the peak-to-peak frequency of the Tana seiche to be about 3 to 4 hours, and amplitude of the rise above general level to be about 20 centimeters. However, recorder charts reveal that waves (of short frequency) occurred with an amplitude of as much as 50 centimeters during the 4 years, 1959 to 1962, and these are probably more destructive than the seiche. Because of the infrequency with which high winds occur during the short period over which it is desirable to have the lake filled to the spillway crests in any year, it is unnecessary to account in the water supply studies for the small amounts that would be spilled through wave or seiche action. Such spills will in some instances be replaced by subsequent inflows which would otherwise have spilled. In other instances, they will replace releases which would otherwise be required for meeting demands at the Tis Isat Falls and Powerplant.

Previous Studies and Plans

In their 1935 Report on Lake Tana, Outlet Works, and Ethiopian Highways, the J. G. White Corporation recommended a plan which would raise the maximum water surface elevation to 1789.07 meters as compared to the historic maximum of 1787.57; but for comparison, they presented a more costly plan, similar to that followed here, which assumed that the 1787.57 level should not be exceeded. (These elevations are given to the USC&GS datum used throughout this report, but in the following quotations from the J. G. White report, elevations are given to a datum 6.07 meters higher, and have not been adjusted). In Appendix V, List of Churches Located Near Lake Tana, the J. G. White Corporation described 85 locations at which there are either presently used churches or ruins and give elevations of all except Locations 77, 78, 81, 82, and 83, which they say are ruins. They summarize as follows (page 36):

TABLE III-114.-FLOOD FREQUENCIES AT DAMSITES

Damsite	Momentary peak inflow in cubic meters per second expected to be exceeded once in				
	5 years	10 years	25 years	50 years	100 years
Megech storage	310	370	420	480	520
Megech diversion	400	460	530	590	630
Ribb storage	470	540	620	690	750
Ribb diversion	630	710	810	850	960
Gumara storage	280	330	390	430	470
Gumara diversion	700	800	900	990	1,070
Beles irrigation diversion 1/	647	727	817	897	962
Dangur storage	2,850	3,030	3,400	3,700	3,900
Giamma storage	2,300	2,600	2,800	3,000	3,200
Chancho storage	360	420	490	540	590
Falls diversion	450	520	600	670	730
Bello storage and diversion	196	230	270	310	340
Motto storage	1,800	2,000	2,200	2,300	2,500
Amarti (w/o Neshe)	200	230	280	310	340
Neshe (w/o Amarti)	240	290	330	380	410
Amarti-Neshe (combined)	400	460	530	600	650
Neshe diversion 2/	35	42	50	60	65
Upper Birr storage	420	480	560	620	670
Selale diversion	27	33	42	50	56
Adefita diversion	8	12	14	19	20
Ghussa diversion	23	29	37	45	50
Debohila storage	73	90	110	128	140
Lower Birr diversion	860	980	1,100	1,200	1,300
Diddessa storage	1,700	1,900	2,100	2,300	2,400
Dabana storage and diversion	1,520	1,700	1,840	2,000	2,100
Boo storage	3,900	4,200	4,600	5,000	5,300
Angar storage	1,090	1,210	1,360	1,470	1,680
Lekkemt storage	1,970	2,180	2,350	2,550	2,700
Angar (6B) diversion	2,150	2,370	2,620	2,800	2,960
Junction storage	1,540	1,700	1,880	2,000	2,100
Dindir storage	2,100	2,300	2,500	2,700	2,900
Galegu storage	400	450	520	590	630
Rahad storage	1,840	2,000	2,200	2,400	2,500
Rahad diversion	1,890	2,090	2,300	2,440	2,610
Karadobi storage	8,000	8,600	9,200	10,100	10,400
Mabil storage	8,900	9,600	10,300	11,300	11,700
Mendaia storage	10,100	10,900	11,800	12,900	13,200
Border storage	11,200	11,900	12,900	13,800	14,400

1/Natural flood inflow plus 77 cu. m. per second power diversion from Lake Tana.
2/Flood inflow below storage dam plus 10 cu.m. per second power release.

TABLE III-115--LAKE TANA--HISTORICAL LAKE LEVEL AND OUTFLOW SUMMARY

Year	Maximum		In order of magnitude	Frequency 100(2m-1)/2n	Minimum		
					Gage height	Discharge	
	Gage height	Dis-charge				Recorded	Adjusted for inflow
1902	1,786.82	240	240	97.22	-	-	-
1915	1,787.04	350	255	91.67	-	-	-
1920	1,787.02	340	310	86.11	-	-	-
1921	1,787.05	350	320	80.56	1,785.46	3.40	3.40
1922	1,787.22	450	340	75.00	1,785.46	3.40	3.40
1923	1,787.28	490	350	69.44	1,785.62	8.70	8.70
1924	1,787.35	530	350	63.89	1,785.61	8.20	8.20
1925	1,786.85	255	350	58.33	-	-	-
1928	1,786.97	310	360	52.78	1,785.56	6.20	6.20
1929	1,787.57	710	449	47.22	1,785.65	10.00	10.00
1930	1,787.07	360	450	41.67	1,785.59	7.60	7.60
1931	1,787.00	320	490	36.11	1,785.52	5.00	5.00
1932	1,787.31	510	510	30.56	1,785.52	5.00	5.00
1933	1,787.06	350	524	25.00	1,785.52	5.00	5.00
1959	1,787.39	622 (9/25)	530	19.44	1,785.45	8.32 (6/21)	7.32
1960	1,787.16	449 (9/26)	583	13.89	1,785.55	10.20 (6/21)	8.20
1961	1,787.37	583.3 (9/21)	622	8.33	1,785.34	2.55 (6/21)	1.55
1962	1,787.31	524 (9/28)	710	2.78	1,785.54	10.20 (6/5)	8.20
Average	1,787.17		430		1,785.53		6.27
Sources:							
1959 -62	Project records adding 1,784.515 to staff	Project records			Project records	Project records	Recorded flow less 1 to 3, 1959-62
	(Reclamation Manual 6.4.36, Vol. IV, explains frequency column.)						
1902 -34	J. G. White, "1935 Report on Lake Tsana," Table IV, gives lake levels daily, 1902-24 and 1930; 10-day means, 1921 to 1934. J. G. White gave only 10-day means. Discharge is from gage height; 6.07 meters are here added to J. G. White's levels to secure C & GS datum.						

"The lowest church is at elevation 1782.5 and the lowest ruins at elevation 1781.5. Therefore, the scheme of development without any rise in the present maximum flood level of elevation 1781.5 would have no detrimental effect on churches and church ruins."

They also list (page 20) seven villages as being near the lake; of these, Fouri is the only one listed as having "tukuls" extending as low as elevation 1781:

"There are 20 tukuls located on a narrow ridge south and west of Fouri Church at Zegi. Most of these tukuls are affected by high-water conditions, although about 10 are located at elevation 1784. Most of them are in fair condition."

To the above-quoted elevations from the J. G. White report, 6.07 meters must be added to secure elevations to the datum established by the Coast and Geodetic Survey and used in accompanying plans. A tukul can be built for Eth$60 (US$24), and rights-of-way are often secured by the Governor assigning a new area.

There have been many studies of the possibility of a control works at Tana, and apparently those who preceded J. G. White assumed that water should not be allowed to reach above elevation 1787.57 (USC&GS datum).

Frequency Study of Annual July-September Inflow Volumes

A frequency study of the estimated annual July-September flood inflow was made to determine the adequacy of the proposed outlet works discussed below. Fifteen years of record are available on lake levels, lake discharge, or the Abbay (Blue Nile) flow a few kilometers downstream from the outflow point. Evaporation pan data at Bahir Dar (near the lake outlet) were used to compute average monthly evaporation on the lake (see Section IV). An area-capacity table, an evaporation-content graph, an elevation-outflow curve (Figure III-54), and estimated inflow between the outflow point and the Abbay (Bahir Dar) gage were utilized in conjunction with the lake level and outflow data to compute the estimated inflow as measured by change in storage in 10-day increments through the July-to-September flood period for each of the 15 years (Table III-116).

These yearly July-through-September totals were then plotted on probability paper by the modified California method, and a frequency curve was drawn (Table III-117 and Figure III-55).

Proposed Outlet Works and Operating Plan

The outlet works was designed to control the outflow from Lake Tana at the outflow point. Releases would only be made downstream to maintain flow as required for the Tis Isat Falls and Powerplant or to pass floods as necessary. The remainder of the water would be released through the Beles Tunnel at the southwest corner of the lake.

The operation plan was set up with the objective of keeping the lake level from exceeding the historical maximum of 1787.57 meters if possible. To do this it was found necessary to have the lake drawn down to elevation 1785.34 on June 30 of every year. Then, water can be stored until the lake level reaches elevation 1787.25. However, whenever it reaches this elevation the gates should be opened as necessary to try to avoid exceeding that elevation and should remain open until the water recedes to that elevation.

Determination of whether reservoir yields, obtained from construction according to these plans, would be commensurate with any damage done by slightly raising the average annual maximum lake level would appear to be something for the Ethiopian Government to decide. The same degree of regulation, while keeping the levels lower, can be accomplished by cutting the outlet channel deeper and providing larger gates. This will, of course, be done at increased construction costs. If more inundation while securing almost as much yield as is shown here can be tolerated, the reservoir can be operated at higher levels than are shown here as was recommended by the J. G. White Corporation, outlet costs can be reduced. This will be at the cost of increased evaporation loss.

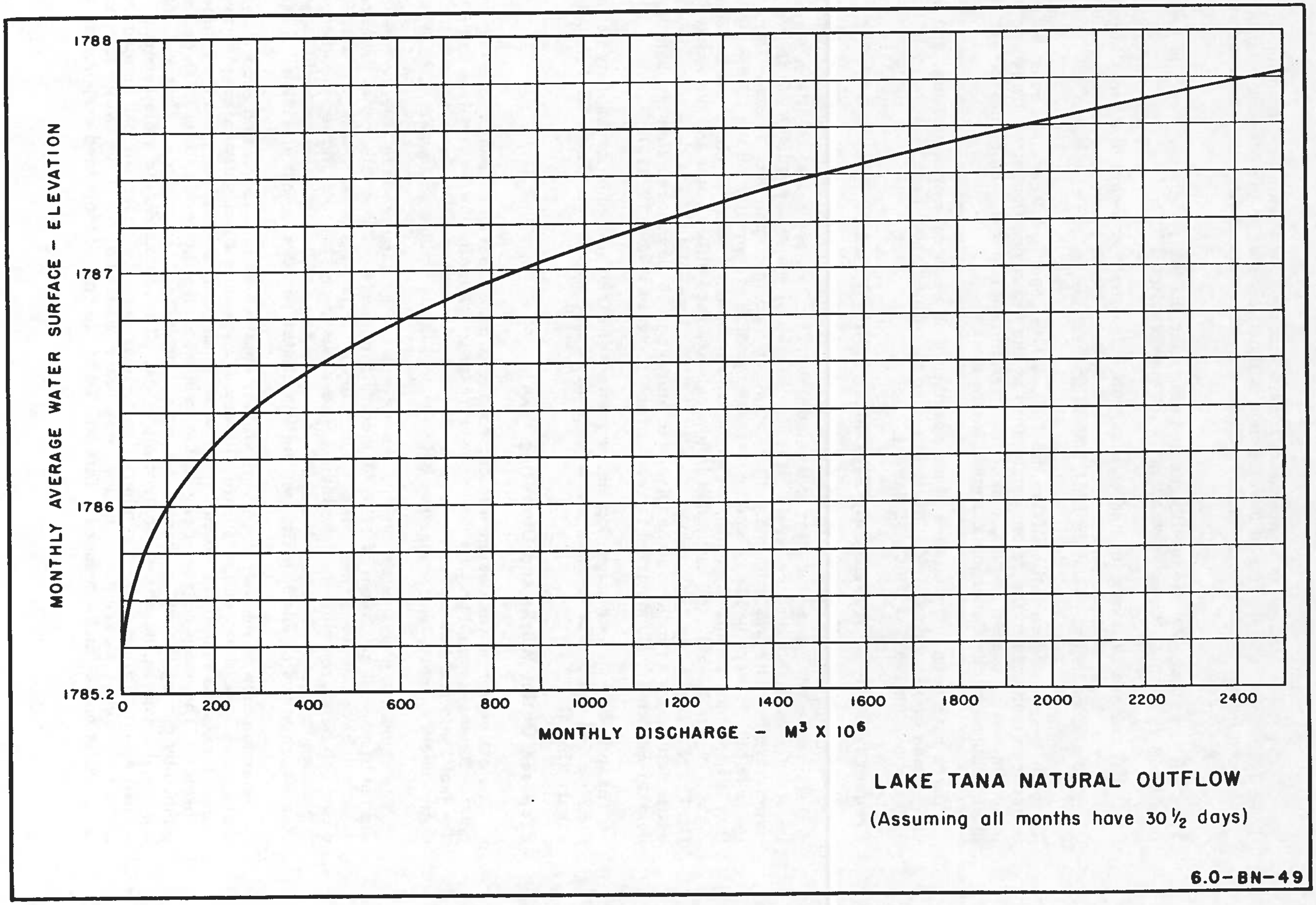


Figure III-54--Lake Tana Natural Outflow

TABLE III-116--LAKE TANA--ESTIMATED INFLOW

(Units are in million cubic meters)

Period	Historical outflow per day	Contents above El. 1783 m.		Evaporation loss	Inflow including precipitation on lake
		Average for period	End of period		
Year 1921			7,528		
Jul 1-10	0.5	7,651	7,836	169	482
11-20	0.9	8,020	8,360	108	641
21-	2.2	8,699	9,226	46	936
Aug 1-10	6.0	9,752	10,142	37	1,013
11-20	10.8	10,531	10,938	28	932
21-	17.8	11,344	11,548	28	834
Sep 1-10	22.6	11,753	11,895	29	602
11-20	25.9	12,037	12,132	38	534
21 -	28.8	12,226	12,010	57	223
					Jul-Sep 6,197
Year 1922			7,790		
Jul 1-10	0.9	8,020	8,298	169	686
11-20	1.9	8,575	8,932	108	761
21-	4.0	9,287	9,800	46	958
Aug 1-10	9.2	10,313	10,625	38	955
11-20	14.2	10,937	11,377	28	922
21-	23.3	11,817	12,196	29	1,104
Sep 1-10	34.0	12,574	12,686	29	859
11-20	37.5	12,797	12,781	38	508
21 -	37.2	12,765	12,749	57	397
					Jul-Sep 7,150
Year 1923			8,205		
Jul 1-10	1.4	8,328	8,590	170	569
11-20	2.6	8,853	9,225	108	769
21-	5.4	9,597	10,080	47	961
Aug 1-10	11.1	10,562	10,984	38	1,053
11-20	18.7	11,407	11,758	29	990
21-	26.7	12,100	12,337	29	902
Sep 1-10	34.0	12,574	12,717	29	749
11-20	38.4	12,860	12,972	38	677
21-	42.5	13,083	12,956	57	466
					Jul-Sep 7,136
Year 1924			8,252		
Jul 1-10	1.6	8,421	8,684	170	618
11-20	2.9	8,946	9,520	108	973
21-	7.9	10,095	10,454	47	1,068
Aug 1-10	13.1	10,812	11,125	38	840
11-20	18.8	11,438	11,974	29	1,066
21-	32.6	12,511	12,940	29	1,354
Sep 1-10	47.9	13,370	13,434	29	1,002
11-20	49.8	13,498	13,434	38	536
21-	47.6	13,370	13,210	58	310
					Jul-Sep 7,767
Year 1925			7,943		
Jul 1-10	0.9	8,020	8,051	169	286
11-20	1.0	8,082	8,375	108	442
21-	2.1	8,668	9,194	46	888
Aug 1-10	5.9	9,721	10,173	37	1,075
11-20	11.7	10,625	10,906	28	878
21-	16.2	11,187	11,344	28	644
Sep 1-10	19.3	11,501	11,627	29	505
11-20	22.6	11,753	11,738	38	375
21-	22.1	11,722	11,722	57	262
					Jul-Sep 5,355

Lake Tana--Estimated Inflow

Sheet 2 of 3

Period	Historical outflow per day	Contents above El. 1783 m. Average for period	End of period	Evaporation loss	Inflow including precipitation on lake
	(Units are in million cubic meters)				
Year 1928			8,174		
Jul 1-10	1.7	8,482	8,668	170	681
11-20	2.6	8,853	9,318	108	784
21-	6.2	9,783	10,001	47	798
Aug 1-10	8.7	10,219	10,578	38	702
11-20	14.3	10,937	11,298	28	891
21-	21.2	11,659	11,832	29	796
Sep 1-10	25.7	12,006	12,022	29	476
11-20	26.0	12,037	11,990	38	266
21-	24.6	11,943	11,801	57	114
					Jul-Sep 5,508
Year 1929			9,039		
Jul 1-10	3.8	9,225	9,442	171	612
11-20	5.7	9,659	10,373	109	1,097
21-	16.2	11,187	11,518	47	1,370
Aug 1-10	23.7	11,848	12,164	38	921
11-20	32.5	12,479	12,813	29	1,003
21-	43.9	13,147	13,514	29	1,213
Sep 1-10	58.5	13,882	14,139	29	1,239
11-20	70.2	14,396	14,316	39	918
21-	66.5	14,235	13,738	58	145
					Jul-Sep 8,518
Year 1930			8,838		
Jul 1-10	2.9	8,946	9,116	170	477
11-20	4.0	9,287	9,738	109	771
21-	7.6	10,188	10,500	47	893
Aug 1-10	13.1	10,812	11,000	38	669
11-20	16.2	11,187	11,297	28	487
21-	18.7	11,407	11,912	29	850
Sep 1-10	31.3	12,416	12,353	29	783
11-20	29.5	12,290	12,242	38	222
21-	28.2	12,195	11,974	57	71
					Jul-Sep 5,223
Year 1931			7,774		
Jul 1-10	0.6	7,774	7,928	169	329
11-20	1.0	8,082	8,328	108	518
21-	1.9	8,575	8,931	46	670
Aug 1-10	4.0	9,287	9,753	37	899
11-20	8.8	10,219	10,766	28	1,129
21-	17.5	11,313	11,518	28	973
Sep 1-10	21.9	11,722	11,880	29	610
11-20	25.9	12,037	12,068	38	485
21-	26.7	12,100	12,132	57	388
					Jul-Sep 6,001
Year 1932			8,020		
Jul 1-10	1.3	8,267	8,390	170	553
11-20	1.8	8,513	9,055	108	791
21-	5.3	9,597	10,095	46	1,144
Aug 1-10	11.3	10,593	10,859	38	915
11-20	15.9	11,125	11,566	28	894
21-	25.8	12,006	12,386	29	1,133
Sep 1-10	37.0	12,765	13,004	29	1,017
11-20	46.0	13,242	12,988	38	482
21-	36.2	12,733	12,606	57	37
					Jul-Sep 6,966

Lake Tana--Estimated Inflow

Sheet 3 of 3

(Units are in million cubic meters)

Period	Historical outflow per day	Contents above El. 1783 m. Average for period	End of period	Evaporation loss	Inflow including precipitation on lake
Year 1933			7,712		
Jul 1-10	0.6	7.774	7,958	169	521
11-20	1.1	8,143	8,143	108	304
21-	1.1	8,143	8,715	46	630
Aug 1-10	4.0	9,287	9,722	37	1,084
11-20	8.3	10,157	10,610	28	999
21-	15.2	11,062	11,534	28	1,119
Sep 1-10	25.6	12,006	12,148	29	899
11-20	29.6	12,290	12,337	38	523
21-	30.9	12,384	12,274	57	303
				Jul-Sep	6,382
Year 1959			7,405		
Jul 1-10	1.1	7,651	7,897	169	672
11-20	2.5	8,205	8,513	108	749
21-	4.8	8,884	9,318	46	904
Aug 1-10	10.1	9,690	10,126	37	946
11-20	16.8	10,625	11,125	28	1,195
21-	29.1	11,627	12,195	29	1,419
Sep 1-10	40.2	12,638	12,987	29	1,223
11-20	49.0	13,210	13,402	38	943
21-	52.5	13,434	13,402	58	583
				Jul-Sep	8,634
Year 1960			7,528		
Jul 1-10	1.0	7,805	7,989	169	640
11-20	2.0	8,267	8,452	108	591
21-	4.7	8,915	9,411	46	1,057
Aug 1-10	9.3	9,845	10,250	37	969
11-20	13.9	10,562	10,937	28	854
21-	21.9	11,407	11,880	28	1,212
Sep 1-10	29.5	12,100	12,416	29	860
11-20	34.2	12,543	12,638	38	602
21-	37.4	12,669	12,606	57	399
				Jul-Sep	7,184
Year 1961			7,774		
Jul 1-10	0.9	7,835	7,897	169	301
11-20	2.0	8,205	8,606	108	837
21-	4.7	8,946	9,380	46	872
Aug 1-10	8.6	10,001	10,687	38	1,431
11-20	21.3	11,250	11,659	28	1,213
21-	29.5	12,100	12,574	29	1,269
Sep 1-10	41.4	12,860	13,210	29	1,079
11-20	49.4	13,370	13,370	39	693
21-	49.3	13,338	13,274	58	455
				Jul-Sep	8,150
Year 1962			8,082		
Jul 1-10	1.1	8,174	8,421	169	519
11-20	2.2	8,668	9,070	108	779
21-	4.8	9,473	10,064	46	1,093
Aug 1-10	11.8	10,656	11,142	38	1,234
11-20	21.0	11,627	11,990	29	1,087
21-	30.2	12,353	12,686	29	1,057
Sep 1-10	41.0	13,019	13,130	29	883
11-20	46.0	13,242	13,226	38	594
21-	45.8	13,210	13,194	58	484
				Jul-Sep	7,730

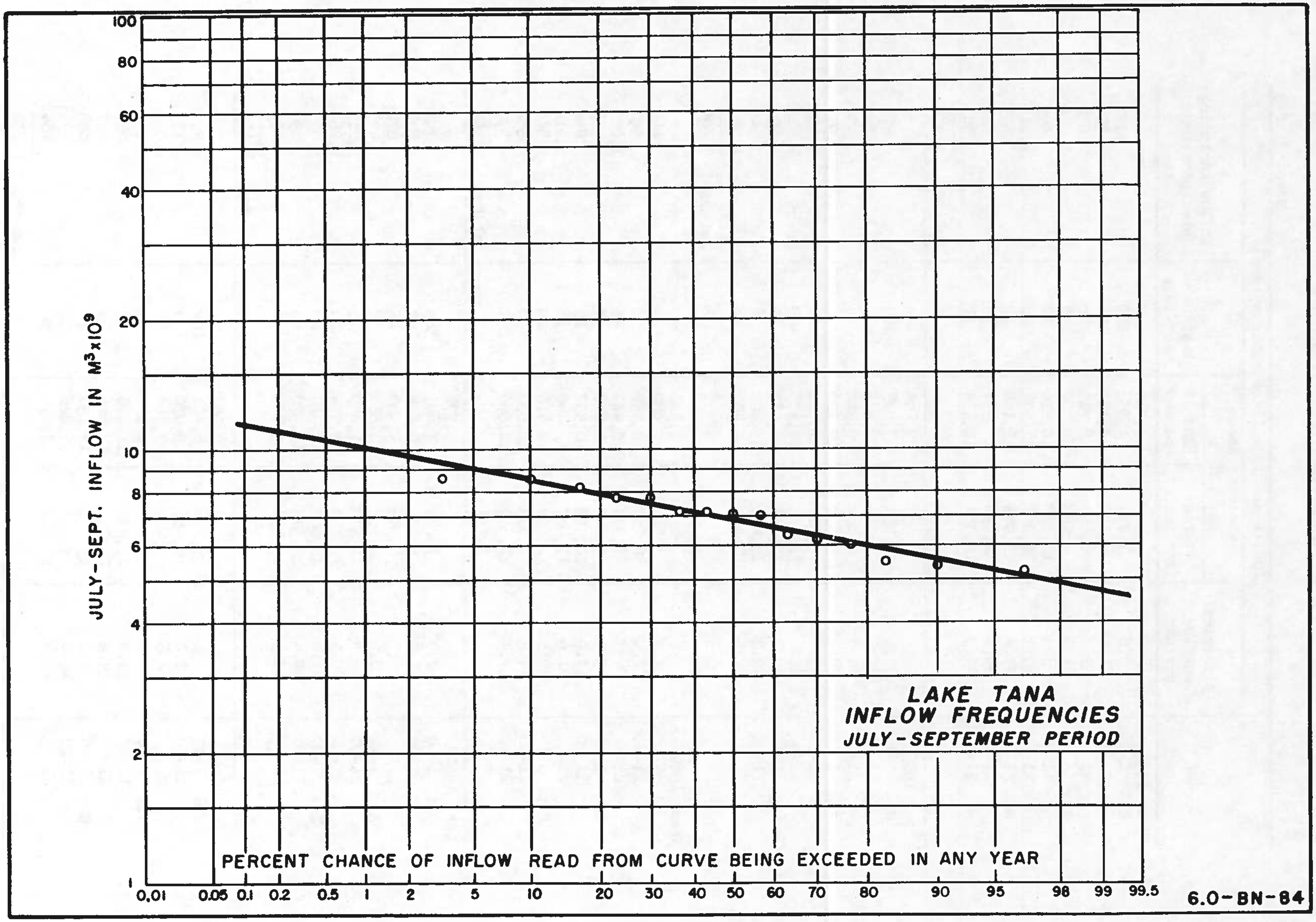


Figure III-55--Lake Tana Inflow Frequencies, July-September Period

TABLE III-117--LAKE TANA--FLOOD FREQUENCY

Year	July-September Lake Tana inflow (including precipitation on lake in million cu. m.)		m.	Percent chance = $100\frac{2m-1}{2n}$	Basic source of inflow estimate
	As estimated	In order of magnitude	m.		
1921	6,197	8,634	1	3.33	The Nile Basin, by H. E. Hirst for Ministry of Public Works, Egypt Phys. Dept., Paper 30, Vol. IV, Government Press, Cairo, 1933.
22	7,150	8,518	2	10.00	
23	7,136	8,150	3	16.67	
24	7,767	7,767	4	23.33	
25	5,355	7,730	5	30.00	
1928	5,508	7,184	6	36.67	
29	8,518	7,150	7	43.33	
1930	5,223	7,136	8	50.00	
31	6,001	6,966	9	56.67	
32	6,966	6,382	10	63.33	
33	6,382	6,197	11	70.00	
1959	8,634	6,001	12	76.67	Abbay Basin, Hydrologic Summaries 1961 and 1962, Abbay near Bahir Dar.
1960	7,184	5,508	13	83.33	
61	8,150	5,355	14	90.00	
62	7,730	5,223	15	96.67	
			n = 15		

As the lake level recedes over the October-through-May period, cattle graze, and there is some farming, on the recently inundated margin of the lake. Drying out of the grass occurs after any particular spot has been unwatered for about a month, except as roots may extend to the water table in areas only slightly above the remaining lake level. It follows that the amount of grazing available around the lake will not change greatly, regardless of what operation plan may be adopted. However, all reservoir operation plans must necessarily smooth out the historical lake yield in order to be justified. That is, outflow immediately after the rainy season must be less than that on record historically, and outflow before the rainy season must be more, in order to secure a fairly constant dry-season outflow. This means that in order to secure any use from a reservoir, the grazing strip must recede down the slope more slowly in the post-rainy season and more rapidly in the prerainy season than it has historically. Lowering the level to which the lake recedes will of course extend the distance to which the grazing strip advances into areas historically occupied by the lake. Since a slower withdrawal of the lake's contents will keep grass inundated over a longer period, it may be desirable to secure expert advice as to whether perennial grasses can tolerate such long periods of inundation and as to whether these areas are presently grassed over by perennials or annuals. There is also the possibility that annuals will come in and provide forage as palatable as any perennials now growing. Plans outlined in this report provide for lowering the lake to elevation 1783.80 when required to sustain the desired yield. The corresponding limit set by J. G. White was 1785.07. It would be physically possible under these plans to draw the water surface to elevation 1783.00; but 80 centimeters of head on the permanent spillway crest is required for meeting demands of the powerplant and scenic value of Tis Isat

Falls. Minor lowering of the annual minimum water surface is not expected to cause any significant inconvenience. Additional lowering and lower operation in general, as discussed above, would permit the saving of some evaporation losses, and, until upstream depletion takes place, it would, by reducing spills, increase firm yield of the reservoir by about 30 percent.

Following a discussion of "lowering the minimum level of the lake amounting to 35 to 65 centimeters in a low year and to 60 to 90 centimeters in a normal year," the J. G. White Corporation says (page 39):

> "In our opinion, a lowering of the lake level in every year by the amounts mentioned above might also result in undesirable changes in existing conditions around the lake."

They do not say what undesirable changes they think might occur. However, it seems desirable to consider advantages obtained by going somewhat below historical levels in accompanying plans. The following table shows content of Lake Tana in relation to water surface elevation. As has been indicated, no water can be stored above elevation 1787.25 (content 12,987 million cubic meters) with the intention of using it under the plans discussed in this report. Capacity available for use therefore increases as follows:

Content of Lake Tana in Relation to Elevation

With drawdown to elevation	Total usable capacity below elevation 1787.25	
	Million cubic meters	Percent of that at elevation 1785.53
1785.53	5,367	100
1785.25	6,226	116
1785.07	6,775	126
1783.80	10,604	198

Flood Routings

The July-through-September inflow for 1959 (the largest quantity of record) was used as the base and a flood from a 15-day rain was added to this base as shown on Figure III-56 to obtain the total inflow to be routed. This 3-month flood with a peak of 5,150 m^3/s and a volume of 10,044 million m^3 was routed through the proposed outlet works under the following criteria:

1. The Beles Tunnel would be discharging at the rates shown in the operation study (Table III-129, Section IV).

2. The lake would be at elevation 1785.34 on June 30.

3. The gates would be opened whenever the lake reached elevation 1787.25 and remain open until the water receded to this 1787.25 elevation.

This flood (routed on Table III-118, using Discharge Curve, Figure III-57) is the maximum 3-month inflow (10,044 million cubic meters) that can be passed under the given criteria without exceeding the maximum historical lake elevation of 1787.57. The frequency curve (Figure III-55) indicates that this flood has a 1 percent chance of occurring in any one year (commonly called a 100-year flood). This same inflow flood was routed through the present natural outlet (Table III-119) with a resultant maximum elevation of 1787.70 (13 centimeters higher than the historical maximum).

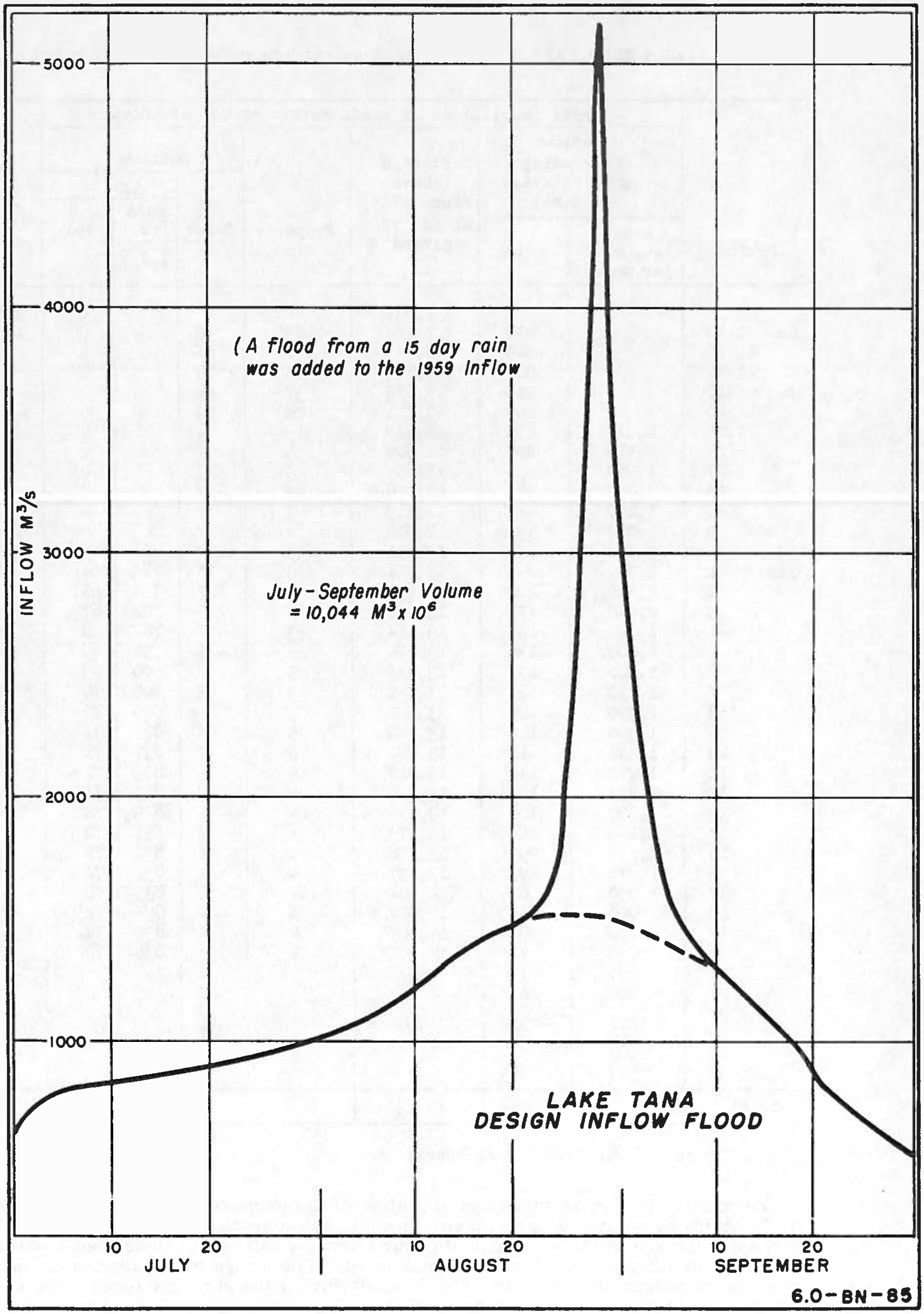


Figure III-56--Lake Tana--Design Inflow Flood

TABLE III-118--LAKE TANA FLOOD ROUTING THROUGH PROPOSED OUTLET WORKS

Period	Units in millions of cubic meters except as shown							Lake surface elevation at end of period (m.)
	Inflow (including precipitation on lake)		Storage (above elev. 1783) at end of period	Evaporation	Outflow			
						Spill		
	Mean (cu. m. per sec.)	Vol.			Beles	Mean (cu. m. per sec.)	Vol.	
			7,037				0	1785.34
Jul 1-10		672	7,474	169	66		0	
11-20		749	8,049	108	66		0	
21-31		904	8,833	46	74		0	
Aug 1-10		946	9,673	37	69		0	
11-20		1,195	10,771	28	69		0	
21-25	1,610	695	11,419	13	34		0	
26	2,310	200	11,609	3	7		0	
27	2,960	256	11,855	3	7		0	
28	3,850	333	12,178	3	7		0	
29	5,150	445	12,613	3	7		0	
30	3,920	339	12,942	3	7		0	1787.24
31	3,170	274	13,151	3	7	1/	55	87.30
Sep 1	2,700	233	13,311	3	6	743	64	87.35
2	2,340	202	13,437	3	7	761	66	87.39
3	2,040	176	13,537	3	6	772	67	87.42
4	1,790	155	13,614	3	7	787	68	87.45
5	1,600	138	13,674	3	6	794	69	87.46
6	1,520	131	13,726	3	7	800	69	87.48
7	1,450	125	13,772	3	6	809	70	87.50
8	1,390	120	13,812	3	7	809	70	87.51
9	1,350	117	13,849	3	6	817	71	87.52
10	1,310	113	13,881	3	7	817	71	87.53
11	1,270	110	13,910	4	6	823	71	87.54
12	1,230	106	13,934	4	7	823	71	87.55
13	1,200	104	13,956	4	6	829	72	87.55
14	1,160	100	13,973	4	7	831	72	87.56
15	1,120	97	13,988	4	6	831	72	87.56
16	1,070	92	13,997	4	7	831	72	87.57
17	1,030	89	14,004	4	6	835	72	87.57
18	990	86	14,007	4	7	835	72	87.57
19	950	82	14,007	4	6	835	72	87.57
20	890	77	14,001	4	7	835	72	87.57
21	850	73			6			
22	800	69			7			
23	750	65			6			
24	720	62			7			
25	680	59			6			
26-30	590	255			33			
Total		10,044						

1/ 730 cu. m. per sec. for 21 hours.

Therefore, the construction and operation of the proposed structures should not worsen flood conditions surrounding the lake. In fact, some small benefit should result. No increased damage to the area should occur from the infrequent (less than 1 percent chance) floods larger than the outlet works can control. The entire outlet area is on hard volcanic rock, so no appreciable erosion should result during the rare instances when some water may go around the outlet structure.

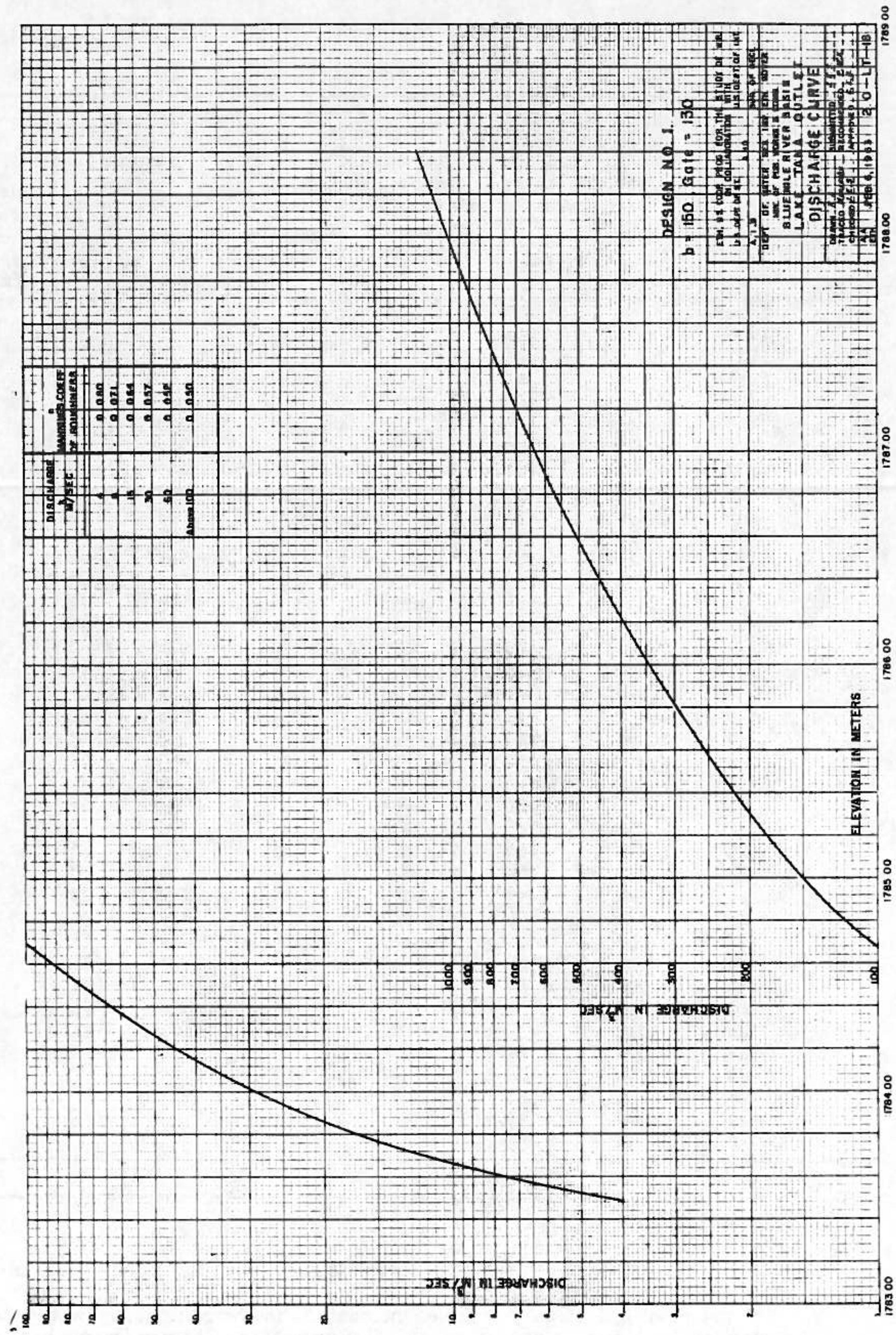


Figure III-57--Lake Tana Outlet--Discharge Curve

TABLE III-119--LAKE TANA FLOOD ROUTING THROUGH NATURAL OUTLET

Period	Units in millions of cubic meters except as shown						Lake surface elevation at end of period (m.)
	Inflow (including precipitation on lake)		Storage (above elev. 1783) at end of period	Evaporation	Natural outflow		
	Mean (cu. m. per sec.)	Vol.			Mean (cu. m. per sec.)	Vol.	
Jul 1-10		672					
11-20		749					
21-31		904					
Aug 1-10		946					
11 20		1,195	11,125				1/ 1786.66
21-25	1,610	695	11,712	13	220	95	86.85
26	2,310	200	11,886	3	270	23	86.90
27	2,960	256	12,114	3	295	25	86.97
28	3,850	333	12,415	3	337	29	87.07
29	5,150	445	12,822	3	402	35	87.20
30	3,920	339	13,118	3	462	40	87.29
31	3,170	274	13,345	3	515	44	87.36
Sept 1	2,700	233	13,526	3	565	49	87.42
2	2,340	202	13,673	3	600	52	87.46
3	2,040	176	13,791	3	635	55	87.50
4	1,790	155	13,885	3	670	58	87.53
5	1,600	138	13,961	3	680	59	87.55
6	1,520	131	14,028	3	703	61	87.58
7	1,450	125	14,088	3	718	62	87.59
8	1,390	120	14,142	3	730	63	87.61
9	1,350	117	14,191	3	750	65	87.63
10	1,310	113	14,235	3	765	66	87.64
11	1,270	110	14,275	4	765	66	87.65
12	1,230	106	14,309	4	790	68	87.66
13	1,200	104	14,341	4	790	68	87.67
14	1,160	100	14,367	4	810	70	87.68
15	1,120	97	14,390	4	810	70	87.69
16	1,070	92	14,408	4	815	70	87.69
17	1,030	89	14,422	4	827	71	87.70
18	990	86	14,433	4	827	71	87.70
19	950	82	14,440	4	827	71	87.70
20	890	77	14,442	4	827	71	87.70
21	850	73	14,438	6	827	71	87.70
22	800	69					
23	750	65					
24	720	62					
25	680	59					
26-30	590	255					
Total		10,044					

1/Lake level August 20, 1959.

FINCHAA

The principal hydrologic feature of the basin is the large Chomen Swamp (see Frontispiece). Map data are not exact. The area of the Chomen Swamp has been estimated as from 500 to 600 square kilometers. A stream gage has been installed

C_1 is a factor to be multiplied against current inflow to the storage (i.e., swamp) area

C_2 is a factor to be multiplied against the immediately previous outflow from the storage (i.e., swamp) area, such that

$C_1 + C_2$ gives current outflow from the storage (i.e., swamp) area.

$$\text{This gives } C_2 = \frac{160 - 0.5(6)}{160 + 0.5(6)} = \frac{157}{163} = 0.963$$

$$C_1 = \frac{6}{160 + 0.5(6)} = \frac{6}{163} = 0.0368$$

say = 0.037

These C_1 and C_2 factors were applied to the swamp inflow hydrograph (Table III-120); then the rain on Finchaa Reservoir was distributed as in Table III-83 and then adjusted to give flows at 6-hour intervals and added; and finally an estimated base flow of 50 cubic meters per second was added to obtain the inflow design flood as on Table III-122 with a peak of 1,195 cubic meters per second and a 10-day volume of 279.7 million cubic meters.

To determine the flood frequencies, the peak flow recorded each year was used to compute plotting positions as in the general flood frequency procedure.

Year	Average (cu. m. per sec.) Maximum day	Average (cu. m. per sec.) In order	m	(2m - 1)	$\frac{2m-1}{2n}$
1959	45.1	38.0	1	1	0.1
1960	53.3	45.1	2	3	0.3
1961	51.2	49.6	3	5	0.5
1962	49.6	51.2	4	7	0.7
1963	38.0	53.3	5	9	0.9
					n = 5 2n = 10

These points were plotted on Figure III-58 and a frequency curve was drawn. From this curve the following frequency values were read.

5 yr. = 53 cu. m. per sec.
10 yr. = 53 cu. m. per sec.
25 yr. = 54 cu. m. per sec.
50 yr. = 54 cu. m. per sec.
100 yr. = 54 cu. m. per sec.

Flood frequencies at the downstream power and irrigation dams were derived as given below:

TABLE III-120--FINCHAA FLOOD HYDROGRAPH FOR AREA ABOVE RESERVOIR

(Disregarding swamp delay)

$$T_p = 0.749 \frac{ad}{q_p} = \frac{0.749 \times 1,221 \times 10^6 \times 0.209}{3,100} = 61,700 \text{ seconds}$$

a = drainage area in square meters = $1,221 \times 10^6$

d = depth of runoff in meters = 0.209

q_p = flood peak in cu. m. per sec. = 3,100

T/T_p	q/q_p	Time in thousand seconds	Hydrograph in cu. m./sec.
0	0	0	0
0.1	0.015	6	47
0.2	0.075	12	232
0.3	0.16	18	496
0.4	0.28	25	868
0.5	0.43	31	1,333
0.6	0.60	37	1,860
0.7	0.77	43	2,387
0.8	0.89	49	2,759
0.9	0.97	55	3,007
1.0	1.00	62	3,100
1.1	0.98	68	3,038
1.2	0.92	74	2,852
1.3	0.84	80	2,604
1.4	0.75	86	2,325
1.5	0.66	92	2,046
1.6	0.56	99	1,736
1.8	0.42	111	1,302
2.0	0.32	123	992
2.2	0.24	136	744
2.4	0.18	148	558
2.6	0.13	160	403
2.8	0.098	173	304
3.0	0.075	185	232
3.5	0.036	216	112
4.0	0.018	247	56
4.5	0.009	277	28
5.0	0.004	308	12

5. Using above volume of runoff and peak discharge, a flood hydrograph for area above the reservoir was computed (Table III-120). This computation gives a design flood such as would occur from an area of 1,221 square kilometers if its timing were unaffected by swamp action.

6. A procedure for evaluating the routing effect of unmeasurable upstream storage was developed. A flood hydrograph that included storage effect was reconstructed by computing a flood unaffected by storage, and then routing the flood for storage effect by using the time-of-storage, T_s, indicated by the recession of Finchaa flood hydrographs.

7. Decline in reservoir outflow was examined in the period following the maximum outflow for each year of record (Table III-121). Such periods were selected because the swamp will sustain flow to a greater extent when it is full than when it is empty. The difficulty in estimating degree to which flow is sustained by the swamp alone is that there may be some rain on the swamp over any such period as may be selected, and it may be incorrectly inferred that a relatively slight decline in outflow was attributable to storage action of the swamp, while it was really attributable to new inflow from the rain. The maximum decline in outflow for any 10-day period (Table III-121) is 9.8 cubic meters per second in the October 2 to 12, 1960 period, or 0.98-cubic-meter-per-second per day. In other years, declines range from 0.53 to 0.74-cubic-meter-per-second per day. A decline of 0.9-cubic-meter-per-second per day was adopted as representative of sustaining power of the swamp at high flows. Treating this decline in swamp outflow as though it were a decline in groundwater outflow during a period of no recharge, it may be expected to plot as a straight line, when time is plotted on an arithmetic scale and quantity is plotted on a logarithmetic scale, just as the recession hydrograph plots as a straight line on Figure 10B (3) of Design of Small Dams. The formula given there for computing a 1-hour recession constant is

$$k_{(1\ hr)} = \sqrt[t]{\frac{q_t}{q_0}}$$

where t = number of hours between measuring of q_0 and q_t

TABLE III-121--FINCHAA RIVER FLOW NEAR COCHION

Period	Cu. m./sec.
1962, Oct. 10	48.5
Oct. 20	43.2
10-day decline	5.3
1961, Oct. 13	50.1
Oct. 23	42.7
10-day decline	7.4
1960, Oct. 2	49.4
Oct. 12	39.6
10-day decline	9.8
1959, Oct. 12	41.2
Oct. 22	34.4
10-day decline	6.8

q_0 = discharge at time 0

q_t = discharge at t hours later

It is estimated that $k_{(24\ hrs)}$ in this formula equals 0.9, from which $k_{(1\ hr)} = \left(k_{(24\ hrs)}\right)^{\frac{1}{24}} = (0.9)^{\frac{1}{24}}$

$$\text{Log } u^n = n \text{ Log } u \text{ or Log } (0.9)^{\frac{1}{24}} = \frac{1}{24} \text{ Log } 0.9$$

$$\text{Log } 0.9 = 9.954243 - 10$$

$$= -0.045757$$

$$\frac{1}{24} \text{ Log } 0.9 = -0.0019065417$$

$$= 9.9980934583 - 10$$

$$(0.9)^{\frac{1}{24}} = 0.9954 = k_{(1\ hr)}$$

Time-of-storage factor for the swamp at its present size may then be derived from the formula

$$T_s = \frac{-1}{\text{Log}_e\, k_{(1\ hr)}} = \frac{-1}{2.3026\ \text{Log}_{10}\, k_{(1\ hr)}}$$

$$= \frac{-1}{2.3026\ (-0.0019065417)} = 228$$

However, the swamp has an area of about 600 square kilometers at present, and by inundating 170 square kilometers of this with the reservoir, the area would be reduced to 430 square kilometers. Assuming the time-storage factor for the swamp would be reduced accordingly, it becomes

$$T_s = 228\ \left(\frac{430}{600}\right) = 163$$

$$\text{say} = 160$$

A 6-hour routing interval was adopted.

Clark1/ finds:

$$C_1 = \frac{T}{T_s + 0.5T},\quad C_2 = \frac{T_s - 0.5T}{T_s + 0.5T}$$

where T = routing interval, in this case 6 hours

T_s = 160 (see above)

1/Clark, C. O., "Storage and the Unit Hydrograph," Proceedings ASCE, Vol. 69, 1943, p. 1333.

just below the damsite, and discharge records are available from May 1959 through December 1962. These records show that streamflow increases gradually from the beginning of the rainy season to a maximum in September or October and there is then a gradual recession. Maximum annual daily discharges are listed below.

Finchaa near Cochion Maximum Daily Flows		
Calendar year	Discharge cu. m. per sec	Date
1959	49.1	September 13, 16, and October 9
1960	53.3	September 19, 21, and 22
1961	51.2	October 9
1962	49.6	October 4, 5, 6, and 7
1963	38	(only one reading presently available)

Runoff from the surrounding mountains enters the swamp area and is temporarily stored. There appear to be no drainage channels entirely traversing the swamp.

The proposed reservoir above Finchaa damsite will inundate approximately 170 square kilometers (65 square miles) of the swamp. There is not sufficient topographical mapping to outline the reservoir boundaries accurately.

The following assumptions have been made for computing a reconnaissance inflow design flood:

1. The swamp area will continue to exert a major storage effect on runoff from the surrounding mountains.

2. The storage effect of the swamp can be approximated by routing inflow to it through a storage time obtained from recession data of recorded inflows at the Finchaa gage.

3. Inflow to the swamp can be estimated by employing design storm data and procedures used in development of design floods for other parts of the Blue Nile Basin.

An inflow design flood was computed as follows:

1. Drainage area 1,391 square kilometers (536 square miles)--two-day design rain equals 0.282 meter (see Figure III-45).

2. Assume 600 square kilometers (230 square miles) as swamp area. Assume reservoir area will inundate 170 square kilometers, leaving a balance of 430 square kilometers of swamp.

3. Assume area not included in swamp and reservoir equals 791 square kilometers (i.e., 1,391 less 600). Runoff volume from this area would be 0.17 meter (from Figure III-47). No retention rate is applicable to rain on swamp area. Volume of runoff from basin area, excluding reservoir surface:

   From hills: $0.17 \times 791 (10)^6 = 134 (10)^6$ cubic meters

   From swamp: $0.282 \times 430 (10)^6 = 121 (10)^6$ cubic meters

   Total: $255 (10)^6$ cubic meters (3,882 sq mi inches) (This equals 0.209 meter from 1,221 square kilometers.)

   or 8.25 inches over 471 square miles, above the reservoir surface.

4. From Figure III-46, design peak discharge for 1,221 square kilometers is 3,100 cubic meters per second.

TABLE III-122--INFLOW DESIGN FLOOD--FINCHAA STORAGE DAM

(10-day volume = 279.7 million cubic meters)						
	Flow in cubic meters per second					
Time (hrs.)	Swamp inflow	C_1 (0.037)	C_2 (0.963)	Rain on reservoir	Base flow	Total
0	0	0	0	0	50	50
6	680	25	0	230	50	305
12	2,400	88.8	24.1	450	50	612.9
18	3,040	112.5	108.7	680	50	951.2
24	2,220	82.1	213.0	850	50	1,195.1
30	1,340	49.6	284.2	0	50	383.8
36	810	30.0	321.4		50	401.4
42	480	17.8	338.4		50	406.0
48	290	10.7	343.0		50	403.7
54	180	6.7	340.6		50	397.3
60	105	3.9	334.4		50	388.3
66	60	2.2	325.8		50	378.0
72	40	1.5	315.9		50	367.4
78	25	0.9	305.7		50	356.6
84	15	0.6	295.3		50	345.9
90			285.0		50	335.0
96			274.4		50	324.4
102			264.2		50	314.2
108			254.4		50	304.4
114			245.0		50	295.0
120			235.9		50	285.9
126			227.2		50	277.2
132			218.8		50	268.8
138			210.7		50	260.7
144			202.9		50	252.9
150			195.4		50	245.4
156			188.2		50	238.2
162			181.2		50	231.2
168			174.5		50	224.5
174			168.0		50	218.0
180			161.8		50	211.8
186			155.8		50	205.8
192			150.0		50	200.0
198			144.4		50	194.4
204			139.1		50	189.1
210			134.0		50	184.0
216			129.0		50	179.0
222			124.2		50	174.2
228			119.6		50	169.6
234			115.2		50	165.2
240			*110.9		50	160.9

*Discharge may be extended by $K_{6hr} = 0.963$.

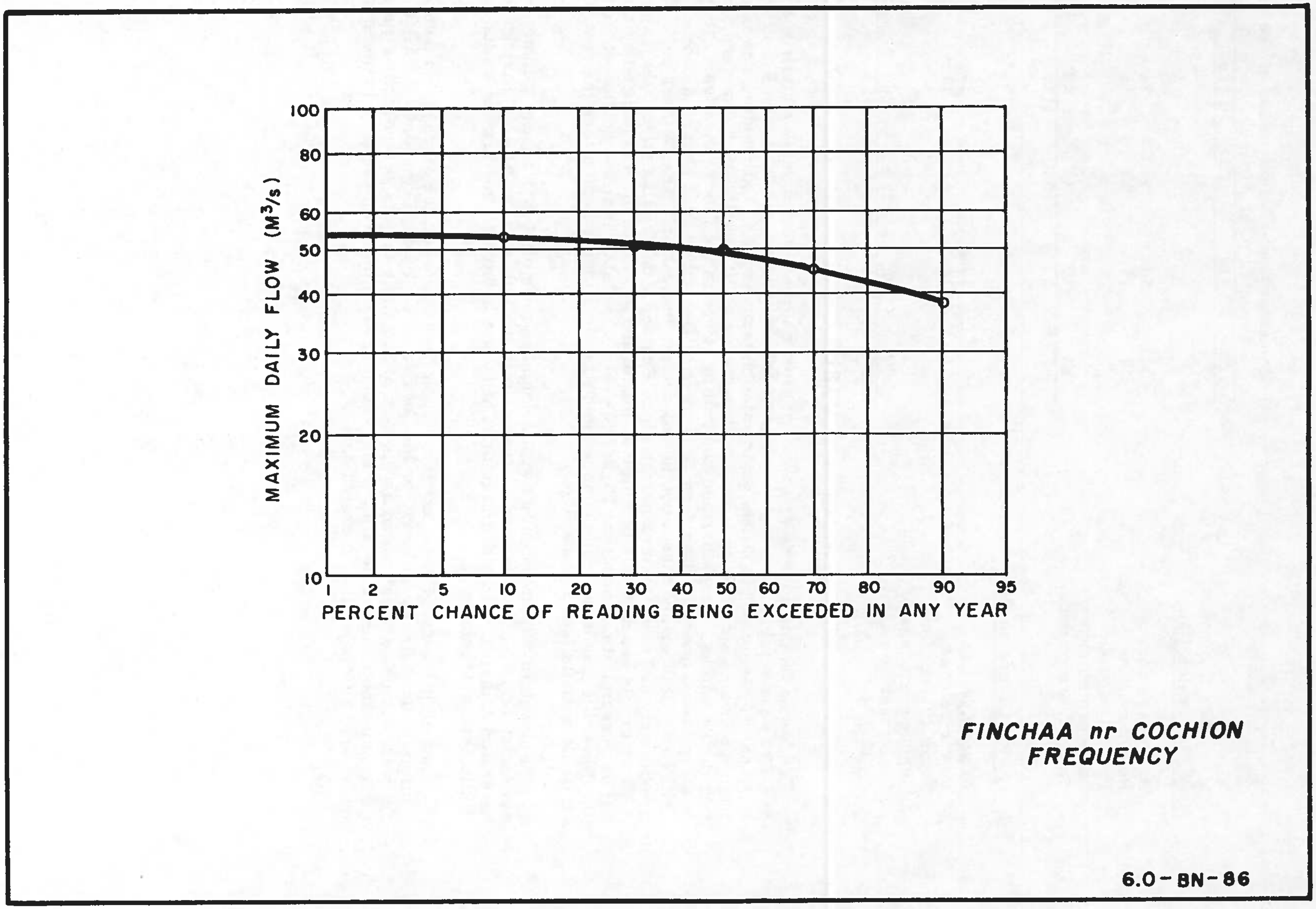


Figure III-58--Finchaa near Cochion Frequency

	Momentary peak inflow in cu. m. per sec. expected to be exceeded once in:				
	5 yrs.	10 yrs.	25 yrs.	50 yrs.	100 yrs.
Power Diversion Dam					
At storage dam	53	53	54	54	54
Power release	11	11	11	11	11
From 21 sq. km. between storage and diversion dam	23	30	38	46	52
TOTAL	87	94	103	111	117
Irrigation Diversion Dam					
At storage dam	53	53	54	54	54
Power release	11	11	11	11	11
From 195 sq. km. between storage and diversion dam	160	190	220	260	290
TOTAL	224	254	285	325	355

DABUS

The Dabus Swamp covers an area of approximately 900 square kilometers of a total of 8,030 square kilometers of drainage area above the swamp outlet (see Frontispiece). One year of record at the Dabus gaging station near Asosa, 50 kilometers downstream from the swamp outlet, with a total drainage area of 10,100 square kilometers, indicates that the swamp has a considerable controlling effect on the flow of the river. Gage height readings taken every 10 days from July through December 1962 showed a continuous rise until early October and then a continuous decline thereafter. The October peak was approximately 500 cubic meters per second. Besides a controlling effect, the swamp has a considerable consumption of water by plants and evaporation as evidenced by a low run-off vs. precipitation ratio (see Figure III-44). The Dabus is in the southwest portion of the Blue Nile Basin, which has more rainfall over a longer period than the rest of the basin as a whole (see Figure III-4).

The power diversion damsite, with a drainage area of 10,355 square kilometers, is approximately 15 kilometers downstream from the Dabus gage, while the irrigation diversion damsite, with a drainage area of 10,438 square kilometers, is an additional 4 kilometers downstream.

Since both diversion dams are low structures with negligible storage, no potential damage to downstream property or loss of life is involved. Therefore, the 5- to 100-year frequency floods are estimated as the sum of 500 cubic meters per second at the swamp outlet plus the expected peak for a storm centered on the drainage area between the swamp outlet and the respective diversion dam.

These flood peaks are tabulated below.

Item	Flood peaks (cu. m. per sec.)				
	5 yr.	10 yr.	25 yr.	50 yr.	100 yr.
Power Diversion Dam (10,355 sq. km. total drainage area)					
Swamp discharge (from 8,030 sq. km.)	500	500	500	500	500
Expected peak from 2,325 sq. km. (Figure III-46)	1,370	1,510	1,670	1,810	1,940
Total peak expected	1,870	2,010	2,170	2,310	2,440
Irrigation Diversion Dam (10,438 sq. km. total drainage area)					
Swamp discharge (from 8,030 sq. km.)	500	500	500	500	500
Expected peak from 2,408 sq. km. (Figure III-46)	1,420	1,560	1,730	1,870	2,000
Total peak expected	1,920	2,060	2,230	2,370	2,500

Flood Routings

The maximum probable floods were routed through the proposed reservoirs and spillways to determine the maximum water surfaces given on the dam drawings.

Tailwater Curves

Tailwater curves were prepared only where necessary to determine tentative powerplant locations and cofferdam heights. Data for this purpose were very meager. The procedure usually followed was to derive a coefficient of friction (Mannings "n") from the stage-discharge relationship at some nearby gaging station; estimate the slope and depth-area relationship at the damsite; and then, using the value "n," compute the stage-discharge relationship at the damsite.

SECTION IV--WATER USE STUDIES

Existing Development of the Nile Basin

The following is a brief description of Nile Basin development. Pertinent locations below the Ethiopian-Sudan border are indicated on Figure III-59. "Abbay," Amharic name for the Blue Nile, is the name used herein for that portion of the Blue Nile Basin lying within Ethiopia. The following sources were drawn upon:

	Reference
Capacities of existing reservoirs and descriptions of their operation were drawn primarily from Agriculture in Sudan by J. D. Tothill, Oxford University Press, 1948.	A
Pamphlets pertaining to irrigation development in the Sudan:	
The Gezira Scheme from Within, edited by the Press and Information Officer, The Sudan Gezira Board, 1959.	B
The Managil Extension, issued by Ministry of Social Affairs, Republic of the Sudan.	C
Irrigation and Power Development in the Sudan, Ministry of Irrigation and Hydroelectric Power, November 1961.	D
The Gezira Scheme, by H. Ferguson, B.Sc., N.D.A., N.D.D., Research Division, Sudan Ministry of Agriculture, reprinted from World Crops, Volume IV, Nos. 1, 2, and 3, January, February, and March, 1952 (with postscript).	E
Sudan Irrigation, published by the Ministry of Irrigation and Hydroelectric Power, Khartoum, 1957.	F
Engineering News-Record, February 23, 1961: "Construction Begins on Aswan Dam--Russian Style."	G

Ethiopia is now building a run-of-river hydroelectric plant at Tis Isat Falls below Lake Tana. Initial installation will consist of two units, each of 10-cubic-meters-per-second and 4,800-kv.-a. capacity. The installation is ultimately expected to be expanded to three units. There are small hydroelectric plants at Ambo and Debre Birhan of 210- and 125-kv.-a. capacity, respectively. There are hydromechanical mills for grinding grain, and small, direct-diversion, irrigation canals 1 or 2 kilometers in length at several locations on the plateau. There are no known developments of the water in the Blue Nile River Basin, at intermediate to low elevations, in Ethiopia.

The principal development on the Blue Nile in Sudan, downstream from the Ethiopia-Sudan border, is the Gezira Irrigation Project which is being expanded from its present area of about 1,000,000 acres (405,000 hectares) to an area of about 2,000,000 acres (809,000 hectares). For many years, the Gezira Project has been dependent upon Sennar Dam and run-of-river diversions for its supply, but Roseires Dam is being built to provide additional regulation.

There are two reservoirs on the White Nile above the confluence with the Blue Nile at Khartoum, and Aswan Dam on the main Nile in Egypt is currently being rebuilt 6 kilometers above the former one and to much greater capacity.

Sudan is building an excellent stream-gaging station with radio reporting on the Blue Nile a short distance below the Ethiopian border. Even though Ethiopia maintains a station above the border, Sudan's station may be necessary for rapid reporting of flood flows which have to be handled at the prospective Roseires and Sennar Dams.

As now under construction, or contemplated for construction in the near future, the several reservoirs in the Nile Basin have capacities as follows:

Reservoir	Stream	Source of capacity data	Conservation capacity before sedimentation (million cubic meters)
Roseires	Blue Nile	Ref. D p. 19	1/7,300
Sennar	Blue Nile	Ref. A p. 594	780
Lake Victoria	White Nile	Ref. F p. 60	200,000
Jebel Aulia	White Nile	Ref. A p. 594	3,500
Aswan	Main Nile	Ref. A p. 594	
(Original 1902)			1,000
(First raising 1912)			2,400
(Second raising 1933)			4,800
Under construction 1961 to 1968		Ref. G p. 38	130,000

1/ Initial to be 2.7; 4.6 to be added.

For comparison, it may be observed that 1912-1942 average annual flow at the Aswan site was 82,000 million cubic meters.

On the Gezira Project, only half the irrigable area is cultivated in any year. One reason for leaving so much land fallow is shortage of water available to Sudan.

At present, Sennar fills to a content of 333 million cubic meters, beginning either on July 15, or when total flow at Roseires and Malakal gaging stations reaches 166 million cubic meters per day. This is an adequate content for diverting water at full capacity of the Gezira Canal. Some sediment accumulates in the bottom of Sennar Reservoir when held at this capacity, but project officials believe that it is largely washed out of the reservoir during subsequent periods of low content.

During the period October 17 to November 30, Sennar Reservoir is filled to capacity from the relatively sediment-free inflow. Because capacity contemplated by Sudan is fairly small with respect to total flow of the Abbay, it appears possible that Sudan can fill the Roseires Reservoir with the relatively sediment-free water at the close of the flood season. An inactive capacity of 30,000 million cubic meters for sedimentation, or to meet minimum power head, has been provided at Aswan, and 30,000 million cubic meters have been provided for flood control, leaving 70,000 million cubic meters for regulating power releases, of which at least a part will be used for irrigation.

High flows send a wave of ground-water recharge into aquifers adjacent to desert streams and are, therefore, beneficial to wells adjacent to stream channels. To some degree, return from such aquifers to the channel will maintain the minimum dry season flows. However, such floods across desert also soak some normally dry streambank areas, and most of the water used in soaking them is consumed by evaporation and streambank transpiration, thus being lost to downstream users. It therefore appears possible that reservoir regulation in Ethiopia might result in greater total flow of the Blue Nile at Sudan and Egyptian reservoir sites. Such regulation in Ethiopia would also reduce sedimentation at Roseires and Aswan Reservoirs. Power use of the water of the main stream of the Blue Nile is the principal potential use in Ethiopia because of a shortage of land that can be irrigated with water from that source. Tributary streams could provide water by storage and diversion to the 434,000 hectares (1,070,000 acres) of irrigable land within the basin in Ethiopia.

Water use in Villages

Villages in the lower parts of the basin are small and situated near the streams. Mostly, water is obtained by carrying it from the streams, or, if situated near a stream which goes dry, by digging a hole in the sandy streambed. These villages and their small farming plots are ordinarily upon alluvium which is recharged by the stream, so that it would be possible, with some expenditure for wells, to obtain water which would be preferable for drinking purposes.

Villages on the intermediate slopes are also quite small. The people usually have hillside farming plots and carry their water from nearby springs or ravines which the tributary streams have cut into the rock. Occasionally, these villages are situated on a stream which goes dry and there is no sandy bed into which a temporary well can be dug. It is then necessary to carry water great distances up the ravine. In this situation, if the bedrock is of volcanic or sedimentary sandstone or conglomerate, it would ordinarily be feasible to dig a well in the rock to the water table, thereby assuring improved quality and a more sustained supply of drinking water.

Most of the villages and all of the towns are on the volcanic plateau at elevations of 1800 to 3000 meters (5905 to 9842 feet). A very few (including Bahir Dar) have municipally operated systems with a water storage tank and a distribution system. Such small systems are usually found only at military or church-sponsored institutions. They often provide a central water hydrant or several such hydrants without providing water in each of the living areas. Even in the larger towns and in almost all of these upland villages, water is supplied largely by occasional wells. These are often dug 10 to 20 meters deep into the earth and rock to a point below the water table. They are often shared by three or four nearby families, who may be related and who presumably have shared in the work of digging the well. Water is usually hoisted from the open well by means of a bucket on a rope. Considerable effort is wasted by attempting to dig wells too near a sharp declivity (as at Goha Tsiyon) where, given technical advice, it could have been anticipated that water would be at too great a depth for the digging of a well. The villages are quite often on a slight ridge near a sharp declivity (Asosa is another example), and during sustained drought periods the ground water runs down the slope toward the nearby canyon, the water table recedes, and the wells are left dry until the next rainy season. This is a situation where considerable improvement could be effected by digging deeper wells, perhaps fewer in number, but farther back from the nearby canyon. By installing community-owned hand pumps and capping the wells with concrete so that waste water could not flow back into the well, sanitation could also be considerably improved.

Water use for Irrigation and Power

INITIAL DEVELOPMENT

Plan

To estimate the ultimate water use within the basin, those projects that seemed the most promising early in the investigation and for which data could be obtained were considered together in what is called the Initial Development. It was also decided to fully control the stream flow through the study period at the various damsites where power was being produced or project land so required and if sufficient reservoir storage was available. This would not necessarily be the most economical project that could be designed. Table III-123 summarizes the average annual natural runoff on the streams at the various projects through the study period and the modified or depleted average annual runoff under this initial development as determined by operation studies performed on the various projects.

Operation Study Procedure

Operation studies were performed on the various projects in the plan for Initial Development. With minor exceptions, the following procedure was followed in making each study:

1. Farm delivery requirements were estimated as discussed and presented in Table III-16 to provide water for an 8-month (October through May) irrigation season.

2. A maximum total water shortage of 80 percent of 1 year's irrigation requirement was allowed in the usual 6-year study period.

3. The study period was selected and monthly natural flow estimates prepared as discussed in Section II.

4. Wherever a project was located downstream from one or more other projects, changes in flow as shown in operation studies for the upstream reservoirs were allowed for in studies of the lower reservoir. However, diversions to any of the upstream projects were always in excess of estimated consumption on those projects. Consumptive use for irrigation was computed as shown on Table III-16 and amounts diverted for the purpose of meeting losses in excess of this consumptive requirement were assumed to start flowing back toward the main tributaries, but estimated to be 20 percent lost to consumption by newly formed marshes enroute to the main tributaries. This means that only 80 percent of the potential return flow was actually assumed to get into the lower reservoir. The same 80 percent return was generally assumed for losses along power canals. In a more detailed study, particularly where losses were delayed by storage in a ground-water reservoir, it should be assumed that there was a delay between the time losses are incurred along a canal or irrigated field, and the time when the lost water returns to the streams below the project. Considering the fine grain of the soil and saturation of the bedrock, common to this area, no such delay was assumed in present studies.

5. Mass diagrams of the modified flows at tentatively selected sites were prepared and preliminary operation studies applicable to alternative sizes of reservoir and service area were made for the purpose of arriving at what seemed to be the best available plan.

6. An allowance for 50 years of sedimentation was derived as indicated in Section I. A more detailed set of studies would show distribution of sediment in the reservoir, but to expedite initial studies, sediment was assumed deposited level in the bottom of the reservoir for the first 14 reservoir operation studies. For the last 11 reservoir operation studies and, subsequently, for purposes of making a layout of each dam, the 50-year sediment volume was distributed on the area-capacity curve. The 100-year level of sediment at the dam was estimated for fixing outlet level. These quantities and elevations are listed in Table III-11.

TABLE III-123--AVERAGE ANNUAL RUNOFF THROUGH STUDY PERIOD

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

7. Upon formulation of the project plans, a final estimate of canal loss and operational waste, based upon length of canal and kind of soil traversed, was prepared by reference to Figure III-12. Soils so consistently fall in the red-friable and black clay groups that no others were considered. Because of high costs for securing on-project storage, the plans assume around-the-clock deliveries. This necessitates allowance for a relatively high operational waste. The difficulty of permitting a large operation waste is that erosion or water-logging of the heavy soils may destroy the land resource. The fairly high operational waste of 20 percent is assumed in the studies.

8. Change in consumption, to be expected as a consequence of building any reservoir, was estimated on a depth-per-month basis for multiplication by water-surface area as derived from the content and the area-capacity curve. In early studies, columns for precipitation on the reservoir water surface and evaporation from the water surface were shown separately. In later studies, these were combined into a single "precipitation and evaporation" column. A net plus value in this column indicates depth by which past evaporation and transpiration exceed future evaporation during the month; a negative item indicates depth to which future evaporation exceeds past evaporation and transpiration. Estimates of average precipitation by months were obtained by analysis of the nearest records and by reference to variation with elevation, as developed in Figure III-7. Past

consumption was estimated to equal precipitation in the dry (October to April) period, and it was estimated to equal irrigation requirements whenever rain was equal to or greater than irrigation requirement. Evaporation was estimated by reference to reservoir elevation and to the evaporation versus elevation curve on Figure III-7.

9. In studies showing a generation of power the estimated net head after allowance for penstock friction was used. Turbine-generator efficiency of 80 percent was assumed and in early studies an effort was made to generate the same number of kilowatt hours during each day of the year. In subsequent studies the generation was varied to meet the expected load curve (Figure III-60). Both regulation and potential depletion by existing and planned upstream facilities are allowed for in computing potential output at any plant. All power shown produced on the operation studies is firm power.

Project-by-Project Studies

The various projects included in the plan for Initial Development are presented below, starting at the upper end of the basin and working downstream with the main stem projects placed last. The locations of the dams and project lands are shown on the frontispiece.

Gilgel Abbay Projects. After two stream-gaging stations had been installed in this area (and land classification performed) under this investigation, the further survey and planning in the upper part of the area was done under a cooperative agreement between the Ethiopian Government and the Government of West Germany. Preliminary data on proposed reservoirs, powerplants, and irrigated lands in that scheme were obtained so that planning could continue at downstream locations under this investigation.

In addition to the German Gilgel Abbay Scheme, an additional 6,300 hectares are served downstream on the left bank of the Gilgel Abbay. The annual farm delivery requirement is estimated as 0.7824 meter. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.1177 meters or 70 million cubic meters for the 6,300 hectares. This can be supplied without shortages by either direct diversion or pumping from Lake Tana. The overall estimated modification to the natural flow during the 1911-1917 study period from the German Scheme plus the downstream 6,300 hectares of irrigated land is shown in Table III-124.

TABLE III-124--MODIFICATIONS TO FLOW FROM WEST GERMAN GILGEL ABBAY SCHEME PLUS 6,300 HECTARES DOWNSTREAM

	(in million cubic meters)					
Date	1911-12	1912-13	1913-14	1914-15	1915-16	1916-17
Oct	-63	-36	-1	-139	-115	-107
Nov	-32	+10	+43	-35	-10	-49
Dec	+16	+30	+20	+44	+13	+15
Jan	+28	+42	+23	+33	+6	+44
Feb	+36	+45	+24	+25	+8	+40
Mar	+44	+13	+23	+18	+12	+19
Apr	+41	+10	+20	+10	+11	+17
May	+33	+9	+29	+5	+24	+47
Jun	-11	+15	+4	-6	-13	-19
Jul	-127	-32	-125	-62	-152	-171
Aug	-396	-151	-510	-168	-688	-601
Sep	-138	-128	-182	-232	-334	-646
Totals	-569	-173	-632	-507	-1,238	-1,411

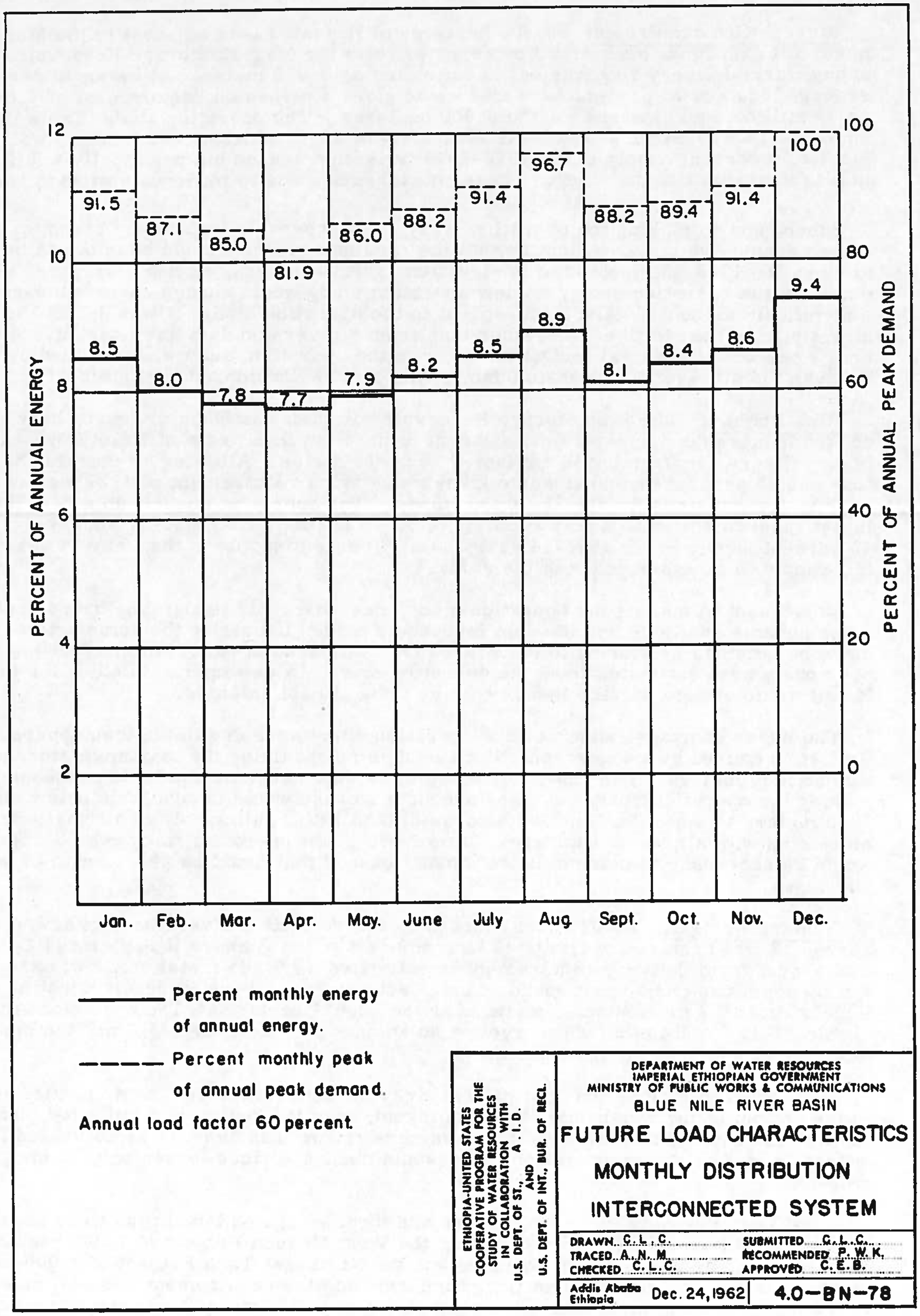


Figure III-60--Future Load Characteristics, Monthly Distribution, Interconnected System

Megech Gravity Project. 6,900 hectares of irrigated land adjacent to the Megech River, north of Lake Tana, are served by releases from the Megech Storage Reservoir. The annual farm delivery requirement is estimated as 0.938 meter. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.34 meters or 93 million cubic meters for the 6,900 hectares. The operation study (Table III-125) shows that a reservoir with an active capacity of 225.1 million cubic meters would only yield a 30 percent supply in the 1915-1916 irrigation season but practically a full supply in all other years of the study. These shortages are due to inadequate stream runoff.

Subsequent to making the operation study, new reservoir topography based upon aerial maps became available, indicating that the required capacity could be obtained by storing to elevation 1946.13, instead of to elevation 1958.00 meters, as had been previously estimated by the operation study. A new operation study would change surface losses only by insignificant amounts. Also, subsequent to the operation study, it was decided to divert directly from the storage dam rather than from a diversion dam downstream. Since less than 3 percent of the total irrigation water in the operation study was provided by the inflow between the storage and diversion dams, this also is considered negligible.

Ribb Project. The Ribb Storage Reservoir with a downstream diversion dam serves 15,300 hectares of irrigated land adjacent to the Ribb River east of Lake Tana. The annual farm delivery requirement is estimated as 0.889 meter. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.27 meters or 193.9 million cubic meters for the 15,300 hectares. The operation study (Table III-126) shows that a reservoir with an active capacity of 300.5 million cubic meters would only yield a 45 percent supply in the 1913-14 year and a 77 percent supply in the 1915-16 year but a full supply in all other years of the study.

Subsequent to making the operation study, new reservoir topography based upon aerial maps became available and the dam layout was made, indicating the same active capacity could be obtained by storing to elevation 1930.9, instead of to elevation 1950.0, as had previously been estimated from the operation study. A new operation study for this dam layout would change surface losses only by insignificant amounts.

The water shortages shown on the operation study were due to the then apparent storage limitation caused by a topographic limit on dam height fixing the maximum storage elevation at 1950 meters. The reservoir topography which became available subsequent to making the operation study indicates adequate storage would be available below elevation 1950 meters to serve the 15,300 hectares of land with a full supply in all years or to serve more land with allowable shortages. However, a new operation study (which was not made) would be necessary to determine the amount of land that could be served with or without shortages.

Gumara Project. The Gumara Storage Reservoir with a diversion dam downstream serves 12,914 hectares of irrigated land adjacent to the Gumara River east of Lake Tana. The annual farm delivery requirement is estimated as 0.885 meter. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.26 meters or 163.2 million cubic meters for the 12,914 hectares. The operation study (Table III-127) shows that a reservoir with an active capacity of 225.7 million cubic meters would yield a full supply in all years.

Subsequent to making the operation study (with the 50-year sediment quantity assumed in the bottom of the reservoir), the dam layout, with the sediment distributed, indicated storage is required to elevation 1954.3 meters rather than 1954.11 as estimated in the operation study. A new operation study would change surface losses only by insignificant amounts.

Lake Tana Pumping Projects. There are three irrigated land areas to be served around Lake Tana by lakeshore pumping; the West Megech Project of 7,080 hectares, the East Megech Project of 5,890 hectares and the Northeast Tana Project of 5,000 hectares. On these lands, the annual farm irrigation consumptive requirement was estimated as 0.563 meter and the farm delivery requirement as 0.938 meter, both the same as for the Megech Gravity Project. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.34 meters. Due to the proximity of Lake Tana, all losses (40 percent farm loss and 30 percent canal loss) were assumed returned to the lake, making the net modification or depletion due to the pumping projects equal to the annual farm irrigation consumptive requirement of 0.563 meter or 101 million cubic meters for the total 17,970 hectares served.

Upper Beles Project. This project consists of a regulating structure at the outlet to Lake Tana, a diversion tunnel from the southwest shore of the lake to the headwaters of the Beles River, the Alefa (BL-1) Powerplant (at the end of a canal, shaft, tunnel, and penstocks), and 63,205 hectares of irrigated land adjacent to the Beles River served by canals from a diversion dam on the Beles River downstream from the Alefa Powerplant.

Limits between which Lake Tana should be operated are, of course, for the Imperial Ethiopian Government to decide. The plan presented utilizes an active capacity of 10,604 million cubic meters between elevation 1783.80 meters and elevation 1787.25 meters. A more extensive discussion of the alternative operating levels appears in Section III where maximum flood level is the major consideration. The minimum water surface of 1783.80 (80 centimeters above the sill of the gates) is required for releasing enough water down the Abbay to provide 10 cubic meters per second at each of the two turbines now being installed at Tis Isat Falls and to provide an additional 3 cubic meters per second for maintaining scenic value of the falls (the Andassa River and other tributaries help to meet this requirement). In the operation study, releases were made so the historical flow up to 20 cubic meters could pass through the Tis Isat Powerplant. In addition, releases were calculated to assure 3 cubic meters per second over the falls for scenic purposes. Table III-128 shows how the required Abbay releases were calculated. Operating Lake Tana to a low level helps to conserve water which would otherwise be lost to evaporation and until upstream depletions occur (as allowed for on the Gilgel Abbay, Megech, Ribb and Gumara Rivers and for pumping from Lake Tana), more reservoir capacity can be used to provide more yield than is shown in the operation study (Table III-129). However, with upstream depletions as provided for in the study, the reservoir cannot be refilled to elevation 1787.25 meters in 1917, if this level is assumed in 1911 at the start of the study period and if sufficient demand is put on the reservoir to draw it to the proposed minimum operating level of 1783.80. Therefore, in the study the initial and final level is shown as 1786.84 meters. The proposed tunnel capacity of 110 cubic meters a second will allow for securing additional yield during early years of operation in case it is decided to operate Lake Tana between 1783.80 and 1787.25 meters as is here suggested, whenever inflow permits filling to the higher level.

The modified inflow (exclusive of precipitation on the lake) in the operation study was derived from the natural inflow (Table III-63) and modified for proposed upstream developments. The evaporation and precipitation column in the operation study is the total net effect of the evaporation and precipitation on the lake surface rather than the change from pre-project conditions to project conditions as is the case in all the other operation studies. Because of the great effect of evaporation on the available water supply, the estimates used of depth of precipitation and evaporation on the lake surface are tabulated below in millimeters.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly totals
Ppt.	0	3	25	49	41	84	309	289	172	45	26	9	1,052
Evap.	141	160	150	179	209	214	105	30	39	143	141	133	1,644
Net Effect	-141	-157	-125	-130	-168	-130	+204	+259	+133	-98	-115	-124	-592

The Alefa (BL-1) hydroelectric plant on the Beles River would utilize head between a canal operating level of 1745 meters and an estimated tailwater elevation of 1496 meters. Allowing for 10 meters of penstock losses, the operation study shows the plant can operate under the monthly load curve with an annual generation of 1,197.4 million kilowatt-hours.

The water going through the powerplant, plus an estimated 90 percent of the power canal seepage loss water enters the Beles River. The 63,205 hectares of irrigated land are served by canals from a diversion dam located on the Beles River downstream from the powerplant. The annual farm delivery requirement is estimated as 1.022 meters. Allowing 15 percent for seepage loss and 20 percent for canal waste gives a diversion require-

TABLE III-128--REQUIRED RELEASES TO ABBAY FROM LAKE TANA

Year	Month	Natural flow at Tis Isat Falls	Natural outflow from Lake Tana	Required flow at Tis Isat Falls	Required release to Abbay from Lake Tana	Year	Month	Natural flow at Tis Isat Falls	Natural outflow from Lake Tana	Required flow at Tis Isat Falls	Required release to Abbay from Lake Tana
		(In million cubic meters)						(In million cubic meters)			
1911	Oct	918	879	62	23	1914	Oct	1,162	1,108	62	8
	Nov	577	559	60	42		Nov	720	693	60	33
	Dec	386	378	62	54		Dec	401	392	62	53
1912	Jan	240	235	62	57	1915	Jan	242	237	62	57
	Feb	151	148	58	55		Feb	101	98	56	53
	Mar	63	60	62	59		Mar	62	59	62	59
	Apr	40	38	48	46		Apr	37	35	45	43
	May	21	18	29	26		May	25	20	33	28
	Jun	36	24	44	32		Jun	34	24	42	32
	Jul	116	70	62	16		Jul	71	43	62	34
	Aug	487	373	62	0		Aug	169	106	62	0
	Sep	650	590	60	0		Sep	912	837	60	0
	Oct	598	579	62	43		Oct	962	920	62	20
	Nov	384	376	60	52		Nov	546	529	60	43
	Dec	242	237	62	57		Dec	339	332	62	55
1913	Jan	153	150	62	59	1916	Jan	206	202	62	58
	Feb	60	57	56	53		Feb	87	84	58	55
	Mar	43	40	51	48		Mar	40	38	48	46
	Apr	42	40	50	48		Apr	34	32	42	40
	May	25	20	33	28		May	24	19	32	27
	Jun	23	19	31	27		Jun	36	25	44	33
	Jul	49	30	57	38		Jul	150	93	62	5
	Aug	130	79	62	11		Aug	1,299	1,036	62	0
	Sep	370	326	60	16		Sep	1,662	1,504	60	0
	Oct	458	447	62	51		Oct	1,377	1,310	62	0
	Nov	209	205	60	56		Nov	708	682	60	34
	Dec	53	50	61	58		Dec	468	456	62	50
1914	Jan	30	28	38	36	1917	Jan	309	303	62	56
	Feb	21	19	28	26		Feb	185	181	56	52
	Mar	22	20	30	28		Mar	112	109	62	59
	Apr	37	35	45	43		Apr	65	62	60	57
	May	19	17	27	25		May	25	20	33	27
	Jun	30	22	38	30		Jun	41	26	49	34
	Jul	111	67	62	18		Jul	170	107	62	0
	Aug	836	663	62	0		Aug	1,101	877	62	0
	Sep	945	868	60	0		Sep	2,604	2,284	60	0

ment of 1.572 meters or 994 million cubic meters for the 63,205 hectares. This can be provided in all years by direct diversion utilizing the releases from the Alefa (BL-1) powerplant.

Middle Beles Project. This project is comprised of the Dangur Dam, Reservoir, and Powerplant (BL-3). The reservoir stores the natural runoff of the Beles River and reregulated diversions from Lake Tana after depletions from the irrigated Beles Lands.

TABLE III-129--RESERVOIR OPERATION STUDY--LAKE TANA RESERVOIR

Sheet 1 of 2
April 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION
Variable	12,987,000,000 cu. m. (10,533,000 acre-ft.)	1787.25 m. (5864 ft.)

FIRM YIELD, 1,197,400,000 kwhr per yr.

Avg. Penstock Losses = 10 m.
Avg. Tailwater Elev. = 1496 m.

Net Generation Head = 239 m.

OPERATING CRITERIA

Minimum Storage

Oct.	2,770	Apr.	2,949
Nov.	2,949	May	2,174
Dec.	2,949	June	2,383
Jan.	2,949	July	2,472
Feb.	3,008	Aug.	1,549
Mar.	2,949	Sep.	1,817

Storages are all above elevation 1783.00 meters. To be able to meet downstream release requirements at Tis Isat Falls at any time, the minimum Lake Tana storages must be maintained each month.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Modified inflow (exclusive of ppt. on lake)	Evap. and precipitation on lake	Abbey release	Cons. use on irrig. pumping areas	Beles Tunnel release	Change in storage	End of month Lake Tana storage	Power water (95% Col.5)	Alefa (BL-1) power generation millions of kwhr
		1	2	3	4	5	6	7	8	9
								11,701		
1911	Oct.	399	-309	23	10	203	-146	11,555	193	100.5
	Nov.	163	-362	42	12	208	-461	11,094	198	103.1
	Dec.	122	-388	54	14	228	-562	10,532	217	113.0
1912	Jan.	101	-439	57	16	206	-617	9,915	196	102.1
	Feb.	94	-488	55	13	194	-656	9,259	184	95.8
	Mar.	92	-387	59	16	189	-559	8,700	179	93.2
	Apr.	76	-401	46	11	186	-568	8,132	177	92.2
	May	77	-515	26	9	191	-664	7,468	181	94.3
	June	140	-398	32	0	198	-488	6,980	188	97.9
	July	689	+626	16	0	206	+1,093	8,073	196	102.1
	Aug.	1,183	+802	0	0	215	+1,770	9,843	204	106.3
	Sep.	518	+415	0	0	196	+737	10,580	186	96.9
TOTALS		3,654	-1,844	410	101	2,420			2,299	1,197.4
1912	Oct.	167	-306	43	10	203	-395	10,185	193	100.5
	Nov.	111	-358	52	12	208	-519	9,666	198	103.1
	Dec.	103	-383	57	14	228	-579	9,087	217	113.0
1913	Jan.	108	-435	59	16	206	-608	8,479	196	102.1
	Feb.	93	-484	53	13	194	-651	7,828	184	95.8
	Mar.	60	-383	48	16	189	-576	7,252	179	93.2
	Apr.	50	-398	48	11	186	-593	6,659	177	92.2
	May.	55	-511	28	9	191	-684	5,975	181	94.3
	June	70	-395	27	0	198	-550	5,425	188	97.9
	July	220	+620	38	0	206	+596	6,021	196	102.1
	Aug.	450	+790	11	0	215	+1,014	7,035	204	106.3
	Sep.	279	+409	16	0	196	+476	7,511	186	96.9
TOTALS		1,766	-1,834	480	101	2,420	-3,069		2,299	1,197.4

UNITS are in millions of cubic meters, except as noted.

Year	Months	Modified inflow (exclusive of ppt. on lake)	Evap. and precipitation on lake	Abbay release	Cons. use on irrig. pumping areas	Beles Tunnel release	Change in storage	End of month Lake Tana storage	Power water (95% Col.5)	Alefa (BL-[illegible]) power generation millions of kwhr
		1	2	3	4	5	6	7	8	9
								7,511		
1913	Oct.	115	-300	51	10	203	-449	7,062	193	100.5
	Nov.	96	-352	56	12	208	-532	6,530	198	103.1
	Dec.	59	-376	58	14	228	-617	5,913	217	113.0
1914	Jan.	64	-430	36	16	206	-624	5,289	196	102.1
	Feb.	61	-475	26	13	194	-647	4,642	184	95.8
	Mar.	61	-377	28	16	189	-549	4,093	179	93.2
	Apr.	50	-391	43	11	186	-581	3,512	177	92.2
	May	70	-504	25	9	191	-659	2,853	181	94.3
	June	146	-388	30	0	198	-470	2,383	188	97.9
	July	1,018	+612	18	0	206	+1,406	3,789	196	102.1
	Aug.	2,801	+785	0	0	215	+3,371	7,160	204	106.3
	Sep.	1,213	+410	0	0	196	+1,427	8,587	186	96.9
TOTALS		5,754	-1,786	371	101	2,420	+1,076		2,299	1,197.4
1914	Oct.	720	-303	8	10	203	+196	8,783	193	100.5
	Nov.	318	-356	33	12	208	-291	8,492	198	103.1
	Dec.	183	-381	53	14	228	-493	7,999	217	113.0
1915	Jan.	122	-434	57	16	206	-591	7,408	196	102.1
	Feb.	85	-480	53	13	194	-655	6,753	184	95.8
	Mar.	75	-381	59	16	189	-570	6,183	179	93.2
	Apr.	53	-395	43	11	186	-582	5,601	177	92.2
	May	75	-508	28	9	191	-661	4,940	181	94.3
	June	137	-393	32	0	198	-486	4,454	188	97.9
	July	478	+617	34	0	206	+855	5,309	196	102.1
	Aug.	1,147	+788	0	0	215	+1,720	7,029	204	106.3
	Sep.	1,224	+410	0	0	196	+1,438	8,467	186	96.9
TOTALS		4,617	-1,816	400	101	2,420	-120		2,299	1,197.4
1915	Oct.	526	-302	20	10	203	-9	8,458	193	100.5
	Nov.	219	-355	43	12	208	-399	8,059	198	103.1
	Dec.	127	-380	55	14	228	-550	7,509	217	113.0
1916	Jan.	60	-432	58	16	206	-652	6,857	196	102.1
	Feb.	43	-479	55	13	194	-698	6,159	184	95.8
	Mar.	48	-380	46	16	189	-583	5,576	179	93.2
	Apr.	41	-394	40	11	186	-590	4,986	177	92.2
	May	52	-507	27	9	191	-682	4,304	181	94.3
	June	90	-391	33	0	198	-532	3,772	188	97.9
	July	700	+616	5	0	206	+1,105	4,877	196	102.1
	Aug.	2,703	+790	0	0	215	+3,278	8,155	204	106.3
	Sep.	1,495	+412	0	0	196	+1,711	9,866	186	96.9
TOTALS		6,104	-1,802	382	101	2,420	+1,399		2,299	1,197.4
1916	Oct.	531	-305	0	10	203	+13	9,879	193	100.5
	Nov.	155	-358	34	12	208	-457	9,422	198	103.1
	Dec.	117	-383	50	14	228	-558	8,864	217	113.0
1917	Jan.	112	-435	56	16	206	-601	8,263	196	102.1
	Feb.	90	-483	52	13	194	-652	7,611	184	95.8
	Mar.	62	-383	59	16	189	-585	7,026	179	93.2
	Apr.	52	-397	57	11	186	-599	6,427	177	92.2
	May	82	-511	27	9	191	-656	5,771	181	94.3
	June	86	-395	34	0	198	-541	5,230	188	97.9
	July	523	+620	0	0	206	+937	6,167	196	102.1
	Aug.	2,514	+795	0	0	215	+3,094	9,261	204	106.3
	Sep.	2,215	+417	0	0	196	+2,436	11,697	186	96.9
TOTALS		6,539	-1,818	369	101	2,420	+1,831		2,299	1,197.4

The reservoir would have an active capacity of 3, 156 million cubic meters (after 50 years of sediment deposition) between the normal maximum water surface of 845.00 meters and the minimum operating level of 791.25 meters. The estimated tailwater elevation is 733 meters. Allowing for 3.0 meters of penstock friction, the operation study (Table III-130) shows the plant (run with the 50-year sediment quantity distributed) can operate under the monthly load curve with an annual generation of 741.7 million kilowatt-hours.

Giamma Project. This project consists of the Giamma Dam, Reservoir, and Powerplant.

The operation study (Table III-131) (with the 50-year sediment quantity assumed in the bottom of the reservoir) had a minimum content of 543 million cubic meters at the then-assumed minimum operating level of 1321 meters, and maximum content was 2980 million cubic meters at the then-assumed spillway crest elevation of 1374.0 meters. Required active capacity is, therefore, 2, 437 million cubic meters.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity distributed) indicated storage is required to elevation 1376.11 meters rather than 1374.0 as estimated in the operation study and the minimum operating level is 1317.00 meters compared to 1321 as estimated in the operation study. Therefore, the average head at the powerplant will be essentially the same.

The estimated tailwater elevation is 1252 meters. Allowing 6.25 meters for penstock losses, the operation study shows the plant can operate at a constant output rate with an annual generation of 270.81 million kilowatt-hours. A new operation study would change surface losses by insignificant amounts.

Muger Project. This project consists of the Chancho Storage Dam and Reservoir (MU-4), a short power canal and penstock, the Chancho Powerplant, the Falls Diversion Dam (MU-1), a penstock beside the Muger Falls, and the Falls Powerplant.

The operation study (Table III-132) (with the 50-year sediment quantity assumed in the bottom of the reservoir) utilized an active capacity of 265.45 million cubic meters between the minimum operating level of 2550.96 meters and a spillway crest elevation of 2566 meters.

The dam layout (with the 50-year sediment quantity distributed) shows the 265.45 million cubic.meters of active capacity between a minimum operating level of 2552.8 meters and a spillway crest elevation of 2566.35 meters. A new operation study would change surface losses by insignificant amounts.

The operation study was run with constant power output and with constant effective heads of 60 meters (after 2 meters of friction loss) for the Chancho Powerplant and 213 meters (after 9 meters of friction loss) for the Falls Powerplant. The study shows a firm annual generation of 77.65 million kilowatt-hours (Alternate "A").

After the operation study was performed an alternate plan "B" was studied with the Falls Powerplant moved downstream, where an effective head of 362 meters (after 20 meters of friction loss) would be utilized. This would require some changes in the operation of the Chancho Storage Reservoir to maintain a total constant output from the two plants with an annual generation of approximately 121.6 million kilowatt-hours.

Upper Guder Project. This project consists of the Bello Storage Dam and Reservoir (GU-4) and 5, 100 hectares of irrigated land served by canals from a downstream diversion dam.

The annual farm delivery requirement is estimated as 0.6991 meter. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 0.9987 meter or 50.93 million cubic meters for 5, 100 hectares.

To provide a full supply in all years, the operation study (Table III-133) (with the 50-year sediment quantity assumed in the bottom of the reservoir) utilized an active capacity of 47.46 million cubic meters between a minimum operating level of 2415.67 meters and a spillway crest elevation of 2424.67 meters.

TABLE III-130--RESERVOIR OPERATION STUDY--DANGUR (BL-3) RESERVOIR

Sheet 1 of 2
November 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
380,000,000 cu. m. (308,000 acre-ft.)	3,536,000,000 cu. m. (2,868,000 acre-ft.)	845.00 m. (2772 ft.)	Avg. Penstock Losses = 3.0 m. Avg. Tailwater Elev. = 733 m.

FIRM YIELD, 741,700,000 kwhr per yr.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7	8
									3,536
1911	Oct.	62.3	253	100.4	-8	263	0	-18	3,518
	Nov.	63.8	173	99.1	-15	270	0	-112	3,406
	Dec.	69.7	179	96.8	-15	299	0	-135	3,271
1912	Jan.	63.0	143	94.0	-15	274	0	-146	3,125
	Feb.	59.3	130	91.0	-16	262	0	-148	2,977
	Mar.	57.9	107	87.5	-18	260	0	-171	2,806
	Apr.	57.1	111	83.7	-16	262	0	-167	2,639
	May	58.6	139	80.1	-13	274	0	-148	2,491
	June	60.8	224	77.5	-8	288	0	-72	2,419
	July	63.1	586	80.1	-3	295	0	+288	2,707
	Aug.	66.0	1,156	92.4	-1	289	37	+829	3,536
	Sep.	60.1	507	100.6	-6	253	248	0	3,536
TOTALS		741.7	3,708		-134	3,289	285	0	
1912	Oct.	62.3	209	100.0	-8	263	0	-62	3,474
	Nov.	63.8	152	98.1	-15	272	0	-135	3,339
	Dec.	69.7	165	95.2	-15	301	0	-151	3,188
1913	Jan.	63.0	136	92.2	-15	276	0	-155	3,033
	Feb.	59.3	126	88.9	-16	265	0	-155	2,878
	Mar.	57.9	105	85.3	-17	263	0	-175	2,703
	Apr.	57.1	111	81.4	-16	265	0	-170	2,533
	May	58.6	145	77.7	-13	277	0	-145	2,388
	June	60.8	203	74.6	-7	293	0	-97	2,291
	July	63.1	352	74.0	-3	305	0	+44	2,335
	Aug.	66.0	648	78.6	-1	311	0	+336	2,671
	Sep.	60.1	383	83.7	-5	275	0	+103	2,774
TOTALS		741.7	2,735		-131	3,366	0	-762	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precip. correction	Power release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7	8
									2,774
1913	Oct.	62.3	192	83.8	-7	285	0	-100	2,674
	Nov.	63.8	141	80.7	-12	297	0	-168	2,506
	Dec.	69.7	154	76.4	-12	332	0	-190	2,316
1914	Jan.	63.0	130	71.7	-11	308	0	-189	2,127
	Feb.	59.3	122	67.6	-12	299	0	-189	1,938
	Mar.	57.9	103	63.4	-13	302	0	-212	1,726
	Apr.	57.1	111	59.0	-11	310	0	-210	1,516
	May	58.6	139	54.7	-9	333	0	-203	1,313
	June	60.8	216	50.9	-5	360	0	-149	1,164
	July	63.1	561	51.3	-2	371	0	+188	1,352
	Aug.	66.0	1,362	64.0	-1	343	0	+1,018	2,370
	Sep.	60.1	658	79.9	-4	281	0	+373	2,743
TOTALS		741.7	3,889		-99	3,821	0	-31	
1914	Oct.	62.3	291	84.2	-7	285	0	-1	2,742
	Nov.	63.8	192	82.9	-13	294	0	-115	2,627
	Dec.	69.7	184	79.8	-12	326	0	-154	2,473
1915	Jan.	63.0	143	75.9	-12	301	0	-170	2,303
	Feb.	59.3	128	71.5	-13	291	0	-176	2,127
	Mar.	57.9	107	67.5	-14	292	0	-199	1,928
	Apr.	57.1	111	63.4	-12	298	0	-199	1,729
	May	58.6	145	59.4	-10	317	0	-182	1,547
	June	60.8	220	56.1	-5	340	0	-125	1,422
	July	63.1	435	55.7	-2	354	0	+79	1,501
	Aug.	66.0	746	60.6	-1	353	0	+392	1,893
	Sep.	60.1	639	68.2	-4	302	0	+333	2,226
TOTALS		741.7	3,341		-105	3,753	0	-517	
1915	Oct.	62.3	259	71.2	-6	306	0	-53	2,173
	Nov.	63.8	169	69.0	-11	319	0	-161	2,012
	Dec.	69.7	173	65.1	-10	358	0	-195	1,817
1916	Jan.	63.0	139	61.0	-10	336	0	-207	1,610
	Feb.	59.3	128	56.6	-10	330	0	-212	1,398
	Mar.	57.9	105	51.7	-10	339	0	-244	1,154
	Apr.	57.1	111	46.0	-9	358	0	-256	898
	May	58.6	143	38.9	-6	401	0	-264	634
	June	60.8	224	31.0	-3	467	0	-246	388
	July	63.1	687	30.3	-1	491	0	+195	583
	Aug.	66.0	1,533	48.8	-1	400	0	+1,132	1,715
	Sep.	60.1	1,007	68.4	-4	301	0	+702	2,417
TOTALS		741.7	4,678		-81	4,406	0	+191	
1916	Oct.	62.3	326	76.9	-6	296	0	+24	2,441
	Nov.	63.8	190	75.6	-12	305	0	-127	2,314
	Dec.	69.7	196	72.0	-11	340	0	-155	2,159
1917	Jan.	63.0	147	68.4	-11	316	0	-180	1,979
	Feb.	59.3	133	64.6	-11	306	0	-184	1,795
	Mar.	57.9	109	60.5	-12	310	0	-213	1,582
	Apr.	57.1	113	55.9	-11	320	0	-218	1,364
	May	58.6	148	51.4	-9	345	0	-206	1,158
	June	60.8	233	47.3	-5	375	0	-147	1,011
	July	63.1	739	49.9	-2	378	0	+359	1,370
	Aug.	66.0	1,462	65.5	-1	338	0	+1,123	2,493
	Sep.	60.1	1,299	89.9	-5	267	0	+1,027	3,520
TOTALS		741.7	5,095		-96	3,896	0	+1,103	
	Oct.	62.3	326	100.4	-8	263	39	+16	3,536

TABLE III-131--RESERVOIR OPERATION STUDY--GIAMMA RESERVOIR

Sheet 1 of 2
November 1962

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
543,000,000 cu. m. (423,000 acre-ft.)	2,980,000,000 cu. m. (2,417,000 acre-ft.)	1374.0 m. (4508 ft.)	Avg. Penstock Losses = 6.25 m. Avg. Tailwater Elev. = 1252 m.

FIRM YIELD, 270,810,000 kwhr per yr.

Operation study was made between tentatively assumed levels without sediment. Sediment distribution at 50 years was later estimated, and (as shown on area-capacity data sheets) operating levels were adjusted slightly to retain active capacity used in the study.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									2,980
1911	Oct.	23.00	160	71.58	-7	91	62	0	2,980
	Nov.	22.26	79	71.58	-10	88	0	-19	2,961
	Dec.	23.00	38	70.82	-10	92	0	-64	2,897
1912	Jan.	23.00	20	69.80	-9	92	0	-81	2,816
	Feb.	21.52	12	68.52	-10	88	0	-86	2,730
	Mar.	23.00	6	67.25	-10	95	0	-99	2,631
	Apr.	22.26	4	65.75	-10	93	0	-99	2,532
	May	23.00	4	64.25	-9	97	0	-102	2,430
	June	22.26	34	63.00	-6	95	0	-67	2,363
	July	23.00	147	62.75	-1	99	0	+47	2,410
	Aug.	23.00	377	65.25	+1	96	0	+282	2,692
	Sep.	22.26	214	68.26	-6	91	0	+117	2,809
TOTALS		271.56	1,095		-87	1,117	62	-171	
1912	Oct.	23.00	83	69.03	-7	93	0	-17	2,792
	Nov.	22.26	38	68.52	-9	90	0	-61	2,731
	Dec.	23.00	20	67.25	-9	95	0	-84	2,647
1913	Jan.	23.00	13	66.00	-8	96	0	-91	2,556
	Feb.	20.77	6	64.75	-9	87	0	-90	2,466
	Mar.	23.00	5	63.25	-10	98	0	-103	2,363
	Apr.	22.26	4	61.56	-9	97	0	-102	2,261
	May	23.00	13	59.92	-8	102	0	-97	2,164
	June	22.26	8	58.50	-5	100	0	-97	2,067
	July	23.00	56	57.30	-1	104	0	-49	2,018
	Aug.	23.00	161	57.30	+1	104	0	+58	2,076
	Sep.	22.26	149	58.27	-5	100	0	+44	2,120
TOTALS		270.81	556		-79	1,166	0	-689	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
1913	Oct.	23.00	51	58.04	-6	103	0	-58	2,062
	Nov.	22.26	18	56.80	-8	101	0	-91	1,971
	Dec.	23.00	6	55.05	-8	107	0	-109	1,862
1914	Jan.	23.00	2	53.05	-7	109	0	-104	1,748
	Feb.	20.77	2	50.84	-7	100	0	-105	1,643
	Mar.	23.00	2	48.64	-8	114	0	-120	1,523
	Apr.	22.26	3	46.18	-7	114	0	-118	1,405
	May	23.00	2	43.49	-6	121	0	-125	1,280
	June	22.26	23	41.11	-4	121	0	-102	1,178
	July	23.00	139	40.27	-1	126	0	+12	1,190
	Aug.	23.00	578	45.20	+1	119	0	+460	1,650
	Sep.	22.26	281	51.58	-5	107	0	+170	1,820
TOTALS		270.81	1,107		-65	1,342	0	-300	
1914	Oct.	23.00	219	54.30	-6	107	0	+106	1,926
	Nov.	22.26	112	55.30	-8	103	0	+1	1,927
	Dec.	23.00	40	54.55	-7	107	0	-74	1,853
1915	Jan.	23.00	20	53.05	-7	109	0	-76	1,757
	Feb.	20.77	10	51.08	-7	100	0	-97	1,660
	Mar.	23.00	6	49.12	-8	113	0	-115	1,545
	Apr.	22.26	3	46.68	-7	113	0	-117	1,428
	May	23.00	12	44.22	-6	120	0	-114	1,314
	June	22.26	29	41.95	-4	119	0	-94	1,220
	July	23.00	89	40.69	-1	126	0	-38	1,182
	Aug.	23.00	200	41.11	+1	125	0	+76	1,258
	Sep.	22.26	275	43.49	-4	117	0	+154	1,412
TOTALS		270.81	1,015		-64	1,359	0	-408	
1915	Oct.	23.00	169	45.45	-5	118	0	+46	1,458
	Nov.	22.26	71	45.45	-6	114	0	-49	1,409
	Dec.	23.00	32	43.98	-6	120	0	-94	1,315
1916	Jan.	23.00	18	41.95	-5	123	0	-110	1,205
	Feb.	21.52	7	39.43	-6	120	0	-119	1,086
	Mar.	23.00	4	36.28	-6	133	0	-135	951
	Apr.	22.26	3	32.38	-5	136	0	-138	813
	May	23.00	10	38.15	-4	150	0	-144	669
	June	22.26	32	24.10	-2	156	0	-126	543
	July	23.00	183	22.30	0	168	0	+15	558
	Aug.	23.00	885	33.75	+1	137	0	+749	1,307
	Sep.	22.26	567	47.66	-4	112	0	+451	1,758
TOTALS		271.56	1,981		-48	1,587	0	+346	
1916	Oct.	23.00	269	53.55	-6	108	0	+155	1,913
	Nov.	22.26	109	54.80	-8	103	0	-2	1,911
	Dec.	23.00	52	54.30	-7	107	0	-62	1,849
1917	Jan.	23.00	28	53.05	-7	109	0	-88	1,761
	Feb.	20.77	14	51.33	-7	100	0	-93	1,668
	Mar.	23.00	10	49.37	-8	113	0	-111	1,557
	Apr.	22.26	7	46.92	-7	112	0	-112	1,445
	May	23.00	13	44.47	-6	120	0	-113	1,332
	June	22.26	42	42.58	-4	118	0	-80	1,252
	July	23.00	202	42.58	-1	122	0	+79	1,331
	Aug.	23.00	752	50.10	+1	112	0	+641	1,972
	Sep.	22.26	1,124	64.00	-6	94	16	+1,008	2,980
TOTALS		270.81	2,622		-66	1,318	16	+1,008	

The dam layout, made with a refined area-capacity curve and with the 50-year sediment quantity distributed, shows the 47.46 million cubic meters of active capacity between a minimum operating level of 2421.89 meters and a spillway crest elevation of 2428 meters. A new operation study would change surface losses only by insignificant amounts.

Lower Guder Project. This project consists of the Motto Dam, Reservoir and Powerplant (GU-I).

The operation study (Table III-134) (with the 50-year sediment quantity assumed in the bottom of the reservoir) had a minimum content of 533.4 million cubic meters at the then-assumed operating level of 1324.73 meters, and maximum content was 2,320 million cubic meters at the then-assumed spillway crest elevation of 1364.67 meters. Required active capacity is, therefore, 1,786.6 million cubic meters.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity distributed) indicated storage is required to elevation 1368.11 meters (compared with 1364.67 in the operation study) and the minimum operating level is 1324.73 meters (as in the operation study). Therefore, the average head will be increased slightly and the annual power generation should be slightly more than that shown on the operation study although a new operation study would increase surface losses slightly.

The estimated average tailwater elevation is 1257 meters. Allowing for 3.5 meters of penstock losses, the operation study shows the plant can operate under the monthly load curve (Figure III-60) with an annual generation of 224.9 million kilowatt-hours.

Finchaa Project. This project consists of the Finchaa Dam at the outlet of the Chomen Swamp, a power diversion dam downstream, a power tunnel and penstock to the Finchaa Powerplant below the Finchaa Falls and 15,000 hectares of irrigated land served by canals from an irrigation diversion dam below the powerplant. During the irrigation season, intervening tributaries would produce no divertible flow. The principal hydrographic problem is whether a loss or a gain in consumption will result from providing a reservoir where there is now a swamp. Rain falling on a water surface would ordinarily be expected to yield a higher percentage of runoff than rain falling on land. However, the fact that Finchaa and Abbay below Tana records show relatively low yields per unit of drainage area suggests that present consumption is much greater on lake and swamp surfaces than for the land area (see Figure III-44).

The Dabus may also be considered to have a low yield. Dabus is in the highest rainfall belt and would fall well above the curve, if swamp losses did not pull the yield down to normal.

The boundary of Chomen Swamp recedes as the dry season progresses, and there may be 30 or 40 centimeters of soil moisture lost to evaporation and transpiration after the surface is unwatered. On most of the lake, grass or fronds extend through the water, even in September when content reaches maximum, and rainy season consumption is probably as great as, or greater than, it would be on a lake of the same area. In fact, grass may be expected to extend to much of the lake surface, even after a reservoir is constructed. But there will be some area where the water is too deep for grass to survive during the period of maximum content, and consumption in this area may decline as a consequence of building the reservoir. Not knowing what the net effect of all these factors will be, the operation study was made on the assumption that future annual consumption with a reservoir would equal past annual consumption without a reservoir.

There are 4 years of record at the damsite. Flow available during the study period years was estimated by a monthly correlation with the Abbay River at Kese record (see Figure III-29). Because of regulation by the swamp, the Finchaa River probably should have been shown to yield lesser flows in relation to Abbay flows, when monthly Abbay flows exceed 6,000 million cubic meters. However, the above-described difficulties of estimating losses in the swamp made it appear improbable that any considerable refinement could be made. There is no question that the facilities as outlined will serve the 15,000-hectare Finchaa Project service area without shortage, and power yields during most periods will equal those shown in the study. If, after further study or with operating experience, it becomes apparent that a drought period could impair power production, additional water may be imported. An unnamed stream and Kontor Creek southeast of Chomen Swamp could be diverted into it at a reasonable cost and would substantially increase the yield.

TABLE III-133--RESERVOIR OPERATION STUDY--BELLO (GU-4) RESERVOIR

Sheet 1 of 2
September 1962

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION
11,200,000 cu. m. (9,080 acre-ft.)	58,660,000 cu. m. (47,580 acre-ft)	2424.67 m. (7955 ft.)

FIRM YIELD, 50,930,000 cu. m. per yr. for 5,100 hectares
(41,310 acre-ft. per yr. for 12,600 acres)

Operation study was made between tentatively assumed levels without sediment. Sediment distribution at 50 years was later estimated, and (as shown on area-capacity data sheets) operating levels were adjusted slightly to retain active capacity used in the study.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Irrigation release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7
								58.66
1911	Oct.	35.80	8.27	-0.21	8.02	27.57	0	58.66
	Nov.	9.50	8.27	-0.68	9.31	0	-0.49	58.17
	Dec.	2.85	7.89	-0.61	6.77	0	-4.53	53.64
1912	Jan.	1.00	6.74	-0.49	8.94	0	-8.43	45.21
	Feb.	0.49	5.35	-0.45	6.95	0	-6.91	38.30
	Mar.	0.25	4.51	-0.41	2.86	0	-3.02	35.28
	Apr.	0.08	3.88	-0.35	3.67	0	-3.94	31.34
	May	0.08	3.24	-0.24	4.41	0	-4.57	26.77
	June	2.35	2.92	-0.10	0	0	+2.25	29.02
	July	31.20	5.60	+0.14	0	1.70	+29.64	58.66
	Aug.	62.90	8.27	+0.50	0	63.40	0	58.66
	Sep.	47.40	8.27	+0.08	0	47.48	0	58.66
TOTALS		193.90		-2.82	50.93	140.15	0	
1912	Oct.	10.65	8.27	-0.21	8.02	2.42	0	58.66
	Nov.	2.85	7.51	-0.62	9.31	0	-7.08	51.58
	Dec.	1.01	6.36	-0.49	6.77	0	-6.25	45.33
1913	Jan.	0.50	5.21	-0.37	8.94	0	-8.81	36.52
	Feb.	0.23	3.88	-0.33	6.95	0	-7.05	29.47
	Mar.	0.14	2.92	-0.27	2.86	0	-2.99	26.48
	Apr.	0.12	2.68	-0.24	3.67	0	-3.79	22.69
	May	0.60	2.28	-0.17	4.41	0	-3.98	18.71
	June	0.30	2.04	-0.07	0	0	+0.23	18.94
	July	5.25	2.28	+0.06	0	0	+5.31	24.25
	Aug.	36.60	5.22	+0.32	0	2.51	+34.41	58.66
	Sep.	32.40	8.27	+0.08	0	32.48	0	58.66
TOTALS		90.65		-2.31	50.93	37.41	0	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Inflow	Average surface area sq. km.	Evap. precip. correction	Irrigation release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7
								58.66
1913	Oct.	4.50	7.89	-0.20	8.02	0	-3.72	54.94
	Nov.	0.75	6.75	-0.55	9.31	0	-9.11	45.83
	Dec.	0.20	5.59	-0.43	6.77	0	-7.00	38.83
1914	Jan.	0.05	4.19	-0.30	8.94	0	-9.19	29.64
	Feb.	0.02	2.69	-0.23	6.95	0	-7.16	22.48
	Mar.	0.03	2.28	-0.21	2.86	0	-3.04	19.44
	Apr.	0.07	1.87	-0.17	3.67	0	-3.77	15.67
	May	0.05	1.52	-0.11	4.41	0	-4.47	11.20
	June	1.24	1.35	-0.05	0	0	+1.19	12.39
	July	28.40	2.92	+0.07	0	0	+28.47	40.86
	Aug.	70.15	6.74	+0.41	0	52.76	+17.80	58.66
	Sep.	55.55	8.27	+0.08	0	55.63	0	58.66
TOTALS		161.01		-1.69	50.93	108.39	0	
1914	Oct.	47.98	8.27	-0.21	8.02	39.75	0	58.66
	Nov.	18.70	8.27	-0.68	9.31	8.71	0	58.66
	Dec.	3.15	7.89	-0.61	6.77	0	-4.23	54.43
1915	Jan.	1.05	6.75	-0.49	8.94	0	-8.38	46.05
	Feb.	0.40	5.59	-0.47	6.95	0	-7.02	39.03
	Mar.	0.22	4.83	-0.44	2.86	0	-3.08	35.95
	Apr.	0.07	4.19	-0.38	3.67	0	-3.98	31.97
	May	0.50	3.40	-0.25	4.41	0	-4.16	27.81
	June	1.85	3.23	-0.11	0	0	+1.74	29.55
	July	11.80	4.51	+0.11	0	0	+11.91	41.46
	Aug.	45.40	6.75	+0.41	0	28.61	+17.20	58.66
	Sep.	54.75	8.27	+0.08	0	54.83	0	58.66
TOTALS		185.87		-3.04	50.93	131.90		
1915	Oct.	38.75	8.27	-0.21	8.02	30.52	0	58.66
	Nov.	7.60	7.90	-0.65	9.31	0	-2.36	56.30
	Dec.	2.02	7.51	-0.58	6.77	0	-5.33	50.97
1916	Jan.	0.74	6.36	-0.46	8.94	0	-8.66	42.31
	Feb.	0.32	4.83	-0.41	6.95	0	-7.04	35.27
	Mar.	0.08	4.19	-0.38	2.86	0	-3.16	32.11
	Apr.	0.07	3.55	-0.32	3.67	0	-3.92	28.19
	May	0.41	2.69	-0.20	4.41	0	-4.20	23.99
	June	2.20	2.68	-0.09	0	0	+2.11	26.10
	July	41.75	5.59	+0.14	0	9.33	+32.56	58.66
	Aug.	76.80	8.27	+0.50	0	77.30	0	58.66
	Sep.	69.80	8.27	+0.08	0	69.88	0	58.66
TOTALS		240.54		-2.58	50.93	187.03	0	
1916	Oct.	54.20	8.27	-0.21	8.02	45.97	0	58.66
	Nov.	17.75	8.27	-0.68	9.31	7.76	0	58.66
	Dec.	4.70	7.89	-0.61	6.77	0	-2.68	55.98
1917	Jan.	1.65	7.12	-0.51	8.94	0	-7.80	48.18
	Feb.	0.68	5.97	-0.51	6.95	0	-6.78	41.40
	Mar.	0.41	5.21	-0.47	2.86	0	-2.92	38.48
	Apr.	0.24	4.51	-0.41	3.67	0	-3.84	34.64
	May	0.62	3.87	-0.29	4.41	0	-4.08	30.56
	June	3.20	3.87	-0.13	0	0	+3.07	33.63
	July	45.60	5.98	+0.15	0	20.72	+25.03	58.66
	Aug.	74.15	8.27	+0.50	0	74.65	0	58.66
	Sep.	81.28	8.27	+0.08	0	81.36	0	58.66
TOTALS		284.48		-3.09	50.93	230.46	0	

TABLE III-134--RESERVOIR OPERATION STUDY--MOTTO (GU-1) RESERVOIR

Sheet 1 of 2
March 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
533,400,000 cu. m. (432,600 acre-ft.)	2,320,000,000 cu. m. (1,882,000 acre-ft.)	1364.67 m. (4477 ft.)	Avg. Penstock Losses = 3.5 m. Avg. Tailwater Elev. = 1257 m.

FIRM YIELD, 224,900,000 kwhr per yr.

Operation study was made between tentatively assumed levels without sediment. Sediment distribution at 50 years was later estimated, and (as shown on area-capacity data sheets) operating levels were adjusted slightly to retain active capacity used in the study.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									2,320.0
1911	Oct.	18.9	116.6	69.6	-6.6	83.3	26.7	0	2,320.0
	Nov.	19.4	32.6	69.1	-9.5	85.8	0	-62.7	2,257.3
	Dec.	21.1	10.4	67.3	-8.9	94.5	0	-93.0	2,164.3
1912	Jan.	19.1	7.4	65.4	-8.2	86.7	0	-87.5	2,076.8
	Feb.	18.0	4.4	63.4	-9.3	82.8	0	-87.7	1,989.1
	Mar.	17.6	7.8	61.5	-9.6	82.1	0	-83.9	1,905.2
	Apr.	17.3	5.8	59.6	-9.2	81.8	0	-85.2	1,820.0
	May	17.8	6.2	57.6	-7.8	85.5	0	-87.1	1,732.9
	June	18.4	29.6	55.9	-4.9	89.6	0	-64.9	1,668.0
	July	19.1	243.0	56.9	-1.3	92.3	0	+149.4	1,817.4
	Aug.	20.0	488.3	63.1	+1.3	92.2	0	+397.4	2,214.8
	Sep.	18.2	186.8	68.5	-4.2	80.8	0	+101.8	2,316.6
TOTALS		224.9	1,138.9		-78.2	1,037.4	26.7	-3.4	
1912	Oct.	18.9	37.5	69.1	-6.6	83.6	0	-52.7	2,263.9
	Nov.	19.4	11.6	67.6	-9.3	86.6	0	-84.3	2,179.6
	Dec.	21.1	6.3	65.6	-8.7	95.6	0	-98.0	2,081.6
1913	Jan.	19.1	5.4	63.5	-7.9	87.9	0	-90.4	1,991.2
	Feb.	18.0	3.8	61.5	-9.0	84.0	0	-89.2	1,902.0
	Mar.	17.6	6.3	59.5	-9.3	83.3	0	-86.3	1,815.7
	Apr.	17.3	5.8	57.6	-8.9	83.1	0	-86.2	1,729.5
	May	17.8	12.3	55.6	-7.6	86.9	0	-82.2	1,647.3
	June	18.4	7.3	53.4	-4.6	91.4	0	-88.7	1,558.6
	July	19.1	62.0	52.0	-1.2	96.1	0	-35.3	1,523.3
	Aug.	20.0	259.4	53.5	+1.1	99.4	0	+161.1	1,684.4
	Sep.	18.2	109.4	55.6	-3.4	88.8	0	+17.2	1,701.6
TOTALS		224.9	527.1		-75.4	1,066.7	0	-615.0	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									1,701.6
1913	Oct.	18.9	16.0	55.0	-5.2	92.8	0	-82.0	1,619.6
	Nov.	19.4	6.1	52.7	-7.3	97.0	0	-98.2	1,521.4
	Dec.	21.1	3.8	50.1	-6.6	107.9	0	-110.7	1,410.7
1914	Jan.	19.1	4.9	47.4	-5.9	100.2	0	-101.2	1,309.5
	Feb.	18.0	4.0	44.7	-6.5	96.8	0	-99.3	1,210.2
	Mar.	17.6	3.8	42.2	-6.6	97.0	0	-99.8	1,110.4
	Apr.	17.3	5.8	39.3	-6.1	98.3	0	-98.6	1,011.8
	May	17.8	5.4	36.4	-5.0	104.7	0	-104.3	907.5
	June	18.4	18.1	33.6	-2.9	112.2	0	-97.0	810.5
	July	19.1	235.7	33.8	-0.8	116.1	0	+118.8	929.3
	Aug.	20.0	536.8	41.6	+0.9	110.9	0	+426.8	1,356.1
	Sep.	18.2	278.5	49.7	-3.1	93.4	0	+182.0	1,538.1
TOTALS		224.9	1,118.9		-55.1	1,227.3	0	-163.5	
1914	Oct.	18.9	187.3	53.0	-5.0	94.3	0	+88.0	1,626.1
	Nov.	19.4	64.9	53.5	-7.4	96.3	0	-38.8	1,587.3
	Dec.	21.1	11.8	51.8	-6.8	106.3	0	-101.3	1,486.0
1915	Jan.	19.1	7.3	49.4	-6.2	98.3	0	-97.2	1,388.8
	Feb.	18.0	4.5	46.8	-6.8	94.9	0	-97.2	1,291.6
	Mar.	17.6	7.0	44.3	-6.9	95.0	0	-94.9	1,196.7
	Apr.	17.3	5.8	41.7	-6.4	95.8	0	-96.4	1,100.3
	May	17.8	11.7	39.0	-5.3	101.5	0	-95.1	1,005.2
	June	18.4	25.1	36.4	-3.2	108.2	0	-86.3	918.9
	July	19.1	155.5	35.8	-0.8	113.2	0	+41.5	960.4
	Aug.	20.0	320.4	39.3	+0.8	113.7	0	+207.5	1,167.9
	Sep.	18.2	268.4	44.5	-2.8	98.1	0	+167.5	1,335.4
TOTALS		224.9	1,069.7		-56.8	1,215.6	0	-202.7	
1915	Oct.	18.9	128.4	47.0	-4.5	99.4	0	+24.5	1,359.9
	Nov.	19.4	29.5	46.3	-6.4	102.7	0	-79.6	1,280.3
	Dec.	21.1	8.7	43.8	-5.8	114.4	0	-111.5	1,168.8
1916	Jan.	19.1	5.9	40.7	-5.1	106.9	0	-106.1	1,062.7
	Feb.	18.0	4.6	37.8	-5.5	104.0	0	-104.9	957.8
	Mar.	17.6	5.5	34.8	-5.4	105.6	0	-105.5	852.3
	Apr.	17.3	5.8	31.7	-4.9	108.2	0	-107.3	745.0
	May	17.8	10.8	28.7	-3.9	116.7	0	-109.8	635.2
	June	18.4	28.1	25.4	-2.2	127.7	0	-101.8	533.4
	July	19.1	285.5	26.2	-0.6	130.7	0	+154.2	687.6
	Aug.	20.0	617.0	35.7	+0.7	118.7	0	+499.0	1,186.6
	Sep.	18.2	480.3	47.8	-3.0	95.0	0	+382.3	1,568.9
TOTALS		224.9	1,610.1		-46.6	1,330.0	0	+233.5	
1916	Oct.	18.9	256.2	54.6	-5.2	93.0	0	+158.0	1,726.9
	Nov.	19.4	62.4	55.9	-7.7	94.5	0	-39.8	1,687.1
	Dec.	21.1	16.1	54.3	-7.2	104.1	0	-95.2	1,591.9
1917	Jan.	19.1	8.4	52.0	-6.5	96.1	0	-94.2	1,497.7
	Feb.	18.0	5.1	49.8	-7.3	92.3	0	-94.5	1,403.2
	Mar.	17.6	10.2	47.3	-7.4	92.3	0	-89.5	1,313.7
	Apr.	17.3	9.1	44.9	-6.9	92.9	0	-90.7	1,223.0
	May	17.8	13.2	42.6	-5.8	97.7	0	-90.3	1,132.7
	June	18.4	38.8	40.3	-3.5	103.4	0	-68.1	1,064.6
	July	19.1	312.3	42.3	-1.0	105.2	0	+206.1	1,270.7
	Aug.	20.0	591.7	51.4	+1.1	101.1	0	+491.7	1,762.4
	Sep.	18.2	649.3	63.6	-3.9	83.6	4.2	+557.6	2,320.0
TOTALS		224.9	1,972.8		-61.3	1,156.2	4.2	+751.1	

Some additional yield could be secured by providing dug channels at the swamp inlets. However, if attempted, this should be done with caution. Perhaps one inlet could be canalized; then, after 10 or 20 years, if the net result appeared advantageous, others could be canalized. The swamp appears to be on slopes adequate to maintain velocities of perhaps 1 meter per second in a channel. Many of the inlets have channels extending for some distance into the swamp, and, at the lower elevations, there are channels through the swamp in which velocities at times of maximum content appear to reach about 1 meter per second. Although on a grade, velocity over the remainder of the swamp is retarded by the grass. Possible effects of connecting each inlet channel with the main outlet channel would be reduction in consumption by grass and evaporation around the upper edges of the proposed reservoir; conduction of silt into the reservoir, which might otherwise be deposited in grass above the high-water line; minor amounts of erosion in and near the upper ends of the channels; less natural irrigation and, therefore, lesser volume growth of grass near the edges of the swamp; and a change, perhaps for the better, in species and quality of grass in such areas.

The operation study (Table III-135) (with the 50-year sediment quantity assumed in the bottom of the reservoir) was made with releases to produce power at a constant rate. These releases were just adequate to meet irrigation requirements in the month of December with an excess in all other months. The required active capacity was 381.42 million cubic meters between the then-assumed minimum operating level of 2209.75 meters and the then-assumed spillway crest elevation of 2213.13 meters.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity distributed) provided 400.1 million cubic meters of active storage between a minimum operating level of 2210.0 meters and a spillway crest elevation of 2213.4 meters.

The constant head powerplant would have an effective head of 467 meters after 18 meters of friction loss. The study shows a firm annual generation of 360.48 million kilowatt-hours.

The annual farm delivery requirement is estimated as 0.954 meter. Allowing 12 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.403 meters or 210.45 million cubic meters for the 15,000 hectares which the operation study shows can be supplied in all years.

Amarti-Neshe Project. This project consists of the Amarti and Neshe Dams with a joint reservoir, a power canal and penstocks to the Neshe Powerplant, and 8,490 hectares of irrigated land served by canals from a diversion dam below the powerplant.

The operation study (Table III-136) (with the 50-year sediment quantity assumed in the bottom of the reservoir) was made with releases to produce power at a constant rate. This release was always in excess of the irrigation requirements. The required active capacity was 586 million cubic meters between the then-assumed minimum operating level of 2209.96 meters and the then-assumed spillway crest elevation of 2233.98 meters.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity distributed) provided 596.8 million cubic meters of active storage between a minimum operating level of 2214.89 meters and a spillway crest elevation of 2236.0 meters. A new operation study would change surface losses only by insignificant amounts.

The constant head powerplant would have an effective head of 560 meters after 20 meters of friction loss. The study shows a firm annual generation of 378.0 million kilowatt-hours.

The annual farm delivery requirement is estimated as 0.954 meter. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.363 meters or 115.72 million cubic meters for the 8,490 hectares. Much more water (plus or minus 60 percent) is released each month on the power pattern than this irrigation diversion requirement would demand.

Upper Birr Project. This project consists of the Upper Birr Storage Dam and Reservoir (B-5) and 24,350 hectares of irrigated land served by a canal starting at the storage dam.

TABLE III-135--RESERVOIR OPERATION STUDY--FINCHAA RESERVOIR

Sheet 1 of 2
September 1962

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
33,000,000 cu. m. (27,000 acre-ft.)	414,420,000 cu. m. (336,110 acre-ft.)	2213.13 m. (7261 ft.)	Ave. Penstock Losses = 18 m. Net power head = 467 m.

FIRM YIELD, 210,540,000 cu. m. per yr. for 15,000 hectares (170,680 acre-ft. per yr. for 37,100 acres) 360,480,000 kw-hr. per yr.

Operation study was made between tentatively assumed levels without sediment. Sediment distribution at 50 years was later estimated, and (as shown on area-capacity data sheets) operating levels were adjusted slightly to retain active capacity used in the study.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Required power release	Power generation million kwhr	Inflow	Irrigation release	Additional release for power	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									414.42
1911	Oct.	30.08	30.61	99.00	20.81	9.27	68.92	0	414.42
	Nov.	29.14	29.65	54.70	28.24	0.90	25.56	0	414.42
	Dec.	30.08	30.61	29.50	30.08	0	0	-0.58	413.84
1912	Jan.	30.08	30.61	15.30	29.99	0.09	0	-14.78	399.06
	Feb.	28.14	28.63	8.80	26.99	1.15	0	-19.34	379.72
	Mar.	30.08	30.61	5.20	24.87	5.21	0	-24.88	354.84
	Apr.	29.14	29.65	4.00	25.64	3.50	C	-25.14	329.70
	May	30.08	30.61	2.90	23.83	6.25	0	-27.18	302.52
	June	29.14	29.65	2.50	0	29.14	0	-26.64	275.88
	July	30.08	30.61	13.90	0	30.08	0	-16.18	259.70
	Aug.	30.08	30.61	50.70	0	30.08	0	+20.62	280.32
	Sep.	29.14	29.65	102.00	0	29.14	0	+72.86	353.18
TOTALS		355.26	361.50	388.50	210.45	144.81	94.48	-61.24	
1912	Oct.	30.08	30.61	70.00	20.81	9.27	0	+39.92	393.10
	Nov.	29.14	29.65	31.00	28.24	0.90	0	+1.86	394.96
	Dec.	30.08	30.61	15.30	30.08	0	0	-14.78	380.18
1913	Jan.	30.08	30.61	9.00	29.99	0.09	0	-21.08	359.10
	Feb.	27.13	27.61	5.20	26.99	0.14	0	-21.93	337.17
	Mar.	30.08	30.61	4.00	24.87	5.21	0	-26.08	311.09
	Apr.	29.14	29.65	3.80	25.64	3.50	0	-25.34	285.75
	May	30.08	30.61	3.00	23.83	6.25	0	-27.08	258.67
	June	29.14	29.65	5.80	0	29.14	0	-23.34	235.33
	July	30.08	30.61	4.30	0	30.08	0	-25.78	209.55
	Aug.	30.08	30.61	21.90	0	30.08	0	-8.18	201.37
	Sep.	29.14	29.65	55.50	0	29.14	0	+26.36	227.73
TOTALS		354.25	360.48	228.80	210.45	143.80	0	-125.45	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Required power release	Power generation million kwhr	Inflow	Irrigation release	Additional release for power	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									227.73
1913	Oct.	30.08	30.61	52.00	20.81	9.27	0	+21.92	249.65
	Nov.	29.14	29.65	20.00	28.24	0.90	0	-9.14	240.51
	Dec.	30.08	30.61	7.00	30.08	0	0	-23.08	217.43
1914	Jan.	30.08	30.61	3.90	29.99	0.09	0	-26.18	191.25
	Feb.	27.13	27.61	2.30	26.99	0.14	0	-24.83	166.42
	Mar.	30.08	30.61	2.10	24.87	5.21	0	-27.98	138.44
	Apr.	29.14	29.65	2.30	25.64	3.50	0	-26.84	111.60
	May	30.08	30.61	2.40	23.83	6.25	0	-27.68	83.92
	June	29.14	29.65	2.30	0	29.14	0	-26.84	57.08
	July	30.08	30.61	6.00	0	30.08	0	-24.08	33.00
	Aug.	30.08	30.61	49.00	0	30.08	0	+18.92	51.92
	Sep.	29.14	29.65	128.00	0	29.14	0	+98.86	150.78
TOTALS		354.25	360.48	277.30	210.45	143.80	0	-76.95	
1914	Oct.	30.08	30.61	85.30	20.81	9.27	0	+55.22	206.00
	Nov.	29.14	29.65	71.00	28.24	0.90	0	+41.86	247.86
	Dec.	30.08	30.61	40.90	30.08	0	0	+10.82	258.68
1915	Jan.	30.08	30.61	16.30	29.99	0.09	0	-13.78	244.90
	Feb.	27.13	27.61	9.00	26.99	0.14	0	-18.13	226.77
	Mar.	30.08	30.61	5.00	24.87	5.21	0	-25.08	201.69
	Apr.	29.14	29.65	4.00	25.64	3.50	0	-25.14	176.55
	May	30.08	30.61	2.40	23.83	6.25	0	-27.68	148.87
	June	29.14	29.65	5.20	0	29.14	0	-23.94	124.93
	July	30.08	30.61	12.00	0	30.08	0	-18.08	106.85
	Aug.	30.08	30.61	32.30	0	30.08	0	+2.22	109.07
	Sep.	29.14	29.65	66.30	0	29.14	0	+37.16	146.23
TOTALS		354.25	360.48	349.70	210.45	143.80	0	-4.55	
1915	Oct.	30.08	30.61	84.00	20.81	9.27	0	+53.92	200.15
	Nov.	29.14	29.65	57.50	28.24	0.90	0	+28.36	228.51
	Dec.	30.08	30.61	26.30	30.08	0	0	-3.78	224.73
1916	Jan.	30.08	30.61	13.50	29.99	0.09	0	-16.58	208.15
	Feb.	28.14	28.63	7.00	26.99	1.15	0	-21.14	187.01
	Mar.	30.08	30.61	4.00	24.87	5.21	0	-26.08	160.93
	Apr.	29.14	29.65	2.90	25.64	3.50	0	-26.24	134.69
	May	30.08	30.61	2.40	23.83	6.25	0	-27.68	107.01
	June	29.14	29.65	5.00	0	29.14	0	-24.14	82.87
	July	30.08	30.61	13.70	0	30.08	0	-16.38	66.49
	Aug.	30.08	30.61	61.00	0	30.08	0	+30.92	97.41
	Sep.	29.14	29.65	165.50	0	29.14	0	+136.36	233.77
TOTALS		355.26	361.50	442.80	210.45	144.81	0	+87.54	
1916	Oct.	30.08	30.61	126.50	20.81	9.27	0	+96.42	330.19
	Nov.	29.14	29.65	82.70	28.24	0.90	0	+53.56	383.75
	Dec.	30.08	30.61	39.40	30.08	0	0	+9.32	393.07
1917	Jan.	30.08	30.61	20.20	29.99	0.09	0	-9.88	383.19
	Feb.	27.13	27.61	11.00	26.99	0.14	0	-16.13	367.06
	Mar.	30.08	30.61	6.90	24.87	5.21	0	-23.18	343.88
	Apr.	29.14	29.65	5.00	25.64	3.50	0	-24.14	319.74
	May	30.08	30.61	4.00	23.83	6.25	0	-26.08	293.66
	June	29.14	29.65	6.00	0	29.14	0	-23.14	270.52
	July	30.08	30.61	16.70	0	30.08	0	-13.38	257.14
	Aug.	30.08	30.61	67.00	0	30.08	0	+36.92	294.06
	Sep.	29.14	29.65	149.50	0	29.14	0	+120.36	414.42
TOTALS		354.25	360.48	534.90	210.45	143.80	0	+180.65	

TABLE III-136--RESERVOIR OPERATION STUDY--AMARTI-NESHE RESERVOIR

Sheet 1 of 2
December 1962

	MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION
NESHE SIDE	152,400,000 cu. m.	674,000,000 cu. m.	2233.98 m.
AMARTI SIDE	12,600,000 cu. m.	77,000,000 cu. m.	2233.98 m.
Total	165,000,000 cu. m. (133,800 acre-ft.)	751,000,000 cu. m. (609,000 acre-ft.)	2233.98 m. (7329 ft.)

Canal elev. at dam	2208 m.
Canal elev. at tunnel	2205 m.
Jet nozzle elev.	1625 m.
Avg. penstock losses	20 m.
Net generator head	560 m.

FIRM YIELD, 115,710,000 cu. m. per yr. for 8,490 hectares
(93,820 acre-ft. per yr. for 20,980 acres)
378,000,000 kwhr per yr.

Operation study was made between tentatively assumed levels without sediment. Sediment distribution at 50 years was later estimated, and (as shown on area-capacity data sheets) operating levels were adjusted slightly to retain active capacity used in the study.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Total inflow Amarti-Neshe Reservoir	Average surface area sq. km.	Evaporation precipitation correction	Power and irrigation release	Spill	Change in storage	End of month reservoir storage	Irrigation demand
		1	2	3	4	5	6	7	8	9
									751	
1911	Oct.	32.9	54	48	0	27	27	0	751	11.44
	Nov.	30.5	8	48	-4	25	0	-21	730	15.52
	Dec.	32.9	0	46	-4	27	0	-31	699	16.53
1912	Jan.	31.7	0	44	-3	26	0	-29	670	16.50
	Feb.	30.5	0	42	-4	25	0	-29	641	14.83
	Mar.	32.9	0	38	-4	27	0	-31	610	13.68
	Apr.	30.5	0	37	-4	25	0	-29	581	14.11
	May	31.7	0	34	-3	26	0	-29	552	13.10
	June	30.5	6	32	+1	25	0	-18	534	0
	July	32.9	20	31	+1	27	0	-6	528	0
	Aug.	31.7	54	32	+1	26	0	+29	557	0
	Sep.	30.5	104	37	0	25	0	+79	636	0
TOTALS		379.2	246		-23	311	27	-115		115.71
1912	Oct.	32.9	42	41	0	27	0	+15	651	11.44
	Nov.	30.5	6	40	-3	25	0	-22	629	15.52
	Dec.	32.9	0	38	-3	27	0	-30	599	16.53
1913	Jan.	31.7	0	35	-3	26	0	-29	570	16.50
	Feb.	29.3	0	33	-3	24	0	-27	543	14.83
	Mar.	32.9	0	31	-3	27	0	-30	513	13.68
	Apr.	30.5	0	31	-3	25	0	-28	485	14.11
	May	31.7	0	30	-2	26	0	-28	457	13.10
	June	30.5	4	29	+1	25	0	-20	437	0
	July	32.9	12	29	+1	27	0	-14	423	0
	Aug.	31.7	28	29	+1	26	0	+3	426	0
	Sep.	30.5	54	29	0	25	0	+29	455	0
TOTALS		378.0	146		-17	310	0	181		115.71

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Total inflow Amarti-Neshe Reservoir	Average surface area sq. km.	Evaporation precipitation correction	Power and irrigation release	Spill	Change in storage	End of month reservoir storage	Irrigation demand
		1	2	3	4	5	6	7	8	9
									455	
1913	Oct.	32.9	22	30	0	27	0	-5	450	11.44
	Nov.	30.5	2	29	-2	25	0	-25	425	15.52
	Dec.	32.9	0	28	-2	27	0	-29	396	16.53
1914	Jan.	31.7	0	28	-2	26	0	-28	368	16.50
	Feb.	29.3	0	27	-2	24	0	-26	342	14.83
	Mar.	32.9	0	26	-3	27	0	-30	312	13.68
	Apr.	30.5	0	25	-2	25	0	-27	285	14.11
	May	31.7	0	23	-2	26	0	-28	257	13.10
	June	30.5	10	22	0	25	0	-15	242	0
	July	32.9	30	22	+1	27	0	+4	246	0
	Aug.	31.7	78	23	+1	26	0	+53	299	0
	Sep.	30.5	152	27	0	25	0	+127	426	0
TOTALS		378.0	294		-13	310		-29		115.71
1914	Oct.	32.9	60	29	0	27	0	+33	459	11.44
	Nov.	30.5	8	30	-3	25	0	-20	439	15.52
	Dec.	32.9	0	29	-2	27	0	-29	410	16.53
1915	Jan.	31.7	0	28	-2	26	0	-28	382	16.50
	Feb.	29.3	0	27	-2	24	0	-26	356	14.83
	Mar.	32.9	0	26	-3	27	0	-30	326	13.68
	Apr.	30.5	0	25	-2	25	0	-27	299	14.11
	May	31.7	0	24	-2	26	0	-28	271	13.10
	June	30.5	6	23	+1	25	0	-18	253	0
	July	32.9	20	22	+1	27	0	-6	247	0
	Aug.	31.7	52	23	+1	26	0	+27	274	0
	Sep.	30.5	100	25	0	25	0	+75	349	0
TOTALS		378.0	246		-13	310		-77		115.71
1915	Oct.	32.9	40	27	0	27	0	+13	362	11.44
	Nov.	30.5	6	27	-2	25	0	-21	341	15.52
	Dec.	32.9	0	26	-2	27	0	-29	312	16.53
1916	Jan.	31.7	0	25	-2	26	0	-28	284	16.50
	Feb.	30.5	0	23	-2	25	0	-27	257	14.83
	Mar.	32.9	0	22	-2	27	0	-29	228	13.68
	Apr.	30.5	0	21	-2	25	0	-27	201	14.11
	May	31.7	0	19	-1	26	0	-27	174	13.10
	June	30.5	16	18	0	25	0	-9	165	0
	July	32.9	46	19	+1	27	0	+20	185	0
	Aug.	31.7	118	22	+1	26	0	+93	278	0
	Sep.	30.5	228	27	0	25	0	+203	481	0
TOTALS		379.2	454		-11	311		+132		115.71
1916	Oct.	32.9	92	31	0	27	0	+65	546	11.44
	Nov.	30.5	12	32	-3	25	0	-16	530	15.52
	Dec.	32.9	0	31	-3	27	0	-30	500	16.53
1917	Jan.	31.7	0	30	-2	26	0	-28	472	16.50
	Feb.	29.3	0	30	-3	24	0	-27	445	14.83
	Mar.	32.9	0	29	-3	27	0	-30	415	13.68
	Apr.	30.5	0	28	-3	25	0	-28	387	14.11
	May	31.7	0	27	-2	26	0	-28	359	13.10
	June	30.5	18	27	+1	25	0	-6	353	0
	July	32.9	56	27	+1	27	0	+30	383	0
	Aug.	31.7	144	29	+1	26	0	+119	502	0
	Sep.	30.5	278	0	0	25	4	+249	751	0
TOTALS		378.0	600		-16	310	4	+270		115.71

The annual farm delivery requirement is estimated as 0.859 meter. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.227 meters or 298.77 million cubic meters for the 24,350 hectares.

The operation study (Table III-137) (with an assumed sediment reservation of 4.25 million cubic meters in the bottom of the reservoir) utilized an active capacity of 517.25 million cubic meters between a minimum operating level of 1885 meters and a spillway crest elevation of 1923 meters. This yielded only a 69 percent supply in the 1913-14 year and a 67 percent supply in the 1915-16 year but a full supply in all other years of the study. These shortages are due to topographic limitations on the dam height and resultant storage capacity.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity of 18.5 million cubic meters distributed) placed the 517.25 million cubic meters of active storage between a minimum operating level of 1884.6 meters and a spillway crest elevation of 1923.56 meters. A new operation study would change surface losses only by insignificant amounts.

Debohila Project. This project consists of small dams on the Selale, Adefita, and Ghussa Rivers diverting water into a collection canal that transports the water to the Debohila Storage Dam and Reservoir, and 4,200 hectares of irrigated land served by a canal starting at the storage dam.

The annual farm delivery requirement is estimated as 0.8590 meter. Allowing 15 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.3215 meters or 55.50 million cubic meters for the 4,200 hectares.

The operation study (Table III-138) (with the 50-year sediment quantity assumed in the bottom of the reservoir) utilized an active capacity of 47.79 million cubic meters between a minimum operating level of 1982.11 meters and a spillway crest elevation of 2020 meters. This yielded only a 92 percent supply in the 1912-13 year, a 49 percent supply in the 1913-14 year and an 85 percent supply in the 1915-16 year with a full supply the other 3 years of the study. These shortages were due both to topographic limitations on the dam height governing storage capacity and to inadequate stream runoff.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity distributed) placed the 47.79 million cubic meters of active storage between a minimum operating level of 1984.41 meters and a spillway crest elevation of 2020.40 meters. A new operation study would change surface losses only by insignificant amounts.

Lower Birr Project. This project consists of a diversion dam (B-3) on the Birr River and a canal serving 6,600 hectares of irrigated land. The project utilizes the stream flow at the diversion dam as modified by the upstream Upper Birr Project, including return flows from the easterly portion of that project.

The annual farm delivery requirement is estimated as 0.9296 meter. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.328 or 87.65 million cubic meters for the 6,600 hectares..

The operation study (Table III-139) shows shortages toward the end of each irrigation season ranging from 12 to 40 percent of the annual diversion requirement. However, many of the expected crops have shorter growing seasons than the October through May period for which water was assumed required when computing the shortages. A more detailed investigation might show that these shortages (if real) could be economically alleviated by intercepting the flows of the Lah and Selale Rivers (carrying return flows from portions of the Upper Birr and Debohila Projects) where the project canal crosses these streams.

Arjo-Diddessa Project. This project consists of the Diddessa Storage Dam and Reservoir (DD-11), a powerplant below the dam, and 16,850 hectares of irrigated land served by canals starting at the storage dam.

The annual farm delivery requirement on the 10,370 hectares on the Arjo area is estimated as 0.720 meter. Allowing 15 percent for seepage loss and 20 percent for canal

TABLE III-137--RESERVOIR OPERATION STUDY--UPPER BIRR (B-5) RESERVOIR

Sheet 1 of 2
June 1962

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION
4,250,000 cu. m. (3,450 acre-ft.)	521,500,000 cu. m. (423,000 acre-ft.)	1923 m. (6309 ft.)

NONFIRM YIELD, 298,770,000 cu. m. per yr. for 24,350 hectares (242,310 acre-ft. per yr. for 60,170 acres)

Operation study was made between tentatively assumed levels without sediment. Sediment distribution at 50 years was later estimated, and (as shown on area-capacity data sheets) operating levels were adjusted slightly to retain active capacity used in the study.

OPERATING CRITERIA

Surface inflow during irrigation season in minimum year = 10.91. Whenever active storage + 10.91 at start of irrigation season is less than 298.77, take an appropriate shortage for the entire season. A 70.7% supply was released in 1913-14 season, except 50% supply in May 1914. A 67.3% supply was released in 1915-16 season.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Inflow	Average surface area in sq. km.	Gain in precipitation	Evaporation	Irrigation release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									521.50
1911	Oct.	27.24	26.30	1.97	2.60	26.29	0.32	0	521.50
	Nov.	7.78	25.87	0.18	2.95	40.04	0	-35.03	486.47
	Dec.	3.12	24.48	0.34	2.79	45.71	0	-45.04	441.43
1912	Jan.	1.56	23.12	0.39	2.50	45.41	0	-45.96	395.47
	Feb.	1.56	21.60	0.32	2.68	41.23	0	-42.03	353.44
	Mar.	0.78	20.37	0.39	2.71	40.04	0	-41.58	311.86
	Apr.	0.78	18.95	0.39	2.48	37.64	0	-38.95	272.91
	May	0.78	18.06	0.79	2.24	22.41	0	-23.08	249.83
	June	2.33	17.63	1.97	1.92	0	0	+ 2.38	252.21
	July	23.35	18.20	3.95	1.80	0	0	+25.50	277.71
	Aug.	105.09	20.37	4.95	1.69	0	0	+108.35	386.06
	Sep.	42.81	22.74	3.95	2.96	0	0	+43.80	429.86
TOTALS		217.18		19.59	29.32	298.77	0.32	-91.64	
1912	Oct.	9.34	23.13	1.97	2.29	26.29	0	-17.27	412.59
	Nov.	3.12	22.35	0.18	2.55	40.04	0	-39.29	373.30
	Dec.	1.56	20.90	0.34	2.38	45.71	0	-46.19	327.11
1913	Jan.	1.56	19.25	0.39	2.08	45.41	0	-45.54	281.57
	Feb.	0.78	18.05	0.32	2.24	41.23	0	-42.37	239.20
	Mar.	0.78	16.51	0.39	2.20	40.04	0	-41.07	198.13
	Apr.	0.78	14.95	0.39	1.96	37.64	0	-38.43	159.70
	May	1.56	13.49	0.79	1.67	22.41	0	-21.73	137.97
	June	1.56	13.00	1.97	1.42	0	0	+ 2.11	140.08
	July	4.68	13.32	3.95	1.32	0	0	+ 7.31	147.39
	Aug.	27.24	14.30	4.95	1.19	0	0	+31.00	178.39
	Sep.	24.12	15.43	3.95	2.01	0	0	+26.06	204.45
TOTALS		77.08		19.59	23.31	298.77	0	-225.41	

Year	Months	UNITS are in millions of cubic meters, except as noted.							
		Inflow	Average surface area in sq. km.	Gain in precipita- tion	Evaporation	Irrigation release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									204.45
1913	Oct.	4.67	15.60	1.97	1.54	18.59	0	-13.49	190.96
	Nov.	1.56	14.79	0.18	1.69	28.31	0	-28.26	162.70
	Dec.	0.78	13.48	0.34	1.54	32.32	0	-32.74	129.96
1914	Jan.	0.78	11.86	0.39	1.28	32.10	0	-32.21	97.75
	Feb.	0.78	10.19	0.32	1.26	29.15	0	-29.31	68.44
	Mar.	0.78	8.24	0.39	1.10	28.31	0	-28.24	40.20
	Apr.	0.78	5.00	0.39	0.66	26.61	0	-26.10	14.10
	May	0.78	1.85	0.79	0.23	11.19	0	- 9.85	4.25
	June	1.56	1.30	1.97	0.14	0	0	+ 3.39	7.64
	July	21.79	3.96	3.95	0.39	0	0	+25.35	32.99
	Aug.	203.96	13.00	4.95	1.08	0	0	+207.83	240.82
	Sep.	66.17	18.50	3.95	2.40	0	0	+67.72	308.54
TOTALS		304.39		19.59	13.31	206.58	0	+104.09	
1914	Oct.	45.14	19.80	1.97	1.96	26.29	0	+18.86	327.40
	Nov.	15.57	19.60	0.18	2.23	40.04	0	-26.52	300.88
	Dec.	3.12	18.50	0.34	2.11	45.71	0	-44.36	256.52
1915	Jan.	1.56	17.06	0.39	1.84	45.41	0	-45.30	211.22
	Feb.	1.56	15.43	0.32	1.91	41.23	0	-41.26	169.96
	Mar.	0.78	13.65	0.39	1.82	40.04	0	-40.69	129.27
	Apr.	0.78	11.73	0.39	1.54	37.64	0	-38.01	91.26
	May	1.56	10.04	0.79	1.24	22.41	0	-21.30	69.96
	June	1.56	9.46	1.97	1.03	0	0	+ 2.50	72.46
	July	10.12	10.04	3.95	0.99	0	0	+13.08	85.54
	Aug.	39.69	11.59	4.95	0.96	0	0	+43.68	129.22
	Sep.	63.06	14.14	3.95	1.84	0	0	+65.17	194.39
TOTALS		184.50		19.59	19.47	298.77	0	-114.15	
1915	Oct.	29.58	15.78	1.97	1.56	17.69	0	+12.30	206.69
	Nov.	7.01	15.60	0.18	1.78	26.95	0	-21.54	185.15
	Dec.	2.33	14.62	0.34	1.67	30.76	0	-29.76	155.39
1916	Jan.	1.56	13.16	0.39	1.42	30.56	0	-30.03	125.36
	Feb.	1.56	11.86	0.32	1.47	27.75	0	-27.34	98.02
	Mar.	0.78	10.33	0.39	1.37	26.95	0	-27.15	70.87
	Apr.	0.78	8.60	0.39	1.13	25.33	0	-25.29	45.58
	May	1.56	6.48	0.79	0.80	15.08	0	-13.53	32.05
	June	2.33	5.80	1.97	0.63	0	0	+ 3.67	35.72
	July	33.47	8.24	3.95	0.82	0	0	+36.60	72.32
	Aug.	385.34	18.20	4.95	1.51	0	0	+388.78	461.10
	Sep.	196.95	25.45	3.95	3.31	0	137.19	+60.40	521.50
TOTALS		663.25		19.59	17.47	201.07	137.19	+327.11	
1916	Oct.	61.50	26.30	1.97	2.60	26.29	34.58	0	521.50
	Nov.	14.79	25.88	0.18	2.95	40.04	0	-28.02	493.48
	Dec.	4.67	24.68	0.34	2.81	45.71	0	-43.51	449.97
1917	Jan.	2.33	23.32	0.39	2.52	45.41	0	-45.21	404.76
	Feb.	1.56	21.98	0.32	2.73	41.23	0	-42.08	362.68
	Mar.	1.56	20.72	0.39	2.76	40.04	0	-40.85	321.83
	Apr.	0.78	19.25	0.39	2.52	37.64	0	-38.99	282.84
	May	1.56	18.35	0.79	2.28	22.41	0	-22.34	260.50
	June	3.12	18.06	1.97	1.97	0	0	+ 3.12	263.62
	July	39.69	18.80	3.95	1.86	0	0	+41.78	305.40
	Aug.	303.61	22.93	4.95	1.90	0	90.56	+216.10	521.50
	Sep.	536.37	26.30	3.95	3.42	0	536.90	0	521.50
TOTALS		971.54		19.59	30.32	298.77	662.04	0	

TABLE III-139--RESERVOIR OPERATION STUDY--LOWER BIRR (B-3) RESERVOIR

Sheet 1 of 2
April 1963

No storage reservoir; diversion only.

NONFIRM YIELD, 87,650,000 cu. m. per yr. for 6,600 hectares
(71,090 acre-ft. per yr. for 16,300 acres)

UNITS are in millions of cubic meters, except as noted.

Year	Months	Modified flow at Lower Birr (B-3)	Irrigation demand	Irrigation release	Shortage	Shortage percent of annual demand	Spill
		1	2	3	4	5	6
1911	Oct.	63.96	6.68	6.68	0	0	57.28
	Nov.	31.04	11.59	11.59	0	0	19.45
	Dec.	15.84	12.63	12.63	0	0	3.21
1912	Jan.	11.56	12.39	11.56	0.83	0.95	0
	Feb.	10.24	11.57	10.24	1.33	1.52	0
	Mar.	9.46	12.15	9.46	2.69	3.07	0
	Apr.	8.76	10.67	8.76	1.91	2.18	0
	May	5.47	9.97	5.47	4.50	5.13	0
	June	4.22	0	0	0	0	4.22
	July	51.05	0	0	0	0	51.05
	Aug.	156.33	0	0	0	0	156.33
	Sep.	82.77	0	0	0	0	82.77
TOTALS		450.70	87.65	76.39	11.26	12.85	374.31
1912	Oct.	29.70	6.68	6.68	0	0	23.02
	Nov.	14.62	11.59	11.59	0	0	3.03
	Dec.	11.51	12.63	11.51	1.12	1.28	0
1913	Jan.	11.15	12.39	11.15	1.24	1.41	0
	Feb.	9.71	11.57	9.71	1.86	2.12	0
	Mar.	9.41	12.15	9.41	2.74	3.13	0
	Apr.	8.88	10.67	8.88	1.79	2.04	0
	May	6.27	9.97	6.27	3.70	4.22	0
	June	1.14	0	0	0	0	1.14
	July	11.70	0	0	0	0	11.70
	Aug.	57.99	0	0	0	0	57.99
	Sep.	52.87	0	0	0	0	52.87
TOTALS		224.95	87.65	75.20	12.45	14.20	149.75

UNITS are in millions of cubic meters, except as noted.

Year	Months	Modified flow at Lower Birr (B-3)	Irrigation demand	Irrigation release	Shortage	Shortage percent of annual demand	Spill
		1	2	3	4	5	6
1913	Oct.	14.30	6.68	6.68	0	0	7.62
	Nov.	7.62	11.59	7.62	3.97	4.53	0
	Dec.	7.75	12.63	7.75	4.88	5.57	0
1914	Jan.	7.54	12.39	7.54	4.85	5.53	0
	Feb.	6.91	11.57	6.91	4.66	5.32	0
	Mar.	6.72	12.15	6.72	5.43	6.20	0
	Apr.	6.37	10.67	6.37	4.30	4.91	0
	May	3.03	9.97	3.03	6.94	7.92	0
	June	2.20	0	0	0	0	2.20
	July	49.03	0	0	0	0	49.03
	Aug.	251.87	0	0	0	0	251.87
	Sep.	110.96	0	0	0	0	110.96
TOTALS		474.30	87.65	52.62	35.03	39.98	421.68
1914	Oct.	89.57	6.68	6.68	0	0	82.89
	Nov.	45.49	11.59	11.59	0	0	33.90
	Dec.	15.91	12.63	12.63	0	0	3.28
1915	Jan.	11.62	12.39	11.62	0.77	0.88	0
	Feb.	10.22	11.57	10.22	1.35	1.54	0
	Mar.	9.46	12.15	9.46	2.69	3.07	0
	Apr.	8.75	10.67	8.75	1.92	2.19	0
	May	6.18	9.97	6.18	3.79	4.32	0
	June	2.85	0	0	0	0	2.85
	July	26.68	0	0	0	0	26.68
	Aug.	77.07	0	0	0	0	77.07
	Sep.	108.55	0	0	0	0	108.55
TOTALS		412.35	87.65	77.13	10.52	12.00	335.22
1915	Oct.	65.43	6.68	6.68	0	0	58.75
	Nov.	24.45	11.59	11.59	0	0	12.86
	Dec.	10.84	12.63	10.84	1.79	2.04	0
1916	Jan.	8.11	12.39	8.11	4.28	4.88	0
	Feb.	7.13	11.57	7.13	4.44	5.06	0
	Mar.	6.45	12.15	6.45	5.70	6.50	0
	Apr.	6.09	10.67	6.09	4.58	5.22	0
	May	4.59	9.97	4.59	5.38	6.14	0
	June	4.15	0	0	0	0	4.15
	July	67.31	0	0	0	0	67.31
	Aug.	398.05	0	0	0	0	398.05
	Sep.	381.95	0	0	0	0	381.95
TOTALS		984.55	87.65	61.48	26.17	29.84	923.07
1916	Oct.	144.60	6.68	6.68	0	0	137.92
	Nov.	44.32	11.59	11.59	0	0	32.73
	Dec.	21.17	12.63	12.63	0	0	8.54
1917	Jan.	12.85	12.39	12.39	0	0	0.46
	Feb.	10.35	11.57	10.35	1.22	1.39	0
	Mar.	9.97	12.15	9.97	2.18	2.49	0
	Apr.	8.96	10.67	8.96	1.71	1.95	0
	May	6.27	9.97	6.27	3.70	4.22	0
	June	6.44	0	0	0	0	6.44
	July	77.24	0	0	0	0	77.24
	Aug.	426.23	0	0	0	0	426.23
	Sep.	1,052.10	0	0	0	0	1,052.10
TOTALS		1,820.50	87.65	78.84	8.81	10.05	1,741.66

waste gives a diversion requirement of 1.108 meters or 115 million cubic meters for the 10,370 hectares. The annual farm delivery requirement on the 6,480 hectares on the Diddessa area is estimated as 0.6877 meter. Allowing 15 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.0580 meters of 68 million cubic meters for the 6,480 hectares. The total annual irrigation demand on the reservoir then is 183 million cubic meters. This full demand can be met in all years.

The operation study (Table III-140) (with the 50-year sediment quantity assumed in the bottom of the reservoir) had an active capacity of 1,839 million cubic meters between the then-assumed minimum operating level of 1382.22 and the then-assumed spillway crest elevation of 1414.97 meters.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity distributed) placed the 1,839 million cubic meters of active storage between a minimum operating level of 1381.3 meters and the same spillway crest elevation of 1414.97 meters. This would make insignificant changes in the surface losses and power heads from those in the operation study.

The estimated average tailwater elevation is 1346 meters. Allowing for 2.5 meters of penstock losses, the operation study shows the plant can operate under the monthly load curve (Figure III-60), with an annual generation of 145.5 million kilowatt-hours, with water not required for irrigation.

Dabana Project. This project consists of the Dabana Storage Dam and Reservoir, the DB-1 Powerplant below the dam, a power diversion dam, canal, and penstock leading to the DB-1A Powerplant, and 6,104 hectares of irrigated land served by a canal from the storage dam.

The annual farm delivery requirement is estimated as 0.983 meter. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.404 meters or 85.7 million cubic meters for the 6,104 hectares. Slightly more than this (87 million cubic meters) is provided in the operation study in all years.

The operation study (Table III-141) (with the 50-year sediment quantity assumed in the bottom of the reservoir) had an active capacity of 1,299 million cubic meters between the then-assumed minimum operating level of 1345.92 meters and the then-assumed spillway crest elevation of 1400 meters.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity distributed) placed the 1,299 million cubic meters of active storage between a minimum operating level of 1343.33 meters and the same spillway crest elevation of 1400 meters. This would make an insignificant change in the surface losses and power heads from those in the operation study.

The estimated average tailwater elevation for the DB-1 Powerplant is 1288 meters and 5 meters were allowed for penstock losses. The DB-1A Powerplant was operated with an effective head of 86.3 meters after allowing 6.7 meters for penstock losses. The operation study shows the two plants can be operated together under the monthly load curve (Figure III-60) with an annual generation of 414 million kilowatt-hours with water not required for irrigation.

Lower Diddessa Project. This project consists of the Boo Storage Dam, Reservoir, and Powerplant (DD-2).

The operation study (Table III-142) (with the 50-year sediment quantity assumed in the bottom of the reservoir) utilized an active capacity of 3,796 million cubic meters between the then-assumed minimum operating level of 1015.49 meters and the then-assumed spillway crest elevation of 1066.4 meters.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity distributed) placed the 3,796 million cubic meters of active storage between a minimum operating level of 1008.9 meters and a spillway crest elevation of 1068.4 meters. Therefore, the average power head and average surface area are essentially the same as in the operation study.

TABLE III-140--RESERVOIR OPERATION STUDY--DIDDESSA (DD-11) RESERVOIR

Sheet 1 of 2
March 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
294,000,000 cu. m. (238,000 acre-ft.)	2,133,000,000 cu. m. (1,730,000 acre-ft.)	1414.97 m. (4642 ft.)	Avg. Penstock Losses = 2.5 m. Avg. Tailwater Elev. = 1346 m.

FIRM YIELD, 183,000,000 cu. m. per yr. for 16,850 hectares (148,000 acre-ft. per yr. for 41,640 acres) 145,500,000 kw-hr. per yr.

Operation study was made between tentatively assumed levels without sediment. Sediment distribution at 50 years was later estimated, and (as shown on area-capacity data sheets) operating levels were adjusted slightly to retain active capacity used in the study.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Irrigation release	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8	9
										2,133
1911	Oct.	12.2	209	94.5	-2	20	84	103	0	2,133
	Nov.	12.5	104	93.8	-8	32	86	0	-22	2,111
	Dec.	13.7	52	92.5	-8	33	96	0	-85	2,026
1912	Jan.	12.4	28	89.8	-7	33	88	0	-100	1,926
	Feb.	11.6	18	86.5	-8	28	84	0	-102	1,824
	Mar.	11.3	12	83.8	-9	20	83	0	-100	1,724
	Apr.	11.2	8	80.3	-9	11	84	0	-96	1,628
	May	11.5	8	75.8	-7	6	88	0	-93	1,535
	June	11.9	46	72.3	-2	0	92	0	-48	1,487
	July	12.4	190	73.2	+3	0	96	0	+97	1,584
	Aug.	13.0	454	83.2	+6	0	96	0	+364	1,948
	Sep.	11.8	278		+2	0	83	12	+185	2,133
TOTALS		145.5	1,407		-49	183	1,060	115	0	
1912	Oct.	12.2	110	94.5	-2	20	84	4	0	2,133
	Nov.	12.5	52	93.2	-8	32	87	0	-75	2,058
	Dec.	13.7	28	92.5	-8	33	97	0	-110	1,948
1913	Jan.	12.4	18	87.2	-7	33	89	0	-111	1,837
	Feb.	11.6	11	83.8	-8	28	85	0	-110	1,727
	Mar.	11.3	9	80.3	-8	20	85	0	-104	1,623
	Apr.	11.2	8	75.0	-8	11	86	0	-97	1,526
	May	11.5	19	70.5	-6	6	90	0	-83	1,443
	June	11.9	13	67.0	-2	0	95	0	-84	1,359
	July	12.4	74	64.3	+3	0	100	0	-23	1,336
	Aug.	13.0	212	66.1	+5	0	104	0	+113	1,449
	Sep.	11.8	195	71.4	+2	0	92	0	+105	1,554
TOTALS		145.5	749		-47	183	1,094	4	-579	

DIDDESSA (DD-11) RESERVOIR, Sheet 2 of 2

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Irrigation release	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8	9
										1,554
1913	Oct.	12.2	69	73.2	-1	20	94	0	-46	1,508
	Nov.	12.5	24	69.6	-6	32	98	0	-112	1,396
	Dec.	13.7	10	63.4	-5	33	111	0	-139	1,257
1914	Jan.	12.4	6	56.4	-4	33	104	0	-135	1,122
	Feb.	11.6	5	50.2	-5	28	101	0	-129	993
	Mar.	11.3	5	45.1	-5	20	102	0	-122	871
	Apr.	11.2	7	42.7	-5	11	107	0	-116	755
	May	11.5	6	40.1	-4	6	117	0	-121	634
	June	11.9	31	37.5	-1	0	129	0	-99	535
	July	12.4	181	37.0	+2	0	136	0	+47	582
	Aug.	13.0	541	42.2	+3	0	126	0	+418	1,000
	Sep.	11.8	365	54.2	+1	0	101	0	+265	1,265
TOTALS		145.5	1,250		-30	183	1,326	0	-289	
1914	Oct.	12.2	283	64.3	-1	20	99	0	+163	1,428
	Nov.	12.5	148	68.8	-6	32	99	0	+11	1,439
	Dec.	13.7	56	66.1	-6	33	110	0	-93	1,346
1915	Jan.	12.4	28	61.7	-5	33	102	0	-112	1,234
	Feb.	11.6	15	55.5	-6	28	98	0	-117	1,117
	Mar.	11.3	11	50.2	-5	20	98	0	-112	1,005
	Apr.	11.2	7	45.5	-5	11	100	0	-109	896
	May	11.5	18	43.4	-4	6	108	0	-100	796
	June	11.9	40	41.3	-1	0	117	0	-78	718
	July	12.4	117	40.4	+2	0	125	0	-6	712
	Aug.	13.0	262	42.0	+3	0	126	0	+139	851
	Sep.	11.8	356	46.6	+1	0	105	0	+252	1,103
TOTALS		145.5	1,341		-33	183	1,287	0	-162	
1915	Oct.	12.2	222	54.6	-1	20	104	0	+97	1,200
	Nov.	12.5	95	56.4	-5	32	105	0	-47	1,153
	Dec.	13.7	43	51.9	-4	33	118	0	-112	1,041
1916	Jan.	12.4	23	46.6	-4	33	110	0	-124	917
	Feb.	11.6	13	43.6	-4	28	109	0	-128	789
	Mar.	11.3	8	40.8	-4	20	113	0	-129	660
	Apr.	11.2	7	37.7	-4	11	121	0	-129	531
	May	11.5	15	34.4	-3	6	134	0	-128	403
	June	11.9	45	30.0	-1	0	153	0	-109	294
	July	12.4	239	29.4	+1	0	161	0	+79	373
	Aug.	13.0	621	38.4	+3	0	138	0	+486	859
	Sep.	11.8	538	51.1	+1	0	102	0	+437	1,296
TOTALS		145.5	1,869		-25	183	1,468	0	+193	
1916	Oct.	12.2	349	67.0	-1	20	97	0	+231	1,527
	Nov.	12.5	144	73.2	-7	32	97	0	+8	1,535
	Dec.	13.7	71	71.4	-6	33	107	0	-75	1,460
1917	Jan.	12.4	38	67.0	-5	33	99	0	-99	1,361
	Feb.	11.6	22	62.6	-6	28	95	0	-107	1,254
	Mar.	11.3	16	57.3	-6	20	95	0	-105	1,149
	Apr.	11.2	12	51.9	-6	11	96	0	-101	1,048
	May	11.5	20	47.5	-4	6	101	0	-91	957
	June	11.9	56	45.1	-1	0	108	0	-53	904
	July	12.4	263	46.6	+2	0	110	0	+155	1,059
	Aug.	13.0	589	62.6	+4	0	106	0	+487	1,546
	Sep.	11.8	676	85.2	+2	0	86	5	+587	2,133
TOTALS		145.5	2,256		-34	183	1,197	5	+837	

The estimated average tailwater elevation is 944 meters. Allowing for 3 meters of penstock losses, the operation study shows the plant can operate under the monthly load curve (Figure III-60) with an annual generation of 1,400 million kilowatt-hours.

Angar Project. This project consists of the Angar (AG-2) and Lekkemt (AG-6) Storage Dams and Reservoirs, three powerplants (AG-2 at the base of Angar Dam and AG-6A and AG-6B downstream from Lekkemt Dam, both served by power canals), and 30,200 hectares of irrigated land served by canals from Angar Dam and by pumping from Lekkemt Reservoir.

The annual farm delivery requirement is estimated as 1.034 meters. Allowing 5 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.379 meters or 416 million cubic meters for the 30,200 hectares (234 million cubic meters for the 17,000 hectares served from Angar Dam and 182 million cubic meters for the 13,200 hectares served from Lekkemt Reservoir). This full requirement can be met in all years.

The operation study (Table III-143) (with the 50-year sediment quantity distributed in Angar Reservoir and disregarded as being negligible in Lekkemt Reservoir) and the subsequent dam layout utilized an active capacity of 1,819 million cubic meters in Angar Reservoir between a minimum operating level of 1403.95 and a spillway crest elevation of 1438 meters and utilized an active capacity of 903 million cubic meters in Lekkemt Reservoir between a minimum operating level of 1304 meters and a spillway crest elevation of 1330 meters.

The estimated average tailwater elevation for the AG-2 Powerplant is 1348.5 meters and the average penstock loss is estimated as 2.5 meters. The AG-6A Powerplant was operated with an effective head of 168 meters after allowing for an average penstock loss of 9 meters. The AG-6B Powerplant was operated with an effective head of 74.5 meters after allowing for an average penstock loss of 3 meters. The operation study shows the three plants can be operated together under the monthly load curve (Figure III-60) with an annual generation of 1,148 kilowatt-hours and still meet the irrigation demands.

Dabus Projects. The Dabus projects are the Dabus Power Project, consisting of a diversion dam, a power canal, and a penstock leading to the Dabus Powerplant, and the Dabus Irrigation Project consisting of a diversion dam below the Dabus Powerplant and a canal serving 15,000 hectares of irrigated land.

Since no storage is provided and the flows during the critical months of February and March are considered to be the same at the diversion dams as at the Dabus near Asosa gaging station upstream, the correlated flows at the gaging station were used in the operation study (Table III-144).

The powerplant has an estimated effective head of 89 meters after allowing for 3 meters of penstock loss. The operation study shows that the plant can operate under the monthly load curve (Figure III-60) with an annual firm generation (set by the minimum flow month of February 1913) of 65.5 million kilowatt-hours.

The annual farm delivery requirement is estimated as 1.0243 meters. Allowing 5 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.3657 meters or 205 million cubic meters for the 15,000 hectares. The operation study shows a shortage of one-half of 1 percent during the 1912-13 irrigation season and a shortage of 1 percent during the 1913-14 irrigation season. A full supply is provided in the other years of the study.

Dindir Project. This project consists of the Junction Storage Dam, Reservoir and Powerplant (DI-7), the Dindir Storage Dam and Reservoir (DI-2), and 58,300 hectares of irrigated land served by a canal from the Dindir Storage Dam.

The Junction Dam operation study (Table III-145) (with the 50-year sediment quantity distributed) utilized an active capacity of 2,257 million cubic meters between a minimum operating level of 954.36 meters and a spillway crest elevation of 993.16 meters. The dam layout (with the same spillway crest elevation) shows an active capacity of 2,421 million cubic meters by lowering the minimum operating level to 947.95 meters.

TABLE III-142--RESERVOIR OPERATION STUDY--BOO (DD-2) RESERVOIR

Sheet 1 of 2
April 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
851,000,000 cu. m. (690,000 acre-ft.)	4,647,000,000 cu. m. (3,769,000 acre-ft.)	1066.4 m. (3499 ft.)	Avg. Penstock Losses = 3 m. Avg. Tailwater Elev. = 944 m.

FIRM YIELD, 1,400,000,000 kwhr per yr.

Operation study was made between tentatively assumed levels without sediment. Sediment distribution at 50 years was later estimated, and (as shown on area-capacity data sheets) operating levels were adjusted slightly to retain active capacity used in the study.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation million kwhr	Modified inflow	Average surface area sq. km.	Evaporation and precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									4,647
1911	Oct.	118	1,127	114	-6	455	666	0	4,647
	Nov.	120	556	114	-16	462	78	0	4,647
	Dec.	132	394	113	-15	510	0	-131	4,516
1912	Jan.	119	291	111	-14	465	0	-188	4,328
	Feb.	112	249	108	-15	445	0	-211	4,117
	Mar.	109	221	105	-14	440	0	-233	3,884
	Apr.	108	202	101	-7	445	0	-250	3,634
	May	110	204	97	-6	465	0	-267	3,367
	June	115	344	93	-3	495	0	-154	3,213
	July	119	852	95	-2	506	0	+344	3,557
	Aug.	125	1,781	107	-0	501	190	+1,090	4,647
	Sep.	113	1,271	114	-8	435	828	0	4,647
TOTALS		1,400	7,492		-106	5,624	1,762	0	
1912	Oct.	118	585	114	-6	455	124	0	4,647
	Nov.	120	374	114	-16	462	0	-104	4,543
	Dec.	132	309	111	-15	515	0	-221	4,322
1913	Jan.	119	262	108	-14	473	0	-225	4,097
	Feb.	112	226	104	-15	453	0	-242	3,855
	Mar.	109	212	101	-13	450	0	-251	3,604
	Apr.	108	207	96	-7	456	0	-256	3,348
	May	110	247	92	-5	476	0	-234	3,114
	June	115	230	87	-3	510	0	-283	2,831
	July	119	456	84	-2	540	0	-86	2,745
	Aug.	125	945	86	0	560	0	+385	3,130
	Sep.	113	864	93	-6	486	0	+372	3,502
TOTALS		1,400	4,917		-102	5,836	124	-1,145	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation million kwhr	Modified inflow	Average surface area sq. km.	Evaporation and precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									3,502
1913	Oct.	118	437	96	-5	500	0	-68	3,434
	Nov.	120	295	93	-14	515	0	-234	3,200
	Dec.	132	273	87	-11	581	0	-319	2,881
1914	Jan.	119	242	83	-11	544	0	-313	2,568
	Feb.	112	229	77	-11	535	0	-317	2,251
	Mar.	109	231	71	-10	534	0	-313	1,938
	Apr.	108	240	63	-5	570	0	-335	1,603
	May	110	245	54	-3	624	0	-382	1,221
	June	115	352	43	-2	720	0	-370	851
	July	119	888	39	-1	776	0	+111	962
	Aug.	125	2,130	61	0	670	0	+1,460	2,422
	Sep.	113	1,470	86	-6	506	0	+958	3,380
TOTALS		1,400	7,032		-79	7,075	0	-132	
1914	Oct.	118	1,194	100	-5	479	0	+710	4,090
	Nov.	120	726	108	-16	477	0	+233	4,323
	Dec.	132	424	109	-14	522	0	-112	4,211
1915	Jan.	119	310	107	-14	477	0	-181	4,030
	Feb.	112	256	104	-15	456	0	-215	3,815
	Mar.	109	239	100	-13	451	0	-225	3,590
	Apr.	108	223	96	-7	460	0	-224	3,346
	May	110	264	92	-5	476	0	-217	3,129
	June	115	354	89	-3	507	0	-156	2,973
	July	119	633	88	-2	526	0	+105	3,078
	Aug.	125	1,148	94	0	535	0	+613	3,691
	Sep.	113	1,439	107	-7	450	26	+956	4,647
TOTALS		1,400	7,210		-101	5,816	26	+1,267	
1915	Oct.	118	985	114	-6	455	524	0	4,647
	Nov.	120	547	114	-16	462	69	0	4,647
	Dec.	132	391	113	-15	510	0	-134	4,513
1916	Jan.	119	276	111	-14	466	0	-204	4,309
	Feb.	112	245	108	-15	445	0	-215	4,094
	Mar.	109	234	105	-14	441	0	-221	3,873
	Apr.	108	235	101	-7	445	0	-217	3,656
	May	110	265	98	-6	461	0	-202	3,454
	June	115	349	95	-3	480	0	-134	3,320
	July	119	783	96	-2	505	0	+276	3,596
	Aug.	125	1,615	104	0	498	66	+1,051	4,647
	Sep.	113	1,550	114	-8	435	1,107	0	4,647
TOTALS		1,400	7,475		-106	5,603	1,766	0	
1916	Oct.	118	1,201	114	-6	455	740	0	4,647
	Nov.	120	559	114	-16	462	81	0	4,647
	Dec.	132	381	113	-15	510	0	-144	4,503
1917	Jan.	119	289	111	-14	466	0	-191	4,312
	Feb.	112	240	108	-15	445	0	-220	4,092
	Mar.	109	226	105	-14	445	0	-233	3,859
	Apr.	108	212	101	-7	446	0	-241	3,618
	May	110	234	97	-6	464	0	-236	3,382
	June	115	319	93	-3	495	0	-179	3,203
	July	119	770	94	-2	510	0	+258	3,461
	Aug.	125	1,718	106	0	502	30	+1,186	4,647
	Sep.	113	2,229	114	-8	435	1,786	0	4,647
TOTALS		1,400	8,378		-106	5,635	2,637	0	

TABLE III-144--RESERVOIR OPERATION STUDY--DABUS RIVER IRRIGATION AND POWER PROJECTS

Sheet 1 of 2
December 1963

No storage reservoirs; diversion only.

NONFIRM YIELD, 205,000,000 cu. m. per yr. for 15,000 hectares
(166,000 acre-ft. per yr. for 37,000 acres)

FIRM YIELD, 65,500,000 kwhr per yr.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow to power & irrig. diversion dams 1/	Diversion to power canal	Irrigation requirement	Irrigation diversion	Spill past irrigation diversion dam
		1	2	3	4	5	6
1911	Oct.	5.50	465	28	15	15	450
	Nov.	5.63	248	29	31	31	217
	Dec.	6.16	140	32	32	32	108
1912	Jan.	5.57	75	29	32	32	43
	Feb.	5.24	55	27	29	29	26
	Mar.	5.11	36	26	35	35	1
	Apr.	5.04	36	26	28	28	8
	May	5.17	73	27	3	3	70
	June	5.37	326	28	0	0	326
	July	5.57	496	29	0	0	496
	Aug.	5.83	747	30	0	0	747
	Sep.	5.31	800	27	0	0	800
TOTALS		65.50	3,497	338	205	205	3,292
1912	Oct.	5.50	336	28	15	15	321
	Nov.	5.63	179	29	31	31	148
	Dec.	6.16	101	32	32	32	69
1913	Jan.	5.57	71	29	32	32	39
	Feb.	5.24	52	27	29	29	23
	Mar.	5.11	34	26	35	34*	0
	Apr.	5.04	34	26	28	28	6
	May	5.17	145	27	3	3	142
	June	5.37	107	28	0	0	107
	July	5.57	467	29	0	0	467
	Aug.	5.83	704	30	0	0	704
	Sep.	5.31	879	27	0	0	879
TOTALS		65.50	3,109	338	205	204	2,905

1/ Assuming losses are negligible.

* Small irrigation shortage.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow to power & irrig. diversion dams 1/	Diversion to power canal	Irrigation requirement	Irrigation diversion	Spill past irrigation diversion dam
		1	2	3	4	5	6
1913	Oct.	5.50	317	28	15	15	302
	Nov.	5.63	169	29	31	31	138
	Dec.	6.16	95	32	32	32	63
1914	Jan.	5.57	51	29	32	32	19
	Feb.	5.24	27	27	29	27*	0
	Mar.	5.11	43	26	35	35	8
	Apr.	5.04	43	26	28	28	15
	May	5.17	86	27	3	3	83
	June	5.37	395	28	0	0	395
	July	5.57	600	29	0	0	600
	Aug.	5.83	904	30	0	0	904
	Sep.	5.31	1,052	27	0	0	1,052
TOTALS		65.50	3,782	338	205	203	3,579

* Small irrigation shortage.

Year	Months	1	2	3	4	5	6
1914	Oct.	5.50	407	28	15	15	392
	Nov.	5.63	217	29	31	31	186
	Dec.	6.16	122	32	32	32	90
1915	Jan.	5.57	103	29	32	32	71
	Feb.	5.24	76	27	29	29	47
	Mar.	5.11	49	26	35	35	14
	Apr.	5.04	49	26	28	28	21
	May	5.17	210	27	3	3	207
	June	5.37	447	28	0	0	447
	July	5.57	680	29	0	0	680
	Aug.	5.83	1,024	30	0	0	1,024
	Sep.	5.31	988	27	0	0	988
TOTALS		65.50	4,372	338	205	205	4,167
1915	Oct.	5.50	460	28	15	15	445
	Nov.	5.63	246	29	31	31	215
	Dec.	6.16	139	32	32	32	107
1916	Jan.	5.57	116	29	32	32	84
	Feb.	5.24	85	27	29	29	56
	Mar.	5.11	55	26	35	35	20
	Apr.	5.04	55	26	28	28	27
	May	5.17	136	27	3	3	133
	June	5.37	502	28	0	0	502
	July	5.57	763	29	0	0	763
	Aug.	5.83	1,150	30	0	0	1,150
	Sep.	5.31	1,209	27	0	0	1,209
TOTALS		65.50	4,916	338	205	205	4,711
1916	Oct.	5.50	517	28	15	15	502
	Nov.	5.63	276	29	31	31	245
	Dec.	6.16	156	32	32	32	124
1917	Jan.	5.57	121	29	32	32	89
	Feb.	5.24	90	27	29	29	61
	Mar.	5.11	58	26	35	35	23
	Apr.	5.04	58	26	28	28	30
	May	5.17	248	27	3	3	245
	June	5.37	527	28	0	0	527
	July	5.57	801	29	0	0	801
	Aug.	5.83	1,206	30	0	0	1,206
	Sep.	5.31	1,164	27	0	0	1,164
TOTALS		65.50	5,222	338	205	205	5,017

1/ Assuming losses are negligible.

TABLE III-145--RESERVOIR OPERATION STUDY--JUNCTION (DI-7) RESERVOIR

December 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
279,000,000 cu. m. (226,000 acre-ft.)	2,700,000,000 cu. m. (2,190,000 acre-ft.)	993.16 m. (3258 ft.)	Avg. Penstock Losses = 3.0 m. Avg. Tailwater Elev. = 899 m.

FIRM YIELD, 178,700,000 kwhr per yr.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7	8
									2,700
1917	Oct.	15.0	144	93.3	-9	75	60	0	2,700
	Nov.	15.4	15	92.3	-15	78	0	-78	2,622
	Dec.	16.8	0	90.1	-14	86	0	-100	2,522
1918	Jan.	15.2	0	87.5	-13	79	0	-92	2,430
	Feb.	14.3	0	85.3	-15	75	0	-90	2,340
	Mar.	13.9	0	83.1	-17	74	0	-91	2,249
	Apr.	13.8	0	81.0	-17	74	0	-91	2,158
	May	14.1	0	78.9	-12	77	0	-89	2,069
	June	14.6	62	77.5	-7	80	0	-25	2,044
	July	15.2	179	78.3	-3	83	0	+93	2,137
	Aug.	15.9	356	82.6	-1	85	0	+270	2,407
	Sep.	14.5	156	86.7	-4	75	0	+77	2,484
TOTALS		178.7	912		-127	941	60	-216	
1918	Oct.	15.0	24	86.9	-9	78	0	-63	2,421
	Nov.	15.4	0	85.0	-14	81	0	-95	2,326
	Dec.	16.8	0	82.6	-13	89	0	-102	2,224
1919	Jan.	15.2	0	80.4	-12	82	0	-94	2,130
	Feb.	14.3	0	78.1	-14	78	0	-92	2,038
	Mar.	13.9	0	76.0	-15	77	0	-92	1,946
	Apr.	13.8	0	73.8	-15	78	0	-93	1,853
	May	14.1	0	71.5	-11	81	0	-92	1,761
	June	14.6	21	69.4	-7	85	0	-71	1,690
	July	15.2	244	70.4	-3	88	0	+153	1,843
	Aug.	15.9	222	74.0	-1	89	0	+132	1,975
	Sep.	14.5	178	76.7	-4	80	0	+94	2,069
TOTALS		178.7	689		-118	986	0	-415	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7	8
									2,069
1919	Oct.	15.0	13	76.9	-8	83	0	-78	1,991
	Nov.	15.4	0	74.8	-12	86	0	-98	1,893
	Dec.	16.8	0	72.3	-11	95	0	-106	1,787
1920	Jan.	15.2	0	69.7	-11	88	0	-99	1,688
	Feb.	14.3	0	67.1	-12	84	0	-96	1,592
	Mar.	13.9	0	64.5	-13	83	0	-96	1,496
	Apr.	13.8	0	61.8	-13	85	0	-98	1,398
	May	14.1	0	59.0	-9	88	0	-97	1,301
	June	14.6	64	57.2	-5	93	0	-34	1,267
	July	15.2	371	60.5	-2	94	0	+275	1,542
	Aug.	15.9	615	71.4	-1	91	0	+523	2,065
	Sep.	14.5	448	82.1	-4	77	0	+367	2,432
TOTALS		178.7	1,511		-101	1,047	0	+363	
1920	Oct.	15.0	137	87.0	-9	78	0	+50	2,482
	Nov.	15.4	9	86.6	-14	80	0	-85	2,397
	Dec.	16.8	0	84.3	-13	88	0	-101	2,296
1921	Jan.	15.2	0	82.1	-13	81	0	-94	2,202
	Feb.	14.3	0	79.9	-14	77	0	-91	2,111
	Mar.	13.9	0	77.8	-16	76	0	-92	2,019
	Apr.	13.8	0	75.5	-15	77	0	-92	1,927
	May	14.1	0	73.3	-11	80	0	-91	1,836
	June	14.6	9	71.2	-7	84	0	-82	1,754
	July	15.2	99	70.3	-3	88	0	+8	1,762
	Aug.	15.9	359	73.7	-1	90	0	+268	2,030
	Sep.	14.5	294	79.4	-4	79	0	+211	2,241
TOTALS		178.7	907		-120	978		-191	
1921	Oct.	15.0	60	81.6	-8	80	0	-28	2,213
	Nov.	15.4	0	80.1	-13	83	0	-96	2,117
	Dec.	16.8	0	77.8	-12	92	0	-104	2,013
1922	Jan.	15.2	0	75.3	-12	85	0	-97	1,916
	Feb.	14.3	0	73.0	-13	81	0	-94	1,822
	Mar.	13.9	0	70.7	-14	80	0	-94	1,728
	Apr.	13.8	0	68.2	-14	81	0	-95	1,633
	May	14.1	0	65.7	-10	84	0	-94	1,539
	June	14.6	21	63.3	-6	88	0	-73	1,466
	July	15.2	136	62.9	-2	92	0	+42	1,508
	Aug.	15.9	300	66.3	-1	94	0	+205	1,713
	Sep.	14.5	372	72.7	-4	82	0	+286	1,999
TOTALS		178.7	889		-109	1,022	0	-242	
1922	Oct.	15.0	84	76.1	-7	83	0	-6	1,993
	Nov.	15.4	4	74.9	-12	86	0	-94	1,899
	Dec.	16.8	0	72.4	-11	95	0	-106	1,793
1923	Jan.	15.2	0	69.9	-11	88	0	-99	1,694
	Feb.	14.3	0	67.3	-12	84	0	-96	1,598
	Mar.	13.9	0	64.7	-13	83	0	-96	1,502
	Apr.	13.8	0	61.9	-13	85	0	-98	1,404
	May	14.1	0	59.2	-9	88	0	-97	1,307
	June	14.6	16	56.7	-5	93	0	-82	1,225
	July	15.2	306	58.4	-2	96	0	+208	1,433
	Aug.	15.9	577	68.0	-1	93	0	+483	1,916
	Sep.	14.5	452	78.5	-4	79	0	+369	2,285
TOTALS		178.7	1,439		-100	1,053	0	+286	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7	8
									2,285
1923	Oct.	15.0	94	83.0	-8	80	0	+6	2,291
	Nov.	15.4	11	82.1	-13	82	0	-84	2,207
	Dec.	16.8	0	79.9	-12	91	0	-103	2,104
1924	Jan.	15.2	0	78.7	-12	83	0	-95	2,009
	Feb.	14.3	0	75.3	-13	80	0	-93	1,916
	Mar.	13.9	0	73.0	-15	79	0	-94	1,822
	Apr.	13.8	0	70.7	-14	79	0	-93	1,729
	May	14.1	0	68.3	-11	82	0	-93	1,636
	June	14.6	24	66.1	-6	87	0	-69	1,567
	July	15.2	91	65.1	-2	91	0	-2	1,565
	Aug.	15.9	506	70.6	-1	91	0	+414	1,979
	Sep.	14.5	284	78.1	-4	79	0	+201	2,180
TOTALS		178.7	1,010		-111	1,004	0	-105	
1924	Oct.	15.0	26	79.7	-8	81	0	-63	2,117
	Nov.	15.4	6	77.9	-12	84	0	-90	2,027
	Dec.	16.8	0	75.6	-12	93	0	-105	1,922
1925	Jan.	15.2	0	73.1	-11	86	0	-97	1,825
	Feb.	14.3	0	70.8	-12	82	0	-94	1,731
	Mar.	13.9	0	68.3	-14	81	0	-95	1,636
	Apr.	13.8	0	65.7	-13	82	0	-95	1,541
	May	14.1	0	63.1	-10	86	0	-96	1,445
	June	14.6	18	60.6	-6	90	0	-78	1,367
	July	15.2	162	60.4	-2	94	0	+66	1,433
	Aug.	15.9	389	65.5	-1	95	0	+293	1,726
	Sep.	14.5	203	69.9	-4	83	0	+116	1,842
TOTALS		178.7	804		-105	1,037	0	-338	
1925	Oct.	15.0	44	71.8	-7	86	0	-49	1,793
	Nov.	15.4	1	69.9	-11	89	0	-99	1,694
	Dec.	16.8	0	67.1	-10	99	0	-109	1,585
1926	Jan.	15.2	0	64.2	-10	91	0	-101	1,484
	Feb.	14.3	0	61.4	-11	88	0	-99	1,385
	Mar.	13.9	0	58.6	-12	87	0	-99	1,286
	Apr.	13.8	0	55.8	-11	89	0	-100	1,186
	May	14.1	0	52.9	-8	93	0	-101	1,085
	June	14.6	35	50.2	-5	99	0	-69	1,016
	July	15.2	243	51.3	-2	102	0	+139	1,155
	Aug.	15.9	589	60.4	-1	98	0	+490	1,645
	Sep.	14.5	352	70.8	-4	83	0	+265	1,910
TOTALS		178.7	1,264		-92	1,104	0	+68	
1926	Oct.	15.0	67	73.8	-7	84	0	-24	1,886
	Nov.	15.4	6	72.3	-12	88	0	-94	1,792
	Dec.	16.8	0	69.7	-11	97	0	-108	1,684
1927	Jan.	15.2	0	67.0	-10	90	0	-100	1,584
	Feb.	14.3	0	64.2	-11	86	0	-97	1,487
	Mar.	13.9	0	61.5	-12	85	0	-97	1,390
	Apr.	13.8	0	58.7	-12	87	0	-99	1,291
	May	14.1	0	56.0	-9	91	0	-100	1,191
	June	14.6	21	53.3	-5	96	0	-80	1,111
	July	15.2	171	53.2	-2	100	0	+69	1,180
	Aug.	15.9	492	59.8	-1	99	0	+392	1,572
	Sep.	14.5	237	67.3	-3	85	0	+149	1,721
TOTALS		178.7	994		-95	1,088	0	-189	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7	8
									1,721
1927	Oct.	15.0	34	68.5	-7	88	0	-61	1,660
	Nov.	15.4	0	66.3	-11	91	0	-102	1,558
	Dec.	16.8	0	63.3	-10	102	0	-112	1,446
1928	Jan.	15.2	0	60.3	-9	94	0	-103	1,343
	Feb.	14.3	0	57.4	-10	91	0	-101	1,242
	Mar.	13.9	0	54.5	-11	91	0	-102	1,140
	Apr.	13.8	0	51.4	-11	92	0	-103	1,037
	May	14.1	0	48.3	-7	97	0	-104	933
	June	14.6	4	45.0	-4	104	0	-104	829
	July	15.2	232	45.4	-2	108	0	+122	951
	Aug.	15.9	444	52.4	-1	106	0	+337	1,288
	Sep.	14.5	192	58.7	-3	91	0	+98	1,386
TOTALS		178.7	906		-86	1,155	0	-335	
1928	Oct.	15.0	63	59.5	-6	94	0	-37	1,349
	Nov.	15.4	1	57.5	-9	98	0	-106	1,243
	Dec.	16.8	0	54.3	-8	110	0	-118	1,125
1929	Jan.	15.2	0	50.8	-8	102	0	-110	1,015
	Feb.	14.3	0	47.6	-8	99	0	-107	908
	Mar.	13.9	0	44.1	-9	100	0	-109	799
	Apr.	13.8	0	40.6	-8	104	0	-112	687
	May	14.1	8	36.8	-6	111	0	-109	578
	June	14.6	115	34.7	-3	119	0	-7	571
	July	15.2	380	39.2	-1	116	0	+263	834
	Aug.	15.9	599	51.2	-1	107	0	+491	1,325
	Sep.	14.5	563	65.0	-3	87	0	+473	1,798
TOTALS		178.7	1,729		-70	1,247	0	+412	
1929	Oct.	15.0	142	71.9	-7	86	0	+49	1,847
	Nov.	15.4	11	71.4	-11	88	0	-88	1,759
	Dec.	16.8	0	68.8	-11	98	0	-109	1,650
1930	Jan.	15.2	0	66.0	-10	90	0	-100	1,550
	Feb.	14.3	0	63.2	-11	87	0	-98	1,452
	Mar.	13.9	0	60.5	-12	86	0	-98	1,354
	Apr.	13.8	0	57.8	-12	87	0	-99	1,255
	May	14.1	0	54.9	-9	91	0	-100	1,155
	June	14.6	36	52.4	-5	97	0	-66	1,089
	July	15.2	278	54.2	-2	99	0	+177	1,266
	Aug.	15.9	371	60.5	-1	98	0	+272	1,538
	Sep.	14.5	205	65.9	-3	86	0	+116	1,654
TOTALS		178.7	1,043		-94	1,093	0	-144	
1930	Oct.	15.0	25	66.6	-7	89	0	-71	1,583
	Nov.	15.4	2	63.7	-10	93	0	-101	1,482
	Dec.	16.8	0	61.2	-9	103	0	-112	1,370
1931	Jan.	15.2	0	58.1	-9	96	0	-105	1,265
	Feb.	14.3	0	55.2	-10	93	0	-103	1,162
	Mar.	13.9	0	52.1	-11	93	0	-104	1,058
	Apr.	13.8	0	49.0	-10	95	0	-105	953
	May	14.1	0	45.7	-7	100	0	-107	846
	June	14.6	5	42.2	-4	108	0	-107	739
	July	15.2	173	41.4	-2	113	0	+58	797
	Aug.	15.9	493	48.4	-1	110	0	+382	1,179
	Sep.	14.5	414	58.7	-3	91	0	+320	1,499
TOTALS		178.7	1,112		-83	1,184	0	-155	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7	8
									1,499
1931	Oct.	15.0	146	63.9	-6	90	0	+50	1,549
	Nov.	15.4	12	63.3	-10	93	0	-91	1,458
	Dec.	16.8	0	60.5	-9	104	0	-113	1,345
1932	Jan.	15.2	0	57.4	-9	97	0	-106	1,239
	Feb.	14.3	0	54.5	-9	93	0	-102	1,137
	Mar.	13.9	0	51.3	-10	93	0	-103	1,034
	Apr.	13.8	0	48.2	-10	95	0	-105	929
	May	14.1	0	44.8	-7	101	0	-108	821
	June	14.6	0	41.3	-4	109	0	-113	708
	July	15.2	189	40.7	-2	114	0	+73	781
	Aug.	15.9	497	48.0	-1	110	0	+386	1,167
	Sep.	14.5	370	57.8	-3	92	0	+275	1,442
TOTALS		178.7	1,214		-80	1,191	0	-57	
1932	Oct.	15.0	54	61.0	-6	92	0	-44	1,398
	Nov.	15.4	5	58.9	-9	97	0	-101	1,297
	Dec.	16.8	0	55.9	-9	108	0	-117	1,180
1933	Jan.	15.2	0	52.6	-8	101	0	-109	1,071
	Feb.	14.3	0	49.3	-9	98	0	-107	964
	Mar.	13.9	0	46.0	-9	98	0	-107	857
	Apr.	13.8	0	42.6	-9	101	0	-110	747
	May	14.1	0	38.8	-6	108	0	-114	633
	June	14.6	4	34.7	-3	119	0	-118	515
	July	15.2	159	33.0	-1	126	0	+32	547
	Aug.	15.9	511	40.6	-1	120	0	+390	937
	Sep.	14.5	417	51.6	-3	97	0	+317	1,254
TOTALS		178.7	1,150		-73	1,265	0	-188	
1933	Oct.	15.0	126	56.7	-6	96	0	+24	1,278
	Nov.	15.4	18	55.7	-9	99	0	-90	1,188
	Dec.	16.8	4	52.7	-8	111	0	-115	1,073
1934	Jan.	15.2	0	49.3	-8	104	0	-112	961
	Feb.	14.3	0	45.8	-8	101	0	-109	852
	Mar.	13.9	0	42.3	-9	102	0	-111	741
	Apr.	13.8	0	38.7	-8	106	0	-114	627
	May	14.1	0	34.4	-5	115	0	-120	507
	June	14.6	64	30.6	-3	125	0	-64	443
	July	15.2	401	34.9	-1	123	0	+277	720
	Aug.	15.9	762	50.1	-1	108	0	+653	1,373
	Sep.	14.5	449	64.7	-3	87	0	+359	1,732
TOTALS		178.7	1,824		-69	1,277	0	+478	
1934	Oct.	15.0	86	69.5	-7	87	0	-8	1,724
	Nov.	15.4	29	68.4	-11	90	0	-72	1,652
	Dec.	16.8	15	66.2	-10	100	0	-95	1,557
1935	Jan.	15.2	1	63.4	-10	92	0	-101	1,456
	Feb.	14.3	0	60.6	-10	88	0	-98	1,358
	Mar.	13.9	0	57.9	-12	88	0	-100	1,258
	Apr.	13.8	0	55.0	-11	89	0	-100	1,158
	May	14.1	0	52.0	-8	94	0	-102	1,056
	June	14.6	53	49.7	-5	99	0	-51	1,005
	July	15.2	237	50.9	-2	102	0	+133	1,138
	Aug.	15.9	480	58.4	-1	100	0	+379	1,517
	Sep.	14.5	393	67.9	-3	85	0	+305	1,822
TOTALS		178.7	1,294		-90	1,114	0	+90	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7	8
									1,822
1935	Oct.	15.0	70	71.5	-7	86	0	-23	1,799
	Nov.	15.4	8	70.1	-11	89	0	-92	1,707
	Dec.	16.8	1	67.5	-10	99	0	-108	1,599
1936	Jan.	15.2	0	64.6	-10	91	0	-101	1,498
	Feb.	14.3	0	62.0	-11	88	0	-99	1,399
	Mar.	13.9	0	59.0	-12	87	0	-99	1,300
	Apr.	13.8	0	56.2	-12	89	0	-101	1,199
	May	14.1	0	53.2	-8	93	0	-101	1,098
	June	14.6	34	50.7	-5	98	0	-69	1,029
	July	15.2	286	52.4	-2	101	0	+183	1,212
	Aug.	15.9	565	61.8	-1	97	0	+467	1,679
	Sep.	14.5	694	75.8	-4	81	0	+609	2,288
TOTALS		178.7	1,658		-93	1,099	0	+466	
1936	Oct.	15.0	240	84.8	-8	79	0	+153	2,441
	Nov.	15.4	3	85.5	-14	81	0	-92	2,349
	Dec.	16.8	0	83.2	-13	89	0	-102	2,247
1937	Jan.	15.2	0	80.9	-12	82	0	-94	2,153
	Feb.	14.3	0	78.7	-14	78	0	-92	2,061
	Mar.	13.9	0	76.5	-15	77	0	-92	1,969
	Apr.	13.8	0	74.3	-15	77	0	-92	1,877
	May	14.1	0	72.1	-11	80	0	-91	1,786
	June	14.6	21	70.1	-7	84	0	-70	1,716
	July	15.2	255	71.2	-3	87	0	+165	1,881
	Aug.	15.9	691	80.5	-1	86	0	+604	2,485
	Sep.	14.5	273	90.3	-5	74	0	+194	2,679
TOTALS		178.7	1,483		-118	974	0	+391	
1937	Oct.	15.0	50	92.3	-9	76	0	-35	2,644
	Nov.	15.4	6	90.8	-15	78	0	-87	2,557
	Dec.	16.8	2	88.4	-14	87	0	-99	2,458
1938	Jan.	15.2	0	85.9	-13	79	0	-92	2,366
	Feb.	14.3	0	83.7	-14	76	0	-90	2,276
	Mar.	13.9	0	81.7	-17	74	0	-91	2,185
	Apr.	13.8	0	79.5	-16	75	0	-91	2,094
	May	14.1	0	77.4	-12	77	0	-89	2,005
	June	14.6	0	75.2	-7	81	0	-88	1,917
	July	15.2	243	76.0	-3	84	0	+156	2,073
	Aug.	15.9	557	83.5	-1	84	0	+472	2,545
	Sep.	14.5	558	91.3	-5	74	324	+155	2,700
TOTALS		178.7	1,416		-126	945	324	+21	
1938	Oct.	15.0	149	93.3	-9	75	65	0	2,700
	Nov.	15.4	18	92.3	-15	78	0	-75	2,625
	Dec.	16.8	3	90.1	-14	86	0	-97	2,528
1939	Jan.	15.2	0	87.7	-14	79	0	-93	2,435
	Feb.	14.3	0	85.4	-15	75	0	-90	2,345
	Mar.	13.9	0	83.2	-17	74	0	-91	2,254
	Apr.	13.8	0	81.1	-17	74	0	-91	2,163
	May	14.1	0	79.0	-12	77	0	-89	2,074
	June	14.6	27	77.2	-7	80	0	-60	2,014
	July	15.2	190	77.8	-3	83	0	+104	2,118
	Aug.	15.9	486	83.7	-1	84	0	+401	2,519
	Sep.	14.5	298	91.0	-5	74	38	+181	2,700
TOTALS		178.7	1,171		-129	939	103		

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7	8
									2,700
1939	Oct.	15.0	82	93.3	-9	75	0	-2	2,698
	Nov.	15.4	8	92.2	-15	78	0	-85	2,613
	Dec.	16.8	2	89.6	-14	86	0	-98	2,515
1940	Jan.	15.2	0	87.0	-13	79	0	-92	2,423
	Feb.	14.3	0	85.1	-15	75	0	-90	2,333
	Mar.	13.9	0	83.0	-17	74	0	-91	2,242
	Apr.	13.8	0	80.8	-17	74	0	-91	2,151
	May	14.1	0	78.7	-12	77	0	-89	2,062
	June	14.6	2	76.6	-7	81	0	-86	1,976
	July	15.2	178	76.7	-3	84	0	+91	2,067
	Aug.	15.9	476	82.4	-1	85	0	+390	2,457
	Sep.	14.5	226	88.9	-5	75	0	+146	2,603
TOTALS		178.7	974		-128	943	0	-97	
1940	Oct.	15.0	28	90.1	-9	77	0	-58	2,545
	Nov.	15.4	5	88.2	-14	79	0	-88	2,457
	Dec.	16.8	0	85.8	-13	88	0	-101	2,356
1941	Jan.	15.2	0	83.5	-13	80	0	-93	2,263
	Feb.	14.3	0	81.4	-14	77	0	-91	2,172
	Mar.	13.9	0	79.2	-16	76	0	-92	2,080
	Apr.	13.8	0	77.0	-16	76	0	-92	1,988
	May	14.1	0	74.6	-12	79	0	-91	1,897
	June	14.6	0	72.6	-7	83	0	-90	1,807
	July	15.2	88	71.4	-3	87	0	-2	1,805
	Aug.	15.9	195	72.7	-1	90	0	+104	1,909
	Sep.	14.5	136	74.6	-4	81	0	+51	1,960
TOTALS		178.7	452		-122	973	0	-643	
1941	Oct.	15.0	54	74.8	-7	84	0	-37	1,923
	Nov.	15.4	16	73.3	-12	87	0	-83	1,840
	Dec.	16.8	1	71.0	-11	96	0	-106	1,734
1942	Jan.	15.2	0	68.3	-11	89	0	-100	1,634
	Feb.	14.3	0	65.7	-11	85	0	-96	1,538
	Mar.	13.9	0	63.0	-13	84	0	-97	1,441
	Apr.	13.8	0	60.2	-12	86	0	-98	1,343
	May	14.1	0	57.5	-9	90	0	-99	1,244
	June	14.6	16	54.9	-5	95	0	-84	1,160
	July	15.2	269	56.1	-2	98	0	+169	1,329
	Aug.	15.9	527	64.5	-1	95	0	+431	1,760
	Sep.	14.5	361	83.8	-4	82	0	+275	2,035
TOTALS		178.7	1,244		-98	1,071	0	+75	
1942	Oct.	15.0	55	76.6	-8	83	0	-36	1,999
	Nov.	15.4	6	75.0	-12	86	0	-92	1,907
	Dec.	16.8	1	72.7	-11	95	0	-105	1,802
1943	Jan.	15.2	0	70.1	-11	88	0	-99	1,703
	Feb.	14.3	0	67.5	-12	84	0	-96	1,607
	Mar.	13.9	0	64.9	-13	82	0	-95	1,512
	Apr.	13.8	0	62.3	-13	84	0	-97	1,415
	May	14.1	0	59.4	-9	88	0	-97	1,318
	June	14.6	47	57.4	-5	93	0	-51	1,267
	July	15.2	223	58.5	-2	96	0	+125	1,392
	Aug.	15.9	405	64.5	-1	95	0	+309	1,701
	Sep.	14.5	345	72.1	-4	83	0	+258	1,959
TOTALS		178.7	1,082		-101	1,057	0	-76	
	Oct.	15.0	99	75.3	-7	84	0	+8	1,967

The estimated average tailwater elevation for the Junction Powerplant is 899 meters. Allowing for 3 meters of penstock losses, the operation study shows the plant can operate under the montly load curve (Figure III-60) with an annual generation of 178.7 kilowatt-hours.

Dindir Dam, downstream from Junction Dam, reregulates releases from that dam, stores inflow from between the two dams, and provides the diversion point for the canal serving the Dindir irrigated lands.

The annual farm delivery requirement is estimated as 1.375 meters. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.964 meters or 1,145 million cubic meters for the 58,300 hectares. Inspection of the inflow to the Dindir Reservoir as modified by the operation of Junction Dam and Powerplant (Table III-146) shows that this irrigation requirement can be met without shortages in all years with only seasonal storage required at Dindir Reservoir. Further inspection of this modified inflow record shows that the minimum inflow year of 1941 is the critical year for determining the reservoir storage required at Dindir Dam.

The Dindir Dam operation study (Table III-147) (with the 50-year sediment quantity distributed) and the subsequent dam layout utilized an active capacity of 532 million cubic meters between a minimum operating level of 733.25 meters and a spillway crest elevation of 754.75 meters.

The Junction and Dindir Dam operation studies were run under the criteria described earlier in this chapter in the plan for Inititial Development. This fully controls the streamflow at Junction Dam through the long 21-year, 1917 to 1938, drought period. Because of this long study period, possible errors in the water supply estimates would be more damaging than in the shorter 6-year drought period of study used in most of the basin. Therefore, estimated yields, active capacities and dam volumes required for shorter study periods are given in Table III-148 in comparison with the plan presented.

Galegu Project. This project consists of the Galegu Storage Dam and Reservoir and 11,700 hectares of irrigated land served by a canal from the dam.

The annual farm delivery requirement is estimated as 1.375 meters (the same as for the Dindir and Rahad lands). Allowing 10 percent for seepage loss and 20 percent for canal waste, gives a diversion requirement of 1.964 meters or 230 million cubic meters for the 11,700 hectares.

To provide a full supply in all years, the operation study (Table III-149) (with the 50-year sediment quantity assumed in the bottom of the reservoir) utilized an active capacity of 644.7 million cubic meters between the then-assumed minimum operating level of 771.92 meters and the then-assumed spillway crest elevation of 819.86 meters.

Subsequent to making the operation study, the dam layout (with the 50-year sediment quantity distributed) placed the active capacity of 644.7 million cubic meters between a minimum operating level of 777 meters and a spillway crest elevation of 822.92 meters. A new operation study would change surface losses only by insignificant amounts.

As in the Dindir project, possible errors in the 21-year water supply estimate would be more damaging than in the shorter 6-year drought period of study used in most of the basin. Therefore, estimated yields, active capacities, and dam volumes in millions of cubic meters, required for shorter study periods are tabulated below in comparison with the plan presented.

TABLE III-146--MODIFIED INFLOW AT DINDIR (DI-2) DAMSITE1/

Year	In millions of cubic meters													Square kilo-meters
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
1917										234	89	86		4,900
1918	79	75	74	74	77	122	205	328	182	94	81	89	1,480	
1919	82	78	77	78	81	99	255	240	201	91	86	95	1,463	
1920	88	84	83	85	88	139	346	510	382	172	86	88	2,151	
1921	81	77	76	77	80	90	155	335	282	121	83	92	1,549	
1922	85	81	80	81	84	102	185	298	335	139	88	95	1,653	
1923	88	84	83	85	88	105	305	486	386	143	89	91	2,033	
1924	83	80	79	79	82	104	153	436	273	99	89	93	1,650	
1925	86	82	81	82	86	102	206	360	221	115	90	99	1,610	
1926	91	88	87	89	93	124	267	499	322	130	92	97	1,979	
1927	90	86	85	87	91	110	221	434	247	110	91	102	1,754	
1928	94	91	91	92	97	108	266	408	221	136	99	110	1,813	
1929	102	99	100	104	117	198	375	515	470	182	95	98	2,455	
1930	90	87	86	87	91	122	288	350	226	107	94	103	1,731	
1931	96	93	93	95	100	112	230	445	372	190	101	104	2,031	
1932	97	93	93	95	101	109	243	449	344	128	101	108	1,961	
1933	101	98	98	101	108	121	234	468	381	182	112	113	2,117	
1934	104	101	102	106	115	169	396	626	393	146	110	111	2,479	
1935	93	88	88	89	94	135	264	427	352	134	95	100	1,959	
1936	91	88	87	89	93	122	296	482	554	242	83	89	2,316	
1937	82	78	77	77	80	98	261	556	259	110	83	88	1,849	
1938	79	76	74	75	77	81	249	464	778	242	91	88	2,374	
1939	79	75	74	74	77	99	212	415	315	130	84	87	1,721	
1940	79	75	74	74	77	82	205	409	229	96	82	88	1,570	
1941	80	77	76	76	79	83	147	223	174	120	99	97	1,331	
1942	89	85	84	86	90	107	281	454	327	120	91	96	1,910	
1943	88	84	82	84	88	125	247	371	319	152				

1/ Natural inflow at DI-2 + (DI-7 releases and spills - DI-7 natural inflow).

TABLE III-147--RESERVOIR OPERATION STUDY--DINDIR (DI-2) RESERVOIR

Sheet 1 of 1
January 1964

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION
50,000,000 cu. m. (41,000 acre-ft.)	582,000,000 cu. m. (472,000 acre-ft.)	754.75 m. (2476 ft.)

FIRM YIELD, 1,145,000,000 cu. m. per yr. for 58,300 hectares (929,000 acre-ft. per yr. for 144,000 acres)

UNITS are in millions of cubic meters, except as noted.

Year	Months	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Irrigation release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7
								582
1940	Oct.	96	47.1	-5	114	0	-23	559
	Nov.	82	43.7	-7	142	0	-67	492
	Dec.	88	39.1	-6	148	0	-66	426
1941	Jan.	80	34.8	-6	146	0	-72	354
	Feb.	77	30.4	-6	135	0	-64	290
	Mar.	76	25.2	-5	162	0	-91	199
	Apr.	76	18.5	-4	160	0	-88	111
	May	79	11.9	-2	138	0	-61	50
	June	83	13.0	-1	0	0	+82	132
	July	147	22.4	-1	0	0	+146	278
	Aug.	223	34.7	-1	0	0	+222	500
	Sep.	174	44.8	-3	0	89	+82	582
TOTALS		1,281		-47	1,145	89	0	

TABLE III-148--DINDIR PROJECT YIELD v. STORAGE STUDY

Study period	Firm power yield (million kw.-hr. per yr.)	Firm water yield for irrigation (million cu. m. per yr.)	Land irrigable without shortages (hectares)	In million cubic meters: Junction Dam, Active capacity required	In million cubic meters: Junction Dam, Dam volume required	In million cubic meters: Dindir Dam, Active capacity required	In million cubic meters: Dindir Dam, Dam volume required	Total volume of embankment required
1917-41*	178.7	1,145	58,300	2,421	32.1	532	2.5	34.6
1939-46	135	1,145	58,300	1,340	18	600	2.7	21
1912-15	90	1,145	58,300	570	8	770	3.2	11
1940-41	45	680	34,600	310	6	390	2.3	8

* Initial development plan.

TABLE III-149--RESERVOIR OPERATION STUDY--GALEGU RESERVOIR

Sheet 1 of 6
February 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION
90,300,000 cu. m. (73,200 acre-ft.)	735,000,000 cu. m. (596,000 acre-ft.)	819.86 m. (2690 ft.)

FIRM YIELD, 230,000,000 cu. m. per yr. for 11,700 hectares
(187,000 acre-ft. per yr. for 28,900 acres)

Operation study was made between tentatively assumed levels without sediment. Sediment distribution at 50 years was later estimated, and (as shown on area-capacity data sheets) operating levels were adjusted slightly to retain active capacity used in the study.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Inflow	Average surface area sq. km.	Evaporation Precipitation correction	Irrigation release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7
								735.00
1917	Oct.	30.6	20.78	-2.26	23.0	5.34	0	735.00
	Nov.	3.3	20.78	-3.50	28.5	0	-28.70	706.30
	Dec.	0	20.39	-3.33	29.6	0	-32.93	673.37
1918	Jan.	0	19.97	-3.24	29.2	0	-32.44	640.93
	Feb.	0	19.49	-3.55	27.2	0	-30.75	610.18
	Mar.	0	19.15	-4.08	32.7	0	-36.78	573.40
	Apr.	0	18.58	-4.03	32.2	0	-36.23	537.17
	May	0	18.51	-3.18	27.6	0	-30.78	506.39
	June	13.1	17.32	-1.80	0	0	+11.30	517.69
	July	37.9	17.72	-0.78	0	0	+37.12	554.81
	Aug.	75.2	18.65	-0.34	0	0	+74.86	629.67
	Sep.	33.1	19.49	-1.13	0	0	+31.97	661.64
TOTALS		193.2		-31.22	230.0	5.34	-73.36	
1918	Oct.	4.9	19.73	-2.15	23.0	0	-20.25	641.39
	Nov.	0	19.55	-3.28	28.5	0	-31.78	609.61
	Dec.	0	19.07	-3.09	29.6	0	-32.69	576.92
1919	Jan.	0	18.65	-3.07	29.2	0	-32.22	544.70
	Feb.	0	18.72	-3.41	27.2	0	-30.61	514.09
	Mar.	0	17.64	-3.72	32.7	0	-36.47	477.62
	Apr.	0	17.01	-3.69	32.2	0	-35.89	441.73
	May	0	16.30	-2.80	27.6	0	-30.40	411.33
	June	4.5	15.45	-1.61	0	0	+2.89	414.22
	July	51.7	15.98	-0.70	0	0	+51.00	465.22
	Aug.	46.9	16.87	-0.30	0	0	+46.80	511.82
	Sep.	37.6	17.64	-1.02	0	0	+36.58	548.40
TOTALS		145.6		-28.84	230.0		-113.24	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Inflow	Average surface area sq. km.	Evaporation Precipitation correction	Irrigation release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7
								548.4
1919	Oct.	2.7	18.09	-2.0	23.0	0	-22.3	526.1
	Nov.	0	17.80	-3.0	28.5	0	-31.5	494.6
	Dec.	0	17.24	-2.8	29.6	0	-32.4	462.2
1920	Jan.	0	16.73	-2.7	29.2	0	-31.9	430.3
	Feb.	0	16.14	-2.9	27.2	0	-30.1	400.2
	Mar.	0	15.52	-3.3	32.7	0	-36.0	364.2
	Apr.	0	14.89	-3.2	32.2	0	-35.4	328.8
	May	0	13.90	-2.4	27.6	0	-30.0	298.8
	June	13.9	12.98	-1.3	0	0	+12.6	311.4
	July	78.4	14.08	-0.6	0	0	+77.8	389.2
	Aug.	130.0	16.30	-0.3	0	0	+129.7	518.9
	Sep.	94.7	18.23	-1.1	0	0	+93.6	612.5
TOTALS		319.7		-25.6	230.0		+64.1	
1920	Oct.	28.9	18.93	-2.1	23.0	0	+3.8	616.3
	Nov.	2.0	19.23	-3.2	28.5	0	-29.7	586.6
	Dec.	0	18.79	-3.0	29.6	0	-32.6	554.0
1921	Jan.	0	18.23	-3.0	29.2	0	-32.2	521.8
	Feb.	0	17.72	-3.2	27.2	0	-30.4	491.4
	Mar.	0	17.16	-3.7	32.7	0	-36.4	455.0
	Apr.	0	16.59	-3.6	32.2	0	-35.8	419.2
	May	0	15.82	-2.2	27.6	0	-29.8	389.4
	June	2.0	15.03	-1.6	0	0	+0.4	389.8
	July	21.0	15.24	-0.7	0	0	+20.3	410.1
	Aug.	75.8	16.14	-0.3	0	0	+75.5	485.6
	Sep.	62.4	17.32	-1.0	0	0	+61.4	547.0
TOTALS		192.1		-27.6	230.0		-65.5	
1921	Oct.	12.6	18.09	-2.0	23.0	0	-12.4	534.6
	Nov.	0	17.95	-3.0	28.5	0	-31.5	503.1
	Dec.	0	17.40	-2.8	29.6	0	-32.4	470.7
1922	Jan.	0	16.87	-2.7	29.2	0	-31.9	438.8
	Feb.	0	16.30	-3.0	27.2	0	-30.2	408.6
	Mar.	0	15.66	-3.3	32.7	0	-36.0	372.6
	Apr.	0	15.10	-3.3	32.2	0	-35.5	337.1
	May	0	14.08	-2.4	27.6	0	-30.0	307.1
	June	4.5	13.06	-1.4	0	0	+3.1	310.2
	July	28.7	13.38	-0.6	0	0	+28.1	338.3
	Aug.	63.3	14.62	-0.3	0	0	+63.0	401.3
	Sep.	78.6	15.98	-0.9	0	0	+77.7	479.0
TOTALS		187.7		-25.7	230.0		-68.0	
1922	Oct.	17.7	16.73	-1.8	23.0	0	-7.1	471.9
	Nov.	0.7	16.87	-2.8	28.5	0	-30.6	441.3
	Dec.	0	16.45	-2.7	29.6	0	-32.3	409.0
1923	Jan.	0	15.66	-2.5	29.2	0	-31.7	377.3
	Feb.	0	14.98	-2.7	27.2	0	-29.9	347.4
	Mar.	0	14.44	-3.1	32.7	0	-35.8	311.6
	Apr.	0	13.54	-2.9	32.2	0	-35.1	276.5
	May	0	12.66	-2.2	27.6	0	-29.8	246.7
	June	3.4	11.48	-1.2	0	0	+2.2	248.9
	July	64.6	12.34	-0.5	0	0	+64.1	313.0
	Aug.	121.9	14.71	-0.3	0	0	+121.6	434.6
	Sep.	95.5	16.73	-1.0	0	0	+94.5	529.1
TOTALS		303.8		-23.7	230.0		+50.1	

GALEGU RESERVOIR, Sheet 3 of 6

UNITS are in millions of cubic meters, except as noted.

Year	Months	Inflow	Average surface area sq. km.	Precip. and evap. correction	Irrigation release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7
								529.1
1923	Oct.	19.7	17.64	-1.9	23.0	0	-5.2	523.9
	Nov.	2.3	17.88	-3.0	28.5	0	-29.2	494.7
	Dec.	0	17.24	-2.8	29.6	0	-32.4	462.3
1924	Jan.	0	16.66	-2.7	29.2	0	-31.9	430.4
	Feb.	0	16.06	-2.9	27.2	0	-30.1	400.3
	Mar.	0	15.52	-3.3	32.7	0	-36.0	364.3
	Apr.	0	14.89	-3.2	32.2	0	-35.4	328.9
	May	0	13.99	-2.4	27.6	0	-30.0	298.9
	June	5.2	12.90	-1.3	0	0	+3.9	302.8
	July	19.1	13.14	-0.6	0	0	+18.5	321.3
	Aug.	106.9	14.71	-0.3	0	0	+106.6	427.9
	Sep.	60.0	16.30	-0.9	0	0	+59.1	487.0
TOTALS		213.2		-25.3	230.0		-42.1	
1924	Oct.	5.6	17.01	-1.9	23.0	0	-19.3	467.7
	Nov.	1.3	16.80	-2.8	28.5	0	-30.0	437.7
	Dec.	0	16.22	-2.6	29.6	0	-32.2	405.5
1925	Jan.	0	15.59	-2.5	29.2	0	-31.7	373.8
	Feb.	0	15.03	-2.7	27.2	0	-29.9	343.9
	Mar.	0	14.35	-3.1	32.7	0	-35.8	308.1
	Apr.	0	13.46	-2.9	32.2	0	-35.1	273.0
	May	0	12.50	-2.2	27.6	0	-29.8	243.2
	June	3.9	11.40	-1.2	0	0	+2.7	245.9
	July	34.4	11.86	-0.5	0	0	+33.9	279.8
	Aug.	82.2	13.30	-0.2	0	0	+82.0	361.8
	Sep.	42.8	14.89	-0.9	0	0	+41.9	403.7
TOTALS		170.2		-23.5	230.0		-83.3	
1925	Oct.	9.3	15.45	-1.7	23.0	0	-15.4	388.3
	Nov.	0.2	15.31	-2.6	28.5	0	-30.0	357.4
	Dec.	0	14.71	-2.4	29.6	0	-32.0	325.4
1926	Jan.	0	13.90	-2.3	29.2	0	-31.5	293.9
	Feb.	0	13.06	-2.4	27.2	0	-29.6	264.3
	Mar.	0	12.42	-2.7	32.7	0	-35.4	228.9
	Apr.	0	11.48	-2.5	32.2	0	-34.7	194.2
	May	0	10.41	-1.8	27.6	0	-29.4	164.8
	June	7.4	9.11	-0.9	0	0	+6.5	171.3
	July	51.2	10.06	-0.4	0	0	+50.8	222.1
	Aug.	124.5	12.42	-0.2	0	0	+124.3	346.4
	Sep.	74.2	14.89	-0.9	0	0	+73.3	419.7
TOTALS		266.8		-20.8	230.0		+16.0	
1926	Oct.	14.2	15.66	-1.7	23.0	0	-10.5	409.2
	Nov.	1.4	15.66	-2.6	28.5	0	-29.7	379.5
	Dec.	0	15.17	-2.5	29.6	0	-32.1	347.4
1927	Jan.	0	14.44	-2.3	29.2	0	-31.5	315.9
	Feb.	0	13.54	-2.5	27.2	0	-29.7	286.2
	Mar.	0	12.98	-2.8	32.7	0	-35.5	250.7
	Apr.	0	12.02	-2.6	32.2	0	-34.8	215.9
	May	0	11.00	-1.9	27.6	0	-29.5	186.4
	June	4.4	9.82	-1.0	0	0	+3.4	189.8
	July	36.6	10.62	-0.5	0	0	+36.1	225.9
	Aug.	103.9	12.26	-0.2	0	0	+103.7	329.6
	Sep.	50.1	14.17	-0.8	0	0	+49.3	378.9
TOTALS		210.6		-21.4	230.0		-40.8	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Inflow	Average surface area sq. km.	Precip. and evap. correction	Irrigation release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7
								378.9
1927	Oct.	7.1	15.03	-1.6	23.0	0	-17.5	361.4
	Nov.	0	14.71	-2.5	28.5	0	-31.0	330.4
	Dec.	0	13.99	-2.3	29.6	0	-31.9	298.5
1928	Jan.	0	13.22	-2.1	29.2	0	-31.3	267.2
	Feb.	0	12.34	-2.3	27.2	0	-29.5	237.7
	Mar.	0	12.66	-2.7	32.7	0	-35.4	202.3
	Apr.	0	10.69	-2.3	32.2	0	-34.5	167.8
	May	0	9.58	-1.7	27.6	0	-29.3	138.5
	June	1.0	8.10	-.8	0	0	+0.2	138.7
	July	48.9	8.97	-.4	0	0	+48.5	187.2
	Aug.	93.7	11.08	-.2	0	0	+93.5	280.7
	Sep.	40.5	12.82	-.7	0	0	+39.8	320.5
TOTALS		191.2		-19.6	230.0		-58.4	
1928	Oct.	13.2	13.46	-1.5	23.0	0	-11.3	309.2
	Nov.	0.2	13.46	-2.3	28.5	0	-30.6	278.6
	Dec.	0	12.74	-2.1	29.6	0	-31.7	246.9
1929	Jan.	0	11.86	-1.9	29.2	0	-31.1	215.8
	Feb.	0	11.00	-2.0	27.2	0	-29.2	186.6
	Mar.	0	10.27	-2.2	32.7	0	-34.9	151.7
	Apr.	0	9.11	-2.0	32.2	0	-34.2	117.5
	May	1.8	7.89	-1.4	27.6	0	-24.5	90.3
	June	24.4	6.84	-.7	0	0	+23.7	114.0
	July	80.2	8.31	-.4	0	0	+79.8	193.8
	Aug.	126.6	11.70	-.2	0	0	+126.4	320.2
	Sep.	118.8	14.80	-.9	0	0	+117.9	438.1
TOTALS		365.2		-17.6	230.0		+117.6	
1929	Oct.	29.9	15.98	-1.7	23.0	0	+5.2	443.3
	Nov.	2.3	16.30	-2.7	28.5	0	-28.9	414.4
	Dec.	0	15.82	-2.6	29.6	0	-32.2	382.2
1930	Jan.	0	15.17	-2.5	29.2	0	-31.7	350.5
	Feb.	0	14.53	-2.7	27.2	0	-29.9	320.6
	Mar.	0	13.81	-2.9	32.7	0	-35.6	285.0
	Apr.	0	12.98	-2.8	32.2	0	-35.0	250.0
	May	0	11.94	-2.1	27.6	0	-29.7	220.3
	June	7.7	10.92	-1.1	0	0	+6.6	226.9
	July	58.7	11.70	-.5	0	0	+58.2	285.1
	Aug.	78.2	13.46	-.2	0	0	+78.0	363.1
	Sep.	43.4	14.98	-.9	0	0	+42.5	405.6
TOTALS		220.2		-22.7	230.0		-32.5	
1930	Oct.	5.4	15.52	-1.7	23.0	0	-19.3	386.3
	Nov.	0.3	15.24	-2.6	28.5	0	-30.8	355.5
	Dec.	0	14.62	-2.4	29.6	0	-32.0	323.5
1931	Jan.	0	13.81	-2.2	29.2	0	-31.4	292.1
	Feb.	0	12.98	-2.4	27.2	0	-29.6	262.5
	Mar.	0	12.34	-2.6	32.7	0	-35.3	227.2
	Apr.	0	11.40	-2.5	32.2	0	-34.7	192.5
	May	0	10.34	-1.8	27.6	0	-29.4	163.1
	June	1.2	8.97	-.9	0	0	+0.3	163.4
	July	36.5	9.58	-.4	0	0	+36.1	199.5
	Aug.	104.0	11.56	-.2	0	0	+103.8	303.3
	Sep.	87.3	13.99	-.8	0	0	+86.5	389.8
TOTALS		234.7		-20.5	230.0		-15.8	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Inflow	Average surface area sq. km.	Precip. and evap. correction	Irrigation release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7
								389.8
1931	Oct.	31.0	15.10	-1.7	23.0	0	+6.3	396.1
	Nov.	2.5	15.45	-2.6	28.5	0	-28.6	367.5
	Dec.	0	14.89	-2.4	29.6	0	-32.0	335.5
1932	Jan.	0	14.17	-2.3	29.2	0	-31.5	304.0
	Feb.	0	13.30	-2.4	27.2	0	-29.6	274.4
	Mar.	0	12.66	-2.7	32.7	0	-55.4	239.0
	Apr.	0	11.70	-2.5	32.2	0	-34.7	204.3
	May	0	10.69	-1.8	27.6	0	-29.4	174.9
	June	0	9.34	-1.0	0	0	-1.0	173.9
	July	40.0	10.06	-.4	0	0	+39.6	213.5
	Aug.	105.0	12.02	-.2	0	0	+104.8	318.3
	Sep.	78.1	14.35	-.8	0	0	+77.3	395.6
TOTALS		256.6		-20.8	230.0		+5.8	
1932	Oct.	11.4	15.31	-1.7	23.0	0	-13.3	382.3
	Nov.	1.1	15.17	-2.6	28.5	0	-30.0	352.3
	Dec.	0	14.53	-2.4	29.6	0	-32.0	320.3
1933	Jan.	0	13.72	-2.2	29.2	0	-31.4	288.9
	Feb.	0	12.90	-2.4	27.2	0	-29.6	259.8
	Mar.	0	12.26	-2.6	32.7	0	-35.3	224.0
	Apr.	0	11.32	-2.5	32.2	0	-34.7	189.3
	May	0	10.27	-1.8	27.6	0	-29.4	159.9
	June	0.8	8.90	-.9	0	0	0.1	159.8
	July	33.6	10.48	-.5	0	0	+33.1	192.9
	Aug.	107.9	11.70	-.2	0	0	+107.7	300.6
	Sep.	88.2	13.99	-.8	0	0	+87.4	388.0
TOTALS		243.0		-20.6	230.0		-7.6	
1933	Oct.	26.6	15.03	-1.6	23.0	0	+2.0	390.0
	Nov.	3.9	15.31	-2.6	28.5	0	-27.2	362.8
	Dec.	0.8	14.80	-2.4	29.6	0	-31.2	331.6
1934	Jan.	0	13.99	-2.3	29.2	0	-31.5	300.1
	Feb.	0	13.22	-2.4	27.2	0	-29.6	270.5
	Mar.	0	12.42	-2.7	32.7	0	-35.4	235.1
	Apr.	0	11.63	-2.5	32.2	0	-34.7	200.4
	May	0	10.55	-1.8	27.6	0	-29.4	171.0
	June	13.6	9.42	-1.0	0	0	+12.6	183.6
	July	84.6	10.84	-.5	0	0	+84.1	267.7
	Aug.	160.9	13.99	-.3	0	0	+160.6	428.3
	Sep.	94.8	16.66	-1.0	0	0	+93.8	522.1
TOTALS		385.2		-21.1	230.0		+134.1	
1934	Oct.	18.2	17.56	-1.9	23.0	0	-6.7	515.4
	Nov.	6.2	17.56	-3.0	28.5	0	-25.3	490.1
	Dec.	3.2	17.16	-2.8	29.6	0	-29.2	460.9
1935	Jan.	0.2	16.66	-2.7	29.2	0	-31.7	429.2
	Feb.	0	16.06	-2.9	27.2	0	-30.1	399.1
	Mar.	0	15.52	-3.3	32.7	0	-36.0	363.1
	Apr.	0	14.80	-2.2	32.2	0	-35.4	327.7
	May	0	13.90	-2.4	27.6	0	-30.0	297.7
	June	11.1	12.90	-1.3	0	0	+9.8	307.5
	July	50.1	13.63	-.6	0	0	+49.5	357.0
	Aug.	101.5	15.38	-.3	0	0	+101.2	458.2
	Sep.	83.0	17.01	-1.0	0	0	+82.0	540.2
TOTALS		273.5		-25.4	230.0		+18.1	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Inflow	Average surface area sq. km.	Precip. and evap. correction	Irrigation release	Spill	Change in storage	End of month storage
		1	2	3	4	5	6	7
								540.2
1935	Oct.	14.8	17.88	-2.0	23.0	0	-10.2	530.0
	Nov.	1.7	17.88	-3.0	28.5	0	-29.8	500.2
	Dec.	0.1	17.32	-2.8	29.6	0	-32.3	467.9
1936	Jan.	0	16.80	-2.7	29.2	0	-31.9	436.0
	Feb.	0	16.22	-3.0	27.2	0	-30.2	405.8
	Mar.	0	15.66	-3.3	32.7	0	-36.0	369.8
	Apr.	0	14.98	-3.3	32.2	0	-35.5	334.3
	May	0	14.08	-2.4	27.6	0	-30.0	304.3
	June	7.2	13.06	-1.4	0	0	+5.8	310.1
	July	60.5	13.81	-0.6	0	0	+59.9	370.0
	Aug.	119.5	15.74	-0.3	0	0	+119.2	489.2
	Sep.	146.8	18.16	-1.1	0	0	+145.7	634.9
TOTALS		350.6		-25.9	230.0		+94.7	
1936	Oct.	50.6	19.43	-2.1	23.0	0	+25.5	660.4
	Nov.	0.5	19.79	-3.3	28.5	0	-31.3	629.1
	Dec.	0	19.37	-3.1	29.6	0	-32.7	596.4
1937	Jan.	0	18.93	-3.1	29.2	0	-32.3	564.1
	Feb.	0	18.44	-3.4	27.2	0	-30.6	533.5
	Mar.	0	18.02	-3.8	32.7	0	-36.5	497.0
	Apr.	0	17.32	-3.8	32.2	0	-36.0	461.0
	May	0	16.66	-2.9	27.6	0	-30.5	430.5
	June	4.4	15.82	-1.7	0	0	+2.7	433.2
	July	53.9	16.38	-0.7	0	0	+53.2	486.4
	Aug.	145.9	18.09	-0.3	0	0	+145.6	632.0
	Sep.	57.5	19.61	-1.1	0	0	+56.4	688.4
TOTALS		312.8		-29.3	230.0		+53.5	
1937	Oct.	10.5	20.04	-2.2	23.0	0	-14.7	673.7
	Nov.	1.4	19.91	-3.4	28.5	0	-30.5	643.2
	Dec.	0.4	19.55	-3.2	29.6	0	-32.4	610.8
1938	Jan.	0	19.15	-3.1	29.2	0	-32.3	578.5
	Feb.	0	18.65	-3.4	27.2	0	-30.6	547.9
	Mar.	0	18.23	-3.9	32.7	0	-36.6	511.3
	Apr.	0	17.56	-3.8	32.2	0	-36.0	475.3
	May	0	16.87	-2.9	27.6	0	-30.5	444.8
	June	0	16.06	-1.7	0	0	-1.7	443.1
	July	51.2	16.52	-0.7	0	0	+50.5	493.6
	Aug.	117.6	18.02	-0.3	0	0	+117.3	610.9
	Sep.	117.8	19.67	-1.1	0	0	+116.7	727.6
	Oct.	31.6	20.53	-2.2	23.0	0	+6.4	734.0
TOTALS		330.5		-31.9	253.0		+45.6	

Study period	Annual firm yield (million cubic meters)	Land irrigable without shortages (hectares)	Active capacity required (million cubic meters)	Dam volume required (million cubic meters)
1/ 1917-38	230	11,700	644.7	29
1939-46	198	10,070	333	17
1912-15	152	7,730	211	13
1940-41	84	4,270	89	9

1/ Period used and plan presented for Initial Development.

Rahad Project. This project consists of the Rahad Storage Dam and Reservoir, a downstream diversion dam, and canals to serve the 53,100 hectares of irrigated land.

The annual farm delivery requirement is estimated as 1.375 meters. Allowing 10 percent for seepage loss and 20 percent for canal waste gives a diversion requirement of 1.964 meters or 1,043 million cubic meters for the 53,100 hectares.

The maximum yield study period as illustrated on Figure III-15 is from 1938 to 1950. However, inspection of the water supply through that period given in Tables III-56 and III-71 shows that for an annual diversion requirement of 1,043 million cubic meters, the shorter 1939 through 1945 period governs.

To provide a full supply in all years, the operation study (Table III-150) (with the 50-year sediment quantity distributed) and the subsequent dam layout show a required active capacity of 1,523 million cubic meters between a minimum operating level of 845.44 meters and a spillway crest elevation of 876.37 meters.

Main Stem Hydroelectric Projects

Four hydroelectric dams and powerplants on the Abbay (Blue Nile River) proper are included in the plan for Initial Development. Each takes into account regulation and depletion of the natural runoff from all upstream reservoirs also in the plan for Initial Development. The 50-year sediment quantity was distributed in each reservoir before the operation study was performed. In each operation study the usual allowance for an 80 percent turbo-generator efficiency was made as well as for penstock losses as shown and each plant was operated separately under the monthly load curve. They are presented starting with the furthest upstream dam and powerplant first and then proceeding downstream.

Karodobi Reservoir (BN-3) will have an active capacity of 25,055 million cubic meters (after 50 years) between a minimum operating level of 1041 meters and a maximum normal water surface of 1153 meters. The estimated average tailwater elevation is 920 meters. Allowing 5 meters for penstock losses, the operation study (Table III-151) shows the Karodobi Powerplant can annually generate 5,835 million kilowatt-hours.

Mabil Reservoir (BN-19) will have an active capacity of 9,687 million cubic meters (after 50 years) between a minimum operating level of 837.8 meters and a maximum normal water surface of 906 meters. The estimated average tailwater elevation is 764 meters. Allowing 4.8 meters for penstock losses, the operation study (Table III-152) shows the Mabil Powerplant can annually generate 5,314 million kilowatt-hours.

Mendaia Reservoir (BN-26A) will have an active capacity of 4,305 million cubic meters (after 50 years) between a minimum operating level of 724.81 meters and a maximum normal water surface of 741 meters. The estimated average tailwater elevation is 615 meters. Allowing 3.5 meters for penstock losses, the operation study (Table III-153) shows the Mendaia Powerplant can annually generate 7,800 million kilowatt-hours.

TABLE III-151--RESERVOIR OPERATION STUDY--KARADOBI (BN-3) RESERVOIR

April 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
1,427,000,000 cu. m. (1,157,000 acre-ft.)	26,482,000,000 cu. m. (21,478,000 acre-ft.)	1153 m. (3783 ft.)	Avg. Penstock Losses = 5 m. Avg. Tailwater Elev. = 920 m.

FIRM YIELD, 5,835,000,000 kwhr per yr.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									26,482
1911	Oct.	490	1,192	407	-30	986	176	0	26,482
	Nov.	502	560	404	-59	1,013	0	-512	25,970
	Dec.	549	281	395	-60	1,117	0	-896	25,074
1912	Jan.	496	196	385	-56	1,019	0	-879	24,195
	Feb.	467	188	376	-64	969	0	-845	23,350
	Mar.	455	214	367	-62	953	0	-801	22,549
	Apr.	449	189	358	-52	950	0	-813	21,736
	May	461	200	349	-44	985	0	-829	20,907
	June	478	533	343	-21	1,031	0	-519	20,388
	July	496	1,589	343	-7	1,070	0	+512	20,900
	Aug.	519	3,863	360	0	1,096	0	+2,767	23,667
	Sep.	473	1,979	380	-24	977	0	+978	24,645
TOTALS		5,835	10,984		-479	12,166	176	-1,837	
1912	Oct.	490	598	383	-28	1,009	0	-439	24,206
	Nov.	502	279	376	-55	1,041	0	-817	23,389
	Dec.	549	209	366	-56	1,151	0	-998	22,391
1913	Jan.	496	204	356	-52	1,052	0	-900	21,491
	Feb.	467	209	347	-59	1,001	0	-851	20,640
	Mar.	455	211	338	-57	988	0	-834	19,806
	Apr.	449	202	330	-48	986	0	-832	18,974
	May	461	311	322	-41	1,024	0	-754	18,220
	June	478	249	314	-19	1,075	0	-845	17,375
	July	496	780	308	-6	1,126	0	-352	17,023
	Aug.	519	1,763	309	0	1,176	0	+587	17,610
	Sep.	473	1,573	315	-20	1,063	0	+490	18,100
TOTALS		5,835	6,588		-441	12,692	0	-6,545	

Sheet 2 of 2

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
1913	Oct.	490	383	313	-23	1,104	0	-744	17,356
	Nov.	502	193	305	-45	1,146	0	-998	16,358
	Dec.	549	236	295	-45	1,275	0	-1,084	15,274
1914	Jan.	496	189	284	-41	1,173	0	-1,025	14,249
	Feb.	467	174	272	-46	1,127	0	-999	13,250
	Mar.	455	190	261	-44	1,121	0	-975	12,275
	Apr.	449	205	250	-37	1,131	0	-963	11,312
	May	461	198	238	-30	1,187	0	-1,019	10,293
	June	478	431	227	-14	1,260	0	-843	9,450
	July	496	1,549	222	-4	1,318	0	+227	9,677
	Aug.	519	5,991	253	0	1,300	0	+4,691	14,368
	Sep.	473	2,441	287	-18	1,113	0	+1,310	15,678
TOTALS		5,835	12,180		-347	14,255	0	-2,422	
1914	Oct.	490	1,533	295	-22	1,137	0	+375	16,052
	Nov.	502	824	295	-43	1,165	0	-384	15,668
	Dec.	549	327	288	-44	1,289	0	-1,006	14,662
1915	Jan.	496	223	277	-40	1,187	0	-1,004	13,658
	Feb.	467	226	266	-45	1,141	0	-960	12,698
	Mar.	455	234	255	-43	1,134	0	-943	11,755
	Apr.	449	204	244	-36	1,144	0	-976	10,779
	May	461	312	232	-29	1,201	0	-918	9,861
	June	478	507	221	-13	1,273	0	-779	9,082
	July	496	1,070	214	-4	1,342	0	-276	8,806
	Aug.	519	2,171	217	0	1,395	0	+776	9,582
	Sep.	473	2,403	230	-14	1,237	0	+1,152	10,734
TOTALS		5,835	10,034		-333	14,645	0	-4,944	
1915	Oct.	490	1,223	237	-17	1,265	0	-59	10,675
	Nov.	502	533	232	-34	1,309	0	-810	9,865
	Dec.	549	279	218	-33	1,472	0	-1,226	8,639
1916	Jan.	496	220	201	-29	1,379	0	-1,188	7,451
	Feb.	467	234	181	-31	1,351	0	-1,148	6,303
	Mar.	455	229	161	-27	1,376	0	-1,174	5,129
	Apr.	449	225	138	-20	1,427	0	-1,222	3,907
	May	461	327	111	-14	1,567	0	-1,254	2,653
	June	478	585	80	-5	1,770	0	-1,190	1,463
	July	496	2,021	65	-1	1,946	0	+74	1,537
	Aug.	519	9,335	155	0	1,587	0	+7,748	9,285
	Sep.	473	5,098	243	-15	1,208	0	+3,875	13,160
TOTALS		5,835	20,309		-226	17,657	0	+2,426	
1916	Oct.	490	1,870	269	-20	1,192	0	+658	13,818
	Nov.	502	799	271	-40	1,217	0	-458	13,360
	Dec.	549	394	262	-40	1,348	0	-994	12,366
1917	Jan.	496	243	250	-37	1,248	0	-1,042	11,324
	Feb.	467	198	238	-40	1,204	0	-1,046	10,278
	Mar.	455	230	225	-38	1,205	0	-1,013	9,265
	Apr.	449	238	211	-31	1,224	0	-1,017	8,248
	May	461	331	196	-25	1,292	0	-986	7,262
	June	478	659	182	-11	1,382	0	-734	6,528
	July	496	2,177	182	-3	1,435	0	+739	7,267
	Aug.	519	7,892	235	0	1,344	0	+6,548	13,815
	Sep.	473	11,132	325	-20	1,046	0	+10,066	23,881 a/
TOTALS		5,835	26,163		-305	15,137	0	+10,721	

a/Computed natural flow at BN-3 for October 1917, equals 3,366. On examination of this flow, it was determined that the reservoir would be filled in October 1917.

TABLE III-152--RESERVOIR OPERATION STUDY--MABIL (BN-19) RESERVOIR

MABIL (BN-19) RESERVOIR, BLUE NILE RIVER

Sheet 1 of 2
May 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
1,155,000,000 cu. m. (937,000 acre-ft.)	10,842,000,000 cu. m. (8,793,000 acre-ft.)	906 m. (2972 ft.)	Avg. Penstock Losses = 4.8 m. Avg. Tailwater Elev. = 764 m.

FIRM YIELD, 5,314,000,000 kwhr per yr.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									10,842
1911	Oct.	446	2,164	244.0	-22	1,492	650	0	10,842
	Nov.	457	1,497	243.3	-40	1,531	0	-74	10,768
	Dec.	500	1,404	241.2	-41	1,685	0	-322	10,446
1912	Jan.	452	1,223	236.3	-38	1,543	0	-358	10,088
	Feb.	425	1,145	232.1	-43	1,467	0	-365	9,723
	Mar.	414	1,115	227.2	-43	1,448	0	-376	9,347
	Apr.	409	1,099	222.3	-37	1,450	0	-388	8,959
	May	420	1,134	216.7	-32	1,512	0	-410	8,549
	June	436	1,304	212.5	-17	1,589	0	-302	8,247
	July	452	1,919	211.8	-4	1,650	0	+265	8,512
	Aug.	473	3,118	223.0	+1	1,674	0	+1,445	9,957
	Sep.	430	2,145	237.0	-19	1,465	0	+661	10,618
TOTALS		5,314	19,267		-335	18,506	650	-224	
1912	Oct.	446	1,494	241.2	-22	1,503	0	-31	10,587
	Nov.	457	1,314	239.1	-39	1,548	0	-273	10,314
	Dec.	500	1,364	234.9	-40	1,713	0	-389	9,925
1913	Jan.	452	1,236	230.0	-37	1,569	0	-370	9,555
	Feb.	425	1,156	225.1	-42	1,495	0	-381	9,174
	Mar.	414	1,146	220.2	-42	1,476	0	-372	8,802
	Apr.	409	1,138	215.3	-36	1,478	0	-376	8,426
	May	420	1,205	209.7	-31	1,542	0	-368	8,058
	June	436	1,257	204.8	-16	1,624	0	-383	7,675
	July	452	1,506	200.6	-4	1,704	0	-202	7,473
	Aug.	473	2,118	201.3	+1	1,780	0	+339	7,812
	Sep.	430	1,894	205.5	-16	1,598	0	+280	8,092
TOTALS		5,314	16,828		-324	19,030	0	-2,526	

MABIL (BN-19) RESERVOIR, Sheet 2 of 2

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									8,092
1913	Oct.	446	1,441	206.2	-19	1,654	0	-232	7,860
	Nov.	457	1,343	201.3	-33	1,720	0	-410	7,450
	Dec.	500	1,451	194.3	-33	1,921	0	-503	6,947
1914	Jan.	452	1,331	185.9	-30	1,781	0	-480	6,467
	Feb.	425	1,273	178.4	-33	1,715	0	-475	5,992
	Mar.	414	1,278	170.1	-32	1,716	0	-470	5,522
	Apr.	409	1,290	162.2	-27	1,741	0	-478	5,044
	May	420	1,347	152.9	-22	1,845	0	-520	4,524
	June	436	1,511	143.3	-11	1,982	0	-482	4,042
	July	452	2,158	138.2	-3	2,094	0	+61	4,103
	Aug.	473	4,078	159.8	0	2,029	0	+2,049	6,152
	Sep.	430	2,655	184.6	-15	1,702	0	+938	7,090
TOTALS		5,314	21,156		-258	21,900	0	-1,002	
1914	Oct.	446	2,335	197.8	-18	1,696	0	+621	7,711
	Nov.	457	1,805	202.7	-33	1,713	0	+59	7,770
	Dec.	500	1,596	200.6	-34	1,885	0	-323	7,447
1915	Jan.	452	1,403	195.4	-32	1,731	0	-360	7,087
	Feb.	425	1,318	189.4	-35	1,657	0	-374	6,713
	Mar.	414	1,309	183.2	-35	1,646	0	-372	6,341
	Apr.	409	1,306	177.0	-30	1,658	0	-382	5,959
	May	420	1,393	170.8	-25	1,737	0	-369	5,590
	June	436	1,541	164.6	-13	1,841	0	-313	5,277
	July	452	1,913	161.9	-3	1,926	0	-16	5,261
	Aug.	473	2,564	166.7	+1	1,983	0	+582	5,843
	Sep.	430	1,045	165.3	-14	1,811	0	-780	5,063
TOTALS		5,314	19,528		-271	21,284	0	-2,027	
1915	Oct.	446	2,205	161.2	-15	1,905	0	+285	5,348
	Nov.	457	1,742	161.2	-26	1,951	0	-235	5,113
	Dec.	500	1,743	155.0	-26	2,181	0	-464	4,649
1916	Jan.	452	1,618	146.1	-24	2,034	0	-440	4,209
	Feb.	425	1,547	136.4	-26	1,981	0	-460	3,749
	Mar.	414	1,559	124.6	-24	2,017	0	-482	3,267
	Apr.	409	1,605	112.0	-19	2,092	0	-506	2,761
	May	420	1,788	98.7	-14	2,269	0	-495	2,266
	June	436	2,133	87.5	-7	2,472	0	-346	1,920
	July	452	3,337	93.8	-2	2,493	0	+842	2,762
	Aug.	473	2,762	109.2	0	2,447	0	+315	3,077
	Sep.	430	4,744	146.8	-12	1,931	0	+2,801	5,878
TOTALS		5,314	26,783		-195	25,773	0	+815	
1916	Oct.	446	3,145	183.9	-17	1,769	0	+1,359	7,237
	Nov.	457	2,026	197.1	-32	1,741	0	+253	7,490
	Dec.	500	1,798	197.8	-33	1,901	0	-136	7,354
1917	Jan.	452	1,531	195.0	-32	1,733	0	-234	7,120
	Feb.	425	1,417	190.8	-36	1,650	0	-269	6,851
	Mar.	414	1,409	186.6	-36	1,628	0	-255	6,596
	Apr.	409	1,407	182.5	-30	1,629	0	-252	6,344
	May	420	1,507	178.4	-26	1,695	0	-214	6,130
	June	436	1,759	176.3	-14	1,771	0	-26	6,104
	July	452	2,871	185.3	-4	1,785	0	+1,082	7,186
	Aug.	473	5,420	220.2	+1	1,687	78	+3,656	10,842
	Sep.	430	1,884	244.0	-19	1,438	427	0	10,842
TOTALS		5,314	26,174		-278	20,427	505	+4,964	

TABLE III-153--RESERVOIR OPERATION STUDY--MENDAIA (BN-26A) RESERVOIR

MENDAIA (BN-26A) RESERVOIR, ABBAY RIVER

Sheet 1 of 2
November 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
6,872,000,000 cu. m. (5,573,000 acre-ft.)	11,177,000,000 cu. m. (9,065,000 acre-ft.)	741 m. (2430 ft.)	Avg. Penstock Losses = 3.5 m. Avg. Tailwater Elev. = 615 m.

FIRM YIELD, 7,800,000,000 kwhr per yr.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									11,177
1911	Oct.	655	4,635	334.1	-34	2,454	2,147	0	11,177
	Nov.	671	2,806	334.1	-58	2,514	234	0	11,177
	Dec.	733	2,698	327.7	-59	2,751	0	-112	11,065
1912	Jan.	663	2,347	314.9	-54	2,499	0	-206	10,859
	Feb.	624	2,182	306.6	-60	2,362	0	-240	10,619
	Mar.	608	2,121	299.3	-60	2,320	0	-259	10,360
	Apr.	601	2,085	292.1	-52	2,313	0	-280	10,080
	May	616	2,092	284.8	-45	2,390	0	-343	9,737
	June	640	2,304	277.5	-26	2,505	0	-227	9,510
	July	663	2,989	279.3	-10	2,589	0	+390	9,900
	Aug.	694	3,923	301.1	-4	2,643	0	+1,276	11,176
	Sep.	632	3,533	334.1	-33	2,367	1,132	+1	11,177
TOTALS		7,800	33,715		-495	29,707	3,513	0	
1912	Oct.	655	2,722	334.1	-34	2,454	234	0	11,177
	Nov.	671	2,438	327.7	-57	2,519	0	-138	11,039
	Dec.	733	2,556	314.8	-56	2,763	0	-263	10,776
1913	Jan.	663	2,310	303.0	-52	2,520	0	-262	10,514
	Feb.	624	2,149	295.7	-58	2,391	0	-300	10,214
	Mar.	608	2,079	288.4	-58	2,349	0	-328	9,886
	Apr.	601	2,091	281.1	-50	2,342	0	-301	9,585
	May	616	2,162	272.0	-43	2,426	0	-307	9,278
	June	640	2,251	266.6	-25	2,543	0	-317	8,961
	July	663	2,416	259.9	-9	2,663	0	-256	8,705
	Aug.	694	3,094	261.2	-3	2,781	0	+310	9,015
	Sep.	632	2,485	263.9	-26	2,522	0	-63	8,952
TOTALS		7,800	28,753		-471	30,273	234	-2,225	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation millions of kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									8,952
1913	Oct.	655	2,499	261.2	-27	2,625	0	-153	8,799
	Nov.	671	2,403	255.8	-44	2,713	0	-354	8,445
	Dec.	733	2,640	249.0	-45	2,996	0	-401	8,044
1914	Jan.	663	2,467	240.7	-41	2,747	0	-321	7,723
	Feb.	624	2,382	233.6	-46	2,615	0	-279	7,444
	Mar.	608	2,367	226.5	-46	2,577	0	-256	7,188
	Apr.	601	2,465	220.8	-40	2,571	0	-146	7,042
	May	616	2,574	217.9	-35	2,648	0	-109	6,933
	June	640	2,718	216.5	-21	2,758	0	-61	6,872
	July	663	3,541	223.6	-8	2,824	0	+709	7,581
	Aug.	694	2,324	225.1	-3	2,949	0	-628	6,953
	Sep.	632	3,240	223.6	-22	2,692	0	+526	7,479
TOTALS		7,800	31,620		-378	32,715	0	-1,473	
1914	Oct.	655	4,040	246.4	-25	2,690	0	+1,325	8,804
	Nov.	671	3,281	265.3	-46	2,672	0	+563	9,367
	Dec.	733	2,930	270.7	-48	2,893	0	-11	9,356
1915	Jan.	663	2,513	269.3	-46	2,623	0	-156	9,200
	Feb.	624	2,324	265.3	-52	2,485	0	-213	8,987
	Mar.	608	2,274	261.2	-53	2,437	0	-216	8,771
	Apr.	601	2,262	257.1	-46	2,425	0	-209	8,562
	May	616	2,292	253.1	-40	2,502	0	-250	8,312
	June	640	2,389	247.7	-24	2,622	0	-257	8,055
	July	663	2,669	243.6	-9	2,735	0	-75	7,980
	Aug.	694	3,203	246.4	-3	2,850	0	+350	8,330
	Sep.	632	5,140	277.5	-27	2,473	0	+2,640	10,970
TOTALS		7,800	35,317		-419	31,407	0	+3,491	
1915	Oct.	655	4,271	334.1	-34	2,454	1,576	+207	11,177
	Nov.	671	3,161	334.1	-58	2,514	589	0	11,177
	Dec.	733	3,101	334.1	-60	2,746	295	0	11,177
1916	Jan.	663	2,745	334.1	-57	2,484	204	0	11,177
	Feb.	624	2,598	334.1	-65	2,338	195	0	11,177
	Mar.	608	2,604	334.1	-67	2,278	259	0	11,177
	Apr.	601	2,680	334.1	-60	2,251	369	0	11,177
	May	616	2,872	334.1	-53	2,308	511	0	11,177
	June	640	3,008	334.1	-32	2,397	579	0	11,177
	July	663	4,075	334.1	-12	2,484	1,579	0	11,177
	Aug.	694	2,677	334.1	-4	2,600	73	0	11,177
	Sep.	632	3,153	334.1	-33	2,367	753	0	11,177
TOTALS		7,800	36,945		-535	29,221	6,982	+207	
1916	Oct.	655	5,533	334.1	-34	2,454	3,045	0	11,177
	Nov.	671	3,421	334.1	-58	2,514	849	0	11,177
	Dec.	733	3,091	334.1	-60	2,746	285	0	11,177
1917	Jan.	663	2,629	334.1	-57	2,484	88	0	11,177
	Feb.	624	2,380	334.1	-65	2,338	0	-23	11,154
	Mar.	608	2,335	334.1	-67	2,278	0	-10	11,144
	Apr.	601	2,292	334.1	-60	2,251	0	-19	11,125
	May	616	2,251	327.7	-52	2,312	0	-113	11,012
	June	640	2,411	321.3	-31	2,407	0	-27	10,985
	July	663	3,541	327.7	-12	2,489	848	+192	11,177
	Aug.	694	167	284.8	-3	2,693	0	-2,529	8,648
	Sep.	632	2,268	253.1	-25	2,566	0	-323	8,325
TOTALS		7,800	32,319		-524	29,532	5,115	-2,852	

Border Reservoir (BN-28) will have an active capacity of 3,638 million cubic meters (after 50 years) between a minimum operating level of 563.43 meters and a maximum normal water surface of 575 meters. The estimated average tailwater elevation is 495 meters. Allowing 2 meters for penstock losses, the operation study (Table III-154) shows the Border Powerplant can annually generate 6,200 million kilowatt-hours. The damsite topography limits the storage capacity to considerably less than the amount necessary to fully control the modified inflow.

The regulation of the Blue Nile (Abbay) River below the Border Dam provided by the plan for Initial Development is illustrated in Figure III-61.

OTHER IDENTIFIED PROJECTS

In addition to the projects studied in more detail as Initial Development, there are several potential power and irrigation projects with sufficient merit to justify mention. They are described here in separate sections headed Power and Irrigation.

Water supply estimates were obtained, in most instances, using the drainage area, the precipitation map (Figure III-4), and the rainfall runoff graph (Figure III-44). If a project is selected for further study, at least 1 year (and preferably more) of streamflow record should be obtained at the damsite or damsites. The required reservoir capacity and annual yield should then be reestimated on the basis of the streamflow record.

No depletion from these projects was assumed in the operation studies of projects in the plan for Initial Development.

Power

These projects are considered less favorable than those studied for Initial Development for one or more of the following reasons: remoteness from load centers, inaccessability, or less desirable damsites and reservoirs. Therefore, if constructed, the power production can generally be expected to be more expensive on a unit basis. However, for 10 of the more promising projects (located on Figure III-62), rough data and estimates are presented in Table III-155.

Irrigation

For many compelling reasons, it was not possible to make detailed studies of all the possible areas in the basin that might be susceptible to irrigation development. However, in some areas where reconnaissance land classification was performed and it was determined that the lands were suitable for irrigation development, examination of the areas for storage facilities indicated they would be uneconomical to be developed, primarily due to topographical deficiency.

Four of these areas totaling some 195,500 hectares of arable land are discussed from the hydrology standpoint, showing the estimated available water supply and quantities of lands that might be irrigated with storage facilities, as well as direct diversion possibilities of a smaller size for two of the areas. No depletions are assumed from these potential projects in downstream Initial Development projects.

Table III-156 gives pertinent information regarding these potential areas. The arable land given is the total of Classes 1, 2 and 3 land. Diversion requirements were computed as was done for the projects in the plan for Initial Development. Land irrigable from storage is most uncertain. Suitable storage sites have generally not been located, and topography for laying out main canals on the service areas was not obtained. Where storage is indicated, it is definitely required, because the streams are so small in most instances as to go practically dry during the January through April period. Since the

TABLE III-154--RESERVOIR OPERATION STUDY--BORDER (BN-28) RESERVOIR

BORDER (BN-28) RESERVOIR, ABBAY RIVER

Sheet 1 of 2
December 1963

MIN. STORAGE	MAX. STORAGE	MAX. ELEVATION	
2,765,000,000 cu. m.	6,403,000,000 cu. m.	575 m.	Avg. Penstock Losses = 2 m.
(2,242,000 acre-ft.)	(5,193,000 acre-ft.)	(1886 ft.)	Avg. Tailwater Elev. = 495 m.

FIRM YIELD, 6,200,000,000 kwhr per yr.

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation million kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									6,403
1911	Oct.	521	5,548	497.9	-57	3,065	2,426	0	6,403
	Nov.	533	3,409	497.9	-86	3,136	187	0	6,403
	Dec.	583	3,242	487.3	-74	3,441	0	-273	6,130
1912	Jan.	527	2,867	445.0	-72	3,151	0	-356	5,774
	Feb.	496	2,688	413.2	-73	2,995	0	-380	5,394
	Mar.	484	2,612	370.9	-87	2,971	0	-446	4,948
	Apr.	477	2,606	335.7	-84	2,978	0	-456	4,492
	May	490	2,746	307.0	-75	3,112	0	-441	4,051
	June	508	3,181	287.6	-55	3,272	0	-146	3,905
	July	527	3,649	292.4	-23	3,382	0	+244	4,149
	Aug.	552	4,285	328.6	-9	3,458	0	+818	4,967
	Sep.	502	5,409	423.7	-22	3,021	930	+1,436	6,403
TOTALS		6,200	42,242		-717	37,982	3,543	0	
1912	Oct.	521	3,399	497.9	-57	3,065	277	0	6,403
	Nov.	533	3,034	487.3	-84	3,146	0	-196	6,207
	Dec.	583	3,184	455.6	-69	3,474	0	-359	5,848
1913	Jan.	527	2,874	413.2	-67	3,182	0	-375	5,473
	Feb.	496	2,708	377.9	-67	3,035	0	-394	5,079
	Mar.	484	2,640	349.7	-82	3,001	0	-443	4,636
	Apr.	477	2,637	316.7	-79	3,009	0	-451	4,185
	May	490	2,873	287.6	-70	3,156	0	-353	3,832
	June	508	2,962	265.6	-50	3,330	0	-418	3,414
	July	527	3,536	254.4	-20	3,492	0	+24	3,438
	Aug.	552	4,065	269.3	-8	3,606	0	+451	3,889
	Sep.	502	4,138	311.9	-17	3,177	0	+944	4,833
TOTALS		6,200	38,050		-670	38,673	277	-1,570	

UNITS are in millions of cubic meters, except as noted.

Year	Months	Power generation million kwhr	Modified inflow	Average surface area sq. km.	Evaporation precipitation correction	Power release	Spill	Change in storage	End of month reservoir storage
		1	2	3	4	5	6	7	8
									4,833
1913	Oct.	521	3,297	349.7	-40	3,231	0	+26	4,859
	Nov.	533	3,199	342.7	-59	3,316	0	-176	4,683
	Dec.	583	3,419	321.6	-49	3,665	0	-295	4,388
1914	Jan.	527	3,096	302.2	-49	3,359	0	-312	4,076
	Feb.	496	2,933	282.7	-50	3,206	0	-323	3,753
	Mar.	484	2,910	265.5	-62	3,172	0	-324	3,429
	Apr.	477	2,918	243.3	-61	3,195	0	-338	3,091
	May	490	3,073	225.4	-55	3,344	0	-326	2,765
	June	508	3,554	214.9	-41	3,505	0	+8	2,773
	July	527	4,037	228.9	-18	3,583	0	+436	3,209
	Aug.	552	4,852	277.9	-8	3,580	0	+1,264	4,473
	Sep.	502	4,777	385.0	-20	3,061	0	+1,696	6,169
TOTALS		6,200	42,065		-512	40,217	0	+1,336	
1914	Oct.	521	3,676	487.3	-56	3,075	311	+234	6,403
	Nov.	533	3,392	497.9	-86	3,136	170	0	6,403
	Dec.	583	3,395	487.3	-74	3,441	0	-120	6,283
1915	Jan.	527	3,046	476.7	-77	3,120	0	-151	6,132
	Feb.	496	2,857	455.6	-80	2,956	0	-179	5,953
	Mar.	484	2,772	434.4	-102	2,903	0	-233	5,720
	Apr.	477	2,766	413.2	-103	2,880	0	-217	5,503
	May	490	3,052	402.5	-98	2,968	0	-14	5,489
	June	508	3,463	413.2	-79	3,067	0	+317	5,806
	July	527	3,925	466.1	-37	3,131	160	+597	6,403
	Aug.	552	4,566	497.9	-14	3,247	1,305	0	6,403
	Sep.	502	4,498	497.9	-26	2,953	1,519	0	6,403
TOTALS		6,200	41,408		-832	36,877	3,465	+234	
1915	Oct.	521	5,035	497.9	-57	3,065	1,913	0	6,403
	Nov.	533	3,798	497.9	-86	3,136	576	0	6,403
	Dec.	583	3,579	497.9	-75	3,430	74	0	6,403
1916	Jan.	527	3,131	497.9	-80	3,100	0	-49	6,354
	Feb.	496	2,936	487.3	-86	2,927	0	-77	6,277
	Mar.	484	2,914	476.7	-112	2,866	0	-64	6,213
	Apr.	477	3,020	476.7	-119	2,824	0	+77	6,290
	May	490	3,361	487.3	-118	2,892	238	+113	6,403
	June	508	3,961	497.9	-95	2,989	877	0	6,403
	July	527	5,396	497.9	-40	3,100	2,256	0	6,403
	Aug.	552	4,375	497.9	-14	3,247	1,114	0	6,403
	Sep.	502	5,088	497.9	-26	2,953	2,109	0	6,403
TOTALS		6,200	46,594		-908	36,529	9,157	0	
1916	Oct.	521	6,340	497.9	-57	3,065	3,218	0	6,403
	Nov.	533	4,008	497.9	-86	3,136	786	0	6,403
	Dec.	583	3,529	497.9	-75	3,430	24	0	6,403
1917	Jan.	527	3,006	487.3	-78	3,110	0	-182	6,221
	Feb.	496	2,726	466.1	-82	2,946	0	-302	5,919
	Mar.	484	2,633	423.8	-100	2,913	0	-380	5,539
	Apr.	477	2,618	385.0	-96	2,909	0	-387	5,152
	May	490	2,909	363.8	-88	3,018	0	-197	4,955
	June	508	3,326	363.8	-69	3,129	0	+128	5,083
	July	527	4,598	423.8	-34	3,172	72	+1,320	6,403
	Aug.	552	4,374	497.9	-14	3,247	1,113	0	6,403
	Sep.	502	4,476	497.9	-26	2,953	1,497	0	6,403
TOTALS		6,200	44,543		-805	37,028	6,710	0	

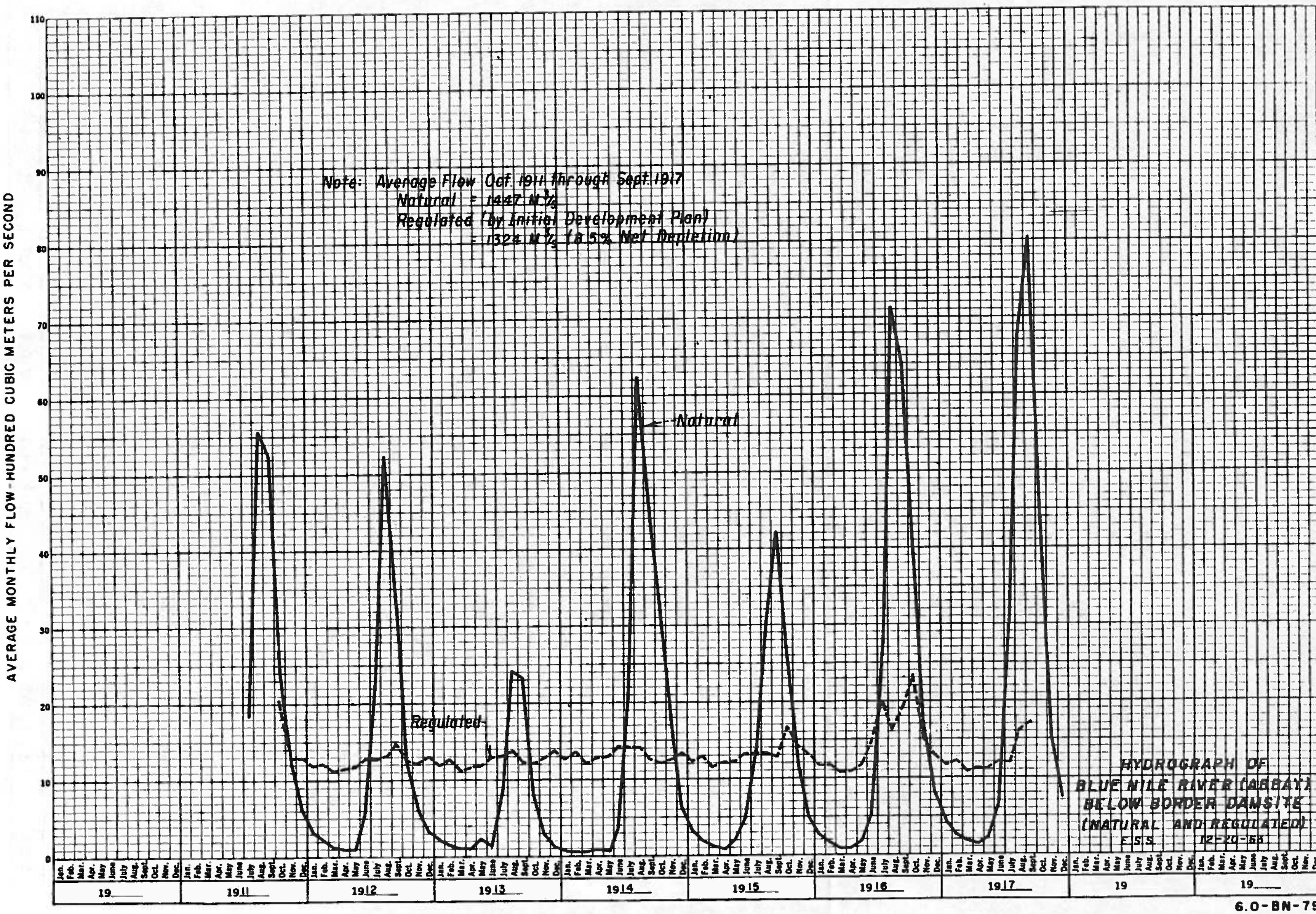


Figure III-61--Hydrograph of Blue Nile River below Border Damsite

TABLE III-155--DATA SUMMARY ON 10 LESS FAVORABLE POWER PROJECTS

River	Site (Dwg. No. 4,0-BN-3)	Drainage area (sq. km.)	Average annual runoff	Sediment inflow (50 years)	Annual reservoir yield	Active storage required	Total storage required	Annual power output (million kw.-hr.)	Comments
		(Units in million cubic meters except as shown)							
Beles	BL-7	831	2,672	54	2,592	450	500	430	With Lake Tana water from BL-1 Powerplant
Beles	BL-2	9,562	3,966	8	3,847	80	90	220	With Lake Tana water, Dangur Dam in operation, and Beles lands under irrigation
Beles	BL-8	11,363	4,169	49	4,044	420	470	600	With Lake Tana water, Dangur Dam in operation, and Beles lands irrigated
Beshilo	BS-2	3,750	1,875	695	1,690	2,940	3,640	340	
Beshilo	BS-1	12,340	4,455	1,652	4,010	5,790	7,640	800	
Cheye	CH-1 & CH-2	214	200	12	180	470	480	200	CH-1 is the storage site, CH-2 is the power site downstream
Welaka	VO-1	2,836	964	358	870	1,620	1,980	95	
Diddessa	DD-4	9,486	4,300	65	3,870	5,350	5,420	1,180	With Diddessa Dam in operation upstream
Fettam	FE-1	746	750	45	675	1,530	1,575	250	Utilizing 170-meter drop at the escarpment--More power could be generated using an additional 500-meter fall in the next 6 kilometers
Guba	GB-2	1,653	2,150	61	1,930	3,890	3,950	290	

TABLE III-156--DATA SUMMARY ON FOUR OTHER IDENTIFIED IRRIGATION AREAS

(Units in million cubic meters except as shown)

Dam number	Stream	Drainage area (sq. km.)	Average annual runoff	50-year sediment inflow	Arable land (ha.)	Annual diversion requirement (mm.)	Irrigable with storage (ha.)	Annual reservoir yield required	Required reservoir capacity: Active	Required reservoir capacity: Total	Comments
CHEYE AREA					3,400						
Nadatra	Cheye tributary	129	124	7		1,314	3,400	32	43	50	Direct diversion of unregulated flows will provide a full supply for 630 hectares plus a one-crop (Oct.-Jan.) supply for 630 hectares more.
Cheye Totals		129	124	7			3,400	32	43	50	
AZENA-FETTAM AREA					130,490						
Upper Fettam	Fettam	439	517	31		1,178	7,700	91	100	130	Poor dam and storage sites.
Middle Fettam	Fettam	510	600	5		1,178	5,480	65	70	75	Direct diversion of unregulated flows will provide a full supply for an additional 5,460 hectares plus a one-crop (Oct.-Jan.) supply for 3,350 hectares.
							5,460 (direct diversion)				
Azena-Fettam Totals		949	1,117	36			18,640	156	170	205	
WAMA AREA					43,130						
#1	Negeso	360	324	11	14,000	1,140	14,000	160	160	171	Good storage potential.
#2	Gimata	51	89	3	5,400	1,140	5,400	62	230	233	Poor storage potential.
#3	Guiso	60	102	4	5,600	1,140	5,600	64	260	264	Poor storage potential.
#4	Lagatora	80	34	1	3,600	1,140	2,400	27	88	89	Poor storage potential. Available land greater than available water supply.
#5	Mudalu	246	128	5	9,500	1,140	9,500	108	300	305	Poor storage potential.
#6	Urghessa	362	188	7	2,600	1,140	2,600	30	30	37	Poor storage potential.
Wama Totals		1,159	865	31	40,700		39,500	451	1,068	1,099	
LEKKEMT AREA					18,535						
#1	Kassa	50	44	3		1,286	2,200	28	84	87	Poor storage potential.
#2	Chererka	75	67	4		1,286	3,900	50	143	147	Poor storage potential.
#3	Moka	78	69	4		1,286	4,300	55	159	163	Poor storage potential.
#4	?	44	39	2		1,286	2,100	27	84	86	Poor storage potential.
#5	?	70	62	4		1,286	3,500	45	130	134	Poor storage potential.
Lekkemt Totals		317	281	17			16,000	205	600	617	

reconnaissance survey did not reveal good sites, it is expected that land cannot be economically irrigated in the quantity shown. Development of a reservoir close enough to the area lands to command adequate water supply is expected to produce the indicated water but at excessive cost; development of a reservoir at some better site, higher on the stream, is expected to make less land irrigable in most instances, because the reservoir will not command adequate water supply. Exceptions to this generalization are noted below in discussions of the specific areas.

Cheye Area. It would be possible to service the 3,400 hectares of arable land in the Cheye area if a reservoir were constructed to store the necessary water. One potential reservoir location is shown on Figure III-63.

The unregulated streamflow is sufficient to service 630 hectares throughout the irrigation season by direct diversion, and is sufficient through January to service an additional 630 hectares.

The Cheye also has a power potential without seriously conflicting with the irrigation. This is shown on Table III-155.

Azena-Fettam Area. Although this area has 130,490 hectares classified as arable, unfortunately only a small portion can apparently be irrigated due to a lack of suitable reservoir sites. The upper one-third of the Fettam area and all of the Azena area are located on a porous rock formation which apparently precludes water storage in reservoirs. Two reservoir sites in the lower portion of the Fettam area (denoted Upper and Middle Storage Sites on Figure III-64) are estimated to have sufficient capacity and to be located high enough to serve 13,180 hectares by gravity.

The unregulated streamflows are sufficient to service an additional 5,460 hectares throughout the irrigation season by direct diversion and are sufficient through January for 3,350 more hectares. These unregulated flows should be utilized on the best (Class 1) lands.

The Fettam also has a potential for power production without seriously conflicting with the irrigation, as shown on Table III-155.

Wama Area. As indicated by Table III-156, it would be possible to service most of the 43,130 hectares classified as arable in the Wama area, provided sufficient funds were expended for constructing six reservoirs. The assumed dam locations are shown on Figure III-65. A good reservoir site is known to exist at Site No. 1 (NE-4). The analysis in Table III-156 does not assume full development at this site, but it might be fully developed to serve more land than the analysis indicates, if reservoirs prove too expensive at Sites No. 2 through 6. There is also a surplus of water, with respect to the service area assumed served from Site No. 6, so that it would be possible to seek a reservoir somewhat upstream from the indicated location without decreasing the service areas. For Sites No. 2 through 5, the estimates assume full development of the flow at the indicated location, and if it proved necessary to move upstream in order to find a less expensive reservoir, the service area would have to be reduced. Assuming flow can be fully regulated at Sites No. 2 through 5, there is only one (No. 4) at which the flow is inadequate for serving the available land.

Lekkemt Area. It would be possible to service 16,000 of the 18,535 hectares classified as arable in the area. However, it would require five expensive reservoirs on five streams that head west of Lekkemt and run on steep gradients generally west into the Diddessa River. The assumed dam locations are shown on Figure III-66. The remaining 2,535 hectares are all Class 3 lands and are too high to be reached from the assumed reservoirs or are on the opposite side of the Diddessa River from the water supply.

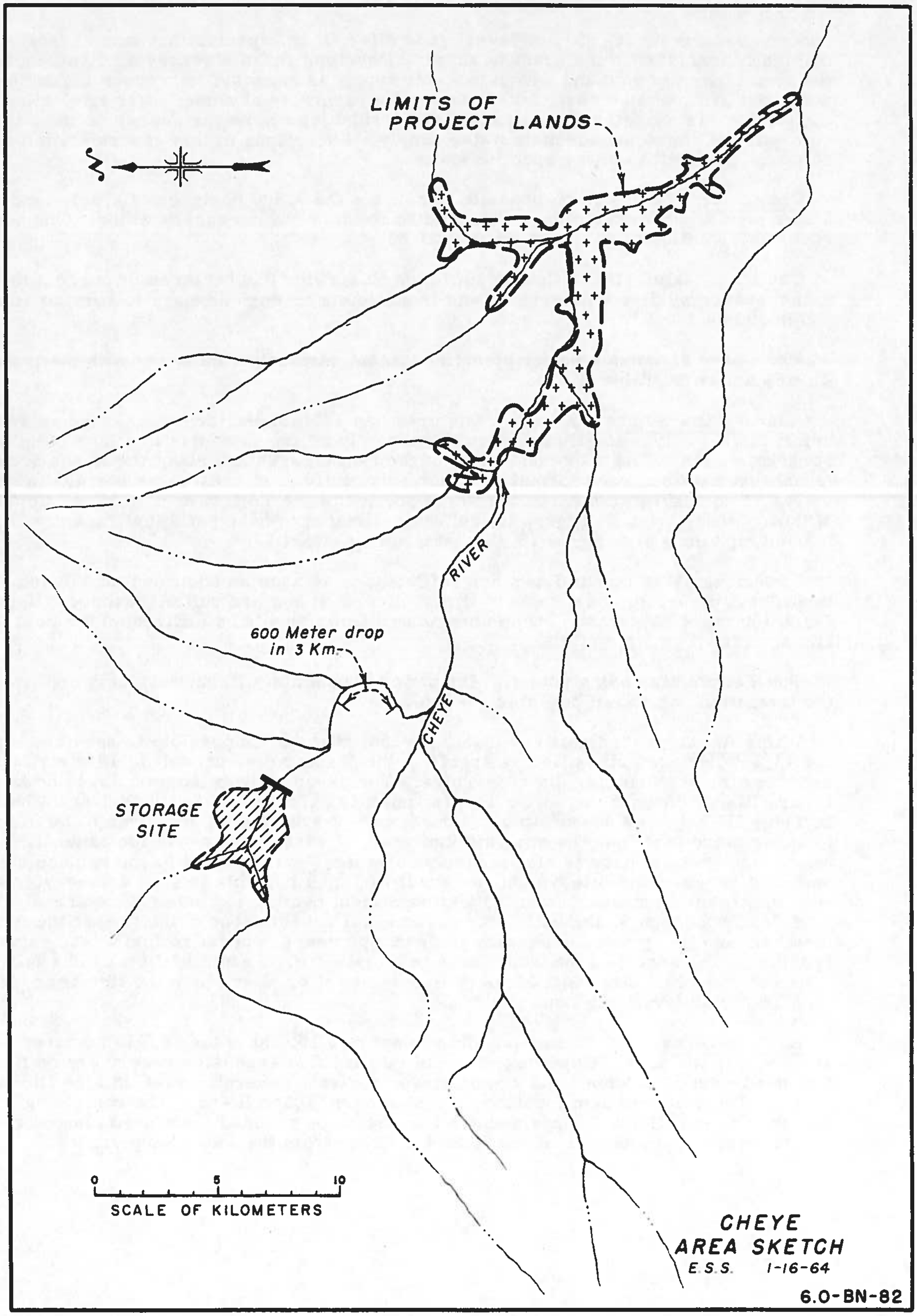


Figure III-63--Cheye Area Sketch

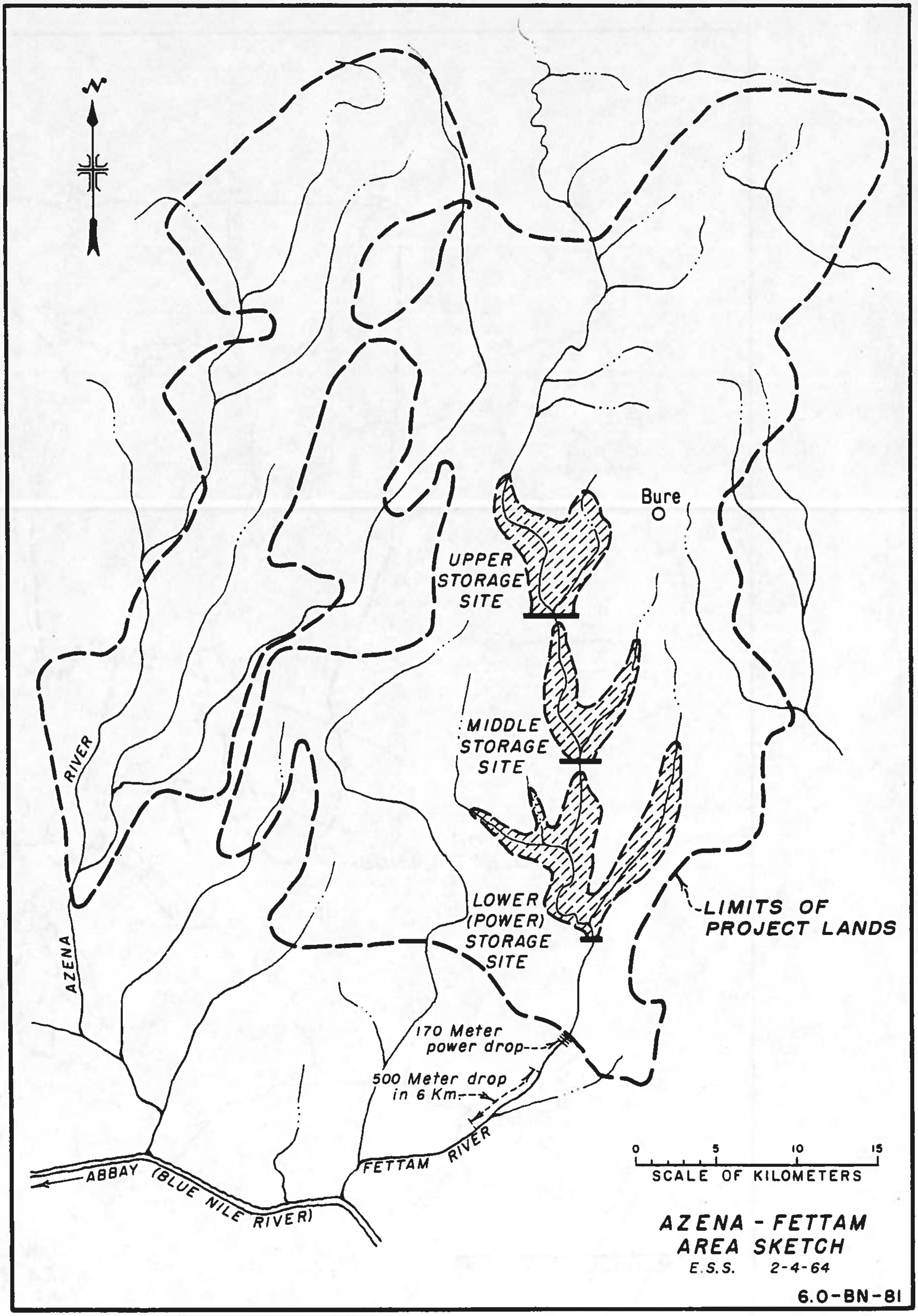


Figure III-64--Azena-Fettam Area Sketch

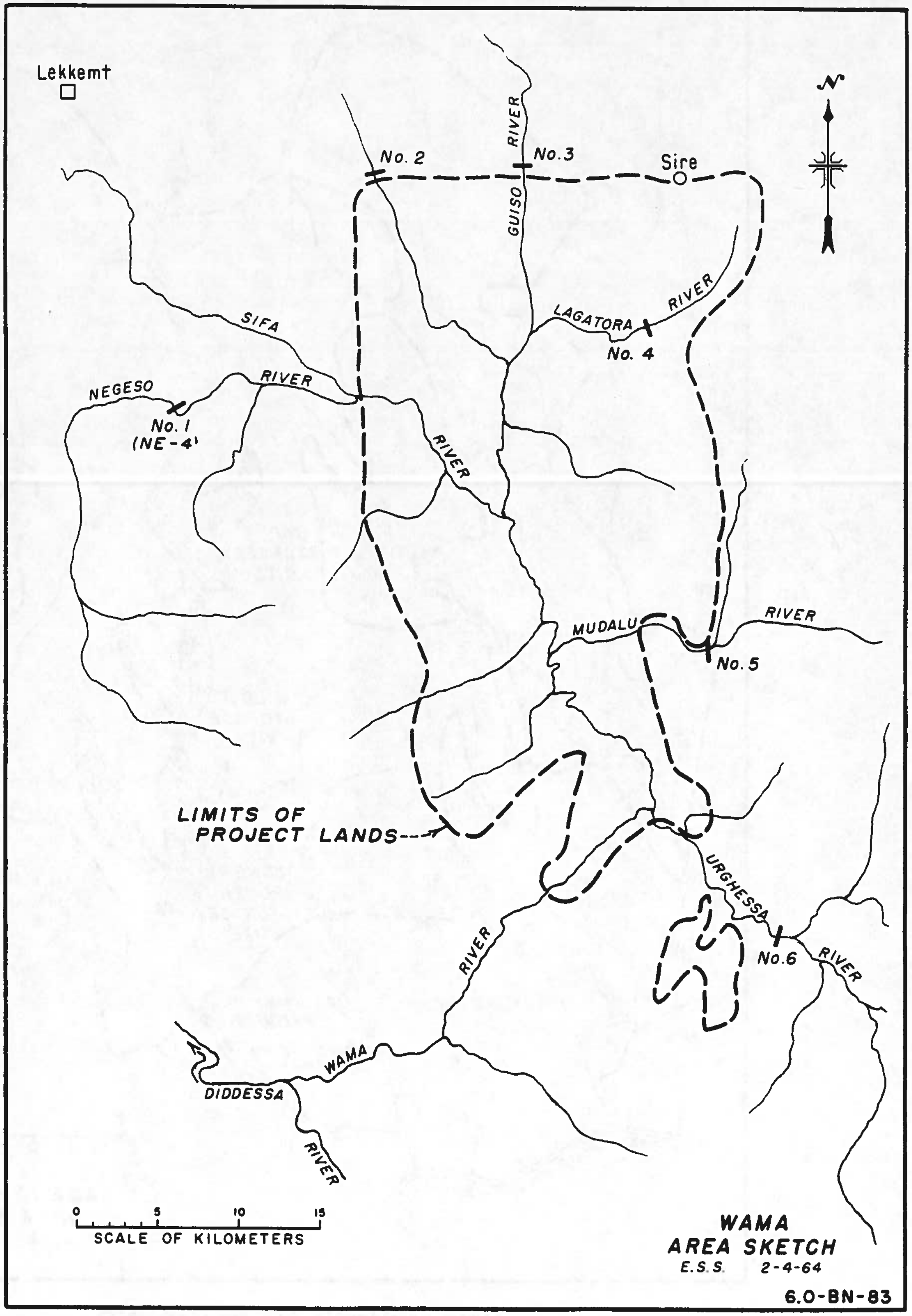


Figure III-65--Wama Area Sketch

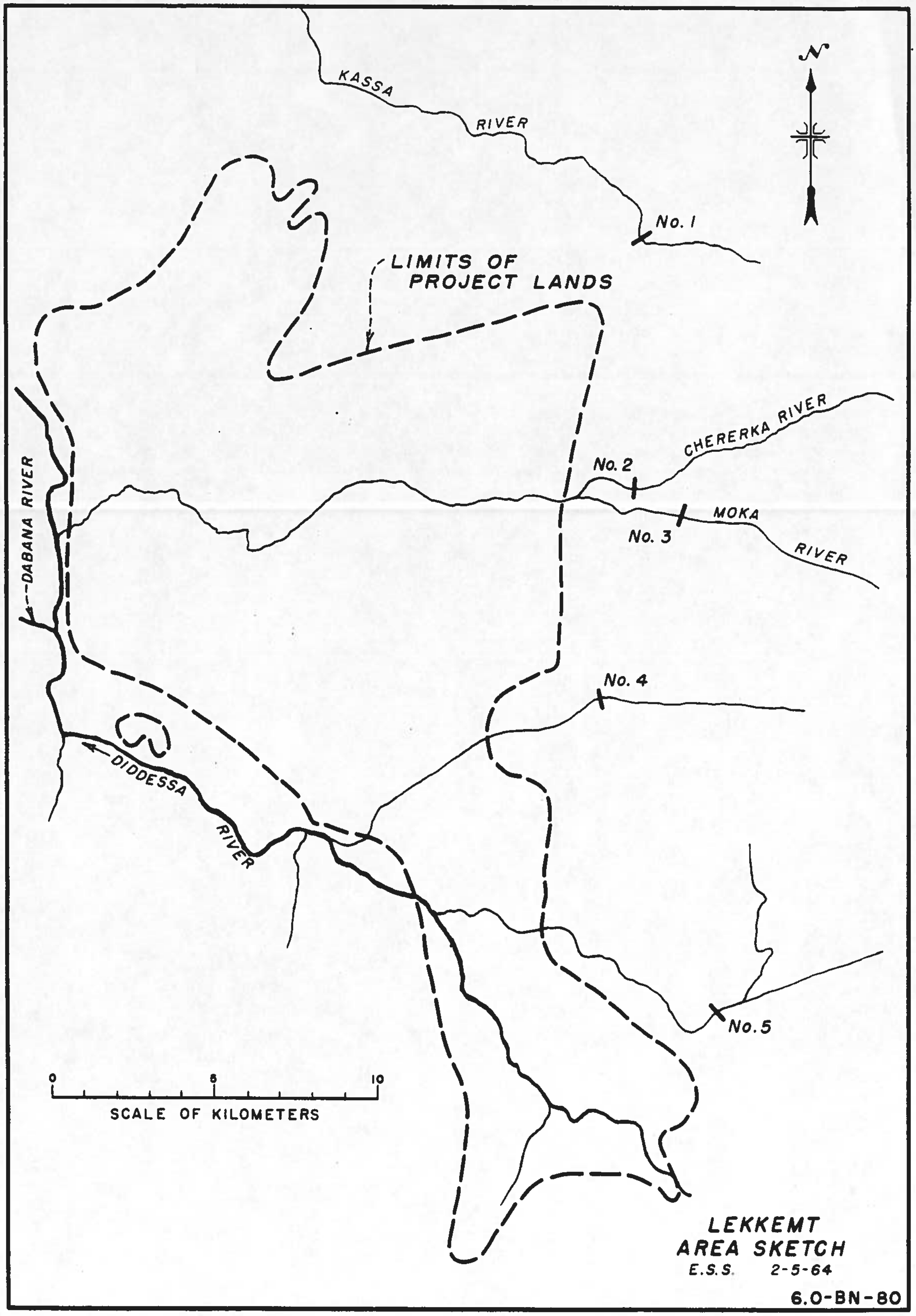


Figure III-66--Lekkemt Area Sketch