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Report on

XAYA - PIXCAYA WATER PROJECT

GUATEMALA CITY AND VICINITY

Presented to

INSTITUTO DE FOMENTO MUNICIPAL
GUATEMALA

Job Number 4198

November 1967

PARSONS CORPORATION

LOS ANGELES
NEW YORK

Parsons Corporation

617 WEST SEVENTH STREET, LOS ANGELES 17, CALIFORNIA

November 20, 1967

Mr. Otto Bianchi Arguello, Manager
Instituto de Fomento Municipal (INFOM)
Guatemala City, Guatemala

SUBJECT Report Submittal
Xaya-Pixcaya Water Supply Projects

Dear Mr. Bianchi:

In accordance with the provisions of the contract between the Parsons Corporation and INFOM dated May 19, 1967, for the "Objective Evaluation of the Xaya-Pixcaya Water Supply Projects", we are pleased to present the findings of our study in this report. The contract directed us to review plans of approach to principally employ the two rivers, Xaya and Pixcaya and their tributaries, to augment the water supply of Guatemala City and environs.

Our evaluation and conclusions were made after careful and complete analysis, both from an economic and technical feasibility standpoint, of two plans. The two plans referred to herein showed unequal comprehensiveness. One scheme, developed, engineered and detailed by the Corps of Engineers of the Guatemalan Army (MDN), was completed in December 1966. The other plan of additional water supply advanced by the Department of Water and Drainage of the Municipality of Guatemala (DAD) was completed five years earlier (February 1962), and needed to be updated and revised in order that the two plans could be equally evaluated. It was also necessary to request both agencies to amplify their designs to include additional long-range water supply programming in order to be able to evaluate each as a long-term project.

The foremat of the report in the following pages is patterned by directly answering the points of concern as listed in the Scope of Analyses, Paragraph 2 of Clause 2 of the subject contract. In this connection, each section of the report and paragraph thereof is identified by letter and numerals that relate directly to the identifying statements in the Scope of Analyses.

Briefly stated, the recommendation of your Consultant is that INFOM accept and implement the plan of approach as presented by the Municipality. Parsons Corporation found this long-range plan of supplying Guatemala City with a potable water supply to be the most desirable compared to the one compiled by the Corps of Engineers. Detailed evaluation and conclusions of both plans are given in the body of the report.

Parsons Corporation is proud and pleased to have had this opportunity to study these two fine engineering projects and to have been of service to the people and Republic of Guatemala. We feel it is important to take immediate action for implementation of this important project in order to ensure the economic progress and growth of Guatemala City and the Republic.

Very truly yours,

PARSONS CORPORATION

By James E. Halferty

James E. Halferty
Vice President

JEH:na

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NOTE: This Table of Contents is based on the outlines contained in the Terms of References and in the INFOM contract.

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A SECTION - SUMMARY

INTRODUCTION

The object of this report is to evaluate two schemes, one prepared by the Corps of Engineers of the Guatemalan Army (MDN) and the other prepared by the Department of Water and Drainage (DAD) of the Municipality of Guatemala, for the expansion of the water supply system in Guatemala City. Upon completing the evaluation, the study that appears to be the most technically and economically feasible shall be recommended.

The two basic studies as presented by the agencies concerned were unequal. The first one (MDN) dated December 1966, was completely finalized in practically all its details and up to date. The second one (DAD) dated 1962, was adequate for its purpose at that time, but was not current enough to be compared to the Army's study. Therefore, it was necessary to request the Municipality to finalize its study and consider current conditions.

The two schemes were of a marginal character unless additional information on long-range prospects were furnished. Neither study contained adequate sound planning to provide water supplies required in the next twenty years. Therefore, further study and information was requested along these lines. More work was required than originally anticipated for the consultant and the two principal agencies concerned, particularly the Municipality. With the supplementary information provided, the conclusions contained herein were reached.

Both projects are feasible and the studies presented show a high order of ability on the part of the engineers who compiled them. This opinion of

their abilities has been further reinforced through actual contacts with them during our studies. It is believed that the plan best suited to the future needs of the City and the Country has been recommended. It has been rather difficult to do this in view of the many advantages each scheme possesses and the many complications involved.

This report has been prepared after studying all available pertinent documents on the subject and consulting all agencies directly or indirectly concerned with it. Field inspections have been made in detail of both routes and of the applicable Guatemala City installations and also in general all of the long range water supply areas involved. The latter included Lake Atitlan and some of its potential feeders, including the Madre Vieja, Nahualate and Samala Rivers. In this connection, the water sheds of the head waters of the Motagua and Usumacinta Rivers were also visited, including the tributaries Negro and Blanco and others.

The personnel associated with the projects were most willing to cooperate and provided all information requested. We have freely used the information furnished us by the personnel and obtained from the various reports and historical records applicable to the evaluation.

We wish to acknowledge the extensive assistance given by the following:

Instituto de Fomento Municipal

Manager: Otto Bianchi

Chief Engineer: Isidoro Cohen

Ministerio de la Defensa Nacional

Minister: Col. Rafael Arriaga Bustos

Representative: Col. Ing. Oscar Meneses Alvarez

Coordinator for the Xaya-Pixcaya Project: Ing. Hector Quezada

Municipality of Guatemala

Mayor: Lic. Ramiro Ponce-Monroy

Director of Dept. of Water and Drainage (DAD): Ing. Kenneth D. Toppe

Coordinator for DAD: Ing. Edgar Willemsen

Instituto Nacional de Electrificacion

Manager: Rolando Castillo Contoux

Consulting Engineer: Jorge Bendix

Principal Engineers: Moises Cohen, Pedro Aragon and Larry Andrade

Banco Interamericano de Desarrollo

Regional Director: Dr. Diego Aria

Chief Engineer: Hugo Romero

Banco de Guatemala

Licenciados Ovidio Gonzalez B. and Martin Carranza O.

Ministerio de Hacienda y Credito Publico

Lic. Gert. K. Rosenthal

Central American Institute of Technological Investigations

Director: Dr. Manuel Noriega Morales

Geologists: Ings. Gabriel Dengo and Otto Bohenberger

United States Agency for International Development/Guatemala

Assistant Director: Edward Marasciulo

Chief Engineer: William M. Campbell

Loan Officer: Charles R. Connolly

Many others in the organizations mentioned and in other agencies contributed in furnishing valuable information.

Abbreviations Used and Conversion Equivalents

INFOM	Institute for Municipal Development
MDN	Ministry of National Defense
DAD	Department of Water and Drainage of the Municipality of Guatemala
ICAITI	Central American Institute of Investigation and Industrial Technology
INDE	National Institute of Electricity
BID	Inter-American Development Bank
USAID/GUA	United States Agency for International Development/ Guatemala
The Consultant	PARSONS CORPORATION
m.s.n.m.	Meters above sea level
MLD	Million liters daily
GPM	Gallons per minute
PAJA	Local unit of flow. It authorizes the use of 60,000 liters of water per month
MGD	Million gallons daily

LPS	Liters per second
FIG.	Figure

Conversion Equivalents

1 Paja equals 60,000 liters per month

1 Paja equals 2,000 liters per day

10 MGD equals 18,900 pajas or 37.8 MLD

10 MLD equals 5,000 pajas

1 LPS equals 43.2 pajas

1 Inch equals 2.54 cm. or 25.4 mm.

Figure No. 1 is a conversion graph of pajas to MLD and MGD.

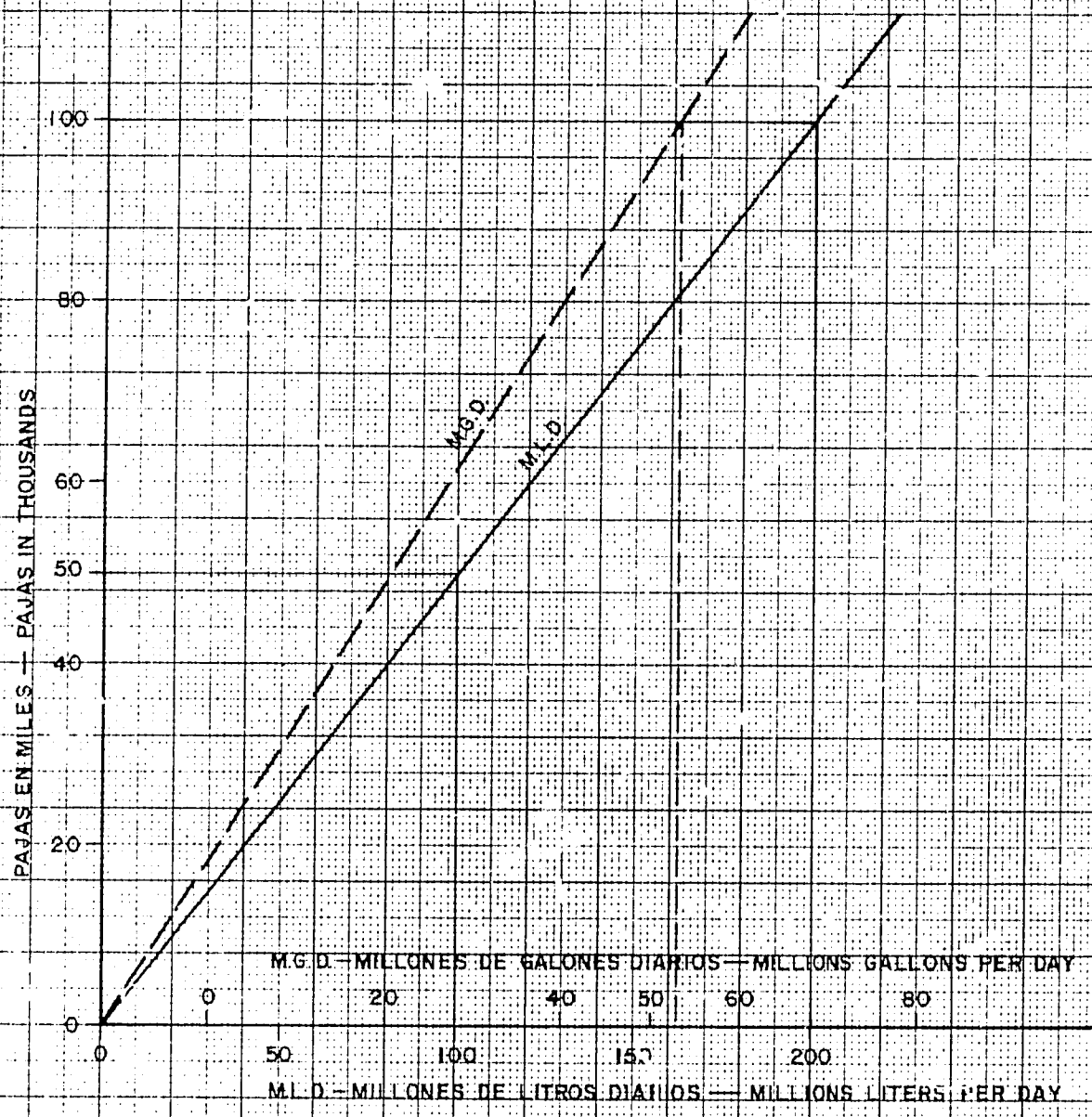


FIG.-N° 1

INFOM INSTITUTO DE FOMENTO MUNICIPAL GUATEMALA		PROYECTO XAYA-PIXCAYA PROJECT
CONVERSION A PAJAS CONVERSION OF PAJAS		
PARSONS CORPORATION LOS ANGELES	ESCALA SCALE	TRABAJO N° JOB N° 4198
PRESTAMO AID N° US/AID LOAN N°	FECHA DATE NOV, 1967	DIBUJO N° DRAWING N°

A.1 LOCATION, NATURE, AND EXTENT OF WORK OF BOTH STUDIES

Both projects are located in the same general area between Guatemala City and the intakes on the Xaya and Pixcaya Rivers. The intakes of both schemes are the same. The Army scheme deviates toward the South, passing through many towns and villages and ending at Lo de Coy near Mixco 3.9 kms. from the La Brigada Treatment Plant and the city distribution system. It proposes to connect to the city's distribution system from a treatment plant to be constructed at Lo de Coy.

The Municipality's Project starts from the same intakes on the Xaya-Pixcaya Rivers, but takes a northern route through less populated areas and ends at the existing La Brigada Water Treatment Plant. This is connected to the Guatemala City distribution system.

The Army project also plans to supply water to 17 towns along its route from sources within the adjacent areas, by installing the necessary facilities (dams, conduits, treatment plant, etc.). Actually they ultimately would take water from the areas involved in an amount somewhat more than that which the Municipality plans to take from Xenacoj I and Xenacoj II Rivers along their route. The Municipality does not contemplate furnishing water to any towns along its route. The water from the Xenacoj Rivers would be introduced about two-thirds of the distance from the city to the Pixcaya intake. In both cases taking water from the areas mentioned would not be detrimental to the present communities.

The following figures show the general geography and location of the projects.

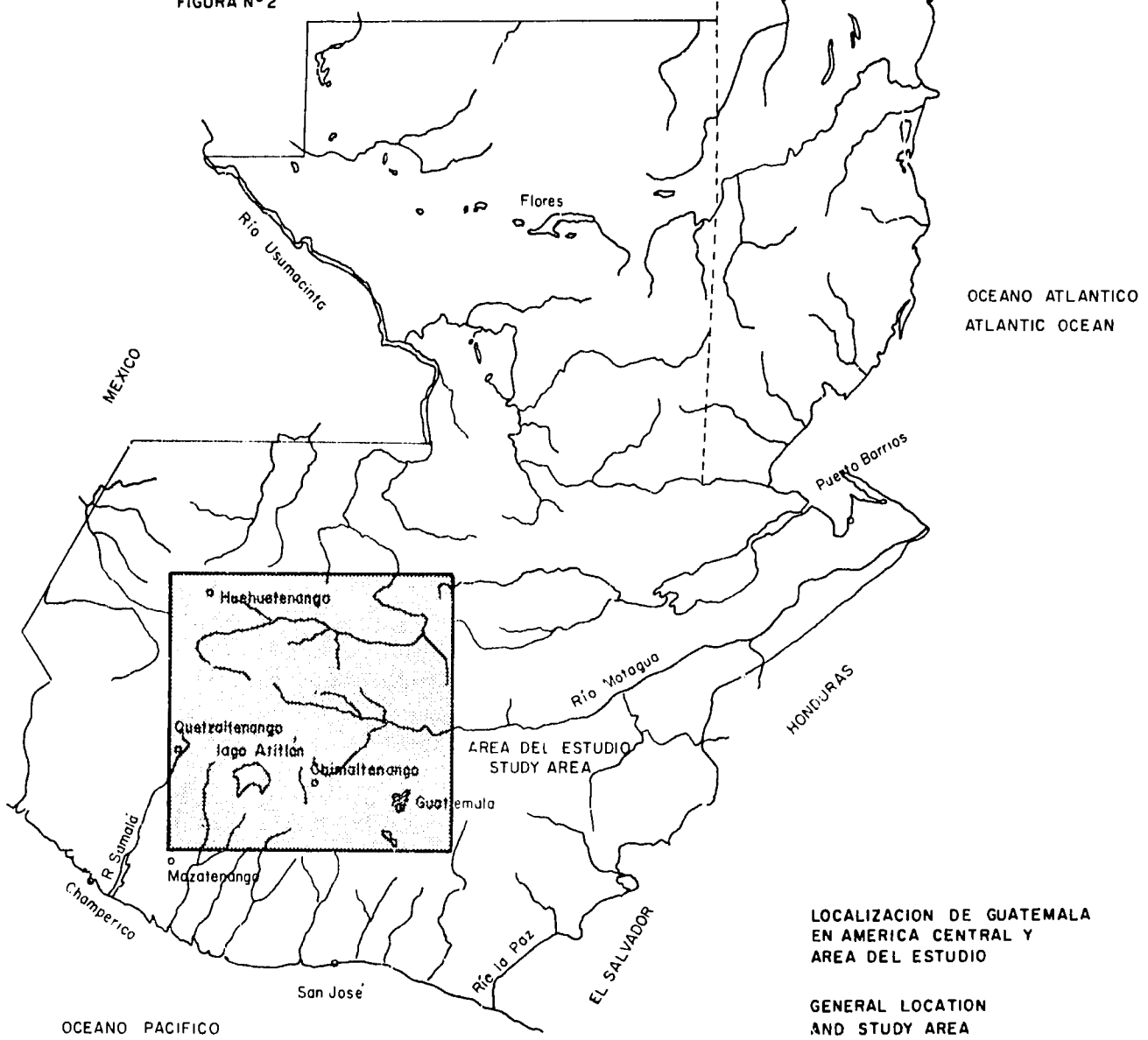
Figure No. 2 - Relation of Guatemala to Central America.

Figure No. 3 - Study Area.

Figure No. 4 - Location of MDN and DAD Routes.

Figure No. 5 - Projects: Existing, Under Construction and Proposed for Immediate Construction.

FIGURA Nº 2



LOCALIZACION DE GUATEMALA
EN AMERICA CENTRAL Y
AREA DEL ESTUDIO

GENERAL LOCATION
AND STUDY AREA

FIGURA Nº 3

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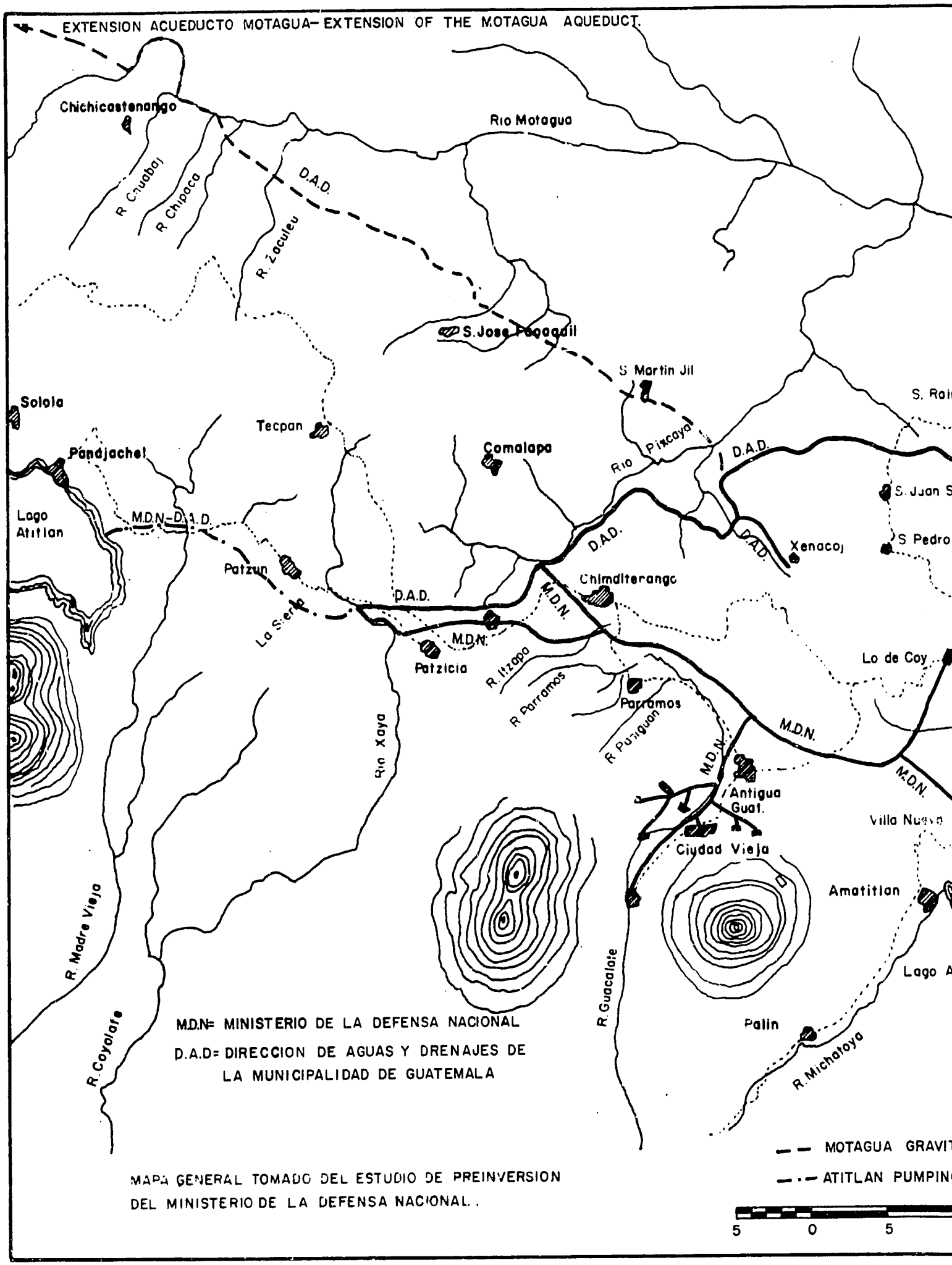
EXTENSION ACUEDUCTO MOTAGUA- EXTENSION OF THE MOTAGUA AQUEDUCT.
Chichicastenango
Rio Motagua
R. Chuabaj
R. Chipaca
D.A.D.
R. Zaculeu
S. Jose Pogogil
S. Martin Jil
Solola
Tecpan
Comalapa
Rio Pixcaya
D.A.D.
Pandjachel
Lago Atitlan
M.D.N.-D.A.D.
Patzun
D.A.D.
Xenacoj
Chimditerango
M.D.N.
La Sierra
D.A.D.
M.D.N.
Patzicia
R. Itzapa
R. Parramos
Parramos
R. Pasaguan
Lo de Coy
M.D.N.
M.D.N.
M.D.N.
Rio Xaya
Antigua Guat.
Villa Nueva
Ciudad Vieja
Amatitlan
R. Madre Vieja
R. Guacalate
Lago A
Palin
R. Michatoya
R. Coyolate
M.D.N= MINISTERIO DE LA DEFENSA NACIONAL
D.A.D= DIRECCION DE AGUAS Y DRENAJES DE LA MUNICIPALIDAD DE GUATEMALA
MOTAGUA GRAVIT
ATITLAN PUMPIN
MAPA GENERAL TOMADO DEL ESTUDIO DE PREINVERSION DEL MINISTERIO DE LA DEFENSA NACIONAL.
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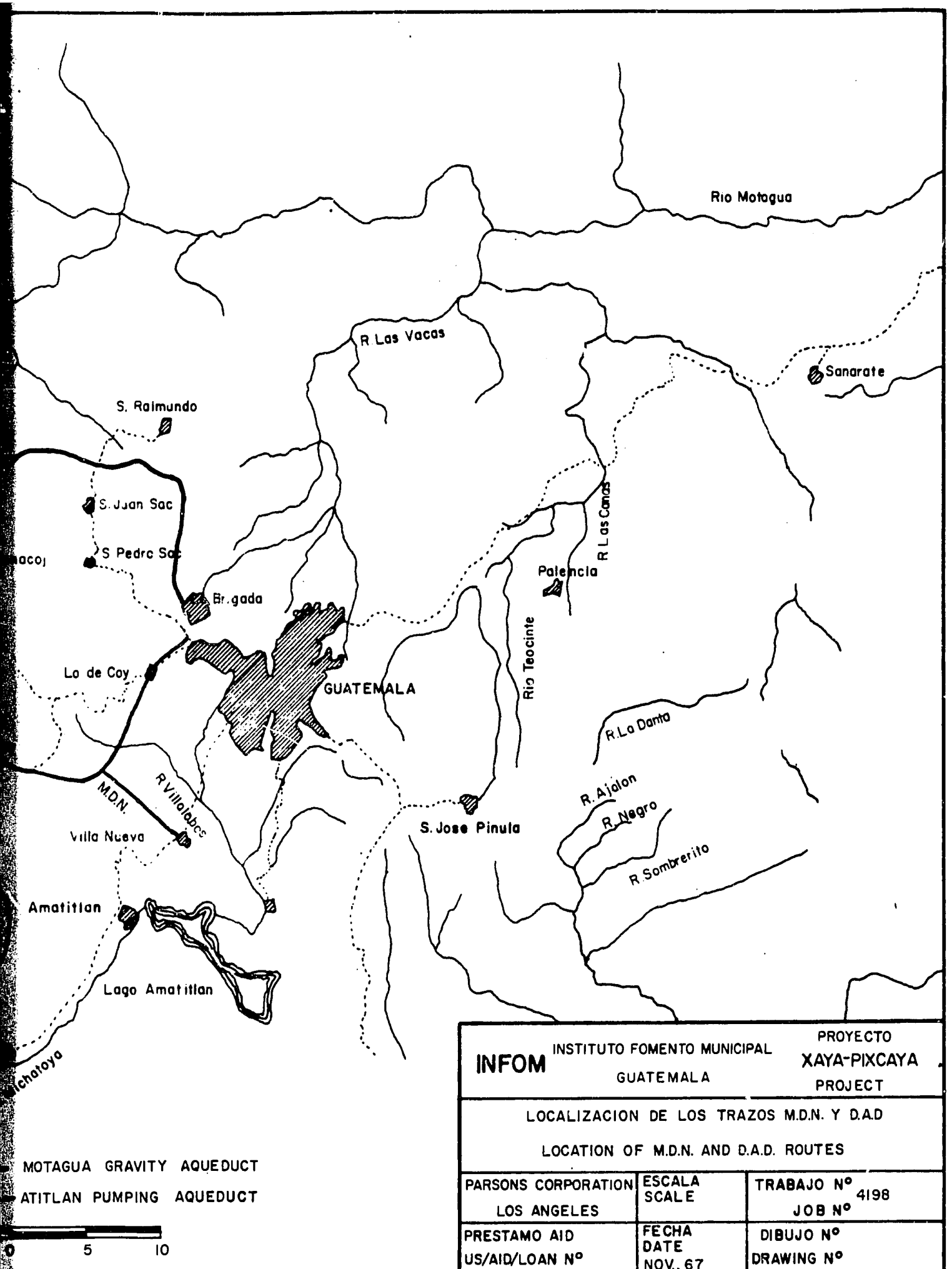
FIGURA Nº 4

a


Rio Motagua
R. Las Vacas
Sanarate
S. Raimundo
S. Juan Sac
S. Pedro Sac
Palencia
R. Las Conas
Br.gada
Rio Teocinte
Lo de Coy
GUATEMALA
R. La Danta
R. Villalobos
M.D.N.
R. Ajalon
R. Negro
S. Jose Pinula
Villa Nueva
R. Sombrerito
Amatitlan
Lago Amatitlan
MOTAGUA GRAVITY AQUEDUCT
ATITLAN PUMPING AQUEDUCT
0 5 10
INFOM
INSTITUTO FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
LOCALIZACION DE LOS TRAZOS M.D.N. Y D.A.D
LOCATION OF M.D.N. AND D.A.D. ROUTES
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO N° 4198
JOB N°
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US/AID/LOAN N°
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DATE
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DIBUJO N°
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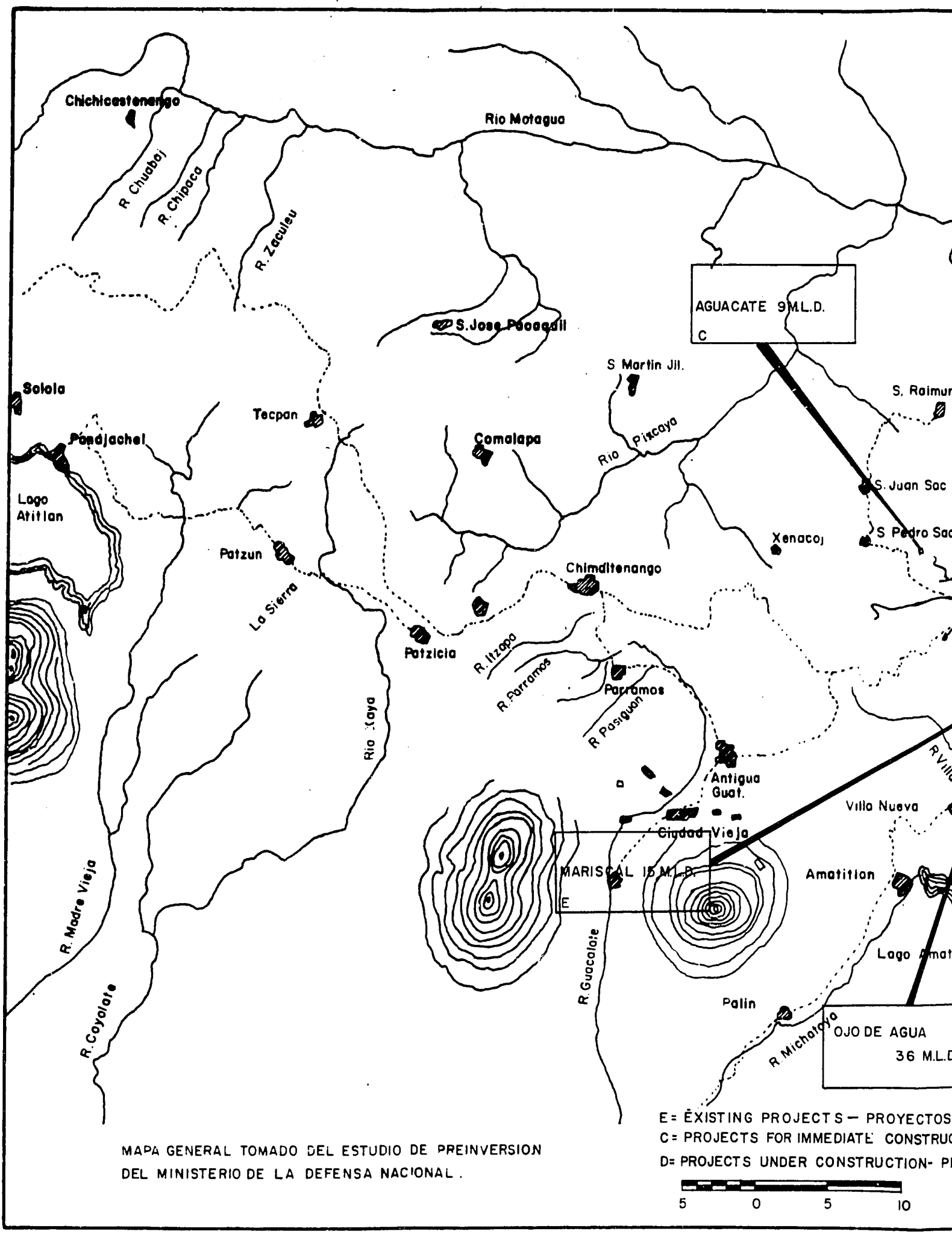
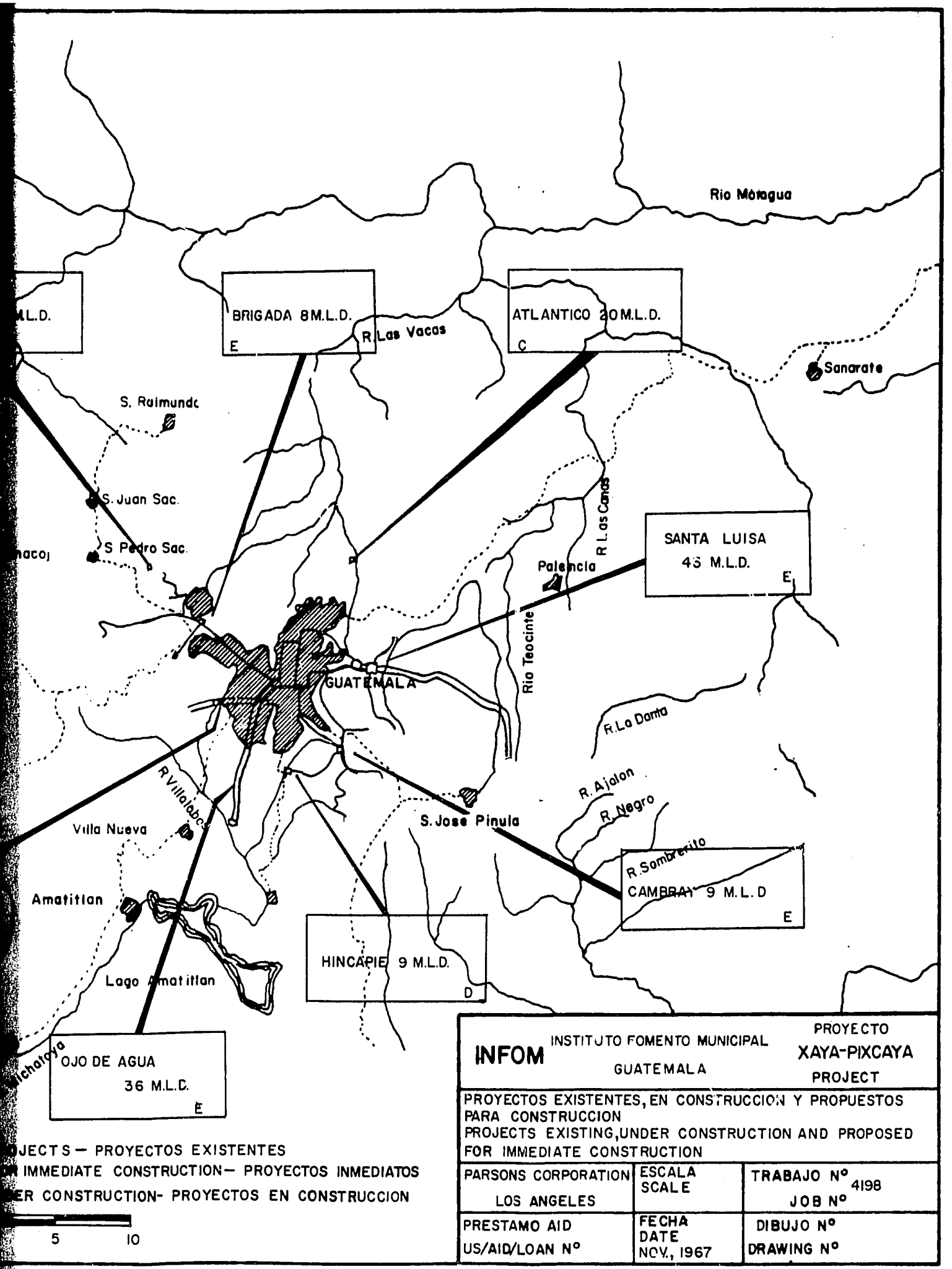


MAPA GENERAL TOMADO DEL ESTUDIO DE PREINVERSION DEL MINISTERIO DE LA DEFENSA NACIONAL.

FIGURA Nº 5


Rio Motagua
BRIGADA 8M.L.D.
E
R. Las Vacas
ATLANTICO 20M.L.D.
C
Sanarate
S. Raimundo
S. Juan Sac.
S. Pedro Sac.
R. Las Canas
SANTA LUISA
45 M.L.D.
E
Palencia
Rio Teocinte
GUATEMALA
R. La Danta
R. Ajalon
R. Negro
R. Villalobos
S. Jose Pinula
Villa Nueva
R. Sombrerito
CAMBRAY 9 M.L.D
E
Amatitlan
HINCAPIE 9 M.L.D.
D
Lago Amatitlan
OJO DE AGUA
36 M.L.D.
E
INFOM
INSTITUTO FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
PROYECTOS EXISTENTES, EN CONSTRUCCION Y PROPUESTOS PARA CONSTRUCCION
PROJECTS EXISTING, UNDER CONSTRUCTION AND PROPOSED FOR IMMEDIATE CONSTRUCTION
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO N° 4198
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FECHA
DATE
NOV., 1967
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DRAWING N°
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ER CONSTRUCTION - PROYECTOS EN CONSTRUCCION
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A.2 DESCRIPTION OF MAJOR FEATURES OF DESIGN

The most important and costly items in the two projects are the conduits, from the intakes to the city distribution system. In the Army system the conduits consist of tunnels, canals and siphons. Two long tunnels and ten short ones are proposed. Their size is determined by the construction methods used. The canals are in reality non-pressure covered conduits consisting of two lines of equal capacity, the first one to be installed in the first stage and the other in the second stage, both of equal capacity. They are 1.37 meters in dia. and of unreinforced concrete. They are of special design and would be constructed by methods compatible to the design. The siphons are steel pipe under pressure up to a static head of 100 meters. Their sizes vary from 42 to 45 inches in diameter. Their minimum thickness is 1/4 inch, increased to 5/16 inches after a head of 100 meters is reached.

The Municipality conduit line originally consisted of tunnels, canals (covered conduits) and pressure siphons similar to the Army line. Recent revisions eliminate the canals in favor of tunnels to reduce costs. The major part of the tunnels are relatively soft, stable materials which can be excavated manually. For tunnels passing through the harder materials, conventional methods would be used. The siphons are planned to be of ductile iron to reduce corrosion, which would be an important factor as they are designed to be buried insofar as practical to reduce cost of concrete supports to the minimum.

The Municipality considers that the annual costs including maintenance would be less for buried ductile iron pipe, based on experience to date. However, for comparative purposes, prices for steel pipe with concrete supports when necessary have been used and provision made for painting and other maintenance charges in annual costs.

Both schemes have similar designs for diversion dams, intakes, storage reservoirs and treatment plants. The conduits differ in that the Municipality does not plan to use covered non-pressure conduits, which are called canals although they are not canals in the usual meaning of the word. The Army conduits consist of tunnels, covered conduits and siphons. Figure No. 5A shows the terrain involved. Their tunnels pass through somewhat harder materials than the Municipality tunnels and have greater lengths on the average.

The Municipality plan more and has shorter tunnels. Originally, they had divided their tunnels, canals (covered conduits) and siphons like the Army but in different proportions. Recent studies indicated because of the nature of the materials encountered, it was more economical to eliminate the canals and substitute tunnels. The elimination of canals shortened the route over eight kilometers with a considerable reduction in total cost.

The Municipality line has the advantage of being on a steeper grade (2 to 1000 versus 1 to 1000 in the Army plan) and, therefore, may use siphons of lesser diameter with consequent savings in cost. The tunnels have a minimum bore dictated by construction methods, results in having an excess capacity at first even when laid on the minimum acceptable grade.

Vista del terreno en que se desarrolla el Acueducto (Estaciones 17+200 a 19+400) mostrando el tipo de condiciones topográficas que requieren la combinación de canal y sifón. (El trazo fue destacado con cal en el terreno).

View of the land on which the aqueduct will be developed (Stations 17+200 to 19+400) showing the type of topographic conditions that require the canal and siphon combination.

Foto courtesy of MDN (from Page 198 Volume I of MDN 1966 Report)

FIG. 5A

The Municipality plans to terminate its conduit at the La Brigada Treatment Plant which is already in operation and is more advantageous to use than the proposed Army site. The plant would be expanded to meet the increased demands and the necessary land is city owned. The elevation is sufficiently high to supply by gravity most of the present distribution systems although a small amount of pumping would be necessary for certain higher sections. The present and proposed (on which work is now in progress) distribution systems is designed to fit into the La Brigada Plant.

The Army plans to terminate its conduit at its proposed Lo de Coy treatment plant (similar in design to La Brigada) 3.9 kms. from the La Brigada Plant and 60 meters higher. This will require a pressure pipe 30 inches in diameter to connect to the city distribution system at La Brigada. The additional height is not a great advantage as it saves only a relatively small amount of pumping and the increased pressures on the city mains is undesirable as it would increase losses due to leaks in street mains and house plumbing designed for lower pressures.

It would be impracticable to revise the Municipality distribution system as now in use and proposed. It has been carefully planned to fit the city's needs. The proposed Army distribution system has been well worked out but under existing conditions can hardly be recommended to supercede the Municipality plan.

The following gives in summary form certain details of the main features of the MDN and DAD projects (intakes, conduits and treatment plants).

1. Water Intake Structures

a. Pixcaya Water Intakes:

Both projects propose to build low gravity concrete dams to tap the Pixcaya River, at elevations 1,742 meters above sea level in the DAD scheme and 1,733.50 in the MDN scheme.

The elevation of end points of the two projects are as follows:

MDN at Lo de Coy near Mixco	1,678.00 meters
DAD at La Brigada W.T.P.	1,612.00 meters

b. Xenacoj Water Intakes:

The Xenacoj Branch of the DAD scheme proposes to divert the water of this river through a similar type of structure located at elevation 1,711.50 meters and will join the main aqueduct at elevation 1,695.66.

2. Conduits for Water Transportation

a. Overall Lengths: Pixcaya - La Brigada

Type of Conduit	MDN Length meters	MDN %	DAD (2) Length meters	DAD (2) %
Concrete cover gravity conduit cast in place	18,890	42.4	-	
Pressure pipe for (1) siphons and connections	12,270	27.5	11,014	24.0
Tunnels lined with concrete	13,426	30.1	34,840	76.0
Totals	44,586	100.0%	45,854	100.0%

(1) This figure includes 3,900 meters of steel pressure pipe from Lo de Coy to La Brigada.

(2) These figures do not include the conduits of the Xenacoj Branch.

b. Sizes, slopes, etcetera of covered conduits and tunnels:

	MDN	DAD
Diameter of covered conduits meters	1.37	-
Diameter of tunnels meters	2.00 - 1.80	1.50
Number of tunnels	12	104
Length of largest tunnel meters	5,630	1,310
Length of shortest tunnel meters	90	25
Slope in long tunnels	0.0005 - 0.001	-
Slope in short tunnels	0.001	0.0005
Slope of covered conduits	0.001	

c. Lengths, diameters, wall thicknesses, and number of siphons and pressure pipe:

Length Meters	Diameter - Thickness	Number MDN	Number DAD
2,583	42" x 1/4" siphons	11	-
3,681	45" x 1/4" siphons	12	-
3,385	45" x 5/16" siphons	4	-
3,900	30" Ø Pressure pipe (+)	-	-
	Total MDN	27	
4,635	34" x 1/4" siphons	-	11
7,747	32" x 1/4" siphons	-	31
200	34" x 3/8" siphons	-	-
624	32" x 1/4" pressure pipe		-
	Total DAD		42

3. Water Treatment Facilities

Both schemes include treatment facilities. The MDN proposes a complete new treatment plant located at elevation 1,680 at Lo de Coy near Mixco. The DAD project calls for a major expansion of the existing treatment facilities at La Brigada at elevation 1,612. The following shows the similarity of design applicable to both plants.

Item	MDN - DAD
Mixing device	Parshal Flume
Floculation	Hydraulic
Detention period, minutes	20
Sedimentation	
Detention period, hours	4.34
Surface loading m^3/m^2 x Day	22.3
Filtration	
Rate of filtration m^3/m^2 x Day	146.0
Chlorination	yes
Fluorination	yes

2.d. Overall Lengths: Xayá - Pixcayá - Xenacoj - La Brigada
2.d. Longitudes Globales: Xayá - Pixcayá - Xenacoj - La Brigada

LONGITUD DE LAS RUTAS DE LOS PROYECTOS

LENGTH OF PROJECT ALIGNMENTS
(Longitud en metros - Length in meters)

RUTAS - ROUTES	ORIGINAL				REVISADA - REVISED			
	Covered Conduits Conductos Cubiertos	Tunnels Túneles	Siphons Sifones	Total	Covered Conduits Conductos Cubiertos	Tunnels Túneles	Siphons Sifones +	Total
RUTA DE LA DAD ROUTE OF DAD								
La Brigada - Xenacoj	11,855	11,677	10,806	34,338	2,490	22,293	6,781	31,564
Xenacoj - Pixcayá	3,420	9,705	6,735	19,860	1,182	8,875	4,233	14,290
Pixcayá - Xayá	275	10,550	3,515	14,340	840	9,970	3,262	14,072
SUB-TOTAL	15,550	31,932	21,056	68,538	4,512	41,138	14,276	59,926
Ramal Xenacoj	1,490	2,340	1,450	5,280	1,285	4,095	1,075	6,455
TOTAL	17,040	34,272	22,506	73,818	5,797	45,233	15,351	66,381
RUTA DEL MDN ROUTE OF MDN								
Lo de Coy - Pixcayá	18,890	13,426	8,370	40,686	18,890	13,426	8,370	40,686
Pixcayá - Xayá	840	9,970	3,262	14,072	840	9,970	3,262	14,072
SUB-TOTAL	19,730	23,396	11,632	54,758	19,730	23,396	11,632	54,758
Lo de Coy - La Brigada			3,900	3,900			3,900	3,900
TOTAL	19,730	23,396	15,532	58,658	19,730	23,396	15,532	58,658

+ Esta longitud de los sifones corresponde a la proyección horizontal
These length of siphons is the horizontal projection

A.3 ESTIMATES OF BENEFITS AND COSTS

A summary of the benefits and costs is given below in accordance with AID Benefit-Cost evaluation manual.

Benefit-Cost Ratio

Annual Benefit - MDN Plan	$ 1,212,444
Annual Cost - Municipality Plan	1,178,346
Ratio	1.03 to 1.00

Secondary Benefits (not used in above computation)

Value of additional housing development annual	0.5.000,000
Savings in hospital treatment - annual	35,000
Savings - storage facilities - annual	314,000
Savings - deep wells and pumps - annual	80,000

Details of the benefit-cost estimates will be found in Section E.3.a. of this report.

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NO. PG. 24

A.4 LIST OF APPLICABLE REPORTS FOR THE PROJECT'S EVALUATION

Following is the list of the reports officially provided by the MINISTRY OF THE NATIONAL DEFENSE (MDN) and by the DIRECTION OF WATER AND DRAINAGE OF THE MUNICIPALITY (DAD) through the INSTITUTO DE FOMENTO MUNICIPAL (INFOM). There are also included in this list other reports obtained from other sources.

I. INFORMATION PROVIDED BY MDN

( ) indicates the identification number of the MDN. Letter A, for the blue numbers and R for the red.

A. General Básico - Basic General

2 Juegos completos de los tres Volúmenes del informe de Preinversión del Acueducto Nacional Xayá-Pixcayá del Ministerio de la Defensa, Dic. 1966 (1 A).

1 Copia del Estudio de Factibilidad de los Túneles de Chimaltenango y Las Cañas, preparado por Electro-Watt, Ingenieros Consultores S.A., Zurich, Julio 1966 (2 A).

1 Copia del Análisis Comparativo de los Proyectos del Ministerio y de la Municipalidad sobre los Ríos Xayá y Pixcayá, Julio 1963 (3 A).

1 Copia del panfleto titulado "El Abastecimiento de Agua a la Ciudad de Guatemala y el Proyecto del Motagua" 1959 (4 A).

2 Separatas del Informe de Preinversión (resumen) des Acueducto Nacional Xayá-Pixcayá, Dic. 1966 (5 A).

2 Copias de la conferencia dictada por el Ing. H. Quezada R. en la Academia de Ciencias Médicas, Físicas y Naturales de Guatemala, 8 de Junio de 1967 (6 A).

1 Copia del Análisis de la Idea de Túneles de Storek, Feb. 1962 (7 A).

1 Copia del panfleto "Aspectos Principales del Acueducto Nacional Xayá -Pixcayá," 20 de Julio de 1966 (8 A).

Anteproyecto - Preliminary Plans

Informe sobre el Acueducto Nacional Xayá-Pixcayá del Ministerio de la Defensa, por Ing. Héctor Quezada, Febrero 1962 (000 R).

B. Topografía - Topography

Hojas (desprendibles) de las libretas de campo:

Trazo preliminar de 1962-63, 9 sobres, (1 R).

Trazo Preliminar de 1965-66, incluyendo tránsito, nivelación, y secciones transversales, 12 sobres (3 R).

Trazo Definitivo (localización) de 1965-66, incluyendo tránsito, nivelación y secciones transversales, 12 sobres (3 R).

Planos de Trabajo:

Línea Preliminar 1962-63, Planta y Perfil, 1 rollo (4 R).

Línea Preliminar 1965-66 en Planta y con curvas de nivel, 8 rollos (5 R).

Planos para replanteo de campo del trazo definitivo 1965-66, 34 rollos (6 R).

Perfiles longitudinales del trazo 1965-66, 4 rollos (7 R).

Secciones transversales del trazo 1965-66, 5 rollos (8 R).

Planos del Instituto Geográfico Nacional, con el Trazo del Acueducto Nacional marcado en ellos, 3 planos (9 R).

Cálculos del Movimiento de Tierras, 1 cartapacio Marzo, 1966 (10 R).

C. Geología - Geology

Reconocimiento Geológico del Proyecto "Quezada" sobre los ríos Xayá y Pixcayá, por Ing. Otto Bohnenberger (20 R).

Terminos de Referencia para Exploración Geológica de Túneles Chimaltenango y Las Cañas (21 R).

Informes diarios de perforación de Electro Watt (21 R).

Informes de la División de Geología y Minería del ICAITI _23 R).

Información Geológica de la Línea de Conducción, 3 planos (24 R).

Informes mensuales y parciales de Electro-Watt (25 R).

Informe Preliminar del Ing. Tomás S. Hirschman del 21 de Enero de 1964 (26 R).

Muestras del material encontrado en las perforaciones efectuadas por Electro-Watt, 11 cajas (27 R).

D. Hidrología - Hydrology

Registros de los Limnígrafos, 5 sobres (40 R):

Río Pixcayá (El Tesoro)
Río Xayá (Los Tres Mojones)
Río Xayá (Molino L de la Sierra, Antigua Estación)
Río Xayá (Molino de la Sierra, Nueva Estación)

Registros de los Pluviógrafos, 5 paquetes (41 R):

Estación Los Jutes
Estación Molino de la Sierra
Estación La Giralda (Tecpán)
Estación Sta. Cruz Balanyá
Estación San Andrés Itzapa

Registros del Evapógrafo en Los Jutes, 1 paquete (42 R).

E. Estudios de Población

Censo de Población de la República, 1964 (60 R).

Dirección General de Estadística.

Censo de la Vivienda, 1964 (61R).

Dirección General de Estadística.

Población de la Ciudad de Guatemala, 1964 (62 R).

Dirección General de Estadística.

F. Consumos y Demandas

Proyecto Hincapié (Municipalidad de Guatemala) (80 R)

Informe sobre el Abastecimiento de Agua en la Ciudad de Guatemala (Municipalidad de Guatemala) (81 R).

Tesis del Ing. Luis Armando Sifontes (82 R).

Datos de la Encuesta hecha por el Proyecto Xayá-Pixcayá del Ministerio, sobre abastecimientos particulares (pozos y fuentes superficiales) en la Ciudad de Guatemala (83 R).

G. Servidumbres

Se ilustran los conceptos del Informe de pre-inversión con la presentacion del informe preparado por el Ing. Jorge Béndix, del Instituto Nacional de Electrificación (INDE) (100 R).

H. Planta de Purificación y Red de Distribución

Los parámetros y criterios utilizados están expresados detalladamente en el Informe de Preinversión. Vol. I.

I. Información General - General Information

Fotos aéreas de gran altura, ocho sobres (120 R).

Fotos aéreas de baja altura, nueve sobres (121 R).

Planos índices de las fotos aéreas, dos planos (122 R).

Informe de la White Engineering Co., 1926 (123 R).

Informes sobre estudios de agua hechos para la Municipalidad de Guatemala por el Ing. Hector Quezada R., 2 volúmenes (124 R).

Memoria Municipal de los años 1949 a 1951 (125 R).

Memoria Municipal de los años 1955 a 1958 (126 R).

Atlas Climatológico de Guatemala (127 R).

Informe sobre Programa de Acueductos en Guatemala-X Reunión de Ministros de Salud Pública en Panamá (128 R).

Programa de Salud Pública para Guatemala, en el Quinquenio 1965-69 (129 R).

Informe del Seminario para el Estudio del Problema de Agua Potable de la Capital (130 R).

Informe del Ing. Sizenando Ribeiro sobre la Organización de la Dirección de Aguas de la Municipalidad de Guatemala (131 R).

Informes trimestrales que se presentaron durante la ejecución de los Estudios del Proyecto Xayá-Pixcayá del Ministerio de la Defensa, 8 informes (132 R).

Maqueta conteniendo el trazo del Acueducto Xayá-Pixcayá del Ministerio de la Defensa (133 R).

Representación gráfica de la Población y de la Disponibilidad de Agua en la Ciudad de Guatemala (134 R).

Información Técnica sobre el sistema de fundición de tuberías de concreto de la casa S.A.T.U.J.O., 1966 (135 R).

Información Técnica sobre el sistema de fundición de tuberías de concreto de la casa No Joint, Agosto, 1966 (136 R).

Análisis y Control de Costos de Ingeniería, 1964 (137 R).

Nuevos Comentarios sobre el Ante-Proyecto Xayá-Pixcayá de la Municipalidad de Guatemala, Oct. 13, 1967.

Especificaciones para la Construcción del Acueducto Nacional Xayá Pixcayá, Octubre 1967.

Informe No. DII-0003 Ref. E-1489 del Instituto Nacional de Electrificación, INDE, sobre la Hidroeléctrica de Selle, Enero 1967.

Publicaciones varias - Other information

II. INFORMACION SUMINISTRADA POR LA DAD

1. Proyecto de Introducción de un Mínimo de 50,000 Pajas del Río Pixcayá con un incremento de caudal proveniente de los Ríos Xayá y Xenacoj, Mayo de 1961.

2. Túnel de Drenaje, Diciembre 1957.

3. Informe sobre Abastecimiento de Agua a la Ciudad de Guatemala, Julio de 1961.

4. Incremento de 50,000 pajas (100 MLD) al Abastecimiento de Agua Potable a la Ciudad Capital, Noviembre 1961.

5. Análisis de Alternativas, Junio de 1963.

6. Proyecto Teocinte III. Informe de la Misión del Señor Bertin de la Cooperación Técnica Francesa, Febrero 1966.

7. Proyecto Hincapié, Incremento de 4,500 pajas (9 MLD) al Abastecimiento de Agua Potable de la Capital, Marzo de 1966.

8. Informe sobre el Anteproyecto de Introducción de 80,000 pajas del Río Motagua a la Capital por gravedad. 12 de Abril, 1967.

9. Proyecto del Aguacate, Junio de 1967.

10. Proyecto de distribución de agua potable de la Ciudad de Guatemala, preparado por SEURECA, París, 30 de Junio de 1967.

11. Conjunto de planos No. 1, "Línea de Conducción Base y Juegos de Planos del Proyecto" Julio 10, 1967.

12. Conjunto de Planos No. 2, "Líne de Conducción Modificada" y cartapacio conteniendo "Secuencia de los diferentes tipos de conducción y sus características," Julio 10, 1967.

13. Análisis de Costos Unitarios de Túneles Circulares de Hormigón para la Ciudad de Guatemala, Agosto de 1967.

14. Información General, 25 de Septiembre de 1967.

15. Documento mostrando geología superficial de la región Patzicía-Guatemala - Identificación de túneles con geología superficial y localización de pozos de exploración, Sept. 27, 1967.

16. Programa del Incremento de los Caudales de abastecimiento de Agua para la Ciudad de Guatemala, 29 de Septiembre, 1967.

17. Proyecto Pixcayá; Xenacoj-Xayá-Pixcayá, Cálculo Hidráulico de la Línea de Conducción, Tabulación de los Diferentes Tipos de Conducción, Septiembre 28, 1967.

18. Informe #67/4.3.1252 de ICAITI sobre la Inspección Geológica relacionada con el Proyecto del Acueducto Municipal Xayá-Pixcayá, Septiembre 1967.

19. Ingresos de la DAD durante los últimos años, Octubre 11, 1967.

20. Reorganización de la Dirección de Aguas y Drenajes, Octubre 11, 1967.

21. Estudio de Ingresos, 1965 - 90, Octubre 19, 1967.

22. Distribución de la Inversión - Moneda Extrajera - Octubre 1967.

23. Pronóstico de Operación y Mantenimiento del Agua Potable a la Ciudad de Guatemala (cuadros generales) Octubre, 1967.

24. Acueducto Xenacoj-Xayá-Pixcayá, Análisis de Costos Unitarios de Túneles de Hormigón, Octubre 19, 1967

25. Proyecto Xayá-Pixcayá, Presupuesto de la Obra, Octubre 1967.

26. Documento mostrando geología superficial de la región Patzicía-Guatemala - Identificación de Túneles con Geología superficial y localización de Pozos de Exploración.

27. Publicaciones varias - other information

III. MATERIAL INFORMATIVO SUMINISTRADO POR OTRAS FUENTES (ICAITI, INDE, USAID/GUA, ETC.)

1. Power and Irrigation Study, Acres International Ltd. Consulting Engineers, Septiembre 1962.

2. Estimación de Caudales con Información Limitada, Instituto Geográfico Nacional, Noviembre 1966.

3. Republic of Guatemala Electric Power Development, 1965 to 1970, Harza Engineering Co. International, Febrero 1965.

4. Guatemala en Cifras, Dirección General de Estadística, 1964, Febrero 1964

5. Censos de Población, Dirección General de Estadística, Junio 1964.

6. Población de la Ciudad de Guatemala, Dirección General de Estadística, Julio 1966.

7. Vivienda, Censos 1964, Dirección General De Estadística.

8. Anuario de Comercio Exterior 1964, Dirección General de Estadística.

9. Catálogo de Publicaciones del Instituto Geográfico Nacional, Junio 1967.

10. III Congreso Nacional de Ingeniería, Junio 1967: Sector Ingeniería Sanitaria, Sector Vivienda y Desarrollo Urbano, Sector Industria, Sector Energía, Sector Vías de Comunicación.

11. Volcanic History of the Guatemalan Highlands, Howell Williams, 1960.

12. Boletín Hidrológico No. 2, Diciembre 1966

13. Términos de Referencia para una Evaluación Comparativa de los Proyectos de los Ríos Xayá y Pixcayá , Enero 1967.

14. Instructions to Geologists Investigating Conduit Routes, Noviembre 1966.

15. Otras Informaciones - Other information

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A.5 EFFECTS ON ALTERNATIVE OR RELATED USES OF WATER RESOURCES

The ordinary priority given to water is first, for domestic supply, second for power and third for irrigation. Therefore, the domestic supply for Guatemala City would have first priority over other uses. An investigation in regard to taking water from the Xaya and Pixcaya headwaters indicates that this will not seriously inconvenience any users except the Selle Power Plant, for which proper alternate provisions must be made.

On the Municipality route, taking water from the Xenacoj will have no appreciable affect as this water is not being utilized at present to any great extent.

On the Army route there is a surplus of water from local sources for the 17 towns involved and the Army proposes to eventually take this surplus to Guatemala City. However, this would involve taking some of the water now being used for irrigation and it might be necessary to augment the amount of water available by other means to avoid trouble with local inhabitants.

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A.6 CONCLUSIONS AND RECOMMENDATIONS

Listed in this subsection are the Consultant's conclusions and recommendations that have been drawn from a comprehenisve study, economic evaluation and survey of the technical soundness of the project. These statements are a brief summary and the reader is referred to the body of the text for more detailed explanations.

Conclusions

1. Historically, Guatemala City has suffered seriously from an inadequate water supply for many years; therefore, it is imperative that one of the two projects be implemented as soon as possible.

2. Both the MDN and the DAD plans of approach and construction schemes are feasible.

3. The time required for each project is considered to be four years from the date when the funds are available to proceed with preparatory work, including the final designs and specifications, which is a necessary precedent to making construction contracts.

4. The MDN scheme could start construction earlier, in one year, because its preliminary plans are practically completed. The DAD would take one and a half years to start construction because DAD needs an extra six months to amplify their preliminary plans, which are fairly complete but not to the same degree as the MDN plans.

5. The MDN project would take three years to complete because it involves two long tunnels which govern the length of time for construction. The DAD can complete its work in two and a half years because its longest tunnel is much less than the two long MDN ones. It has a greater number of relatively short tunnels but these can be finished quickly because more men can be utilized in their construction. DAD plans to introduce water from the Xenacoj branch within two years after starting construction, and this is quite possible.

6. The project cost of the Pixcaya-La Brigada portion of the MDN plan is estimated to be $12,681,000. DAD's comparable unit will cost $11,688,200. Therefore, the DAD project would cost $992,800 less than the MDN plan, which represents a 7.9 percent cost differential.

7. The annual cost of operation is different for each of the two plans. The MDN plan is estimated at $1,212,444 annually compared to $1,178,346 for DAD's plan. In this context the DAD plan is more attractive by $34,098 annually, which represents a 2.8 percent cost savings.

8. It would be best for the 17 towns included in the MDN project to work out their own water plans singly or in combination. Their inclusion in the Guatemala City system would be an unnecessary complication for all concerned. They could better work out supplies closely adapted to their economies by utilizing the water resources, which are considered adequate, in their vicinity. The MDN planned to obtain

a relatively small amount, somewhat more than that from the Xenacoj Rivers under the DAD plans, from the vicinity of the 17 towns, including Antigua which was by far the most important.

9. The second stage of construction for each project is estimated at Q/$10,000,000 cost, or more. This and further stages were considered in order to fairly evaluate the two projects with respect to their long-range plans.

10. The long-range plans for the DAD are considered more economical than the MDN plans, not only for the city but also for the country. This is mainly because the northern route is capable of being developed more efficiently, due to topographical conditions. Both projects previously relied on increasing the flow in the second stage by regulating the Xaya and Pixcaya Rivers through a series of storage reservoirs. However, further studies have indicated that this system may prove impracticable from an economic standpoint. This is because of the heavy sediment load carried by the rivers, and lack of natural reservoir basins. The rivers follow a steep gradient and excessively high dams would be needed to control them, and their tributaries, and also for the sedimentation. The net result would probably be that the expense could not be justified. In view of this, further long-range possibilities had to be investigated as indicated below.

11. Both projects could use water pumped from Lake Atitlan and/or Madre Vieja River. This would adequately supply Guatemala City reasonably far into the future. However, there are two disadvantages, which follow:

a. The cost of electric power would be quite high, even though pumping could be confined to the dry season and be used only on an off-peak basis.

b. Water taken from the Madre Vieja River or from Lake Atitlan would diminish the supply from the proposed hydroelectric plants to be installed below Lake Atitlan using the lake as a source of water. This would be a disadvantage even though it could be planned that after using the water in Guatemala City it would be drained into Lake Amatitlan through a sewage treatment plant and would benefit the Jurun Marinala Plant which needs all the water it can possibly get.

The DAD plans to use the headwaters of the Motagua, Cuilco and the Usumacinta Rivers in their long-range proposals. It is believed that the development of these sources would be cheaper than the use of Lake Atitlan or Madre Vieja River, as indicated by preliminary investigations, and possibly the alternative of the Pixcaya-Sactzi pumping project. It would be necessary to make an extensive study to determine the economic possibilities of the Motagua system and its extension. However, there is no doubt that this source of water is feasible and gives a great advantage to the northern route, since over half of the Pixcaya Aqueduct can be used to transport water from the Motagua Aqueduct at a relatively low cost.

12. It was not necessary for the MDN to revise its estimates as its studies had been much more comprehensive and were current.

13. The DAD report had not been worked on since 1962 and had not been finalized to the point where construction was ready to start. Therefore, in order to bring the studies to a comparative level, it was necessary to ask the DAD to revise it and bring it up to date. DAD has done this and has reduced the length of the Pixcaya-La Brigada line by over eight kilometers with large savings in cost. The DAD reports are now adequate to request funds to proceed initially with the preparatory work in case their project is approved.

14. As can be seen from the above, the two projects are equal in time of construction and DAD is slightly less costly on an annual basis than MDN and appreciably less on initial cost. DAD long range projects are more economical and more advantageous.

Recommendations

The conclusions listed above lead your Consultant to make the following recommendations:

1. The DAD project for the first stage (Pixcaya-La Brigada) as outlined herein be immediately approved and construction started as soon as financing is made available.

2. The DAD implement and record long-range studies, including streamflow measurements, on a permanent basis.

3. The DAD review and refine their long-range water-supply program for implementation at some future date.

B. ECONOMIC ASPECTS AND BENEFITS

B.1 DESCRIPTION OF THE COMMUNITY OR COMMUNITIES TO BE SERVED

a. Geography, Topography, Type of Soil and Seismic Activities

The Republic of Guatemala has an area of 108,889 sq. kms. and is located between 14 degrees and 18 degrees latitude north and 88 degrees and 92 degrees of longitute west. Economic development is restricted to certain regions due to the topography and hydrographic systems.

Two mountain systems of first magnitude are prominent, the north-south Cuchumatanes system and the east-west Sierra Madre system. The central part of the Sierra Madre Range is a high plain, referred to as the central plateau of the Republic, within which is located the capital Guatemala City, and the Xaya-Pixcaya Project's general area.

The system of mountains clearly establishes two great hydrographic systems, one draining to the Pacific Ocean and the other draining to the Atlantic Ocean. Within the two systems, it is interesting to note that the Coyolate and Xaya Rivers discharge into the Pacific Ocean and the Motagua and Pixcaya discharge into the Atlantic Ocean in the Gulf of Honduras.

The Xaya and Pixcaya Rivers are the principal sources of water proposed for the expansion of the water supply system of Guatemala City, in the studies prepared by the Ministry of the National Defense (MDN) and by the Department of Water and Drainage of the Municipality of Guatemala (DAD). Within the project's area, Lake Atitlan lies to the west and

Lake Amatitlan to the south of the city. Lake Atitlan is at an elevation of 1,562 meters above sea level. It is 19 kms. long and 10 kms. wide, with a maximum depth of about 320 meters. Atitlan is about 65 kms. from the city, by straight line and only about 16 kms. from the intake sites proposed by the MDN and DAD on the Xaya River. Lake Amatitlan is situated about 15 kms. to the south of Guatemala City at an elevation of 1,186 meters above sea level.

Guatemala City, capital of the Republic, is located on the central plateau of the country, about 1,500 meters (4,920 feet) above sea level. Guatemala City is on the continental divide so that part of the runoff from the city goes to the Motagua River to the north, thence into the Atlantic Ocean and the rest to Lake Amatitlan south and thence into the Pacific Ocean. The temperature in the city if very equitable; most of the year it varies between a minimum of 15°C and a maximum of 25°C.

The population of the city, according to the 1938 census was 77,400 and the 1964 census reported 577,120. Curves of population growth are shown on Figure 8 under Section C.1b of this report and in the basic MDN and DAD reports. The total population of Guatemala in 1964 was 4,210,000. Thirteen point five percent of the population lives in Guatemala City, not including the rural population within the Municipality of Guatemala.

The study prepared by the MDN for the expansion of the capital's water supply system also contemplates the water supply to 17 additional towns including Antigua.

Generally, these communities are small, and their economy is based on agriculture. Per capita income is lower than that of the workman in the city. These seventeen towns are all located at an elevation below 1,680 meters above sea level, in the Antigua or Panchoy Valley and classed as follows:

Municipalities	Villages
1. Antigua Guatemala	9. San Juan del Obispo
2. Alotenango	10. San Juan Gascon
3. Ciudad Vieja	11. San Pedro las Huertas
4. Pastores	12. Sta. Caterina Bobadilla
5. Jocotenango	13. San Lorenzo El Cubo
6. San Antonio Aguas Calientes	14. San Luis Las Carretas
	15. San Lorenzo El Tejar
7. Santa Caterina Barahona	16. San Andres Ceballos
8. San Miguel Duenas	17. Santiago Zamora

The Panchoy Valley is crossed from north to south by the Guacalate River whose flow has been estimated by DAD at 40.8 MLD at an elevation of 1,640 meters above sea level during the low-water period. There are a number of ground-water wells in the valley; some of them are artesian and produce between 30 to 115 GPM with static levels between 12 and 38 meters approximately.

Soil

The top soil in the study area consists mainly of detritus forming loams of various types deposited over volcanic material. Generally, the soil is of a red color consisting of silted-loam or clay loam. Some of these soils show cracks due to the presence of expansive clay of the Bentonite group. Some of the samples of the soil observed have a high content of glass shards and pumice fragments. The depth of this soil observed in the slopes varied from 0.30 meters to 1.50 meters.

Geology

The areas of the studies prepared by the MDN and by DAD are located in the mountainous center part of Guatemala, which is characterized by the presence of an impressive chain of Quaternary volcanoes. The Quaternary volcanic period created numerous cones and blanketed the tertiary landforms with glowing avalanche deposits that interbedded with thick zones of fluviable tuffaceous sediments. The tertiary volcanic and sedimentary rocks were deposited on the Cretaceous limestones and dolomites and earlier igneous and metamorphic rocks. The tertiary and earlier rocks have been folded and broken by numerous faults of varying magnitudes.

Based on the available geologic maps and on the field inspections by the Consultant's Geologist over the routes proposed by the MDN and by the DAD the rock materials have been subdivided into six units on their engineering properties. Such geological units are:

1. Quaternary Alluvion (Qal). This alluvium is composed of sand and gravel that have been derived from volcanic materials by erosion.

2. Quaternary Volcanic Pumice (Qvp). This pumiceous unit has special engineering properties, due to its apparent cohesive character. It stands stable in near-vertical cuts. In the area of Guatemala City DAD has made several drainage tunnels through this type of material that have stood without any support for more than a year, after having been excavated easily with pick and shovel. Other examples of the stability of unlined tunnels extending over many years are the

Infiltration tunnel 14 kms. long, 40 years old, to supply El Mariscal water plant and the test tunnels for the Pixcaya Central route five years old. The experience within Guatemala City has shown that the overbreak that occurs during tunneling operations is minimal (plus two percent).

3. Tertiary Volcanic and Sediments (Tvs). The lithologic materials that constitute this map unit are sediments from volcanic origin. The two geological units Tscl and Tsc2 from Bohenberger's map are included together in our report due to insufficient time available for the field inspections to delineate the two units in the field for both alignments. The overbreak during tunneling operations will be about 15 percent.

4. Tertiary Volcanic (Tv). This unit of tertiary volcanic rocks include rhyodocite, andesite, basalt intercalated of basalt conglomerates, glowing avalanche deposits, and water-laid tuffs. It has been estimated that the overbreak in this material will be approximately about ten percent.

5. Cretaceous Limestones and Dolomites (Kld) To this type of rock belongs the most endurated that will be encountered in the project's area. The overbreak during tunneling operations should be about 10 percent. As far as could be established from the limited investigations of the Geologist, this type of material will only be encountered in sections of the route selected by DAD.

6. Granite Rocks (gr) This geological unit has only a limited exposure in the vicinity of San Raimundo and on the area of the route selected by DAD. The overbreak to be encountered when excavating the tunnels is estimated to 10 percent.

Seismic Activity Data on the seismic activity in the study area was obtained from the National Observatory. This data indicates that both projects, the one by DAD and the one by MDN would expect the same seismic forces. The epicenters of this seismic activity within the project's area are in Petapa and the Pacaya Volcano in the Department of Escuintla, and two or three near the litoral zone of Suchitepequez and in San Marcos near the Mexican border. In the pre-investment study of the "Jurun-Marinala" Project, located within the area exposed to be seismic activity epicenters referred to, it is shown that all construction including tunnels and penstock are exposed to earthquake intensity of modified Mercalli scale VIII.

All of the geological engineering aspects related to this water supply project are included in Appendix "B" of this report.

b. Industries

Of the 2,021 industrial establishments in the Republic of Guatemala, 1,400 or nearly 70 percent are located in or immediately adjacent to Guatemala City. The following tabulation lists the type and number of these industries:

Type of Industry	Number of Enterprises
Leather Products	2
Food Products	231
Beverages	15
Tobacco	3
Textiles	80
Clothing	224
Furniture	96
Paper Products	13
Graphic Arts	124
Rubber Products	24
Chemicals	106
Non-metallic Minerals	124
Metal Products	62
Machinery (manufacture and repair)	10
Electrical Products (manufacture and repair)	60
Transportation Equipment (manufacture and repair)	71
Miscellaneous	155

The above information is contained in the Sector Industrial Report issued by the III Congreso Nacional de Ingenieria, June 1967.

In Poblacion de la Ciudad de Guatemala, Censos 1964, issued by the Ministerio de Economia, July 1966, a total of 52,280 persons are shown to be employed by industries in the municipality which is 26 percent of the total numbers of employed persons.

It is desirable to point out two factors for promoting industrial development: First, the common facilities essential for the industry, such as water, electric energy, et cetera, and second the facilities of public services, such as health and welfare. These are evaluated for certain towns in the following Table No. 1:

TABLE No. 1

EVALUATION OF PUBLIC FACILITIES

	Public Facilities			Schools		
	Water	Electri-city	Sanita-tion	Prim.	Sec.	Dwelling
Guatemala	-	x	x	x	x	x
Quezaltenango	-	x	x	x	x	-
Escuintla	x	x	x	x	-	-
Suchitepequez	x	-	x	x	x	-
Retalhuleu	x	-	x	x	-	-
Izabal	-	-	-	x	-	-
Zacapa	x	x	x	x	-	-

x= Sufficient - = Deficient

c. Prevalence of Water Borne Diseases

Records of the Pan American Health Organization lists water-borne diseases in second place among the serious health problems in Guatemala. Medical officers of the U.S. Agency for International Development also rate this category of diseases near the top of the list of diseases requiring medical care. Officials of these organizations do not hesitate to emphasize the importance of a safe and adequate supply of water as a prime requisite to the decrease of these diseases.

The following Table No. 2 lists the water-borne diseases reported in Guatemala City during 1965 which were serious enough to require hospitalization:

TABLE No. 2

SECTION OF PUBLIC HEALTH

GENERAL STATISTIC DIRECTION

Hospital Cases Reported In The Capital During 1965

	Total	Alive	Dead
Infection sickness that originate from the areas of the digestive tract:			
Typhoid Fever	142	134	8
Paratyphoid Fever	3	3	-
Gastroenteritis and Colitis, except the Colitis Ulcerous, in the ages of four years and more:			
In between four weeks and two years	290	281	9
From two years and more age	281	253	28
Amoebiasis:			
Not including Hepatic Abscess	242	241	1
Including Hepatic Abscess	12	12	-
With dysentery caused by protozoa	10	10	-
Infestation by worm of other types, by types mixed and without specification:			
Anquilostomiasis (Uncinariasis)	41	41	-
Ascariasis	50	50	-
Oxiuriasis	1	1	-
Digestive Infestation mixed with Helminthics	-	-	-
Others (Digestive Worms, Triquiuriasis, Dracunculosis, et cetera).	321	318	3
Total Cases	1,393	1,344	49

Table No. 3 reveals a serious situation in the capital city. This information was provided by the Department of Bio-Estadistica of the Health Department of Guatemala on October 4, 1967. In 1964 when the last census was taken, there were 577,120 inhabitants in the city. In that same year 47,660 cases of water-borne diseases were reported. More than eight percent of all residents were victims of these attacks, sufficiently severe to be reported to the authorities. In 1965, 44,354 cases were reported, 1,393 were severe enough to require hospitalization. These statistics emphasize the urgent need for an adequate and safe supply of water for the capital city.

The water supplied to the city is safe when it leaves the city's treatment plants. However, the present supply is not equal to the demand and consequently, the pressure in the water mains drops at times. During periods of low pressure it is possible for impure water surrounding the mains to seep into the pipes at places where there may be breaks or leaks. This contamination presents real dangers and the water supply must be adequate to maintain positive pressure in the mains at all times.

d. Population and Water Consumption

The 1964 census population of Guatemala city was 577,120, application of the 94.5 percent criterion established by the DAD in its study of the Hincapie Project indicates an urban population of 545,376. This population was distributed over eighteen (18) zones

TABLE No. 3

WATER-BORNE DISEASES REPORTED IN THE
CAPITAL CITY OF GUATEMALA FROM 1962 TO AUGUST 12, 1967

SICKNESS	1962	1963	1964	1965	1966	1967
Typhoid Fever	363	382	326	455	351	171
Paratyphoid Fever	5	3	4	5	28	1
Dysenteries	4,320	6,250	7,112	5,261	5,792	4,405
Parasitismo Intestinal	12,186	20,596	24,196	22,044	20,234	14,255
Gastronenteritis, Colitis and diarrhea	8,146	13,883	16,022	16,589	14,164	9,586
Total	26,020	41,114	47,660	44,345	40,569	28,388*

Sources: weekly records from the medical service institutions

* Calculated to be 46,257 for full year.

of the actual urban area of the capital, with populations which varied between 78,740 in zone one and 4,360 in zone 15.

Information published by the Direction of Census (Statistics), shows that for the urban population areas only 66 percent of the buildings had a water supply. At that time approximately 86 percent of the total volume of water supplied to the community was provided by the DAD of the Municipality of Guatemala system and approximately 14 percent was supplied by the El Mariscal Company.

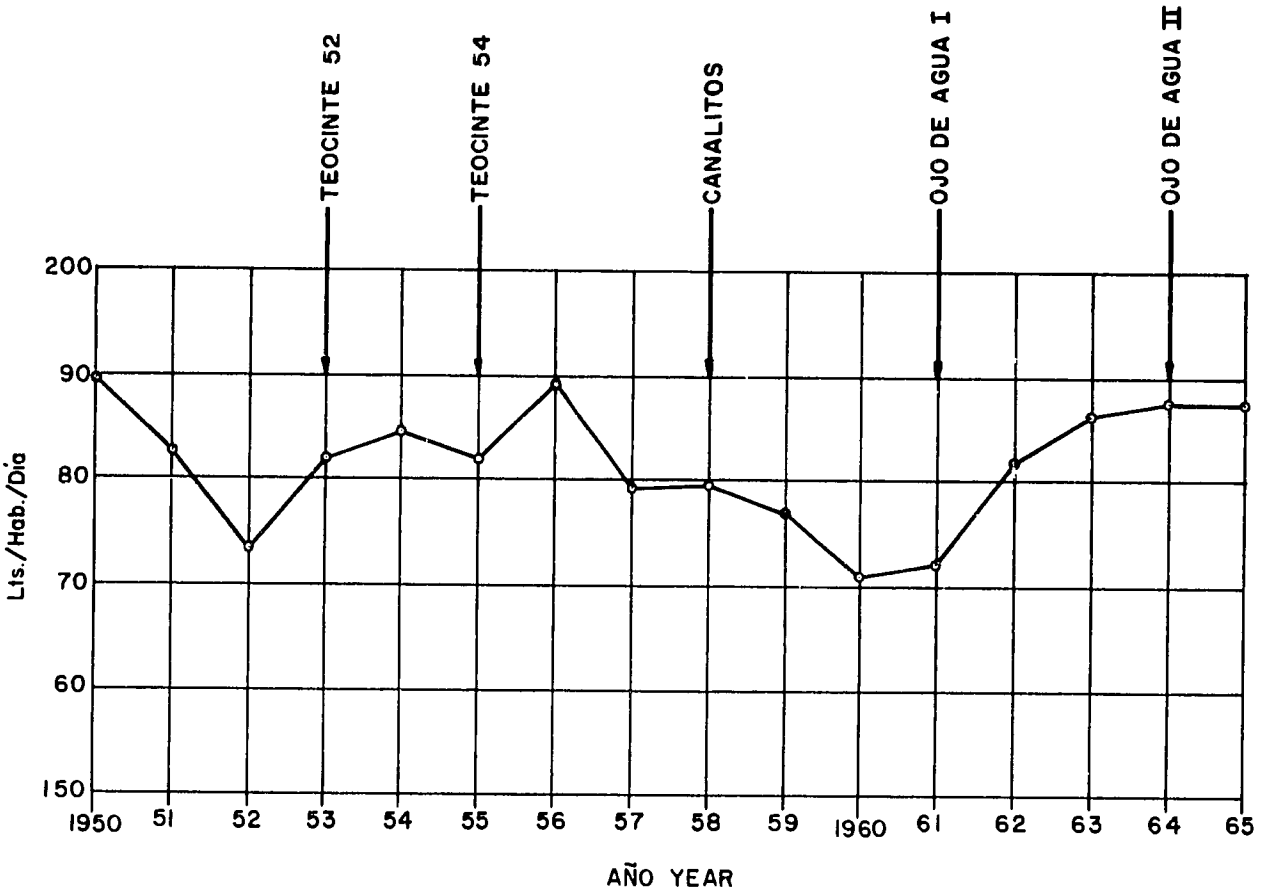
Assuming an average water requirement in 1964 of 250 liters per inhabitant per day, a supply of 136 MLD would have been necessary to serve the urban population. However, only 110 MLD was provided by the DAD installations and El Mariscal Company.

The information available to the consultant did not include a detailed analysis of the past water consumption in the capital. Without detailed historical records, an analysis covering the characteristics of the domestic, commercial and industrial consumption cannot be made. Preparation of projections for probable water consumption characteristics in the future could not be made from the past records available.

Figure No. 6, taken in part from the Preinvestment Report of MDN, indicates the water use per capita in the city during the period 1950-1965. This figure also indicates that when an additional water

supply was introduced the consumption per capita increased. This is evidence that the consumption of water in the past and at present has been limited, due to the lack of adequate supplies of water to satisfy the increasing demand. Increases in the average consumption per capita is a logical consequence of commercial and industrial development and the associated improvement in the standard of living.

The studies prepared by DAD and MDN foresee future increases in per capita consumption to 220 and 296 liters per inhabitant per day respectively by the year 1987. Figure No. 7 shows a graphic comparison of the consumption increase per capita projected by DAD and MDN. Also shown is the estimated rate of consumption increase per capita, adopted by the Consultant for technical and economic evaluation of the two solutions proposed for expansion of the water supply to Guatemala City.



DOTACIONES PASADAS DE AGUA PER CAPITA

PAST WATER CONSUMPTION PER CAPITA

NOTA.- TOMADO PARCIALMENTE DEL INFORME DE PREINVERSION DEL M.D.N.

FROM M.D.N. PREINVESTMENT REPORT, 1966.

FIG. N° 6

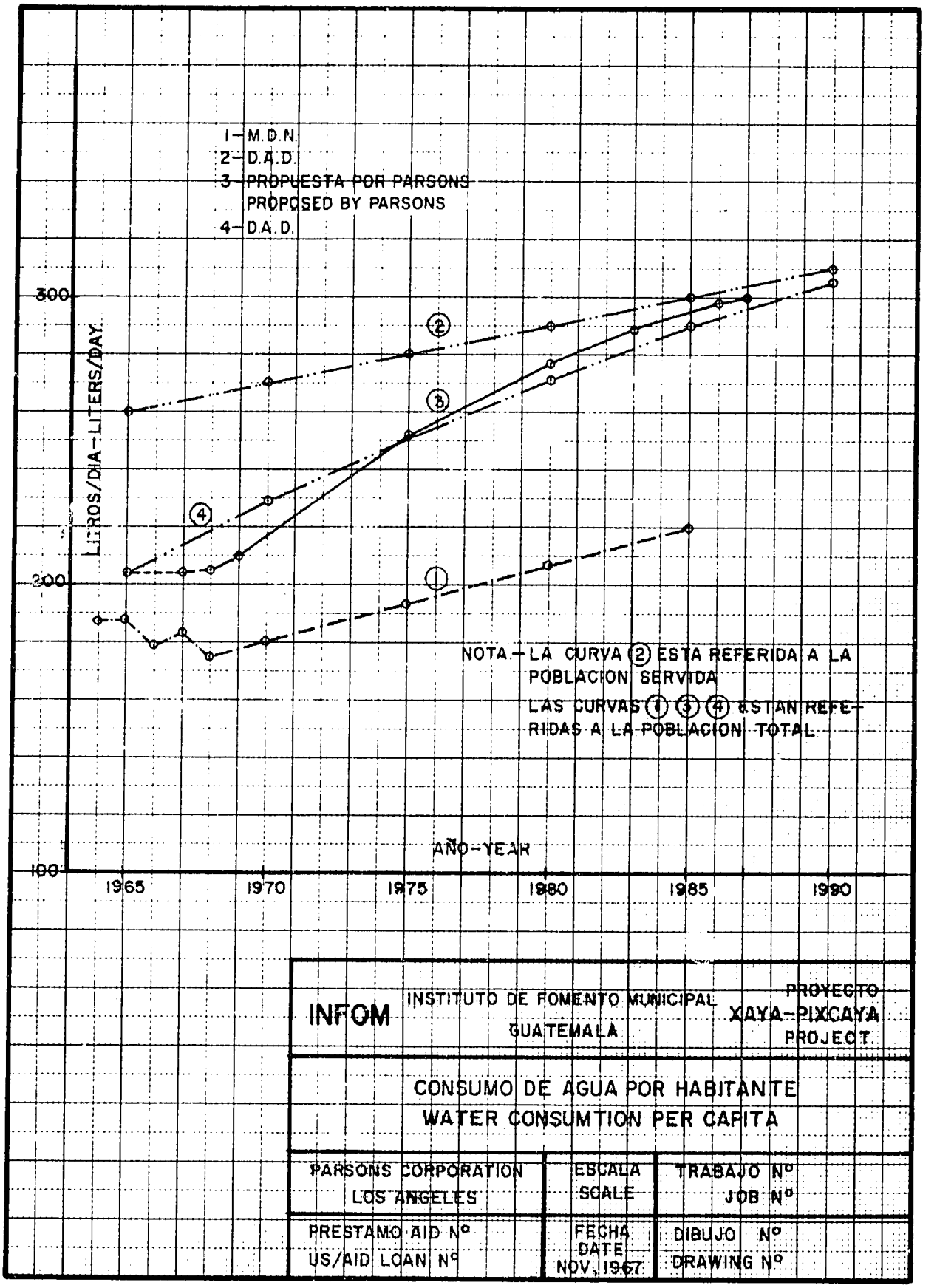

1—M.D.N.
2—D.A.D.
3—PROPUESTA POR PARSONS
PROPOSED BY PARSONS
4—D.A.D.
LITROS/DIA—LITERS/DAY
300
200
100
1965
1970
1975
1980
1985
1990
AÑO—YEAR
NOTA.—LA CURVA (2) ESTA REFERIDA A LA POBLACION SERVIDA
LAS CURVAS (1) (3) (4) ESTAN REFERIDAS A LA POBLACION TOTAL
INFOM
INSTITUTO DE FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
CONSUMO DE AGUA POR HABITANTE
WATER CONSUMTION PER CAPITA
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO Nº
JOB Nº
PRESTAMO AID Nº
US/AID LOAN Nº
FECHA
DATE
NOV. 1967
DIBUJO Nº
DRAWING Nº

FIG. Nº 7

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B.2 PRESENT WATER SYSTEM

a. Extent and Population Served

The 87 square kilometers which constitute the urban area of Guatemala City is provided water by two principal systems, one by the DAD and the other by El Mariscal Company. The total water currently distributed through these two systems is approximately 110 MLD, 86 percent from the sources of the DAD and 14 percent from the sources of El Mariscal.

The following Tables No. 4 and No. 5 report the number of dwelling units in Guatemala City and in the rest of the country that are provided with sanitary facilities. This information was obtained from the 1964 housing census prepared by the Direccion General de Estadistica.

From an analysis of this information, it is observed that in 1964, only 34.2 percent of the dwelling units of Guatemala City had available an individual water connection and only 27.5 percent of them had sewage connections for their exclusive use. Of the total number of dwelling units in the capital, 19.4 percent had no facilities for the disposal of excreta or if they existed were not reported in the census.

Analyzing the figures of the above tables, the situation of water supply in Guatemala City in 1964 was as follows:

TABLE No. 4

STATUS OF WATER SERVICE CONNECTIONS

Sector		Location Of Water Supply			
Urban-Rural	Number Of Dwellings	In The House	Outside The House But Within The Building	Outside The Building But Closer Than 100 Meters	Without Running Water
Guatemala City					
Urban	118,300	48,220	28,960	26,660	14,460
Rural	26,260	1,180	60	5,500	19,520
	144,560	49,400	29,020	32,160	33,980
Republic					
Urban	277,760	82,940	44,960	66,760	83,100
Rural	527,180	8,020	2,660	32,300	484,200
	804,940	90,960	47,620	99,060	567,300

TABLE No. 5

STATUS OF SANITARY SERVICE CONNECTIONS

Sector		Number Of Sanitary Services						None existing Or None Reported
		Water Closet		Trapless W.C.		Seepage Pit		
Urban-Rural	Number Of Dwellings	Excl.	Joint	Excel.	Joint	Excel.	Joint	
Guatemala City								
Urban	118,300	38,840	14,760	7,720	13,600	17,660	16,080	9,640
Rural	26,260	900	--	360	--	6,080	560	18,360
	144,560	39,740	14,760	8,080	13,600	23,740	16,640	28,000
Republic								
Urban	277,760	53,600	17,880	20,160	20,760	58,760	25,020	81,580
Rural	527,180	4,560	1,200	6,260	1,200	33,680	3,120	477,160
	804,940	58,160	19,080	26,420	21,960	92,440	28,140	558,740

Population of the Municipality	577,120 inhabitants
Urban population	545,378 inhabitants
Urban area	87 square kilometers
No. of dwelling units with water supply	76,180
No. of inhabitants per dwelling	4.7
No. of inhabitants with water supply	358,000
Population with water supply	66 percent
No. of water connections in the city	45,557

Since 1964 there has been an increase in the number of connections and improvements made in the operation of the distribution system. However, the supply of water per capita has decreased due to population growth, and the fact that the quantity of water available, 110 MLD, has not been increased in the last three years. Population growth, urban development and the lack of increased supplies to the water system, have required strict rationing of water during the dry months. The available flow in the DAD system decreased from 95 MLD to 86.28 MLD during the 1966 dry months.

There are areas in the city where water is provided only for a few hours during the day. It is probable that the number of inhabitants presently without a water supply is much higher than the number reported in 1964.

According to information available to the Consultants, it is difficult to establish exactly which areas of the city are served by the El Mariscal System only, as its distribution system serves sectors which are served by the DAD system also. It could be said that both

systems are complementary to each other in that the supplies of some sectors of the city are served together.

The total water supply of 110 MLD is treated in plants of the DAD and El Mariscal Company in accordance with accepted practices. The quality of the product that is delivered for public consumption complies with the established requirements of local health authorities and the international recommendations for potable water. Although sanitary measures are taken to control possible contamination in the distribution system, the danger of contamination exists permanently due to the sudden fall of the pressure in the mains. Low pressures permit the entrance of contaminated water into the mains through effective joints and poses a constant threat to the health of the community. In view of the importance of leaks, from a health standpoint and the cost of lost water, a leakage survey should be carried out and corrective action taken.

Some of the water supplies of Guatemala City are transported to the treatment plants and to consumption centers, by gravity and others by pumping. The principal sources of the DAD and the El Mariscal system according to information provided by DAD is summarized in Table Nos. 6A, 6B and 6C.

In its Preinvestment Report of Xaya-Pixcaya National Aqueduct, the MDN proposes, in a second stage, to supply water to 17 towns or villages situated in the Antigua Valley. According to the census

TABLE No. 6A

WATER SUPPLY SYSTEMS OF GUATEMALA CITY

Source	Type	System	Mean Daily Pajas	Supply M.L.D.	Supply Total M.L.D.
Canalitos	Pumping	Santa Luisa	2,000	4	-
Teocinte - Acatan	Gravity	Santa Luisa	19,000	38	-
Cambray	Gravity	Cambray	4,500	9	-
Ojo de Agua	Pumping	Ojo de Agua	18,000	36	-
Molino	Pumping	Brigada	500	1	-
Brigada System	Pumping and Gravity	Brigada	3,500	7	-
	Total Municipal Supply		47,500	95	95
Mariscal	Pumping	Mariscal	7,500	15	-
	Total Mariscal Supply		7,500	15	15
	Total Supply		55,000	110	110

Supply Summary: Gravity 57 percent, Pumped 43 percent.

TABLE No. 68

L A B R I G A D A S Y S T E M

WATER SOURCE	TREATMENT PLANT	LOCATION OF WATER SOURCE	LOCATION OF TREATMENT PLANT
Rivers: San Miguel, El Milagro, Panchchá	La Brigada Treatment Plant	San Pedro Sacatepéquez.	KILOMETER 14 ALONG SAN JUAN HIGHWAY
4 underground water wells	La Brigada Treatment Plant		
River: Yumar	El Sifón Pumping Plant	Concepción Farm	
River: Naranjo	Colonia Bethania Pumping Plant	Colonia Bethania	Colonia Bethania
1 underground water well	El Molino Pumping Plant	Kilometer 15.5 old highway to Mixco.	Kilometer 15.5 old highway to Mixco.

C A M B R A Y S Y S T E M

El Cambray Dam Rivers: Pinula, Las Minas	El Cambray Treatment Plant	Sta. Catarina Pinula	Kilometer 8 along Sta. Catarina highway
River: Agua Bonita	Agua Bonita Treatment Plant	Concepción Las Lomas	Kilometer 11 along Interamerican highway

From: DAD data available to the Consultant

TABLE No. 68

LOCATION TER SOURCE	OF TREATMENT PLANT	WATER INTAKE STRUCTURES	MEAN ANNUAL DRAFT MLD	SIZE AND CA-CITY OF CON-DUIT.
n Pedro Sa-tepéquez.	KILOMETER 14 ALONG SAN JUAN HIGHWAY	Concrete gra-vity dam 47 meters long.	6.6 M.L.D.	One 12" dia-meter cast iron pipe 12.4 M.L.D.
		Deep wells, Electric power	2.4 M.L.D.	2.4 M.L.D.
ncepción rm		Concrete gra vity dam and suction tank Pumping sta-tion. Diesel power plant.	1.3 M.L.D.	One 20" and one 12" dia-meter concre te pipes. 1.3 M.L.D.
lonia Be-nia	Colonia Be-thania	Suction well, pumping sta-tion. Electric power.	0.4 M.L.D.	0.4 M.L.D.
lometer 15.5 highway to xco.	Kilometer 15.5 old highway to Mixco.	Deep well. E-lectric power	1.2 M.L.D.	1.2 M.L.D.
a. Catari-Pinula	Kilometer 8 along Sta. Catarina highway	Concrete gra-vity dam	9 M.L.D.	Two 14" dia-meter cast iron pipe 12.7 M.L.D.
ncepción Lomas	Kilometer 11 along Inter-american high way	Collection well	0.5 M.L.D.	One 4" dia-meter cast iron pipe 0.6 M.L.D.

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TABLE No.6C

SANTA LUISA SYSTEM

WATER SOURCE	TREATMENT PLANT	LOCATION OF WATER SOURCE	LOCATION OF TREATMENT PLANT	WATER STRUC
Rivers: Teocinte San Antonio La Manguita La Piedrona Pinula	SANTA LUISA TREATMENT PLANT	San José Pinula	SANTA LUISA TREATMENT PLANT. SAN MIGUEL ACATAN VILLAGE, IN JURISDICTION OF SANTA ROSITA. MUNICIPALITY OF GUATEMALA	Concre 25 met high b meters
Rivers: Acatán Monjitas		Puerta Parada Village in San José Pinula.		Concre 3.5 me by 10. long.
Canalitos Pumping Plant Canalitos River		Canalitos village in Guatemala City		Concre Diesel Plant
Santa Rosita Pumping Plant Santa Rosita River		Las Vacas village in Guatemala City		Suctio Diesel Plant

OJO DE AGUA SYSTEM

SPRING EL FRUTAL	Ojo de Agua Pumping Plant	San Miguel Petapa	Kilometer 17 along Petapa highway	Infilt Galler

From: DAD data available to the Consultant

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TABLE No.6C

LOCATION OF TER SOURCE	TREATMENT PLANT	WATER INTAKE STRUCTURES	MEAN ANNUAL DRAFT MLD	SIZE AND CAPACITY OF CONDUIT.
n José Pi la	SANTA LUISA TREATMENT PLANT. SAN MIGUEL ACATAN VILLAGE, IN JURISDICTION OF SANTA ROSITA. MUNICIPALITY OF GUATEMALA	Concrete Dam 25 meters high by 70 meters long.	29.5	One 18" and one 20" diameter Cast iron pipes
erta Para Village San José nula.		Concrete Dam 3.5 meters high by 10.5 meters long.	6.5	One 16" diameter asbestos cement pipe and one 24", one 14" and one 12" diameter cast iron pipes.
nalitos village in Guatemala City		Concrete Dam Diesel Power Plant	4.0	One 8" diameter cast iron pipe 4 MLD.
s Vacas village in Guatemala City		Suction well Diesel Power Plant	3.0	One 8" diameter cast iron pipe 3 MLD.
n Miguel tapa	Kilometer 17 along Petapa highway	Infiltration Gallery	39.6	Two 18" diameter cast iron pipes 40 MLD

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of 1964, the total population of these 17 communities was 38,621. Assuming an average annual rate of increase of 3.1 percent, the population for these communities in the year 1987 would be approximately 78,790. A supply of 200 liters per inhabitant per day will require a volume of approximately 16 MLD.

In Appendix "A" of this report, dealing with the hydrological aspects, it is shown how the mean flows of all the water sources considered in the projects prepared by the MDN and the DAD were estimated. Among these are the Itzapa, Parramos and Pasiguan Rivers, all located in the Pacific Ocean's watershed and contributing to the stream flow of Guacalate River. The flow of all of these rivers diverted at a proper elevation together with ground-water supplies in the area where these 17 populations are located can be utilized to improve or to be sources of public water supply for these 17 communities.

The following Table No. 7 summarizes the available information as to the status of water supply in the 17 communities located along the route of the MDN project. At present no treatment is given to the water provided to these communities.

b. Quality, Dependable Supply and Treatment Facilities

Table No. 8 gives information provided by the DAD regarding the physical, chemical and bacteriological quality of untreated water after treatment before it is delivered to the community for consumption. With the exception of groundwater sources, an analysis of these results indicates that the turbidity of the surface sources can reach a higher level than

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TABLA-TABLE Nº

ESTADO DEL ABASTECIMIENTO DE AGUA

PRESENT STATUS OF WATER SUPPLY

Nº	POBLACIONES TOWNS	NUMERO DE HABITANTES (1) NUMBER OF HABITANTS	TIPO DE ABASTECIMIENTO DE AGUA TYPE OF WATER SUPPLY			FUENTE WATER SOU	
			S.C.	S.P.	S.A.	NOMBRE NAME	CA DIV
1	ANTIGUA	13,576	X			LAS CAÑAS STA. ANA PAMPUTIC	
2	JOCOTENANGO	1,653	X			PAMPUTIC TAMAISCAL	
3	PASTORES	2,176	X			EL JUTE	
4	SAN LORENZO EL TEJAR	713					
5	SAN LUIS LAS CARRETAS	282					
6	CIUDAD VIEJA	5,721	X	X		ALMOLONGA	
7	SAN LORENZO EL CUBO	964			X		
8	SAN MIGUEL DUEÑAS	2,225	X			EL MANANTIAL	
9	ALOTENANGO	4,718	X			DE TOBAR	
10	SAN ANTONIO AGUAS CAL.	2,708	X			DAMA PASIVAN	
11	SAN ANDRES CEBALLOS	273		X			
12	SANTIAGO ZAMORA	267		X			
13	SANTA CATARINA BARAHONA	916	X			PACUA LOS PACATALES	
14	SAN JUAN GASCON	117					
15	SAN PEDRO LAS HUERTAS	929					
16	SAN JUAN DEL OBISPO	1,148					
17	SANTA CATARINA BOBADILLA	235					
	TOTAL	38,621					

(1)—TOMADO DEL CENSO DE 1964
AS PER 1964 CENSUS

-TABLE Nº 7

DE AGUA EN EL VALLE DE ANTIGUA

SUPPLY IN THE ANTIGUA VALLEY

FUENTES WATER SOURCES		ABASTECIMIENTO TYPE OF SUPPLY			DISTRIBUCION DISTRIBUTION SYSTEM	
OMBRE NAME	CAUDAL DERIVADO Lts./seg. DIVERTED FLOW Lts./sec.	GRAVEDAD GRAVITY	BOMBEO PUMPING	FECHA CONSTRUCCION DATE OF CONSTRUCTION	ESTADO ACTUAL PRESENT STATUS	UNCIONAMIENTO OPERATION
S CAÑAS TA. ANA MPUTIC		X			REGULAR	REGULAR
MPUTIC MAISCAL		X		1966	NUEVO	BUENO
JUTE		X		1956	REGULAR	REGULAR
MOLONGA			X	1964	NUEVO	BUENO
			X		REGULAR	REGULAR
ANANTIAL	5.42	X		1960	CONDUCCION NUEVA	BUENO
TOBAR	12.52	X		1952	REGULAR	REGULAR
DAMA SIVAN	4.73	X		1966	RED NUEVA	DEFICIENTE
	0.50	X		1965	NUEVO	BUENO
		X				BUENO
ACUA	2.66					
CATALES	2.08	X		1965-6	NUEVO	REGULAR

S.C.—CON SERVICIOS PRIVADOS Y PUBLICOS—PUBLIC AND PRIVATE WATER SERVICE

S.P.—CON SERVICIOS PUBLICOS—PUBLIC SERVICE ONLY

S.A.—SIN ABASTECIMIENTO—WITHOUT WATER SUPPLY SYSTEM

MISSING PAGE

NO. B-30

TABLA-TABLE N° 8

CALIDAD DE AGUA EN PLANTAS DE TRATAMIENTO

QUALITY OF WATER IN TREATMENT PLANTS

ITEM	FUENTE- SOURCE	SANTA LUISA		EL CAMBRAY		LA BRIGADA		OJO DE AGUA	
		AGUA CRUDA RAW WATER	AGUA TRATADA TREATED WATER	AGUA CRUDA RAW WATER	AGUA TRATADA TREATED WATER	AGUA CRUDA RAW WATER	AGUA TRATADA TREATED WATER	AGUA CRUDA RAW WATER	AGUA TRATADA TREATED WATER
N° MUESTRA	SAMPLE N°	A-262	A-263	A-258	A-259	A-256	A-257	A-260	A-261
TEMPERATURA °C	TEMPERATURE °C	18	17	18	18	19	19	20	19
TURBIDEZ	TURBIDITY	9.5	1.0	25.0	3.5	25.0	2.5	2.5	1.5
COLOR	COLOR	12.5	1.0	30.0	5.0	50.0	1.0	1.0	1.0
p h	ph	7.1	6.8	7.4	6.8	7.5	7.2	8.1	7.4
N (AMONIACO LIBRE	N (AMONIA)	0.007	0.006	0.01	0.008	0.004	0.004	0.008	0.012
N (AMONIACO ALBUMINOIDEO)	N (ALBUMINOID NITROGEN)	—	—	0.01	0.01	—	—	—	—
N (NITRATOS)	N (NITRATES)	0.06	0.10	0.20	0.14	0.20	0.20	0.20	0.20
N (NITRITOS)	N (NITRITES)	—	—	—	—	—	—	—	—
OXIGENO CONSUMIDO	OXYGEN DEMAND	1.9	0.9	3.1	2.4	2.7	1.4	1.0	0.6
CLORUROS (Na Cl)	SODIUM CHLORIDE	—	—	—	—	—	—	—	—
FLUOR	FLUORIDE	0.1	0.1	—	—	—	—	—	—
HIERRO TOTAL	IRON	0.5	0.1	0.6	0.3	0.7	0.1	—	—
DUREZA TOTAL	TOTAL HARDNESS	35.0	35.0	40.0	45.0	50.0	50.0	75.0	70.0
SOLIDOS TOTALES	TOTAL SOLIDS	178	174	176	74	226	186	224	214
CLORO RESIDUAL	RESIDUAL CHLORINE	—	0.2	—	0.3	—	0.3	—	—
COLIFORMES NMP/100ml	COLIFORM MPN/100ml	>2400	0	>2400	0	>2400	0	79	0
MUESTRA N°	SAMPLE N°		A-7428	A-7501	A-7502	A-7474	A-7475	A-7527	A-7528

RESULTADOS SE DAN EN MILIGRAMOS POR LITRO

RESULTS ARE IN MILIGRAMS PER LITER

FUENTE DE INFORMACION "D.A.D."

INFORMATION SOURCE FROM "D.A.D."

reported by the DAD. This can occur especially during the rainy seasons and requires a greater quantity of chemicals for adequate conditioning.

The water that comes from surface sources prior to treatment has the following general characteristics: total solids reach a level of 230 p.p.m. The presence of iron in these waters varies in quantities from 0.5 to 0.7 p.p.m., but with treatment this is reduced to an acceptable level. The quality of the water is such that treatment of the water for public consumption, in accordance with standard practice, can be done at an economically acceptable cost.

In the Preinvestment Report for the National Aqueduct Xaya-Pixcaya, prepared by the MDN, results were reported of the investigation carried out to ascertain the amount of extra water supplies existing in Guatemala City. The MDN found that these sources reached 9.3 MLD, coming from 32 wells and 2 springs. Water from these sources are for the supply of businesses, industries and institutions. The type and amount of treatment, if any, or the specific uses of this water were not reported.

Information from the DAD indicates that once it has been realized that an adequate expansion of the municipal system of water supply is planned and expected, additional private water supply will not be developed. However, the DAD expects that a good part of these installations will continue in operation for a long period, as they have

required considerable investment on the part of the businesses, industries or institutions.

For public health and proper control and management of water resources, private water supply must be controlled and restricted. The best way to limit private water supply is for the minicipal water supply system to be in a position to satisfy the water demands in quantity, quality and price which also stimulates industrial development.

The water supplied by El Mariscal Company is principally from deep wells and by a big infiltration gallery at the Mariscal River. These sources are located in the south-western part of the city. It has not been possible to obtain adequate information concerning the quality of the non-treated and treated waters that this company provides. The water from the wells is chlorinated and that from the other sources is passed through sedimentation basins and filters and is chlorinated. The plant is apparently well operated, therefore, the water should be potable. The daily volume delivered for consumption is about 15 MLD.

The volume of the private water supplies (9.3 MLD) as estimated by MDN plus the volume provided by the systems operated by DAD (95 MLD) and by El Mariscal Company (15 MLD) total 119.3 MLD which is not sufficient to satisfy the actual water demand.

According to the Consultants' estimates, the actual water demand in Guatemala City is at present about 130 MLD, based on a daily average

consumption per capita of 204 liters. This estimated use is very low for a community with the characteristics of Guatemala City.

Accepting these estimated quantities, the actual deficit of water supply in Guatemala City is about 11 MLD, a situation that will grow worse unless long-term plans sufficiently ambitious are developed. Such plan should be constructed in stages in order to improve the present critical situation of water supply at the earliest possible date.

According to the information given by DAD, 57 percent of the total volume of water delivered for consumption in Guatemala City comes from sources located at elevations lower than the city. Hence, it is necessary to pump this water to the treatment plants or to distribution reservoirs before delivery for consumption. The remaining 43 percent of the supply is supplied by gravity.

Treatment Plants

Following is a brief description of the treatment plants operated by DAD.

Santa Luisa Plant

Actually there are two plants. The first inaugurated in 1936 with 18 MLD capacity is composed of a hydraulic mixing channel 70 feet long with an agitation period of 4 minutes, a sedimentation reservoir 39.50 meters long by 19 meters wide and 7 meters deep and a battery of 10 pressure filters.

Construction on the addition was started in 1954 and finished in 1957. It consists of the following installations: Entrance wells, measuring weirs, measuring equipment for chemicals, mixing channels, sedimentation tanks and filters.

The following mean flows pass through this plant annually from the sources indicated:

Teocinte	1936	12 MLD	6000 pajas
Teocinte	1952	15 MLD	7500 pajas
Acatan	1896	7 MLD	3500 pajas
Canalitos (pumping)	1959	4 MLD	2000 pajas
Sta. Rosita (pumping)	1966	3 MLD	1500 pajas

The mixing channel is 56 meters long by 14 meters wide, is the horizontal screen type with separation varying from 1.40 to 2.65 meters and a depth of 1.40 meters at the entrance and 2.2 meters at the exit.

The capacity of this channel is of 60 MLD. Actually, it is utilized for both stages of construction of the plant. The sedimentation is accomplished with three reservoirs in parallel 45 meters long by 15 meters wide and 7 meters deep. The water goes into these reservoirs by an admission channel, common to the older reservoir. The flow is regulated by gates which allows them to be cleaned separately.

These reservoirs are designed for a maximum flow of 45 MLD with a retention period of 6 1/2 hours. The water flow of the sedimentation reservoirs is checked by a double flow which discharges to a channel that leads to the outlet well, from which it is carried to the filters by cast iron piping.

Filteration is accomplished in two batteries of 10 pressure filters. One of the batteries has a filtering-bed of sand and the other a filtering-bed of anthracite. Gaseous chlorine is used from a special shed where the respective gauges are erected.

La Brigada Plant

This plant can treat a maximum flow of 14 MLD. Treatment consists of the following stages: coagulation, sedimentation, filtration and disinfection.

This plant consists of the following items: two entry wells of 1.40 x 1.50 x 3.90 meters each, mixing channel of horizontal screen type, like the ones of Santa Luisa and with 25 MLD capacity; two sedimentation reservoirs working parallel 11.00 meters wide by 40 meters long with 10 MLD capacity.

Rapid gravity filters consisting of two units with a filter of sand with its elevated concrete reservoir for washing. This filter is operated by hydropneumatic controls.

El Cambray Plant

With the exception of the filtration and the distribution reservoirs this plant has the same characteristics as the La Brigada Plant.

The filtration consists of three rapid pressure filters. In this plant the DAD proposes to treat the nine MLD of water from the Hincapie Project under construction.

El Mariscal System

This private company distributed 15 MLD of water for Guatemala City consumption. Water from the deep well is only chlorinated while the waters from Mariscal River are submitted to a complete treatment in a plant of conventional type provided with rapid pressure filters. All water so treated is pumped to the distribution reservoirs located in El Guarda. From this location the water is delivered to the consumer.

c. Distribution System

The latest DAD analysis of the distribution system were made on the basis that all of the population is supplied from its respective water supply sources, which together constitute the municipal system operated by the DAD. This analysis did not take into account the water supply provided by El Mariscal Company. It was calculated that the maximum available flow delivered to the consumer was the minimum flow registered in water supply sources during the early summer 1966 and was estimated at 86.28 MLD. Table No. 9 summarizes the figures utilized by DAD in this analysis.

The mean daily supply of 154 liters per capita estimated by DAD referred only to the actual population served. Including the 15 MLD that El Mariscal Company provides and deducting a prudential percentage for losses and other uses, the per capita consumption would be at a higher level. In the Consultant's opinion, this rate is too low for Guatemala

TABLE No. 9

Water Supply System	Population Served	Total Water Supply MLD	Daily Consumption Per Capita LPC Average
Brigada - Molino	65,675	9.73	148
Ojo de Agua - Tanque El Guarda	204,508	36.00	176
Santa Luisa - Acatan	256,652	33.94	132
Cambray	33,050	6.61	200
Total	559,885	86.28	154

City.

From the information provided by the DAD covering their analysis of the actual functioning of the distribution system, it is desirable to quote the following:

Brigada-Molino System

"The two existing systems separated from the rest of the city and supplied by the Brigada-Molino system are working well."

"Part of the system of 12 inch diameter is deficient in hours of maximum consumption, not because of lack of flow, but of carrying capacity."

"Based on direct experience, problem of the bad service in the 12 inch system could be partly rectified if its service area is decreased, thereby increasing the service area of the 8 inch system at the end of this system and over the zones Ciudad de Plata and Kaminal Juyu."

"It is necessary to install a higher pumping capacity in El Molino plant, in order to be able to have available in the net all the flow that El Molino's wells are able to produce."

"The pumping units of the system must develop full efficiency. If there is any failure in one of them it must be rectified immediately with a change of unit or, if necessary install a new one."

Ojo de Agua System

"The Ojo de Agua system source is able to supply its area, and its installations permit adjustment to the demand, but it is necessary to program the pumping of the plant over line II of Ojo de Agua."

The Cambray System

"Due to the lack of exact population data, it is impossible to produce exact results."

"In the Cambray system great differences of elevation exist in the system. This produces good service in low areas and deficient service in high areas."

"With completion of the Hincapie Project, the problem of the area including Cambray will be resolved."

"The system in zone 15 of the city was improved early in 1967 in order to provide a good service. Present deficiencies come only from the lack of available flow in The Cambray."

"Based on past experiences, it is considered perfectly possible to continue operating the zonification system as in previous years."

Santa Luisa - Acatan System

"In its analysis the DAD concludes that the available flow of 34.10 MLD is enough to supply the water demand in the sector of the city supplied by this system, without commentary concerning the service pressure or other functional aspect of this distribution net."

General Conclusions of DAD's Project About The Function Of The Actual Distribution System:

"Based on the preceeding project, DAD - Document No. 67/0834, September 1967, it is estimated that the available flows are sufficient to supply the existing population of the city. If bad service actually exists in several zones, it is due to the characteristics of the system which do not permit a logical distribution of available flows. That is why zonification of the system was thought to be desirable in such a way that each supply system serves an area with its share of the produced flow to the present population and through the network of the distribution system, and not to be inter-connected among the different obtained zones."

"Under this program were obtained several nets independent one from the other and from that system are the following:"

Brigada-Molino System

Net from Ø 12 inch
Net from Ø 8 inch
High circuit net

Ojo de Agua System - El Guarda Reservoir

By-pass net of Ojo de Agua
Ø 8 inch net from Ojo de Agua
Net from El Guarda high reservoir
El Guarda reservoir net

Santa Luisa System

Net from Acatan reservoir

Cambray System

Zone 15 net
Zones 10 and 14 nets

"The area of Guatemala City which covers each of the systems and each particular net is pointed out in the enclosed plan, "Zonification of the distribution network for summer 1967"."

"It should be pointed out that the proposed zonification is not definite as experience obtained in its operation will dictate necessary adjustments as the assumed population data and per capita consumption can actually be different from the assumptions."

"Every deficiency in each of the zones formed can be easily studied and solved as it would not be necessary to study all the nets of the city, but only the problem zone."

"More than the 50 percent of the available flows come from the pumping system, so depending on the efficiency of the pumping system, we say again that it is absolutely necessary that each of the system units operate efficiently, and in case of any failure in some of the pumping units it is necessary to correct it at once and the substitution of a whole unit may be necessary."

"It is foreseen that some zones in which the service will be deficient will exist because the lines installed are unable to carry the flows of maximum demand or that the available flow in the system would not be sufficient."

To be able to make immediate improvements in the functioning of its distribution network, the DAD of the Municipality in Document No. 67/0834 of September 5, 1967 defined the function of its distribution network. The areas and zones of the city where poor service of water supply we've identified and the measures considered necessary to remedy the situations proposed.

Table No. 10 reports the age, quantity and type of piping of the principal distribution systems of DAD installed in the period 1930 - 1967.

Table No. 11 sums up the available information relating to the distribution network and storage tanks of the Municipal System operated by DAD.

TABLE No. 10

Date Of Installation	Diameters And Pipe Length							
	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.	20 in.	24 in.
1930 - 1939	18,655(1)		2,200(1)	5,500(1)				11,700(1)
1940 - 1949			6,000(1)					
1950 - 1959	23,050(1)		6,400(1)	3,300(1)	4,750(1)	10,000(1)		
1960 - 1967		1,150(3)	4,250(1)	1,400(1)		1,200(1)	80(1)	
			2,900(3)	1,000(2)		10,000(2)		
Total	52,505	1,150	21,750	11,200	4,750	21,200	80	11,700

(1) Cast Iron
(2) Ductile Iron
(3) Asbestos

TABLE No. 11

DISTRIBUTION TANKS

Name	Storage Capacity Cubic Meters	Elevation Meters Above Sea Level	Location
Acatan (old)	13,140	1,547.92	East
Acatan (old)	30,940	1,546.89	East
El Guarda No. 1	4,212	1,537.20	South
El Guarda No. 2	8,647	1,537.20	South
Elevated Tank	730	1,558.65	
La Brigada (new)	9,150	1,600.99	West
La Brigada (old)	959	1,589.09	West
El Cambray (old)	2,920	1,590.14	East
El Cambray (new)	2,880	1,602.33	East
Total Volume	73,578		

Recently, the French Company S.E.U.R.E.C.A., 91 Avenue Kleber, Paris, prepared for DAD a project for the expansion and improvement of the distribution system of the city. It is understood that the Municipality has approved this project and the necessary steps are being taken to build the first phase of that project with the Municipality's own financial resources. Following this, the second phase of this project will be carried on with part of the financial resources that are to be used in the execution of the Xaya-Pixcaya Project.

d. Adequacy Of Service

e. Demand For Improved Service

The above two subjects are covered under Sections B.3 a. and b., C.1 c, d and e.

B.3 POSITION OF PROJECT IN OVERALL PROGRAM

a. Effects of Inadequacy

An open water faucet with no water flowing from it is a sure test of an inadequate water supply. This happens in many households of Guatemala City daily. To say the least, such an experience is frustrating. But worse, it poses serious problems to the health of the city's residents, for lack of pressure in the water mains is an almost certain way for the water supply to become contaminated.

Such contamination can result by seepage or flow of impure water adjacent to the mains through existing leaks, at pipe joints, or elsewhere, into an empty or low pressure water system. Too frequently this impure inflow may be sewage from nearby septic tanks or cesspools. Medical history contains many cases of epidemics resulting, particularly in cities, from contamination caused by such circumstances as mentioned above. No city's health is safe as long as the possibility of contamination of its water supply system exists.

Even though an industry may not require a large quantity of water, its operations may require a positive supply of water at all times. Lack of a supply when required may cause spoilage of an expensive batch of materials essential for the production process. While this problem may be overcome by provision of water storage on the premises, this solution may be costly or inadequate.

The existence of this problem may well deter an investor from proceeding with a given industrial development in the community. A safe and reliable water supply is an essential element to any industry.

b. National or Regional Development Program

An effective solution to this water shortage problem is so urgently required that the Guatemala City Government has been and is taking steps to secure additional supplies of water and to expand and improve the city's water supply system.

Progress is being made toward the completion within the next twelve months of projects which will bring additional water from different sources. But these will increase the present supply by only 21 MLD (10,500 pajas). Without allowance for leakage, et cetera, this amount when added to present supplies will provide only 205 liters per capita per day to a population of approximately 660,000 people. Early in 1957, the city's engineers began studies looking toward long-range water supply planning. The possibility of bringing 161 MLD of additional water from the upper reaches of the great Motagua River was investigated.

Although the cost of the proposal caused it to be shelved, continuing studies produced a Report on Proyecto Pixcaya prepared by the Municipality in 1961. This report with subsequent modifications and refinements is the basis for the Municipality's study and report which is part of the present evaluation.

Inasmuch as it necessarily will be several years before water from the Pixcaya Project will be available, the Municipality is continuing its effort to supplement the present insufficient supply from nearby sources, which by nature are limited in the amount of water that may be obtained.

From these sources it is hoped that the amounts shown on the following Table No. 12, will be delivered to the city by the dates shown:

TABLE No. 12

Project	Date Of Completion (Estimated)	Quantity M.L.D.
Hincapie	Jan. 1968	9.0
Aguacate (1st phase)	March 1968	6.4
Pozos Diamante	March 1968	3.0
Aguacate (2nd phase)	June 1968	2.6
Atlantico	Jan. 1969	20.0
Sur-Oriental (Future Possibility)	Jan. 1970	24.0
	Total	65.0

If all of the above are completed by the given dates and, more particularly, if these various small sources produce the amount estimated, a total supply of 175 MLD will be delivered to the various treatment plants. This quantity would meet the minimum demand until January 1971. The Municipality plans to deliver the first increment of 13 MLD from the Pixcaya Project by that date, increased six months later by 24 MLD. The additional supply of 64 MLD should be delivered by January 1972, according to the plans of the Municipality.

The plan developed by the MDN likewise proposes to bring water to the capital city from the Xaya and Pixcaya Rivers. Its plan proposes a southern route to the city from the same starting points. It would have the ability of serving 17 towns and villages that lie reasonably close to the suggested route when additional water supply is required.

The MDN report outlines its proposal in detail, both as to physical plan of development and financial planning. It was completed and submitted on December 31, 1966. The project as outlined in that report is the other part of the present evaluation. The fact that the national funds were authorized for the Corps of Engineers of the Army to make the study and report on a project to bring an adequate supply of water to the Nation's capital emphasizes the high priority of this project.

B.4 ANTICIPATED BENEFITS

a. Increased Revenues

Guatemala City is one of a number of cities in the world that sell as a title of property the right to purchase a fixed volume of water. A description of this negotiable piece of property called "Paja de Agua" follows:

DESCRIPTION OF "PAJA DE AGUA"

"In Guatemala it is used by law the name "Paja de Agua" to designate a title of property that is obtainable as a right to consume a fixed volume of water. A "Paja" authorizes the use of a maximum of 60,000 liters monthly, that is an average of 2,000 liters per day, within the purchase price (which officially is Q.350.00 cash per paja of the Municipality of Guatemala City). Any extra consumption over 60,000 liters monthly, is charged as an excess of this volume, at a nominal price per cubic meter. In addition, a fixed rate named "canon", which is Q. 1.50 monthly per "paja" of the Municipality of Guatemala, is charged for the maintenance of the water system. The consumer has to buy the water meter and pay, for only once, a right of connection to the system."

"There are also titles of "medias pajas" "half a paja" (30,000 liters monthly) and of "tercios de paja" "one-third of a paja" (20,000 liters monthly), their purchase price and canon varying approximately in proportion to the use amount; but the price of the excess of water per cubic meter is always the same, no matter whether the consumer owns a paja or a fraction of it."

"The owner of a titla "paja", "media paja", or "tercio de paja" is practically a stockholder in the water system, whose only benefit is the right to use it. He can at any moment, sell or negotiate the title, which is the reason why the market prices vary considerably from the nominal price, according to the law of offer and demand."

"Usually, when a new introduction of water of considerable volume is planned, the Municipality applied for a loan at a Bank in order to finance the construction job. When the negotiation is approved, the Municipality gets the funds and the Bank permits titles of "pajas" to put on sale in order to recover the investment in a convenient period of time for its interests. Under this system, it is possible to count on, from the beginning, the capital to carry on the construction job and the Bank guarantees its investment with the sale of titles."

"Note: To convert liters per second to pajas, multiply liters per second by the factor 43.2".

At present, a connection to the municipal water system cannot be obtained unless the ownership of a paja is evidenced. A person may own more than one paja. Industrial firms will generally desire the ownership of several pajas. Under existing conditions, then, it is apparent that water revenues will increase considerably when an increased supply is available.

To cover this important subject adequately, it seems desirable to include some of the detailed studies made by the MDN and included in their report. Studies by the Municipality on the subject of revenues and water rates will be found in Section D. 3a. It is recognized that the figures developed are somewhat different in the two studies but the trends and basic elements are the same.

Table No. 88 from Section 13.2 2 of the MDN Report shows the estimated number of titles that should be in public ownership during each year for the duration of the project, and the annual increase in the percentage of connections owning one title. This percentage is expected to increase from the present 57 percent to 75 percent for the alternate "A" and 70 percent for alternate "B".

The following pertinent information is quoted from the MDN report:

"13.2 FORECAST OF REVENUES

13.2.1 Revenue Due to Water Titles Sales"

"According to the demand for water titles as estimated in Table 23, the forecast of annual sales necessary to satisfy this demand gave the figures shown on Table 88. The demand for titles maintain an increasing percentage of titles per dwelling, or in an unfavorable situation, this relation will not diminish."

"It was not considered necessary to repeat the analysis of the water titles sales tendency since it was carefully explained previously in this same study. It is hoped that by having a more adequate and extense distribution net and by simplifying the administrative steps in water titles sales, actual demand may very easily surpass all predictions."

"The titles sales have been planned to keep their present price and the same length of time for installment sales, as in the present municipal system, with the same interest charge. The prices considered are:"

	Cash	3 Years Term
1 paja	Q.350.00	Q.455.00
1/2 paja	Q.190.00	Q.247.00
1/3 paja	Q.130.00	Q.169.00

"This means that 10 percent per year is added to the cash price during the time of payment. It is considered convenient to put on the market 1/3 of a paja to make the water service available to people of small economic resources."

"Even though the unit price per paja on the first stage is more than Q.350.00 estimated in accordance with the investment's budget, it was considered wise not to increase the price of the titles as long as sufficient funds were obtained to pay for the loans. The revenue forecasted for the sales of water titles was estimated based on the average cost of the same, and in accordance with the issue calculated in Volume I for A and B alternatives. This gave an average cost of Q.202.40 per title for "A" alternative and of Q.219.34 for "B" alternative. In both cases it was taken into consideration that 40 percent of these titles would be sold cash and 60 percent on a three-year term."

"The amount of water titles to be sold every year was estimated according to the demand calculated on Table 23, and the estimates are shown on Table 87 only for "A" alternative."

"Even though the same calculations were made for "B" alternative, it was noted that it would be necessary to sell the water titles before the project was finished, in order to obtain enough funds with which to meet the construction costs financed with Bonds, as there was not a grace period for this alternative. The practice of selling the water titles before the project is functioning is a common practice and the Municipality has done this in its most recent offering. The forecast was done in a conservative way, smaller than the amount obtained in other Municipal evaluations, estimating the sales as follows: 10 percent of the total in 1959, 10 percent in 1970, 10 percent in 1971, 30 percent in 1972 and 40 percent in 1973. The estimated revenues from the sale of water titles are shown on Table 88."

TABLE 87

ALTERNATIVE "A" - DEMAND OF TITLES

Year	Demand of Titles	Additions	Title Sales per Year	MPLS Titles Demand	Pixcayá Titles Demand	Pixcayá II
1964	61,541	61,541	-	-	-	-
1965	64,500	-	2,959	2,959	-	-
1966	67,800	-	3,300	3,300	-	-
1967	72,400	5,800	4,600	4,600	-	-
1968	77,300	-	4,900	4,900	-	-
1969	82,600	35,559	5,300	5,300	-	-
1970	88,100	-	5,500	5,500	-	-
1971	94,000	-	5,900	5,900	-	-
1972	100,400	-	6,400	6,400	-	-
1973	107,100	35,800	6,700	2,500	4,200	-
1974	114,200	-	7,100	-	7,100	-
1975	121,700	-	7,500	-	7,500	-
1976	129,700	-	8,000	-	8,000	-
1977	138,200	86,600	8,500	-	8,500	-
1978	147,300	-	9,100	-	500	8,600
1979	157,000	-	9,700	-	-	9,700
1980	167,100	-	10,100	-	-	10,100
1981	178,000	-	10,900	-	-	10,900
1982	189,400	-	11,400	-	-	11,400
1983	201,600	-	12,200	-	-	12,200
1984	214,600	-	13,000	-	-	13,000
1985	225,300	-	10,700	-	-	10,700

Table 88

FORECAST OF REVENUE DUE TO TITLE SALES - ALTERNATIVE "A"

First Stage - Xayá-Pixcayá Project

Year	Demand for Titles	Revenue from Cash Sales	Revenue on Time-payments	Cumulative Revenue on Time-payments	Total Revenue from Sale of Titles in Each Year
1973	4,200	340,000	204,200	204,200	544,200
1974	7,100	574,800	345,200	549,400	1,124,200
1975	7,500	607,200	364,600	914,000	1,521,200
1976	8,000	647,700	389,000	1,098,800	1,746,500
1977	8,500	688,200	413,300	1,166,900	1,855,100
1978	500	40,500	24,300	826,600	867,100
1979	-	-	-	437,600	437,600
1980	-	-	-	24,300	24,300
		2,898,400		5,221,800	8,120,200

"13.2.2 REVENUE FROM SALE OF WATER RATES"

"Leaving aside the finance mechanics followed until now by Guatemala City for paying the investments on the new water introductions only through the sale of water titles, it has been considered that the First Stage of the Xaya-Pixcaya Project can be financed, besides the before mentioned revenue, by the revenue obtained from the sale of water. This has been done in order to keep the water title prices as they are without having to increase their cost."

"Even though several water-rate structures were studied, it was considered convenient to keep the same rates, as to increase their value would mean an increase in the cost of living. Therefore, the estimate of water-rates revenues were based on the present rates."

"The only change effected was to group the consumers according to the size of their connections, as proposed by the Municipality. The water rates for each diameter of connection are:"

Size of Meters in Inches	Basic Allowance Cubic Meters Per Month	Monthly Rates
1/2	20	0.50
5/8	30	0.75
3/4	60	1.50
1	120	3.00
1 1/2	300	7.50
2	720	18.00
3	1,350	33.75
4	2,700	67.50
6	5,100	127.50
8	6,000	150.00

"The estimate of revenue for these rates was done by distributing the total number of municipal services estimated for each year of the project, according to the percentage estimated by the Municipality for each meter size. The services expected each year by meter size are shown on Table 90. The calculations for the annual water rates revenue were done according to the number of services during each year and are shown on Table 92."

"13.2.3 REVENUE DUE TO EXTRA WATER SALES"

"The annual revenue due to the sale of water use beyond the minimum allowance assuming that of the annual production only 70 percent is used by the public, was estimated, and also assuming that of the 70 percent used, 20 percent will be counted for as excess flow. This volume was calculated at Q.0.15 per m^3 which is the present rate charged by the Municipality."

TABLA-TABLE Nº 90

NUMERO DE CONEXIONES FUTURAS-ALTERNATIVA "A"

NUMBER OF FUTURE WATER SERVICES-ALTERNATIVE "A"

AÑO	DIAMETRO- DIAMETER										NO. TOTAL DE CONEXIONES
YEAR	1/2	5/8	3/4	1	1 1/2	2	3	4	6	8	TOTAL NUMBER OF WATER SERVICES
1964	4,828	15,587	11,114	1,314	520	114	30	10	7	2	33,526
1965	5,122	16,533	11,797	1,394	551	121	32	11	7	[illegible]	35,570
1966	5,471	17,650	12,587	1,488	589	129	34	11	8	3	37,940
1967	5,928	19,142	13,648	1,614	638	140	37	12	8	3	41,170
1968	6,605	21,327	15,206	1,798	711	156	41	14	9	3	45,870
1969	7,253	23,418	16,698	1,975	781	171	45	15	10	4	50,370
1970	7,937	25,597	18,256	2,159	854	187	50	17	11	4	55,070
1971	8,658	27,911	19,913	2,355	931	204	54	18	12	4	60,070
1972	9,451	30,477	21,736	2,570	1,016	223	59	20	13	5	65,570
1973	10,277	33,173	23,669	2,798	1,106	243	64	21	14	5	71,370
1974	11,184	36,111	25,748	3,045	1,204	264	70	23	16	5	77,670
1975	12,135	39,180	27,935	3,303	1,306	287	76	25	17	6	84,270
1976	13,172	42,528	30,322	3,586	1,418	311	82	27	18	6	91,470
1977	14,252	46,007	32,815	3,880	1,534	336	89	30	20	7	98,970
1978	15,447	49,865	35,567	4,205	1,663	365	97	32	21	8	107,270
1979	16,719	53,955	38,482	4,550	1,799	395	104	35	23	8	116,070
1980	18,060	58,276	41,565	4,915	1,943	426	113	38	25	9	125,370
1981	19,530	63,020	44,945	5,315	2,101	461	122	41	27	9	135,570
1982	21,039	67,900	48,430	5,726	2,264	497	131	44	29	10	146,070
1983	22,700	73,245	52,238	6,177	2,442	536	142	47	32	11	157,570
1984	24,450	78,920	56,287	6,655	2,631	577	153	51	34	12	169,770
1985	25,980	83,845	59,800	7,071	2,796	613	162	54	36	13	108,370

TOMADO DE: INFORME DE PREINVERSION DEL M.D.N. 1966
FROM: PREINVESTMENT REPORT BY M.D.N. 1966

TABLA - TABLE Nº 92

INGRESOS POR TARIFA-ALTERNATIVA "A"

REVENUE- ALTERNATIVE "A"

TARIFA MENSUAL MONTHLY CHARGE	0.50	0.75	1.50	3.00	7.50	18.00	33.75	67.50	127.50	150.00	TOTAL MENSUAL TOTAL MONTHLY	TOTAL ANUAL TOTAL PER YEAR
TAMAÑO CONEXION DIAMETER OF CONECTION	1/2"	5/8"	3/4"	1"	1.5"	2"	3"	4"	6"	8"		
AÑO-YEAR											QUETZALES	
1964	2,414	11,690	16,671	3,942	3,900	2,052	1,013	675	893	300	43,550	522,600
1965	2,561	12,400	17,696	4,182	4,133	2,178	1,080	743	893	300	46,166	554,000
1966	2,736	13,238	18,881	4,464	4,418	2,322	1,148	743	1,020	450	49,420	593,000
1967	2,964	14,357	20,472	4,802	4,785	2,520	1,249	810	1,020	450	53,429	641,100
1968	3,303	15,995	22,809	5,394	5,333	2,808	1,384	945	1,148	450	59,569	714,800
1969	3,627	17,564	25,047	5,925	5,858	3,078	1,519	1,013	1,275	600	65,506	786,000
1970	3,969	19,198	27,384	6,477	6,405	3,366	1,688	1,148	1,403	600	71,638	859,700
1971	4,329	20,933	29,870	7,065	6,983	3,672	1,822	1,215	1,530	600	78,019	936,200
1972	4,726	22,858	32,603	7,710	7,620	4,014	1,991	1,350	1,658	750	85,280	1,023,400
1973	5,139	24,880	35,504	8,394	8,295	4,374	2,160	1,418	1,785	750	92,699	1,112,400
1974	5,592	27,083	38,622	9,135	9,030	4,752	2,363	1,553	2,040	750	100,920	1,211,000
1975	6,068	29,385	41,903	9,909	9,795	5,166	2,565	1,688	2,168	900	109,547	1,314,600
1976	6,586	31,896	45,485	10,758	10,635	5,598	2,768	1,823	2,295	900	118,742	1,424,900
1977	7,126	34,505	49,223	11,640	11,505	6,048	3,004	2,025	2,550	1,050	128,672	1,544,000
1978	7,724	37,399	53,351	12,615	12,473	6,570	3,274	2,160	2,678	1,200	139,454	1,673,400
1979	8,360	40,466	57,723	13,650	13,493	7,110	3,510	2,363	2,933	1,200	150,808	1,809,700
1980	9,030	43,707	62,348	14,745	14,573	7,668	3,814	2,565	3,188	1,350	162,988	1,955,900
1981	9,765	47,265	67,418	15,942	15,758	8,249	4,118	2,768	3,443	1,350	176,125	2,113,500
1982	10,520	50,925	72,645	17,178	16,980	8,946	4,421	2,970	3,698	1,500	189,783	2,227,400
1983	11,350	54,934	78,357	18,531	18,315	9,648	4,792	3,173	4,080	1,650	204,830	2,458,000

TOMADO DE: INFORME DE PREINVERSION M.D.N. 1966

FROM: PREINVESTMENT REPORT BY M.D.N 1966

"It must be noted that the percentages mentioned before correspond to the one used in other cities, and that they can be realistic figures as long as an adequate administrative system is followed. The Municipality of Guatemala has applied these factors to its project, even though at the present time their deficit is larger. It is known that they are taking the necessary steps to re-adjust this to the average values mentioned in this report."

"Table 94 shows the calculations made to estimate the revenue from sale of excess water use."

"13.2.4 OTHER REVENUE"

"The water supply system has a series of additional revenues for reconnection after the service has been cut off to debtors that don't pay their water service promptly, repairs to water meters, sale of water meters, sale of the right to connect, and many others."

"These revenues, even though smaller than the ones analyzed before, are very important. It should be enough to note that by estimating 22,000 new services for the first stage of the project, a considerable amount will be obtained from the sale of the right to connect to the system. In effect, the Municipality charges an additional sum for the right to connect to the Municipal System, which varies from Q.35.00 in the poorest areas of the city, to Q.100.00 in certain residential areas. Assuming an average value of Q.40.00 and income of Q.880,000 will be obtained. At the same time, if the practice of selling the meters with an overcharge of Q.7.00 over the cost price is continued, an additional Q.150,000 will be obtained."

"However, the figures given above have been left out from the revenue estimates, considering them as a security factor to cover any contingencies on the financial forecast."

"This is the reason why the revenue from the salvage value of the milling machines to be used on the major tunnels, that can be sold afterwards has not been considered, except as a safety factor."

For simplicity it is suggested that alternative "A" in the MDN report be used in estimating increased revenues. This is in line with present planning of the Municipality and tends to be on the conservative side. Additional comments, data and tables prepared by the MDN concerning revenues will be found in Section D.3.a of this report. Exact figures

TABLE 94

REVENUE FROM WATER EXCESS SALES - ALTERNATIVE "A"

Year	Total Production-MLD	% Excess	Excess MLD	Revenue per Year
1965	87.38	20	12.23	669,600
1966	87.38	20	12.23	669,600
1967	96.38	20	13.49	738,600
1968	96.38	20	13.49	738,600
1969	104.64	20	14.65	802,100
1970	113.34	20	15.87	868,900
1971	122.62	20	17.17	940,100
1972	132.50	20	18.55	1,015,600
1973	142.90	20	20.00	1,095,000
1974	154.03	20	21.57	1,181,000
1975	165.73	20	23.20	1,270,000
1976	178.26	10	12.48	683,300
1977	191.57	10	13.41	734,200
1978	205.56	10	14.39	787,900
1979	220.61	10	15.44	845,300
1980	236.42	10	16.55	906,100

can be noted in that reference which show approximately the following anticipated increase in revenues following completion of this project:

Revenue from sale of "pajas"		Q. 8,120,200
Annual Revenues from a regular monthly charge based on size of connection increasing in 1983 to Q. 2,458,000 from (in 1972)	Q. 1,023,400	Q. 1,434,600
Charges for 22,000 new services Connections expected in first phase of project (a profit is made on each)		Q. 880,000
Profit from sale of meters Profit of Q. 7.00 on each of 22,000 new services		Q. 154,000

Annual revenue from water sales above minimum monthly charge in 1972 - Q. 1,015,600 - no increase or decrease expected.

b. Economic Effect

An official responsible for municipal planning states that private enterprise recently has been studying the possibility of constructing a development of 10,000 homes, but that the project has been dropped temporarily. This water development project could well provide the incentive and opportunity for the contemplated home-building program to get under way.

Certainly many of the blocks that now impede industrial and commercial development will be removed as the supply of water available increases. In all likelihood, the economic climate of the entire central Guatemalan area should improve as result of the construction and subsequent operation of this project.

Improvement is expected as indicated in that portion of Report of the III Congreso Nacional De Ingenieria quoted in Section B.1.b above, which points out the deficiency of water supply for industrial development in the City of Guatemala.

Discussions with the Manager of the Guatemala Chamber of Commerce verified that a considerable demand for new housing exists and that the current shortage of water supply is impeding action to meet the housing demand. Many of the new industries are having to go to considerable expense to drill and install deep wells in order to be sure of a water supply. This action is undesirable from economic and health aspects.

This official commented further that the expenditures required for this project, including wages, would boost the local economy through the increased purchasing power that would be generated. It is estimated that more than sixty percent of the total cost will be spent in Guatemala.

During the past several years, it has been the practice to construct water storage facilities at each new home in the above average class and for apartment buildings. This has been done because frequently water is not available from the municipal system. For the same reasons, many industrial and some business establishments, both new and old have been forced to install adequate water storage facilities.

Cost estimates for complete installations including necessary pumps, controls, extra plumbing, et cetera, are as follows:

Industrial and commercial - average -	Q. 8,000
Dwelling or apartment house - average -	Q. 500

Replacement in 15 years - partial

Industrial and commercial - average -	Q. 3,500
Dwelling or apartment house - average -	300

Many industries, all new hotels and most new apartment houses are drilling deep wells and installing pumping equipment. Automatic controls are installed to be assured of an adequate water supply when required and of reasonably good quality. Costs of these installations will average about Q. 10,000 to Q. 12,000 and have a life of only about 10 to 15 years. The cost of the well is the major item and for varying reasons, its capacity drops rather rapidly after seven or eight years. On the basis of an original cost of Q. 11,000, 10 years life and eight percent interests, these annual costs are Q. 1,639. Allowances for maintenance, repairs and operation could increase the average annual cost to Q. 2,000.

Tangible benefits as a result of cost savings to the community when the subject project is completed are tabulated below:

ANNUAL BENEFITS

Storage Facilities

Industrial and commercial - new 30 per year at Q. 8,000	240,000
Industrial and commercial replacements - $\frac{120}{15}$ x 3,500	28,000
Dwellings and apartments - new 80 per year at Q. 500	40,000
Dwellings and apartments - replacements - $\frac{300}{15}$ x 300	6,000

Deep Wells and Pumping Facilities

Annual costs - 40 x Q. 2,000	80,000
Total Annual Benefits	Q.394,000

c. Increase in Tax Receipts

At present the increase in general tax receipts resulting from increased property values and economic activity of the community have not been estimated by officials of the Municipality. It is anticipated that the increases will be substantial. Provision of an adequate water supply in Guatemala City could materially assist in encouraging the construction of not less than 500 housing units per year costing an average of Q. 10,000. This additional value of Q. 5,000,000 created each year would increase the tax receipts considerably each year and the increases would be cumulative.

d. Direct Benefits

It is estimated that approximately half of the cost of the project will be in Guatemalan Quetzals. The nature of the construction work involved, especially for tunnel construction, will require many laborers. One-third or more of the work force employed may be unskilled laborers. The project will be constructed over a two and one-half to three-year period and will provide long-term employment. The project extends over 60 Kms., and will require construction camps. This arrangement will minimize the daily transportation requirements, another three-year construction period.

Following completion of the project the present maintenance and operating force of the Municipality of Guatemala Water Department will be increased. This department's increase can provide employment for outstanding employees observed during construction.

e. Health Improvements

Section B.1.c. listes 1,400 cases in which persons were hospitalized from water-borne diseases during the year 1965. Undoubtedly, there were as many persons or more who were ill from such diseases during this period that were not hospitalized but required some medical treatment.

A saving in the cost of hospital treatment to 1,400 persons averaging five days each may amount to Q. 35,000 per year. While this cannot be given as a positive estimate of savings in the cost of health services that may result from this project, it can be assumed to be a reasonable estimate. The savings in drugs and "home remedies" would be a substantial amount.

In addition, a saving of not less than half of this amount may result from wages presently lost annually by wage earners as a result of illnessses from water-borne diseases.

f. Effect on Existing Facilities

Guatemala's economy is oriented to agriculture and consideration must be given to the effect on present users of water taken from the same source. Fortunately, the intakes for the water required in this project are located at a reasonably high elevation. This permits the water supply to flow by gravity to Guatemala City. At frequent intervals downstream from the intakes on the Pixcaya and Xaya Rivers, numerous small streams flow into the rivers which provide an adequate supply for all of the agricultural needs in the areas downstream.

There are two major reasons why the diversion of the water required for this project will not be detrimental to the agricultural needs:

1. The land lying between the intakes and the areas of additional stream flow into the lower reaches of the rivers is extremely steep and not usable for agricultural purposes.

2. The programed withdrawal of water at the proposed sources is based on the minimum available supply during the year. On this basis, engineering studies presently on record show that the total percentage of withdrawal of the water supply proposed by the project is a very small percentage of the total flow of water in the rivers.

A problem does exist with relation to one facility utilizing water from these sources. This involves the Selle Hydro-Electric Plant located on the Pixcaya River downstream from the proposed point of intended diversion of water for this project. Gage readings on the river show that sufficient water flows into the Pixcaya River between the proposed point of withdrawal of water for this project and the intakes for the Selle Hydro-Electric Plant, so that even in times of minimum flow the flow at the Selle Plant is twice that recorded at the proposed intake for this project.

During most of the months of the year, the flow at the Selle Plant is considerably more than can be utilized by the Hydro-Electric Plant. Several plans are being studied to avoid serious interference with the production of electric power by the Selle Plant. Inasmuch as the plan agreed upon will apply equally to the two plans under study, no differential cost estimate of this item is included in this section.

C. ENGINEERING ASPECTS AND TECHNICAL SOUNDNESS

C.1 FACTORS AFFECTING WATER SUPPLY REQUIREMENTS

a. Size, Distribution and Economic Activities Of The Population

The population of the City of Guatemala according to the national census taken in 1964 was 577,120. In 1938, the population was only 77,400 and in 1950, 294,300, practically doubling in the past 14 years. To emphasize the importance of the capital city, it may be pointed out that the city contained 13.5 percent of the total population of the Republic. There were 777,400 inhabitants in the Department (State) of Guatemala.

Compared with all of the capital cities of the Americas in population, Guatemala City ranks just below Washington, D.C. (population of District of Columbia only). Guatemala City is the largest capital of the Central America countries, having more than double the population of Panama City, which ranks second in population among the capitals of Central America.

Fortunately, the city is not densely populated as it has an area of 180 square kilometers within the boundaries of the Municipality. The urban area comprises only 80 square kilometers, but this is adequate to limit overcrowding. Few apartment buildings exceed three stories however, several new buildings have been erected in the downtown area that range from six to fourteen stories.

The city is well laid out and has developed and grown in an orderly fashion. There is space for development of industry and for housing reasonably close to the downtown area which will not require long, expensive

extensions of the water system. The area is well served by bus transportation.

Division of the city into eighteen zones assists in the street naming and numbering system as well as simplifying the problem of locating a given address. These zones are referred to in the following material contained in the 1964 Census Report on the Ciudad de Guatemala issued in July, 1966, by the Department of Census y Encuestas, Ministerio de Economia.

"OCCUPATION OF THE ACTIVE POPULATION"

"Of 201,200 economically active people from seven years old and more that resided in the capital up to April, 1964, 30.3 percent consisted of artesans (mechanics), operators and other skilled laborers, and 22.4 percent were in the services and similar categories amongst whom are included public employees engaged in public services. Both groups, together, included a little over three-fourths of the working force of the city."

"ECONOMICALLY ACTIVE POPULATION, SEVEN YEARS AND OVER OF GUATEMALA CITY, ACCORDING TO THEIR OCCUPATION, 1964"
(Base: shows the five percent)

Occupation*	Number	Total Percentage
Total	201,200	100.0
Professionals, technicians and similar	17,480	8.7
Managers, administrators, directors	10,840	5.4
Office clerks and similar	18,220	9.1
Salesmen and similar	18,200	9.1
Farmers, fishermen, hunters and lumbermen	6,860	3.4
Mines and quarries workmen	100	0.0
Transport operations	10,540	5.2

* According to the occupations classification of the American Census 1960 program. (1960)

Occupation*	Number	Total's Percentage
Artisans, factory operators and similar	60,920	30.3
Manual and day laborers, n.e.o.c.	9,460	4.7
Public services employees and similar	45,060	22.4
Other workmen n.e.o.c. unknown occupations or not definite ones	3,500	1.7

"In eight of the city's 18 zones, the artisans, factory operators and similar were in the majority, the figures varying relatively from 45.3 percent on zone 12 to 31.9 percent on zone 8. Another group that also scored a high figure in these zones was the public service employees and similar, varying from 49.2 percent on zone 9 to 25.2 percent on zone 4. That the before mentioned occupations have a high participation is due not only to the fact that there is a substantial industrial activity in the city but also that the central authorities of the government are located here, concentrating, therefore all their offices and public agencies."

"There are a few cases that are worth mentioning, for not being under the same circumstances as the ones described before; for example, zones 16 and 17, the greater number of laborers were the farmers, fishermen, hunters, and lumbermen, because these zones are located on the peripheral areas of the city. Zones 9 and 10 are residential areas for people with higher income with managers, administrators and directors registering 10.9 percent and 12.2 percent respectively. The second place in zone 18 went to the farmers, fishermen, hunters and lumbermen with 24.8 percent."

"In zone 15, the second group was the professional, technical and similar workmen with 15.1 percent of the zone's total."

"ECONOMICALLY ACTIVE POPULATION, BY ECONOMIC SECTORS"

"According to the situation prevailing up to April 1964, the economically active population that lives in Guatemala City is engaged in "Services" 39.0 percent, "Manufacturing Industries" 26.0 percent and "Commerce" 16.0 percent, typical of the urban zones. All together, these three groups contained more than 4/5 of the total working force, that is 81.0 percent.

* According to the occupational classification of the American Census 1960 Program (1960).

"ECONOMICALLY ACTIVE POPULATION, SEVEN YEARS AND OVER IN GUATEMALA CITY, BY ECONOMIC SECTORS, 1964"
(Base: shows the five percent)

Economic Sector*	Number	Percentage
Total	201,200	100.00
Agriculture, forestry, hunting and fishing	7,060	3.5
Mining and quarries	120	0.0
Manufacturing industries	52,280	26.0
Construction	14,140	7.0
Electricity, water, sanitary services	580	0.3
Commerce	32,020	16.0
Transportation, storage, communications	11,140	5.5
Services	78,440	39.0
Non-specified activities	5,420	2.7

* According to the uniform international classification on all economical activity branches, United Nations.

"OCCUPATION OF THE ACTIVE POPULATION"

"Of Guatemala's active population, a 75.9 percent of the total was working up to April, 1964 as employees the 17.1 percent were working independently; 4.6 percent as employers, and 2.4 percent was formed by family workers, and others that were not remunerated."

"The "employee" group participation was bigger in the city than in the whole Republic, where the figure came to 46.0 percent. The independent workers had the major participation in the rest of the Republic, with a 30.1 percent, the same as the family workers and others not remunerated with the 19.6 percent. The group of employers had its greatest participation in Guatemala City, with the 4.3 percent."

b. Population Growth

The estimation of population growths is an inaccurate art. Estimations can miss the mark considerably when the data available are scarce or are not sufficiently reliable. In addition to these factors are added the possible variations that could occur in the population growth in an area

such as Guatemala City, facts such as the grade of economic development in different sectors of the country, better opportunity to obtain education, sanitary facilities in housing, employment, et cetera, the analysis problem becomes even more complicated.

Central Government programs directed toward economic development and the communities' social well-being will have considerable impact on the population growth in certain areas. As a result some sectors that in the past had a rate of growth less than the national average 3.1 percent may surpass this average in a short period of time.

As a consequence of political action on the contrary, various sectors, communities or cities that in the past have shown a certain tendency in their population growth rate, superior to the general nation average, as is the case of Guatemala City, 4.9 percent annual, can decrease or standardize their population growth to a level similar to that of the general population growth in the country.

The studies prepared by the MDN and DAD for expansion of the water supply system in Guatemala City, estimate that the city's population will grow according to the following rate:

Study	Considered Period	Growing Rate	Population
MDN (1)	1964-1990	5.00 percent	2,084,300
DAD (2)	1964-2000	3.50 percent	1,847,000

(1) MDN Preinvestment Report Metropolitan Guatemala
(2) DAD Distribution of Potable Water, SEURECA Project

The growth rate of 4.25 percent annually has been adopted as an intermediate value between the population growth rates adopted in the two projects under consideration. This rate is, in the consultant's judgement, more realistic when all factors are taken into consideration and compared with actual increases in similar areas.

Figure No. 8 shows the probable curves of population growth suggested in the projects prepared by MDN and DAD as well as the consultant's estimate. By the year 1987, the probable population has been estimated as follows:

MDN Project	Estimate	1,800,500
DAD Project	Estimate	1,180,000
Consultant's	Estimate	1,469,400

c. Contemplated Zoning Changes

d. Demand For Additional Home Building

e. Anticipated Industrial or Commercial Development

Evidently a considerable amount of planning has been done in anticipation of the continued growth of the Municipality. In conference with engineers and officers of the Unidad Sectorial de Planificacion, Ministry of Communications and Public Works, considerable information was obtained. These engineers have been engaged for several years in planning work for the Municipality.

Industrial development is planned for the area to the south of the central area specifically along the highway towards Petapa (east of the University) and along the highway toward Amatitlan. Home building in these areas

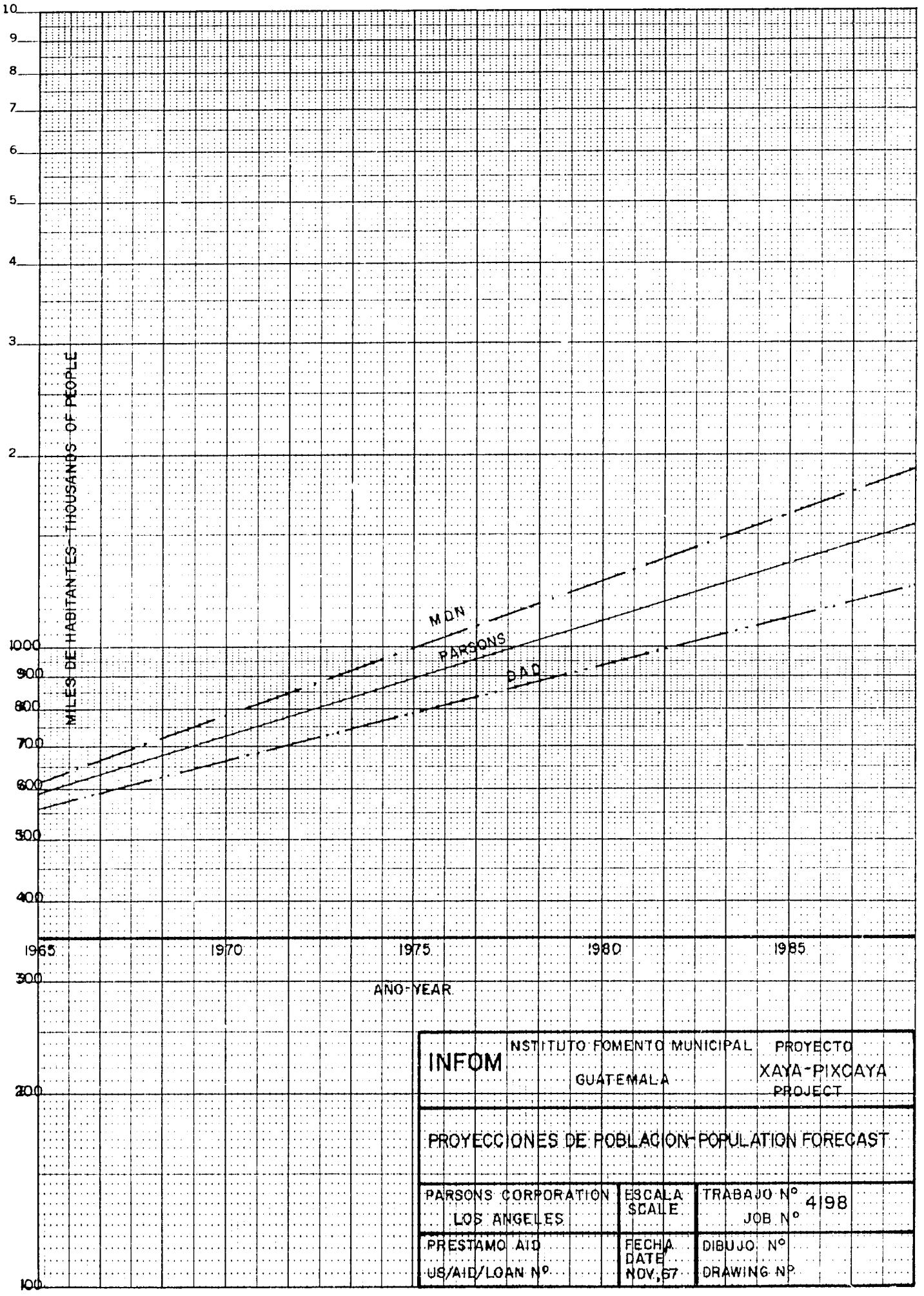
MILES DE HABITANTES THOUSANDS OF PEOPLE
10
9
8
7
6
5
4
3
2
1000
900
800
700
600
500
400
300
200
100
MDN
PARSONS
DAD
1965
1970
1975
1980
1985
AÑO-YEAR
INFOM
NSTITUTO FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
PROYECCIONES DE POBLACION-POPULATION FORECAST
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO Nº
JOB Nº
4198
PRESTAMO AID
US/AID/LOAN Nº
FECHA
DATE
NOV. 67
DIBUJO Nº
DRAWING Nº

FIGURA Nº 8

can be expected to house workers for these industries. Heavy industrial development is planned to be located in the area adjacent to the northeast part of the city. Industrial development, particularly by pharmaceutical firms has been taking place along the Pan American highway leading to the west. A number of new housing projects are under construction in that direction.

Considerable housing development has been planned for the area east of Colonia La Florida, filling in the open land toward the main city to the south. Additional home building is expected adjacent to La Florida on the northwest. A large area immediately to the west of Colonia La Florida and adjacent to the La Brigada water purification plan is zoned for industry. Similarly there are areas along the Pan American highway to the east zoned for industrial use.

General information on the zoning plan of the city of Guatemala, contained in an official document follows:

"The characteristics of the different districts in which Guatemala City is divided, in respect to land use and population density per hectare is the following:

Residential Zones R-1

Minimal size of the lots:	600 mts.^{2}
Population density (number of inhabitants):	between 50 and 150 average 80

Residential Zones R-2

Minimal size of the lots:	400 mts.^{2}
Population density (number of inhabitants):	between 100 and 200 average 150

Residential Zones R-3

Minimal size of the lots:	250 mts.^{2}
Population density (number of inhabitants):	between 200 and 300 average 250

Residential Zones R-4

Minimal size of the lots:	160 mts.^{2}
Population density (number of inhabitants):	between 300 and 400 average 350 "

"Commercial Zones C-1

Commercial zones in neighborhoods with dwellings and businesses on the ground floor situated near the residential zones R-1, with the same population density."

"Commercial Zones C-2

Commercial zones in neighborhoods with dwellings near the residential zone type R-2, with the same population density."

"Commercial Zones C-3

Commercial zones with 7-floor buildings, in which the average is 6 floors provide for commerce and offices and one floor for apartments, with a population density of 150 inhabitants."

"Commercial Zones C-4

Central zones of commerce, with buildings of 9 floors, in which 7 floors are occupied by commerce and offices and the remaining with apartments, with a population density of 300 inhabitants."

"Industrial Zones I

These zones are reserved for industries with only the necessary dwellings for vigilance, et cetera, permitted with a population density of 20 inhabitants."

"Administrative and Educational Zones

Where the administrative offices, schools and Universities are located; only the necessary dwellings for vigilance, et cetera, are permitted with a population density of five inhabitants."

"The Zoning Plan for the population of Guatemala City, according with the different districts contemplated in the using of lands plan, and according to average density is the following: "

"Types of Zones	Total Surface Hectare	Population Density Inhabitant/Hectare	Total Population No. Inhabitants
R-1	1190	80	95,200
R-2	698	150	104,700
R-3	1721	250	430,250
R-4	2934	350	1,026,900
C-1	49	80	3,920
C-2	140	150	21,000
C-3	106	150	15,900
C-4	159	300	47,700
I	951	20	19,020
A.V.	758	5	3,790
Total	8706		1,768,380 "

C.2. CAPACITY OF THE WATER SYSTEM

a. Present and Anticipated Water Consumption Per Capita

The water distributed to the community through the distribution system is designed to satisfy the needs in the domestic, commercial, industrial and public buildings and for fire protection.

The following tabulation presents, percentage-wise, the average consumption of water per capita in a community of the United States, similar in size to Guatemala City. Guatemala City has a different climatic condition and at present a different degree of industrial and commercial activity. It is probable that the domestic and commercial and industrial consumption in Guatemala is about 45 percent and 20 percent of the total water consumption per capita respectively, compared to 35 percent and 30 percent. These percentages are only assumed, as a detailed analysis of the uses of the water in the capital city is not available.

Consumption	Percentage
Domestic	35
Commercial and Industrial	30
Public	10
Other uses (Includes losses in the distribution system)	25

The amount of water supplied to a community, will vary over a wide range; depending on such factors as: weather, standard of living, extension of the sewerage system, type of commercial and industrial activities, water-rates, private supply water systems, proper quality of water for the

different uses, pressures on the distribution net, water meters, and the administrative efficiency of the local agency that operates the system.

When discussing the economic aspects and benefits it was mentioned that the water demand in Guatemala City has been restricted by the available amount of water. At least at the present time, and since 1950, it has been less than the amounts needed to provide the population with a reasonable supply per capita, compatible with its grade of urban, commercial and industrial development. This development is expected to increase at a faster rate in the near future, thus causing higher water demands. Guatemala has a position of major importance as a manufacturing center and consumer within the Central American Common Market. Maintaining this position is dependent on increased water supply.

From 1950, and until recently, the average per capita consumption of water varied between 170 and 200 liters daily. Compared with the per capita consumption in certain other cities of Latin America, as shown on Table No. 13, it will be noted that, even if the local conditions are different, the per capita consumption in Guatemala City is below the average consumption of those cities. Those cities also are in a process of development and have plans to improve the standard of living and to stimulate an increase of activities, such as construction of dwellings and establishment of new industries.

Figure No. 7 shows the trend toward an increasing consumption of water per capita, forecasted in the studies prepared by MDN and DAD for the expansion

TABLE No. 13

City	Daily Water Consumption Per Capita (Liters)	Information From
Bogota, Columbia	300	Proposed in 1961 for new system
Cali, Columbia	246	Miscellaneous 1951
Guayaquil, Ecuador	250	THE RALPH M. PARSONS CO. Guayaquil Sewerage Project, 1967
Lima, Peru	368	Greeley & Hansen Feasibility Study for Sewago Disposal, 1966
San Juan, Puerto Rico	290	Miscellaneous 1949
Santo Domingo, Dominican Republic	400	PARSONS CORPORATION Study on Ozama, Haina, Nigna, Nizao, Bani and Ocoa River Basins, 1967
A V E R A G E	309	

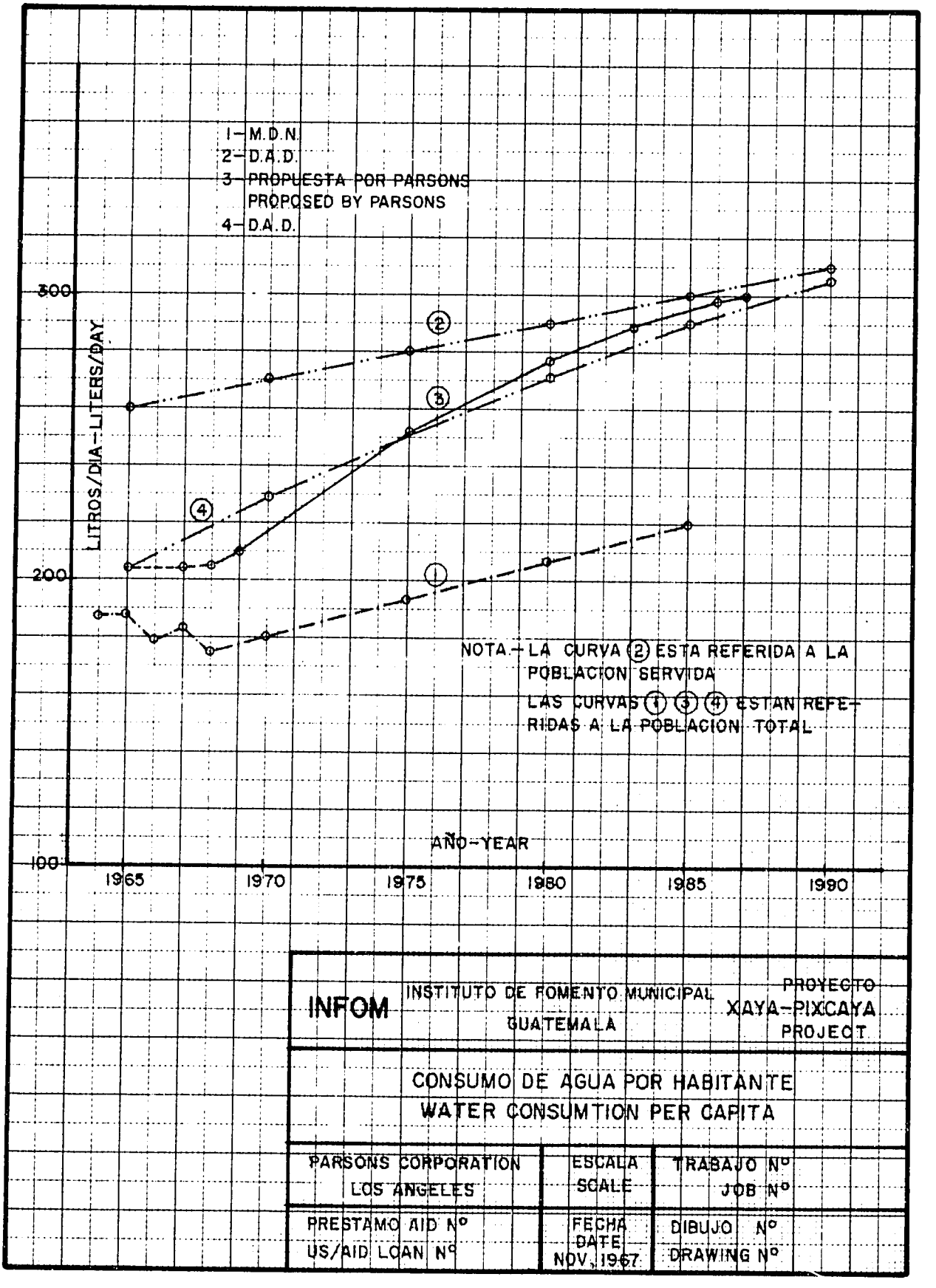
1-M.D.N.
2-D.A.D.
3-PROPUESTA POR PARSONS
PROPOSED BY PARSONS
4-D.A.D.
LITROS/DIA-LITERS/DAY
300
200
100
NOTA-LA CURVA (2) ESTA REFERIDA A LA POBLACION SERVIDA
LAS CURVAS (1) (3) (4) ESTAN REFERIDAS A LA POBLACION TOTAL
AÑO-YEAR
1965
1970
1975
1980
1985
1990
INFOM
INSTITUTO DE FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
CONSUMO DE AGUA POR HABITANTE
WATER CONSUMTION PER CAPITA
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO Nº
JOB Nº
PRESTAMO AID Nº
US/AID LOAN Nº
FECHA
DATE
NOV. 1967
DIBUJO Nº
DRAWING Nº

FIG. Nº 7

of the Water Supply System of the City of Guatemala, until 1987. Based on total population, it can be noted in this graph that the MDN foresees an annual increase of the per capita consumption smaller than the one forecast by the DAD, reaching 220 liters per capita per day for 1987. DAD forecasts an annual increase in the per capita comsumption reaching a figure of 296 liters per capita per day in 1987. The Consultant estimates that the per capita consumption in Guatemala will increase at an annual rate higher than either one suggested and will, reach an average of 300 liters/per day per inhabitant in 1987.

The consultant concludes that estimates on the future water demand of the city for 1987 cannot be based on an average consumption per capita less than 300 liters. As shown on Figure 7, the consultant believes that the annual increase of per capita consumption will tend to be greater in the first few years after an adequate supply system is available, through the expansion of the actual system.

It has been mentioned in this report that Guatemala City has two main systems of water supply, the Municipal, operated by DAD, and a private one operated by Compania El Mariscal. These two systems at present distribute approximately 86 percent and 14 percent respectively, of the total supply.

It appears that the water supply sources for Mariscal are highly utilized at the present time, and that any future plans to expand its service must be from other sources. According to DAD representatives, this would be very difficult to achieve. As a result this gives DAD the sole responsibility for the planning, development, construction and operation of all

future water supply programs necessary to carry on and satisfy the increasing demand for water.

b. Total Water Supply and Number of Services

Based on their respective projections of population growth and increase of per capita consumption as presented in studies by DAD and MDN a comparison of estimates of the total volume of water that the city of Guatemala will demand in the future is shown on Table No. 14. The estimate of the total water demand as prepared by the Consultants, for the evaluation of the studies is shown on Table No. 15.

Figure 9 shows that the curves of total water demand forecast by MDN and DAD differ relatively little until 1980 and only from the year 1985 on are considerable differences evidenced. This situation results because the MDN, for its estimates employed the 5 percent rate for population increase, while DAD utilized a rate of 3.5 percent. As a result, annual consumption per capita adopted by the MDN is smaller than the estimate adopted by DAD. The curve of future water demand adopted by the Consultant indicates a larger requirement than is estimated in the studies of the MDN and DAD for the period of 1967-1987

It was mentioned before in this report that the future benefits (see Item B.4. a) that will probably derive from the expansion of the water supply system of Guatemala will be a large increase in the number of connections to the system. The number of future connections estimated by the MDN are shown in Volume II of their Pre-investment Study of the Xaya-Pixcaya Project. Such a study foresees an increase of 138,600 new connections of water services for 1985, according to their alternative A.

TABLE No. 14

Year	Population x 10^3		Daily Consumption Per Capita (Liters)		Total Water Demand MLD	
	MDN	DAD	MDN	DAD	MDN	DAD
1965	615.5	560.0	187.6	204	115.45	114.40
1970	785.6	665.0	180.0	229	141.41	152.55
1975	1,002.6	797.0	193.3	251	193.80	200.76
1980	1,279.6	941.0	206.7	271	264.49	255.49
1985	1,633.1	1,102.0	220.0	290	359.28	318.60

TABLA-TABLE Nº 15

DEMANDA TOTAL DE AGUA

TOTAL DEMAND OF WATER

AÑO YEAR	POBLACION ESTIMADA (*) POPULATION ESTIMATED	CONSUMO Lts/Hab./Día CONSUMPTION L/C/D	DEMANDA TOTAL TOTAL DEMAND	
			M.L.D.	Lts./seg. Lts./sec.
1965	587,750	204	119.90	1,388
1966	612,700	204	125.00	1,447
1967	638,700	204	130.20	1,507
1968	665,800	205	136.50	1,580
1969	694,100	210	145.70	1,686
1970	724,000	217	157.10	1,818
1971	754,800	224	169.07	1,957
1972	786,900	231	181.77	2,104
1973	820,300	238	195.23	2,260
1974	855,200	245	209.52	2,425
1975	891,800	252	224.73	2,601
1976	929,700	257	238.93	2,765
1977	969,200	262	253.93	2,939
1978	1,010,400	267	269.77	3,122
1979	1,053,300	272	286.49	3,316
1980	1,098,500	277	304.28	3,522
1981	1,145,200	281	321.80	3,725
1982	1,193,900	285	340.26	3,938
1983	1,244,600	289	359.68	4,163
1984	1,297,500	292	378.87	4,385
1985	1,353,100	295	399.16	4,620
1986	1,410,600	298	420.35	4,865
1987	1,469,400	300	440.82	5,102
1988	1,532,900	302	462.93	5,358

(*)—ESTIMADA POR PARSONS, CON UNA TASA DE CRECIMIENTO DEL 4.25%
AS ESTIMATED BY PARSONS, 4.25% RATE OF GROWTH

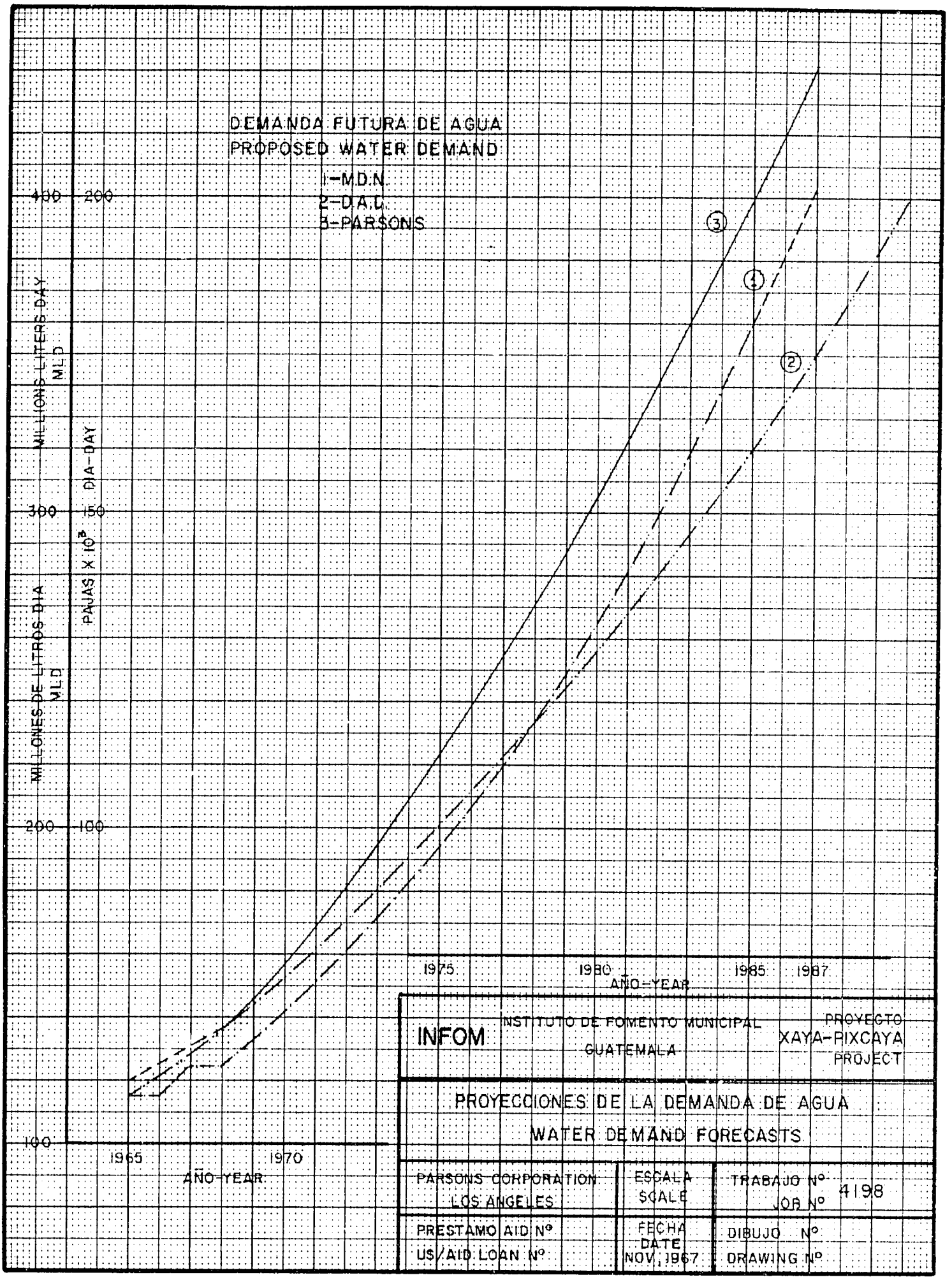
DEMANDA FUTURA DE AGUA
PROPOSED WATER DEMAND
1-M.D.N.
2-D.A.C.
3-PARSONS
MILLONES LITROS DIA
MLD
PAUAS X 10³ DIA-DAY
400 200
300 150
200 100
100
1965
1970
AÑO-YEAR
1975
1980
1985
1987
AÑO-YEAR
INFOM
INSTITUTO DE FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
PROYECCIONES DE LA DEMANDA DE AGUA
WATER DEMAND FORECASTS
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO Nº
JOB Nº
4198
PRESTAMO AID Nº
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FIGURA Nº 9

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C.3. JUSTIFICATION OF THE PROJECT

a. Desirability of Construction By Stages

b. Areas Served By Initial Stage

c. Theoretical and Ultimate Capacities

d. Project In Relation To Development

The studies prepared by both the MDN and the DAD proposing the expansion of the water supply system to the City of Guatemala, analyze the actual situation caused by the lack of water. Both studies recognize and emphasize the seriousness of the situation. In these studies it is shown that it is not only necessary to introduce the additional supplies of water in order to satisfy the present and future demands of the community, but they also point out that it is essential to proceed in the development of the Project by stages.

Both studies take into consideration the use of the hydrological resources in the basins of the Xaya and Pixcaya Rivers, as well as from other minor rivers, as sources of supply for the expansion of the water supply system of Guatemala City.

There is no doubt that construction by stages to increasing the water supply system of any community, is a proper step, not only from the engineering point of view, but also because it decreases the amount of interest paid for construction costs in advance of actual need.

Additionally, construction by stages of the proposed structures will permit the utilization of labor forces over a longer period of time. This will permit a more regular curve of employment without creating a heavy demand for laborers at any one time. Increasing the period of construction also spreads the personal income over a longer period, instead of concentrating it in a one or two year period.

The execution by stages of the project will permit observation of the technical engineering aspects, so that when future stages are being designed, advantage can be taken of any need to adjust to special situations, such as increase or decrease of estimated demand, availability of new construction techniques, new materials and other factors.

The MDN study as well as the DAD, agree that the total amount of water to be diverted from the proposed sources for the first stage, will be designated for the exclusive supply of the city, where it is needed more urgently than in any other section in the project area. Not only is this additional volume necessary to satisfy the present demand, but also to provide for the future needs created by dwelling-construction plans and industry development, that now are delayed due to the lack of an adequate supply of good quality water.

Figure 9 shows the curves of the forecast of water demand in the city, prepared by the MDN, by DAD and by the Consultant.

On Figures Nos. 10, 11 and 12, the capacity of the stages and the volume of total water demand foreseen for the next 20 years are shown. Section C. 11 (Long Range Planning For Future Water Supplies), report comments on various aspects related to the future planning for increasing further the supply of water for the community.

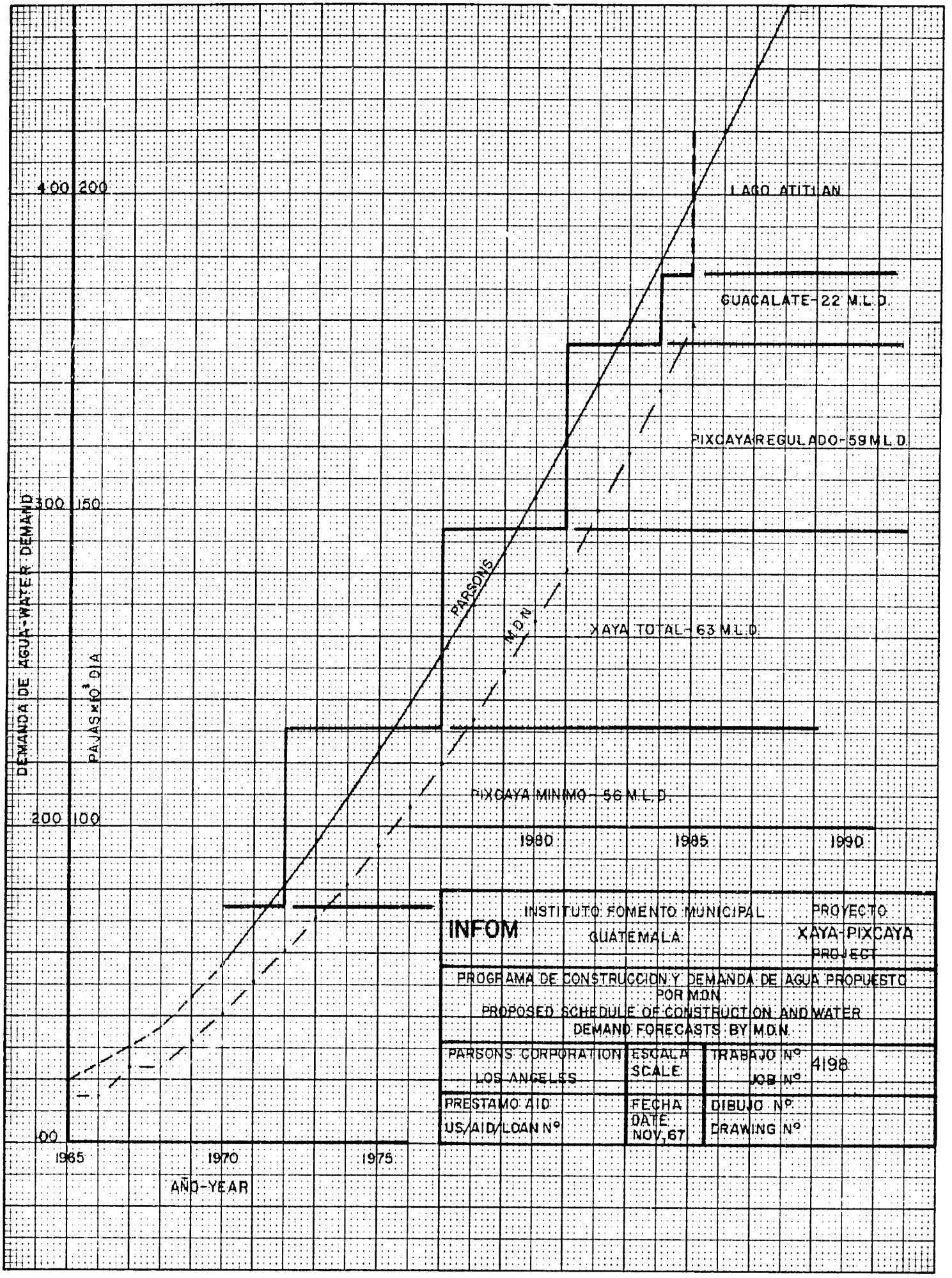
LAGO ATITLAN
GUACALATE-22 M.L.D.
PIXCAYA REGULADO-59 M.L.D.
XAYA TOTAL-63 M.L.D.
PIXCAYA MINIMO-56 M.L.D.
PARSONS
M.D.N.
DEMANDA DE AGUA-WATER DEMAND
PAJAS×10³ DIA
400 200
300 150
200 100
100
1965
1970
1975
1980
1985
1990
AÑO-YEAR
INFOM
INSTITUTO FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
PROGRAMA DE CONSTRUCCION Y DEMANDA DE AGUA PROPUESTO POR M.D.N.
PROPOSED SCHEDULE OF CONSTRUCTION AND WATER DEMAND FORECASTS BY M.D.N.
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO Nº
JOB Nº
4198
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FIGURA Nº 10

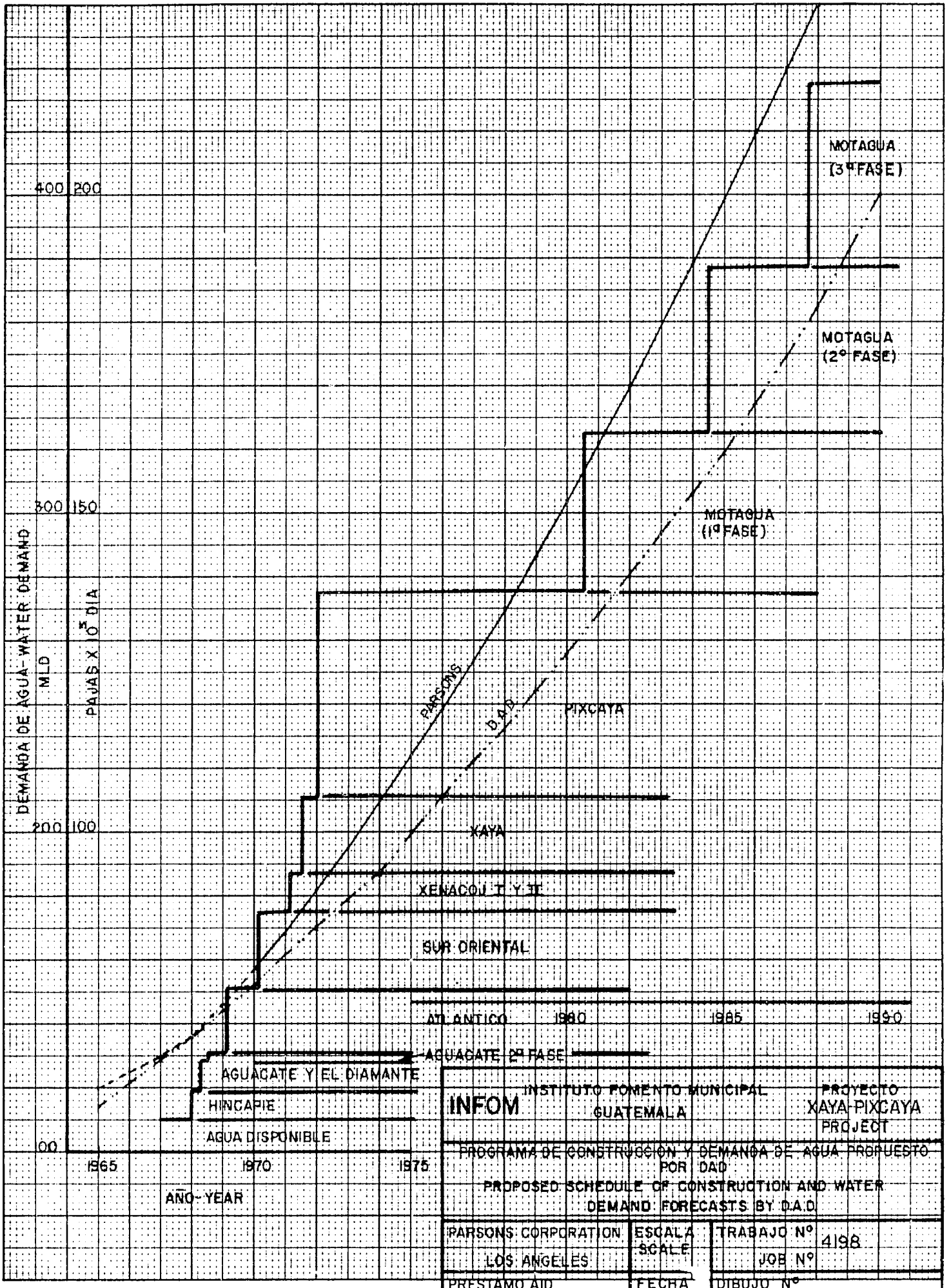
DEMANDA DE AGUA-WATER DEMAND
MLD
PAJAS X 10³ DIA
400 200
300 150
200 100
00
1965
1970
1975
1980
1985
1990
AÑO-YEAR
MOTAGUA (3ª FASE)
MOTAGUA (2° FASE)
MOTAGUA (1ª FASE)
PARSONS
D.A.D.
PIXCAYA
XAYA
XENACOJ I Y II
SUR ORIENTAL
ATLANTICO
AGUACATE 2ª FASE
AGUACATE Y EL DIAMANTE
HINCAPIE
AGUA DISPONIBLE
INFOM
INSTITUTO FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
PROGRAMA DE CONSTRUCCION Y DEMANDA DE AGUA PROPUESTO POR DAD
PROPOSED SCHEDULE OF CONSTRUCTION AND WATER DEMAND FORECASTS BY D.A.D.
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO Nº
JOB Nº
4198
PRESTAMO AID
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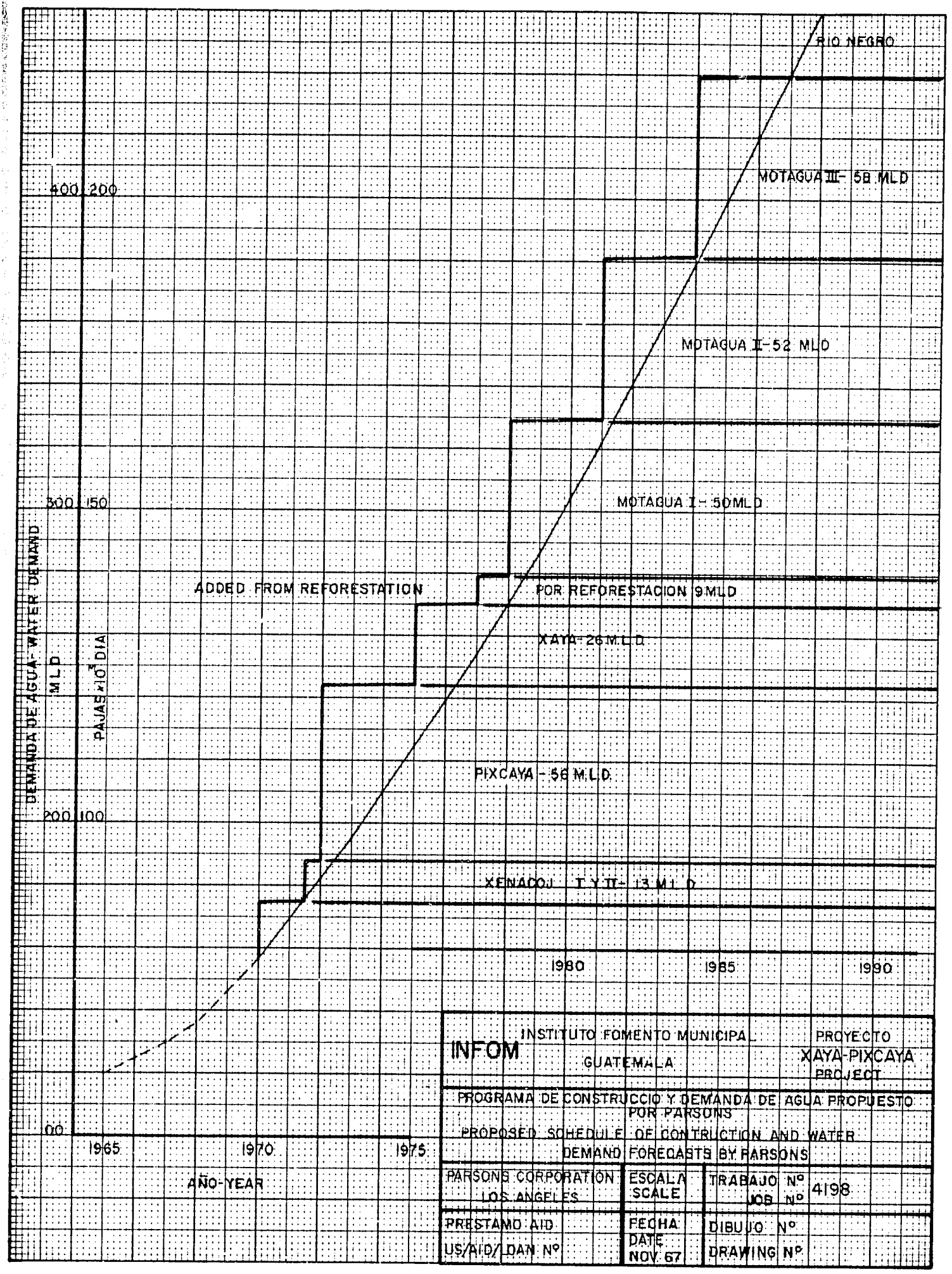
FIGURA Nº II


RIO NEGRO
MOTAGUA III- 58 MLD
MOTAGUA II-52 MLD
MOTAGUA I- 50MLD
ADDED FROM REFORESTATION
POR REFORESTACION 9MLD
XAYA-26 M.L.D.
PIXCAYA - 56 M.L.D.
XENACOJ I Y II- 13 M.L.D.
DEMANDA DE AGUA-WATER DEMAND
MLD
PAJAS x 10³ DIA
400 200
300 150
200 100
00
1965
1970
1975
1980
1985
1990
AÑO-YEAR
INFOM
INSTITUTO FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
PROGRAMA DE CONSTRUCCIO Y DEMANDA DE AGUA PROPUESTO POR PARSONS
PROPOSED SCHEDULE OF CONTRUCTION AND WATER DEMAND FORECASTS BY PARSONS
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO Nº
JOB Nº
4198
PRESTAMO AID
US/AID/LOAN Nº
FECHA
DATE
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DIBUJO Nº
DRAWING Nº

FIGURA Nº 12

C.4. CRITERION OF DESIGN

a. Reliability Of Water Supply

b. Initial Capacity Relation To Future Requirements

c. Maximum and Minimum Pressures

d. Degree Of Water Purification

In Appendix "A" of this report is discussed and analyzed all of the hydrological information available to the consultants in order to assess the reliability of the Xaya, Pixcaya and Xenacoj Rivers. These rivers constitute the main sources to be used in the first phase of expanding the system of potable water supply for Guatemala City. Although these hydrological data do not cover as long a period of time as the Consultant would desire, the hydrologist added considerable information to this respect, by the use of proper techniques and additional information he secured. In this manner the mean flow data was expanded from three (3) to thirteen (13) years and the minimum flow data from seven (7) to fourteen (14) years for the principal sources of the project.

Even though the analysis of the hydrological data show that the water supply sources are marginal, there are reasons to believe that the minimum flows will improve in the future. Guatemalan authorities should take the necessary measures to assure the proper administration of the hydraulic resources of the basin of these rivers. In Section C.11 of this report, the long-term planning suggested by MDN and also by DAD, for the expansion of the water

supply in Guatemala City in future stages, the possibility is discussed of utilizing other water sources that may be available and conveying those supplies by means of the first stage aqueduct.

The immediate program for expansion of the water supply in Guatemala being carried forward by DAD will increase the total supply available to 175 MLD. That amount added to the 95 MLD estimated to be the combined minimum flow of the Pixcaya, Xaya and Xenacoj Rivers, that would be utilized in the first stage of the project will increase the amount of water available to 270 MLD, sufficient to satisfy the estimated water demand until 1978.

The studies prepared by the MDN and by the DAD propose the utilization of the water resources of the principal sources considered in their projects, which are shown on Table No. 16.

From the information given in Table No. 16, it can be concluded that the major difference in the estimates by the MDN and the DAD of the total water resources available, is in the volumes they propose to store in the reservoirs that would be constructed in future stages. The consultant considers that due to the present lack of basic information, it is premature to judge the possibility that these reservoirs should be constructed. However, for the comparative analysis of the carrying capacity of the aqueduct proposed by both the MDN and the DAD, the Consultant used as a base flow, 1,500 liters per second or 130 MLD.

For the hydrological analysis of the channels a 0.014 value for the coefficient n of Manning formula and 120 for the coefficient C in Hazen-Williams

TABLE No. 16

Water Sources	River Run-Off MLD MDN	River Run-Off MLD DAD	Storage Reservoirs MLD MDN	Storage Reservoirs MLD DAD	Totals MLD MDN	Totals MLD DAD
Xaya River	26.8	24.0	36.2	20.0	63.0	44.0
Pixacaya River	56.0	64.0	59.0	20.8	115.0	84.8
Xenacoj Rivers	-	14.0	-	-	-	14.0
Other minor Rivers	-	-	22.0	-	22.0	-
Totals	82.8	102.0	117.2	40.8	200.0	142.8

formula were assigned.

The MDN, in order to convey the total of 200 MLD, it proposes plans in its second stage to build an additional covered channel and additional siphons with hydraulic and structural characteristics similar to the ones proposed in the first stage.

The study prepared by the DAD plans in the later stage for a total use of 142.8 MLD. To convey this quantity, it will only be necessary to build a siphon line parallel to the first one with similar hydraulic and structural characteristics and with capacity to transport the difference between the regulated and minimum flows detailed in the previous Table No. 16.

MDN and the DAD adopted a cross section and adequate slope in their tunnels to permit the total flow proposed to be utilized. It should be noted that the size of the tunnels has been governed not by the flow to be transported but by the necessary minimum size required by the construction methods proposed.

In Section C.6 of this report, there are brief comments concerning the principal characteristics of the criteria of design adopted in the MDN and the DAD's projects, for the expansion and improvements to the water distribution network in Guatemala City.

DAD plans to execute the first stage of the network improvements in the near future according to the plan prepared by SEURECA. The topography

of some sectors of the urban area of Guatemala City have major differences in elevation, and to maintain pressure in the pipes and house connections within acceptable limits, equipment and/or special structures will be necessary for pressure control. The control of unusually high pressures is good practice as it helps to decrease the water losses caused by leaks in the distribution network and to diminish, on the other hand, the damages to the plumbing installations of the consumers. Good practice recommends that high heads should be avoided wherever practicable. MDN and DAD plans provide for pressures within acceptable limits.

Chemical analysis of the raw water coming from sources to be utilized in this first stage of Xaya-Pixcaya project has a variation in quality during the year as is to be expected. The physical and chemical variations are within acceptable limits for economical treatment by existing and planned treatment facilities. The engineers responsible for the final design of the Treatment Plants must establish definitely the bases of the treatment so as to permit construction in stages and also consider flexibility in operation in both the new and the existing system. The costs estimate for both studies included an estimated cost for construction of the first stage of the treatment plant.

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C.5. CONSTRUCTION STANDARDS

a. and b. Standard Specifications and Special Standards:

The Army has drafted construction specifications applicable to their method of operation. A review of these specifications indicates that they would insure properly built structures with possibly some modifications. The Municipality has some specifications covering their work but these should be amplified to make them acceptable to an international financing agency.

Local cement is considered adequate. Care must be taken regarding the aggregates used to insure that no chemical reaction occurs between the various ingredients in the concrete. This is referred to in the latter part of Appendix "B", Geology.

Before final approval, the cost of using special materials, such as ductile iron as proposed by the Municipality, should be carefully evaluated from all aspects, including maintenance costs, availability and use.

The use of special methods as proposed by the Army for covered conduits, should be studied intensively before recommending adoption. However, where there are unique methods, which have proved economical from long local experience, they should be adopted. A case in point is the tunneling method proposed to be used in pumice or similar materials by DAD.

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C.6. PRELIMINARY STUDIES AND PLANS

a. Location Map

b. Rainfall and Runoff Data and Flow Calculations Indications Sufficiency

c. Soil and Surface Investigations To Determine Foundations For Major Structures and Materials In Trenches

d. Information About Major Elements Of The Projects

The studies of MDN and DAD for the expansion of the water supply system in Guatemala City in the initial stages were based on excellent maps prepared by the Instituto Geografico Nacional de Guatemala. In their preliminary design stages, both agencies have developed topographic maps of sufficient detail for the purpose, which, in each case, were prepared by their engineering personnel. The surface aqueduct routes selected by these agencies, lead from the water sources. They have been located on the ground and drawn up, both in plan and profile. This provided the Consultants with an opportunity to observe , during the several field inspections, the lines chosen for both routes. Likewise, for the planning of the distribution network of the city, the MDN as well as the French firm of Consulting Engineers S.E.U.R.E.C.A. (under contract to DAD for the design of improvements to the distribution network of the municipal system), have utilized plans prepared by the Instituto Geografico Nacional de Guatemala.

Shown in detail in Appendix "A" is the analysis of hydrologic data for the project area. It has been developed by the consultant in order to establish

the reliability of the proposed sources for water supply in Guatemala City.

The soils of the project area, are primarily residual soils that have been formed over materials of volcanic source. Generally, they consist of a deep red colored sandy loam or clay loam, which in some cases show shrinkage cracks due to the presence of expansive clays. In road cuts of the project area the depth of the soil varies between one and five feet.

In the urban area of Guatemala City, no soil studies have been made that would establish the degree of acidity and/or alkalinity, in order to be able to specify the type of water mains to be installed. However, a general criterion has been established by DAD based primarily on experience. This experience has led to using different types of pipe in different areas of the city. The DAD has determined areas in the city where installations of galvanized iron pipes have been discontinued due to the soil's corrosive action in these sectors. In the last few years the DAD, for its distribution network mains has used cast iron pipe and asbestos cement pipe made in Guatemala to relieve the corrosion problem. Likewise, it has established the use of copper pipes for construction of house connections.

As for the geological aspects of the project area, in Appendix "B" is shown the analysis of the information available to the consultant, such as the result of the geological inspections carried out in the project area.

For the first phase of development of the water supply system for Guatemala City, in the studies made by the MDN and by the DAD, the principal sources considered are the Xaya and Pixcaya Rivers. The first one of these rivers

belongs to the Pacific Ocean watershed and the second to the Atlantic Ocean watershed. Additionally, the MDN considers the possibility of using the water supply from the Coloya River and three tributaries of the Guacalate River. The DAD proposes in this first stage the utilization of the minimum flow of Xenacoj I and II Rivers, which are tributaries of the Pixcaya River.

In Section C.11, Long Range Planning for Future Water Supplies, of this report is discussed the aspects related to the long-term plan for the utilization of other water sources proposed by the MDN and DAD for future stage development of their respective programs.

In the relative documents provided to the Consultant, preliminary plans are shown for the construction of principal structures considered in each of the projects, such as: diversion works, typical tunnel section, channels, siphons, treatment plants, et cetera.

The MDN proposes the construction of a completely new treatment plant west of the city, as a part of the first stage of the expansion. A major expansion of the present treatment plant La Brigada, is included in DAD's project.

Although the engineering details provided by the MDN are more complete, in the Preinvestment National Aqueduct Xaya-Pixcaya Report, regarding the new treatment plant MDN proposes to construct, the DAD also provided among other documents available to the Consultant, the general details for the expansion of the treatment plant of La Brigada. In either case, it will

be necessary to treat the water supply before it is delivered for consumption. In making an evaluation of these two studies, the Consultant considered that the information supplied in both cases is adequate to permit preliminary development. However, such preliminary plans will have to be fully developed in the final design.

The new plant proposed by the MDN is located in the vicinity of Mixco, at an elevation of 1680 above sea level. This is 70 to 80 m. higher than the La Brigada Plant of the municipal system proposed. It will be necessary to consider in this project cost, the value of about 3.9 kms. of watermains necessary to interconnect the proposed plant with the municipal distribution system. Though the construction of the new MDN treatment plant, at a place known as Lo de Coy, would permit the supply by gravity to all the urban area, problems would result because of the relatively high pressures. At many of the network nodes, dynamic pressures greater than normal would exist, which during the hours of minimum consumption will reach even higher values. These extreme pressures would cause considerable water loss due to leaks in the pipes and valves, and in defective plumbing installations. Such a situation will result in greater operation and maintenance expenses as well as excess cost due to wasted water. Therefore, the higher pressure, could actually be a disadvantage.

There is an area of the city near the La Brigada treatment plant that is located at a higher elevation, requiring the necessity to pump an estimated (SEURECA) 200 liters per second.

In Volume I of the MDN Preinvestment of National Aqueduct Xaya-Pixcaya Report, as in the project Report prepared for the DAD by SEURECA, are shown the complete details of the criteria adopted for the planning and design of the proposed distribution systems. As mentioned in Section B, in the DAD approved and adopted the SEURECA project for the expansion and improvement of its distribution network. They are in process of the necessary administrative transactions to proceed with construction of the first phase of this project.

In Table No. 17 are shown some general aspects of the studies of the distributing network performed by the MDN and the DAD.

The studies prepared by the MDN and the DAD for the remodeling and extending the distribution network of the municipal system of water supply in Guatemala City have been planned to meet the requirements, of years 1985 and 1983 respectively. These plans include the possibility of being constructed in stages to meet the incremental demands of the city. Both MDN and DAD, in their cost estimates, contemplate stage construction of the the distribution network. As a result the DAD is using the distribution network plan as prepared by SEURCA and is taking the necessary steps to begin the first stage of the project.

At present the quantity of water metered is slightly more than 90 percent of the total quantity of water delivered for consumption. The DAD proposes to install meters for 100 percent of their service connections. In their plans for extending the distribution system, DAD intends to reach that goal as soon as possible together with serving increased numbers of customers.

TABLE No. 17

Main Features for the Year	MDN 1985	DAD 1983
Estimated Population	1,633,100	954,470
Total Area Served Ha	6,706	8,706
Total Daily Demand Qm in l/sec.	2,039	3,296
Daily Maximum Demand	3 x Qm	2 x Qm
Maximum Peak Demand	3.3 x Qm	
Discharge Coefficient (Hazen-Williams)		
a. old pipes	70-100	80
b. new pipes	130	120
Maximum Dynamic Pressures in Meters	110	69
Cost of First Stage	Q.1.415,300	Q.3.105,729

In the studies submitted for the Consultant's consideration both the MDN and the DAD shows the detail of the sizes and quantities of mains to be installed in the first stage of extension of the distribution network. Typical details for the construction of house connections are shown in accordance with established practices of the DAD. These details concerning pipe quality, quantity, diameters and costs are given in Section 7, Page No. 139 of Volume II of the MDN Report and Section 4.2, Page 29 of the Estimate (Oct. 1967 of the Xenacoj-Xaya-Pixcaya Project prepared by DAD.

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C.7 CONSTRUCTION LABOR, MATERIALS AND EQUIPMENT

a, b, c, d, e, f and g. Labor, Technical and Supervisory Personnel, Major Construction, Materials and Equipment, Yard and Campsites, Local Contractors, et cetera:

The various items for consideration listed above were examined. When comparing two feasible plans of construction generally including the same materials and similar personnel requirements, anything that affects one plan will affect the other. This is to say that any problems concerning material supply, selection or application or personnel acquisition or training will naturally affect any plan that is ultimately selected.

The Consultant reviewed the local labor market and learned that there are available an adequate number of skilled and unskilled workers. Certain technical jobs will require local training. One of these is welding. It was learned that welders are in short supply and that a training program or apprenticeship program will need to be implemented. Engineering staff and designers and supervisory personnel are available within the country and any shortage of special technically trained persons can be made up by foreign assistance arrangements.

The common major construction materials such as lumber, sand, and cement are locally available and adequate for the work and in ample supply. Some common construction equipment is also available within the country. The only area of specific concern to any contractor would be the acquisition of more specialized construction materials or equipment such as reinforcing

steel, malleable iron pipe, large specialized earth-moving and tunneling equipment, et cetera will probably need to be imported. No excessive time delays or costs in the form of Customs duties are known at this time.

Construction camps, supply yards, and local construction contractors are readily available. No problems are anticipated for the large foreign contractor in these areas.

C.8 SPECIAL CONSTRUCTION PROBLEMS

a. Effects of Climatic Conditions

b. Soil Conditions and Ground Water

c. Limitations on Schedule Due To Long Lead Time Of Equipment and Material

d. Possible Major Causes of Delay

No special problems are anticipated during construction because of climatic conditions. The rainy season in the project area is generally limited to the months of May to October with an average annual rainfall of about 1200 millimeters.

It can be expected that interruptions in the work, due to the rain, will be moderate especially if the contractors are prepared to provide adequate clothes to the workers that will permit them to work satisfactorily on a rainy day. It is interesting to note that in the rainy season, the rain falls in the afternoon and night. Construction scheduling on a seasonal basis must be employed by the contractor so as to take advantage of periods of low flow in the rivers and dry ground. The flow records of the principal rivers, proposed to be utilized as water supply sources in this first stage, show periods of low flow long enough so that flooding during the construction of diversion structures are not anticipated. These rivers at flood stage could cause considerable damage to the structures.

In Appendix "B" the necessity of having sufficient access roads for the correct handling of materials and construction personnel is noted. Although many access roads presently exist through the MDN's and DAD's routes, most of them must be improved considerably, to provide safe transport of materials and personnel to the different places of work, during not only the dry season but also during the rainy season.

Special attention will be required in tunnel construction utilizing conventional methods in order to minimize the overbreak to an acceptable percentage, particularly in drilling through hard rock. In such cases the contractor should use the proper techniques and experienced personnel for this work so as to avoid an overbreak larger than is acceptable. The excavated materials from the tunnels must be disposed of in a proper manner in order to prevent sedimentation problems in nearby low-water rivers. Some of this material properly selected, could be used in the access road construction.

In the initial selection of a general contractor sufficient consideration must be given to his experience and ability to cope with construction-under-water problems. Intake structures and some tunneling will pose such problems. He must be able to provide dry work areas, either by caissons and pumps or other conventional de-watering construction techniques.

Considerable periods of time loss are not expected in the acquisition of materials and equipment which would affect the total time schedule of the construction. One exception might be the special equipment such as

the drilling machines for tunnel drilling as suggested by MDN in its report. This kind of equipment is not standard and is only fabricated on a special order and according to specialized specifications.

If reasonable efforts are made to assure that the relations between worker and contractor are cordial and adequate provisions are made for housing and equipping the workers in the field, no problems should develop that would cause delays in the construction program.

Based on a review of contracts that have already been made, no problem in negotiations to acquire the necessary rights of way or the necessary areas for the construction of the structures is anticipated.

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C.9 PLANS FOR EXECUTION OF PROJECT

a, b, c, and d. Sequences, Construction Methods, Engineering and Supervising Methods and Phased Schedules

Both the MDN and the DAD have worked out acceptable plans for the execution of their projects and they have submitted detailed estimates of time and costs.

Because of differences in designs they vary in the methods used for construction. The DAD makes more use of manual labor than the MDN. In both cases it is proposed to contract engineering, construction and supervision of construction to foreign firms where desirable. As much as possible of the work would be done by local firms.

The MDN has worked up a plan which requires nearly two years before work is started and a little over three years (governing factor is construction of long tunnels) for the construction, or a total of over 5 years, as shown on the accompanying two bar charts, Figures Nos. 13A and 13B. It is believed that the two years of preparatory work including final designs can be reduced to one year as many of the necessary items can be carried on simultaneously, especially in view of the complete nature of the MDN study. Also, it is believed the time of construction could be decreased slightly to three years. Although the reduction in time may be considered somewhat abnormal, it is justified by the urgency of supplying additional water to Guatemala City as soon as practicable. It is considered that any additional cost would be more than balanced by a reduction in interest charges during the construction period.

The DAD allowed only one year of preparatory work, including designs, specifications, et cetera, as shown on the attached bar chart, Figure 14A for their first stage. However, because many changes have been made in their preliminary plans and because these plans are not as comprehensive as those of the MDN, it is consdiered that it will be one and a half years before construction can be started. The DAD plans to carry on simultaneously many of the necessary phases of preparatory work needed to obtain a construction loan and advertise for a contract . The period of construction is given in their original report as three years but there is no doubt that this can be accomplished in two and one half years. Concerning construction period, the limiting factor in both plans is the tunnel work. The DAD plan envisions many short tunnels while the MDN plan shows fewer, longer ones. The DAD plans to use much more manual labor than the MDN in excavating the tunnels and past experiences justify acceptance of their plans. However, it is believed that their estimates are somewhat lower in comparison with those for the MDN and standard practice. Therefore, the Consultant has estimated their costs higher as covered in Section D.

Attached for general information is the DAD bar chart, Figure 14B, for their second stage.

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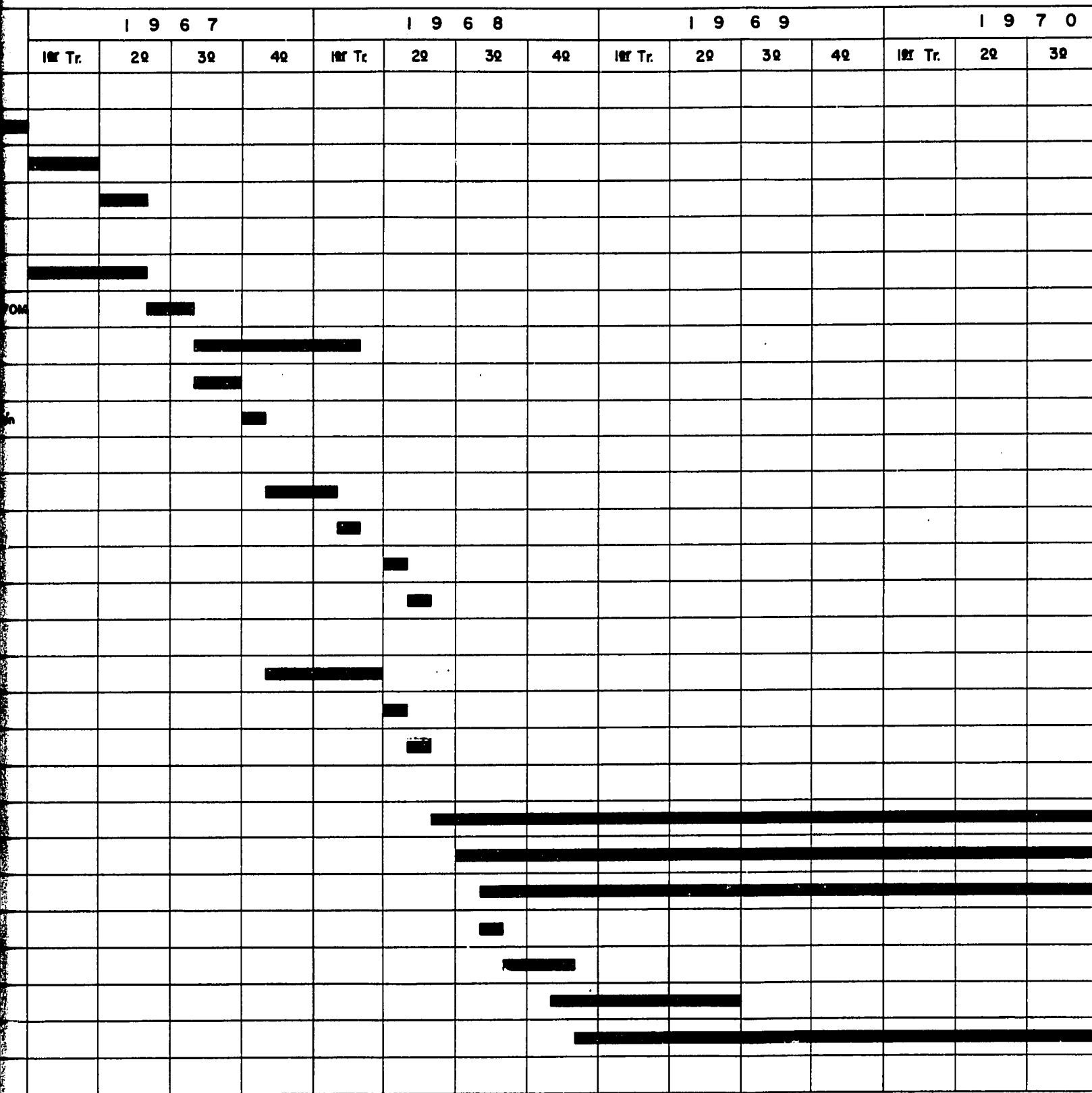
ITEMS	RESPONSIBLE ORGANIZATION
Studies	
Feasibility Studies	Xaya-Pixcaya Project
Specifications	Xaya-Pixcaya Project
Bidding Documents	Xaya-Pixcaya Project
Administrative Process	
Approval for Execution	Government of Guatemala
Agreements between National Organizations	Ministry of National Defense, Municipality and INFOM
Approval of organization, operation, titles tariffs, et cetera	INFOM and Municipality
National and Foreign Loan Application, Preparation	Ministry of Finance
Approval by Planning Council	Secretary of Planning Council
National Financing	
Approval by Financial Agencies	Ministry of Finance, Bank of Guatemala
Agreement Negotiations	Financial Organizations
Approval by Congress for issue of bonds	Congress of the Republic
Issue of bonds	Bank of Guatemala and INFOM
Exterior Financing	
Approval by Financial Agencies	BID and Government of Guatemala
Approval of Congress to loan	Congress of the Republic
Signing of the Loan Agreement	Government and BID
Construction	
Top Administration	Board of Directors INFOM
National Supervision	INFOM
Foreign Supervision	Consulting Firm
Revision of Plans, Specifications and Bidding documents	National and Foreign Supervision
Advertising for Bids	INFOM
Awarding of Contracts	INFOM
Physical Execution of the Work	Contractors
Aqueduct Administration	To be decided at Governmental level

Translation For Figure 13A

MEDIDAS	RESPONSABLE	1967				
		1er Tr.	2º	3º	4º	1er Tr.
ESTUDIOS:						
Estudios Factibilidad	Proyecto Xayá Pixcayá					
Especificaciones	Proyecto Xayá Pixcayá					
Bases de Licitación	Proyecto Xayá Pixcayá					
PROCESO ADMINISTRATIVO:						
Aprobación de la Ejecución	Gobierno de la República					
Acuerdos entre Organismos Nacionales	M. de la Defensa, Municipalidad e INFOM					
Aprobación de organización, operación, títulos, tarifas, etc.	INFOM y Municipalidad					
Solicitud de Préstamos, Nac. y Ext., Preparación	Ministerio de Hacienda					
Aprobación por Consejo de Planificación	Secretaría del Consejo de Planificación					
FINANCIACION NACIONAL:						
Aprobación por Agencias Financieras	M. de Hacienda, Bco. de Guatemala					
Negociación de Convenios	Organismos Financieros					
Aprobación por Congreso a Emisión Bonos	Congreso de la República					
Emisión Bonos	Banco de Guatemala e INFOM					
FINANCIACION EXTERIOR:						
Aprobación por Agencias Financieras	B. I. D.					
Aprobación por Congreso al Préstamo	Congreso de la República					
Firma del Convenio de Préstamo	Gobierno y B. I. D.					
CONSTRUCCION:						
Administración Superior	Junta Directiva INFOM					
Supervisión Nacional	INFOM					
Supervisión Extranjera	Firma Consultora					
Revisión de Planos, Esp. y Bases de Licit.	Supervisión Nacional y Extranjera					
Llamada a Licitaciones	INFOM					
Adjudicación de Contratos	INFOM					
Ejecución Física de la Obra	Contratistas					
ADMINISTRACION DEL ACUEDUCTO	Por decidirse a Nivel Gubernativo					

MINISTERIO DE LA DEFENSA SERVICIO DE INGENIEROS PROYECTO XAYA – PIXCAYA	PRESTAMO B. I. D. 42/SF — GU-	DIBUJO: E. R. RIVERA	APROBADO POR Ing. Jefe del Proyecto VISTO BUENO Ing. Representante Ministerio	SIN ESCALAS



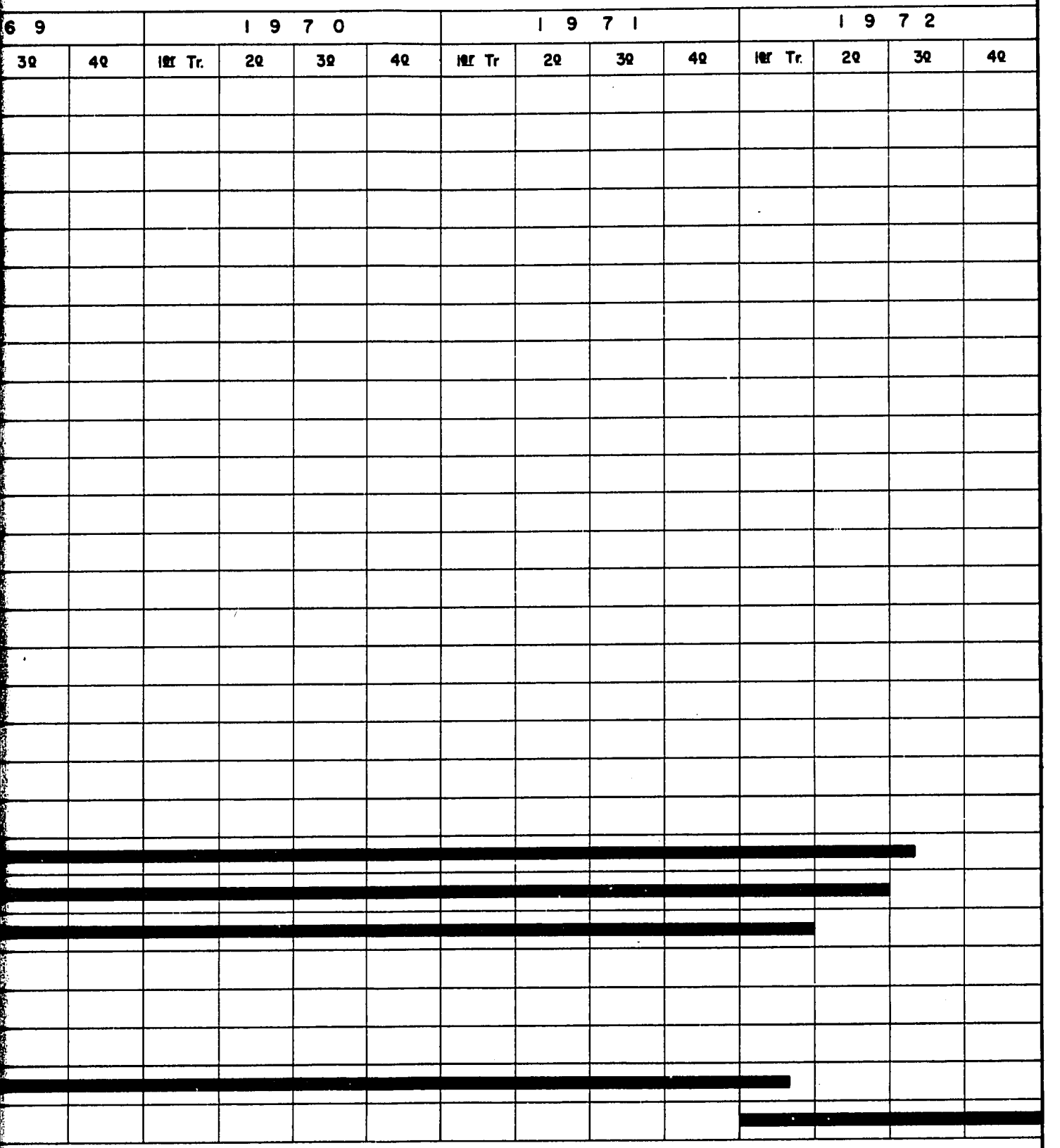
APROBADO POR
Ing. Jefe del Proyecto
VICTOR BUENO
Ing. Representante Ministerio

SIN ESCALAS

ACUEDUCTO NACIONAL XAYA PIXCAYA

GUATEMALA C.A.

PROGRAMA DE MEDIDAS PA



PREPARADO EN BASE A RECOMENDACIONES GENERALES DE INGENIEROS DE LA MISION CONJUNTA DE PROGRAMACION PARA CENTRO AMERICA.

FIGURE 13A

CAYA	PROGRAMA DE MEDIDAS PARA LA EJECUCION DEL PROYECTO	DICIEMBRE 1966	
	C-53	HOJA 060	

MISSING PAGE

NO. C54 - C55

Intake

Access Road
Land
Dam and desedimentation Chamber
Connection to the Tunnel

Tunnel Of Chimaltenango

Access Road
Land for Portals
Installations
Excavation
Concrete
Final Structures

Las Canas Tunnel

Access Road
Land for Portals
Installations
Excavation
Concrete
Final Structures

Canals

Right of Way
Access Roads
Earthwork
Bridges, Water passageways, Walls
Ditches
Concrete pouring
Siphon transitions

Siphons

Right of Way
Access Roads
Pipe purchase
Lining and Internal Transportation
Ditches and Auxiliary Structures
Installation

Trimestres-Quarters

Puesto en Servicio-
Placed in Service

Minor Tunnels

Access Roads
Land For Portals
Installations
Excavation
Concrete
Final Structures
Transitions

Treatment Plant

Land
Construction

Distribution System

Right of Way
Pipe Purchase
Installation

Note: The starting date depends on the previous preparatory work.

Translation For Figure 13B

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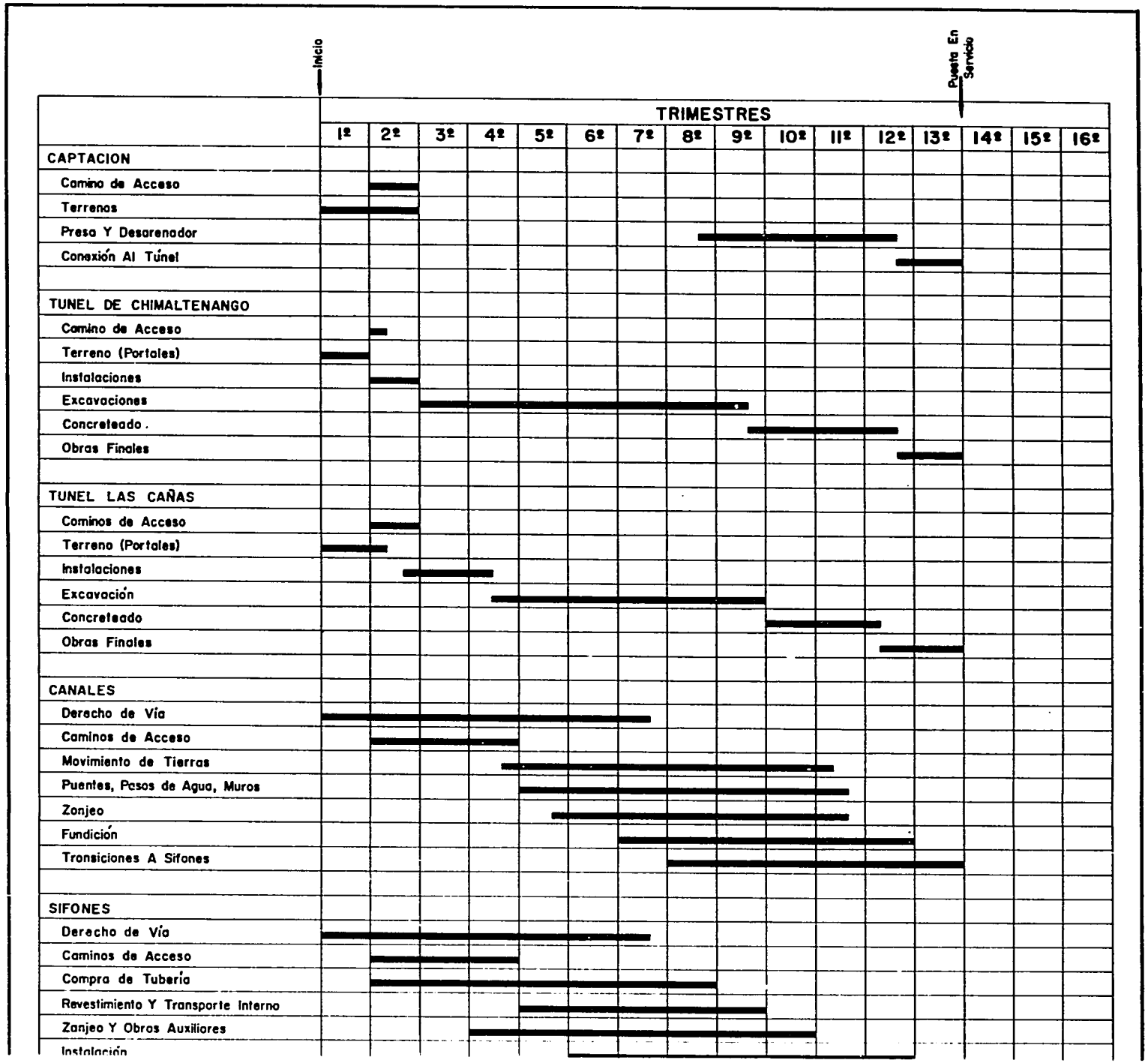
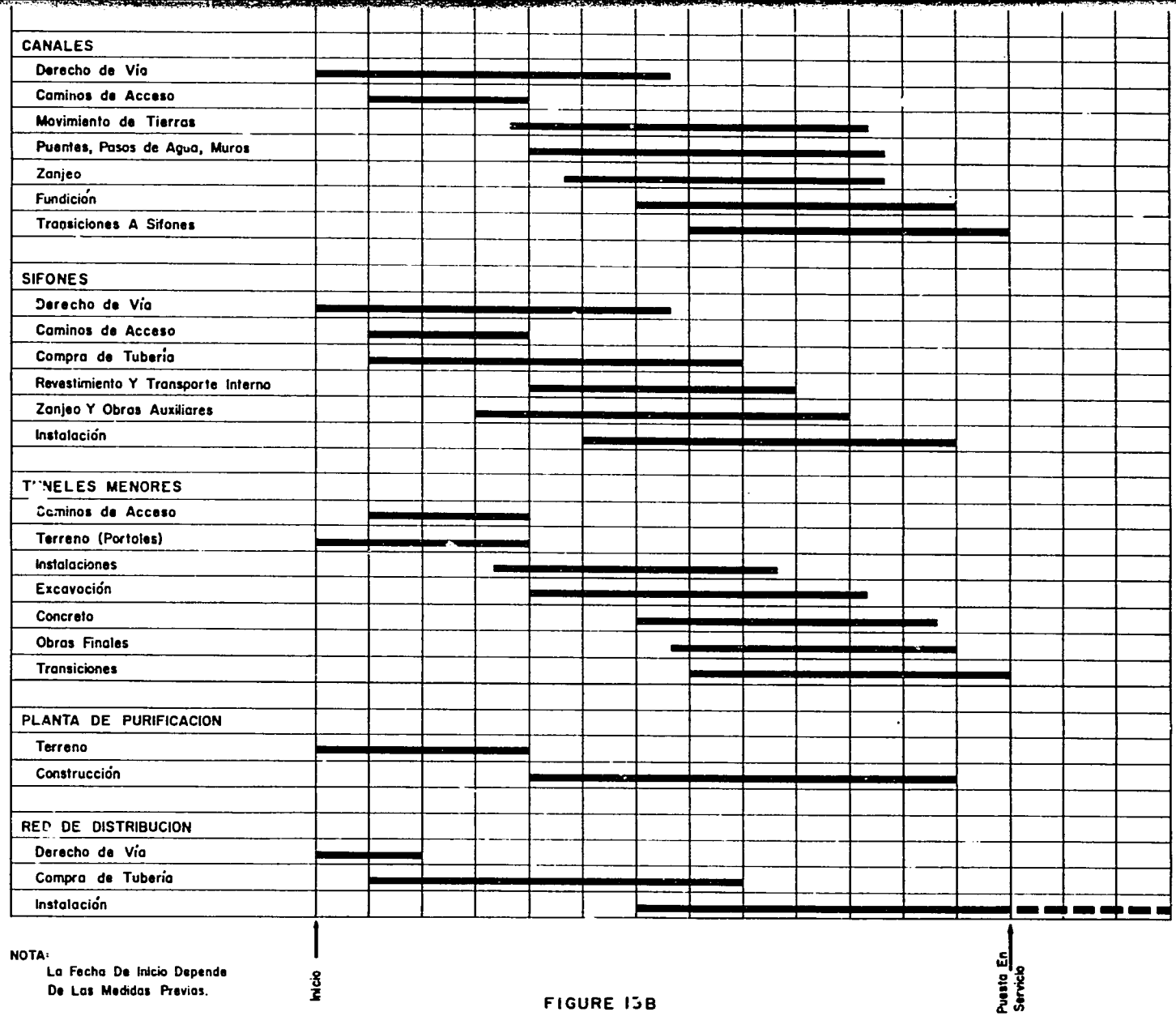

Inicio
Puesta En Servicio
TRIMESTRES
1º
2º
3º
4º
5º
6º
7º
8º
9º
10º
11º
12º
13º
14º
15º
16º
CAPTACION
Camino de Acceso
Terrenos
Presa Y Desarenador
Conexión Al Túnel
TUNEL DE CHIMALTENANGO
Camino de Acceso
Terreno (Portales)
Instalaciones
Excavaciones
Concreteado.
Obras Finales
TUNEL LAS CAÑAS
Caminos de Acceso
Terreno (Portales)
Instalaciones
Excavación
Concreteado
Obras Finales
CANALES
Derecho de Vía
Caminos de Acceso
Movimiento de Tierras
Puentes, Pasos de Agua, Muros
Zonjeo
Fundición
Transiciones A Sifones
SIFONES
Derecho de Vía
Caminos de Acceso
Compra de Tubería
Revestimiento Y Transporte Interno
Zanjeo Y Obras Auxiliares
Instalación



NOTA:
La Fecha De Inicio Depende
De Las Medidas Previas.

FIGURE 13B

MINISTERIO DE LA DEFENSA SERVICIO DE INGENIEROS PROYECTO XAYA – PIXCAYA	PRESTAMO B I D 42/SF – GU	DIBUJO J. EFRAIN GARMENTOS	APROBADO POR APROBADO POR	SIN ESCALA	ACUEDUCTO NACIONAL XAYA-PIXCAYA GUATEMALA C A	CRONOGRAMA PARA LA EJECUCION FISICA DE LA OBRA	DICIEMBRE 1966 HOJA 070

PIXCAYA PROJECT

SCHEDULE OF EXPENDITURES AND WORK
1st Phase

Item	Total Cost Quetzales	Time For Construction Mon.	Completion Year	Monthly Expenditure Quetz	Period of Construction
Organization and Preparation					
Intakes					
a. Xenacoj I				E: January	
b. Xenacoj II				F: February	
c. Xaya				M: March	
d. Pixcaya				A: April	
				M: May	
Conduit				J: June	
a. Brigada-Junction (Xenacoj) Section				J: July	
b. Junction-Xenacoj I Section				A: August	
c. Xenacoj I-Xenacoj II Section				S: September	
d. Junction-Pixcaya Section				O: October	
e. Xaya-Balanya Section				N: November	
				D: December	
Treatment Plant (La Brigada)					
a. Dosing Building					
b. Mixing Chambers					
c. Sedimentation Basins					
d. Filters, control and washing					
e. Conduits to the filters					
f. Clear water reservoirs					
g. Dwellings and fluoride shed					
Distribution					
a. Regulating reservoir					
b. Primary system					
Pumping and Generating Stations (La Brigada)					
a. Foundations and sheds					
b. Turbine, pump and control board					
c. Generator and regulator					
d. Crane and equipment erection					
Operating Capital					
a. Secondary distribution system					
b. Others (water meters, house connections, et cetera)					
c. Chlorine and other treatment products					
GRAND TOTAL					

Translation Figure 14A

Concepto	Costo Total Quetzales	Tiempo de construc. meses	Año de introduc
ORGANIZACION Y PREPARACION	36,000.00	12	1962
CAPTACIONES			
a) Xenacej I.	40,374.95	3	1963
b) Xenacej II.	18,419.86	3	1963
c) Xavá	26,439.65	4	1965
d) Pixcayá	80,251.99	6	1965
CONDUCCION			
a) Tramo Brigada-Entronque	3,220,671.08	18	1964
b) Tramo Entronque-Xenacej I.	263,031.70	7	1964
c) Tramo Xenacej I-Xenacej II.	15,994.18	3	1963
d) Tramo Entronque-Pixcayá	1,991,749.55	15	1965
e) Tramo Xayá-Balanyá	638,940.78	15	1965
PLANTA DE TRATAMIENTO (La Brigada)			
a) Edificio de desificación	130,164.00	12	1965
b) Canales de mezcla	75,929.00	6	1965
c) Sedimentadores	195,246.00	12	1965
d) Filtros, control y lavado	368,798.00	18	1964
e) Canales a los filtros	32,541.00	6	1964
f) Tanque de aguas claras	EXISTE		
g) Viviendas y caseta de fluoración	43,388.00	12	1965
DISTRIBUCION			
a) Tanques de regulación	275,618.10	18	1965
b) Red primaria	1,414,108.21	24	1965
ESTACION DE BOMBEO Y GENERACION (La Brigada)			
a) Cimientos y casetas	15,000.00	12	1965
b) Turbina, bombas y tablero	23,000.00	12	1965
c) Generador y regulador	15,000.00	12	1965
d) Grua y montaje de equipo	7,000.00	12	1965
CAPITAL DE OPERACION			
a) Red secundaria	240,000.00	24	
b) Otros (contadores, acometidas, etc.)	144,000.00	24	
c) Cloro y otros productos para tratamiento	360,000.00	12	
GRAN TOTAL	9,671,666.05		

PROYECTO PIXCAYA

CALENDARIO DE INVERSIONES Y TRABAJO

1a. ETAPA

duc.	Inversión mensual Quetzales	Lapso de construcción	1962 E	F	M	A	M	J	J	A	S	O	N	D	1963 E	F	M	A	M	J	J
2	3,000.00	Ene.62-Dic. 62																			
3	13,458.31	Ene.63-Marzo 63																			
3	6,139.95	Mar.63-Mayo 63																			
5	6,609.91	Ene.64-Abril 64																			
5	13,375.33	Nov.64-Abril 65																			
4	178,926.17	Ene.63-Junio 64																			
4	37,575.95	May.63-Nov. 63																			
3	5,331.39	Nov.63-Ene. 64																			
5	132,783.30	Ene.64-Marz. 65																			
5	42,596.05	Ene.63-Mayo 63																			
		Nov.63-Mayo 64																			
		Oct.64-Dic. 64																			
5	10,847.00	Ene.63-Dic. 63																			
5	12,654.83	Ene.64-Junio 64																			
5	16,270.50	Ene-64-Dic. 64																			
4	20,488.78	Ene.63-Junio 64																			
4	5,423.50	Ene.63-Junio 63																			
5	3,615.67	Ene.64-Dic. 64																			
5	15,312.12	Ene.63-Junio 64																			
5	58,921.17	Ene.63-Dic. 64																			
5	1,250.00	Ene.63-Dic. 63																			
5	1,916.17	Ene.63-Dic. 63																			
5	1,250.00	Ene.63-Dic. 63																			
5	583.33	Ene.63-Dic. 63																			
	10,000.00	Ene.64-Dic. 65																			
	6,000.00	Ene.64-Dic. 65																			
	30,000.00	Ene.65-Dic. 65																			

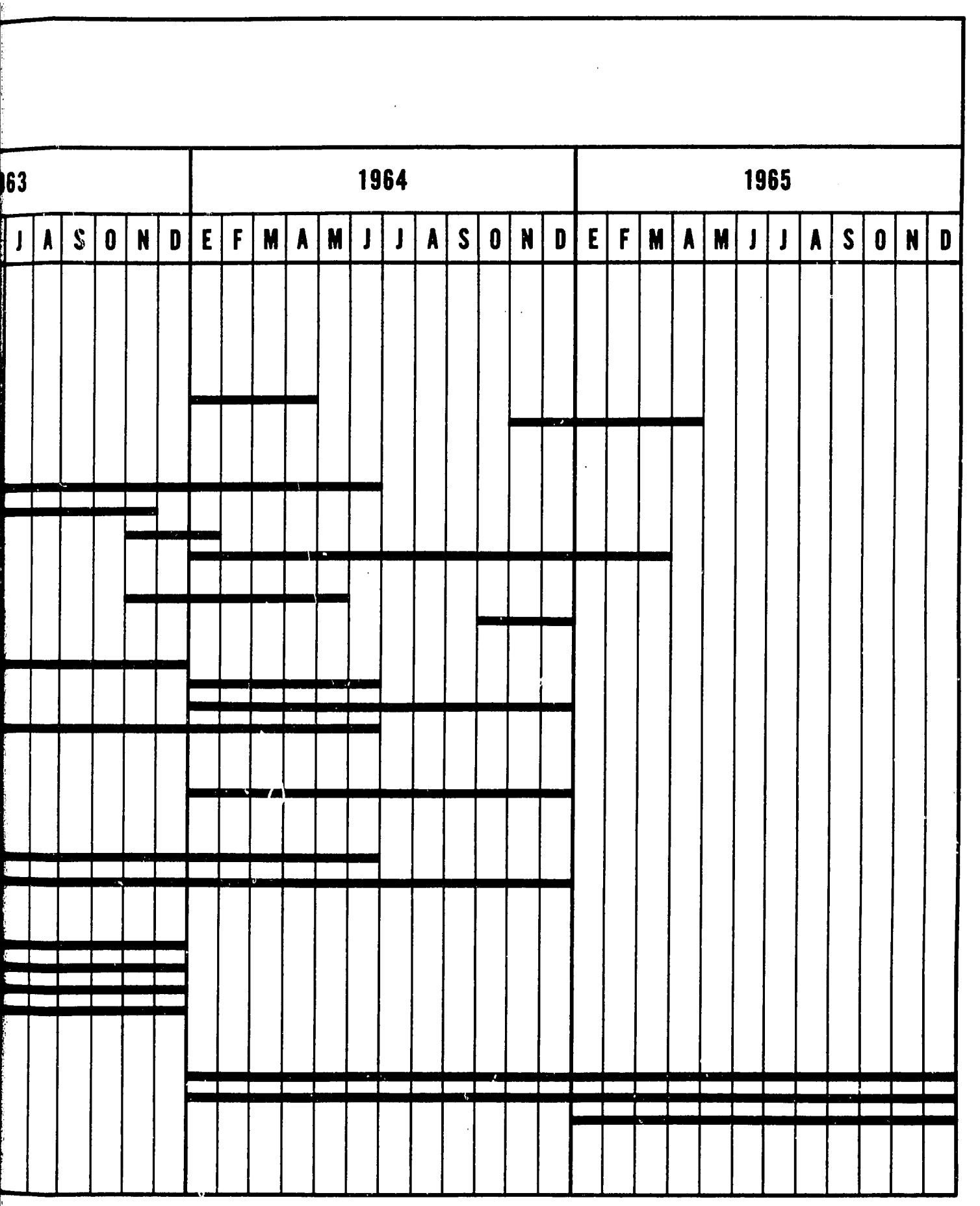


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FIGURE 14 A

PIXCAYA PROJECT

SCHEDULE OF EXPENDITURES AND WORK
2nd Phase

Item	Total Cost Quetzales	Time For Construction Mon.	Completion Year	Monthly Expenditure Quetz	Period of Construction
Preparation and Organization					
Intakes					
a. Balanya					
Conduits					
a. Balanya-Pixcaya Section					
Treatment Plant (La Brigada)					
a. Sedimentation Basins					
b. Filters					
c. Clear Water Reservoir					
d. Storehouse					
Distribution					
a. Regulating Reservoir					
b. Primary system					
Hydroelectric Plant					
a. Civil engineering construction					
b. Turbine					
c. Generator and control board					
d. Substation and transmission line					
Contingencies					
GRAND TOTAL					

Translation For Figure 14B

Concepto	Costo Total Quetzales	Tiempo de construc. meses	Año de introdu
PREPARACION Y ORGANIZACION	12,000.00	12	1967
CAPTACIONES			
a) Balanyá	17,950.34	3	1967
CONDUCCIONES			
a) Tramo Balanyá-Pixcayá	919,352.45	18	1967
PLANTA DE TRATAMIENTO (La Brigada)			
a) Sedimentadores	293,328.00	18	1967
b) Filtros	162,960.00	12	1966
c) Tanque de aguas claras	195,552.00	15	1967
e) Bodega	38,024.00	6	1967
DISTRIBUCION			
a) Tanques de regulación	71,593.20	8	1967
b) Red primaria	723,851.37	24	1967
HIDROELECTRICA			
a) Construcciones civiles	80,000.00	13	1967
b) Turbina	30,000.00	6	1967
c) Generadores y tableros	60,000.00	6	1967
d) Subestación y línea de transmisión	30,000.00	6	1967
IMPREVISTOS	265,000.00	24	1967
G R A N T O T A L	2,899,611.36		

PROYECTO PIXCAYA

CALENDARIO DE INVERSIONES Y TRABAJO

2a. ETAPA

Año de introduc.	Inversión mensual Quetzales	Lapso de construcción	1965												1					
			E	F	M	A	M	J	J	A	S	O	N	D	E	F	M	A	M	J
1967	1,000.00	Ene.65-Dic. 65																		
1967	5,893.44	Nov.66-Ene. 67																		
1967	51,075.14	Ene.65-Jun. 66																		
1967	16,296.00	Ene.65-Jun. 66																		
1966	13,580.00	Ene.65-Dic. 65																		
1967	13,036.80	Nov.65-Ene. 67																		
1967	6,337.33	Jul.66-Dic. 66																		
1967	8,949.15	Nov.65-Jun. 66																		
1967	30,160.47	Ene.65-Dic. 66																		
1967	6,153.85	Dic.65-Dic. 66																		
1967	5,000.00	Sep.65-Nov. 65 Agos.66-Oct.66																		
1967	10,000.00	Sep.65 -Nov.65 Agos.66-Oct.66																		
1967	5,000.00	Sep.65 -Nov.65 Agos.66-Oct.66																		
1967	11,041.67	Ene. 65-Dic.66																		

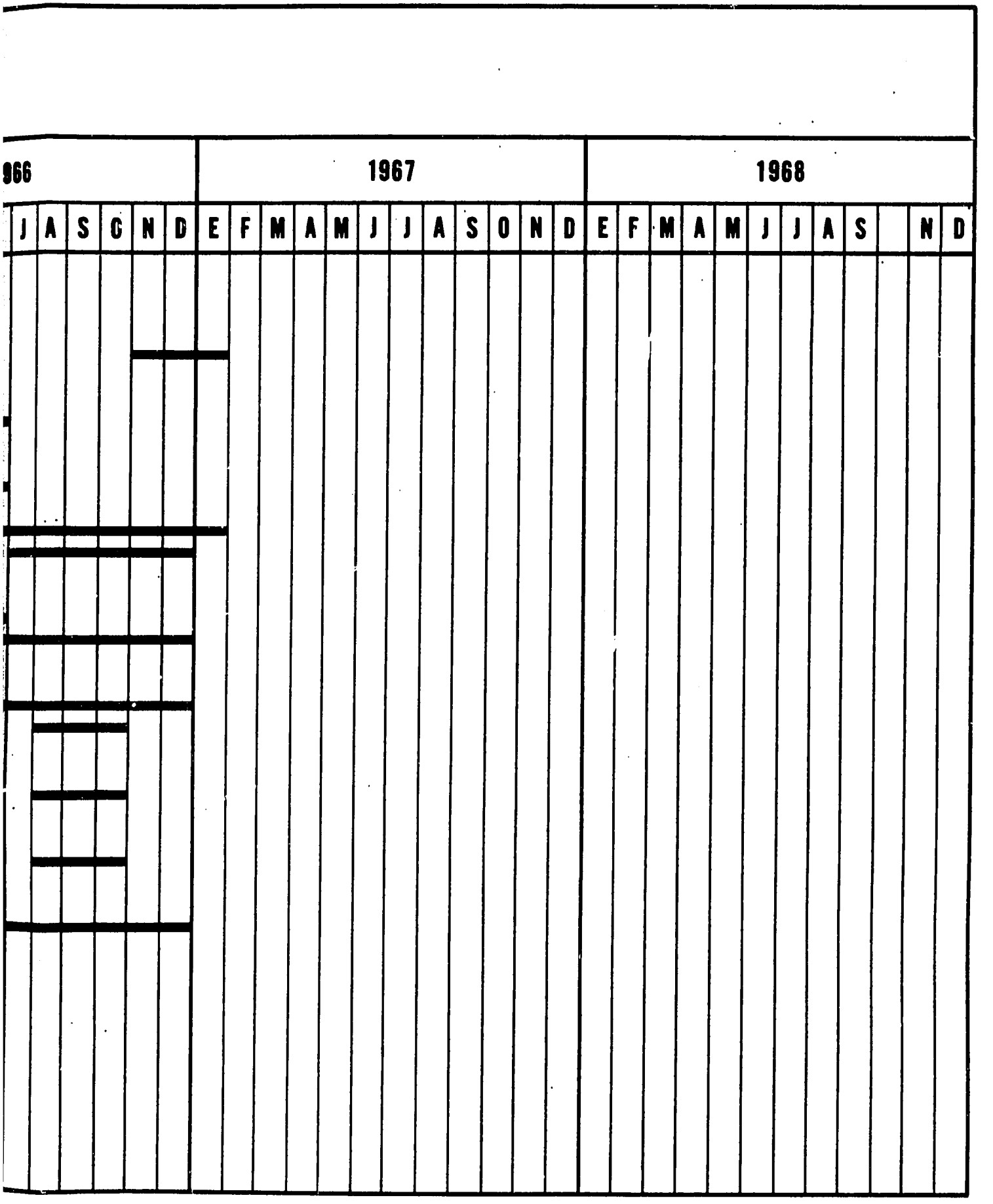

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FIGURE 14 B

C.10 MAINTENANCE AND OPERATING ORGANIZATIONS

a. Present and Proposed Organization

b. Ability of Operating Institution To Provide Proper Maintenance For New System

c. Availability of Personnel and Equipment

d. Plan To Finance Additional Maintenance and Operation

e. Training Personnel and Purchasing Maintenance Equipment and Spare Parts

This specific study, as has been noted before, is concerned with two proposals: one prepared by the Ministry of Defense (MDN), the other prepared by the Department of Water of the Municipality of Guatemala (DAD). The proposal of the MDN contemplates serving 17 towns and municipalities as well as Guatemala City. In order to accomplish this objective, a new organization is proposed which is quite clearly described, together with the reasons therefore, in the MDN's Report and is included herein:

"ADMINISTRATION OF THE CONSTRUCTION AND OPERATION OF THE SYSTEM"

"16.1 INTRODUCTION"

"The fundamental concept of the Xaya-Pixcaya National Aqueduct, as first contemplated in the water supply systems in the country, is that of a transportation line that will be constructed not only to serve a certain community but along its route would benefit several communities of minor importance, but which within the integral development of the country must have modern and efficient public services."

"With the exception of Guatemala City, whose economic capacity has permitted its Municipality to construct a water supply system in the last decade, it has been the Central Government that has covered most of the expenses to bring the potable water supplies to the towns of the Republic,

contributing with financial assistance in some of the cases above 80 percent of the total value of the systems, including the cost of planning, design and supervision of the constructions."

"Consequently, the National Aqueduct structure is foreseen to be carried out under government assistance and would not depart from the established system that is necessary in countries of centralized structure like ours, in which most of the communities need the Central Government's help for development of their health programs. The only difference in regard to this administrative procedure would be that instead of building small water systems independent for other communities, the Government would apply its resources to develop a unit with capacity to provide for several of them a service of the same quality as the planned for the Capitol City."

"The construction of aqueducts to serve several communities has been accomplished successfully and there are examples of such type of systems in South America, in the United States of America and other countries. Authorities in this matter point out that one of the larger obstacles to the supply of good quality water insufficient quantity, is the superabundance of political subdivisions, each one trying to resolve its problems in its own way, which is often impossible or impractical and inefficient. The connected action by means of regional systems can eliminate unnecessary duplication and be able to provide water in a better way and at a lower cost."

"In Guatemala, the Republic Constitution forsees cases in which the State can undertake the development of a system such as the Xaya-Pixcaya National Aqueduct and determine procedures to be carried out (Article 238). On the other hand, since it was originally planned the National Aqueduct was considered not to interfere with the Municipal Autonomy, guaranteed by the Constitution that the administration of the public services is a function which is assigned exclusively to the Municipalities (Article 233)."

"The constitutional aspects stated have served as a base to separate in two different administrative phases, the introduction of the Xaya and Pixcaya flows through the National Aqueduct: the physical execution of the system and later the operation of the system."

"To practice each one of these would necessarily be implied; however, some modifications in the administrative structures actually existent would have to be studied and resolved at a governmental level. Because of that, the Project Planning Office gives only general outlines regarding the proposed procedures without attempting to provide details."

"16.2 CONSTRUCTION OF THE SYSTEMS"

"There is an automatous institution within the administrative organization of the country, which is properly organized and of financial prestige;

adequate to be in charge of the execution of a system of this nature: the Instituto de Fomento Municipal (INFOM). There are also among the State's Organizations and banking entities that have been related with the development of the actual Preinvestment studies, an agreement of opinions in the belief that INFOM is an adequate organization to take charge of such functions. Also conferences with the directors of said Institute have provided favorable answers concerning the willingness of INFOM to assume this responsibility in case something is arranged as proposed herein."

"For these reasons, the organization plans shown that follow name the Instituto de Fomento Municipal as the more probable solution."

"It is also mentioned that the Bank of Guatemala should be considered as an internal finance source and the Interamerican Bank of Development (BID) as a possible source of external finance; the last one, as it has been the Banking entity which has financed in part the actual preinvestment studies, having a complete knowledge of the project and is the major source of finance in Latin America for similar systems would undoubtedly facilitate some of the operations involved in the loan proceedings."

"In the Organization Chart proposed for the construction of the system (Plan No. 061) the INFOM Management is shown as the Executive head responsible to the Board of Directors of the same. It is suggested a lateral relation of coordination should exist with two organizations closely related with the National Aqueduct system: the Ministry of the National Defense which originated and carried out the preparation of the project studies and which has shown its wishes to be in contact with the system during its execution; and the Municipality of Guatemala which necessarily has to have knowledge of the same, since the contributed flows in the first stage will be distributed in the Metropolitan Area of the capital by the existing pipes and by the expansion of the actual network."

"On the other hand, there are also shown in the organization chart the direct relations from the INFOM Management with the internal and external finance sources, that is the Bank of Guatemala and the Interamerican Bank of Development. For the purposes of simplicity, the functions of financial administration, audit, et cetera, are not indicated but these necessarily must exist in accordance with the agreements to be signed."

"Responsible to the Management is shown the office which will be specifically organized for the construction of the system named in the chart "National Executive Supervision". This will be in charge of an executive supervisor or chief, the technical and administrative personnel necessary to provide the National Supervision. As part of this office's responsibility will be the functions inherent to the execution of the works, from the preparations of the specifications and the actions of the international agencies to the completion of design and plans for construction. It will

also have as its responsibility the supervision of the Contractor's work, the receiving of finished works, approval of payments, et cetera."

"If the Bank that provides the external finance requires foreign Consultants be engaged, the Bank will depend on the Management, having direct relationship with the office of National Supervision and through that office to the Contractors."

"It is recommended that the works be accomplished by international bidding, but in such a manner that in different lines of the works the opportunity may be given to national firms to participate in the competition with foreign firms. Also this procedure may reduce the cost of the total project."

"The National Supervisory personnel would be named by the INFOM, which would also carry out the functions of Administrative Superior qualification of bidders contract assignments, et cetera. All of the rules relative to the organization proposed will naturally have to be studied by the INFOM, in accordance with the administrative regulations and with the agreements to be signed."

"16.3 ADMINISTRATION AND OPERATIONS OF THE NATIONAL XAYA-PIXCAYA AQUEDUCT SYSTEM

"The National Xaya-Pixcaya aqueduct plan has several well-defined stages. In the first one, studied here, the contribution of 56 million liters daily (28,000 pajas) of the minimum flow of Pixcaya River will serve only the Metropolitan Area of Guatemala City. In future stages the total Project flow, that is 200 million liters daily (100,000 pajas), will benefit the Metropolitan Area of Antigua Guatemala also and other communities of the valley."

"The previous division was principally based on the priority of attention that the immediate necessities has in the urban nucleus, as they show an increased potable water demand. The requirements of the Metropolitan Area of Guatemala City are much higher due to the high population growth rate and to its major industrial development; therefore, much more urgency is demanded."

"As a corollary of the above a similar division in the phases of operation and administration of the National Aqueduct system when the structure is finished is proposed. In other words the administrative and operation aspects of the first stage and of the later stages must be considered separately."

"As far as the administrative aspects of the first stage it is possible to give only a general outline but only as recommendations for consideration."

"Since at the present time a technical-administrative agency for the water service exists that can be remodeled adequately to the new operation requirements."

"But the administrative aspects of the National Aqueduct of the Antigua Guatemala Valley that corresponds to future stages will require detailed studies about organization in order to function harmoniously with the general administrative system; therefore, it is only possible in the present study to give general suggestions that could serve as a base to the necessary studies."

"In all cases, the organization plans proposed above are only tentative and must be subject to the consideration and approval of the entities and organizations involved."

"16.3 1. SERVICE TO THE METROPOLITAN AREA OF GUATEMALA CITY IN THE FIRST STAGE OF THE PROJECT"

"ADMINISTRATIVE ASPECTS OF THE ACTUAL SYSTEM"

"As a necessary step previous to study the Administration and operation of the Xaya-Pixcaya National Aqueduct system, it must be known how the organization in charge of the administration of the major part of the water supply that serves the Metropolitan Area operates."

"As mentioned in Chapter II of Volume I, the public water supply systems serving the Capital of the Republic are handled by two organizations: El Mariscal, a private enterprise, and the Municipality of Guatemala City. Both have separate sources, installations and distribution networks. The Mariscal Company is not considered in this study, as this study is only interested in the organizational aspects mentioned here of the Municipal System, which will be the one to benefit from the water supplied by the National Aqueduct."

"The office directly in charge of the water system within the Municipality of Guatemala is the Direction of Water and Drainage, one of the departments that form the Municipal Organization, and that stem from the Mayor (Alcaldia). The revenues and expenses of water service are provided through a common municipal fund, which gives very little administrative and financial freedom. The charges to public services that could be earned from the water supply service - and that come up to Q.200,000 per year are lost in the total municipal revenue, from which each year, budget assignments are prepared to cover the needs of all departments. Thus, the normal operation of the water supply system is frequently harmed due to monetary needs caused by the limitations and irregularities on these assignments and for delays of an administrative nature."

"In the first stage of his report, Engr. Ribeiro makes a general comment on the organization, indicating that he believes it is not normal that the sewerage service belongs to another department, instead of being incorporated in with the potable water service. He summarizes the defects of the organization in four parts, as follows:

a. Certain chiefs without specific duties.
b. Many sections performing the work corresponding to others, due to the lack of engineers.
c. Services not being performed because of the lack of personnel and of adequate installations.
d. Technical activities that are not under the engineers' supervision."

"He also mentions the relation between low salaries and the loss of experienced personnel; the inefficiency of the purchasing system, causing delays on the constructions and on the quality of the service; and the studies performed by the DAD personnel to correct the organization. He concludes that his analysis of the situation shows only one fault, that causes the rest: the lack of administrative and financial freedom. He recommends that to begin big projects, a new organization is necessary, starting from the fundamental principle of autonomy."

"In the second part of his report, Engr. Ribeiro proposes that such an organization be created in the form of a Municipal Enterprise, under a Directors Council, headed by the Mayor and consisting of representatives from the pertinent agencies of the city, assigned by representative entities. It is suggested to transform the Direction of Waters into an autonomous Municipal Organization, without modifications in the administrative aspects but in the financial, in order to have the revenues more readily available and to be able to handle them freely."

"The Organization Chart shows the structure of the proposed Enterprise, which includes: One Manager subordinate to the Board of Directors, who would direct three Sub-Directions divided in departments and these in Sections, as follows:

"1. The Technical Sub-Direction: would have in its charge the following Departments:"

"a. The Planning Department, with three technical sections respectively named Section of Basic Studies (organization, statistics and rules); Estimate and Design Section (distribution networks design, structures, housing water installations and outlets budgets) and New Introductions Section (hydrology, topography, reservoirs, conveyances, purification plants and potable water, pumping and outlets studies)."

"b. The House Connection Installations Department, with three specialized sections: Meter Section (reception, sale, lecture, repair,

situation, et cetera); House Connections Installations Section (drill, connections, maintenance, substitutions, flows, demands, et cetera); Internal House Connections Section (approval and financing of water and outlet installations, dangerous interconnections investigations, et cetera)."

"c. Treatment and Operation Department, with three technical sections: Plants and Aqueduct Section (intake inspection, aqueduct, treatment and pumping plants, distribution tanks); Laboratory Section (water and outlets analysis), shops, storage and Communication Section, (mechanic, electricity, iron works, carpentry, storage of water and sewerage materials, garage, vehicles maintenance, radio-communication system)."

"d. Maintenance and New Structures Department, with two technical sections: the Technical Section of Installation and Maintenance of Pipes; containing two specialized sections (the Installation and Maintenance-Water Pipes and the Installation and Maintenance of Outlet Pipes); and the Technical Sections of Civil Structures and Maintenance (tanks construction, buildings structures receipts of contracts)."

"e. The Sewerage Department, that would be created after the transference of the Sewerage Service to the Direction of Waters; it would absorb the functions of the above mentioned sections in (d) and would have two specialized sections; the Sewer and Sewerage Section (sewage, collecting nets, maintenance), and the Section of Treatment and Pumping Plant."

"II The Administrative Sub-Direction would have at its charge no technical sections, as follows: Section of Resources (distribution of internal and external resources, typing for all the sectors, filing); Public Relations Section (public information, visitors reception, newspaper, radio and television); Personnel and Materials Section (admission, dismiss, assistance, punishments, purchase and stock control); Costs Section (service accounts, unit costs, data provided to the Municipality); Finance Section (shown with two alternatives, to be created a Water Company or to be organized an autonomous water department among the Municipality; and would have bookkeeping functions, budgets, rates, expense accounts, accounts, payments and treasury)."

"III Among the organization plan, Engr. Ribeiro also includes a NEW INTRODUCTION SUB-DIRECTION, specifically planned for the structures of the Pixcaya Project of the Municipality, with five departments: (intakes, conveyance, treatment plant, tunnels and bookkeeping) and two Sections (purchase and sellers, and personnel expenditures)."

"1. The including of this Sub-Directions in Engr. Ribeiro's Report is because it was presented in June 1963, two months before the Municipal Council resolved to delegate to the Ministry of Defense the definite studies of the Xaya-Pixcaya Project."

The Consultant learned that efforts are underway to establish the Water Department (DAD) as an autonomous agency of the Municipality. Thinking at this stage proposes a Board of Directors - probably seven members - with the Mayor as chairman. One member would be a bank official, probably of the Bank of Guatemala, another an attorney. Funds of the DAD would be separate from those of the Municipality. Actual direction of the activities of the Water Department would be vested in a general manager directly responsible to the Board of Directors.

While it should be emphasized that little progress on the suggested reorganization has been made, the fact that constructive thinking is being done is worthy of note. This comment applies equally to the plans of the Army and the Municipality.

As mentioned in other parts of this study, several small additions to the city's water system have been completed during the past six years and several more small additions are either at the construction stages or are being planned to bridge the gap until the larger Xaya-Pixcaya Project can be completed. Additional water treatment facilities and extensions and improvements to the water distribution system are parts of the expansion program. As a result, the maintenance and operating staff of the municipality has gradually increased, though probably not always to the desired or required degree.

A major feature of the Project as proposed in both plans, is improvement and expansion of the distribution network at a cost of about 1 1/2 to

2 million quetzales. Both plans propose construction of a new or additional water treatment plant costing between one and 1 1/2 million quetzales. The suggested financial plans in each case contain reasonable allowances for the additional costs of manpower, materials and transportation in order to provide a proper level of maintenance for the new system when completed.

The Municipality has an advantage in that it has a nucleus in an operating organization which can be expanded. On the other hand, there can be an advantage in the Army plan by being able to start from scratch, selecting qualified men to form the new organization without having to work around "deadwood" that nearly always exists in an old organization. This advantage would have to be based on the assumption that there exists an adequate supply of personnel skilled and trained in water treatment plant operation and distribution system maintenance and operation. That an adequate supply of such personnel is available is questioned. In either case it is very probable that there is need of a training program for treatment plant operators. Such a program could be initiated during the period of construction.

The proposal of the Municipality of Guatemala (DAD) contemplates water service only to that municipality but includes provision of sufficient supply to serve nearby municipalities which may annex in the future.

Figure No. 15 shows the present position of the Department of Water and Drainage (DAD) in the overall organization of the Municipality. Figure

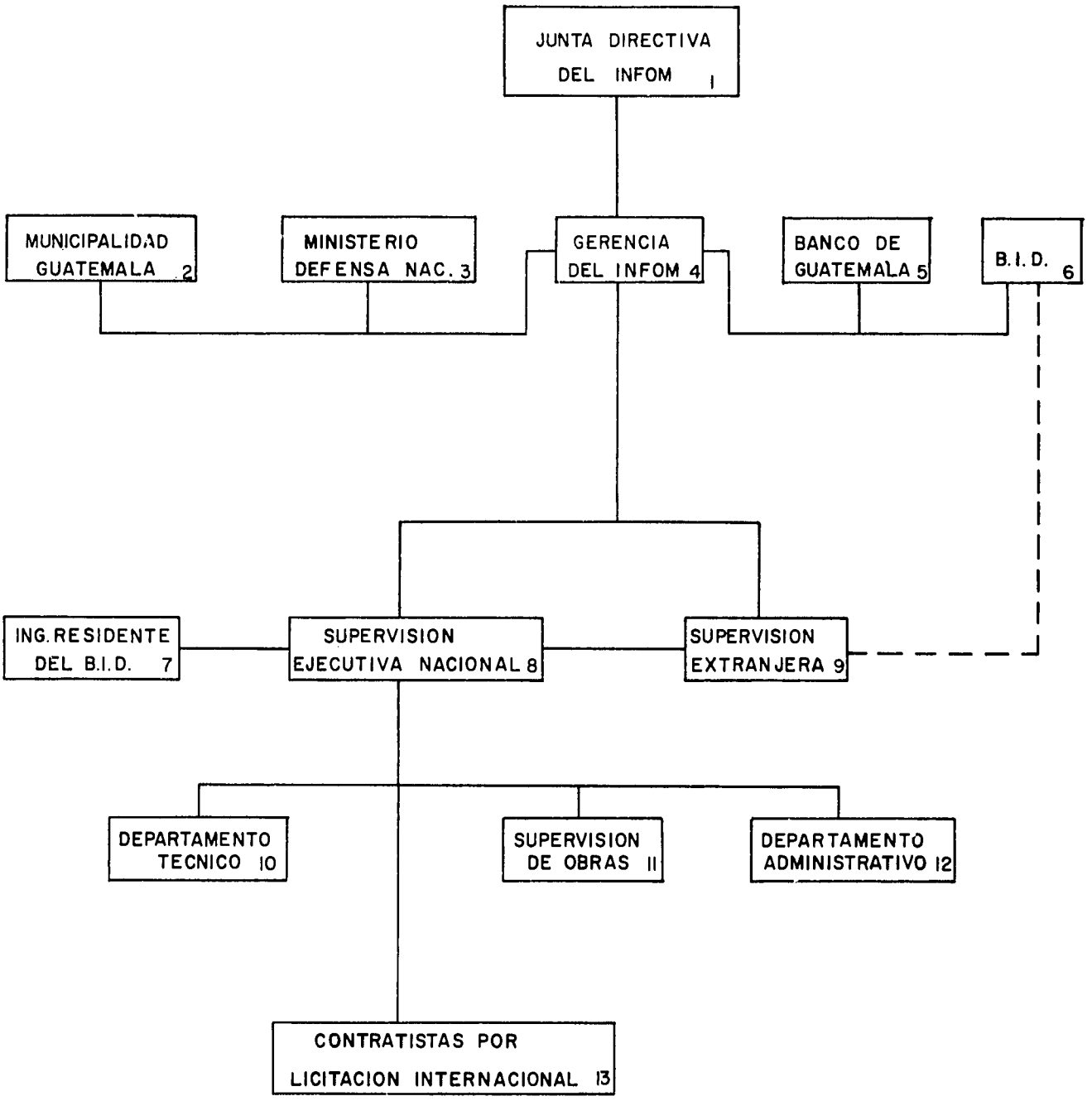
No. 16 shows the form of organization of DAD as of September 1964 to the present. Figure No. 17 shows the form or organization recommended to the Mayor and Council for approval in October 1967. A major change is the provision of two new positions in order to assist the Assistant Director responsible for Technical Direction and an improvement in grouping of personnel engaged in planning, design and construction, and operations and maintenance.

The work of this Department has been increasing recently. Planning and construction of additional water supplies and improvements to the water distribution network and water treatment facilities are the major areas of activity.

The details of the revised organization of the DAD are contained in their report, "Revised Organization of the Department of Water and Drainages of October 1967".

EJECUION del ACUEDUCTO NACIONAL

IMPLIMENTATION CHART FOR ACUEDUCTO NACIONAL



1 INFOM BOARD OF DIRECTORS
2 MUNICIPALITY OF GUATEMALA
3 MINISTRY OF NATIONAL DEFENSE
4 GENERAL MANAGER INFOM
5 BANK OF GUATEMALA
6 INTER-AMERICAN DEVELOPMENT BANK
7 RESIDENT ENGINEER INTER-AMERICAN DEVELOPMENT BANK
8 NATIONAL SUPERVISION
9 FOREIGN SUPERVISION
10 TECHNICAL DEPARTMENT
11 SUPERVISION OF CONSTRUCTION
12 ADMINISTRATIVE DEPARTMENT
13 CONTRACTORS BY INTERNATIONAL BIDDING

TOMADO DE: INFORME DE PREINVERSION DEL M.D.N. 1966
FROM: PREINVESTMENT REPORT BY M.D.N. 1966

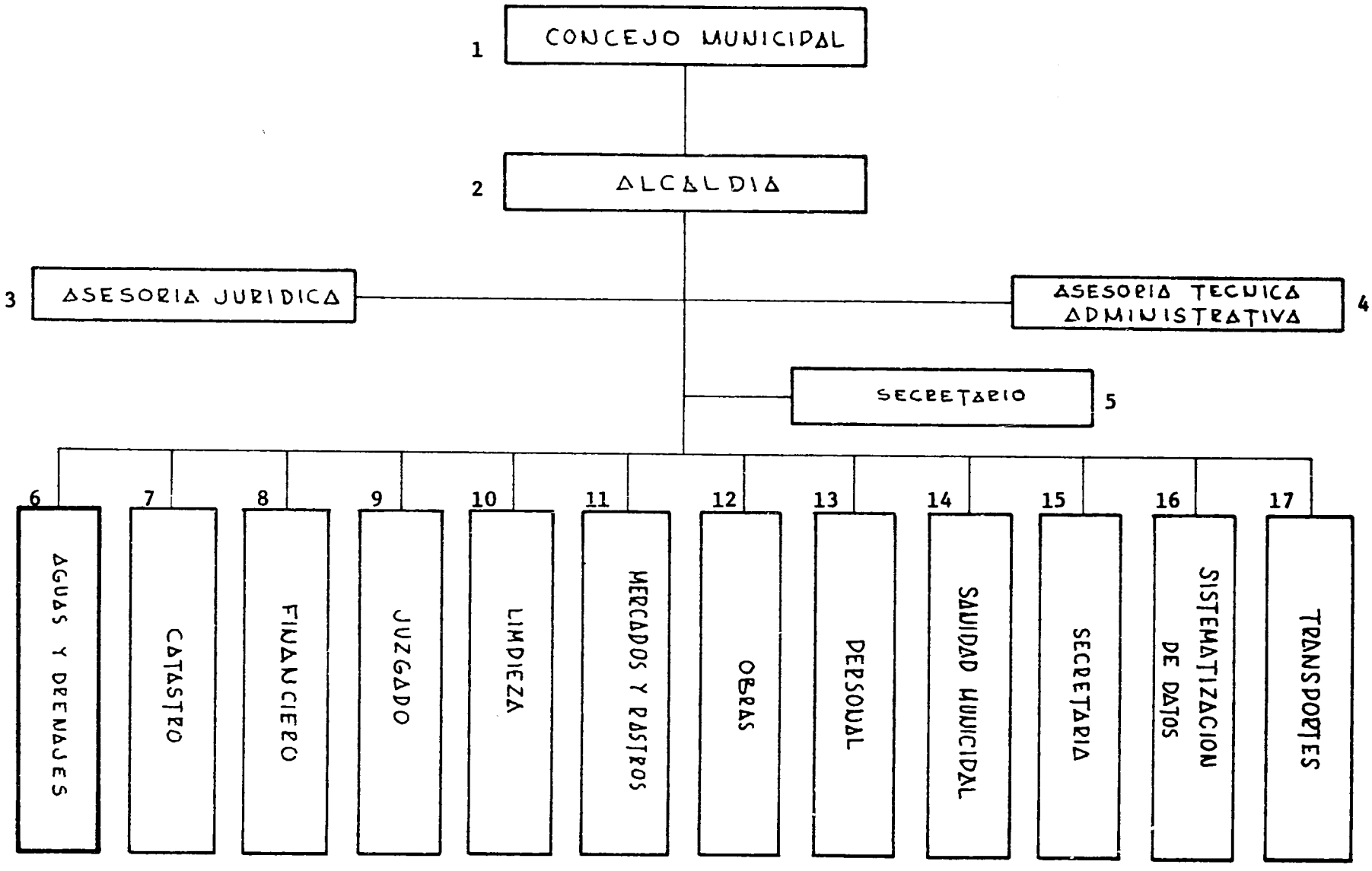
ORGANIZATION CHART OF THE

MUNICIPALITY

1. Municipal Council
2. Mayor
3. Legal Advisor
4. Technical and Administrative Advisor
5. Secretary
6. Water and Drainage
7. Tax Assessment
8. Finance
9. Justice
10. Sanitation
11. Markets
12. Public Works
13. Personnel
14. Public Health
15. City Clerk
16. Data Processing
17. Transportation

ORGANOGRAMA DE LA MUNICIPALIDAD

Figure No. 15

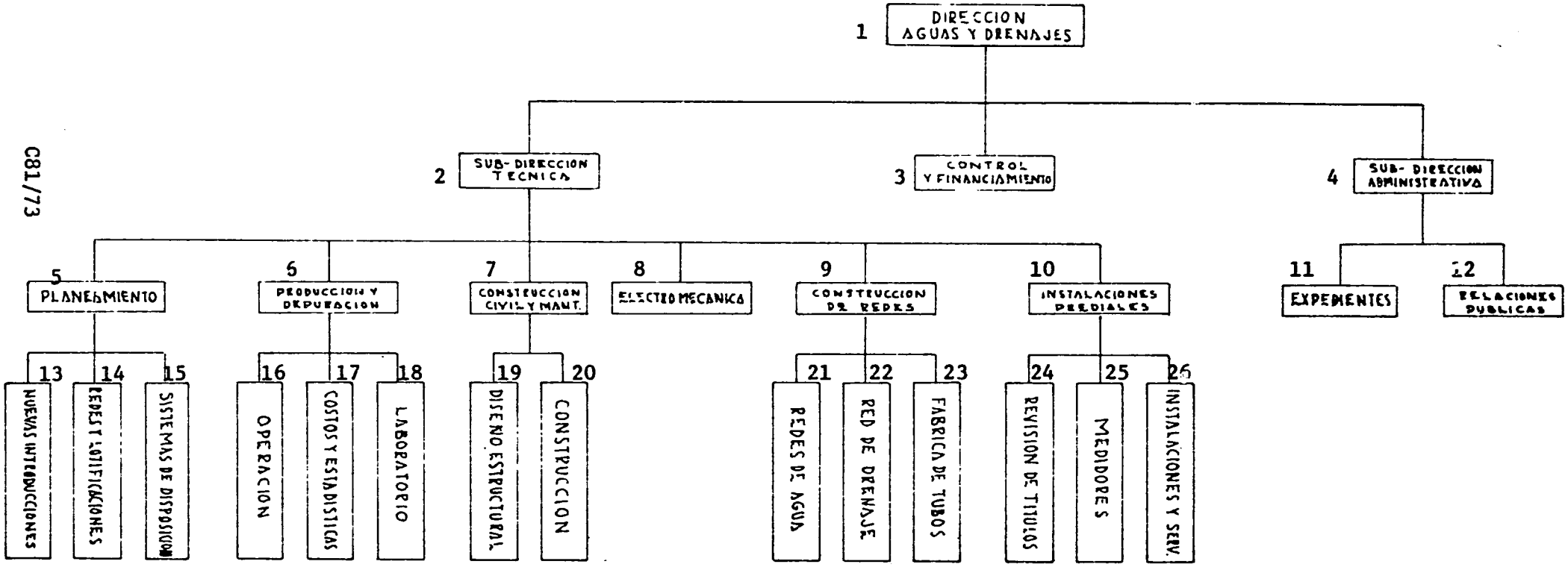


ORGANIZATION CHART OF THE DEPARTMENT OF WATER AND DRAINAGE (SEPTEMBER 1964)

1. Department of Water and Drainage
2. Assistant Manager - Technical
3. Financial Control
4. Assistant Manager - Administrative
5. Planning
6. Treatment and Production
7. Construction and Maintenance
8. Electrical and Mechanical
9. Construction of Distribution System
10. Installation of Water Services
11. Complaints and Records
12. Public Relations
13. New Supplies
14. Distribution Expansion
15. Sewage Disposal
16. Operations
17. Costs and Statistics
18. Laboratory
19. Structural Design
20. Construction
21. Water Distribution
22. Drainage System
23. Concrete Pipe Fabrication
24. Registry of Titles
25. Water Meters
26. Installations and Services

ORGANOGRAMA DE LA DIRECCION DE AGUAS Y DRENAJES

Figure No. 16



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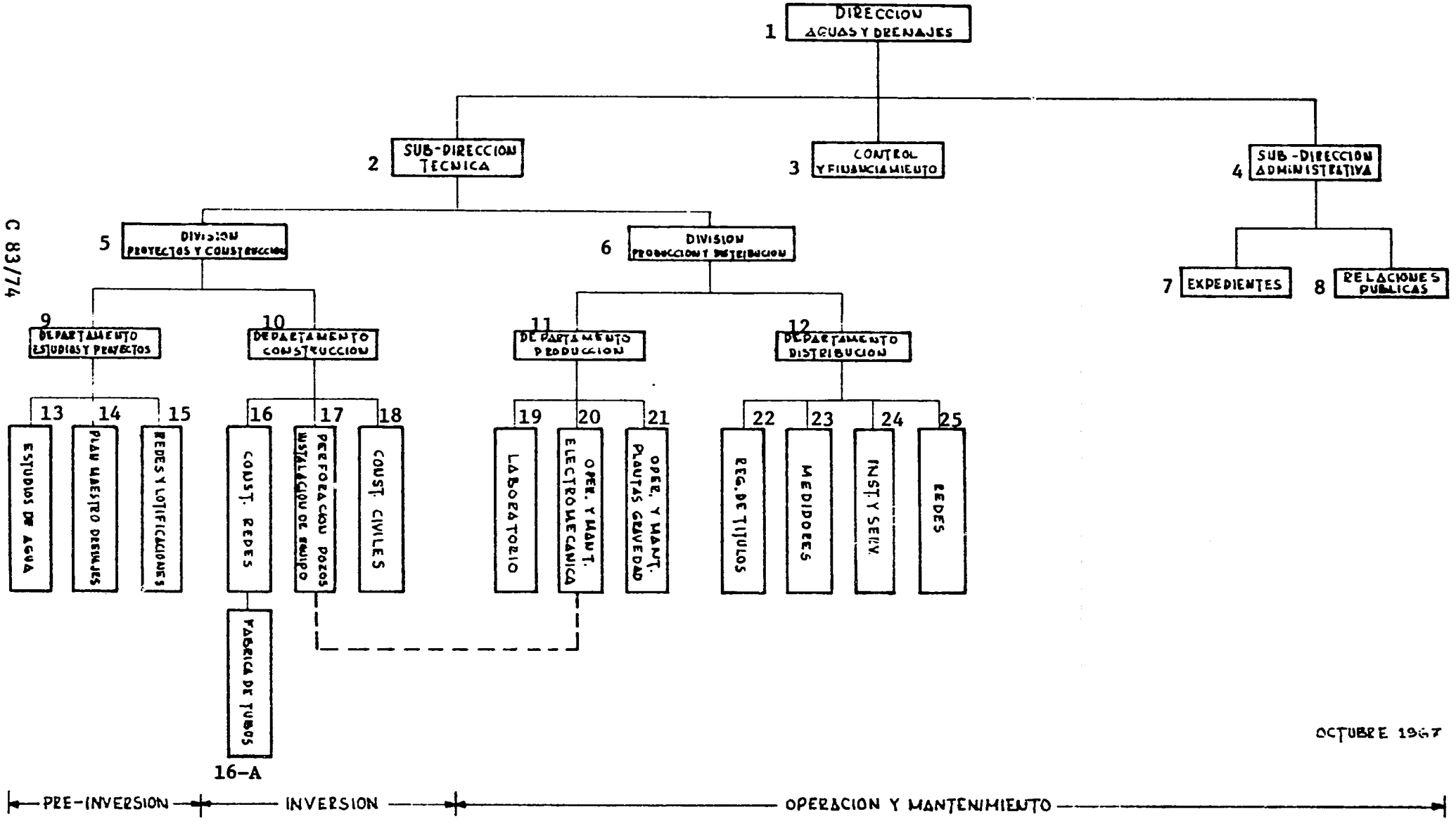
ORGANIZATION CHART OF THE DEPARTMENT OF

WATER AND DRAINAGE
(OCTOBER 1967)

1. Department of Water and Drainage
2. Assistant Manager - Technical
3. Financial Control
4. Assistant Manager - Administrative
5. Design and Construction Division
6. Production and Distribution Division
7. Complaints and Records
8. Public Relations
9. Planning and Design Department
10. Consuruction Department
11. Production Department
12. Distribution Department
13. Water Supply Studies
14. Sewerage Master Planning
15. Distribution Expansion
16. Construction and Distribution System
16A. Concrete Pipe Fabrication
17. Well Drilling and Pumping
18. Construction
19. Laboratory
20. Operation and Maintenance - Electrical and Mechanical
21. Operation and Maintenance - Treatment Plants
22. Registry of Titles
23. Water Meters
24. Installation and Services
25. Distribution System

ORGANOGRAMA DE LA DIRECCION DE AGUAS Y DRENAJES

Figure No. 17



OCTUBRE 1967

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C.11 LONG RANGE PLANNING FOR FUTURE WATER SUPPLIES

The cost of this Project represents a considerable sum of money. Naturally the Consultant, in the early stages of his study, was interested to know the date at which this Project would meet the potable water supply needs of the community or communities it is to serve.

It was noted that the Army (MDN) plan calls for construction of the first phase of the Project to be completed about January 1972, and to produce 56 MLD which would meet the demands of Guatemala City for five years - to 1977. By that date, the MDN proposed that the second phase would be completed. This second phase, involving one or more storage reservoirs on the Xaya River, would produce an additional 63 MLD. See Figure No. 10.

The construction of additional dams and reservoirs in the third and fourth phases, would bring the total of water from the four phases of the Project to a total of 200 MLD. The needs of Guatemala City, according to the MDN Report would be met until 1985. This is only 13 years after the first phase of the Project would go into operation. (Refer to Plan No. 009, Page 101, Volume I of the MDN Report). The expected cost of the four phases approximates Q.23 million.

The other report was made by the Municipality Department of Water and Drainage (DAD) in 1961. It is called, "Proyecto Pixcaya". It planned that the first phase of construction would be completed by January 1965, the third phase being completed by January 1969. These three phases would

supply 100 MLD, without dam and reservoir construction. The DAD plan estimated the demand to be met until 1974, a total of nine years. In the Municipality Report on the chart on Page 13, Volume I, it is indicated that the headwaters of the Motagua River would (might be) tapped in 1980 for additional supplies. On Page 20, Volume I, it is indicated that DAD planned to obtain an additional supply of 30 MLD beyond the 100 MLD from construction of a dam and reservoir on either the Xaya or Pixcaya Rivers. No mention is made in that section about utilizing the Motagua River.

Both the geologist and the hydrologist employed by the Consultant reported that the feasibility of dam and reservoir construction on the Xaya and Pixcaya Rivers in the study area was very doubtful. The Engineering Coordinator for the Army on this Project, Ing. Hector Quezada R. and the Director, Department of Water and Drainage of the Municipality, Ing. Kenneth Toppe, were asked by the Consultant what the plans of their organizations were for a water supply to serve Guatemala City at least until 1988 if engineering studies showed that reservoir construction as a part of this Project was not feasible.

In answering, the Army proposed to pump from Lake Atitlan, conveying the water to the proposed intake on the Xaya River, from whence the water could be conducted through the acqueduct proposed by the Army. The Municipality proposes to submit preliminary studies, showing that the acqueduct from the headwaters of the Motagua River will bring water by gravity to connect with its Xaya-Pixcaya Project at a point about 28 kilometers from the treatment plant located at La Brigada.

With these assurances of future water supply sources, the Consultant believes the Project can be fully justified. Without this, serious questions as to the merit of the Project could be asked.

Figures Nos. 9 and 12 show the various stages and dates of completion of construction of each including the water demand as suggested by the Consultant.

It may be noted that the Municipality could utilize Lake Atitlan by pumping in the same manner suggested by the Army.

Preliminary economic studies made by the Consultant indicate that at the present cost of power, the Motagua proposal would be more economical, particularly if INDE proceeds to develop Lake Atitlan to its maximum hydroelectric capacity. The Instituto Nacional de Electrificación (INDE) has plans to begin development of electric power from Lake Atitlan. Lowering the existing level of the water in Lake Atitlan is presently against national policy and it is doubtful that this policy will be changed in the near future. To solve this restriction INDE plans to divert several rivers into the lake to offset the withdrawals they make to generate power. INDE's action, which now seems probable, would shorten the life of any water supply installation to supply Guatemala City from Lake Atitlan.

The plan to withdraw water from the lake to augment the supply to Guatemala City involves a pumping lift of about 500 meters from the Lake. This plan, although it has large power requirements, can be supplemented by withdrawals from the Madre Vieja River with a pumping lift of about 315 meters.

Besides the cost of power, the limiting factor would be the rate of development by INDE and resultant increase in withdrawal of water from Lake Atitlan - which at some stage would stop the withdrawal of water from the Lake and from Madre Vieja River for diversion to Guatemala City.

Current studies by the Municipality, as delineated on Figure No. 11, propose to bring water from the headwaters of the Motagua River into the Xaya-Pixcaya acqueduct by phases as required by extending the acqueduct to the west. This source is estimated to supply 160 MLD.

Further planning by the Municipality would involve tapping the headwaters of Rio Negro to supply an additional 100 MLD. This would not be a very costly project since it would only be necessary to extend the Motagua acqueduct a relatively short distance. Next it is proposed to pick up water from Rio Cuilco and its basin, estimated to provide 160 MLD.

All of the above supplies can be conveyed to Guatemala City by gravity, according to present preliminary studies. Sufficient capacity in the aqueduct would be required. Care in design planning should be taken to assure economical designs in the lower reaches of the aqueduct.

The DAD plans to obtain ultimately 500,000 pajas from the Motagua route with its extension to the Negro, San Juan and Cuilco Rivers. Half the supply would be by gravity and half would involve pumping as shown in the accompanying Figure No. 18.

It should be noted that in Figure No. 18 is also shown a scheme for pumping water from the Pixcaya River at the junction with the Sactzi River. This is presented as a better alternative to pumping water from Lake Atitlan and/or Madre Vieja River.

Figure 18 also shows the basins for the following short range projects: Nor Oriental, Sur Oriental and Teocinte III.

The Municipality's project plans tunnel capacity from the point where the futrue Motagua project would enter the Xaya-Pixcaya aqueduct to the La Brigada treatment plant of 1,650 L/sec. While this capacity is sufficient to meet requirements of the Xaya-Pixcaya Project, consideration should be given when final design may be undertaken of the economic desirability of constructing larger tunnel capacity in this particular length of aqueduct.

Capacity of the major tunnels in the Army's (MDN) plan is 3,000 to 3,300 L/sec providing tunnel capacity for some of the future water supply requirements. Actually this size is dictated by the method of tunnel construction required for the MDN route.

TRANSLATION FOR FIGURE No. 18

MUNICIPALITY OF GUATEMALA CITY-WATER AND DRAINAGE DEPARTMENT
INTEGRAL PROGRAM FOR WATER SUPPLY TO THE
CITY OF GUATEMALA (500,000 pajas)

Carretera Panamericana	Inter-american Highway
Carreteras y caminos	Highways and dirt roads
Divisoria de cuenca	Basin Division-primary
Divisoria secundaria	Basin Division-Secondary
Acueducto	Aqueduct
rio	river
lines ferrea	railroad
Cuenca Xenacoj-Xaya	Xenacoj-Xaya-Pixcaya
Pixcaya	Basin
Cuenca Motagua	Motagua Basin
Cuenca Negro (gravedad)	Negro Basin (gravity)
Cuenca Cuilco	Cuilco Basin
Ceunca Negro (bombeo)	Cuenca Negro (pumping)

Note: Vertical solid lines indicate Pixcaya-Sactzi.

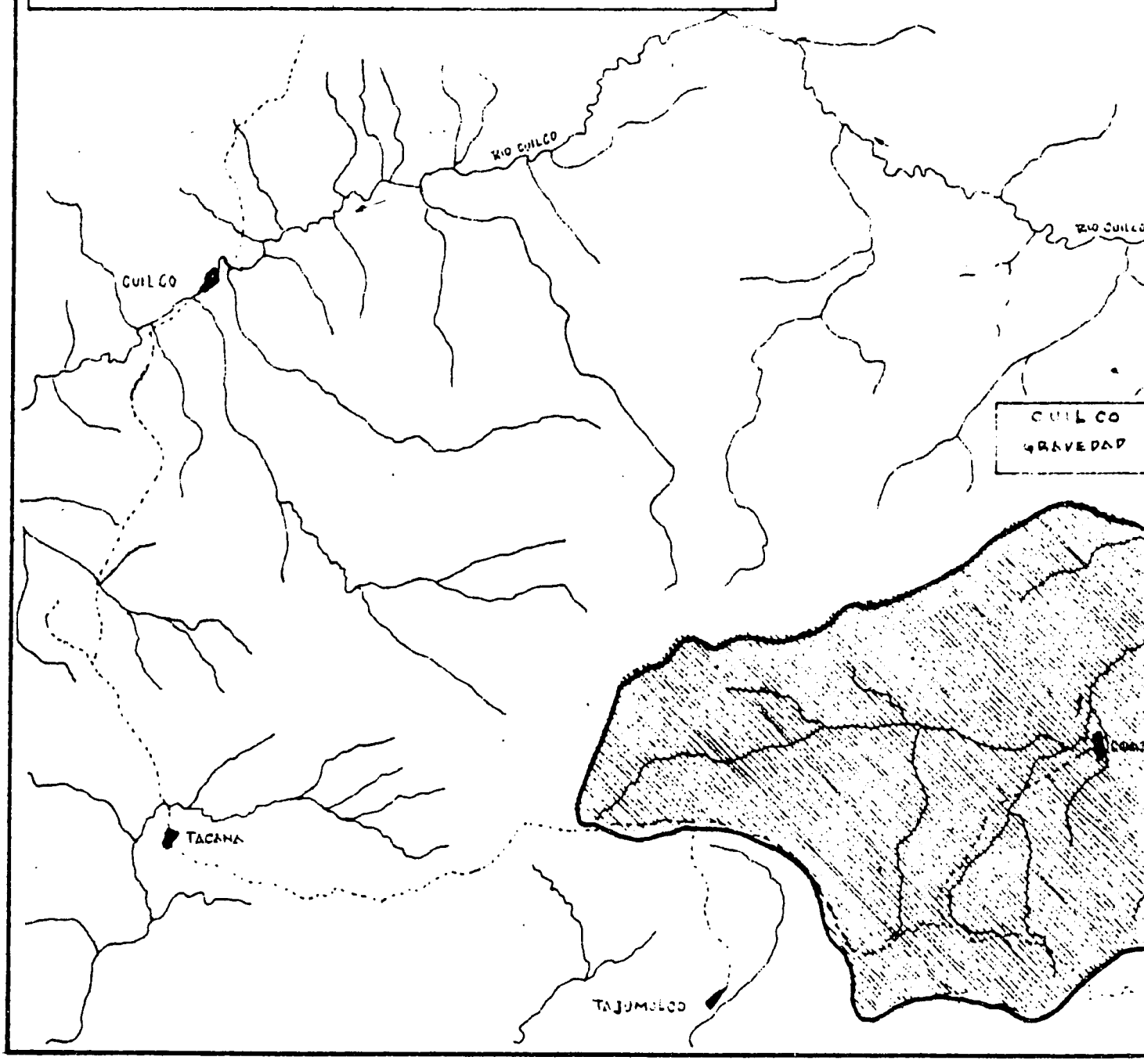
MUNICIPALITY OF GUATEMALA CITY-WATER AND DRAINAGE DEPARTMENT
INTEGRAL PROGRAM FOR WATER SUPPLY TO THE
CITY OF GUATEMALA (500,000 pajas)

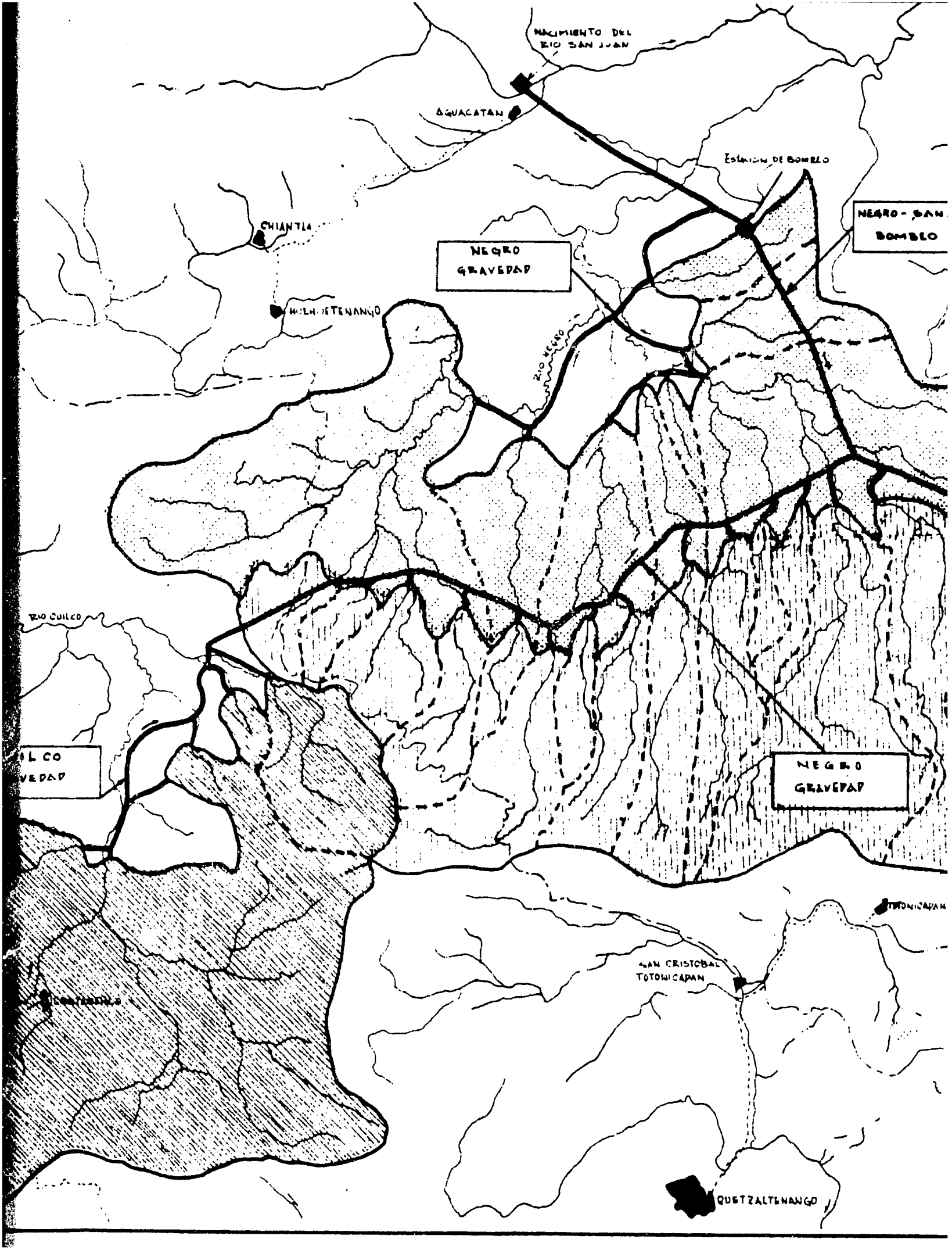
Aqueduct	Gravity (G) Pumping (B)	Gaged (A) Estimated (E)	Flow (Pajas)
Xenacoj-Xaya-Pixcaya	G	A	50,000
Motagua	G	A	70,000
Negro (gravity)	G	E	50,000
Cuilco	G	E	80,000
San Juan	B	A	150,000
Negro (pumping)	B	E	100,000
			500,000

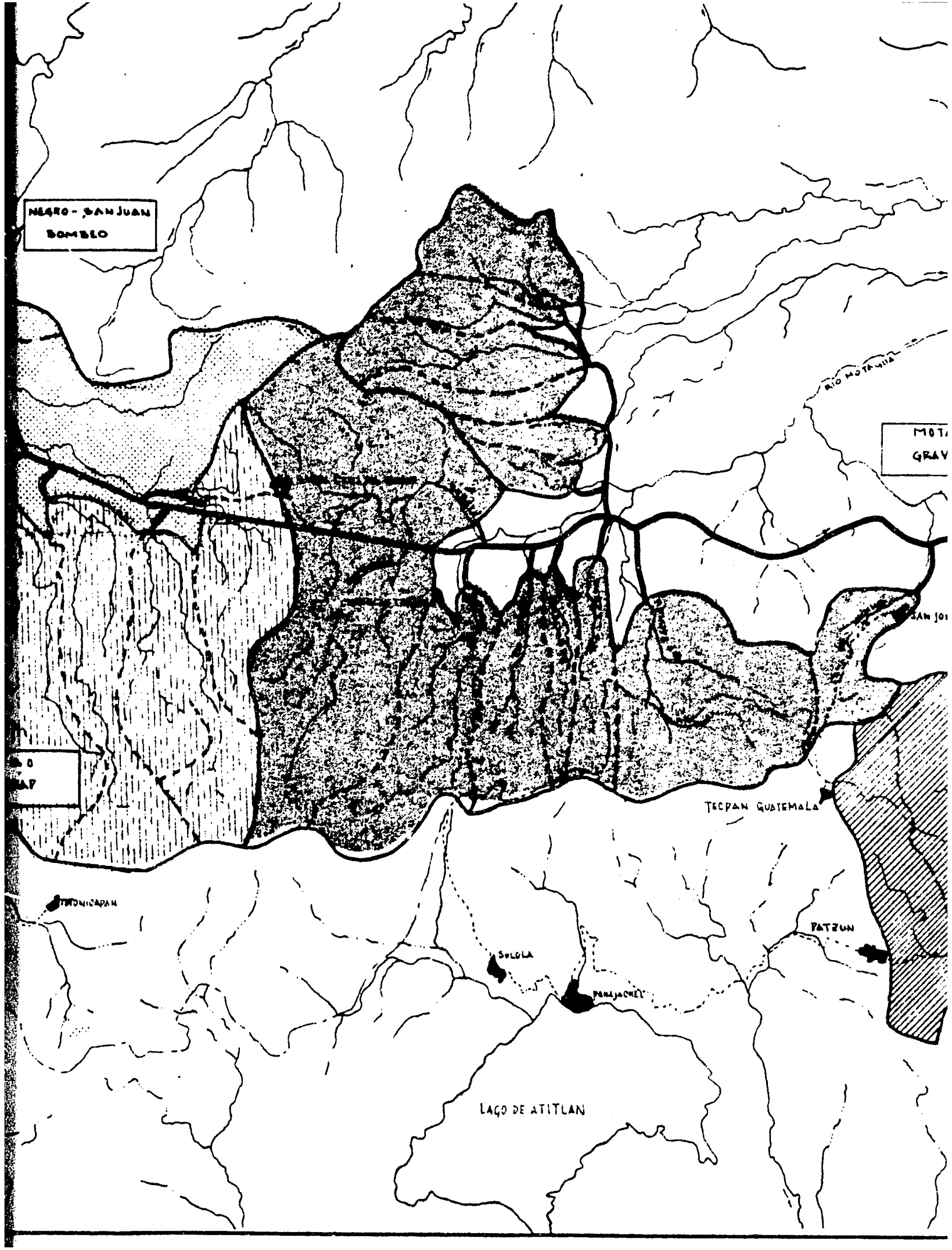
AQUEDUCT BY GRAVITY	250,000 pajas	50%
AQUEDUCT BY PUMPING	250,000 pajas	50%
	500,000 pajas	100%

PROGRAMA INTEGRAL DE ABASTECIMIENTO DE AGUA POTABLE A LA CIUDAD DE GUATEMALA

ACUEDUCTO	GRAVEDAD (G) BOMBEO (B)	AFORADO (A) ESTIMADO (E)	CAUDAL (pajas)
XENACOJ-XAYÁ-PIXCAYÁ	G	A	50.000
MOTAGUA	G	A	70.000
NEGRO (GRAVEDAD)	G	E	50 000
CUILCO	G	E	80 000
SAN JUAN	B	A	150.000
NEGRO (BOMBEO)	B	E	100 000
			500 000
ACUEDUCTO POR GRAVEDAD		250 000 pajas	50 %
ACUEDUCTO POR BOMBEO		250 000 pajas	50 %
		500 000 pajas	100 %




NACIMIENTO DEL RIO SAN JUAN
AGUACATAN
ESTACION DE BOMBEO
CHIANTLA
NEGRO - SAN
BOMBEO
NEGRO
GRAVEDAD
RIO NEGRO
RIO CUILCO
NEGRO
GRAVEDAD
SAN CRISTOBAL
TOTONICAPAN
QUETZALTENANGO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RIO MOTAGUA
TECPAN GUATEMALA
PATZUN
SOLOLA
PANAJACHEL
LAGO DE ATITLAN

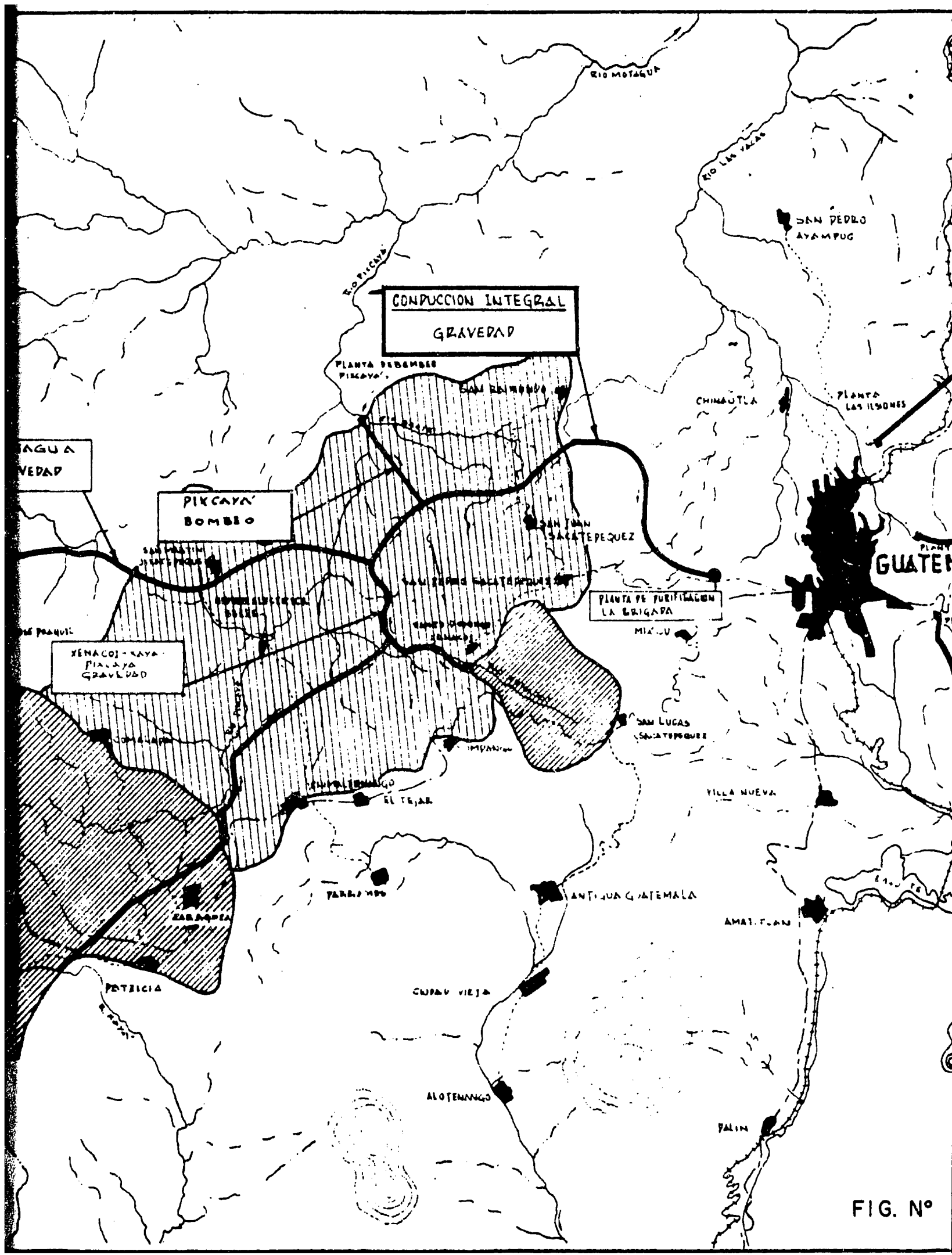
CONDUCCION INTEGRAL
GRAVEDAD
PIKCAYA
BOMBEO
XENACOJ - CAYA
PIKCAYA
GRAVEDAD
PLANTA DE PURIFICACION
LA BRIGADA
SAN PEDRO
AYAMPUC
CHINAUTLA
PLANTA
LAS ILUSIONES
SAN JUAN
SACATEPEQUEZ
SAN LUCAS
SACATEPEQUEZ
EL TEJAR
VILLA NUEVA
ANTIGUA GUATEMALA
AMATITLAN
PALIN
ALOTENANGO
CIUDAD VIEJA
PATZICIA
RIO MOTAGUA
RIO LAS VACAS
RIO PIKCAYA

FIG. Nº

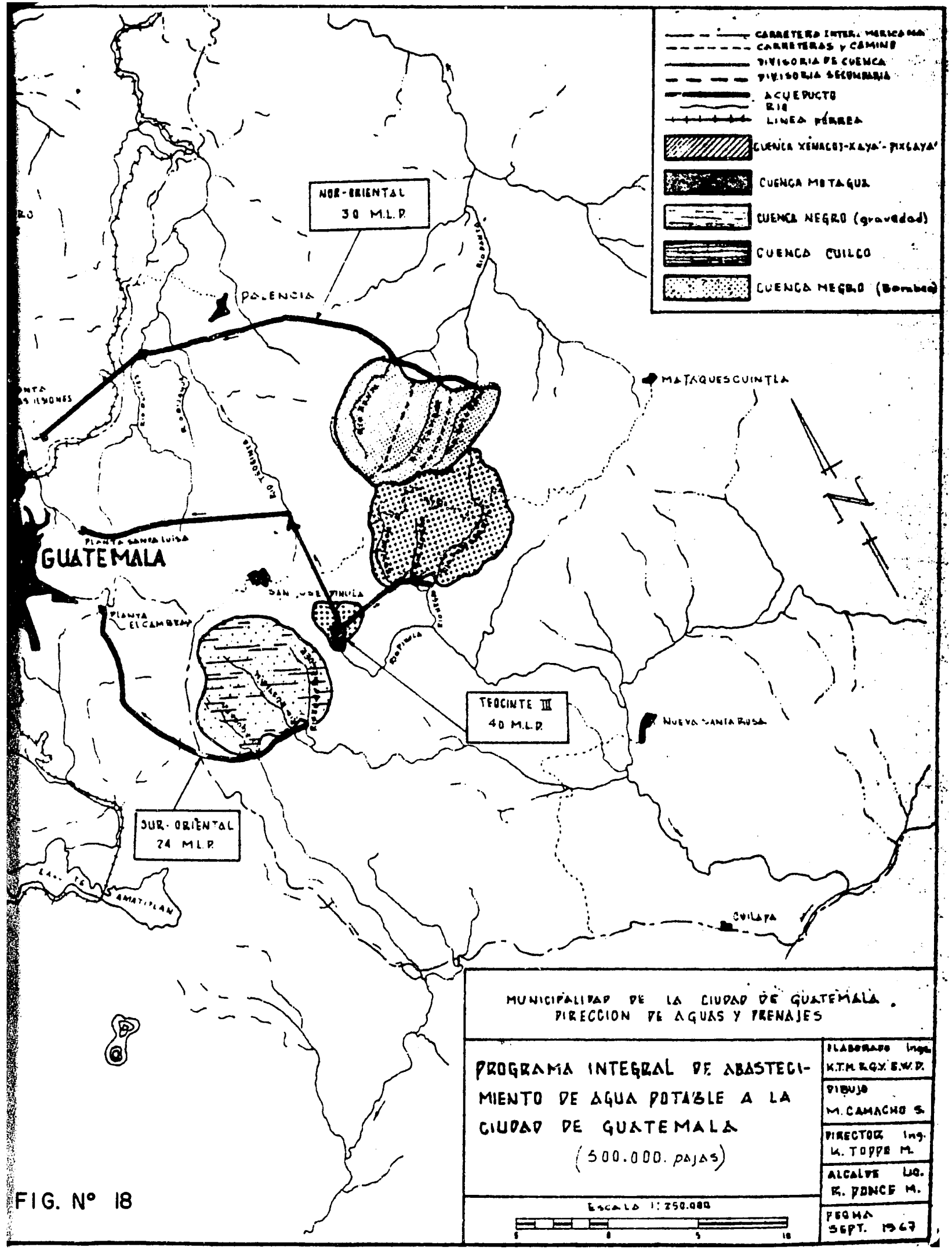
CARRETERA INTER. AMERICANA
CARRETERAS Y CAMINOS
DIVISORIA DE CUENCA
DIVISORIA SECUNDARIA
ACUEDUCTO
RIO
LINEA FERREA
CUENCA XEMACHI-KAYA'-PIXCAYA'
CUENCA MOTAGUA
CUENCA NEGRO (gravedad)
CUENCA CUILCO
CUENCA NEGRO (Bombeo)
NOR-ORIENTAL
30 M.L.P.
PALENCIA
MATAQUESCUINTLA
GUATEMALA
PLANTA SANTA LUISA
SAN JOSE PINULA
PLANTA EL CAMBRAY
TEOCINTE III
40 M.L.P.
NUEVA SANTA ROSA
SUR-ORIENTAL
24 M.L.P.
AMATITLAN
CUILAPA
MUNICIPALIDAD DE LA CIUDAD DE GUATEMALA
DIRECCION DE AGUAS Y DRENAJES
PROGRAMA INTEGRAL DE ABASTECIMIENTO DE AGUA POTABLE A LA CIUDAD DE GUATEMALA
(500.000. pajas)
ELABORADO Ings. K.T.M. R.G.Y. E.W.D.
DIBUJO M. CAMACHO S.
DIRECTOR Ing. K. TOPPE M.
ALCALDE Lic. R. PONCE M.
FECHA SEPT. 1967
ESCALA 1:250.000
5 0 5 10

FIG. Nº 18

D. FINANCIAL ASPECTS

D.1 ESTIMATED CAPITAL COST

a. Cost Estimates for Land, Engineering and Construction

Attached are three tables giving cost estimates for land, engineering and construction items for the first stage Pixcaya - La Brigada. These are listed below:

1. Table No. 106 (MDN)

   This table is contained on page 219 of Vol. II of the MDN report. It gives the estimated cost by MDN for both the MDN and the DAD schemes, totaling $/Q 12,299,600 and $/Q 13,297,200 respectively.

2. Table No. 18

   This gives the costs as estimated by MDN and DAD. The first mentioned are identical with Table No. 106 (MDN). The DAD estimate was compiled by the Consultant from data furnished by DAD.

3. Table No. 19

   This gives the costs as estimated by the Consultant. In the case of the MDN estimate, the only change from Tables 106 (MDN) and 18 has been to add an item of $343,200 ($381,400 including engineering, etc.) for a 30 inch steel pressure pipe to connect the Lo de Coy Treatment Plant with the city distribution system at La Brigada. It is considered that this cost should be included in the MDN estimate to make it properly comparable to the DAD estimate.

The Consultant has increased the DAD estimate by approximately 16-1/2% in order to bring it to a level comparable to the MDN estimate, particularly with respect to unit prices for tunneling. It is possible that the work can be done for the DAD estimate if as much favorable materials as assumed by the DAD are encountered. However, there are some doubts regarding this and the Consultant has taken a conservative attitude in this respect by increasing the DAD costs by an amount sufficient to cover all contingencies which could be expected. A reduction has been made in the amount allowed for indemnity of the hydro-electric plant involved. The DAD estimate was to cover all possible contingencies and avoid lengthy and costly litigation. However, it is believed that the planning proposed by the MDN is adequate. It is to install diesel generators for peak loads in the dry season or to obtain current from the proposed INDE power lines. Actually, DAD considered the MDN methods but preferred to estimate on the most unlikely solution to be on the safe side because of unfortunate similar experiences in the past. The Consultant does not believe it necessary to estimate for such remote possibilities.

TABLE NO. 106

NECESSARY EXPENDITURES ON THE TWO ALTERNATIVES ANALYZED BASED ON SIMILAR UNIT COSTS, TO SERVE THE 28,000 PAJAS OF THE FIRST STAGE

ITEM	MDN QUANTITY	MDN UNIT	MDN UNIT PRICE Q.	MDN TOTAL COST Q.	DAD QUANTITY	DAD UNIT	DAD UNIT PRICE Q.	DAD TOTAL COST Q.
Intake	-	-	-	Q 49,200	-	-	-	49,200
Covered Conduits (Bordeos)	18,750	mts.	61.89	1,160,500	11,346	mts.	Q 55.00	624,000
Tunnels	13,312	mts.	359.62	4,787,200	25,693	mts.	180.00	4,624,700
Siphons	8,470	mts.	153.77	1,302,400	19,814	mts.	150.00	2,972,100
Transition Structures[1]	69	cajas	-	53,900	191	cajas	-	160,000
Treatment Plant[2]	-	-	-	1,660,000	-	-	-	1,675,000[3]
Distribution Systems[2]	-	-	-	1,415,300	-	-	-	1,414,100[4]
Access Roads	32	Km.	5,156.00	165,000	61	Km.	5,100.00	311,100
Right of Way and Land	-	-	-	297,500	-	-	-	58,400
Indemnity	-	-	-	300,000	-	-	-	300,000
Supervision and Administration	-	-	-	1,108,600	-	-	-	1,108,600
TOTALS				12,299,600				13,297,200

1) See Table 105
2) Applicable section for the first stage considered
3) Includes Q.40,000 for power generation and pumping for the high zones
4) From the Municipal Report (it is not known if there are included materials for house connections)

TABLE NO. 18

RENGLON ITEM	UNID. UNIT	MDN CANTIDAD QUANTITY	PRECIO UNIT. UNIT PRICE Q.	COSTO TOTAL TOTAL COST Q.	DAD CANTIDAD QUANTITY	PRECIO UNIT. UNIT PRICE Q.	COSTO TOTAL TOTAL COST Q.
Captaciones Intake	-	-	-	49,200	-	-	77,990.28
Conductos cubiertos Covered conduits (bordeos)	m.	18,750	61.89	1.160,500	3,672	86.73	318,476.86
Tuneles Tunnels	m.	13,312	359.62	4.787,200	31,168	98.18	3.060,213.27
Sifones Siphons	m.	8,470	153.77	1.302,400	12,582	(a) 130.89	1.646,847.34
Estructuras de transicion Transition structures	-	69	-	53,900	-	(b) -	-
Planta de tratamiento Treatment plant	-	-	-	1.660,000	-	-	1.305,917.92
Sistema de distribucion Distribution system	-	-	-	1.415,300	-	-	1.415,300.00
Caminos de Acceso Access roads	km.	32	5,156.00	165,000	56.7	5,000.00	283,500.00
Derecho de via y terreno Right of way and land	-	-	-	297,500	-	-	48,331.50
Campamentos Camps	-	-	(c)-	-	-	-	128,000.00
Remuneracion de indemnizaciones Indemnity compensations	-	-	-	300,000	-	-	946,404.73
Supervision de Ing. administracion Eng. supervision administration	-	-	-	1.108,600	-	-	(d) 799,463.19
				12.299,600			10.030,445.09

a. Estos precios en el estimado de la DAD, incluye el costo de portales y estructuras de Transicion.
These prices in the DAD estimate include the cost of portals and transition structures.
b. Ver nota (a) - See Footnote (a).
c. Este Item en el estimado del MDN esta incluido en el costo de los tuneles.
This item in the MDN estimate is included in the cost of tunnels.
d. Parte de la Supervision de Ingenieros y Administracion es considerado para ser incluido en los items antes mencionados
Part of the Engineering Supervision and Administration is considered to be included in above items.

TABLE NO. 19

RENGLON ITEM	UNID. UNIT	MDN CANTIDAD QUANTITY	MDN PRECIO UNIT. UNIT PRICE Q.	MDN COSTO TOTAL TOTAL COST Q.	DAD CANTIDAD QUANTITY	DAD PRECIO UNIT. UNIT PRICE Q.	DAD COSTO TOTAL TOTAL COST Q.
Captacion Intake	-	-	-	[illegible],200	-	-	78,000
Canales Covered conduits (bordeos)	m.	18,750	61.89	1.160,500	3,672	87.00	319,500
Tuneles Tunnels	m.	13,312	359.62	4.787,200	31,168	165.00	5.142,700
Sifones Siphons	m.	8,470	153.77	1.302,400	12,582	(a) 131.00	1.648,200
Tubos de presion Pressure pipe	m.	3,900	88.00	343,200	-	-	-
Estructuras de transicion Transition structures	-	69	-	53,900	-	(b)-	-
Planta de tratamiento Treatment plant	-	-	-	1.660,000	-	-	1.305,900
Sistema de distribucion Distribution system	-	-	-	1.415,300	-	-	1.415,300
Caminos de acceso Access roads	Km.	32	5,156.00	165,000	56.7	5,000.00	283,500
Derecho de via y terreno Right of way and land	-	-	-	297,500	-	-	48,300
Indemnizacion Indemnity compensation	-	-	-	300,000	-	-	300,000
Supervision de Ing. admin. Eng. supervision, administration	-	-	-	1.146,800	-	-	1.146,800

a) El precio en el estimativo de la DAD incluye el costo de los portales y estructuras de transicion
The price in the DAD estimate includes the cost of portals and transition structures

b) Ver nota a)
See footnote a)

b. Estimated Total Cost in U.S. Dollars and Guatemalan Quetzales

The total estimated cost in dollars and quetzales for each scheme is as follows:

	MDN	DAD
$	6,892,000	5,676,150
Q	5,789,000	6,012,050
Total $/Q	12,681,000	11,688,200

Details on the above are given in Section E.1.a. of this report.

The amounts to be financed by local resources and loans are roughly 30% and 70%, respectively, as indicated below.

	MDN		DAD	
$ Local resources	2,070,000		1,710,000	
$ Loan	4,822,000		3,966,150	
		6,892,000		5,676,150
Q Local resources	1,740,000		1,800,000	
Q loan	4,049,000		4,212,000	
		5,789,000		6,012,000
		12,681,000		11,688,150

D.2 MAINTENANCE AND OPERATION COST

a. Estimated Annual Cost of Operation and Maintenance

b. Comparative Costs

In the MDN report, an estimate is made of the maintenance and operation costs. It includes costs of the Municipality's Water Department for 1965 and projects the costs by year to 1985. Attempts are made in these estimates to recognize the changes in maintenance and operating expenses when new supplies of water become available to the city's system. In order to be conservative, these cost estimates include an addition of 10% of the salaries and then add 25% to the total to allow for fringe benefits and contingencies.

The following Table No. 20 summarizes the MDN estimates for cost of maintenance and operation of the entire water system of the Municipality and endeavors to anticipate the growth of the department.

TABLE NO. 20

MAINTENANCE AND OPERATION COSTS

1965 - 1980 - Prepared by MDN

In Thousands of Quetzales

Year	Production Cost	Distribution	Commercial or Admin.	Total
1965	769.0	153.6	91.7	1,014.3
1966	769.0	153.6	91.7	1,014.3
1967	879.1	156.0	91.7	1,126.8
1968	879.1	156.0	100.7	1,135.8
1969	749.0	167.4	110.6	1,027.0
1970	838.8	167.4	121.0	1,127.2
1971	932.7	167.4	132.0	1,232.1
1972	911.4	221.1	144.0	1,276.5
1973	930.4	221.1	156.7	1,308.2
1974	1,001.0	221.1	170.5	1,392.6
1975	1,193.8	221.1	185.0	1,599.9
1976	1,290.6	221.1	200.9	1,712.6
1977	1,372.4	245.9	217.3	1,835.6
1978	1,213.9	245.9	235.6	1,695.4
1979	1,389.2	245.9	254.9	1,890.0
1980	1,565.2	252.1	275.3	2,093.3

In the above Table No. 20 changes in costs in 1969 result largely from an additional anticipated supply of 49 million liters per day from local sources, now being planned by the Municipality. The drop in cost of production results from savings in purchases of electric energy since the new supply will flow by gravity and some pumping of more costly supplies can be reduced. Similar reductions occur in 1972 when the first phase of the Xaya-Pixcaya Project is expected to be received.

Similar estimates have been received from the Municipality DAD and are shown in the Table No. 21 below. Costs shown for 1965 and 1966 are actual. These maintenance and operating costs in both studies are broken down to show costs of labor, power, chemicals, supplies and spare parts, transportation, supervision and administration, etc. Specifically mentioned by DAD, beginning in 1969 is an additional amount of Q.36,000 per year for rental of IBM equipment, and another item of Q.12,000 per year for rent.

As shown in the cost estimate prepared by MDN, changes in the pattern occur when additional supplies of water are added to the system from new sources. Table No. 23 in Section D.3 of this Report lists these new sources and dates of expected additions.

TABLE NO. 21

MAINTENANCE AND OPERATION COSTS

1965 - 1984 - Prepared by DAD

Year	Production Cost	Distribution	Commercial or Admin.	Total
1965	Q 769,853	Q 251,353	Q 67,618	Q 1.088,824
1966	797,597	253,251	67,618	1.118,466
1967	797,597	260,408	72,380	1.130,385
1968	1.001,500	339,540	75,080	1.416,120
1969	1.206,551	319,263	214,580	1.740,396
1970	1.117,056	340,296	216,580	1.673,932
1971	987,875	354,639	218,580	1.561,094
1972	709,797	378,541	232,238	1.320,576
1973	1.124,438	396,460	234,238	1.755,136
1974	737,613	412,504	236,238	1.386,355
1975	827,854	435,434	238,238	1.501,526
1976	925,961	455,053	240,238	1.621,256
1977	1.048,178	483,539	255,062	1.786,779
1978	1.145,024	503,157	257,062	1.905,243
1979	1.189,200	522,774	261,062	1.978,036
1980	994,148	550,979	263,062	1.808,189
1981	1.054,917	582,234	279,168	1.916,319
1982	1.130,535	605,438	281,168	2.017,141
1983	1.321,217	630,541	283,168	2.239,926
1984	1.043,389	648,472	285,168	1.977,029

Variations will be noticed in the amounts estimated for maintenance and operation costs between the two tables. It would seem that the costs for 1965 would be identical; however, it will be noticed that the distribution costs in the table prepared for MDN are Q.98,000 less than the expenditures recorded by the Municipality. The difference in the estimate of costs of distribution become further and further apart until it will be noted that the difference in 1977 is Q.237,000. On the other hand, it may be noticed that the production costs estimated by the Municipality for 1977 are Q.324,000 less than the MDN estimates, so that actually the total difference in 1977 is only Q.49,000.

One reason why DAD estimates for maintenance and operating costs are somewhat higher than those of MDN is that DAD plans for a slightly higher water demand than MDN during the years 1965 to 1977. In 1978, the water demand curves of the two studies cross and the MDN curves become a little higher. The Consultant believes that both studies have endeavored to be reasonably conservative in these calculations and that both are acceptable.

In order to arrive at an estimate of costs for maintenance and operation to be used in connection with the analysis of the benefit-cost ratio, the Consultant has used the cost estimated by the DAD for 1977 and deducted therefrom the total estimated cost in 1972 when the first water from the Xaya-Pixcaya Project is due to come to the city.

MAINTENANCE AND OPERATING COST

1977	Q.1.786,779
1972	1.320,576
	Q. 466,203

While these figures cannot be accurate they give a reasonable representation of the maintenance and operating costs of the new element of water supplied, taking into account the annual savings that result since much of the pumping costs will be materially reduced when the new supplies will come into the city by gravity.

In making the benefit-cost analysis, there should be noted one difference between the maintenance and operating costs of the Municipality and of the MDN. Because the La Brigada treatment plant is located lower than an area that must be supplied by the Municipality's system a pumping cost of approximately Q.22,000 annually is required. This amount can properly be deducted from the estimate of annual maintenance and operating costs for the MDN.

D.3 ESTIMATED REVENUE

a. Proposed Water Rates or Taxes

b. Estimated Annual Income for First Ten Years

In Section B.4 of this report was included, in considerable detail, the estimated made by the MDN of revenues that would result from the Xaya-Pixcaya Project under their plan. A definition of a "paja" or title was also included. The MDN plan for the Project would bring 28,000 pajas (56 MLD) to Guatemala City in the first phase of their plan. The MDN estimate of revenue from the sale of pajas for the first phase shown in Table No. 88 (MDN) totals Q.8.120,200.

Table No. 87 (MDN) shows the dates of completion and the additional supplied of water planned to be available under the MDN plan. Table No. 87 (MDN) shows their estimate of the demand for titles of pajas to 1985. By 1981, the Army plan would provide an additional supply of 61,000 pajas (122 MLD) to a total of 178 MLD.

The original sale of titles or pajas is handled exclusively by the Bank of Guatemala. The Bank handles collections on the sale of pajas which may be paid for over a one to five year period by including 10% interest. All of this income, less a 1/4% service charge, goes toward retirement of the loan. This is an important feature of the paja plan.

The continuing practice of the Municipality has been and may be expected to sell only 70% of the number of pajas that are created

by additional water supplies. This is important for this practice makes provision for water that may be used at the treatment plants, losses by leakage and incorrect metering and some public uses. In general, estimates of revenues from the sale of water is based on no more than 70% of the total supplied to the system. The balance is made up of public service use, fire protection and leakage.

As was described in Section B.4, the ownership of a paja entitles the owner to 60,000 liters per month. Water used beyond this amount (practically all services are metered) is charged for at a rate of Q.0.15 per cubic meter. This rate was established on July 1, 1964, when the rate was raised from the previous charge of Q.0.10 per cubic meter. The method used by MDN in calculating probable revenue from what is referred to as the sale of "excess water" is contained in that portion of their Report included in Section B.4 (see Section 13.2.3). Their estimate of revenues, in accordance with their plan to 1980, is shown in Table No. 94 (MDN).

Before the rate for "excess" at Q.0.15 per cubic meter is levied, there are two basic, flat rate charges that are made. One is Q.1.50 per month per paja, Q.0.75 per month for 1/2 paja, and Q.0.50 per month for 1/3 paja. The other charge is based on the size of meter installed.

Included in the rate structure is a flat charge per month based on the size of the meter used in the service. These charges, rates,

and estimate of probably new connections and the various sizes by year, together with estimated revenue is shown in Section 13.2.2 of the MDN Report and is included in Section B.4. Table No. 92 (MDN) shows the amounts of monthly and annual revenues estimated by MDN.

Additional revenues that may be expected are descirbed in Section 13.2.4 of the MDN Report and included in Section B.4 above. Among other items, it estimates a revenue of Q.880.000 from 22,000 new services which are reasonably expected during the first phase of the Xaya-Pixcaya Project with corresponding amounts as subsequent phases are completed.

In summary then, the MDN Report estimates the revenues for the ten year period beginning in 1972. Table No. 22, which is attached, tabulates these revenues.

TABLE NO. 22

ANNUAL REVENUE - 1972 - 1981

Year	Income Based on Size of Connection Q.	Income from Sale Of Extra Water Used Q.	Total Q.
1972	1,023,400	1,015,600	2,039,000
1973	1,112,400	1,095,000	2,207,400
1974	1,211,000	1,181,000	2,392,000
1975	1,314,600	1,170,200	2,584,800
1976	1,424,900	683,300*	2,108,200
1977	1,544,000	734,200	2,278,200
1978	1,673,400	787,900	2,461,300
1979	1,809,700	845,300	2,655,000
1980	1,955,900	906,106	2,862,006
1981	2,113,500	-	-

(*) A decrease in percent of sale of extra water due to increased number of service connections.

In addition to Annual Revenue, a gain is realized from one-time revenues that accrue from establishing new service as follows:

From sale of 28,000 x 70% = 19,600 pajas	Q.8,120.200
From fees for 22,000 new services	880.000
From profit on sale of meters - Q.7.00 x 22,000	154.000
Total one-time revenue	Q.9,154.200

"A Study of Revenues 1965 - 1990" was completed by the DAD and made available to the Consultants in October 1967. It follows the general form of the study by MDN. Table No. 23, taken from the DAD Study of Revenues, gives a list of the small water supply projects intended to augment the present supply between January 1968, and the time when the Xaya-Pixcaya Project can be in production. Also shown are the number of pajas to be developed by each project and the number that will be put up for sale to the public.

Table No. 24 from the DAD Study of Revenues, shows 63,038 as the number of titles (pajas) in possession of the public at the end of 1966. Also included are the anticipated number of sales each year as additional pajas are issued at the completion of an additional project. Proyecto Sur-Oriental is only under study. Its construction may either be carried out as indicated in this Plate or it may be delayed indefinitely - the decision depends on the progress made on the Xaya-Pixcaya Project. If the Proyecto Sur-Oriental is delayed, the sale of pajas (titles) on the Xaya-Pixcaya Project would be moved up to begin in 1972 instead of 1975.

Table No. 25 shows the revenues from the Sale of Titles and the Sale of Water from 1965 and 1966. A comparison with revenues estimated by MDN shows close similarity. For example, not including sale of titles:

	DAD Estimate	MDN Estimate
1972	Q.2.027,900	Q.2.039,000
1975	2.435,000	2.584,800

Neither the MDN or the DAD study have included in their tabulations the "Other Revenues" previously referred to in amount of Q.880,000 and Q.154,000. Both agencies state they did not include the "Other Revenues" purposely to provide a factor of safety and to emphasize that the revenues anticipated are more than adequate to finance the Xaya-Pixcaya Project. Mention should be made of the fact that no special taxes are planned to be charged on the land served or to be served in the Municipality.

Fig. No. 7, Water Consumption per Capita, shows the increasing per capita demand as developed by MDN and DAD. Fig. No. 9, Water Demand Forecasts, shows the curves incorporating both Water Consumption per Capita and Population Growth as developed by MDN and DAD. On these basis, the revenue forecasts were developed in both studies.

TABLA - TABLE 23

NUEVAS EMISIONES DE TITULOS DE AGUA

NEW ISSUES OF WATER TITLES

PROYECTO PROJECT	ESTADO DEL PROYECTO PROJECT STATUS	FECHA ENTRADA DATE OF COMPLETION	CAUDAL (EN PAJAS) QUANTITY (IN PAJAS)			EMISIONES EN TITULOS ISSUES OF TITLES			
			TOTAL TOTAL	VENDIBLE SALEABLE		1 PAJA	1/2 PAJA	1/3 PAJA	TOTAL
Hincapié	En Construcción	Enero 1968	4,500	71%	3,200	600	5,200	---	5,800
Aguacate	Aprob. por H.C.M.	Marzo 1968	4,500	50%	2,250	800	2,900	---	3,700
Pozos Diamante	En Construcción	Marzo 1968	1,500	-	---	---	---	---	---
Atlántico	Estudio Terminado	Enero 1969	10,000	80%	8,000	1,600	10,800	3,000	15,400
Sur-Oriental	En estudio	Enero 1970	12,000	70%	8,400	1,680	13,440	---	15,120
Sub-Total I			32,500	67%	21,850	4,680	32,340	3,000	40,020
XE-XA-PIX	En Evaluación	1971	50,000	70%	35,000	12,250	31,500	21,000	64,750
			82,500	69%	56,850	16,930	63,840	24,000	104,770

NOTA: La emisión de los Títulos del Proyecto Hincapié ya fué efectuada por el Honorable Concejo Municipal.
NOTE: The issue of titles for Hincapié Project has been ordered by the Municipal Council

PROYECTO-XENACOJ-XAYA-PIXCAYA
CAUDAL NOMINAL - NOMINAL QUANTITY = 50,000 PAJAS
Caudal Vendible - Saleable Quantity (70%) = 35,000 Pajas

	Pajas Vendibles	Nº Títulos
1 paja	35% x 35,000 = 12,250	12,250
1/2 paja	45% x 35,000 = 15,750	31,500
1/3 paja	20% x 35,000 = 7,000	21,000
	35,000	64,750

DIB. 5

TABLA - TABLE 24

ANNUAL DEMAND FOR TITLES IN GUATEMALA CITY
AND DISTRIBUTION BY SOURCES
DEMANDA ANUAL DE TITULOS DE LA CIUDAD DE GUATEMALA.
SU DISTRIBUCION POR FUENTES

Year / Año	Demand for Titles / Demanda de Títulos	Issues of Titles / Adiciones de Títulos	Sales of Titles in each Year / Venta de Títs. en el año	Sources of Supply / FUENTES DE ABASTECIMIENTO				
				Hincapié	Aguacate	Atlántico	Sur-Oriental	Xe-Xa-Pix
66	63,038	63,038	2,227	2,227				
67	66,727	5,800	3,689	3,573	116			
68	70,662	3,700	3,935		3,584	351		
69	74,940	15,400	4,278			3,658		
1970	79,458	15,120	4,518			4,518		
71	84,103	64,750	4,645			4,645		
72	89,000		4,897			2,228	2,669	
73	94,157		1,157				5,157	
74	99,582		5,425				5,425	
1975	105,285		5,703				1,869	3,834
76	111,272		5,987					5,987
77	117,553		6,281					6,281
78	124,134		6,581					6,581
79	131,026		6,892					6,892
1980	138,382		7,356					7,356
81	143,088		4,706					4,706
82	148,088		5,000					5,000
83	153,235		5,147					5,147
84	156,618		3,383					3,383
1985	162,059		5,441					5,441
86	167,794		5,735					4,142
87	173,677		5,883					
88	179,706		6,029					
89	186,030		6,324					
1990	192,500		6,470	5,800	3,700	15,400	15,120	64,750

1 = Números de Títulos Actuales - Number of titles issued at present
2 = Proyecto Hincapié
3 = Proyecto Aguacate
4 = Proyecto Atlántico
5 = Proyecto Sur-Oriental
6 = Proyecto Xenacoj-Xayá-Pixcayá

DIB. 6

T A B L A - T A B L E 25

I N G R E S O S

POR VENTA DE TITULOS Y COBROS A CONSUMIDORES

1965 - 1990

REVENUES
FROM SALE OF TITLES AND CHARGES TO CONSUMERS
1965 - 1990

AÑO YEAR	I N G R E S O S REVENUES			INGRESOS TOTALES
	Venta Títulos	Canon	EXCESOS	
1965	557,900	588,200	601,700	1,747,800
66	675,100	625,300	567,800	1,868,200
67	852,500	672,000	715,600	2,240,100
68	967,700	723,900	771,400	2,463,000
69	1,124,500	782,100	837,700	2,744,300
1970	1,197,400	842,900	908,300	2,948,600
71	1,252,500	905,400	976,700	3,134,600
72	1,313,800	972,400	1,100,500	3,386,700
73	1,377,000	1,040,700	1,167,800	3,585,500
74	1,449,500	1,115,100	1,237,900	3,802,500
1975	1,524,600	1,193,300	1,241,700	3,959,600
76	1,601,700	1,273,100	1,314,000	4,188,800
77	1,681,300	1,358,300	1,389,000	4,428,600
78	1,762,800	1,450,400	1,466,800	4,680,000
79	1,846,900	1,543,400	1,461,300	4,851,600
1980	1,955,800	1,645,700	1,542,300	5,143,800
81	1,593,600	1,711,900	1,622,200	4,927,700
82	1,506,100	1,784,000	1,707,100	4,997,200
83	1,385,400	1,858,200	1,689,000	4,932,600
84	1,139,800	1,907,900	1,750,400	4,798,100
85	1,359,300	1,986,800	1,838,500	5,184,600
86	1,422,600	2,069,700	1,931,000	5,423,300
87	1,466,800	2,153,100	1,900,400	5,520,300
88	1,516,300	2,238,300	1,992,400	5,747,000
89	1,579,700	2,332,700	2,089,300	6,001,700
1990	1,750,800	2,425,900	2,189,500	6,366,200
	35,861,400	37,200,700	36,010,300	109,072,400

MUNICIPALIDAD DE LA CIUDAD DE GUATEMALA
Dirección de Aguas y Drenajes

Mecanografía: Helen Kestler	INGRESOS POR VENTAS DE TITULOS MUNICIPALES Y COBRO A LOS CONSUMIDORES DE AGUA POTABLE.	Director: Ing. Kenneth Toppe M.
Diseño: Ing. E. Willemsen D.	1965 - 1990	Alcalde: Lic. Ramiro Ponce M.
Cálculo: Ing. E. Willemsen D.	DIB. 20	Fecha: Octubre 1967

E. COMPARISON OF BENEFITS AND COST

E.1 COMPARISON OF TANGIBLE AND INTANGIBLE BENEFITS

Readily apparent tangible benefits resulting from construction and implementation of this water project are increased revenues. If we accept the Estimate of Receipts from the sale of pajas shown in Table 88 of the MDN Report, the total from those sales are Q.8,120,200 received during a seven-year period.

In accordance with existing policy, this amount can only be used to pay off loans and interest, or to accumulate while earning interest for those purposes. The MDN Report in its Section 13.2.4 and included in Section B.4 of this report estimates 22,000 new services. At an average charge of Q.40.00 per connection, additional income of Q.880,000 accrues. This amount added to the above totals Q.900,200. Thus, the balance to be raised from Monthly Revenues from water users together with the one-time sources of income, are more than adequate to pay costs of maintenance and operation, to extend the distribution system as required, and to meet debt payments.

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E.2 ABILITY OF PROJECT TO MEET COSTS

Tables have been included in Sections B.4 - Increase in Revenues from Water Charges, D.2 - Maintenance and Operation Costs, and D.3 - Estimated Revenues that show the anticipated revenues as against maintenance and operating cost, interest, and depreciation or amortization of debts for more than 10 years after completion of the project. Three additional tables from the MDN Report are included in this Section in order that the financial results may be seen more readily.

Table 97 of the MDN Report outlines the financial plan of MDN for an external loan of $8,198,800 at 4% plus, 1/4% service charges, and 1/2% charge currency for conversion (quetzales to dollars) - a total of 4-3/4%.

Table 99 of the MDN Report outlines the financial plan for the internal loan - probably a sale of bonds - in the amount of Q.4,100,800 at 5% plus 1/4% service charge - a total of 5-1/4.

Table 101 of the MDN Report develops the totals for debt services of both loans including the payment of the service charges. The column entitled Net, or Neta, is the balance obtained after deducting the cost of operation from the table of revenues for the particular year. Since depreciation reserves were included in the cost of operations, these amounts are added to the Net

column. The amounts in the Total column are seen to be more than adequate to meet the requirements for financing the project.

Table 87 of the MDN Report, "Demand for Titles", shows the dates of anticipated additions of water to the city supply from Project Hincapie, Project Teocinte III and the first and second phases of the Xayá-Pixcaya Project. Table No. 23 in Section D.3 of this report shows the dates and amounts of several additional supplies of water to the city before water is received from the Xaya-Pixcaya Project. This represents the latest planning of the Municipality (DAD). The costs reflected by these newest plans cause differences between the "profit and loss" statements as prepared by MDN and DAD.

Table 101 of the MDN Report does not include the plan for financing the second or subsequent phases of the Xaya-Pixcaya Project. The first phase will provide 28,000 pajas supply (56 million liters per day).

The "profit and loss" statement prepared in October 1967 by DAD in pencil form included the cash flow anticipated taking into account the financing of the small additional supplies previously referred to and financing maintenance, operations and debt service including repayments of capital as required, depreciation reserves, etc., for construction of the first and second stages of the Xaya-Pixcaya

Project. In addition, DAD plans to start construction of the Motagua Project in 1976 to bring additional supplies to the Capital City. On this basis, DAD financial plans propose an indefinite delay of construction on the Sur-Oriental Project. The following tabulation of the Net Profit and Loss results (in thousands) are provided from 1972 to 1982, ten years after the first phase of the Xaya-Pixcaya Project is completed:

Year	Surplus	Deficit
1972	Q. 314.9	
1973	137.0	
1974	776.5	
1975	872.1	
1976		42.7
1977	169.5	
1978	311.3	
1979	437.2	
1980	916.2	
1981	601.0	
1982	578.7	

Thus, it is apparent that the financial plan for this project with water rates and revenues listed in previous Sections of this report are adequate.

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E.3 COMPUTATION OF BENEFIT-COST RATIO

a. Benefits Measured by Alternative Means

1. Project Description

The study prepared by DAD (the Municipality) proposes to divert 650 liters per second (56.16 million liters per day) for water supply purposes from the Pixcaya River, as a first phase, and to convey this water supply by means of an aqueduct consisting of tunnels, siphons and a pressure pipe to the existing treatment plant of Guatemala City at La Brigada. An addition to the treatment plant will be constructed to handle this new supply, and extensive improvements will be made to the city's distribution system, plans for which improvements have been recently completed by a French engineering firm.

In October 1967, the city, with about 660,000 inhabitants, has a water supply of 110 million liters per day, approximately 167 liters per capita per day (44.1 gpcd). In most areas of the city, during several hours each day, there is no water supply.

The first phase of construction will provide an aqueduct carrying capacity of 1,500 liters per second into the city. This is an inadequate amount for a long period, and the second phase of construction will follow immediately to provide an additional 43.2 million liters per day. In order to be able to make direct comparison between the plan of the Municipality and the plan of

MDN, the first phase of the Municipality plan is shown to produce only 56.16 m.l.d. and the same for the MDN. However, the Municipality proposes construction of the aqueduct to pick up the water of Xenacoj Rivers I and II, an additional 12.96 m.l.d., in its first phase, since all facilities included in the project shown in this Section of the Consultants report are designed to handle somewhat more than the sum of these two - 69.12 m.l.d. Supplementary computations are shown therefore in order to provide a clearer picture of the cost per 1,000 gallons of water delivered from construction of the first phase of the project. When construction is complete, the water diverted from the Pixcaya River will decrease the flow available to the Selle hydroelectric plant. An allowance is included in both studies to indemnify the owners.

Following a long established custom, water rights, or pajas, (described in Section b.4) will be sold which for the first phase of the project are estimated by MDN to produce Q.8,120,200. Other one-time sources of income should produce Q.1,034,000 or a total of Q.9,154,200 which at the present rate of exchange equals $9,154,200.

2. Estimated Installation Cost and Initial Investment

The costs in this Section of this report are reivsed by the Consultant on the maintenance and operation cost estimates of the DAD study as they are contained in Section D.1 above. The cost

of the Xenacoj addition (supplementary supply) is not included in this Section.

Steel pipe for the siphons and cast iron pipe for the distribution system will be imported; also most of the treatment plant equipment. The breakdown between local costs in quetzales and other costs in U.S. dollars cannot be accurate, but since there is little difference between the interest rates charged, no appreciable difference results. Access roads are given a life of 15 years because nearly all of them are on side hill and the largest increment of construction cost is earth moving. Breakdown of main cost items including contingencies is as follows:

	Local Cost (Equivalent U.S.$)	U.S.$ Cost
Diversion works	Q./$ 39,000	$ 39,000
Tunnels	3,420,000	1,722,700
Covered conduits	215,000	104,500
Siphons - estimated life 40 years	486,500	1,161,700
Treatment plan (equipment to be replaced in 25 years at a cost of $465,000 including pumping equipment)	714,700	591,200
Distribution system improvements	437,200	978,100
Access roads	141,750	141,750
Purchase of land and rights of way	48,300	
Indemnity allowance for hydro-electric plant	120,000	180,000
Engineering and administration	389,600	757,200
Total installation cost	Q./$ 6,012,050	$ 5,676,150
Interest during construction 2-1/2 years	394,540	337,020
Total initial investment	Q./$ 6,406,590	$ 6,013,170

3. Annual Costs

Maintenance and operation of project facilities	Q./$	466,000
Replacement of treatment plant equipment at 25 years - 6% $465,000 x 0.2330 x 0.06344		6,873
Replace siphons at 40 years - 6% $1,648,200 x 0.0972 x 0.06344		10,163
Replace access roads at 15 years - 6% $283,500 x 0.4173 x 0.06344 30 years - 6% $283,500 x 0.1741 x 0.06344 45 years - 6% $283,500 x 0.0727 x 0.06344		11,944
Amortizations of investment cost Local cost in Quetzales Q.6,406,590 - 50 years - 5-1/4% (0.05692)		364,663
U.S. dollar cost $6,048,650 - 50 years - 4-3/4% (0.05269)		318,703
Total annual cost	Q./$	1,178,346

Average annual supply - 56.16 m.l.d. x $\frac{365}{3.7853}$ = 5,415 million gallons

Cost of water at delivery point Q 0.2176 per 1,000 gallons

A rough estimate from costs provided show that the addition of water supplies from Xenacoj I and II would increase the total annual cost to about Q./$ 1,217,280, providing an annual supply of 69.12 million liters per day. The resultant cost at delivery point then would be Q.0.1826 per 1,000 gallons.

4. Cost of Equivalent Supply from Best Alternative Source (Primary Benefit)

The plan proposed by the Ministerio de la Defensa Nacional (MDN) would take the same volume of water - 56.16 m.l.d. - from approximately the same point of diversion but by a different route. The carrying capacity of the aqueduct is also 1,500 liters per second, but its tunnels would have a carrying capacity somewhat in excess of twice this amount because of construction problems. Smaller diversion works are planned.

Construction of a treatment plant at a location 60 to 70 meters higher than the city's La Brigada treatment plant is proposed. This would obviate the necessity of pumping to the area of the city which is higher than the city's treatment plant and to which the city must pump. However, purchase of land would be required at the proposed treatment plant site. Cost of annual maintenance of access roads would be less, because there are less of them. Capital and annual costs are calculated as follows:

a. Estimated Installation Cost and Initial Investment

	Local Cost (Equivalent U.S.$)	U.S.$ Cost
Purchase of land and rights of way	Q./$ 297,500	
Diversion works	25,400	$ 23,800
Canals (covered-concrete)	796,600	388,100
Tunnels	2,474,400	2,312,800

	Local Cost (Equivalent U.S.$)	U.S.$ Cost
Siphons	Q./$ 189,200	$1,142.900
Connecting line	71,600	271,600
Treatment plant (equipment to be replaced in 25 years, at a cost of $465,000)	905,000	755,000
Distribution system	437,200	978,100
Access roads	82,500	82,500
Indemnity allowance for hydro-electric plant	120,000	180,000
Engineering	389,600	757,200
Total installation cost	Q./$ 5,789,000	$6,892,000
Interest during construction 3 years	455,884	491,055
	Q./$ 6,244,884	$7,383,055

b. Annual Costs

Maintenance and operation of project facilities	Q./$ 444,000	
Replacement of treatment plant equipment at 25 years - 6% $465,000 x 0.2330 x 0.06344	6,873	
Replace siphons and connecting line at 40 years - 6% $1,645,600 x 0.0972 x 0.06344	10,147	
Replace access roads at 15 years - 6% $165,000 x 0.4173 x 0.06344 30 years - 6% $165,000 x 0.1741 x 0.06344 45 years - 6% $165,000 x 0.0727 x 0.06344	6,952	

Amortization of investment costs Local cost in Quetzales Q.6,244,884 - 50 years - 5-1/4% (0.05692)	Q./$ 355,459
U.S. dollar cost $7,383,055 - 50 years - 4-3/4% (0.05269)	389,013
Total annual cost	1,212,444

Cost of water at delivery point $ 0.224 per 1,000 gallons

5. Benefit - Cost Ratio

Annual Benefit	$ 1,212,444
Annual Cost	1,178,346
Ratio	1.03 to 1.00

The cost per 1,000 gallons at delivery point compares very favorably with the present rate of Q.0.56 per 1,000 gallons (Q.0.15 per cubic meter) for excess water.

6. Secondary Benefits (not used in above computations)

Value of additional housing development - annual	Q.5,000,000
Savings in hospital treatment - annual	35,000
Savings - storage facilities - annual	314,000
Savings - deep wells and pumps - annual	80,000

b. Benefits from Betterment of Water Quality Control

In the preceding Section of this Report annual savings in hospital treatment of Q.35,000 are listed. These savings are direct result of improvements in quality control. Reference is also made to

Section B.1.c where the tables show that more than 40,000 cases of water-borne diseases were reported each year since 1963 in Guatemala City. While many of the cases were undoubtedly caused by an inadequate supply of water, many were the result of poor quality of water outside of the city system. Certainly it can be expected that the number of cases of water-borne diseases should be decreased at least by 50% as a result of this project.

c. Opportunity Costs

Opportunity costs of each project are shown in tabular form under Annual Costs, Section E.3.a.2.

As mentioned in E.3.a.1. above (Project Description) the Municipality plans to construct the Xenacoj addition to the Pixcaya Project and to bring the water to the city from that source before the balance of the aqueduct is completed to the Pixcaya River. This additional supply will increase the Total Annual Cost to about $1,217,280 but will result in reducing the cost at delivery point to about Q.0.1826 per 1,000 gallons. This information is not included in the development of costs earlier in this section so as to keep them equally related. The Xenacoj addition applies only to the DAD plan.

APPENDIX A

HYDROLOGY

INTRODUCTION

Separate plans for augmenting the municipal water supply of Guatemala City by diversion from the Xaya, Pixcaya, Coloya, Xenacoj, Itzapa, Parramos and Pasiguan Rivers have been developed by the Direccion de Aguas y Drenajes (DAD) of the Municipality of Guatemala City (MCG) and the Guatemalan Ministry of Defense (MDN). Details of the plans are discussed in other sections of this report. However, it is desirable here to discuss briefly the sources of water.

Only the first stage of the Municipality scheme has been developed in detail. It is proposed in this scheme to divert the low-water flow of Xaya, Pixcaya and Xenacoj Rivers. The MDN in its first stage diverts 90 percent of the low-flow of the Pixcaya River. In its final stage, the MDN has proposed reservoirs on Xaya, Pixcaya, Coloya, Itzapa, Parramos and Pasiguan Rivers and established diversion rates for each.

The DAD on the other hand proposes reservoirs on Xaya and Pixcaya Rivers but states that establishment of rates of diversion must await the collection of more hydrologic data on the streams. It is the purpose of this report to assess the reliability of the water source by evaluating the available streamflow records and extending those records, wherever possible, by correlation methods. It is proposed also to make recommendations as to improvements in the current hydrologic data collection program.

STREAM FLOW

Available Records

Stream-flow data are limited in Guatemala. Acres International Limited, Niagara Falls, Canada, made a thorough search for stream-flow data as reported in POWER AND IRRIGATION STUDY, dated September 1962. They found that only ten stream-flow stations had been operated prior to 1960, and of those, only three were in operation in 1960. The accumulated record for these ten stations totaled 49 years. However, 32 years of that 49 had been collected on Michatoya River, which is the outlet of Lake Amatitlan. Because the outlet is controlled by gates, this record does not reflect runoff trends. If this record is eliminated, there remain less than two years per record per station.

The situation is somewhat better today; BOLETIN HIDROLOGICO NO. 2, published by INSTITUTO NACIONAL DE ELECTRIFICACION in which agency is housed the SECCION DE HIDROMETEOLOGIA, lists 20 stream-flow stations, most of which have been started since 1962.

There is only one stream-flow record of any length in study area that collected at the Selle Power Plant on the Pixcaya River. This record has been collected at low water each year since 1927 by the owner and operator of the plant, a private citizen. Collection of stream-flow data on other streams in the project was not started until the conception of the project about 1957. The available records are listed on Table No. 1. There have been no stream-flow data collected on Coloya, Parramos and Pasiguan Rivers.

TABLE NO. 1

Stream	Drainage Area Km^2	Records Available	
		Low flow only	Complete daily records
Xaya River-La Sierra	85.8	1960-1	January 1962 to date
Xaya River-Los Tres Mojones	57.2		March 1966 to date
Pixcaya River-El Tesoro	154	1960-1	January 1962 to date
Pixcaya River-Selle Power Plant	219	1927 to date	
Itzapa	25.3		August 1965 to date
Guacalate			August 1965 to date
Xenacoj I	34.9	1957-66	
Xenacoj II	8.4	1957-66	

The locations of the above stations are shown on Figure No. 1A.

A sufficient number of chemical analyses of Xaya and Pixcaya River waters have been collected to establish the chemical quality of the waters and to establish the degree of treatment required.

A few water samples have been taken to establish the sediment content of the water, but the number taken is far from sufficient to establish annual loads, a particularly important item in reservoir design.

Quality of Stream-Flow Stations and Data

The stream-flow stations and water-stage recorders were inspected by the consultant; the stations themselves were well constructed and the equipment much better than are usually found in countries where the USAID program operates. The water-stage recorders are European made and produce good records of stage although the consultant considers the Stevens Water Stage Recorder, an American made instrument, a more fool-proof and more easily operated instrument.

There is one serious deficiency in the stream-flow stations. There are no structures, cableways or footbridges from which to make highwater discharge measurements. As a result, only the low flows can be measured, and the medium and highwater portions of the rating (calibration) curves are unsubstantiated. For example, the highest discharge measurement made at El Tesoro on Pixcaya River was at a gage reading of 50 cms. The resulting discharge was 4,000 lts. per second. During the period of available record, the river has reached a height of 159 cms. The discharge at this stage is estimated to have exceeded 100,000 lts. per second. The absence of such discharge measurements casts serious doubt on a large portion of the record, that part which is of particular importance when reservoirs are involved.

The accuracy of determinations of basin yield, spillway design floods, sediment loads and reservoir operation rules are all dependent on quality medium and high-flow data. There is nothing that can be done at this time to improve the quality of these records, so they must be used as computed.

The records of daily discharge as computed by the Guatemalan Government have been reviewed and found satisfactory within the limitations implied by lack of data discussed above. The degree of sophistication does not approach that practised by government agencies in other countries in Europe and America, but the records produced, especially at low water, are deemed satisfactory for this appraisal.

Computations by The Consulting Engineer

The daily stream-flow records furnished included only those for Xaya-La Sierra and Pixcaya-El Tesoro through May 1966. No records were computed for Xaya-Los Tres Mojones nor for Itzapa River. The daily records for La Sierra and El Tesoro were not complete for 1962 so that only three full years of daily records were available at each station. By estimating the missing record and computing daily discharge from June 1966 to April 1967, the consultant was able to add two more complete years of daily discharge, and one more year of low-water record at each of these stations.

The consultant also computed daily discharge for Los Tres Mojones for the period July 1966 to February 1967 and for Itzapa for the period July 1966 to April 1967. The Guatemalan Government made available all of the water-stage recorder charts, and discharge measurements were made during 1967 so records

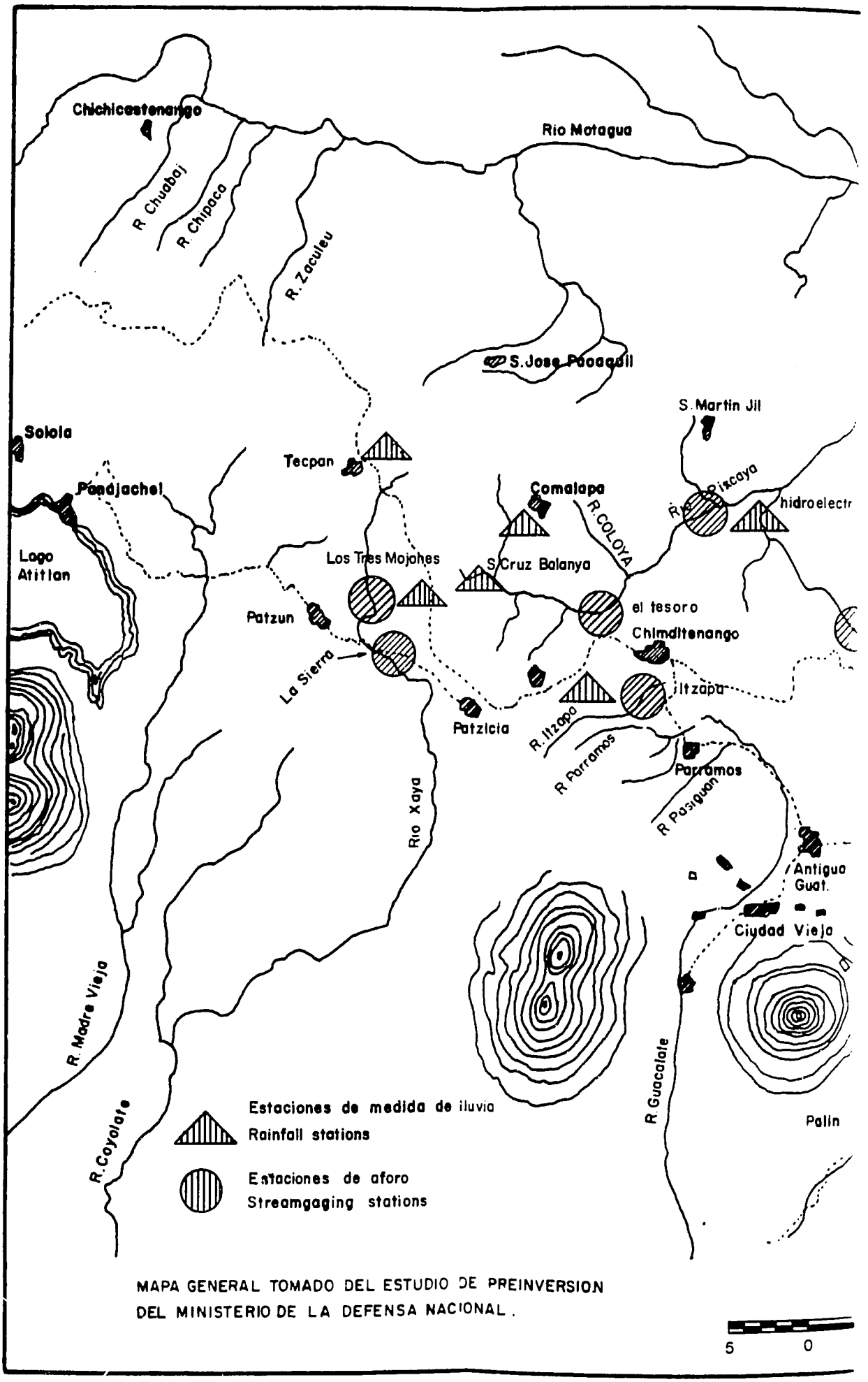
for that year were based on previous measurements. Hydrographs of monthly discharge for Xaya River-La Sierra and Pixcaya River-El Tesoro are shown on Figure 1. Mean monthly discharges for all stream-flow stations are shown in Tables 2 through 5.

Analysis of Data

The DAD and the MDN alike base their plans on the assumption that the records of stream flow available are of sufficient length to establish the reliability of the Xaya and Pixcaya Rivers as sources of water for the development of the first stage of the project. The MDN goes even further in that it carries its project through the final stage which includes reservoirs on Xaya, Pixcaya, Coloya, Itzapa, Parramos and Pasiguan Rivers. The DAD states that planning for the final stage must await the collection of more stream-flow records.

The DAD plan is based on four years of low-flow record on Xaya and Pixaya Rivers and eight years on Xenacoj River. The MDN's first stage is based on seven years of low-water record on Xaya and Pixcaya Rivers. Its final stage is based on three complete years of record for Xaya and Pixcaya Rivers, and no record on Coloya, Itzapa, Parramos and Pasiguan Rivers except that which was synthesized based on Xaya and Pixcaya Rivers.

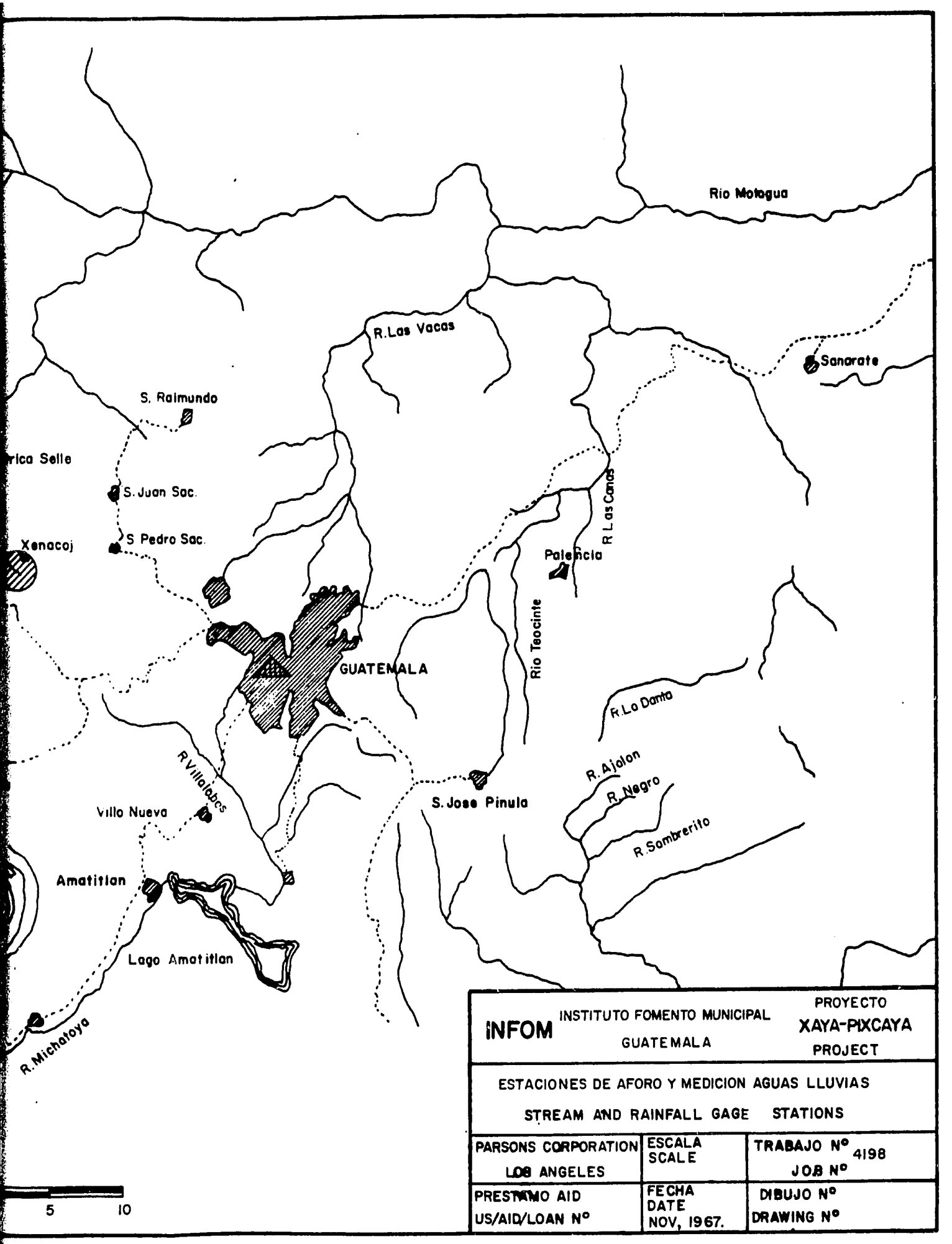
Both the DAD and MDN analysis produce results that indicate that either plan is marginal with respect to the source of water. In its first stage, the DAD proposes to divert 741 ltrs. per second from Pixcaya River. During the seven years of low-water record available, the monthly mean flow of Pixcaya River was below that proposed diversion, four months in 1963, two months in 1964, and



MAPA GENERAL TOMADO DEL ESTUDIO DE PREINVERSION DEL MINISTERIO DE LA DEFENSA NACIONAL.

FIGURA Nº

APENDICE-APPE'


Rio Motagua
R.Las Vacas
Sanarate
S. Raimundo
rica Selle
S. Juan Sac.
S Pedro Sac.
Xenacoj
R Las Canas
Palencia
Rio Teocinte
GUATEMALA
R.La Danta
R.Ajolon
R.Negro
R.Sombrerito
R Villalobos
S. Jose Pinula
Villo Nueva
Amatitlan
Lago Amatitlan
R.Michatoya
5
10
INFOM
INSTITUTO FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
ESTACIONES DE AFORO Y MEDICION AGUAS LLUVIAS
STREAM AND RAINFALL GAGE STATIONS
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO N° 4198
JOB N°
PRESTAMO AID
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PENDIX A

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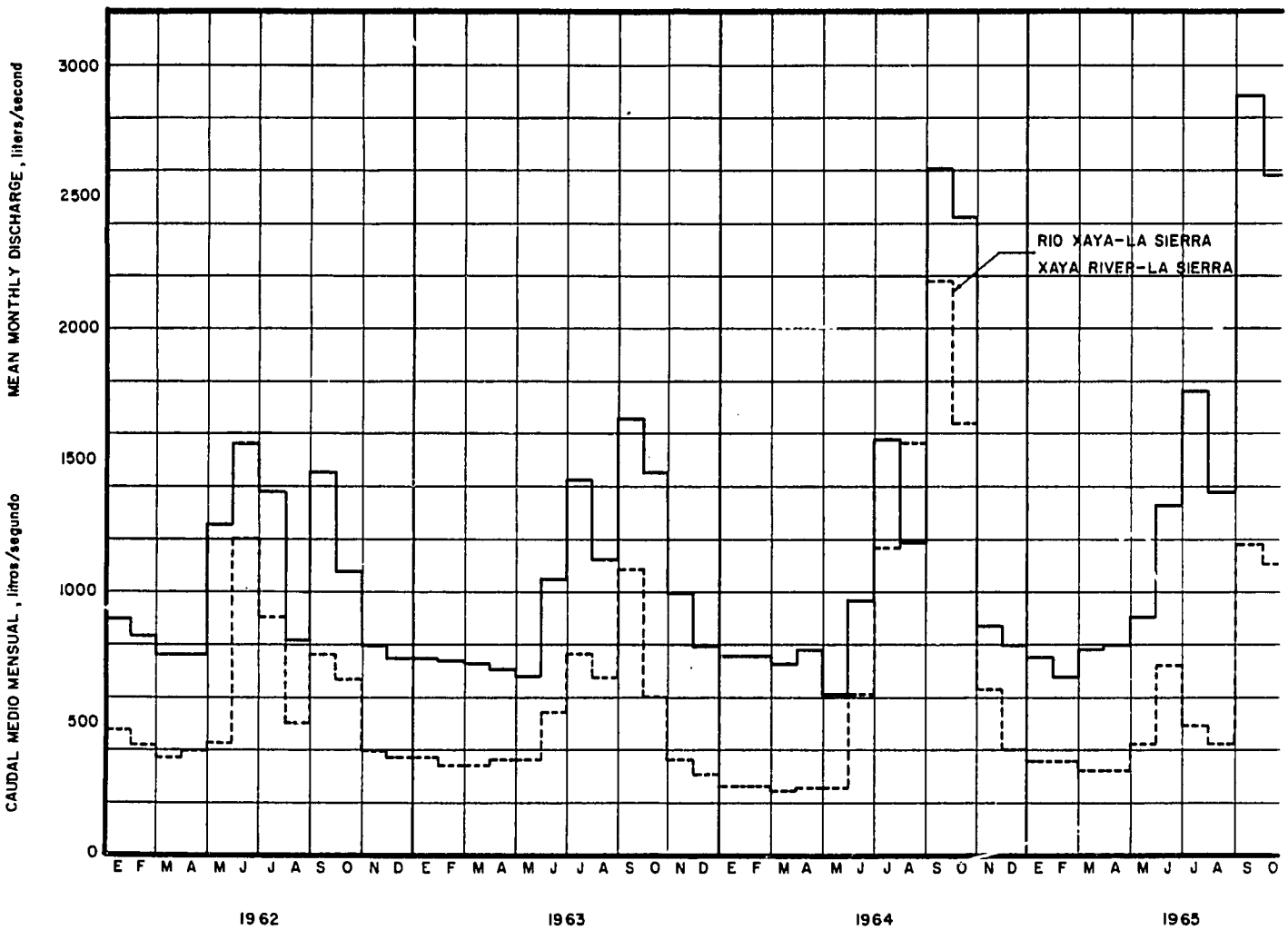
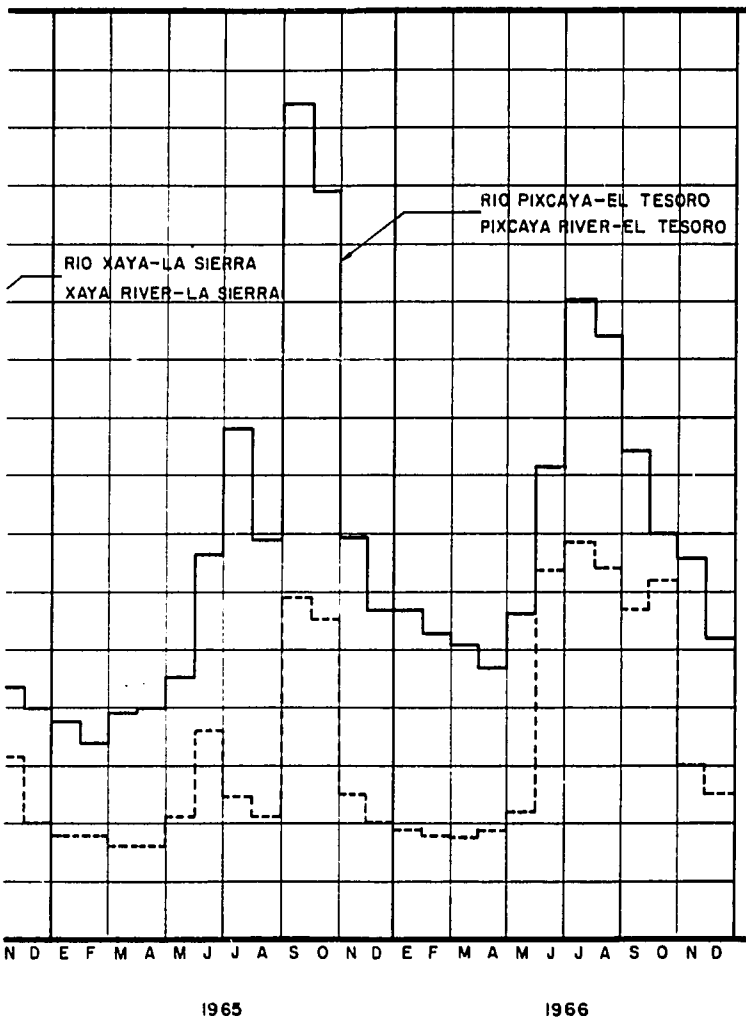


FIGURA Nº I
APENDICE-APPENDIX A



INFOM INSTITUTO DE FOMENTO MUNICIPAL GUATEMALA		PROYECTO XAYA-PIXCAYA PROJECT
HIDROGRAFO DE CAUDAL MEDIO MENSUAL HYDROGRAPH OF MONTHLY MEAN DISCHARGE		
PARSONS CORPORATION LOS ANGELES	ESCALA SCALE	TRABAJO Nº JOB Nº 4198
PRESTAMO AID Nº US/AID LOAN Nº	FECHA DATE NOV, 1967	DIBUJO Nº DRAWING Nº

FIGURA Nº I
APENDICE-APPENDIX A

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NO. A-10

T A B

CAUDALES MEDIOS MENSUAL

Año	Enero	Feb.	Marzo	Abril	Mayo	Jun
1962	895	831	761	761	+1,260	+1,5
1963	751	734	723	714	676	1,0
1964	758	749	722	778	611	9
1965	752	675	781	793	911	1,3
1966	1,138	1,054	1,014	938	1,130	1,6
1967	1,150	1,095	975	984		

+Calculados con base en la precipitación lluviosa en

T A B

CAUDALES MEDIOS MENSUAL

Año	Enero	Feb.	Marzo	Abril	Mayo	Jun
1966						
1967	284	243				

T A B

CAUDALES MEDIOS MENS

Año	Enero	Feb.	Marzo	Abril	Mayo	Jun
1962	477	411	370	390	427	+1,2
1963	+377	+335	336	367	362	+ 5
1964	263	268	247	256	252	+ 6
1965	357	357	329	323	426	7
1966	371	358	349	373	434	1,2
1967	439	423	406	508		

+ Calculados total o parcialmente con base en el río

T A B

CAUDALES MEDIOS

Año	Enero	Feb.	Marzo	Abril	Mayo	Jun
1965						
1966	126	86	82	164	192	1
1967	141	131	120	164		

T A B L A No. 2

S MENSUALES: RIO PIXCAYA - EL TESORO L/SEG.

Mayo	Junio	Julio	Ago.	Sept.	Oct.	Nov.	Dec.	Anual
+1,260	+1,560	+1,380	811	1,449	1,069	794	750	1,025
676	1,054	1,422	1,119	1,654	1,452	982	793	1,006
611	965	1,574	1,182	2,603	2,416	867	792	1,168
911	1,334	1,767	1,383	2,879	2,577	1,393	1,129	1,286
1,130	1,627	2,210	2,076	1,687	1,398	1,310	1,031	1,384

lluviosa en la Ciudad de Guatemala

T A B L A No. 3

S MENSUALES: RIO XAYA - LOS TRES MOJONES L/SEG.

Mayo	Junio	Julio	Ago.	Sept.	Oct.	Nov.	Dec.	Anual
		1,139	1,152	1,064	1,140	555	434	

T A B L A No. 4

MEDIOS MENSUALES: RIO XAYA - LA SIERRA L/SEG.

Mayo	Junio	Julio	Ago.	Sept.	Oct.	Nov.	Dec.	Anual
427	+1,210	+ 910	502	773	669	391	374	575
362	+ 543	769	+ 677	+1,090	607	361	307	511
252	+ 608	1,173	1,569	2,178	1,634	627	404	790
426	724	492	421	1,172	1,106	503	408	571
434	1,267	1,371	1,289	1,141	1,236	610	509	776

e en el río Pixcayá o en la precipitación lluviosa en la ciudad de Guatemala

T A B L A No. 5

ALES MEDIOS MENSUALES: RIO ITZAPA L/SEG.

Mayo	Junio	Julio	Ago.	Sept.	Oct.	Nov.	Dec.	Anual
192	171	196	155	211	165	105	97	146

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NO. A-12

one month in 1965. The mean monthly flow of Xaya River was below the proposed diversion rate of 278 lts. per second for five months in 1964.

The MDN's first stage is somewhat more favorable in that the monthly mean flow of Pixcaya River was below the proposed diversion of 650 lts. per second only during one month in the seven years of record. However, the MDN's proposed rate of withdrawal for the final stage exceeded the mean flow of Xaya River two of the three years of record available and that of Pixcaya River all three years. It is implied in the MDN Report that the years of stream-flow record are years of below average rainfall and on this basis, the withdrawal rates proposed are sound. This implication cannot be accepted without further analyses. Such analyses have been made by the consultant and are described herein.

By estimating missing records, by computing the records from June 1966 to May 1967 on Xaya and Pixcaya Rivers, and by seeking out the additional low-water data collected at Selle Power Plant, the consultant has added considerably to the data available for analysis. Additionally, the consultant has taken advantage of the long-term rainfall record at Guatemala City to provide a basis for the application of correlation techniques. Two facets of the stream-flow records were analyzed: The low-water months, and the annual flows.

Low-Water Analysis

The minimum flows at Selle Power Plant on Pixcaya River for each year since 1927 except 1950 are listed on Table No. 6; prior to 1940, the minimum flow was at an average rate exceeding 2,000 lts. per second. However, in 1940, a gradual reduction in the minimum flow occurred and persisted until 1949,

TABLE No. 6

MINIMUM FLOW OF PIXCAYA RIVER, SELLE POWER PLANT, IN LITERS PER SECOND

Year	Minimum Month	Flow l/Sec.	Year	Minimum Month	Flow l/Sec.
1927	March	2,200	1948	April	1,270
1928	March	2,150	1949	March	1,100
1929	March	2,180	1950	-	-
1930	March	2,040	1951	March	1,310
1931	March	1,920	1952	March	1,220
1932	April	2,110	1953	March	1,090
1933	March	2,180	1954	March	1,350
1934	March	2,040	1955	April	1,480
1935	March	1,900	1956	April	1,360
1936	March	2,220	1957	April	1,420
1937	March	2,180	1958	March	1,410
1938	March	2,040	1959	April	1,480
1939	April	1,970	1960	April	1,540
1940	April	1,710	1961	April	1,410
1941	April	1,760	1962	April	1,320
1942	March	1,590	1963	April	1,390
1943	March	1,410	1964	April	1,270
1944	March	1,320	1965	April	1,480
1945	March	1,120	1966	April	1,410
1946	March	1,030	1967	April	1,480
1947	March	1,240			

reaching a minimum of 1,030 lts. per second in 1946. After 1950, the minimum flow shows a steady increase. These consistent trends in the minimum flow cannot be accounted by rainfall. Rather, the reduction rates in the 1940-1949 period is the result of denudation of the mountain slopes.

The denudation resulted in quicker surface runoff during the rainy seasons with a resulting reduction in infiltration into ground water. The minimum flows occur normally during the months of March and April, a period of little rainfall and no surface runoff. Thus, the minimum flow is the result of groundwater inflow into the streams. With greatly reduced infiltration into ground water during the rainy seasons, the quantity of ground water available to maintain stream flow during the low-water periods is greatly reduced. By 1949, the second growth timber was of such size as to exert an influence on surface runoff and ground-water infiltration and the minimum flow started increasing. It will be many years before the effect of the second-growth timber will reach the peak of influence apparent during the 1927-1939 period.

Because of the conditions discussed above, the period 1954-67 has been selected as the base period for this analysis. Rainfall in Guatemala City during this period averaged 1,292 mm. per year only slightly greater than the long-term average.

All available low-flow data in the area for the period 1954-67 are listed in Table No. 8. Also, shown in Table No. 8 are low-flow estimates for Xaya-La Sierra and Pixcaya-El Tesoro for the years 1954-1959. These estimates are based on the low-flow data for Selle Power Plant and a coefficient relating

those flows to the minimum flows at La Sierra and El Tesoro for the years 1960-1967 during which these are simultaneous records at all these sites. The derivation of these coefficients is shown in Table No. 7.

Analysis of Annual Stream Flow

Only 11 full years of stream-flow records are available on the streams considered by the DAD in the development of their respective plans. Of these 11, five were the result of the consultant working up additional records and filling in missing records for imcomplete years. There are five full years each on Xaya-La Sierra and Pixcaya-El Tesoro and one on Itzapa River. Reservoirs are proposed on Xaya and Pixcaya Rivers as well as for the minor streams, Itzapa, Parramos and Pasiguan Rivers, tributary to the Guacalate and on Coloya River, tributary to the Pixcaya River.

It is apparent that the available data is insufficient for a reliable analysis and design of the final stages of the project. An attempt is made herein to extend the available stream-flow data to provide a basis for evaluation of the subject streams as the water source for the final stage of the project.

Rainfall records for Guatemala City, Comalapa and Selle Power Plant have been used in this analysis. Records of rainfall have been kept at Guatemala City since 1928, and at the Selle Power Plant since 1955. Records at Comalapa cover the periods 1934-1939, 1960-1965. Annual rainfall totals for the three stations are shown in Tables 9 through 11. Rainfall at Selle Power Plant and Comalapa, because of their locations in the Pixcaya River Basin are considered to be indicative of rainfall over the project area. They were, therefore, used to

TABLE NO. 7

Year	Selle Power Plant l/sec.	Pixcaya - El Tesoro l/sec.	Pixcaya - El Tesoro Selle Plant	Xaya - La Sierra l/sec.	Xaya - La Sierra Selle Plant
1960	1,540	767	0.498	355	0.231
1961	1,410	876	0.621	423	0.300
1962	1,320	750	0.568	370	0.280
1963	1,390	676	0.486	307	0.221
1964	1,270	611	0.481	247	0.194
1965	1,480	675	0.456	323	0.218
1966	1,410	938	0.665	349	0.248
1967	1,480	975	0.656	406	0.295
Mean			0.554		0.248

Estimates of the low-flow of both Xaya and Pixcaya Rivers can be made on basis of the above coefficients with standard error of less than 15 percent.

TABLE No. 8

MINIMUM MONTHLY MEAN FLOW

Year	Pixcaya River El Tesoro	Pixcaya River Selle	Xaya River La Sierra	Xenacoj River No. I	Xenacoj River No. II
1954	+ 750	1,350	+ 335		
1955	+ 830	1,480	+ 365		
1956	+ 750	1,360	+ 335		
1957	+ 790	1,420	+ 350		
1958	+ 780	1,410	+ 350	160	26
1959	+ 820	1,480	+ 365	141	13
1960	767	1,540	355	156	18
1961	876	1,410	423	169	21
1962	750	1,320	370	159	20
1963	676	1,390	307	153	12
1964	611	1,270	247	144	12
1965	675	1,480	323	-	-
1966	938	1,410	349	143	10
1967	975	1,480	406		
Mean	785	1,420	349	-	-

+ Estimated on basis of low-water record at Selle Power Plant.

develop rainfall-runoff relationships. These records are, however, of short duration only 12 years each so they were used in conjunction with records of rainfall at Guatemala City to develop rainfall relationships that would permit extension of annual stream-flow records back to 1954. The year 1954 was selected because of the effect of denudation discussed previously. The relation between annual rainfalls at Guatemala City and both Selle Plant and Comalapa are shown on Figures 2 and 3.

The use of these relationships will permit the estimation of annual rainfall at Selle Power Plant with a standard error of 12 percent and at Comalapa with a standard error of 10 percent. The standard error, at the mean rainfall over the project area estimated on basis of Comalapa and Selle Power Plant estimates will be somewhat less than the standard error of either individually. This results from the fact that estimates at one station might be high at the same time that estimates at the other station are low. Standard errors of this magnitude are considered to be within acceptable limits for this analysis.

Using the relationship described above and coefficients of runoff for Pixcaya and Xaya Rivers developed from the stream-flow records for the period 1962-1966 and records of rainfall at Selle Power Plant and Comalapa for the same period, annual discharge values have been computed for the years 1954-1961. The rainfall runoff coefficient for the period was computed to be 0.166 for Xaya River and 0.168 for Pixcaya. The agreement of these coefficients supports the assumptions made as the rainfall, the rainfall relationships developed, and the stream-flow data, meager though they are. A mean coefficient of 0.167 was used for the entire project area. This coefficient is not considered applicable prior

TABLE NO. 9

ANNUAL RAINFALL, IN MILLIMETERS, AT GUATEMALA CITY

Year	Rainfall	Year	Rainfall	Year	Rainfall	Year	Rainfall
1928	1,390	1938	1,134	1948	1,226	1958	1,654
1929	1,370	1939	1,097	1949	1,423	1959	1,213
1930	770	1940	1,224	1950	1,046	1960	1,477
1931	1,440	1941	1,063	1951	1,112	1961	1,012
1932	1,329	1942	957	1952	1,421	1962	1,303
1933	1,831	1943	1,285	1953	1,042	1963	948
1934	1,236	1944	1,115	1954	1,446	1964	1,237
1935	1,291	1945	1,312	1955	1,439	1965	1,049
1936	1,431	1946	760	1956	1,317	1966	1,217
1937	1,211	1947	1,518	1957	1,231		

Mean - 1,246 mm.

TABLE NO. 10

ANNUAL RAINFALL, IN MILLIMETERS, AT SELLE POWER PLANT

Year	Rainfall	Year	Rainfall
1955	1,785	1961	1,076
1956	1,263	1962	1,395
1957	1,261	1963	1,061
1958	1,867	1964	1,712
1959	1,208	1965	1,364
1960	1,737	1966	1,599

Mean = 1,440 mm.

TABLE NO. 11

ANNUAL RAINFALL, IN MILLIMETERS, AT COMALAPA

Year	Rainfall	Year	Rainfall
1934	1,700	1960	1,660
1935	1,460	1961	1,220
1936	1,720	1962	1,280
1937	1,580	1963	1,380
1938	1,420	1964	1,580
1939	1,650	1965	1,280

Mean = 1,411 mm.

TABLE NO. 12

ESTIMATION OF ANNUAL DISCHARGES IN LTRS/SEC

XAYA RIVER - LA SIERRA AND PIXCAYA RIVER - EL TESORO

	Rainfall mm.			Mean Discharge l/Sec.	
Year	Selle	Comalapa	Mean	Xaya	Pixcaya
1954	1,680	1,760	1,720	782	1,400
1955	1,785	1,660	1,720	782	1,400
1956	1,263	1,220	1,240	563	1,010
1957	1,261	1,500	1,380	627	1,130
1958	1,867	2,000	1,930	877	1,330
1959	1,208	1,480	1,340	609	1,090
1960	1,737	1,790	1,760	800	1,430
1961	1,076	1,240	1,160	527	946

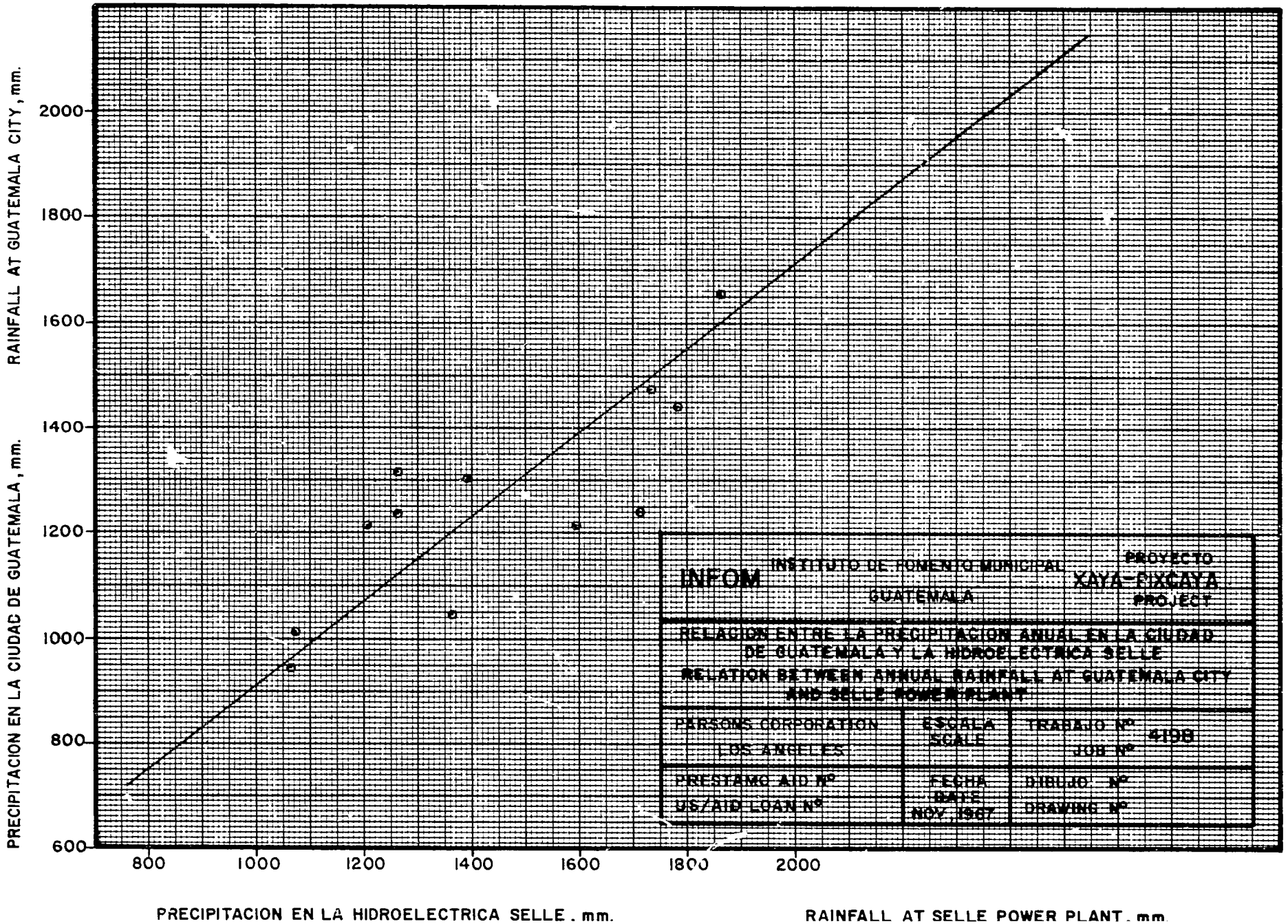
to 1954, however, because of the changed conditions of the watershed caused by denudation. The results of application of this coefficient are shown in Table No. 12. The average flows, then, for the period 1954-1966 are:

Xaya River	-	La Sierra	676 lts. per second
Pixcaya River	-	El Tesoro	1,200 lts. per second

In order to estimate the mean flows for all streams under consideration in this project, a mean discharge-drainage area relationship for the period 1954-1966 was determined. The mean discharges for the year 1966, the only year for which there are complete records for three stations, were used to establish the slope of the relation and the 13 year means of Xaya and Pixcaya used to establish its position, (See Figure 4). The similarity of topography soil cover, and rainfall over all of the area indicates that the annual means for all the streams will have a fixed relationship to rainfall. The mean discharges for all the streams considered for the period 1954-1966 are shown on Table No. 13. These, except for La Sierra and El Tesoro, were computed from the relationship shown on Figure No. 4.

FIGURA Nº 2

APENDICE- APPENDIX A



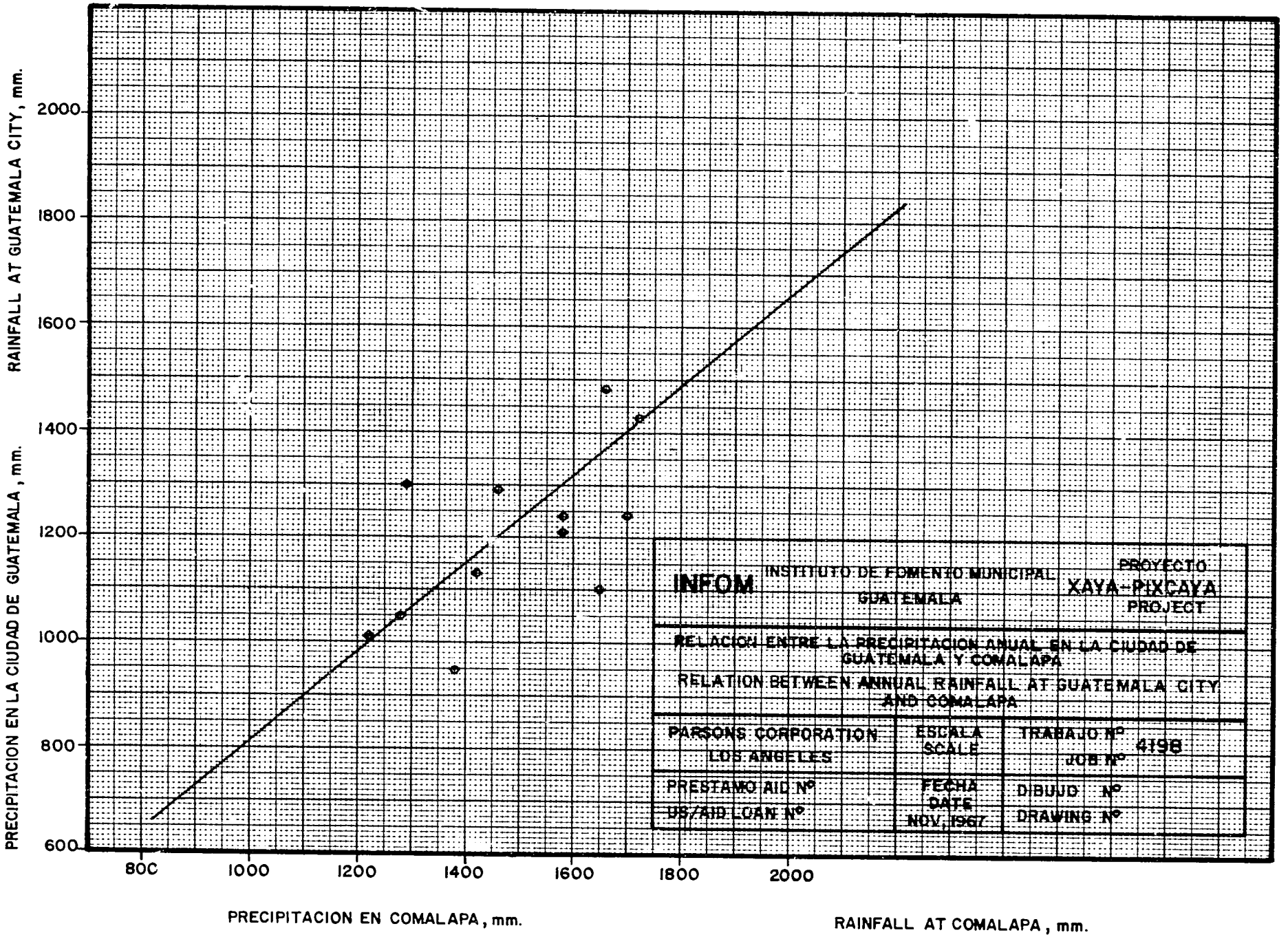

PRECIPITACION EN LA CIUDAD DE GUATEMALA, mm.
RAINFALL AT GUATEMALA CITY, mm.
2000
1800
1600
1400
1200
1000
800
600
800
1000
1200
1400
1600
1800
2000
PRECIPITACION EN COMALAPA, mm.
RAINFALL AT COMALAPA, mm.
INFOM
INSTITUTO DE FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
RELACION ENTRE LA PRECIPITACION ANUAL EN LA CIUDAD DE GUATEMALA Y COMALAPA
RELATION BETWEEN ANNUAL RAINFALL AT GUATEMALA CITY AND COMALAPA
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO Nº
JOB Nº
4198
PRESTAMO AID Nº
US/AID LOAN Nº
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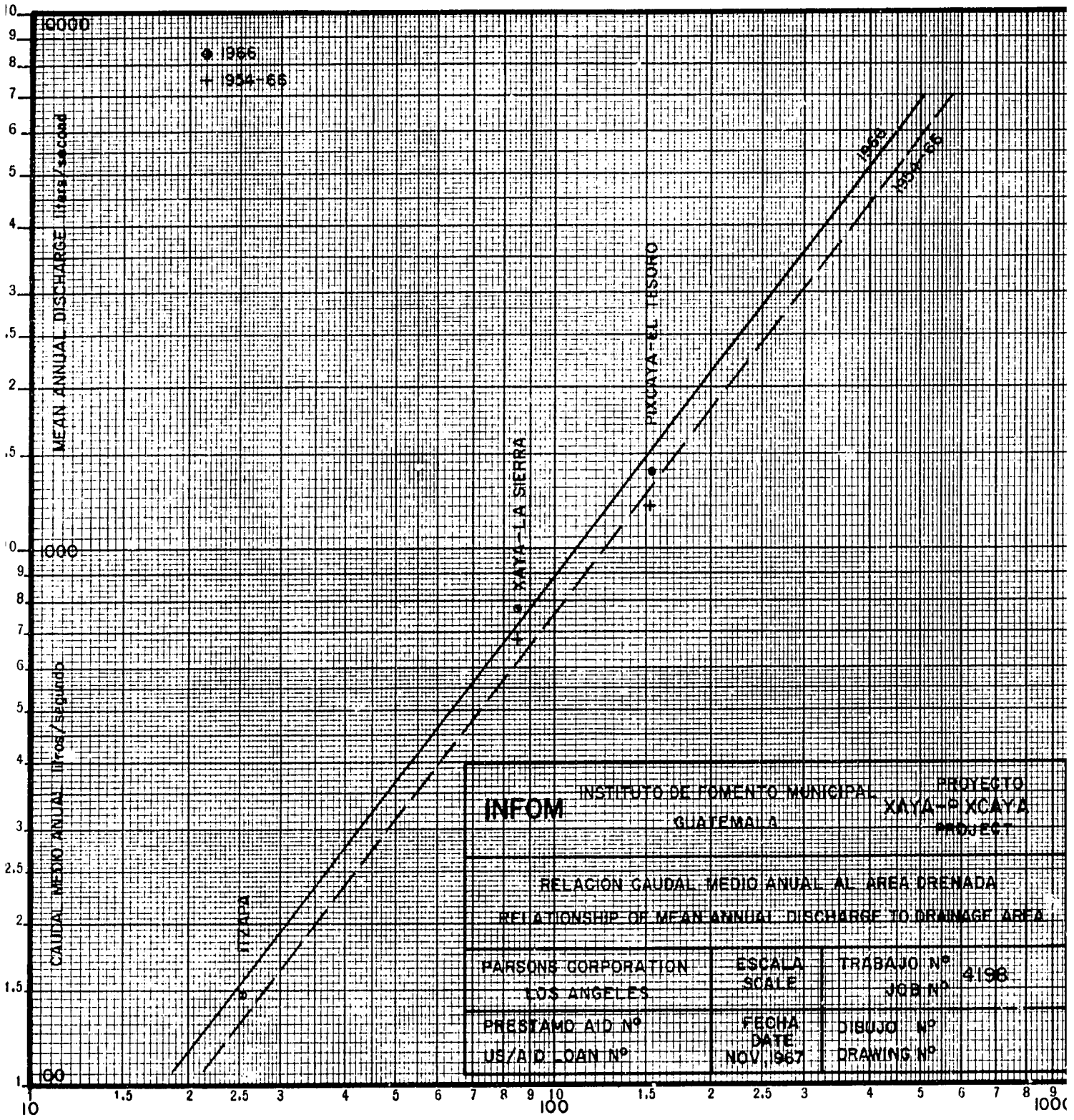
FIGURA Nº 4
APENDICE-APPENDIX A



AREA DRENADA , Km.² .

DRAINAGE AREA , Km.²

TABLE NO. 13

MEAN DISCHARGE, IN LITERS PER SECOND FOR PROJECT STREAMS

Stream	Drainage Area Km.^{2}	Mean Discharge Ltrs. per Sec.
Xaya-La Sierra	85.8	676
Xaya-Los Tres Mojones	57.2	370
Pixcaya-El Tesoro	154	1,200
Coloya	20.5	100
Itzapa	25.3	130
Parramos	29.2	160
Pasiguan	13.4	60

These estimates are somewhat lower than those made by the MDN by reason of the fact that that MDN estimates were based on a three-year period, 1964-1966, during which the mean flows at La Sierra and El Tesoro were higher than those estimated herein for the period 1954-1966. The estimates made herein are considered to be more reliable: First, because they were based on a longer period of stream-flow record, five years as against three; and second, because a somewhat sounder approach was used in relating to long-term rainfall records by considering all available information.

GENERAL DISCUSSION

The feasibility reports of the MDN and the DAD were based on short-term stream-flow records; three full years record each on Pixcaya-El Tesoro and Xaya-La Sierra, and on seven years of low-water flow at each of the above stations. Records of such length are rather sketchy data upon which to base such an important project. The consultant has added considerably to the length of record available by extending the period from which the mean discharge is available from three to 13 years and the low-flow record from seven to 14 years. He has

also made estimates of mean discharge for Coloya, Itzapa, Xaya-Los Tres Mojones, Parramos and Pasiguan Rivers; all of which are included in the final stage. He has made these extensions on the basis of computing stream-flow records which were previously uncomputed and by correlation. He had available for use, a long-term low-flow record on Pixcaya River at Selle Power Plant. These records were apparently not available to either MDN or DAD. Analyses of the stream-flow records developed herein with respect to the quanitites of water called for by the two plans, indicate that the supply is marginal. The DAD, for example, proposes to divert 741 ltrs. per second from Pixcaya River at El Tesoro. During the 14 years for which low flows have been measured or synthesized by the consultant, the mean monthly flow has been below 741 ltrs. per second, a total of seven months during three years and has been over 741 ltrs. per second by marginal amounts during six other years. The MDN's proposal calls for a diversion of 650 ltrs. per second. The monthly flow was below that figure for five months during one of the 14 years, and exceeded it by a marginal amount two other years.

A somewhat better situation exists on the Xaya River, where the monthly flow was below the DAD's expected withdrawal of 278 ltrs. per second only during one year of the 14 and there are no so called marginal years. The DAD's proposed withdrawal of 139 ltrs/sec from the Xenacoj River is less than the low-water flow observed over the past nine years.

Only the MDN has discussed water requirements for the final stages and proposed magnitudes of withdrawal. In the following Table No. 14, is shown the mean flow as estimated for the period 1954-1966 at each of the proposed reservoirs and the withdrawal as proposed by the MDN.

TABLE NO. 14

Stream		Mean Discharge Lts./Sec.	Proposed Diversion Lts./Sec.
Xaya		676	731
Pixcaya		1,200	1,330
Coloya		100	
Itzapa	Guacalate River	130	
Parramos		160	
Pasiguan		60	405

In each case, it will be noted that the proposed diversion exceeds the mean flow. The proposed diversion from the combined Pixcaya and Coloya Rivers is 1,330 lts./sec. as compared to a mean flow of 1,300 lts/sec. The mean flow of Xaya River is 676 lts./sec. as compared to a proposed withdrawal of 731 lts./sec.

Even though the above analysis indicates a marginal source of water, there is reason to believe that the low-water flow in the future may improve. The effect of the denudation of the mountain slopes was noted earlier in connection with the 40 years of low-flow record collected on Pixcaya River at Selle Power Plant. Prior to 1940, the low-water flow averaged in excess of 2,000 lts./sec. In 1940, the low-water flow began falling off so that by 1945 the low-water flow was not much greater than 1,000 lts./sec. This reduction persisted until about 1951, when the flow started increasing until now the mean low water flow is in the order of 1,400 lts./sec., indicating that the second-growth timber is now exerting a favorable effect on the watershed. This beneficial effect will persist until complete forest cover is again attained.

RECOMMENDATIONS

There can be no doubt that a major weakness in the proposed Xaya-Pixcaya River Project is the lack of stream-flow records of sufficient length to establish definitely the reliability of the water source. What records are available are satisfactory insofar as the low-water records are concerned, but are open to question at the medium and higher flows because of the lack of discharge measurements at stages greater than can be waded. Nor are there enough stations to provide adequate coverage for all of the streams considered. Sedimentation records have not been kept. With the above deficiencies in mind, the following recommendations are made:

1. Continue the stream-flow stations on Xaya, Pixcaya and Itzapa Rivers, but make provisión for discharge measurements covering the complete range in stage. It will probably be necessary to install cableways or small foot bridges across the streams from which to measure the depths and velocities.
2. Install stream-flow stations on Coloya, Parramos and Pasiguan Rivers. These too should be equipped with cableways or bridges for higher stage discharge measurements.
3. Start a program of sediment sampling on all streams for which reservoirs are proposed. From what is visible at Selle Power Plant, siltation of reservoirs will be a real problem.
4. Establish stream-flow stations on all streams such as Motagua River that might be considered a possible source of water supply for Guatemala City in the future.
5. When high-water discharge measurement have been made at existing stations, the computed records should be reviewed and changes made where such changes are indicated.

APPENDIX B

GEOLOGY

I. ALIGNMENTS

Scope

The purpose of this study is to provide a geologic framework on which to base an evaluation of the two different water conveyance systems, from the Pixcaya River to the City of Guatemala. One month was spent in Guatemala; during this time numerous trips were made to the field and discussions were held with various people familiar with the project. A station-by-station breakdown of the tunnels, siphons, conduit, et cetera was made with regard to geologic materials to be encountered. This information was later put in two summary tables (10 pages) which are included in this Appendix. They cover both the MDN and DAD routes.

The two water supply systems, one designed by the Army Corps of Engineers (Ministry of National Defense-MDN), the other designed by the Municipality of Guatemala City (Direction of Waters and Drainage-DAD) follow different routes to reach the city from the Pixcaya. In this stretch the MDN scheme envisages the use of 12 tunnels with a total length of 13,426 meters ranging from 5,630 meters to 90 meters. The DAD scheme as currently modified proposes 104 tunnels with a total length of 34,840 meters ranging from 1,310 to 25 meters.

Previous Geologic Work

Previous geological works that cover the area of investigation include the classic work of Howell Williams entitled "Volcanic History of the Guatemalan Highlands", 1960. This paper includes a geologic reconnaissance map that covers approximately 12,000 square kms. The primary rock units of the region were determined along with age relationships. A geologic reconnaissance was performed by Otto H. Bohnenberger for the Proyecto Quezada del Acueducto Nacional Xaya-Pixcaya in June of 1962. This work included a geologic map, scale of 1:50,000 compiled from aerial photographs with limited field work. This report has served as a geologic basis for the MDN alignment. Additional geologic mapping performed by Oscar Salazar and Carlos Mendoza of Instituto Geografico Nacional in 1963 provided additional coverage in the vicinity of the DAD alignment. Discussions with Otto Bohnenberger indicated that the two works were of equivalent detail. The two alignments have been evaluated on an areal basis utilizing the base map of Bohnenberger, Salazar and Mendoza.

The 1966 report of Electro Watt (Swiss Boring) concerning the Chimaltenango and Las Canas tunnels utilized this same base map. Subsequent letter reports by ICAITI in 1966 have been prepared on the minor tunnels of the MDN alignment. These letter reports include geologic sections. Exploratory work completed to date include 4 diamond core holes on the two major tunnels of the MDN alignment drilled by Electro-Watt, and trenches were excavated in the majority of portal areas of the MDN alignment. Twenty-eight hand-dug shafts 1.5 meters in diameter have

been recently started on the Municipal alignment. These shafts range in depth from about 10 to 50 meters.

Location

The area of investigation extends from the City of Guatemala northwesterly for an airline distance of about 40 kms. The points of diversion for both projects are located near the Finca del Tesoro, which is in the vicinity of Chimaltenango. The DAD alignment follows a northerly route for the large part within the drainage of the Rio Pixcaya, turning south in the vicinity of San Raimundo, then southerly into the La Brigada Purification Plant.

The MDN alignment pursues a southeasterly route to the vicinity of Antigua, then easterly for about 10 kms., thence northerly to the proposed Mixco Purification Plant. The Mixco Plant is about 3.75 kms. southwest of the existing La Brigada Plant.

Site Conditions

The topography traversed by both alignments is rather severe. The natural stream drainage pattern is presently in a youthful stage of development and so characterized by steep-sided, narrow canyons being incised into a rolling surface of not great relief. Headward erosion is presently progressing at a greater rate than lateral erosion. The streams have exceedingly steep gradients and are working their way headward through relatively soft materials. Some of the headward ends of streams observed in the field have vertical faces of up to 70 meters in height with little tributary drainage area. The crossing of such an area with

a gravity water supply system requires many tunnels, siphons and side-hill covered conduits. Canalling, in the strict sense, is precluded from consideration in this area due to topographic conditions.

Soil

The soils of the investigational area are primarily residual soils developed on volcanic parent materials. They are generally a deep red-colored silty loam or clay loam, some of them exhibiting shrinkage cracks due to the presence of expansive clays of the bentonite group. Samples of the soils observed contained a fairly high content of glass shards and pumice fragments. The depth of soil profiles observed in cut slopes varied from 1 to 5 feet.

Regional Seismicity

Data on the seismicity of the study area have been obtained from the Observatorio Nacional, Direccion General de Recursos Naturales Renovables, Ministerio de Agricultura. These data indicate that both projects would expect the same seismic forces. There are several areas where epicentres frequently reoccur. These are in the region of Petapa and the zone north of Lake Amatitlan, southwest of the Volcano Pacaya in the Department of Escuintla, and two or three near the litoral zone in the Department of Suchitepequez and San Marcos, near the Mexican border. Even though the MDN line is closer to the Petapa and Pacaya epicenters, it is felt that due to the harder rock environment as compared to the DAD line that the lines are moreorless equal from a seismic

standpoint. Information in the pre-investment study for the Jurun-Marinala Project indicates that all construction including tunnels and penstock are exposed to earthquake intensity of modified Mercalli Scale VIII. For sake of clarity, the definitions of intensities VII, VIII and IX are given.

VII. Everyone runs outdoors. Damage negligible in buildings of good design and construction, however. Shock noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary buildings; great in poorly built structures, fall of chimneys, stacks, columns. Persons driving motor cars disturbed.

IX. Damage considerable even in specially designed structures; well-designed frame structures thrown out of plumb. Buildings shifted off foundations. Ground cracked conspicuously.

A curve of intensity versus acceleration plotted by the Observatorio Nacional indicates a relationship of 70 gals. for intensity VII and 150 gals. for intensity VIII. The curve as plotted does not reach intensity IX.

Final design criteria should probably utilize a value between .15 and .20 gravity.

II. GEOLOGY

General

The two water supply schemes are situated in the central portion of the Guatemalan Highlands. This highland area is characterized by the presence of an impressive line of Quaternary volcanoes. The Quaternary period of volcanism has created numerous cones as well as blanketed the tertiary landforms with glowing avalanche deposits and interbedded with thick zones of fluviable tuffaceous sediments. The Tertiary volcanic and sedimentary rocks are, in part, deposited on Cretaceous limestones and dolomites and earlier igneous and metamorphic rocks. The Tertiary and earlier rocks have been folded and broken by numerous faults of varying magnitudes.

Rock Types

Based on the available geologic mapping and field inspection, the rock materials within the study area have been subdivided into six units based primarily on their engineering properties. These units are Quaternary Alluvium (Qal), Quaternary Volcanic pumice (Qvp), Tertiary Volcanics (Tv) including both flows and pyroclastic, upper Cretaceous limestones and dolomites (Kld) and granitic rocks (gr) of middle or upper Cretaceous age. Accompanying this report are two maps showing the geology along both alignments, Figure 1 and Figure 2.

Quaternary Alluvium (Qal)

This unit is only encountered in several localities crossed by the alignments. The only areas where it is noteworthy of describing are

along the MDN line and in the valley of Antigua. The alluvium at these points has a width of 500,300 and 200 meters and are crossed by siphons and will only be encountered for support blocks. The alluvium is composed principally of sand and gravel that have been derived from volcanic materials by erosion.

Quaternary Volcanic Pumice (Qvp)

This unit is composed of all the Quaternary pyroclastics delineated by Bohnenberger, such as recent pumice, pyroclastic sands deposited predominately in water, and massive pumice deposits of glowing avalanche origin, partially reworked by water. This pumiceous unit has unique engineering properties, due to its apparent cohesive character and due to the interlocking of angular grains. It stands stable in near-vertical cuts. Circular tunnels up to 4.50 meters in diameter stand unsupported for periods in excess of a year and yet the material can be excavated easily with pick and shovel. The pumice deposits contain numerous weathered zones which are a yellow-brown color. These zones locally called "talpetate" are paleosols. The paleosols are, in turn, overlain by fairly fresh white deposits. The paleosol horizons are slightly harder to work by hand due to a higher residual content of clay. It has been the experience within the City of Guatemala that only a minimal amount of overbreak (2 percent ±) occurs during tunneling operations in these deposits. The permeability of this unit appears to be very low in spite of a high apparent porosity. The numerous paleosol zones render it nearly impervious for tunneling considerations. Even

though the area has a high rate of annual rainfall (50 inches ±), it appears that most of the water that penetrates the ground surface is held in storage within the root zone and is utilized by the consumptive use of the rather heavy vegetal cover. The amount of water in storage evidently varies between the field capacity which is fairly high and the wilting point, with only a small amount of moisture remaining for deep percolation under unsaturated flow conditions. This unit will be encountered by both alignments.

Tertiary Volcanics and Sediments (Tvs)

The litologic materials that constitute this map unit are sediments of volcanic origin. The two map units of Bohnenberger, Tscl and Tsc2 are included together in this report due to insufficient field time to delineate the two units in the field for both alignments. The volcanic sediments overlie the Tertiary Volcanic (Tv) unit. They include fanglomerates, pumiceous sands, diatomites, conglomerates of mudflow type origin and tuffs. These materials have been slightly folded and faulted to a presently unknown degree. It is estimated that overbreak during tunneling operations will be on the order of 15 percent. Small to moderate water inflows may be encountered in the more indurated zones where the materials have been fractured or sheared. This unit will be encountered primarily by the MDN alignment. This unit would be classified as stratified rock under the Terzaghi Classification System.

Tertiary Volcanics

The Tertiary volcanics rock unit includes flows of rhyodocite, andesite, basalt intercalated with conglomerates of basalt, glowing avalanche deposits and water-laid tuffs. This unit will probably be the most problematic formation that will be encountered by either alignment. This unit is quite variable in lateral extent. Limited observations indicate that there is a greater percentage of flow materials along the southern line, while the northern line has more pumiceous and tuffaceous materials. Overbreak in the volcanic flow materials will be a large problem, especially if relatively unskilled labor is used. The overbreak in the softer materials will be much less. The average for the unit should be about 10 percent. Water inflows from the volcanic flows can be large, especially in areas where they have been effected by faulting and there is a considerable amount of cover or where crossed by stream channels. The pumiceous and tuffaceous phases should transmit only small quantities of water. The flow phases of this rock unit would be classed as very blocky and seamy whereas the soft phase would be stratified.

Cretaceous Limestones and Dolomites (Kld)

Rocks of this unit are possibly the most indurated that will be encountered within the area of investigation. According to Williams (1960), most of the limestones are massive and unstratified. They range in color from gray-white to dark gray. Numerous joints have been healed with deposits of white calcium carbonate. Overbreak during tunneling

operations should be about 10 percent. Although no solution cavities were observed in the field, their presence should not be discounted. Solution cavities can be a serious problem when encountered below the water table. The limestones are fairly brittle and where they have been sheared or faulted, water inflows of moderate to high magnitude could be anticipated depending on the amount of cover. The rock would be generally classified as moderately blocky and seamy according to the Terzaghi system.

The limestones and dolomites, as far as is presently known, will only be encountered by the DAD alignment.

Granitic Rocks (gr)

This rock unit has only a limited exposure in the vicinity of San Raimundo on the DAD line. According to Williams, it is quartz diorite. Surface exposures are rather deeply weathered. It is doubtful that much hard and intact diorite will be encountered at tunnel grade. Overbreak is estimated to be 10 percent or less. Water inflows are anticipated to be relatively low. The rock would classify as moderately blocky and seamy to very blocky and seamy by the Terzaghi system.

Faults

The largest known fault within the area of investigation is the Mixco fault. This feature forms the western side of the Guatemala City graben. Rocks of the Tertiary volcanic series are found in the mountains to the west of the fault, whereas thick deposits of Quaternary

pumice are found in the valley to the east of the fault. The MDN line crosses this fault down gradient from the El Zope tunnel. The fault appears to die out to the north by forming a series of smaller faults and shears with less displacement. The DAD line crosses part of the area of small faults and shears. The primary effect of this fault on either line is to break the rock of the area into smaller blocks, thereby causing the likelihood for greater support requirements. Several unnamed faults are known to bound the limestone bodies in the vicinity of the DAD line. Again such faults are of importance in that they may create water and/or support problems.

Temperature

The only information available concerning the temperature of the rock that might be anticipated has been obtained from the four diamond drill holes on the Las Canas and Chimaltenango tunnels. These are as follows:

Drill Hole	Depth in Meters	Temperature in Degrees Centigrade
CH 1	150	23
CH 2	105	24
LC 1	250	22
LC 2	275	21

These temperatures compare with the mean annual temperature and a normal geothermal gradient of 1 degree centigrade increase for each 30 meters of depth. Several hot springs are known to exist within the study area. The hot springs of San Lorenzo are near the MDN alignment but considerably lower in elevation than the hydraulic grade line of the

conduit. Abnormal rock temperature or hot waters do not appear to be a great problem for either alignment.

Slope Stability

The problems of slope stability are considered to be common to both alignments. Where the conduit is near the surface and in a side hill position, there is a strong likelihood that areas of unstable ground (soil and rock creep and landslide) will be encountered. Only a detailed investigation will be able to delineate such areas. The areas where the conduit is to be placed in cut, the inclination of the cut slope becomes a problem. The inclination of the natural slope in many cases is stable only with a safety factor 1.0. Any steepening of the slope by natural or artificial means will change the safety factor to less than 1.0. and a failure can be expected at any time. Cutting or trenching a given slope, therefore, can create stability problems. Both reports, the MDN and the DAD, originally proposed near-vertical cuts when placing the conduit along the sides of natural slopes. The Municipality has now eliminated conduits in favor of tunnels. These steep inclinations have been based on the observations of the performance of road cuts in quaternary pumice deposits. These inclinations cannot be applied to the other materials present within the area of investigation. The pumice deposits having unique engineering properties can stand at the 1/6 horizontal to 1 vertical inclinations, and such slopes will be able to withstand the ever-present problems of erosion as there is less cut surface area exposed to the elements. Recent 1:1

and 2:1 cut slopes on pumice have been observed to erode very badly. Due to the obvious cut slope stability problems, the following inclinations are suggested for use in cost estimates:

Quaternary Volcanic Pumice	1/6 :1
Tertiary Volcanic and Sediments	1:1
Tertiary Volcanics (basalt, andesite)	1/2 :1
Cretaceous Limestone	1/2 :1
Granitic Rocks	1/2 :1

In cases where bedding planes or other planes of geologic weakness are undercut, the suggested cut slope inclinations will have to be flattened or supported by an engineered device, such as a retaining wall or buttress fill. Some degree of slope stability will have to be attained to minimize failures along either alignment, as no provision for terminal or regulatory storage has been provided for on either alignment.

Dam Problems

The construction of impounding dams is not a consideration of either present water supply system. However, it should be pointed out for future planning that the river systems carry a high content of sediment. Reservoir life will be very short unless special works are designed to combat this problem. The pumice deposits are an unsuitable foundation for any concrete-type dam. Due to the steep stream gradients and narrow valleys, earth embankments would occupy a fair portion of the desired storage area. The possibility of off-stream storage in cut-type reservoirs may be a solution to the dam construction problem; however, the cost will be large. Leakage from reservoirs and around the dams will probably be high in pumice-type deposits.

III. CONSTRUCTION MATERIALS

The scope of the engineering geology study did not include time for a detailed investigation of construction materials. Observations in the field, together with discussions with representatives of concrete firms in the area, have led to the following results:

Cement

The only cement available in Guatemala is Portland Cement type 1. This is obtained from the Novella Plant in the northern part of Guatemala City. Specialty items such as low-alkali cements are not locally available.

Aggregate

Two rock sources for the coarse fraction of aggregate are available. Crushed limestone is most commonly used in city concrete. Another source of coarse aggregate is available south of the city from the Rio Villalobos. Sand is also obtained at this location. The latter source contains volcanic fragments and in the writer's opinion is suspect of possible reactive aggregate problems. To date, no known supplies of suitable aggregate are known to be developed along the up-stream ends of either project. The valley of Antigua presents the only obvious area where additional quantities of Alluvial aggregate might be developed. The quarrying and crushing of some of the Tertiary conglomerates near Chimaltenango might present another source. However the degree of weathering plus reactive aggregate problems may preclude

such a source. The stream bottoms have such steep gradients and narrow configuration that sizable deposits for mining are not likely to be found.

Rip-rap

Supplies of rip-rap for embankment and slope protection may be developed from the fresher rock exposures of this volcanic rock such as andesite and basalt as well as from the limestone areas. The availability of rip-rap in the areas of Quaternary pumice deposits may be a problem. However, quarries should be able to be developed within reasonable haul distances.

Water Supply

Sufficient water for construction can be developed along either right-of-way from existing sources or through minimal additional development. Some tankage will have to be provided to meet peak demands due to the low yields of most existing supplies. The use of Xaya or Pixcaya water directly from the stream channels should be discouraged, due to the high suspended solid contents, without prior treatment.

IV. CONSTRUCTION PROBLEMS

Access Roads

The problem of access roads for construction of either alignment is a problem in terms of cost estimation. Vehicular access roads should be constructed to the portals of all tunnels that are driven by conventional methods. Access roads will have to be constructed to each siphon to allow trucks to unload pipes. Access roads will have to be constructed to the vicinity of each large pour of concrete. The majority of existing roads that reach or cross either alignment will have to be improved. Construction of access roads will require conventional earth-moving equipment. Blasting will only be required in some areas of volcanic flows and possibly in the limestones.

Tunnel Problems

The tunnels that are to be driven by conventional methods are to be minimum-size tunnels. Observation of other tunnels in the area that are under construction point out that overbreak in the harder rocks will be a serious problem unless special steps are taken to control it. The tunnels should be driven full face through the use of a specially designed jumbo or drill carriage. The spacing of perimeter holes should be less than one meter. Supervision by people with considerable experience in the construction of water supplies tunnels, not mining, is a necessity. An adequate supply of support will have to be readily available. The spoil from the tunnels should be placed in areas where

they will not be subject to undue erosion with the resulting sedimentation problems on the streams and rivers downstream. Some of the tunnel spoil from the harder rocks can be utilized in surfacing access roads.

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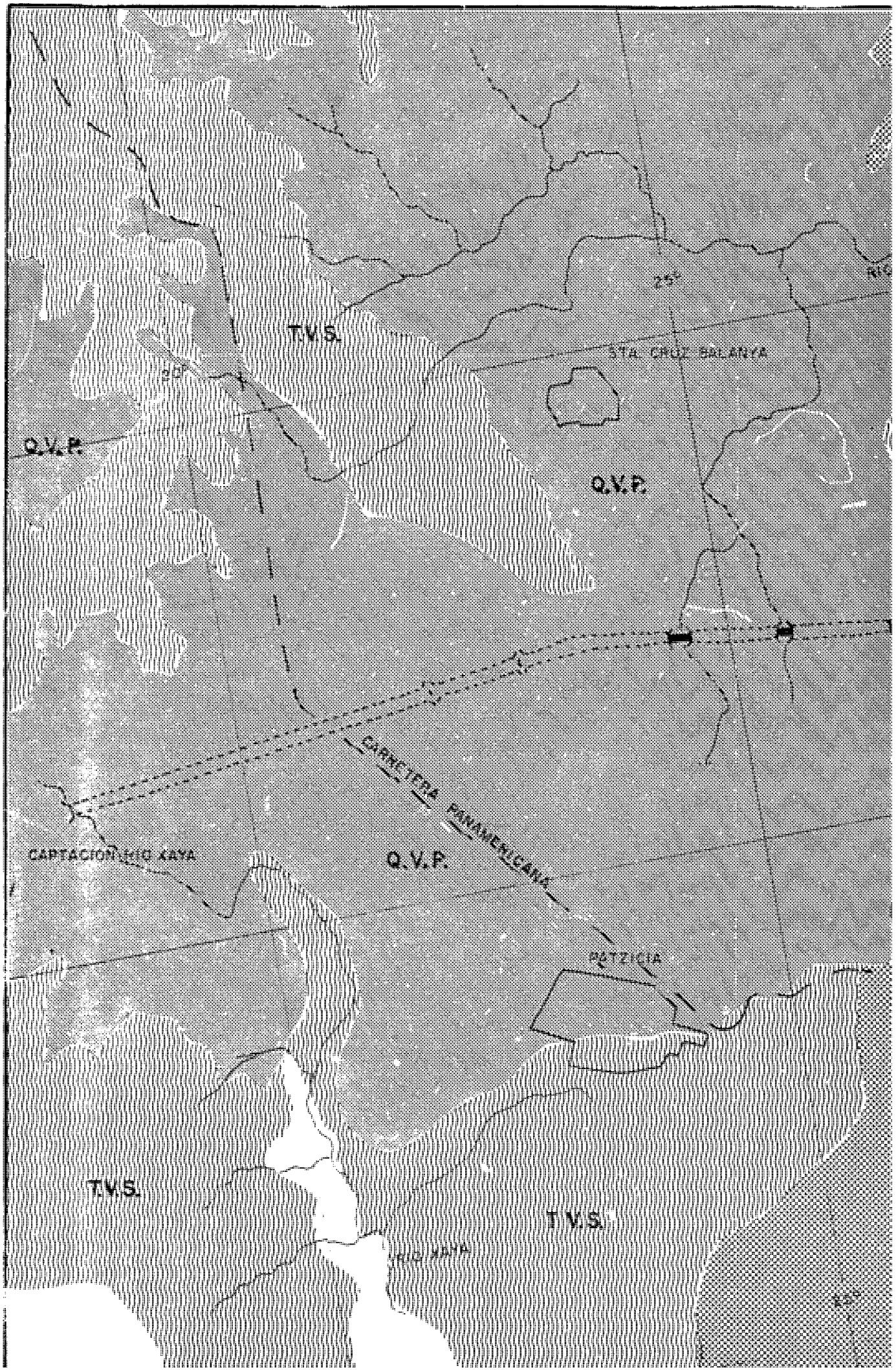
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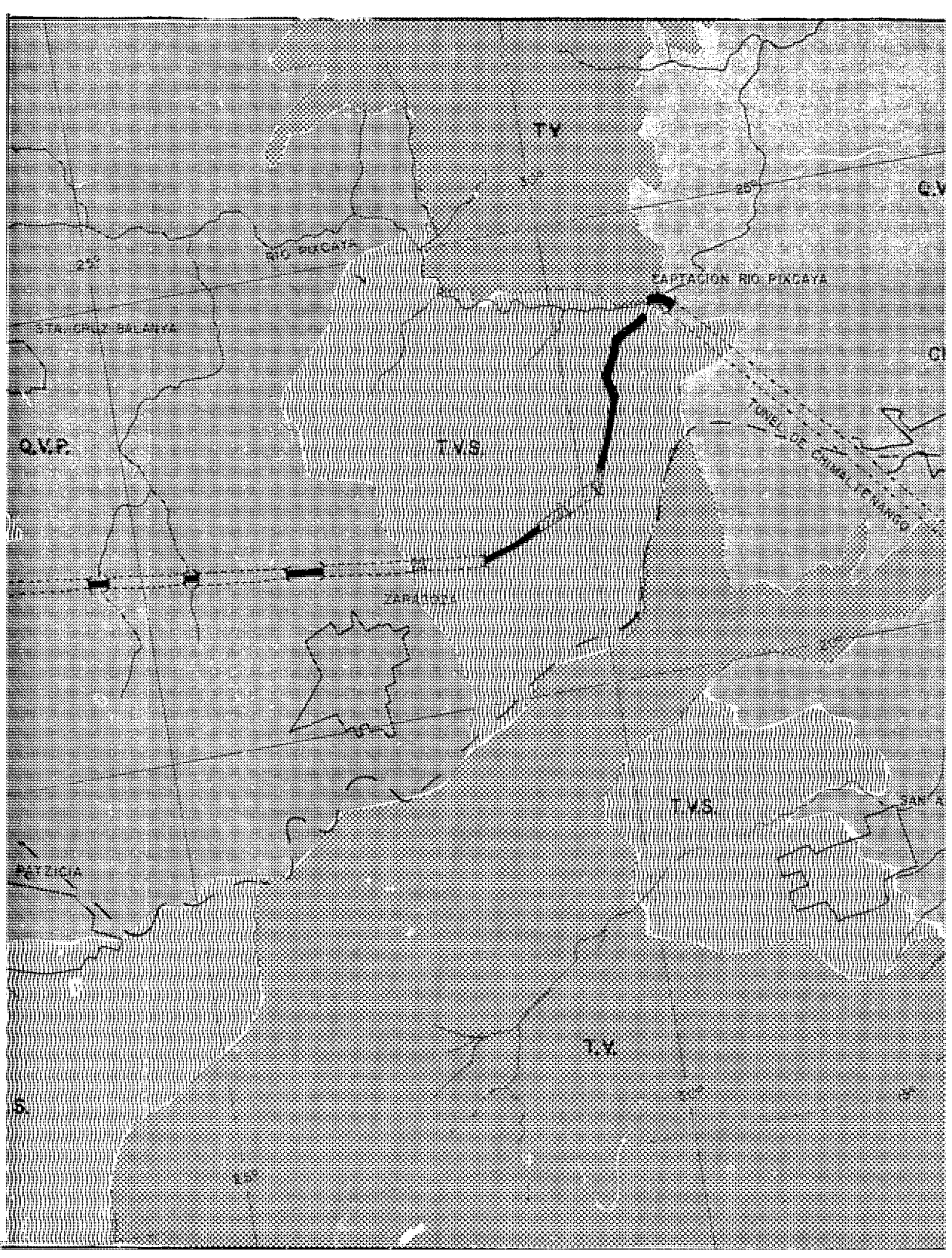
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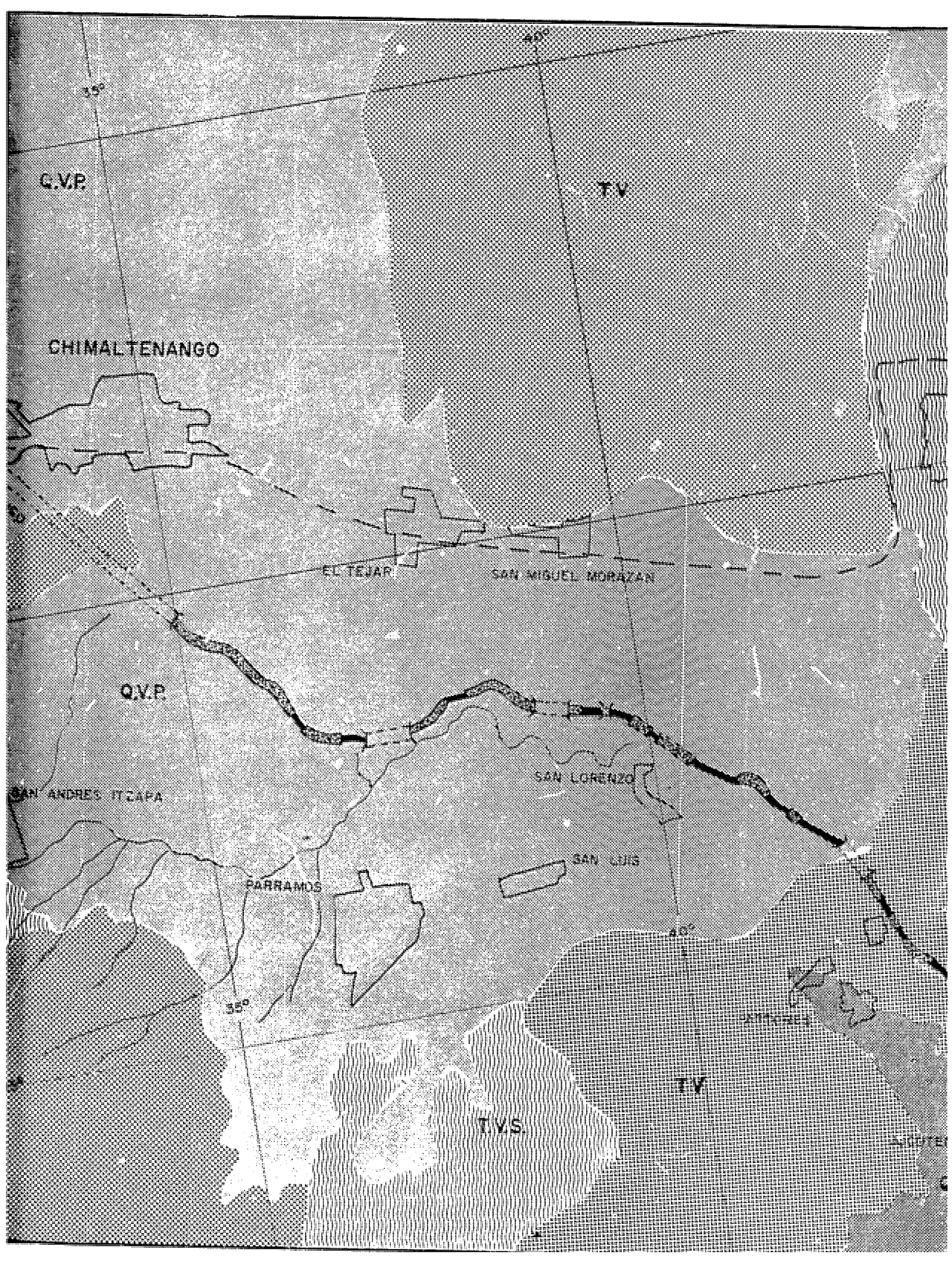
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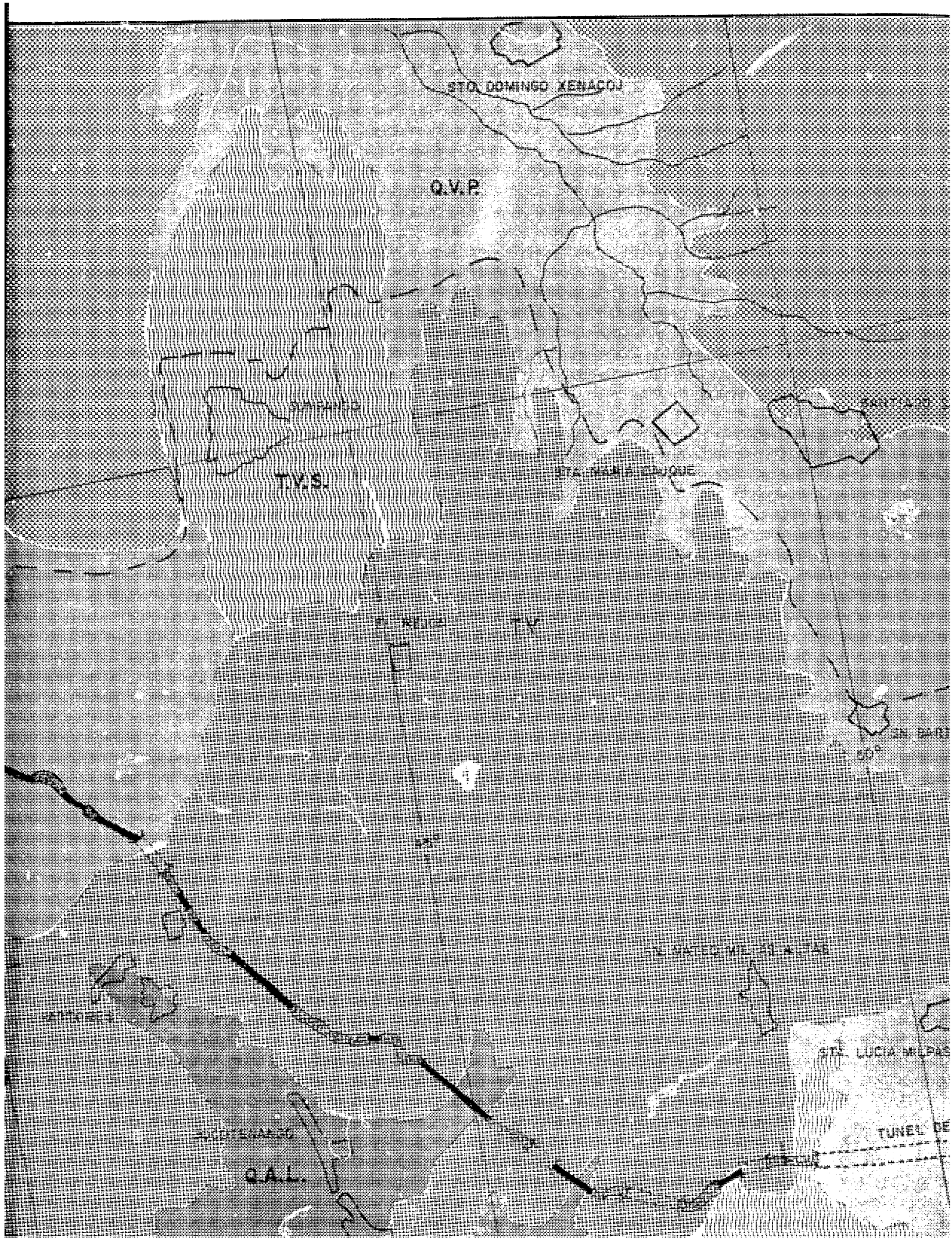
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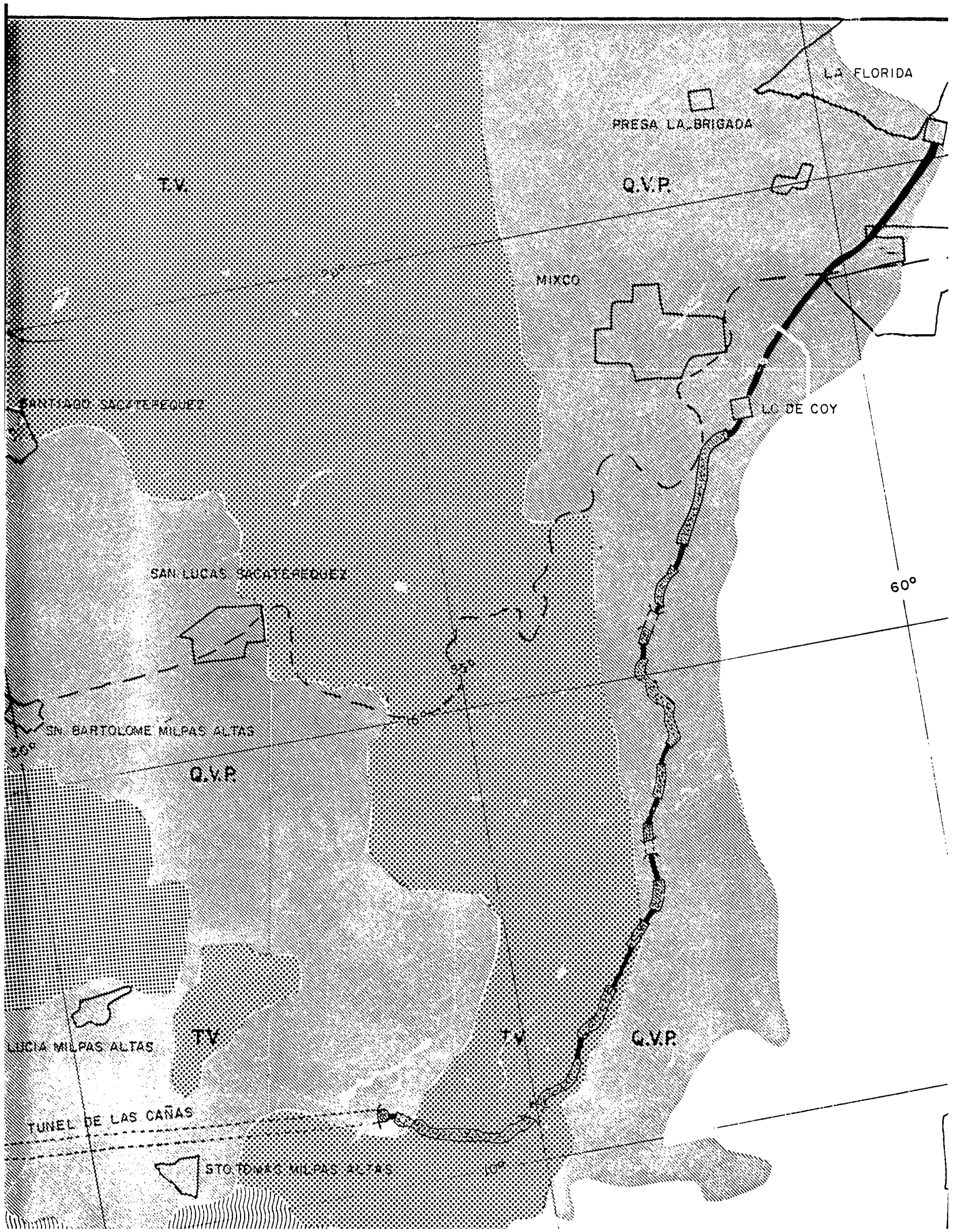
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60°
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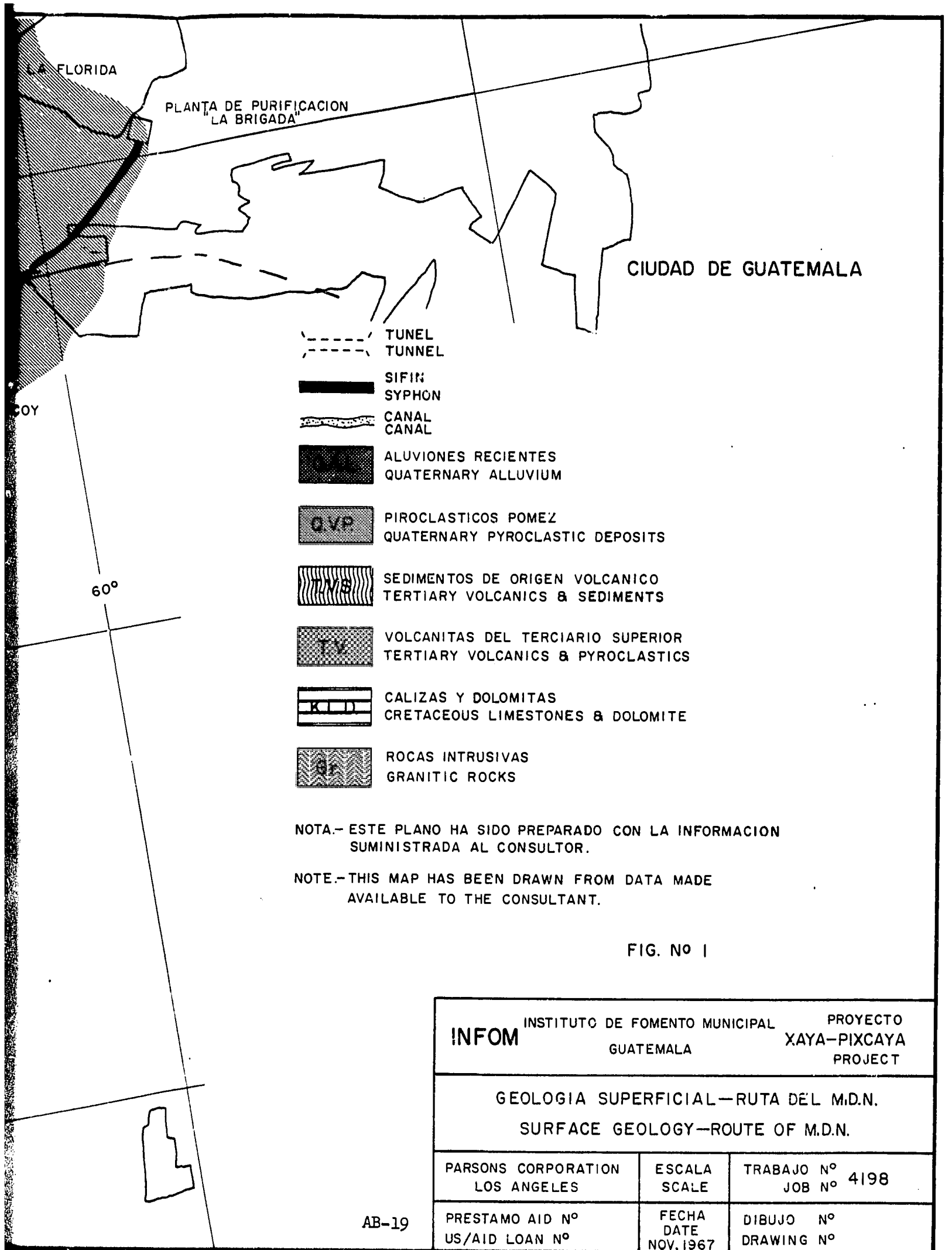
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CANAL
CANAL
ALUVIONES RECIENTES
QUATERNARY ALLUVIUM
Q.V.P.
PIROCLASTICOS POMEZ
QUATERNARY PYROCLASTIC DEPOSITS
T.V.S.
SEDIMENTOS DE ORIGEN VOLCANICO
TERTIARY VOLCANICS & SEDIMENTS
T.V.
VOLCANITAS DEL TERCIARIO SUPERIOR
TERTIARY VOLCANICS & PYROCLASTICS
K.L.D.
CALIZAS Y DOLOMITAS
CRETACEOUS LIMESTONES & DOLOMITE
Gr
ROCAS INTRUSIVAS
GRANITIC ROCKS
NOTA.- ESTE PLANO HA SIDO PREPARADO CON LA INFORMACION SUMINISTRADA AL CONSULTOR.
NOTE.- THIS MAP HAS BEEN DRAWN FROM DATA MADE AVAILABLE TO THE CONSULTANT.
FIG. Nº 1
INFOM
INSTITUTO DE FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
GEOLOGIA SUPERFICIAL—RUTA DEL M.D.N.
SURFACE GEOLOGY—ROUTE OF M.D.N.
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
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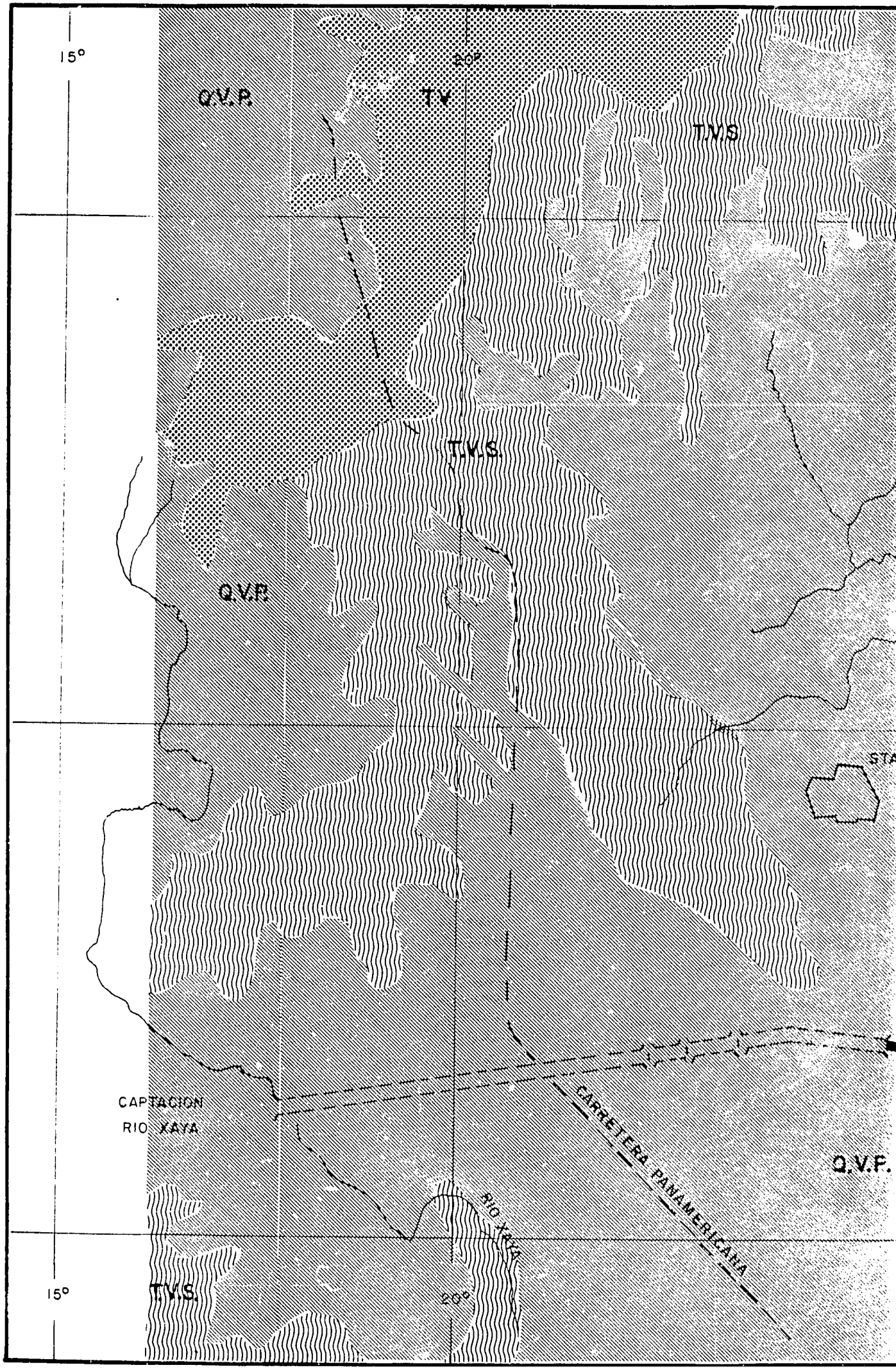
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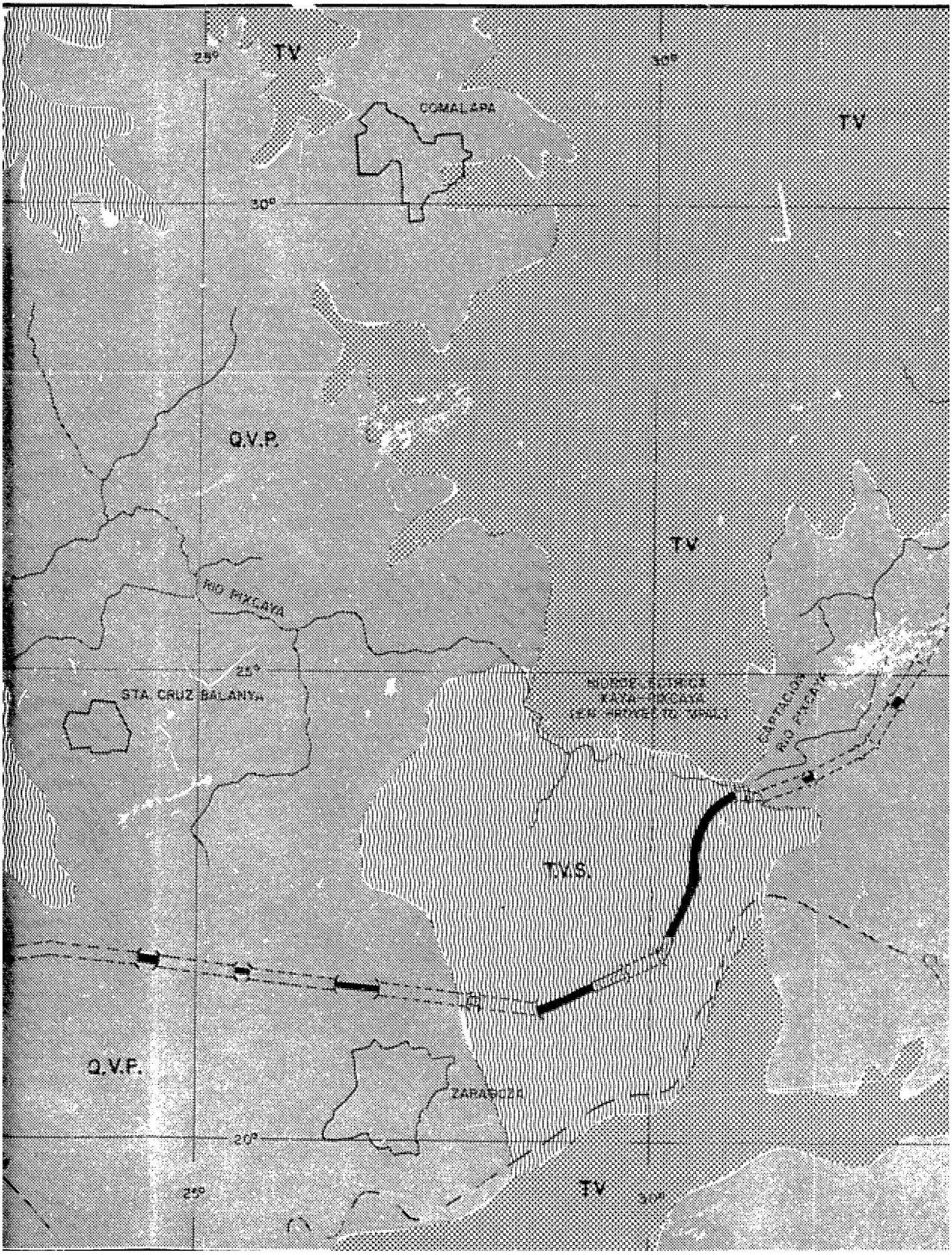
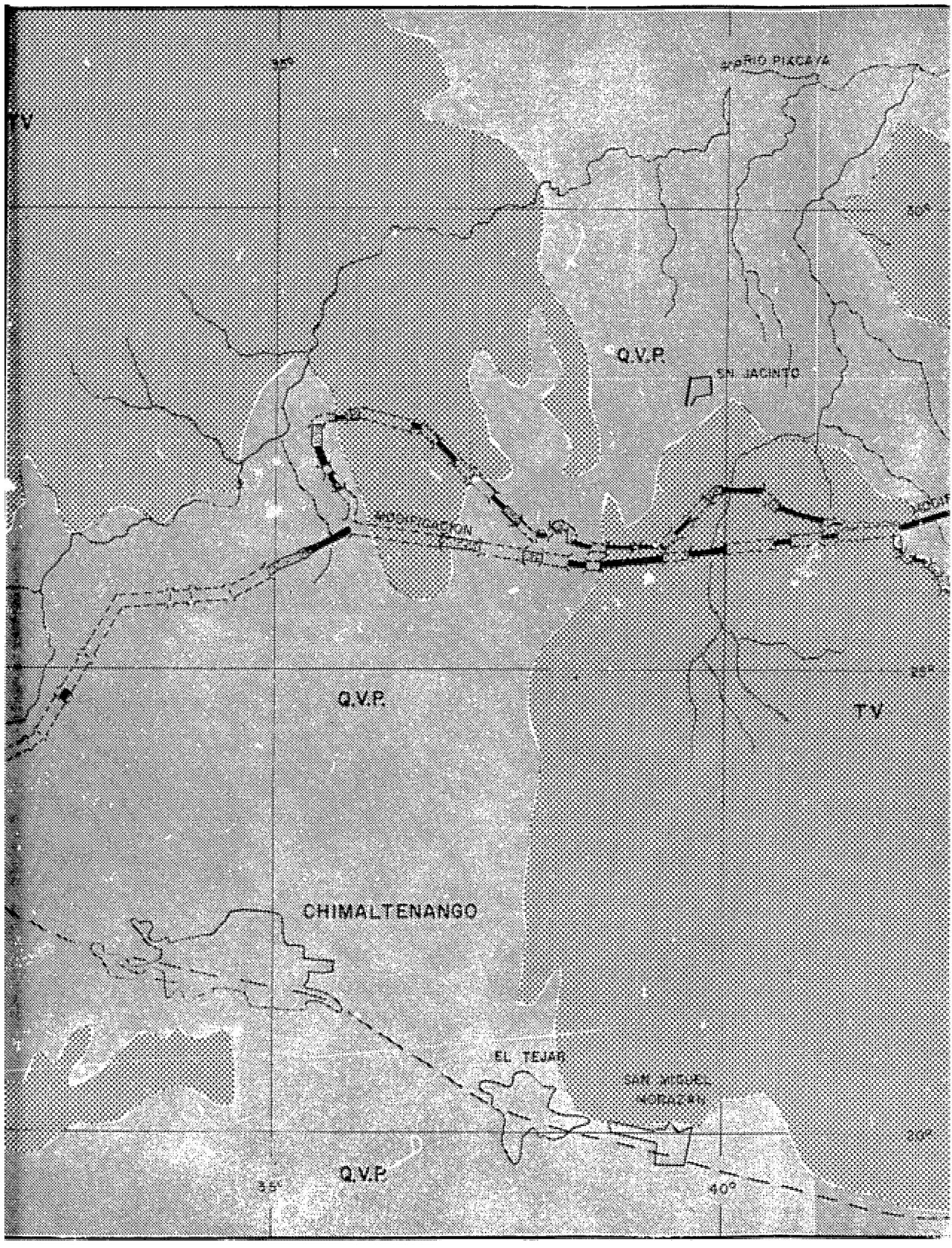
Q.V.P.
RIO XAYA
15°
T.V.S.
20°


25°
TV
30°
COMALAPA
TV
30°
Q.V.P.
TV
RIO PIXCAYA
25°
STA. CRUZ BALANYA
T.V.S.
Q.V.F.
ZARAGOZA
20°
25°
TV
30°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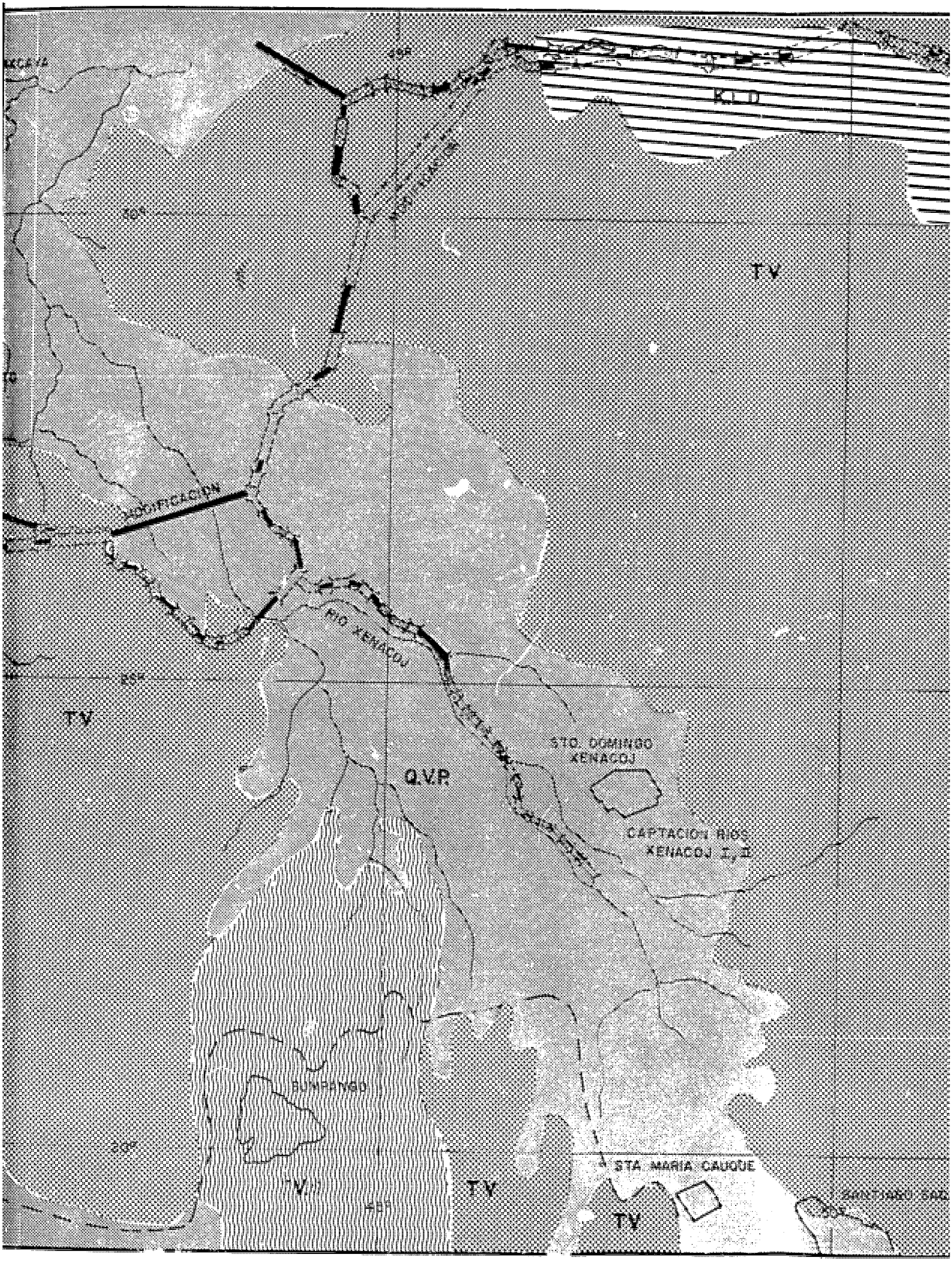
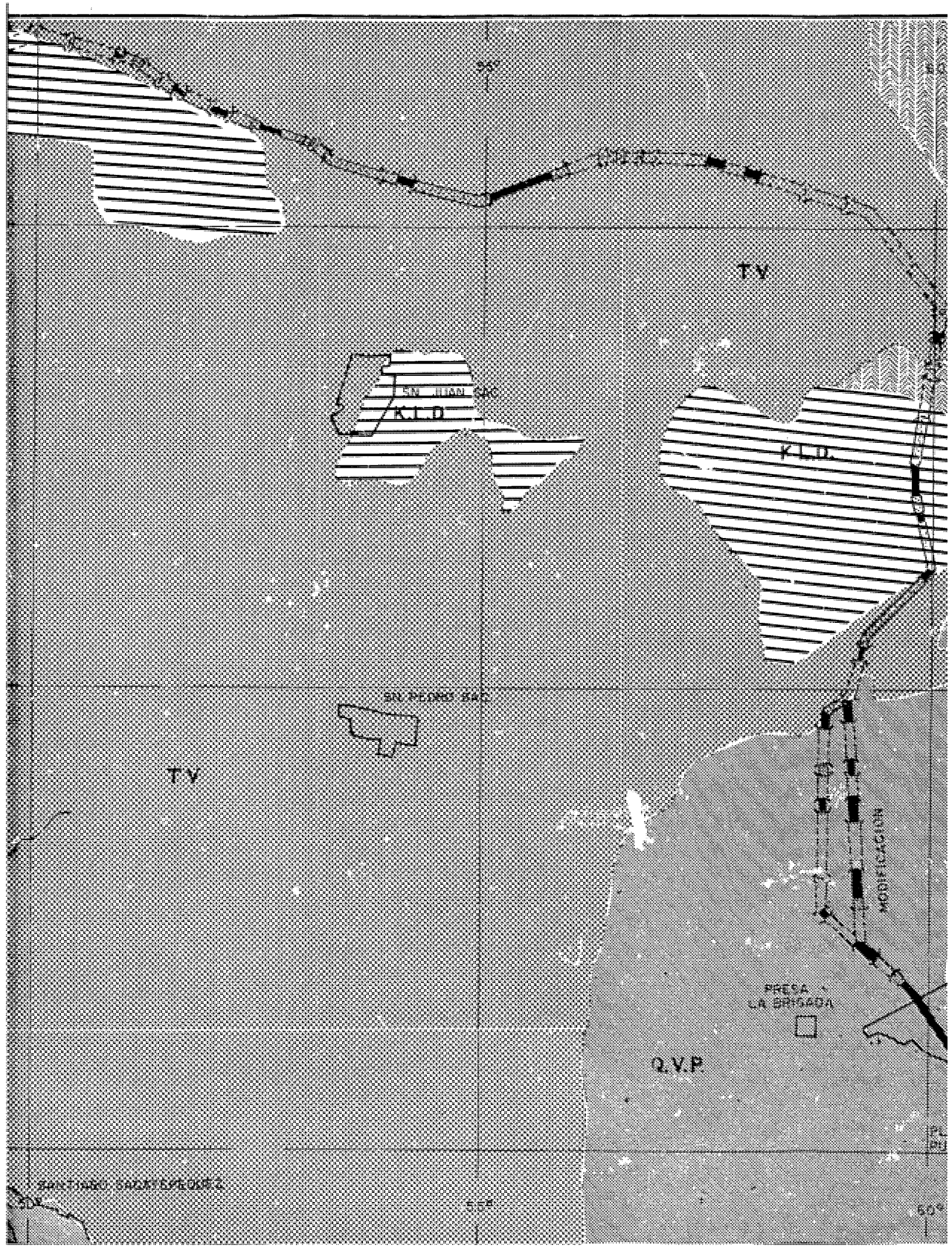
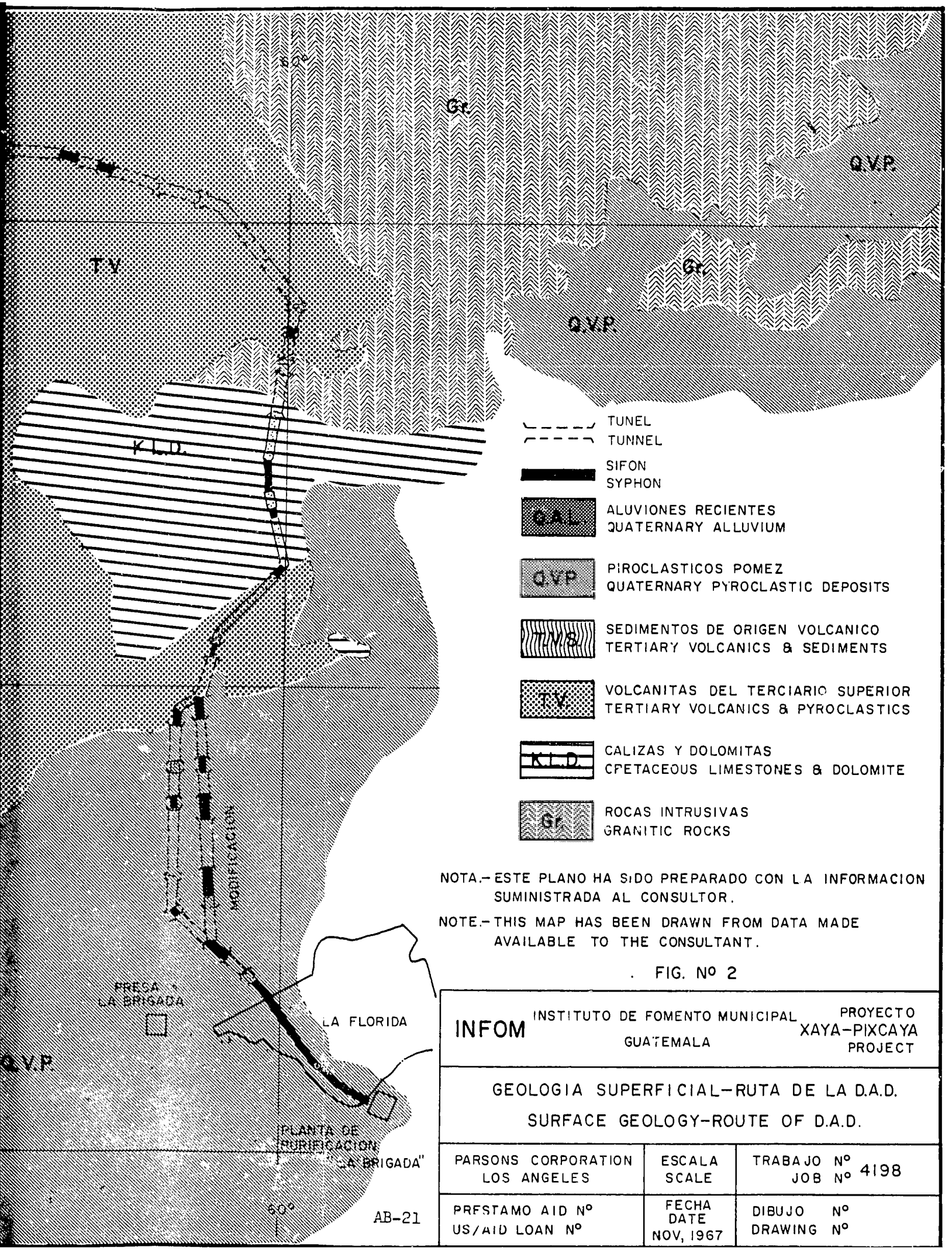
RIO PIACAYA
Q.V.P.
SN. JACINTO
MOYOGALPON
Q.V.P.
TV
CHIMALTENANGO
EL TEJAR
SAN MIGUEL
NORAZAN
Q.V.P.
35°
40°


K.I.D.
T.V.
LOMICACION
RIO XENACOJ
STO. DOMINGO XENACOJ
Q.V.P.
CAPTACION RIOS XENACOJ I, II
BUMPANGO
STA. MARIA CAUQUE
T.V.
T.V.
T.V.


TY
SAN JUAN SAC
K.L.D.
K.L.D.
SAN PEDRO SAC
TY
MODIFICACION
PRESA
LA BRIGADA
Q.V.P.
SANTIAGO SACATEPEQUEZ


Gr.
Q.V.P.
T.V.
K.L.D.
MODIFICACION
PRESA
LA BRIGADA
LA FLORIDA
PLANTA DE
PURIFICACION
"LA BRIGADA"
TUNEL
TUNNEL
SIFON
SYPHON
Q.A.L.
ALUVIONES RECIENTES
QUATERNARY ALLUVIUM
Q.V.P.
PIROCLASTICOS POMEZ
QUATERNARY PYROCLASTIC DEPOSITS
T.V.S.
SEDIMENTOS DE ORIGEN VOLCANICO
TERTIARY VOLCANICS & SEDIMENTS
T.V.
VOLCANITAS DEL TERCIARIO SUPERIOR
TERTIARY VOLCANICS & PYROCLASTICS
K.L.D.
CALIZAS Y DOLOMITAS
CRETACEOUS LIMESTONES & DOLOMITE
Gr.
ROCAS INTRUSIVAS
GRANITIC ROCKS
NOTA.- ESTE PLANO HA SIDO PREPARADO CON LA INFORMACION SUMINISTRADA AL CONSULTOR.
NOTE.- THIS MAP HAS BEEN DRAWN FROM DATA MADE AVAILABLE TO THE CONSULTANT.
FIG. Nº 2
INFOM
INSTITUTO DE FOMENTO MUNICIPAL
GUATEMALA
PROYECTO
XAYA-PIXCAYA
PROJECT
GEOLOGIA SUPERFICIAL-RUTA DE LA D.A.D.
SURFACE GEOLOGY-ROUTE OF D.A.D.
PARSONS CORPORATION
LOS ANGELES
ESCALA
SCALE
TRABAJO Nº
JOB Nº 4198
PRESTAMO AID Nº
US/AID LOAN Nº
FECHA
DATE
NOV, 1967
DIBUJO Nº
DRAWING Nº
AB-21

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NO. AB-22

NOMBRE DEL SECTOR Name of Sector	DIAMETRO ø m.m Diameter	PENDIENTE °/oo Mtrs./Km. Slope	SIFONES Syphor PROFUNDIDAD Mtrs. Depth	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection	L
BRIGADA-PIXCAYA					
C		3			
T Chimaltenango	2000	0.5			
CC	1370	1			
S Las Avispas	1143		30	273	
CC	1370	1			
S De Parramos	1143		33	33	
T Parramos	1800	1			
CC	1370	1			
S El Tejar	1143		66	289	
CC	1370	1			
T Tzanjuyu 1	1800	1			
CC	1370	1			
S Tzanjuyu	1143		61	213	
T Tzanjuyu II	1800	1			
S Tocan	1143		94	255	
CC	1370	1			
S Chico	1143		20	72	
CC	1370	1			
S San Lorenzo	1143		96	638	
CC	1370	1			
S Tizate	1143		114	451	
CC	1370	1			
S Papur	1143		95	487	
T La Cipresalada	1800	1			
CC	1370	1			
S La Agüita	1143		69	308	
CC	1370	1			
S Santa Rosa	1143		37	144	
CC	1370	1			
S Tegucigalpa	1143		133	951	
CC	1370	1			
S Las Victorias	1143		47	104	
CC	1370	1			
S Filadelfia	1143		147	1104	
CC	1370	1			
T El Hato	1800	1			
S La Chacra	1143		113	561	

VEASE NOTAS COMPLETAS EN
SEE FULL SET OF NOTES ON L

Syphons			TUNELES Tunnels				TALUDES
D mtrs. ION TAL tal ion	Length mtrs. LONGITUD REAL Real Length	ESPESOR (pulg) Thick-ness (in)	PROFUNDIDAD Max.Cover. Tunnel (mtrs.)	TUNELES Tunnels (mtrs.)	BORDEO Covered Conduits (mtrs.)	PROFUNDIDAD Max. cover Height	Estimat Cut Slop
							1/6 : 1
			175	5630			
					1737	9	1/6 : 1
	297	1/4					
					612	8	1/6 : 1
	108	1/4					
			38	449			
					663	8	1/6 : 1
	327	1/4					
					736	13	1/6 : 1
			30	543			
					158	9	1/6 : 1
	253	1/4					
			15	90			
	326	1/4					
					323	4	1/6 : 1
	87	1/4					
					342	8	1/6 : 1
	684	1/4					
					309	6	1/6 : 1
	518	1/4 5/16					
					107	5	1/6 : 1
	544	1/4					
			30	393			
					323	6	1/2 : 1
	340	1/4					
					176	5	1/2 : 1
	164	1/4					
					342	7	1/2 : 1
	1076	1/4 5/16					
					1142	12	1/2 : 1
	143	1/4					
					550	18	1/2 : 1
	1169	1/4 5/16					
					720	8	1/2 : 1
			80	259			
	622	1/4 5/16					

VEASE NOTAS COMPLETAS EN LA ULTIMA PAGINA

SEE FULL SET OF NOTES ON LAST PAGE

TUNELES	Tunnels			TALUDES	TIPO DE ROCA	LONGITUD CANAL
PROFUNDIDAD Max.Cover Tunnel (mtrs.)	TUNELES Tunnels (mtrs.)	BORDEO Covered Conduits (mtrs.)	PROFUNDIDAD Max. cover Height	Estimated Cut Slope	Rock Type	Channel Length (mtrs.)
				1/6 : 1	Q.V.P.	233
175	5630				Tvs 60% TV 40%	
		1737	9	1/6 : 1	Q.V.P.	
					Q.V.P.	
		612	8	1/6 : 1	Q.V.P.	
					Q.V.P.	
38	449				Q.V.P.	
		663	8	1/6 : 1	Q.V.P.	
					Q.V.P.	
		736	13	1/6 : 1	Q.V.P.	
30	543				Q.V.P.	
		158	9	1/6 : 1	Q.V.P.	
					Q.V.P.	
15	90				Q.V.P.	
					Q.V.P.	
		323	4	1/6 : 1	Q.V.P.	
					Q.V.P.	
		342	8	1/6 : 1	Q.V.P.	
					Q.V.P.	
		309	6	1/6 : 1	Q.V.P.	
					Q.V.P.	
		107	5	1/6 : 1	Q.V.P.	
					Q.V.P.	
30	393				Q.V.P.	
		323	6	1/2 : 1	T.V.	
					T.V.	
		176	5	1/2 : 1	T.V.	
					T.V.	
		342	7	1/2 : 1	T.V.	
					T.V.	
		1142	12	1/2 : 1	T.V.	
					T.V.	
		550	18	1/2 : 1	T.V.	
					T.V.	
		720	8	1/2 : 1	T.V.	
80	259				T.V.	
					T.V.	

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NO. AB-24

NOMBRE DEL SECTOR Name of Sector	DIAMETRO ø m.m. Diameter	PENDIENTE °/oo Mtrs./Km. Slope	SIFONES Sy		
			PROFUNDIDAD Mtrs. Depth	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection	
CC	1370	1			
T La Chacra	1800	1			
CC	1370	1			
S El Cabrejo	1143		71	374	
T El Cabrejo	1800	1			
CC	1370	1			
B		1			
T Las Cañas	2000	1			
CC	1370	1			
S Mashul	1067		26	68	
CC	1370	1			
CC	1370	1			
T El Zope	1800	1			
CC	1370	1			
S Cruz Grande	1067		68	186	
CC	1370	1			
S La Embaulada	1067		94	430	
CC	1370	1			
S La Selva	1067		15	86	
CC	1370	1			
S San Lucas	1067		109	325	
T La Esmeralda	1800	1			
CC	1370	1			
S El Refugio	1067		35	274	
CC	1370	1			
S El Naranjito	1067		63	210	
CC	1370	1			
S El Aguacate	1067		24	83	
CC	1370	1			
T Labor de Castilla	1800	1			
S Labor de Castilla	1067		37	76	
CC	1370	1			
S Cachiuir	1067		69	325	
CC	1370	1			

CLASES DE CONDUCTOS:
TYPES OF CONDUITS:

CC: TUNELES POCO PROFUNDOS — TU
T : TUNELES — TU
S : SIFONES — SY

HB-25a

PROYECTO XAYA-PIXCAYA Xayá-Pixcayá Project
INGENIERIA GEOLOGICA Engineering Geology

MINISTERIO DE LA DEFENSA NACIONAL Ministry of National Defense

RUTA-ROUTE

SIFONES Syphons				TUNELES Tunnel		
PROFUNDIDAD Mtrs. Depth	LONGITUD mtrs. Length mtrs. PROYECCION HORIZONTAL Horizontal Projection	LONGITUD REAL Real Length	ESPESOR (pulg) Thickness (in)	PROFUNDIDAD Max.Cover Tunnel (mtrs.)	TUNELES Tunnels (mtrs.)	BORDEO Covered Conduit (mtrs.)
						382
				180	633	
						502
71	374	408	1/4			
				47	220	
						566
				286	4588	
						201
26	68	90	1/4			
						1151
						863
				67	226	
						755
68	186	235	1/4			
						781
94	430	506	1/4			
						344
15	86	96	1/4			
						360
109	325	408	1/4			
				31	191	
						170
35	274	317	1/4			
						437
63	210	251	1/4			
						1566
24	83	99	1/4			
						212
				40	204	
37	76	114	1/4			
						533
69	325	372	1/4			
						1516

CC: TUNELES POCO PROFUNDOS — TUNNELS WITH LOW COVER
T : TUNELES — TUNNELS
S : SIFONES — SYPHONS

C: CANAL — CHANNEL
B: PUENTE — BRIDGE

TUNELES Tunnels				TALUDES	TIPO DE ROCA	LONGITUD PUENTE
ROFUNDIDAD Max.Cover Tunnel (mtrs.)	TUNELES Tunnels (mtrs.)	BORDEO Covered Conduits (mtrs.)	PROFUNDIDAD Max. Coverd Height	Estmated Cut Slope	Rock Type	Bridge Length (mtrs)
		382	8	1/2: 1	T.V.	
180	633				T.V.	
		502	9	1/2: 1	T.V.	
					T.V.	
47	220				T.V.S.	
		566	11	1 ½: 1	T.V.S.	
					T.V.S.	28
286	4588				T.VS 67% TV33%	
		201	12	1/2: 1	T.V.	
					T.V.	
		1151	10	1/2: 1	T.V.	
		863	10	1/6: 1	Q.V.P.	
67	226				QVP 45% TV 55%	
		755	12	1 ½: 1	T.V.S.	
					T.V.S.	
		781	8	1 ½: 1	T.V.S.	
					T.V.S.	
		344	4	1 ½: 1	T.V.S.	
					T.V.S.	
		360	5	1/6: 1	Q.V.P.	
					Q.V.P.	
31	191				Q.V.P.	
		170	8	1/6: 1	Q.V.P.	
					Q.V.P.	
		437	4	1/6: 1	Q.V.P.	
					Q.V.P.	
		1566	11	1/6: 1	Q.V.P.	
					Q.V.P.	
		212	9	1/6: 1	Q.V.P.	
40	204				Q.V.P.	
					Q.V.P.	
		533	7	1/6: 1	Q.V.P.	
					Q.V.P.	
		1516	4	1/6: 1	Q.V.P.	

C: CANAL — CHANNEL
B: PUENTE — BRIDGE

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NO. AB-26

NOMBRE DEL SECTOR Name of Sector	ø m.m.	S°/oo PENDIENTE SLOPE Mtrs./Km.	CONDUCTOS A PRESION--- Pressu SIFONES - Syphons PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection
PLANTA LA BRIGADA				
Bp-1	900	3.3		
B-1	1500	2		
T-1	1500	2		
S-1	900	3.3	27	120
T-2	1500	2		
S-2	900	3.3	66	175
T-3	1500	2		
S-3	900	3.3	76	180
T-4	1500	2		
S-4	900	3.3	68	260
T-5	1500	2		
S-5	900	3.3	45	155
T-6	1500	2		
S-6	900	3.3	55	200
B-2	1500	2		
T-7	1500	2		
S-7	900	3.3	52	200
T-8	1500	2		
T-9	1500	2		
T-10	1500	2		
T-11	1500	2		
S-8	900	3.3	16	75
T-12	1500	2		
T-13	1500	2		
T-14	1500	2		
S-9	900	3.3	18	55
T-15	1500	2		
S-10	900	3.3	67	340
T-16	1500	2		
T-17	1500	2		
T-18	1500	2		
T-19	1500	2		
T-20	1500	2		
T-21	1500	2		
T-22	1500	2		
S-11	900	3.3	16	48
T-23	1500	2		

CLASES DE CONDUCTOS: AB-27 a Bp- TUBERIA A PRESION — PRESSURE LINE

VEASE NOTAS COMPLETAS EN
SEE FULL SET OF NOTES ON L

GUAS Y DRENAJES DE LA MUNICIPALIDAD DE GUATEMALA

RUTA-ROUTE

---- Pressure Conduits Syphons			TUNELES - Tunnels				TALUDES
ITUD mtrs. YECCTON ZONTAL zontal ection	Length mtrs LONGITUD REAL Real Length	TUBERIA mtrs Pipe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estimated Cut-Slope
		624					
						650	
			3		300		
20	130						
			33	7	620		
75	220						
			30	4	615		
30	250						
			25		570		
60	280						
			24		215		
55	210						
			20		415		
0	230						
						30	
			29		415		
0	230						
			12		145		
			11		295		
			12		205		
			11		390		
75	80						
			11		140		
			15		260		
			13		225		
5	65						
			12		255		
0	375						
			11	6	220		
			12	1	110		
			11	6	250		
			33		185		
			54		274		
			24	7	90		
			73	7	330		
8	65						
			34	18	249		

ICIPALIDAD DE GUATEMALA

VEASE NOTAS COMPLETAS EN LA ULTIMA PAGINA

SEE FULL SET OF NOTES ON LAST PAGE

TUNELES - Tunnels				TALUDES	TIPO DE ROCA
PROFUNDIDAD Vertical Cut mtrs.		TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estimated Cut-Slope	Rock Type
Max	Min				
					Q.V.P.
			650		Q.V.P.
3		300			Q.V.P.
					Q.V.P.
33	7	620			Q.V.P.
					Q.V.P.
30	4	615			Q.V.P.
					Q.V.P
25		570			Q.V.P.
					Q.V.P.
24		215			Q.V.P.
					Q.V.P.
20		415			Q.V.P.
					T.V.
			30		T.V.
29		415			T.V.
					T.V.
12		145			T.V.
11		295			T.V.
12		205			T.V.
11		390			T.V.
					T.V.
11		140			K.L.D.
15		260			K.L.D.
13		225			K.L.D.
					K.L.D.
12		255			K.L.D.
					K.L.D.
11	6	220			K.L.D.
12	1	110			K.L.D.
11	6	250			K.L.D.
33		185			K.L.D.
54		274			K.L.D.
24	7	90			K.L.D.
73	7	330			K.L.D.
					T.V.
34	18	249			T.V.

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NO. 28

NOMBRE DEL SECTOR Name of Sector	ø m.m.	S°/oo PENDIENTE SLOPE Mtrs./Km.	CONDUCTOS A PRESION P SIFONES Syph PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection
T-24	1500	2		
T-25	1500	2		
T-26	1500	2		
T-27	1500	2		
T-28	1500	2		
T-29	1500	2		
S-12	900	3.3	35	170
T-30	1500	2		
S-13	900	3.3	34	175
T-31	1500	2		
T-32	1500	2		
T-33	1500	2		
T-34	1500	2		
T-35	1500	2		
T-36	1500	2		
con T-36	1500	2		
S-14	900	3.3	91	730
T-37	1500	2		
T-38	1500	2		
T-39	1500	2		
T-40	1500	2		
T-41	1500	2		
B-3	1500	2		
S-15	900	3.3	42	123
B-4	1500	2		
T-42	1500	2		
T-43	1500	2		
B-5	1500	2		
T-44	1500	2		
T-45	1500	2		
T-46	1500	2		
T-47	1500	2		
S-16	900	3.3	120	375
T-48	1500	2		
B-6	1500	2		
S-17	900	3.3	22	130
T-49	1500	2		
T-50	1500	2		
S-18	900	3.3	16	45

ROYECTO XAYA-PIXCAYA Xayá-Pixcayá Project
INGENIERIA GEOLOGICA Engineering Geology
AGUAS Y DRENAJES DE LA MUNICIPALIDAD DE GUATEMALA
RUTA-ROUTE

RESION Pressure Conduits / ONES Syphons			TUNELES Tunnels				TALUDE
ONGITUD mtrs. OYECCION ORIZONTAL orizontal rojection	Length mtrs LONGITUD REAL Real Length	TUBERIA mtrs. Pipe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estima Cut-S
			85	25	1310		
			10		110		
			22		205		
			43		345		
			18		150		
			40		545		
170	185						
			33		260		
175	190						
			63		585		
			16		150		
			41		210		
			37		160		
			69		422		
			10		145		
			8		25		
730	800						
			14		95		
			13		150		
			20		335		
			16		185		
			10		135		
						45	
123	155						
						160	
			22		150		
			17		165		
						365	
			23		175		
			20		90		
			10		145		
			11		100		
375	445						
			45	11	400		
						35	
130	135						
			49		320		
			13		110		
45	50						

A	TUNELES Tunnels				TALUDES	TIPO DE ROCA
	PROFUNDIDAD Vertical Cut mtrs.		TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estimated Cut-Slope	Rock Type
	Max	Min				
	85	25	1310			T.V.
	10		110			T.V.
	22		205			T.V.
	43		345			T.V.
	18		150			T.V.
	40		545			T.V.
						T.V.
	33		260			T.V.
						T.V.
	63		585			T.V.
	16		150			T.V.
	41		210			T.V.
	37		160			T.V.
	69		422			T.V.
	10		145			T.V.
	8		25			T.V.
						T.V.
	14		95			T.V.
	13		150			T.V.
	20		335			T.V.
	16		185			T.V.
	10		135			T.V.
				45		T.V.
						T.V.
				160		T.V.
	22		150			T.V.
	17		165			T.V.
				365		T.V.
	23		175			T.V.
	20		90			T.V.
	10		145			T.V.
	11		100			T.V.
						T.V.
	45	11	400			T.V.
				35		T.V.
						T.V.
	49		320			T.V.
	13		110			T.V.
						T.V.

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NO. 30

NOMBRE DEL SECTOR Name of Sector	ø m.m.	S°/oo PENDIENTE SLOPE Mtrs./Km.	CONDUCTOS A PRESION SIFONES Syph PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection
T-51	1500	2		
T-52	1500	2		
T-53	1500	2		
T-54	1500	2		
S-19	900	3.3	27	70
T-55	1500	2		
T-56	1500	2		
T-57	1500	2		
S-20	900	3.3	50	122
T-58	1500	2		
S-21	900	3.3	21	180
T-59	1500	2		
T-60	1500	2		
T-61	1500	2		
T-62	1500	2		
T-63	1500	2		
S-22	900	3.3	29	122
T-64	1500	2		
T-65	1500	2		
T-66	1500	2		
S-23	900	3.3	71	160
T-67	1500	2		
T-68	1500	2		
S-24	900	3.3	38	195
T-69	1500	2		
S-25	900	3.3	28	155
T-70	1500	2		
B-7	1500	2		
T-71	1500	2		
B-8	1500	2		
T-72	1500	2		
B-9	1500	2		
ENTRONQUE MOTAGUA				
B-10	1500	0.5		
S-26	800	5.8	24	150
B-11	1500	0.5		
S-27	800	5.8	59	295
B-12	1500	0.5		
T-73	1500	0.5		

ROYECTO XAYA-PIXCAYA Xayá-Pixcayá Project
INGENIERIA GEOLOGICA Engineering Geology
AGUAS Y DRENAJES DE LA MUNICIPALIDAD DE GUATEMALA

RUTA-ROUTE

A PRESION Pressure Conduits			TUNELES Tunnels				TALUDE
ONES Syphons							
ONGITUD mtrs. ROYECCION ORIZONTAL Horizontal Projection	Length mtrs. LONGITUD REAL Real Length	TUBERIA mtrs. Pipe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estima Cut-S
			25		180		
			54		260		
			15		130		
			32		130		
70	90						
			58		547		
			49	28	410		
			89	45	651		
122	175						
			45	25	340		
180	190						
			30	13	300		
			26		190		
			25		160		
			18		320		
			16	10	235		
122	140						
			46		390		
			37		175		
			57		220		
160	220						
			12	6	300		
			57	28	350		
195	240						
			19	13	180		
155	175						
			26		140		
						420	
			15		120		
						215	
			12		115		
						55	
						40	
150	200						
						325	
295	325						
						100	
			16	10	235		

RIA s.	TUNELES Tunnels				TALUDES	TIPO DE ROCA
	PROFUNDIDAD Vertical Cut mtrs.		TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estimated Cut-Slope	Rock Type
	Max	Min				
	25		180			T.V.
	54		260			T.V.
	15		130			T.V.
	32		130			T.V.
						T.V.
	58		547			T.V.
	49	28	410			T.V.
	89	45	651			K.L.D.
						K.L.D.
	45	25	340			K.L.D.
						K.L.D.
	30	13	300			K.L.D.
	26		190			K.L.D.
	25		160			K.L.D.
	18		320			K.L.D.
	16	10	235			K.L.D.
						K.L.D.
	46		390			K.L.D.
	37		175			K.L.D.
	57		220			K.L.D.
						T.V.
	12	6	300			T.V.
	57	28	350			T.V.
						T.V.
	19	13	180			T.V.
						T.V.
	26		140			T.V.
				420		T.V.
	15		120			T.V.
				215		T.V.
	12		115			T.V.
				55		T.V.
				40		T.V.
						T.V.
				325		T.V.
						T.V.
				100		T.V.
	16	10	235			T.V.

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NO. AB-32

NOMBRE DEL SECTOR Name of Sector	ø m. n.	S°/oo PENDIENTE SLOPE Mtrs./Km.	CONDUCTOS A PRESION SIFONES Syp PROFUNDIDAD DEPTH Mtrs.	LONGITUD Mtrs PROYECCION HORIZONTAL Horizontal Projection
S-28	800	5.8	70	280
T-74	1500	0.5		
S-29	800	5.8	120	515
T-75	1500	0.5		
S-30	800	5.8	65	250
T-76	1500	0.5		
T-77	1500	0.5		
T-78	1500	0.5		
S-31	800	5.8	13	107
T-79	1500	0.5		
ENTRONQUE XENACOJ				
T-80	1500	0.4		
S-32	700	8.6	220	1625
T-81	1500	0.4		
T-82	1500	0.4		
B-13	1500	0.4		
S-33	700	8.6	17	50
T-83	1500	0.4		
S-34	700	8.6	26	160
T-84	1500	0.4		
S-35	700	8.6	70	385
T-85	1500	0.4		
S-36	700	8.6	61 100	773
T-86	1500	0.4		
S-37	700	8.6	52	235
T-87	1500	0.4		
S-38	700	8.6	18	215
T-88	1500	0.4		
B-14	1500	0.4		
T-89	1500	0.4		
S-39	700	8.6	135	570
B-15	1500	0.4		
B-16	1500	0.4		
T-90	1500	0.4		
T-91	1500	0.4		
T-92	1500	0.4		
T-93	1500	0.4		
T-94	1500	0.4		
S-40	700	8.6	22	140

RUTA-ROUTE

A PRESION Pressure Conduits			TUNELES Tunnels				TALUD
IFONES Syphons							
ONGITUD Mtrs. ROYECCION HORIZONTAL Horizontal Projection	Length mtrs. LONGITUD REAL Real Length	TUBERIA mtrs. Pipe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estim Cut-S
280	313						
			74	22	760		
515	575						
			42	10	430		
250	260						
			21		140		
			48	21	410		
			60	27	490		
107	125						
			11		35		
			39		265		
1625	1900						
			105		445		
			50		225		
						50	
50	60						
			68		430		
160	200						
			102		555		
385	440						
			32	10	295		
773	850						
			23		125		
235	250						
			56		270		
215	225						
			28		403		
						54	
			52		977		
570	650						
						90	
						420	
			50	5	470		
			66	34	460		
			26	10	225		
			102	30	1275		
			101	44	390		
140	160						

	TUNELES Tunnels				TALUDES	TIPO DE ROCA
ERIA trs. ipe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estimated Cut-Slope	Rock Type
						T.V.
	74	22	760			T.V.
						T.V.
	42	10	430			T.V.
						T.V.
	21		140			Q.V.P.
	48	21	410			Q.V.P.
	60	27	490			Q.V.P.
						Q.V.P.
	11		35			Q.V.P.
	39		265			Q.V.P.
						Q.V.P.
	105		445			T.V.
	50		225			T.V.
				50		T.V.
						T.V.
	68		430			T.V.
						T.V.
	102		555			T.V.
						T.V.
	32	10	295			Q.V.P.
						Q.V.P.
	23		125			Q.V.P.
						Q.V.P.
	56		270			Q.V.P.
						Q.V.P.
	28		403			Q.V.P.
				547		Q.V.P.
	52		977			T.V.
						Q.V.P.
				90		Q.V.P.
				420		Q.V.P.
	50	5	470			Q.V.P.
	66	34	460			Q.V.P.
	26	10	225			Q.V.P.
	102	30	1275			Q.V.P.
	101	44	390			Q.V.P.
						Q.V.P.

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NO. AB-34

NOMBRE DEL SECTOR Name of Sector	ø m.m.	S°/oo PENDIETE SLOPE Mtrs./Km.	CONDUCTOS A PRESION SIFONES S- PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtr PROYECCION HORIZONTAL Horizontal Projection
T-95	1500	0.4		
T-96	1500	0.4		
T-97	1500	0.4		
T-98	1500	0.4		
T-99	1500	0.4		
S-41	700	8.6	23	60
T-100	1500	0.4		
S-42	700	3.6	20	20
T-101	1500	0.4		
T-102	1500	0.4		
B-17	1500	0.4		
T-103	1500	0.4		
T-104	1500	0.4		
CAPTACION PIXCAYA				
TOTAL Totals				10390

AB-35a

PROYECTO XAYA-PIXCAYA Xayá-Pixcayá Project
INGENIERIA GEOLOGICA Engineering Geology
DIRECCION DE AGUAS Y DRENAJES DE LA MUNICIPALIDAD DE GUATEMALA

RUTA-ROUTE

CONDUCTOS A PRESION Pressure Conduits				TUNELES Tunn		
SIFONES Syphons						
PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection	Lenghtt mtrs. LONGITUD REAL / Real Length	TUBERIA mtrs. Pipe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnel mtrs.
				65	29	385
				15		65
				12		55
				31	7	145
				131	5	630
23	60	75				
				23		35
20	20	25				
				47	7	450
				13		80
				10		55
				20	6	165
	10390	11958	624			31168

AB-35b

	TUNELES Tunnels				TALUDES	TIPO DE ROCA
ERIA rs. pe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estimated Cut-Slope	Rock Type
	65	29	385			Q.V.P.
	15		65			Q.V.P.
	12		55			Q.V.P.
	31	7	145			Q.V.P.
	131	5	630			Q.V.P.
						Q.V.P.
	23		35			Q.V.P.
						Q.V.P.
	47	7	450			Q.V.P.
	13		80			Q.V.P.
				75		Q.V.P.
	10		55			Q.V.P
	20	6	165			Q.V.P/T.V.
24			31168	3672		

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NO. AB-36

NOMBRE DEL SECTOR Name of Sector	ø m.m.	S°/oo PENDIENTE SLOPE Mtrs./Km.	CONDUCTOS A PRESION SIFONES PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection
RAMAL XENACOJ				
T-1 Xe	450	2		
T-2 Xe	450	2		
B-1 Xe	450	2		
T-3 Xe	450	2		
T-4 Xe	450	2		
T-5 Xe	450	2		
S-1 Xe	450	2	50	135
T-6 Xe	450	2		
S-2 Xe	450	2	65	180
T-7 Xe	450	2		
S-3 Xe	450	2	25	100
T-8 Xe	450	2		
T-9 Xe	450	2		
T-10 Xe	450	2		
S-4 Xe	450	2	8	40
T-11 Xe	450	2		
S-5 Xe	450	2	61	325
T-12 Xe	450	2		
S-6 Xe	450	2	5	85
B-2 Xe	450	2		
T-13 Xe	450	2		
T-14 Xe	450	2		
T-15 Xe	450	2		
B-3 Xe	450	2		
T-16 Xe	450	2		
B-4 Xe	450	2		
T-17 Xe	450	2		
B-5 Xe	450	2		
T-18 Xe	450	2		
T-19 Xe	450	2		
B-6 Xe	450	2		
T-20 Xe	450	2		
S-7 Xe	450	2	18	45
T-21 Xe	450	2		
B-7 Xe	450	2		
T-22 Xe	450	2		
S-8 Xe	450	2	10	65
T-23 Xe	450	2		

PROYECTO XAYA-PIXCAYA Xayá-Pixcayá Project
INGENIERIA GEOLOGICA Engineering Geology

DIRECCION DE AGUAS Y DRENAJES DE LA MUNICIPALIDAD DE GUATEMALA
RUTA-ROUTE

------- CONDUCTOS A PRESION Pressure Conduits				TUNELES Tunne		
SIFONES Siphons						
PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtrs. Length mtrs. PROYECCION HORIZONTAL Horizontal Projection	LONGITUD REAL Real Length	TUBERIA mtrs. Pipe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnels mtrs.
				58		305
				40	12	565
				7		15
				11		195
				12		270
50	135	166				
				22		178
65	180	220				
				20		178
25	100	140				
				12		95
				11		65
				13	5	185
8	40	60				
				23		104
61	325	355				
				10		100
5	85	100				
				17		90
				19		100
				12	5	85
				17		125
				16		100
				17	8	95
				15	9	35
				16		105
18	45	60				
				19		160
				15		95
10	65	75				
				22	7	220

ICIPALIDAD DE GUATEMALA

	TUNELES Tunnels				TALUDES	TIPO DE ROCA
RIA	PROFUNDIDAD Vertical Cut mtrs.		TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estimated Cut-Slope	Rock Type
	Max	Min				
	58		305			Q.V.P.
	40	12	565			Q.V.P.
				290		Q.V.P.
	7		15			Q.V.P.
	11		195			Q.V.P.
	12		270			Q.V.P.
						Q.V.P.
	22		178			Q.V.P.
						Q.V.P.
	20		178			Q.V.P.
						Q.V.P.
	12		95			Q.V.P.
	11		65			Q.V.P.
	13	5	185			Q.V.P.
						Q.V.P.
	23		104			Q.V.P.
						Q.V.P.
	10		100			Q.V.P.
						Q.V.P.
				115		Q.V.P.
	17		90			Q/V.P.
	19		100			Q.V.P.
	12	5	85			Q.V.P.
				55		Q.V.P.
	17		125			Q.V.P.
				55		Q.V.P.
	16		100			Q.V.P.
				90		Q.V.P.
	17	8	95			Q.V.P.
	15	9	35			Q.V.P.
				125		Q.V.P.
	16		105			Q.V.P.
						Q.V.P.
	19		160			Q.V.P.
				75		Q.V.P.
	15		95			Q.V.P.
						Q.V.P.
	22	7	220			Q.V.P.

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NO. AB-38

NOMBRE DEL SECTOR Name of Sector	ø m.m.	S°/oo PENDIENTE SLOPE Mtrs./Km.	CONDUCTOS A PRESION SIFONES PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection
S-9 Xe	450	2	8	35
B-8 Xe	450	2		
1-24 Xe	450	2		
B-9 Xe	450	2		
S-10 Xe	450	2	7	65
T-25 Xe	450	2		
T-26 Xe	450	2		
B-10 Xe	450	2		
T-27 Xe	450	2		
B-11 Xe	450	2		
T-28 Xe	450	2		
B-12 Xe	450	2		
CAPTACION XENACOJ				
TOTALES Totals				1075

AB-39 a

DIRECCION DE AGUAS Y DRENAJES DE LA MUNICIPALIDAD DE GUATEMALA

RUTA-ROUTE

CONDUCTOS A PRESION Pressure Conduits				TUNELES Tun		
SIFONES Siphons						
PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection	Length mtrs. LONGITUD REAL Real Length	TUBERIA mtrs. Pipe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnels mtrs.
8	35	40				
				14		85
7	65	80				
				17		90
				10		70
				14		135
				20		200
	1075	1296				4095

AB-39b

ICIPALIDAD DE GUATEMALA

	TUNELES Tunnels				TALUDES	TIPO DE ROCA
RIA . e	PROFUNDIDAD Vertical Cut mtrs.		TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estimated Cut-Slope	Rock Type
	Max	Min				
						Q.V.P.
				40		Q.V.P.
	14		85			Q.V.P.
				125		Q.V.P.
						Q.V.P.
	17		90			Q.V.P.
	10		70			Q.V.P.
				120		Q.V.P.
	14		135			Q.V.P.
				95		Q.V.P.
	20		200			Q.V.P.
				100		Q.V.P.
			4095	1285		

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NO. AB-40

NOMBRE DEL SECTOR Name of Sector	ø m.m.	S°/oo PENDIENTE SLOPE Mtrs./Km.	CONDUCTOS A PRESION SIFONES S	
			PROFUNDIDAD DEPTH Mtrs.	LONGITUD mtrs. PROYECCION HORIZONTAL Horizontal Projection
CAPTCION PIXCAYA				
BP-Xa				
B-1 Xa	1500	0.7		
T-1 Xa	1500	0.7		
B-2 Xa	1500	0.7		
S-1 Xa	400	12	37	615
T-2 Xa	1500	0.7		
B-3 Xa	1500	0.7		
T-3 Xa	1500	0.7		
S-2 Xa	400	12	85	430
T-4 Xa	1500	0.7		
S-3 Xa	400	12	36	140
T-5 Xa	1500	0.7		
S-4 Xa	400	12	80	230
T-6 Xa	1500	0.7		
T-7 Xa	1500	0.7		
T-8 Xa	1500	0.7		
T-9 Xa	1500	0.7		
CAPTACION XAYA TOTALES Totals				1415

CLASIFICACION DE ROCAS

ROCK CLASSIFICATION

Q.V.P.	POMEZ PUMICE	BLANDO SOFT
T.V.	LAVA, etc. LAVA, etc.	MEDIO DURO MEDIUM HARD
T.V.S.	LAVA, etc. y SEDIMENTOS LAVA, etc. and SEDIMENT	MEDIO DURO MEDIUM HARD
K.L.D	CALIZAS Y DOLOMITAS LIMESTONE AND DOLOMITE	DURO HARD
Gr.	GRANITO GRANITE	DURO HARD

AB-41 G

PROYECTO XAYA- PIXCAYA Xayá-Pixcayá Project
INGENIERIA GEOLOGICA Engineering Geology

DIRECCION DE AGUAS Y DRENAJES DE LA MUNICIPALIDAD DE

RUTA-ROUTE

n.m.	S°/oo PENDIENTE SLOPE Mtrs./Km.	CONDUCTOS A PRESION Pressure Conduits — SIFONES Syphons: PROFUNDIDAD DEPTH Mtrs	LONGITUD mtrs. Lenggth mtrs.: PROYECCION HORIZONTAL Horizontal Projection	LONGITUD REAL Real Length	TUBERIA mtrs. Pipe	TU — PROFUNDIDA Vertical Cut mtrs.: Max	M
					1847		
0	0.7						
0	0.7					18	
0	0.7						
0	12	37	615	660			
0	0.7					50	
0	0.7						
0	0.7					28	
0	12	85	430	475			
0	0.7					36	
0	12	36	140	150			
0	0.7					40	
0	12	80	230	275			
0	0.7					50	
0	0.7					48	
0	0.7					60	
0	0.7					120	
			1415	1560	1847		

IFICACION DE ROCAS
K CLASSIFICATION

	BLANDO SOFT
	MEDIO DURO MEDIUM HARD
MENTOS EDIMENT	MEDIO DURO MEDIUM HARD
OMITAS D DOLOMITE	DURO HARD
	DURO HARD

Bp - TU
B - TU
T - TU
S - SIF

AB-41 b

UNICIPALIDAD DE GUATEMALA

	TUNELES Tunnels				TALUDES	TIPO DE ROCA
UBERIA mtrs. Pipe	PROFUNDIDAD Vertical Cut mtrs. Max	Min	TUNELES Tunnels mtrs.	BORDEO COVERED CONDUITS mtrs.	Estimated Cut-Slope	Rock Type
1847						T.v.s.
				280		T.v.s.
	18		390			T.v.s.
				450		T.v.s
						T.v.s.
	50	15	660			T.v.s.
				110		T.v.s.
	28		1020			Q.V.P.
						Q.V.P.
	36	22	960			Q.V.P.
						Q.V.P.
	40		780			Q.V.P.
						Q.V.P.
	50		1540			Q.V.P.
	48	30	520			Q.V.P.
	60	20	400			Q.V.P.
	120	62	3700			Q.V.P.
1847			9970	840		

CLASES DE CONDUCTOS

TYPES OF CONDUITS

Bp - TUBERIA A PRESION	PRESSURE LINE
B - TUNELES POCO PROFUNDOS	TUNNELS WITH LOW COVER
T - TUNELES	TUNNELS
S - SIFONES	SYPHONS