PN-AAU-244
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DIAGNOSTIC STUDY OF THE REGIONAL DEVELOPMENT POTENTIAL OF THE AGUAYTIA NATURAL GAS FIELD IN PERU

Prepared for the United States Agency for International Development

July 1984

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PREFACE

This report was prepared by the E/DI team members during their three week field visit in Peru for presentation to the USAID Mission in Lima. The members of the team wish to acknowledge the assistance of the staff at the USAID mission in Lima in the preparation of this draft, and that of many officials and professionals in the agencies that were visited, in particular those of the PEAH offices in Lima and of many departments of PetroPeru.

Finally, we wish to acknowledge the collaboration and support of Alberto Sabadell of USAID Office of Energy (S&T/EY), who was an integral part of the team and participated in all phases and discussions leading to the preparation of this report.

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CONVERSION FACTORS USED IN THIS REPORT

Natural Gas	1023 Btu/CF; 1.08 GJ/MCF; 23.4 TOE/MCF
Residual Oil	41.0 GJ/ton; 6.1 GJ/bbl
Diesel	42.7 GJ/ton; 5.7 GJ/bbl
Kerosene	43.1 GJ/ton; 5.6 GJ/bbl
Gasoline	44.0 GJ/ton; 5.2 GJ/bbl
LPG	45.2 GJ/ton; 3.9 GJ/bbl

Aguaytia Natural Gas (80% methane) — 900 Btu/CF

1 bbl diesel = 6.00 MCF Aguaytia gas (167 bbls/MMCF)
1 bbl residual = 6.43 MCF Aguaytia gas (157 bbls/MMCF)

Sawmill Wastes — 6 GJ/ton; 0.6 tons/m^3

Abbreviations

CF:	cubic foot; MCF: thousand cubic feet; MMCF: million cubic feet; BCF: billion (10^9) cubic feet
MMCF/D:	million cubic feet per day (also MMCFD)
bbl:	barrel (1 barrel = 42 U.S. gallons) bbls/d: barrels per day, or BCD: barrels per calendar day
GJ:	gigajoule (10^9 joules)
Btu:	British thermal unit (1055 joules)
kWh:	kilowatt-hour (0.0036 GJ); MW: megawatt; gWh: gigawatt-hour (10^6 kWh)
TOE:	ton of oil equivalent (41.87 GJ)
ton:	metric ton (1000 kgs)

Acronyms

E/DI	Energy/Development International
PEAH	Upper Huallaga Special Project
USAID	United States Agency for International Development
S&T/EY	Science and Technology, Energy Office, USAID
CORDEU	Corporacion de Desarrollo de Ucayali

I EXECUTIVE SUMMARY

A. OBJECTIVE

This diagnostic focuses on an investigation of the potential of the Aguaytia gas field to catalyze and support regional development and economic growth in the Upper Huallaga valley and in the Pucallpa area. It was prepared for the USAID mission in Lima, Peru as part of the activities of the Upper Huallaga Development Project (PEAH) in the Central Jungle of Peru. At the same time the field development program proposed here is cognizant of the plan of PetroPeru for this field. This PetroPeru plan emphasizes further exploration, a major development program and production of gas for markets outside the region. However, it is not our purpose to evaluate the potential impact of the Aguaytia natural gas resource at a national level, and our findings and the recommendations are primarily influenced by needs and expectations in the city of Pucallpa and the PEAH project area centered around the city of Tingo Maria.

The study, which was conducted over a three week period by a three person team of specialists, has not included the level of effort nor the broad range of skills necessary for a prefeasibility study. Rather, it was organized to determine the type and timing of the next logical steps.

B. FINDINGS

1. General Findings

- The testing, development and production of the Aguaytia gas reserve has been considered many times and continues to be a viable candidate for further study in line with PetroPeru's emphasis on large projects to provide for the fuel needs of the country's large markets. Our diagnostic study has determined that small scale development of the gas resource is technically and economically possible without adversely affecting the site's eventual large scale development.

- The estimates of energy demand in the region are only approximate, particularly for one area where no field visit was possible. Considering only the industrial sector there are significant shortfalls in electric generation capacity in the region.

- In addition to natural gas, both agricultural wastes and wood wastes from sawmills represent large available energy resources that are currently not exploited efficiently. Furthermore, most petroleum products are readily available from the refinery in Pucallpa at prices which are competitive with other regions of the country. If freight costs are considered, prices become progressively higher in the northern portions of the PEAH area.

- The potential demand for natural gas in Pucallpa is estimated to be 4.9 million cubic feet per day (MMCF/D) in 1986, and will grow to 8.7 MMCF/D by 1995 on a par with the growth in electric demand. The potential demand for natural gas in the PEAH area will be minimal in the medium term, and will only come about with a change in emphasis from production of agroindustrial intermediate goods to food processing and other consumer products.

2. <u>PEAH - Pucallpa</u>

- The major demand centers of the PEAH area, Tingo Maria and Aucuyacu, will be served by the Central-Norte electrical grid, the country's largest system by 1985-1986. Planning and development of electricity generation plants (predicted to remain largely hydro based for many years) will therefore be the concern of ElectroPeru Central Lima offices.

- The PEAH area agroindustry and other planned economic development proposed for the next 4 to 6 years will not be very energy intensive. Electricity and heat from the combustion of agricultural wastes will meet much of the necessary energy needs. Most planned industries will be either small, involving partial processing and/or will be located in widely distributed parts of the valley.

- A preliminary estimate of the costs for a 6" to 8" pressure gas pipeline from the Aguaytia field to Tingo Maria would be $15,000,000 to $20,000,000.

- The estimated cost of developing the Aguaytia field to serve the needs of Pucallpa, including transmission via pipeline, is US$11,400,000. This estimate excludes distribution costs and retrofit of existing equipment presently using residual oil.

- Pucallpa presently has a number of established energy uses which are large and centralized enough to warrant considering switching to natural gas. The 1986 estimate of the amount of demand which could be supplied by gas is 4.9 MMCF/D. The major demand centers include ElectroPeru electric generation, the PetroPeru refinery and the San Juan brewery. Major potential gas users are all within 15 km of the refinery in Pucallpa.

- The economic development of Pucallpa and the region around it has long been a goal of the Central Government. Incentives include duty-free status, tax exonerations to industries locating there and tax exemptions on selected products including industrial fuels. Development has been hindered by a severe shortfall in installed capacity of the ElectroPeru system, and the high cost of selfgeneration. The Pucallpa ElectroPeru system is heavily subsidized and the nationwide tariffs do not cover the cost of operating isolated diesel generation. Locally produced natural gas could therefore be a resource which will remove one major barrier to industrial development, dimish ElectroPeru costs and increase revenues.

- In Pucallpa, gas and condensate use would not compete with available wood or biomass resources. Any petroleum products produced at the local refinery which do not find a market locally can be transported to other markets.

- PetroPeru is planning a major demand study of petroleum products for the Jungle area in late 1984. It is also currently undertaking a market study for natural gas in the area extending from Aguaytia to the mining areas of the Central Sierra. ElectroPeru does not incorporate development and production of the Aguaytia resource in its long-term planning because the information on the probable reserves is uncertain.

3. Aguaytia Resources

- Currently known proven reserve is 240 billion ft^3 (BCF) of gas and 3,500,000 barrels of condensate, capable of production rates as high as 26 MMCF/D of gas and 480 bbls/d and capable of sustaining commercial rates of production of gas for a period of at least 20 years. Condensate production of over 200 bbls/d can also be sustained over 20 years.

- PetroPeru has been planning a more thorough testing and development program for several years . Funding for this program has continually been removed from their

budget. The presently proposed program, budgeted at US$18 - 20 million, is not likely to be initiated in the near future.

- Several field development projects proposed in the past have not been deemed feasible because reserves were not sufficiently known, projects were not economically viable, and costs were too great to attract financing or development. One scheme for the reservoir involved flaring most of the gas. Projects involving transformation of the gas into fertilizers or petrochemicals face adverse market conditions from excess worldwide capacity.

4. Field Development Program

- A minimum development program for the field is proposed. A development approach suitable for the area and based on sound gas field engineering involves reconditioning the two existing wells and drilling one new 8700 ft. well. The estimated cost for this field development is US$5,000,000.

- PetroPeru appears to be willing to execute this minimum development and production program if substantiated by a feasibility study, even if their add-on exploration package is not included.

- We believe that this development and production program may, in fact, increase the likelihood that part or all of the oft postponed PetroPeru exploration program will be carried out, since the development program proposed herein will cover part of the cost of the proposed exploration effort and demonstrate the viability of the region as a gas market.

5. Financial Analysis

- A two phase development and production program has been found to be most appropriate. In Phase I in the initial year, 4.9 MMCF/D of gas and 90 bbls/d of condensate would be produced and transported in an 8" reduced wellhead pressure pipeline. The costs assumed in this analysis, including field development, production, pipeline and storage, amounts to US$11.4 million (1984). This would not include gas distribution or user retrofit.

- A discounted cash flow analysis for a 20 year life at 12 percent interest and a 14 percent discount rate yields costs of US$0.94 per million Btu of gas and $7.20 per barrel of condensate. This does not include taxes or distribution costs. This compares to current world prices of $3.00per million Btu and $26/bbl

respectively. A sensitivity analysis involving increasing estimated costs by 50 percent raises costs to $1.39 pr million Btu and $ 10.6/bbl respectively. This is still substantially cheaper than the world price.

- In Phase II, a transmission pipeline to Alto Huallaga is envisioned but the cost of and timing for this will depend on developing a level of economic activity which can sustain a firm demand in the region. Terrain considerations will also require more thorough pipeline engineering feasibility studies.

C. RECOMMENDATIONS

The logical next step in the process of considering the Aguaytia gas resource as a stimulant and support to regional development is to circulate this diagnostic study for review and comment. Our cost estimates and the resultant favorable economics of a first phase production for use in Pucallpa suggest funding of a feasibility study. In addition to verifying and refining the field development costs and potential demand estimates presented in this study, the feasibility study must also include many factors which were not treated here, including calculation of retrofit costs as well as investigation of institutional, legal, and financing details.

The obvious past and continuing problems of matching potential gas needs and known available reserves seem to have been overcome with the recommended first phase program for Pucallpa. We recommend that an electric demand study for the Pucallpa system be conducted, because the rate of growth in demand for natural gas is dependent on electricity use growth. For the same reason, a separate study should be conducted of the cost of retrofitting the new Pucallpa power plant to burn natural gas. A detailed comparison of the economics of gas-fired power generation in the new power plant versus extension of the Central-Norte grid to Pucallpa should also be undertaken.

Development of natural gas, in conjunction with the extension of the electrical grid to Tingo Maria and Aucuyacu, will have a significant impact on the future demand of petroleum products in the

region. This in turn will have an effect on the operations of the Pucallpa refinery. Therefore, the long term plans for this refinery must be reviewed in light of potential development of natural gas in the region.

Finally, a number of measurements have to be taken at the field before final development is undertaken. These include core and fluid samples, as well as temperature, pressures and oil, gas and water saturation measurements. A detailed list of the data needs for the field is included in Chapter IV of this report.

II DIAGNOSTIC OVERVIEW

A. PURPOSE

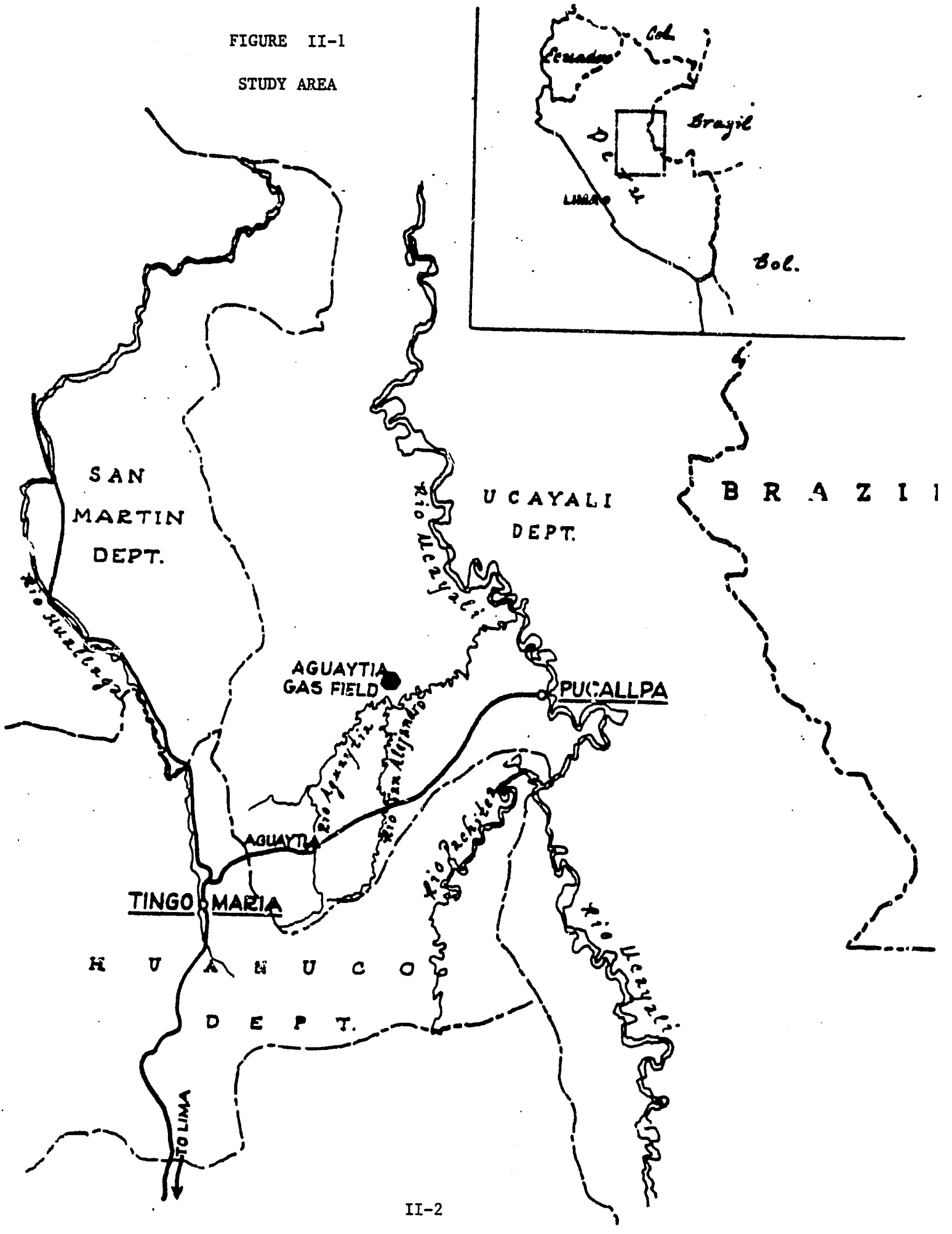
USAID/LIMA, as a part of their Upper Huallaga Area Development Project, requested USAID/WASHINGTON to plan and implement a diagnostic study of the commercial viability of the AguaytiaPeru natural gas field. The field, which was discovered in 1961, is located near the confluence of the Aguaytia and San Alejandro rivers, about 100 km northeast of the town of Aguaytia (see Figure II-1). It could serve as a regional energy supply for electrical power generation and agricultural and industrial development. Because the gas field is located between Tingo Maria (at the Southern end of the Upper Huallaga area) and Pucallpa, the area surrounding and including Pucallpa was also to be considered as a potential user from the Aguaytia field. USAID/WASHINGTON (S&T/EY) selected Energy/Development International (E/DI) to carry out the diagnostic study. A team of energy specialists, James D. Westfield, Andres Doernberg, and Philip Woodside, was assembled by E/DI to complete the task with coordination and assistance from Alberto J. Sabadell of S&T/EY. The team's scope of work included a general assessment of the overall market potential for Aguaytia gas, cost estimates for appropriate gas field development and production and a preliminary determination of whether a more in-depth study of the resource and its development potential is warranted.

B. APPROACH

The study approach included approximately 50 person days of work in Peru by the team to collect and evaluate available information in Lima, visit the Huallaga valley and the Pucallpa area, prepare a draft report and present a final briefing. The three-person team was composed of a team leader and technology consultant, a market assessment consultant, and a geologist. The S&T/EY also provided an Engineer project advisor during the Peru visit.

FIGURE II-1

STUDY AREA



The study approach involved collecting information in Lima from the Ministry of Mines and Energy, the Upper Huallaga Special Project Offices (both at USAID and the Lima Liaison offices), ElectroPeru, PetroPeru, the Embassy of the Canadian Government and other sources. Following approximately one week of time spent in Lima, the plan called for a second week visiting the Upper Huallaga and Pucallpa areas to collect additional information not available in Lima and to formulate and discuss development options and scenarios. Unfortunately, the visit to Upper Huallaga Valley had to be cancelled at the last minute because the road from Pucallpa was not open. The project was completed with a third and final week in Lima during which time additional meetings were held, the collected information was analyzed, scenario development was completed, and a draft of this report prepared.

The study required several specific tasks including a market analysis and a preliminary assessment of existing and potential future uses of Aguaytia gas in the Tingo Maria and Pucallpa areas. The second task involved the estimation of the amount and availability of natural gas in the Aguaytia reservoir. This task also included first order but conservative cost estimates for a field development and production program. The third task required a description of the general requirements and costs for a gas transmission and distribution system to possible delivery and use at sites in the Upper Huallaga Valley and Pucallpa. The final task was to produce integrated gas resource and energy use scenarios and to discuss and evaluate their utility and appropriateness.

The study team was to deliver a final briefing and the major portions of their handwritten report to the USAID Mission prior to leaving Peru. Upon receiving review comments from the Mission, 30 copies of the final report were to be produced and delivered to S&T/EY in Washington for distribution and transmittal to the Mission in Lima.

USAID, as a major contributor from a group of international organizations providing expertise and funding to the Proyecto

Especial de Alto Huallaga (PEAH), is providing technical assistance and financing to the Government of Peru in this project. In addition to its participation in the forest and agroindustry elements of the project, AID is assisting in planning for the provision of the few infrastructure elements not yet in place in the valley. One of these is energy. The valley has energy resources including wood and other biomass and is not far from known reserves of oil and natural gas. There is a need to assist in the development of these in such a way as to facilitate the growth and agro industrial expansion potential that exists.

This diagnostic study was commissioned to look at the Aguaytia gas field development not solely as a commercial gas development project, as has been done in the past since discovery 20 years ago, but more as a way of providing the catalyst and support for the economic and regional development program planned for the valley. In this sense, the approach was not guided by those economic and technical limits or the development philosophy of PetroPeru and other commercial or business enterprises. It did not start with normal gas industry practice to determine the minimum number of wells to be drilled or the amount of gas necessary to even consider commercial development and production of the field. Our project approach was dictated by the form and amount of gas which could be used in the project area over the next 10 to 20 years. It assumed that the rate and extent of development and production for the Aguaytia gas field would be defined by the energy needs in the study area. At the same time, this rate and level of field development would be provided within the bounds of good engineering. Neither could the development threaten the integrity of the site's as yet undetermined gas reserve or prevent fuller and more rapid development in the future.

C. GENERAL STUDY BACKGROUND

The USAID mission in Lima has been working with the Government of Peru in support of the Proyecto Especial Alto Huallaga (PEAH). The project, covering an area of approximately one million hectares,

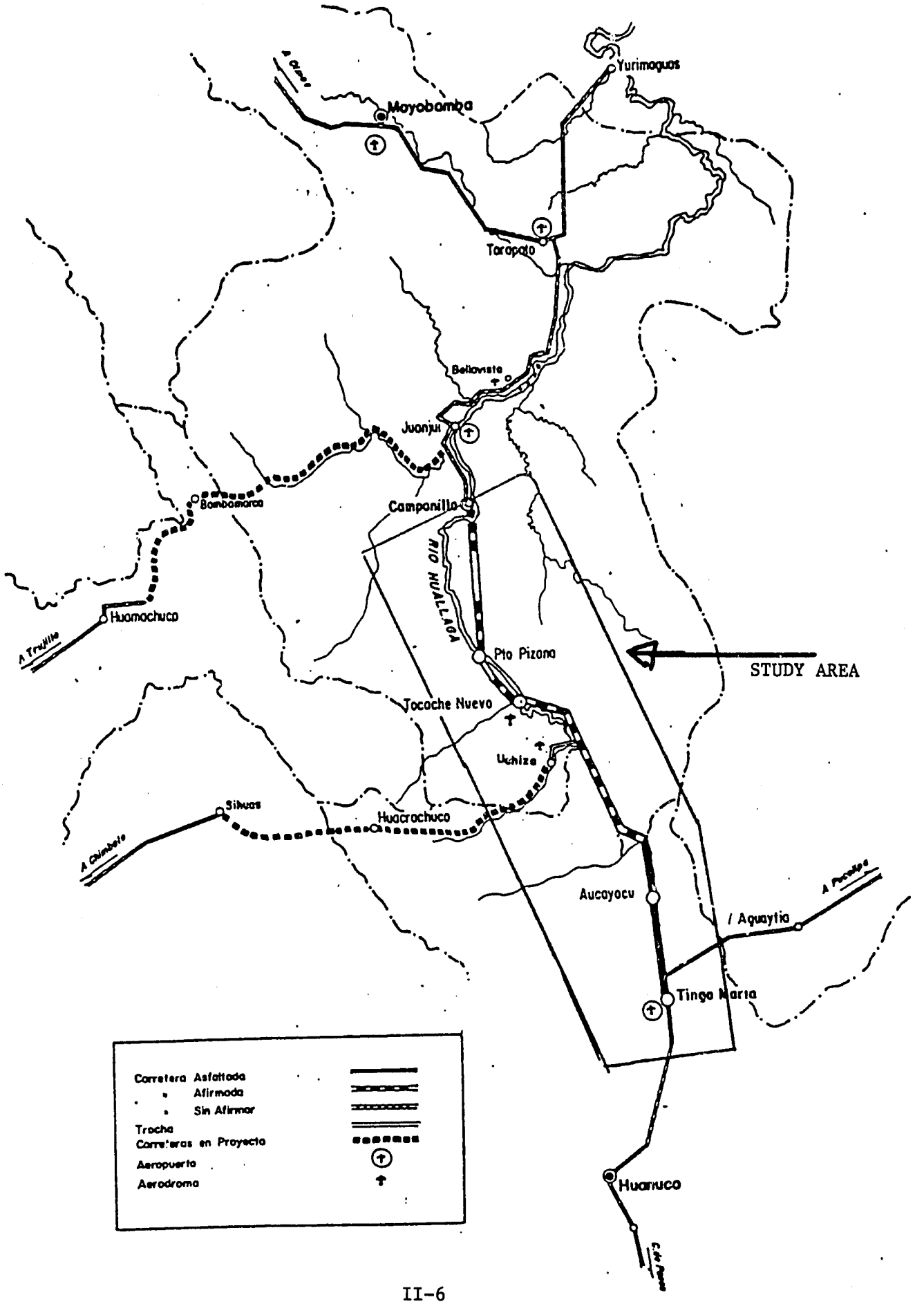
includes activities throughout the whole area but focuses on creating agricultural and agro industrial activities in and near the city of Aucayacu. The project includes colonization, cattle raising, farming, processing and manufacturing in the valley. The intended impact of this activity is increased use of the lands and resources of the valley to create employment and value added by processing goods for markets in and outside of Peru. In addition to USAID, the governments of Canada, the United Kingdom, and Czechoslavakia are also participating.

Although Pucallpa is not in the region of the PEAH project area it has been included in our study area because it has similar resources, needs, development potential and also is close the Aguaytia natural gas field. The agricultural production and industrial futures of these two areas are similar. In and around Pucallpa, a Regional Development Corporation is also actively planning and promoting agricultural and industrial development; in addition, a government supported Pucallpa-area Special Project funded by the Inter American Development Bank, is providing infrastructure.

D. UPPER HUALLAGA VALLEY DEVELOPMENT PROGRAM

In 1981, the Government of Peru decided to initiate the PEAH project as one of their most ambitious rural development efforts. The project, designed by the National Foundation for Development (FPDN) and implemented by a special body created under FPDN, has as its focus the provision of permanent study, extension and assistance services associated with credit and market development and promotion. The project was also designed to offer help to the region with infrastructure such as roads, energy and other services. The Upper Huallaga Valley (see Figure II-2) begins at the Cayumba Bridge which is 35 km south of Tingo Maria and expands north for approximately 200 km to Campanilla. This portion of the Upper Huallaga Valley contains about 120,000 people, approximately 65 percent rural and 35 percent urban. The priority area within PEAH include 10,000 farms and 110,000 hectares of land presently defined as suitable for agricultural uses.

FIGURE II-2 UPPER HUALLAGA VALLEY STUDY AREA



Principal crops currently being grown include plantains, bananas, corn, rice, coffee, tea, cacao, yuca and citrus fruits.

Although the valley is rich in potential and resources, there are a number of elements which have prevented the realization of this potential. Agricultural practices currently emphasize migratory, small yield, low energy farming, and low level market development and exploitation. Basic agricultural production is generally not converted into higher valued intermediate and end products in the valley. The present situation is such that with research, study, extension and assistance it is expected that the valley can yield much more for both its inhabitants and the country. It was the combination of the potential and recognized need plus other considerations, that led the Government to initiate the project.

III. DEMAND ANALYSIS

A. PUCALLPA

1. Economic Activity

Pucallpa is a city of 100,000 inhabitants situated on the Ucayali River in the Ceja de Selva (Upper Jungle), about 70 km from the Aguaytia gas field. It is now the terminal of the Central Selva highway, which links Lima and the Central Sierra mining district with the Upper Jungle. Plans exist to link Pucallpa with the Brazilian frontier by highway, opening communications with Cruzeiro do Sul, the terminal of Brazil's TransAmazon highway.

The mainstay of the Pucallpa economy is the lumber industry, which consists of 52 sawmills and 4 laminating and triplay plants (plywood). Many sawmills are now closed, victims of the economic downturn and import competition. Milled lumber produced around Pucallpa, in the form of boards, is trucked 30 hours away to Lima.

Future area development will be based on continued processing of wood products, and a nascent livestock industry along the Pucallpa-Tingo Maria highway. The Pucallpa 2500 Bbl/d oil refinery is now 40 years old, and local oil production has tapered off. Recent discoveries of natural gas south of Pucallpa, in addition to Aguaytia, may reverse the decline of the hydrocarbon industry in the region.

The remaining industrial activity is limited, with few exceptions, to consumer products for the local market, largely food and beverages.

2. Sources of Energy

a. Petroleum Products

PetroPeru operates a depot ("planta") next to the Pucallpa refinery. Table III-1 shows sales figures from this depot for 1981 to 1983. The effects of the economic downturn are evident in these sales figures, which show declines across fuel category: diesel sales have

TABLE III-1

SALES AT PUCALLPA PETROPERU PLANT
(thousand barrels)

	1981	1982	1983
Gasoline 84 octane	186.1	149.2	126.5
Domestic Kerosene	111.0	112.1	97.1
Industrial Kerosene	32.5	17.2	7.4
Diesel 2	275.9	254.3	232.4
Residual Oil	60.4	30.2	21.9
TOTAL	665.9	563.0	485.3

dropped 16 percent, gasoline sales 32 percent, and due to special circumstances, residual sales are only 36 percent of what they were two years ago. In 1984, the decline in sales has continued.

The Pucallpa depot serves the entire Upper Jungle area, including most of the needs of Tingo Maria and the area of the Upper Huallaga Special Project. Based on our field trip we believe, however, that most of the fuel sold by the plant to industry is consumed in Pucallpa. This is particularly true for residual oil.

Pucallpa Oil Refinery: The capacity of the refinery is 2500 bbls/day, and at one time, it processed crude from the Agua Caliente and Ganso Azul fields which are 80 km to the south on the Pachitea river and from the Maquia field to the north. Current crude production in Maquia and Agua Caliente is down to 700 bbls/day; the rest of the supply is taken from the Northern Peru pipeline (this links the Northern jungle oil fields with the Pacific) and is barged south to Pucallpa.

The refinery produces 54 percent residual, 30 percent diesel, 8 percent kerosene and 8 percent 30-octane gasoline. Approximately 1200 bbls/day of residual are sent via barge back to the pipeline for consumption on the Coast or exported. Table III-2 shows current refinery production.

In order to meet the demand in the region for high octane gasoline, 88-octane gasoline is brought by truck from Lima and mixed with the low octane gasoline in proportions of 100 bbls high octane to 200 bbls refinery product. LPG, which is not produced at the refinery, is trucked from the Coast by independent distributors.

b. Electric Sector

Pucallpa is served by ElectroPeru for the electric needs of the population and industry depends almost entirely on self-generation. Current installed capacity of ElectroPeru is 11.0 MW, of which

TABLE III-2

PUCALLPA REFINERY PRODUCTION, 1984

	bbls/day
Gasoline, low octane	200
Kerosene	200
Diesel	750
Residual	1350
Total	2500

PUCALLPA REFINERY, SUPPLY, 1984

Gasoline, 80 octane(*)	300
Kerosene	200
Diesel	750
Residual	150
Residual, returned to Northern Peru Pipeline	1,200
Total	2,600

(*) Blend of 200 bbls/day Pucallpa refinery production and 100 bbls/day high octane gasoline trucked from Lima.

Source: PetroPeru, Dept. de Planeamiento, Gerencia Central Produccion Industrial.

available capacity is 7.4 MW. Installed capacity in industry is 18.5 MW, although much of it is not in use at this time. Table III-3 shows the basic statistics of the electric sector, which, in addition to the capacity mentioned above, is supplemented by numerous gasoline and diesel sets in shops and residences.

At present, ElectroPeru and all selfgenerators produce electricity with diesel sets. A 20MW steam generator using residual oil will be put into service by ElectroPeru in a year or so. This plant, which consists of equipment supplied by the Czechoslovakia Government (SKODA) in 1972, has been under construction for more than a decade and even when completed will not be able to supply all the city's industrial demand. Distribution lines now reach about 65 percent of the population, but the shortage in capacity prevents many residences from connecting (the number of residential customers amount to 5500, or 35 percent of the urban families). There is, therefore, an "unmet" demand that is an important factor in estimating future electricity demand in the city.

Recent ElectroPeru sales data are shown in Table III-4. The rapid growth in sales during the period is not a reflection on the growth in economic activity but results from new connections; the system is relatively new (installed between 1976 and 1979) and distribution lines are even newer. By 1983, generation reached 26.96 gWh, only 6.2 percent higher than in 1982. In the first half of 1984 production has shown a decrease, as a result of higher tariffs and lower income of the population.

Residential consumers account for 35 percent of total production, commercial customers 15 percent and services (including street lighting and the city's water supply system) account for 13 percent. Industry accounts for only 16 percent, because, as explained above, large users are not on the ElectroPeru system. Line and other losses are 21 percent.

TABLE III-3

PUCALLPA ELECTRIC SECTOR

1. ElectroPeru System, Pucallpa/Yarinacocha

Capacity - 1983	Installed Capacity	11.0 MW
	Available Capacity	7.4 MW
	Guaranteed Capacity	5.15 MW
Demand - 1983	Maximum demand	6.1 MW
	Production	29.96 gWh
	No. of domestic customers	5,500
	Electrification rate	35%
	Plant Factor*	0.42

2. Rural Areas	Number of isolated systems	23
	ElectroPeru	6
	Municipalities, etc.	17
	Installed Capacity	908 KW

3. Selfgenerators - Industry, Services		
	Installed Capacity	18.5 MW
	Generation	NA

4. Selfgenerators - Residences, etc.	NA

* Calculated

Source: ElectroPeru, Situacion Actual del Servicio Electrico en el Departamento de Ucayali, Informe No. TPMH-010-84

TABLE III-4

ELECTRICITY SALES
PUCALLPA/YARINACOCHA
(gWh)

	1982	1978	Annual Growth
Public Lighting	0.98	1.19	-5.1%
Residential	8.91	3.88	23.1%
Commercial	3.93	2.48	12.2%
Small Industry	0.59	0.25	23.6%
Large Industry	3.39	1.07	33.3
General Use	1.20	0.50	25.6
Pumps (Water Supply System)	1.06	0.41	27.0
TOTAL	20.06	9.77	19.7
Line Losses	5.33	1.56	
TOTAL SUPPLY	25.39	11.33	

Source: ElectroPeru, Reference 4

The large proportion of sales to residential and commercial customers is reflected in the daily load distribution curve (Figure III-1). The low demand period, which extends from 2 AM to 7 AM, has a load that is less than one half the steep peak which occurs at 7 PM. As a result, the plant factor is 0.42 (measured against available capacity).

c. Wood Wastes

Because of the availability of wastes from sawmills in and around Pucallpa, the demand for wood for fuel is met almost in its entirety by wastes from sawmills. There is no evidence of regular firewood sold in the city; the trade in wood consists almost solely of sawmill wastes. Charcoal is also made from sawmill wastes in the vicinity of the mills.

In order to estimate the available wood waste resource, the members of the team tried to ascertain the portion of wood wasted in milling in several interviews. Estimates varied widely, from 15 percent to 100 percent of the amount of feet-board produced. The available resource greatly exceeds the demand for wood fuel in the city, and sawmills dispose of it by incineration in open fires.

The capacity of the region's mechanized forest extraction equipment (180 tractors) is estimated at 981,000 m^3 per year, and that of the 52 sawmills is 670,000 m^3 per year (plus an additional 100,000 m^3 annually in plywood and parquet factories). In 1981, only 191,622 m^3 (42.16 million feet-board) were extracted, or 25 percent of capacity. That year 157,919 m^3 were consumed in sawmills, and sawn wood amounted to 116,746 m^3. This yields an apparent waste of 41,173 m^3 of wood in sawmills. Table III-5 shows production and waste figures for 1978 to 1981. Between 1981 and 1984 production volumes have decreased sensibly due to decreased domestic demand and competition from exports (tariffs were lowered in the last three years).

FIGURE III-1

DAILY LOAD CURVE, PUCALLPA ELECTROPERU SYSTEM 1982

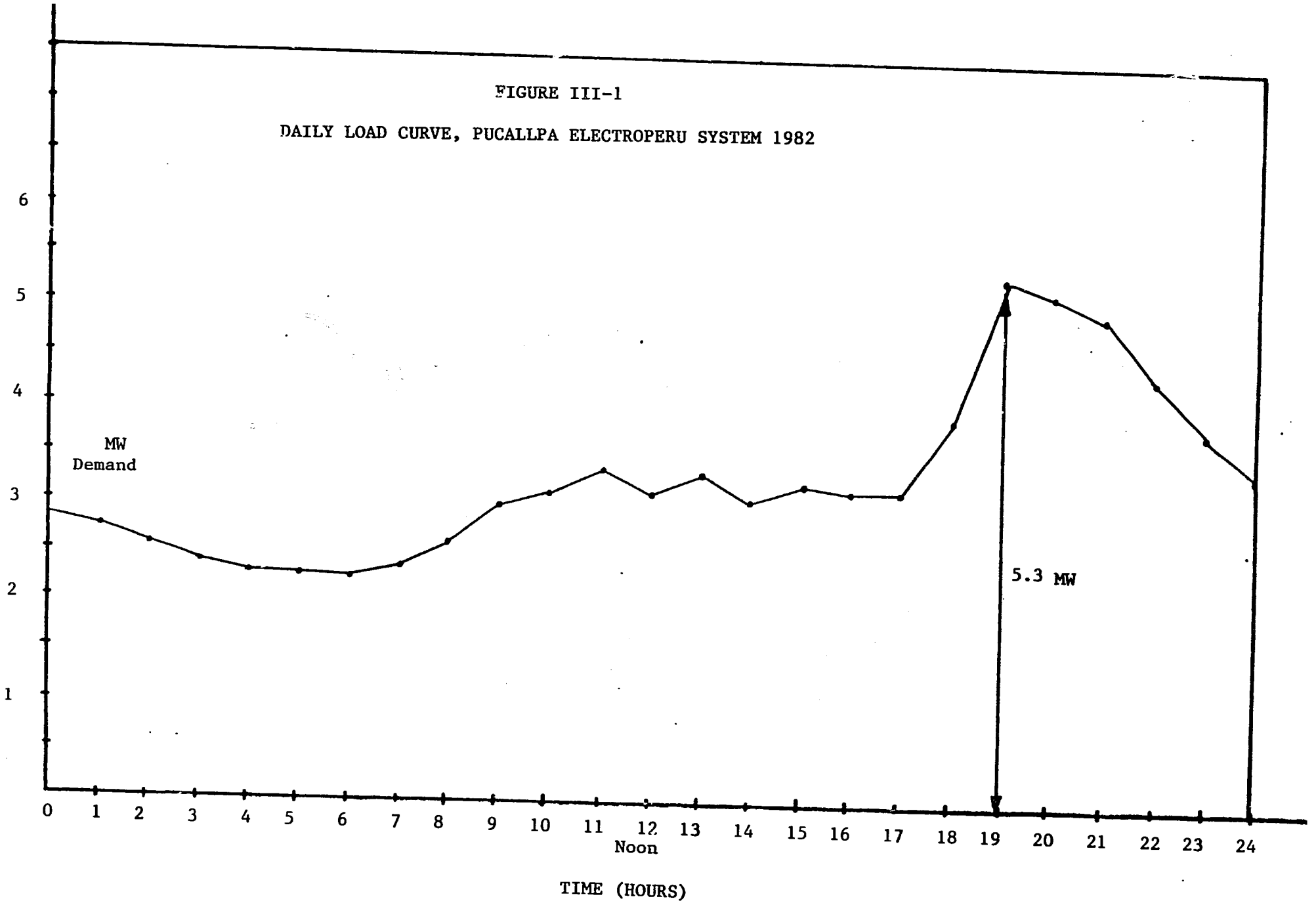


TABLE III-5

WOOD RESOURCE - PUCALLPA

	1978	1979	1980	1981
Extraction (m^3)	160,536	189,351	283,191	191,622
Input to sawmills (m^3)	116,726	146,762	177,290	157,919
Sawmill production (m^3)	77,738	107,664	100,868	116,746
Sawmill Wastes (m^3)	38,988	39,098	76,422	41,173
(%)	33	27	43	26
Approx. barrels of residual equivalent	40,000 (1)	40,000	79,000	42,000

(1) Using 5.80 GJ/barrel of residual equivalent. A density of 0.6 tons/m^3 per wood, and 10GJ per metric ton of wood has been used in the conversion (E/DI estimate).

Source: Reference 1

The heat content of the sawmill waste is approximately some 40,000 barrels of residual equivalent. This value is nearly twice the amount of residual used in industry in the city; another comparison is the 50,000 barrels per year of diesel that ElectroPeru currently consumes.

No estimates have been made on the fraction of this resource that is currently used in the area. Sawmill wastes are used in brickmaking and for charcoal; usage probably accounts for less than one quarter of the volume available.

The distribution of sawmills closely located along 20 km on the main highway leading out of town (with the exception of less accessible mills south of the city along the river, served by extremely poor roads) has led to consideration by CORDEU of a collection system that may allow for the use of wood in the generation of electricity. This proposition may be of value and should be investigated further. The estimate of available wood resource of 30,000-40,000 barrels of residual equivalent is to be taken as conservative; the waste produced at the points of extraction should also be considered and transportation costs estimated. Estimates of the percentage of total wood extracted from the forest which is actually used range from 40 to 60 percent. Because of this, the ultimate energy resource that could be tapped from the wood industry in the area could be as high as 200,000 barrels of residual equivalent. These estimates reflect conditions in the past years. The downturn in the lumber industry may be permanent, because the resource is being exhausted rapidly in the vicinity of Pucallpa.

3. Current and Future Energy Demand

a. Industry

Local industries are at present dependent on diesel and residual oil for their energy needs; this is supplemented by electricity purchased from ElectroPeru and by wood wastes from sawmills. Diesel is used in selfgeneration of electricity, to operate logging tractors and trucks owned by the major industries, and as a source of heat.

Residual oil is consumed by six major industries, four plywood factories, the brewery and one brickmaker, and it was being used by the paper mill before it shut down.

Consumption of residual has dropped from 30,125 barrels in 1982 to 19,142 barrels in 1983, as shown in Table III-6. The drop is caused by the same factors which have diminished the market for wood products. One major brickmaking operation also may have substituted wood as fuel for its kilns (other brickmaking in the area is fueled with wood wastes entirely).

Diesel sales to large industries in Pucallpa amounted to 34,315 barrels in 1983, up from 28,775 barrels in 1982 (see Table III-7). These amounts exclude diesel purchased by industries at service stations. Because the PetroPeru Pucallpa depot (source of the sales data reported here) is easily accessible and substantial cost savings (dealer margin plus freight) can be realized, few industries routinely purchase fuel from gas stations.

Diesel is consumed principally in the generation of electricity. Installed capacity of diesel sets in industry is 17.3 MW, as detailed in Table III-8. Estimating the amount of diesel used in selfgeneration is difficult in light of the low demand for the region's products and current plant shutdowns. One must also assume that some selfgenerators are not included in the sales data presented here (they purchase diesel from distributors), that current demand is only a fraction of installed capacity in plants which are presently operating, and that industry is highly seasonal.

We estimate that of total diesel sales to large customers, about 75 percent is used for electric generation. Total diesel currently consumed by industry is estimated to be 37,000 barrels, this includes purchases from distributors.

TABLE III-6

RESIDUAL OIL PURCHASES

(barrels)

	1981	1982	1983
Brewery	10,310	7,444	6,962
Brickmaker	3,903	2,460	637
Wood Products(1)	18,561	17,748	11,298
Papermill(2)	26,333	1,307	--
Others, Pucallpa	752	1,166	245
	59,859	30,125	19,142

(1) Represents 4 plants
(2) Shut down in 1982

Source: PetroPeru

TABLE III-7

INDUSTRIAL DIESEL PURCHASES

Largest Consumers
(Barrels)

	1981	1982	1983
Cerveceria San Juan	9,655	8,848	8,190
Embotelladora Sisley	1,782	1,845	1,607
Embotelladora del Oriente	2,324	2,143	2,738
Industrial Maderera del Oriente	7,714	7,055	4,893
Maderas S.A.	--	2,406	4,389
Crown Cork del Peru	--	--	3,266
Triplay Amazonico	2,920	2,954	2,091
Papelera Pucallpa	4,097	1,139	733
Mapesa	774	774	--
Comapsa Aserradero	1,139	714	--
Other Food & Beverage	--	216	1,679
Other Wood & Wood Prods.	1,889	1,681	3,556
TOTAL	32,294	28,775	34,315

Source: PetroPeru

TABLE III-8

INDUSTRIAL SELFGENERATION

	Installed Capacity (KW)	Maximum Demand (KW)
Papelera Pucallpa	3,184	
Cerveceria San Juan	2,125	1,030
Embotelladora Sisley	820	260
Embotelladora La Loretana	263	
PetroPeru	500	
Ladrillera Montebello	200	
Ladrillera Ucayali	265	
Maderas S.A.	780	500
Cia. Industrial Pucallpa	420	270
Triplay Amazonico	420	350
Aserradero Loa Angeles	600	
Maderas Manantay	385	
Aserradero Monteblanco	350	
Other Sawmills, Wood Products(1)	3,513	
Other Industries	265	
Subtotal	14,090	
Other, non-industrial	1,188	
TOTAL	15,278	

(1) Represents 17 industries, typically with 210 KW

Source: ElectroPeru, Reference 4

Future industrial development will continue to be based, for the most part, in the wood and wood products industry. The local office of the Ministry of Industry reports that they expect new demand for up to 5,000 KW of new electric demand. The development corporation, CORDEU, quotes figures that are much higher, in excess of 10 MW for new industry. A cement plant, proposed 10 years ago for the Pucallpa Jungle region, would demand 10 MW and consume about 8,000 tons (about 60,000 barrels) of residual at 80 percent capacity. The plant, however, is no closer to being built than at the time of inception. A large metal products plant is also proposed with an electric demand of several megawatts.

A more detailed analysis of future electric demand is contained in the following section. Demand for residual will grow, with a recovery of the lumber industry, to about 30,000 barrels, and if the papermill reopens, total demand will reach 60,000 barrels. It is not possible to add new industries to this demand, because of the large uncertainty regarding all these preliminary plans.

Demand for diesel is dependent on ElectroPeru's power projects: as described above, most diesel is used in selfgeneration, and consumption by industry will decrease significantly in the medium and long term as they gain access to the grid, the rate and magnitude of this shift will be affected by ElectroPeru's capacity expansion plans. Selfgeneration costs are estimated at 13.5 U.S. cents per kWh. Of this $0.06/kWh is for fuel alone. Selfgeneration costs have traditionally exceeded ElectroPeru's electricity prices which are currently at about $0.03/kWh and because of this industry will consider connection to the grid as soon as the utility installs the required capacity.

With the exception of some of the sawmills along the river south of the city (approximately 3,000 kW of demand), the remaining industries, and in particular, any new ones, should have access to the grid.

b. Electric Utility

ElectroPeru's Pucallpa system consumed 52,288 barrels of diesel fuel in 1983, at the rate of 12.3 kWh/gallon (Table III-9). Additional details of the ElectroPeru's system are given in section A.2 of this chapter.

After the 20 MW steam generator is in operation at the new Pucallpa plant, total consumption is expected to rise to about 210,000 barrels of residual. This assumes the diesel sets will continue to consume at the rate of 50,000 barrels per year. It is not possible to predict when the new plant will come on line since ElectroPeru is seeking an additional US $2 million in capital. For purposes of this report, we have used a startup date of 1986. According to most recent estimates, at that time the Pucallpa system may be serving a peak load of some 25 MW; most of the existing 10 MW or so of industrial demand is expected to be still excluded from the grid.

There is a wide range of estimates for long term electric demand in Pucallpa. The plant itself has been designed for an additional two SKODA generators of 30 MW each, for a total of 80 MW installed capacity. No definite time schedule exists for these additions.

ElectroPeru's Master Plan projects maximum demand in Pucallpa at 25.5 MW in 1990, 33.5 MW in 1995 and 44.4 MW in 2000. A more recent ElectroPeru memorandum (Reference 4) presents a low demand which is in rough agreement with the Master Plan projections, and presents a high scenario with maximum demands of 96.5 MW in 1990, 130.1 MW in 1995 and 171.4 MW in 2000. These cases assume that most major selfgenerators are replaced by grid supply by 1990.

Interviews conducted during our visit to Pucallpa in July of 1984 indicate that the low projections are conservative, while the high projections are most likely unrealistic. The indications are that after the new plant is in operation (in 1986, when 37 MW of installed capacity will be available), ElectroPeru will still be unable to supply industry demand from the grid. This implies a maximum demand

TABLE III-9

ELECTRIC UTILITY FUEL DEMAND

Current	1981	1982	1983
Diesel purchases (barrels)	51,225	58,060	52,288
Generation (gWh)	23.36	26.97	26.96
Fuel use rate (kWh/gallon)	10.9	11.1	12.3

Short Term (after 1985)	
Steam Plant Generation (gWh), Phase I (10MW, 4,000 hours/year)	40.0
Fuel Use Rate (kWh/gallon)*	9.0
Residual oil demand (barrels)	105,000
Diesel Sets Generation (kWh) (6MW, P.F. 0.45)	23.65
Diesel Demand (barrels)	50,000

Medium Term (1986-87)	
Steam Plant 2 x 10 MW Phase II	
Generation (gWh)	80.0
Resdiual oil demand (barrels)	210,000

* ElectroPeru estimate

Source: E/DI estimates

of 32 to 37 MW in 1986. Assuming a 6 percent annual demand growth rate this yields a projected high case demand of 40 to 47 MW in 1990 and 54 to 63 MW in 1995. Corresponding installed capacity, assuming a 20 percent reserve factor, would be 50 to 59 MW in 1990 and 68 to 79 MW in 1995.

c. Other Sectors

The demand for fuels in the other sectors can be partially determined from sales data for various types of fuels. The transportation consumes most of the gasoline sold in the area (126,400 barrels in 1983), and also the largest part of the diesel sold at gas stations and to distributors (83,484 barrels that year). These figures represent the total volumes sold to gas stations and distributors from the Pucallpa depot, and therefore, include an undetermined amount of fuel sold to retailers in the region but used outside the city. The largest of these sales are to retailers in Tingo Maria and the Upper Huallaga Valley. Furthermore, not all the diesel and gasoline is used in transportation: the sales figures presented include uses for mechanized agricultural and forestry equipment and small scale electric generation in homes, shops and small industries. It is not possible to estimate these other uses and thus accurate estimates of transport sector usage is difficult.

Households, shops, and restaurants consume kerosene (97,100 barrels in 1983) for cooking, refrigeration, and lighting. Low volumes of charcoal are consumed in households while the largest users are food vendors. In addition to kerosene, cooking consumes approximately 1,000 bottles of LPG per month (24 lb/bottle) or an amount equivalent to about 1,000 barrels of kerosene per year. Small amounts of wood wastes are also used for cooking.

The government/services sector, comprised of government offices, military, hospitals and hotels purchased approximately 9,000 barrels of diesel in 1983.

Sales of diesel and gasoline dropped sharply between 1981 and 1983. Diesel sales by retailers reached 138,000 barrels in 1981, 65 percent higher than in 1983. Gasoline sales dropped about 18 percent during the same period. Near term prospects for a reversal of the trend are not very good.

In the long term, demand for gasoline and diesel for transportation will grow as a function of population growth and increases in industrial production. The lumber industry with its growing demand for freight to the Coast will also influence this growth. With the refinery slated to be expanded by 25 percent in the near future, there should be no problems supplying the expected increased needs of the city for diesel and gasoline.

4. Energy Prices

Energy prices for petroleum products and electric tariffs are set by the central government in Lima. The costs of petroleum products sold at any depot in the Selva region are uniformly priced (and in practical terms also vary little from those prices at coast or Sierra depots). In the last years there have been increases nearly every month at all depots as a consequence of inflation and gradual devaluation of the currency. The increases in prices have often lagged the rate of devaluation and inflation, leading to reduced real income for PetroPeru. ElectroPeru fares much worse, and must be subsidized by the government. In 1983, it had a deficit of 90,000 million soles (about US$50 million); this amount is almost entirely attributed to the costs of operating the isolated systems such as the one in Pucallpa. At these facilities operating costs greatly exceed the income produced by tariffs. Electricity tariffs are essentially equal throughout the country, and appear to be set at levels commensurate with hydroelectricity generating costs.

Retail prices for petroleum products contain the ex-depot PetroPeru price, taxes, dealer margin and a freight cost (freight from the depot to the distributor). These are fixed by the central

government with the exception of freight, which is set by local authorities. Table III-10 shows the structure of prices for diesel and residual at Selva depots.

Retail prices for kerosene are also government controlled, and include a margin for distributors, who bottle it and sell through numerous vendors. LPG is marketed via independent distributors, who in the case of Pucallpa, truck the product from the Coast.

Table III-11 shows current Pucallpa retail prices for all petroleum products used in industry or power generation. The estimate for wood wastes, delivered by the truckload, is based on the asking price set by middlemen who obtain the wastes at lumber yards. This wood, in the form of broken or irregular boards assures close packing. We have assumed one truckload will carry 5 m^3 of board (about 3 tons of wood). Because the wastes are not dry wood, we used a heat content of only 6 gigajoules per ton (about one barrel of oil equivalent per ton). This results in an equivalency of US$0.70 to 0.88 per million Btu. This is approximately one sixth of the price of residual oil. Wood ovens and boilers do not operate as efficiently as oil operated ones, so that per effective Btu the price differential is somewhat smaller, a fourth or one fifth of that of residual.

The values used in calculating wood costs on the basis of million Btu are extremely rough and have been quantified only to present an order of magnitude comparison with the cost of residual oil. The results, however, show that even allowing for a large margin of error, wood costs are substantially lower than petroleum-derived fuels. This apparent economic advantage has been recognized by industries in Pucallpa; one large brickmaker uses wood wastes exclusively, and another one is gradually switching to wood.

TABLE III-10

STRUCTURE OF INDUSTRIAL FUEL PRICES
(excluded freight, soles per gallon)

	Diesel (May 1, 1984)		Residual (March 1, 1984)	
Ex-depot	1,402.33	57%	1,142.52	62%
Consumption Tax	518.86	21%	422.73	23%
General Sales Tax	345.81	14%	281.75	15%
Dealer Margin	177.00	7%		
TOTAL	2,444.00	(US$0.83)	1,847.00	(US$0.73)

Conversion rates:

May 1, 1984	S/. 2,930.94 per US$
March 1, 1984	S/. 2,540 per US$

Source: PetroPeru

TABLE III-11

FUEL PRICES, PUCALLPA

		US$/Million Btu
Diesel[1] (May 1, 1984)	2444 soles/gallon	6.49
Residual[2] (March 1, 1984)	1847 soles/gallon	5.42
Kerosene[3] (July 1, 1984)	1800 soles/gallon	4.25
LPG[3] (July 1, 1984)	18,500 soles/24 lb bottle	11.04
Wood Wastes (July 1984)	40-50,000 soles/truckload	0.70-0.88

Conversions Used:		
	March 1, 1984	2540 soles/US$
	April 1, 1984	2692 soles/US$
	May 1, 1984	2931 soles/US$
	June 1, 1984	3160 soles/US$
	July 1, 1984	3350 soles/US$

(1) Includes dealer margin and excludes freight cost
(2) Excludes dealers and freight
(3) Retail price of distributors and vendors
(4) Assumes $5m^3$/truckload, 0.6 tons/m^3 wood, 6 GJ/ton (wetwood)

Source: PetroPeru, and field survey.

5. Potential Natural Gas Use

a. ElectroPeru steam generation

Because of the large investment required for a distribution pipeline, use of natural gas is often feasible only when large consumers are available. The single largest potential user of natural gas in the area would be the new steam generation plant of ElectroPeru, about 10 km from Pucallpa on the road to Yarinacocha. This plant will use residual oil, which , if the plant is converted to gas, can be exported from the region.

Tables III-12 and III-13 show the estimated demand for natural gas if conversion is carried out. A conservative, "low case" demand for the Pucallpa system was prepared assuming loads obtained from the ElectroPeru Master Plan. Natural gas consumption at the plant would be 1.35 BCF in 1986, 2.03 BCF in 1990, 2.70 BCF in 1995 and 3.38 BCF in 2000, this is equivalent to 3.7 MMCF/D in 1986, 5.6 MMCF/D in 1990, 7.4 MMCF/D in 1995, and 9.3 MMCF/D in 2000. The calculations are based on the following:

- Aguaytia gas is 900 Btu/CF
- The SKODA equipment is rated at 9 kWh/gallon of residual, and this efficiency (22.3%), is used to calculate gas requirements
- The steam generators run 4,000 hours per year

A "high case" prepared on the basis of perceptions by ElectroPeru staff in Pucallpa and Lima yields a potential natural gas demand of 1.35 BCF (3.7 MMCF/D) in 1986, 4.05 BCF (11.1 MMCF/D) in 1990 and 5.4 BCF (14.8 MMCF/D in 1995).

b. Pucallpa Petroleum Refinery

The refinery fuel needs met by residual oil amount to approximately 4% of crude input. Refinery capacity is scheduled to be expanded to 3,100 bbls/day. The amount of fuel oil which could be displaced by natural gas is therefore 125 bbls/day of residual.

TABLE III-12

PUCALLPA ELECTRIC SUPPLY SYSTEM, CONSERVATIVE CASE
ESTIMATED FUEL REQUIREMENTS

Year	Projected[1] Demand (MW)	Installed Capacity (MW)	Plant Additions (MW)	Fuel Use/Year Residual(2) barrels	Fuel Use/Year Diesel barrels	Aguaytia Natural Gas[3] BCF/Year	MMCF/D
1984	6.5	7.4		0	52,000		
1985	8.3	17.4	+10.0	105,000	---	0.68	1.9
1986	13.1	27.4	+10.0	210,000	---	1.35	3.7
1987	20.1	27.4	---	210,000	10,000	1.35	3.7
1988	23.8	37.4	+10.0	315,000	---	2.03	5.6
1989	25.0	37.4		315,000	---	2.03	5.6
1990	26.5	37.4		315,000	10,000	2.03	5.6
1995	35.5	47.4	+10.0	420,000	10,000	2.70	7.4
2000	46.7	57.4	+10.0	525,000	20,000	3.38	9.3

(1) ElectroPeru Master Plan
(2) Assumes 9 kWh/gallon, and 4000 hours per year
(3) Substitution of residual oil consumption in the steam generator to natural gas. No substitution in diesel plant.

TABLE III-13

PUCALLPA ELECTRIC SUPPLY SYSTEM, HIGH CASE
ESTIMATED FUEL REQUIREMENTS

	Projected Demand	Installed Capacity	Plant Additions	Fuel Use/yr Residual	Fuel Use/yr Diesel	Aguaytia Natural Gas	
	MW[1]	MW	MW	barrels		BCF/yr	MMCF/D
1984	6.5	7.4	--	--	52,000	--	--
1986	32-37	27.4+18[2]	+20	210,000	50,000	1.35	3.7
1990	40-47	50-59	+40	630,000	52,000	4.05	11.1
1995	54-63	68-79	+20	840,000	50,000	5.40	14.8

(1) see text, section A.3 of this chapter
(2) 18MW installed in industry

Assuming the refinery operates 365 days per year, total gas demand would be 0.3 BCF per year of Aguaytia gas.

c. San Juan Brewery

The brewery is located 13 km from the refinery. It is projected to consume 10,000 barrels of residual or 0.06 BCF of Aguaytia gas per year for its boilers.

d. New Industry and Hotel

In the vicinity of the brewery there is a large hotel under construction, and a site for a future industrial park. The hotel could use 1,000 barrels per year of oil for hot water and cooking, and the new industries could total an additional 10,000 barrels of residual per year for boilers and/or heat. This would amount to 0.07 BCF per year of gas, growing at 5 percent per year.

e. Summary

Total potential natural gas demand in the Pucallpa area amounts to 1.78 BCF (4.9 MMCF/D) 1986, 2.48 - 4.50 BCF (6.8 - 12.3 MMCF/D) in 1990, and 3.18 - 5.88 BCF (8.7 - 16.1 MMCF/D) in 1995 (see Table III-14).

B. UPPER HUALLAGA

1. Economic Activity

The area of the PEAH is a stretch of the Huallaga River Valley about 200 km long from Tingo Maria to Campanilla. About 120,000 persons live in the region, one third of them in urban areas, concentrated in Tingo Maria (20,000), Aucuyacu (9,000), Tocache (5,000), Uchiza and Nuevo Progreso (2,000 each). Tingo Maria is 670 m above sea level, and downriver, Tocache is at an elevation of 450 m.

The agricultural area at one time produced lumber, but this resource has been largely depleted. Recent efforts have focused on agroindustries; the most important are palm oil, rice, cocoa, tea and coffee. Plans exist for production of small animal feed (processed

TABLE III-14

POTENTIAL AGUAYTIA GAS USE
PUCALLPA AREA, (BCF/yr)

	1986	1990	1995
ElectroPeru	1.35	2.03-4.05	2.70-5.40
Refinery	0.30	0.30	0.30
S.J. Brewery	0.06	0.06	0.06
Other	0.07	0.09	0.12
TOTAL BCF	1.78	2.48-4.50	3.18-5.88
TOTAL MMCF/D	4.9	6.8 -12.3	8.7 - 16.1

from maize and yuca), tobacco, milk products, and fruits. The agroindustries mostly produce intermediate goods used as inputs in food processing industries on the coast or for export. Otherwise, little economic activity exists. An exception is a recently started dolomite rock crushing operation which produces lime for soil conditions. Future options include production of construction materials, ceramics, metal products and soft drinks. Plans to develop a wood products industry have been abandoned.

2. Sources of Energy

a. Petroleum Products

The PEAH project area is supplied with gasoline, diesel and kerosene from PetroPeru depots in Pucallpa (284 km to the east) and Cerro de Pasco (239 km to the south of Tingo Maria). In order to accurately determine yearly sales in the area, it would have been necessary to interview retailers in the area, since PetroPeru does not keep records at this level of detail. It was not possible to conduct the field trip, and therefore, the estimates of fuel sales in the area are only approximate. No use of residual oil is made in the area. LPG is sold by distributors and transported from Lima. No estimate of its use has been made.

b. Electric sector

ElectroPeru operates two small generation-distribution systems in the PEAH region. In Tingo Maria there is an installed capacity of 3650 KW, and in Aucuyacu there is 600 KW; all are diesel sets. There are small municipal systems (about 30 KW) in Tocache and six other communities (Table III-15).

Generators in private hands may add to 1,000 KW, and the 29 sawmills scattered in the area (many of which are not operating) each have 100-200 KW. The PEAH project camp has a 220 KW diesel set. The largest agroindustry in the area near Tocache, a palm oil producer, has about 700 KW.

TABLE III-15

ELECTRIC SECTOR, PEAH PROJECT AREA

Locality	Installed Capacity (KW)	Peak Demand (KW)	Annual Electricity Generation (gWh)
Tingo Maria			
ElectroPeru	3650	1880	8.5
Other	NA(1)		
Aucuyacu			
ElectroPeru	600		
Private	300		
PEAH	220		
Poligono (projected)	300		
Tocache			
Municipal	30		
Other(2)	180 (est)		
	5280		

(1) There is some autogeneration but no estimates were available

(2) Uchiza, Nuevo Progreso, La Palma, Santa Rosa, Pacal, Pucayacu

An extension of the Central North grid to Tingo Maria (a 138 Kv, 33 MVA line) is scheduled to be completed by 1985, followed by an addition to Aucuyacu (33 KV) by 1986. This will supply electricity from mostly hydroelectric sources to the two largest centers of demand in the PEAH area, including a planned industrial zone ("Poligono" Industrial) in Aucuyacu.

c. Biomass

Wood wastes from sawmills provided a source of energy in the recent past, when 35-45,000 m^3 were cut annually, yielding wastes equivalent to about 8,000 barrels of oil. Current cutting, however, is down to negligible amounts.

Two important agricultural wastes are produced in the area which are used as energy sources: palm nut shells and rice straw. The wastes from crushing 100,000 tons of palm nuts annually are enough to meet the steam requirements of the oil extraction process (including steam for its electric generation needs). Rice straw is used in rice milling operations.

3. Current and Future Energy Demand

a. Industry

The PEAH project area does not contain sizable industries, and most of the fuel requirements are met by biomass. Only two sites (palm oil processing) operate boilers and these are fueled by palm nut shell wastes. Diesel is mostly consumed for generation of electricity. Total diesel consumption for all diesel sets in industries, shops, sawmills and public service does not exceed 8,000 barrels per year. Endepalma a palm oil processing plant is the largest consumer at about 500 to 600 barrels per year. A large part of this diesel consumption will be replaced once the grid is completed to Tingo Maria and Aucuyacu.

New industry planned for the area will not require large volumes of hydrocarbon fuels. A rock crusher which processes dolomite into a

calcium and magnesium rich product used as soil conditioner, will use diesel at the rate of 1,400 barrels per year to allow processing of 30,000 tons of dolomite. A cocoa processing plant with a capacity of 2,200 tons per year will require yearly about 600 barrels of diesel for its boiler and 700 barrels of diesel for its electricity needs. A larger demand is scheduled for coffee processing, which according to its feasibility study, will require 2,800 barrels per year of residual in each of two plants. Coffee and cocoa processing generate wastes that can be used to fuel boilers. These have not been considered in the feasibility studies.

It is clear that agroindustrial processing plants planned for the area are either low energy consumers, or can use agricultural wastes, such as in palm oil processing, cocoa and coffee, rice hulling or in a small sugar plantation and mill suggested for the area. Larger demand for hydrocarbons will occur at the time the extractive sector becomes industrialized. Examples of more energy-intensive proposed industries based on the limestone, gypsum and clay resources found in the area, include production of construction materials, tiles, mayolicas and bathroom fixtures.

b. Electric sector

The diesel sets operated by ElectroPeru consumed 19,429 barrels of diesel in 1983, up 36 percent from 1982. Most of this fuel consumption will be replaced by 1986, when the grid will reach Aucuyacu.

Growth in demand for electricity in the areas north of Aucuyacu which will continue to be isolated from the grid will remain small. Tocache, the largest town outside the grid, is projected to meet its need with a 200 KW addition to its current 30 KW, and therefore will consume no more than 1,200 barrels of diesel per year.

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Pucallpa - Economy

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10. "Aprovechamiento del Gas de Aguaytia: Estudio de Mercado," PetroPeru (Diciembre, 1979).

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IV AGUAYTIA GAS FIELD EVALUATION

A. INTRODUCTION

In 1961, the Aguaytia area was explored by a consortium of Mobil Oil Company and Philips Petroleum Company under an exploration license granted by the Government of Peru. Two wells were drilled: the first, completed in 1962 tested from three zones; the second well was completed the same year and tested gas from one zone. Both wells were capped and have not been re-opened. Based on an evaluation of this exploration, plus later seismic work, PetroPeru estimated a proven gas reserve which is large enough for potential development of the site. Since the date of the initial drilling, the rights to the gas have passed to the Peruvian Government. Interest in developing the field and determining the proven and possible gas reserves has been studied since 1967. A number of projects have been proposed and studies have been made of possible uses of the gas reserves including on site power generation, pipeline transmission to Lima, feedstock supply for a fertilizer plant, and feedstock for a petrochemical industry. None of the above approaches has proven feasible because demand for the products has not been clearly determined, costs were too high and/or attractive financing was not available.

PetroPeru has had a plan for the last several years to drill two additional wells in order to prove up the Aguaytia field. Their plans include an additional deep well to 14,000 feet near well No. 1 at the apex of the structure and to drill deeper than the existing wells into structures which may potentially hold oil. The second well would be approximately 5 km to the south in a newly discovered area which could also produce both gas and oil. This exploration program, though officially part of PetroPeru budget, has not been funded because it is not a high enough priority to escape budgetary cutbacks. The program is again included in the proposed 1985 budget at levels between eighteen and twenty million U.S. dollars. It is possible that it will again be eliminated. A detailed definition of the petroleum geology

of the area is found in Appendix B. The Aguaytia field, as shown in Figure IV-1, is located in the south central part of the Ucayali Basin, 78 km west of Pucallpa near the Aguaytia River in the Department of Ucayali (formerly part of the Department of Loreto), at 75' 15" longitude west, 8' 25" latitude south. The Aguaytia structure on the top of the Cushabatay Formation is a NNE-SSW anticline, 20 km (12 mi) long and 3 km (1.8 mi) wide. (See Figure IV-2.) The east side of the Aguaytia structure is bounded by a N-S fault, upthrown to the west. Both of the Aguaytia 1 and 2 wells were drilled on what is known as the "North Structure." The Cushabatay sandstone formation comprising the Aguaytia reservoir is a clean, white, fine to medium grained subangular with minor amounts of calcite and kaolin cement. Porosity ranges from 13.7 to 22.8%; permeabilities range from 30 to 400 millidarcies.

The present mechanical condition of Aguaytia 1 and 2 wells is uncertain. These wells should be cleaned-out, packers removed and the wells made serviceable before new production tests to re-establish producible flow rates. The mechanical condition of these wells must be established before production rates can be known.

B. RESERVOIR CONSIDERATIONS

The proved and probable gas reserves for the Aguaytia structure have been computed by PetroPeru to be:

	billion (10^9) cubic feet
North Structure	497
South Structure	470
Total	968
Proved gas reserves	240.1 BCF
Proved reserves, gas condensate	8.41 million bbls

Condensate production is computed by PetroPeru to be 38.8 bbls per million cubic feet of gas. The specific gravity of the gas and the 65' API gas condensate are 0.70 and 0.72 respectively.

FIGURE IV-1

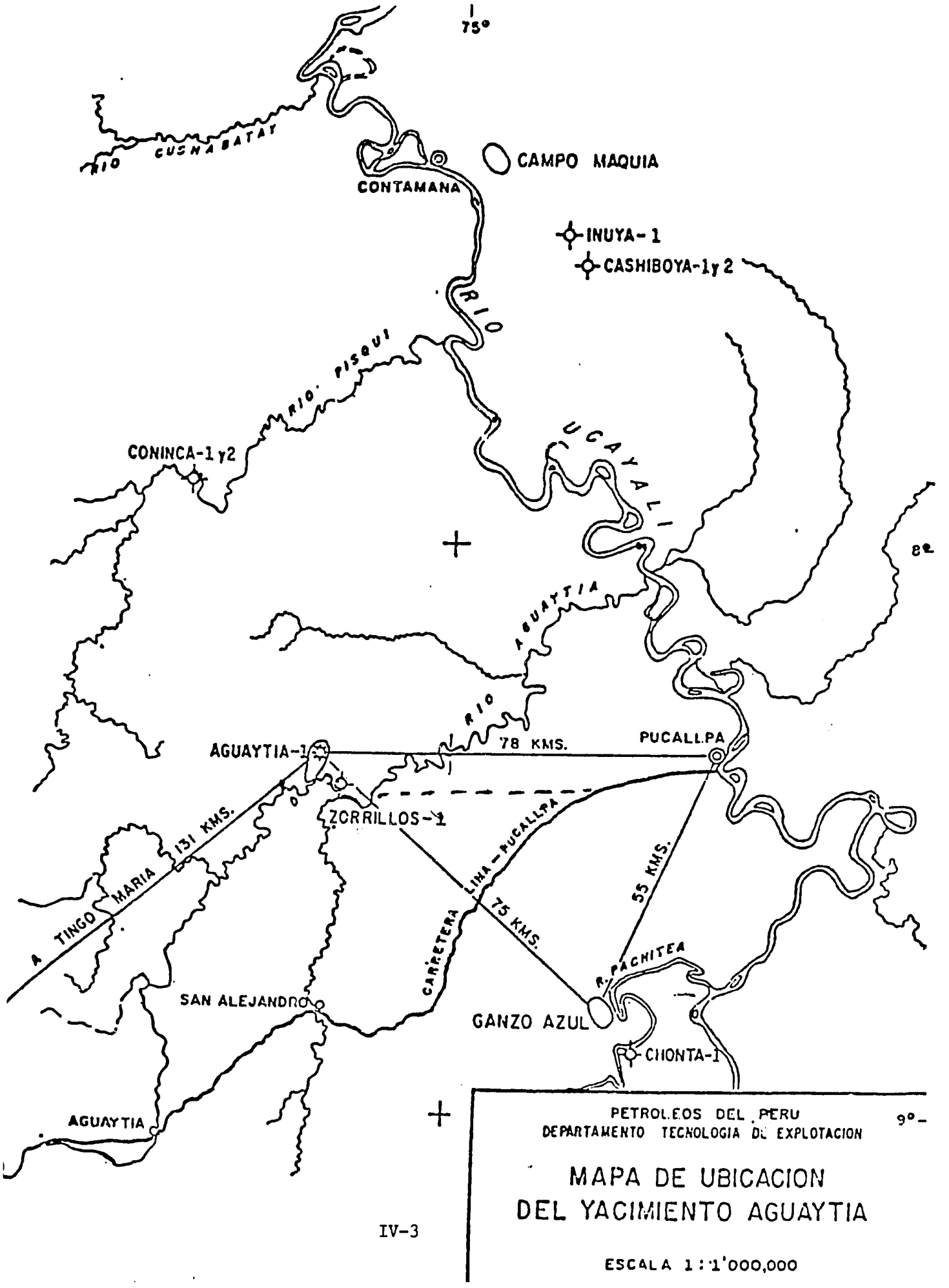
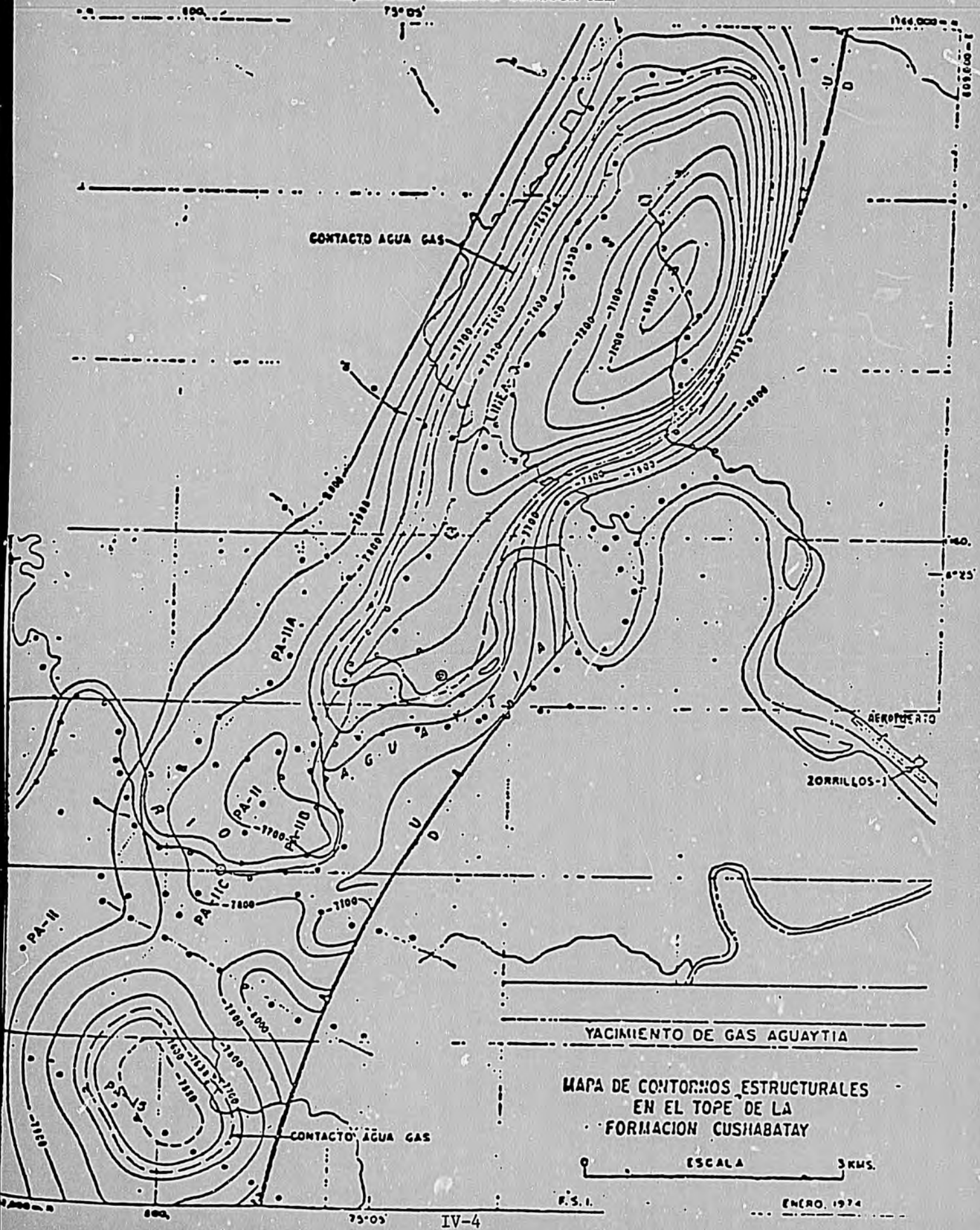

75°
RIO CUSHABATAY
CAMPO MAQUIA
CONTAMANA
INUYA-1
CASHIBOYA-1 y 2
RIO
RIO PISQUI
CONINCA-1 y 2
UCAYALI
AGUAYTIA
RIO
78 KMS.
PUCALLPA
AGUAYTIA-1
ZORRILLOS-1
131 KMS.
A TINGO MARIA
LIMA-PUCALLPA
55 KMS.
CARRETERA
75 KMS.
R. PACHITEA
SAN ALEJANDRO
GANZO AZUL
CHONTA-1
AGUAYTIA
8°
9°
PETROLEOS DEL PERU
DEPARTAMENTO TECNOLOGIA DE EXPLOTACION
MAPA DE UBICACION
DEL YACIMIENTO AGUAYTIA
ESCALA 1:1'000,000

FIGURE IV-2

AQUAYTIA RESERVE CONTOUR MAP



The Cushabatay Formation is a sandstone-shale sequence. Three sandstone zones called A, B, and C (Figure IV-3) yielded gas and gas condensate in Aguaytia 1. Production tests reported by PetroPeru in the Aguaytia 1 well are as follows:

TABLE IV-1

RESULTS OF PRODUCTION TESTS
AGUAYTIA - 1

Productive Zones	Interval Feet	Gas MMCF/D	Condensate bbls/day	bbl/MMCF	Choke
A.	8339 - 8380	3.48	131.2	37.73	¼"
		2.79	108.3	38.86	3/16-1/8
		2.17	71.7	33.06	3/16
		1.83	6.02	32.97	1/8
B.	8597 - 8562	3.19	133.9	43.79	¼"
		2.47	96.7	38.98	3/16-1/8
		1.80	72.4	40.16	3/16
		1.99	60.4	38.87	1/8
C.	8602 - 8607	2.94	120.9	41.14	¼"
		2.39	96.7	40.15	3/16-1/8
		1.90	72.5	38.24	3/16

Source: Zevallos, PetroPeru (Reference 1)

Zones A, B, and C have a gross thickness of 80, 180, and 50 feet respectively. Zone D, 35 feet, is water bearing; however, drilling up dip from Aguaytia 1, Zone D may be gas bearing.

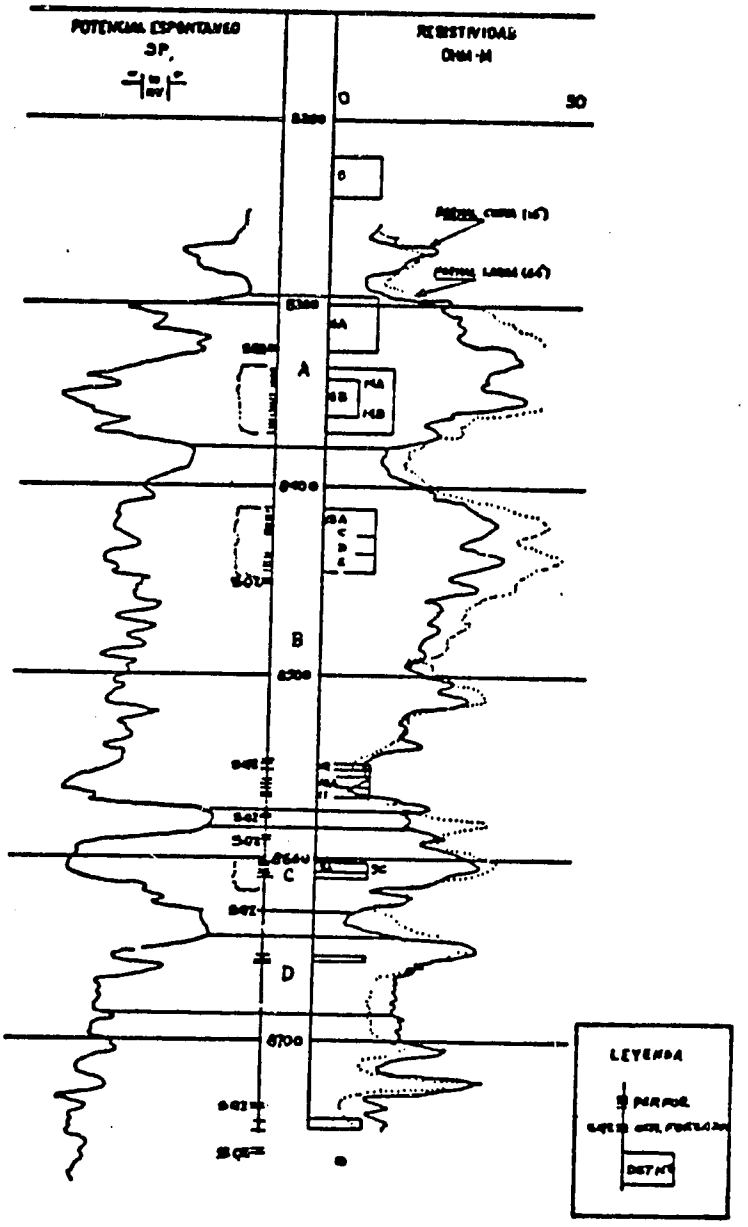
In the Aguaytia 2 well only Zone A is productive; Zones B, C and D were wet. Aguaytia 2 drill stem tests as reported by PetroPeru are:

		PRODUCTION	
Interval	Choke	Gas MMCF/D	Condensate bbls/d
8381 - 8379	3/8"	4.66	370
8300 - 8290		6.48	300

The gas-water contact is placed at approximately -7,638 feet, subsea (Kelly Bushing). Bushing elevation at Aguaytia 1 is 996' (304 m) for the North structure. However, the gas-water contact cannot be

FIGURE IV-3

POZO AGUAYTIA - I
FORMACION CUSHABATAY
REGISTRO ELECTRICO CONV.



postulated on the downdip South structure. No wells have yet been drilled on this South structure. Therefore, gas reserves on this South structure cannot as yet be termed proved and/or possible gas reserves.

The analysis of the hydrocarbon composition in Aguaytia is as follows:

Composition	Gas Mol %	Condensate Vol %
Nitrogen*	5.75	
Carbon Dioxide	2.63	
Methane	80.05	0.37
Ethane	6.35	0.48
Propane	2.17	0.95
Butane	0.61	0.98
Isobutane	0.80	1.86
Pentane	0.33	2.66
Isopentane	0.22	2.60
Hexane	0.44	90.10
	100.00	100.00

* The presence of nitrogen will create corrosion problems as it reacts to form other substances during processing . Steps to minimize its effects should be considered. Also, because of the reduced methane content, no more than 900 Btu/CF can be expected, compared with 1024 Btu/CF normally in natural gas that is 99% methane.

Source: PetroPeru, Reference 2

A summary tabulation of the field characteristics is presented in Table IV-2.

C. EVALUATION

There are a number of reserve estimates of the Aguaytia field. This is primarily because of the long standing and continued interest in development and the limited amount of test data. The World Bank Mission which produced the report entitled "Peru: Issues and Options in the Energy Field"(3), gives proven plus probable reserves as 862 billion cubic feet. PetroPeru's recent estimates provided to this team claim 946 billion cubic feet of proven reserves. This higher figure results from reinterpretation of existing data and well logs.

TABLE IV-2

CHARACTERISTICS OF THE
AGUAYTIA GAS-CONDENSATE FIELD

Total wells drilled: 2 gas condensate wells, shut-in
Total depth: Aguaytia 1: 9,094 ft (2772.56 m)
Aguaytia 2: 8,914 ft (2717.68 m)
Bottom hole formation: Aguaytia 1 - Jurassic
Depth to top of reservoir:
Aguaytia 1: 8,339 ft (2542.24 m)
Aguaytia 2: 8,290 ft (2527.44 m)
Kelly Bushing elevation, Aguaytia 1: 996ft (304 m)
Producing reservoirs: Cushabatay formation
Aguaytia 1: A, B, and C Sandstone Zones
Aguaytia 2: A Sandstone Zones
Reservoir Pressure:
Aguaytia 1: 3980 psia
Aguaytia 2: 4100 psia
Oil shows:
Upper Cretaceous Vivian Sandstone Formation
Condensate: 58 - 65° API
Con/gas ratio: 38.8 bbls/MMCF
Specific gravity: 0.72
Structure: asymmetrical NNE-SSW trending anticline,
20 km (12 mi) long
and 3 km (1.8 mi) wide
Gross reservoir thickness:
Aguaytia 1: 328 ft
Aguaytia 2: 250 ft
Net reservoir thickness:
Aguaytia 1: 280 ft
Aguaytia 2: 164 ft
Porosity: 13.7 to 22.8%
Permeability: 30 to 400 millidarcies
Estimated proved, probable & possible gas reserves determined by
PetroPeru: 240.21 BCF

N. structure, proved, possible:	497 BCF
S. structure	470 BCF
	908 BCF

Condensate reserves: 8.41 million barrels;
38.8 bbls/MMCF

Note: The S. structure has not yet been drilled; therefore, the reserves attributed to the S. structure are possible reserves with little likelihood of ever being proved gas reserves.

Source: Petroconsultants, Geneva, Switzerland

In order to arrive at a figure for this diagnostic study we have reviewed all available information including well logs and data supplied by Mobil and PetroPeru. Our evaluation is based on reservoir parameters, and agree with those in the December 28, 1972 Memorandum by Oswaldo Zevallos of PetroPeru: 240.1 billion cubic feet of gas and 8.41 million barrels of condensate. We consider this to be a conservative estimate of the recoverable (proven) reserves of the field. We did not use the new higher proven reserve estimate of PetroPeru because of the following:

- PetroPeru treats the A, B, and C Zones as one reservoir despite the fact that each zone is separated by short intervals. The electric well logs strongly suggests a gas-water contact for each zone. If these zones are considered as three separate reservoirs, gas reserves will be more conservative than 493 billion cubic feet.

- PetroPeru's reserve determination was computed by the volumetric-method apparently without considering that the reservoir(s) are water saturated. A consideration of water saturation will lower the recoverable gas reserve by a quantity equal to the product of pore space times the saturation of water. For example, at 35 percent water saturation, the estimate of 493BCF at 100 percent gas saturation is reduced to 493x(1-0.35). or 320 BCF.

- The sandstone reservoir thickness containing gas decreases from 100m in Aguaytia 1 to 50m in Aguaytia 2. Therefore, using a net sandstone thickness of less than 100 m would be more realistic and consequently lower the recoverable gas reserve determination.

- A recovery factor of 62 percent for the recovery of Aguaytia gas reserves is low when compared to the recovery factor for the typical gas field which ranges from 70-90 percent.

D. NEXT STEPS

To develop the field according to sound reservoir engineering practices, one needs the following set of data:

- Obtain as many core samples as possible from the various parts of the field. Conduct on these samples

measurements of permeability, porosity, capillary pressure, relative permeability to oil, gas and water.

- Obtain fluid samples from various parts of the field and measure composition. The gas composition is important in evaluating the critical temperature and pressure of the in situ gas.

- Obtain total and net thickness of producing horizons

- Measure/calculate the density, specific gravity and viscosity of the fluids, gas, oil and water.

- Obtain depth of the top of the producing horizons.

- Conduct various logs on all available wells.

- Measure oil, gas and water saturations on cores obtained from the periphery of the field.

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V AGUAYTIA FIELD DEVELOPMENT PROGRAM

A. DEVELOPMENT ALTERNATIVES

Development of the Aguaytia field , if dictated by current PetroPeru plans, will involve the drilling of two more wells in order to define and prove up the field. The budget for this first phase of the development is 18 to 20 million US dollars. If this establishes proven reserves at the level currently predicted, a major development involving 30 wells is anticipated. The cost of this production phase is estimated to be over 120 million dollars. It is obvious that a major potential demand for gas must be verified before this type of additional exploration and development is initiated. At present, this level of natural gas demand has not been shown to exist; this could change after completion of an ongoing study by PetroPeru of possible gas users in the Cerro de Pasco and other mining areas south of the field (and possibly including Lima). Before a demand potential is established, a development program of this magnitude will not be initiated. Even a more modest second phase development of only 5 wells would cost approximately US$35 million. It is apparent that even this level of development of the field (if no oil except the condensate is produced) is not commercially viable at this time.

The World Bank[1] has estimated a cost of US$0.85 per MCF (about $5 per barrel equivalent) for field development (not including pipeline). The World Bank further indicates that Lima and the intervening areas, La Oroya-Cerro de Pasco-Tarma, are the only current and mid-term viable users of gas. They conclude that the Government should consider developing the Aguaytia gas fields only if 862 billion cubic feet of reserve computed by PetroPeru were proven (more than three times currently proven reserves).

In 1974, a PetroPeru study of the Aguaytia gas field was completed which considered a very limited development. This pre-feasibility study proposed reconditioning of the two existing

wells, drilling 4 new wells and operation of the wells for 5 years to recover condensate. All gas produced would have had the condensate removed and the dry gas reinjected. After completion of the 5 year initial phase additional development for gas production and marketing was anticipated. If this did not occur the project would have been terminated after 5 years. The recovered condensate amounting to 870 barrels per day could have been produced for a cost of US$8.20 per barrel (1974 dollars). The design, purchasing, installation and operation of the oil pipeline to Pucallpa was not considered. This project was not developed because the economics were not favorable, the regional market for gas and oil (condensate) was not established and other projects were of higher priority.

Another alternative field development considered in the PetroPeru study was only reconditioning the two existing wells producing the gas, recovering condensate and reinjecting or flaring the dry gas. This was by far the least capital cost alternative. Approximately 350 barrels per day of condensate were anticipated. This alternative was rejected because it wasted a gas resource of potential future value.

B. FIELD DEVELOPMENT PROGRAM SELECTED

In light of the above field development plans and recommendations, and based on our study rationale stated in Chapter II, we have used a different set of planning bases. We have selected a minimum field development program consistent with sound gas field engineering and potential gas demand in our study area. This proposed minimum development program will:

- Prepare the existing two wells for production by reconditioning them.
- Produce the minimum amount of gas consistent with good natural gas field engineering practices.
- Supply only existing and future gas and oil (condensate) needs in the PEAH-Pucallpa areas.
- Invest the minimum initial amount assuming that at a later time additional production capabilities will be added.

- Drill only one additional new well on the existing structure to support dependably at least 20 million cubic feet per day production of gas. This anticipates that the new well will come in at this level.

This development program, which does not fulfill the oil exploration and field evaluation plans of PetroPeru, will produce gas and condensate from four wells. This mixture will be delivered by two 8 inch pipelines (rated ANSI 600), one to Pucallpa and one to the Tingo Maria area with a maximum allowable operating pressure of 1440 psi. The pipelines will be designed for two phase flow and with an inlet pressure of 1000 psi. It is assumed that the line to Pucallpa will not need auxiliary pumping and can operate off diminished well head pressure. The line to the Tingo Maria area (PEAH) would require at least one intermediate pumping station and possibly more. Recovery of condensate would be at the outlet end of the pipeline and be a function of the demand for gas at each terminal location. A number of general considerations and assumptions necessary for developing and costing this minimum field testing and development program are presented below:

- An inlet pressure of 1000 psi was selected because with an inlet pressure of 3000 psi, the tonnage of the pipeline would be excessive due to high wall thickness. Economic savings normally associated with pressure pipe would not be appreciable. The high pressure drop expected at 3000 psi could cause hydrate problems in the pipeline and an appreciable maintenance problem in quite a remote area.

- Developing liquid separation at the well site and a dry gas pipeline, would create a problem of liquid disposal. Trucking liquids (assumed 50 miles at from $1500 to $2000 per truck trip) would be costly and unreliable. In addition, the cost of stage separation and storage of the liquids at the site and at Pucallpa would render this alternative unattractive. River barging would also be costly and problematical.

- Gas reservoirs generally cannot sustain the initial reservoir pressures for appreciable periods of time unless they are subjected to waterdrive, which may or not be successful. There is insufficient data on projected reservoir performance or pressure decline curves.

- Dry season in the project area is from June to October which would be the period for pipeline construction.

- Construction equipment could traverse the area except for low areas.

- The area has heavy timber (12"-18" diameter) and dense undergrowth. Timber can be used to build a corduroy road through marsh areas.

- Truck trail from Pucallpa to well site is available for use during pipe construction.

- Materials and equipment can be shipped by sea to Lima and thence overland by trucks to job site.

- Pipeline route and terrain conditions to PEAH are not as well defined as for Pucallpa and the per kilometer cost could be as much as four times higher than the line to Pucallpa.

- Since gas use estimates for PEAH are based mostly on development of new users (planned industrialization associated with project) the demand projections for this area are much less certain.

- Considerations should be given to internal pipeline coating because CO_2 content of the gas is reported as 2.63 percent. This will increase costs slightly.

- Although recovery of the condensate with re-injection of the gas might be a reasonable field development alternative, it is not considered to be especially attractive or beneficial to regional development in the PEAH or our study area. For this reason it was not included in our proposed minimum testing and development program. It would also require more wells to be drilled and thus have a higher initial field development and production cost.

- We have assumed the drilling of a third contingency well which we are projecting to have between 6.5 and 20 million cubic feet per day of gas production. If this well does not produce at the upper level, the reliable continuous gas production from the field would be the sum of the production of the two lowest yielding wells; moreover, in this case a fourth well would possibly be needed.

- We have assumed annual operation and work over costs for the field to be US$30,000 per year to increase by 4 percent per year.

- Energy uses associated with field operating and pipeline operations, condensate separation or distribution of gas to users have not been included in our cost estimates.

C. COSTS

On the basis of our preliminary investigation, we have developed a table of costs and a time schedule for the field development program selected. This information is shown in Table V-1. The program is initiated by reconditioning the two existing wells, at a total cost of $1.2 million during six months. The new well is estimated to cost $5 million. This first phase would include a pipeline which will carry wet gas to Pucallpa which will cost $5 million and take six months to build. Finally, condensate separation and storage at the Pucallpa refinery adds US$200,000 to the investment. Excluding gas distribution costs and boiler retrofiting by end-uses, total investment amounts to $11.4 million. Detailed breakdown of the pipeline costs is shown in Table V-2.

This program would produce up to an average of 26.5 million cubic feet of gas per day and 480 barrels of condensate and be expected to sustain varying but commercial rates of production of gas for a period of at least 20 years. Dry natural gas would be used as fuel for the power plant at Pucallpa and the condensate portion could be stored and used as a standby fuel source in the event gas service was disrupted for maintenance. Surplus condensate could be processed at the Pucallpa refinery by spiking into crude oil to improve API gravity. It could also be used to upgrade gasoline to higher octane. At present, approximately 100 barrels per day of high octane gasoline are brought to Pucallpa from Lima for blending with 200 barrels of lower grade gasoline from the refinery in order to produce the 85 octane mixture which is needed. Gas would also be used as a fuel for selected industries in the Pucallpa area. In the PEAH area the potential demand for natural gas is much smaller and development is not foreseen in the near term.

TABLE V-1

SUMMARY OF MINIMUM TESTING AND DEVELOPMENT PROGRAM FOR AGUAYTIA GAS FIELD

Item	Action	Total Time	Cost ($US)	Effect	Remarks
PHASE I					
(A) Existing Well #1	Recondition	4 months	$700,000	Allow production of 20 million cf/day gas containing condensate	PetroPeru crew and rental work over rig
(B) Existing Well #2	Recondition	2 months	$500,000	Allow production of 6.5 million cf/day gas containing condensate	same crew and rig moved from #1 well
(C) New Well	Drill to 8700 ft	2 months	$5,000,000	Expected production between 6.5 and 20 million cf/day	located at apex of structure closure
(D) Three wells	Testing, cementing & logging	included above	included above	Confirm reserves & establish production rates	
(E) Pipeline	Design,purchase & install 8" pipeline to Pucallpa	6 months	$5,000,000	Transport gas & condensate to refinery	separation of condensate will be at refinery in Pucallpa
(F) Condensate Separation and Storage	Design, purchase & install condensate separation & 2000 bbl storage	included above	$200,000	Allow use of condensate in refinery & dry gas elsewhere	
(G) Distribution System	Gas distribution system to major end uses in Pucallpa	4 months	not included	Allow distribution of gas to major endusers	

TABLE V-1 (continued)

Item	Action	Total Time	Cost ($US)	Effect	Remarks
(H) End User Retrofit	Burners, gas turbines etc.	--	not costed	Allow use of/or conversion to gas	Estimation was not possible at this time
PHASE II					
(A) Condensate Separation	Separate condensate at Aguayita of gas going to PEAH	--	not costed	Allow dry gas to be supplied to PEAH	Assumes demand for gas is created in the area.
(B) Separate Condensate Piping	Invest Condensate into pipeline to Pucallpa	--	not costed	Increase volume of condensate available in Pucallpa	
(C) Pipeline	Build dry gas pipeline to PEAH	--	not costed	Transport gas to PEAH	
(D) Distribution Systems	Supply major users in PEAH	--	not costed	Supply gas to major users	
(E) End User Retrofit	Equipment	--	not costed	Allow use of/or conversion to gas	

TABLE V-2

ESTIMATED COST FOR GAS PIPELINE FROM
AGUAYTIA FIELD TO PUCALLPA

Parameters	
Pipe Size	8"
Volume Gas	26 MMCFD Dry Gas
Liquids	480 B/D
Inlet Press Pressure	1,000 psi
Pipe O.D.	8.625"
Pipe Weight Tons	1,490

Costs	
Pipe Cost	$1,120,000
Freight	484,000
Coating	365,000
Construction Cost	2,431,000
Surveying	50,000
Inspection	70,000
X-Ray	60,000
Communication	50,000
Cathodic Protection	50,000
Scraper Traps & Blk Valves	65,000
Inlet Facilities	5,000
Outlet Facilities	5,000
Subtotal Cost	$4,755,000
TOTAL (Inc. 5% Engineering)	$4,992,750

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CHAPTER V

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VI REGIONAL DEVELOPMENT SCENARIO

A. INTRODUCTION

Based on the information developed and presented above and our scope of work we have selected two major development centers in the study area as the focus of this diagnostic study. The development phases we have considered are based on existing and future energy demands in the following two areas:

- Pucallpa area
- Tingo Maria-Aucayacu or PEAH area

The Aguaytia gas reserves were assumed to be available as a base energy supply for electrification, heat needs and as a feed stock in the study area over the next 20 years. Wherever possible the two principal areas were considered separately to see what growth and demand each could justify in terms of gas use. They were also considered separately in order to permit a combination scenario to be independently defined using the separate demand projections in each area. Rather than being an a- priori imposition on the study, a built-up combination development scenario results from our analyses and considerations. This scenario, in fact, represents a time phased use of gas in the study area.

The proposed development does not conflict with any long-term plans for utilization of the Aguaytia resource by ElectroPeru, PetroPeru, or the fertilizer/petrochemical industry.

ELECTROPERU: The current ElectroPeru Master Plan envisions for the medium-term that the two southern most towns in the PEAH area, Tingo Maria and Aucayacu, will be part of the Central-North System grid, whereas the remaining towns in the PEAH area will continue to be served by isolated diesel sets. In addition, three minihydro sites are being developed for the area. Pucallpa will continue to be served

by an isolated system, consisting of steam generation and supplemented by diesel sets. The Central-North System is the principal grid of the country, serving Lima and the mining centers of the Sierra. Of its 1800 MW, more than 1500 MW are hydro; the Mantaro hydro station alone accounts for more than half this amount. Between now and the end of the decade, three additional 150-200 MW hydro stations will be commissioned. By the mid 1990's, power requirements will necessitate a large new facility for the grid. The current Master Plan identifies this project as a plant ultimately having 600 MW on the Huallaga River south of Tingo Maria, at a location called Chagalla. A transmission line to Chimbote on the coast would be included, greatly strengthening reliability of the grid.

ElectroPeru has ignored the Aguaytia gas resource in its long-term planning. The reason for this is that at this stage the amount of the known resource is too small to permit ElectroPeru to include it in its plans. In the opinion of ElectroPeru officials, confirmation of a resource of gas at Aguaytia large enough to supply 200 MW or more will almost certainly lead to reconsideration of its long-term plans.

PETROPERU: PetroPeru is currently undertaking a natural gas demand study for the region extending from Aguaytia to the mining centers of Cerro de Pasco-La Oroya. A minimum criterion for committing in-depth analysis to this option, which ultimately could extend a gas pipeline to Lima, would be the confirmation of a proven reserve capable of yielding 80-100 MMCF/D. The World Bank examined the costs of a TransAndean pipeline of 700 or 800 km in length from Aguaytia to Lima. Depending on the extent of gas distribution in the mining centers, transportation costs would range from $300 to $433 million for the pipeline, or $1.46 to $1.80 per million BTU of gas.

FERTILIZER/PETROCHEMICAL INDUSTRY: The financial feasibility of a urea plant or a petrochemical industry (a 50,000 ton/year ethylene unit, a 200 ton/d methanol plant) has been reviewed in the past and rejected. Given current depressed ammonia/urea prices, the World Bank

concludes that the natural gas resource of the country (including that of the Northwest) is considerably more valuable as a substitute for petroleum products in electric generation and industrial uses than as a feedstock.

B. DEVELOPMENT SCENARIOS

As can be seen in Chapter III, Table III-14, gas demand in the study area for the near to mid-term will not exceed an optimistic 16.1/MMCF/D by 1995, which is less than the production capability of 25.0 MMCF/D of the development program of the existing wells. In 1986, demand in the Pucallpa area is estimated to be 4.9 MMCF/D. The initial year 1986 was chosen solely as a base year for estimating demand and does not suggest a recommended date for production and delivery of the natural gas. For the PEAH area, no potential demand for the 1986 base year exists. We therefore propose a two phased program for delivery and use of gas. The first phase will supply only the Pucallpa area. The supply would start with 4.9 MMCF/D in 1986 and grow to 6.8 MMCF/D by 1990 and 8.7 MMCF/D by 1995. These values reflect the "conservative" prospects for electricity demand growth. The condensate would be delivered to Pucallpa at an initial rate of 94 barrels per day and this will increase to 125 barrels per day in 1990.

Table VI-1 shows that cumulative natural gas demand potential for a 20 year period starting in 1986 totals 183.9 MMCF/D. This demand assures gas demand grows at 5 percent yearly after 1995.

Using the field development and gas/condensate piping costs, a discounted cash flow analysis was prepared and is summarized in Table VI-2. This analysis assumes a project life of 20 years at an interest rate of 12 percent and a discount rate of 14 percent. The analysis is for Phase I pipeline to Pucallpa only. The basic field development and piping capital outlay of $11.4 million does not include a contingency for unexpected occurrences, the Pucallpa distribution system construction costs and end user retrofit capital requirements.

TABLE VI-1

CUMULATIVE NATURAL GAS DEMAND
CONSERVATIVE CASE
(MMCF/D)

	YEARLY DEMAND	CUMULATIVE
1986	4.9	4.9
1987	5.3	10.2
1988	5.8	16.0
1989	6.3	22.3
1990	6.8	29.1
1991	7.1	36.2
1992	7.5	43.7
1993	7.9	51.6
1994	8.3	59.9
1995	8.7	68.6
1996	9.1	77.7
1997	9.6	87.3
1998	10.1	97.4
1999	10.6	108.0
2000	11.1	119.1
2001	11.7	130.8
2002	12.3	143.1
2003	12.9	156.0
2004	13.6	169.6
2005	14.2	183.8

TABLE VI-2

DISCOUNTED CASH FLOW ANALYSIS FOR THE MINIMUM DEVELOPMENT PROGRAM (1986)
for 4.9 MMCF/D Gas and 90 Barrels/day Condensate
(US $, million)

Oper. Year	Required Gross Income	Oper. and Main Cost including Depreciation	Loan Interest Payment	Loan Principal Payment	Capital Outlay	Cash Flow	Discounted Cash Flow	Accumulated Discounted Cash Flow
0	0.0	0.0	0.0	0.0	11.40	0.0	0.0	0.0
1	1.7023	0.1141	1.3686	0.5702	0.0	-0.3507	-0.3507	-0.3076
2	1.7023	0.1187	1.3002	0.5702	0.0	-0.2868	-0.2207	-0.5283
3	1.7023	0.1234	1.2317	0.5702	0.0	-0.2231	-0.1506	-0.6789
4	1.7023	0.1283	1.1633	0.5702	0.0	-0.1596	-0.0945	-0.7734
5	1.7023	0.1335	1.0949	0.5702	0.0	-0.0963	-0.0500	-0.8234
6	1.7023	0.1388	1.0264	0.5702	0.0	-0.0332	-0.0151	-0.8386
7	1.7023	0.1444	0.9580	0.5702	0.0	0.0296	0.0118	-0.8267
8	1.7023	0.1501	0.8896	0.5702	0.0	0.0923	0.0324	-0.7944
9	1.7023	0.1562	0.8212	0.5702	0.0	0.1547	0.0476	-0.7468
10	1.7023	0.1624	0.7527	0.5702	0.0	0.2169	0.0585	-0.6883
11	1.7023	0.1689	0.6843	0.5702	0.0	0.2788	0.0660	-0.6223
12	1.7023	0.1757	0.6159	0.5702	0.0	0.3405	0.0707	-0.5517
13	1.7023	0.1827	0.5474	0.5702	0.0	0.4019	0.0732	-0.4785
14	1.7023	0.1900	0.4790	0.5702	0.0	0.4630	0.0740	-0.4045
15	1.7023	0.1976	0.4106	0.5702	0.0	0.5239	0.0734	-0.3311
16	1.7023	0.2055	0.3422	0.5702	0.0	0.5844	0.0718	-0.2593
17	1.7023	0.2137	0.2737	0.5702	0.0	0.6446	0.0695	-0.1898
18	1.7023	0.2223	0.2053	0.5702	0.0	0.7640	0.0634	-0.0598
19	1.7023	0.2311	0.1369	0.5702	0.0	0.8232	0.0599	-0.0598
20	1.7023	0.2404	0.0684	0.5702	0.0	0.8232	0.0599	0.0001

Assumptions:

Life of Project	= 20 years	Depreciation & O&M Escalation rate	= 0.040/yr
Capital Outlay I	= 11.400 Mil. Dol.	Operation & Main I	= 0.114 Mil Dol/yr
Capital Outlay II	= 0.0 Mil. Dol.	Operation & Main II	= 0.114 Mil Dol/yr
Capital Outlay III	= 0.0 Mil. Dol.	Interest Rate	= 0.120/yr
Loan Period	= 20. Years	Discount Rate	= 0.140/yr
Loan/Outlay Ratio	= 1.00		

It was not possible to estimate these within the scope of this diagnostic. Depreciation and operation and maintenance costs of 1 percent of capital investment is assumed for the first year, growing at 4 percent per year in real (1984 $) terms. No costs for phase II were estimated because more study would be required on pipeline route, field development alternative, and location and growth of uses in the PEAH.

The discounted cash flow analysis shows that the minimum required gross income for the project (one that makes the 20-year accumulated discounted cash flow zero) is $1.7023 million per year.

Revenues are obtained from sales of gas and the condensate produced with the wet gas. In the first year, 4.9 MMCF/D of gas and 90 bbls/day of condensate would be produced and sold. Using a world price of $3.0 per MCF for gas and $26/bbl for condensate, revenues are distributed 86.5 percent to gas and 13.5 percent to condensate. By allocating required gross revenue in this proportion, we obtain for the first year a cost of production for gas of $0.85 per MCF ($0.94 per million Btu), and of condensate of $7.2 per barrel ($1.46 per million Btu). Distribution costs and taxes must be added to these estimates. The tax structure currently imposes a 23 percent consumption tax and a 15 percent sales tax to residual oil, the competing fuel. Pucallpa, besides being a duty-free frontier city, has a special tax-free status for corporations which choose to locate there. In addition, the consumption tax for fuels was exonerated in Pucallpa until August of 1984, at which time the exoneration was scheduled to be removed.

Residual oil currently sells for approximately $5.42 per million Btu in Pucallpa. Adding 100 percent for distribution costs and profit margins to the production and transmission cost of $0.94 per million Btu for natural gas calculated above, plus 38 percent for taxes yields a tariff of $2.59 per million Btu. Although these preliminary estimates will in all likelihood be revised upwards in a full

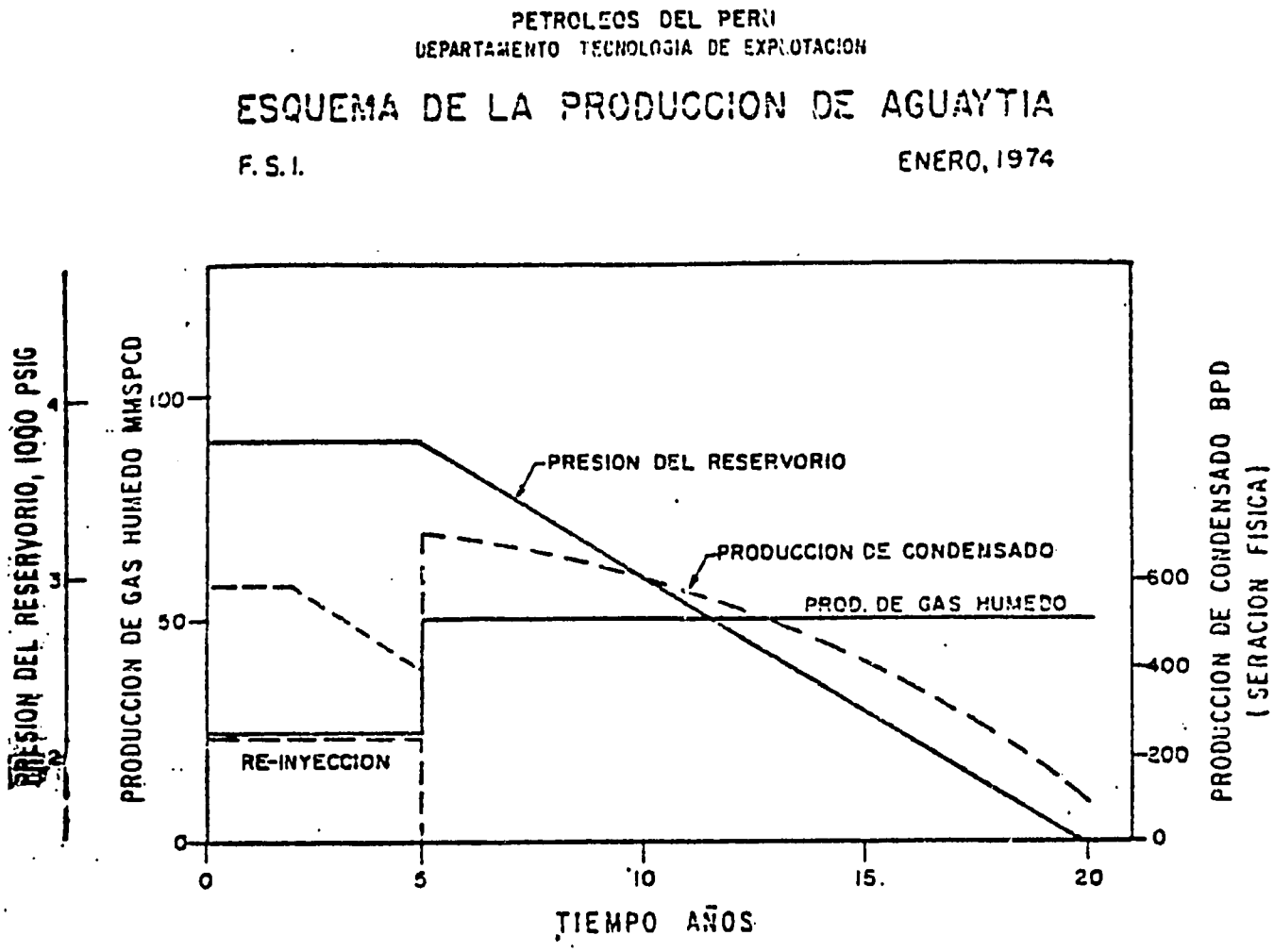
feasibility study they show that the gas is competitive with current residual oil prices.

A preliminary sensitivity analysis of the cost estimate for the phase I work indicates that even with a 50 percent increase in costs from $11.4 to $17 million dollars, the required annual gross income to achieve a zero accumulated discounted cash flow at the end of 20 years would be approximately $2.5 million per year. The cost of production (not including margins, taxes and distribution) in this case rises to $1.25 per thousand cubic feet of gas and $10.61 per barrel of condensate.

The calculations above assume a constant production and sales of 4.9 MMCF/D of gas. This introduces a conservative bias in the cost calculated, because natural gas deliveries in the field are projected to rise over time to about 14.2 MMCF/D by 2005; average demand for the 20 year period is projected at 9.2 MMCF/D, more than two times the average constant demand of 4.9 MMCF/D assumed in the unit cost calculations. On the other hand, there are factors which will tend to increase unit costs. One of these is the probable reduction over time of the condensate to natural gas production ratio.

Figure VI-1 shows that over time with depletion of the reserve and a reduction of reservoir pressure, the delivery rate of condensate will decrease. This has not been considered in our preliminary calculations.

FIGURE VI-1


PETROLEOS DEL PERU
DEPARTAMENTO TECNOLOGIA DE EXPLOTACION
ESQUEMA DE LA PRODUCCION DE AGUAYTIA
F. S. I.
ENERO, 1974
PRESION DEL RESERVORIO, 1000 PSIG
PRODUCCION DE GAS HUMEDO MMSPCD
PRODUCCION DE CONDENSADO BPD
(SEPARACION FISICA)
PRESION DEL RESERVORIO
PRODUCCION DE CONDENSADO
PROD. DE GAS HUMEDO
RE-INYECCION
TIEMPO AÑOS
0
5
10
15
20
100
50
600
400
200
4
3
2

APPENDICES

APPENDIX A	INSTITUTIONS AND INDIVIDUALS CONTACTED
APPENDIX B	THE PETROLEUM GEOLOGY OF THE MARANON & UCAYALI BASINS, EASTERN PERU

APPENDIX A

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Ministerio de Industria, Comercio, Turismo e Integracion, Pucallpa

A. Solorzano

APPENDIX B

The Petroleum Geology of the Maranon & Ucayali Basins Eastern Peru

Ucayali Basin

The Ucayali Basin lies east of the Andean Mountains between the Contamana Arch on the north and eastward to the Brazilian Shield in western most Brazil (Figure B-1). To the southeast, the basin limit is questionable as little is known of the region. The Ucayali Basin may continue into the as yet non-productive Madre de Dios Basin near the Bolivian border. In most respects it is a smaller version of the Maranon Basin (sometimes known as part of the larger Oriente or Amazon Basin). The stratigraphy and geological structure trends are generally similar. However, the intensity of folding in the Ucayali Basin is greater than in the Maranon Basin to the north (Figure B-2). The western edge of the Ucayali Basin by the Sierra is a fault-bounded massif with a core of pre-Cambrian to Devonian rocks which plunge North-Northwest into the center of the basin. The same tectonic events which affected the Maranon Basin occurred in the Ucayali Basin. The Ucayali Basin is 80,000 sq. km and contains a sedimentary volume of 240,000 cubic km.

The Ucayali Basin is a shelf or platform area, located south of the Contamana Arch, comprises a wide region on the folded foreland belt which includes the ridge and plains on the fairly shallow Basement (Figure B-3). The Ucayali River appears to mark the boundary between the structures that have the average west dipping west flanks and the steep east flanks which may be faulted and overturned, found on the west side of the river. On the east, the major structures are also asymmetric but the steeper limbs face west.

The structures show complications involving thrusting and both longitudinal and cross faulting while other faults are simpler. Some of the closed anticlines show closure within Tertiary or Cretaceous

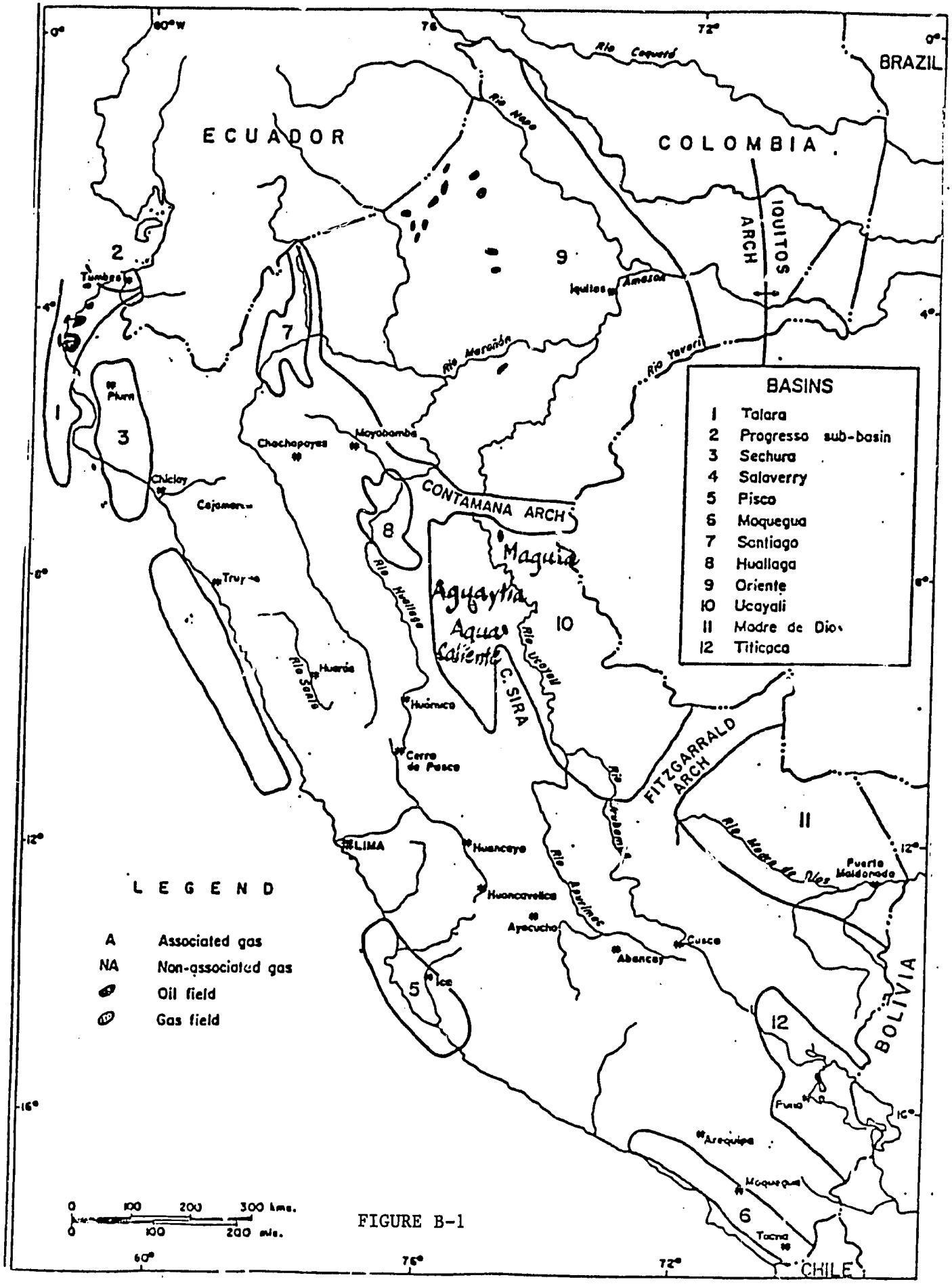
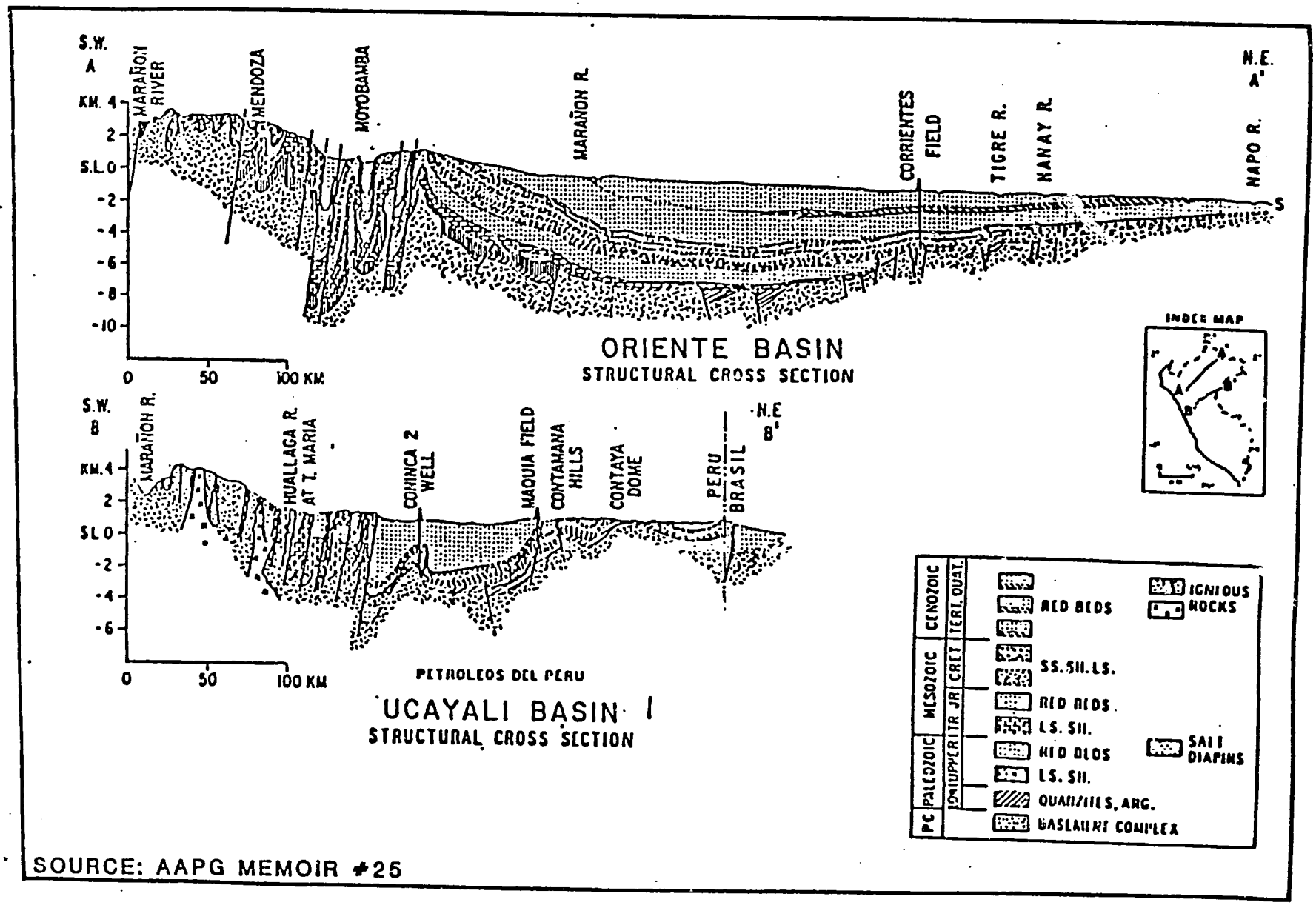


FIGURE B-1

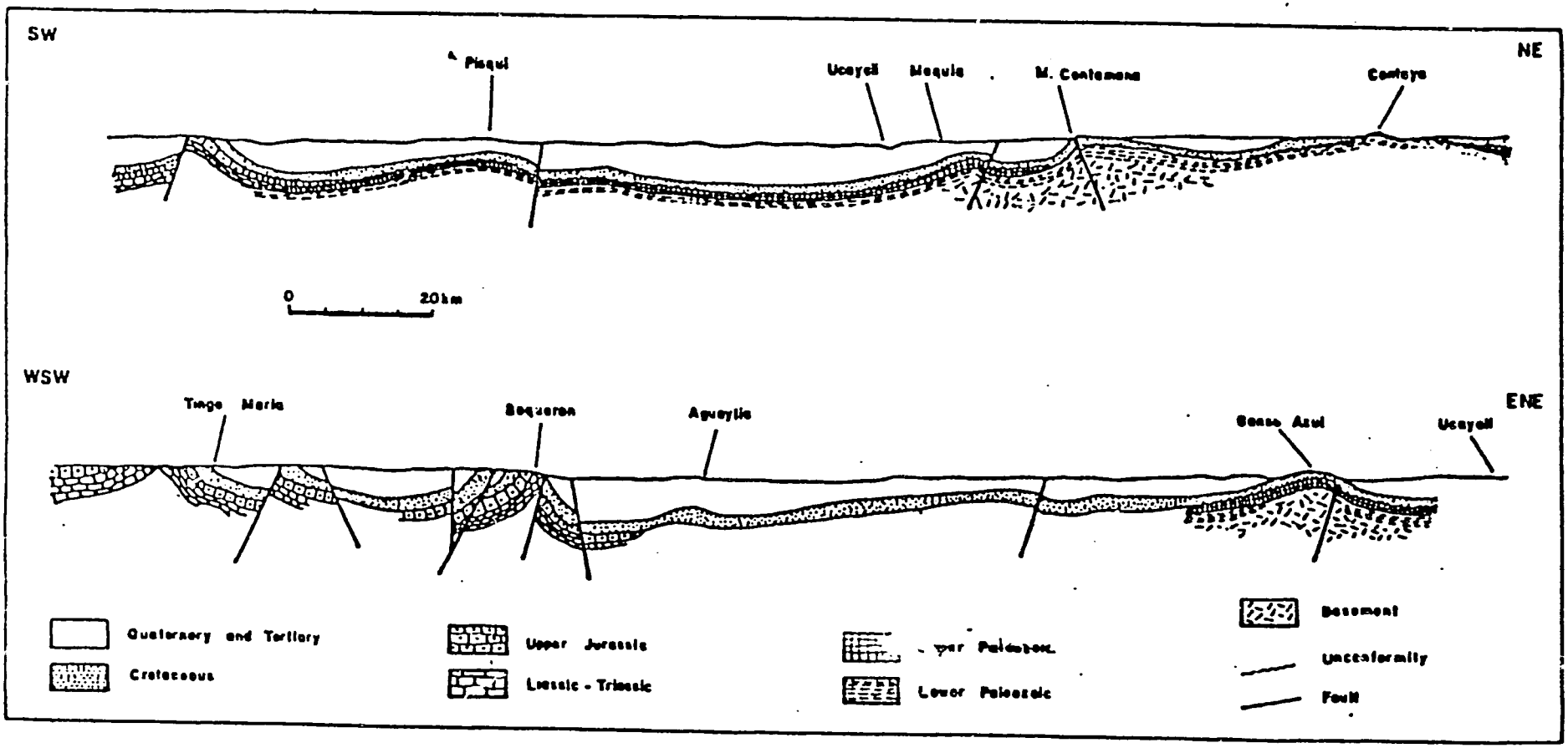
BASINS

FIGURE B-2



STRUCTURAL CROSS SECTIONS OF ORIENTE AND UCAYALI BASINS

PERU
UCAYALI BASIN



SCHEMATIC GEOLOGICAL CROSS SECTIONS ACROSS THE UPPER AMAZON BASIN

(from ENI-Enciclopedia del Petrolio)

FIGURE B-3

formations, while other anticlines are deeply eroded revealing older cores. The general strike of the structural grain is NW-SE or N-NW to S-SE, the typical Peruvian Andes strike. Many other less pronounced structures probably exist to the SE or NE of the Contamana high.

Stratigraphy

The stratigraphy of the Ucayali Basin is the same as that described for the Maranon Basin to the north (Figure B-4).

PETROLEUM CONSIDERATIONS

Two small oil fields, and one gas field have been discovered in the Ucayali Basin:

Agua Caliente Oil Field discovered in 1939, now abandoned
Maquia Oil Field discovered in 1957
Aguaytia Gas Field discovered in 1961

The two oil fields have a combined cumulative production of about 24 million barrels of oil and cumulative gas production estimated at about 40 billion cubic feet.

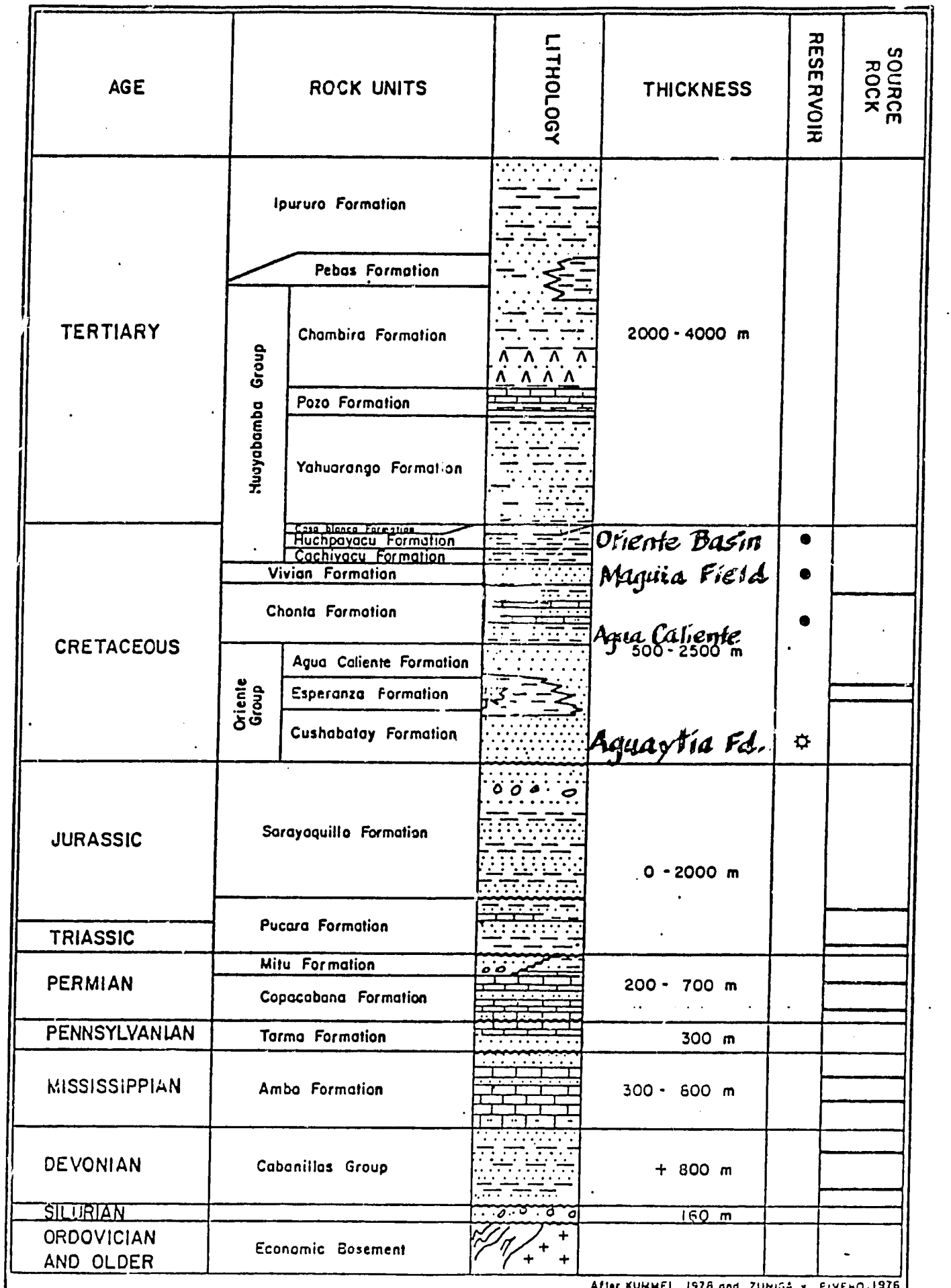
Cap Rocks

Cap rocks are necessary to contain the hydrocarbon within the reservoir. In the Ucayali Basin, shales of the Esperanza Shale usually cap the Cushabatay sandstone reservoirs. Where the Esperanza Shales are not found, the Cushabatay sandstones cannot be expected to contain hydrocarbons (oil and gas). The interbedded shale facies of the Chonta Formation overlie the Agua Caliente sandstone reservoir and provide the seal for the Vivian sandstone reservoirs.

Source Rocks

Source rocks are sedimentary rocks deposited together with organic material under pressure, heat and time, which was transformed

FIGURE B-4



After KUMMEL, 1978 and ZUNIGA y RIVERO, 1976

GENERALIZED STRATIGRAPHY ORIENTE AND UCAYALI BASINS, PERU.

TABLE B-1

Agua Caliente Oil Field

Wells drilled: Total 35; oil 30, abandoned 5
Deepest well drilled: Agua Caliente No. 5 (1955) 1,564 m (5,129 ft) into the Paleozoic
Depth to top of reservoir: 311 m (1,021 ft)
Producing Reservoir: Lower Cretaceous Agua Caliente formation
Lithology: sandstone
Structure: Eastward dipping monocline, asymmetrical with two local domes. Closure amounts to more than 1.096 m (3,600 ft)
Gross Reservoir thickness: 30 m (100 ft)
Porosity: 20-25%
Permeability: 225 to 540 md
Gravity: 43.5 API at 15° C (60° F)
Viscosity: 4 CS at 38° C (100° F)
Pour Point: -6° C (21° F)
Base: paraffinic
Sulphur: 0.08% weight
Water & sediment: 0.15% weight
Cumulative production: 14 million bbls
Initial recoverable reserve estimates: 15 million bbls
Current field status: apparently shut-in

Source: Petroconsultants S.A.

TABLE B-2

Maquia Oil Field

Wells drilled: total 22 oil wells
Current well status: 19 wells on artificial lift
3 wells shut-in
Average field production: 677 b/d
Deepest well drilled: Maquia - No. 1, 1623 m (5324 ft)
Bottom hole formation: Permo-Carboniferous
Depth to top of reservoir: 530 m (1,740 ft)
Producing Reservoir:
Upper Cretaceous Vivian sandstone;
the reservoir contains three sandstone horizons
Structure: oval-shaped anticline 7 km (4 mil) long
and 3 km (2 mil) wide, cut by faults
Gross reservoir thickness: 192 m (642 ft)
Net reservoir thickness: average 15 m (50ft)
Porosity: 20-25%
Permeability: more than 1,000 md
Depth to oil water contact
Upper sandstone: -330 m (-1,082 ft)
Lower sandstone: -455 m (-1,493 ft)
Water saturation: 30%
Gravity: 37 to 39° API at 15° C (60° F)
Viscosity: 6 cs at 38° C (100° F)
Pour Point: -1° C (30° F)
Gas-oil ratio: very low
Base: paraffinic
Sulphur: 0.03% weight
Water & sediment: 0.2% wt
Cummulative production: 10.2 millionbbls
Initial recoverable reserve estimate: 11 millionbbls

Source: Petroconsultants S.A.

to liquid or gaseous hydrocarbons. Source rocks are usually shale and/or limestone.

At Aguaytia, the basal Lower Cretaceous Cushabatay sandstone reservoir underlies the source beds for the younger Agua Caliente and Vivian reservoir oils. Consequently, the source of the gas is thought to be derived from the underlying Upper Paleozoic marine rocks. The fact that the Aguaytia reservoir contains largely gas with some condensate rather than the typical low gas-oil ration of all other fields in the Oriente of Peru, reinforces the idea that deeper source rocks are undoubtedly more mature. As a result gas was generated but not oil.

Trap

An oil trap is the accumulation of hydrocarbons (oil and gas) in a reservoir rock under conditions where its migration and escape is prevented. Sealing can be affected by the abutment of impermeable formations against the reservoir by lateral variations within the beds to reduce permeability.

The typical trap is the Peruvian Oriente including the Ucayali Basin, is anticlinal, oriented N-NW. Stratigraphic variations supplement the structural control.

Time of Trap Formation

The present traps in the Peruvian Oriente including the Ucayali Basin, began to form at the dose of the Cretaceous with the onset of the Andean orogeny. These traps continued to grow throughout the Tertiary and their final configuration was determined by the late Pliocene.

Time of Migration

The oil and gas in the Ucayali Basin moved into the interbedded or immediate superjacent reservoirs as the depth of burial permitted its generation, probably in early Tertiary time. However, this is not the case in the Aguaytia gas-condensate field. As the late Paleozoic rocks are the source of the gas, the time of migration was delayed until late Cretaceous.

Retention

Much of the oil and gas generated in the Ucayali Basin may have been dissipated. The probability is great that Aguaytia reservoir received hydrocarbons generated in the Devonian and late Paleozoic geological time rock sequence and were destroyed or severely damaged by the several periods of past orogenic activity. The numerous dry holes drilled into Paleozoic rocks support this conclusion.

The Maquia and Agua Caliente structures are both huge but contain only minor accumulations at the crest of the folds (Figure B-5). Either only minor amounts of hydrocarbons were generated originally or the structures that contain the fields only developed after the hydrocarbons were dissipated.

The Aguaytia wells are apparently located on the NW portion of the Smira Uplift (Figure B-6). The wells: Total depth

Zorillos No. 1	2,709 m (8886 ft)
Aguaytia No. 1	2,777 m (9108 ft)
Aguaytia No. 2	2,688 m (8817 ft)

delimit the gas reservoirs to the north and east. The area to the east and south are the only prospects for defining gas reservoir limits.

FIGURE B-5

MAQUÍA FIELD

GEOLOGICAL MAP

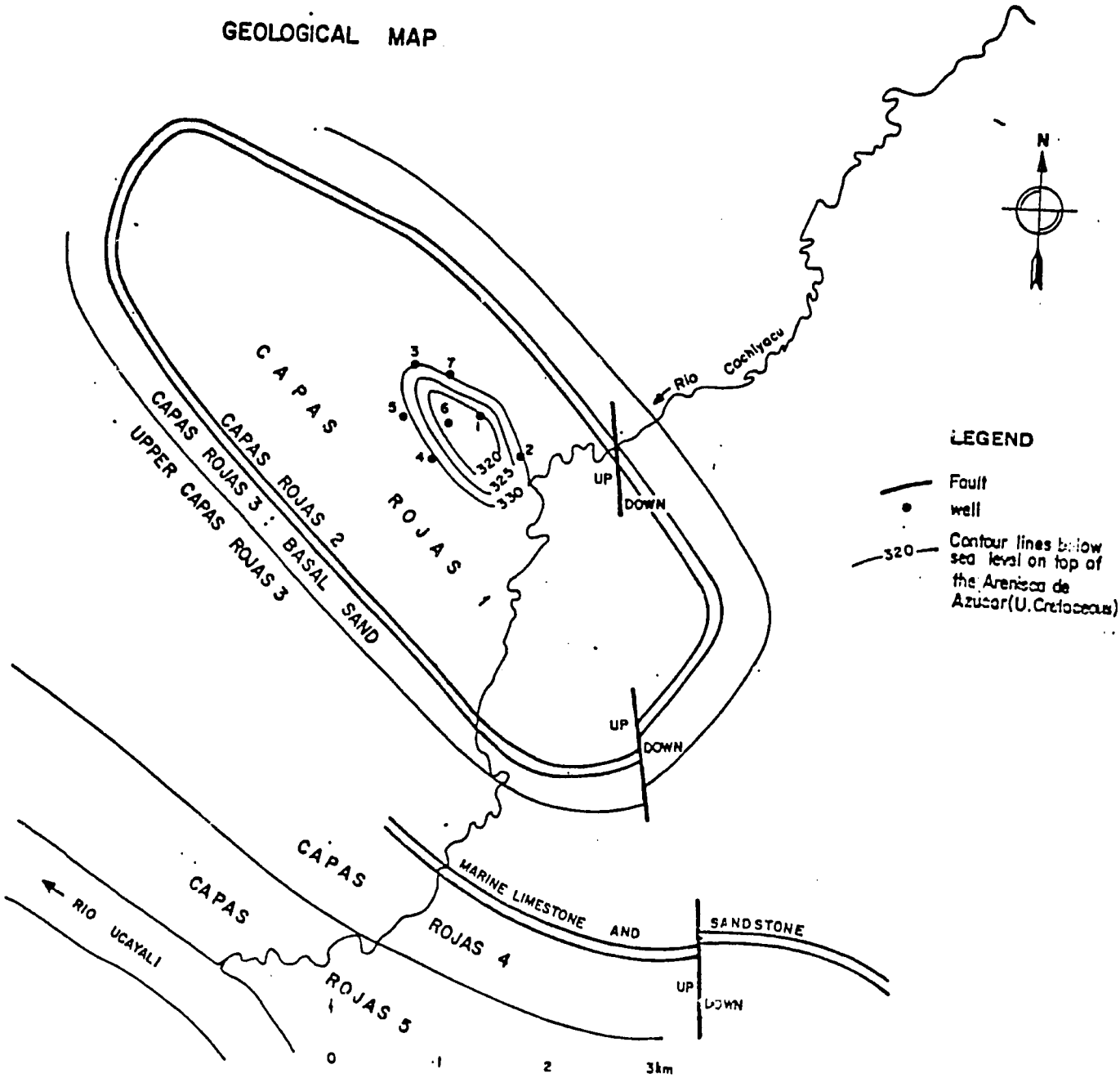
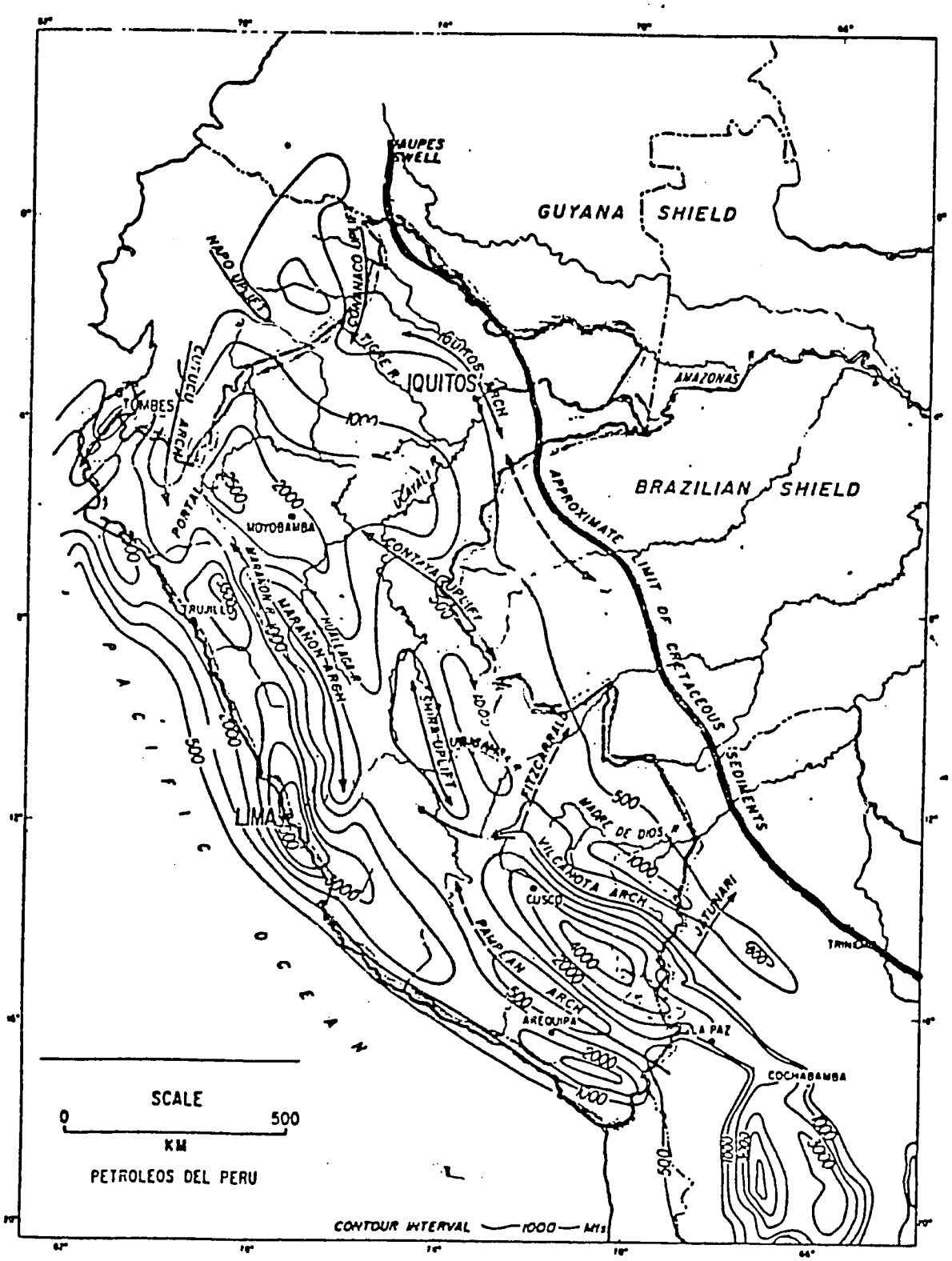


FIGURE B-6



Cretaceous isopach map showing main tectonic features.

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