Pond Dynamics/Aquaculture Collaborative Research Data Reports

Volume I
Second Edition
General Reference: PD/A CRSP Site Descriptions

Pond Dynamics Aquaculture
Collaborative Research Support Program
Oregon State University
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July 1996

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The Pond Dynamics/Aquaculture Collaborative Research Support Program is one of a family of international agricultural research programs headquartered at US Land Grant Universities. CRSPs were initiated under Title XII legislation enacted by the US Congress. Research conducted by these programs helps farmers improve their incomes and alleviate hunger without depleting the natural resource base on which they depend for food, fuel, fiber, and shelter.

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Introduction

Background of PD/A CRSP Research

The Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) represents an international community of researchers and institutions dedicated to strengthening health and nutrition in developing countries by improving the efficiency of pond aquaculture systems. It is one of several agricultural CRSPs supported by the U.S. Agency for International Development under the authority of Title XII of the International Development and Food Assistance Act of 1975.

The Global Experiment is the major PD/A CRSP research activity, covering the period from 1982 to the present. It was designed to quantitatively describe the physical, chemical and biological principles of pond culture systems. The information gained from the global experiment is being used to improve production technologies and develop quantitative production functions to facilitate rigorous economic analyses of aquaculture systems.

Standardization is a key element of the global experiment. Standardization permits the comparison of data from diverse geographic locations. The experimental design involves monitoring specified environmental and fish production variables in accordance with standardized work plans in twelve or more ponds at each of the CRSP research sites. The variables observed, frequency of observation, and materials and methods are uniform for all locations. The field data are filed in a centralized data base, called the CRSP Central Data Base. Statistical methods are used to test hypotheses about correlation between variables and to evaluate the sources of variance within ponds, between ponds within locations, and between locations.

The CRSP Data Base is being used to develop predictive models of the processes occurring in pond culture systems. The models will be used to provide guidance for ongoing and future research, to predict the performance of existing and proposed pond systems subject to specific inputs and constraints, and to improve the operation and efficiency of pond culture systems.

The global experiment originally included three cycles of experiments. Each cycle consisted of two series of observations, one during the dry season and one during the wet season. The objective of the first cycle was to create a detailed baseline of chemical, physical, and biological data on all ponds treated with a standard level of inorganic fertilizer. In the second experimental cycle, ponds treated with inorganic fertilizer were compared to ponds treated with organic fertilizer. In the third cycle, the responses of ponds to different levels of organic fertilizer were compared. The global experiment has been continued at all active CRSP sites in subsequent years through 1996; site-specific research that complements the global experiment has also been conducted.

CRSP Data Report Series

The results of the first three cycles of experiments were reported in the Pond Dynamics/Aquaculture Data Reports (referred to as Data Reports). The goal of the Data Reports was to record the PD/A CRSP Data Base and to present interpretations of site specific results. Research results from experiments conducted after the first three cycles have been published in various aquaculture journals or in the program's own PD/A CRSP Research Report series. The PD/A CRSP has conducted the global experiment at sites in seven developing countries: Egypt, Rwanda, Honduras, Panama, Thailand, the Philippines, and Indonesia.

The first of these reports, General Reference, Volume I, provides descriptive information for each of the PD/A CRSP sites and serves as a reference guide for the entire report series. It presents the physical characteristics of each site, including a geographical sketch, climatology, and water and soil analyses. This second edition of Volume I provides additional information about the CRSP research sites, including several sites added to the program since its inception. A more comprehensive revision, which will include tabular data and other information, is in progress.

Subsequent volumes of the Data Reports focus on each site separately. Each volume includes one cycle (wet and dry seasons) of the PD/A CRSP global experiment. Therefore, with few exceptions, each project site has three volumes devoted to it, representing the results of the three cycles of the global experiment. The experimental cycles are described in PD/A CRSP Work Plans which are available from the Program Management Office.

Data Reports of the CRSP Global Experiment are:

Vol.	Title	Experiment cycle and publication date		
1	General Reference	(8/87)		
1.2	General Reference, 2nd Ed.	(7/96)		
2	Thailand	I (4/87)	II (12/90)	III (3/91)
3	Indonesia	I (6/88)	II (6/91)	III (8/89)
4	Philippines	I (6/91)	II (6/91)	III (6/91)
5	Rwanda	I (10/89)	No Vol. II	III (5/91)
6	Honduras	I (4/90)	II (3/90)	III (12/89)
7	Gualaca, Panama	I (4/91)	No Vol. II	III (4/91)
8	Aguadulce, Panama	I (6/91)	II (6/91)	III (6/91)

To order PD/A CRSP publications, including a complete List of Publications, contact:

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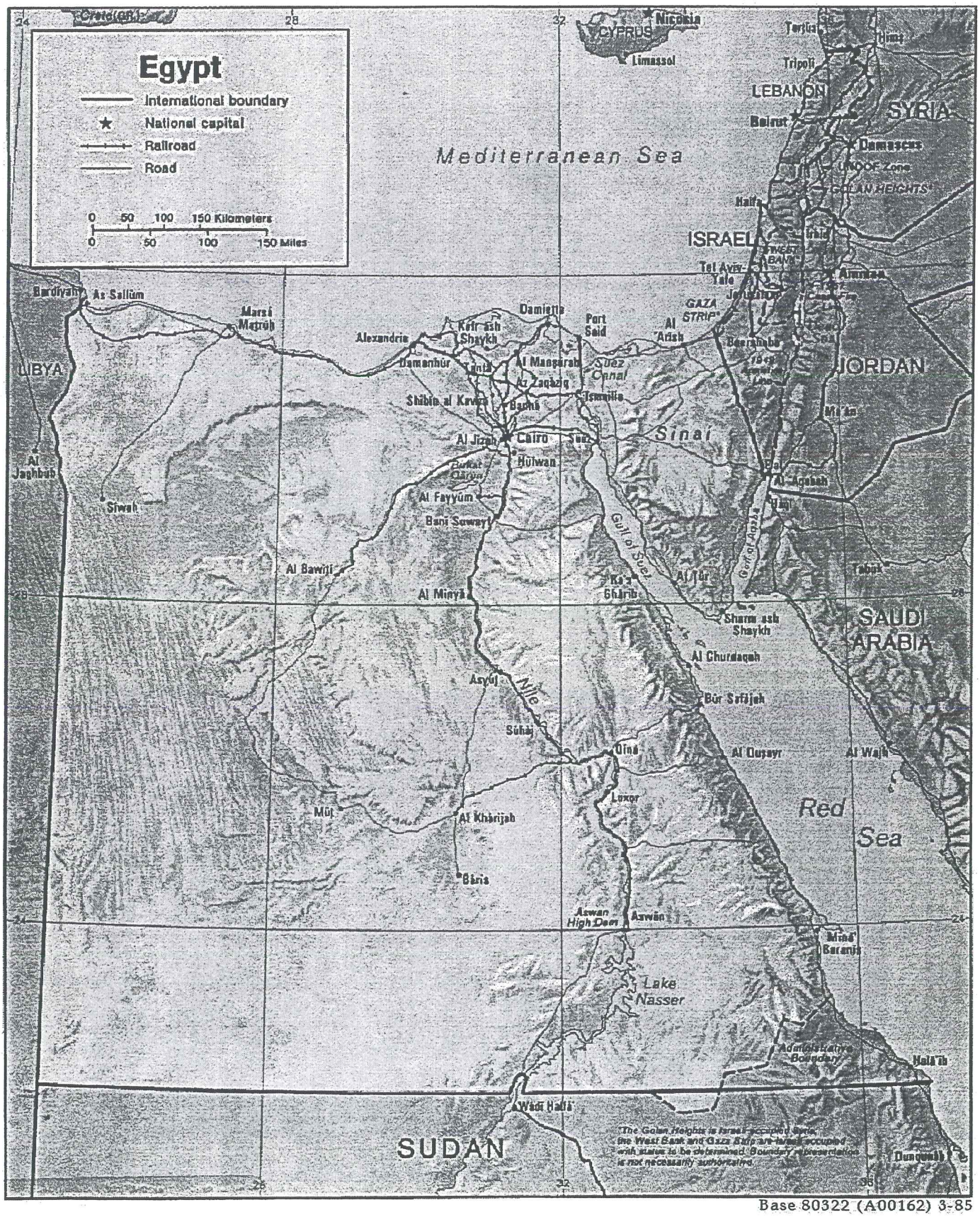

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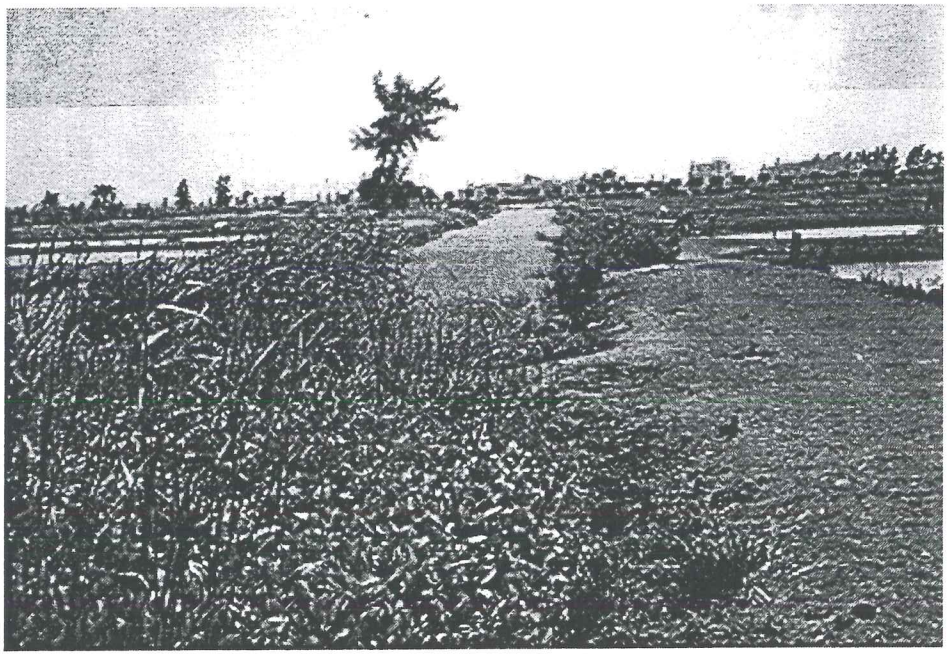
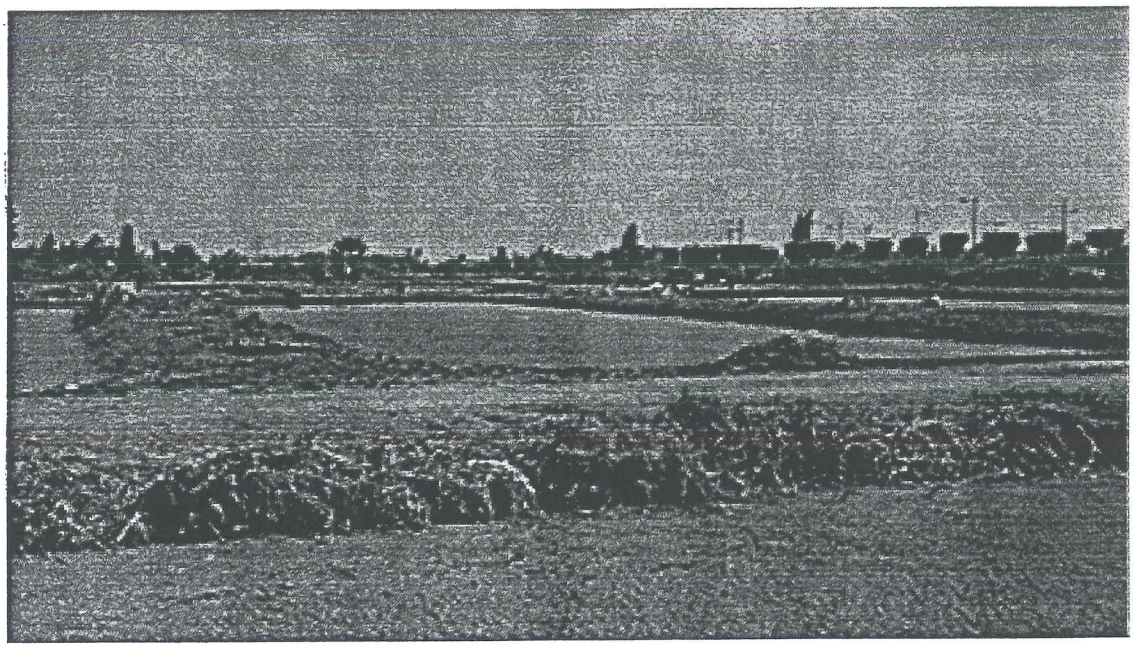
Abbassa



A central theme of CRSP - supported research at the Central Laboratory for Aquaculture Research (CLAR), Abbassa, Egypt, was the effort to control the encroachment of aquatic weeds such as *Azolla*, *Typha*, and *Phragmites* into pond areas.



CLAR lies in the heart of the Nile Delta, a vast, fertile plain that stretches from Cairo northwards to the Mediterranean coast.

Abbassa
Central Laboratory for Aquaculture Research

Site Status: Former Prime Site, 1992 - 1995
Location: Abbassa, Abou Hammad, Sharkia, EGYPT
Caption/Description: The Central Laboratory for Aquaculture Research (CLAR) is located in Abbassa, Abou Hammad, Sharkia Governorate, approximately 70 km northeast of Cairo and 25 km east of the city of Zagazig. It is about 80 km inland from the Mediterranean Sea.

Description of Area/Region

Climate

Köppen and Trewartha classifications **BWh***: *Dry desert (arid)* group (BW); *hot tropical-subtropical* type (h).

Temperatures	Precipitation
In the coastal areas temperatures range from approximately 14 to 37°C, while in the desert areas the range is greater, with lows around 6 (as low as 0°C in winter) and highs reaching 46°C. Prevailing northern winds throughout the year moderate potential extremes of temperature. Average air temperatures around Cairo range from about 13 to 30°C, while those at Abbassa range from 4 to 40°C, with pond water temperatures ranging from 9 to 34°C.	Rainfall is low throughout the country, but increases somewhat towards the north, nearer the Mediterranean, where it averages about 200 mm annually. In Cairo the average annual rainfall is between 25 and 29 mm, while at Abbassa (part way between Cairo and the Mediterranean) annual rainfall averages between 25 to 50 mm. Rainfall may occur only once in several years in many of Egypt's desert areas.
Humidity	**Seasonality**
Very dry climate, with slightly greater humidities along the Mediterranean.	Nearly constantly dry, with a hot season from May to September, and a cool season from November to March.

Topography

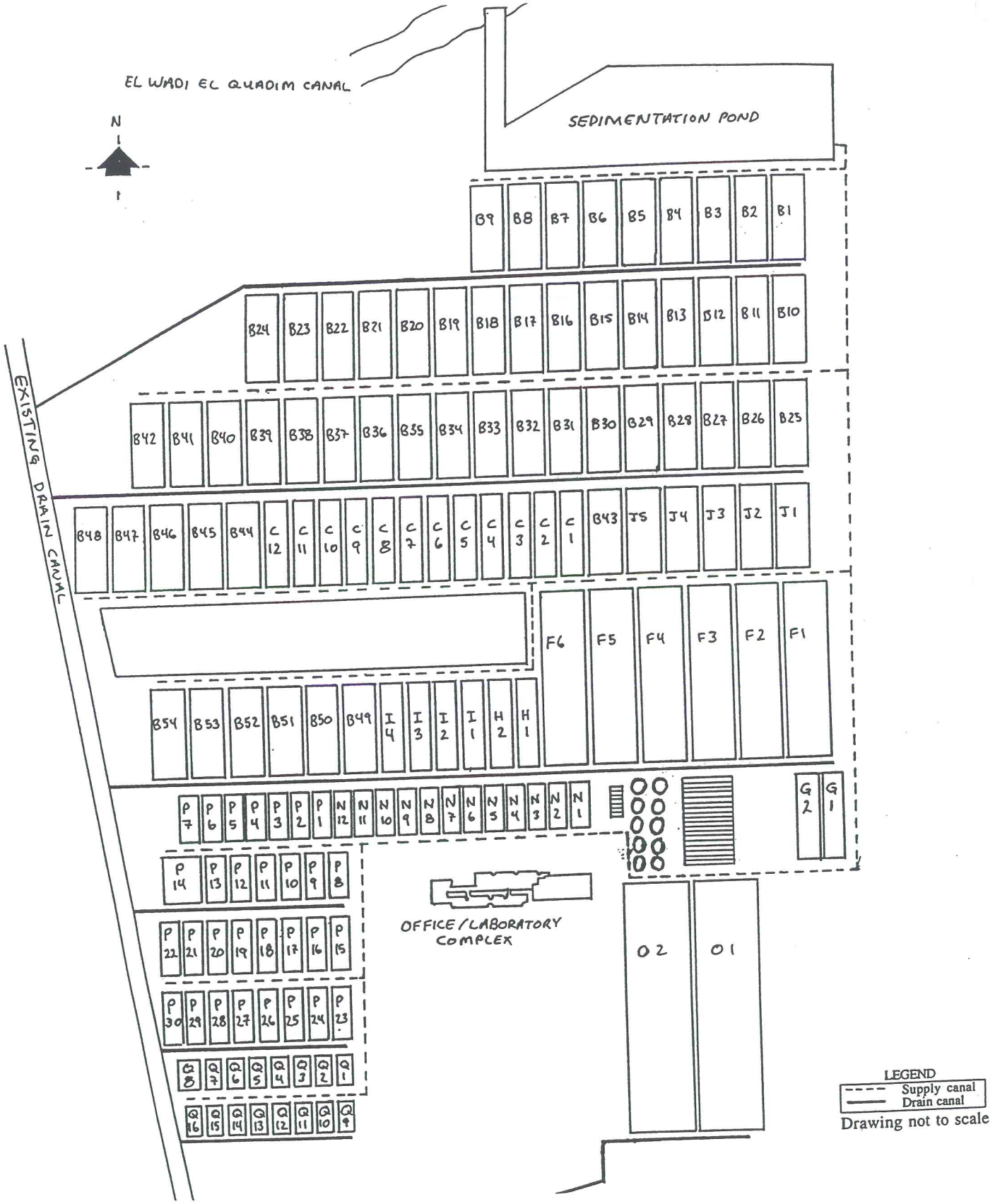
CLAR is north of Cairo in "Lower Egypt," the relatively flat, fan-shaped delta of the Nile River after it leaves the narrow, cliff-lined valley to which it is confined further south. The delta, formed by the deposition of silt by the Nile and Rashid and Dumyat rivers, is the most fertile region in Egypt; its perimeter lines nearly 250 km of the coastline of the Mediterranean Sea. Other than along the Nile valley south of Cairo, little vegetation is found outside the Nile delta. Elevations throughout the delta are low, and some localized depressions are below sea level. The only significant natural relief in the area is outside the delta to the south and west, including a plateau area gradually rising from Cairo to elevations of about 600 m near the Gulf of Suez in the east and extending southward into the Arabian Desert, as well as a narrow ridge running west/southwest from Cairo. A few peaks in the eastern plateau/Arabian desert area reach elevations of 2100 m along the coast of the Red Sea. To the west the Western Desert (or Libyan Desert) contains a vast expanse of sand known as the Great Sand Sea as well as several areas below sea level. The Qattarah Depression is the most extensive, covering an area of about 18,000 km^2 and reaching a depth of 133 m, the lowest elevation anywhere in Africa.

Geology and Soils

Silt and other materials deposited by the Nile have formed the vast and highly fertile Nile Delta.

* Asterisked items are defined or described in the glossary.

Layout of Central Laboratory for Aquaculture Research



Description of Central Laboratory for Aquaculture Research

Map Coordinates	Elevation
30 32'N and 31 44'E	6 m

General	Water Supply
CLAR is divided into nine departments: aquaculture, limnology, nutrition, genetics, biology/ecology, aquacultural economics, processing/quality control, fish health, and hatchery/reproductive physiology. CLAR facilities include staff and administrative offices, a library, an auditorium, numerous dry and wet laboratories, a garage/workshop, central stores, and 155 earthen ponds and 56 concrete tanks/raceways that are all available for research. Pond areas range from 0.05 to 2.1 ha and total approximately 46 ha, while concrete tank/raceway areas range from 15 to 250 m^2. PD/A CRSP research was conducted in 0.01- (round ponds), 0.1- (P series), and 0.42-ha (B series) earthen ponds. CRSP research at the CLAR included studies to identify methods for dealing with the continuing problem of encroachment of emergent and floating vegetation into the ponds. Foremost among problem species were Phragmites (papyrus) and Typha—both emergent types—and Azolla (water fern) and water hyacinths—both floating plants. CLAR and CRSP collaborators also worked to reduce problems associated with the contamination of ponds by "wild" fish. All laboratories are well equipped, with sophisticated analytical instruments that permit most routine analyses to be conducted in-house.	The source of practically all surface water in Egypt is the Nile River. CLAR is supplied with water from the Ismalia canal by way of the El Wadi El Quadim supply canal. The Ismalia canal originates from the Nile River in Cairo and flows eastward to the Suez Canal. Water flows from the El Wadi El Quadim supply canal to the CLAR sedimentation pond and then into the CLAR supply canal. Ponds can be drained only partially by gravity; pumps are required to completely drain them. Water flows from the ponds to CLAR drain canals, which drain into an existing irrigation drainage canal. Water entering the ponds at CLAR is alkaline, with a pH of about 8.0, total alkalinity of about 220 mg/L, total hardness of near 190 mg/L, and calcium hardness of about 120 mg/L.

Soils
Soils of most of the CLAR research ponds used in CRSP research are clayey (40 - 60% clay), with CEC*s that range from 34 to 45 meq/100 g. The soils are alkaline and contain high levels of Ca, Mg, and Na.

* Asterisked items are defined or described in the glossary.

Support Facilities at Central Laboratory for Aquaculture Research

There are twenty-one other research institutes and central laboratories within the Agricultural Research Center. CLAR researchers are able to consult with colleagues in these institutes as necessary. Many CLAR senior researchers have advanced degrees (Ph.Ds), and are affiliated with one or more universities in Egypt, where they direct student research and periodically teach. The majority of the CLAR technical staff are pursuing advanced degrees (MS or Ph.D.) at Egyptian universities; these students conduct their theses research at CLAR under supervision of the major professors and the CLAR department head.

Affiliations

In-Country	US
Central Laboratory for Aquaculture Research Agricultural Research Center Ministry of Agriculture and Land Reclamation Abbassa, Abou Hammad, Sharkia EGYPT	Department of Fisheries and Allied Aquacultures Auburn University, Alabama 36849 USA Zoology Department University of Oklahoma Norman, Oklahoma 73019-0235 USA

Current Contacts

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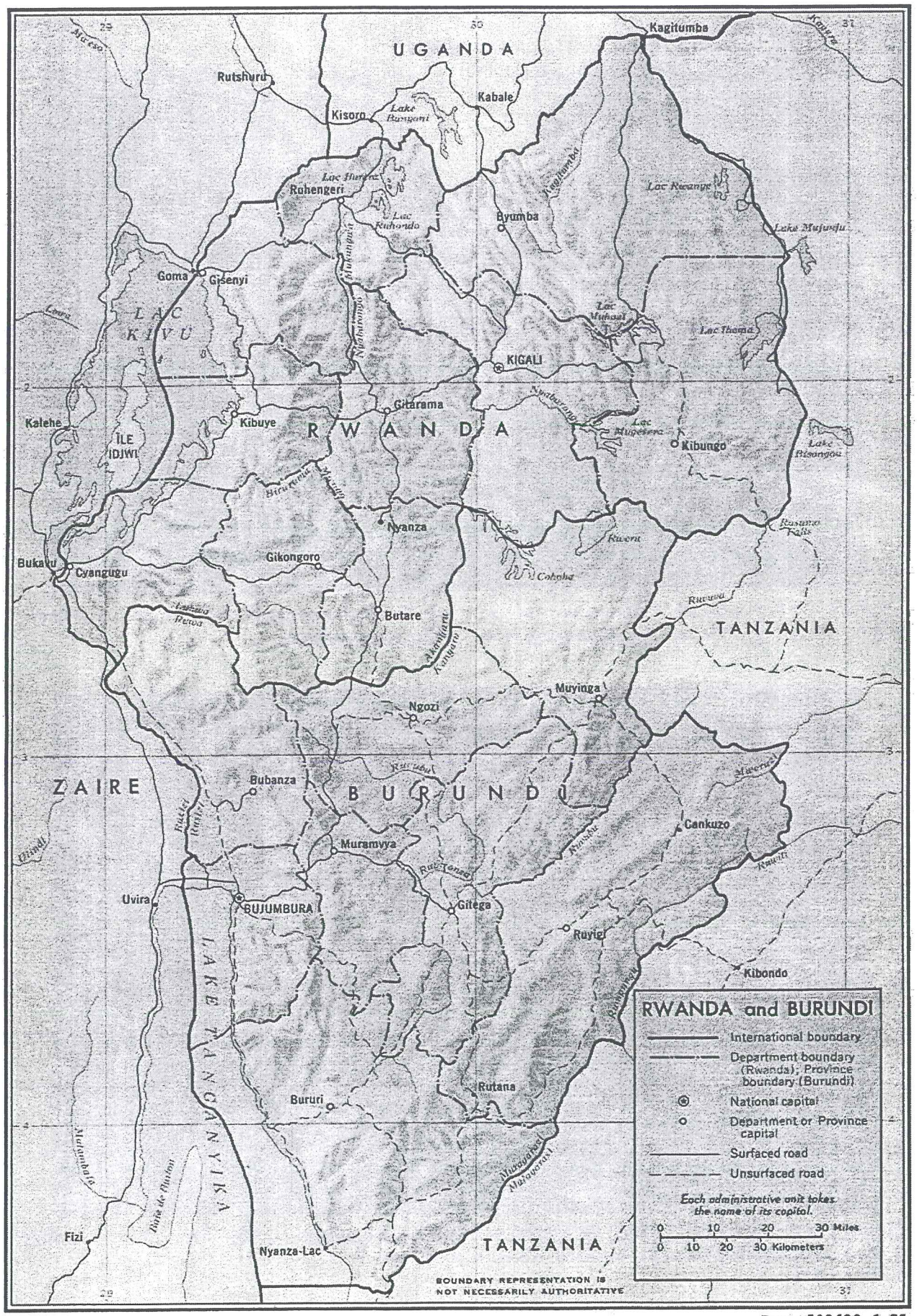

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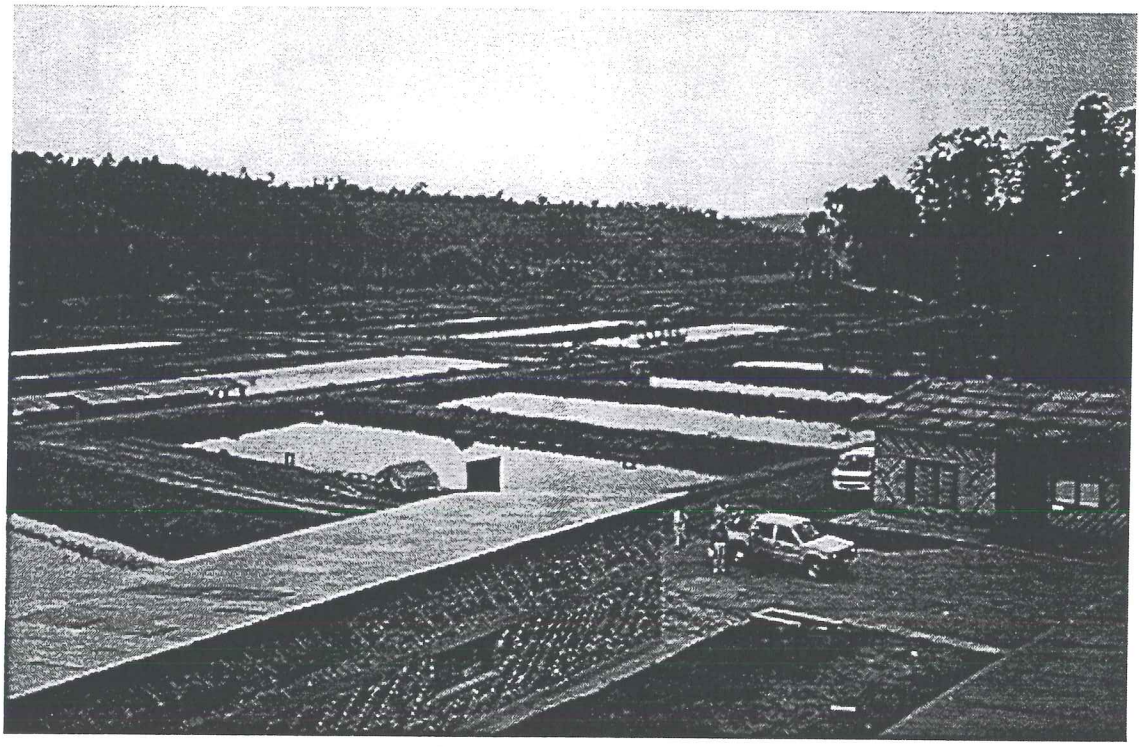
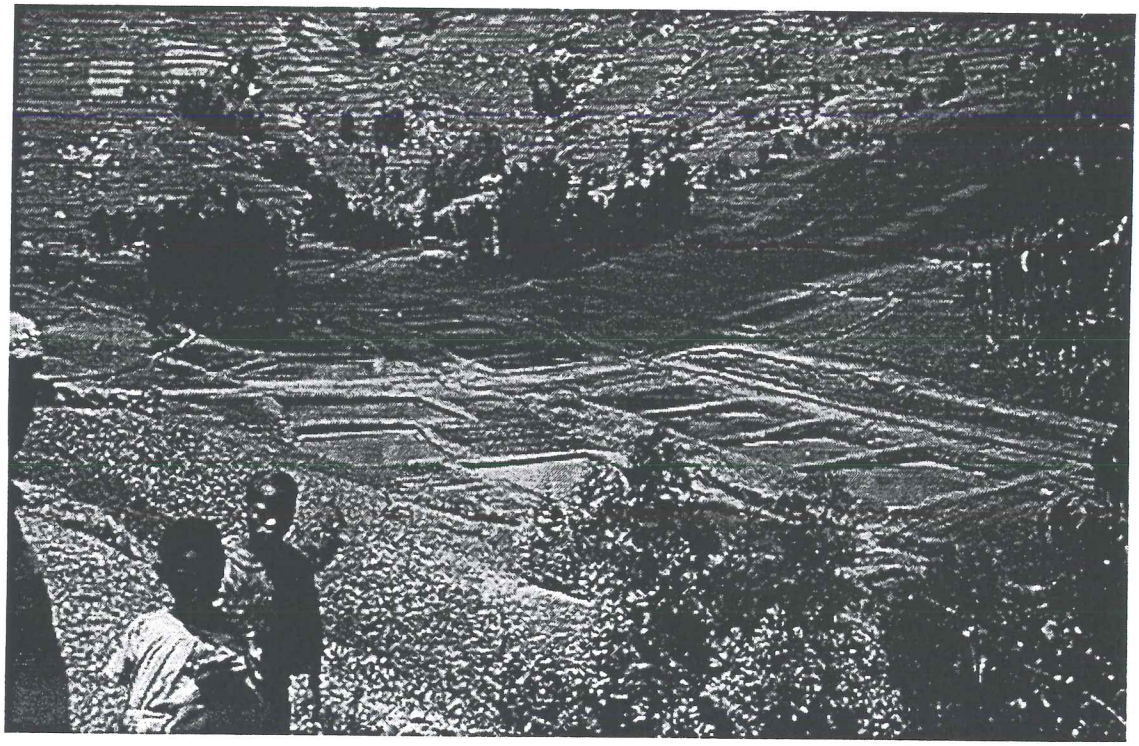
Rwasave



The Rwasave Fish Culture Station consists of more than 60 research and production ponds, as well as office, laboratory, training, fish processing, and holding tank facilities.



The steep slopes and deep valleys of much of central and western Rwanda limit fish pond development to smaller sized ponds on valley bottoms. Access to markets and supplies is also made more difficult by the rugged terrain.

Rwasave Fish Culture Station (Station Piscicole de Rwasave)

Site Status: Former Prime Site, 1985 - 1994
Location: Rwasave, Butare, RWANDA
Caption/Description: Rwasave is located approximately 2 km from Butare, Rwanda's second largest city, and about 130 km south of the capital city of Kigali.

Description of Area/Region

Climate

Köppen-Trewartha classification* **GAw***: *Hills or low mountains* (G), humid tropical climatic group (A), *tropical wet-and-dry* type (w).

Temperatures	Precipitation
Mean monthly temperatures for the country range from 21.3°C in October to 19.0°C in November. Nighttime temperatures can fall below 10°C in the mountainous areas where aquaculture is practiced; afternoon temperatures are seldom greater than 35°C. Average annual air temperatures at Rwasave range between 14 and 28°C. Pond temperatures range between 19 and 23°C.	Rainfall for the country as a whole ranges from 700 to 2000 mm annually. Mean monthly rainfall values at Rubona (near Rwasave) range between a low of 7.3 mm (July) and a high of 182.7 mm (April), with an average annual rainfall of 1139 mm. Average annual rainfall at the Rwasave Station is about 1200 mm.
Humidity	**Seasonality**
Mean monthly humidity values at Rubona range from 59% in July to 83% in April.	Rwanda has four identifiable seasons: a long dry season (mid-June to mid-September), a short rainy season (mid-September to mid-December), a short dry season (mid-December to mid-February), and a long rainy season (mid-February to mid-June).

Topography

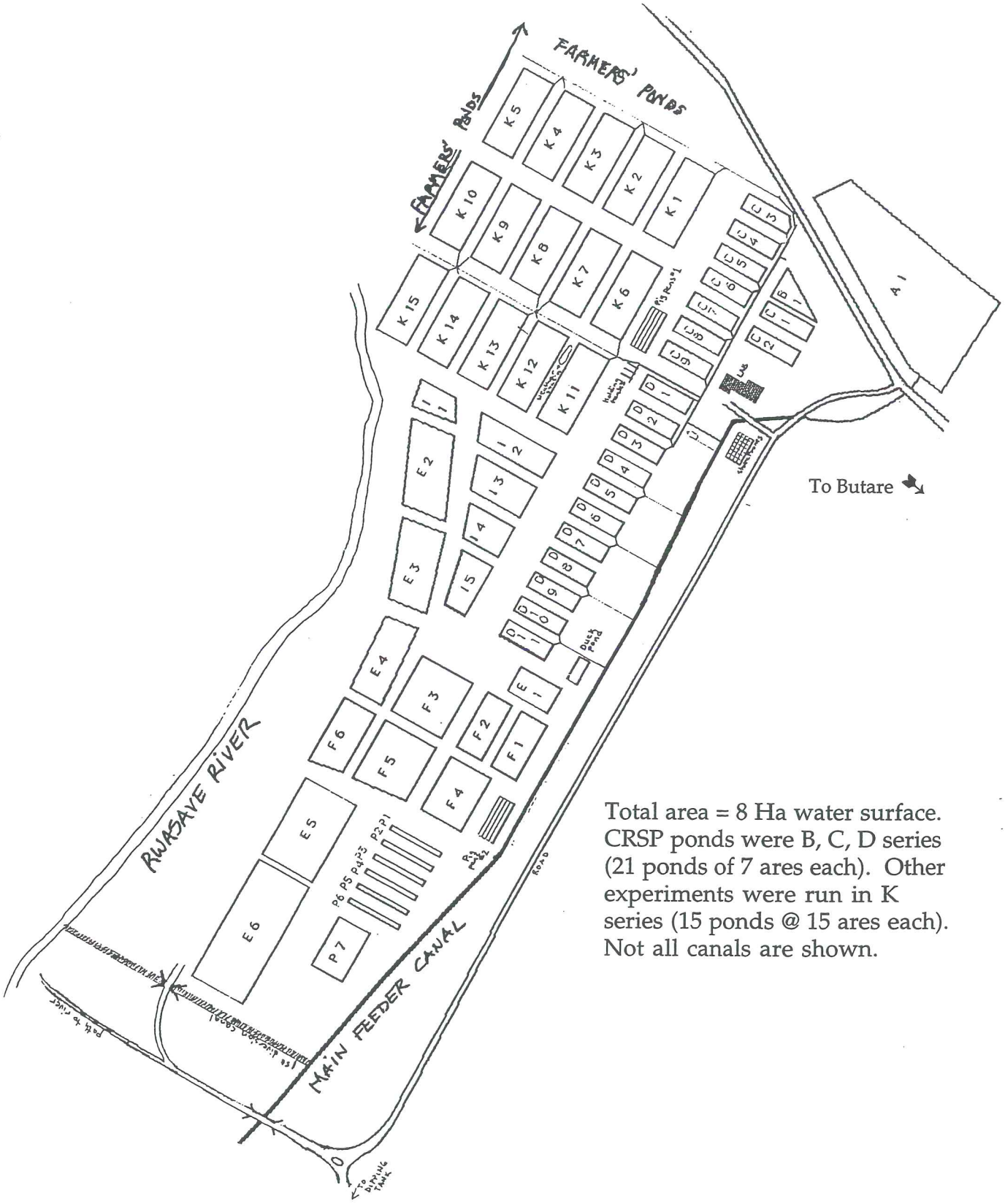
Rwanda's three major geographic regions are the Eastern Shelf (1000 to 1500 m), a hilly Central Plateau (1500 to 2000 m), and the Zaire/Nile divide, a range of high mountains (2000 to 3000 m) running north/south parallel to Lake Kivu on the western border with Zaire. Most of the country is hilly or mountainous and lies above 1500 m. The western mountain range includes five volcanoes whose peaks range from 3000 to 4500 m in elevation. Rwanda has 23 major lakes (including the 2370 km^2 Lake Kivu) and numerous rivers. Most aquaculture occurs at altitudes of 1300 to 2500 m, water being limited at lower elevations regions. The ruggedness of the terrain of most of the aquacultural area limits the sizes of ponds that can be built as well as access to supplies and markets. Pond development is restricted to *marais**. Marais belong to the state, while uplands are private lands. To develop marai lands farmers must get permission from the local officer (buromeister) of the commune.

Geology and Soils

Most of the land mass of Rwanda is very rugged and broken up, with steep mountain slopes and deep valleys. The exposed materials are weathered Pre-Cambrian materials and outcrops or sedimentary deposits derived from such materials. Soils in the Virunga Mountains, a chain of volcanoes in the north, are poorly developed and mostly uncultivable due to the young age of these volcanoes. Some valleys in the north have organic soils, but much of the Central Plateau is dominated by lateritic soils on the hillsides and alluvial soils in the valley marais*, with occasional pockets of organic soils.

* Asterisked items are defined or described in the glossary.

Layout of Rwasave Fish Culture Station



Total area = 8 Ha water surface. CRSP ponds were B, C, D series (21 ponds of 7 ares each). Other experiments were run in K series (15 ponds @ 15 ares each). Not all canals are shown.

Description of Rwasave Fish Culture Station

Map Coordinates	Elevation
2 40'S and 29 45'E	1625 m
General	**Water Supply**
The station is approximately 3 km from the National University of Rwanda, Butare campus. It has a total area of 18 ha, of which over 7 are in ponds. There are 21 700-m^2, 15 1500-m^2 ponds, and at least 25 other ponds of various sizes. The 21 700-m^2 ponds were reserved for CRSP research. The remainder served for fingerling production and as grow-out ponds. The laboratory building has three offices, each with an area of 12 m^2, a laboratory, and a storage area. Another building includes a training room, an office, a holding tank/aquarium area, and a large, covered, outdoor multipurpose area for training, aquarium experiments, fish processing and so forth. Another, smaller building includes a wet lab and a holding tank area. Personnel at the station included a station manager, a CRSP research associate, a driver, and a secretary/computer operator.	Water is supplied by the Rwabuye River. The supply canal runs 2.5 km from a small dam in the river to the station. The canal passes through some cultivated marshlands where there is some exchange with standing water. At the beginning of CRSP work at Rwasave, the supply water had a pH of 6.5 - 7.0, alkalinity of 17 mg/L, and a hardness of 43 mg/L (alkalinity and hardness given as mg $CaCO_3$/L).
Soils	
Soils at the Rwasave Station are quite acidic, with pH values reported prior to the beginning of experiments in 1995 ranging from 4.5 to 4.8. Organic matter contents ranged from 0.7 to 5.1, and CEC*'s ranged from 4.5 to 17.6.	

* Asterisked items are defined or described in the glossary.

Support Facilities at Rwasave Fish Culture Station

Library and university facilities were near but limited. The station employed one laboratory technician and two assistants, a computer-trainee, and 60 station workers and guards. The only feed available was rice bran, which was available in limited but adequate quantities. Fertilizer was available but expensive. Animal manure was in short supply but also adequate for station needs.

Affiliations

In-Country	US
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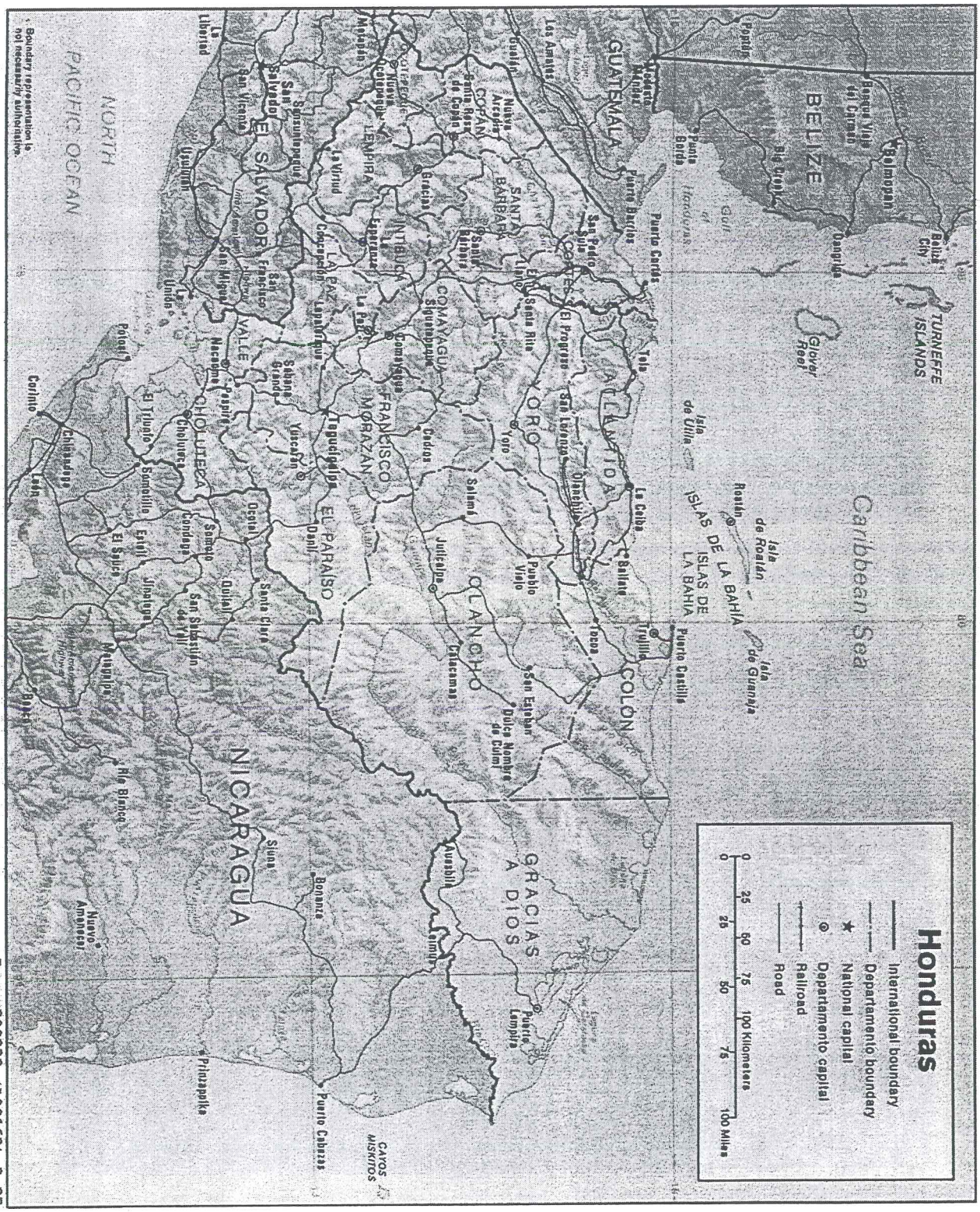
Honduras
International boundary
Departamento boundary
National capital
Departamento capital
Railroad
Road
100 Kilometers
100 Miles
BELIZE
GUATEMALA
EL SALVADOR
NICARAGUA
NORTH PACIFIC OCEAN
Caribbean Sea
TURNEFFE ISLANDS
ISLAS DE LA BAHIA
COPAN
SANTA BARBARA
CORTES
ATLANTIDA
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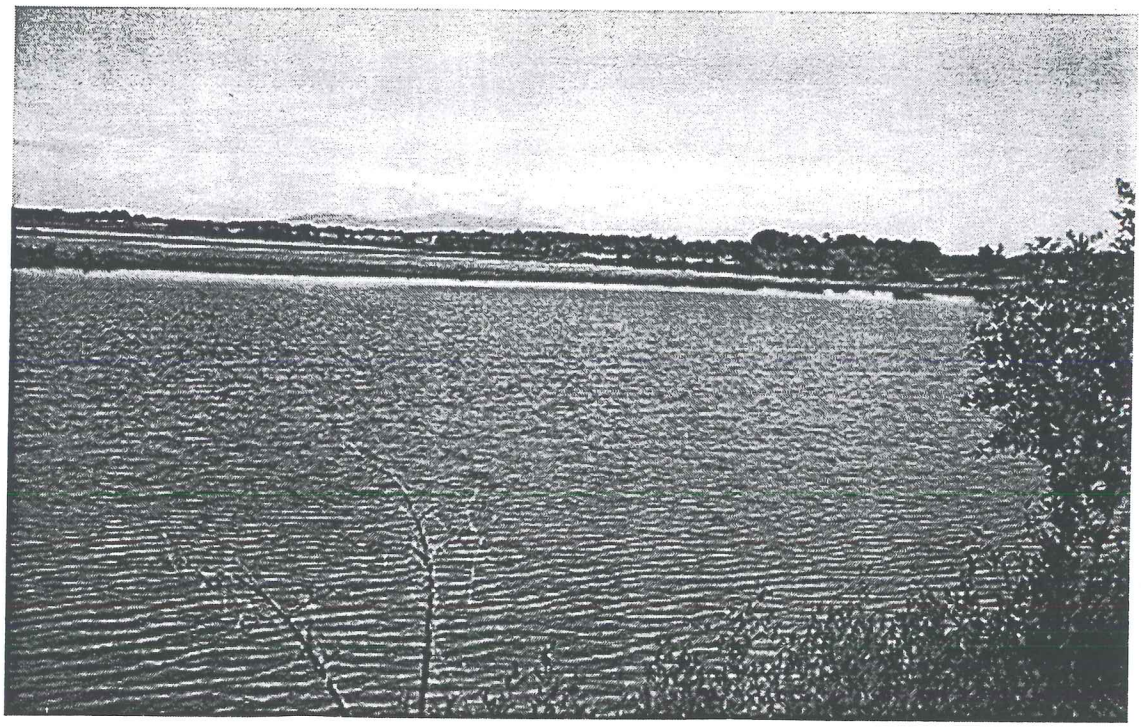
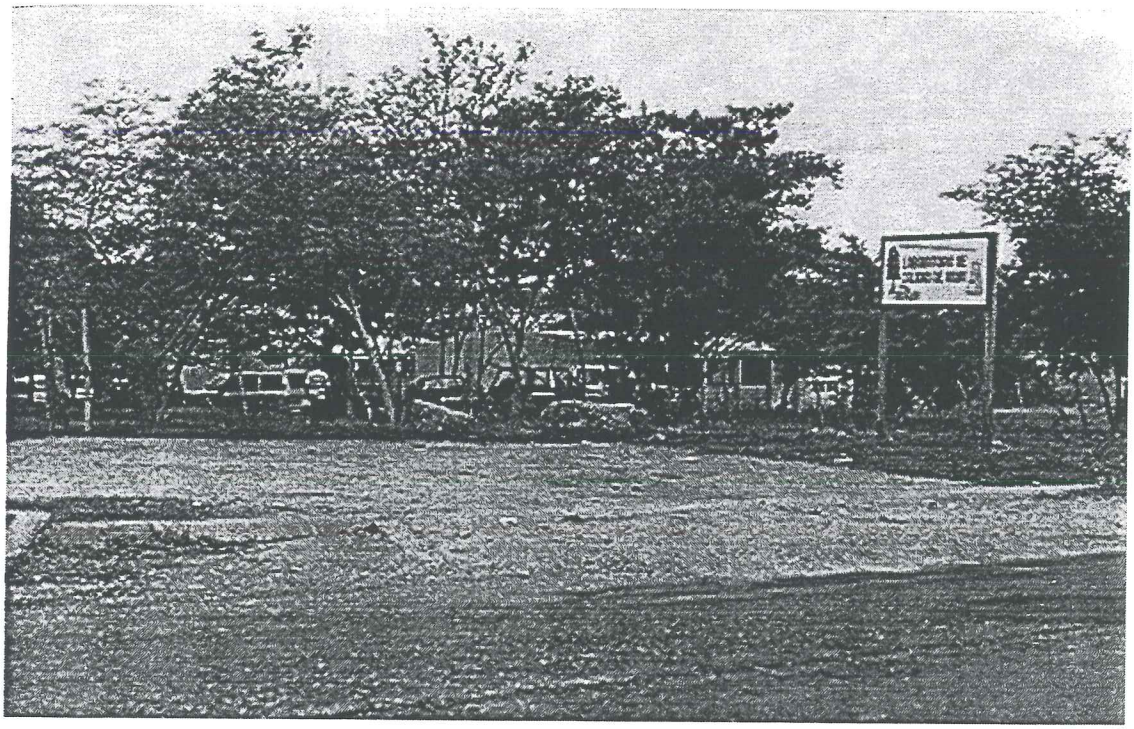
Choluteca



Shrimp ponds in the Choluteca area are constructed in extensive, low - lying salt flats ("playones") found in the coastal area along the Gulf of Fonseca, southern Honduras.



Soil and water chemical analyses for CRSP - supported research in the Choluteca area are carried out at the La Lujosa Water Quality Laboratory.

Choluteca

Site Status: Active Prime Site, 1992 - present
Location: Selected sites in the shrimp-producing area around the periphery of the Gulf of Fonseca, Department of Choluteca, southern Honduras.
Caption/Description: Research in the Choluteca area is conducted at selected estuarine sampling sites and on selected collaborating shrimp farms around the periphery of the Gulf of Fonseca, Department of Choluteca, southern Honduras.

Description of Area/Region

Climate

Köppen classification **Aw***: *Humid tropical* group (A), *tropical wet-and-dry* type (w).

Temperatures	Precipitation
Mean annual air temperatures in the coastal regions are around 27°C. Monthly average maximum air temperatures near the Gulf range from 33°C during October and November to 38°C during April. Monthly minimum air temperatures range from 19°C in December to 24°C in April.	Annual rainfall averages 1450 mm, with most of this falling during the period from May through October (rainy season). Less than 12 mm rain is observed per month between December and April. River flows in the area fluctuate in accordance with precipitation; for example, the discharge of the Negro River becomes negligible during prolonged dry periods, and that of the Choluteca may be less than 2 m^3/s during such periods. The mean annual flow of the Choluteca is about 45m^3/s.
Humidity	**Seasonality**
Humidity is very low in Choluteca during the period from November to February.	The climate of southern Honduras is characterized by a distinct dry season, which lasts from November to April and is characterized by lower air temperatures and rainfall than during the rainy season.

Topography

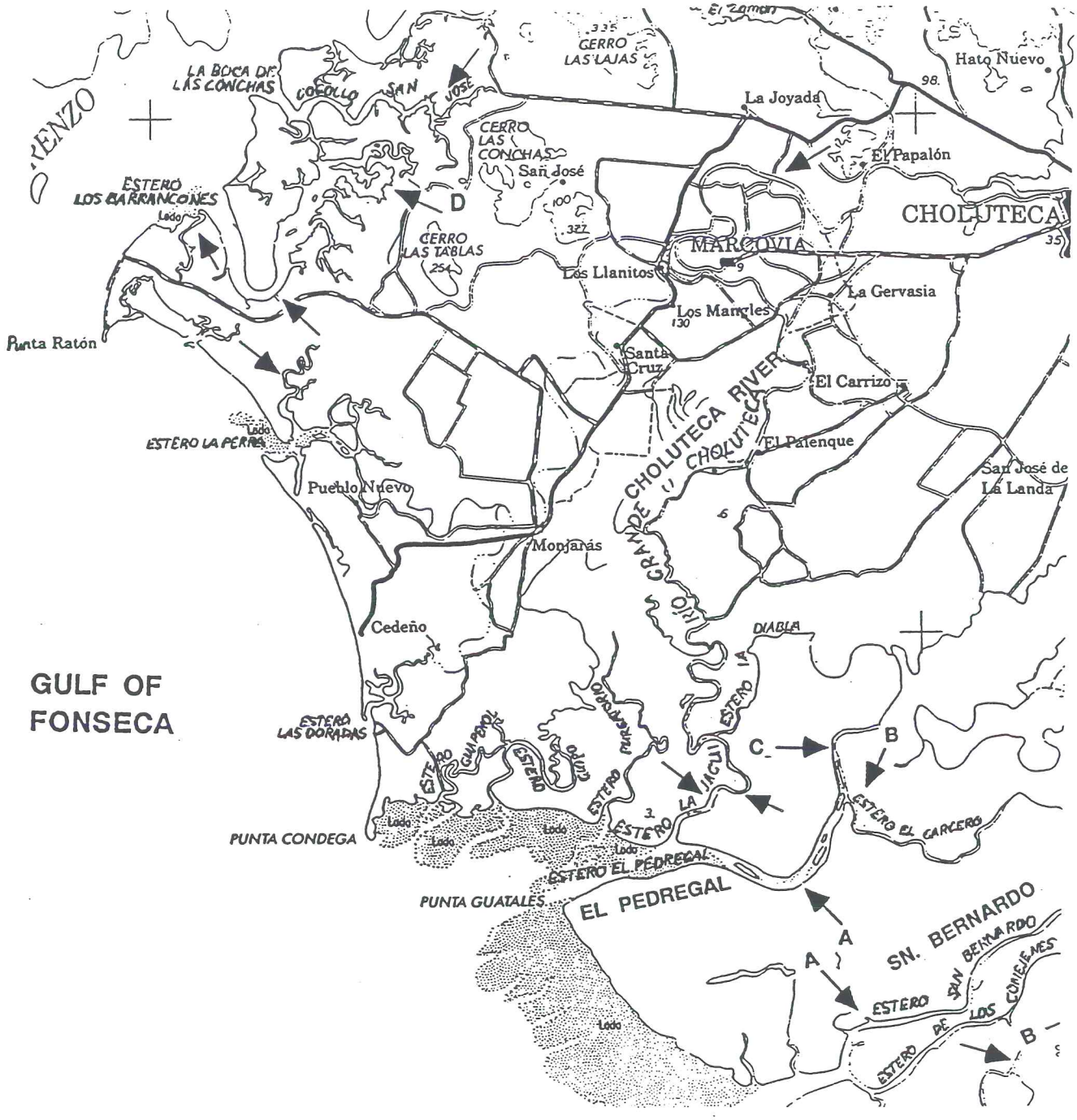
The Choluteca research area is in the low, coastal, estuarine environment of several major rivers and numerous embayments around the periphery of the Gulf of Fonseca. Mangrove forests fringe the Gulf, and coastal plains dominate the landscape up to 60 km inland from the Gulf.

Geology and Soils

The entire southern (Pacific) side of Central America is considered a seismic area, containing several active volcanoes. Soils in the study area are of volcanic origin, formed by processes of alluviation and sedimentation in a brackishwater environment.

* Asterisked items are defined or described in the glossary.

Layout of Choluteca



Map of study area in Southern Honduras bordering the Gulf of Fonseca. Letters and arrows indicate farms and sampling points where research has been conducted

Description of Choluteca

Map Coordinates	Elevation
13 20'N and 87 15'W	0m

General	Water Supply
The characteristics (e.g., size of ponds and total area in ponds) of the commercial shrimp-producing farms involved in CRSP research in this area vary widely, so descriptions of individual facilities are not included here.	Supply water for all shrimp farms in the area comes from estuaries of the Gulf of Fonseca, and is delivered to the farms by pumping. River flows are highly variable throughout the year, due to the distinct differences between the rainy and dry seasons. The Choluteca River, for example, may exhibit a dry season flow rate as low as 2 m^3/s, whereas it is as high as 1500 m^3/s during the rainy season. Quality of water is highly variable, depending on the specific source used (gulf embayment, Choluteca River, or riverine estuaries) and on the season. Seasonal differences are large in the rivers and riverine estuaries, but relatively minor in gulf embayments. Total alkalinity and salinity are higher in the estuaries during the dry season, but are kept relatively low by rainfall and river flow during the rainy season. Estuarine salinities may be near zero during the rainy season while reaching hypersaline levels during the dry season.

Soils

Ponds are excavated primarily in salt flats. Pond soils contain sodium concentrations as high as 10,000 mg/L and concentrations of calcium, magnesium, and potassium as high as 2100, 2300, and 1000 mg/L, respectively. Most soils in the area are alkaline, with pH values greater than 7 (range 6.73 - 7.49). Cation exchange capacities range from 19.5 to 22.1 meq/100 g soil, and clay percentages range from 20 to 45%, depending on the location.

Support Facilities at Choluteca

The La Lujosa Water Quality Laboratory is available for conducting all the water quality analyses needed in CRSP-sponsored studies. The research program is supported by the Honduran National Association of Aquaculturists (ANDAH), the Federation of Export Producers (FPX), and the Dirección General de Pesca y Acuicultura, Secretarĺa de Recursos Naturales, Honduras.

Affiliations

In-Country	US
Dirección General de Pesca y Acuicultura Secretaría de Recursos Naturales Gobierno de Honduras HONDURAS	Department of Fisheries and Allied Aquacultures Auburn University Auburn, Alabama 36849 USA

Current Contacts

In-Country	US
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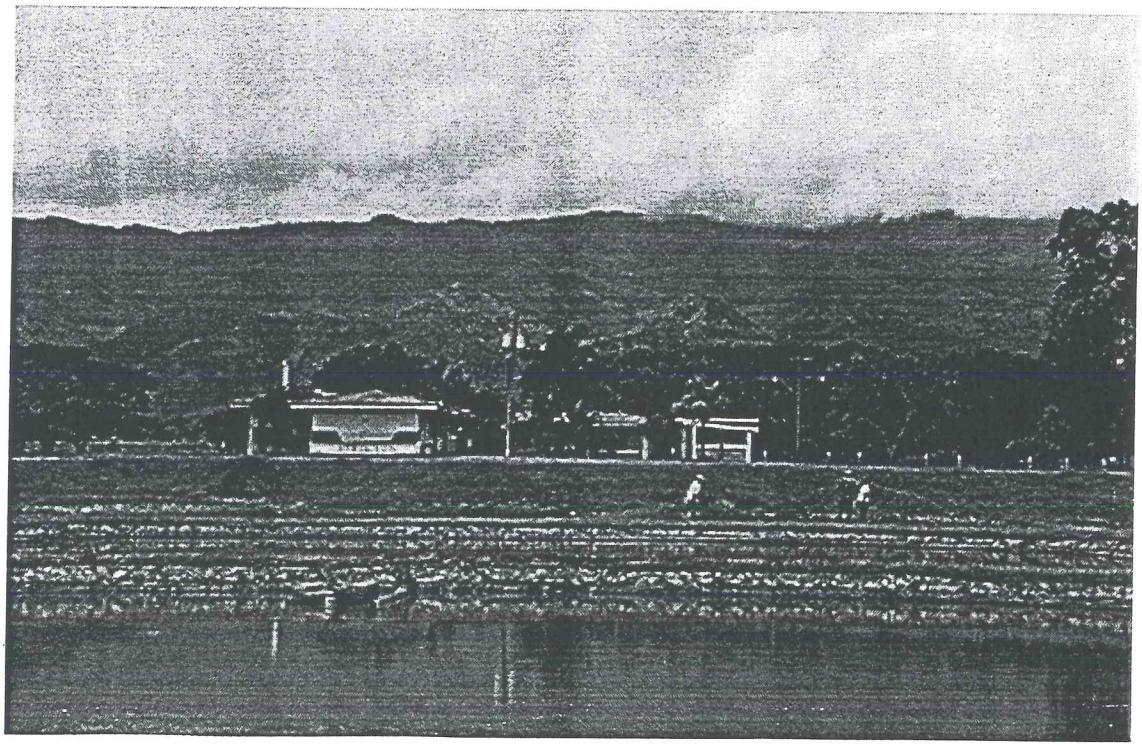
Notes:

El Carao



The El Carao National Fish Culture Research Center is located in the Comayagua Valley, in the mountainous area of central Honduras.

Drained tilapia spawning ponds at El Carao, showing drain structures and complete coverage of the pond bottom by tilapia nests.

El Carao
El Carao National Fish Culture Research Center
(Centro Nacional de Investigación Piscicola El Carao)

Site Status: Active Prime Site, 1983 - present
Location: Dirección Regional de Recursos Naturales, Comayagua, Comayagua, HONDURAS
Caption/Description: The El Carao Aquaculture Experiment Station is located in the Comayagua Valley, 8 km from the city of Comayagua and 131 km north of the capital city of Tegucigalpa, approximately halfway between the northern and southern coasts.

Description of Area/Region

Climate

Köppen classification **Aw***: *Humid tropical* group (A), *tropical wet-and-dry* type (w). The higher elevations in the interior mountains of Honduras temper the generally tropical climate of the region.

Temperatures	Precipitation
Mean annual air temperatures in the coastal regions are around 27°C, while those in the upland, interior areas are cooler, at about 21°C. Annual air temperatures at the El Carao station range from 19.6 to 31.0°C, with a mean of about 25.5°C. Pond water temperatures at El Carao average around 26.5°C.	The average annual rainfall of some mountain valley areas is just over 1000 mm, but rainfall may be over 2500 mm annually in northern coastal areas; at El Carao it is about 765 mm. During Cycle I of the CRSP experiments, rainy season precipitation was 565 mm, whereas it was 200 mm in the dry season.
Humidity	**Seasonality**
Mean annual humidity in Tegucigalpa (131 km to the south of Comayagua) is 74%. Humidity is lowest in March and April, when it is around 63%, and highest in September and October, at about 80 - 81%.	The climate of Honduras is characterized by a distinct dry season, which lasts from November to May and has both lower air temperatures and rainfall than does the rainy season. The average number of days with rain in Tegucigalpa (131 km southeast of Comayagua) ranges from 1 in January and February to 14 in September and October.

Topography

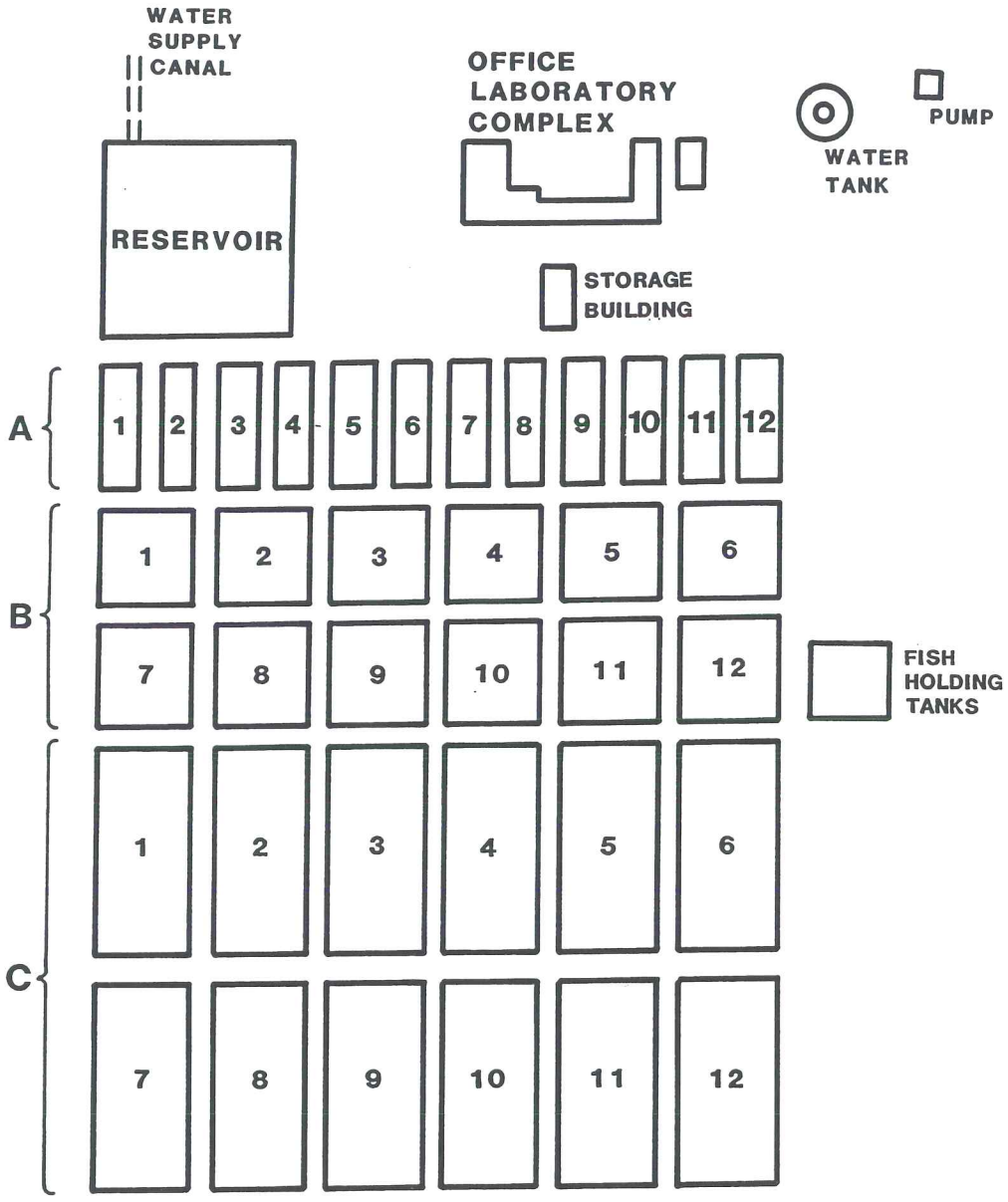
Most of the interior of Honduras is a plateau of fertile plains, broken by deep valleys and mountain ranges of volcanic origin, and with elevations in the range of 500 to 2000 m. The ridges of these ranges generally parallel the coastlines, running in a northwestern to southeastern direction. The town of Comayagua and the El Carao station are situated in the Comayagua Valley of this plateau area; elevations in the valley range from 550 to 750 m above sea level. The mountainous interior plateau is bracketed by two coastal strips—the 640-km northern coast along the Caribbean Sea and the short, 64-km strip on the Gulf of Fonseca on the Pacific.

Geology and Soils

Mountain ranges throughout Central America are a part of the Andes - Rockies mountain chain, formed by tectonic activity and stretching through the western portion of the Americas from Alaska to Chile. All of the Central American isthmus is considered semi-stable with respect to seismic activity, and the entire southern (Pacific) side is considered a seismic area, containing several active volcanoes. Soils are thus of volcanic origin.

* Asterisked items are defined or described in the glossary.

Layout of El Carao



"EL CARAO" AQUACULTURE EXPERIMENT STATION

COMAYAGUA, HONDURAS

NOTE: CRSP PONDS ARE NUMBERED B1 THROUGH B12

Description of El Carao

Map Coordinates	Elevation
14 26'N and 87 41'W	583 m
General	**Water Supply**
The El Carao Station is the largest of a series of aquaculture stations operated by the Ministry of Natural Resources. (Direccion General de Pesca y Acuicultura, Secretaria de Recursos Naturales). It has major responsibilities in production of tilapia*, Chinese carp*, tambaqui*, and guapote tigre* fingerlings for distribution to fish farmers. In addition, the station provides technical assistance to fish farmers, as well as a broad range of training courses. The station consists of offices, a water quality/biological limnology laboratory, a modest technical library, a storage building, and a complex of 36 ponds. The latter includes twelve ponds of 500 m^2, twelve 1000 m^2 ponds, and twelve 2000 m^2 ponds. All ponds have concrete sumps for fish harvesting. The twelve 1000 m^2 ponds were assigned to the CRSP. A wet lab area includes ten 20-m^2 and eight 2-m^2 concrete holding tanks and four 2-m diameter round concrete spawning tanks.	Water for the station is supplied by gravity from a 4000 m^2 reservoir, which itself is fed by irrigation canals originating at the Selguapa River. The wet lab area is supplied with water from an on-site well. Surface (canal) water is slightly alkaline, with a pH of approximately 8.0, a total alkalinity of about 30 - 43 mg/L, and a total hardness of about 23 - 31 mg/L. The wet lab is supplied with water from a well.
Soils	
The soils in the twelve CRSP-operated ponds average just over 50% clay in the upper 15 cm. The initial organic matter contents of the pond soils was relatively low, the highest level being about 1.3%. The soils are alkaline, with pH values of 8.0 to 8.9 and free $CaCO_3$ levels ranging from 3.8 to 9.6%. Accordingly there was no lime requirement for any of the CRSP-operated ponds. The CECs* of the El Carao soils ranged from 17.7 to 33.6 meq/100 g soil. Further details on the soil characteristics of pond soils at El Carao can be seen in the data tables.	

* Asterisked items are defined or described in the glossary.

Support Facilities at El Carao

Students from the Nacional Autonomous University of Honduras conduct senior thesis research and assist in various station activities at El Carao. The Honduran Foundation for Agricultural Research, La Lima, is used for soil and complete water analyses. Pelleted fish feeds are available from two in-country feed mills. A variety of agricultural by-products, e.g., corn gluten, wheat bran, rice bran, etc., are available from the various mills; some products are only available at agricultural supply stores; fertilizer is usually available. Layer chicken litter is widely available at low cost.

Affiliations

In-Country	US
Dirección General de Pesca y Acuicultura Secretaría de Recursos Naturales Gobierno de Honduras HONDURAS	Department of Fisheries and Allied Aquacultures Auburn University Auburn, Alabama 36849 USA

Current Contacts

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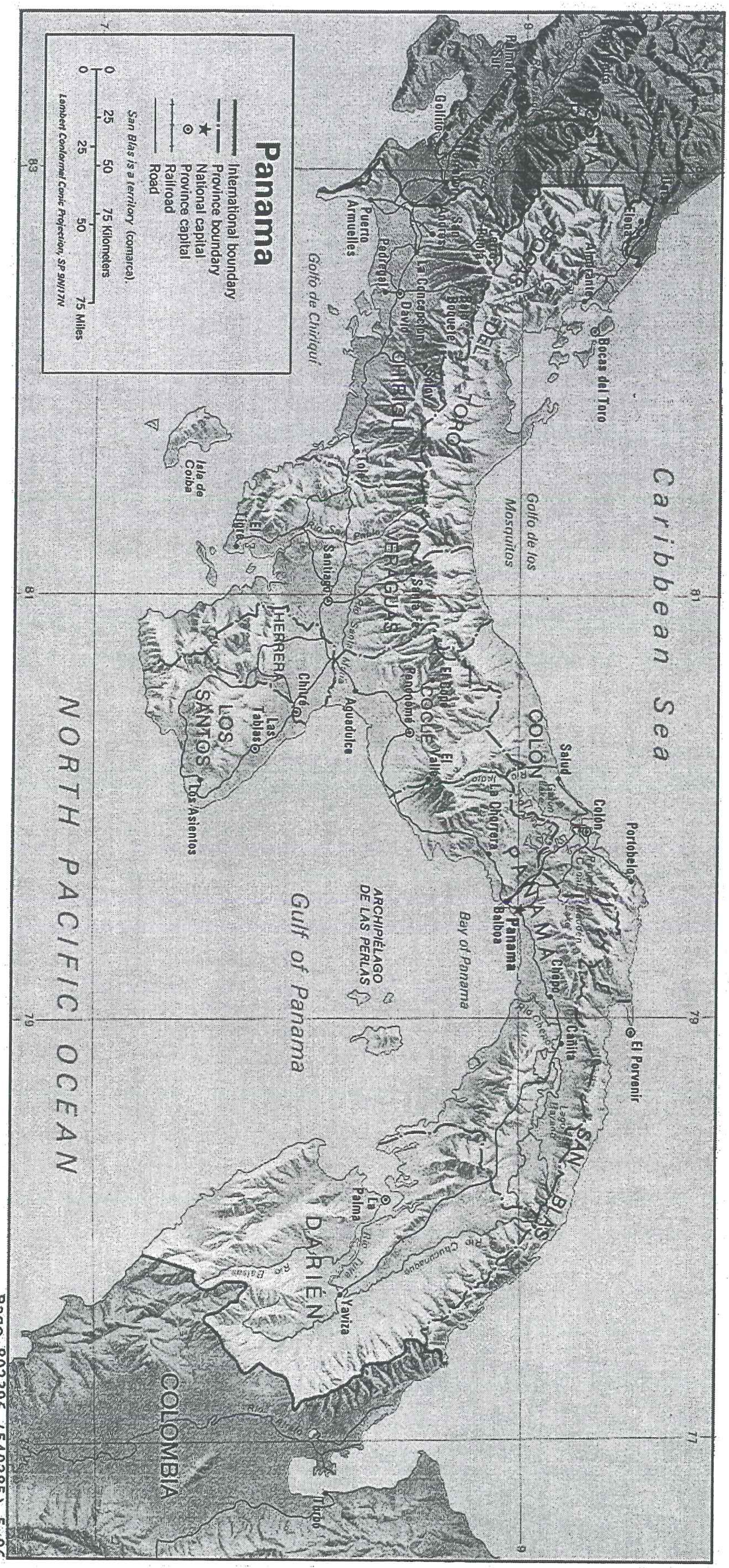

Panama
International boundary
Province boundary
National capital
Province capital
Railroad
Road
San Blas is a territory (comarca).
0 25 50 75 Kilometers
0 25 50 75 Miles
Lambert Conformal Conic Projection, SP 9N/17N
Caribbean Sea
NORTH PACIFIC OCEAN
Gulf of Panama
Bay of Panama
Golfo de Chiriquí
Golfo de los Mosquitos
ARCHIPIÉLAGO DE LAS PERLAS
Isla de Coiba
Bocas del Toro
BOCAS DEL TORO
CHIRIQUÍ
VERAGUAS
HERRERA
LOS SANTOS
COCLÉ
COLÓN
PANAMÁ
SAN BLAS
DARIÉN
COLOMBIA
Puerto Armuelles
David
Santiago
Chitré
Las Tablas
Los Asientos
Aguadulce
Penonomé
Colón
Portobelo
Salud
Panamá
Balboa
Chepo
El Porvenir
La Palma
Yaviza
Base 802396 (540285) 5-96

Aguadulce
Brackishwater Experiment Station "Ingeniero Enrique Ensenat" (BES)

Site Status: Former Prime Site, 1983 - 1987
Location: Aguadulce, Cocle, PANAMÁ
Caption/Description: The Ingeniero Enrique Ensenat Brackishwater Experiment Station is located approximately 5 km south of the town of Aguadulce, 0.5 km north of the Port of Aguadulce, and 190 km west of Panama City. It is within a zone of approximately 1500 ha of commercial shrimp farms adjacent to Parita Bay on the Pacific coast of Panama.

Description of Area/Region

Climate

Köppen classification **Aw***: *Humid tropical* group (A), *tropical wet-and-dry* type (w). Distinct rainy and dry seasons are observed.

Temperatures	Precipitation
Average annual temperatures for Panama as a whole range from 23 to 27°C. At higher altitudes in the interior regions the average annual temperature is nearer to 19°C. Average annual temperatures at the BES were between 23.8 and 33.5°C. This resulted in average pond water temperatures of 28.4°C.	Average annual rainfall for the Pacific side of the country is about 1650 mm; at the BES it was 1453 mm.
Humidity	**Seasonality**
Humidity is generally high during the rainy season, but lower during the remainder of the year.	Panama experiences a tropical wet-and-dry climate, with a dry season that lasts from December to April and rains during the remainder of the year. 26.5°C.

Topography

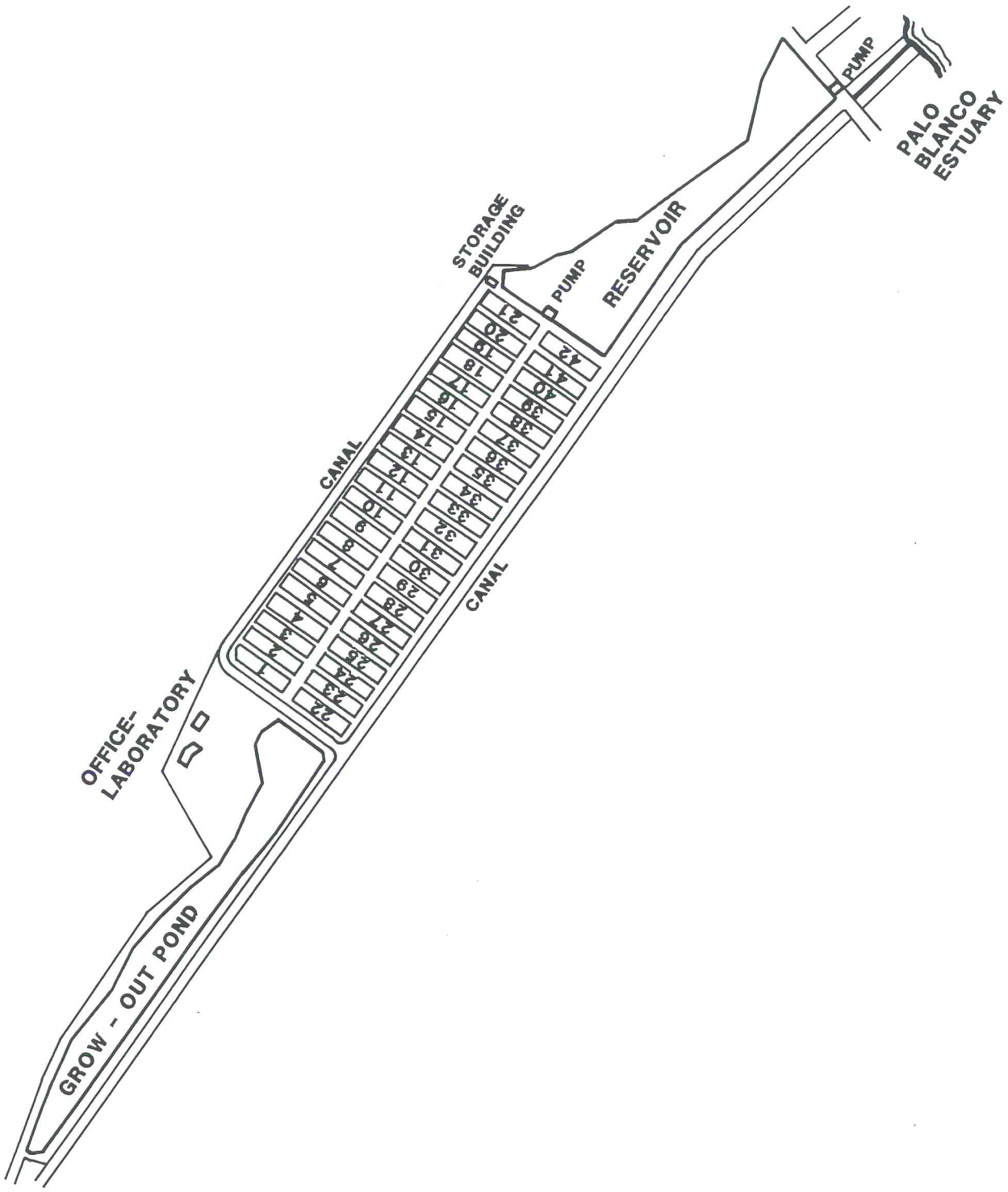
The area immediately around the station is characterized topographically by extensive mud flats and mangrove forests on the seaward side and coastal plain on the landward side.

Geology and Soils

Mountain ranges throughout Central America are a part of the Andes - Rockies mountain chain, stretching through the western portion of the Americas from Alaska to Chile. The Central American isthmus is considered semi-stable with respect to seismic activity, and the entire southern (Pacific) side is considered a seismic area, containing several active volcanoes. Soils in Panama are of volcanic origin, although in the flat coastal area around Aguadulce they are predominantly formed by recent alluvial processes, together with changes brought about by weathering, sedimentation, and exposure to seawater. Soils around Aguadulce have high clay contents, and the influence of seawater is reflected in relatively high contents of elements such as Na.

* Asterisked items are defined or described in the glossary.

Layout of Aguadulce



NOTE: CRSP PONDS ARE NUMBERED 4, 7, 13, 14, 16, 21, 25, 28, 34, 35, 37, 42.

Description of Aguadulce

Map Coordinates	Elevation
8°15'N and 80°29'W	0m

General	Water Supply
The Brackishwater Experiment Station (BES) was part of the aquaculture station network established and administered by the General Directorate of Aquaculture (Direccion Nacional de Acuicultura - DINAAC) of the Ministry of Agriculture Development (Ministerio de MIDA) of the government of the Republic of Panama. Its primary functions included both research and seed production. The BES consisted of two phases of earthen ponds. Phase 1 included 42 experimental ponds measuring from 500-650 m^2 in surface water area, a 1.4-ha reservoir pond, a 1.1-ha production pond, two pump stations, an office-laboratory building, a processing building, and a storage building. Phase 2 was located 1 km from Phase 1 and consisted of 10 production ponds ranging from 0.2 to 1.0 ha in area, a pump station, and a storage building.	Water for Phase 1 and Phase 2 was pumped from a branch of the Palo Blanco Estuary. The same branch served both as a source of water and a drainage canal for the BES and neighboring shrimp farms. Water to Phase 1 CRSP ponds was pumped by a diesel-powered hydraulic pump from the estuary to the 1.4-ha reservoir pond, then pumped to the ponds by a diesel-powered hydraulic pump. This water had a pH of between 7.2 and 8.6. Salinity ranged from about 10 ppt during the wet season to over 45 ppt during the dry season.

Soils

The texture of soils in the CRSP research ponds averaged 51% clay, 31% silt, and 16% sand, and they contained, on the average, approximately 1% organic matter (range of 0.7 to 1.5 in 12 ponds. They were approximately neutral, with pH values ranging from 6.4 to 7.6, and contained very little free $CaCO_3$ (0.2% in all ponds).

Support Facilities at Aguadulce

A joint agreement with the Agricultural Research Institute of Panama (IDIAP) allowed DINAAC to request occasional assistance in the analysis of feedstuffs and fertilizers and to determine concentrations of chemical constituents in water and soil samples. All fertilizer and feed was generally provided by DINAAC for the CRSP experiments. Organic fertilizer was in short supply, and inorganic fertilizer could be purchased in unmixed form from importers and blended to the desired combinations. University of Panama students conducted thesis research at the BES on special topics related to the pond dynamics trials. There was a small library at the BES; a larger collection was available at the DINAAC offices in Santiago, one hour from the BES.

Affiliations

In-Country	US
Dirección Nacional de Acuicultura (DINAAC) Ministerio de Desarrollo Agropecuario (MIDA) Santiago de Veraguas PANAMÁ	Department of Fisheries and Allied Aquacultures Auburn University Auburn, Alabama 36849 USA

Current Contacts

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Notes:

Gualaca Freshwater Aquaculture Research Station (Estacion Experimental Dulce Agricola de Gualaca)

Site Status: Former Prime Site, 1983 - 1987
Location: Estacion Experimental Dulce Acuicola de Gualaca, Agricoles de Panamá, Gualaca, Chiriquí, PANAMÁ
Caption/Description: The Gualaca Freshwater Aquaculture Research Station (Estacion Experimental Dulce Agricola de Gualaca) is located at the base of the Andes mountain chain, 2 km south of the town of Gualaca, in western Panama. The nearest city, David, is 27 km to the southwest.

Description of Area/Region

Climate

Köppen classification **Aw***: *Humid tropical* group (A), *tropical wet-and-dry* type (w). Distinct rainy and dry seasons are observed.

Temperatures	Precipitation
Annual air temperature at Gualaca ranges from 17 to 34°C, and pond water temperatures at the station range from 23 to 29°C.	Average annual rainfall at Gualaca is 4320 mm. Most of this rainfall occurs during the rainy season (May - November), with little rain falling between December and April.
Humidity	**Seasonality**
Mean annual relative humidity in the Gualaca area is 83%. It ranges from lows of 67 - 68% in February and March to highs of 88 - 90% during the period from June through November.	A distinct dry season, running from December through April, is observed in the Gualaca area. During this period there is often no rainfall. Towards the end of April rainfall begins to increase, reaching an average of 11 to 13 mm per day during May and June, slacking off a bit during July, then again increasing to a maximum of around 27 mm per day in September.

Topography

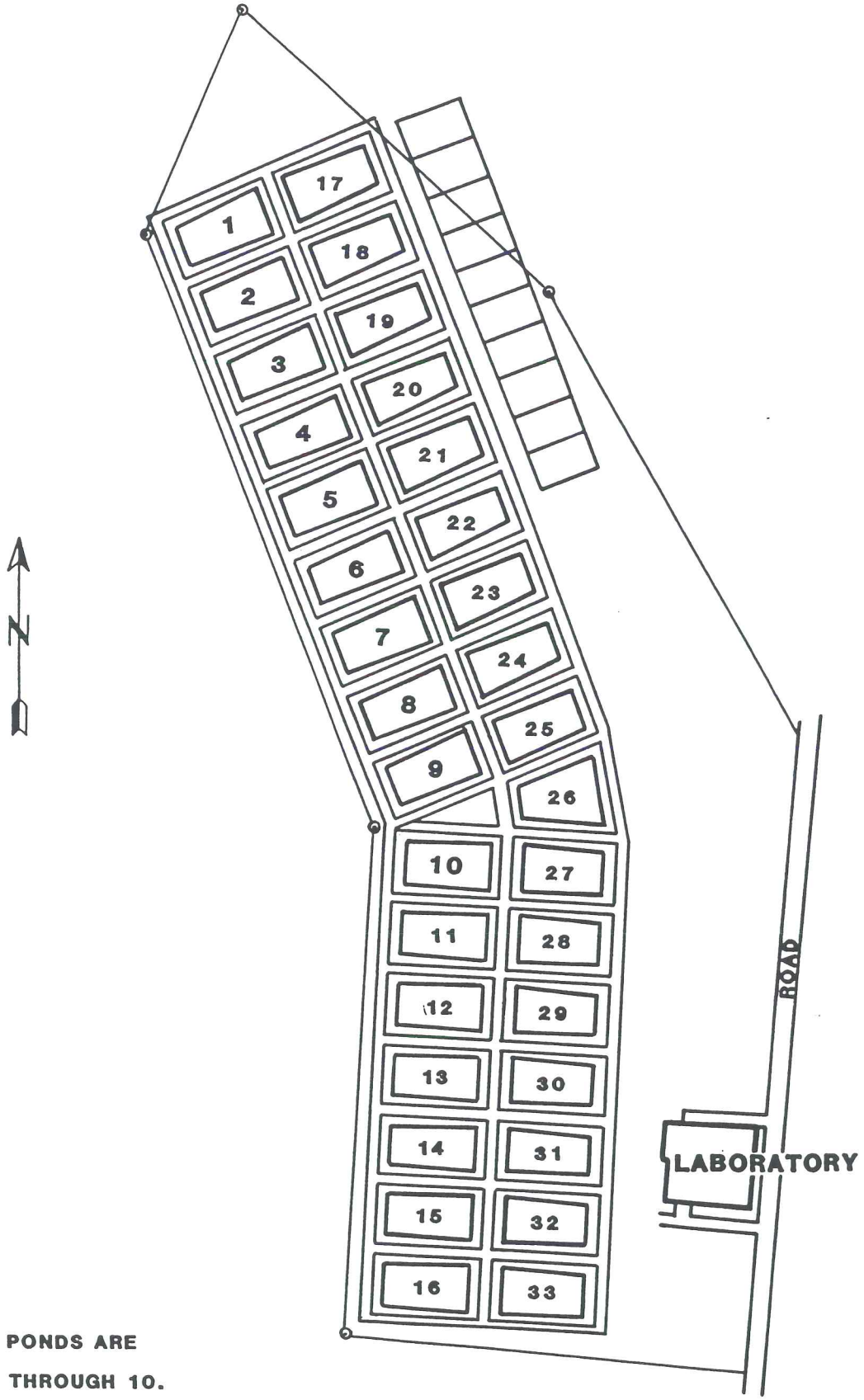
The Cordillera Central mountain chain forms the backbone of the portion of Panama west of the Panama Canal. Average elevations here range from 1000 to 2000 m, but the highest peaks, including the Volcan de Chiriqui, approximately 45 km northwest of Gualaca, rise to elevations of over 3350 m. Gualaca lies near the foot of the southern slopes of these mountains, at an elevation of 100 m, and approximately 25 km from the coast at the Gulf of Chiriqui on the Pacific Ocean.

Geology and Soils

Mountain ranges throughout Central America are a part of the Andes - Rockies mountain chain, formed by tectonic activity and stretching through the western portion of the Americas from Alaska to Chile. All of the Central American isthmus is considered only semi-stable with respect to seismic activity, and the entire southern (Pacific) side is considered a seismic area, containing several active volcanoes. Soils in Panama are thus of volcanic origin; those in the area around the Gualaca site are alluvial Inceptisols that are acidic and highly permeable.

* Asterisked items are defined or described in the glossary.

Layout of Gualaca



NOTE: CRSP PONDS ARE NUMBERED 1 THROUGH 10.

Description of Gualaca

Map Coordinates	Elevation
8 31'N and 82 19'W	100 m

General	Water Supply
The Gualaca station was built in 1984 to supply fingerlings of tilapia, carps, and other fish to producers in the area and to conduct aquacultural research. It is administered by DINAAC (Dirección Nacional de Acuicultura) but it also functions as part of an IDIAP (Instituto de Investigación Agropecuaria de Panamá) facility located in Gualaca. The station is comprised of 33 earthen ponds of 800 m^2, 10 earthen ponds of 300 m^2, a water analysis laboratory, a feed formulation laboratory, a wet laboratory for aquarium studies, a drive-in fish holding area with 16 concrete tanks equipped with gravity-fed running water, space for a fish hatchery, and a dormitory for students.	The water supply for the station is gravity fed by a canal (Quebrada del Pueblo), which diverts water from the Rio ChiriquÍ, a river draining the mountains north of the station. Water from these mountain watersheds are typically soft and infertile. At the beginning of CRSP research at this site (1983), water from the canal had a pH of 6.4 and low alkalinity and hardness readings of 18.4 and 14.6 mg/L (as $CaCO_3$), respectively.

Soils

The ponds at Gualaca were excavated in the alluvial soils that are typical of the area, but because these soils proved to be too permeable, a layer of red clay (Ultisol) material was later added in an attempt to reduce seepage. Ultisols are typically high in kaolinitic clay minerals, however, and although clay contents ranged from 24 to 36% in the Gualaca ponds, seepage remained high even after the ponds were lined. The soils were quite acidic at the beginning of CRSP work, with pH values ranging from 4.7 to 5.2 and base saturations between 8 and 13%. The cation exchange capacities of the soils were less than 24 meq/100 g. Organic matter in these pond soils ranged from 2.0 to 3.9%.

Support Facilities at Gualaca

During the time that the CRSP conducted research at the Gualaca aquaculture station it was jointly supported by IDIAP and DINAAC. IDIAP supplied the land, helped maintain the facility and paid the salary of the station manager. IDIAP also ran a chemical analysis and soil lab near the fish station, where feed, soils, and minor elements of water could be analyzed. Lab personnel provided expertise on topics related to local soils, chemical analysis, forage, and animal husbandry. A library with materials pertinent to aquaculture was located 2 1/2 hours away at DINAAC headquarters in Santiago. Fertilizer and limestone were readily available in David, and feed could be obtained in bulk from a supplier near Santiago. Additional personnel resources in the form of student labor were occasionally available from a branch of the University of Panama in David. These students had the option of doing their theses in an area of aquaculture or aquatic biology.

Affiliations

In-Country	US
Dirección Nacional de Acuicultura (DINAAC) Ministerio de Desarrollo Agropecuario (MIDA) Santiago de Veraguas PANAMÁ Instituto de Investigación Agropecuaria de Panamá (IDIAP) Gualaca, Chiriquí PANAMÁ	Department of Fisheries and Allied Aquacultures Auburn University Auburn, Alabama 36849 USA

Current Contacts

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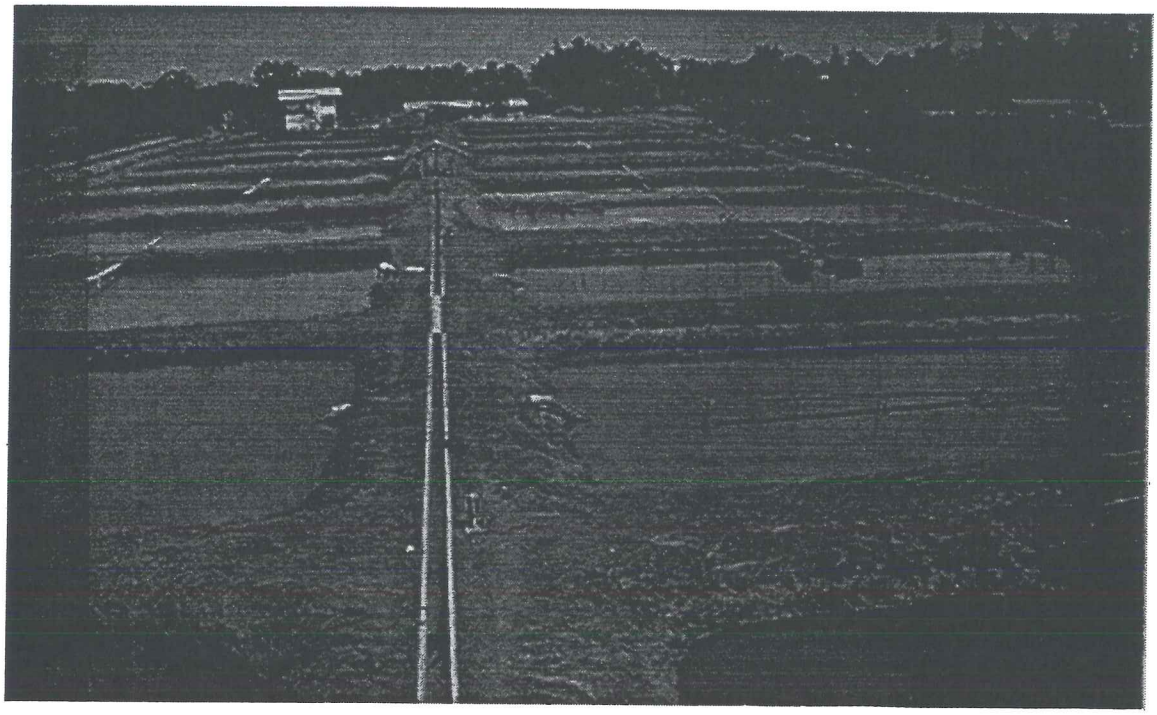
BURMA
LAOS
VIETNAM
CAMBODIA
Gulf of Tonkin
Andaman Sea
Gulf of Thailand
South China Sea
Strait of Malacca
MERGUI ARCHIPELAGO
Ko Chang
Ko Kut
Ko Phangan
Ko Samui
Ko Phuket
Ko Tarutao
Pulau Langkawi
Dao Phu Quoc
Con Dao
Hanoi
Ninh Binh
Thanh Hoa
Vinh
Ha Tinh
Dong Hoi
Ho Chi Minh City
Vung Tau
Can Tho
Ca Mau
Bien Hoa
Tay Ninh
Loc Ninh
Kratie
Stung Treng
Lumphat
Attapu
Champasak
Saravan
Khemmarat
Savannakhet
Muang Xepon
Muang Khammouan
Nakhon Phanom
Sakon Nakhon
Udon Thani (Udorn)
Nong Khai
Vientiane
Muang Pakxan
Muang Vangviang
Muang Xaignabouri
Luangphrabang
Muang Pakbang
Ban Ban
Tuong Duong
Muang Sing
Mong Nai
Mong Yon
Loi kaw
Chiang Rai
Mae Hong Son
Phayao
Chiang Mai
Nan
Lampang
Phrae
Mae Sariang
Nammeiok
Uttaradit
Loei
Sukhothai
Tak
Phitsanulok
Phetchabun
Phichit
Khon Kaen
Kalasin
Roi Et
Chaiyaphum
Nakhon Sawan
Chai Nat
Lop Buri
Buriram
Surin
Sisaket
Warin Chamrap
Ubon Ratchathani
Nakhon Ratchasima (Korat)
Kantharalak
Sara Buri
Phra Nakhon Si Ayutthaya
Suphan Buri
Nam Tok
Kanchanaburi
Tavoy
Ratchaburi
Bangkok
Samut Songkhram
Chon Buri
Aranyaprathet
Sisophon
Phnum Thbeng Meanchey
Samraong
Battambang
Phetchaburi
Mergui
Sattahip
Rayong
Trat
Pouthisat
Kampong Cham
Kracheh
Prachuap Khiri Khan
Krong Kaoh Kong
Phnom Penh
Svay Rieng
Kampot
Kampong Saom
Chumphon
Kawthaung
Ranong
Surat Thani
Takua Pa
Nakhon Si Thammarat
Phuket
Trang
Phatthalung
Kantang
Songkhla
Hat Yai
Pattani
Satun
Narathiwat
Kota Baharu
Alor Setar
Betong
MALAYSIA
Thailand
International boundary
National capital
Railroad
Road
0 50 100 150 Kilometers
0 50 100 150 Miles
Boundary representation is not necessarily authoritative. Names in Vietnam are shown without diacritical marks.
Base 800605 (B00150) 2-88

AIT



Earthen research ponds used for CRSP research at the Asian Institute of Technology (AIT) outside of Bangkok, Thailand.

Aquaculture research at the Asian Institute of Technology has also included work in the area of integrated aquaculture - agriculture systems, using pigs, buffaloes, ducks, vegetables, and goats in various combinations.

AIT
Asian Institute of Technology

Site Status: Active Prime Site, Southeast Asia, 1987 to present
Location: Km. 42, Klong Luang, Pathum Thani Province, THAILAND
Caption/Description: AIT is located near the town of Rangsit, in the southern portion of Thailand's central plain and approximately 40 km north of Bangkok.

Description of Area/Region

Climate

Köppen classification **Aw***: *Humid tropical* group (A), *tropical wet-and-dry* type (w). Distinct dry and rainy seasons are observed.

Temperatures**	Precipitation**
Annual averages for the area: 26.7 -28.9°C Range of monthly averages: 25.7 - 30.1°C Absolute minimum temps: 5.0 - 12.2°C Absolute maximum temps: 39.4 - 43.9°C	5.1 - 269.2 mm per month and 1092 - 1600 mm annually; low month is January, with an average of 1 day of precipitation, and high month is September, with an average of 21 days of precipitation.
Humidity**	**Seasonality**
A warm and humid atmosphere prevails throughout the year, with an annual mean relative humidity of 64 - 76%.	All of Thailand has clearly defined wet and dry seasons, with little temperature variation throughout the year; the *rainy season* is from May to October, the *cool dry season* is from November to February, and the *hot dry season* is from March to May; the hottest month is generally April, and the coolest is January.

Topography

The area is part of Thailand's vast, nearly level central alluvial plain (the Chao Phraya Plain or Menam Plain). A slope of 1:10,000 results in an elevation of just 4 m at Ayutthaya, which is approximately 60 km inland from Bangkok, and 23 m at Paknampho, which is 241 km from the Gulf. Many canals criss-cross the region, connecting the Chao Phraya and other rivers and providing communication links and irrigation. In the dry season tidal influences are clearly seen up to 80 km inland; in the rainy season flooding makes the area appear to be a single vast lake.

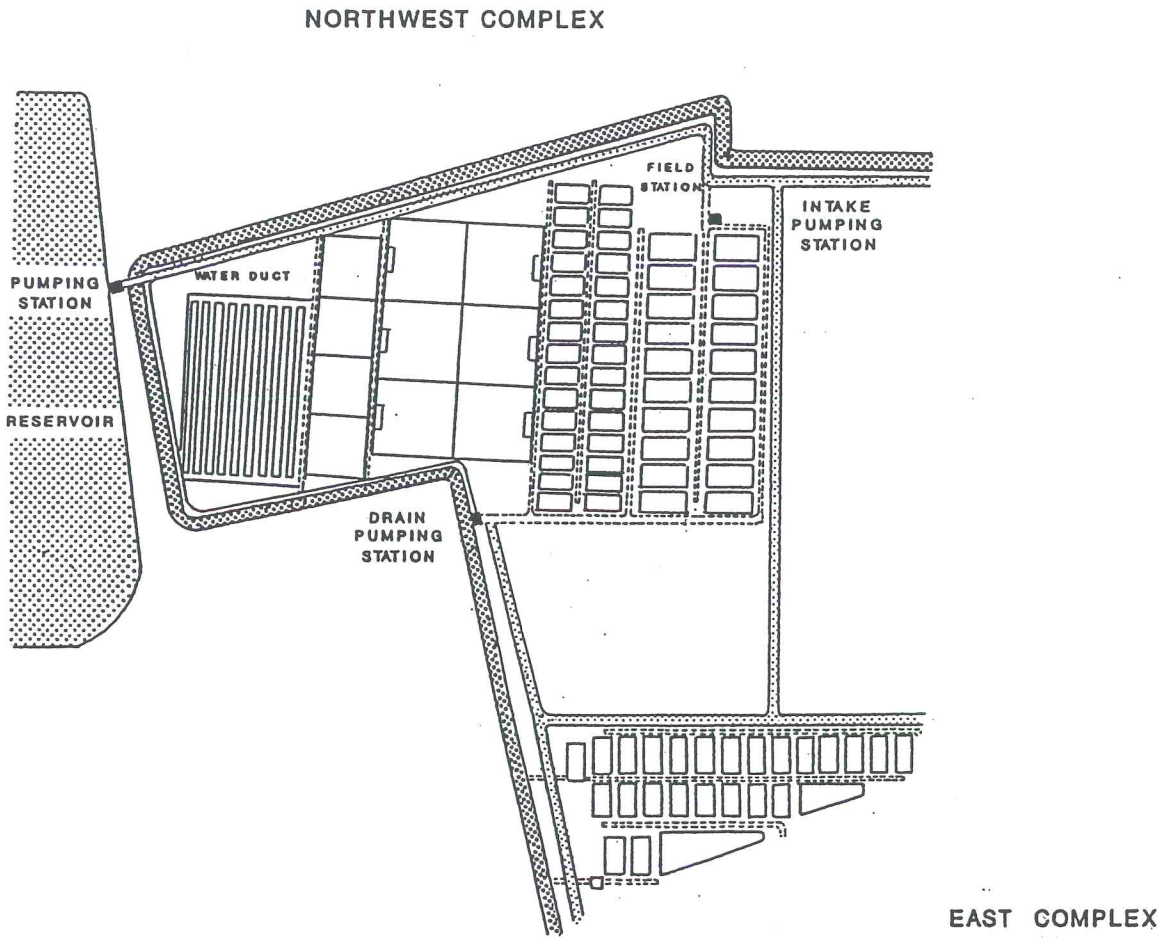
Geology and Soils

The central plain is in the basin of the Chao Phraya river and its tributaries. It was formed by the continual deposition of clays, silts, and sands by these rivers during annual flood periods, resulting in depths of alluvial material exceeding 100 m above bedrock in much of the area. The load of alluvial material carried by the Chao Phraya River has been estimated to extend the delta into the Gulf of Thailand by as much as 7 m annually. The plain is flanked in the north by the Uttaradit Mountains, in the west by the Bilauktaung Range (which forms the boundary with Burma), in the South by the Gulf of Thailand, and by the Khorat Plateau in the east. "Bangkok Dark Heavy Clay" soils are typical in the area around Rangsit and AIT. These soils have a developed profile to a depth of about 1.8 m, have nearly black surface layers, are typically low in organic matter, and are often saturated with ground water.

* Asterisked items are defined or described in the glossary.

** Data are for Rangsit, from the years 1927 - 1955.

Layout of AIT



Description of AIT

Map Coordinates	Elevation
14 20'N and 100 35'E	5m
General	**Water Supply**
The AIT campus occupies an area of approximately 160 hectares near the town of Rangsit, north of Bangkok. AIT's research pond complex is one of several aquacultural facilities operated by its *Agricultural and Food Engineering Division*. It includes about 150 earthen ponds, in sizes ranging from 200 to 2000 m^2, a 5-ha reservoir, 120 concrete tanks, and an area for growing terrestrial crops that may be of interest as fish feed components. An adjacent area is used for rearing livestock (ducks and goats) that can be used in integrated aquaculture/agriculture reasearch. Other facilities include a 500 m^2 laboratory complex that houses instruments for measurement of the biological, physical, and chemical parameters of importance in aquaculture, a covered fish feed preparation area, a fish harvest processing area, and a covered hatchery area. The hatchery facility includes 100 indoor rearing tanks and a water conditioning and recirculating system.	Supply water for the AIT pond complex comes from a rain-fed canal and reservoir. In 1995 the pH of this source was 7.3 and the total alkalinity was about 84 mg/L. Ammonia-N was 6.16 mg/L, and nitrate-nitrite was 0.01 mg/L. Reactive phosphorus was measured at 0.02 mg/L and total phosphorus PO_4-P was 0.15 mg/L.
Soils	
The pond soils at AIT (20 ponds) are quite acidic, with pH values averaging between 3.6 and 4.5. They have clay contents averaging 51% and organic matter contents averaging 1.08%.	

Support Facilities at AIT

AIT has a close working relationship with the Royal Thai Department of Fisheries, NACA (Network of Aquacultural Centers for Asia), and Kasetsart University. In addition to opportunities for collaboration in research and facility sharing, an internet website (FISHNET) relating to fish nutrition, aquatic animal health, and professional services in aquaculture is being initiated.

Affiliations

In-Country	US
Agricultural and Aquatic Systems Program Asian Institute of Technology Bangkok THAILAND Department of Fisheries Kasetsart University Campus Bangkhen Bangkok THAILAND	School of Natural Resources and Environment The University of Michigan Ann Arbor, Michigan USA

Current Contacts

In-Country	US
Dr. C. K. Lin Agricultural and Aquatic Systems Program Asian Institute of Technology G.P.O. Box 2754 Bangkok 10501 THAILAND TEL: 66-2-524-5458 FAX: 66-2-524-6200 or 66-2-516-2126 e-mail: lin@rccsun.ait.ac.th	Dr. James Diana School of Natural Resources & Environment The University of Michigan Dana Building, 430 E. University Ann Arbor, MI 48109-1115 USA TEL: 1-313-763-5834 FAX: 1-313-936-2195 e-mail: jimd@umich.edu

PD/A CRSP Site Descriptions

Notes:

Ayutthaya

Sampling of CRSP tilapia ponds at the Ayutthaya Freshwater Fisheries Station, which is located near the town of Bang Sai, near Ayutthaya, in the central plain of Thailand.

The Ayutthaya site, like those at AIT and Nong Sua, is located in the vast Chao Phraya Plain of central Thailand. Elevations throughout much of this area are so low that tidal influences are seen up to 80 km inland during the dry season.

Ayutthaya
Ayutthaya Freshwater Fisheries Station

Site Status: Active Prime Site, Thailand, 1984 to present
Location: Ayutthaya Freshwater Fisheries Station, Bang Sai, Ayutthaya Province, THAILAND
Caption/Description: The Ayutthaya Freshwater Fisheries Station is located at Bang Sai, near the town of Ayutthaya in Thailand's central plain, and approximately 60 km north of Bangkok. It is approximately 30 km east of the Asian Institute of Technology (AIT) research site.

Description of Area/Region

Climate
Köppen classification **Aw***: *Humid tropical* group (A), *tropical wet-and-dry* type (w). Distinct dry and rainy seasons are observed.

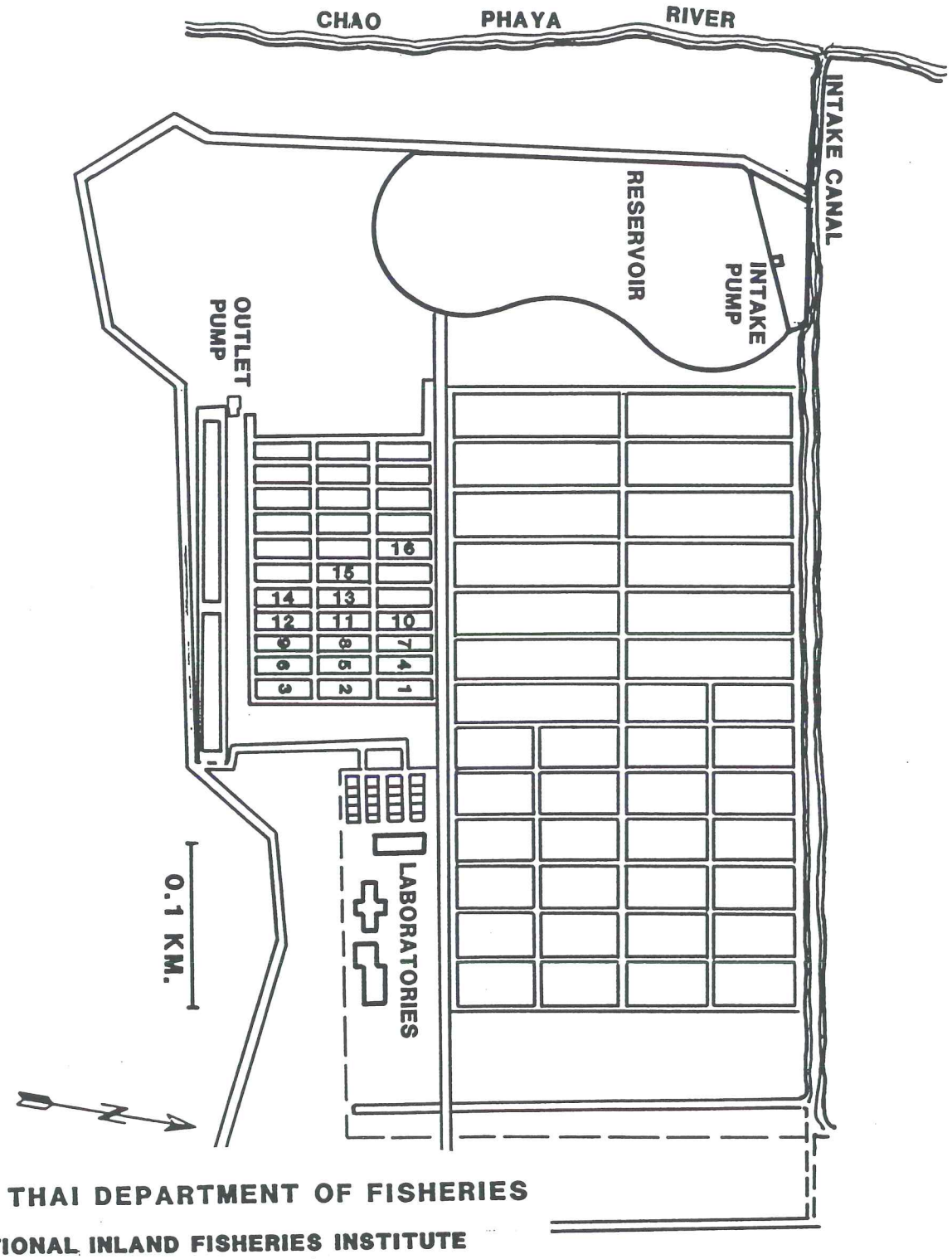
Temperatures**	Precipitation**
Annual averages for the area: 26.7 -28.9°C Range of monthly averages: 25.7 - 30.1°C Absolute minimum temps: 5.0 - 12.2°C Absolute maximum temps: 39.4 - 43.9°C	5.1 - 269.2 mm per month and 1092 - 1600 mm annually; low month is January, with an average of 1 day of precipitation, and high month is September, with an average of 21 days of precipitation.
Humidity**	**Seasonality**
A warm and humid atmosphere prevails throughout the year, with an annual mean relative humidity of 64 - 76%.	All of Thailand has clearly defined wet and dry seasons, with little temperature variation throughout the year; the *rainy season* is from May to October, the *cool dry season* is from November to February, and the *hot dry season* is from March to May; the hottest month is generally April, and the coolest is January.

Topography
The area is part of Thailand's vast, nearly level central alluvial plain (the Chao Phraya Plain or Menam Plain). A slope of 1:10,000 results in an elevation of just 4 m at Ayutthaya, which is approximately 60 km inland from Bangkok, and 23 m at Paknampho, which is 241 km from the Gulf. Many canals criss-cross the region, connecting the Chao Phraya and other rivers and providing communication links and irrigation. In the dry season tidal influences are clearly seen up to 80 km inland; in the rainy season flooding makes the area appears to be a single vast lake.
Geology and Soils
The central plain is in the basin of the Chao Phraya River and tributaries. It was formed by continual deposition of clays, silts, and sands during annual flood periods, resulting in depths of alluvial material exceeding 100 m above bedrock in much of the area. The load of alluvial material carried by the Chao Phraya River has been estimated to extend the delta into the Gulf of Thailand by as much as 7 m annually. The plain is flanked in the north by the Uttaradit Mountains, in the west by the Bilauktaung Range (which forms the boundary with Burma), in the South by the Gulf of Thailand, and by the Khorat Plateau in the east. "Bangkok Dark Heavy Clay" soils are typical in the area around Ayutthaya. These soils have a developed profile to a depth of about 1.8 m, have nearly black surface layers, are typically low in organic matter, and are often saturated with ground water.

* Asterisked items are defined or described in the glossary.

** Data are for Rangsit, from the years 1927 - 1955.

Layout of Ayutthaya



ROYAL THAI DEPARTMENT OF FISHERIES

NATIONAL INLAND FISHERIES INSTITUTE

NOTE: CRSP PONDS ARE NUMBERED 1 THROUGH 16.

Description of Ayutthaya

Map Coordinates	Elevation
14 11'N and 100 30'E	5m
General	**Water Supply**
The Ayutthaya station covers a total area of 32 hectares, which includes an office building, laboratory, hatchery complex, a pumping station, 20 concrete ponds, 68 earthen ponds varying in size between 400 and 3200 m^2, a 29,200 m^2 reservoir, and staff housing. Sixteen ponds, each approximately 245 m^2 in area, were available for CRSP research when Ayutthaya was the active site in Thailand.	The water is pumped to the reservoir from which it is supplied to the ponds by gravity flow or pumping. Water supplied from the reservoir is alkaline, with a pH of about 8.6 and a total alkalinity of 92 mg/L. Ammonia is about 0.038 mg/L, nitrate-nitrite about 0.033 mg/L, total phosphorus about 0.05 mg/L, and orthophosphate less than 0.005 mg/L.
Soils	
The soils at the Ayutthaya station have high clay and low sand contents. The clay fraction in ponds used by the CRSP averages about 66%, whereas the sand fraction averages about 11%. The soils are alkaline, with an average pH of 7.4 and relatively high calcium and magnesium contents. They have relatively low organic matter contents, averaging around 0.75% in the CRSP-operated ponds.	

Support Facilities at Ayutthaya

Laboratory and personnel at the National Inland Fisheries Institute (NIFI) and the Faculty of Fisheries at Kasetsart University are available to the CRSP project. NIFI has an adequate library, including FAO literature. Fish feeds are available through either commercial dealers or manufactured by NIFI's nutrition department. Organic fertilizers are abundantly available from local farms.

Affiliations

In-Country	US
National Inland Fisheries Institute Royal Thai Department of Fisheries Bangkok THAILAND	School of Natural Resources & Environment The University of Michigan Ann Arbor, Michigan USA

Current Contacts

In-Country	US
Dr. C. K. Lin Agricultural and Aquatic Systems Program Asian Institute of Technology G.P.O. Box 2754 Bangkok 10501 THAILAND TEL: 66-2-524-5458 FAX: 66-2-524-6200 or 66-2-516-2126 e-mail: lin@rccsun.ait.ac.th	Dr. James Diana School of Natural Resources & Environment The University of Michigan Dana Building, 430 E. University Ann Arbor, MI 48109-1115 USA TEL: 1-313-763-5834 FAX: 1-313-936-2195 e-mail: jimd@umich.edu

Notes:

Nong Sua
Nong Sua Fish Hatchery

Site Status: Former Prime Site, Thailand, 1983 - 1984
Location: Nong Sua Fish Hatchery, Nong Sua, Pathum Thani Province, THAILAND
Caption/Description: The Nong Sua Fish Hatchery is located on the eastern edge of Thailand's Chao Phraya plain, near the village of Nong Sua, and approximately 100 km northeast of Bangkok.

Description of Area/Region

Climate

Köppen classification **Aw***: *Humid tropical* group (A), *tropical wet-and-dry* type (w). Distinct dry and rainy seasons are observed.

Temperatures**	Precipitation**
Annual averages for the area: 26.7 -28.9°C Range of monthly averages: 25.7 - 30.1°C Absolute minimum temps: 5.0 - 12.2°C Absolute maximum temps: 39.4 - 43.9°C	5.1 - 269.2 mm per month and 1092 - 1600 mm annually; low month is January, with an average of 1 day of precipitation, and high month is September, with an average of 21 days of precipitation.
Humidity**	**Seasonality**
A warm and humid atmosphere prevails throughout the year, with an annual mean relative humidity of 64 - 76%.	All of Thailand has clearly defined wet and dry seasons, with little temperature variation throughout the year; the *rainy season* is from May to October, the *cool dry season* is from November to February, and the *hot dry season* is from March to May; the hottest month is generally April, and the coolest is January.

Topography

The area is part of Thailand's vast, nearly level central alluvial plain (the Chao Phraya Plain or Menam Plain). A slope of 1:10,000 results in an elevation of just 4 m at Ayutthaya, which is approximately 60 km inland from Bangkok, and 23 m at Paknampho, which is 241 km from the Gulf. Many canals criss-cross the region, connecting the Chao Phraya and other rivers and providing communication links and irrigation. In the dry season tidal influences are clearly seen up to 80 km inland; in the rainy season flooding makes the area appears to be a single vast lake.

Geology and Soils

The central plain is in the basin of the Chao Phraya River and tributaries. It was formed by the continual deposition of clays, silts, and sands during annual flood periods, resulting in depths of alluvial material exceeding 100 m above bedrock in much of the area. The load of alluvial material carried by the Chao Phraya River has been estimated to extend the delta into the Gulf of Thailand by as much as 7 m annually. The plain is flanked in the north by the Uttaradit Mountains, in the west by the Bilauktaung Range (which forms the boundary with Burma), in the South by the Gulf of Thailand, and by the Khorat Plateau in the east. "Ongkharak Clays" are typical of the soils in the area around the Nong Sua site. These soils typically have a black surface layer with dark organic matter and are usually very acid.

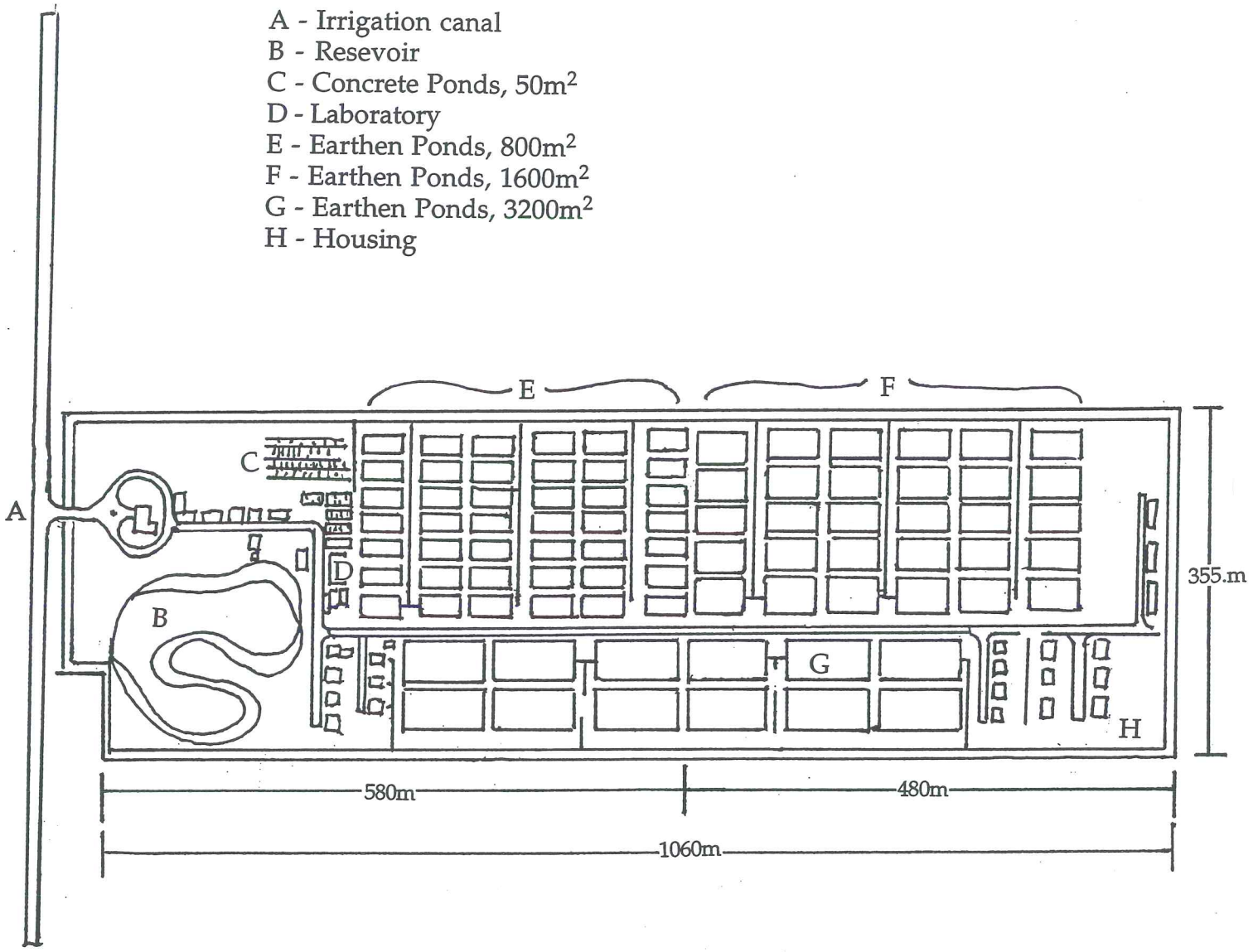
* Asterisked items are defined or described in the glossary.

** Data are for Rangsit, from the years 1927 - 1955.

Layout of Nong Sua

Legend:

A - Irrigation canal
B - Resevoir
C - Concrete Ponds, 50m^2
D - Laboratory
E - Earthen Ponds, 800m^2
F - Earthen Ponds, 1600m^2
G - Earthen Ponds, 3200m^2
H - Housing



Description of Nong Sua

Map Coordinates	Elevation
14 11'N and 100 54'E	5m
General	**Water Supply**
The Nong Sua facility covered a total of 38 ha. Pond facilities included 50 10-m^2 concrete ponds, 30 50-m^2 concrete ponds, 42 800-m^2 earthen ponds, 30 1600-m^2 earthen ponds, 12 3000-m^2 earthen ponds, and a 14,500-m^2 reservoir. In addition to the ponds, there were an office building, 2 laboratories, 30 staff housing units, a water tower and treatment pond, a pumping station, and a storage building.	The water supply for the station was from the Krong Yai irrigation canal, which filled the station reservoir through a sluice gate. Water for the irrigation canal came from the Chao Phraya River. Fish ponds received their water from the reservoir through a series of primary and secondary concrete inlets. The ponds could be filled by gravity flow when the reservoir water level was greater than 5 m. Pumping was occasionally required to fill the ponds. Water quality in the canal was adversely affected by large quantities of silt from the Chao Phraya, leachates from the acid sulfate soils of the area, and a variety of pesticides from nearby plantations. The oxygen content of the water was often low, particularly during the dry season, and nutrient levels were too low to be detected.
Soils	
The soils at Nong Sua are typical acid sulfate soils, with pH readings averaging 4.1 for the 12 ponds used in CRSP research. The highly acidic nature of these soils was reflected in their lime requirements, which ranged between 16.6 to 21.05 tons/ha during the first CRSP experiments at Nong Sua. Aluminum concentrations in the soils were relatively high, averaging 1131 ppm. The clay content of these soils was also very high, averaging close to 67%, and the sand content was correspondingly low, averaging just 9.8%.	

Support Facilities at Nong Sua

Excellent logistic and facility support was received by the CRSP project at Nong Sua. Almost all of the laboratories and personnel at the National Inland Fisheries Institute (NIFI) and the Faculty of Fisheries at Kasetsart University were accessible for the project. In addition, many laboratories of the Thai Department of Agriculture were located on the Kasetsart campus and available to the project on request. There was a moderate library facility at NIFI. Fish feeds were available either from commercial dealers or from NIFI's nutrition section. Both organic and inorganic fertilizers were readily available in the area.

Affiliations

In-Country	US
National Inland Fisheries Institute Royal Thai Department of Fisheries Bangkok THAILAND	School of Natural Resources & Environment The University of Michigan Ann Arbor, Michigan USA

Current Contacts

In-Country	US
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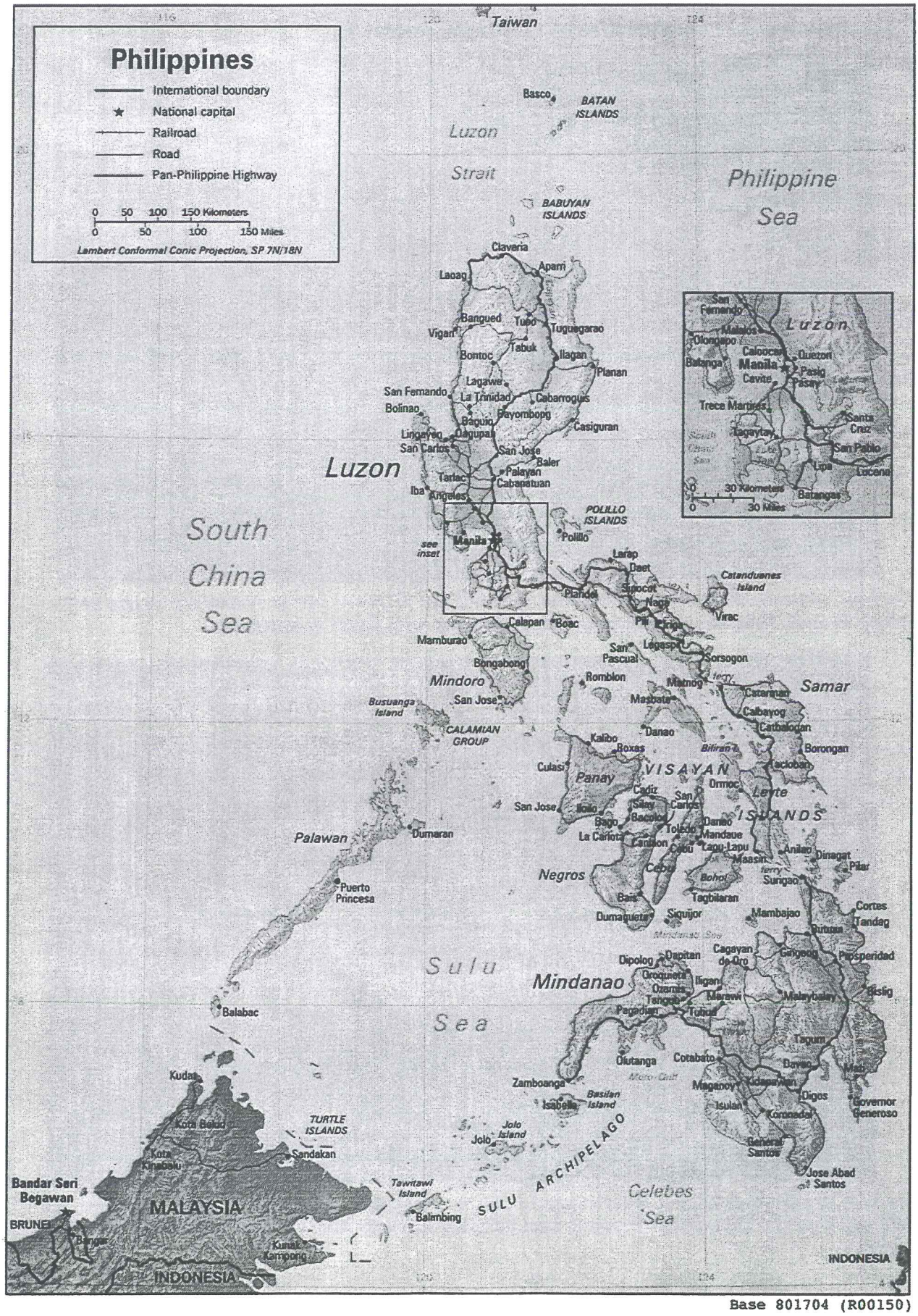
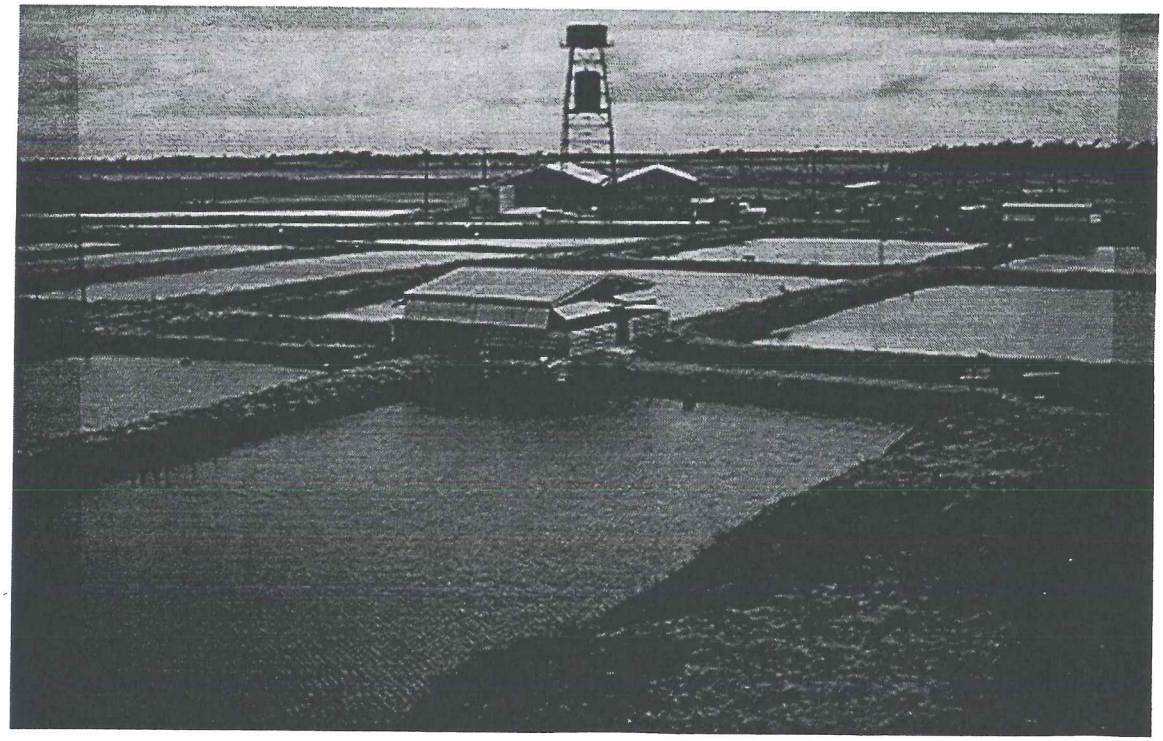


Base 801704 (R00150)

Freshwater Aquaculture Center/Central Luzon State University

The FAC has over 100 earthen ponds, some up to 2500 m^2. CLSU's College of Fisheries shares FACs technical staff, facilities, and research responsibilities with CRSP researchers.



The FAC is located at Munoz, Nueva Ecija, Luzon, in a vast, low - lying alluvial plain known as the "rice bowl" of the Philippines. Research here includes a considerable effort in the area of rice - fish systems.

Freshwater Aquaculture Center (FAC)
Central Luzon State University

Site Status: Active Companion Site; 1992 - present
Location: Central Luzon State University, Munoz, Nueva Ecija, PHILIPPINES
Caption/Description:
FAC is located at the northeastern most extension of Central Luzon State University, 1.5 km from the main university campus. CLSU is 3.5 km northeast of the town of Munoz, in the province of Nueva Ecija. Munoz is approximately 150 km north of Manila, and lies in the heart of the central valley of Luzon, which is the "rice bowl" of the Philippines.

Description of Area/Region

Climate

Köppen classification **Aw***: *Humid tropical* group (A), *tropical wet-and-dry* type (w).

Temperatures	Precipitation
The average annual temperature in the province of Nueva Ecija is 27.8°C. In 1995 the maximum and minimum air temperatures at the FAC were 35.5 and 23.1°C, respectively.	Average annual rainfall in the province is about 2250 mm. Most of the rainfall occurs between the months of May and October.
Humidity	**Seasonality**
Mean annual relative humidity is normally in the range of 74 to 78%. It is hot and dusty from March to May.	There are two distinct seasons in this part of the Philippines. The dry season begins in about December and lasts through April or May, and the rainy season begins in June and continues through November.

Topography

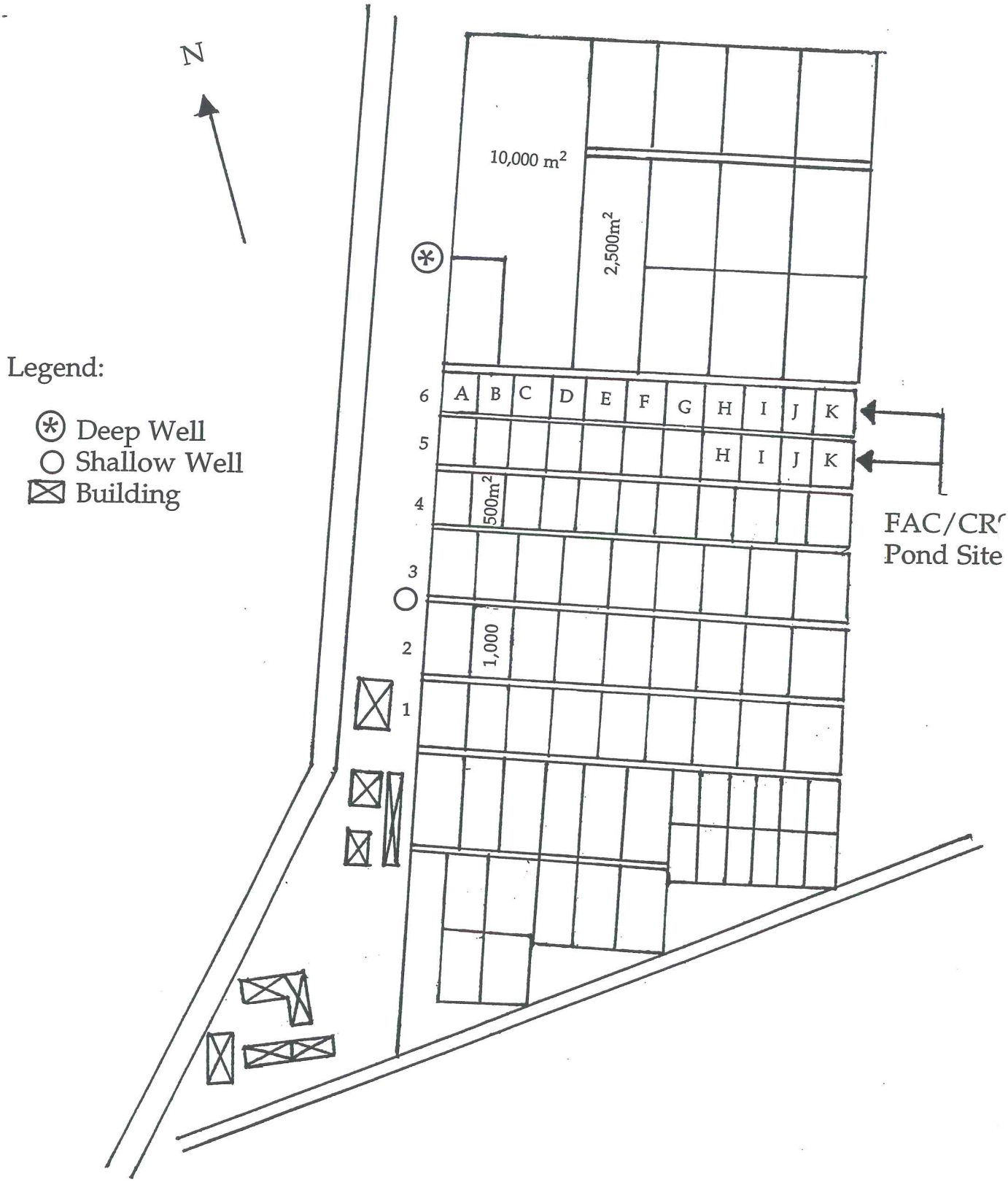
The central valley is a vast, relatively flat lowland that stretches approximately 150 km from Manila Bay in the south to the Lingayen Gulf on the western coast of Luzon. The elevation of most of this lowland area is less than 40 m. The Zambales Mountains flank the plain to the west, while the Sierra Madre range lies on its eastern side.

Geology and Soils

The Philippines archipelago is part of a major western Pacific seismic fault system. The entire region is characterized by active volcanoes (12 of them in the Philippines), and all of the Philippine islands are subject to occasional earthquakes. Many of the peaks of the rugged mountains that make up the Philippine islands are dormant or extinct volcanoes. Soils in the central valley of Luzon are largely alluvial, clayey, and alkaline.

* Asterisked items are defined or described in the glossary.

Layout of Freshwater Aquaculture Center



Description of Freshwater Aquaculture Center

Map Coordinates	Elevation
15 43'N and 120 54'E	30 m
General	**Water Supply**
FAC is a semi-autonomous unit in the University, loosely linked with the Research, Extension and Training Unit (RET) of CLSU in its organizational and management structure, such that RET only monitors FAC's activities. FAC is a separate unit parallel in status to the College of Fisheries (CF). At present the two units are sharing technical staff and facilities. The total work force is 60. The senior staff (14) devote half of their time to research at the Center and the other half to academic duties in the CF and Department of Aquaculture, Institute of Graduate Studies. Pond facilities include 98 earthen ponds ranging in size from 400 to 2500 m^2. Twelve 500 m^2 ponds are assigned to the CRSP research program. Additional ponds are being used by the University College of Swansea-FAC Project on "YY-GMT"; another 8 ha are used as ICLARM-BFAR-CLSU "GIFT" breeding facilities, and there is a rice-fish experimental area. There are numerous concrete and fiberglass tanks and a hatchery/wet lab building. The Center maintains laboratories equipped with facilities and equipment for fish physiology, soil and water quality analytical chemistry, fish pathology, fish nutrition, and feed development.	Water comes to the station through open canals from the 8420-ha Pantabangan Reservoir, which is located about 30 km from the FAC. Two deep wells and six shallow wells provide additional water for the Center.
Soils	
Pond soils at the FAC have very high clay contents, with an average of 62.5% for the ponds used in CRSP experiments. In 1993 the mean CEC* for the CRSP ponds was 38.8 meq/100 g; exchangeable base measurements were 23.7, 14.5, and 1.1 meq/100 g for Ca, Mg, and Na, respectively. The soils are alkaline, with base saturation* values of 100% and an average pH of 7.6.	

* Asterisked items are defined or described in the glossary.

Support Facilities at Freshwater Aquaculture Center

The Center has more than ten PC's, and the e-mail and FAX machines of the UCS-FAC project are available for use by other FAC staff. Eight to twelve local and international graduate students conduct their research at the FAC each year. Improved breeds of tilapia, carp, and catfish, feeds and fertilizers, and labor for pond operation and maintenance are always readily available.

Affiliations

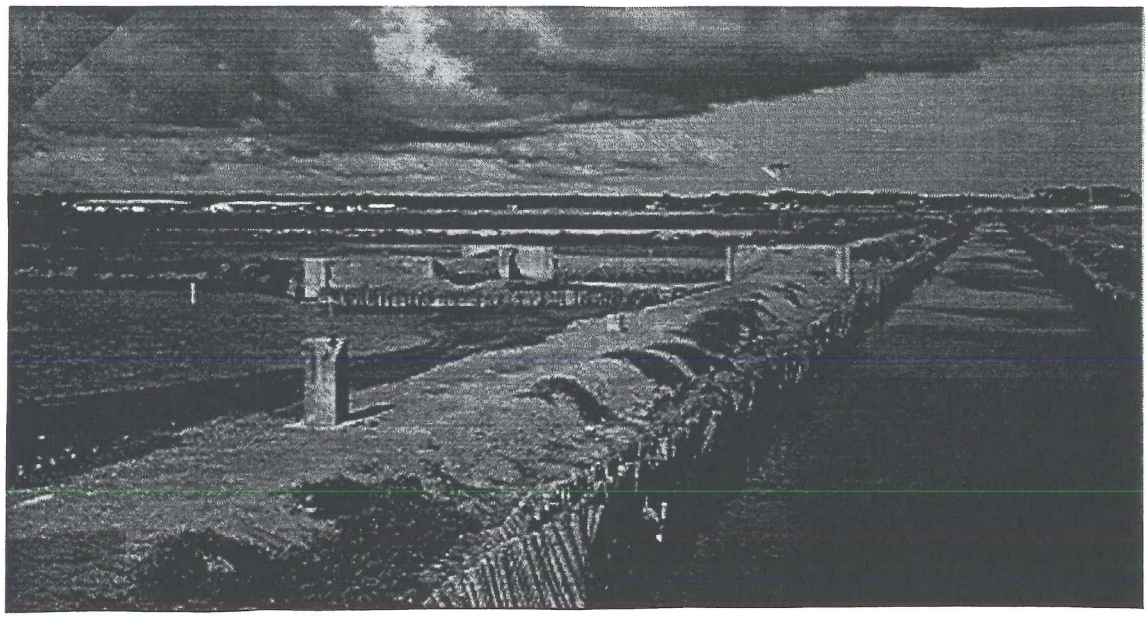
In-Country	US
Central Luzon State University Munoz, Nueva Ecija PHILIPPINES	University of Hawaii at Hilo Hilo, Hawaii USA

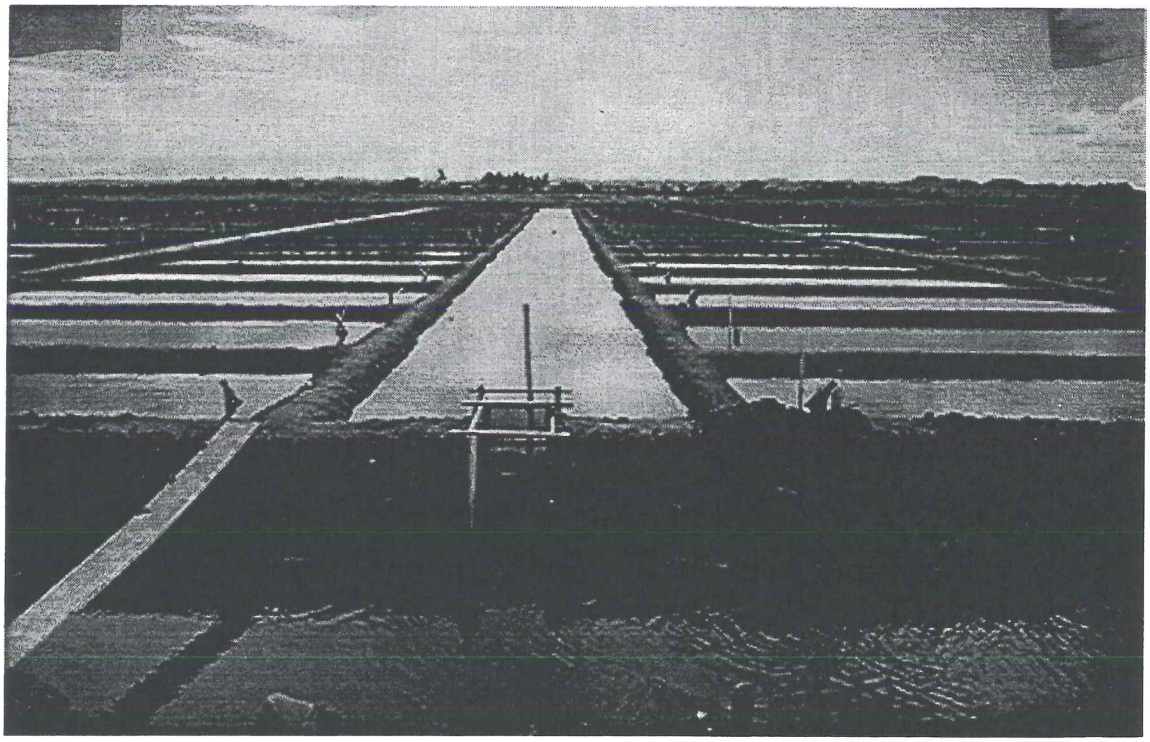
Current Contacts

In-Country	US
Antonio V. Circa Freshwater Aquaculture Center Central Luzon State University Munoz, Nueva Ecija 3120 PHILIPPINES TEL: 63-912-301-7323 FAX: 63-912-301-7323 e-mail: uws@phil.gn.apc.org	Dr. James Szyper Hawaii Institute of Marine Biology Coconut Island P.O. Box 1346 Kaneohe, HI 96744-1346 USA TEL: 808-236-7420 FAX: 808-236-7443 e-mail: jszyper@uhunix.uhcc.hawaii.edu

Notes:

Iloilo





There are over 215 ponds, covering more than 18 ha of area, at the Brackishwater Aquaculture Center (BAC) in Iloilo, Philippines. Each pond is served by two water canals, one for filling by tidal flow and one for draining. Twenty - one 1000 m2 of the BAC ponds were assigned to the CRSP research program.

Iloilo
Brackishwater Aquaculture Center

Site Status: Former Prime Site, 1984 - 1987
Location: Brackishwater Aquaculture Center, Leganes, Iloilo, PHILIPPINES
Caption/Description: The Brackishwater Aquaculture Center (BAC) is located 650 km south of Manila on the island of Panay, in the island group known as the Visayas. The BAC is located at Leganes, Iloilo Province, 22 km northeast of the site of the University of the Philippines in the Visayas (UPV) in Iloilo City proper.

Description of Area/Region

Climate

Köppen classification **Am***: *Humid tropical* group (A), *tropical rainforest* type *with short dry season* (m).

Temperatures	Precipitation
Temperatures throughout the Philippines average around 26°C during the dry season (December to May), with the lowest average monthly temperatures (25.5°C) being observed in January. The hottest average monthly temperatures – in May – are around 28°C. The average annual temperature in Leganes is 27°C. Average pond water temperatures at the BAC are between 24.9 and 33.5°C.	Average annual rainfall at the site of the BAC is 2100 mm.
Humidity	**Seasonality**
Humidity ranges from 71% in the dry season (March) to 85% in the rainy season (September).	Climate is characterized by a long rainy and a short but distinct dry season. Heavy rains are experienced between May and October; between July and October these may include damaging typhoon-type storms. During the dry season – December through February - the lowland areas are generally hot and dusty although temperatures rarely exceed 37°C.

Topography

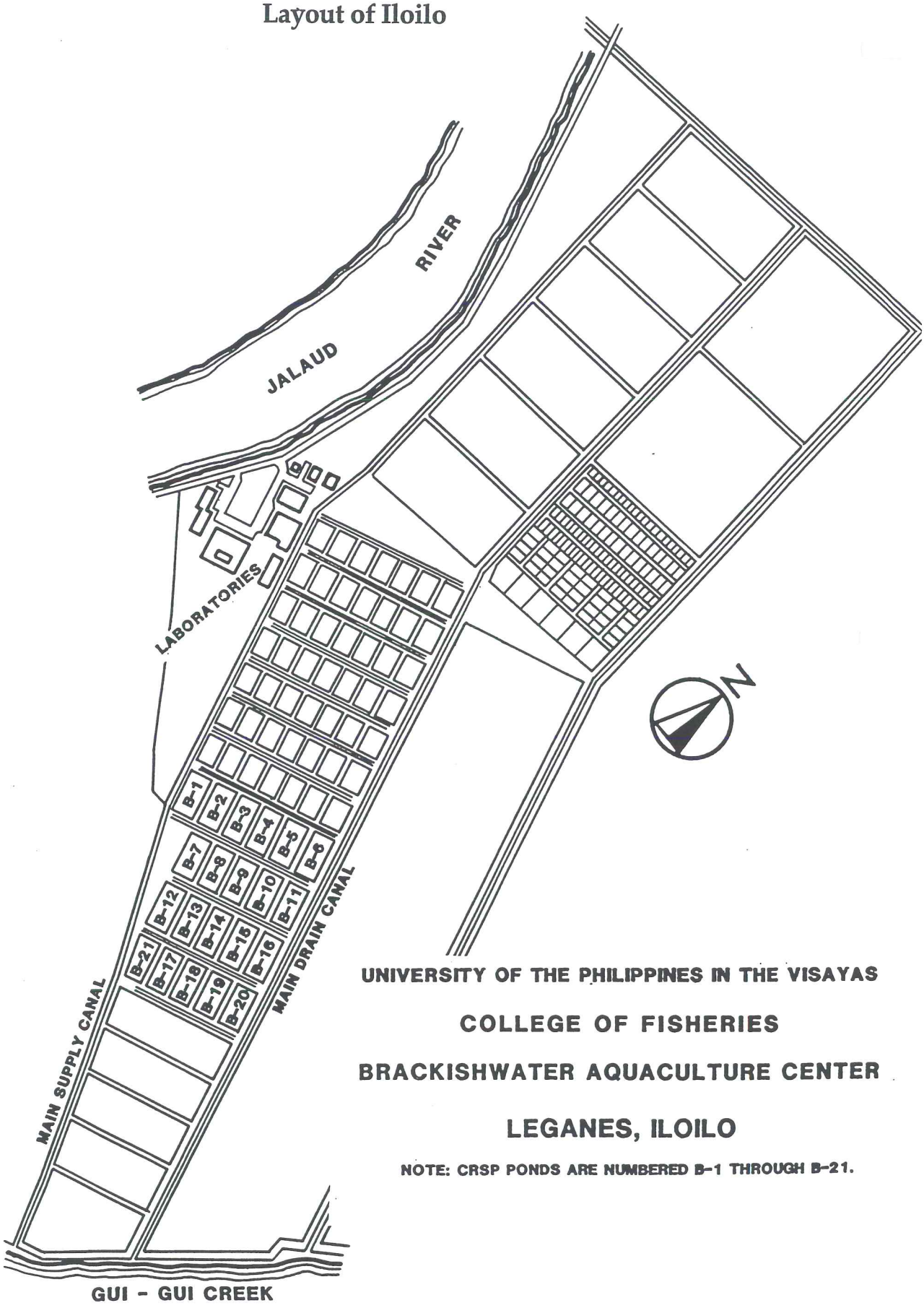
The BAC is located in a triangle of coastal flatland on the southern side of the Island of Panay. The town of Leganes lies between the Jaro and Jalaud rivers, which drain the higher-elevation areas to the north and northeast, and empty into the Iloilo Strait east of Iloilo City. The Iloilo Strait separates the island of Iloilo from nearby smaller Guimaras Island and the larger Negros Island to the southeast. The Cordilleras Range, with its highest peaks at just over 2000 m in elevation, flanks this valley area to the west, running north and south along the entire western side of Panay Island. Lower mountains and hills occupy the eastern point of Panay Island.

Geology and Soils

The Philippines archipelago is part of a major western Pacific seismic fault system, and all of the Philippine islands are subject to occasional earthquakes. In addition, the entire region is characterized by active volcanoes (12 of them in the Philippines), and many of its mountains are dormant or extinct volcanoes.

* Asterisked items are defined or described in the glossary.

Layout of Iloilo



UNIVERSITY OF THE PHILIPPINES IN THE VISAYAS

COLLEGE OF FISHERIES

BRACKISHWATER AQUACULTURE CENTER

LEGANES, ILOILO

NOTE: CRSP PONDS ARE NUMBERED B-1 THROUGH B-21.

Description of Iloilo

Map Coordinates	Elevation
10 45'N and 122 30'E	4 m
General	**Water Supply**
The BAC is one of three brackishwater sites at which the CRSP has collaborated. Pond facilities include 215 ponds with a water surface area of 18 ha. The 21 ponds assigned to the CRSP research program were 1000 m^2 each. Site facilities included a comprehensive administrative building with offices, classrooms, a conference room, a library, a radio room, chemistry labs, and a wet laboratory with aquaria and supplied with fresh and sea water and compressed air. Other facilities included a feed processing and storage building, a nursery and hatchery building, a soil chemistry laboratory, a utility building, a dormitory and cafeteria for students, and staff housing for security and pond management personnel. There were over 60 permanent employees for research and administration and 21 faculty members from the College of Fisheries who participated actively in research and training at the BAC.	Each of the 215 ponds is served by two water canals, which allows independent filling and draining by tidal flow from Gui-gui Creek, Leganes. Water supplied to the ponds had a pH ranging from 7.05 to 9.72, alkalinity ranging from 51 to 194 mg/L (as $CaCO_3$), and salinity ranging from 6 to 37 ppt. Additional source water information can be found in the data tables for the Iloilo site.
Soils	
The BAC was constructed on acid-sulfate soils typical of coastal areas. Because the dikes are very large relative to pond size, acidic runoff was a major problem during the early days of the station. After several years of use and treatment, the soils at the BAC had pH values ranging from 5.25 to 7.50 (dry) and levels of organic matter ranging from 1.34 to 4.52%. Aluminum levels were all low (<0.100 ppm) but iron concentrations varied widely among ponds, ranging from a low of 36.50 ppm to a high of 2469 ppm.	

Support Facilities at Iloilo

Those conducting research at the BAC include BAC staff, academic staff, and graduate students from the University of the Philippines in the Visayas. Approximately 10 to 15 graduate students conduct thesis research at the BAC each year. Numerous commercial aquaculture operatives are located in the vicinity of the BAC. Feed and organic and inorganic fertilizers are readily available. Shrimp and prawn post-larvae can be obtained from both wild and hatchery sources. A variety of finfish fry, including tilapia, milkfish, and seabass are also available on a seasonal basis.

Affiliations

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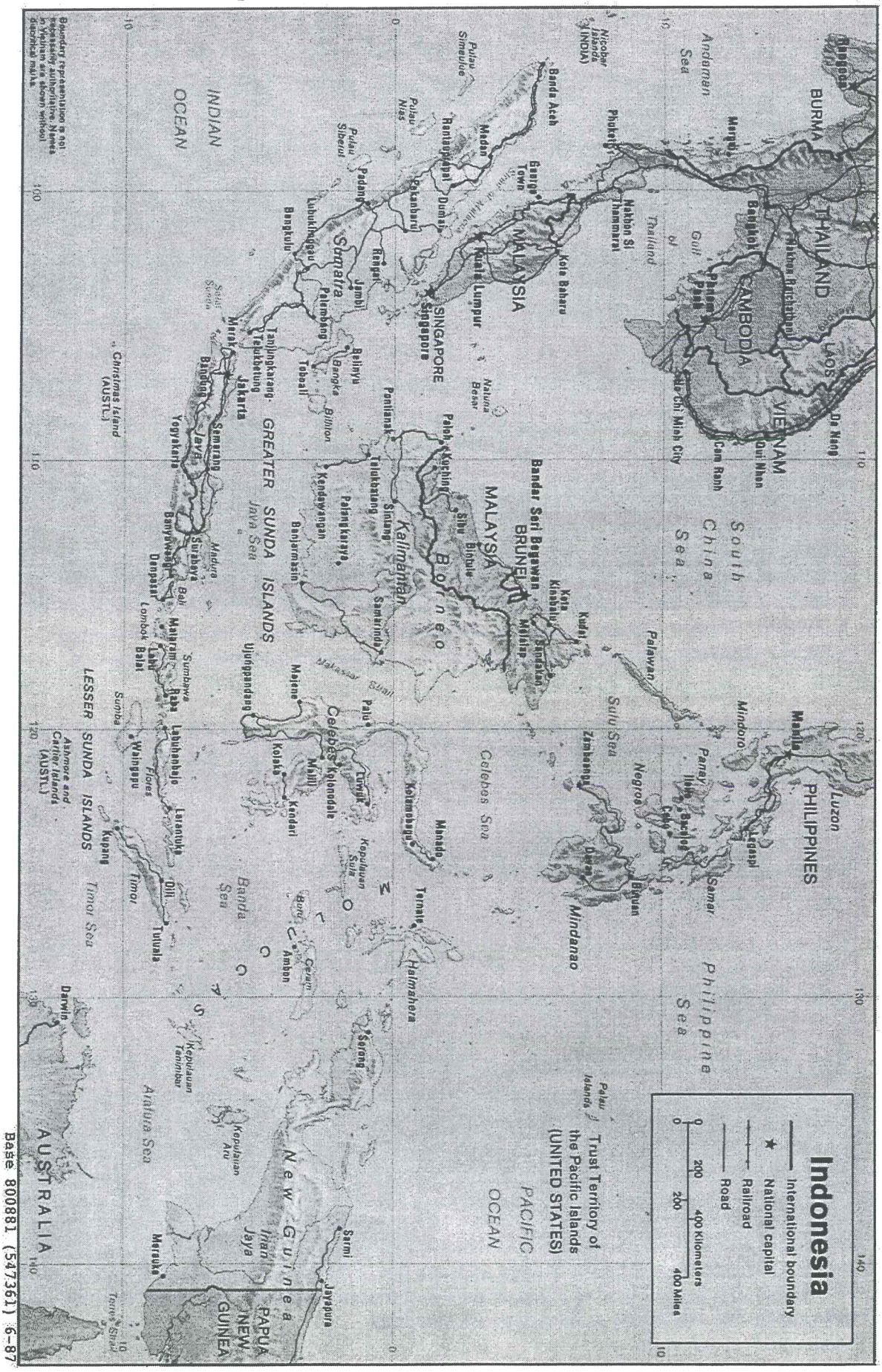
Indonesia
International boundary
National capital
Railroad
Road
0 200 400 Kilometers
0 200 400 Miles
Trust Territory of the Pacific Islands (UNITED STATES)
PACIFIC OCEAN
INDIAN OCEAN
South China Sea
Philippine Sea
Celebes Sea
Banda Sea
Timor Sea
Arafura Sea
Andaman Sea
Gulf of Thailand
Sulu Sea
Java Sea
Makassar Strait
Malacca Strait
Bangkok
Hanoi
Manila
Luzon
Mindoro
Panay
Negros
Samar
Mindanao
Palawan
Kuala Lumpur
Singapore
Bandar Seri Begawan
Kota Kinabalu
Kuching
Pontianak
Palangkaraya
Banjarmasin
Samarinda
Kalimantan
Borneo
Celebes
Kendari
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Yogyakarta
Semarang
Jakarta
Bandung
Merak
Tanjungkarang
Telukbetung
Bengkulu
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Medan
Banda Aceh
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Pulau Siberut
Nicobar Islands (INDIA)
Phuket
Nakhon Si Thammarat
Kota Baharu
Bangkok
Pattani
Nakhon Ratchathani
Ho Chi Minh City
Cam Ranh
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Rangoon
BURMA
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CAMBODIA
LAOS
VIETNAM
MALAYSIA
BRUNEI
PHILIPPINES
SINGAPORE
Sumatra
Java
Madura
Bali
Lombok
Sumbawa
Flores
Timor
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Kepulauan Sula
Kepulauan Tanimbar
Kepulauan Aru
Kepulauan Sulu
Kepulauan Tanimbar
Irian Jaya
New Guinea
PAPUA NEW GUINEA
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Christmas Island (AUSTL.)
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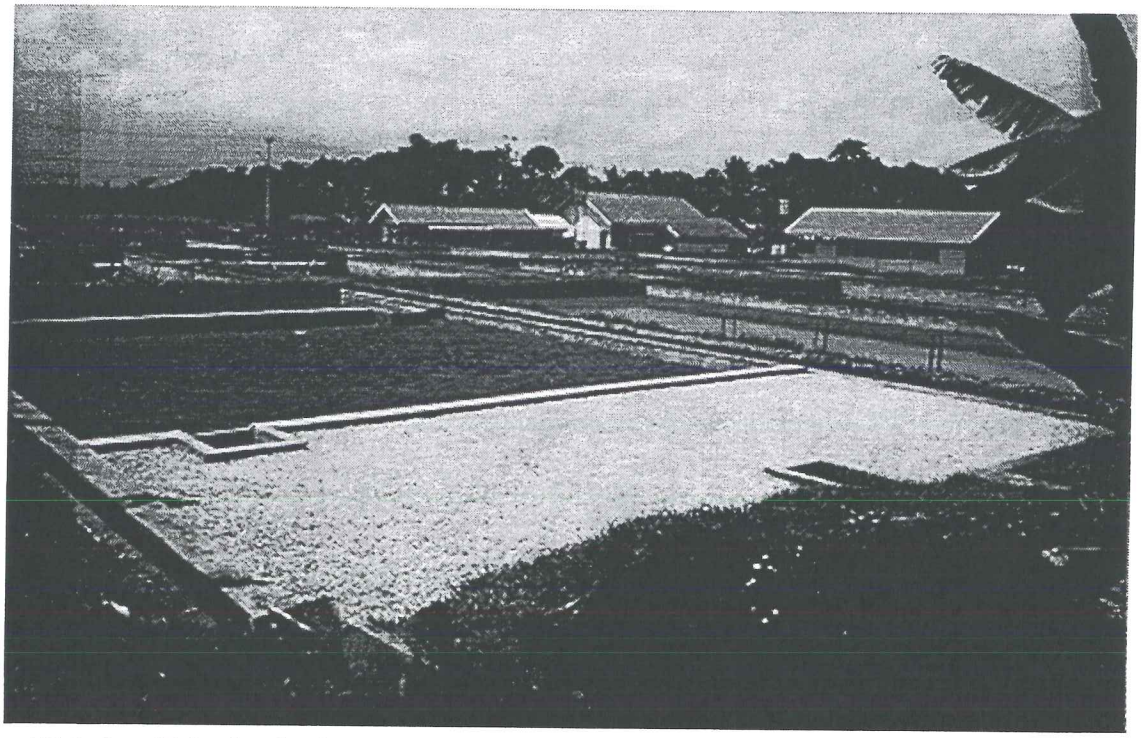
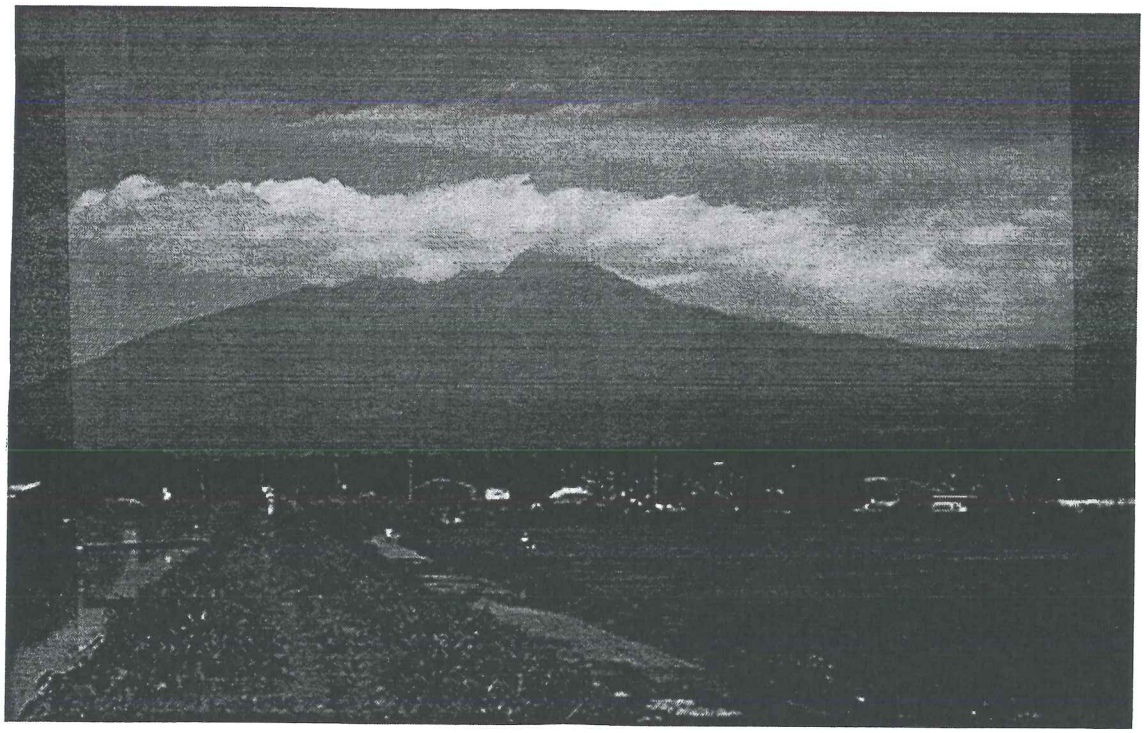
Base 800881 (547361) 6-87

Bogor



Ponds at Babakan Fisheries Station were lined with concrete to eliminate water loss by seepage through highly permeable soils. Offices and analytical laboratories are shown in background.



Source water for the Babakan Fisheries Station and area rice paddies comes as runoff from the slopes of nearby Mt. Salak. The highly leached volcanic soils in this area are acidic, and water flowing over and through them has low levels of hardness and alkalinity.

Bogor
Babakan Fisheries Station, Bogor, Indonesia

Site Status: Former Prime Site, 1983 - 1987
Location: Darmaga, Bogor, West Java, INDONESIA
Caption/Description: The Babakan Fisheries Station of the Institute Pertanian Bogor (IPB) is located near the village of Darmaga, approximately 10 km from Bogor, in West Java.

Description of Area/Region

Climate

Köppen classification Af*: *Humid tropical* climatic group (A), *tropical wet* climatic type (f). No month has less than 60 mm rain.

Temperatures	Precipitation
Average annual temperatures range from 23 to 33°C.	Rainfall on the volcanic peaks and surrounding uplands of Java is high: greater than 3000 mm per year along the mountain chain and as much as 7500 mm per year in parts of Central Java. The average annual rainfall at the Babakan Station is consistent with these figures—it was reported to be 3500 mm at the beginning of CRSP research activities at the site.
Humidity	**Seasonality**
Humidity is high, with frequent low clouds, low visibility, and little evaporation from the ponds.	Climatic conditions at Babakan lack seasonal attributes and show little variation over an annual cycle.

Topography

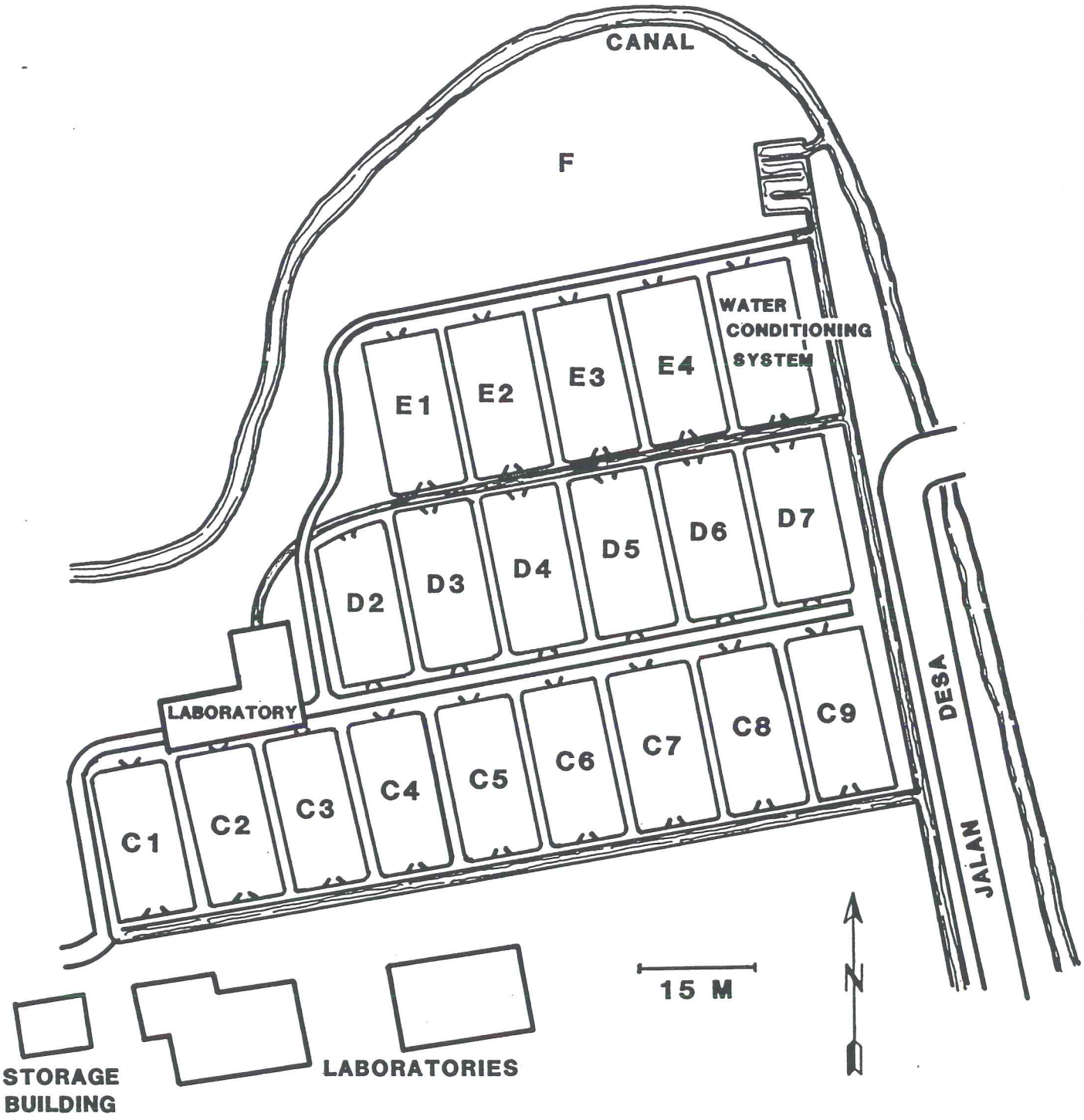
The island of Java is part of the Indonesian archipelago that stretches 5,600 km from east to west on the southwest rim of the Pacific basin. The backbone of Java consists of 25 major volcanic peaks that rise between 1900 and 3700 m above mean sea level. The volcanoes and intervening land constitute a chain approximately 940 km long between the latitudes 6.0 and 8.5 S.

Geology and Soils

Java's volcanoes were formed by the upward extrusion of materials by plate tectonic activity associated with the Java Trench in the Indian Ocean south of the island. The peaks continue to grow by lava flows and upheaval of ash. Among the peaks are low-elevation ridges of limestone. These are uplifted coral reefs largely of Miocene origin. The distribution of soils that developed from materials of volcanic and coral reef origin is of great significance for aquaculture, because groundwater and runoff from volcanic regions of high rainfall can be expected to be low in minerals, while mineral concentrations can be eight to ten times greater in drainage from limestone regions. The drainage basin in which the Babakan Station is located is characterized by highly leached and permeable volcanic soils that are low in alkalinity.

* Asterisked items are defined or described in the glossary.

Layout of Bogor



THE DARMAGA FISHERIES STATION
INSTITUTE PERTANIAN BOGOR
WEST JAVA, INDONESIA

NOTE: CRSP PONDS ARE NUMBERED C1 - C9, D5 - D7.

Description of Bogor

Map Coordinates	Elevation
6 6'S and 106 7'E	220 m
General	**Water Supply**
There were 40 ponds at the Babakan Fisheries Station, 12 of which were used for CRSP research. Each pond had an area of 200 m^2 (10 m wide x 20 m long) and was 1 m deep. A water conditioning system was completed in 1984. One of the three laboratory buildings on site was used in support of the CRSP project. It was equipped with the necessary instruments for performing chemical, biological, and physical analyses. There was also a small library and an office equipped with a computer.	The water source is precipitation which falls on Mount Salak, a volcanic peak located south of Bogor. The water is supplied by an irrigation canal which flows by the fisheries station. Water is diverted from the irrigation canal into a baffled, cement-walled settling basin, and from there flows either through the water conditioning system or through a feeder channel from which water can be diverted into the individual ponds. The supply water has a nearly-neutral pH (7.2) and relatively low alkalinity and hardness levels (23.8 and 21.2 mg/L, respectively, as $CaCO_3$).
Soils	
The pond soils are predominately clays of volcanic origin. Although the clay content is high (62%), they are dominated by halloysite (a non-swelling clay mineral) and therefore quite permeable, and the ponds are susceptible to high rates of water loss due to seepage. Initial pH readings for the CRSP-operated ponds ranged from 5.5 to 6.3, and organic matter contents ranged from 0.8 to 3.7%. Free $CaCO_3$ was 0.3% or less in all ponds, and lime requirements ranged from 2025 to 6375 kg/ha (agricultural limestone). Soil phosphorus was 7 ppm or less in all ponds.	

Support Facilities at Bogor

Members of the Faculty of Fisheries of the IPB conducted their research at the station and were available to interact with CRSP personnel. The services of the analytical laboratory of the Faculty of Soils at IPB were available for analyses of fertilizers and pond soils (particularly for lime requirements by the SMP method). The Soils Laboratory of the Ministry of Agriculture in Bogor was used for x-ray diffraction identification of clay minerals in the pond soils. Personnel of the Inland Fisheries Research Center (Ministry of Agriculture) and the National Institute of Biology, both in Bogor, were available for consultation.

Affiliations

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Glossary

Acid-sulfate soils: highly acidic soils (pH usually < 3.5) that derive their acidity from the presence of acid-forming minerals (e.g., sulfur compounds), rather than from simple exchange acidity; oxidation of the sulfur compounds (e.g., upon exposure to air and drying) produces sulfuric acid.

Af climate (Köppen system): climatic regime in which the average temperature of the coldest month of the year is 18°C or higher (A) and in which every month has 60 or more mm of precipitation (f).

Am climate (Köppen system): climatic regime in which the average temperature of the coldest month of the year is 18°C or higher (A) and which has a short dry season; precipitation in the driest month is less than 60 mm, but equal to or greater than 10 - (annual rainfall in cm/25) (m).

Ar climate (Trewartha system): tropical wet climate, with not more than two dry months.

Aw climate (Köppen system): climatic regime in which there are well-defined wet and dry seasons ("tropical wet-and-dry" climate); the average temperature of the coldest month of the year is 18°C or higher (A) and in which there is a well-defined dry season during the winter, with precipitation during the driest month less than 10 - (annual rainfall in cm/25) (w).

Aw climate (Trewartha system): tropical wet-and-dry climate, high-sun wet season and low-sun dry season.

Base Saturation (also sometimes referred to as Base Saturation Percentage): the portion (percentage) of the cation exchange capacity of a soil that is occupied by basic cations; the remainder is occupied by acidic cations, and is referred to as the "base unsaturation."

Base Unsaturation: the portion (percentage) of the cation exchange capacity of a soil that is occupied by acidic cations; the remainder is occupied by basic cations, and is referred to as the "base saturation."

BWh climate (Trewartha system): Dry, desert climate; hot, tropical-subtropical, and constantly dry. Potential evaporation exceeds precipitation, and the average annual temperature is not less than 18°C.

Cation Exchange Capacity (CEC): the capacity of a soil to adsorb cations; cations are adsorbed at exchange sites, and can be released in exchange for other cations.

CEC: see Cation Exchange Capacity.

Chinese carp: any of several cyprinid (family Cyprinidae) fishes originating from China, including the "grass carp" (Ctenopharyngodon idella), "silver carp" (Hypophthalmichthys molotrix), and "bighead carp" (Aristichthys nobilis).

Common carp: the species Cyprinus carpio.

Companion site: a secondary research site of the CRSP in a given geographic region; a limited program of research is supported by periodic visits by the US researcher stationed at a prime site.

Csb climate (Köppen system): climatic regime in which the average temperature of the coldest month is below 18°C and above -3°C; at least three times as much precipitation in a winter month as in a summer month; precipitation in driest summer month is less than 40 mm; no month has a temperature of over 22°C, but at least 4 months are over 10°C.

GAw climate (Köppen-Trewartha system): Aw climate modified by effects of higher elevation (i.e., cooler temperatures) in low hills or mountains. In the case of high mountains, the modifier H is used instead of the G.

Guapote tigre: the species Cichlasoma managuense.

Inceptisols: In the Soil Taxonomy classification, soils in humid regions that are as yet poorly developed, e.g., with little accumulation of clay or iron or aluminum oxides; a cambric horizon (a subsurface layer that has been changed by physical movement or chemical reactions) is often present.

Köppen classification for climate: The most commonly used system of classification of climates world wide, based primarily on temperature and precipitation regimes; published first in 1901, the most commonly referred-to version, including maps, is the publication Grundriss der Klimakunde, published in Berlin in 1931.

Köppen-Trewartha classification: Climatic classification system modified from the Köppen and Trewartha systems, as described by Willy Rudloff in World Climates, with tables of climatic data and practical suggestions, 1981.

Lateritic soils: tropical soils that contain a subsurface layer that is rich in iron and that becomes very hard upon exposure and drying and will not soften when re-wetted; the presence of iron often lends a distinctive red color to the soil.

Marais: swampy, moist valley floors and river flood plains (Rwanda).

Prime site: the primary research site of the CRSP in a given geographic region; a full-time US researcher is stationed at each prime site, and a full research program is carried out at the site.

SMP lime requirement method: a laboratory buffer method for estimating the lime requirement of agricultural soils; this method is commonly used in many parts of the United States, and has sometimes been used for aquaculture ponds.

Tambaquí: the species Colossoma macropomum.

Tilapia: may include any of several species in the genus Oreochromis, the genus Sarotherodon, or the genus Tilapia; in PD/A CRSP usage, "tilapia" most commonly refers to the species Oreochromis niloticus (sometimes also classified as Tilapia nilotica).

Trewartha classification for climate: a modification of the Köppen classification system by Glenn Trewartha (most recent publication is An Introduction to Climate, fifth edition, by Glenn Trewartha and Lyle Horn); like Köppen the system, this system is based mainly on temperature and precipitation patterns.

Ultisols: In the Soil Taxonomy classification, soils that have subsurface accumulations of clay but are low in bases (low base saturation); usually moist, but some are dry some of the time during the warm season; often high in 1:1 clay minerals such as kaolinite.