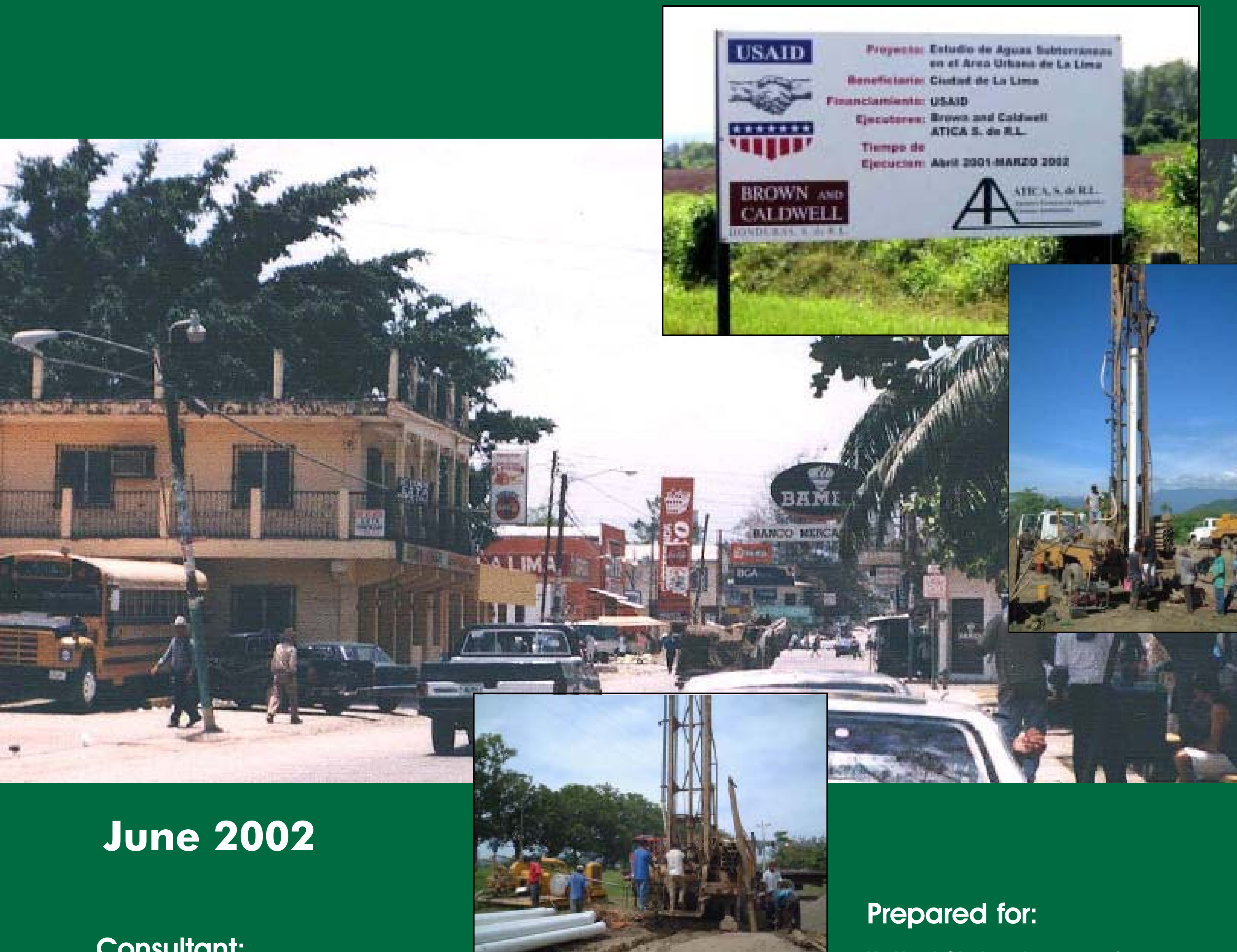
GROUNDWATER RESOURCES MONITORING REPORT AND MANAGEMENT PLAN

La Lima, Republic of Honduras, C. A.



June 2002

Consultant:

BROWN AND CALDWELL

Sub-Consultant:

ATICA, S. de R. L.
Asesores Técnicos en Ingeniería y Ciencias Ambientales

Prepared for:

United States Agency for International Development

USAID

2701 Prospect Park Drive
Rancho Cordova, California 95670

Tel: (916) 444-0123
Fax: (916) 635-8805

www.brownandcaldwell.com

BROWN AND CALDWELL

July 25, 2002

Ing. Mauricio Cruz
Chief Technical Officer
Agencia de los Estados Unidos para el Desarrollo Internacional
Frente a la Embajada Americana
Avenida La Paz, Post Office Box 3453
Tegucigalpa, M.D.C., Honduras

Subject: Groundwater Resources Monitoring Report and Management Plan, La Lima, Honduras, Contract No. 522-C-00-01-00287-00

Dear Ing. Cruz:

In accordance with the above referenced contract, Brown and Caldwell is pleased to forward two copies of the English version of the Groundwater Resources Monitoring Report and Management Plan for La Lima, Honduras. The Spanish language version of this report is being submitted separately. Each report includes the electronic file of the report and the Water Resources Management System on two separate compact disks.

The submittal of this report and the reports for Utila, Choloma, Villanueva, and Limón de la Cerca complete our work under this contract.

We appreciate the opportunity to have been of service to USAID. If you have any questions, please do not hesitate to give me a call at (925) 210-2278.

Sincerely,

BROWN AND CALDWELL

Jeff Nelson, P.E.
Project Director

JN:PS:ap
Enclosure

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Signatures of principal personnel responsible for development and execution of this report.

Jeff Nelson, P.E.
Project Director

Horacio Juarez, P.E.
Project Manager

Paul Selsky, P.E.
Phase 5 Report Preparation Manager

Gregory L. Christians, P.G.
Florida Professional Geologist #2219
Principle Geologist

Milton Sagastume
Local Project Coordinator - Honduras

PROJECT PARTICIPANTS

United States Agency for International Development (USAID)

Ing. Mauricio Cruz, Tegucigalpa, Honduras
Ing. Carlos Flores (Retired September 2001), Tegucigalpa, Honduras
Ing. Carlos Verdial, Tegucigalpa, Honduras

United States Geological Survey (USGS)

Wes Meehan, Tuscon, AZ

Fondo Hondureño de Inversión Social (FHIS)

Antonio Morales, Honduras, Project Supervisor

Municipalidad de La Lima

Evaristo Euceda, Alcalde Anterior
Nery López, Asistente de Jefatura de Catastro
Alejandrina Meza, Alcalde
Doris Pérez, Coordinadora de Servicios Públicos
Jackeline Reyes, Calculista en Comercialización
Aurora Rodriguez, Asistente de Ingeniería
Rubén Saravia, Jefe de Servicios Públicos

Brown and Caldwell, Lead Consultant

Voytek Bajsarowicz, Walnut Creek, CA, Principal-in-Charge
Greg Christians, Nashville, TN, Conceptual Model Development
Dana Downs, Phoenix, AZ, Groundwater Modeling
Chris Gardner, Phoenix, AZ, Field Geologist
Barbara Goodrich, Walnut Creek, CA, Drilling and Groundwater Monitoring Manager
Bob Grace, Walnut Creek, CA, Project Advisor
Brad Hart, Carson City, NV, Groundwater Modeling
Horacio Juarez, El Paso, TX, Project Manager
Jay Lucas, Sacramento, CA, Phase 2 Field Investigation Manager
Amanda Mortl, Houston, TX, Field Geologist
Jeff Nelson, Walnut Creek, CA, Project Director
Jim Oliver, Phoenix, AZ, Phase 3 Groundwater Modeling Manager
Karen Perez, El Paso, TX, Field Engineer
Tom Peters, Denver, CO, Infrastructure Evaluation
Ah'lai Phelps, Sacramento, CA, Report Preparation
Allan Scott, Sacramento, CA, Phase 4 Database Manager
Paul Selsky, Sacramento, CA, Phase 5 Report Preparation Manager
Dean Wolcott, Baton Rouge, LA, Field Sampling Techniques Training

PROJECT PARTICIPANTS
(continued)

Asesores Técnicos en Ingeniería y Ciencias Ambientales (ATICA) – Hydrogeology Subconsultant, San Pedro Sula, Honduras

Lesbia Castellón, Water Quality Monitoring
David Espinoza, Database Input
Fanny Letona, Infrastructure Evaluation and Well Testing
Marlon Pineda, Field Activities Supervisor
Melvin Sagastume, Field Technician
Milton Sagastume, Local Project Coordinator
Darwin Vallecillo, Field Technician

Hidro Sistemas Engineering and Drilling, S. de R. L. (Hidro Sistemas) – Well Drilling Subcontractor, San Pedro Sula, Honduras

Servicios de Perforación, S. de R. L. de C. V. (SERPE) – Well Drilling Subcontractor, Tegucigalpa, Honduras

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amsl	above mean sea level
bgs	below ground surface
ft	feet
GIS	geographic information system
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
in	inch
km	kilometer
lpcd	liters per capita per day
lps	liters per second
m	meter
mg/L	milligrams per liter
mgd	million gallons per day
mi	mile
mld	million liters per day
mm	millimeter
TDS	total dissolved solids
USAID	United States Agency for International Development
VOC	volatile organic chemicals
WHO	World Health Organization
WRMS	Water Resources Management System
ZIP	zoned industrial park

GLOSSARY OF TERMS

Alluvial: Pertaining to or composed of alluvium or deposited by a stream or running water.

Alluvium: A general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope.

Aquifer: A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.

Aquifer Test: A test involving the withdrawal of measured quantities of water from or addition of water to, a well and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or addition.

Fault: A fracture in the continuity of a rock formation caused by a shifting or dislodging of the earth's crust, in which adjacent surfaces are displaced relative to one another and parallel to the plane of fracture.

Fracture Trace: Natural linear features less than 1.6 kilometers (1 mile) long that can be identified by aerial photographs.

Graben: A portion of the Earth's crust, bounded on at least two sides by faults that has dropped downward in relation to adjacent portions.

Groundwater: The body of water that is retained in the saturated zone that tends to move by hydraulic gradient to lower levels.

Irrigation: Application of water to the land to meet the growth needs of plants.

Lithology: The study of rocks; primarily mineral composition.

Metamorphic Rocks: Pertaining to, produced by, or exhibiting, certain changes which minerals or rocks may have undergone since their original deposition; -- especially applied to the recrystallization which sedimentary rocks have undergone through the influence of heat and pressure, after which they are called metamorphic rocks.

Normal Faults: When the fault plane is so inclined that the mass on its upper side has moved up relatively.

Specific Yield: The ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. This ratio is states as a percentage.

Transmissivity: The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

REFERENCES

Asociacion CH2M Hill – CONASH – CSA, 2001. *Rehabilitacion Del Sistema De Agua Potable De La Ciudad De La Lima, Cortes, Reporte De Diseno Final.*

Attica. 2001. *"Informacion de Tanques.xls"*

Departmento Desarrollo Comunitario. 1997. *Table titled "Censo Poblacional".*

Dirección General de Censos y Estadísticas. *Population Statistics.*

Empresa Nacional de Energía Eléctrica, ENEE. *Energy Users Statistics for La Lima.*

FUNDEMUM. *La Lima Urban Map.*

Hidrosistemas S. de R. L. *Existing Well Construction Reports.*

ING. Doris M. Perez, Coordinadora de Obras y Servicios Publicos, Municipalidad de La Lima. January 23, 2001. *Table titled "Listado de Colonias y Barrios del Municipio".*

Instituto Geográfico Nacional. *Mapa hidrogeológico de la Zona Norte.*

Instituto Geográfico Nacional. *Mapas Topográficos Escala 1:50,000 No. 2662 III.*

La Lima Urban Maps. *Departamento de Catastro Municipal.*

Munipalidad De La Lima, Departmento De Cortes, Republica De Honduras. January 23, 2001. *"Informacion solicitada por esa dependencia el Listado de los Abonados de Servicios Publicos Municipales".*

Munipalidad De La Lima, Departmento De Cortes, Republica De Honduras. December 13, 2000. *"Listado de los pozos existentes en el Municipio".*

Red Panamericana de Manejo Ambiental de Residuos (REPAMAR). 2000. *"Assessment of Drinking Water and Sanitation 2000 in the Americas".* www.cepis.ops-oms.org

Rogers, R.D., 2000. *Slab Break-off Mechanism for Late Neogene Uplift of Honduras, Northern Central America, AGU Fall Meeting, San Francisco, CA.*

SERPE S de R.L. *Existing Well Construction Reports.*

Servicio Autonomo Nacional de Acueductos y Alcantarillados (SANAA), 1977. *National Autonomous Aqueduct and Sewerage Service, Water Supply Feasibility Study, Final Report, Cinsa, Consulting Architects and Engineers*. February.

United States Agency for International Development (USAID), 2000. *Results Review and Resource Request, USAID/Honduras.* March.

University of Texas Institute for Geophysics, 2001. *Tectonic Origin History of the Chortis Block: Integration of Onshore Geological and Offshore Well and Seismic Data from Eastern Honduras.* From: UTIG Web Site: http://www.ig.utexas.edu/research/projects/chortis/chortis.htm

USAID/Brown and Caldwell, 2001. "Groundwater Monitoring Study Technical Procedure for Phase II Water Quality Sampling, Limon De La Cerca, Villanueva, Choloma, La Lima".

Water Systems Maps. *Departamento de Servicios Públicos de la Municipalidad de La Lima.*

World Health Organization (WHO), 1996. *Guidelines for Drinking Water Quality 2nd Edition, Volume 2 Health Criteria and other Supporting Information.* pp 940-949.

EXECUTIVE SUMMARY
Groundwater Recourses Monitoring Report and Management Plan
La Lima, Honduras
June 2002

The United States Agency for International Development (USAID) contracted Brown and Caldwell to perform groundwater monitoring studies for the Island of Utila and the municipalities of Villanueva, Choloma, La Lima, and the resettlement community of Limón de la Cerca near Choluteca. This Groundwater Resources Monitoring Report and Management Plan (Report) presents the results of the groundwater monitoring study and includes a groundwater resource management plan to help ensure the sustainable management of the groundwater resources for La Lima, Honduras.

Background

The municipality of La Lima is located approximately 15 kilometers (km) (9 miles (mi)) southeast of San Pedro Sula. The airport that serves the San Pedro Sula area, Ramon Villeda Morales International Airport, is located adjacent to La Lima. La Lima is situated along the Chamelecón River, which flows east out of the Merendon Mountains. The surrounding Merendon mountains serve as the major surface and groundwater recharge areas for the alluvial materials of the Chamelecón River valley. The Ulua River is located approximately 5 km (3 mi) to the east of La Lima. La Lima lies within the Caribbean lowlands, which have a tropical wet climate with consistently high temperatures and humidity.

Description of Existing Water System and Water Demands

Sixteen municipal wells provide the municipal water supply for La Lima. These municipal wells have a combined capacity of 124 liters per second (lps) (1,985 gallons per minute (gpm)). Some of the industrial facilities of La Lima have constructed their own private wells to supplement the municipal water distribution system. Water is stored in nine storage tanks that have a total capacity of 2,170,934 liters (573,500 gallons). There are several private water storage tanks that are not connected to the municipal water system.

In 2000, the La Lima population was 51,141. Since published population projections prepared by others have not been identified, the future population has been projected as a part of this study. The population annual growth rate assumed for 2000 through 2010 is based on the growth rate of the developed land area occurring from 1995 to 2000, which was nine percent per year. It is assumed for this study that the 1995 to 2000 historical growth rate will continue through 2010. This study assumes that the growth rate for La Lima will decrease following the year 2010 to be equivalent to that of the nearby city of San Pedro Sula, which is 5.48 percent per year. The population is expected to reach 206,413 by 2020.

Groundwater use is not precisely known due to lack of water meters. Current average annual municipal water use is estimated at 7.9 million liters per day (mld) (2.3 million gallons per day (mgd)). Water demands through the year 2020 were estimated based on the unit water use factor of 172 liters per capita day (45 gallons per capita day) and the urban area population projections. By 2020, average annual municipal water demands are expected to increase to 36.4 mld (9.6 mgd). Maximum day water demand is estimated to be 1.2 times the average annual day. Therefore, maximum day demand is estimated to increase from 10.6 mld to 43.6 mld (2.8 mgd to 11.5 mgd) by the year 2020. If well pumping is limited to a maximum of 20 hours per day, there is a current well supply deficit of 48 lps (763 gpm) during the maximum demand day. By 2020, additional well capacity of 480 lps (7,615 gpm) will be required.

Groundwater Resources Evaluation

The groundwater resource evaluation consisted of the development of a conceptual hydrogeologic model, field investigations, the development of a numeric groundwater model, and the identification of potential contamination sources to groundwater.

The conceptual model for La Lima was developed based on the understanding that the upland areas of the Merendon Mountains on the western side of the Sula Valley serve as the major surface and groundwater recharge areas for the alluvial materials in the area of La Lima. Once the groundwater from the upland areas enters the valley alluvium, groundwater flow generally begins to move down the valley and towards the Chamelecón River, which, along with the Ulua River, serves as a major groundwater discharge area for the valley hydrologic system. The conceptual groundwater budget indicates that the basin is approximately in balance. Approximately 618 lps (9,800 gpm) recharges the La Lima aquifer through mountain front and areal recharge and inflow from the up-gradient valley aquifer. Approximately 467 lps (7,400 gpm) flows to the Chamelecón and Ulua Rivers. Total existing groundwater pumping is estimated to be approximately 158 lps (2,500 gpm).

Three test wells were installed as part of the field investigation. Test holes BCLL-1, BCLL-2, and BCLL-3 were drilled to depths of 152, 155, and 152 meters (m) (500, 510, and 500 feet (ft)) below ground surface (bgs), respectively. Aquifer pump tests were performed on selected wells. The results indicate that there are several sand and gravel deposits above the clay deposit that is up to 110 m (360 ft) bgs and are a source of sustainable water supply. The thicker sand and gravel deposits in the southern and western portions provide the best source of groundwater.

Groundwater samples were collected from each of the wells installed by Brown and Caldwell during this investigation, as well as several of the existing wells. Total coliform was detected in all of the sampled wells. Fecal coliform, an indicator of bacteriological contamination, was detected in several wells. In addition, several wells had levels of iron, manganese, antimony, and nickel over the provisional drinking water standard.

A predictive model simulation was performed to evaluate the potential effects of increasing groundwater production to year 2020 requirements. Future wells were located west of La Lima. The simulation results indicate that the aquifer drawdown would be approximately 2 to 3 m in the well field area. The predictive simulation indicates that the aquifer system could support the projected groundwater pumping.

Potential sources of contamination to the alluvial aquifers near La Lima include sugar cane that is grown in large fields west of La Lima along the Chamelecón River flood plain, however, no indication of pesticide and herbicide contamination was found for the wells and parameters tested. Other potential contamination sources include large zoned industrial parks located in the southeastern part of La Lima. Although there is some treatment for both industrial and sanitary wastes, most of the wastes are discharged to small surface drainages, and eventually to the Chamelecón River. The La Lima sewer system was built in the 1940s and it is suspected that the concrete sewer pipes are badly eroded. Similarly, some residential areas rely mostly on latrines that discharge directly to the ground.

It is recommended that future wells be established in the southern and western portions of the study area. The total thickness of the well-developed sand and gravel deposits are greatest in theses areas. Also, these areas are up gradient of the industrial areas and the municipal sewer system, which are believed to be possible sources of contamination.

Water Resources Management System

The Water Resources Management System developed for this project is a desktop computer application developed to store, manage, and analyze groundwater technical information gathered for this project plus data that the municipality will collect in the future. The application is a management tool that can be used by the municipality and other decision-makers to sustainably manage La Lima's groundwater resources. The system is composed of both a data management system and a geographic information system linked together as one application.

Recommended Groundwater Resources Management Plan

Figure ES-1 presents a groundwater resources planning map. Figure ES-2 depicts a geologic cross-section. The following recommendations are made regarding the management of La Lima's groundwater resources:

1. As water demands increase, install additional wells in the western portion of La Lima. As shown on Figure ES-1, install future wells on both sides of the Chamelecón River. Approximately 19 new wells will be needed by year 2020, assuming an average well pumping capacity of 25 lps (400 gpm). These new wells will be required approximately every year. Obtain sites (30 m by 30 m (100 ft by 100 ft)) for these future well sites. New wells should be constructed to include disinfection equipment and a 15 m (50 ft) well seal to address bacteriological contamination. The new wells should utilize water lubed vertical turbine pumps and have a water meter. Convert test wells BCLL-1 and BCLL-2 to production wells by installing pumps and connecting pipelines.

2. Conduct a regular groundwater monitoring program consisting of monitoring groundwater levels, groundwater useage, and water quality in selected wells. Twenty-one wells are suggested for the initial monitoring program. Conduct monitoring quarterly or every three months. Utilize the database, known as the "Water Resources Management System", to

store and analyze the collected data. Conduct a groundwater resources evaluation every 10 to 15 years.

3. Work with other municipalities to help form a regional groundwater management agency. The purpose of this agency would be to help address technical and management issues regarding the groundwater resources.

4. Establish a wellhead protection program to reduce the chance of groundwater contamination impacting water supply wells.

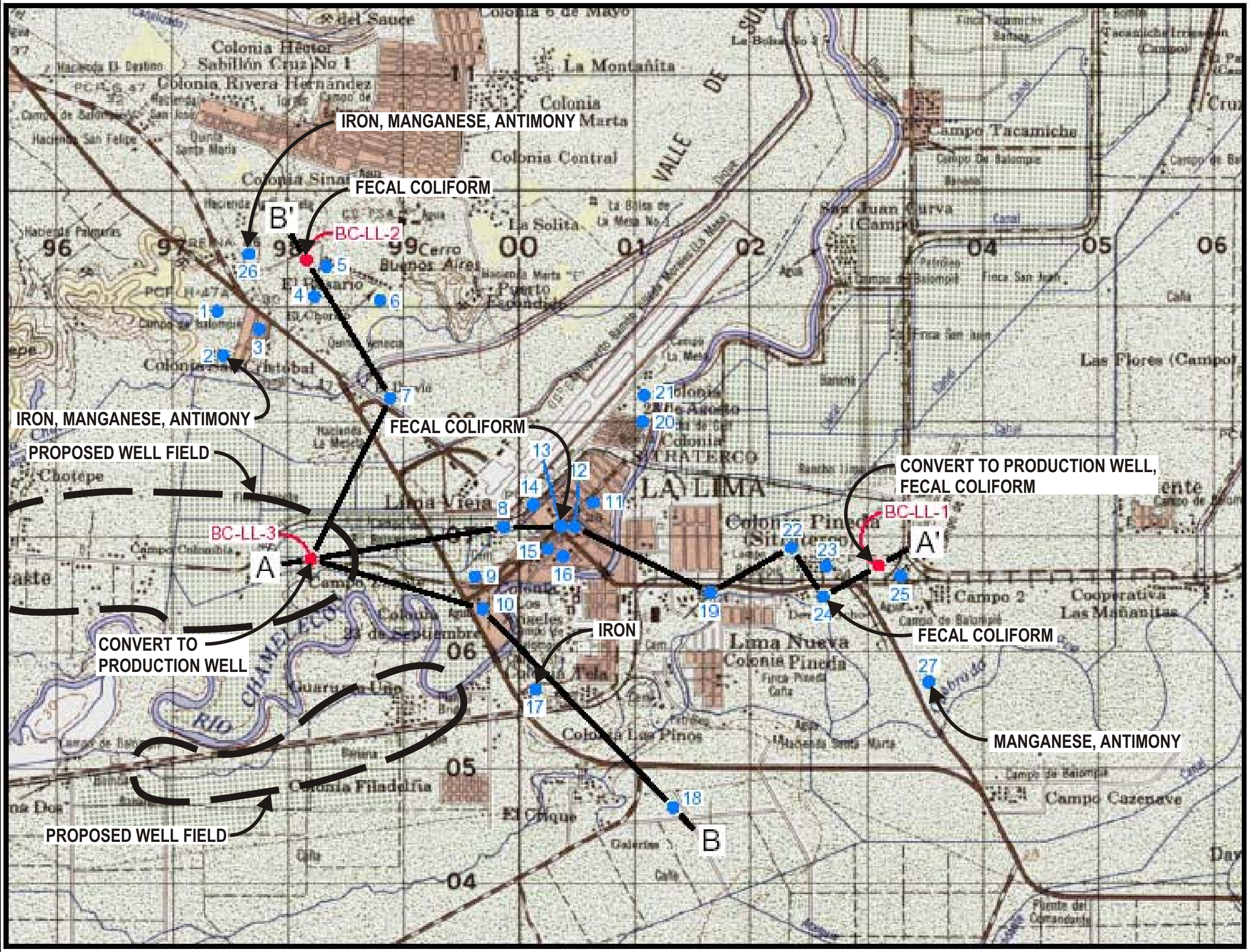
5. Ensure a functioning water utility that is financially self-sufficient by continuing to:
   a. maintain and update the customer inventory;
   b. update the financial plan and charge customers for water useage to ensure that water utility revenues are sufficient to pay for costs;
   c. have trained staff that is familiar with operating a municipal water system; and
   d. investigate potential funding sources for grants and loans.

6. Reduce the number of wells that will be needed in the future by promoting water conservation and reducing leaks from the water distribution system. The first step is to conduct a study to define the amount of water loss and recommend the best areas for leak repair and/or water main replacement.

7. Establish control over well construction by others through municipal regulation that provides construction standards and well drilling reporting requirements.

8. Disinfect and retest the wells which have a presence of coliform and fecal coliform.

9. Prepare a water system expansion plan that defines needed improvements such as tanks and pipelines.



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APPROXIMATE SCALE IN FEET

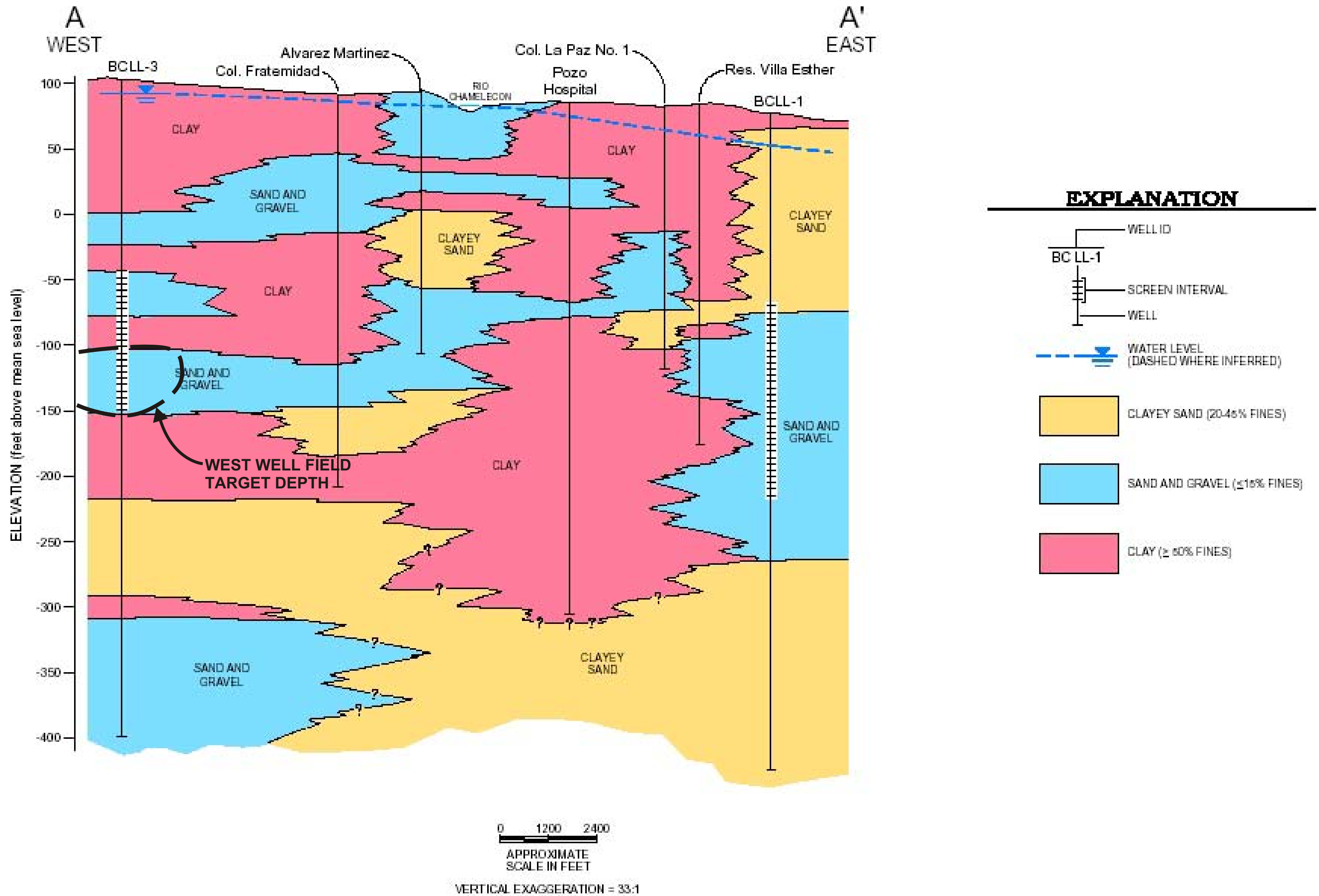
EXPLANATION

- ● BC-LL-3 — APPROXIMATE WELL LOCATION; WELL ID
- A —— A' — LINE OF GEOLOGIC CROSS-SECTION

OTHER WELLS

1 Colonia Jerusalem
2 Guaymuras
3 San Cristobal No. 2
4 Ciudad Planeta 1 (Fusep)
5 Ciudad Planeta 3
6 Ciudad Planeta 4
7 San Cristobal Texaco
8 Colonia Fraternidad
9 Colonia Los Angeles
10 Pozo Profundo
11 Sitraterco Club Sula
12 Alvarez Martinez
13 Cruz Roja
14 Colonia El Maestro
15 Escuela Gabriela Mistral
16 Vivero Municipal
17 Colonia Martinez Rivera
18 Atlantic Fish
19 Hospital Pozo
20 Colonia La Mesa Nuevo
21 Colonia La Mesa Viejo
22 Colonia La Paz No. 1
23 Colonia La Paz No. 2
24 Residencial Villa Esther
25 Campo Dos
26 22 de Mayo
27 Oro Verde

BROWN AND CALDWELL	DATE 7-15-02	SITE La Lima, Republic of Honduras	FIGURE ES-1
	PROJECT 21143	TITLE Groundwater Resources Planning Map	



BROWN AND CALDWELL

DATE	SITE	FIGURE
7-3-02	La Lima, Republic of Honduras	ES-2
PROJECT	TITLE	
21143	Cross Section A-A’	

1.0 INTRODUCTION

The United States Agency for International Development (USAID) retained Brown and Caldwell to provide architecture and engineering services as part of the Honduras Hurricane Reconstruction Program to assure the sustainability of permanent repairs and expansions of selected water supply systems damaged by Hurricane Mitch. Specifically, this project consists of performing groundwater monitoring studies for the Island of Utila, the Sula Valley (La Lima, Villanueva, and Choloma), and the resettlement community of Nueva Limón de la Cerca near Choluteca.

This Groundwater Resources Monitoring Report and Management Plan (Report) presents the results of the groundwater monitoring study and includes a groundwater resource management plan to help ensure the sustainable management of the groundwater resources of La Lima, Honduras.

This chapter provides a description of the project objectives, scope of work, project background, and the report organization.

1.1 Project History and Objectives

The municipality of La Lima is located in the northwestern portion of Honduras, as depicted in Figure 1-1. La Lima depends exclusively on groundwater as its primary source of municipal water supply. It is anticipated that reliance on groundwater for the municipal water supply will increase as the population growth continues in the future. This project was initiated by USAID due to the increasing population in La Lima, the need to quantify the available groundwater resources for sustainable development in this area, and the need to develop the groundwater resources while avoiding damage due to contamination and floods.

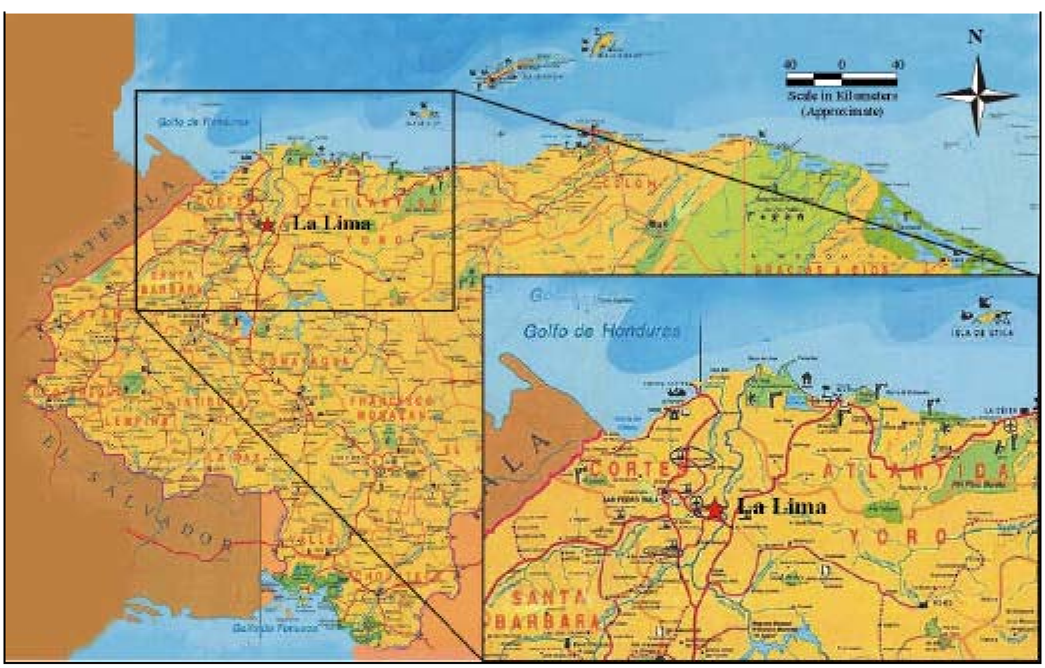


Figure 1-1. Site Location

This project is an important element in meeting overall USAID objectives in Honduras. The two objectives that are addressed best by this project are the sustainable improvements in family health and more responsive and effective municipal governments, as described below (USAID, March 2000).

Sustainable improvements in family health. One of this objective's desired results is the rehabilitation of water system facilities, given that access to potable water reduces child diarrheal deaths, especially in rural areas. The USAID performance indicator for this result is the percentage of rural water systems operating at the "A" level. This is defined as a system where a) water is disinfected, b) there is a water board that meets at least every three months, c) there is a water fee paid by users, d) there is a maintenance employee, and e) water is available from the system on a daily basis.

More responsive and effective municipal government services. This objective includes a desired result of increased coverage of public services, including potable water supply, as measured by the percent of inhabitants receiving public utility services.

To help meet the above objectives, this project evaluated the sustainable yield of the groundwater resources in the La Lima area and developed a groundwater resources management plan to help ensure a sustainable municipal water supply for the urban area of La Lima. Key components of the project include the following:

- identification of groundwater resources available to provide residents with a safe and sustainable water supply;
- development of a groundwater resource management plan and related tools that can be implemented and maintained by the municipality and its staff;
- training of local individuals in groundwater monitoring techniques, data collection, and database management for sustainable management of the groundwater resource; and
- project completion meetings with municipalities to discuss study results, present reports, and describe recommendations to help ensure sustainable water supplies.

1.2 Contract and Scope of Work

This study was conducted by Brown and Caldwell for the USAID under contract No. 522-C-00-01-00287-00, dated March 21, 2001. The scope of work for this project defines five phases under which to conduct the study. These five phases are described below.

Phase I – Analysis of Existing Information/Development of Conceptual Hydrogeological Model. This phase consisted of establishing consensus on the projects goals and objectives, data collection, preliminary conceptual hydrogeologic model development, and the identification of additional data needs.

Phase II – Field Investigation. This phase consisted of well drilling, aquifer testing, and water quality monitoring to fill data gaps and help provide data for refining the preliminary conceptual model. In addition, training was provided to local personnel in groundwater monitoring techniques.

Phase III – Hydrogeologic Modeling and Analysis. This phase consisted of refining the conceptual hydrogeologic model through quantitative groundwater modeling and analysis, and development of estimates of the long-term sustainable yield of water resources in the study area.

Phase IV - Database and Training in Monitoring and Database Management. This phase consisted of groundwater database development, database training of local municipal staff, and preparation of training manuals for both the database and monitoring methods. The database is known as the Water Resources Management System. The training manuals are included as Appendices D and E. This phase was executed concurrently with the other four phases.

Phase V – Final Report. This phase consisted of the development of a final project report that summarizes project data, activities, study results, and recommendations for sustainable management of the water resource in the area. The development of a groundwater resource management plan that includes appropriate measures for the development of the groundwater resources was also completed under this phase. This report represents the Phase V work product for the La Lima urban area.

1.3 Report Organization

This report is organized into six chapters and associated appendices. The contents of each of the remaining chapters is briefly described below:

Chapter 2 – Background: This chapter provides a description of the community, climate, geology and soils, hydrogeology, wastewater management, and the regulatory setting.

Chapter 3 - Existing Water System and Water Demands: This chapter describes the existing water system and summarizes the historical demographics and projects future population and water use.

Chapter 4 - Groundwater Resources Evaluation: This chapter summarizes the methods, procedures, and results of the field investigation program. This chapter also presents a conceptual hydrogeologic model and a numeric groundwater model, recommends and numerically simulates well fields, and identifies potential sources of contamination to the groundwater resource. The training conducted on groundwater monitoring techniques is described in Appendix G.

Chapter 5 - Water Resources Management System: This chapter provides an overview of the water resource database and management tool developed for La Lima and presents instructions for using this tool to assist in the management of La Lima's water resource. The training conducted on the use of the database is described in Appendix G.

Chapter 6 – Conclusions and Recommendations: This chapter presents the conclusions and groundwater resources management recommendations. This chapter also describes the scope for recommended additional studies, if needed. Finally, this chapter presents a recommended groundwater resource management plan and includes policy and institutional recommendations for sustainable management of the resource.

2.0 BACKGROUND

This chapter describes the geographic setting of the community of La Lima, as well as the climate, geology and soils, hydrogeology, land use, wastewater management, and regulatory setting.

2.1 Geographical Setting

The municipality of La Lima is located approximately 15 kilometers (km) (9 miles (mi)) southeast of San Pedro Sula. The Chamelecón River flows through La Lima. The airport that serves the San Pedro Sula area, Ramón Villeda Morales International Airport, is located adjacent to La Lima. The Ulua River is located approximately 5 km (3 mi) to the east of La Lima. Figure 2-1 depicts a topographic map of the La Lima area. The municipality of La Lima is divided into urban and rural areas, as illustrated on Figure 2-2.

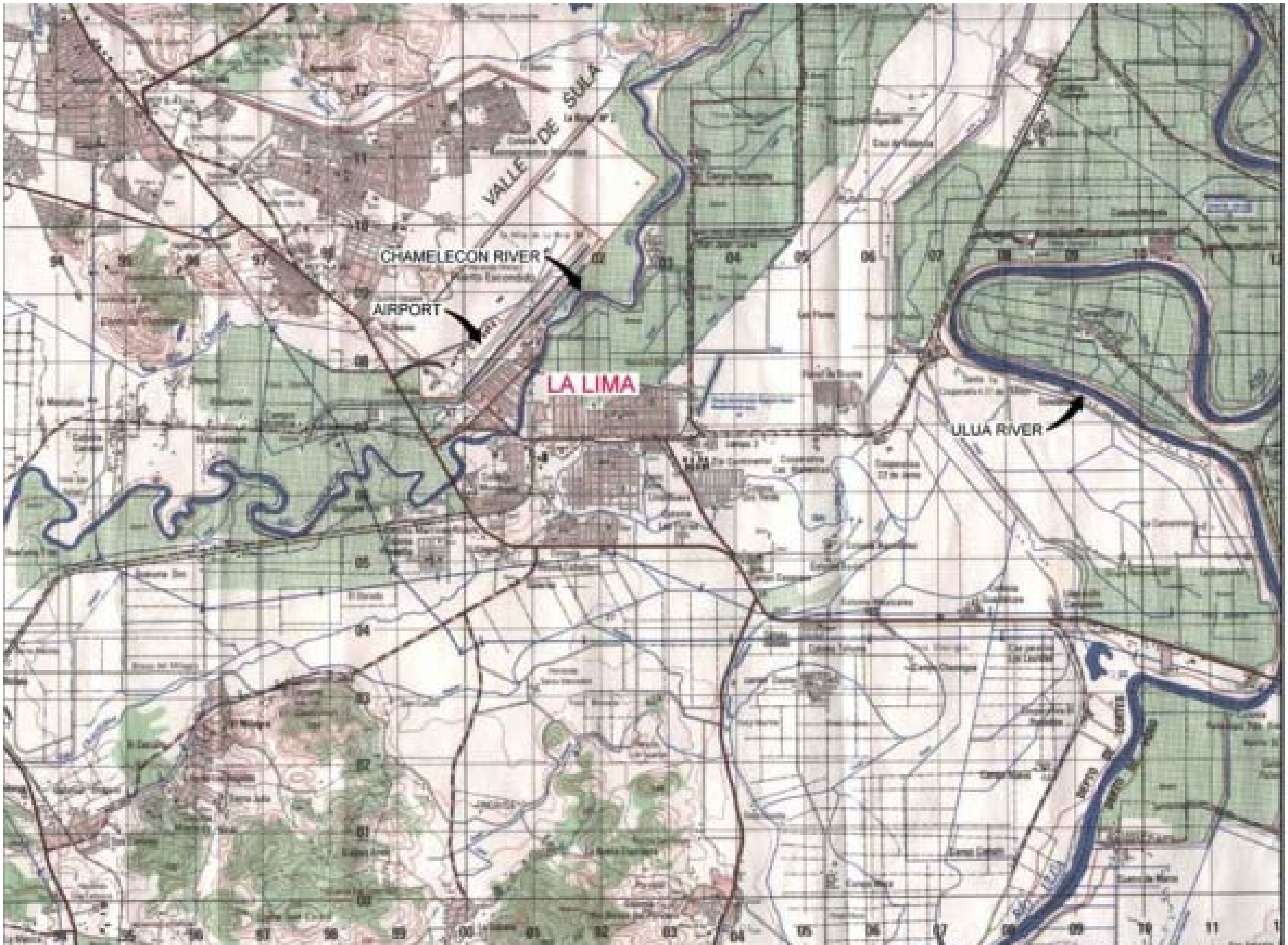
2.2 Climate

The entire country of Honduras lies within the tropics and consists of three different physiographic regions, referred to as the Caribbean lowlands, Pacific lowlands, and interior highlands. La Lima lies within the Caribbean lowlands, which have a tropical wet climate with consistently high temperatures and humidity, and receives approximately 1,800 millimeters (70 inches) of precipitation a year. Most rainfall occurs between July and November, (Library of Congress, Federal Research Division, 1993). Due to the availability of historical precipitation data, no supplemental precipitation data were collected for this study. La Lima has a climate similar to San Pedro Sula, which has an average temperature of about 30-35 degrees Celsius.

2.3 Geology and Soils

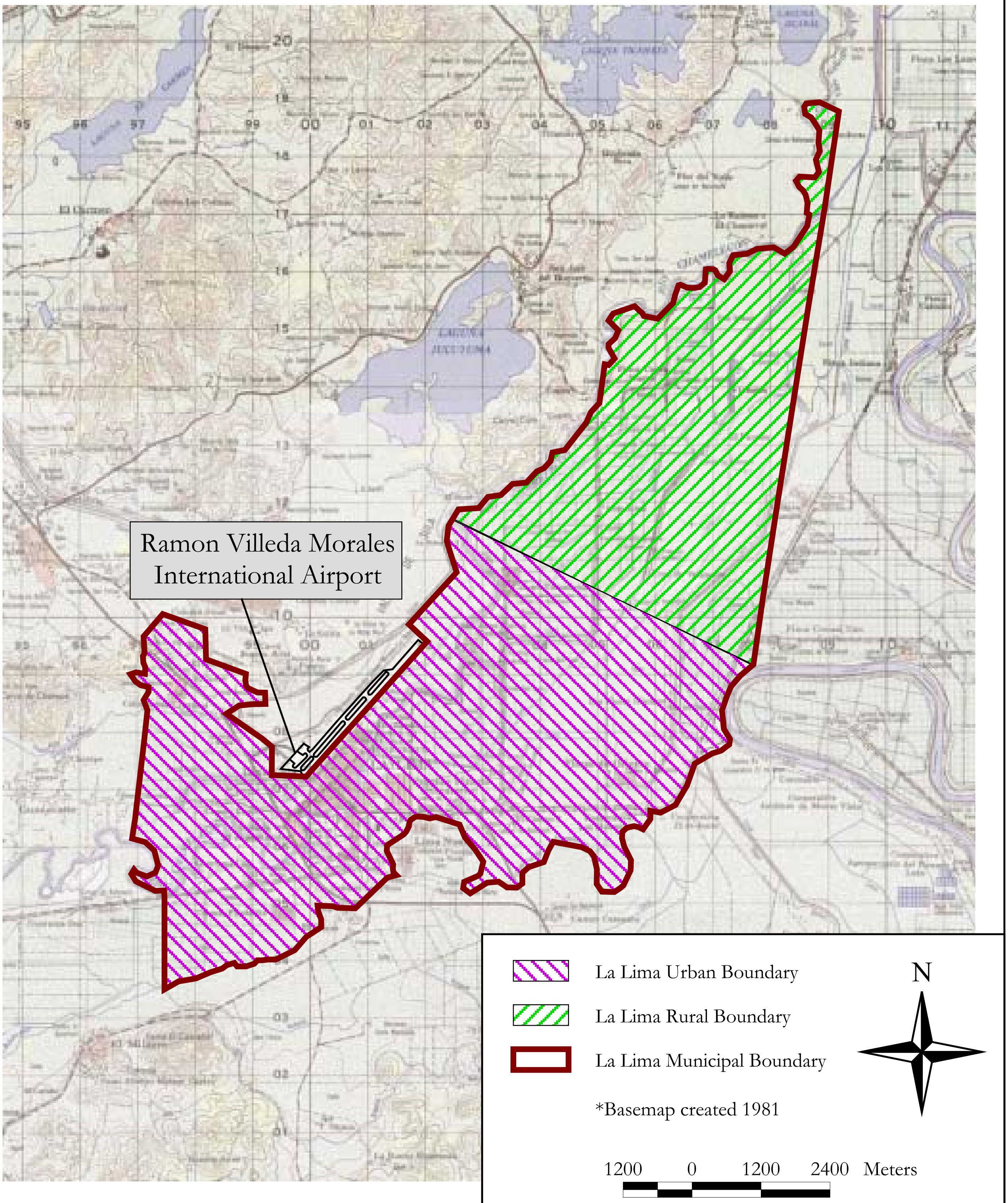
La Lima is located in the Sula Valley. The Merendon Mountains make up the western portion of the Sula Valley; a prominent north-south trending graben located in the north-central portion of the country. The valley is bound by high-angle normal faults to the east and west (Figure 2-3), which are represented by an abrupt change in topography from the broad flat plain of the valley at an elevation of 100 feet (ft) above mean sea level (amsl) to steep rugged uplands, reaching more than 1,500 ft amsl in elevation.

Honduras and most of Central America is situated in an area characterized by significant volcanic activity and structural deformation as a result of plate tectonics. Although most of the relief and geology were controlled by volcanism, there are currently no active volcanoes in Honduras. The northern coast of Honduras is part of a strike-slip plate boundary between the North American Plate and Caribbean Plate. This zone is represented by a series of northeast- trending transverse faults, which extend throughout the country. North of La Lima, this boundary is represented in part by the northeast trending Chamelecón fault.

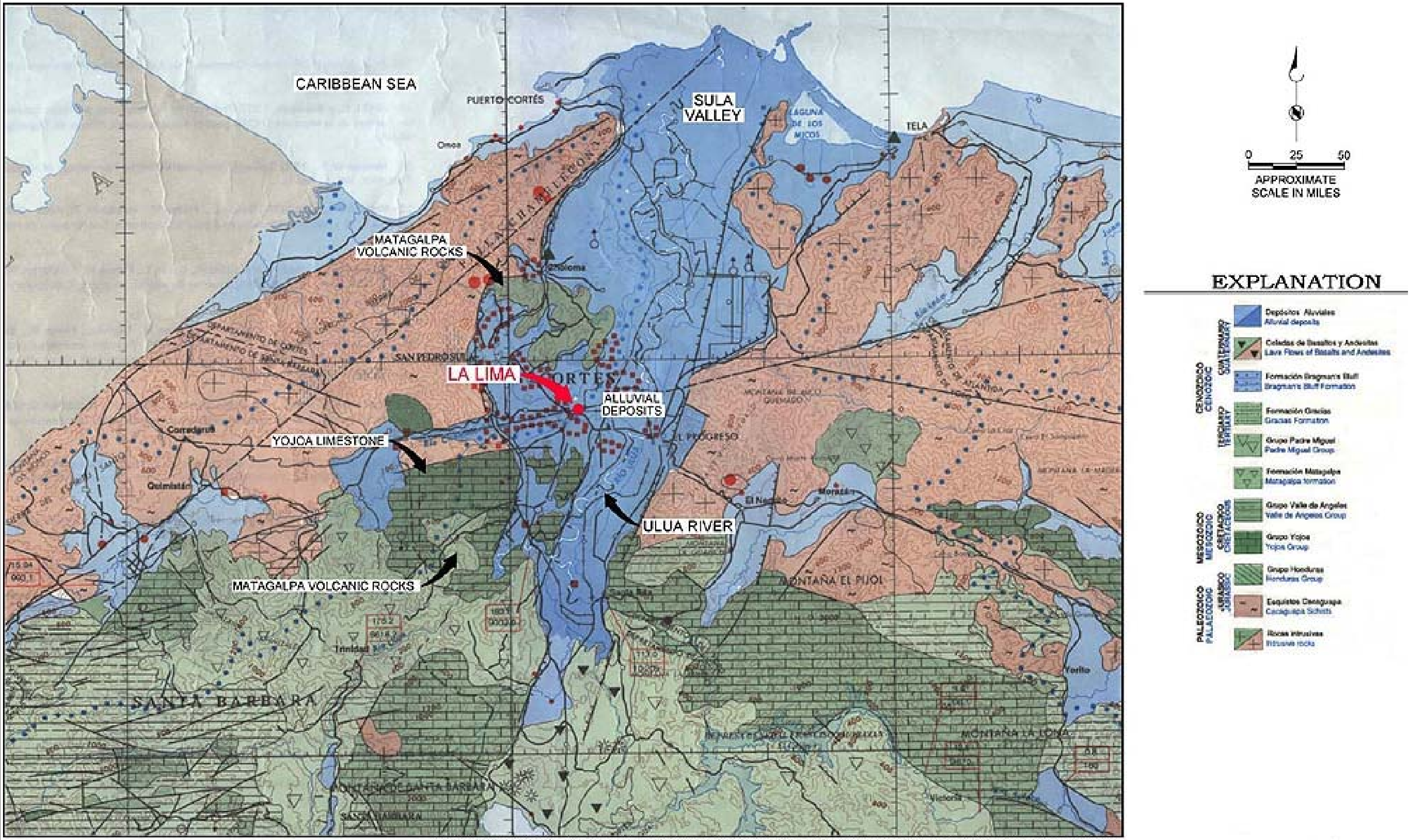


SOURCE: INSTITUTO GEOGRAFICO NACIONAL. EL PROGRESSO TOPOGRAPHIC MAP, 1994.

BROWN AND CALDWELL	DATE 3-26-02	SITE La Lima, Republic of Honduras	FIGURE 2-1
	PROJECT 21143	TITLE Topographic Map Showing La Lima	



BROWN AND CALDWELL	DATE 3/28/2002	SITE La Lima, Honduras, C.A.	FIGURE 2-2
	PROJECT 21143	TITLE Municipal, Urban and Rural Boundaries	



SOURCE: HYDROGEOLOGIC MAP OF THE REPUBLIC OF HONDURAS, 1995. BRITISH GEOLOGIC SURVEY, INSTITUTO GEOGRAFICO NACIONAL

BROWN AND CALDWELL	DATE 3-26-02	SITE La Lima, Republic of Honduras	FIGURE 2-3
	PROJECT 21143	TITLE Geologic Map of the Sula Valley	

La Lima is situated along the Chamelecón River, which flows east out of the Merendon Mountains, and flows north to the Caribbean Sea. The Ulua River is located approximately 5 km east of La Lima. The Ulua River basin comprises one of the most extensive watersheds in the Honduras. The river enters the Sula Valley from the southwestern highlands and flows to the north. Prior to the formation of the Sula Valley, the area was part of a large uplifted plateau. During this time, the ancestral Chamelecón River rapidly eroded downward to create an incised channel that cut deeply into bedrock of the Merendon Mountains, possibly following faults or fracture traces that trend perpendicular to the Sula Valley. Subsequent regional plate extension processes lead to normal faulting of surrounding highlands and the formation of the graben areas of the Sula Valley.

Both river valleys, Chamelecón and Ulua, are characterized as broad flat alluvial plains, with a number of lagoons, wetlands, and meandering rivers. In the vicinity of La Lima, the Sula Valley is more than 60 km wide. Upon entering the Sula Valley, the Chamelecón River flow has been channelized into a flood control canal, located about 1 km west of the Ulua River.

2.4 Hydrogeology

The surrounding Merendon Mountains serve as the major surface and groundwater recharge areas for the alluvial materials of the Chamelecón River Valley. Surface water infiltrates into the fracture networks of the metamorphic and igneous rocks, and provides groundwater recharge to the valley bedrock and alluvial materials. Groundwater from these uplands generally flows towards the alluvial valley. Once the groundwater from the upland areas enters the Valley alluvium, groundwater flow will generally begin to move down valley and towards the Chamelecón River, which, along with the Ulua River, serves as a major groundwater discharge point for the valley hydrologic system.

The total thickness of the alluvial materials is estimated to be greater than 500 ft in the vicinity of La Lima. Boring logs completed within the alluvium indicated that the upper 325 ft of the alluvial materials are characterized as an upper sequence that consist of fine-grained sediments. The upper 75 to 125 ft of alluvial materials are characterized as inter-bedded clayey-silts, silts and sands. These materials grade into inter-bedded silts and fine- to medium-grained sands from approximately 125 to 150 ft. Below 150 ft, approximately 150 ft of inter-bedded fine-, medium-, to course-grained sands and gravels have been observed. This lower sand and gravel unit has been observed throughout the valley. A laterally extensive clay unit has been observed at a depth of approximately 325 ft. Groundwater production from existing wells screened within the sand and gravel aquifer range from 80 to 500 gallons per minute (gpm) with an average yield of 210 gpm. Additionally, there are unconfirmed reports of irrigation wells screened within this aquifer to the south of La Lima that produce in excess of 1,000 gpm.

2.5 Land Use

Land is used in La Lima for residential, industrial, and agricultural purposes. Originally an agricultural community with large banana plantations, La Lima is now host to some industrial development and the airport.

2.6 Wastewater Management

An understanding of wastewater management is important because certain disposal practices can impact groundwater quality. There is a central wastewater collection and treatment system in La Lima. However, some of the larger industrial facilities have constructed separate wastewater treatment facilities.

2.7 Regulatory Setting

The water system in La Lima is owned by the municipality. There are several small independent water systems that are operated by community water boards. Many of the industrial facilities have their own water systems.

The water systems in Honduras are regulated by the Honduran Ministry of Health. The drinking water standards in Honduras are equivalent to standards defined by the World Health Organization (WHO). Currently, drinking water standards are not enforced and water compliance monitoring and reporting are not required in Honduras.

The Panamerican Health Organization (PAHO) provides technical support to municipalities through the Ministry of Health for water issues. Some other organizations have been formed in Central America to share experiences in water and sanitation management with municipalities.

3.0 DESCRIPTION OF EXISTING WATER SYSTEM AND WATER DEMANDS

This chapter describes the existing water supply system and municipal water demands in La Lima. The information was obtained from reports prepared by others, discussions with municipal representatives, and our field reconnaissance.

3.1 Water Supply System

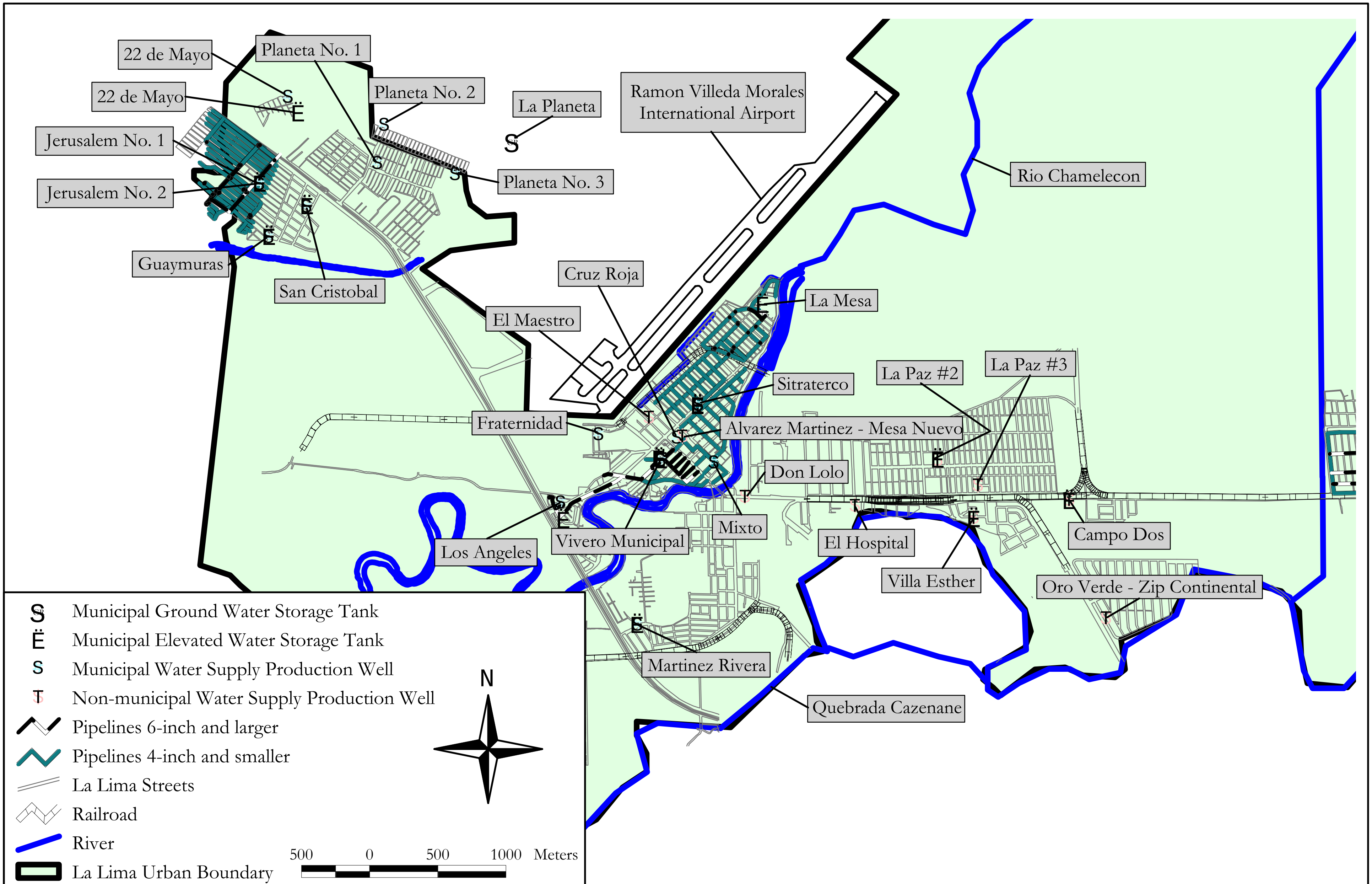
The water supply system is owned and operated by the municipality of La Lima. Groundwater is the sole source of water supply. There are also independent water supply systems operated by their own water boards. Currently there is no daily treatment or disinfection of the water prior to distribution. However, there is a program to disinfect wells and tanks every six months. Figure 3-1 depicts the locations of the key water system facilities. The municipal water system serves three different service areas that are geographically separated. Features and capacities of municipal and non municipal wells, reservoirs, and the distribution system are described in this section. There are no booster pump stations in the water system.

3.1.1 Municipal Water Supply Wells. Sixteen municipal wells provide the municipal water supply for La Lima. These municipal wells have a combined capacity of 124 liters per second (lps) (1,985 gallons per minute (gpm)). Table 3-1 summarizes information regarding the existing wells. Table 3-1 also presents the estimated hours of pumping per day and resulting daily production of each well based on information collected during the field investigation. Figure 3-2 depicts one of the municipal wells in the city center.

Table 3-1. Municipal Well Information

Name	Capacity		Daily pumping time, hours	Daily production		Well depths, bgs	
	lps	gpm		lps	gpm	m	ft
22 de Mayo	6	90	18	4	68	55	180
Club Sula[a]	13	200	18	28	450	--[b]	--[b]
Cruz Roja	9	150	18	7	113	61	200
Fraternidad	11	180	24	11	180	69	225
Guaymuras	6	100	18	5	75	110	362
Jerusalem #1 (entrada)	3	45	24	3	45	--[b]	--[b]
Jerusalem #2 (Kinder)	11	180	24	11	180	49	160
Los Angeles	4	60	24	4	60	47	154
Martinez Rivera	9	150	18	7	113	55	180
Mixto	9	150	18	7	113	53	175
Planeta 1 (Fusep)	4	60	11	2	28	61	200
Planeta 2	4	60	11	2	28	76	250
Planeta 3	13	200	18	9	150	66	215
San Cristobal	4	60	18	3	45	60	197
Sitraterco	9	150	18	7	113	--[b]	--[b]
Vivero Municipal	9	150	24	9	150	53	175
Total	124	1,985	--	119	1,611	--	--

[a] Well not shown on existing water system figure
[b] Unknown
m = meter
bgs = below ground surface
ft = feet
gpm = gallons per minute
lps= liters per second



BROWN AND CALDWELL

DATE	SITE	FIGURE
6/19/2002	La Lima, Honduras	3-1
PROJECT	TITLE	
21143	Existing Water System	

Figure 3-2. View of a Municipal Well in the center of the City

3.1.2 Non-Municipal Water Supply Wells. Some of the industrial facilities of La Lima have constructed their own private wells to supplement the municipal water distribution system. There are 14 non municipal wells used for public water supply with a combined total capacity of 120 lps (1,950 gpm). These wells are not connected to the municipal distribution system. Table 3-2 summarizes the available information for the known non-municipal wells in La Lima.

Table 3-2. Non-Municipal Well Information

Name	Capacity		Daily pumping time, hours	Daily production		Well depth, bgs	
	lps	gpm		lps	gpm	m	ft
Alvarez Martinez-Mesa Nuevo	13	200	6	3	50	61	200
Campo Dos	6	150	16	6	100	–[b]	–[b]
Don Lolo	9	150	10	4	63	82	270
El Hospital	6	90	24	6	90	119	390
El Maestro	8	133	4	1	22	98	320
Filadelfia[a]	6	100	10	3	43	59	193
La Paz #2 (Luis Thiegaud)	3	55	20	3	46	–[b]	–[b]
La Paz #3 (Rosenthal)	6	91	20	5	76	–[b]	–[b]
La Suyapa[a]	6	100	8	2	33	–[b]	–[b]
Oro Verde-Zip Continental	13	200	4	2	33	–[b]	–[b]
San Jose[a]	6	100	8	2	33	–[b]	–[b]
Usula[a]	15	231	16	10	154	–[b]	–[b]
Villa Esther	13	200	2	1	17	79	260
Zona Americana (Marco Lud)[a]	10	150	20	8	125	81	265
Total	120	1,950	–	56	884	–[b]	–[b]

[a] Well not shown on existing water system figure
[b] Unknown
bgs = below ground surface
ft = feet
gpm = gallons per minute
lps= liters per second
m = meter

3.1.3 Water Storage Facilities. Water is currently stored in nine municipal storage tanks within La Lima. Figure 3-1 depicts the locations of the storage tanks. The municipal storage tanks have a total capacity of 2,170,934 liters (573,500 gallons) as seen in Table 3-3. There are several private and non municipal water storage tanks as described in Table 3-4. These tanks are not connected to the municipal water system. Figure 3-3 depicts one of the elevated tanks.

Seven water storage tanks are reportedly used for storage of water from non-municipal wells. The non-municipal storage tanks have a total capacity of 1,259,126 liters (332,627 gallons) as presented in Table 3-4.

Figure 3-3. View of Elevated Tank

3.1.4 Piping System. The La Lima distribution system consists of primarily 76-mm to 203-mm (3-in to 8-in) diameter piping. The distribution system consists of one pressure zone. The system is divided into three areas that are not interconnected. One area is northwest of the airport, the second serves the city center, and the third is sough of the Chamelecón River.

Table 3-3. Municipal Storage Tanks

Name	Volume		Type of tank
	liters	gallons	
22 de Mayo	75,708	20,000	elevated, concrete
Centro (Escuala Gabriela Mistral)[a]	227,124	60,000	elevated, metal
Guaymuras	151,416	40,000	elevated, metal
Jerusalen	75,708	20,000	elevated, concrete
La Planeta	1,135,620	300,000	ground, metal
Martinez Rivera	75,708	20,000	elevated, concrete
San Cristobal	51,103	13,500	elevated, concrete
Sitraterco	151,416	40,000	elevated, metal
Vivero Municipal	227,124	60,000	elevated, concrete
Total	2,170,927	573,500	--

[a] Not shown on existing water system figure

Table 3-4. Non-Municipal Storage Tanks

Name	Volume		Type of tank
	Liters	gallons	
Campo Dos	75,708	20,000	elevated, metal
El Maestro [a]	113,562	30,000	elevated, metal
La Mesa	113,562	30,000	elevated, concrete
La Paz	336,814	88,977	elevated, metal
Los Angeles	445,352	117,650	elevated, metal
Usula [a]	75,708	20,000	elevated, metal
Villa Esther	98,420	26,000	elevated, metal
Total	1,259,126	332,627	--

[a] Not shown on existing water system figure

3.2 Historical and Projected Water Demands

Water demand projections provide the basis for sizing and staging future water facilities. Water use and production records, combined with projections of population, provide the basis for estimating future water requirements. This section presents a summary of demographic information and water use data as well as the resulting projections of future water needs for La Lima.

3.2.1 Demographics. There are approximately 11,973 active connections in the La Lima water system (Ing. Doris M. Perez, January 23, 2001). In 1997, the La Lima population was reported to be 43,517 people and there were 6,315 households (Department Desarrollo Comunitario, 1997). This results in an average of 3.6 people per connection and 6.9 people per household.

Since published population projections prepared by others have not been identified for use in this study, the future population has been projected as a part of this study. The population annual growth rate assumed for 2000 through 2010 is based on the growth rate of the developed land area occurring from 1995 to 2000. For this study, it is assumed that the growth of developed area can serve as a surrogate for population growth. The 1995 developed land area was measured from the 1995 topographic map (Instituto Geografico Nacional, Honduras). The 2000 developed land area was estimated from the March 2000 aerial photograph (USGS, March 2000.). The developed land area in 1981, 1995, and 2000 are illustrated on Figure 3-4 and presented in Table 3-5.

Table 3-5. Developed Land Area

Year	Land area	
	km^2	acres
1981[a]	1.9	473
1995[b]	2.9	715
2000[c]	4.5	1,120

[a]Based on developed area in the 1981 Instituto Geografico Nacional, Honduras, est. 1981.
[b]Based on developed area in the 1995 Instituto Geografico Nacional, Honduras
[c]Based on developed area in the USGS March 2000 aerial photograph

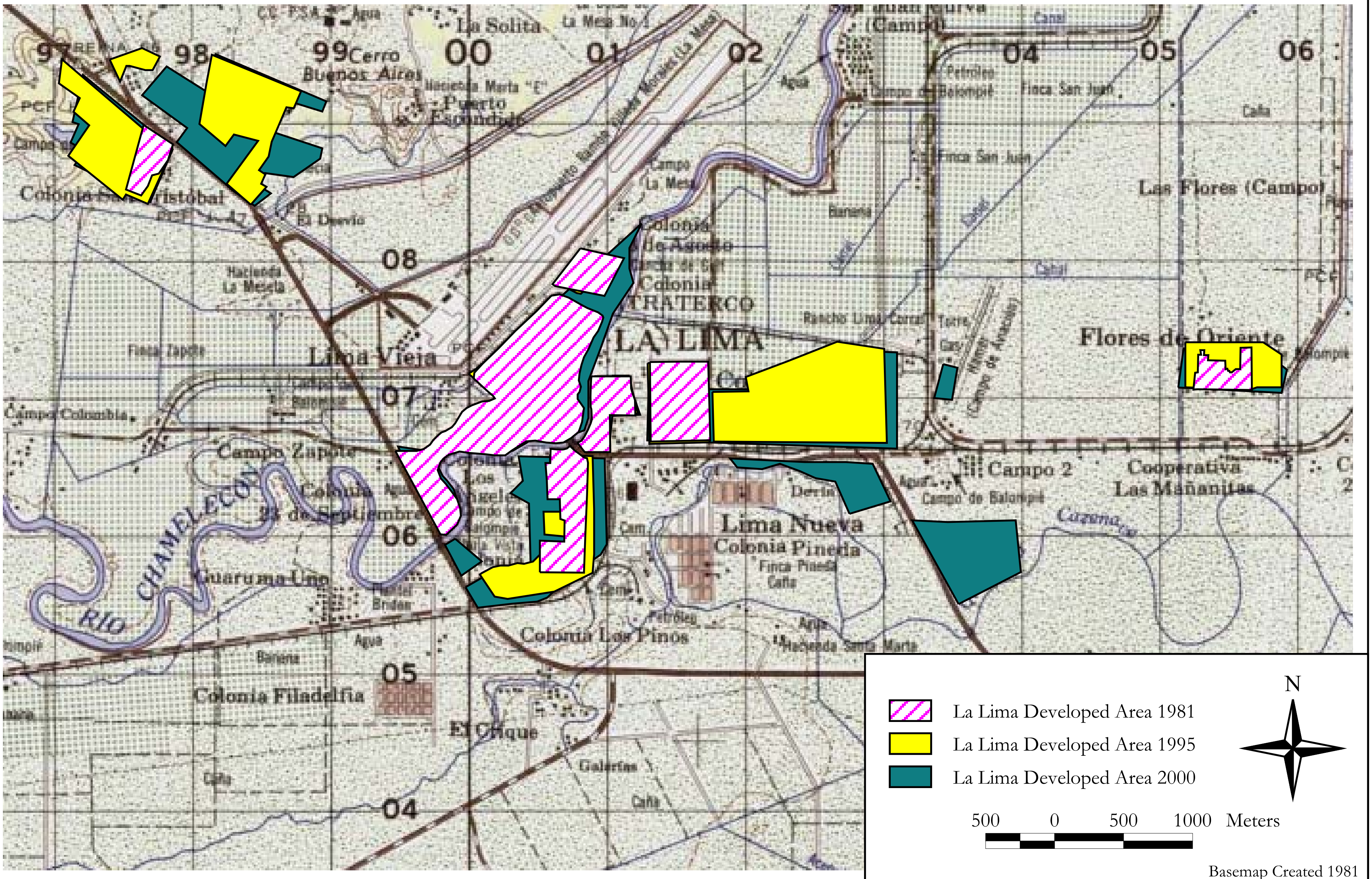
From 1995 to 2000, the developed land area expanded at an average growth rate of nine percent per year. The current population density is approximately 34 people per acre.

Table 3-6. Projected Population

Year	Population
1997	43,517
2000	51,141
2005	78,687
2010	121,070
2015	158,084
2020	206,413

Population projection based on 9% annual growth rate through 2010, and 5.48% thereafter.

It is assumed for this study that the 1995 to 2000 historical growth rate will continue through 2010. It is unlikely that this rapid growth rate will be maintained over the long-term. As communities become larger, their annual growth rates tend to decline. This study assumes that the growth rate for La Lima will decrease following the year 2010 to be equivalent to that of the nearby and much larger city of San Pedro Sula, which is 5.48 percent per year (REPAMAR, 2000). The historical and projected population are presented in Table 3-6 and illustrated on Figure 3-5.



BROWN AND CALDWELL

DATE	SITE	
6/13/2002	La Lima, Honduras, C.A.	FIGURE 3-4
PROJECT	TITLE	
21143	Urban Growth	

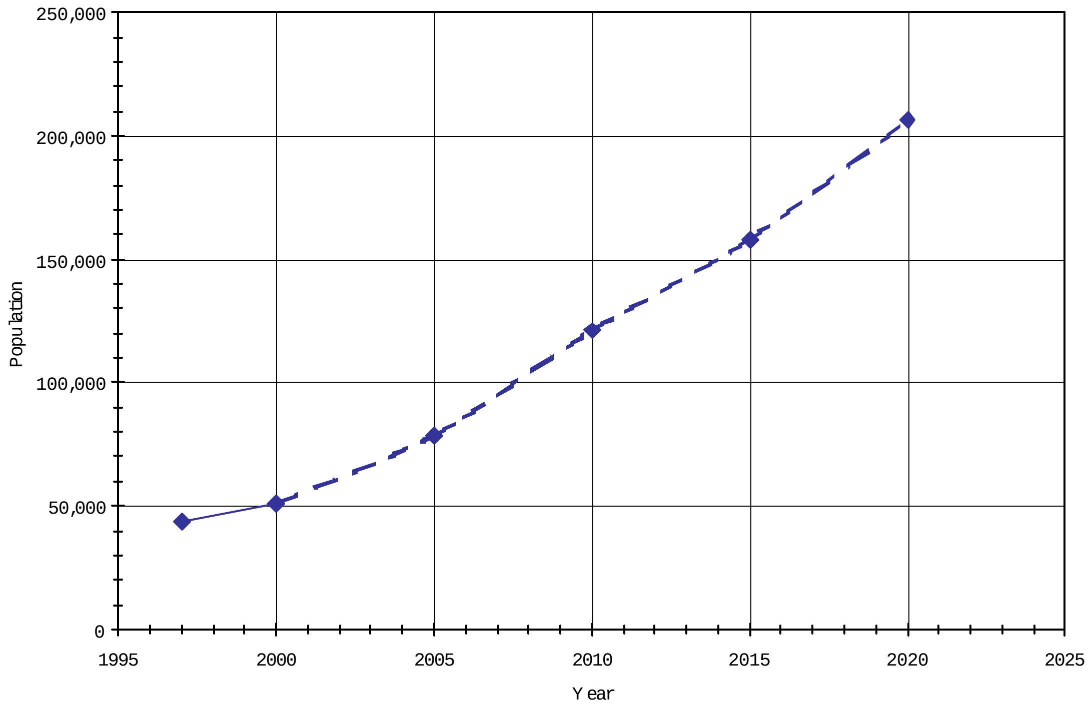


Figure 3-5. Projected Population

3.2.2 Historical Water Use. Water production is the volume of water measured at the source, which includes all water delivered to residential, commercial, and public authority connections, as well as unaccounted-for water. Water production data is not available because La Lima's wells are not metered. An estimate of year 2000 annual water production by the municipal wells based on the number of hours each well is pumping (Table 3-1) is 7.9 million liters per day (mld) (2.1 million gallons per day (mgd)). This is approximately equivalent to an estimate of current water production based on a per capita production including system losses of 172 liters per capita per day (lpcd) (45 gallons per capita per day (gpcd)) and a year 2000 population of 51,141. These water demand estimates do not include water pumped from the non-municipal wells.

Daily demand fluctuates throughout the year based primarily on seasonal climate changes. Water demands are higher in the dry seasons and decrease in the wet seasons. System production facilities must be sized to meet the demand on the maximum day of the year, not just the average. The maximum day peaking factor, which is defined as the one day of the highest water use during a one-year period divided by average daily use, is estimated to be 1.2 for the purposes of this study, based on common engineering practice. The actual maximum day water demand is not known, but it is estimated to be 10.6 mld (2.8 mgd).

Unaccounted-for water use is water use for activities such as fire protection and training, system and hydrant flushing, sewer cleaning, construction, system leaks, and unauthorized connections. Unaccounted-for water can also result from meter inaccuracies. The water system in La Lima is not metered, therefore, data are unavailable for determining the percent of unaccounted-for water.

3.2.3 Unit Water Use. Unit water use factors are developed to estimate future water needs, based on the population discussed previously. Future water needs are determined using the population projections within the La Lima water service area, coupled with a unit water use factor per person.

Unit water use in nearby San Pedro Sula, one of the largest cities in Honduras, is estimated to be 379 lpcd (100 gpcd). This includes San Pedro Sula's 52 percent unaccounted-for water use (REPAMAR, 2000). It is estimated for this study that unit water use per person in La Lima is less than San Pedro Sula, at approximately 172 lpcd (45 gpcd). This unit water use is assumed to include unaccounted-for water.

3.2.4 Projected Water Demands. Water demands through the year 2020 were estimated based on the unit water use factor of 227 lpcd (60 gpcd) and the urban area population projections. These water demand projections are shown on Figure 3-6 and presented in Table 3-7. By 2020, average annual water demands are expected to increase from 8.6 million liters per day (mld) (2.3 million gallons per day (mgd)) in 2000 to 36.4 mld (9.6 mgd) in 2020. Impacts to water use due to any conservation measures implemented in the future are not reflected in the projected water demands.

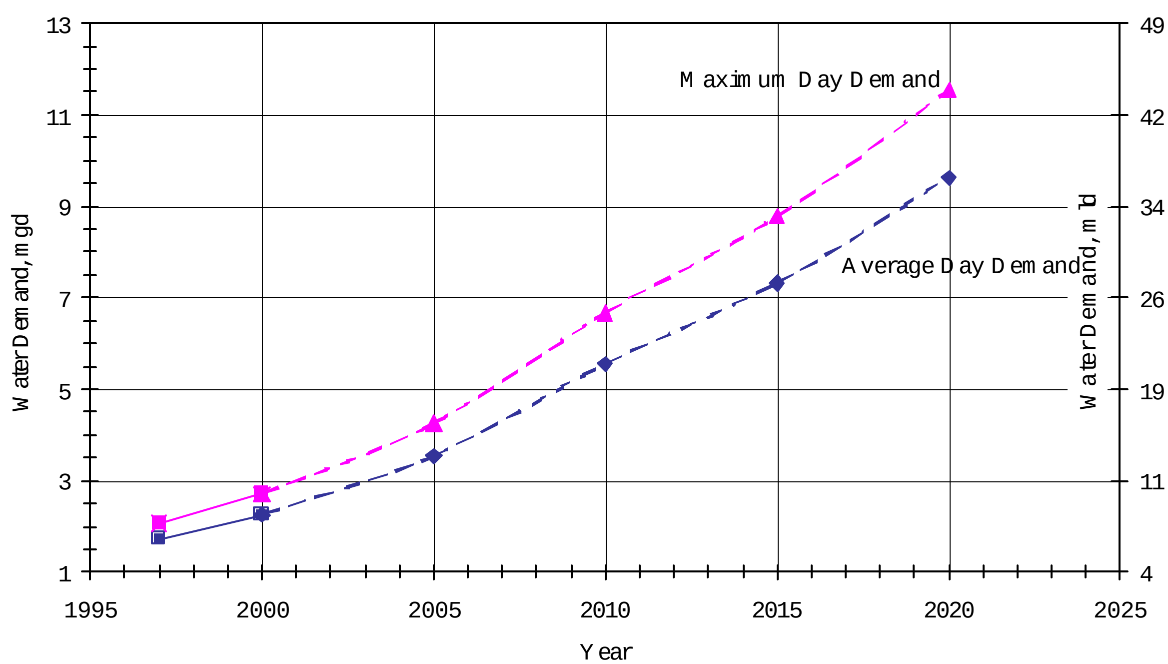


Figure 3-6. Projected Water Demand

Table 3-7. Projected Water Demands for La Lima Urban Area

Year	Average day water use		Maximum day water use[a]	
	mld	mgd	mld	mgd
2000	8.6	2.3	10.6	2.8
2005	13.4	3.5	15.9	4.2
2010	21.1	5.6	25.4	6.7
2015	27.7	7.3	33.4	8.8
2020	36.4	9.6	43.6	11.5

[a] Maximum day projected water demands based on assumed 1.2 maximum day peaking factor.

Table 3-8 presents a comparison of water demands versus source capacity. The required supply is based on the assumption that wells are limited to a minimum of 20 hours per day of operation.

Table 3-8. Comparison of Water Requirements to Supply

	2002		2020	
	lps	gpm	lps	gpm
Average day demand	120	1,908	421	6,667
Maximum day demand[a]	145	2,290	506	8,000
Required supply capacity[b]	174	2,748	607	9,600
Available capacity[c]	125	1,985	125	1,985
Deficit[d]	48	763	481	7,615

[a] Maximum day demand based on assumed 1.2 maximum day peaking factor.
[b] Based on 20 hour/day pumping and meeting maximum day demand.
[c] Identified existing municipal wells capacity.
[d] Required well capacity to meet maximum day demand.

4.0 GROUNDWATER RESOURCES EVALUATION

The groundwater resource evaluation for La Lima consisted of the review and analysis of existing geologic, hydrogeologic, and groundwater resource information for the area. Following the initial records review, a site reconnaissance of the area was conducted, followed by the development of a conceptual model, and the performance of a field investigation which included drilling and testing of test wells to explore deep hydrogeologic conditions in the valley. Following data collection and interpretation, a numeric groundwater flow model was developed using data obtained during this evaluation. This chapter presents the results of the groundwater evaluation at La Lima.

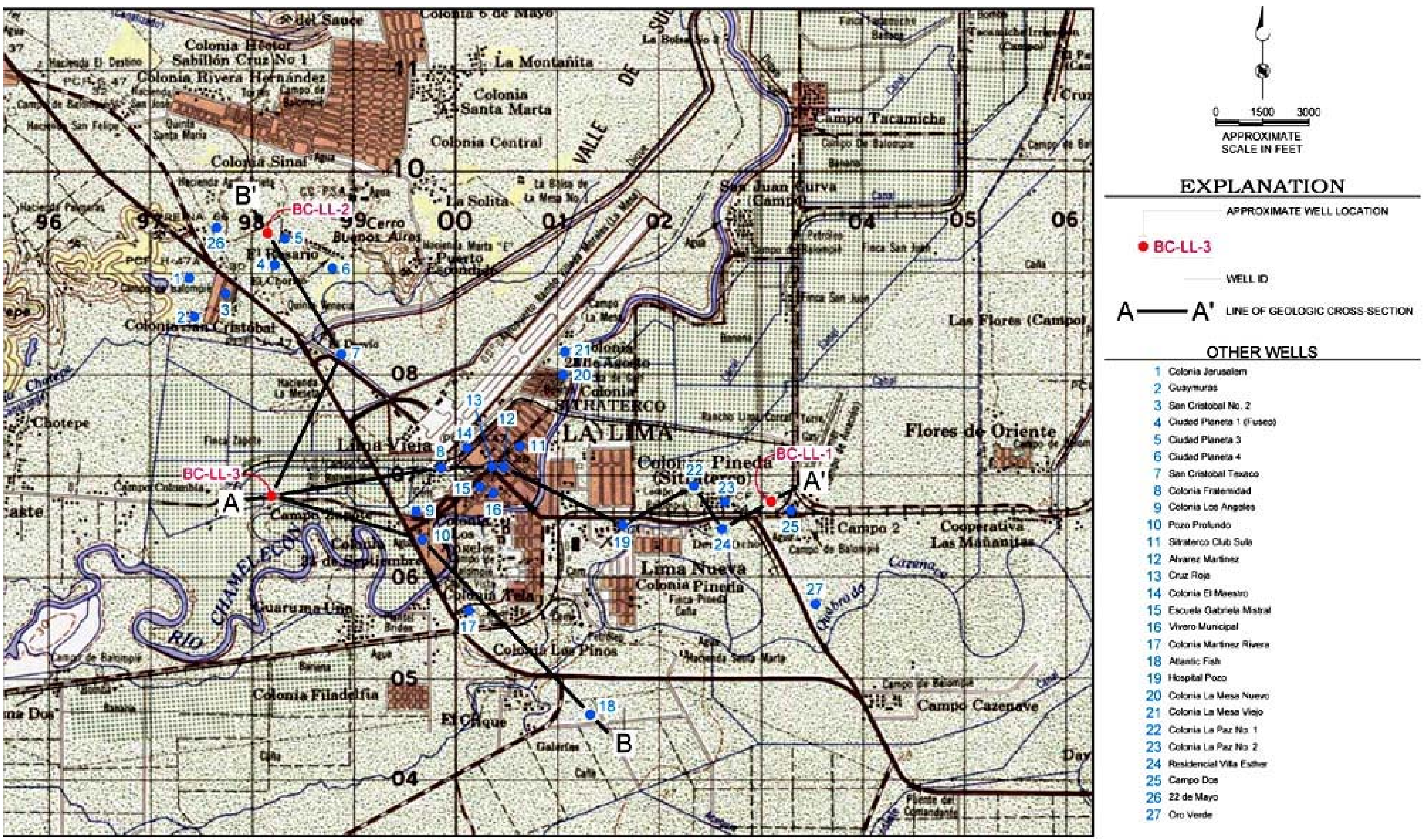
4.1 Conceptual Hydrogeologic Model

The conceptual model for Lima was developed based on the understanding that the upland areas of the Merendon Mountains on the western side of the Sula Valley serve as the major surface and groundwater recharge areas for the alluvial materials in the area of La Lima. Topographic and geologic maps of the area are presented on Figures 2-1 and 2-2. Surface water infiltrates into the fracture networks of the metamorphic and igneous rocks that comprise the Merendon Mountains, and provides groundwater recharge to the Chamelecón valley alluvial materials. Once the groundwater from the upland areas enters the valley alluvium, groundwater flow generally begins to move down the valley and towards the Chamelecón River, which, along with the Ulua River, serves as a major groundwater discharge area for the valley hydrologic system. The Chamelecón River eventually discharges to the Ulua River that flows north and discharges to the Caribbean Sea.

The city of La Lima relies completely on groundwater for its water supply. A well location map is presented on Figure 4-1. Depth to water is generally less than 30 feet bgs, and available data indicate that the wells in the area range in depth from approximately 100 to 350 feet bgs. Groundwater production from these wells ranges from 40 to 400 gpm. The lithology is generally fine-grained, consisting of interbedded sand, silt, and clay. Well-developed sand and gravel deposits encountered between land surface and the top of a laterally continuous clay deposit (between approximately 175 and 250 feet bgs) reportedly present the greatest potential for producing sustainable yields.

4.2 Field Investigation Program

The field investigation conducted at La Lima was tailored to locate sustainable groundwater supplies to accommodate the rapid growth of industry and population in the area. Existing wells in the area demonstrate that the well-developed sand and gravel deposits associated with the Chamelecón River are the primary aquifers for groundwater supplies. However, the available information on the character and extent of these deposits is limited. Thus, the objective of the field investigation was to further explore the water producing zones in the well-developed sand and gravel deposits and to investigate a potentially deeper aquifer below what is believed to a laterally continuous clay deposit.



BROWN AND CALDWELL	DATE 3-28-02	SITE La Lima, Republic of Honduras	FIGURE 4-1
	PROJECT 21143	TITLE Well Location Map	

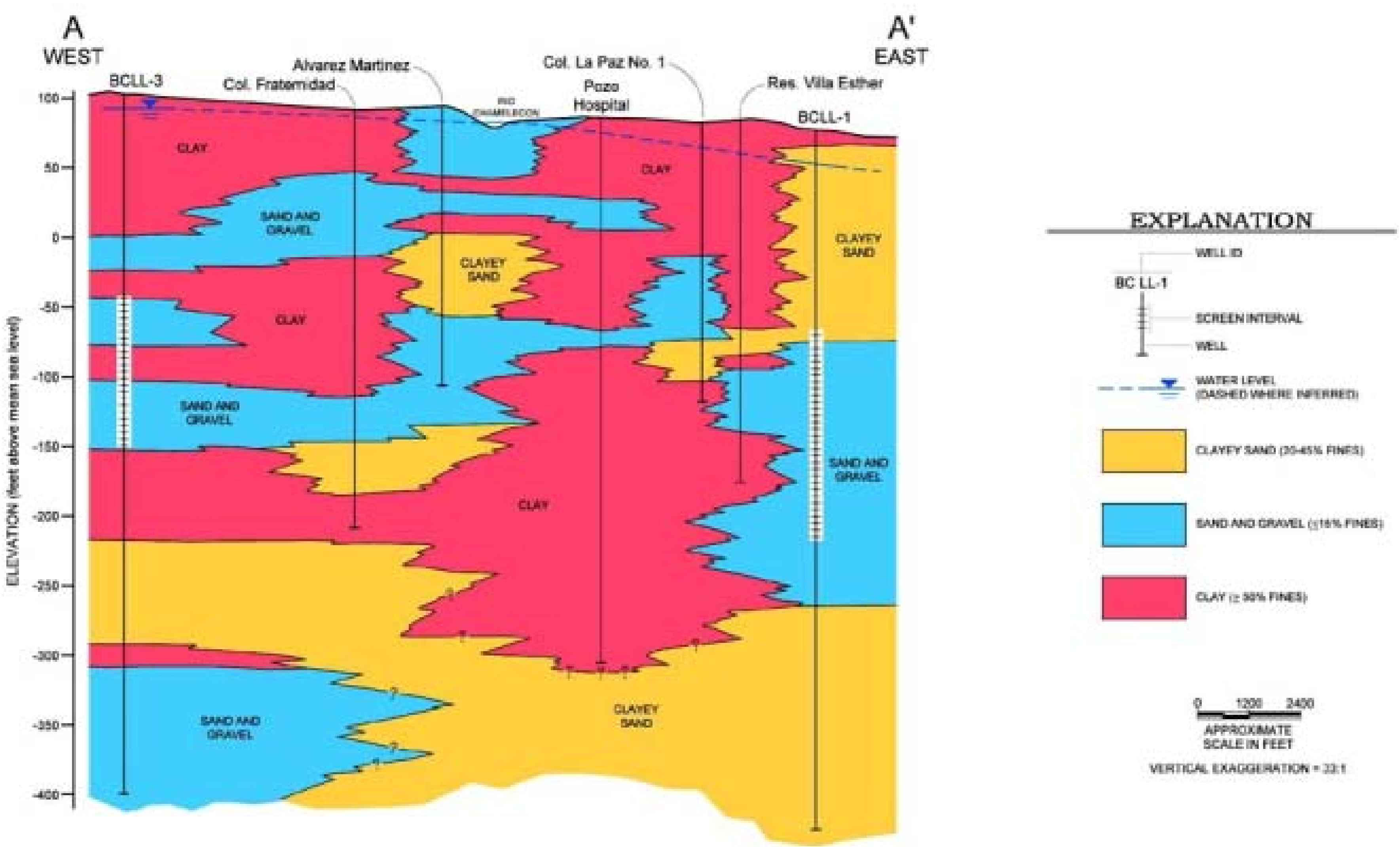
This included a preliminary characterization of hydrogeologic conditions in the vicinity of La Lima, as well as determining water quality, aquifer transmissivities, specific yields and yield sustainability for these deposits.

In support of these objectives, the field investigation consisted of the drilling and geophysical logging of boreholes to characterize the alluvial deposits. The boreholes were completed as test wells to characterize the aquifer in areas where additional information is needed to support the development of the numeric groundwater flow model. This section summarizes the results of the field investigation. Appendix B describes the results of the field investigation in greater detail.

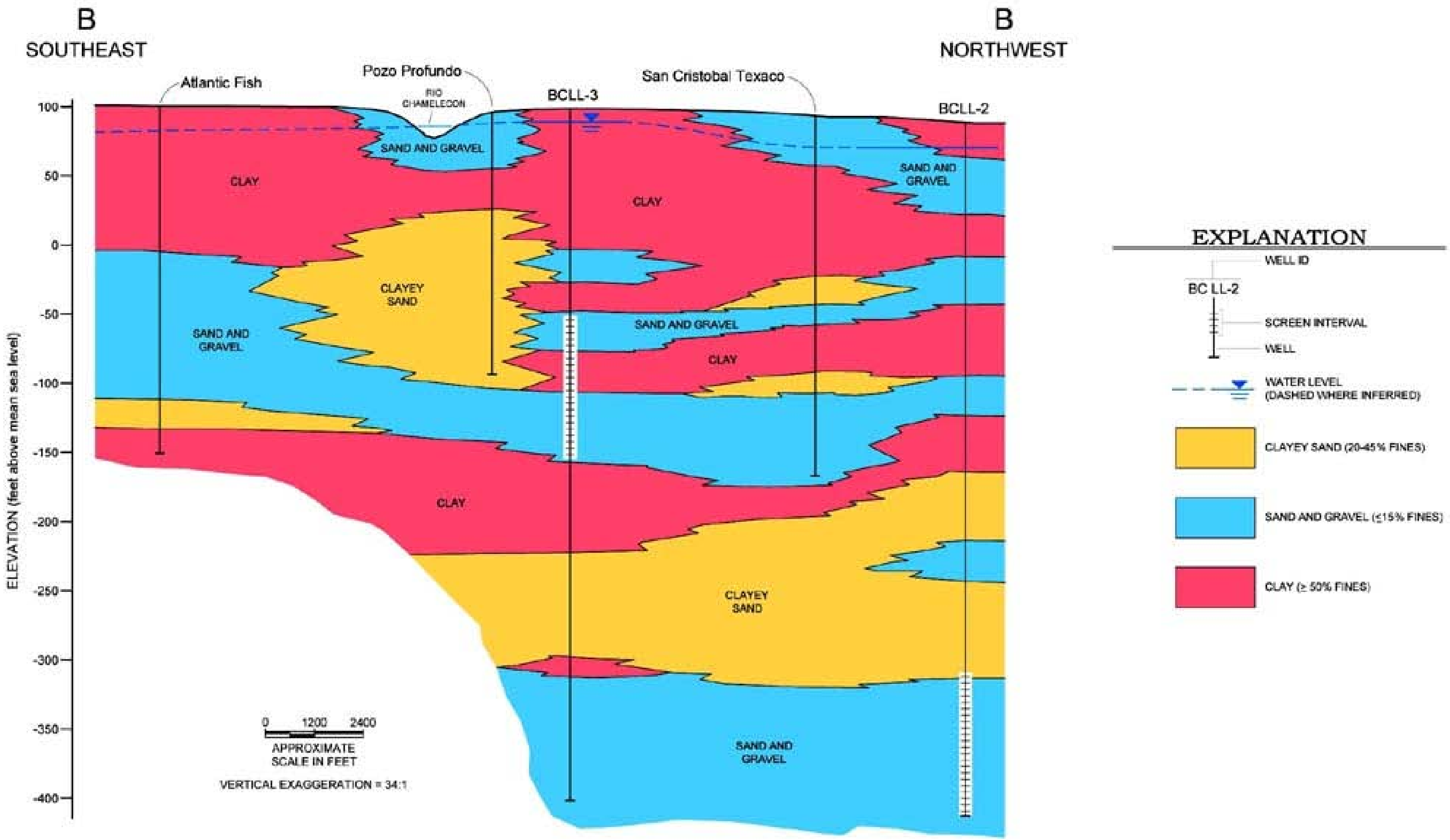
4.2.1 Borehole Analysis and Test Well Installation. Three test wells, BCLL-1, BCLL-2, and BCLL-3, were installed as part of the water resource field investigation (Figure 4-1). Well BCLL-1 is located on the south side of La Lima, approximately 450 meters west of the intersection of the road to Flores de Oriente and the road to the San Juan Curva. This well was installed to investigate the productive sand unit encountered between 150 and 300 feet bgs in nearby wells. Well BCLL-2 was installed in northwest La Lima, approximately four kilometers northwest of the point where the road from San Pedro Sula crosses the Rio Chamelecón , and approximately 1 kilometer east of the road to San Pedro Sula in colonia Gracias a Dios. Test well BCLL-2 was installed to investigate the sand and gravel encountered between 400 and 500 feet bgs. Well BCLL-3 is located west of La Lima, along the road to Campo Chotepe, within in the Rio Chamelecón flood plain, approximately two kilometers northwest of the point where the road from San Pedro Sula crosses the Rio Chamelecón . Similar to well BCLL-1, this well was installed to investigate the productive sands encountered between 150 and 300 feet bgs in nearby wells

Test holes BCLL-1, BCLL-2 and BCLL-3 were drilled to depths of 500, 510, and 500 feet (ft) below ground surface (bgs) respectively (reportedly the deepest borehole penetrations in the area) to investigate various production zones tapped by existing wells in the area. Based on a review of information for existing wells in La Lima, sand and gravel deposits are present from land surface to the top of a laterally continuous clay deposit (between approximately 175 and 250 feet bgs). The three test wells were installed to investigate these upper coarse-grained deposits, and to explore the potential for a deeper aquifer below the laterally continuous clay deposit. A cross-section location map and generalized cross-sections of the study area are presented on Figures 4-1 through 4-3.

Drilled cuttings and the geophysical logs were evaluated to determine the lithology encountered at each site. Exploratory borehole BCLL-1 penetrated clayey-sand (with approximately 20 percent fine-grained material) from land surface to approximately 150 feet bgs. Medium- to coarse-grained sand, with approximately 10 percent fine-grained material, was encountered from approximately 150 to 220 ft bgs. This sand unit is underlain by clayey-sand. The clayey-sand, observed from 220 to 340 feet bgs, consists of medium- to coarse-grained sand, with about 15 percent silt and clay. From approximately 340 feet bgs, to the total depth of the boring (500 feet bgs), the amount of fine-grained material in the deposit of clayey-sand increased to somewhere between 30 and 35 percent. The sand with clay and clayey-sand encountered between 150 and 300 feet bgs are believed to be the major water-bearing stratum penetrated by the boring.



BROWN AND CALDWELL	DATE 3-28-02	SITE La Lima, Republic of Honduras	FIGURE 4-2
	PROJECT 21143	TITLE Cross Section A-A'	



BROWN AND CALDWELL

DATE	SITE	FIGURE
3-28-02	La Lima, Republic of Honduras	4-3
PROJECT 21143	TITLE Cross Section B-B’	

The test boring for well BCLL-2 penetrated alternating sand and fine-grained alluvium from land surface to the approximately 250 feet bgs. The sandy alluvial deposits are approximately 30 feet thick, and are comprised of medium- to coarse-grained sand with up to 15 percent gravel and up to 15 percent fine-grained material. The fine-grained alluvial deposits range between 30 and 50 feet thick, and are comprised of silt and clay with 10 to 50 percent sand-size fraction. The total thickness of the three sandy alluvial deposits in the upper portion of the borehole is approximately 95 feet. In the lower portion of the borehole, a deposit of clayey-sand was penetrated from 250 to 400 feet bgs, with a layer of sand and gravel between 300 and 330 feet bgs. Sand and gravel was also encountered between 400 to 500 feet bgs, consisting of medium- to coarse-grained sand with approximately 15 percent gravel.

Figure 4-4. Mud Rotary Drilling at BCLL-3

The boring for test well BCLL-3 encountered alternating sand and gravel, and fine-grained deposits from land surface to the approximately 320 feet bgs. The coarse-grained deposits are generally comprised of medium to coarse-grained sand with up to 40 percent gravel fraction. The fine-grained deposits consist of clay and sandy-clay with three different interbedded sand-gravel units from 100 to 125 feet bgs, 145 to 175 feet bgs, and 205 to 255 feet bgs. In the lower portion of the borehole, clayey-sand was encountered from 320 feet bgs to the total depth of the borehole (approximately 500 feet bgs). This clayey-sand encountered in the lower portion of BCLL-3 contains between 15 and 20 percent silt and clay and is finer-grained than the deep coarse-grained deposit encountered in the lower portion of BCLL-2. The drilling of BCLL-3 is shown on Figure 4-4. A summary of well construction and completion details are provided in Table 4-1 below.

After completion of the exploratory boreholes, geophysical logging was conducted. The exploratory boreholes were then drilled to a larger diameter to accommodate the test wells. Lithologic logs, geophysical logs, and well designs for wells BCLL-1, BCLL-2, and BCLL-3 are discussed and presented on Figures B-3, B-4, and B-5 in Appendix B.

Table 4-1. Summary of New Well Completion Details

Well	Total depth of borehole (feet, bgs)	Total depth of well (feet, bgs)	Screened Interval (feet, bgs)	Function
BCLL-1	500	299	144 to 289	Investigate the productive shallow alluvial deposits.
BCLL-2	510	505	400 to 500	Investigate a potential deep aquifer.
BCLL-3	500	250	152 to 248	Investigate the productive shallow alluvial deposits

bgs = below ground surface

4.2.2 Aquifer Testing. Short-term and long-term aquifer tests were performed on selected wells to evaluate the water resource development potential of the continuous coarse-grained deposits identified in the area and a deeper coarse-grained deposit encountered between 400 feet bgs to the total depth of BCLL-2. Short- and long-term tests were conducted at test well BCLL-1. Only two short-term constant-rate tests were conducted at BCLL-2 due to excessive drawdown. Finally, only a short-term test was needed at BCLL-3 to demonstrate aquifer parameters. Drawdown and recovery plots for the long- and short-term aquifer tests are presented in Appendix B.

The 7.5-hour step-rate aquifer discharge test was conducted at BCLL-1 at between 150 and 450 gallons per minute (gpm) on October 3, 2001. The initial static water level was measured at approximately 22 feet bgs. During this test, the specific capacity ranged between 25.3 and 18.5 gallons per minute per foot of drawdown (gpm/ft). At the maximum pumping rate of 450 gpm, drawdown was measured at approximately 24 feet (Figure B-6). The constant-rate discharge test at BCLL-1 commenced on October 4, 2001. Drawdown and recovery plots are presented on Figure B-8 and B-9. The test well was pumped at an average rate of approximately 450 gpm for 72 hours. At the end of the test, the total drawdown in BCLL-1 was approximately 31 feet, and the specific capacity was calculated at approximately 14.6 gpm/ft. After the pump test was complete, recovery water levels were recorded. After approximately 2 hours, the water level recovered approximately 66 percent. Analysis of the long-term test data indicates aquifer transmissivity at this site to be between approximately 15,800 and 27,200 gallons per day per foot (gpd/ft).

Two three-hour constant-rate aquifer tests were conducted at test well BCLL-2 on December 19 and 20, 2001. Drawdown and recovery plots are presented on Figures B-10 through B-13. At a pumping rate of 40 gpm, the maximum drawdown at the end of the test was approximately 275 feet. At a pumping rate of 25 gpm, the maximum drawdown at the conclusion of the test was approximately 164 feet. Specific capacities calculated at the end of the tests were approximately 0.15 gpm/ft. After each of the constant rate tests, recovery water levels were recorded. After approximately 2.5 hours, water levels recovered 95 percent in both tests. Analysis of the aquifer test data indicates aquifer transmissivity at this well site to be between approximately 49 and 73 gallons per day per foot (gpd/ft). Based on this information, groundwater production from the lower coarse-grained deposits at well BCLL-2 is likely not sufficient to meet the needs of the community.

Figure 4-5. Step-Rate Test at BCLL-3

A ten-hour step-rate test was conducted at BCLL-3 on November 9, 2001, shown on Figure 4-5. The well was pumped at five step-rates of approximately 150, 220, 290, 360, and 430 gpm. The drawdown plot is presented on Figure B-7. At a maximum rate of 430 gpm, the maximum drawdown at the end of the test was approximately 8 feet. Specific capacities measured during the step-rate test ranged between approximately 55 and 71 gpm/ft. The final step-rate at 430 gpm was pumped for a total of two hours. Based on analysis of the final step discharge and groundwater recovery data (presented on Figures B-15 and B-16), the aquifer transmissivity is between 31,000 and 72,000 gpd/ft.

4.2.3 Water Quality Survey. Groundwater samples were collected from each of the wells installed by Brown and Caldwell during this investigation. In addition, the following Choloma municipal and private wells were selected for water quality evaluation: 22 de Mayo, Cuidad Planeta 1, Colonia Martinez Rivera, Cruz Roja, Guaymuras, Oro Verde, and Residencial Villa Esther. These particular wells were selected to provide a comprehensive understanding of the general water quality throughout La Lima. The wells selected represent groundwater conditions in residential, agricultural and industrial areas as well as public and private facilities. Also, these particular well locations provide adequate spatial distribution to provide a sufficient amount of data to establish a water quality baseline to build on in the future. Not all drinking water constituents were tested for in the sampled wells. The results of the water quality testing are summarized in Table 42 and presented in Appendix B. Steps to establish and maintain a comprehensive groundwater monitoring program are outlined in Appendix E of this report. Training in groundwater monitoring techniques was conducted for local staff as described in Appendix G.

Results for each of these constituents were compared to the Guidelines for Drinking-Water Quality as published by the World Health Organization (WHO). It should be noted that while the Honduran government has not established country-specific guidelines for drinking-water quality, the Honduran Ministry of Health has accepted the guidelines established by WHO.

The results of the water quality survey show that the groundwater meets drinking water standards, except as noted below:

1. Iron was detected over the customer complaint level in three of the seven existing wells that were tested. Manganese was detected over the provisional standard in three of the existing wells.

2. Antimony was detected over the provisional standard in three of the existing wells.

3. Total coliform was detected in all of the test wells and in all of the tested existing wells. Fecal coliform was detected in two of the three test wells and two of the tested existing wells. Fecal coliform indicates bacteriological contamination.

4.3 Numerical Simulation of Well Fields

A numerical groundwater flow model was developed for the City of La Lima to assess the sustainability of future groundwater supply development for the community. Data collected from the installation and testing of the three new wells and from previously determined information, field reconnaissance, and local knowledge were incorporated into a conceptual hydrogeologic model.

Table 4-2. Summary of Well Analytical Results

Analytical constituent	Drinking water standard[c]	Test wells			Existing wells[a]							
		BCLL-1	BCLL-2	BCLL-3	Existing wells (range)	Col. Martinez Rivera	Cruz Roja	Fusep Planeta	Guaymuras	Oro Verde	Villa Esther	22 de Mayo
General												
Acidity	mg/l[g]	52	150	19	18-83	18	18	28	83	33	34	22
Alkalinity	mg/l CaCO3[g]	277	152	150	104-274	247	201	174	104	353	337	274
Chloride	mg/l[g]	51	23	8.5	23-78	24	23	45	41	29	57	78
Conductivity	us/cm[g]	928	430	396	44-678	539	44	477	48	528	575	678
Hardenss	mg/l CaCO3[g]	120	68	96	160-276	180	160	200	228	308	236	276
Iron	0.3[f] mg/l	<0.03	0.35	<0.03	<0.03-1.86	0.71	0.02	0.05	1.86	<0.03	0.09	0.33
Manganese	0.5 mg/l (P)[e]	<0.03	<0.03	<0.03	0.04-2.23	0.2	0.4	0.15	1.12	2.23	0.4	1.9
Nitrate	50 mg/l	<0.01	0.11	0.53	0.05-1.38	0.41	0.06	1.35	0.34	0.08	0.05	0.41
Metals												
Antimony	0.005 mg/l (P)[e]	<0.005	<0.005	<0.005	<0.005-0.0258	<0.005	<0.005	<0.005	0.0149	0.0258	<0.005	0.0206
Arsenic	0.01 mg/l (P)[e]	<0.005	<0.005	<0.005	<0.005-0.0121	<0.005	0.01	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel	0.02 (P)[e]	<0.02	<0.02	<0.02	<0.02-0.323	<0.02	<0.02	<0.02	0.0323	<0.02	<0.02	<0.02
Zinc	3 mg/l	<0.02	0.174	<0.02	<0.02-0.105	<0.02	<0.02	<0.02	0.105	<0.02	0.0373	<0.02
Bacteriology												
Total Coliform	UFC/100 ml	2	84	4	3-67	67	26	30	3	9	32	40
Fecal Coliform	UFC/100 ml	1	22	0	0-10	0	5	0	0	0	10	0
Radiochemistry												
Gross Alpha activity	5 pCi/L[h]	1.4 pCi/L	2.0 pCi/L	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]
Gross Beta activity	50 pCi/L[h]	2.8 pCi/L	5.2 pCi/L	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]
Pesticides	(range)[b] mg/l	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]
Herbicides	(range)[b] mg/l	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]
Volatile Organics	(range)[b] ug/l	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]

Source: SPL Houston Laboratory and Jordanlab Laboratorio de Analysis Industrial laboratory results. Test dates vary.
Note: Numbers in bold are those over the drinking water standard.
UFC – must not be detectable in any 100 ml sample.
[a] Existing wells that exceed drinking water standards.
[b] Drinking water standard varies by individual constituent.
[c] World Health Organization, 1996. Guidelines for Drinking Water Quality, 2nd ed. Vol 2 Health criteria and other supporting information and Addendum to Vol. 2, 1998.
[d] Lab reports not available/not tested for this constituent.
[e] (P) – provisional guidance value for constituents for which there is some evidence of a potential hazard but where the available information on health effects is limited; or where an uncertainty factor greater than 1000 has been used in the derivation of the tolerable daily intake.
[f] Levels likely to give rise to customer complaints.
[g] No drinking water standard.
[h] US standard.

The conceptual hydrogeologic model, which includes a conceptual groundwater budget for the La Lima area, was then used as the basis for the development of a numerical groundwater flow model. The numerical groundwater flow model incorporates all of the known sources and sinks of groundwater in the modeled area, including recharge to the aquifer system from precipitation and discharge from the aquifer system through pumping wells and discharge to the Chamelecón and Ulua rivers.

The groundwater flow model was first calibrated to the existing groundwater conditions in the La Lima area, which represents the current groundwater extraction from the local aquifers. The groundwater model was then used to predict what the potential effects of the projected increase in groundwater demands may be on the aquifer system through the year 2020. For the predictive simulation, a total of 15 hypothetical production wells with an average production rate of 22 lps (350 gpm) were included in the model. The hypothetical wells were located to the west and southwest of La Lima, all of which are up-gradient of the community.

The conceptual groundwater budget for the La Lima aquifer system indicates that approximately 700 gpm could be extracted on a long-term basis without removing groundwater from storage. Thus, this additional amount could be removed from the aquifer system without appreciable effects on the aquifer.

The groundwater model predictive simulation indicates that the aquifer could support a groundwater production rate of approximately 6,900 gpm over the next 20 years. However, the simulation predicts that aquifer drawdown in the vicinity of the hypothetical well fields would be approximately two to three meters.

4.4 Potential Contamination Sources

There are several potential sources of contamination to the alluvial aquifers near La Lima. The local economy is driven by both agriculture and manufacturing. Sugar cane is grown in large fields west of the La Lima along the Chamelecón River flood plain. The fields are flood-irrigated from aqueduct channels. It is possible that any fertilizers, pesticides and herbicides that are not carried off with the unused irrigation water, percolate downward to the shallow groundwater, potentially contaminating groundwater supplies of the alluvial aquifer.

Also, large zoned industrial parks (ZIP) are located in the southeastern part of La Lima near the Campo Dos well, and northwest of La Lima along the road to San Pedro Sula in the area of the San Cristobal No.2 and San Cristobal Texaco wells. The ZIPs in southeastern La Lima include factories primarily associated with agricultural processing. The ZIPs northwest of La Lima include clothing manufacturing and agricultural processing facilities and an Aquazul bottled water treatment plant. Although there is some treatment for both industrial and sanitary wastes, most of the wastes are discharged to small surface drainages, and eventually to the Chamelecón River.

The La Lima sewer system was built in the 1940s. It is suspected the concrete sewer pipes are badly eroded. Similarly, many of the existing and new residential areas possess inadequate sanitary facilities and most rely on latrines which discharge directly to the ground. Sanitary wastes likely migrate to the shallow aquifer, contaminating groundwater with coliform and nitrate. Further, many of the existing residential water wells in the area are screened from the aquifer all the way up to or near land surface, which provides a direct vertical conduit for contaminants to migrate from the shallow subsurface to saturated zones below.

4.5 Aquifers and Recommended Well Field

The results of the early site reconnaissance, the field investigation, and the preliminary groundwater flow model indicate the well-developed sand and gravel deposits encountered between land surface and the top of a laterally continuous clay deposit (between approximately 175 and 250 feet bgs) are a source of sustainable water supplies for La Lima. Below this clay deposit, a coarse-grained deposit was encountered in the lower portion of boreholes BCLL-1, BCLL-2, and BCLL-3, however yield from this deposit is considered poor and not a viable option for the community.

A well location map is presented on Figure 4-1 and generalized cross-sections are presented on Figures 4-2 and 4-3. The well developed sand and gravel deposits represent the major water-bearing stratum in the area. In the western and central portion of the study area, individual sand and gravel deposits are between 10 and 100 feet thick and are separated by fine-grained deposits. The thickness of these deposits is approximately 100 feet in the western and southern portion of the study area (BCLL-3, BCLL-2, and Atlantic Fish Well). The total thickness of these sand and gravel deposits thin to the east and are approximately 50 feet thick at the Hospital Well and Colonia La Paz No. 1. However, at BCLL-1, in the far eastern portion of the study area, a thick coarse-grained deposit was encountered from approximately 150 to 340 feet bgs.

The thick coarse-grained deposit penetrated at BCLL-1 consists of sand and clayey sand with less than 15 percent fines. This deposit is finer-grained than the well-developed sand and gravel deposits in other portions of the study area; however this coarse-grained deposit represents a major water-bearing stratum. The continuous clay deposit encountered in other portions of the study area was not encountered at BCLL-1. The clayey sand becomes more fine-grained with depth below the coarse-grained deposit at approximately 350 feet.

Underlying the continuous clay deposit, a deep sand and gravel deposit was encountered by BCLL-2 and BCLL-3 in the northwestern and western portions of the study area from approximately 400 feet bgs to the total depth of the boreholes at 500 feet bgs. Well BCLL-2 was screened adjacent to the deep sand and gravel deposit, however excessive drawdown during pump testing indicate that this aquifer is not capable of yielding significant amounts of water for a municipal production well.

Production from the shallow sand and gravel deposits should continue to provide a reliable source of water for the municipality. However, it is recommended that any well field be established in the southern or western portion of the study area. The total thickness of the well-developed sand and gravel deposits are greatest in theses areas. Also, these areas are up-gradient of the ZIPs and the municipal sewer system, which are believed to be the major source of contamination in the area.

The existing wells within La Lima municipality limits could potentially provide a flow path for contaminants to migrate downward into the aquifer. As well production increases, the cone of depression for a well increases, and thereby presents an increased potential for contaminants to be drawn into this area. As La Lima grows, there is a concern that wells installed within municipality limits could be impacted in the future by industrial and municipal waste.

5.0 WATER RESOURCES MANAGEMENT SYSTEM

The Water Resources Management System (WRMS) is a desktop computer application developed to store, manage, and analyze technical information gathered and generated for this project. The application is a management tool that can be used by the municipalities and other decision-makers to support sustainable management of their groundwater resources. The system is composed of both a data management system and a geographic information system (GIS) linked together as one application. Through the WRMS, users can:

- manage and generate reports for wells, storage tanks, and springs;
- view well logs and well completion diagrams;
- analyze water quality and water level data;
- track statistics on water use; and
- view wells, water quality information, and aquifer characteristics on maps of the study area.

The WRMS is considered an important component for the water resource management plan. The system is briefly described in this chapter and is described in more detail in the Water Resources Management System Users Guide (Appendix D). The application consists of two primary components; a data management system and a GIS. The application is written so that the two components work together and function as one system. Data are shared back and fourth between the data management system and the GIS.

The data management system used is Microsoft Access, which is a relational database designed to efficiently manage complex data. The data are stored in a series of tables. Each table stores a different type of information, and each table is linked to others by a key field that defines the relationship. For example, one table contains a record of each well, while another table contains all the water level measurements. The table containing the water levels also contains the name of each well so that it can be linked back to the appropriate well in the well table. This way, detailed information on each well and water level measurements can be stored most efficiently, without the need to maintain the same piece of information more than once, which would potentially introduce erroneous data into the system.

The GIS used is ArcView®, by Environmental Science Research Institute. A GIS is an electronic mapping and analysis system. The power of GIS lies in its ability to manipulate, display, and analyze information on a map by linking map elements to attribute data in a database. For example, a well whose location is identified as a dot on the map is connected to the construction data, sampling results, and water level information in the database. The user can post any of this information as text on the map, choose specific symbols or colors to represent these data, and overlay this layer of information on other map features. Because the data management system and GIS work together, it provides the user with a powerful set of management and analysis tools.

Both of these components are linked through a common interface developed in Microsoft Visual Basic. The interface is a series of screens that guide the user through various application functions. Through the interface, the user can enter or update data, view reports, generate graphs, display scanned images, and create customized maps. The interface can be displayed in English or Spanish, uses water resource terminology, and is designed to be user-friendly. Through this interface, municipalities will be able to continue to update their water resource data and use it for decision-making in the future.

5.1 Benefits of the WRMS

The WRMS consolidates, perhaps for the first time, the most critical water resource information for a municipality. It provides a central place to manage, analyze, and display water resource information in both map and tabular form. The WRMS accommodates all major types of information needed for sound water resource management including data on wells and other water sources, future demand and growth, infrastructure and organizational boundaries, and water quality and aquifer characteristics.

Because the system is designed to accommodate additional data as more information is collected and wells are created or modified in the future, it can be used to facilitate sound water resource decision-making in the future. It is easy to use and requires minimal training, which will facilitate continued system use. It uses a standard methodology for identifying and prioritizing future well sites, which will allow municipalities to continue to apply a consistent planning approach.

5.2 Use and Management

The WRMS is designed to work in conjunction with the findings of this report. Most of the data collected or developed for the report are contained in system, and are available for continued analysis, display, and incorporation with new data as it is collected. The system can be used to view and explore additional details of the existing water system.

The WRMS should be used to provide a common environment for communication among stakeholder agencies for water resource planning. The system provides a consistent view and methodology for analyzing water resource data. Consistently using it as a communication tool among stake-holders will make the sometimes confusing and complex technical information easier to understand. New data, such as new wells, additional sampling results, or new water level measurements should be entered into the system on a regular basis (annually) in order to have the most up-to-date information available for decision-making.

5.3 La Lima Data

Table 5-1 summarizes mapping information collected on La Lima. This data is included for review in the WRMS. There are 53 wells with information collected. Ten wells; (22 de Mayo, BC-LL-1, BC-LL-2, BC-LL-3, Ciudad Planeta 1 (fusep), Col. Martinez Rivera, Cruz Roja, Guaymuras, Oro Verde, and Residencial Villa Esther), have water quality information in the WRMS.

A compact disk containing the WRMS and all of the La Lima data described above is included with this report.

Table 5-1. La Lima GIS Data Dictionary

File name	File type	Description	Date	Source	Scale of source data
Cad-lima-ruralbndrypoly.shp	shape	La Lima rural boundary as a polygon from Cad files.		Cad Files	
Cad-lima-urbanbndrypoly.shp	shape	La Lima urban boundary as a polygon from Cad files.		Cad Files	
Cad-lima-munibndry-poly.shp	shape	La Lima municipal boundary as a polygon from Cad files.		Cad Files	
Cad-lima-munibndry.shp	shape	La Lima municipal boundary from Cad files		Cad Files	
Topo-lalima-developd_area-1981.shp	shape	Polygons of developed areas traced from topographic map.	1981	Topographic Map Instituto Geografico Nacional, Tegucigalpa, D.C., Honduras	
Topo-lalima-developd_area-1995.shp	shape	Polygons of developed areas traced from topographic map.	1995	Topographic Map Instituto Geografico Nacional, Tegucigalpa, D.C., Honduras	
Aerial-lalima-developd_area-2000.shp	shape	Polygons of developed areas traced from Aerial photo.	Mar 2000	USGS Aerial Photograph	1:40,00
Lalimaaerial2000.img	image	Aerial photo of La Lima scanned in and aligned in Nad 27.	Mar 2000	USGS Aerial Photograph	1:40,00
LaLima1995.img	image	Scanned topographic map covering La Lima (aligned in Nad 27).	1995	Topographic Map Instituto Geografico Nacional, Tegucigalpa, D.C., Honduras	
Cholomа_utm.tif	image	Scanned topographic map (aligned in Nad 27) encompassing Choloma and the top portion of La Lima.	1981	Topographic Map Instituto Geografico Nacional, Tegucigalpa, D.C., Honduras	
Villa&lima_utm.tif	image	Scanned topographic map (aligned in Nad 27) of a large area encompassing Villanueva and La Lima.	1981	Topographic Map Instituto Geografico Nacional, Tegucigalpa, D.C., Honduras	
Cad-lima-rivers.shp	shape	La Lima Rivers		Cad files	
Cad-lima-pipe.shp	shape	Partial existing pipeline from 2 inch through 8 inch.		Cad files	
Topo-la lima-airport.shp	shape	Outline of La Lima airport as traced off of topographic map		Topographic Map	
Cad-lima-streets.shp	shape	Streets of La Lima		Cad files	
Cad-lima-rr.shp	shape	Line of La Lima railroad.		Cad files	
Villalalima-4of4.shp	shape	Vector contour file purchased from Intec America. 4 of 4 vector contour files for Villanueva, also serves as vector contour file for La Lima area.		Intec America	30 meter, one arc second

6.0 RECOMMENDED GROUNDWATER RESOURCES MANAGEMENT PLAN

This chapter presents recommendations to ensure water supply sustainability. Recommendations for groundwater management, wells, groundwater monitoring, wellhead and recharge area protection, water utility management, and water supply are presented.

6.1 Groundwater Management

Considering the growing use of groundwater in the Sula Valley, control should be kept to protect the groundwater resource, including control of excessive aquifer water level declines and control of potential contamination sources. Due to financial and technical limitations at each municipality in the Sula Valley and surrounding areas, it is recommended that joint efforts be initiated to create a groundwater management agency. This agency would provide technical advice, keep records of aquifer behavior, and maintain the hydrogeological database. As the private sector of the Sula Valley depends on groundwater for commercial, industrial, and agricultural purposes, it is recommended to develop an agency with a board of directors formed by representatives of the municipalities and private organizations, such as the Chamber of Commerce. This model of institution would give assurance that the agency would maintain independence and stay free of periodic staff changes.

Considering the need to start properly managing the main watershed basins that contribute to the Sula Valley as part of a flood mitigation project, a general plan to protect aquifers would be complementary.

6.2 Drilling Plan

The following recommendations are made regarding drilling of future wells:

1. Drill the future production wells in the western area of La Lima. Test wells BCLL-1 and BCLL-2 are suitable to be converted to production wells.
2. Drill a well approximately every year until a total of 19 have been completed by the year 2020. This assumes a well capacity of 25 lps (400 gpm) each.
3. Acquire in advance the land needed to construct production wells. A well site with a size of approximately 30 m by 30 m (100 ft by 100 ft) is recommended.
4. The wells should have a depth of approximately 80 m (250 ft).
5. The production wells need to have a sanitary seal with a minimum length of 15 m (50 ft).
6. The diameter of the well casings need to be adequate to install a pump with a capacity sufficient to supply the 25 lps (400 gpm) and lift the water to the water tanks.
7. It is recommended that the wells be equipped with water lubed vertical turbine pumps.
8. Each production well should be equipped with the equipment necessary to disinfect the water, monitor the groundwater level, quality, and production quantity.

6.3 Groundwater Monitoring

An important component of managing the current water supply in La Lima and ensuring compliance with drinking water standards is the development and maintenance of a regular groundwater monitoring program. A regular monitoring program will ensure compliance with drinking water standards and will provide a useful tool for tracking groundwater quality, groundwater levels, and usage, as well as help with growth planning in the future.

There are several components that contribute to a successful monitoring program, each of which are equally important. These components include groundwater level data collection, groundwater production data collection, water sample collection, analysis of water samples and review, and compilation and understanding of water chemistry results. Each of these components is necessary in order to maintain a successful groundwater monitoring program. Information regarding the steps necessary to complete a monitoring program are outlined in the Groundwater Level and Monitoring Program, Field Manual, December 2001, included as Appendix E. This document was distributed to various members of the municipality during the groundwater level and monitoring training provided by Brown and Caldwell in December 2001.

The following recommendations are made regarding groundwater monitoring:

1. The monitoring of the wells should be continued at a three-month frequency.
2. The well monitoring should consist of monitoring and recording the groundwater level and the quantity and quality of the water.
3. It is recommended that the well monitoring network consist of 21 wells, as listed in Appendix E.
4. The collected monitoring information should be recorded in the computer database.

6.4 Wellhead Protection

An important component in protecting the groundwater quality used for public water supply in La Lima is establishing a wellhead protection program. Wellhead protection is the practice of managing the land area around a well to prevent groundwater contamination. Prevention of groundwater contamination is essential to maintain a safe drinking water supply.

Development of a wellhead protection plan for La Lima consists of five key steps that are described in Appendix F. To implement a management plan to protect the well capture areas and the general aquifer recharge areas it is recommended that municipal control be established for the following items:

1. Discharge of municipal wastewater.
2. Discharge of industrial wastewater.
3. Disposition of solid waste.
4. Storage and distribution of hydrocarbon products.
5. Storage and distribution of chemical products (agricultural and industrial).

6.5 Water Resource Management System

Brown and Caldwell developed a Water Resources Management System to store, manage, and analyze water resource related data gathered and generated for this project, and for data to be collected in the future by municipality. The following recommendations are made regarding the Water Resource Management System:

1. The database should be regularly updated by the municipality by adding groundwater level, groundwater production, and water quality data for the wells in the monitoring network.
2. Routinely use the database to input information regarding new wells, well monitoring information, and general water system operation data.

6.6 Water Utility Management

An important aspect of ensuring a sustainable water supply is having a functioning water utility with the proper organizational structure. The water utility is responsible for properly managing, operating, and maintaining the water system, and must be financially self-sufficient. Several water utility management recommendations are listed below.

1. Continue to maintain a complete list of all water system customers that includes descriptive information for each customer. This information should include name, address, service line size, and type of customer (residential, commercial, etc.).
2. Update the financial plan for the water utility that establishes budget needs and defines an equitable rate and new connection fee structure that is adequate to cover the costs of expanding, operating, and maintaining the water system. Continue to ensure that users are routinely charged for and pay for water supply.
3. The water utility should have adequate staff that is trained on a regular basis to address operational and maintenance needs.
4. Investigate possible sources of grant and loan financing to help improve and expand the water system.

6.7 Control Over Well Construction

It is recommended that control over the construction of wells by others be established through municipal regulation. The objectives are to ensure that wells constructed by other parties meet appropriate construction standards and that information obtained during well construction is recorded and placed in the database.

6.8 Control of Water Losses

A program should be developed to detect and eliminate leaks in the water distribution system. The first step is to conduct a study to define the amount of water loss and recommend the best areas for leak repair and/or main replacement. A water conservation program should be initiated to ensure that customers are using water efficiently.

6.9 Water Quality

The wells should be disinfected with chlorine. For the several wells with a detected presence of total coliform and fecal coliform, it is recommended that they be immediately disinfected followed by a new water quality analysis after the chlorine level is reduced back down to zero. This will determine if the contamination is still entering the well. If the well still has coliform or fecal coliform, consider other measures, including permanent disinfection, identification and elimination of the contamination source, and well closure.

6.10 Water System Expansion Plan

The preparation of a water system expansion plan is recommended. The municipality is responsible for the water supply system. Therefore, the municipality must ensure that the public or private investment for the water system expansion is properly planned. Several objectives are recommended.

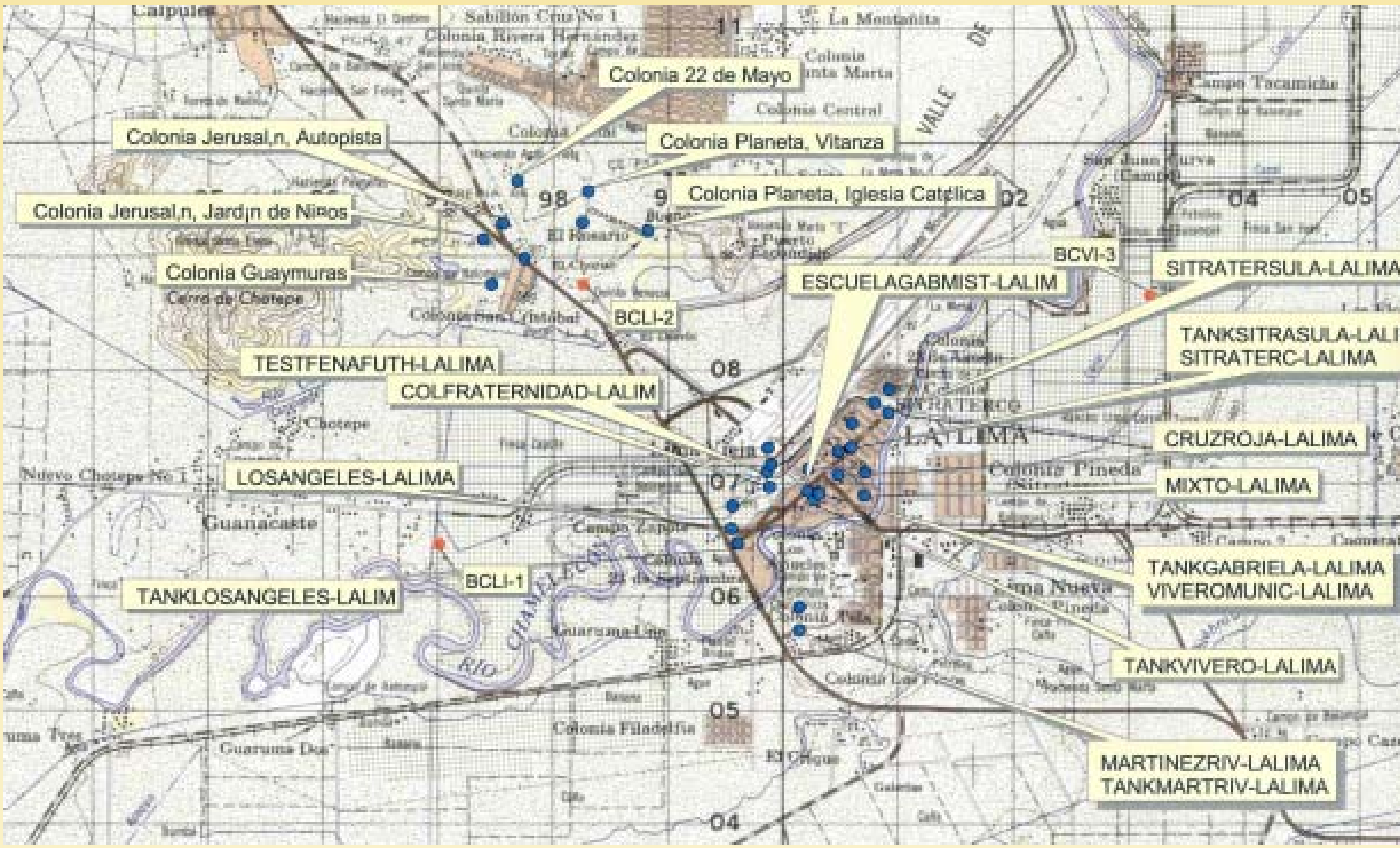
1. Reduce the total number of production wells by planning fewer, larger capacity wells in the south area.
2. Operate more efficient wells with a greater specific yield.
3. Plan for the construction of new wells, pumping lines, and storage tanks to serve all sectors of the city.
4. Investors who wish to start new development projects should receive water from the municipal water system after paying the appropriate connection fees.

APPENDIX A

Conceptual Model and Rationale for Phase II Field Investigation

CONCEPTUAL MODEL AND RATIONALE FOR PHASE II FIELD INVESTIGATION

Muncipality of La Lima, Republic of Honduras, C. A.



July 2001

USAID

Sub-Consultant:

ATICA, S. de R. L.
Asesores Técnicos en Ingeniería y Ciencias Ambientales

Consultant:

BROWN AND CALDWELL
Environmental Engineering and Consulting

INTRODUCTION

This document represents the hydrogeological conceptual model for the La Lima area and the rationale for the conduct of the Phase II field investigation studies. The project background, available water resources and needs, hydrological setting, data gaps, and recommended areas for field investigation and activities are described.

BACKGROUND

The purpose of this project is to develop a water resources management plan for the City of La Lima which addresses a sustainable municipal water supply. This project is funded by the US Agency for International Development (USAID).

The City of La Lima is located in the Province of Cortes, approximately 15 kilometers southeast of the City of San Pedro Sula. The terrain of the area is relatively flat. Population, water consumption and water production data rate is not available at this time, however this information is being gathered under Phase I. This information will be presented in the final project report.

The City currently relies on groundwater for all of its municipal water supply. It is anticipated that continued reliance on groundwater for municipal water supply will increase in direct proportion to population growth.

The Chamelecon River flows through the City. Upstream of La Lima, the flow rate of the Chamelecon River is estimated to be 67,100 cubic feet per second. The Chamelecon River is not presently considered a sustainable municipal water source due to the heavy raw sewage load it causes which could require considerable water treatment facilities. The main airport for the San Pedro Sula area, the Villeda Morales International Airport, is located adjacent to the City. A portion of the City is served by a private water system located approximately 2 kilometers northwest of the main part of the City, along the highway to San Pedro Sula.

EXISTING WATER RESOURCES

The City of La Lima relies completely on groundwater for its water supply. There are at least six private water agencies producing groundwater in the La Lima area.

The City uses approximately 12 wells located in and around the City. In addition, several industrial and agricultural wells are located within the region. The combined capacity of the City wells is approximately 2,300 gallons per minute (gpm). The wells range in depth from 160 to 362 feet. No disinfection treatment is provided. Water is pumped either into elevated water storage tanks or directly into the water distribution system. The pumps generally operate between 4 and 18 hours per day.

The depth to groundwater ranges from 25 to 60 feet below ground surface (bgs), with well yields ranging from 60 to 450 gpm.

The water distribution system consists of a single pressure zone with multiple water storage reservoirs. Most of the water storage tanks are elevated. The majority of the water piping system consists of a looped network of 2, 3, and 4-inch water lines. The amount of water lost through the distribution system is not known.

FUTURE WATER NEEDS

The City has experienced rapid growth in recent years. Between 1991 and 1992 a large industrial park was built in the city resulting in an accelerated increase in residential customers well as increased water use due to an increase of employees. The City expects that most future growth will occur to the northwest along the highway to San Pedro de Sula. No population projections are available at this time. Population data is being collected for the purpose of developing population growth rates and projections.

Since the existing wells lack totalized production meters, the amount of water used by the City cannot be precisely determined. Information on water demand usage and projections are being collected for the purpose of developing an estimated projected consumption rate by using a portable flow meter that was purchased for this project. The meter will be attached to the discharge side of the well and the flow of the well recorded on a weekly basis. From this information, the need for additional wells and the total production required will be determined. Recommendations will be presented in the final report.

RATIONALE FOR WATER RESOURCE EXPANSION

The objective is to locate sustainable groundwater supplies that can be used in a cost effective manner. The most cost effective groundwater supplies are to the existing water system infrastructure having acceptable water quality and a yield that meets anticipated supply needs.

GEOLOGICAL SETTING

Geologically, the low lying areas of the Sula Valley floor are characterized by Quaternary Valle de Sula alluvial deposits, with the valley walls comprised of Jurassic Cacaguapa Schists to the east and west, the Tertiary Matagalpa Formation and Padre Miguel Group and Cretaceous Yojoa Group to the south and southeast. The Sula Valley drains into the Caribbean Sea to the north. Generally, this area receives between 55 to 85 inches of precipitation per year. Additional rain gauging and climatical stations were not necessary to successfully complete this study.

Along the flanks of the Sula Valley a number of river systems drain the surrounding upland areas. These river systems have associated valleys that adjoin the Sula Valley. La Lima is located within one such valley system that is located on the western flanks of the Sula Valley. The Chamelecom River traverses the central portion of the valley and serves as the major drainage for the area. Upland areas surround the valley to the north, west and southwest and are comprised of Jurassic Cacaguapa Schists (see Figure 1).

The valley is oriented in an east west direction and ranges from 6 to 10 kilometers in width. The valley is characterized as a broad flat alluvial plain, which has been deposited by the Chamelecom and Blanco rivers. The total thickness of the alluvial materials is estimated to be greater than 500 feet in the vicinity of La Lima. Boring logs completed within the alluvium indicated that the upper 325 feet of the alluvial materials are characterized as a fining upper sequence (see Figure 2). The upper 75 to 125 feet of alluvial materials are characterized as inter-bedded clayey silts, silts and sands. These materials grade into inter-bedded silts and fine to medium sands from approximately 125 to 150 feet. Below 150 feet, approximately 150 feet of inter-bedded fine, medium, to course sands and gravels have been observed. This lower sand and gravel unit has been observed throughout the valley. A laterally extensive clay unit has been observed at a depth of approximately 325 feet. The material below the top of this clay unit has not been characterized to date.

Vegetation and Land use maps are not included in this report as they are not considered appropriate at this time.

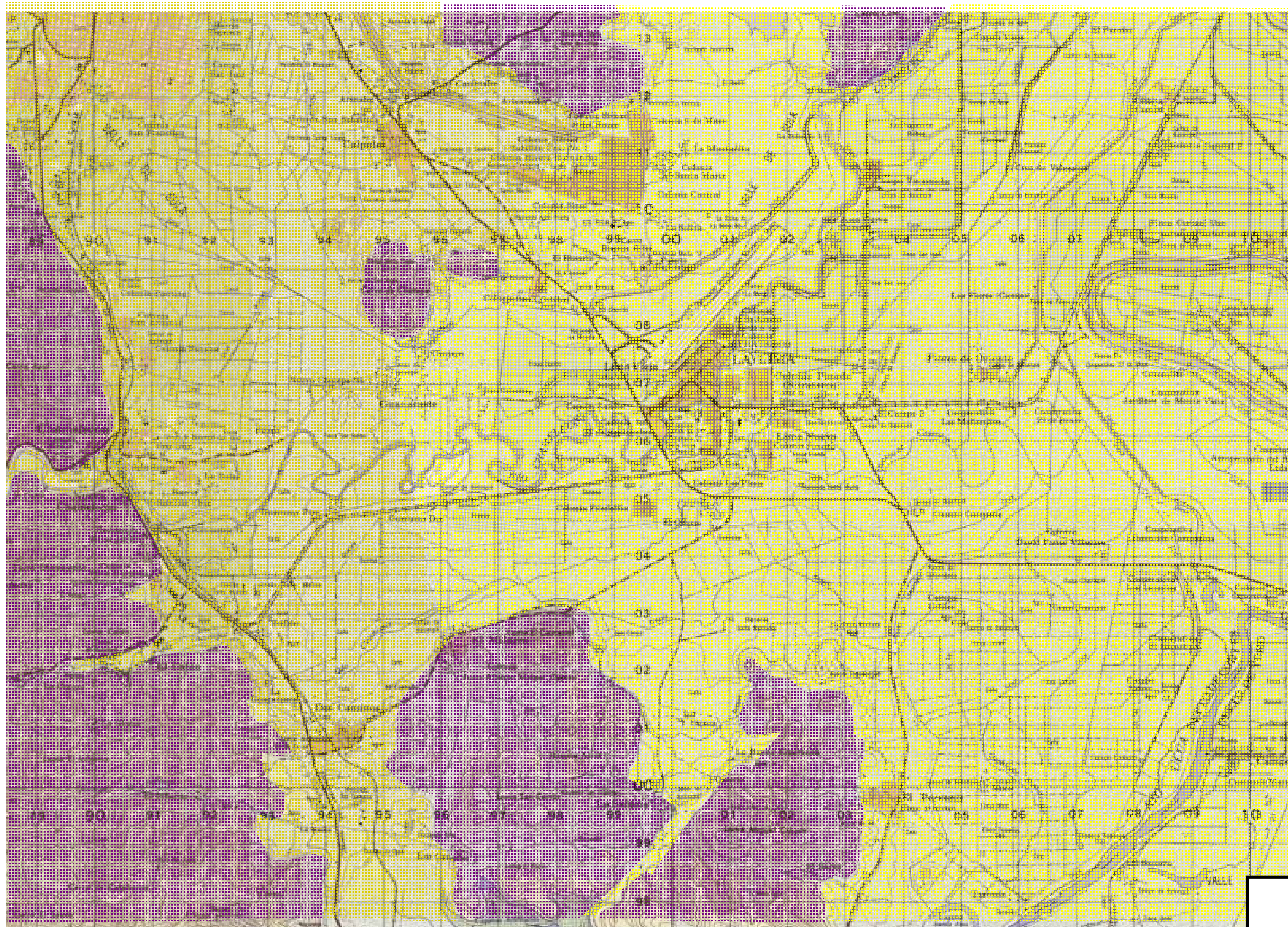
HYDROGEOLOGICAL SETTING

The La Lima valley is bounded to the north, west, and southwest by upland areas comprised of Jurassic Cacaguapa Schists. These upland land areas serve as the major surface and groundwater recharge areas for the alluvial materials of the valley. Surface water infiltrates into the fracture networks of the uplands providing groundwater recharge to the valley bedrock and alluvial materials. Groundwater from these uplands generally flows towards the alluvial valley. Once the groundwater from the upland areas enters the valley alluvium, groundwater flow will generally begin to move down valley and towards the Chamelecom River, which serves as the major groundwater discharge point for the valley hydrologic system.

The laterally continuous sand and gravel aquifer found from a depth of 150 to 325 feet presents the greatest potential for producing sustainable yields. Currently 25 wells (see Figure 3) are screened within the sand and gravel aquifer. Groundwater production from these wells range from 80 to 500 gpm with an average yield of 210 gpm. Additionally, there are unconfirmed reports of irrigation wells screened within this aquifer to the south of La Lima that produce in excess of 1,000 gpm.

RECOMMENDED AREAS FOR FIELD INVESTIGATION

Based on a review of the available data for La Lima, the laterally continuous sand and gravel aquifer found from a depth of 150 to 325 feet has been identified as having the highest probability of providing sustainable groundwater supplies. As a result, it is recommended that this laterally continuous aquifer and potentially deeper aquifer be further investigated.



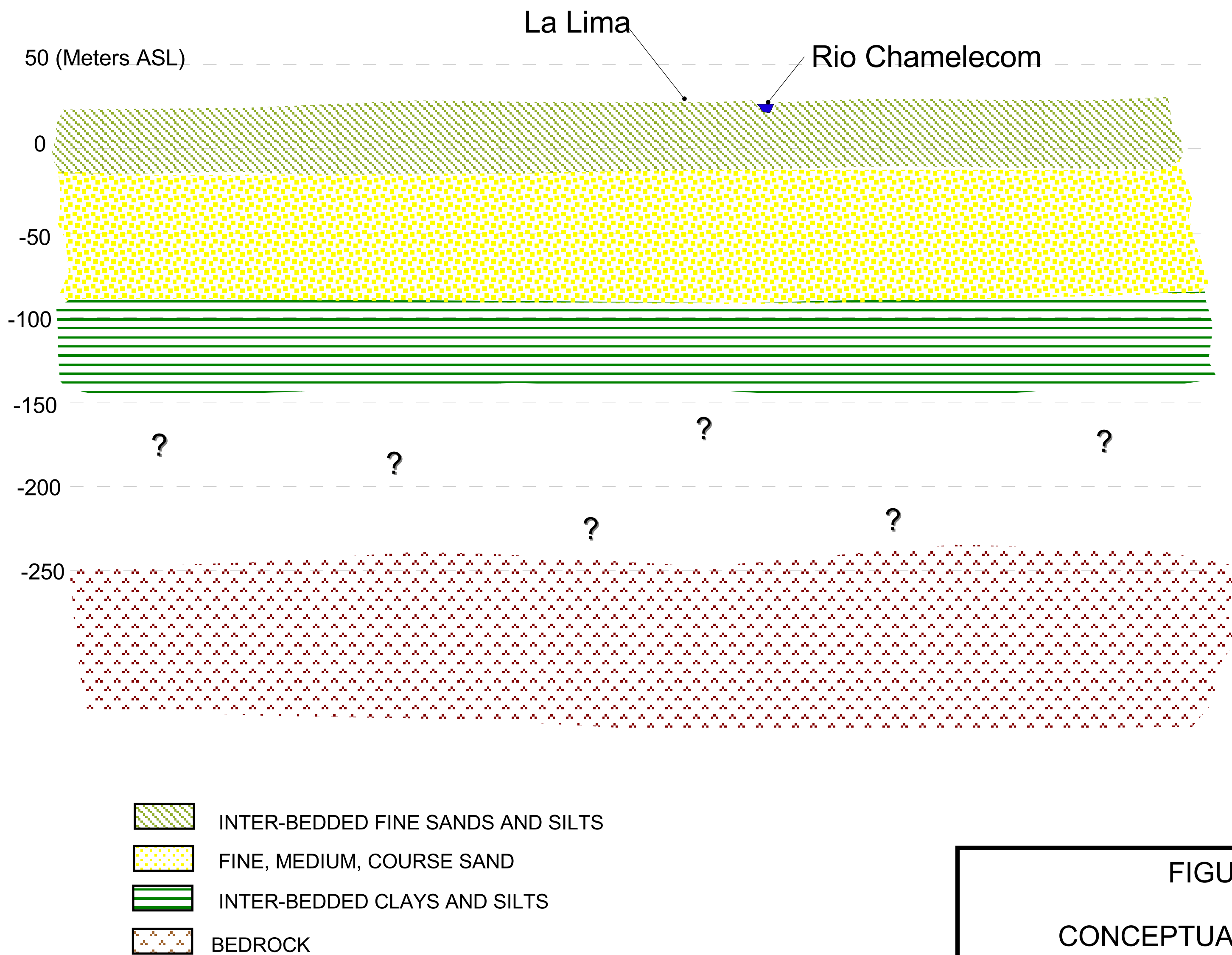
LA LIMA VALLEY ALLUVIUM

METAMORPHIC BEDROCK (PRIMARY RECHARGE AREAS)

0.9 0 0.9 1.8 Kilometers

FIGURE 1

CONCEPTUAL GEOLOGY OF THE LA LIMA AREA

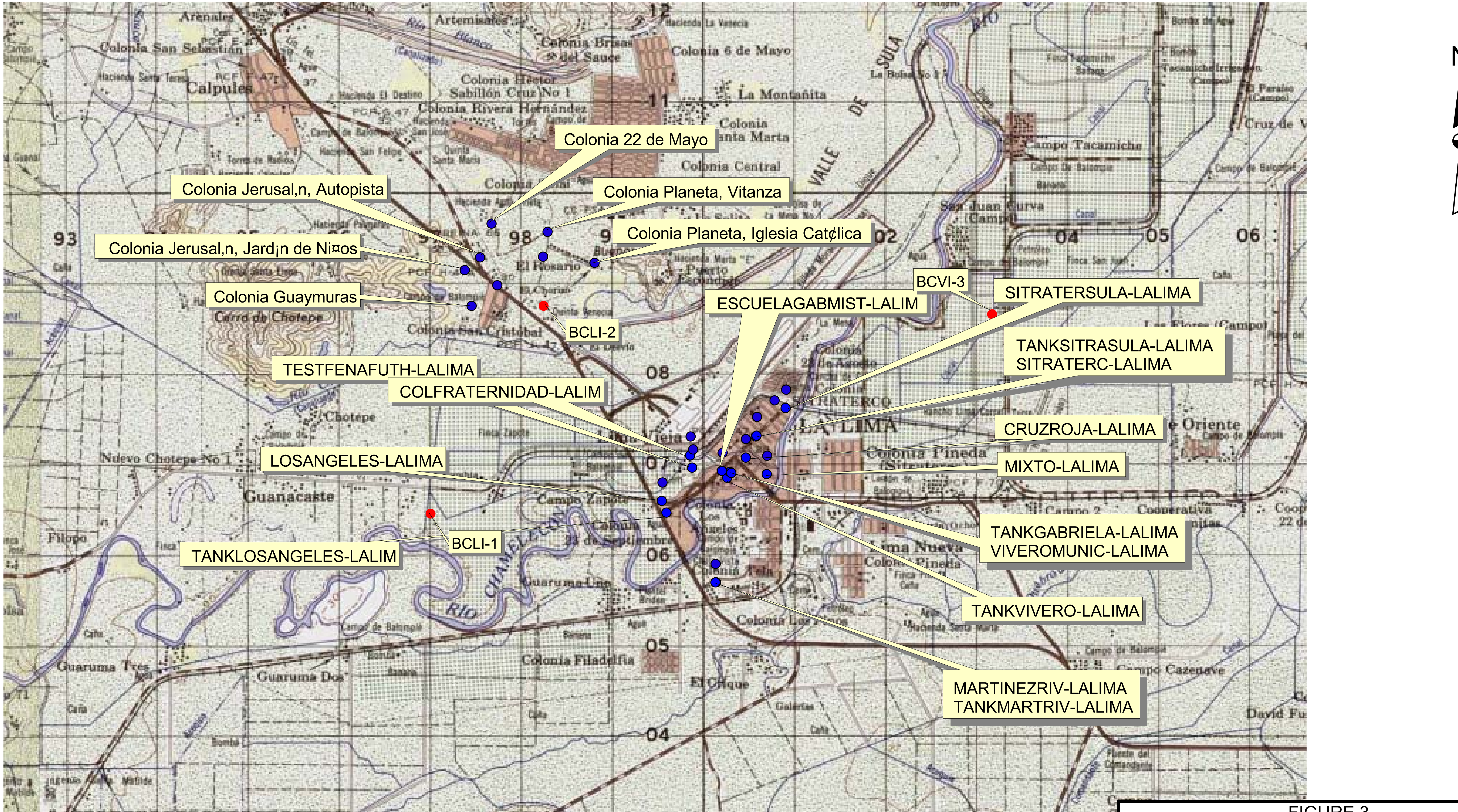


Drawing not to scale.

FIGURE 2

CONCEPTUAL GEOLOGIC CROSS-SECTION

LA LIMA



EXISTING PRODUCTION WELLS

PROPOSED TEST WELLS

0.5 0 0.5 1 Kilometers

FIGURE 3

EXISTING AND PROPOSED WELL LOCATIONS

LA LIMA

DATA GAPS

The Phase I data collection and evaluation has identified the following data gaps:

- Additional information is required to evaluate the alluvial aquifer for sustainable yields of groundwater.
- Additional information is required to support the premise that the aquifer system is laterally continuous.
- Additional information is required to evaluation the potential for deeper aquifers within the alluvial materials.

RECOMMENDED FIELD ACTIVITIES

Geophysical Surveys

Down-hole geophysics should be conducted on each of the boreholes installed during this evaluation. The geophysical suite will include resistivity, spontaneous potential, gamma, caliper, and temperature.

Test and Monitoring Wells

We recommend the installation of three test wells (BCLI-1, BCLI-2, and BCLI-3) to evaluate the La Lima valley alluvium. These wells are located in an area where additional information is required to support the conceptual and numerical model development. The locations of these wells are presented on Figure 3. Each test boring will be drilled to a depth between 400 to 500 feet to evaluate the vertical extent of the aquifer system. Each well will be completed in PVC. The screen intervals will be based on the results of the field observations and the downhole geophysical survey.

Aquifer Tests

Step testing and recovery testing will be conducted on each newly installed test well to calculate specific capacity, well efficiency, and transmissivity. The step test will be conducted over a 6 to 8 hour period. Following the step tests the wells will be pumped at a constant rate for approximately 12 hours. During this testing drawdown and recovery data will be collected. The recovery data will be collected until the well has recovered to within 90 percent of the original static water level.

Water Quality Sampling

Each interval that is identified as yielding a sufficient amount of groundwater will be tested for the following parameters:

- total dissolved solids
- specific conductance
- pH
- $CaCO_3$
- acidity
- alkalinity as $CaCO_3$
- nitrate/nitrite
- coliform
- chloride
- TAL metals (arsenic, barium, cadmium, chromium, iron, fluoride, lead, manganese, mercury, nickel, selenium, silver, sodium, and zinc)

ANTICIPATED FIELD RESULTS

The anticipated field results are as follows:

- The installation of the wells will provide information on the geometry of the aquifer system, aquifer transmissivities, aquifer specific yields, and yield sustainability.
- Identification of groundwater production zones of suitable groundwater quality.

APPENDIX B

Phase II Field Investigation Results

PHASE II FIELD INVESTIGATION RESULTS

La Lima, Honduras

June 2002

1.0 INTRODUCTION

As part of Contract Number 522-C-00-01-00287-00, Phase 2 between United States Agency for International Development (USAID) and Brown and Caldwell, three wells were installed and tested in La Lima. Work performed included drilling of exploratory boreholes, down-hole geophysical logs, installation of wells in exploratory boreholes, development of wells, and pump tests. The following sections provide details on the installation and testing of these wells.

The wells installed are named BCLL-1, BCLL-2, and BCLL-3. Figure 4-1, in Chapter 4 of this report, shows their location in relation to the surrounding municipality. The technical rationale for the location of each well was provided to USAID in the document entitled "Conceptual Model for La Lima" and the technical procedures for conducting the work were outlined in the document entitled "Technical Procedure for Phase II Field Investigation Boreholes and Wells for La Lima". The construction of the wells is summarized in Table B-1. The details of the work performed during the exploration, drilling, well construction and testing of each well are presented in the following sections.

Table B-1. Summary of Installed Wells

Name of well	Total depth of borehole (ft bgs)	Total depth of well (ft bgs)
BCLL-1	500	299
BCLL-2	510	505
BCLL-3	500	250

bgs – below ground surface

2.0 EXPLORATORY BOREHOLES

Figure B-1. Mud Rotary Drilling at BCLL-3

At each location an exploratory borehole was drilled first (Figure B-1). This borehole was later converted to a test well. Well BCLL-1 was installed by ESABAE Drilling, S. de R. L. (ESABAE) under the direction of HidroSistemas Drilling, S. de. R. L. (HidroSistemas). Well BCLL-2 was installed by SERPE Drilling, S. de R. L. (SERPE), and the final well, BCLL-3 was installed by ESABAE under the direction of SERPE. Details of borehole completion are provided in Table B-2. Completion of the boreholes was overseen by both Brown and Caldwell and ATICA S. de R. L. (ATICA) staff.

Table B-2. Summary of Boreholes

Name of Well	BCLL-1	BCLL-2	BCLL-3
Name of Driller	ESABAE	SERPE	ESABAE
Date Started	9/10/2001	10/17/2001	10/11/2001
Date Completed	9/18/2001	11/27/2001	10/18/2001
Drilling Equipment and Technique	Badger, Mud Rotary	Badger, Mud Rotary	Badger, Mud Rotary
Drilling Fluid	water, bentonite, polymer	water, bentonite, polymer	water, bentonite, polymer
Drill Bit and Size	8-inch nominal	8 7/8-inch	8-inch nominal
Total Borehole Depth	500 feet	510 feet	500 feet
Penetration Rate (ft/hr)	not available	3.2 to 36.4	12.0 to 41.0
Geophysical Company and Date	HidroSistemas, 9/18/2001	SERPE, 11/27/2001	SERPE, 10/18/2001

Water used for drilling was obtained from a lake in the nearby sugar cane fields. This water was transported to the various sites and stored in a tanker truck. Drilling was planned to be conducted continuously but occasional mechanical problems with the drill rigs and access problems caused by wet weather resulted in delays of approximately 7 to 10 days. Wells BCLL-2 and BCLL-3 were delayed for two days during Hurricane Michelle. BCLL-1 was already completed at the time of the storm. The storm is reported to have brought 20 inches of rain in two days and the river was reported to be 10 feet overbank. The flooding of the river affected the area surrounding BCLL-3 in the sugar cane fields, however, a ten-foot extension was added to the well head to prevent flooding of the casing (Figure B-2). The drilling of borehole BCLL-2 was also delayed due to not having immediate right-of-entry permission. In addition, the pump test for this well was delayed 10 days due to equipment difficulties and failure of the well to produce a significant amount of water.

Figure B-2. BCLL-3 with 10-foot Extension

3.0 LITHOLOGIC LOGGING

A lithologic log was prepared describing the stratigraphy penetrated throughout each borehole. The information for these logs came from drilled cuttings collected every 10 feet. Cuttings were collected from the drilling fluid with a slotted strainer and were preserved in plastic trays designed for this use. Generalized lithologic logs, geophysical logs, and well designs for wells BCLL-1, BCLL-2, and BCLL-3 are presented on Figures B-3, B-4, and B-5, respectively.

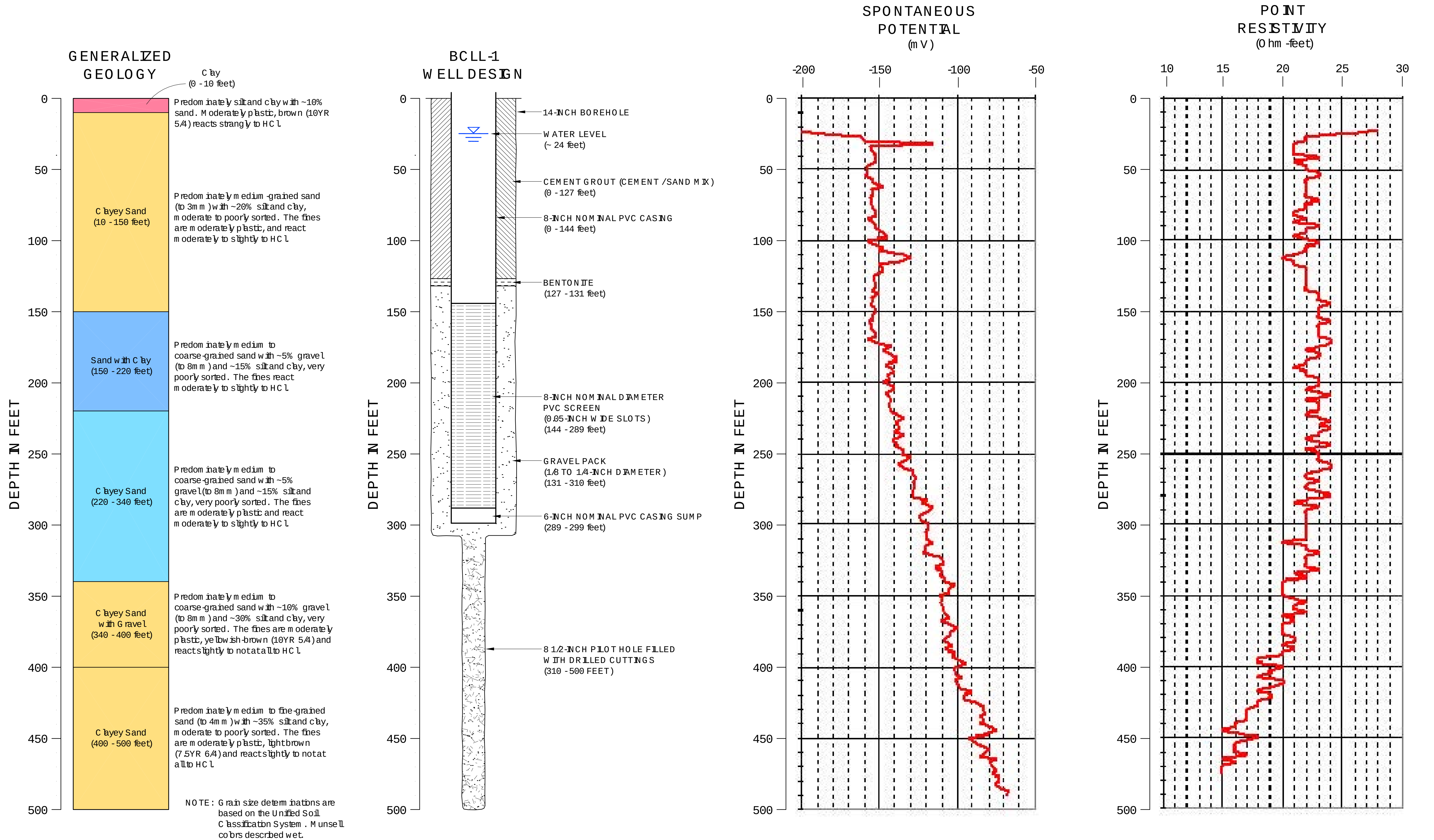
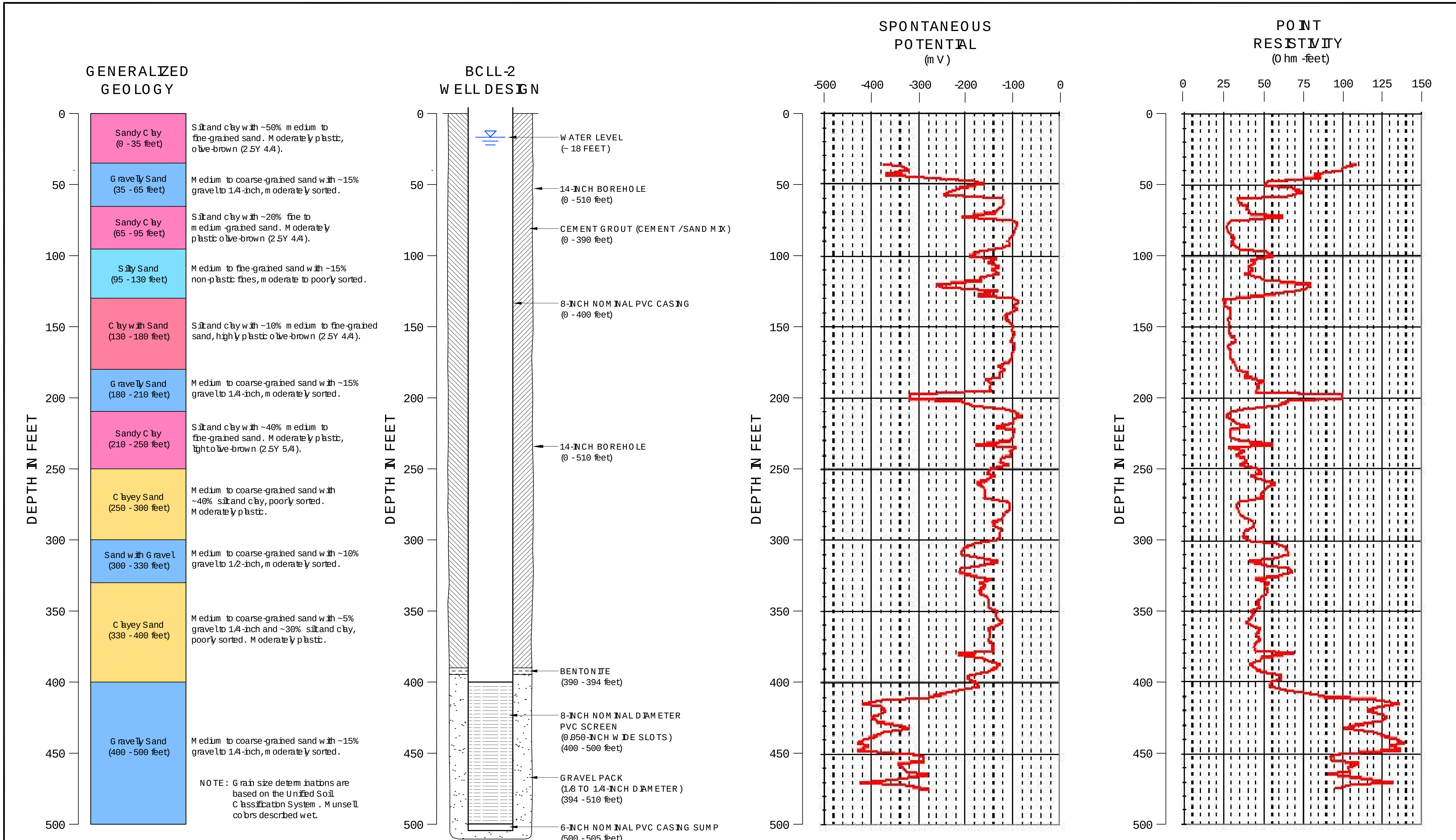


Figure B-3
BCLL-1 WELL DESIGN
LA LIMA, HONDURAS



BROWN AND CALDWELL

Figure B-4

BCLL-2 WELL DESIGN

LA LIMA, HONDURAS

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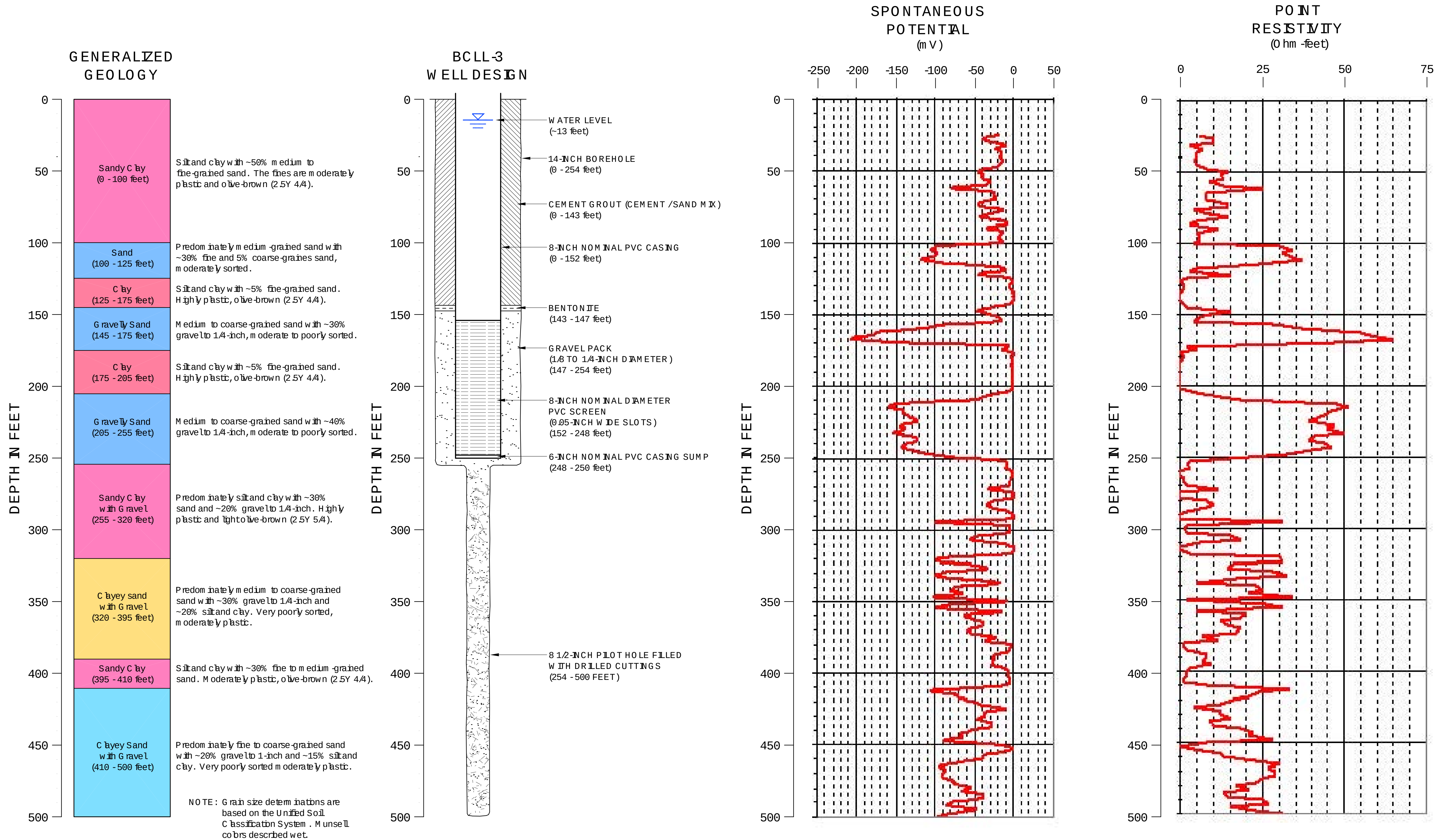


BROWN AND CALDWELL

Figure B-5

BCLL-3 WELL DESIGN

LA LIMA, HONDURAS

In summary, drilling at each borehole location penetrated two principal alluvial units. The upper alluvial unit is between 250 and 350 feet thick and is predominately fine-grained, however, well developed sand and gravel deposits are present. The total thickness of the sand and gravel deposits in the upper unit is between 100 and 200 feet thick and represents the major water bearing deposits in the study area. The lower alluvial unit is predominately clayey-sand, however, a coarse grained deposit was encountered at BCLL-2 from approximately 400 feet below ground surface (bgs) to the total depth of the boring at 510 feet. Bedrock was not encountered.

4.0 GEOPHYSICAL LOGGING

After completion of the exploratory boreholes, geophysical logging was conducted. The geophysical logging suite included spontaneous potential and electrical resistivity logs. HidroSistemas logged BCLL-1 on September 18, 2001. BCLL-2 and BCLL-3 were logged by SERPE on November 27, 2001 and October 18, 2001 respectively. The geophysical logs for BCLL-1, BCLL-2, and BCLL-3 are presented on Figures B-3, B-4, and B-5, respectively.

5.0 WELL DESIGN

Figure B-6. Installation of PVC Casing at BCLL-1

Each of the wells in La Lima were designed to exploit water from the saturated sand and gravel rich deposits. Blank PVC casing was installed from land surface to the top of the screened interval (Figure B-6). The water bearing units were screened with PVC casing with 0.050-inch wide slots. A gravel pack was installed adjacent to the screened interval and was isolated from upper portion of the borehole with a thin layer of bentonite chips and a sanitary seal. The sanitary seal consists of sand/cement grout installed from the top of the bentonite layer to land surface (Figure B-7).

Figure B-7. Installation of Sanitary Seal at BCLL-1

Wells BCLL-1 and BCLL-2 were screened adjacent to the well-developed sand and gravel deposits between approximately 150 feet and 300 feet bgs. At BCLL-2, a newly investigated coarse-grained deposit for the La Lima area was screened between 400 and 500 feet bgs. The diameter of each well was selected on estimated yield from evaluation of lithologic log, the driller's penetration rate, and the geophysical logs. Eight-inch nominal diameter PVC well casing was installed at each location in La Lima.

6.0 WELL CONSTRUCTION

Wells were constructed after reaming the exploratory borehole to the final diameter. Both Brown and Caldwell and ATICA staff oversaw completions of the wells. Well construction details for BCLL-1, BCLL-2, and BCLL-3 are presented Figures B-3, B-4, and B-5, respectively and summarized in Table B-3.

Table B-3. Summary of Well Construction

Name of Well	BCLL-1	BCLL-2	BCLL-3
Date Started	9/25/2001	11/21/2001	10/25/2001
Date Completed	9/27/2001	11/23/2001	10/25/2001
Diameter of Borehole	14-inches	14-inches	14-inches
Total Depth of Well	299 feet	505 feet	250 feet
Casing/Screen Material	8-inch nominal PVC casing	8-inch nominal PVC casing	8-inch nominal PVC casing
Screen Interval	144′-289′	400′-500′	152′-248′
Screen Slot Size	0.05-inch	0.05-inch	0.05-inch
Sanitary Seal Material	sand/cement grout	sand/cement grout	sand/cement grout
Sanitary Seal Interval	0-127′	0-390′	0-143′
Bentonite Seal Interval	127′-131′	390′-394′	143′-147′
Gravel Pack Size	1/8 to 1/4-inch	1/8 to 1/4-inch	1/8 to 1/4-inch
Gravel Pack Interval	131′-310′	394′-510′	147′-254′

The surface completion of each well consisted of a concrete block housing for the wellhead including a locking steel cover. Additionally, each well includes a stainless steel plaque identifying the well.

7.0 WELL DEVELOPMENT

Following installation of casing, each well was developed by the swab and airlift method. Airlifting was conducted at various rates and was continued until the water was predominantly clear and free of sand and silt. Activities relating to well development are summarized in Table B-4.

Table B-4. Well Development Summary

Name of Well	BCLL-1	BCLL-2	BCLL-3
Date Started	9/27/2001	1st cleaning: 11/23/2001 2nd cleaning: 12/1/2001	10/26/2001
Date Ended	9/28/2001	1st cleaning: 11/23/2001 2nd cleaning: 12/2/2001	10/26/2001
Total Hours	12 hours	1st cleaning: 6 hours 2nd cleaning: 12 hours	8 hours
Description of Method	swab and airlift	swab and airlift	swab and airlift

8.0 STEP-RATE DISCHARGE TESTS

A step-rate discharge test was conducted to evaluate the specific capacity of the well and collect data to be used in groundwater modeling. The purpose of a step-rate discharge test is to determine the maximum pumping potential of the well. A step-rate discharge test was not conducted at BCLL-2 because of the low production of the well did not allow for enough step-rates to analyze the test. Instead, two constant-rate discharge tests were conducted at BCLL-2. Drawdown plots for the step-rate discharge tests at wells BCLL-1 and BCLL-3 are presented on Figures B-8 and B-9, respectively. The step-rate discharge tests for BCLL-1 and BCLL-3 are summarized in Table B-5 and Table B-6.

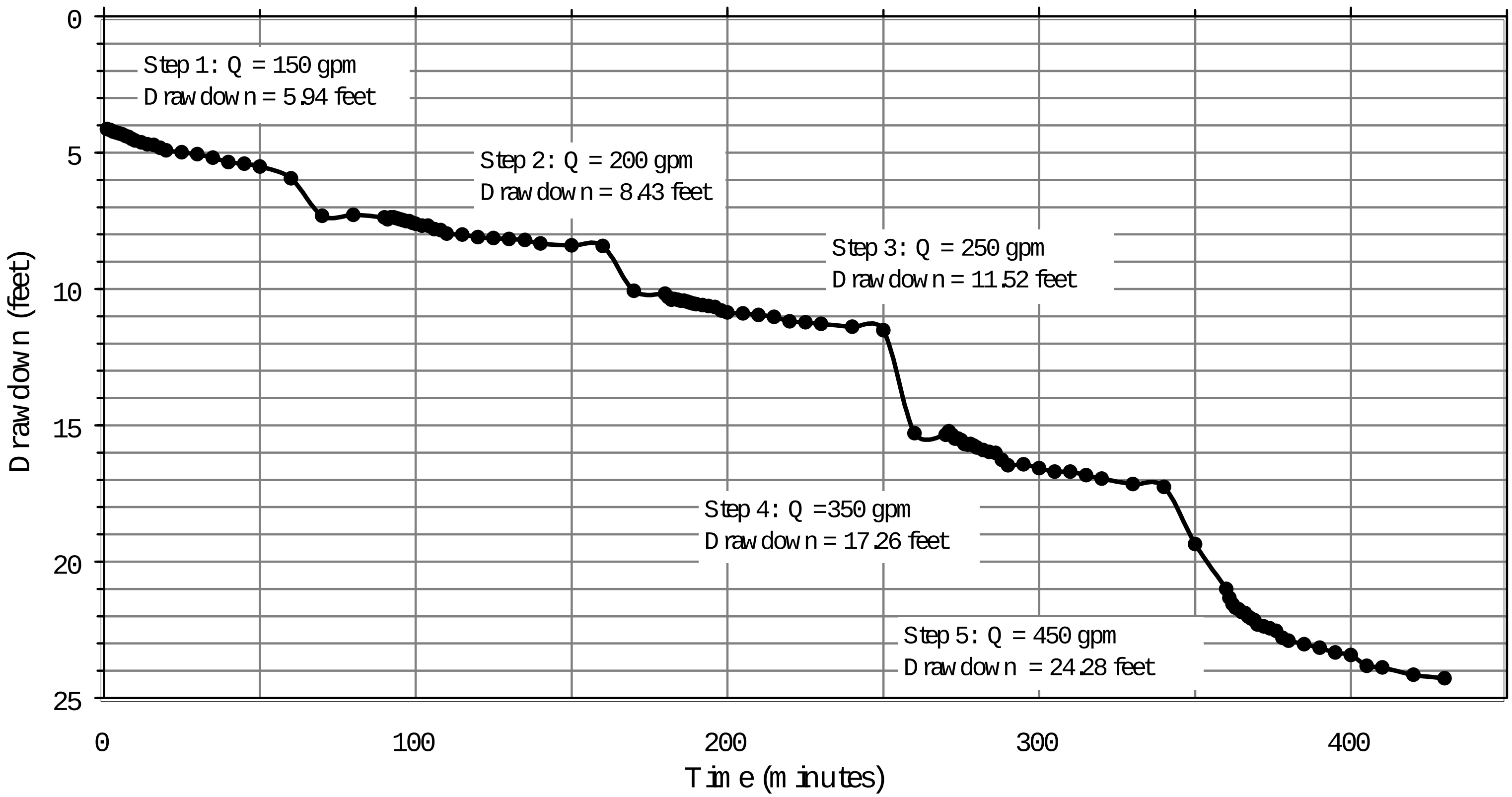
Table B-5. Summary of Step-Rate Discharge Tests

Name of Well	BCLL-1	BCLL-3
Date Started	10/3/2001	11/9/2001
Duration (hours)	7 ½ hours	10 hours
Pump Size/Type	25 HP, Myers	25 HP, Myers
Pump Depth	130′	100′
Static Water Level (ft, bgs)	22.31	13.05
Specific Capacity (gpm/ft)	25.25 @ 150 gpm 23.72 @ 200 gpm 21.70 @ 250 gpm 20.28 @ 350 gpm 18.53 @ 450 gpm	71.09 @ 150 gpm 64.32 @ 220 gpm 60.80 @ 290 gpm 58.63 @ 360 gpm 54.78 @ 430 gpm

Table B-6. Summary of Field Parameters during Pump Tests*

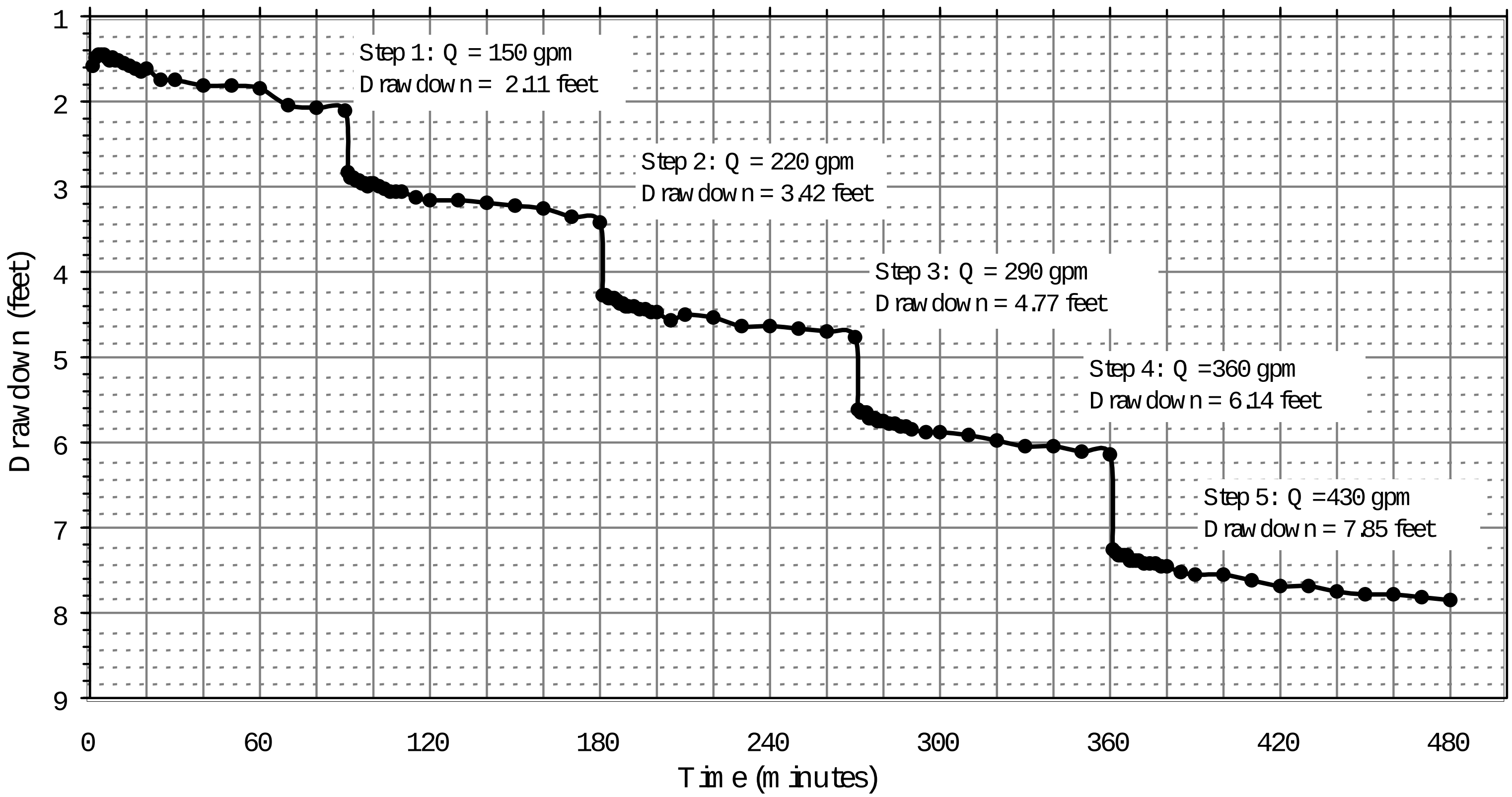
Name of Well	BCLL-1	BCLL-3
pH	7.41 @ 150 gpm 7.40 @ 200 gpm 7.42 @ 250 gpm 7.54 @ 350 gpm 7.49 @ 450 gpm	7.69 @ 150 gpm 7.81 @ 220 gpm 7.91 @ 290 gpm 7.94 @ 360 gpm 7.91 @ 430 gpm
Temperature (degrees F)	82.1 @ 150 gpm 81.7 @ 200 gpm 85.9 @ 250 gpm 93.4 @ 350 gpm 85.8 @ 450 gpm	71.9 @ 150 gpm 73.1 @ 220 gpm 76.8 @ 290 gpm 76.4 @ 360 gpm 74.4 @ 430 gpm
Conductivity (µSiemens per cm)	927 @ 150 gpm 1,001 @ 200 gpm 957 @ 250 gpm 846 @ 350 gpm 943 @ 450 gpm	493 @ 150 gpm 486 @ 220 gpm 463 @ 290 gpm 465 @ 360 gpm 484 @ 430 gpm

*Data presented for each step represent an average of independent readings spread over the course of each step.



Q - Discharge Rate
gpm - gallons per minute

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BCLL-1	Figure B-8 STEP-RATE PUMPING TEST



Q - Discharge Rate
gpm - gallons per minute

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BCLL-3	Figure B-9 STEP-RATE PUMPING TEST

P:\Gen\GW_RES\Honduras\La Lima\Pump Tests\BC LL-3 PUMP TEST ANALYSIS.xls\Figure B-9

9.0 CONSTANT RATE DISCHARGE TESTS

Figure B-10. Water Level Indicator Used to Determine Depth to Groundwater

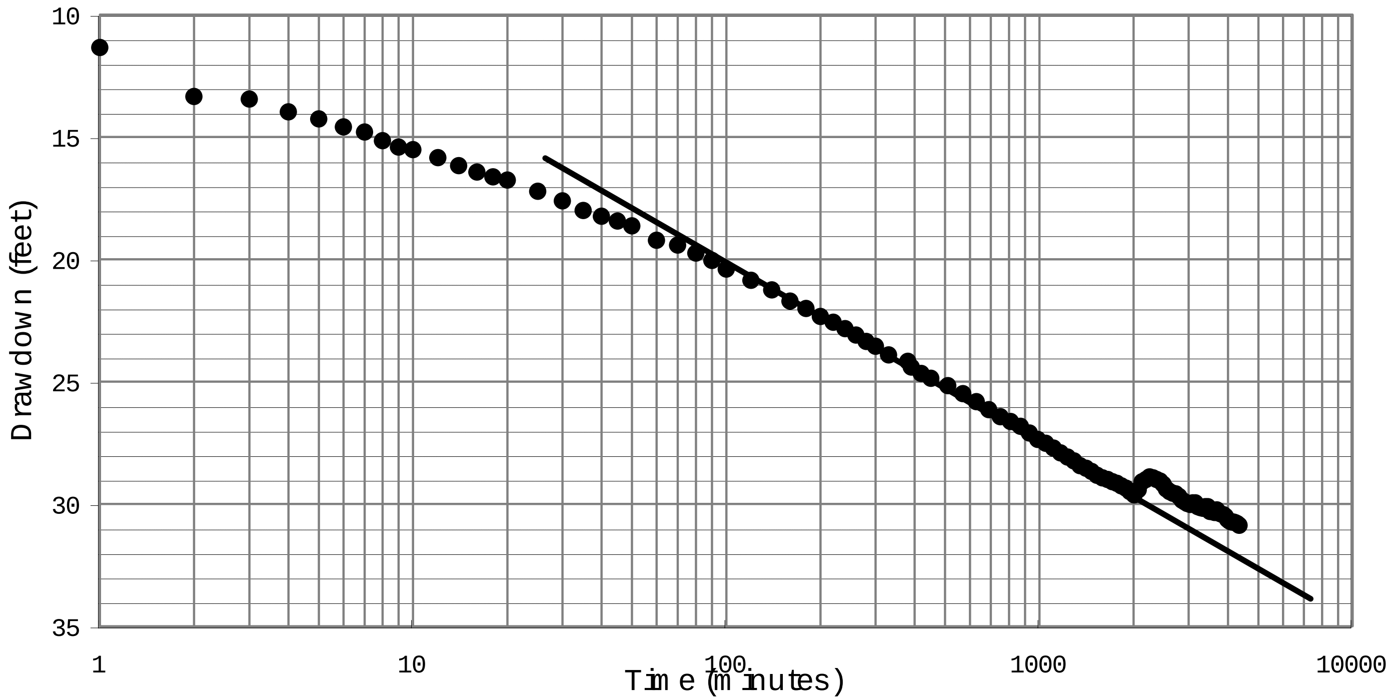
The purpose of a constant rate discharge test is to determine how the aquifer behaves when subjected to continual pumping at a constant rate over an extended period of time. Constant rate discharge tests were performed at wells BCLL-1 and BCLL-2. At well BCLL-3, the final step during the step-rate test was extended for analysis.

During each test, drawdown data was collected with a water level indicator (Figure B-10). After pumping was complete, recovery water levels were recorded.

Transmissivity was calculated using the Cooper-Jacob method (Cooper and Jacob, 1946) for analyzing non-equilibrium flow in a confined aquifer system. This method utilizes a semi-log plot of drawdown verses time. Transmissivity can be estimated by measuring the slope of the drawdown plot. An analysis of the water-level recovery test data was used as a verification of aquifer parameters estimated from the constant-rate pumping test. Recovery tests are a more accurate method of estimating aquifer characteristics due to the absence of pumping effects on the water levels. Recovery test data were analyzed using the Theis recovery method (Theis, 1935), which utilizes a semi-log plot of drawdown verses the time since the pump test started divided by the time since the recovery test started. Transmissivity is estimated from the slope of the recovery plot.

The drawdown and recovery plots for BCLL-1 are presented on Figures B-11 and B-12, the plots for the two tests conducted at BCLL-2 are presented on Figures B-13 through B-16, and the plots for BCLL-3 are presented on Figures B-17 and B-18.

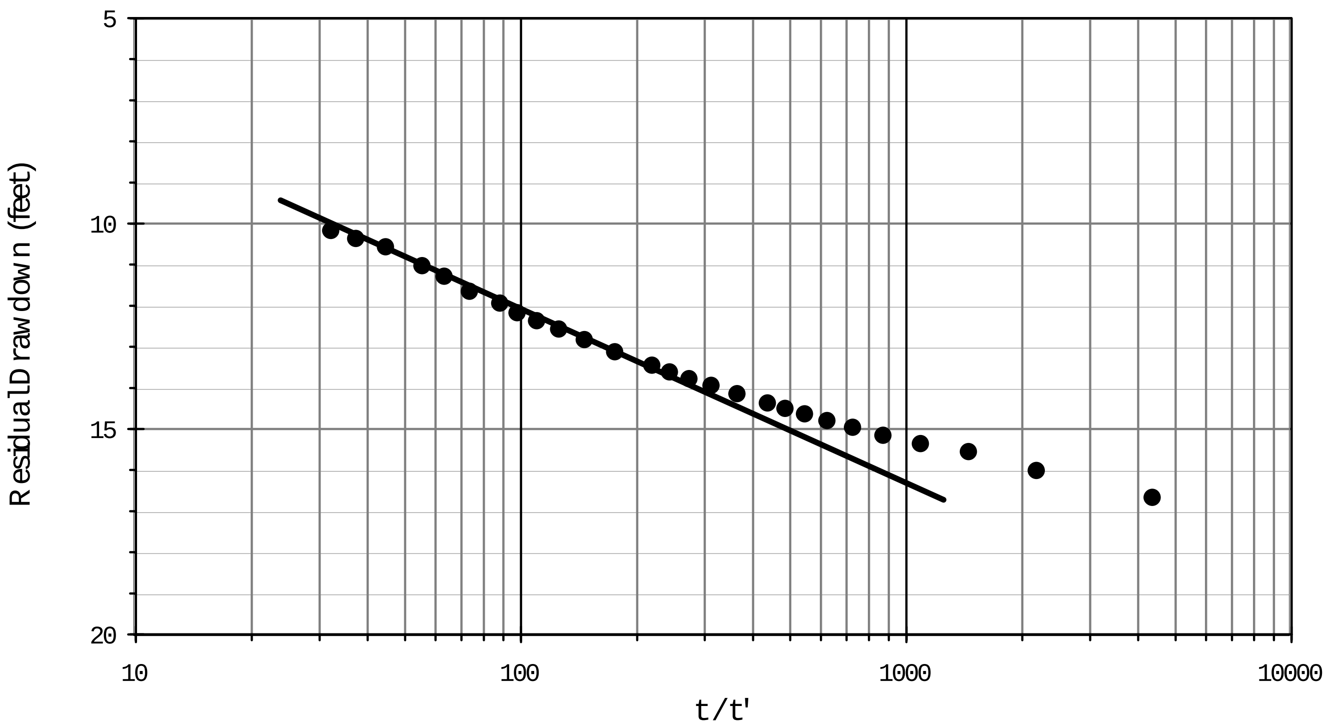
General test information and preliminary analysis of the results of the constant rate tests are also included in Table B-7.



Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(450)/(7.5)
T ~ 15,800 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BCLL-1	Figure B-11 COOPER-JACOB PLOT

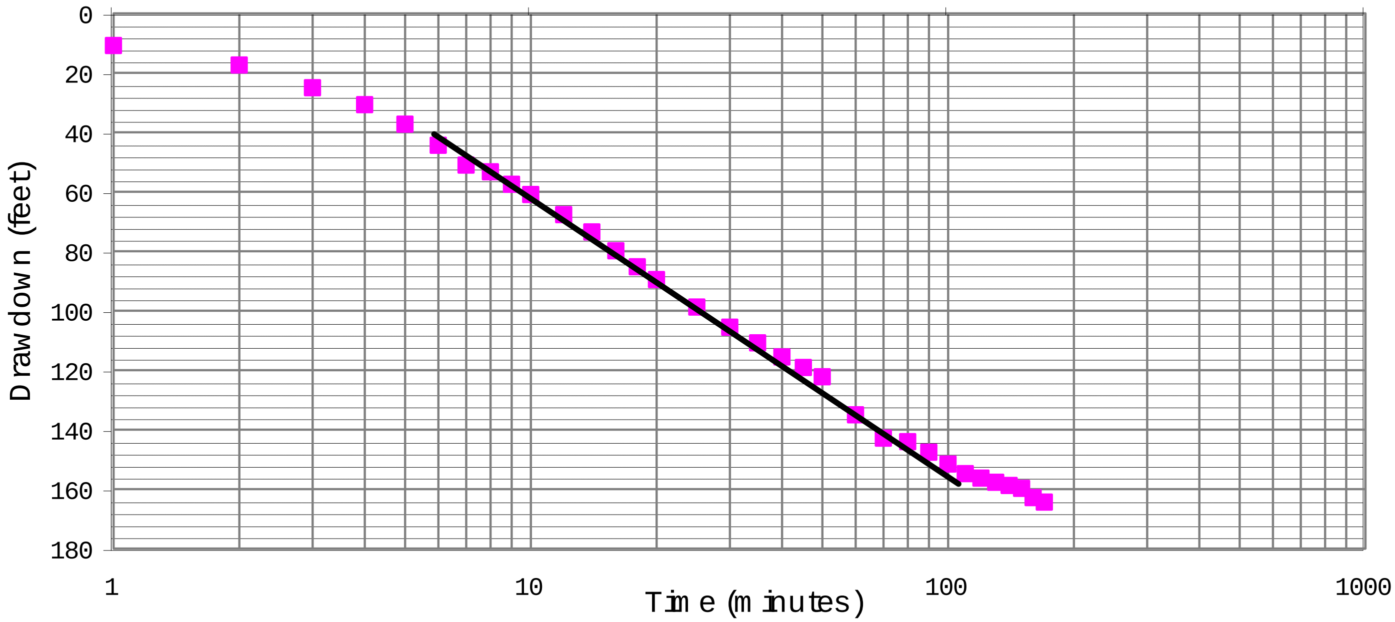


t= time since pumping started (min)
t'= time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(450)/(4.375)
T ~ 27,200 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BCLL-1	FIGURE B-12 THEIS RECOVERY PLOT

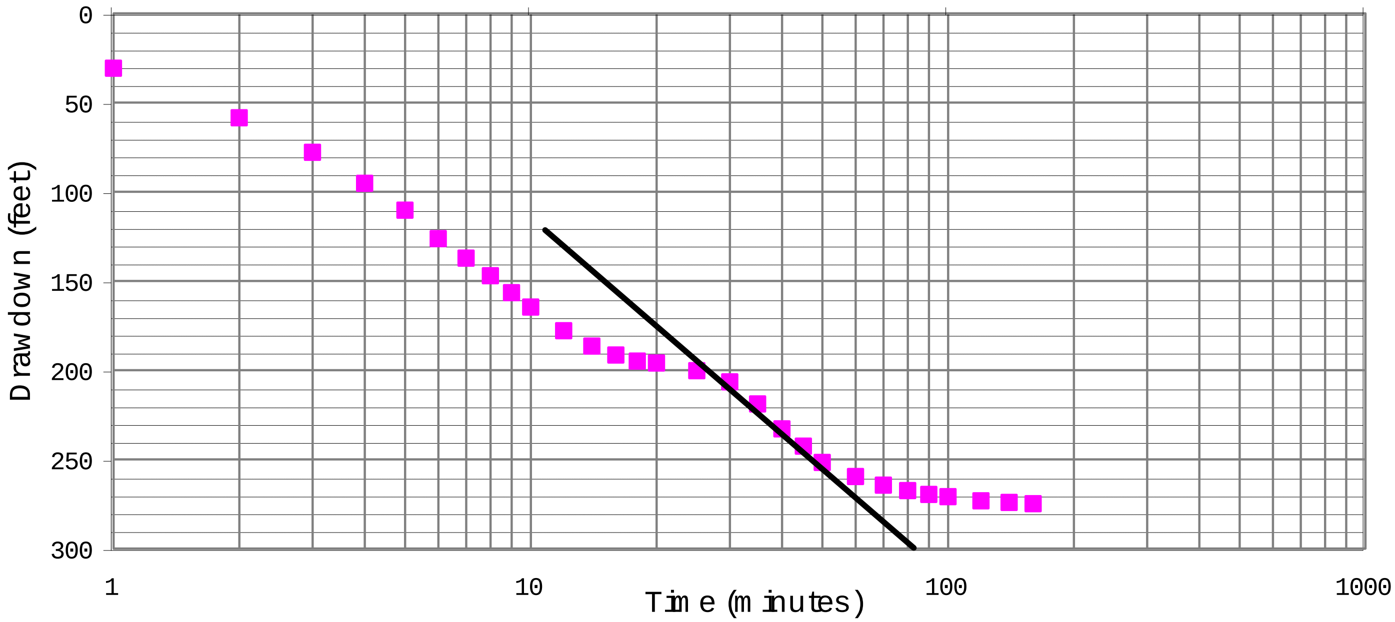
P:\Gen\GW_RES\Honduras\La Lima\Pump Tests\BCLL-1 PUMP TEST ANALYSIS.xls\Figure B-12



Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(25)/(90.6)
T ~ 73 gpd/ft

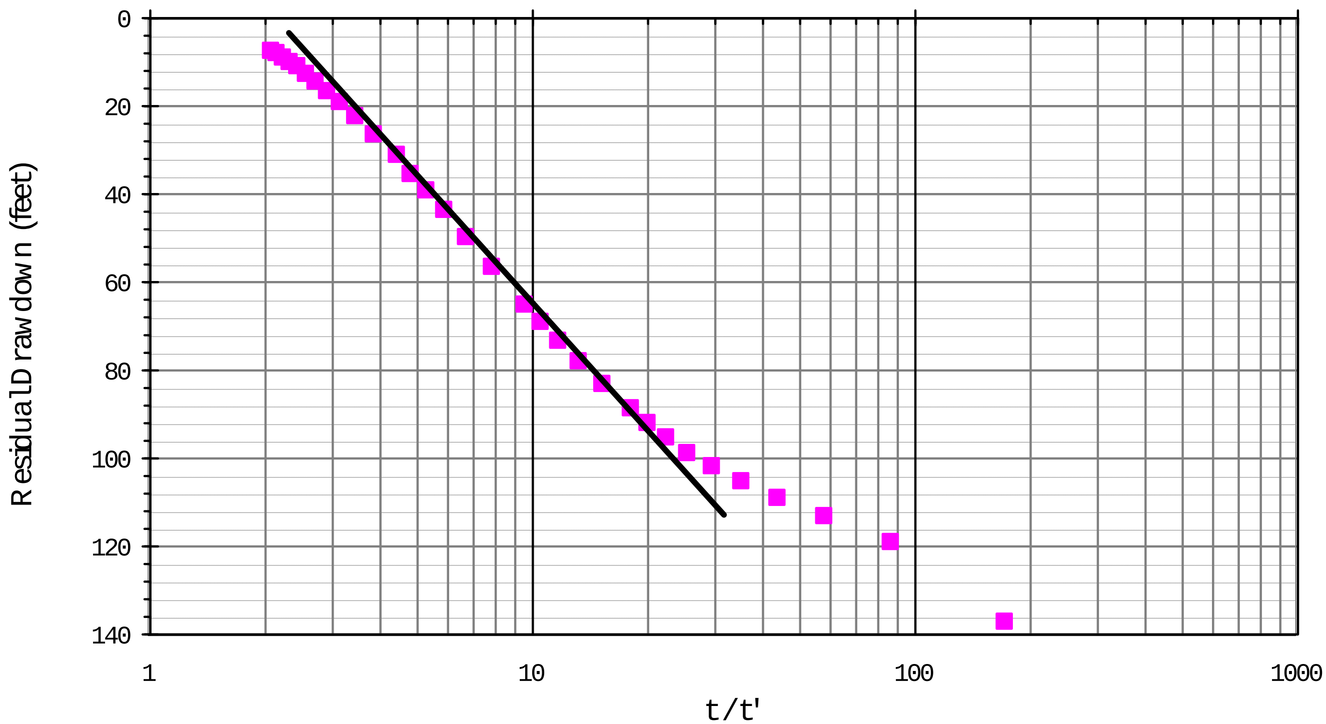
BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BCLL-2	Figure B-13 COOPER-JACOB PLOT (25 GPM)



Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(38)/(205)
T ~ 49 gpd/ft

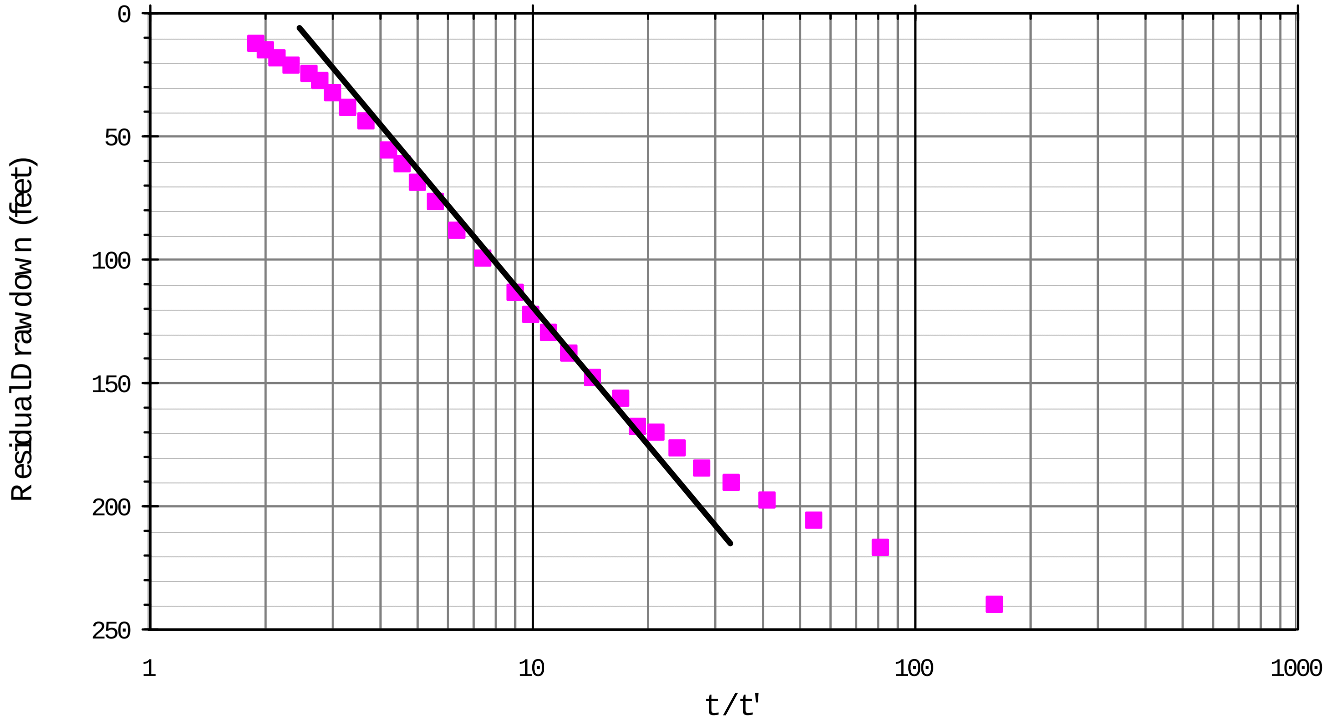
BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BCLL-2	Figure B-14 COOPER-JACOB PLOT (40 GPM)



t = time since pumping started (min)
t' = time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(25)/(93.9)
T ~ 70 gpd/ft

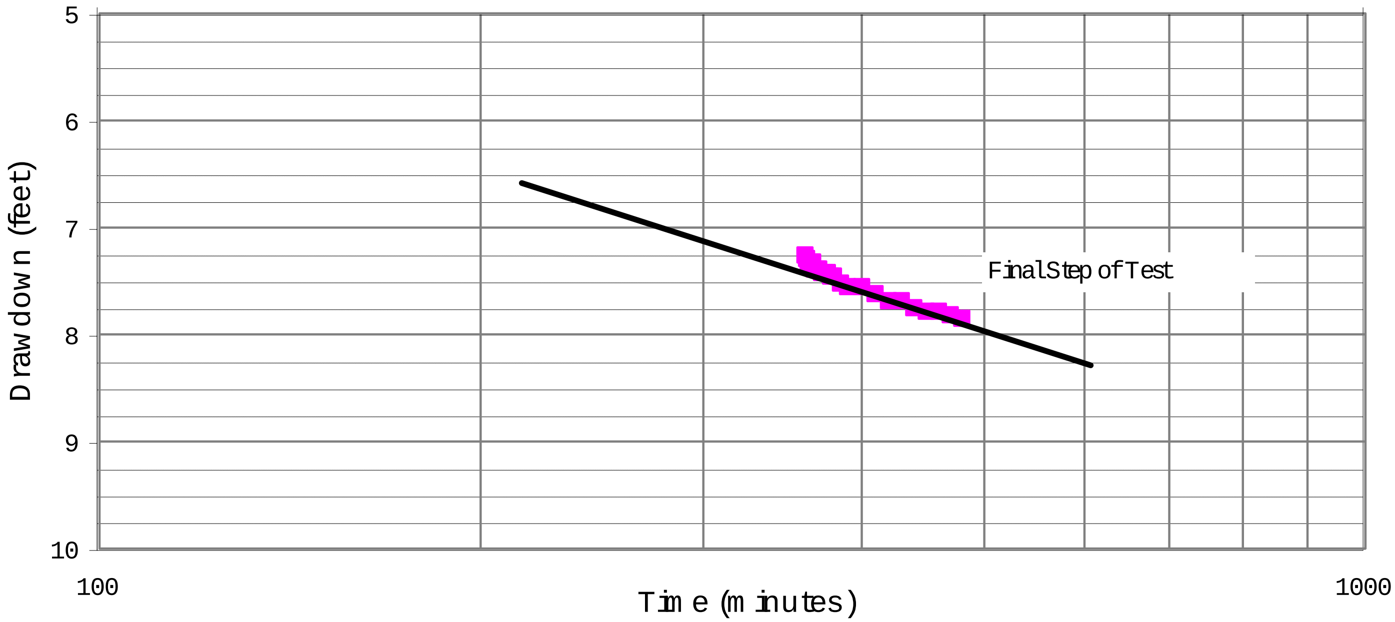
BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BCLL-2	FIGURE B-15 THEIS RECOVERY PLOT (25 GPM)



t= time since pumping started (min)
t'= time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(40)/(174)
T ~ 61 gpd/ft

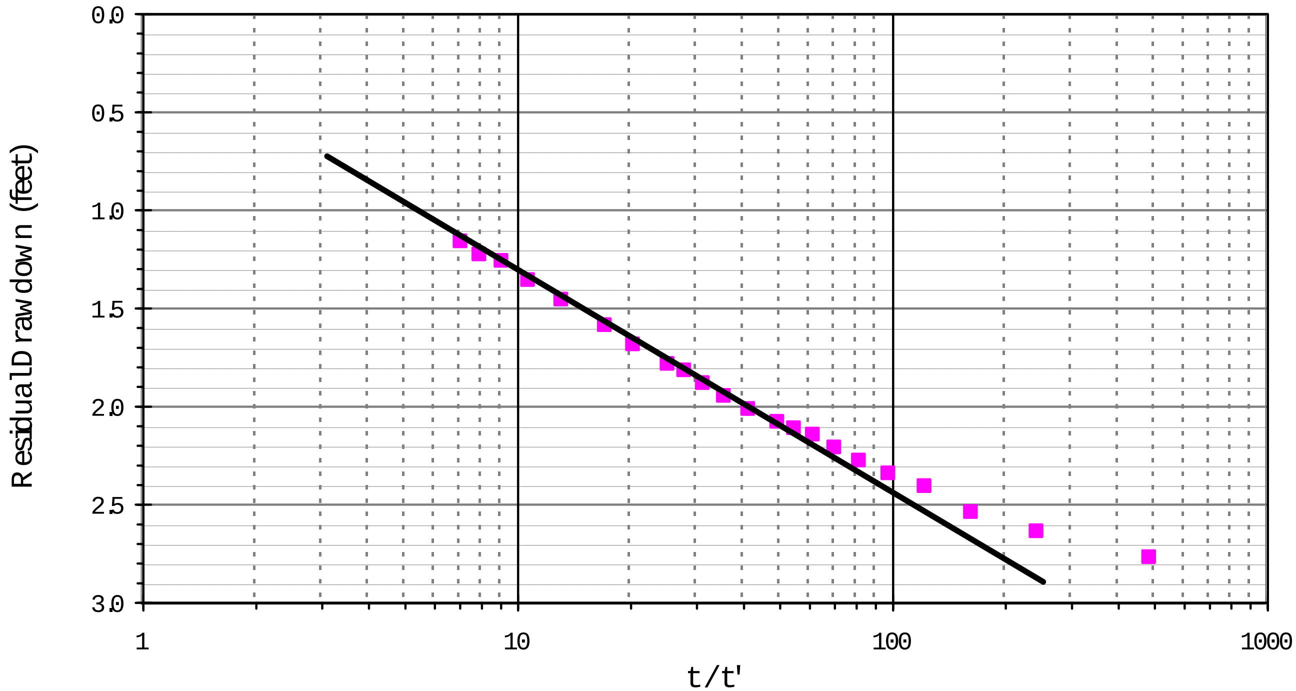
BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BCLL-2	FIGURE B-16 THEIS RECOVERY PLOT (40 GPM)



Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(430)/(3.66)
T ~ 31,000 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BCLL-3	Figure B-17 COOPER-JACOB PLOT



t = time since pumping started (min)
t' = time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(299)/(1.1)
T ~ 72,000 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BCLL-3	FIGURE B-18 THEIS RECOVERY PLOT

P:\Gen\GW_RES\Honduras\La Lima\Pump Tests\BCLL-3 PUMP TEST ANALYSIS.xls\Figure B-18

Table B-7. Summary of Constant Rate Discharge Tests

Name of Well	BCLL-1	BCLL-2	BCLL-3
Transmissivity Estimated from Drawdown (gpd/ft)	15,800	73 (@ 25 gpm) 49 (@ 38 gpm)	31,000
Transmissivity Estimated from Recovery (gpd/ft)	27,200	70 (@ 25 gpm) 61 (@ ~38 gpm)	72,000
Date Started	10/4/2001	12/19/2001	11/9/2001
Date Ended	10/7/2001	12/20/2001	11/9/2001
Duration (hours)	72 hours	2 tests, ~3 hours each test	2 hours
Depth of Pump	130 feet	300 feet	100 feet
Pump Rate (gpm)	450	25 and 38	430
Specific Capacity (gpm/ft)	14.6	0.15 @ 25 gpm 0.15 @ 40 gpm	54.8
Static Water Level (ft bgs)	22.61	21.33 (12/19/2001) 18.14 (12/20/2001)	13.05

gpm=gallons per minute
gpd=gallons per day
ft bgs=feet below ground surface

10.0 WATER QUALITY SAMPLING

A sample of groundwater was collected from each new project well either at the end of well development or at the end of the step-rate discharge test. This sampling was conducted in support of the water quality component of the Honduras Groundwater Monitoring Study.

Each well was sampled for general chemistry constituents that include but are not limited to acidity, alkalinity, hardness, bicarbonate, calcium, magnesium, manganese, sulfates, nitrates and nitrites, sodium and potassium. Each well was also sampled for a limited number of heavy metals including antimony, arsenic, lead, mercury, selenium, cadmium, chromium, nickel, silver and zinc. In addition, most wells were analyzed for total and fecal coliform to assess the amount of fecal matter infiltrating into the groundwater supply.

The groundwater sampling procedure for all wells included field water quality measurements (pH, temperature, and conductivity) to confirm that pumped groundwater was representative of aquifer pore water. Figure B-19 depicts the field equipment used to measure various parameters. Samples were collected in containers supplied by Jordan Laboratories of San Pedro Sula or Southern Petroleum Laboratories (SPL) in Houston, Texas. Samples were immediately labeled and placed on ice in laboratory-supplied coolers. Samples for physical parameters and bacteriological analysis were delivered on the same day to Jordan Laboratories in San Pedro Sula. Samples for metals analysis were shipped to SPL in Houston, Texas. Proper chain-of-custody documentation was filled out and accompanied samples from collection to laboratory analysis.

The water quality sample for laboratory analysis for BCLL-1 was collected on October 5, 2001 during the constant-rate test. The water quality sample for BCLL-2 was collected on December 13, 2001 during the step-rate test. The water quality sample for BCLL-3 was collected November 9, 2001 during the final 2-hour step of the step-rate discharge test.

Figure B-19. Equipment Used to Measure pH, Temperature, and Conductivity in the Field

Water quality samples for laboratory analysis were also collected from selected existing municipal wells that may serve as the future groundwater monitoring network for La Lima. Water quality samples were collected from Guaymuras, Rapidito, 22 de Mayo, Martinez Rivera, FUSEP Planeta, Oro Verde, Villa Esther, and Cruz Roja between November 15, 2001 and November 19, 2001. These analytical results are presented in Table B-8, as well as laboratory reports, at the end of this appendix.

No metals were detected in the wells installed by Brown and Caldwell. However, concentrations of certain metals were detected in most of the other wells sampled. Antimony was detected in 22 de Mayo (0.0206 mg/L), Oro Verde (0.0258 mg/L), and Guaymuras (0.0149 mg/L). The WHO provisional guideline concentration for antimony in groundwater is 0.005 mg/L. Zinc was detected in Guaymuras (0.105 mg/L) and Residencial Villa Esther (0.0373 mg/L). There is no WHO guideline for zinc in groundwater. Concentrations of nickel were reported in Guaymuras (0.0323 mg/L). The WHO provisional guideline for nickel is 0.02 mg/L. Arsenic was detected in groundwater sampled from 22 de Mayo (0.0121 mg/L) and Cruz Roja (0.01 mg/L). The WHO provisional guideline concentration for arsenic in groundwater is 0.01 mg/L. The concentrations of these heavy metals are generally low. The source of these metals are likely the acidic and intermediate composition igneous and metamorphic rocks found in the surrounding highlands.

The electrical conductivity of samples collected from BCLL-1, BCLL-2, and BCLL-3 ranged between approximately 400 and 930 mS/cm, which is approximately 240 to 560 mg/L total dissolved solids (TDS). Conductivity measurements collected from the remaining La Lima wells ranged from 396 mS/cm (approximately 248 mg/L TDS) at well BCLL-3 to 928 mS/cm (approximately 580 mg/L TDS) at well BCLL-1. Generally, conductivity measurements for the rest of the wells were between 450 and 575 mS/cm (approximately 281 to 344 mg/L TDS). TDS is proportional to electrical conductivity, with conductivity being about 1.6 times greater than TDS concentrations. Normal drinking water has a TDS range of 300 to 800 mg/L. Seawater has a TDS of approximately 32,000 mg/L. The recommended limit for TDS by the WHO is 500 mg/L, with a maximum of 1,500 mg/L.

Nitrate concentrations in the wells installed by Brown and Caldwell were below 2 mg/L; well below the WHO guideline of 50 mg/L. Reported nitrate concentrations in the remaining La Lima wells were also low: BCLL-1 (<0.01 mg/L), BCLL-2 (0.11 mg/L), BCLL-3 (0.53 mg/L), 22 de Mayo (0.41 mg/L), Oro Verde (0.08 mg/L), Guaymuras (0.34 mg/L), Cruz Roja (0.06 mg/L), Residencial Villa Esther (0.05 mg/L), Cuidad Planeta 1 (1.35 mg/L), and Colonia Martinez Rivera (0.41 mg/L). The WHO acute exposure guideline for nitrate in water is 50 mg/L.

Total coliform concentrations were detected in all of the wells sampled in La Lima. The maximum concentration was reported at Colonia Martinez Rivera at 67 UFC/100 mL). Total coliform concentrations were low in wells BCLL-1 and BCLL-3 (between 2 and 4 UFC/100 mL) however; coliform concentrations at BCLL-2 were higher (84 UFC/100 mL total coliform, and 22 UFC/100 mL fecal coliform). Total coliform concentrations were also low in wells Oro Verde, and Guaymuras. Wells 22 de Mayo, Cuidad Planeta 1, and Colonia Martinez Rivera had concentrations of total coliform between 30 and 67 UCF/100 mL, with no detections of fecal coliform. Wells Cruz Roja, and Residencial Villa Esther had the greatest total coliform concentrations between 26 and 84 UFC/100 ml, and fecal coliform concentrations between 5 and 22 UFC/100 ml. For drinking water, the WHO guidelines state that coliform must not be detected in a 100 ml sample. The guidelines indicate that where sufficient samples are examined, coliform must not be present in 95% of samples taken throughout any 12-month period.

Hardness was measured in each of the wells sampled in La Lima. In general, hardness between 50 and 150 mg/L is not considered a significant problem, however hardness above 150 mg/L generally causes scale build-up or staining. Hardness measured in wells BCLL-1, BCLL-2, and BCLL-3 was 120, 68, and 96 mg/L as $CaCO_3$, respectively. However, the existing wells sampled in La Lima produced significantly harder water. The average hardness of the pre-existing wells sampled for this study is approximately 225 mg/L as $CaCO_3$ with a maximum concentration of hardness of 308 mg/L as $CaCO_3$ at Oro Verde. Based on these data, groundwater hardness is an issue that should be considered when designing a water distribution system for La Lima.

11.0 REFERENCES

Cooper, H.H. Jr., and Jacob, C.E., 1946. *A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-field History*, Transactions, American Geophysical Union, 27:526-34.

Theis, C.V., 1935. *The Lowering of the Piezometric Surface and the Rate and Discharge of a Well Using Groundwater Storage*. Transactions, American Geophysical Union, 16:519-24.

Work Health Organization, 1996. *Guidelines for Drinking Water Quality 2nd Edition, Volume 2 Health Criteria and Other Supporting Information*, pp 940-949.

Table B-8. Analytical Results
(Page 1 of 5)

Water Quality	Analytical Constituent	Analytical Method	Result	Unit	WHO Guideline (health based)
Water Quality					
Villa Esther	Acidez Total	2310-B	34	mg/l	-
Villa Esther	Alcalinidad Total	2320-B	337	mg/l CaCO3	-
Villa Esther	Bicarbonato (HCO3)	2320-B	337	mg/l	-
Villa Esther	Dureza Total	2340-C	236	mg/l CaCO3	-
Villa Esther	Conductividad	25100-B	575	us/cm	-
Villa Esther	Calcio	3500-Ca D	59	mg/l CaCO3	-
Villa Esther	Hierro Total	3500-Fe-D	0.09	mg/l	-
Villa Esther	Magnesio	3500-Mg E	21	mg/l CaCO3	0.3
Villa Esther	Manganeso Total	3500-Mn C	0.4	mg/l	0.5
Villa Esther	Cloruros	4500-Cl-B	57	mg/l	250
Villa Esther	Nitritos	4500-NO2-B	< 0.01	mg/l	1
Villa Esther	Nitratos	4500-NO3-B	0.05	mg/l	50
Villa Esther	Sulfatos	4500-SO4	74	mg/l	250
Villa Esther	Sodio (Na)	AA	110.1	mg/L	200
Villa Esther	Potasio (K)	AA	3.78	mg/L	10
Villa Esther	Coliformes Totales	9222-B	32	UFC/100 ml	0
Villa Esther	Coliformes Fecales	9222-D	10	UFC/100 ml	0
Metals					
Villa Esther	Antimony	6010B	< 0.005	mg/l	0.005
Villa Esther	Arsenic	6010B	< 0.005	mg/l	0.01
Villa Esther	Cadmium	6010B	< 0.005	mg/l	0.003
Villa Esther	Chromium	6010B	< 0.01	mg/l	0.05
Villa Esther	Lead	6010B	< 0.005	mg/l	0.01
Villa Esther	Nickel	6010B	< 0.02	mg/l	0.02
Villa Esther	Selenium	6010B	< 0.005	mg/l	0.01
Villa Esther	Silver	6010B	< 0.01	mg/l	-
Villa Esther	Zinc	6010B	0.0373	mg/l	3
Villa Esther	Mercury	7470A	< 0.0002	mg/l	0.001
Water Quality					
Guaymuras	Acidez Total	2310-B	83	mg/l	-
Guaymuras	Alcalinidad Total	2320-B	104	mg/l CaCO3	-
Guaymuras	Bicarbonato (HCO3)	2320-B	104	mg/l	-
Guaymuras	Dureza Total	2340-C	228	mg/l CaCO3	-
Guaymuras	Conductividad	25100-B	48	us/cm	-
Guaymuras	Calcio	3500-Ca D	35.2	mg/l CaCO3	-
Guaymuras	Hierro Total	3500-Fe-D	1.86	mg/l	0.3
Guaymuras	Magnesio	3500-Mg E	34	mg/l CaCO3	50
Guaymuras	Manganeso Total	3500-Mn C	1.12	mg/l	0.5
Guaymuras	Cloruros	4500-Cl-B	41	mg/l	250
Guaymuras	Nitritos	4500-NO2-B	0.03	mg/l	1
Guaymuras	Nitratos	4500-NO3-B	0.34	mg/l	50
Guaymuras	Sulfatos	4500-SO4	185	mg/l	250
Guaymuras	Potasio (K)	AA	6.35	mg/l	10
Guaymuras	Sodio (Na)	AA	54.7	mg/l	200
Guaymuras	Coliformes Totales	9222-B	3	UFC/100 ml	0
Guaymuras	Coliformes Fecales	9222-D	0	UFC/100 ml	0
Metals					
Guaymuras	Antimony	6010B	0.0149	mg/l	0.005
Guaymuras	Arsenic	6010B	< 0.005	mg/l	0.01
Guaymuras	Cadmium	6010B	< 0.005	mg/l	0.003
Guaymuras	Chromium	6010B	< 0.01	mg/l	0.05
Guaymuras	Lead	6010B	< 0.005	mg/l	0.01
Guaymuras	Nickel	6010B	0.0323	mg/l	0.02
Guaymuras	Silver	6010B	< 0.01	mg/l	-
Guaymuras	Zinc	6010B	0.105	mg/l	3
Guaymuras	Mercury	7470A	< 0.0002	mg/l	0.001

Table B-8. Analytical Results
(Page 2 of 5)

Water Quality	Analytical Constituent	Analytical Method	Result	Unit	WHO Guideline (health based)
Water Quality					
Oro Verde	Acidez Total	2310-B	33	mg/l	-
Oro Verde	Alcalinidad Total	2320-B	353	mg/lCaCO3	-
Oro Verde	Bicarbonato (HCO3)	2320-B	353	mg/l	-
Oro Verde	Dureza Total	2340-C	308	mg/lCaCO3	-
Oro Verde	Conductividad	25100-B	528	us/cm	-
Oro Verde	Calcio	3500-Ca D	70	mg/lCaCO3	-
Oro Verde	Hierro Total	3500-Fe-D	< 0.03	mg/l	0.3
Oro Verde	Magnesio	3500-Mg E	32	mg/lCaCO3	50
Oro Verde	Manganeso Total	3500-Mn C	2.23	mg/l	0.5
Oro Verde	Cloruros	4500-Cl-B	29	mg/l	250
Oro Verde	Nitritos	4500-NO2-B	< 0.01	mg/l	1
Oro Verde	Nitratos	4500-NO3-B	0.08	mg/l	50
Oro Verde	Sulfatos	4500-SO4	55	mg/l	250
Oro Verde	Sodio (Na)	AA	45.1	mg/L	200
Oro Verde	Potasio (K)	AA	5.32	mg/L	10
Oro Verde	Coliformes Totales	9222-B	9	UFC/100ml	0
Oro Verde	Coliformes Fecales	9222-D	0	UFC/100ml	0
Metals					
Oro Verde	Antimony	6010B	0.0258	mg/l	0.005
Oro Verde	Arsenic	6010B	< 0.005	mg/l	0.01
Oro Verde	Cadmium	6010B	< 0.005	mg/l	0.003
Oro Verde	Chromium	6010B	< 0.01	mg/l	0.05
Oro Verde	Lead	6010B	< 0.005	mg/l	0.01
Oro Verde	Nickel	6010B	< 0.02	mg/l	0.02
Oro Verde	Selenium	6010B	< 0.005	mg/l	0.01
Oro Verde	Silver	6010B	< 0.01	mg/l	-
Oro Verde	Zinc	6010B	< 0.02	mg/l	3
Oro Verde	Mercury	7470A	< 0.0002	mg/l	0.001
Water Quality					
Cruz Roja	Acidez Total	2310-B	18	mg/l	-
Cruz Roja	Alcalinidad Total	2320-B	201	mg/lCaCO3	-
Cruz Roja	Bicarbonato (HCO3)	2320-B	201	mg/l	-
Cruz Roja	Dureza Total	2340-C	160	mg/lCaCO3	-
Cruz Roja	Conductividad	25100-B	44	us/cm	-
Cruz Roja	Calcio	3500-Ca D	44	mg/lCaCO3	-
Cruz Roja	Hierro Total	3500-Fe-D	0.02	mg/l	0.3
Cruz Roja	Magnesio	3500-Mg E	12	mg/lCaCO3	50
Cruz Roja	Manganeso Total	3500-Mn C	0.4	mg/l	0.5
Cruz Roja	Cloruros	4500-Cl-B	23	mg/l	250
Cruz Roja	Nitritos	4500-NO2-B	< 0.01	mg/l	1
Cruz Roja	Nitratos	4500-NO3-B	0.06	mg/l	50
Cruz Roja	Sulfatos	4500-SO4	88	mg/l	250
Cruz Roja	Potasio (K)	AA	3.42	mg/l	10
Cruz Roja	Sodio (Na)	AA	71.9	mg/l	200
Cruz Roja	Coliformes Totales	9222-B	26	UFC/100ml	0
Cruz Roja	Coliformes Fecales	9222-D	5	UFC/100ml	0
Metals					
Cruz Roja	Antimony	6010B	< 0.005	mg/l	0.005
Cruz Roja	Arsenic	6010B	0.01	mg/l	0.01
Cruz Roja	Cadmium	6010B	< 0.005	mg/l	0.003
Cruz Roja	Chromium	6010B	< 0.01	mg/l	0.05
Cruz Roja	Lead	6010B	< 0.005	mg/l	0.01
Cruz Roja	Nickel	6010B	< 0.02	mg/l	0.02
Cruz Roja	Selenium	6010B	< 0.005	mg/l	0.01
Cruz Roja	Silver	6010B	< 0.01	mg/l	-
Cruz Roja	Zinc	6010B	< 0.02	mg/l	3
Cruz Roja	Mercury	7470A	< 0.0002	mg/l	0.001

Table B-8. Analytical Results

Water Quality	Analytical Constituent	Analytical Method	Result	Unit	WHO Guideline (health based)
Water Quality					
Col. Martinez Rivera	Acidez Total	2310-B	18	mg/l	-
Col. Martinez Rivera	Alcalinidad Total	2320-B	247	mg/l CaCO3	-
Col. Martinez Rivera	Bicarbonato (HCO3)	2320-B	247	mg/l	-
Col. Martinez Rivera	Dureza Total	2340-C	180	mg/l CaCO3	-
Col. Martinez Rivera	Conductividad	25100-B	539	us/cm	-
Col. Martinez Rivera	Calcio	3500-Ca D	14	mg/l CaCO3	-
Col. Martinez Rivera	Hierro Total	3500-Fe-D	0.71	mg/l	0.3
Col. Martinez Rivera	Magnesio	3500-Mg E	49	mg/l CaCO3	50
Col. Martinez Rivera	Manganeso Total	3500-Mn C	0.2	mg/l	0.5
Col. Martinez Rivera	Cloruros	4500-Cl-B	24	mg/l	250
Col. Martinez Rivera	Nitritos	4500-NO2-B	< 0.01	mg/l	1
Col. Martinez Rivera	Nitratos	4500-NO3-B	0.41	mg/l	50
Col. Martinez Rivera	Sulfatos	4500-SO4	79	mg/l	250
Col. Martinez Rivera	Potasio (K)	AA	2.98	mg/l	10
Col. Martinez Rivera	Sodio (Na)	AA	49.9	mg/l	200
Col. Martinez Rivera	Coliformes Totales	9222-B	67	UFC/100 ml	0
Col. Martinez Rivera	Coliformes Fecales	9222-D	0	UFC/100 ml	0
Metals					
Cuidad Planeta 1	Antimony	6010B	< 0.005	mg/l	0.005
Cuidad Planeta 1	Arsenic	6010B	< 0.005	mg/l	0.01
Cuidad Planeta 1	Cadmium	6010B	< 0.005	mg/l	0.003
Cuidad Planeta 1	Chromium	6010B	< 0.01	mg/l	0.05
Cuidad Planeta 1	Lead	6010B	< 0.005	mg/l	0.01
Cuidad Planeta 1	Nickel	6010B	< 0.02	mg/l	0.02
Cuidad Planeta 1	Selenium	6010B	< 0.005	mg/l	0.01
Cuidad Planeta 1	Silver	6010B	< 0.01	mg/l	-
Cuidad Planeta 1	Zinc	6010B	< 0.02	mg/l	3
Cuidad Planeta 1	Mercury	7470A	< 0.002	mg/l	0.001
Water Quality					
Cuidad Planeta 1	Acidez Total	2310-B	28	mg/l	-
Cuidad Planeta 1	Alcalinidad Total	2320-B	174	mg/l CaCO3	-
Cuidad Planeta 1	Bicarbonato (HCO3)	2320-B	174	mg/l	-
Cuidad Planeta 1	Dureza Total	2340-C	200	mg/l CaCO3	-
Cuidad Planeta 1	Conductividad	25100-B	477	us/cm	-
Cuidad Planeta 1	Calcio	3500-Ca D	40	mg/l CaCO3	-
Cuidad Planeta 1	Hierro Total	3500-Fe-D	0.05	mg/l	0.3
Cuidad Planeta 1	Magnesio	3500-Mg E	24	mg/l CaCO3	50
Cuidad Planeta 1	Manganeso Total	3500-Mn C	0.1	mg/l	0.5
Cuidad Planeta 1	Cloruros	4500-Cl-B	45	mg/l	250
Cuidad Planeta 1	Nitritos	4500-NO2-B	0.15	mg/l	1
Cuidad Planeta 1	Nitratos	4500-NO3-B	1.35	mg/l	50
Cuidad Planeta 1	Sulfatos	4500-SO4	54	mg/l	250
Cuidad Planeta 1	Sodio (Na)	AA	48.4	mg/l	200
Cuidad Planeta 1	Coliformes Totales	9222-B	30	UFC/100 ml	0
Cuidad Planeta 1	Coliformes Fecales	9222-D	0	UFC/100 ml	0
Metals					
Cuidad Planeta 1	Antimony	6010B	< 0.005	mg/l	0.005
Cuidad Planeta 1	Arsenic	6010B	< 0.005	mg/l	0.01
Cuidad Planeta 1	Cadmium	6010B	< 0.005	mg/l	0.003
Cuidad Planeta 1	Chromium	6010B	< 0.01	mg/l	0.05
Cuidad Planeta 1	Lead	6010B	< 0.005	mg/l	0.01
Cuidad Planeta 1	Nickel	6010B	< 0.02	mg/l	0.02
Cuidad Planeta 1	Selenium	6010B	< 0.005	mg/l	0.01
Cuidad Planeta 1	Silver	6010B	< 0.01	mg/l	
Cuidad Planeta 1	Zinc	6010B	< 0.02	mg/l	3
Cuidad Planeta 1	Mercury	7470A	< 0.002	mg/l	0.001

Table B-8. Analytical Results

Water Quality	Analytical Constituent	Analytical Method	Result	Unit	WHO Guideline (health based)
Water Quality					
22 de Mayo	Acidez Total	2310-B	22	mg/l	-
22 de Mayo	Alcalinidad Total	2320-B	274	mg/lCaCO3	-
22 de Mayo	Bicarbonato (HCO3)	2320-B	274	mg/l	-
22 de Mayo	Dureza Total	2340-C	276	mg/lCaCO3	-
22 de Mayo	Conductividad	25100-B	678	us/cm	-
22 de Mayo	Calcio	3500-Ca D	23	mg/lCaCO3	-
22 de Mayo	Hierro Total	3500-Fe-D	0.33	mg/l	0.3
22 de Mayo	Magnesio	3500-Mg E	72	mg/lCaCO3	50
22 de Mayo	Manganeso Total	3500-Mn C	1.9	mg/l	0.5
22 de Mayo	Cloruros	4500-Cl-B	78	mg/l	250
22 de Mayo	Nitritos	4500-NO2-B	0.01	mg/l	1
22 de Mayo	Nitratos	4500-NO3-B	0.41	mg/l	50
22 de Mayo	Sulfatos	4500-SO4	83	mg/l	250
22 de Mayo	Potasio (K)	AA	1.82	mg/l	10
22 de Mayo	Sodio (Na)	AA	47.3	mg/l	200
22 de Mayo	Coliformes Totales	9222-B	40	UFC/100ml	0
22 de Mayo	Coliformes Fecales	9222-D	0	UFC/100ml	0
Metals					
22 de Mayo	Antimony	6010B	0.0206	mg/l	0.005
22 de Mayo	Arsenic	6010B	0.0121	mg/l	0.01
22 de Mayo	Cadmium	6010B	< 0.005	mg/l	0.003
22 de Mayo	Chromium	6010B	< 0.01	mg/l	0.05
22 de Mayo	Lead	6010B	< 0.005	mg/l	0.01
22 de Mayo	Nickel	6010B	< 0.02	mg/l	0.02
22 de Mayo	Selenium	6010B	< 0.005	mg/l	0.01
22 de Mayo	Silver	6010B	< 0.01	mg/l	-
22 de Mayo	Zinc	6010B	< 0.02	mg/l	3
22 de Mayo	Mercury	7470A	< 0.0002	mg/l	0.001
Water Quality					
BCLL-1	Acidez Total	2310-B	52	mg/l	-
BCLL-1	Alcalinidad Total	2320-B	277	mg/lCaCO3	-
BCLL-1	Bicarbonato (HCO3)	2320-B	277	mg/l	-
BCLL-1	Dureza Total	2340-C	120	mg/lCaCO3	-
BCLL-1	Average Field Conductivity		928	us/cm	-
BCLL-1	Calcio	3500-Ca D	31	mg/lCaCO3	-
BCLL-1	Fosfatos	4500-P C	< 0.01		-
BCLL-1	Hierro Total	3500-Fe-D	< 0.03	mg/l	0.3
BCLL-1	Magnesio	3500-Mg E	10	mg/lCaCO3	50
BCLL-1	Manganeso Total	3500-Mn C	<0.03	mg/l	0.5
BCLL-1	Cloruros	4500-Cl-B	51	mg/l	250
BCLL-1	Nitritos	4500-NO2-B	< 0.01	mg/l	1
BCLL-1	Nitratos	4500-NO3-B	< 0.01	mg/l	50
BCLL-1	Sulfatos	4500-SO4	53	mg/l	250
BCLL-1	Potasio (K)	AA	4.1	mg/L	10
BCLL-1	Sodio (Na)	AA	114	mg/L	200
BCLL-1	Coliformes Totales	9222-B	2	UFC/100ml	0
BCLL-1	Coliformes Fecales	9222-D	1	UFC/100ml	0
Metals					
BCLL-1	Antimony	6010B	< 0.005	mg/l	0.005
BCLL-1	Arsenic	6010B	< 0.005	mg/l	0.01
BCLL-1	Cadmium	6010B	< 0.005	mg/l	0.003
BCLL-1	Chromium	6010B	< 0.01	mg/l	0.05
BCLL-1	Lead	6010B	< 0.005	mg/l	0.01
BCLL-1	Nickel	6010B	< 0.02	mg/l	0.02
BCLL-1	Selenium	6010B	< 0.005	mg/l	0.01
BCLL-1	Silver	6010B	< 0.01	mg/l	-
BCLL-1	Zinc	6010B	< 0.02	mg/l	3
BCLL-1	Mercury	7470A	< 0.0002	mg/l	0.001

Table B-8. Analytical Results
(Page 5 of 5)

Water Quality	Analytical Constituent	Analytical Method	Result	Unit	WHO Guideline (health based)
Radionucleotides					
BCLL-1	Alpha		1.4	pCi/l	5
BCLL-1	Beta		2.8	pCi/l	50
Water Quality					
BCLL-2	Acidez Total	2310-B	150	mg/l	-
BCLL-2	Alcalinidad Total	2320-B	152	mg/l CaCO3	-
BCLL-2	Bicarbonato (HCO3)	2320-B	152	mg/l	-
BCLL-2	Dureza Total	2340-C	68	mg/l CaCO3	-
BCLL-2	Conductividad	25100-B	430	us/cm	-
BCLL-2	Calcio	3500-Ca D	15	mg/l CaCO3	-
BCLL-2	Hierro Total	3500-Fe-D	0.35	mg/l	0.3
BCLL-2	Magnesio	3500-Mg E	9	mg/l CaCO3	50
BCLL-2	Manganeso Total	3500-Mn C	< 0.03	mg/l	0.5
BCLL-2	Cloruros	4500-Cl-B	23	mg/l	250
BCLL-2	Nitritos	4500-NO2-B	< 0.01	mg/l	1
BCLL-2	Nitratos	4500-NO3-B	0.11	mg/l	50
BCLL-2	Sulfatos	4500-SO4	32	mg/l	250
BCLL-2	Potasio (K)	AA	4.29	mg/l	10
BCLL-2	Sodio (Na)	AA	61.15	mg/l	200
BCLL-2	Coliformes Totales	9222-B	84	UFC/100 ml	0
BCLL-2	Coliformes Fecales	9222-D	22	UFC/100 ml	0
Metals					
BCLL-2	Antimony	6010B	< 0.005	mg/l	0.005
BCLL-2	Arsenic	6010B	< 0.005	mg/l	0.01
BCLL-2	Cadmium	6010B	< 0.005	mg/l	0.003
BCLL-2	Chromium	6010B	< 0.01	mg/l	0.05
BCLL-2	Lead	6010B	< 0.005	mg/l	0.01
BCLL-2	Nickel	6010B	< 0.02	mg/l	0.02
BCLL-2	Selenium	6010B	< 0.005	mg/l	0.01
BCLL-2	Silver	6010B	< 0.01	mg/l	-
BCLL-2	Zinc	6010B	0.02	mg/l	3
BCLL-2	Mercury	7470A	< 0.0002	mg/l	0.001
Radionucleotides					
BCLL-2	Alpha		2	pCi/l	5
BCLL-2	Beta		5.2	pCi/l	50
Water Quality					
BCLL-3	Acidez Total	2310-B	19	mg/l	-
BCLL-3	Alcalinidad Total	2320-B	150	mg/l CaCO3	-
BCLL-3	Bicarbonato (HCO3)	2320-B	150	mg/l	-
BCLL-3	Dureza Total	2340-C	96	mg/l CaCO3	-
BCLL-3	Conductividad	25100-B	396	us/cm	-
BCLL-3	Calcio	3500-Ca D	27	mg/l CaCO3	-
BCLL-3	Hierro Total	3500-Fe-D	< 0.03	mg/l	0.3
BCLL-3	Magnesio	3500-Mg E	7	mg/l CaCO3	50
BCLL-3	Manganeso Total	3500-Mn C	< 0.03	mg/l	0.5
BCLL-3	Cloruros	4500-Cl-B	8.5	mg/l	25
BCLL-3	Nitritos	4500-NO2-B	< 0.01	mg/l	1
BCLL-3	Nitratos	4500-NO3-B	0.53	mg/l	50
BCLL-3	Sulfatos	4500-SO4	20.8	mg/l	250
BCLL-3	Potasio (K)	AA	2.94	mg/l	10
BCLL-3	Sodio (Na)	AA	42.25	mg/l	200
BCLL-3	Coliformes Totales	9222-B	4	UFC/100 ml	0
BCLL-3	Coliformes Fecales	9222-D	0	UFC/100 ml	0
Metals					
BCLL-3	Antimony	6010B	< 0.005	mg/l	0.005
BCLL-3	Arsenic	6010B	< 0.005	mg/l	0.01
BCLL-3	Cadmium	6010B	< 0.005	mg/l	0.003
BCLL-3	Chromium	6010B	< 0.01	mg/l	0.05
BCLL-3	Lead	6010B	< 0.005	mg/l	0.01
BCLL-3	Nickel	6010B	< 0.02	mg/l	0.02
BCLL-3	Selenium	6010B	< 0.005	mg/l	0.01
BCLL-3	Silver	6010B	< 0.01	mg/l	-
BCLL-3	Zinc	6010B	< 0.02	mg/l	3
BCLL-3	Mercury	7470A	< 0.0002	mg/l	0.001

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID 22MAYO112001 **Collected:** 11/15/01 2:46:00 **SPL Sample ID:** 01110913-01

Site: La Lima-Villanueva

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		12/05/01 11:10	R_T	937611

Prep Method	Prep Date	Prep Initials
SW7470A	12/05/2001 9:00	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	0.0206	0.005		1		12/06/01 2:22	NS	938719
Arsenic	0.0121	0.005		1		12/06/01 2:22	NS	938719
Lead	ND	0.005		1		12/06/01 2:22	NS	938719
Selenium	ND	0.005		1		12/06/01 2:22	NS	938719
Cadmium	ND	0.005		1		12/07/01 21:25	EG	940227
Chromium	ND	0.01		1		12/07/01 21:25	EG	940227
Nickel	ND	0.02		1		12/07/01 21:25	EG	940227
Silver	ND	0.01		1		12/07/01 21:25	EG	940227
Zinc	ND	0.02		1		12/07/01 21:25	EG	940227

Prep Method	Prep Date	Prep Initials
SW3005A	11/25/2001 11:00	MW

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable, Residual o Industrial Ambientales de Trabajo, Alimentos

6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrich
Fecha de Ingreso: 15/11/01, Hora: 3:15
Lugar Toma de Muestras: La Lima

	Norma Nacional			Fecha	15/11/2001	15/11/2001
				Hora	14:46	12:56
				Muestra	22 de Mayo	Martinez Rivera
Parametros	**Unidades**	**Recomen.**	**Max. Adm.**	**Metodo &**	**1248**	**1249**
Acidez Total	mg/l			2310-B	22	18
Conductividad	us/cm	400		25100-B	678	539
Alcalinidad Total	mg/l CaCO3			2320-B	274	247
Dureza Total	mg/l CaCO3	400		2340-C	276	180
Bicarbonato (HCO3)	mg/l			2320-B	274	247
Calcio	mg/l CaCO3	100		3500-Ca-D	23	14
Magnesio	mg/l CaCO3	30	50	3500-Mg E	72	49
Hierro Total	mg/l		0.3	3500-Fe D	0.33	0.71
Hierro Filtrado	mg/l			3500-Fe D	0.29	0.41
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	1.9	0.2
Manganeso Filtrado	mg/l			3500-Mn C	1.8	0.2
Cloruros	mg/l	25	250	4500-Cl-B	78	24
Sulfatos	mg/l	25	250	4500-SO4	83	79
Nitritos	mg/l		1	4500-NO2-B	0.01	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	0.41	0.41
Sodio (Na)*	mg/l	25	200	AA	47.30	49.90
Potasio (K)*	mg/l		10	AA	1.82	2.98
ANALISIS MICROBIOLOGICOS						
Coliformes Totales		UFC/100ml	0	9222-B	40	67
Coliformes Fecales		UFC/100ml	0	9222-D	0	0

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL
LIC. LILIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 21 de Noviembre del 2,001

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-LL-1 **Collected:** 10/5/01 2:45:00 **SPL Sample ID:** 01100511-01

Site: **La Lima, Honduras**

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED		**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002	1		10/23/01 11:26	R_T	875243

Prep Method	Prep Date	Prep Initials
SW7470A	10/23/2001 9:30	R_T

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED		**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005	1		10/23/01 21:32	NS	875085
Arsenic	ND	0.005	1		10/23/01 21:32	NS	875085
Lead	ND	0.005	1		10/23/01 21:32	NS	875085
Selenium	ND	0.005	1		10/23/01 21:32	NS	875085
Cadmium	ND	0.005	1		10/21/01 19:03	EG	873529
Chromium	ND	0.01	1		10/21/01 19:03	EG	873529
Nickel	ND	0.02	1		10/21/01 19:03	EG	873529
Silver	ND	0.01	1		10/21/01 19:03	EG	873529
Zinc	ND	0.02	1		10/21/01 19:03	EG	873529

Prep Method	Prep Date	Prep Initials
SW3005	10/12/2001 8:00	MW

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

ACCULABS INC. GOLDEN, CO
RADIOCHEMISTRY DATA PACKAGE
SAMPLE RESULTS SUMMARY
FORM 1

Client: SPL, Inc.
Proj. Name:
Proj. Number:

Acculabs Work Order: G01100276
Received Date: 10/16/2001

Field Sample ID	Acculabs ID	Test	Matrix	Analyte	Result +/-CSU	MDC	Report Units	Report Basis	Qual Flag	Date Analyzed	Batch Id
01100511-1B	G01100276-01A	Gross Alpha/Beta	Aqueous	Alpha	1.4 +/- 3.5	8.4	pCi/L	total	U	11/01/2001	GP00119
01100511-1B	G01100276-01A	Gross Alpha/Beta	Aqueous	Beta	2.8 +/- 2.3	4.9	pCi/L	total	U	11/01/2001	GP00119

Comments:

Footnotes and Abbreviations:

MDC - Minimum Detectable Concentration (ANSI N42.23)
CSU - Combined Standard Uncertainty (TPU)

Lab Qualifiers:

U = Result < MDC or CSU
J = Estimated result - see narrative for discussion
B = analyte detected in Blank > MDC
JI = Estimated result, bias high due to interference
M = Requested MDC not met - see narrative for discussion

Y = Yield outside default limits
H = High
L = Low
* = DER outside 2 sigma limits

Queried: 11/15/2001 09:20:25 AM
Printed: 11/15/2001 09:20:25 AM

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable, Residual e Industrial Ambientes de Trabajo, Alimentos

6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por:Ing. Barbara Goodrich BC-LL-1
Muestra # 1100, ~~BC-LV-1~~, Agua de Pozo
Fecha de Ingreso: 5/10/01

	Norma Nacional				
Parametros	Unidades	Recomendado	Máx. Admisib	Método &	Resultados
Acidez Total	mg/l --			2310-B	52
Alcalinidad Total	mg/l CaCO3			2320-B	277
Dureza Total	mg/l CaCO3	400		2340-C	120
Bicarbonato (HCO3)	mg/l			2320-B	277
Calcio	mg/l CaCO3	100		3500-Ca D	31
Magnesio	mg/l CaCO3	30	50	3500-Mg E	10
Hierro Total	mg/l		0.3	3500-Fe-D	<0.03
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	<0.03
Fosfatos	mg/l			4500-P C.	<0.01
Cloruros	mg/l	25	250	4500-Cl-B	51
Sulfatos	mg/l	25	250	4500-SO4	53
Nitritos	mg/l		1	4500-NO2-B	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	<0.01
Sodio (Na)*	mg/1	25	200	AA	114
Potasio (K)*	mg/l		10	AA	4.10
ANALISIS MICROBIOLOGICOS					
Coliformes Totales			0 UFC/100 r	9222-B	2
Coliformes Fecales			0 UFC/100 r	9222-D	1

Norma Nacional: Decreto No.084 del 31de Julio de 1995

& Basados en Standard Methods for the Examination of Water and Wastewater 20 Edition.

Subcontratado

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. LILIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 10 de Octubre del 2,001

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-LL-2 **Collected:** 12/13/01 11:55:0 **SPL Sample ID:** 01120795-01

Site: **Gracias a Dios, La Lima, Honduras**

Analyses/Method	Result	Rep.Limit	*	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		12/21/01 16:34	R_T	960919

Prep Method	Prep Date	Prep Initials
SW7470A	12/21/2001 9:15	R_T

Analyses/Method	Result	Rep.Limit	*	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		12/24/01 13:53	NS	961985
Arsenic	ND	0.005		1		12/24/01 13:53	NS	961985
Lead	ND	0.005		1		12/24/01 13:53	NS	961985
Selenium	ND	0.005		1		12/24/01 13:53	NS	961985
Cadmium	ND	0.005		1		12/21/01 17:19	EG	960606
Chromium	ND	0.01		1		12/21/01 17:19	EG	960606
Nickel	ND	0.02		1		12/21/01 17:19	EG	960606
Silver	ND	0.01		1		12/21/01 17:19	EG	960606
Zinc	0.174	0.02		1		12/21/01 17:19	EG	960606

Prep Method	Prep Date	Prep Initials
SW3005A	12/20/2001 21:00	MME

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

ACCULABS INC. GOLDEN, CO
RADIOCHEMISTRY DATA PACKAGE
SAMPLE RESULTS SUMMARY
FORM 1

Client: SPL, Inc.
Proj. Name: H9-3550
Proj. Number:

Acculabs Work Order: G01120365
Received Date: 12/27/2001

Field Sample ID	Acculabs ID	Test	Matrix	Analyte	Result +/- 2 s CSU	MDC	Report Units	Report Basis	Qual Flag	Date Analyzed	Batch Id
01120795-1B	G01120365-01A	Gross Alpha/Beta	Aqueous	Alpha	2.0 +/- 2.2	4.1	pCi/L	total	U	01/17/2002	GP00229
01120795-1B	G01120365-01A	Gross Alpha/Beta	Aqueous	Beta	5.2 +/- 2.1	3.4	pCi/L	total		01/17/2002	GP00229

Comments:

Footnotes and Abbreviations:

MDC - Minimum Detectable Concentration (ANSI N42.23)
CSU - Combined Standard Uncertainty (TPU)

Lab Qualifiers:

U = Result < MDC or CSU
J = Estimated result - see narrative for discussion
B = analyte detected in Blank > MDC
JI = Estimated result, bias high due to interference
M = Requested MDC not met - see narrative for discussion

Y = Yield outside default limits
H = High
L = Low
* = DER outside 2 sigma limits

Queried: 01/22/2002 03:52:31 PM
Printed: 01/22/2002 03:52:31 PM

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable, Residual e Industrial Ambientes de Trabajo Alimentos

6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrich
Fecha de Ingreso: 13/12/01
Lugar Toma de Muestras: Col. Gracias a Dios, La Lima → BC-LL-2

		Norma Nacional			
				Fecha	**13/12/2001**
				Hora	**11:55am**
Parametros	**Unidades**	**Recomen.**	**Max. Adm.**	**Metodo &**	**1321**
Acidez Total	-- mg/l			2310-B	150
Conductividad	us/cm	400		25100-B	430
Alcalinidad Total	mg/l CaCO3			2320-B	152
Dureza Total	mg/l CaCO3	400		2340-C	68
Bicarbonato (HCO3)	mg/l			2320-B	152
Calcio	mg/l CaCO3	100		3500-Ca-D	15
Magnesio	mg/l CaCO3	30	50	3500-Mg E	9
Hierro Total	mg/l		0.3	3500-Fe D	0.35
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	<0.03
Cloruros	mg/l	25	250	4500-Cl-B	23
Sulfatos	mg/l	25	250	4500-SO4	32
Nitritos	mg/l		1	4500-NO2-B	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	0.11
Sodio (Na)*	mg/l	25	200	AA	61.15
Potasio (K)*	mg/l		10	AA	4.29
ANALISIS MICROBIOLOGICOS					
Coliformes Totales	UFC/100ml	0		9222-B	84
Coliformes Fecales	UFC/100ml	0		9222-D	22

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. LILIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 19 de Diciembre del 2,001

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-LL-3 **Collected:** 11/9/01 **SPL Sample ID:** 01110644-09

Site: **USAID Groundwater 21365**

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		11/28/01 12:59	R_T	932137

Prep Method	Prep Date	Prep Initials
SW7470A	11/28/2001 8:45	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		11/27/01 6:02	NS	927035
Arsenic	ND	0.005		1		11/27/01 6:02	NS	927035
Lead	ND	0.005		1		11/27/01 6:02	NS	927035
Selenium	ND	0.005		1		11/27/01 6:02	NS	927035
Cadmium	ND	0.005		1		11/25/01 15:48	EG	925323
Chromium	ND	0.01		1		11/25/01 15:48	EG	925323
Nickel	ND	0.02		1		11/25/01 15:48	EG	925323
Silver	ND	0.01		1		11/25/01 15:48	EG	925323
Zinc	ND	0.02		1		11/25/01 15:48	EG	925323

Prep Method	Prep Date	Prep Initials
SW3005	11/16/2001 14:30	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable, Residual e Industrial Ambientes de Trabajo Alimentos

6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrich
Fecha de Ingreso: 9/11/01
Lugar Toma de Muestras: Chotepe, La Lima.

		Norma Nacional			
				Fecha	09/11/2001
				Hora	12:10
				Muestra	BC-LL-3
Parametros	**Unidades**	**Recomen.**	**Max. Adm.**	**Metodo &**	**1230**
Acidez Total	mg/l			2310-B	19
Conductividad	us/cm	400		25100-B	396
Alcalinidad Total	mg/l CaCO3			2320-B	150
Dureza Total	mg/l CaCO3	400		2340-C	96
Bicarbonato (HCO3)	mg/l			2320-B	150
Calcio	mg/l CaCO3	100		3500-Ca-D	27
Magnesio	mg/l CaCO3	30	50	3500-Mg E	7
Hierro Total	mg/l		0.3	3500-Fe D	<0.03
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	<0.03
Cloruros	mg/l	25	250	4500-Cl-B	8.5
Sulfatos	mg/l	25	250	4500-SO4	20.8
Nitritos	mg/l		1	4500-NO2-B	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	0.53
Sodio (Na)*	mg/l	25	200	AA	42.25
Potasio (K)*	mg/l		10	AA	2.94
ANALISIS MICROBIOLOGICOS					
Coliformes Totales	UFC/100ml		0	9222-B	4
Coliformes Fecales	UFC/100ml		0	9222-D	0

San Pedro Sula, 21de Noviembre del 2,001

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. LINA J. DE RIVERA
JORDANLAB

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Cruz Roja 112001 **Collected:** 11/19/01 11:38:0 **SPL Sample ID:** 01110913-07

Site: La Lima-Villanueva

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		12/05/01 11:10	R_T	937621

Prep Method	Prep Date	Prep Initials
SW7470A	12/05/2001 9:00	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		12/06/01 3:35	NS	938735
Arsenic	0.01	0.005		1		12/06/01 3:35	NS	938735
Lead	ND	0.005		1		12/06/01 3:35	NS	938735
Selenium	ND	0.005		1		12/06/01 3:35	NS	938735
Cadmium	ND	0.005		1		12/07/01 22:32	EG	940238
Chromium	ND	0.01		1		12/07/01 22:32	EG	940238
Nickel	ND	0.02		1		12/07/01 22:32	EG	940238
Silver	ND	0.01		1		12/07/01 22:32	EG	940238
Zinc	ND	0.02		1		12/07/01 22:32	EG	940238

Prep Method	Prep Date	Prep Initials
SW3005A	11/25/2001 11:00	MW

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL

>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable, Residual e Industrial Ambiental de Trabajo, Alimentos

6 Ave. 5-6 Calle S.O. plaaza Victoria, Local # 4, Bo. El Benque, San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, 227-2753 Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrich
Fecha de Ingreso: 19/11/01
Lugar Toma de Muestras: La Lima

	Norma Nacional			Fecha	19/11/2001	19/11/2001	19/11/2001
				Hora	10:10	11:38	10:55
				Muestra	Oro Verde	Cruz Roja	Villa Esther
Parametros	**Unidades**	**Recomen.**	**Max. Adm**	**Metodo &**	**1252**	**1253**	**1254**
Acidez Total	mg/l			2310-B	33	18	34
Conductividad	us/cm	400		25100-B	528	44	575
Alcalinidad Total	mg/l CaCO3			2320-B	353	201	337
Dureza Total	mg/l CaCO3	400		2340-C	308	160	236
Bicarbonato (HCO3)	mg/l			2320-B	353	201	337
Calcio (Ca)	mg/l CaCO3	100		3500-Ca-D	70	44	59
Magnesio (Mg)	mg/l CaCO3	30	50	3500-Mg E	32	12	21
Hierro Total	mg/l		0.3	3500-Fe D	<0.03	0.02	0.09
Hierro Filtrado	mg/l			3500-Fe D	<0.03	<0.03	0.05
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	2.23	0.4	0.4
Manganeso Filtrado	mg/l			3500-Mn C	1.7	0.3	0.3
Cloruro (Cl^-)	mg/l	25	250	4500-Cl-B	29	23	57
Sulfatos (SO4)	mg/l	25	250	4500-SO4	55	88	74
Nitritos (NO2)	mg/l		1	4500-NO2-B	<0.01	<0.01	<0.01
Nitratos (NO3)	mg/l	25	50	4500-NO3-B	0.08	0.06	0.05
Sodio (Na)*	mg/l	25	200	AA	45.10	71.9	110.1
Potasio (K)*	mg/l		10	AA	5.32	3.42	3.78
ANALISIS MICROBIOLOGICOS							
Coliformes Totales		UFC/100ml	0	9222-B	9	26	32
Coliformes Fecales		UFC/100ml	0	9222-D	0	5	10

San Pedro Sula, 21 de Noviembre del 2,001

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. LIDIA J. DE RIVERA
JORDANLAB

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Fusep Planeto 112001 **Collected:** 11/15/01 10:29:0 **SPL Sample ID:** 01110913-03

Site: La Lima-Villanueva

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED		**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002	1		12/05/01 11:10	R_T	937615

Prep Method	Prep Date	Prep Initials
SW7470A	12/05/2001 9:00	R_T

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED		**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005	1		12/06/01 2:54	NS	938727
Arsenic	ND	0.005	1		12/06/01 11:45	NS	938768
Lead	ND	0.005	1		12/06/01 2:54	NS	938727
Selenium	ND	0.005	1		12/06/01 2:54	NS	938727
Cadmium	ND	0.005	1		12/07/01 21:56	EG	940232
Chromium	ND	0.01	1		12/07/01 21:56	EG	940232
Nickel	ND	0.02	1		12/07/01 21:56	EG	940232
Silver	ND	0.01	1		12/07/01 21:56	EG	940232
Zinc	ND	0.02	1		12/07/01 21:56	EG	940232

Prep Method	Prep Date	Prep Initials
SW3005A	11/25/2001 11:00	MW

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable, Residual e Industrial Ambientes de Trabajo Alimentos

6 Ave. 5-6 Calle S.O. San Pedro Sula, Cortés
R. T. N. X4RRMA-U TELFAX: 557-5802, Email: jordanlab@hn2.com

BROWN AND CALDWELL

Solicitado por: Ing. Barbara Goodrich
Fecha de Ingreso: 15/11/01
Lugar Toma de Muestras: La Lima

	Norma Nacional			Fecha	15/11/2001	15/11/2001	15/11/2001
				Hora	10:29	09:51	11:00
				Muestra	Fusep	Guaymuras	Rapidito
Parametros	Unidades	Recomen.	Max. Adm.	Metodo &	1245	1246	1247
Acidez Total	mg/l			2310-B	28	83	35
Conductividad	us/cm	400		25100-B	477	48	479
Alcalinidad Total	mg/l CaCO3			2320-B	174	104	187
Dureza Total	mg/l CaCO3	400		2340-C	200	228	280
Bicarbonato (HCO3)	mg/l			2320-B	174	104	187
Calcio (Ca)	mg/l CaCO3	100		3500-Ca-D	40	35.2	43
Magnesio (Mg)	mg/l CaCO3	30	50	3500-Mg E	24	34	41
Hierro Total	mg/l		0.3	3500-Fe D	0.05	1.86	<0.03
Hierro Filtrado	mg/l			3500-Fe D	<0.03	1.43	<0.01
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	0.15	1.12	0.30
Manganeso Filtrado	mg/l			3500-Mn C	0.1	0.95	0.15
Cloruro (Cl⁻)	mg/l	25	250	4500-Cl-B	45	41	65
Sulfatos (SO4)	mg/l	25	250	4500-SO4	54	185	92
Nitritos (NO2)	mg/l		1	4500-NO2-B	<0.01	0.03	<0.01
Nitratos (NO3)	mg/l	25	50	4500-NO3-B	1.35	0.34	1.38
Sodio (Na)*	mg/l	25	200	AA	48.40	54.70	44.80
Potasio (K)*	mg/l		10	AA	1.80	6.35	1.80
ANALISIS MICROBIOLOGICOS							
Coliformes Totales		UFC/100ml	0	9222-B	30	3	23
Coliformes Fecales		UFC/100ml	0	9222-D	0	0	0

San Pedro Sula, 21 de Noviembre del 2,001

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. LILIA J. DE RIVERA
JORDANLAB

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Guaymoros 112001 **Collected:** 11/15/01 9:51:00 **SPL Sample ID:** 01110913-05

Site: La Lima-Villanueva

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		12/05/01 11:10	R_T	937619

Prep Method	Prep Date	Prep Initials
SW7470A	12/05/2001 9:00	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	0.0149	0.005		1		12/06/01 3:06	NS	938730
Arsenic	ND	0.005		1		12/06/01 11:51	NS	938769
Lead	ND	0.005		1		12/06/01 3:06	NS	938730
Selenium	ND	0.005		1		12/06/01 3:06	NS	938730
Cadmium	ND	0.005		1		12/07/01 22:08	EG	940234
Chromium	ND	0.01		1		12/07/01 22:08	EG	940234
Nickel	0.0323	0.02		1		12/07/01 22:08	EG	940234
Silver	ND	0.01		1		12/07/01 22:08	EG	940234
Zinc	0.105	0.02		1		12/07/01 22:08	EG	940234

Prep Method	Prep Date	Prep Initials
SW3005A	11/25/2001 11:00	MW

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Martinez Rivera 112001 **Collected:** 11/15/01 12:56:0 **SPL Sample ID:** 01110913-02

Site: La Lima-Villanueva

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		12/05/01 11:10	R_T	937614

Prep Method	Prep Date	Prep Initials
SW7470A	12/05/2001 9:00	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		12/06/01 2:48	NS	938725
Arsenic	ND	0.005		1		12/06/01 11:39	NS	938767
Lead	ND	0.005		1		12/06/01 2:48	NS	938725
Selenium	ND	0.005		1		12/06/01 2:48	NS	938725
Cadmium	ND	0.005		1		12/07/01 21:50	EG	940231
Chromium	ND	0.01		1		12/07/01 21:50	EG	940231
Nickel	ND	0.02		1		12/07/01 21:50	EG	940231
Silver	ND	0.01		1		12/07/01 21:50	EG	940231
Zinc	ND	0.02		1		12/07/01 21:50	EG	940231

Prep Method	Prep Date	Prep Initials
SW3005A	11/25/2001 11:00	MW

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
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MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Oro Verde 112001 **Collected:** 11/19/01 10:10:0 **SPL Sample ID:** 01110913-06

Site: **La Lima-Villanueva**

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		12/05/01 11:10	R_T	937620

Prep Method	Prep Date	Prep Initials
SW7470A	12/05/2001 9:00	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	0.0258	0.005		1		12/06/01 3:29	NS	938734
Arsenic	ND	0.005		1		12/06/01 3:29	NS	938734
Lead	ND	0.005		1		12/06/01 3:29	NS	938734
Selenium	ND	0.005		1		12/06/01 3:29	NS	938734
Cadmium	ND	0.005		1		12/07/01 22:25	EG	940237
Chromium	ND	0.01		1		12/07/01 22:25	EG	940237
Nickel	ND	0.02		1		12/07/01 22:25	EG	940237
Silver	ND	0.01		1		12/07/01 22:25	EG	940237
Zinc	ND	0.02		1		12/07/01 22:25	EG	940237

Prep Method	Prep Date	Prep Initials
SW3005A	11/25/2001 11:00	MW

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Rapidito 112001 **Collected:** 11/15/01 11:00:0 **SPL Sample ID:** 01110913-04

Site: La Lima-Villanueva

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		12/05/01 11:10	R_T	937616

Prep Method	Prep Date	Prep Initials
SW7470A	12/05/2001 9:00	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		12/06/01 3:00	NS	938728
Arsenic	ND	0.005		1		12/06/01 3:00	NS	938728
Lead	ND	0.005		1		12/06/01 3:00	NS	938728
Selenium	ND	0.005		1		12/06/01 3:00	NS	938728
Cadmium	ND	0.005		1		12/07/01 22:02	EG	940233
Chromium	ND	0.01		1		12/07/01 22:02	EG	940233
Nickel	ND	0.02		1		12/07/01 22:02	EG	940233
Silver	ND	0.01		1		12/07/01 22:02	EG	940233
Zinc	ND	0.02		1		12/07/01 22:02	EG	940233

Prep Method	Prep Date	Prep Initials
SW3005A	11/25/2001 11:00	MW

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID Villa Esther 112001 **Collected:** 11/19/01 10:55:0 **SPL Sample ID:** 01110913-08

Site: La Lima-Villanueva

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002		1		12/05/01 11:10	R_T	937622

Prep Method	Prep Date	Prep Initials
SW7470A	12/05/2001 9:00	R_T

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED			**MCL**	**SW6010B**		**Units: mg/L**		
Antimony	ND	0.005		1		12/06/01 3:41	NS	938737
Arsenic	ND	0.005		1		12/06/01 3:41	NS	938737
Lead	ND	0.005		1		12/06/01 3:41	NS	938737
Selenium	ND	0.005		1		12/06/01 3:41	NS	938737
Cadmium	ND	0.005		1		12/07/01 22:38	EG	940239
Chromium	ND	0.01		1		12/07/01 22:38	EG	940239
Nickel	ND	0.02		1		12/07/01 22:38	EG	940239
Silver	ND	0.01		1		12/07/01 22:38	EG	940239
Zinc	0.0373	0.02		1		12/07/01 22:38	EG	940239

Prep Method	Prep Date	Prep Initials
SW3005A	11/25/2001 11:00	MW

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

APPENDIX C

Groundwater Flow Model

GROUNDWATER FLOW MODEL

La Lima, Honduras

June 2002

1.0 INTRODUCTION

A numerical groundwater flow model was constructed for the City of La Lima to assess the sustainability of future groundwater supply development to meet the needs of the community. The modeling process produced a preliminary groundwater flow model used to simulate groundwater production of the alluvial aquifer.

The City of La Lima is located in the Province of Cortes approximately 15 kilometers southeast of San Pedro Sula. La Lima relies exclusively on groundwater for its water supply. The Chamelecón River flows through the City but is not presently considered a sustainable municipal water source due to the heavy raw sewage load and lack of water treatment facilities. The City has experienced rapid growth in recent years. The population of the municipality is approximately 40,000 people. Between 1991 and 1992 a large industrial park was built in the city, resulting in an accelerated increase in residential customers and therefore an increase in water use.

The City expects that most future growth will occur to the northwest. A portion of the City is served by a private water system located approximately 2 kilometers northwest of the main part of the City, along the highway to San Pedro Sula. Since existing wells lack totalized production meters, the amount of water used by La Lima residents cannot be precisely determined.

1.1 Objectives

The following sections describe the purpose, goals, applicability, and predictions of the groundwater flow model.

1.1.1 Purpose and Goals. The primary purpose and goal of the numerical groundwater flow model for the City of La Lima was to assess the sustainability of future groundwater supply development to meet the needs of the community.

1.1.2 Applicability. The groundwater flow model was developed to numerically represent the hydrogeologic conceptual model of the Chamelecón River valley aquifer system. The groundwater flow model is intended for use in the evaluation of potential groundwater resources available to support the projected future water supply needs of the La Lima community.

Based on the available data and the data collected by Brown and Caldwell (BC), BC feels that the conceptual and numerical hydrogeologic models are reasonable representations of the valley aquifer system. Therefore, they can be used in planning and developing future groundwater resources. However, as additional geologic and hydrogeologic information is collected, the site conceptual and numerical models should be refined, thereby increasing the effectiveness of the numerical model as a tool to manage the community's groundwater resources.

1.1.3 Predictions to be Made. The groundwater flow model will be used to predict potential groundwater resources, including the long-term sustainability of the aquifer system.

1.2 General Topography of Model Area

Along the flanks of the Sula Valley, a number of river systems drain the surrounding upland areas. These river systems have associated valleys that adjoin the Sula Valley. La Lima is located within one such valley system that is located on the western flanks of the Sula Valley. The Chamelecón River traverses the central portion of the valley and serves as the major drainage for the area. The valley is oriented in an east-west direction and ranges from 6 to 10 kilometers wide. The valley to the west and north is characterized by a broad flat alluvial plain, which has been deposited by the Chamelecón and Blanco Rivers. The valley to the east is characterized by the broad, flat floodplain of the Ulúa River. The Sula Valley eventually drains into the Caribbean Sea to the north. Steep topographic features are located to the north and southwest. Figure C-1 presents a topographic map of the Chamelecón River valley.

2.0 CONCEPTUAL MODEL

The hydrostratigraphic setting beneath the Chamelecón River valley is characterized by a sequence of interbedded silts and sands grading into interbedded fine to medium sands and gravels. Numerous wells have been installed at different depths for domestic and industrial water production. During the BC investigation, three wells were installed (BC-LL-1, BC-LL-2, and BC-LL-3) in an effort to evaluate the hydrogeologic and water quality conditions at the site. The current conceptual model was revised based on the installation of the three new wells.

2.1 Aquifer System

The site is conceptually divided into two units in order to represent the aquifer system. This has been primarily accomplished on the basis of site stratigraphy, geophysical logs, and the observed aquifer response to various aquifer tests that have been performed at the site.

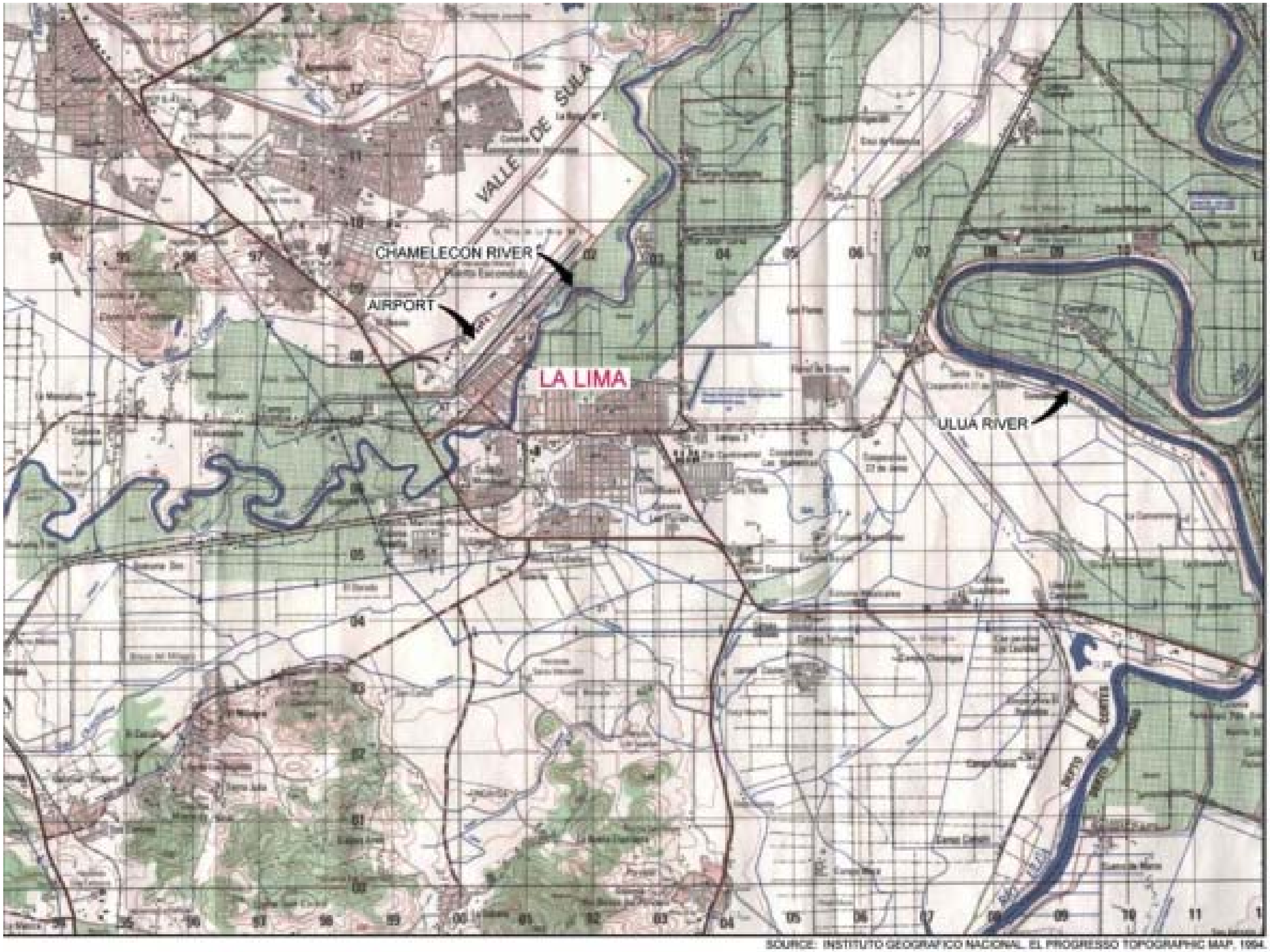
The hydrostratigraphic units are depicted in the generalized cross-section presented in Figures C-2 and C-3. The hydrostratigraphic units are described briefly, as follows:

1st Unit – represents a layer of interfingering sand, clayey sand, and clay, which has a somewhat low hydraulic conductivity and is unconfined.

2nd Unit – represents a thinner layer of interfingering clay, clayey sand, and sand with variable high and low hydraulic conductivity throughout the area of interest.

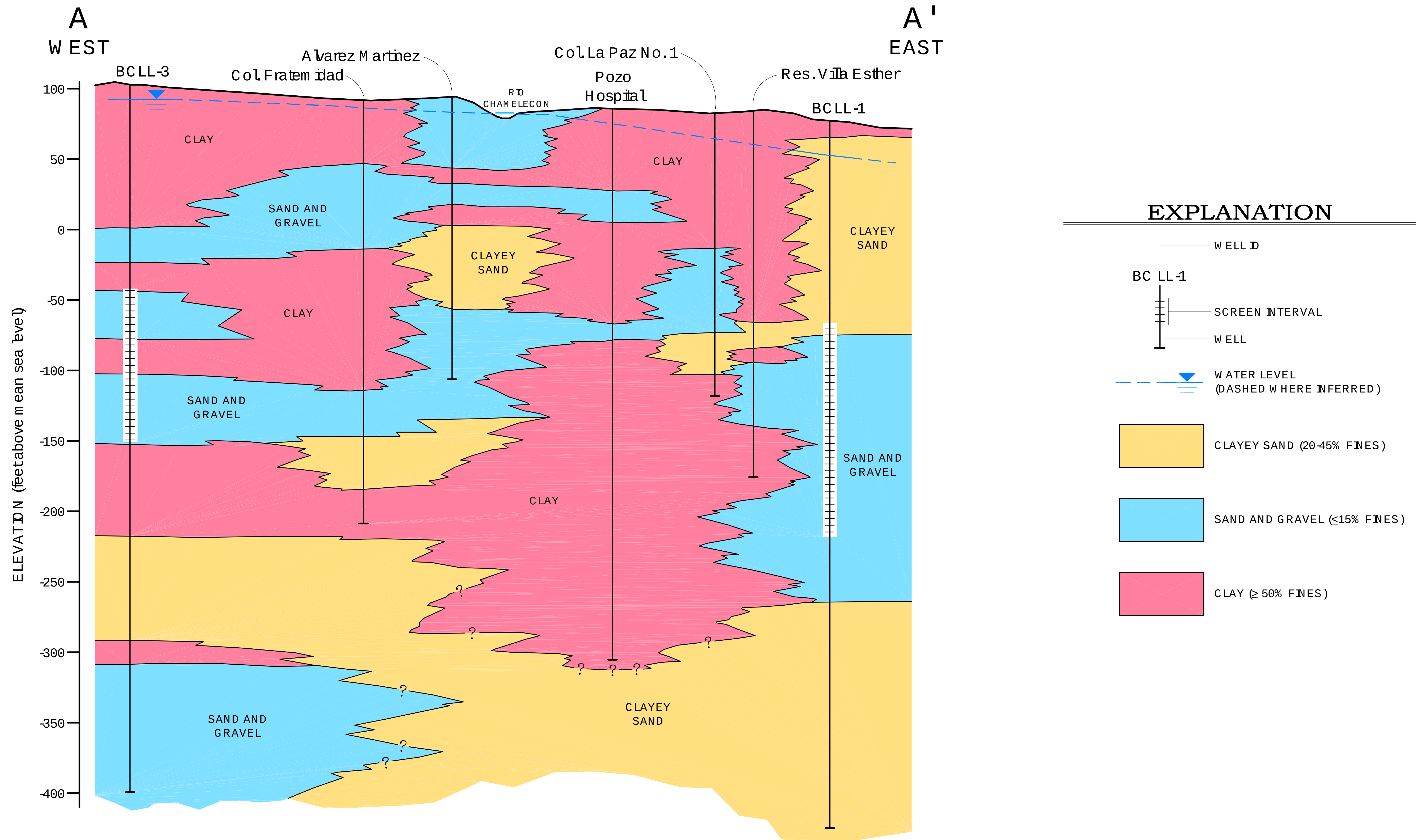
2.2 Hydrogeologic Boundaries

In the conceptual model, precipitation falling on the surrounding upland areas infiltrates the fractured metamorphic rocks and migrates toward the Chamelecón River valley. The infiltrated



BROWN AND CALDWELL

DATE	SITE	FIGURE
3-26-02	La Lima, Republic of Honduras	C-1
PROJECT 21143	TITLE Topographic Map Showing La Lima	



BROWN AND CALDWELL

Figure C-2

CROSS-SECTION A-A'

LA LIMA, HONDURAS

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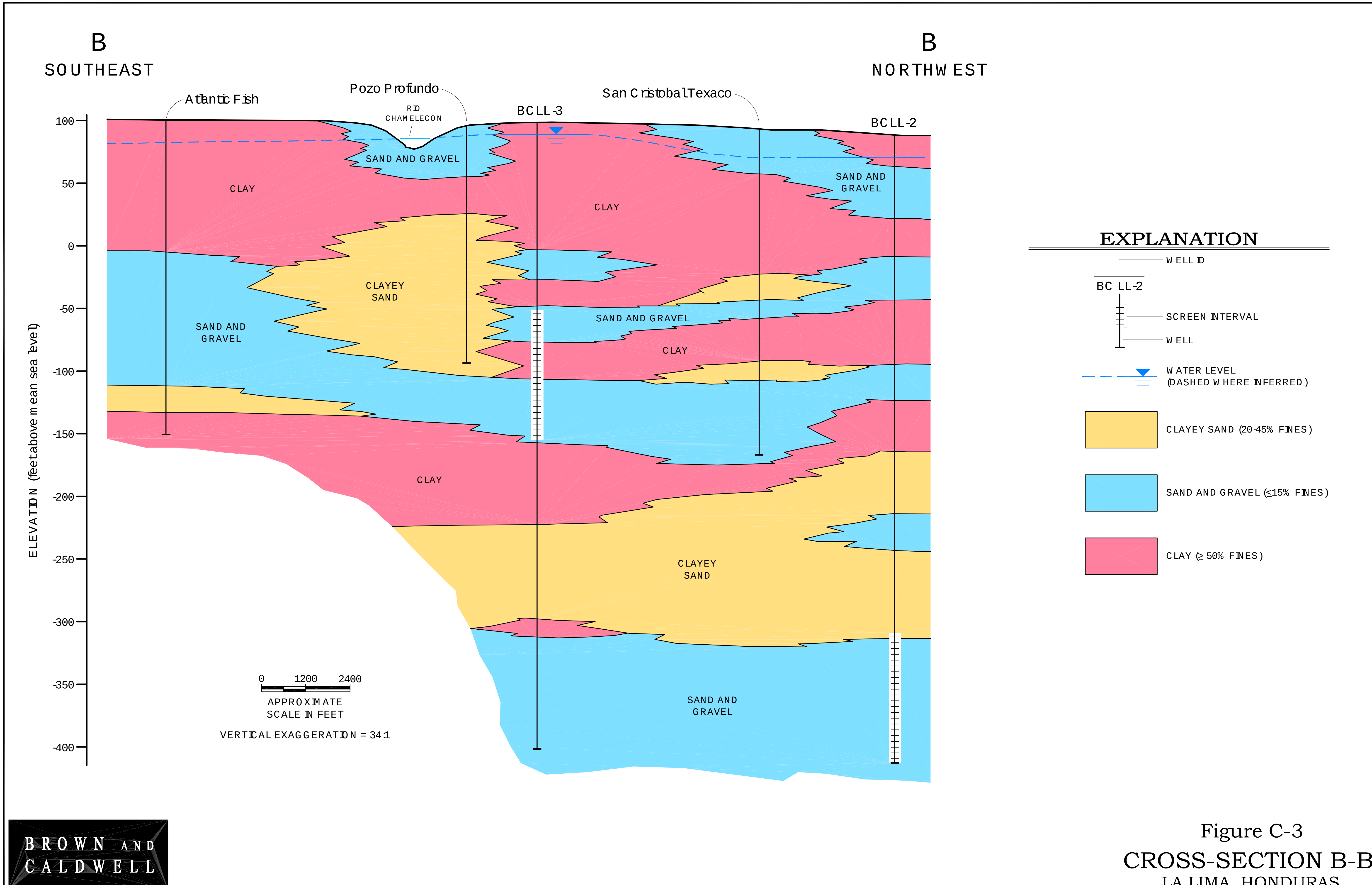

Figure C-3
CROSS-SECTION B-B'
LA LIMA, HONDURAS

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precipitation from the upland areas recharges the alluvial aquifers of the valley along the surrounding mountain front. Additional recharge to the aquifers occurs through precipitation falling directly on the surface of the valley floor. Recharge from precipitation is believed to be the major source of groundwater recharge to the alluvium.

The Chamelecón River, which traverses the model from west to east, is believed to act primarily as a sink for groundwater. Groundwater generally flows from the aquifer to the river. The Ulúa River forms the eastern hydrogeologic boundary of the modeled area.

Groundwater entering the aquifer system of the La Lima area that is not removed by pumping or discharge to the Chamelecón River flows generally to the east, and leaves the modeled area at the Ulua River.

2.3 Hydraulic Properties

Step-drawdown and constant-rate aquifer tests were performed on selected La Lima wells to help evaluate the water resource development potential and to provide aquifer hydraulic data. Step-drawdown aquifer tests were performed on test wells BC-LL-1, BC-LL-2, and BC-LL-3. Because of marginal yields during the step-drawdown test in BC-LL-2, no further aquifer testing was performed on the well. The step-drawdown test in BC-LL-3 indicated that the aquifer yield at BC-LL-3 could be as high as 430 gpm, but due to well inefficiency, the well could only be pumped at a maximum rate of 300 gpm. A 72.5-hour constant-rate aquifer test was then performed on well BC-LL-1. BC-LL-1 was selected for the constant-rate test because of its high yield. During the constant-rate aquifer test, the well maintained a flow rate of 450 gpm with a maximum draw-down of 30.87 feet. Table C-1 summarizes the transmissivities determined during step-drawdown and constant-rate aquifer tests of wells BC-LL-1, BC-LL-2, and BC-LL-3.

Table C-1. Aquifer Transmissivity and Hydraulic Conductivity

WELL ID	Transmissivity (m^2/day)	Hydraulic Conductivity (m/day)
BC-LL-1	196 - 249	4.7 - 8.1
BC-LL-2	0.61 – 0.91	0.02 - 0.03
BC-LL-3	895	31

2.4 Sources and Sinks

The sources of groundwater for the La Lima area aquifer include recharge at the valley margins from precipitation falling on the uplands and migrating toward the valley, infiltration of precipitation falling directly on the valley floor, and groundwater underflow from the region outside the model boundary to the northwest. The groundwater sinks in the modeled area include production well pumping, discharge to the Chamelecon River, and discharge to the Ulua River.

2.5 Conceptual Water Budget

A conceptual water budget for the aquifer system in La Lima was calculated to provide constraints for numerical modeling. The conceptual budget is based on previous investigations, field data collection, and anecdotal information from long-term residents.

For the modeled area, inflow to the aquifer system consists mainly of recharge from precipitation and groundwater influx from the upper northwestern valley. Groundwater is removed from the system via (1) industrial and municipal well pumping, and (2) discharge to the Chamelecón and Ulúa Rivers.

2.5.1 Inflow. The valley receives between 1.4 and 2.2 meters of precipitation annually, most of which occurs during the monsoon season. Approximately 2 percent of the annual precipitation falling on the surrounding highlands and approximately 2.5 percent of the annual precipitation falling on the valley floor, is assumed to infiltrate into the aquifer system underlying the La Lima area. Approximately 76,118,000 m2 was estimated for the upland recharge area associated with the model domain. Assuming 1.8 meters of annual precipitation and a 2 percent infiltration rate, an estimated 7500 m3/day is recharging to the aquifer system from the upland areas. The rest of the valley is approximately 304,176,000 m2 in size. Using 2.5 percent of the average precipitation value, an estimated 37,500 m3/day enters the aquifer in the form of areal recharge.

Influx from the valley to the northwest of the modeled area enters the system through an upper and lower aquifer. The influx to the upper aquifer was based on the assumption that the aquifer is approximately 11,000 meters wide and 123 meters thick, and the average gradient is approximately 0.0007. The hydraulic conductivity was estimated to be 2.5 meters per day. Approximately 2,370 m3/day is estimated to be flowing into the upper aquifer from the northwest corner of the valley. The influx to the lower aquifer was based on the assumption that the aquifer is approximately 11,000 meters wide and 23 meters thick, and the average gradient is approximately 0.0007. The hydraulic conductivity was estimated to be 32.5 meters per day. Approximately 5,790 m3/day is estimated to be flowing into the lower aquifer from the northwest corner of the valley.

2.5.2 Outflow. There are numerous domestic, municipal, commercial/agricultural, and industrial wells pumping in the La Lima area. Because an official estimate of total pumping from these wells is not available, it was assumed that the cumulative total pumping is approximately 8,990 m3/day. This number is derived from pumping rates from wells for which sufficient information was available. The rates are based on the assumption that the wells are pumping approximately 18 hours per day. Table C-2 summarizes the pumping rates of the wells.

Table C-2. Pumping Wells

Pumping Well	Pumping Rate (m^3/day)	Pumping Rate (gallons per minute)
Col. Martinez Rivera	736.9	135.2
Escuela Gabriela Mistral	736.9	135.2
Col. Fraternidad	884.25	162.2
22 de Mayo	442.125	81.1
Pozo Mixto	1228.125	225.3
Guaymuras	491.25	90.1
Cruz Roja	736.9	135.2
Col. La Mesa Nuevo	1965	360.5
Sitraterco Club Sula	736.9	135.2
Col. Los Angeles	294.6	54.0
Alvarez Martinez	736.9	135.2
TOTAL PUMPING	8,990	1,649.2

Discharge of groundwater to the Chamelecón River was calculated using the MODFLOW river package flux formulation. Based on a 38,900-meter river segment length, 15-meter average channel width, an estimated vertical hydraulic conductivity of 0.3 meters per day, an estimated river bed thickness of five meters, and a head difference between the aquifer and the river surface of 0.5 meters, the discharge to the Chamelecón River is estimated to be approximately 17,500 m3/day.

Discharge to the Ulúa River was calculated using Darcy's Law, assuming that groundwater flow through a cross-sectional area of the upper and lower aquifers would represent discharge to the river. The discharge from the upper aquifer was based on the assumption that the aquifer is approximately 17,500 meters wide and 43 meters thick, and the average gradient is approximately 0.001. The hydraulic conductivity was estimated to be 15 meters per day. Approximately 11,300 m3/day is estimated to discharge through the cross-sectional area of the upper aquifer. The discharge from the lower aquifer was based on the assumption that the aquifer is approximately 17,500 meters wide and 23 meters thick, and the average gradient is approximately 0.001. The hydraulic conductivity was estimated to be 29 meters per day. Approximately 11,670 m3/day is estimated to discharge through the cross-sectional area of the lower aquifer. Assuming that all groundwater passing through this cross-sectional area discharges to the river, it is estimated that the discharge to the Ulúa River is approximately 22,970 m3/day.

Table C-3 is the annualized, conceptual groundwater budget for the La Lima model region.

Table C-3. Conceptual Groundwater Budget

IN	M^3 per day	M^3 per year	Gallons per minute
Recharge Up-lands	7,500	2,737,500	1,376
Recharge Valley Alluvium	37,500	13,687,500	6,879
Chamelecón River Leakage to Aquifer	0	0	0
Influx from Upgradient Boundary	8,160	2,978,400	1,497
Total	53,160	19,403,400	9,752
OUT			
La Lima Pumping Wells	8,990	3,281,350	1,649
Discharge to Chamelecón River	17,500	6,387,500	3,210
Discharge to Ulúa River	22,970	8,384,050	4,214
Total	49,460	18,052,900	9,074
IN – OUT (change in storage)	3,700	1,350,500	679

Based on these estimates, there is a daily surplus of 3,700 m3, indicating that groundwater supplies are being added to storage.

3.0 COMPUTER CODE

The modular, three-dimensional, finite difference groundwater model code, typically referred to as MODFLOW, was used for this project. The U.S. Geological Survey (McDonald and Harbaugh, 1988) developed the original code. However, a slightly modified version of the code marketed by Environmental Simulations Inc. was used for this site. The version is designed to interact with Groundwater Vistas, a pre- and post-processor used for data input and output.

3.1 Model Assumptions

Several assumptions were necessary in the development of the La Lima groundwater flow model because of limited data available on the hydrogeologic system of the valley. The data that are available are primarily from recently completed borehole logs and aquifer testing, and are limited to a small portion of the modeled area where recent groundwater development has occurred.

The following is a summary of the assumptions used in the development of the La Lima groundwater model:

- Groundwater flow directions throughout the modeled area are generally to the east, toward the Ulúa River, which controls the hydraulic head at the eastern model boundary.
- Areal recharge occurs over the entire surface of the modeled area at a uniform rate; seasonal precipitation can be normalized to daily averages.
- Upland recharge to the modeled area is proportional to the areas of watersheds in the surrounding highlands.

4.0 MODEL CONSTRUCTION

The following sections describe the model domain used in this analysis, layer hydraulic parameters, groundwater sources, and boundary conditions.

4.1 Model Domain

The model domain and grid used in this analysis are presented on Figure C-4. The model grid is centered on the City of La Lima and consists of 169 rows and 244 columns. The dimensions of the individual cells are 100 by 100 meters. The grid has been oriented so that the X-axis of the grid parallels primary groundwater flow direction within the upper aquifer.

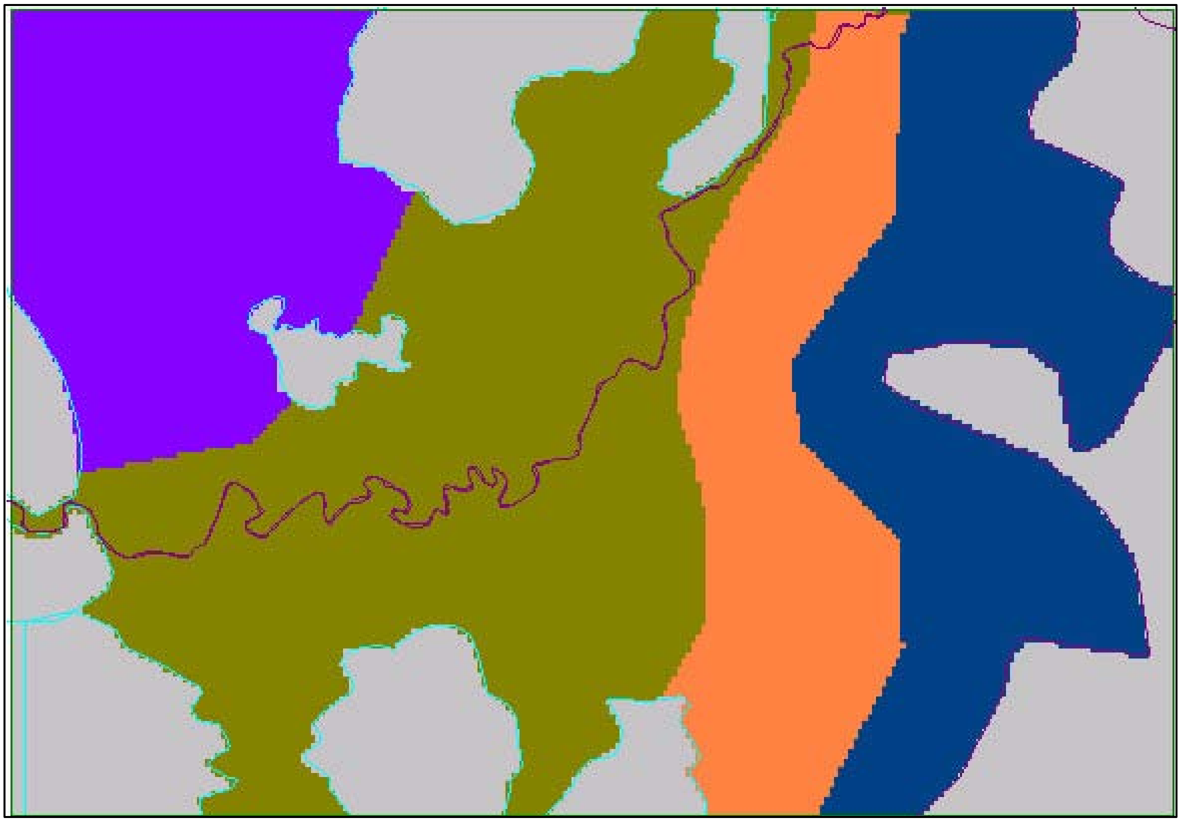
As presented earlier, the hydrostratigraphic setting beneath the study area is characterized by an alluvial aquifer system comprised of sand, clayey sand, and clay. Vertically, the grid consists of 2 layers to represent the aquifer system. The top elevation of layer 1 is based on digital ground surface elevation data. The base of layers 1 and 2 were based on hydrogeologic divisions. That is, layer 1 represents the upper most portions of the aquifer comprised of silts, sand, and clay. This unit is not considered to be the primary water resource. The bottom of layer 1 was selected to be 22.86 meters below mean sea level, which corresponds to the top of layer 2. Layer 2 represents the primary aquifer system. The base of Layer 2 was estimated to be 45.72 meters below mean sea level.

4.2 Hydraulic Parameters

Layer 1 simulates groundwater flow within a predominately clayey sand unit across the site. The thickness of layer 1 varies with changes in ground surface elevation across the site. Hydraulic conductivity was chosen to be 0.5 m/day along the northwestern reaches of the valley and 2.5 m/day in the south and southwestern reaches (Figure C-5). Vertical hydraulic conductivity was assumed to be one tenth of horizontal hydraulic conductivity (Figure C-5).

Layer 2 represents groundwater flow within a sand and clayey sand unit. The thickness of layer 2 was 22.86 meters. Figure C-6 presents the horizontal and vertical hydraulic conductivity in layer 2. Hydraulic conductivity values ranged from 45 m/day in the northwestern portion of the model area (representing the sand unit), and 4.5 m/day in the central portion of the model area (representing the clayey sand unit). Vertical hydraulic conductivity was assumed to be one tenth of horizontal hydraulic conductivity. The linear distribution of hydraulic conductivity in the eastern portion of the model domain corresponds to the speculated depositional sequences associated with the Ulúa River.

DATE: MAR. 2002	PROJECT NUMBER: 21143	SCALE: 0 1500 3000 SCALE IN METERS	Explanation	FIGURE C-4
BROWN AND CALDWELL Carson City, Nevada		N	Active Area Inactive Area	MODEL GRID



Inactive Model Cells

K=2.5 m/day
Vertical K = 0.25 m/day

K= 3.0 m/day
Vertical K = 0.3 m/day

K=10.0 m/day
Vertical K = 1.0 m/day

K=15.0 m/day
Vertical K = 1.5 m/day

North

*Not to Scale

FIGURE C-5

LAYER 1 HYDRAULIC CONDUCTIVITY (K) AND VERTICAL HYDRAULIC CONDUCTIVITY

La Lima, Honduras

USAID

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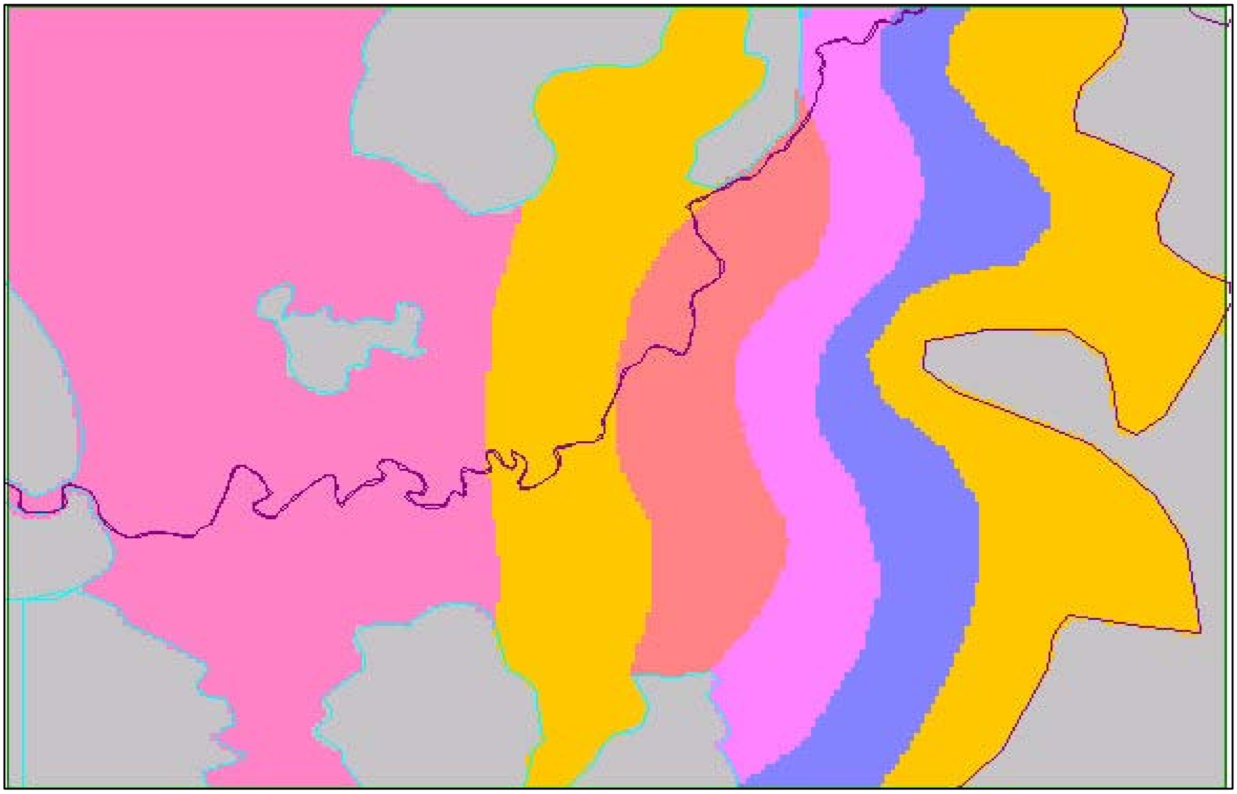

Inactive Model Cells

K = 32.5 m/day
Vertical K = 3.25 m/day

K=29.0 m/day
Vertical K = 2.9 m/day

K = 5.0 m/day
Vertical K = 0.5 m/day

K = 8.0 m/day
Vertical K = 0.8 m/day

K = 17.5 m/day
Vertical K = 1.75 m/day

North

*Not to Scale

FIGURE C-6

LAYER 2 HYDRAULIC CONDUCTIVITY (K) AND VERTICAL HYDRAULIC CONDUCTIVITY

La Lima, Honduras

USAID

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4.3 Sources

The following sections describe groundwater sources including rivers, recharge, and wells.

4.3.1 Rivers. The Chamelecón River is considered to be the primary discharge area for model layer 1. This discharge was simulated using river node cells. An average elevation of the river surface (specified head) in these cells was obtained from the topographic map of the area. The river nodes are presented on Figure C-7.

4.3.2 Recharge. Assuming an infiltration rate of approximately 1 to 2 percent, 6,750 m3/day is recharging to the aquifer system from the upland areas. This is represented in the model as flux boundaries along the margins of the upland areas. The flux boundary for all layers is shown in Figure C-7. The 6,750 m3/day of water was distributed among the flux boundaries located in layers 1 and 2. Each flux cell provided 6 m3/day.

Approximately 1 to 2 percent of the average precipitation value provides 38,754 m3/day in the form of areal recharge. A recharge value of 1.3 x 10-4 m/day was assigned to the uppermost active layer.

4.3.3 Wells. Eleven wells are included in the La Lima groundwater model, with a total extraction of 8,990 m3/day. These wells are used for domestic, municipal, commercial/agricultural, and industrial water purposes. There are several other wells pumping in the area, but data from these wells were not available. Figure C-8 shows the locations of the pumping wells.

4.4 Boundary Conditions

Boundary conditions including no-flow, general head, constant flux, and river boundaries are described in the following sections.

4.4.1 No-Flow Boundaries. No-flow boundary conditions are utilized in the southern portion of the model and in the northeastern portion of the model where groundwater flow directions are parallel to the model boundaries. The no-flow boundaries are indicated on Figure C-7.

4.4.2 General Head Boundaries. The northwest perimeter is simulated using "general head" boundary (GHB) cells. These boundary cells simulate the extension of the aquifer beyond the model boundary by allowing water to enter or exit the model domain as a function of the local gradient, transmissivity, and cell dimensions. The specific head values used were estimated by projection of groundwater elevation data and topographical information. The general head boundaries are presented in Figure C-7.

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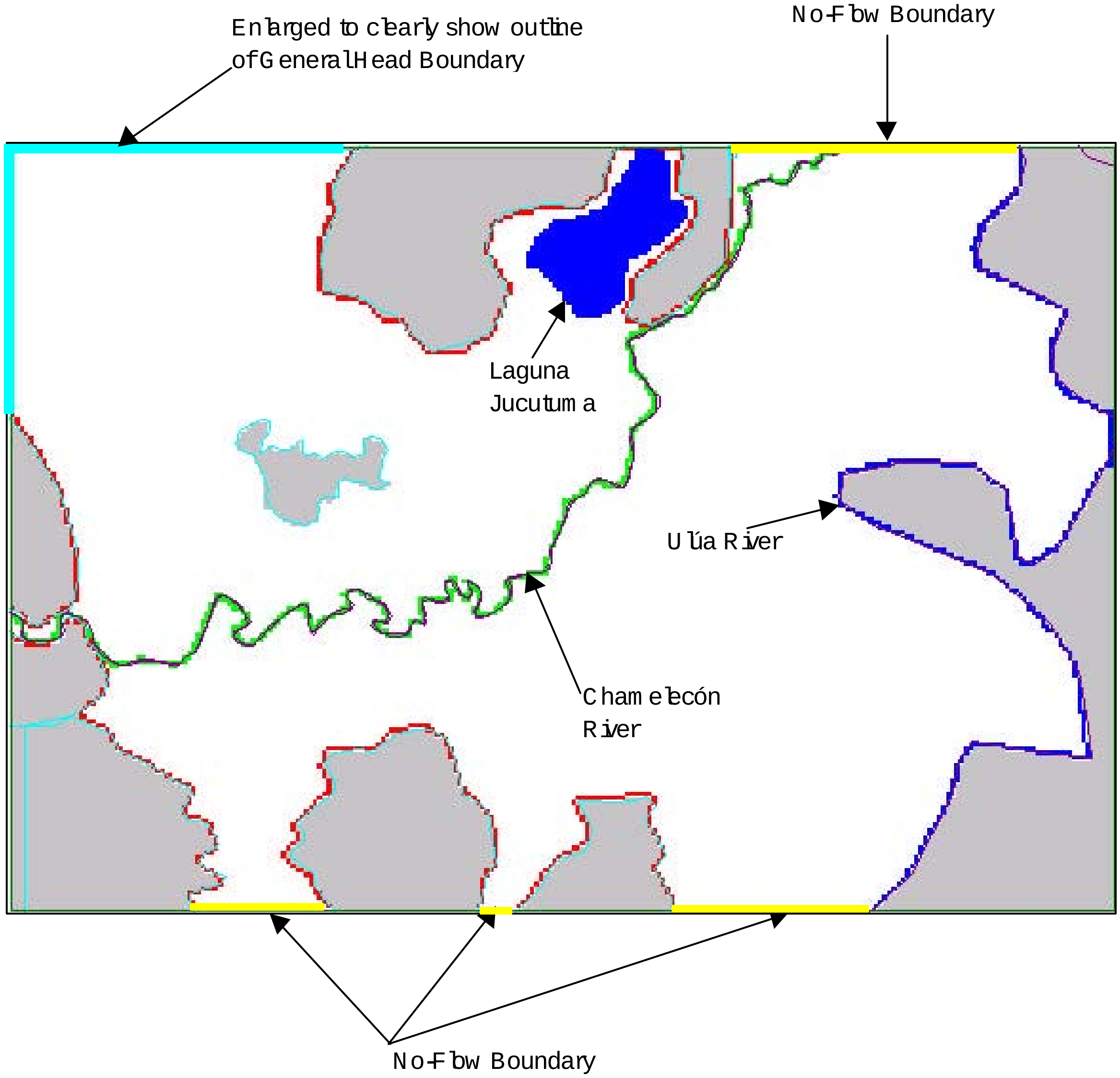

Inactive Model Cells

River Nodes

General Head Boundary

Flux Boundary

Constant Head Boundary

No-Flow Boundary

North

FIGURE C-7

LAYER 1 BOUNDARY CONDITIONS

La Lima, Honduras

USAID

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*Not to Scale

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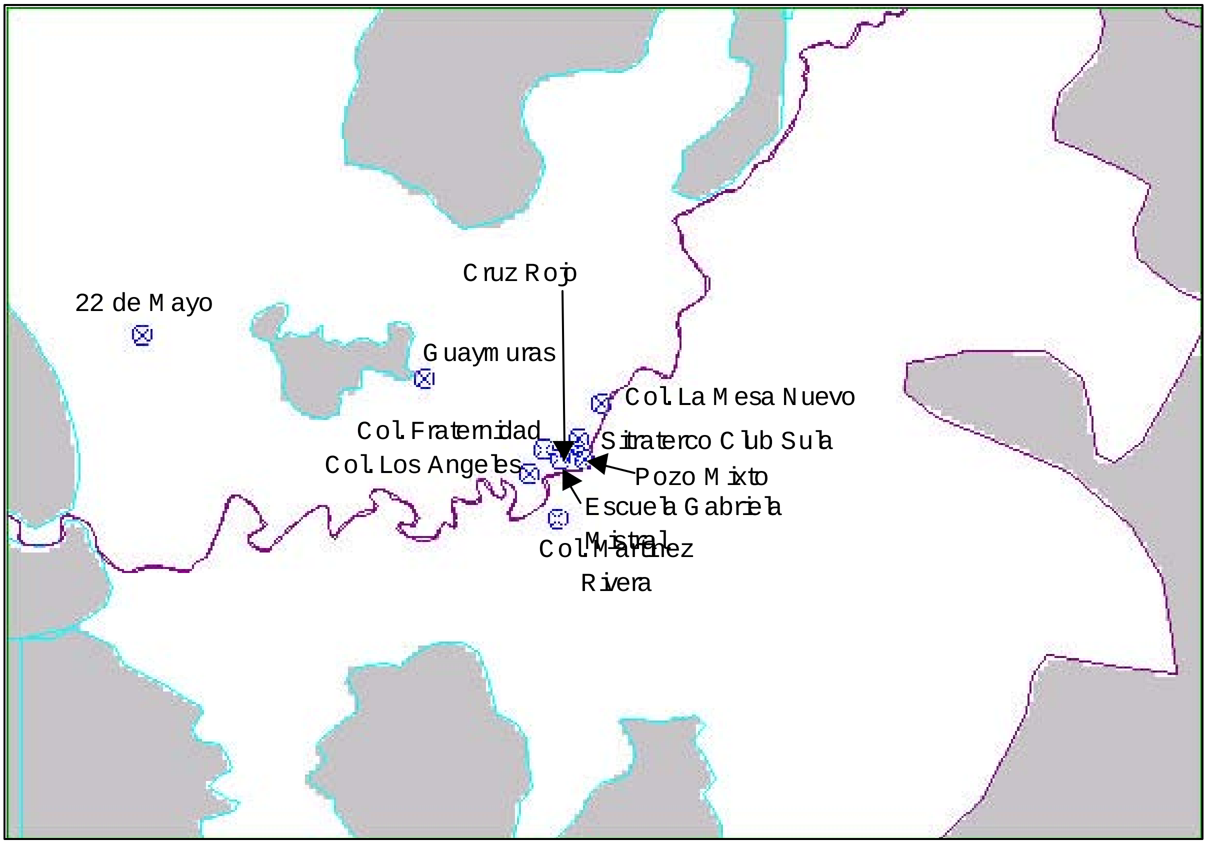

North

Inactive Model Cells

*Not to Scale

FIGURE C-8

LOCATION OF LAYER 2 PUMPING WELLS

La Lima, Honduras

USAID

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4.4.3 Constant Head Boundaries. The Ulúa River was simulated using constant head cells. Laguna Jucutuma, a lake located north of La Lima, was also modeled using constant head boundary cells. An average elevation of the surface water in these cells was obtained from the topographic map. The constant head boundaries are presented in Figure C-7.

4.4.4 Constant Flux Boundaries. Constant flux boundaries are used to represent mountain front recharge to the alluvial aquifer system from the surrounding highlands. The assignment of flux values to these boundaries is discussed in Section 4.3. The constant flux boundaries are presented in Figure C-7.

4.4.5 River Boundaries. River nodes are utilized in the model to represent flux to and from the Chamelecón River. The assignment of head values to the river nodes is discussed in Section 4.3. The river boundaries are presented in Figure C-7.

4.5 Selection of Calibration Targets and Goals

Nine wells with available static water level data were chosen within the modeled area as calibration targets. Water levels across the site have been measured sporadically since April 2001. BC-LL-2 was not utilized because it was completed in a lower unit. Figure C-9 shows the location of these target wells. Table C-4 shows the water levels of the nine calibration targets taken in September 2001.

Table C-4. Calibration Targets

Calibration Target Name	Water Level Elevation (meters above MSL)
Col. Martinez Rivera	23.77
Escuela Gabriela Mistral	23.47
Col. El Maestro	20.83
BC-LL-1	17.09
BC-LL-3	26.80
Pozo Mixto	22.00
Zapote #1	26.08
Zapote #2	26.78
Col. La Paz No. 2	18.75

5.0 CALIBRATION

For this report, the term calibration refers to the standard approach of matching measured heads to model heads at steady-state conditions and adjusting input parameters within reasonable limits until an acceptable match is achieved.

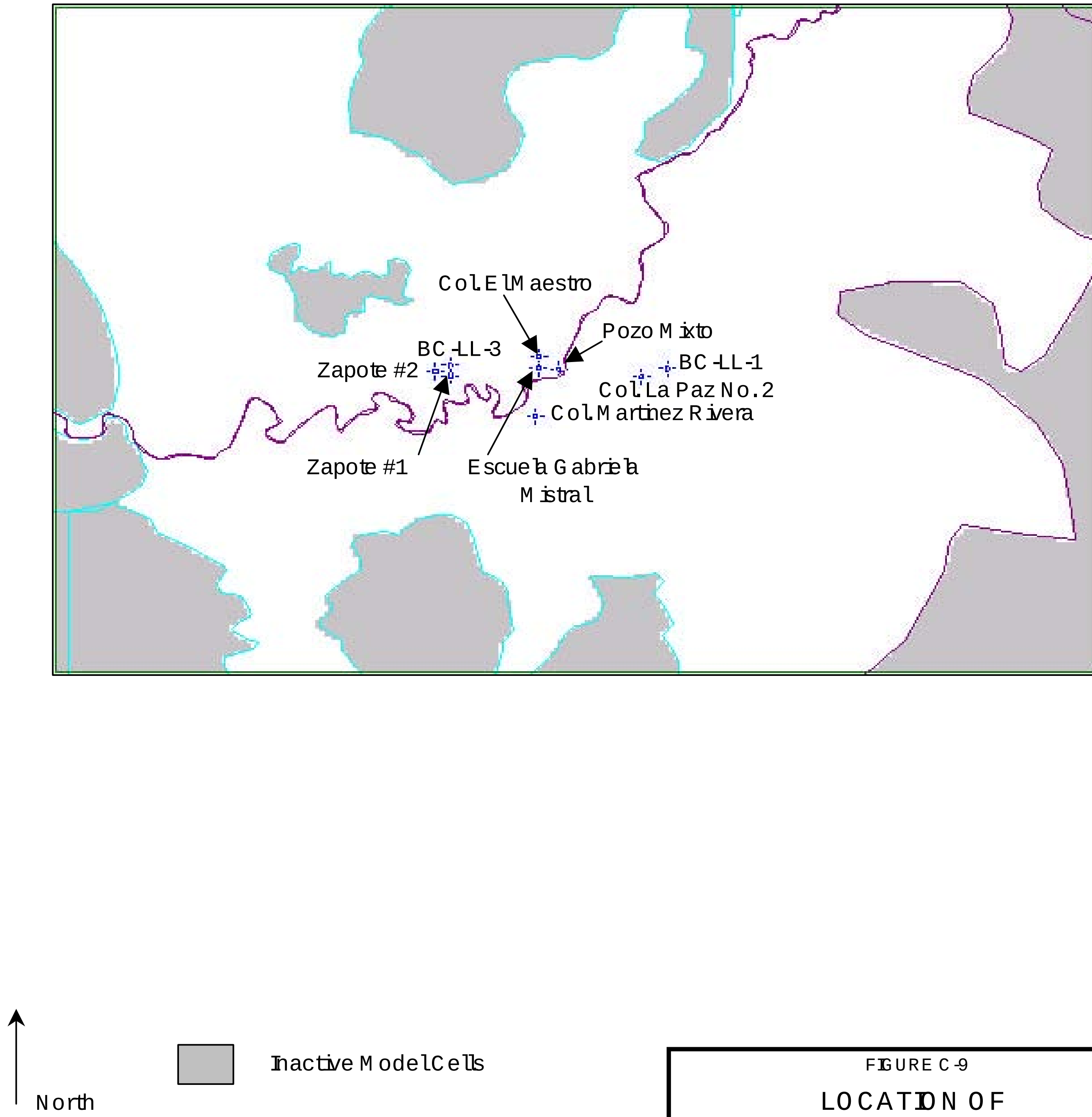

FIGURE C-9

LOCATION OF CALIBRATION TARGETS IN LAYER 2

La Lima, Honduras

USAID

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*Not to Scale

5.1 Qualitative and Quantitative Analyses

The first step in the calibration process is the selection of initial input parameters. The values used for the initial run were obtained from previous and ongoing investigations. Once the initial input parameters were selected, the initial base case simulations were conducted and results were evaluated using a head residual analysis. A head residual is the difference between the measured head in a well and the model-predicted head in the cell that represents the location and depth of the well. Positive residuals indicate the predicted head is lower than the measured value, whereas negative residuals indicate the predicted head is higher than the measured value. The residual sum of squares is an indicator of an overall bias (heads generally too high or too low) in the prediction. If, for example, the predicted heads were quite close to the measured heads but most were slightly higher, this term would be elevated in the negative direction. The absolute residual mean is an indicator of the accuracy of the match and, as a general rule, should be less than 10 percent of the steady-state head change across the project area.

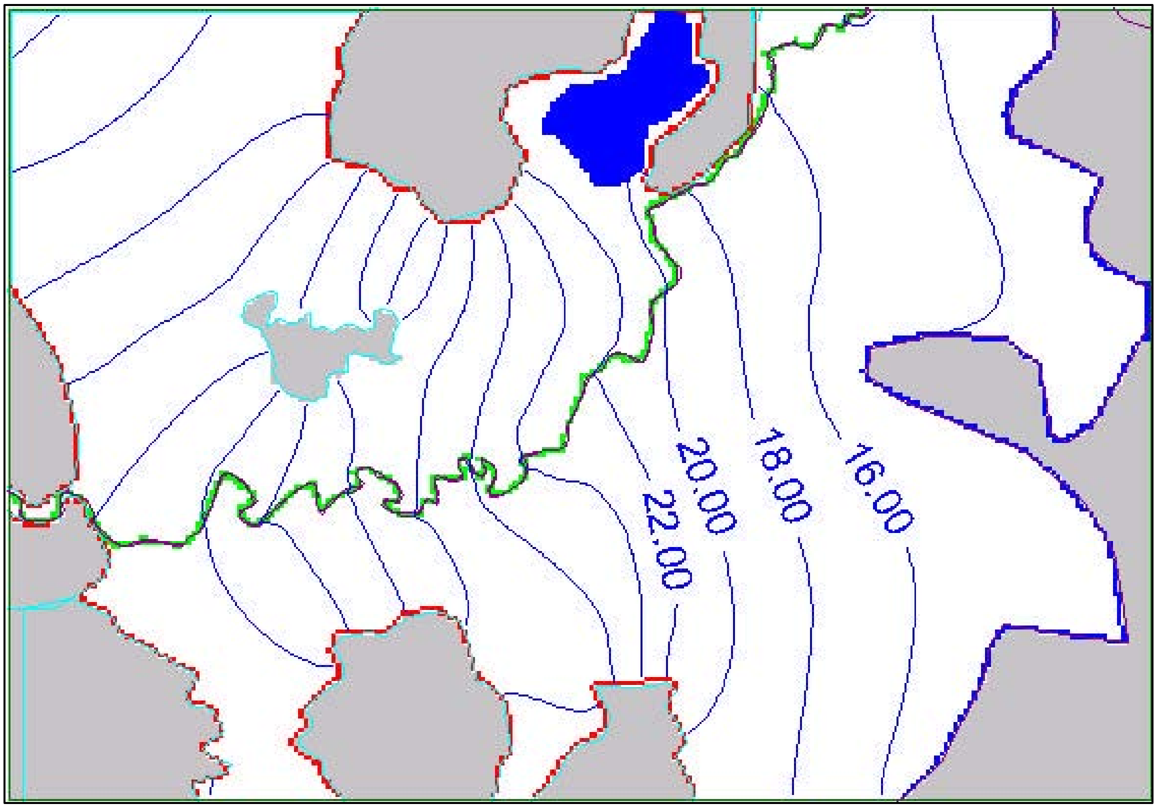
During the steady-state calibration process, the various input parameters were adjusted within reasonable limits and the results noted. This process was continued until an acceptable match was made with averaged head values. Table C-5 presents the results of the calibration simulation. The overall sum of residual is 23.7 m, with an absolute residual mean of 1.32 m. There were no calibration targets in layer 1. Considering the reliability of the water level data, these calibration results are reasonable matches to our understanding of the field conditions. The calibrated modeled groundwater elevations are presented in Figures C-10 and C-11, respectively.

Table C-5. Calibration Statistics

Calibration Statistics	(m)
Residual Mean	-1.18
Residual Standard Deviation	1.11
Residual Sum of Squares	23.7
Absolute Residual Mean	1.32
Minimum Residual	-2.97
Maximum Residual	0.60
Observed Range in Head	9.71
Residual Std. Dev./Range	0.114

5.2 Sensitivity Analysis

A sensitivity analysis was performed to evaluate the sensitivity of the model output to uncertainties inherent in the input data. The first step in this process was to establish reasonable ranges within which to vary the input parameters. Where ranges of values were available based on field data, the upper and lower values were used. Otherwise parameter values were increased and decreased to represent reasonable upper and lower limits. The sensitivity analysis was conducted by varying one input parameter at a time and comparing the predicted steady-state match with that of the calibrated simulation.



Inactive Model Cells

Constant Head Boundary

Flux Boundary

River Nodes

Potentiometric Surface Lines

Contour Interval = 2 meters

North

*Not to Scale

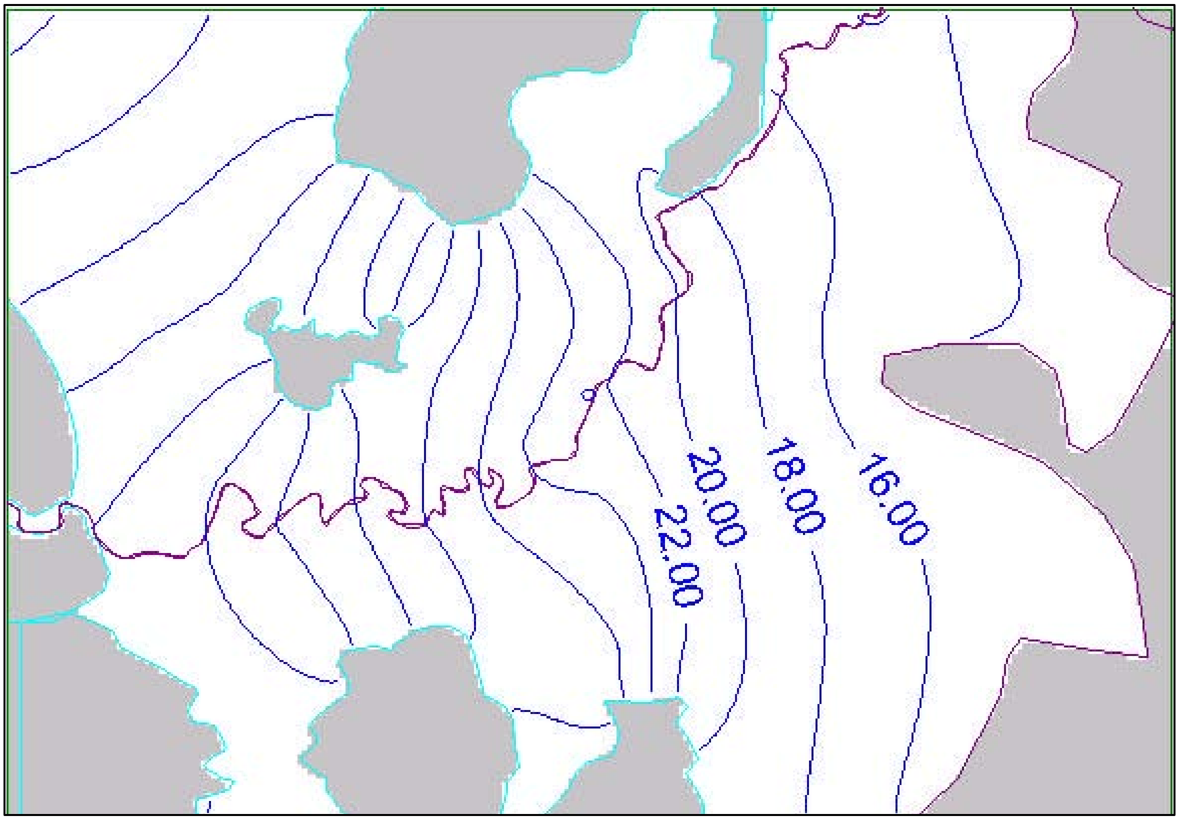
FIGURE C-10

LAYER 1 HEADS

La Lima, Honduras

USAID

BROWN AND CALDWELL



North

Inactive Model Cells

Potentiometric Surface Lines
Contour Interval = 2 meters

FIGURE C-11

LAYER 2 HEADS

La Lima, Honduras
USAID

BROWN AND CALDWELL

*Not to Scale

The results of the sensitivity analysis indicate that the model is most sensitive to variations in hydraulic conductivity, the flux boundary, and recharge. The residuals did not increase substantially with changes in recharge until it was increased by a factor of two. The model residuals increased slightly after a factor of two, but increased greatly after changes of a factor of three within the flux boundary. Generally, residuals increased substantially with decreases and increases in hydraulic conductivity zones vertically and horizontally across the model.

6.0 PREDICTIVE SIMULATIONS

A predictive model simulation was performed to evaluate the potential effects of increased groundwater production on the La Lima Valley aquifer system. The transient simulation incorporates an increase in groundwater demands for La Lima by the year 2020. Pumping rates were increased over the duration of the simulations to a maximum groundwater production rate of 6,900 gpm. The simulation was run for a predictive period of 20 years. The simulation uses hypothetical production wells located to the west of the current population growth (See Figure C-12). Because of a lack of appropriate data, the transient model was not calibrated.

To accomplish the predictive simulations, the groundwater model was first converted to run in transient mode, with the calibrated steady-state water levels used for initial water level conditions. Transient model simulations are used to analyze time-dependent problems and produce a set of hydraulic heads for each pre-determined time step (Anderson and Woessner, 1992). A steady state model simulation produces a set of hydraulic heads that are in equilibrium with stresses on the model, whereas a transient simulation produces a set of hydraulic heads that may not have yet reached equilibrium. Therefore, the hydraulic heads (or water levels) presented in the results of transient simulations may continue to change with time after the end of the simulation period.

For the simulation, a total of 15 hypothetical production wells were included in the model. The wells were located to the west and up-gradient of La Lima. The locations of the hypothetical well fields were selected in areas that are up-gradient and outside of the projected urban growth areas. Development of wells fields and wellhead projection areas outside of urban growth areas would ensure adequate groundwater quality for the projected future needs. Eleven wells were located to the west (up-gradient) of La Lima and north of the Chamelecón River. The remaining 4 wells were located to the southwest (up-gradient) of La Lima and south of the Chamelecón River. The locations of the wells are presented in Figure C-12. Each well was assigned a pumping rate of approximately 350 gpm, with all production from model Layer 2. As a conservative approach, all hypothetical wells were turned on during year 1 of the simulation. Model-predicted water levels are presented for year 20 of the simulation in Figure C-12.

The performance of the existing wells and newly installed BC wells indicates that new wells located in this area would likely produce at the rate assigned in the predictive simulation. The simulation results (Figure C-13) indicate that the aquifer drawdown would be approximately 2 to 3 meters in

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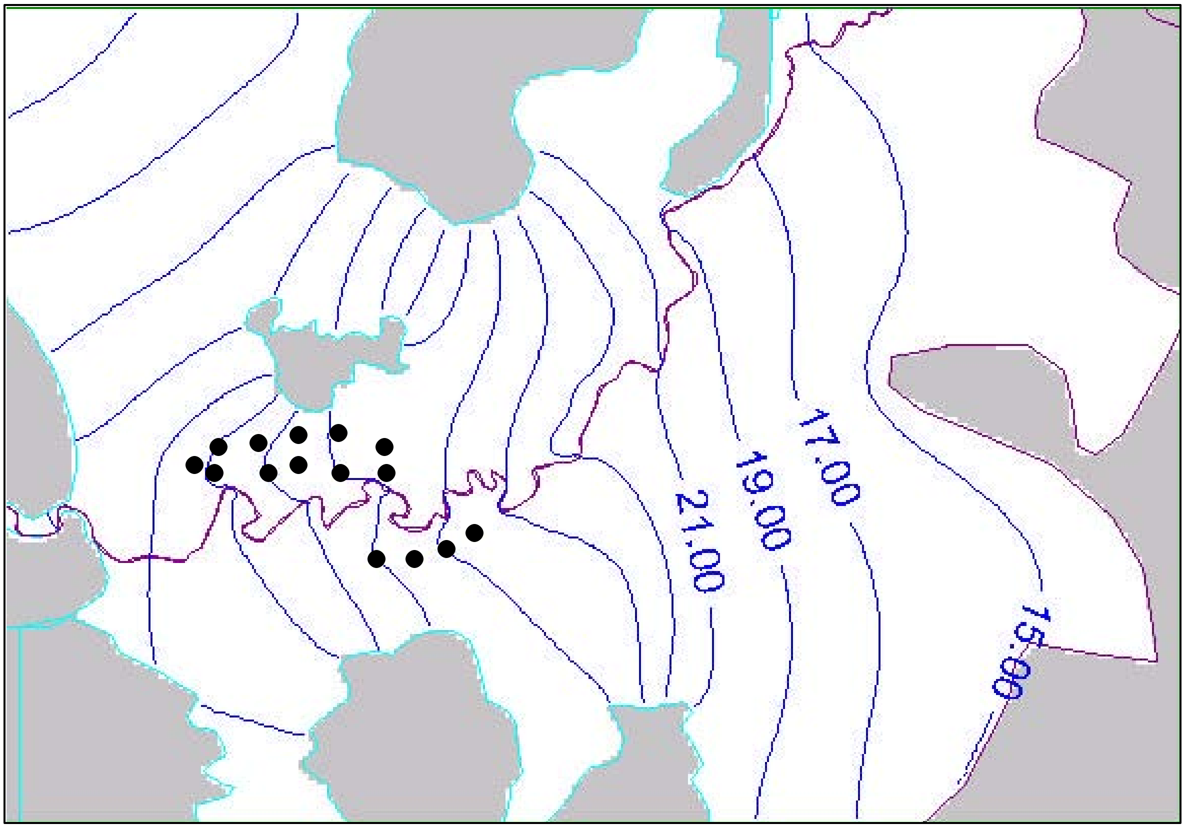


Pumping Well

Inactive Model Cells

North

Potentiometric Surface
Contour Lines

Contour Interval = 2 meters

*Not to Scale

FIGURE C-12

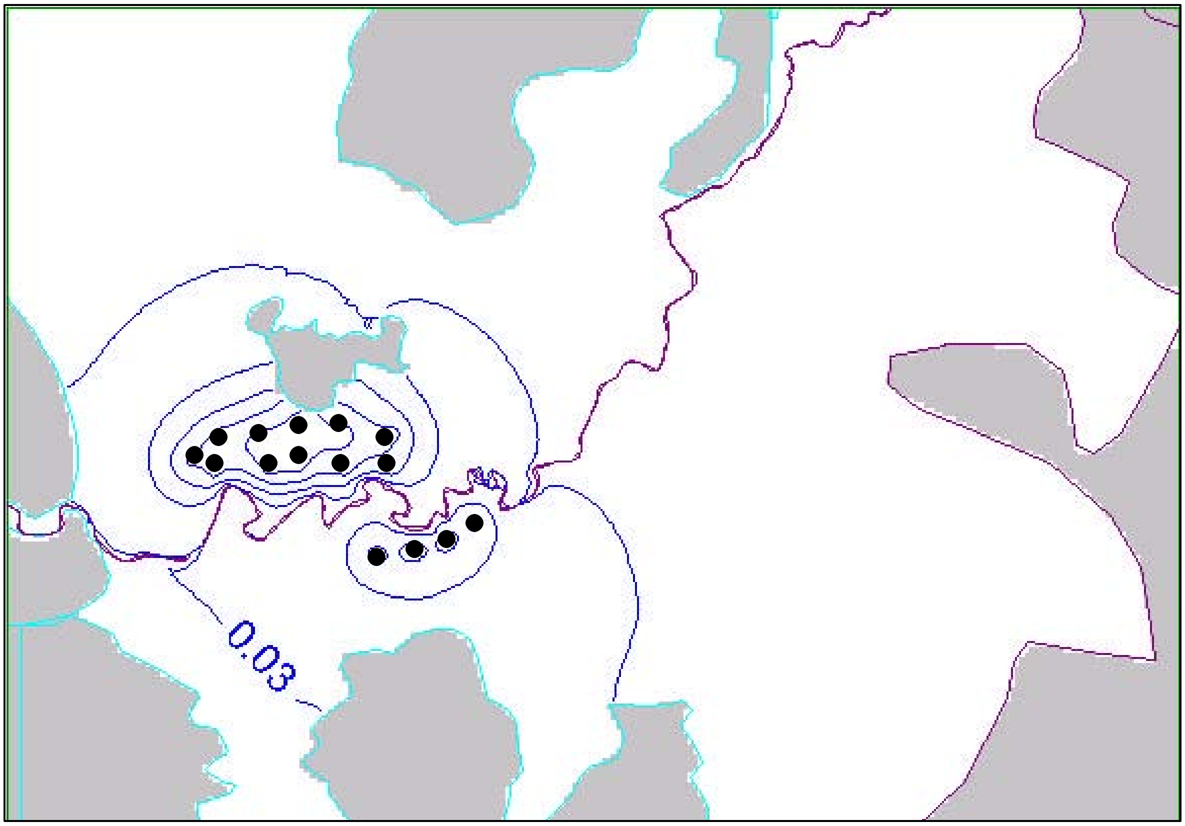
PREDICTIVE SIMULATION
POTENTIOMETRIC SURFACE
SIMULATION YEAR 20

La Lima, Honduras

USAID

BROWN AND CALDWELL

21143.311



Pumping Well

Inactive Model Cells

North

Drawdown Contours

Contour Interval = 0.5 meters

FIGURE C-13

PREDICTIVE SIMULATION
DRAWDOWN CONTOURS
SIMULATION YEAR 20

La Lima, Honduras

USAID

BROWN AND CALDWELL

*Not to Scale

the well fields. These predicted drawdowns may have an impact to existing shallow wells in the La Lima Valley by reducing the saturated zones within the screened intervals or dropping water levels below the screened intervals of some wells.

The predictive simulation indicated that the aquifer system could support the projected groundwater needs through the year 2020. Similar results can be obtained by locating wells closer to and within the urban area of La Lima. However, this is not advised due to the significant risk of degradation of groundwater quality from urban activities. Although the La Lima Valley aquifer can support the water needs into the future, it is very important that a well-head protection program be developed to protect the community's groundwater resources.

7.0 SUMMARY AND CONCLUSIONS

Based on the available data and the data collected by BC, BC feels that the conceptual model and numerical hydrogeological models can reasonably represent the Chamelecón River valley aquifer system, and therefore can be used in the planning and development of future resources. The most sustainable water resources are located in the sand unit, which currently sustains most of the production wells in the area. Areas upgradient of La Lima are also viable groundwater resources, although information on the quality of the groundwater is incomplete.

The conceptual groundwater budget indicates that of the estimated 9,752 gpm that enters the La Lima Valley aquifers through mountain front, aerial recharge and influx from up-gradient valley aquifer, approximately 1,649 gpm is currently extracted by production wells, approximately 3,210 gpm flows to the Chamelecón River and approximately 4,214 gpm flows out to the Ulua River. This result suggests that the current estimated extraction rate could be increased to approximately 2,300 gpm on a long-term, continuous basis before groundwater discharge from the La Lima aquifer system is being taken from storage.

Transient model simulations indicate that it is possible to increase groundwater production in the La Lima Valley to approximately 6,900 gpm, although this magnitude of production increase will cause significant changes in the groundwater flow system underlying the valley. Though the majority of La Lima groundwater needs can be met by continued pumping within the current urban areas, this in not advised due to the significant risk of degradation of groundwater quality from urban activities. This highlights the important need to develop a well-head protection program to protect the community's groundwater resources. Drawdowns produced by the additional pumping may impact shallow wells screened within the upper portion of the aquifer.

8.0 REFERENCES

Anderson and Woessner, 1992. Applied Groundwater Modeling, Simulation of Flow and Advective Transport, Academic Press.

Environmental Simulations, Inc., 1997. Groundwater Vistas.

McDonald, M.G. and Harbaugh, A.W., 1988. A Modular Three-dimensional Finite-Difference Groundwater Flow Model, United States Geological Survey Techniques of Water-Resources Investigations, Book 6, Chapter A1.

APPENDIX D

Water Resources Management System Users Guide

WATER RESOURCES MANAGEMENT SYSTEM USER'S GUIDE

La Lima, Honduras

June 2002

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1.0 INTRODUCTION

The Water Resources Management System (WRMS) is a desktop computer application developed to store, manage, and analyze technical information gathered and generated for this project. The application is a management tool that can be used by the municipalities and other decision-makers to sustain and manage their groundwater resources. The system is composed of both a data management system and a geographic information system linked together as one application. Through the WRMS, users can:

- Manage and generate reports for wells, storage tanks, and springs
- View well logs and well completion diagrams
- Analyze water quality and water level data
- Track statistics on water use
- View wells, water quality information, and aquifer characteristics on maps of the study area
- Identify and prioritize future well sites

The application consists of two primary components; a data management system and a geographic information system (GIS). The application is written so that the two components work together and function as one system. Data are shared back and fourth between the data management system and the GIS.

1.1 Overview

The WRMS consolidates the most critical water resource information for a municipality. It provides a central place to manage, analyze, and display water resource information in both map and tabular form. The WRMS accommodates all major types of information needed for sound water resource management including data on wells and other water sources, future demand and growth, infrastructure and organizational boundaries, and water quality and aquifer characteristics.

Because the system is designed to accommodate additional data as more information is collected and wells are created or modified in the future, it can be used to facilitate sound water resource decision-making in the future. Is easy to use and requires minimal training, which will facilitate continued system use. It uses a standard methodology for identifying and prioritizing future well sites, which will allow municipalities to continue to apply a consistent planning approach.

The WRMS is designed to work in conjunction with the findings of the Water Resources Management Report. Most of the data collected or developed for the report are contained in this system, and are available for further analysis, display, and incorporation with new data as it is collected. The system can be used to view and explore additional details of the existing water system, as well as explore in detail the conceptual model of the aquifer system and the groundwater modeling results.

The WRMS should be used to provide a common environment for communication among stakeholder agencies for water resource planning. The system provides a consistent view and methodology for analyzing water resource data. Consistently using it as a communication tool among stake-holders will make the sometimes confusing and complex technical information easier to understand. New data, such as new wells, additional sampling results, or new water level measurements should be entered into the system in order to have the most up-to-date information available for decision-making.

1.2 How to Use the Manual

This manual is divided into two parts:

- **Users Guide** – This section describes the application and use of the system from the users perspective. It explains the functionality of the system, presents step-by-step instructions for adding and managing data, creating reports, generating maps, and using the analysis tools. Anyone who needs to use the system should read this section to find the proper procedures for adding, managing, and analyzing data.

- **Administrators Guide** – This section describes the operation of the system and covers the procedures necessary to keep the system functioning properly. It is written for the person who is responsible for making sure the system is configured and operating properly.

2.0 USER GUIDE

This section explains how the system can be used to manage, analyze, and report on water resource data. First the organization of the data will be discussed, and then an overview of the functionality of the interface will be explained. Finally, the user will be walked through a series of common tasks that are typically performed using the system.

2.1 Data Organization

Figure 2-1 shows how the data are organized in the WRMS. The data organization is presented in a hierarchy shown on the left. The types of data collected at each level are shown on the right. The highest level of data is at the Municipality level. All other data entered into the system will be associated with a Municipality. Information collected at this level includes map data in the GIS system and pre capita growth/water consumption statistics for each municipality.

Within each municipality, there will be one or more service areas. A service area is a self-contained portion of the distribution system. It is comprised of wells, storage tanks, piping, and other infrastructure designed to supply a specific portion of the municipality. Typically, it is self-contained, with its own operating characteristics[1]. The user can store water usage information for each storage area (e.g. population served, pressure, and water usage).

Within each service area, there may be one or more wells and storage tanks. Most of the information stored in the WRMS is related to wells. For each well, its construction, location, and operational specifications can be stored. Water sample records and water level records can be entered, and scanned images can be loaded (e.g. well completion diagrams, photographs, and well logs). For storage tanks, operational and construction specifications can be entered.

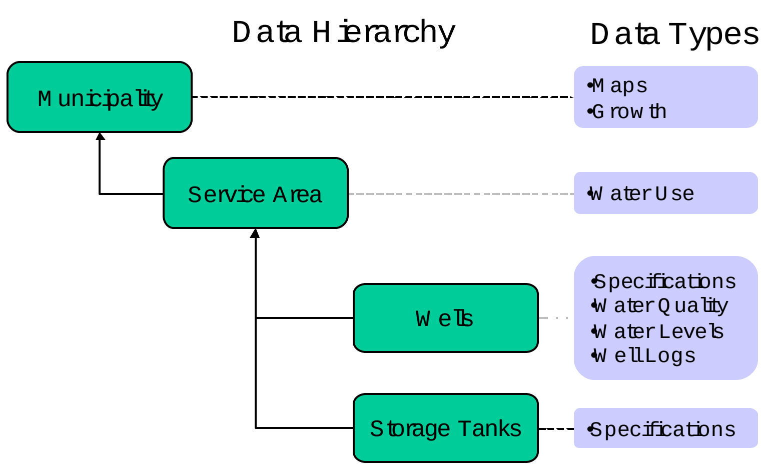

Figure 2-1. Data Organization

[1] This system is delivered with one service area defined for each municipality, which may or may not reflect the actual service area configuration for each municipality. The WRMS will work fine without changing this, however, the capability of redefining the service areas to more accurately reflect the conditions of each municipality is available. See Entering Infrastructure Data for more details.

2.2 User Interface

Once the application is started, the user is presented with a variety of options via the Main Menu at the top left-hand corner of the screen.

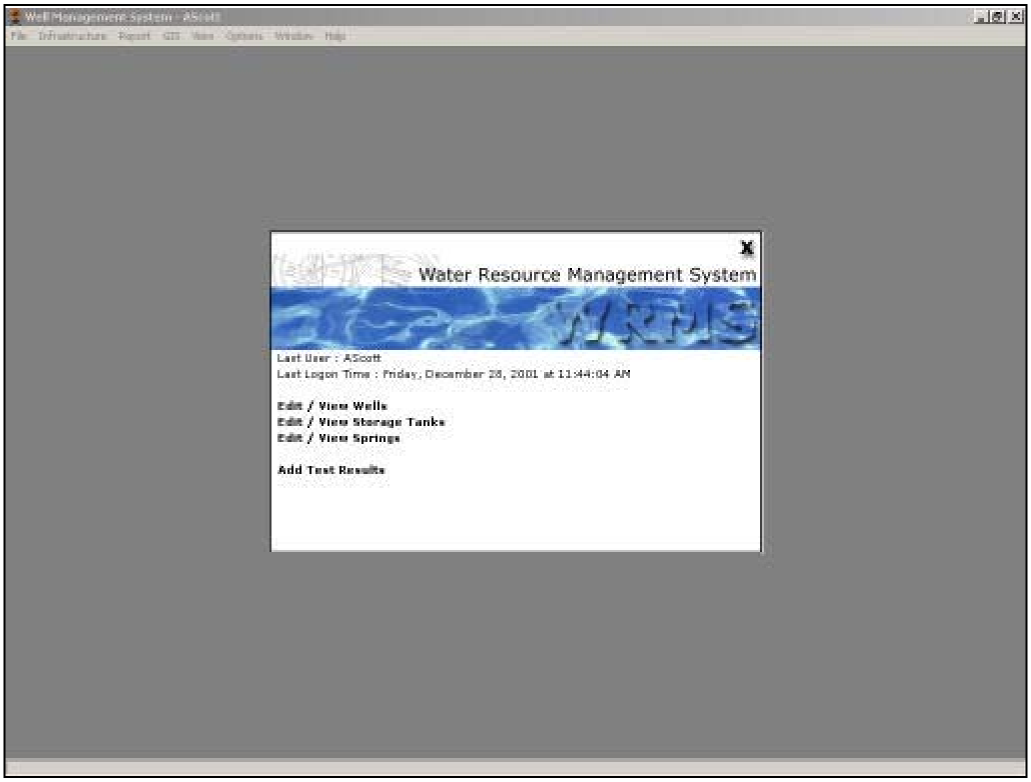

Figure 2-2. Startup Screen

The options available are:

- **FILE** – Exit the application.
- **INFRASTRUCTURE** – Used to manage data for the municipality, service areas, wells, and storage tanks.
- **REPORT** – Used to run reports and graphs for selected infrastructure data.
- **GIS** – Opens ArcView® to create maps or run the Well Site Prioritization tool.
- **VIEW** – Opens the USGS Database or the Water Resources Management Plan report.
- **OPTIONS** – Mostly an administrative area, it is where the user can change the language or to manage system configuration.
- **WINDOW** – Used to manage different application windows that are opened.
- **HELP** – Opens the help file for the WRMS.

2.3 Interface Terms

The following figure shows a typical interface screen and its components. The system functionality is selected via the **MAIN MENU** shown at the upper left-hand portion of the screen. Infrastructure components are navigated via the **DATA TREE** on the left. The **DATA TREE** allows the user to navigate through the infrastructure hierarchy. For example, each **MUNICIPALITY** contains a

SERVICE AREA, and each **SERVICE AREA** contains **WELLS** and **STORAGE TANKS**. Each element in the tree has a '+' box associated with it. Clicking on the '+' expands that branch of the tree. For example, clicking on the '+' next to **WELLS** opens a list of all wells within the selected **SERVICE AREA**. When the branch is expanded, the '+' symbol turns into a '-' symbol. Close the branch by clicking on the '-'. By expanding and contracting each branch, the user can quickly navigate to the desired information.

The area on the right is used to present information about the selected infrastructure element. In this example, the data entry screen for Well LC-1 is shown. This screen is composed of the following kinds of elements:

- **TEXT BOX**: Used for entering free-form text.
- **PICK LIST**: Used to make a select from a list. The lists are managed under **VALID VALUES** in the **OPTIONS** menu selection. See the Administrators Guide for more information.
- **CHECK BOX**: Represents a Yes (if checked) or No (if unchecked).
- **BUTTON**: Click on the button to initiate an action (e.g. Close the window, save data, etc.).

This terminology will be used throughout this Users Guide.

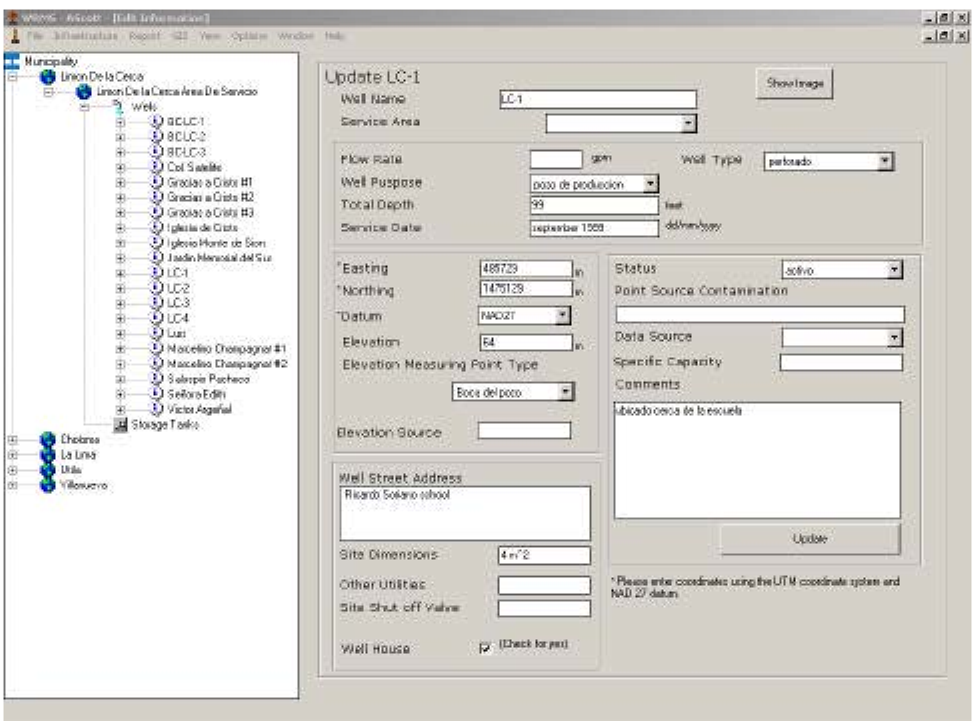

Figure 2-3. Interface Terms

Two additional terms are needed associated with the mouse-pointing device:

- **CLICK** – When instructed to click on something, point the arrow on the screen over the object and click the *left* mouse button.

- **RIGHT-CLICK** – When instructed to right-click, point the arrow on the screen over the object and click the *right* mouse button.

2.4 Common Tasks

This section describes the common tasks that can be performed using the WRMS. These are:

- Opening the application – How to start the WRMS.
- Changing the Interface Language – The WRMS interface can be translated between Spanish and English.
- Managing Infrastructure Data – Entering and managing data related to Municipalities, Service Areas, Wells, and Storage Tanks.
- Creating Reports – Generating standard reports for infrastructure data.
- Map Analysis – Using ArcView® to generate maps.
- Well Site Prioritization – Using the well site prioritization decision-support tool.
- Assessing Related Information – Opening up other applications.
- Getting Help – Accessing this manual on-line.

2.4.1 Opening the Application. This application comes already installed on the computers provided. To start the WRMS, do the following:

1. Click on the **START** button in the bottom left-hand corner of the screen to open the system menu.
2. Click on **PROGRAMS**. This will open a sub-menu of available programs and program folders
3. Click on on **WRMS**. The application will open when WRMS is clicked.

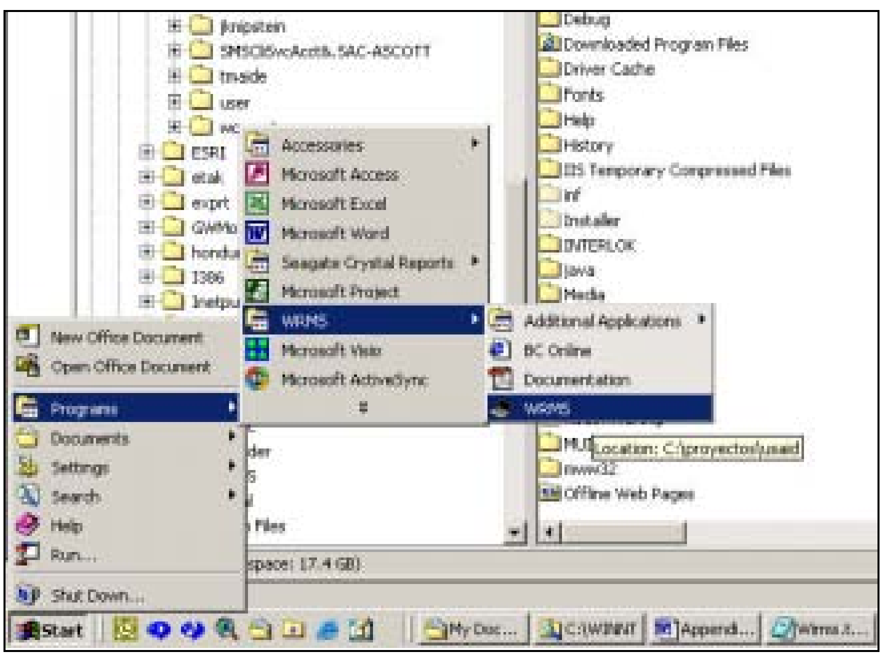

Figure 2-4. Starting the WRMS

2.4.2 Changing the Interface Language. The user may change the language used in the WRMS interface. To do this:

1. Click on **OPTIONS** from the menu. A sub-menu will appear.
2. Click on language from the sub-menu.
3. A pop window will appear with a list of available languages. Select the language desired and click **OK**.

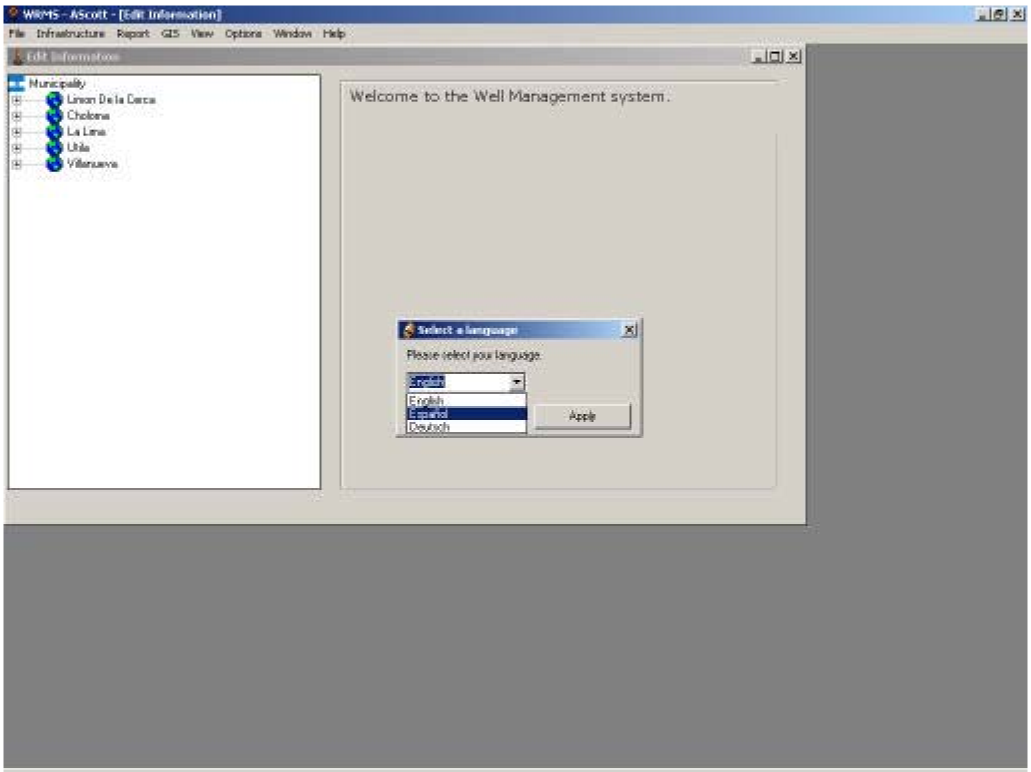

Figure 2-5. Changing the Language

The interface will be translated into the selected language.

Note: It may be necessary to close a window and re-open it for the translation to take effect. Also, if a phrase is not translated, it means that the translation has not been entered into the translation database. Please see the Administrators Guide for the steps to add a new translation.

2.4.3 Managing Infrastructure Data. Infrastructure data includes information on municipalities, service areas, wells, and storage tanks. These data are organized in a hierarchy in the database (see Data Organization, above) and are presented the same way in the user interface. To access the data entry and management screens:

1. Click on **INFRASTRUCTURE** from the **MAIN MENU**. A sub-menu for **WELLS** and **STORAGE TANKS** will appear.
2. Click on **WELLS** or **STORAGE TANKS**.

Selecting **WELLS** or **STORAGE TANKS** will open the **DATA TREE** and expand the desired branch of information. The first element of the desired type (either the first well or first storage tank) will be shown, presenting the general information for that particular record on the right. The user may then change or review any of the information associated. If data are changed, click on the **UPDATE** button to save the changes.

To navigate through the data, click on the desired branch. The branch will expand to the next level, allowing the user to view its contents. Depending upon the level selected, a data form will appear on the right. The table below shows the information provided at each level.

Table 2-1. Data Screens for Each Level

Level	Data Shown
Municipality	Growth and Water Consumption
Service Area	Service Area Characteristics
Wells	Well Depth Graph
Individual Wells	Well General Information
Individual Storage Tanks	Storage Tank General Information

2.4.3.1 Municipalities. Municipalities are the study areas defined for this project. Typically, they incorporate the urban and developed areas of a community, but may not include the entire municipal boundary. When a **MUNICIPALITY** is selected from the **DATA TREE**, water consumption data will be shown on the right. This is a simple table showing per-capita consumption per year. To enter a new record, click on the empty row on the bottom of the table. Enter the year, estimated population, and the average per-capita water consumption in gallons per day per person. The table can accommodate historical data as well as predicted growth. This information enables the user to view expected water consumption patterns over time.

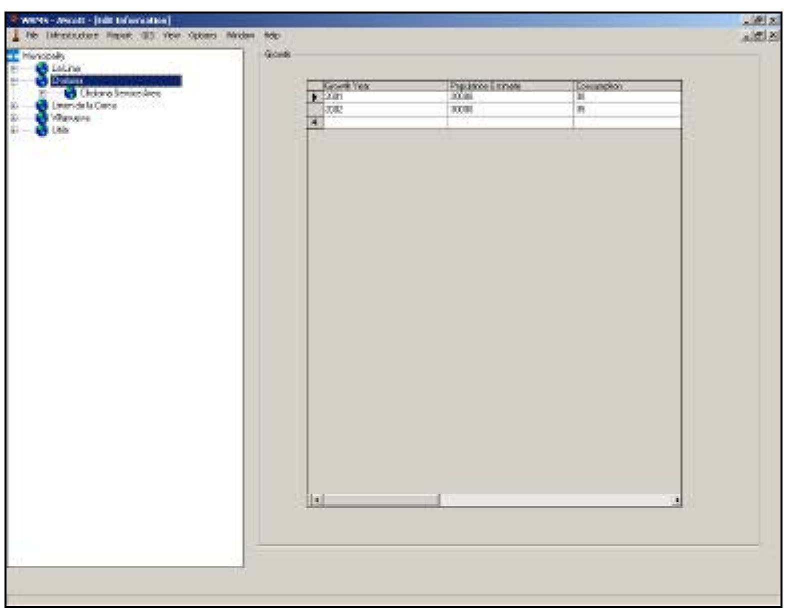

Figure 2-6. Predicted Growth Data Screen

2.4.3.2 Service Areas. To create a new **SERVICE AREA** for a **MUNICIPALITY**:

1. Click on the **MUNICIPALITY** desired, then right-click to bring up a popup menu.
2. Select **ADD SERVICE AREA**. A blank service area form will appear.

Enter the service area name and other data as desired, then click **UPDATE**. The **DATA TREE** will insert the new **SERVICE AREA**.

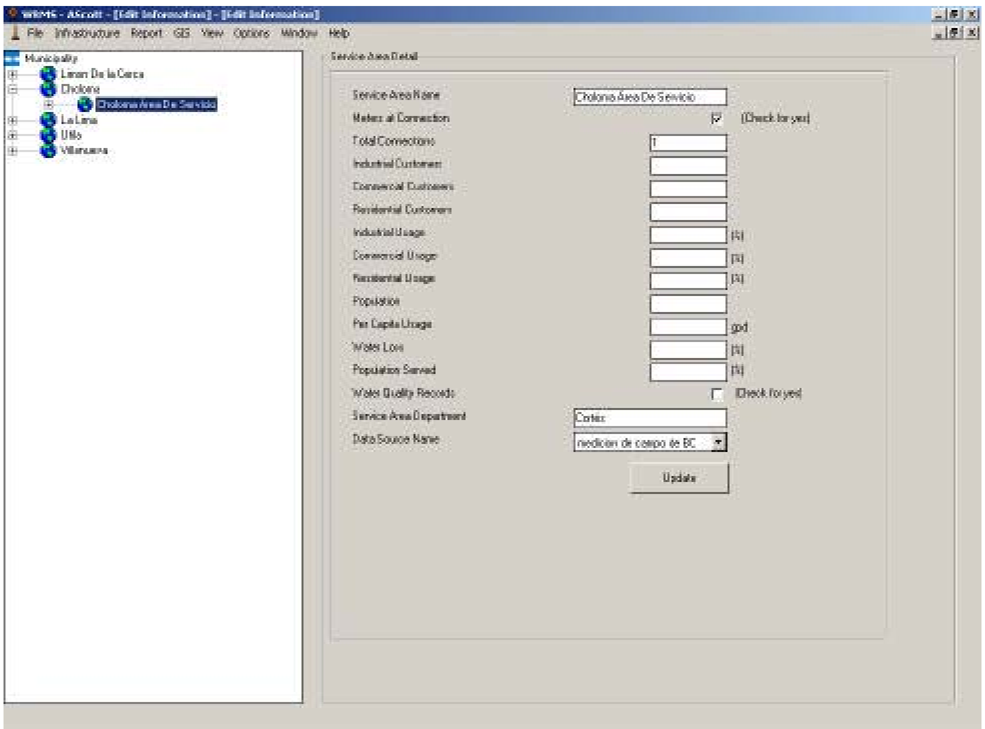

Figure 2-7. Service Area Data Screen

Clicking on an existing **SERVICE AREA** brings up a form displaying water consumption information for the area selected. This information can be entered for each service area for quick reference when evaluating service area needs. The following table describes the service area information:

Table 2-2. Service Area Data

Data Field	Description
Service Area Name	Enter the name of the Service Area
Meters at Connection (yes/no)	Check **YES** if present
Total Connections	Enter number
Industrial Customers (number)	Enter number
Commercial Customers (number)	Enter number
Residential Customers (number)	Enter number
Industrial Usage	Percent of total usage
Commercial Usage	Percent of total usage
Residential Usage	Percent of total usage

Data Field	Description
Per Capita Usage	Gallons per person per day
Percent Water Loss	Percent of total production
Percent Population Served	Percent of total service area population
Water Quality Records?	Check if water quality records are available
Service Area Municipality	Pick municipality name from pick list
Service Area Department	Pick department name from pick list
Data Source	Select data source. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.

2.4.3.3 Wells. To add a new well to a service area:

Click on the desired **SERVICE AREA** and right-click the mouse. A pop-up menu will appear.

Select **ADD WELL TO SERVICE AREA**. A blank entry form will appear. Enter the new well name and it will be added.

Click on the desired data field and enter the desired information. Click on the **UPDATE** button to save. The new well will be added to the database.

2.4.3.4 General Information. Clicking on a **SERVICE AREA** opens up two additional branches: **WELLS** and **STORAGE TANKS**. Clicking on **WELLS** will expand that branch to show all the wells associated with the service area. Clicking on an individual **WELL** opens the general information form for the well.

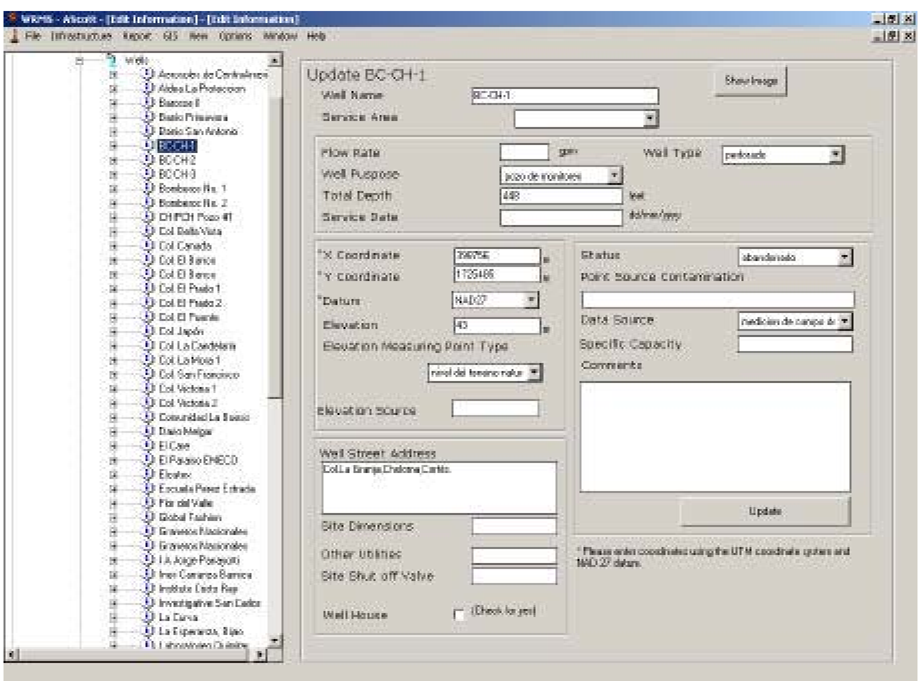

Figure 2-8. Well General Information

The table below describes the data fields available in the **WELL GENERAL INFORMATION** screen.

Table 2-3. Well General Information Data Fields

Data Field	Description
Well Name	Name of the well
Assign a New Service Area	Use the pick list to assign the well to a new service area
Flow Rate	Enter the flow rate in gallons per minute
Well Purpose	Select the purpose of the well from the list
Total Depth	Enter the total well depth in feet
Service Date	Enter the date the well went into service
Well Type	Select the type of well from the list. . If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.
Easting	Enter the easting coordinate in UTM meters, NAD27
Northing	Enter the northing coordinate in UTM meters, NAD 27
Datum	Select the datum used. If not known select unknown.
Elevation	Enter the well elevation in meters
Elevation Measuring Point Type	Select the type from the list
Elevation Source	Enter source (GPS, survey, map coordinates, etc.)
Well Street Address	Enter address, if known
Site Dimensions	Enter dimensions of site
Other Utilities	Enter other utilities present on site
Site Shut off valve	If present, describe location
Well House	Check if present
Status	Select current status of well from list
Point Source Contamination	List any potential contamination sources present
Data Source	Select data source of this information
Specific Capacity	Enter specific capacity of the well
Comments	Any additional information can go here.

Once data edits are complete, click on the **UPDATE** button to save changes.

Note: Coordinate must be entered in UTM meters using the NAD27 datum in order for the location to be properly placed on the GIS map. The user has the option of storing the coordinates using other datum, but these will not show up properly on the GIS map. It is important that these data be recorded accurately and correctly to avoid confusion about their physical location when display with other data.

2.4.3.5 Adding Images. Images and other electronic files, such as .jpg files of well completion diagrams, boring logs, spreadsheets of technical data, and site photographs can be loaded into the database for each well. To load a new image:

1. Click on the **SHOW IMAGES** button. This will open a pop-up window.
2. Click on **ADD**. A file navigation window will appear.

3. Navigate to the desired image or file.
4. Click on the image file and click the **SAVE** button.

If images are already present, they will be shown in the list. Double-click on an image to view it.

2.4.3.6 Construction. Clicking on an individual **WELL** opens these additional options:

- **CONSTRUCTION** – View/edit the well construction details
- **OPERATIONS** – View/edit the well operation details
- **SAMPLES** – View/edit the water quality samples for the well
- **WATER LEVELS** – View/edit the water level data for the well

An empty well construction record is automatically created when a new well is created. To update a construction record for a well:

1. Click on the desired **WELL** so that the **GENERAL INFORMATION** screen is showing,
2. Click **ON WELL CONSTRUCTION** in **THE DATA TREE**. The well construction data screen will appear.

Enter the desired construction data and click the **UPDATE** button. Construction details will be added for the well.

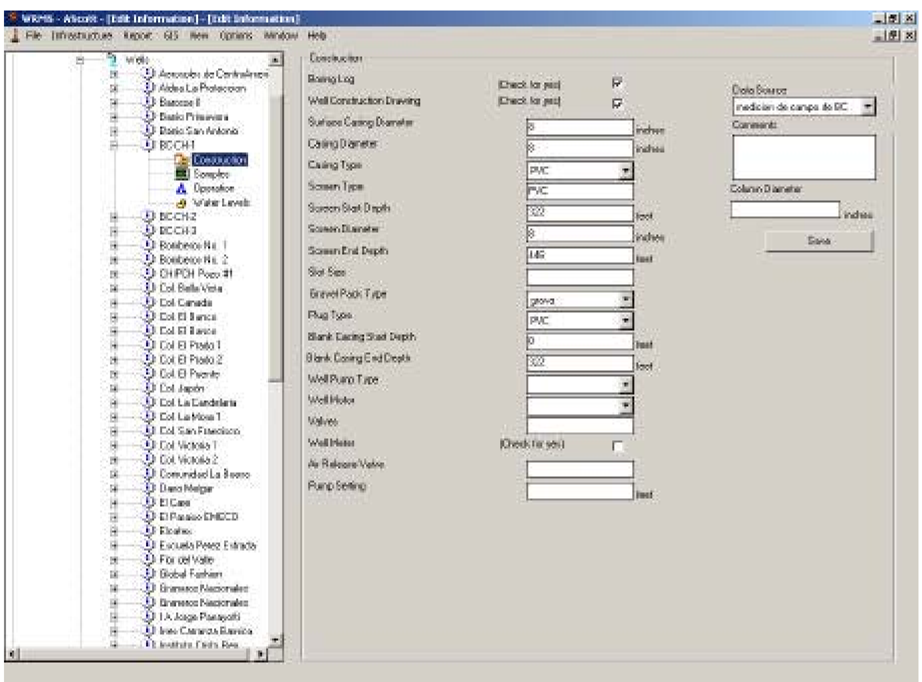

Figure 2-9. Well Construction Details Screen

The table below describes the data fields available in the **WELL CONSTRUCTION** screen.

Table 2-4. Well Construction Data Fields

Data Field	Description
Boring Log	Check (**YES**) if a boring log is available.
Well Construction Drawing	Check (**YES**) if a well construction drawing is available
Surface Casing Diameter	Enter the surface casing diameter if different from the casing diameter, in inches
Casing Diameter	Enter the casing diameter for the well, in inches
Screen Diameter	Enter the screen diameter for the well, in inches
Casing Type	Pick the casing type from the list. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.
Screen Type	Pick the screen type from the list
Screen Start Depth	Enter the start depth, in feet from the ground surface, for the first screen
Screen End Depth	Enter the end depth, in feet from the ground surface, for the last screen
Slot Size	Enter the slot size for the screen
Gravel Pack Type	Pick the gravel pack type from the list
Plug Type	Pick the plug type from the list
Start Casing Depth	Enter the start depth, in feet from the ground surface, for the beginning of the casing
End Casing Depth	Enter the end depth, in feet from the ground surface, for the end of the casing.
Well Pump Type	Pick the type of well pump from the list
Motor	Enter the rating of the motor, in horsepower (hp)
Valves	Enter the types of valves present
Well Meter	Check if the well flow is metered
Air Release Valve	If an air release valve is present, describe
Pump Setting	Enter the depth of the pump setting from the ground surface, in feet
Data Source	Pick the data source for the construction information from the list
Comments	Enter any comments about the well construction
Column Diameter	Enter the column diameter in inches

2.4.3.7 Operation. When a new well is created, an operation record is automatically created for it. To update the data for a well:

1. Click on the desired **WELL** so that the **GENERAL INFORMATION** screen is showing,
2. Click on **OPERATION** in the **DATA TREE**. The well operation data screen will appear.

Enter the desired construction data and click the **UPDATE** button. Operational information will be added for the well.

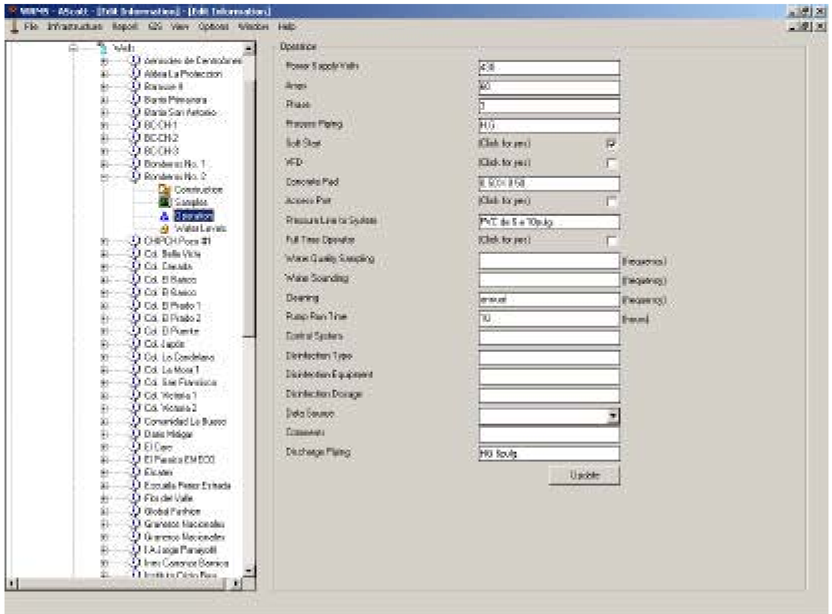

Figure 2-10. Well Operation Data Screen

The table below describes the data fields available in the **WELL OPERATION** screen.

Table 2-5. Well Operation Data Fields

Data Field	Description
Power Supply Volts	Enter the voltage of the power supply
Amps	Enter the amperage of the power supply
Phase	Enter the number of phases for the power supply
Soft Start	Check if a soft start device is present
VFD	Check in a variable flow device is present
Concrete Pad	Describe the concrete pad
Access Port	Check if an access port is present
Pressure Line to System	Describe the line to the system
Full-time Operator (yes/no)	Check (**YES**) if there is a full-time operator at the well
Frequency of Water Quality Sampling	Enter the frequency of water quality sampling (e.g. monthly, semi-annually, etc)
Frequency of Water Sounding	Enter the frequency of water level measurements
Frequency of Cleaning	Enter the frequency of cleaning
Pump Run Time	Enter the number of hours a day the pump is set to run
Control System	Describe the control system, if any
Disinfection (yes/no)	Check (**YES**) if there are any disinfection practices
Disinfection Type	Pick the type of disinfection from the list. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.

Data Field	Description
Disinfection Equipment	Describe disinfection equipment
Disinfection Dosage	Enter the amount, including units (e.g. 10 mg/l)
Data Source	Pick the data source for the construction information from the list
Comments	Enter any additional operation comments
Discharge Piping	Describe the discharge piping

2.4.3.8 Water Quality. Water quality sample results can be stored and viewed for each well. The data are organized by sampling event. Each sampling event must be entered into the system in order to record the resulting water quality. Three types of information are needed to enter water quality information:

- **CHAIN-OF-CUSTODY (COC)** – Information about the form used to describe the sample for the analyzing laboratory.
- **SAMPLE** – The type of sample taken. A COC can contain more than one sample. Multiple samples can be entered for one COC.
- **RESULTS** – The analytical results from the tests performed at the laboratory. Each sample will have one or more test results.

Please see the Sample Manual Reference for more details on water quality sampling procedures.

To enter new water quality sampling results, navigate to the desired well in the **DATA TREE** and click the '+' to open well options. Click on the **SAMPLES** option. An empty grid will be shown on the right like the one below.

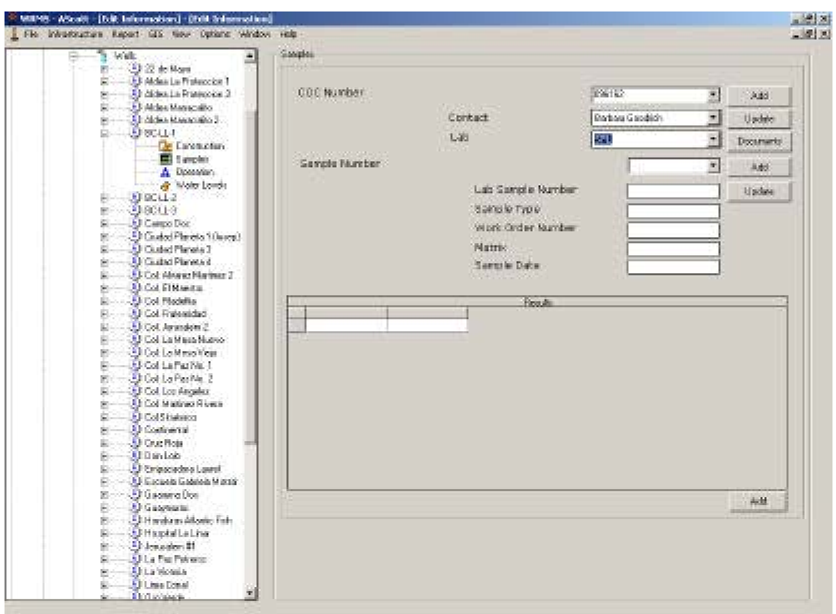

Figure 2-11. Initial Form for Water Quality Samples

Start by entering a new chain-of-custody number. Click on the upper-most **ADD** button. A popup form will appear prompting the user to enter the COC number, sampler, and analytical laboratory. Enter the data and click the **UPDATE** button.

Note: As a best practice, a unique COC number should be present on every chain of custody in order to accurately track and identify the samples when communicating with the laboratory or identify the sample results. A COC number must be entered for each sampling event. If no number is available, create a number that will be unique within the database. A good system, for example, would be to use the following pattern:

UNK-{Well Name}-{DDMMYY}

For well LC1 sampled on October 28, 2001 the COC number would be:

UNK-LC1-281001

By concatenating the well name and the sample date, a unique identifier can be created.

Descriptions of all the COC fields are shown in the table below:

Table 2-6. Chain-of-Custody Data Fields

Data Field	Description
COC Number	Unique chain-of-custody number. See Note describing required COC numbering
Contact	Pick the name of the person in responsible for the sampling. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.
Laboratory Name	Pick the name of the laboratory responsible for the analysis.

Once the COC is created a sample number must be entered. This sample number is the number for the sample identified on the COC. To enter a new sample, click on the second **ADD** button. A popup screen will appear prompting the user for sampling information.

When adding a new sample, make sure that the correct COC is selected. The sample number, sample name, laboratory sample number (enter UNKNOWN if not available) and sample date are required fields. The following table shows the sample data fields.

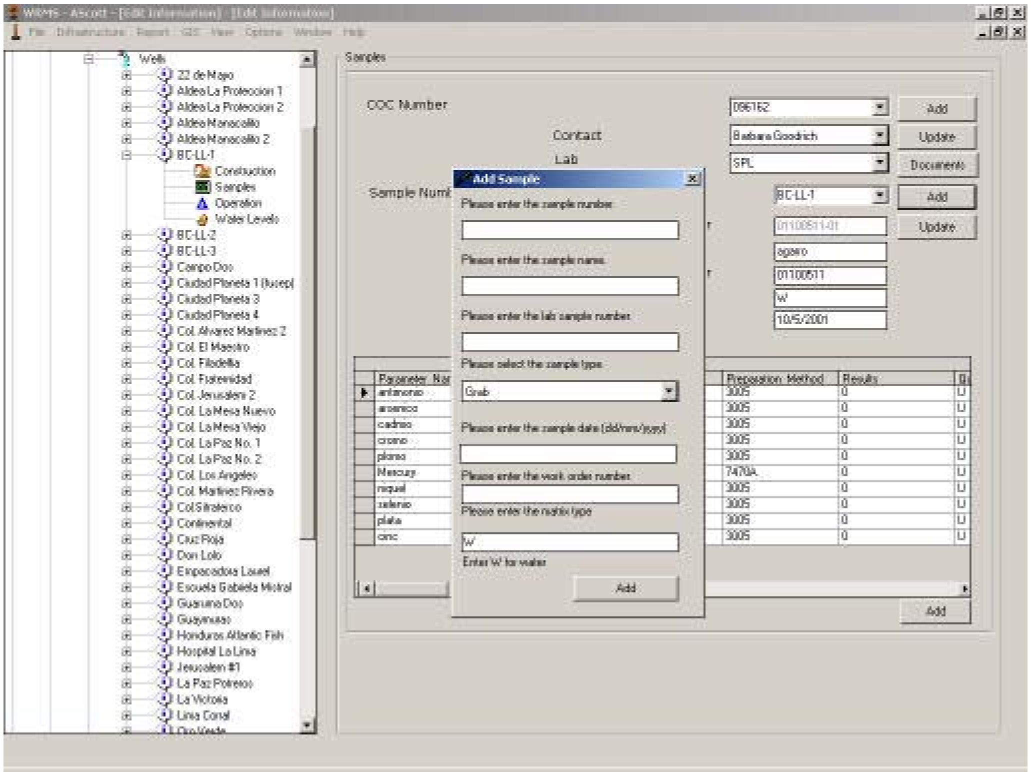

Figure 2-12. Sample Data Entry Screen

Table 2-7. Sample Information Data Fields

Data Field	Description
Sample Number	Designated sample number. This field is required
Sample Name	Name of sample, if used.
Laboratory Sample Number	Sample number designated by the laboratory. Enter UNKNOWN if not available.
Sample Type	Pick the sample type from the list. Grab sample is the most common type
Sample Date	Date sample was taken
Work Order Number	Number of the work order, if used
Matrix	Matrix of the sample. W, or Water, is most common

Once the sample is entered, analytical results can now be entered into the system. To start adding results click the third **ADD** button. A pop-up screen for sample results will be displayed.

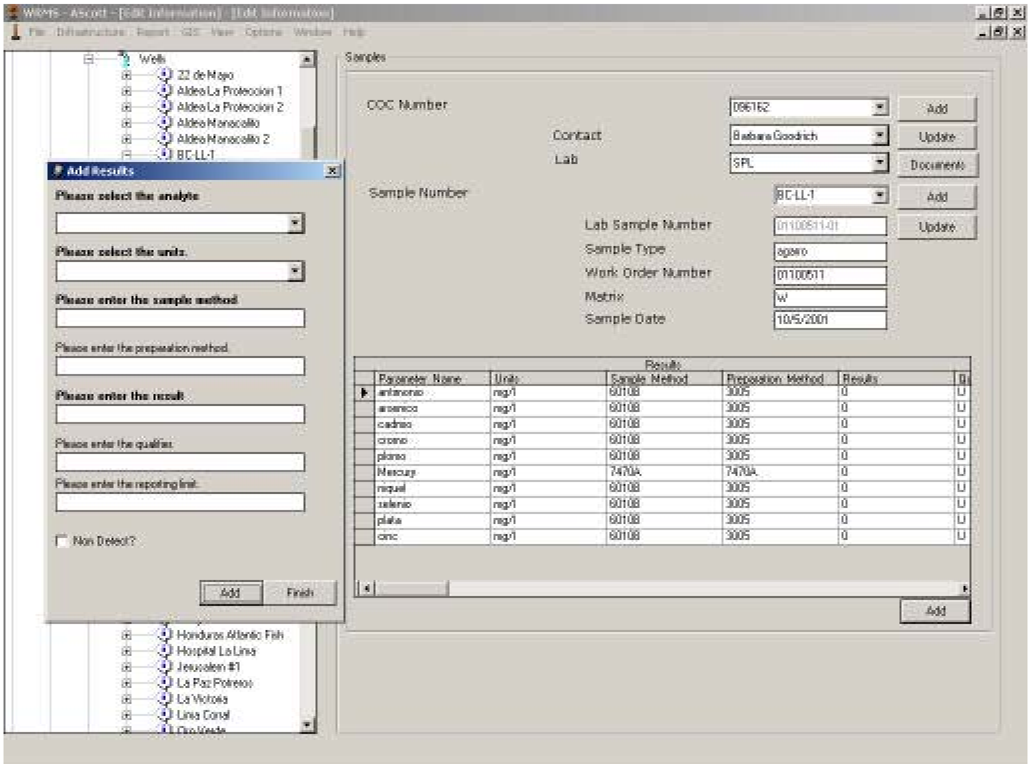

Figure 2-13. Analytical Results Data Entry Screen

The following table shows the results data fields.

Data Field	Description
Analyte Name	Pick the analyte name from the list
Units	Pick the analysis units from the list
Sample Method	Pick the analysis method from the list
Preparation Method	Pick the preparation method from the list, if known
Result	Enter the result. If it is a non-detect, enter 0, and check (YES) the ND checkbox. Otherwise, enter the value. See note below.
Qualifier	Enter any data qualifiers identified by the laboratory
Method Reporting Limit	Enter the reporting limit if known. Required for non-detects.
ND Flag	Check (YES) if the result is a non-detect.

Note: Typically a laboratory will report a non-detect as 'less than a specified reporting limit' as the result. For example, if a result of '< 5 mg/l' is reported by the laboratory, where '<' indicates that the nothing was detected and '5 mg/l' is the reporting or detection limit tested against. To report non-detects in the database:

- *Enter a zero (0) in the* **RESULTS** *field.*
- *Check (***YES***) the* **ND CHECKBOX**
- *Enter the reporting limit in the* **METHOD REPORTING LIMIT** *field.*

This procedure must be followed in order for the reports to properly format non-detect results.

To view water quality results for a well, navigate to the well in the **DATA TREE**, expand the options for the well, and click on **WATER QUALITY**. Select the desired **COC** and **SAMPLE** from the pick list. The analytical results will be displayed in the grid below.

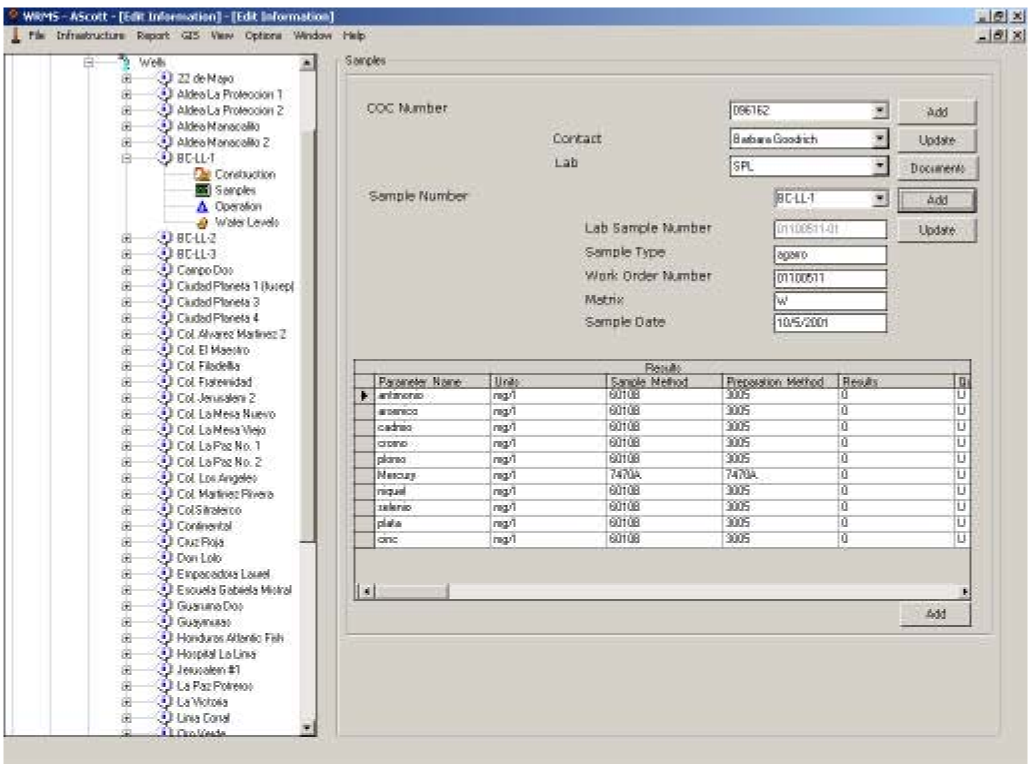

Figure 2-14. Analytical Results Table

To view an analytical summary for the well, go to the **REPORT** menu and select the **HITS REPORT**. See the Creating Reports section below for further details.

2.4.3.9 Water Levels. Water level measurements can be stored for each well by clicking on the **WATER LEVELS** option under the desired well in the **DATA TREE**. This will open a table of water levels for the well. To add one, click on the **ADD** button. A pop-up window will appear, prompting for entry of a new water level measurement. Enter the data and click on the **OK** button to save the entry. The following table shows the data elements associated with water levels.

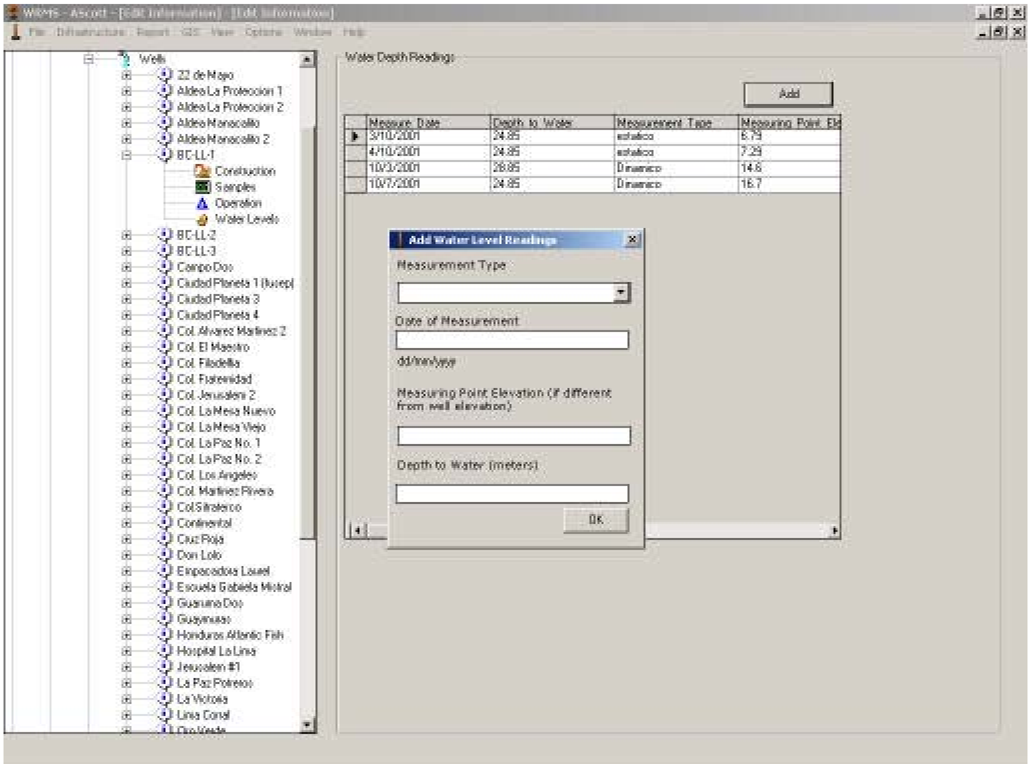

Figure 2-15. Water Level Measurement Data Entry Form

Data Field	Description
Measure Date	Enter the date the measurement was taken (DD/MM/YYYY)
Water Level	Enter the depth to water, in meters
Measurement Type	Pick the type of measurement (e.g. static or dynamic)
Measuring Point Elevation	Enter the elevation of the measuring point, in feet, if different from the well elevation. This is important in order to accurately identify the water table elevation at the well.

2.4.3.10 Storage Tanks. Storage tanks within a service area are also stored in the WRMS. To navigate to storage tanks, expand the **STORAGE TANKS** branch of a particular service area.

To enter a new storage tank, click on the **SERVICE AREA** and right-click the mouse. A popup menu will appear. Select **ENTER STORAGE TANK**. A blank storage tank form will appear, prompting for the name of the new storage tank. Enter the name and click **OK**. A new storage tank will be entered into the database.

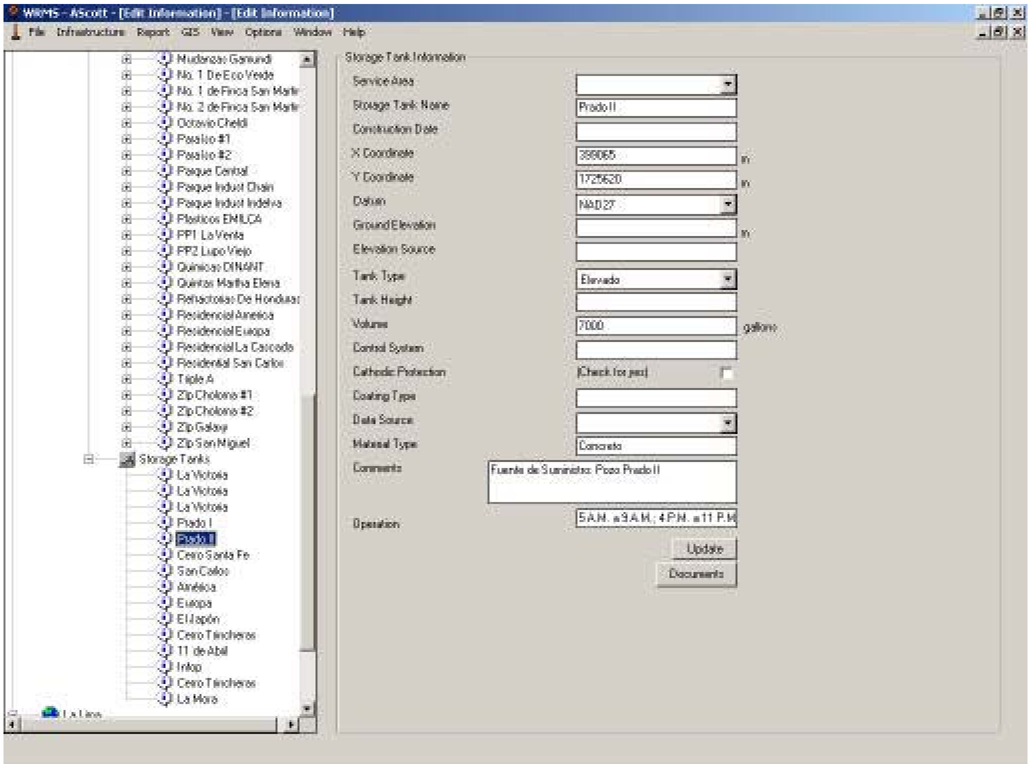

Figure 2-16. Storage Tank Data Entry Screen

The following table shows the data elements for storage tanks:

Data Field	Description
Service Area	Pick a service area from the list to change the designated service area
Storage Tank Name	Enter the name of the storage tank
Construction Date	Enter the construction date
Easting	Enter the Easting Coordinate in UTM meters., NAD27 Datum.
Northing	Enter the Northing Coordinate in UTM meters, NAD27 Datum.
Datum	Enter the Datum (e.g. NAD 27, WGS 84)
Elevation	Enter the elevation in meters
Elevation Source	Enter the source of elevation data (GPS, survey, map coordinates, etc)
Tank Type	Pick the type of tank from the list
Tank Height	Enter the height of the tank in meters
Volume	Enter the volume of the tank in gallons
Control System	Describe the Control System, if any
Cathodic Protection	Check (YES) if cathodic protection is available
Coating Type	Pick the type of coating from the list
Material Type	Pick the type of material from the list
Operation	Enter the hours of operation or enter continuous if operated 24 hours a day
Comments	Enter other descriptive information here

Data Field	Description
Data Source	Pick the source of the data. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.

Note: Coordinate must be entered in UTM meters using the NAD27 datum in order for the location to be properly placed on the GIS map. The user has the option of storing the coordinates using other datum, but these will not show up properly on the GIS map. It is important that these data be recorded accurately and correctly to avoid confusion about their physical location when display with other data.

2.4.4 Creating Reports. The WRMS allows the user to create standard reports from information in the database. These reports are tabular or graphical output that can be viewed on screen or printed to a standard printer.

The following reports are available:

- **HITS REPORT** – Lists all the positive analytical results for a selected well.
- **ANALYTE TREND** – Presents a linear graph showing concentration over time for a selected analyte for a well.
- **WELL CONSTRUCTION** – Print out well construction specifications for a set of wells.
- **WELL EQUIPMENT** – Lists equipment installed on selected wells.
- **WELL OPERATIONS** – Presents operational, maintenance, and cleaning information for wells.
- **STORAGE TANKS** – Lists storage tank specifications.
- **MUNICIPAL GROWTH** – Shows historical and projected growth and consumption information for municipalities.
- **SERVICE AREA STATISTICS** – Lists water consumption and use information for a service area.

Each report will be created using a similar process. To create a report:

1. Click on **REPORTS** on the main menu. The reports submenu will open up.
2. Click on the desired report from the submenu.
3. Once a report is selected, a series of popup windows will open prompting the user to make selections. For example, the **ANALYTE TREND REPORT** prompts the user to select one or more wells and then one or more analytes to display.
4. When selection is complete, the report will be generated for the wells identified.

2.4.5 Map Analysis. The WRMS can be used to create customized maps of water resource data. This is done using ESRI's ArcView® software. ArcView® is a geographic information system (GIS) used to view, analyze, and print customized maps and data.

ArcView® is integrated into the WRMS so that the user can launch a customized project from the WRMS user interface. This will open ArcView® showing all available GIS data for the municipality. The user will then turn on or off specific layers, change the map extent, interactively query the database for wells or storage tanks, and print out maps on a standard printer.

In order to the most flexibility and to leverage the existing capability of the ArcView® software, the standard ArcView® user interface has been used with minor enhancements. This users guide will present a brief overview of the inherent capabilities of ArcView®. For a detailed discussion using ArcView®, please see 'USING ARCVIEW GIS' users guide that comes with ArcView® or access the on-line help by clicking on **HELP; HELP TOPICS** from the menu bar.

The ArcView® system draws data from the WRMS database. For example, the coordinates for wells and storage tanks are derived directly from the database. Other information can be queried or viewed on the maps as well.

To open ArcView® from the WRMS, click on **GIS** from the main menu. A submenu will appear. Click on **BASE MAP**. This will open ArcView® and show all available data.

The figure below shows the main components of the ArcView® interface:

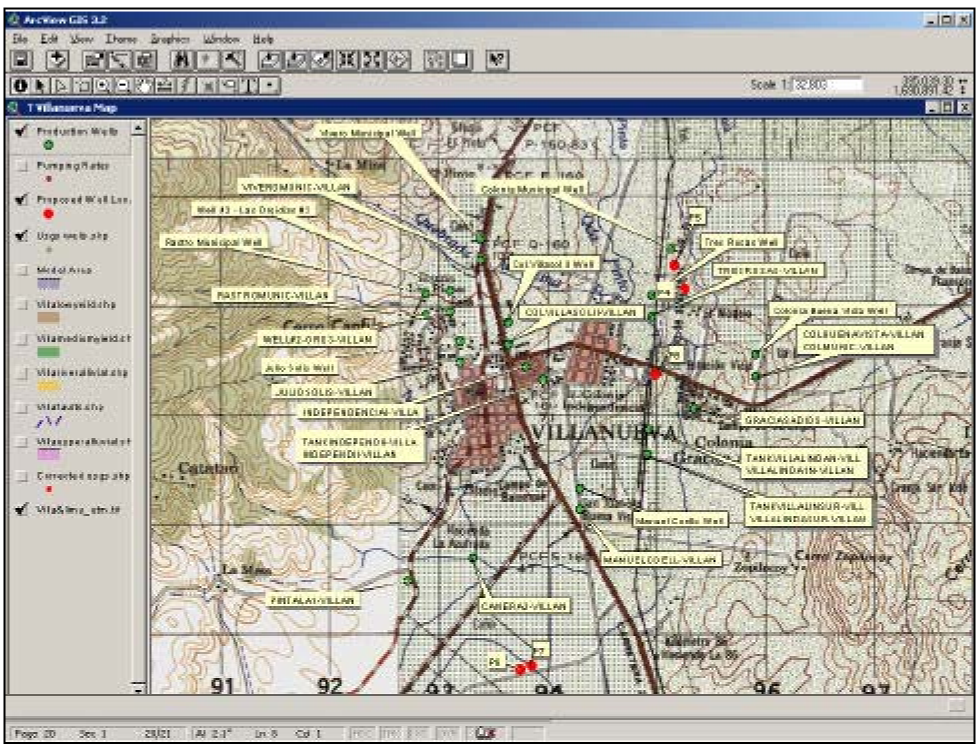

Figure 2-17. ArcView® Interface

The **MENU BAR**, **BUTTON BAR**, and **TOOL BAR** contain functions and controls for manipulating the map information, which is displayed in the map display area. The **LEGEND** is used to turn on and off data layers, and to change colors or symbols. The **MAP DISPLAY AREA** is where the map's elements are displayed.

Below, some of the most common ArcView® functionality is described, to enable the user to perform basic operations. Detailed description of ArcView® is beyond the scope of this document.

2.4.5.1 Close the ArcView® Interface. ArcView® is opened automatically when **BASE MAP** is selected from the **GIS** option on the WRMS main menu. This will open a separate ArcView® session every time the menu choice is selected. ArcView® and the WRMS window can both be open and operational simultaneously. To close the ArcView® session, select **FILE; EXIT** from the ArcView® Menu Bar. Alternatively, click on the 'X' in the upper right corner of the window. The user may be prompted to save changes before exiting. Saving changes will enable ArcView® to open to the same settings that were in place when the session was closed. Otherwise, ArcView® reverts to the previously saved settings.

2.4.5.2 Save Changes. The user can save changes made during the ArcView® session at any time. Either click on the **SAVE** button on the tool bar, or select **FILE; SAVE PROJECT** from the menu bar

2.4.5.3 Turn On or Off Layers. Each map layer that can be displayed is shown in the legend on the left side of the screen. Turn on each layer by clicking on the checkbox to check it. The map display area will be redrawn with the new layer shown. Uncheck the box to turn off the layer.

Each map layer (called a 'Theme' in ArcView®) corresponds to a source data file, called a Shapefile. Shapefiles each have an extension (file suffix) of 'shp' and are stored as regular files on the computer system. The shapefile contains the graphics and attribute data necessary to select and display information in the map display area. Please see the 'USING ARCVIEW GIS' users guide or access the on-line help (by clicking on **HELP; HELP TOPICS** from the menu bar) for more information on manipulating and adding shapefiles.

2.4.5.4 Change Symbol. The symbols for each of the map layers can also be changed. To do so, click on the layer so that it is highlighted by a box, then click on the **EDIT LEDGEND** button on the tool bar. This will open the legend editor pop-up window. Double click on the symbol (put the pointer on the symbol and click the left mouse button twice rapidly) to open the symbol window. Chose a new symbol, color, or line symbol and click the 'X' in the upper right hand corner of the symbol window. When the symbol window has closed, click on the **APPLY** button on the legend editor window to update the map with the new symbol. Close the legend editor window by clicking on the 'X' in the upper right hand corner.

2.4.5.5 Zoom In or Out. The geographical extent of the map view can be changed by zooming in or out. To zoom in (examine a smaller area in more detail), click on the **ZOOM IN** button on the tool bar. The cursor will change to a cross. Place the cursor on the new upper left-hand corner, press *and hold* the left mouse button. Drag down and to the right to define the new area for the map. When the button is released, the map will be redrawn to the new boundaries in the map display area. To return to the previous image, click on the **PREVIOUS EXTENT** button on the button bar.

To zoom out (see more area), click on the **ZOOM OUT** button on the tool bar. Place the pointer in the center of the map display area and click the mouse. The area will be enlarged by a power of two. Continue to zoom out until the appropriate display is shown.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.6 Pan. The user may want to move to a new area of the map without changing the scale of the display. This is called a pan. To pan, click on the **PAN** button on the tool bar . The pointer will turn into a hand.

Place the hand on the location on the map that will become the new center in the map display. Press *and hold* the left mouse button. Drag the location to the center of the display. The map will be dragged over to become the new center of the display.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.7 Identify Data. ArcView® allows the user to explore associated data for any of the data layers shown. To do so, click on the desired data layer in the **LEGEND** so that it is highlighted with a box. Then, click on the **IDENTIFY** button on the tool bar . The pointer will become an 'i' with cross-hairs. Put the pointer over the desired feature and click the mouse. A popup window will appear showing related data for the feature selected.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.8 Measure Length. To measure the distance between map features, click on the **MEASURE** button on the tool bar . The pointer will turn into a ruler. Click on a point to begin measurement. Click as many times as needed to define the line (the measurement does not have to be a straight line). The segment length and total length will be shown on the status bar on the bottom left-hand side of the screen. When finished double-click the last point.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.9 Print a Map. There are two ways to print a map. Either print the current view or create a layout for printing. Printing the current view is a quick way to produce a paper copy. Using a layout allows the user to produce a more formal map.

To print the current view, click on **FILE; PRINT** from the menu bar. A printer popup window will appear. Click **OK** to print

To create a default layout for printing, click on **VIEW; LAYOUT** from the menu bar. This will open the **LAYOUT MANAGER** popup window. Select the **LAYOUT TEMPLATE** and click **OK**. Select a new layout and click **OK**. A new layout will be created for printing. To print the layout, make sure the layout window is the active window (click on the layout once to make sure). Then print using the **FILE; PRINT** menu selection from the menu bar.

Close the layout by clicking the 'X' in the upper right-hand corner of the window.

For a detailed discussion on customizing layouts, please see 'USING ARCVIEW GIS' users guide that comes with ArcView® or access the on-line help by clicking on **HELP; HELP TOPICS** from the menu bar.

2.4.5.10 Well Classification. Well data can be displayed in the current view. The wells will be color coded by the type of data selected. The types of data that can be displayed for wells are:

- **TOTAL DEPTH** – Plots the wells by total well depth (in feet),
- **STATUS** – Plots the wells by their status (e.g. active, abandoned),
- **WELL TYPE** – Plots the wells by their construction type (e.g. bored, hand dug),
- **WATER LEVEL** – Plots the wells by their water level elevation,
- **WQ PARAMETER** – Plots the wells by the concentration of a selected analyte.

To plot well classifications, do the following:

1. Select **WELL ANALYSIS** from the menu bar. This will open a sub-menu.
2. Select **WELL CLASSIFICATION** from the submenu. A pop-up window will appear.
3. Select the desired well classification. Once selected, the well symbols will be color coded by the type of classification selected.
4. (For **WQ PARAMETER** only**)** An additional menu will appear listing the analytes that can be plotted. Select the desired analyte.
5. (For **WQ PARAMETER** only**)** Once an analyte is selected, a threshold value or reporting limit can be entered. Enter the limit or value and click ok. Wells with analytical data above the limit will be colored red.

2.4.6 Well Site Prioritization. The purpose of the well site prioritization tool is to identify and prioritize candidate locations for new wells based on a user-defined set of selection criteria. The typical process for evaluating well sites is to evaluate each site against a list of specified criteria. Each site gets a numerical score for each item in the list based on how well it meets the specification. The scores are then totaled for each site, and the site with the best score becomes the best candidate for new well facilities.

An example matrix of this prioritization approach is shown in the table below.

Criterion	Multiplier	Site 1		Site 2		Site 3		Site 4	
		Rank	Value	Rank	Value	Rank	Value	Rank	Value
Pumping Cost	1	2	2	2	2	2	2	1	1
Proximity to Existing Pipelines	1	3	3	3	3	2	2	2	2
Land Ownership	2	3	6	3	6	3	6	2	4
Groundwater Quality	3	4	12	4	12	4	12	3	9
Impacts on Existing Wells	4	1	4	1	4	1	4	0	0
Aquifer Characteristics	8	5	40	5	40	5	40	4	32
Aquifer Thickness	10	3	40	1	10	3	30	2	20
Total			**97**		**77**		**96**		**68**

The candidate sites are listed across the top of the matrix and the criteria to be scored are listed on the left. Each criterion is assigned a weighting factor shown in the multiplier column above. This multiplier enables the criterion that is most important to contribute the most to the final score, and thus have the most influence on the prioritization. Each site is assigned a rank, which is multiplied by the multiplier to get an overall value for each individual criterion. The values are then summarized to a final score for each site, which is used to determine the sites that best meet the criteria.

The well site prioritization tool performs this process on the entire region to be evaluated. Each criterion in the matrix table is represented by an ArcView® shapefile theme (Please see 'Turning on or off layers in the section above for a description of shapefiles[2]). In some cases, an item from the shapefile's attribute table will need to be identified. The tool will process each shapefile into a grid (Grids are discussed in the ArcView® 'USING SPATIAL ANALYST' users guide) is developed for the entire study area, and each cell in the grid is evaluated and scored against the criteria. The scores are then added together and the cells are categorized based on how well they meet the criterion. These categories are then displayed on the basemap. The areas with the highest total scores (green) are the best candidates for new well production, and the worst are shown in red.

2.4.6.1 Entering Criterion. The Well Site Prioritization Tool already contains an example set of pre-configured criteria for analysis and decision-making. The user may start with these and make changes to evaluate the study area. This section describes in detail the concepts and procedures involved in creating and manipulating new criteria. The last part of this section describes the user interface and how to change criterion parameters.

When entering criteria, there are three types of criteria evaluation methods used in the model. These are shown in the table below:

Table 2-8. Types of Analysis Methods Used in the Well Site Prioritization Tool

Method	Description	Example	Shapefile Type	Shapefile Item	Fields Used
Value	Areas that *EQUAL* a specific value are assigned a specific rank	Any area that falls within a municipal boundary.	Polygon	Any text item	Text Value

[2] Note: Adding and defining criteria in the Well Site Prioritization tool requires an understanding of ArcView® shapefile construction, which is beyond the scope of this manual. . For a detailed discussion, please see 'USING ARCVIEW GIS' users guide that comes with ArcView® or access the on-line help by clicking on HELP; HELP TOPICS from the menu bar.

Method	Description	Example	Shapefile Type	Shapefile Item	Fields Used
Range	If the value falls within a specific *RANGE*, it is assigned a specific rank	Aquifers greater than 150 feet thick are best; aquifers between 100 and 150 feet are good; anything less in unacceptable	Line	Any numeric item	Low Value and High Value
Buffer	Used to assign rankings based on *DISTANCE FROM* a map feature	New well sites should be within 500 meters of existing infrastructure	Line or Point	None required	Buffer, Text Value (optional)

The first step in defining criteria for the model is to complete a worksheet like the example shown below. Blank forms are located in the back of this manual. In the first column, list the criterion or theme name and the significance of the criterion by assigning a multiplier. Next, select the method to be used from the table above. Next, identify the shapefile to be used in the analysis (the type of shapefile is specified for each method in the table above). Identify an attribute item to be used in the evaluation, if required by the method. Then, identify the appropriate key word for the selected method from the description field in the table above (the *CAPITALIZED / ITALICIZED* words). Next, using as many lines as necessary, fill in the possible values and their corresponding rank. Remember, these values must be present with the exact spelling and case in the attribute field selected.

In the example, there are five criterion specified, but the user can enter as many sets of criteria required for the analysis. It is even permissible to enter multiple sets of criteria for the same type of information. For example, if there are multiple aquifers present, the user can enter a set of aquifer characteristics (e.g. specific capacity) and water quality parameters for each aquifer as separate criteria.

Table 2-9. Example Worksheet for Defining Criteria for Well Site Prioritization

Criterion/ Theme	Weight/ Multiplier	Method	Shape File Name	Item for evaluation	Key Words	Value	Rank
Municipal Boundary	9	Value	boundary.shp	ID	EQUALS		
						"IN"	10
Specific Capacity	7	Range	aquifer.shp	Value	RANGE		
						0 - 50	1
						50-100	5
						100-200	7
						200-10000	10
Infrastructure	4	Buffer	infrastructure.shp		DISTANCE FROM		
						< 500	10
						> 500	0
Water Quality	4	Value	quality.shp	Value	EQUALS		
						"EXCELLENT"	10
						"GOOD"	5
						"POOR"	0
Supply Wells	5	Range	wells.shp	Status	DISTANCE FROM		
						< 100	0
						> 100	10

Once the sheet has been completed and the multipliers and ranks have been satisfactorily assigned, the data can be input into the WRMS. To do so, click on **GIS** from the main menu and pick **WEIGHTED VALUES**. The data entry form shown below will open.

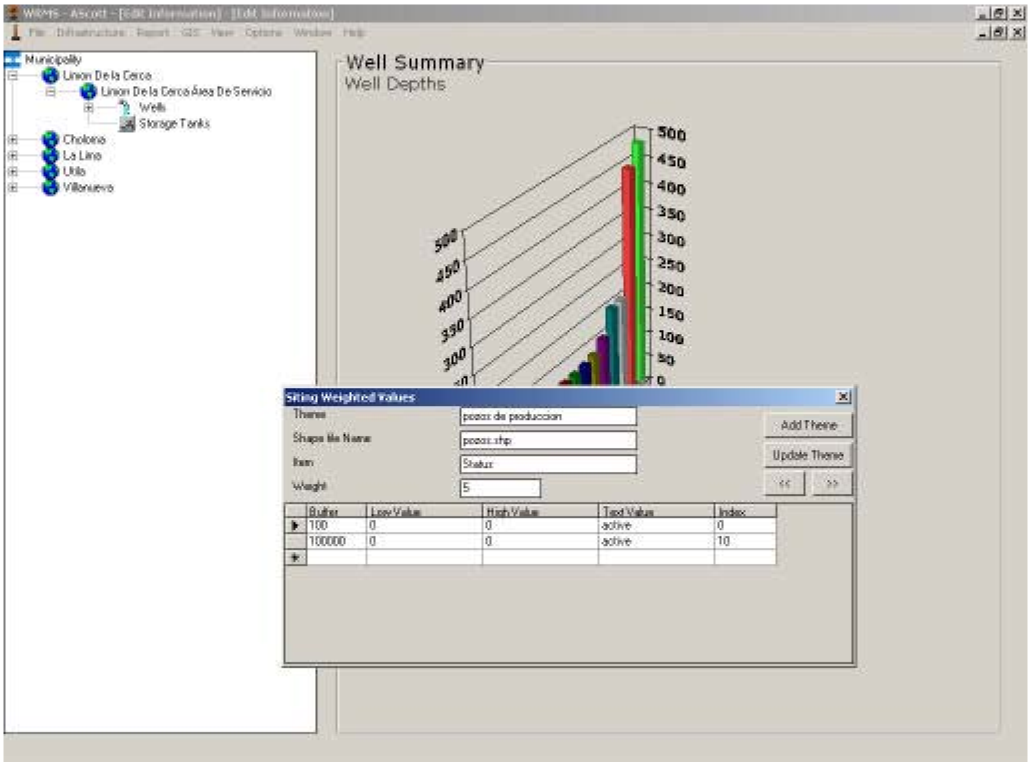

Figure 2-18. Well Siting Criterion Data Entry Screen

To enter a new criterion, do the following:

1. Click on the **ADD THEME** button. A pop-up window will appear.
2. Enter the theme name, shapefile name, field used (if any) and the weight value for the criterion.
3. Click on the **SAVE** button to store the new record.

To update a theme, enter the changes and click on the **UPDATE THEME** button.

To navigate between criteria records, click on the forward (>>) and back (<<) buttons.

1. To specify the parameters for the new criterion, click on the blank row and start entering data

Once the criteria are entered, use the same procedure to make updates and adjustments to the ranking and multiplier fields to calibrate or tune the model.

2.4.6.2 Performing the Analysis. Once the criteria are specified, the site prioritization process can be run. To start the process:

2. Click on **GIS** from the main menu and select **WELL SITE PRIORITIZATION**. An ArcView® GIS session will be initiated.
3. Select **WELL ANALYSIS** from the **MENU BAR**.
4. The analysis will begin. When completed, a new layer will be added to the map display area with its corresponding scores in the legend. The values are color-coded, based on the colors shown in the legend. The higher the values, the better the match to the specified criteria.

Typical results are shown in the figure below

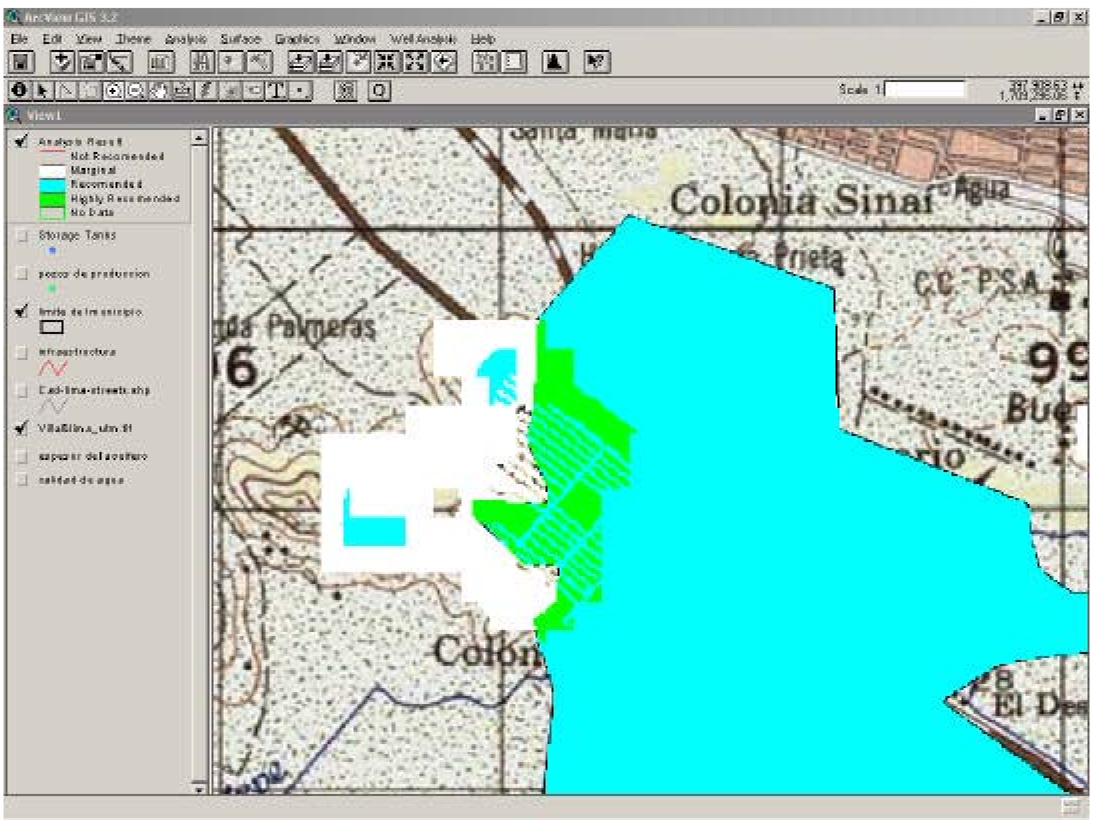

Figure 2-19. Well Site Prioritization Results

2.4.6.3 Querying the Results. The user may adjust the criteria and run the model as many times as necessary to identify reasonable ranking and multiplier values. In order to explore the results and identify the most significant contributing criteria for any location, a criteria query tool has been provided. To use the tool perform the following steps:

1. While in the ArcView® session, click on the criteria query tool button in the tool bar [Q].

2. Locate the pointer over the location to be explored and click the mouse. A series of pop-up windows will appear displaying the criteria, the value, the weight, and total value for the point selected.

Typical results are shown in the figure below.

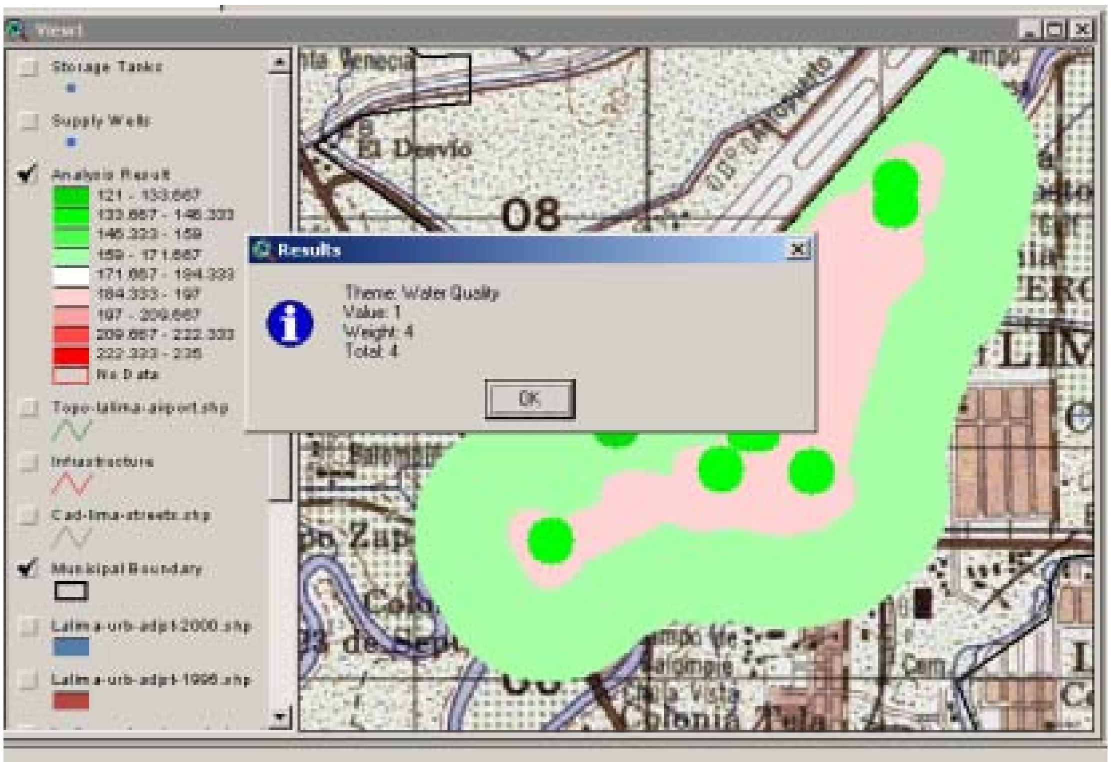

Figure 2-20. Using the Query Tool for Exploring the Siting Analysis

Using this tool, the user can evaluate the scoring characteristics for any location in the study area.

2.4.7 Assessing Related Information. The WRMS provides access to the GW Monitor – the USGS database of water supply wells – and the Water Resources Management Plan developed as part of this project. GW Monitor is an Access database that contains specifications on many of the water supply wells throughout Honduras. Many of the wells identified in WRMS are also present in GW Monitor, and it will be useful to compare the information between the two databases. To access GW Monitor, click on VIEW option from the WRMS main menu, then select USGS DATA. The GW Monitor application will open in a new window.

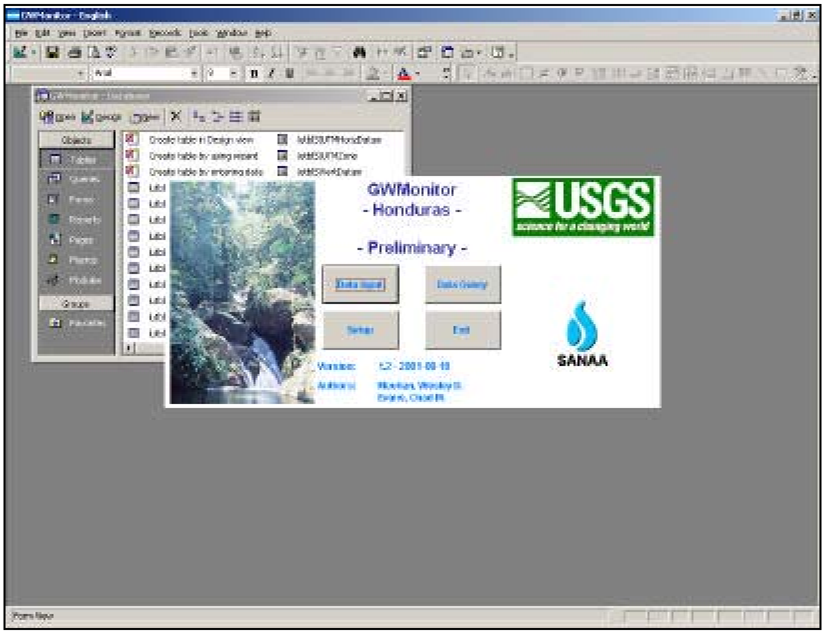

Figure 2-21. GW Monitor; the USGS Wells Database for Honduras

Once open, wells in the GW Monitor database can be queried through the functionality provided by the USGS. Please contact the USGS for information on how to use the GW Monitor database.

The Water Resources Management Plan is a report developed for each municipality containing a summary of water resource information, analysis of sustainable yield and aquifer characteristics, and recommendations for water resource management programs. The Water Resources Management Plan and WRMS are to be used in conjunction with each other. There are detailed data in the WRMS discussed and summarized in the plan, and recommendations from the plan can be explored using the WRMS. To access the Water Resources Management Plan, click on the **VIEW** button from the main menu, then select **WATER RESOURCES MANAGEMENT PLAN**. The plan will be opened in PDF format for viewing.

2.4.8 Getting Help

There are two type of user assistance available in the WRMS; assistance with the application and assistance with the ArcView® software.

2.4.8.1 WRMS Help. This users guide is available in PDF format from within the WRMS. To access help, click on **HELP** from the main menu, then select **USERS GUIDE**. The users guide will then open up in a new window. To access version information regarding the WRMS application, click on **HELP** from the main menu, then select **ABOUT**. This will open a popup screen showing the application version.

2.4.8.2 ArcView® Help. As mentioned previously, comprehensive discussions of ArcView® structure and functionality is available on-line from the ArcView® application. To access, click on **HELP** from the menu bar, then select **HELP TOPICS**. This will open a new window with help documentation.

3.0 ADMINISTRATORS GUIDE

3.1 Architecture

As mentioned previously, the data management system used in the WRMS is Microsoft Access, which is a relational database designed to efficiently manage complex data. The data are stored in a series of tables. Each table stores a different type of information, and each table is linked to others by a key field that defines the relationship. For example, one table contains a record of each well, while another table contains all the water level measurements. The table containing the water levels also contains the name of each well, so that it can be linked back to the appropriate well in the well table. This way, detailed information on each well and water level measurements can be stored most efficiently, without the need to maintain the same piece of information more than once, which would potentially introduce erroneous data into the system.

The GIS used is ArcView®, by Environmental Science Research Institute (ESRI). A GIS is an electronic mapping and analysis system. The power of GIS lies in its ability to manipulate, display, and analyze information on a map by linking map elements to attribute data in a database. For example, a well whose location is identified as a dot on the map, is connected to the construction data, sampling results, and water level information in the database. The user can post any of this information as text on the map, choose specific symbols or colors to represent these data, and overlay this layer of information on other map features. Because the data management system and GIS work together, it provides the user with a powerful set of management and analysis tools.

Both of these components are linked through a common interface developed in Microsoft Visual Basic. The interface is a series of screens that guide the user through various application functions. Through the interface the user can enter or update data, view reports, generate graphs, display scanned images, and create customized maps. The interface can be displayed in English or Spanish, uses water resource terminology, and is designed to be easy to use. Through this interface, municipalities will be able to continue to update their water resource data and use it for decision-making into the future.

3.2 Installation

The WRMS Application requires the following components to be fully installed on the system.

3.2.1 Hardware Requirements:

Minimum (Untested) configuration:

- Intel Pentium 200 MHz
- 64Mb RAM
- EIDE Drive (at least 100Mb free).

Recommended (Tested) configuration:
- Intel Pentium III 733+ MHz
- 128+Mb RAM
- EIDE RAM (at least 100Mb free)

3.2.2 Software Requirements:

The WRMS is designed to function on Microsoft Windows ME, NT4, 2000 or XP.

Additional Required Software:
- ESRI ArcView® 3.1
- ESRI Spatial Analyst
- Seagate Crystal Reports for ESRI
- Adobe Acrobat Reader (http://www.adobe.com/products/acrobat/)

3.3 Operations

This section explains how to back-up and restore the WRMS data and what to do if a system error occurs.

3.3.1 Backups and Recovery. WRMS features a basic backup and recovery system. The system allows the data stored in the system to be backed up whenever necessary. It is recommended that you set this system to backup your data at least once a week. This will enable you to recover your data if something goes wrong.

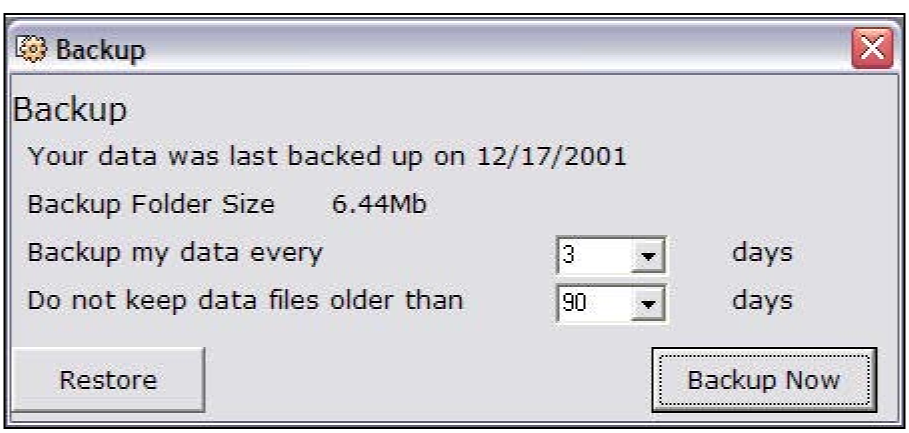

Figure 3-1. Backup and Restore Information

3.3.1.1 <u>How to Backup Your Data.</u> Backups are automated so there is no need to manually backup anything.

However, if you are planning on making major changes to your data or would just like to force a backup, you can force the backup by clicking the **BACKUP NOW** button.

3.3.1.2 <u>How to Restore Your Data.</u>

Click the **RESTORE** button on the **BACKUP** screen.

Figure 3-2. Restore Warning

Read the warning and make sure you understand the consequences of restoring OLD data.

Press **YES**.

You will then be presented by the following screen.

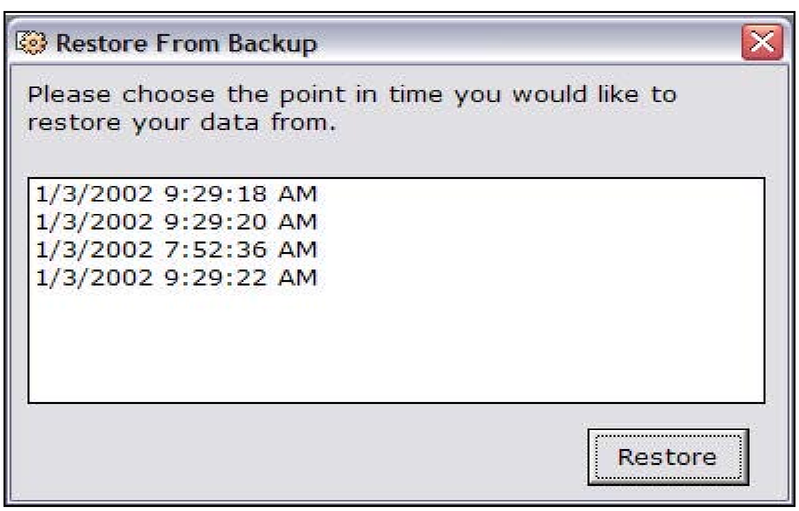

Figure 3-3. Restore from Selection of Backups

Select one of the items from the backup list. Then click **RESTORE**.

Your data will be backed up and then restored from the old data. It is recommended that you exit the application before using it again.

3.3.2 What to do if Error Occurs. We do not anticipate you encountering any errors. However, if you do encounter any errors make sure you write down the error number and what you were trying to do at the time that the error occurred. Send the details to the following email address: sac-support@brwncald.com.

3.3.3 Options

This section describes how to manage valid values, data paths, and interface translations.

3.3.3.1 Valid Values. Valid values allow you to alter and add to the contents of the drop-down menus. The illustration below shows part of the WRMS application. It includes a drop-down menu to change the well purpose of a well. The menu is populated using valid values.

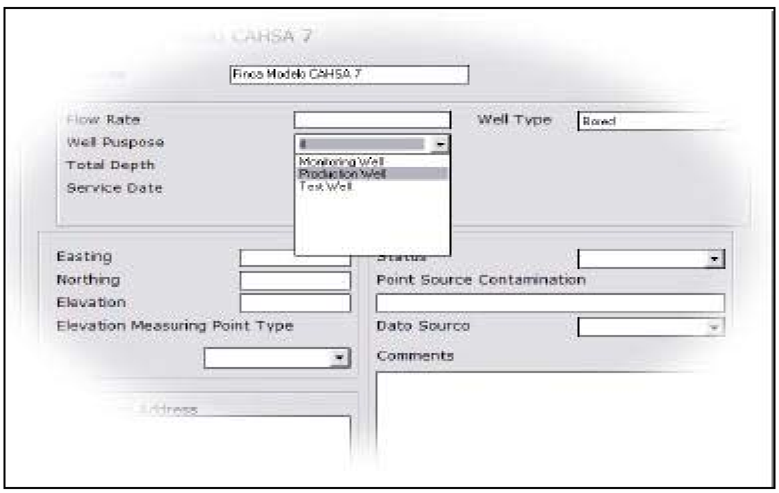

Figure 3-4. Well Purpose Drop-Down Menu Populated with Valid Values

You can easily change the valid values for this drop-down menu by pointing to **OPTIONS; VALID VALUES** then clicking on **WELL PURPOSE**.

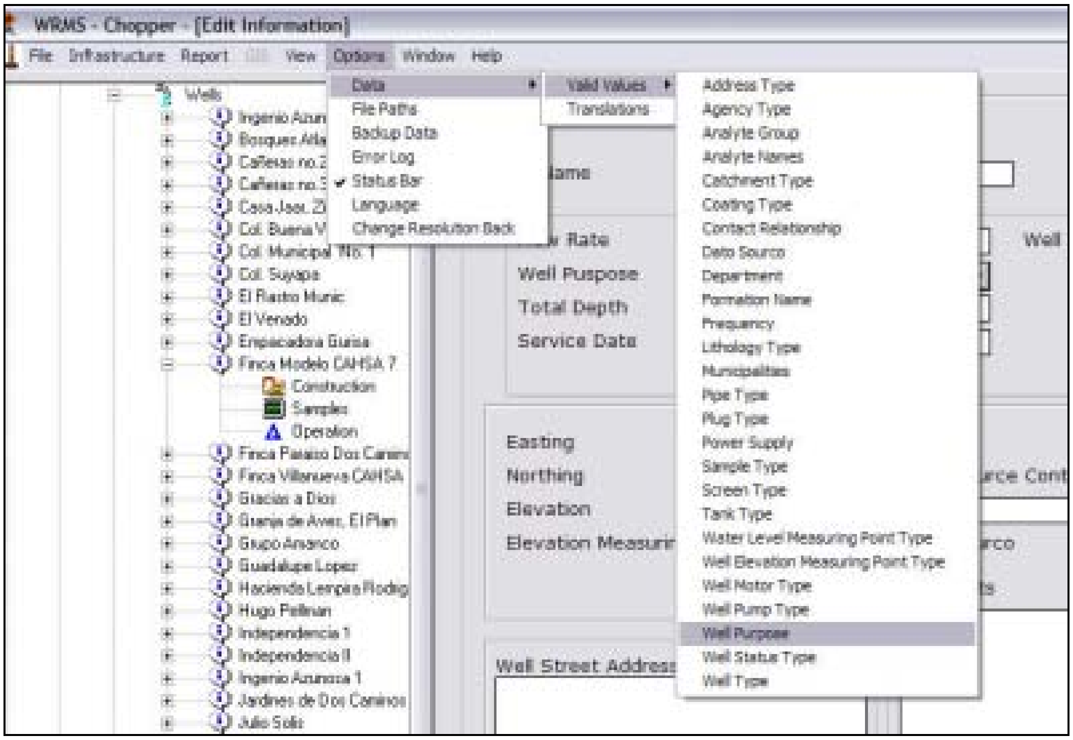

Figure 3-5. Valid Values Menu

You should follow the same process for any other drop-down menu in the application. This way the values can be easily managed.

3.3.3.2 Data Paths. WRMS requires some additional files to run with the full functionality. The following files should be setup in the **FILE PATHS** menu under **OPTIONS**.

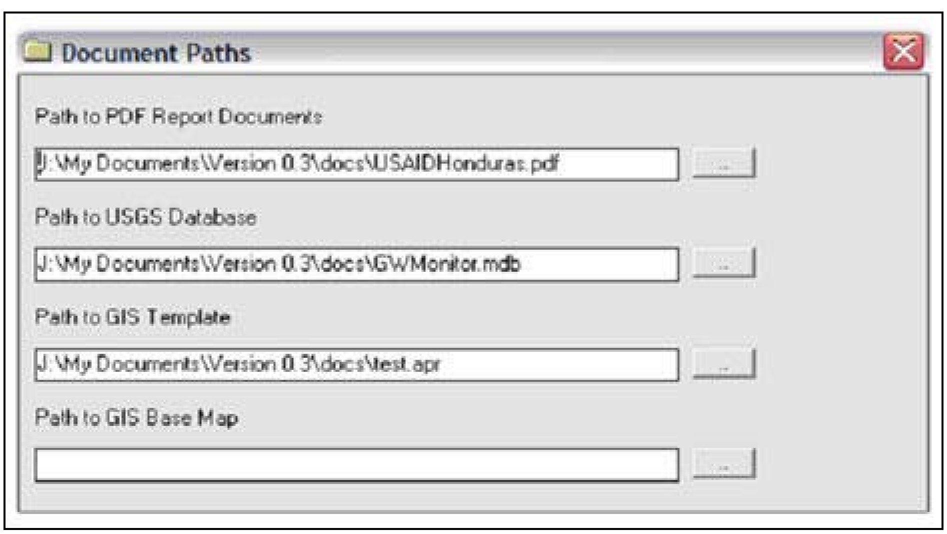

Figure 3-6. File Paths

Unless you are sure what you are doing, we strongly suggest you stay away from these options.

3.3.3.3 Translations. WRMS supports both English & Spanish. Because WRMS was developed in English, some of the translations may be incorrect. You may change these at any time by pointing to **OPTIONS; DATA** and then clicking on **TRANSLATIONS**. Here you will be presented with the English version of all the phrases that the application uses. You can update the Spanish by typing in the cell to the right of the English.

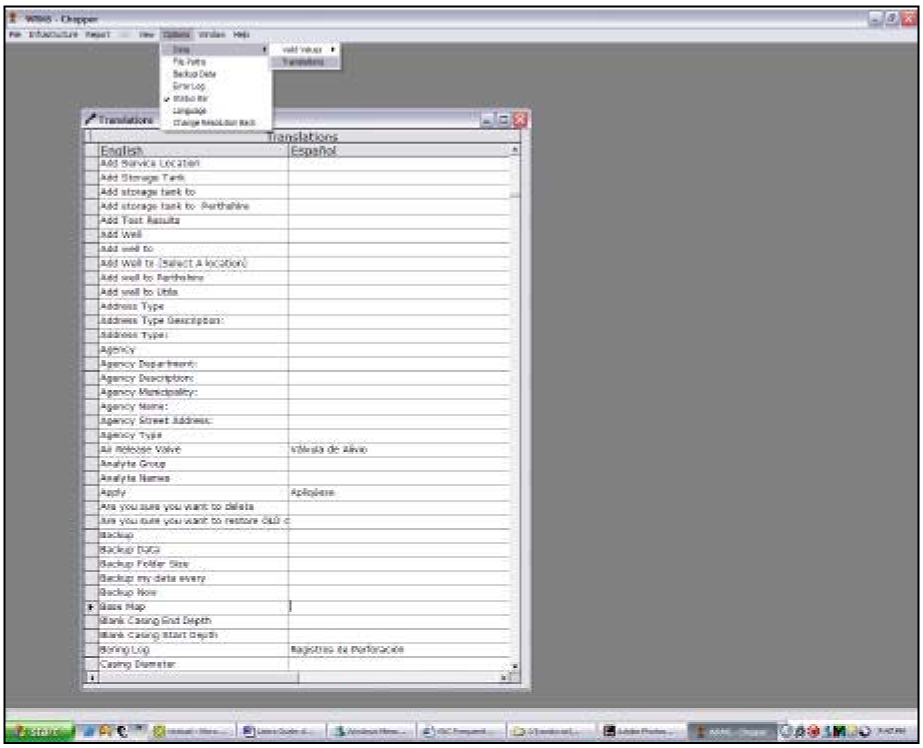

Figure 3-7. Translations Screen

ATTACHMENT

Criteria Worksheet

CRITERIA WORKSHEET

Criterion/Theme	Weight/ Multiplier	Method	Shape File Name	Item for Evaluation	Key Words	Value	Rank

Key Words: Equals
Range
Distance From

APPENDIX E

Groundwater Level and Monitoring Program
(Field Manual)

GROUNDWATER LEVEL AND MONITORING PROGRAM

FIELD MANUAL

BROWN AND CALDWELL

DECEMBER 2001

USAID

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APPENDICES

1.0 PURPOSE AND OBJECTIVES

The purpose of this Sampling and Analysis Plan (SAP) is to outline the essential elements for establishing an effective groundwater level and monitoring program at various municipalities in Honduras, Central America. This report and guidance document is written in support of the Groundwater Monitoring Study conducted by Brown and Caldwell under USAID contract number 522-C-00-01-00287-00. This report covers the technical approach for the groundwater level and monitoring program, the rational for established procedures and step-by-step guidance for the continuation of the monitoring program into the future.

2.0 OVERVIEW

The groundwater level and monitoring program is being established to provide a tool that will be used in support of the current groundwater modeling effort. In addition, the monitoring program will provide a tool for future data collection that will be useful for growth planning.

The groundwater level and monitoring program has several components that are all equally important. These components include groundwater level data collection, water sample collection, analysis of water samples and review, compilation and understanding of water chemistry results. Each of these components is necessary in order to maintain a successful groundwater monitoring program. Each of these components is used to support and enhance the groundwater modeling effort and is discussed in more detail in later sections of this report.

3.0 TECHNICAL APPROACH

3.1 Well Selection

For this study, two types of wells were selected for monitoring: existing municipal or private wells, and new test and observation wells recently installed by Brown and Caldwell. All of the newly test and observation wells will be sampled for this study. Only a selected group of existing municipal and private wells were selected from each municipality for use in this monitoring program. The rational for choosing the existing wells included the following criteria:

- Geographic location—no more than one well per square kilometer was chosen to provide enhanced spatial distribution over the study areas.
- Proximity to Contamination—priority was given to wells located in areas that are assumed to be beyond the extent of agricultural or industrial contamination.
- Depth of the Screen—priority was given to wells screened in deeper aquifers with less chance of contamination from outside sources.
- Daily Use of Well—a representative number of wells that are heavily used and wells that are not pumped often were selected for the monitoring program.
- Use of Water—a representative number of wells used for residential, industrial and agricultural purposes were selected for this monitoring program.

In total, it is proposed to monitor and sample 52 wells for the survey. These wells consist of:

- 14 wells in Villanueva (nine existing wells and five newly installed wells)
- 17 wells in Choloma (14 existing wells and three newly installed wells)
- 12 wells in La Lima (nine existing wells and three newly installed wells), and
- 9 wells in Limon de la Cerca (six existing wells and three newly installed wells)

These wells are listed individually in Tables 1 through 4, and located on the figures in Chapter 3 of the report. It is important to note that the same wells will be sampled during each monitoring event to provide consistency in data and allow for ease of tracking trends in data over time.

3.2 General Groundwater Level and Sampling Procedures

The groundwater level and monitoring program has several components that are essential to support and enhance the groundwater modeling effort as well as provide a base of historical data that can be tracked over time. These components include groundwater level data collection, water sample collection, analysis of water samples, and review, compilation and understanding of water chemistry results. Each of these components is descried separately below.

3.2.1 Groundwater Level Data Collection. Groundwater levels will be measured so that changes in groundwater elevations can be documented and analyzed over time. For example, analysis of groundwater elevations over time can reveal seasonal trends. To collect groundwater levels, field personnel lower an electronic water level indicator down the well until groundwater is encountered (indicated by a beeping noise from the equipment). This depth to groundwater is then recorded in the log book. The water level measurement will be converted into an elevation by subtracting the depth to water from the well surface elevation. A more detailed description of the procedure for collecting groundwater level data is provided later in this text.

3.2.2 Groundwater Sampling. Following collection of the groundwater level measurement, a water sample will be collected. At a minimum, all wells included in this program will be sampled and analyzed for general chemical parameters, pH, electrical conductivity, bateriology and heavy metals. All wells in the monitoring program will also be analyzed for gross alpha and gross beta to establish the presence or absence of radiological compounds. Any of these minimum analytical parameters that are not detected in large quantities in the initial sampling event will be considered for elimination from future monitoring events.

In addition to analyzing for the minimum parameters described above, other important water quality parameters, including pesticides/herbicides and volatile organic compounds (VOCs), should be considered on a well-by-well basis. Sampling and analysis for these parameters will be based on information such as local land use and proximity to industrial activities. For example, the Caneras well fields in Villanueva will likely be sampled and analyzed for the presence of pesticides and herbicides because they are located within a sugar cane plantation. In Choloma, Well Colonial Canada is located near industrial runoff sources, and will likely be sampled and analyzed for VOCs.

Tables 2 through 5 provide a list of suggested monitoring parameters for each well included in this monitoring program.

3.2.3 Groundwater Chemical Analysis. After collecting groundwater samples from each well, the samples will be transported to the laboratory for analysis. For the initial sampling, conducted by Brown and Caldwell, some of the samples will be shipped to Southern Petroleum Laboratory in Houston, Texas, United States of America and some will remain locally in Honduras at Jordanlab located in San Pedro Sula.

3.2.4 Laboratory Data Review and Compilation. When the laboratory has completed the analysis of the samples, the data must be reviewed and compiled. For the initial sampling conducted by Brown and Caldwell, a chemist in the Sacramento, California office will evaluate the data and the data will be input into a project database. For subsequent sampling efforts, each municipality must assess the analytical data separately — look for trends with historical data, be aware of constituents that exceed health based guidelines, and perform quality assurance measures to verify the accuracy of the laboratory data. Once the data have been reviewed for accuracy and consistency, the data should be input into the database provided by Brown and Caldwell and the original copies from the laboratory filed for future reference.

3.3 Quality Assurance/Quality Control

Specific Quality Assurance/Quality Control (QA/QC) steps will be taken in the field and by the laboratory in order to document and ensure that the analytical data have the maximum amount of integrity. The QA/QC program for the groundwater monitoring will include collecting Quality Control samples, use of qualified laboratories, a specific laboratory reporting format, review of laboratory data packages, and consistency in sample identification. These QA/QC items are reviewed below:

- Samples will be carefully labeled with sample designation, the initials of the sampler, and the analysis to be performed. Date and time of sample collection will be added s the sample is collected.
- Field personnel involved in sample collection will wear disposable gloved to prevent potential contamination of samples. Gloves will be discarded after sampling each well.
- Groundwater samples collected from wells with dedicated pump systems will be collected with minimal potential agitation of the sample between the adductor pipe outlet and sample containers. All samples should be collected as closely as possible to the well head.
- Sampling heads should be constructed of non-metallic material, preferably polyethylene or Teflon®. Before collection of samples at all stations, the sampling heads will be cleaned in a non-phosphatic detergent and rinsed with tap water. This will be followed with a distilled-deionized water rinse.
- Groundwater samples collected from monitoring wells without dedicated pump systems will be collected with disposable Teflon or polyethylene bailers and nylon cord. The bailer and cord will be disposed of after the sample has been collected.
- Sample bottle guides for all parameters (bottle type, volume of sample needed, and type of preservatives used) are given in Table 3.

- Samples collected for dissolved metals will be filtered and preserved in the field.
- Immediately after collection of the sample is completed, the sample will be placed in a cooler at 4 degrees C.
- All pertinent information generated during the groundwater sampling event will be recorded on the Field Data Form and in the field log book.
- Duplicate samples will be collected as needed and are intended to be identical to the original sample. A field duplicate sample will originate from the project site and be in a separate sample container. Duplicates will be taken for approximately every 10 percent of samples collected during the sampling event, or a minimum of one per municipality per monitoring event. The location for duplicate sample collection will be determined prior to the sampling round.
- Equipment blanks will not be required because samples will be collected using dedicated pumps and disposable filters and bailers.
- Trip blanks will be provided by the laboratory whenever analysis of volatile compounds occurs.

3.3.1 Quality Control Samples. During each monitoring event, one blind duplicate sample will be collected from each municipality. A blind duplicate sample is a second sample collected from a predetermined well that is given a new (false) name so the laboratory does not know which well the sample is from. This method is commonly used to verify the accuracy of laboratory reports. In addition, a trip blank will be included in every cooler that is used to transport samples to be analyzed for VOCs. It is strongly recommended that this practice continue for all subsequent sampling events completed by the municipalities. A list of the wells that have been selected for duplicate sampling is illustrated in Tables 5 through 8.

3.3.2 Laboratory Qualifications. All chemical analyses will be performed by a laboratory certified by the USEPA or the Government of Honduras. Analytical methods and SOPs that are acceptable, in accordance with EPA recommendations, will be consistently maintained by the laboratory to satisfy the required QA/AC protocol.

3.3.3 Laboratory Data Packages. All results from USAID groundwater samples will be reported in modified Level 3+ QC data packages that provide the following documentation: sample chain-of-custody, method blank results, matrix spike/spike duplicate summary results, and detection limits listed on all reports. Data packages including all surrogate recoveries, laboratory control samples, initial and continuing calibrations, run logs, extraction logs, and correction action reports will be obtained from the laboratories as needed for individual samples.

3.3.4 Sample Naming Convention. For this groundwater level and monitoring program, the naming system will consist of three components: well name, month of the sampling event, year of the sampling event. For example, for the well named Cañeras 2 in Villanueva that will be sampled in October 2001 the sample name will be Cañeras 2 102001. It is important to follow this naming protocol so all samples have a unique identifier when they are entered into the database.

3.4 Schedule

The initial round of monitoring and sampling is scheduled for late October 2001. Sampling activities will be completed for one municipality prior to beginning sampling at the next municipality. This practice will be maintained in future monitoring events to reduce data analysis issues that may arise from weekly, monthly and seasonal changes in the water system. For the initial round of sampling, field work is anticipated to begin in Choloma and then move to Villanueva and La Lima. Finally, the samples will be collected in Limon de la Cerca.

4.0 DETAILED PROCEDURES

The following narrative provides a step-by-step outline of the activities necessary to complete the groundwater level and monitoring program. These steps should be followed each time groundwater samples are collected to ensure accuracy, consistency, and representativeness of data collected during this program.

4.1 Sampling Team and Responsibilities

The sampling team will consist of both field and office personnel. Each person on the team will have specific duties and responsibilities as described below.

- **Sampling Coordinator.** The sampling coordinator will have the overall responsibility for the sampling program and will be responsible for timing and scheduling of the sampling events, oversight of the sampling crew, and liaison with the laboratories. In order to respond to the changing requirements of the project, the sampling coordinator may, after consultation with the project manager, adjust the number and locations of samples to be collected, and the analytes for each sample.
- **Field Sampling Crew.** The field crew may consist of either two or three persons depending on the number of samples to be collected, and the time span allowed for that sampling. The field sampling crew will report directly to the sampling coordinator, and will be responsible for the physical collection of the samples according to the protocol described in this SAP.
- **Quality Assurance (QA) Reviewer.** This person will perform a detailed review of all data generated by this sampling program. The person will chart and document the water quality and will compare the analytical results to acceptable standards as they are available. After the results of each sampling event are reviewed, they will be compiled and a short data report will be prepared for each municipality for use by the project manager to document the results, any deviations from standards, and trends that may occur.

To ensure valid water chemistry determinations, the procedures outlined herein are based on guidelines established by the United States Environmental Protection Agency (USEPA, 1986) in the Code of Federal Regulations (40 CFR 100-149) and the U.S. Geological Survey (USGS, 1984).

4.2 Water Level Measurements

The following steps will be used to obtain water level measurements:

- On arrival at the wellhead, condition of the surface seal and protector or well cover will be checked and observations will be recorded in the field book.
- The area around the well will be cleared prior to unlocking the protector or well cover and removing the cap from the top of the well.
- Before taking any measurements, any previous data of water levels for the well will be reviewed.
- Measuring points will be established based on historical information. If no information is available, a notch on the north side of the well casing or the top of the sounding tube will be used.
- Each well will be sounded three times for depth to water with an electronic water sounder. Water level measurements will be continued until a difference of less than 0.02 feet between consecutive measurement is obtained.
- Depth to water and date of measurement will be recorded on the Field Data Form.
- The previous measured water level will be reviewed. If the difference between the current water level and historical water level measurement is greater than 1 foot, the current measurement will be rechecked.

Smoking, eating, or drinking in the vicinity of the well head, pump output, or field analytical setups will be forbidden in order to eliminate the potential for induced contamination.

Water level data will be collected and documented on the field sheet provided as Appendix A to this sampling manual.

4.3 Well Purging

Well purging activities include the following items:

- A minimal volume of water will be purged, taking into consideration the local hydrologic factors together with the stabilization of pH, temperature, and electrical conductance (EC) over at least two to three borehole volumes. The wells are expected to have very low-flow rates. Purging will possibly draw the water level down to a point that the pump will shut off due to lack of water. When this occurs, the well will be allowed to recover 80 percent of the original static water level, or for 24 hours. Sampling will proceed when these recovery conditions have been met.
- Readings of pH, temperature, and EC, will be recorded, and the cumulative volume pumped will be measured and recorded.
- Purge water will not be containerized but will be discharged directly to the surrounding ground surface.

4.4 Field Tests

During groundwater and surface water sampling activities, the following field tests will be conducted:

- Measurement of pH, temperature, EC, and depth to water in the well to be sampled will be taken and recorded immediately before and after collection of each groundwater sample.
- Conductivity, pH, and temperature meter probes will be thoroughly rinsed with distilled water prior to each use.
- The pH meter will be calibrated in pH 4 and pH 10 buffer solutions at the beginning and end of each sampling day. Calibration data will be recorded on the Field Data Form and in the field log book.
- The conductivity meter will be calibrated using manufacturer specified solutions before and after the sampling. Calibration data will be recorded on the Field Data Form and in the field log book.
- All field parameters will be collected and documented on the field data sheet provided as Appendix A to this sampling manual.

4.5 Groundwater Sample Collection

In order to ensure that proper groundwater samples are collected, the following items are required:

- The laboratory will be contacted at least two working days before receipt of the samples to establish a schedule for sample analysis. The following information will be provided for the laboratory:
  --approximate number of samples the laboratory will be receiving;
  --parameters to be tested;
  --holding time; and
  --number and types of sample bottles to be provided to the laboratory.
- All sample containers obtained from the laboratory shall be factory new. The exception to this is the jars received from JordanLabs in San Pedro Sula, Honduras for fecal and total coliform. These jars will be sterilized by way of an autoclave.
- An adequate number of forms will be obtained for documentation of field activities.
- Groundwater sample collection will be scheduled and performed to accommodate the required laboratory holding times, and to ensure that a maximum representation of the aquifer condition.

4.6 Sample Containers and Preservatives

Sample containers and appropriate sample preservatives will be provided by the laboratories performing analytical services. All container preparation by the laboratory will be done in a designated area. Containers will be labeled to indicate the added preservative. A full list of sample containers and preservatives for this project can be reviewed in Tables 2 through 5. Preparation is accomplished using the following SOPs for bottle preservation:

- Bottles for organic analyses will be provided by the laboratory. These will be purchased from suppliers who certify the containers to have been cleaned by protocols as prescribed in the Environmental Protection Agency (EPA) methods for organic analyses.
- Coolers, and applicable chain-of-custody forms will also be provided by the laboratories. Brown and Caldwell will be responsible for the purchase of bulk block ice that is appropriate for overseas shipping. Blue ice will not be used for cooling samples on this project.
- All sample containers with appropriate preservatives and coolers will be delivered at lease one week prior to sample collection.
- After a sample is collected, preserved, and labeled, it will be stored on ice at 4 degrees C in a plastic ice chest. No ice chest will be allowed to stay in the field beyond its ability to keep the temperature at 4 degrees C.
- All samples will be wrapped in plastic packing when necessary to avoid breakage, and will be clearly labeled and sealed to prevent tampering.
- All samples will have a label containing (at a minimum) the following information:
  --Sample designation;
  --Project name and number;
  --Date and time of collection; and
  --Comments – These may include parameters to be analyzed, whether the sample is filtered or unfiltered water, and any preservatives added to the sample.

4.7 Chain-of-Custody

Chain-of-Custody procedures will include:

- Samples collected by field personnel will be accompanied by a Chain-of-Custody Record Form, which will include date and time of collection, container type, preservatives used, number of samples, sample descriptions, and others.
- Sample identification labels and chain-of-custody records will be completed with waterproof ink, and placed in a waterproof bag for shipment.
- Chain-of-Custody documentation will be completed at each sample location prior to sampling at the next well.
- Samples will be hand delivered to JordanLabs in San Pedro Sula the day of the sampling. Samples that are being analyzed by Southern Petroleum Laboratory (SPL) in Houston, Texas will be delivered via DHL overnight shipment service. It should be noted that coliform samples have a short holding time of only 24 hours. It is imperative that field crew communicate with JordanLabs prior to sampling to verify that the analysis can be run in the appropriate time frame.
- The integrity of the samples will be examined, and the final signature of the Chain-of-Custody form will be completed by a receiving agent of the selected laboratory.
- A sample chain-of-custody is provided as Appendix B to this sampling manual.

5.0 DATA MANAGEMENT

Field and laboratory data management, data review, and reduction are given below to create a centralized working system, and to maintain data quality.

- Field Data. Water quality records for each sampling location will be produced, copied, and filed under the appropriate category for each groundwater quality well. Records completed in the field will include physio-chemical (pH, temperature, EC) parameters of groundwater and chain-of-custody records. These forms will be forwarded by the field manager to the project manager at the conclusion of the sampling effort.
- The following field documentation will be completed by the field personnel:
  --Complete entry in dedicated field notebook;
  --Complete the Field Data Form, and one Chain-Of-Custody Form.
- Laboratory Data. Analytical results and QC data relating to analytical precision and accuracy will be obtained from the laboratory. Laboratory analytical result data sheets will be specific to sampling location and method of analysis. The original Chain-Of-Custody Forms will be filed with the analytical results. Data will be organized with respect to date, original water quality results, and QA/QC results.
- Data Review. Field data will be reviewed for measurements collected during sampling, order of sample collection , and the observations and notes recorded during he course of the sampling day. Laboratory data forms will be reviewed for the completion of required measurements, including parameter results, limits of detection, and dilution factor. Validity of both the field and laboratory data will be determined by evaluating the completeness of the data for the required parameters as documented on the chain-of-custody form.
- The following data will also be reviewed:
  --Use of EPA methods with detection limits below water standards, where applicable;
  --Chemical data of control matrix blanks, control matrix spikes, standards, control matrix duplicates; and
  --Confirmation of sample analyses within specific holding times.

6.0 REPORTING

A general assessment of the groundwater and surface water quality for the fall of 2001 will be submitted to USAID in the final report presented at the termination of the project. It will be the responsibility of each municipality to report the water quality results to the appropriate individuals after each sampling event in the future.

7.0 GLOSSARY OF TERMS

Aquifer: The geological stratum that can produce enough water to support consumption. It is the section of the well where screening in a well is installed.

Bailer: a PVC tube one meter long used to collect water samples from wells that do not have a pump installed.

Casing: PVC or steel tubing installed into a borehole with perforated sections and non-perforated sections used to capture the water from an aquifer.

Chain-of-Custody: a legal document used to track groundwater samples. A chain-of-custody includes information such as the name of the sample, the date of collection, the time of collection, the name of the technician and the analysis requested by the laboratory. A chain-of-custody should remain with the samples at all times.

Database: A computer system used to archive historical data.

Drawdown: the difference, measured in feet or meters, between the water table or static water level and the level of the water after pumping.

Electrical Conductivity: a chemical parameter that quantifies the potential for water to conduct or carry electricity. Electrical conductivity is a function of the the quantity of dissolved minerals (particularly salt) in the water.

General Bacteriology: water quality analysis performed to determine the presence of bacteria and sometimes to determine the amount of fecal material present in a sample.

Holding Time: the amount of time between sample collection and when a laboratory needs to analyze the sample. For example, for fecal coliform samples, less that 24 hours can pass between sampling activities and analysis or the data will be invalid.

JORDANLAB: analytical laboratory in San Pedro Sula used to analyze samples for the USAID project.

Preservatives: chemicals—typically acids—added to sample bottles collected in the field to increase the time allowable between sampling and analysis. Preservatives are also used to retain potential contaminants in the sample so the laboratory can get a true understanding of what is in the water.

Radiological Chemicals (Gross a, Gross ß): chemical parameters used to demonstrate the amount of radiological chemicals in a sample.

Screening: the portion of PCV or steel casing that is perforated to allow the passage of aquifer water into the well.

Sounder: a device used to determine the level of water in the well. It measures feet or meters below ground surface.

SPL: Southern Petroleum Laboratories, laboratory used for the USAID Groundwater Resources Study for metals, radiological chemicals, pesticides and herbicides and VOCs.

Static Water Level: the level at which water stands in a well or unconfined aquifer when no water is being removed from the aquifer etiher by pumping or free flow.

QA/QC: Quality Assurance/Quality Control, a method of checking data to be sure it is valid.

Volatile Organic Chemicals: man-made organic chemicals that are widely used for industrial and domestic purposes including solvents for cleaning and pesticides/herbicides.

Tabla No.1 Pozos seleccionados para muestreo en los municipios de Villanueva, La Lima, Choloma

Nombre del Pozo	Municipio	UTM	Q GPM	Fuente de contaminación	Profundidad del Pozo (Pies)	Profundidad Rejilla (pies)	Llave para muestreo	Elevación Terreno natural	Sector abastecido No. de Viviendas Abastecidas	Producción Diaria (Gal)
La Victoria	Villanueva	16P 0394395 1693962	120	Ninguna	195		SI	67.3278	Col. La Victoria 543	172,800
Pintala I	Villanueva	16P 0392752 1691490	400	Ninguna	240	41	SI	53.3728	Col. 1 de Mayo y San Antonio 96	48,000
Manuel Coello	Villanueva	16P 0394328 1692334	202	Ninguna	270	49	SI	50.1758	A tanque Col. Victoria y Col. Sitiahmacs 543	115,140
Villa Linda Norte	Villanueva	16P 0394962 1695873	105	Letrinas a 10 metros	300	25	SI	54.1698	Col. Villa Linda Norte 144	25,200
Villa Sol	Villanueva	16P 0393671 1693850	27.24	Ninguna	184		SI	78.8138	Parte de la Col. Villa Sol 40	37,591
Cañeras II	Villanueva	16P 0393345 1691699	600	Ninguna	250	100	SI	47.2048	Conectado al Plan Maestro (Red baja y alta) 3369	864,000
Guadalupe Lopez	Villanueva	16P 0396098 1693853	150	Letrinas a 10 metros	260	70	SI	70.7248	Tanque 21 de Abril 315	216,000
22 de Mayo	La Lima	16P 0391650 1709438	90	Letrinas a 5 metros	180		SI	29.238	Tanque Col. 22 de Mayo 105	97,200
Villa Esther	La Lima	16P 0402604 17006467	200	Canal de aguas negras a 100 metros	260	154	SI	26.83	Residencial Villa Esther 9	252,000
Oro Verde	La Lima	16P 0403573 1705732	298	canal de aguas negras a 100 metros			SI	25.43	Residencial Oro Verde y Zip Continental	
Guaymuras	La Lima	16P 0397437 1708534	100	Letrinas a 30 metros	362		SI	28.937	A Tanque Guaymuras 155	108,000
Planeta #1 (Fusep)	La Lima	16P 0398234 1709076		Ninguna	200	40	SI	28.091	Red de la Col. Planeta 2312	
La Mesa (Nuevo)	La Lima	16P 0401055 1708035	400	Ninguna	200	63		27.755	Col. La Mesa NO HAY BOMBA	
Cruz Roja	La Lima	16P 0400429 1707065	150	Ninguna	200	150	SI	27.87	A la red del Centro de Lima Vieja	162,000
Martinez Rivera	La Lima	16P 0400140 1705694	150	Ninguna	180		SI	28.993	Tanque de la Col. Martinez Rivera 101	162,000
San Carlos	Choloma	16P 0399179 1726619	296	Ninguna	176	41	SI	26.223	Tanque de la Col. San Carlos 885	337,400

Nombre del Pozo	Municipio	UTM	Q GPM	Fuente de contaminación	Profundidad del Pozo (Pies)	Profundidad Rejilla (pies)	Llave para muestreo	Elevación Terreno natural	Sector abastecido No. de Viviendas Abastecidas	Producción Diaria (Gal)
Prado I	Choloma	16P 0399065 1728223	60	Quebrada con aguas negras a 75 metros	100		SI	26.298	Tanque de la Col. Prado I 161	14,400
Residencial Europa	Choloma	16P 0399366 1725680	225	Ninguna	117		SI	24.423	Tanque de la Col. Europa 389	283,500
San Antonio	Choloma	16P 0397599 17267087	450	Contaminación por infiltración de heces fecales	120	60	SI	33.852	A la red del centro de Choloma	648,000
Bella Vista	Choloma	16P 0398794 1725376	196.2	Quebrada contaminada por aguas negras 400 metros	200		SI	27.282	Sector Sur (Sector López Arellano) 2751	282,528
Bomberos I	Choloma	16P 0397867 1726032	257.2	Ninguna	200	40	SI	32.422	Sector SE, SO, NE de Choloma	370,368
San Francisco	Choloma	16P 0397287 1726970	100	Quebrada contaminada por aguas negras a 1 metro	80		SI	37.315	Col. Los Almendros y Col. Care 439	108,000
Barrosse II	Choloma	16P 0398472 1728223	587	Ninguna	200	60	SI	25.813	Sector N.O. de Choloma	845,280
Victoria (Gas. Depesa)	Choloma	16P 0397645 1721746	68	Ninguna	329	40	SI	52.523	A tanque Col. La Victoria 90	24,480
Canada	Choloma	16P 0397831 1725769	400	Canal de aguas negras a 30 metros y quebrada contaminada con aguas negras y desechos de fabricas a 150 metros	200		SI	31.992	A la red de la Col. Canadá 127	576,000.00
Parque Central	Choloma	16P 0397918 1726067	350	Ninguna	200		SI	32.077	A la red del centro de Choloma	420,000
Primavera	Choloma	16P 0397194 1726282	180	Ninguna	200		SI	36.434	Col. La Primavera 312	259,200

Tabla No. 2 Método Analítico, Envase, y Especificaciones de Control de Calidad para Villanueva, Cortés, Honduras.

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	No. de Envases	Preservantes	Duplicado	MS	MSD
Cañeras 2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
	A.S.	Pesticidas/Herbicidas	32 oz. Ámbar	2	Ninguno			
Pintala 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Pintala 2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Plástico	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Guadalupe Lopez 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno	X	X	X
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno	X	X	X
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio	X	X	X
Manuel Coello 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Colonia Victoria 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Plástico	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Villa Linda Norte	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
BC-VI-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
BC-VI-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Plástico	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-VI-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-VI-4 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Totala, Totalß	32 oz. Plástico	2	Ácido Nítrico			
BC-VI-5 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No.3 Método Analítico, Envase, y Especificaciones de Control de Calidad para Choloma, Cortés, Honduras.

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	Número de Envases	Preservantes	Duplicado	MS	MSD
Parque Central 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Bomberos 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Bella Vista 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Perez Estrada 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
San Carlos 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Res. Europa 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Col El Prado II 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Barrosse 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno	X	X	X
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno	X	X	X
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio	X	X	X
San Antonio 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
San Francisco 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
La Primavera 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
Victoria 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
Inez Carranza Barrica 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
Res. América 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-CH-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-CH-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Acido Nítrico			
BC-CH-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No.4 Método Analítico, Envase, y Especificaciones de Control de Calidad para La Lima, Cortés, Honduras

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	Número de Envases	Preservantes	Duplicado	MS	MSD
Don Lolo 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Oro Verde 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Martínez Rivera 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
22 de Mayo 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Guaymuras 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Villa Esther 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Planeta Fusep 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno	X	X	X
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno	X	X	X
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio	X	X	X
Cruz Roja 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Vivero Municipal 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-LL-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	32 oz. Plástico	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-LL-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Ácido Nítrico			
BC-LL-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No.5 Método Analítico, Envase, y Especificaciones de Control de Calidad para Limón de la Cerca, Choluteca, Honduras.

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	Número de Envases	Preservantes	Duplicado	MS	MSD
Panamerica LC 4 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Bolsa Samaritana LC 3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Ricardo Soriano LC 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Iglesia Cristo Rey 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Atlas LC 2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Luis 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
BC-LC-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-LC-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Ácido Nítrico			
BC-LC-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No. 6 Red de Monitoreo de Pozos
La Lima, Honduras

No	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (m snm)	Elevación Nivel de Referencia (m snm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estatico (m)	Fecha lectura	Observaciones
1	Colonia Fraternidad	16P 0399855 1707090	Observación	28.06	28.38	15.00	04-Oct-01			
2	Los Maestros	16P 0400224 1707203	Monitoreo	27.19	27.62	6.79	06-Sept-01			
3	El Mixto	16P 0400700 1706883	Procucción	28.51	29.42	6.67	04-Jan-02			
4	Cruz roja	16P 0400469 1707065	Procucción	27.87	28.37	12.88	04-Jan-02			
5	Sitraterco	16P 0400587 1707306	Procucción	27.57	28.01	8.56	04-Jan-02			
6	Martínez Rivera	16P 0400135 1705691	Procucción	28.99	29.05	4.54	04-Jan-02			
7	Gabriela Mistral	16P 0400294 1706908	Procucción	28.45	29.11	5.64	06-Jan-01			
8	Zapote No.1	16P 0398158 1706728	Procucción	31.09	31.75	4.95	04-Jan-02			
9	Zapote No.2	16P 0397798 1706836	Procucción	30.57	31.17	3.35	04-Jan-02			
10	Planeta No.1 (Fusep)	16P 0398803 1708994	Procucción	28.09	28.39	5.97	04-Jan-02			
11	Planeta No.3	16P 0398284 1709356	Procucción	27.89	28.16	6.46	04-Jan-02			
12	FHA No.1 (Fuerza Aérea Hondureña)	16P 0399594 1707531	Monitoreo	27.41	27.98	5.50	04-Jan-02			
13	FHA No.2 (Fuerza Aérea Hondureña)	16P 0399624 1707517	Monitoreo	27.31	27.61	4.10	04-Jan-02			
14	Aeropuerto	16P 0399349 1707864	Monitoreo	26.51	26.67	6.67	04-Jan-02			
15	Jerusalem No.1	16P 0397548 1709059	Procucción	28.48	28.76	5.50	04-Jan-02			

No	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (msnm)	Elevación Nivel de Referencia (msnm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estatico (m)	Fecha lectura	Observaciones
16	Jerusalem No 2 (Kinder)	16P 0397368 1708923	Procucción	28.42	28.60	7.10	04-Jan-02			
17	Guaymuras	16P 0397437 1708534	Procucción	28.94	29.99	8.85	04-Jan-02			
18	San Cristobal	16P 0397715 1708758	Procucción	29.37	31.45	13.60	04-Jan-02			
19	La Paz No 2 (Luis Thiebaud)	16P 0400263 1706706	Procucción	25.90	26.41	7.21	04-Jan-02			
20	Oro Verde	16P 0403573 1705732	Procucción	25.43	25.72	4.02	04-Jan-02			
21	Villa Esther	16P 0402604 1706467	Procucción	26.83	27.11	9.25	04-Jan-02			

Tabla No. 7 Red de Monitoreo de Pozos
Choloma, Honduras

No.	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (msnm)	Elevación terreno Referencia (msnm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estático (m)	Fecha lectura	Observaciones
1	San Francisco	16P 0397287 1726970	Producción	37.32	37.66	5.97	17-Dec-01			
2	San Antonio	16P 0397599 1726708	Producción	33.85	34.39	5.14	17-Dec-01			
3	Primavera	16P 0397194 1726282	Producción	36.43	36.68	5.74	17-Dec-01			
4	Prado I	16P 0399065 1728223	Producción	26.30	26.49	5.92	05-Dec-01			
5	Prado II	16P 0399065 1725620	Producción	25.61	26.21	5.76	05-Dec-01			
6	Residencial El Japón	16P 0400206 1725865	Producción	21.42	21.77	4.27	05-Dec-01			
7	Inés carranza Barrica	16P 0398277 1720762	Producción	42.23	42.74	13.86	18-Dec-01			
8	Bomberos I	16P 0397867 1726032	Producción	32.42	33.61	9.90	17-Dec-01			
9	Residencial San Carlos	16P 0399179 1726619	Producción	26.22	26.30	4.92	05-Dec-01			
10	Residencial América	16P 0399292 1726913	Producción	26.92	27.26	3.98	05-Dec-01			
11	Victoria #1 (gasolinera)	16P 0397645 1721746	Producción	52.52	52.94	21.32	18-Dec-01			
12	Residencial Europa	16P 0399366 1725680	Producción	24.42	24.92	4.10	05-Dec-01			
13	Canadá	16P 0397831 1725769	Producción	31.99	33.87	9.61	17-Dec-01			
14	La Mora No.1	16P 0396909 1725541	Producción	35.78	35.96	10.77	18-Dec-01			

Tabla No. 8 Red de Monitoreo de Pozos
Villanueva, Honduras

No.	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (m snm)	Elevación terreno Referencia (m snm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estático (m)	Fecha lectura	Observaciones
1	Orquidea II	16P 0393142 1694141	Producción	92.66	92.82	33.80	29-Nov-01			
2	Orquidea III	16P 0393034 1694095	Producción	94.51	94.95	43.56	29-Nov-01			
3	Col. Municipal	16P 0395157 1694522	Producción	64.93	65.50	10.60	29-Nov-01			
4	Buena Vista	16P 0395939 1693554	Producción	71.48	72.09	34.43	29-Nov-01			
5	Villa Linda Norte	16P 0394962 1692873	Producción	54.51	54.96	13.50	29-Nov-01			
6	Guadalupe Lopéz	16P 0396098 1693853	Producción	71.10	71.40	30.17	29-Nov-01			
7	La Victoria	16P 0394395 1693962	Producción	67.98	68.76	32.66	29-Nov-01			
8	Cañeras II	16P 0393445 1691699	Producción	47.51	47.91	10.94	06-Julio-01			
9	Pintala I	16P 0392752 1691490	Producción	53.37	53.78	8.77	29-Nov-01			
10	Villasol	16P 0393671 1363850	Producción	71.81	72.04	28.17	30-Nov-01			
11	Independencia I	16P 0393832 1693445	Producción	72.52	73.02	23.00	30-Nov-01			
12	Manuel Coello	16P 0394328 1692334	Producción	50.18	50.56	14.57	20-Nov-01			
13	Vivero Municipal	16P 0393415 1694607	Producción	97.28	97.48	32.64	29-Nov-01			
14	Llanos de Canadá	16P 0395814 1692807	Producción	52.00	52.84	6.49	19-Julio-01			
15	Zip Villanueva #6	16P 0394991 1694016	Producción	61.73	63.93	18.32	18-Julio-01			

APPENDIX A

Field Form

WATER SAMPLE DATA LOG

Project No.:	Project:
Well No.:	Date:
Location:	Weather:
Purpose of Sampling Event:	

WELL DATA

Total Depth of Well (ft bls):	Depth to Water (ft bls):
Screened Interval (ft bls):	Date/Time:
Casing Diameter (in):	Pt. of Measurement:

FIELD SAMPLING DATA

Time	Discharge Rate (gpm)	Total Discharge (gallons)	pH	Temp. °F	Specific Conduct. (µmhos/cm)	Sand Content (mL/l)	Comments

Time Pumping Started: ____________ Time of Sample Collection: ____________

Type of Samples Collected: ____________

Total Discharge (gpm): ____________ Type of EC-T-pH Meter: ____________

Sample Collected by: ____________

How Sample Collected: ____________

Comments: ____________

APPENDIX B

Chain of Custody

SPL, Inc.

Analysis Request & Chain of Custody Record

SPL Workorder No: 104520

page 1 of 1

Client Name: Brown & Caldwell

Address/Phone: Barbara Goodrich

Client Contact: 925-937-9010

Project Name: USAID Groundwater Monitoring

Project Number: 21365

Project Location: Villanueva, Cortés, Honduras

Invoice To: Brown & Caldwell, Walnut Creek

SAMPLE ID	DATE	TIME	comp	grab	matrix (W=water S=soil SL=sludge O=other:)	bottle (P=plastic A=amber glass G=glass V=vial)	size (1=1 liter 4=4oz 40=vial 8=8oz 16=16oz)	pres. (1=HCl 2=HNO3 3=H2SO4 O=other:)	Number of Containers	metales	coliformes	VOCs							
nombre de muestra	11/30/2001	1420		X	W	P	1	–	1	X									
nombre de muestra	11/30/2001	1425		X	W	G	16	1	1		X								
nombre de muestra	11/30/2001	1425		X	W	G	40	3				X							

Barbara Goodrich

Client/Consultant Remarks:

Laboratory remarks:

Intact? ☐ Y ☐ N

Temp:

Requested TAT: 24hr ☐ 72hr ☐ 48hr ☐ Standard ☒ Other ☐

Special Reporting Requirements: Fax Results ☒ Raw Data ☐ Standard QC ☒ Level 3 QC ☐ Level 4 QC ☐

Special Detection Limits (specify):

PM review (initial):

	date	time	
1. Relinquished by Sampler: Barbara Goodrich to DHL	11/30/2001	1750	2. Received by:
3. Relinquished by:			4. Received by:
5. Relinquished by:			6. Received by Laboratory:

☒ 8880 Interchange Drive, Houston, TX 77054 (713) 660-0901

☐ 500 Ambassador Caffery Parkway, Scott, LA 70583 (318) 237-4775

☐ 459 Hughes Drive, Traverse City, MI 49684 (616) 947-5777

APPENDIX C

Groundwater Sampling Event Checklist

CHECKLIST FOR GROUNDWATER SAMPLING EVENT

<u>Before leaving for the field:</u>

1. Contact the laboratory responsible for bacteriological analysis before sampling event.
2. Arrangements made for international transport of water samples.
3. Access to well and proper pump function have been verified before water sample.
4. The following materials and equipment are available:
   Electronic water level meter
   Field meter for conductivity, pH, and temperature
   Field meter calibration solutions
   Water sample containers (supplied by laboratory)
   Ice chests
   Ice
   Water sample labels
   Disposable gloves
   Zipper-lock plastic bags
   Water sampling field forms
   Chain of custody form
   Camera and film
   Sample packing material
   Water sample field filtering equipment
   Flame disinfection equipment
5. Confirm proper function of the electronic water level meter

<u>In the field:</u>

1. Observation and proper documentation of conditions at the well site prior to sampling.
2. Locate elevation reference point for water level measurement.
3. Conduct three consecutive measurements of groundwater level and record results on the field data form.
4. Disinfection of the sampling port using flame.
5. Proper purging of three well volumes before water sampling.
6. Calibration of the field conductivity, pH, and temperature meter.
7. Measurement of conductivity, pH, and temperature and documentation in field form.
8. Water sampling personnel use disposable gloves during water sampling.
9. Collection of the necessary quantity of groundwater for each analysis.
10. Samples for iron and magnesium analysis were filtered in the field.
11. Sample containers for volatiles analysis were free of bubbles.
12. Sample date and time are recorded and documented on field form.
13. All samples are properly labeled.
14. Chain of custody documentation is filled out prior to sampling of next well.
15. Periodic confirmation that water sample ice chest contains sufficient ice to maintain a temperature not greater than 40 C.

After water sampling:

1. Water samples for bacteriological analysis were delivered to the laboratory within the appropriate holding time.
2. The laboratory signed the chain of custody for receipt of water samples.
3. Water samples for shipment were carefully packed in protective material, preferably bubble-wrap.
4. Ice for the ice chest is placed in zipper-lock plastic bags to avoid spilling.
5. Water samples and ice are placed in a large plastic bag within the ice chest.
6. The signed and dated chain of custody is placed in the ice chest for shipping.
7. The ice chest was carefully sealed prior to shipping.
8. An international air bill and a commercial invoice are filled out to accompany the ice chest during shipping and transport.
9. The laboratory in Houston was contacted to notify of the shipment, the number of samples in the shipment, the requested analyses, and the estimated time of arrival of the shipment.

APPENDIX D

Photographs

Containers for water samples

Water level sounder

Temperature, pH and conductivity meter


Flame cleaning of sampling port prior to sample collection


Field filtering of water samples to be analyzed for dissolved iron and manganese


Cleaning of sampling port

APPENDIX F

Wellhead Protection Plan

WELLHEAD PROTECTION PLAN

La Lima, Honduras

June 2002

INTRODUCTION

The most effective means in protecting the groundwater quality used for public water supply in La Lima is establishing a wellhead protection program. Wellhead protection is the practice of managing the land area around a well to prevent groundwater contamination. Prevention of groundwater contamination is essential to maintain a safe drinking water supply.

The control measures included in this section should be incorporated into municipal regulations to ensure control on water use and to protect the area covered with dense vegetation that represents potential groundwater recharge areas through rainfall infiltration.

Groundwater may become contaminated through natural sources or numerous types of human activities. One of the main causes of groundwater contamination induced by human activity is the effluent from septic tanks, cesspools, and latrines. Although each disposal system releases a relatively small amount of waste into the ground, the large number and widespread use of these systems results in a significant contamination source. Similarly, improper disposal of gray water, hazardous wastes, leaking fuel storage tanks, and chemical storage and spill sites are sources of contamination to groundwater.

KEY STEPS

Development of a wellhead protection plan for La Lima consists of five key steps that are described in detail below:

Step 1: Planning. The municipality should assemble a team to arrive at a cooperative effort for wellhead protection objectives. The team may include municipal officials, representatives from the public works departments, environmental managers, and members from the local health department.

Team objectives should focus on delineation of a wellhead protection area to protect the water wells from unexpected contaminant releases, as well the development of a plan for controlling high-risk activities within the well recharge area.

Step 2: Delineate the Wellhead Protection Area. The geographic limits most critical to the protection of a well water supply must be delineated. Based on this information, a base map should be developed that shows detailed information on the natural features of the area, both surface and subsurface, land use including roadways and utilities, and location of all public supply wells and water recharge areas. Clear acetate overlays can be added that illustrate the radius of influence (even if estimated) for every pumping residential and municipal water supply well, location of aquifers and aquifer recharge zones, watershed in which the aquifers are located, wetlands, lakes and flood zones that may affect recharge, and potentiometric surface information that illustrates groundwater flow direction.

The actual delineation of a wellhead protection area ranges in complexity from drawing a circle of specified radius around each well, to more sophisticated techniques involving analytical methods and groundwater modeling. Using an arbitrary fixed radius - calculating a fixed radius measured from the well to the wellhead protection area boundary - is an inexpensive, easily implemented method of wellhead delineation. Choosing a large fixed radii will increase the protective effectiveness, but alternatively, could lead to overcompensation and unnecessary wellhead protection costs. However, a disadvantage of the fixed radius approach is that it is not based on hydrogeologic principles and could lead to inadequate protection of recharge areas. Given the limited aerial extent of the freshwater aquifer at La Lima, the entire area may be included inside the protection zone.

Step 3: Identify and Locate Potential Sources of Contamination. The objective of this step is to prepare a master wellhead protection area map that shows all existing contaminant sources and identifies potential threats. First, a comprehensive inventory of potential and known contaminant sources should be developed within each wellhead protection area. Sources should include past and present waste sites such as sewage treatment and disposal areas, landfills, and chemical storage and disposal areas, including small commercial and any future industrial waste areas. The inventory should also include agricultural sources such as crops where pesticides and insecticides may have been used, animal feedlots, livestock waste disposal areas, and agricultural drainage ditches and canals. In addition, residential areas with septic systems, latrines, cesspools, and buried waste disposal areas should be inventoried. Once all of the potential sources of contamination have been identified, each source should be plotted on an overlay of the wellhead protection area.

Following identification of source areas, an evaluation of the immediacy and degree of risk associated with each potential source of contamination should be conducted. Values of risk can be assigned and ranked based on their proximity to groundwater supply, the nature of the contaminant, and the intended use of groundwater. By assigning risk values, it is possible to prepare a map illustrating the location and magnitude of potential threats to the groundwater supply, as well as aid in determining which areas require immediate attention to prevent contamination to the water supply.

Step 4: Manage the Wellhead Protection Area. A long term, low cost management wellhead protection plan can be tailored for the municipality. It may be initiated by addressing identified immediate threats to the groundwater supplies followed by a program of prevention and protection of future supplies. One easily achieved component of the plan is to institute a public education program to increase awareness of the threats of groundwater contamination and encourage groundwater protection and conservation measures. Other programs may include the municipality acquiring sensitive recharge areas and converting them to park land, recreational facilities, or other community-based land uses.

Another component of wellhead protection is groundwater monitoring. Regular groundwater monitoring around municipal and residential water supply wells can detect potential sources of contamination before they infiltrate the municipal water supply. A good groundwater monitoring program consists of collecting numerous groundwater samples on a regular basis and performing laboratory tests to detect various contaminants, which will identify problems quickly. The further the monitoring wells are located from the pumping well, the sooner problems can be identified and more time will be available to rectify the situation or provide adequate substitute water supplies.

Step 5: Plan for the Future. A critical component of a successful wellhead protection plan is regular annual review and update of the plan. This will allow for improvement of management strategies and provide time to act on new information regarding sources of contamination. A critical aspect of the plan is the identification of future hazards that could threaten the wellhead protection areas. Early identification will allow time to develop solutions or contingency plans for alternate water supplies.

APPENDIX G

Training and Workshops

TRAINING AND WORKSHOPS

La Lima, Honduras

June 2002

INTRODUCTION

Brown and Caldwell conducted a series of workshops and training sessions throughout the project. These sessions consisted of project kick-off, status meetings, training sessions, and project wrap-up meetings, as described below.

Project Kick-off and Status Meetings

Initially, Brown and Caldwell held two project kick-off meetings to introduce the project to interested stakeholders and build consensus regarding project objectives. The kick-off meetings were held in Tegucigalpa on 3 May 2001 and in San Pedro Sula on 22 May 2001. Kick-off meeting agendas and lists of attendees are included at the end of this section.

On 11 July 2001, Brown and Caldwell held a workshop to present the conceptual hydrogeologic models we developed for each of the study areas and update interested parties on the status of the project. This meeting was held in San Pedro Sula. A workshop agenda and list of attendees is also included at the end of this section.

Training Sessions

To help ensure project sustainability, Brown and Caldwell held seminars to train local municipal personnel in groundwater monitoring techniques and in operating the water resource database developed for each project municipality. Groundwater monitoring training sessions were held on December 4th, 6th, and 10th, 2001 at Limon de la Cerca, the Sula Valley, and Utila, respectively. A training session agenda and list of municipal personnel who participated in the training is included at the end of this section. The training sessions on how to use and update the project databases developed by Brown and Caldwell were held in San Pero Sula and Tegucigalpa on February 12th and 14th, respectively. These training sessions were held at the local UNITEC campuses. Again, a training session agenda and list of attendees is included at the end of this section.

Project Wrap-Up Meetings

The project also calls for project wrap-up meetings to be held with mayors and other representatives of each municipality. These meetings are intended to help ensure project sustainability by introducing the project to the new municipal governments, discussing project results, and making recommendations for implementing components of the water resource management plans developed for each municipality. Although these meetings were not completed at the time of the writing of this report, the meetings were scheduled as follows:

Limon de la Cerca/Choluteca – 20 June 2002
Isla de Utila – 22 June 2002
Choloma – 24 June 2002
La Lima – 25 June 2002
Villanueva – 26 June 2002.

A copy of the agenda for the wrap-up meetings is included at the end of this section.

PROJECT KICK-OFF AND STATUS MEETINGS

AGENDA
May 3, 2001 Kickoff Meeting – Tegucigalpa
USAID Groundwater Monitoring (Water Resource Management) Studies
Choloma, La Lima, Limón de la Cerca, Utila, Villanueva

I. Introduction
- A. USAID Project Background (audience introductions)
- B. Brown and Caldwell Project Team

II. Project Goals and Objectives – Jeff Nelson
- A. Background
- B. Meeting Objectives (consensus)
- C. Project Objectives (sustainability)
- D. Scope of Work/5 Phases
- E. Municipality Needs

III. Program Implementation – Horacio Juarez
- A. Development of Partnerships
- B. Sustainability
- C. Project Schedule

10:30 – 10:45 Coffee Break

IV. Project Overview – Jim Oliver
- A. Conceptual Model
- B. Hydrogeology
- C. Modeling
- D. Matrix Prioritization

V. Water Resource Management Plans – Paul Selsky
- A. Water Needs
- B. Water Supply and Delivery
- C. Recommendations
- D. Management Plan Development

12:00 – 1:30 Lunch Break

VI. Municipality Input – Audience

VII. Technical Approach – Jay Lucas/Milton Sagustume
- A. Phases (update)
- B. Drilling
- C. Project Schedule

3:00 – 3:15 Coffee Break

VIII. Data Base – Allan Scott
- A. USGS Data Base
- B. Project GIS
- C. Technology Transfer and Training

IX. ReCap and Open Discussion
- A. Consensus

5/3/2001

Name	Organization	Phone Number
ALLAN SCOTT	BROWN & CALDWELL	916 853-5380
Barbara Goodrich	Brown & Caldwell	925-210-2345
Francisco Casco	Municipalidad Villanueva	504-670-4445
Ramón Jiménez Flores	Municipalidad Villanueva	670-44-45
Rodolfo Ochoa	SANAA.	2206506
Carlos M. Flores	USAID	236-9320-x-44
Paul Selsky	Brown & Caldwell	
Alicia Villar Landa	PRIMHOR	239-41-14/41-8
Maurice James	U.S. Army Corps of Engineers	991-9189
Mauricio Cruz	USAID	236-9320 (479
Carlos Vendin	USAID	236-9320 (4
Juan Benito Guevara	Alcaldía Choloma	882-7171
John Walker	USGS	9928312
Olman O. Rivera	USACE - USAID	995-74-79
Jason Grant	Brown and Caldwell	925-210-2383
Mario A. Soreis	Fundemun	
César H. Monroy	Fundemun	882-4298
Ricardo Valle	FUNDEMUN.	985 4930
James Oliver	Brown & Caldwell	602-222-4463
Alfredo Stein	Embajada de Suecia	221-1736
DAVID BOURAN	USAID (dbouran@usaid.gov)	236-9320 (466
ARGELIA SALGADO	USAID (a.salgado@usaid.gov)	236-9320 (4663
Jeff Nelson	Brown & Caldwell jnelson@browncald.com	988-5927 (cell
Francisco Joen	Gerente DIMUSEE	552 5211
Jorge Flores	FHIS	2348619 / 99 633
Isidro Alberto Mondragon	Fundemun	882-429
Horacio Juarez	Brown & Caldwell	(915) 545-44 / 188-59

Name	Organization	Phone Number
LOURDES RETES	CHF	2396815/31/2325
Lisa Pacholek	CHF	LPacholek_CHF@cablecolor.hn
Karen Perez	Brown & Caldwell	983-1604

AGENDA
22 de Mayo 2001
Estudio y Monitoreo de Aguas Subterráneas (Manejo de Recursos de Agua)
Los Municipios de Choloma, La Lima, Limón de la Cerca, Utila, Villanueva
Financiado por USAID

I. Introducción – Ing. Carlos Flores
   A. Antecedentes del Proyecto USAID (Presentación de los Participantes)
   B. Presentación de Brown and Caldwell y el equipo técnico del Proyecto

II. Metas y Propósitos del Proyecto – Ing. Jeff Nelson
   A. Antecedentes
   B. Propósitos de la Reunión (consenso)
   C. Propósitos del Proyecto (sostenibilidad)
   D. Alcance del Trabajo (cinco fases)

III. Implementación del Programa – Ing. Horacio Juarez
   A. Desarrollo de Asociaciones entre Agencias Participantes
   B. Sostenibilidad
   C. Programa del Proyecto

IV. FUNDEMUN – Ing. Jenny Chávez
   Aplicación de Tasas de Cobre por Explitación de Aguas Subterráneas según Plan de Arbitrios

   DESCANSO (Quince minutos)

V. Resumen de Actividades del Proyecto
   A. Evaluación de Sistemas Existentes y Recopilación de Datos – Ing. Dean Wolcott
   B. Base de Datos Hidrogeológicos – Lic. Dean Wolcott
   C. Modelación Hidrogeológica – Ing. Milton Sagastume
   D. Manejo de Recuros Hídricos – Ing. Milton Sagastume
   E. Programa de Perforación de Pozos – Ing. Milton Sagastume

VI. Comentarios por parte de Alcaldes, Gerentes o Jefes de Servicios

US AGENCY FOR INTERNATIONAL DEVELOPMENT
USAID/Honduras

Tegucigalpa, M.D.C.
21 de mayo de 2001

A QUIEN INTERESE

De todos es conocido, que cada vez es más frecuente y significativa la utilización y explotación de acuíferos subterráneos para satisfacer las demandas de agua de las poblaciones de varias comunidades y ciudades alrededor del país. Por lo que es fácilmente previsible que el uso de las aguas subterráneas para el abastecimiento de agua potable en estas localidades, se incrementará en la misma medida que haya un crecimiento de la población futura y por lo tanto los rendimientos de estos acuíferos se verán disminuidos en una mayor proporción.

Los sistemas de abastecimiento de agua de las ciudades de La Lima, Choloma y Villanueva en el valle de sula, de la Isla de Utila y de Choluteca, que utilizan las aguas subterráneas como principal fuente de abastecimiento, fueron severamente dañados durante el paso del Huracán Mitch. Actualmente, la Agencia Internacional para el Desarrollo de los Estados Unidos (USAID) realiza fuertes inversiones en estas regiones para construir nuevos centros habitacionales y para rehabilitar y a su vez expandir los sistemas de abastecimiento de agua respectivos.

Recientemente, la USAID ha contratado los servicios de la Firma Consultora Brown and Caldwell para elaborar un estudio de monitoreo de aguas subterráneas en las ciudades arriba mencionadas. El desarrollo de dicho proyecto conlleva el realizar estudios hidrogeológicos, recopilar una base de datos que provea información suficiente para implementar planes prácticos y efectivos en la administración del recurso agua subterránea en cada localidad y determinar si este recurso cumple y satisface adecuadamente las expectativas y requerimientos de demanda actual y futura. Así mismo, el Estudio contempla realizar una evaluación preliminar de la infraestructura de abastecimiento de agua subterránea existente en cada municipalidad y desarrollar costos estimados preliminares para el mejoramiento de esta infraestructura.

El éxito de este proyecto será medido al asegurar la sostenibilidad de los objetivos planteados en el mismo, una vez que éste finalice. Por lo tanto, un componente fundamental para asegurar dicha sostenibilidad será el de crear relaciones de trabajo permanentes entre el Consultor y cada una de las municipalidades involucradas, así como con otros organismos y/o instituciones relacionadas con el tema de aguas subterráneas, como ser SANAA, FUNDEMUN, Acción Contra el Hambre, UNITEC y la Comisión Ejecutiva del Valle de Sula. Dentro de este contexto, cabe mencionar que es menester de la Municipalidad designar el recurso humano necesario para que sea debidamente

Mailing Addresses: From USA: USAID/Honduras, UNIT 2927, APO AA 34022. Tel. 011-504-236-9320
In Honduras: Apartado Postal 3453, Tegucigalpa, M. D. C. Tel. 236-9320, Fax (504) 236-7776

capacitado por la Firma Consultora en el manejo, seguimiento y monitoreo del modelo y de la base de datos que será proporcionada a la Municipalidad.

En base a lo anterior, solicitamos su gentil cooperación para proporcionar toda aquella información que usted estime conveniente a la Firma Brown & Caldwell, la cual ha sido contratada para elabora este estudio. Su cooperación y asistencia son vitales para alcanzar el éxito y garantizar los futuros recursos de agua subterránea en Honduras.

Atentamente,

Todd Sloan
Director
Oficina de Desarrollo Municipal
e iniciativas Democráticas

Lista de Invitados

22 de Mayo 2001

No.	Nombre	Empresa/Corporación	Teléfono	E-mail
1	Jorge Flores	FHIS/USAID	992 6334	Jorgeflores@optinet.hn
2	Carla R. Kindel	USAID		[illegible]@usaid.gov
3	Ruben C. Rosales	COE	334-990-3193	ruben.c.rosales@sam.usarmy.mil
4	Antonio Morales Flores	FHIS/USAID	980-2090	
5	Jose Francisco Casco	Municipalidad Villanueva	226-7269 / 670-04-[illegible]	
6	Ramon Jimenez Flores	Municip. de Villanueva	670-04-45	
7	Hector H. Cabrera	MUNIC de Villanueva	6704084	
8	Javier Reyes	MUNIC de Villanueva	670-[illegible]	
9	Rigoberto Rivera C	Municip de Villanueva	670-58-80	
10	Ruben - Saravia	Municip. de Lima	668.29.00	
11	Dilcia Fernandez	Regidora La Lima	991-6547	DIFzelaya@
12	Monterey Cárdenas	Municipalidad de Utila	425-3293	—
13	Juan Ramón Mejia A.	Municipalidad Choloma	669-39-22	— " —
14	Deud Ordaino	Municipalidad de Choloma	669 5322	
15	Osman O. Alvarenga M.	MUNICIPALIDAD DE CHOLOMA	669-3223	oalvarengam@hotmail.com
16	Atilio Boanerges Alvarez	Municipalidad de Choluteca	983 4055	— " —
17	Maria Alejandrina Meza	Municipalidad. La Lima	668 0656	
18	Raul E. Durón	FUNDEMUN	232 1846	Fundemu1@hondotel.hn
19	Jenny Chávez	FUNDEMUN	566-16-23	
20	José Julio Gomez	FUNDEMUN	556-82 42	Jfgomez@Yahoo.com
21	Carlos M. Flores R.	USAID/MDDI	236-9320	cflores@usaid.gov
22	DAVID D. LARDIZABAL	SERPE	554-3055	serpe@hn2.com
23	Milton Sagastume	ATICA	558-17-51	
24	Vanessa Castellanos L.	TRADUCTORA	985-9767	Vanessacast@terra.com.
25	Jason Grant	Brown and Caldwell	988-5904	JGrant@brwncald.com
26	Jeff Nelson	" "	988-5927	JNelson@brwncald.com
27	David Espinoza	ATICA	551 5686	David_Espinoza@hotmail.com
28	Dean Wolcott	Brown + Caldwell		dwolcott@brwncald.com
29	Karen Perce	Brown + Caldwell		
30	Darwin A. Vallecillo	Atica	566-0701	[illegible]@[illegible]ach.com
31	Marlon Yineda	Atica	558-7751	~~HJuarez@Brwncald.com~~
32	Horacio Juarez	Brown & Caldwell		HJuarez@brwncald.com • Cell Honduras 988-593[illegible] • Cell USA (915) 588-031 • Tele USA (915) 545-44 • Tele Hond 558-7751
33	Fabiola Andrade M.	Brown & Caldwell	980-1906	@9562005@hotmail.com
34	Nelly R. Lemus	ATICA	558-1751	— o —
35	Aurora Rodriguez	Municipalidad La Lima	668-2400	Edlalima@hotmail.com.
36	José Evaristo Ercida F.	Municipalidad La Lima	668-2601	
37	Doris Marlena Pérez Lagos	Municipalidad La Lima	668-26-01	
38	Mario Ramón Jiménez Soto		651 27 35	

USAID

BROWN AND CALDWELL

Lista de Invitados

22 de Mayo 2001

No.	Nombre	Empresa/Corporación	Teléfono	E-mail
	Germán Wilfredo Henríquez	Municipalidad Lima	6682488	

AGENDA
USAID Monitorio y Estudios de Aguas Subterráneas
Presentación del Modelo Conceptual Hidrogeológico Preliminar
Utila, Valle de Sula y Limón de la Cerca

11 de Julio 2001
9:30 a.m.
Hotel Princess
San Pedro Sula

I. INTRODUCCION

II. RECURSOS DE AGUA EXISTENTES
  A. Fuentes de Agua
  B. Localización de Pozos

III. MODELOS CONCEPTUALES HIDROGEOLOGICS PRELIMINARES
  A. Geología
  B. Hidrogeología

IV. DATOS
  A. Geología
  B. Hidrogeología
  C. Calidad de Agua
  D. Modelación
  E. Información del Sistema de Agua

V. FASE II INVESTIGACION DE CAMPO
  A. PERFORACION
    1. Pozos de Prueba
    2. Aquíferos de Prueba
    3. Muestreo y Análisis de Agua

  B. ESTUDIOS GEOFISICOS
    1. Estudios EM
    2. Estudios Sísmicos y Reflexión

VI. EVALUACION DE LA INFRAESTRUCTURA DEL SISTEMA DE AGUA
  F. Población
  G. Uso de Agua
  H. Facilidades de Sistema de Agua

VII. DISCUSION

11 de Julio 2001
Invitee List

VILLANUEVA MUNICIPALITY 670-4788/670-4445

1. Lic. José Felipe Borjas (Alcalde Municipal)
2. Lic. Francisco Casco (Jefe de Obras y Servicios Públicos)
3. Lic. Rigoberto Rivera (Jefe de Servicios Públicos)
4. Juan Pago Avila (Jefe de Departamento de Agua)
5. Alfredo Cabrera (Jefe de Operación de Mantenimiento)
6. Ramón Jímenez Flores
7. Hector Cabrera

LA LIMA MUNICIPALITY 668-2400/668-2601

1. Lic. Evaristo Euceda (Alcalde Municipal)
2. Ing. Doris Pérez (Directora de Servicios Públicos)
3. Ruben Saravia (Jefe de Servicios Públicos)
4. Ing. Aurora Rodríguez (Asistente)
5. Jorge Nery López (Asistente Departamento de Catastro)
6. Dilcia Fernandez
7. Lic. José Luis Caballero-- ASITENCIA SOLICITADA POR ALCADE
8. Ing. German Henríquez-- ASITENCIA SOLICITADA POR ALCADE

CHOLOMA MUNICIPALITY 669-3322/6693223

1. Lic. Armando Gale (Alcalde Municipal) (no)
2. Ing. Osman Alvarenga (Director de Servicios Públicos)
3. Ing. Julio César Hernández (Jefe de Servicios Públicos)
4. Ing. Edy Martínez (Asistente de Ingeniería)
5. Juan Ramón Mejía
6. Dario Perdomo

LIMON DE LA CERCA 882-5079/ 882-5011

1. Actilio Alvarez (Técnico DIMUSED)
2. Manuel Mejía (Técnico DIMUSED) (no)
3. Juan Benito Guevara (Alcalde Municipal) (no)

FUNDEMUN

1. Ing. Mario Alberto Garcia
2. Ing. Jenny Chávez (Choloma, Villanueva) 984-1577
3. Ing. Jose Tulio Gómez (La Lima) 647-3136

COE

1. Rueben Rosales

UTILA MUNINICIPALITY 425-3255

1. Monterrey Cárdenas (Alcalde Municipal)

UNITEC

11 de Julio 2001
Invitee List (Continued)

AGUAS DE SAN PEDRO

1. Ing. Claudia Enamorado

SANAA

1. Rodolfo Ochoa (Arturo Trochez en representación) (220-6506)

USAID (236-9320)

1. Carlos Verdial
2. Mauricio Cruz
3. Frank Almaguer (Embajador)
4. John Jones (Consul)
5. Timothy M. Mahoney (Director de la Misión)
6. Glenn Berce-Oroz (Director Interino de la oficna de Desarrollo Municipal e Iniciativa Democrática)
7. Charles Oberbeck

PRIMHOR (239-4114)

1. Alicia Villar Landa (Ing. Victor Manuel Leva Coordinador unidad SPS)

USGS (236-7776

1. John Walkey
2. Olman O. Rivera
3. Jeff Phillips

FHIS

1. Jorge Flores (992-6334)
2. Antonio Morales (980-2090)
3. Gunther Von-Weise
4. Ing. Samuel Alvarado

USAGE

1. Carlos Selva

CHF

1. Lourdes Retes (Asistirá *Nohemy Carrasco* de parte de HOGAR)
2. Lisa Pacholek (no asistirá)

LISTA ASISTENTES

11 de Julio 2001

HOTEL PRINCESS, SAN PEDRO SULA

NOMBRE	EMPRESA	CARGO	TELEFONO	FAX	E-MAIL	FIRMA
José Tulio Gómez	FUNDEMUN.	CONSULTOR	556-8242	556-8242	jtgomez@Yahoo.com	
Ben. Saravia	Municipalidad	Jefe S. P.	668-24-00			
Jorge Nery Lopez	Munic - La Lima	Asistente-Catastro	668-24-00			
Ramón Jiménez Flores	Munic. de Villanueva	Obras Publicas	670-44-45	670-44-04		
Victor M. Leiva	PRIMHUR	Gerente Regional	550-40-06	550-40-06		
Noemi Carrasco	CHF	Oficial Tecnico	2325758	idem		
Claudia Enamorado	ASP	Jefe Control Calidad	556-8955	556-9084		
Marlon Pineda	Alica	Supervisor	558-17-51	558-18-04		
Julio G. Alvarez	DIMUSEB chol.	Tecnico Mantenimiento	983 4055			
Antonio Morales Flores	FHIS	Supervisor Proy	980-2090	276-7264		
Dania Andrade	B&C	Secretaria	557-1176	980-1906	a95620005@hotmail.com	
Vaytek Bajsarowicz	B&C	VP	557-1176		VBAJSAROWICZ@BROWNCALD.COM	
Horacio Juarez	BC		557-1176		HJuarez@brown	
Jay Lucas	BC	Geologist	557-1176		jlucas@brwncald.com	
Paul Selsky	BC		557-1176		pselsky@browncald.com	
Jeff Nelson	BC	Ingeniero	557-1176		jnelson@browncald.com	

LISTA ASISTENTES

11 de Julio 2001

HOTEL PRINCESS, SAN PEDRO SULA

NOMBRE	EMPRESA	CARGO	TELEFONO	FAX	E-MAIL	FIRMA
[illegible] Trochez	SANAA	Coordinador de hidrogeologia	220-6506	237-8552	etrochez@yahoo.com	[illegible]
[illegible] Cárdenas	Munic- Utila	Alcalde Municip	4253093	4253255		[illegible]
Marley Howell	Utila Lodge Resort	Secretary	425-3143	425-3209	marleyhowell@hotmail.com	[illegible]
Alton Cooper	Alton's Dive Center	Owner/Dueño	425-3337	425-3108	altons@hondutel.hn	[illegible]
[illegible] Alvarenga	Munic. Choloma	Jefe Obras y Serv.	669-3223	669-1774	calvarenga[illegible]@hotmail.com	[illegible]
[illegible] Francisco Cacer	Municip. Villanueva	Gerente Obras y Ser	P. 670-4445	670-4404		[illegible]
[illegible] M. Lopez	FUNDEMUN	Consultora	557-8078	557-8078	graciaml@yahoo.com	[illegible]
[illegible] Rodriguez	Muni-La Lima	Asist. de Ing.	668-2900		[illegible]latinmail.com	[illegible]
[illegible] H. Pérez L.	Municipalidad La Lima	Ingeniero Municipal	668-26-01	668-26-01		[illegible]
[illegible] Nery Lopez	Municipalidad La Lima	Asist. - Dept. Catastro	668-24-00	668-26-01		[illegible]
[illegible] Sarmiento	Municipalidad Lima	Jefe. Serv. Pub.	668-24.00	668-26-01		[illegible]
Julio César Hernández	Municipalidad Choloma	Asesor Tecnico	669-32-23	669-17-74	—	[illegible]
Víctor M. Leva	PRIMHUR	Gerente Regional	552-4590	554-40-04		[illegible]
Jenny M. Chávez	FUNDEMUN	Asesora	566-16-23			[illegible]
José Julio Gómez	FUNDEMUN	Consultor	556-8292	556-8292	jgomez@yahoo.com	[illegible]
Milton Sagastume	ATICA	Gerente General	558-17-51	558-18-04	atica@hn2.com	[illegible]
[illegible] R. Vardin	USAID	Ingeniero Proyectos	236-9320	238-2812	[illegible]@usaid.gov	[illegible]
Mauricio Cruz	USAID	Oficial de Proyectos	236-9320	238-2812	mcruz@usaid.gov	[illegible]

TRAINING SESSIONS

GROUNDWATER MONITORING STUDIES/HONDURAS
GROUNDWATER MONITORING TRAINING
December 4, 6, and 10, 2001

INTRODUCTION

Brown and Caldwell performed three groundwater monitoring training events in early December, 2001, covering the five project municipalities. Similar training was conducted throughout Phase II of the project and the purpose of the recent training was to reinforce knowledge and practices learned by the participants during earlier fieldwork and training. Attached is the outline that was presented for the training session.

The training of Honduran personnel is essential to one of the project's main goals: project sustainability. The purpose of the training program is to ensure that each municipality will continue the Groundwater Level and Monitoring Program after the current project is completed.

These training sessions were conducted by Dean Wolcott, P.G., with the assistance of Barbara Goodrich and Fabiola Andrade (Sula Valley and Utila). Mr. Atilio Alvarez, technician for the municipality of Choluteca, assisted the BC staff in the Limon de la Cerca/Choluteca training session.

TRAINING PARTICIPANTS

The following lists describe the individuals who participated in the groundwater monitoring training. While the majority of participants are municipal engineers and technicians, personnel from non-governmental organizations were also invited and participated.

Site: Limon de la Cerca / Choluteca
Conducted by: Dean Wolcott, P.G., and Atilio Alvarez
Training date: December 4, 2001

PARTICIPANT	ORGANIZATION
Romulo Vivas	DIMUSEB/Choluteca
Guillermo Ordonez	DIMUSEB/Choluteca
Atilio B. Alvarez	DIMUSEB/Choluteca
Rosa Fiallos	PNUD/DIMUSEB
Cesar H. Mondragon	FUNDEMUN
Jorge Flores	FHIS

Site: La Lima, Villanueva, and Choloma
Conducted by: Dean Wolcott, P.G., Barbara Goodrich, and Fabiola Andrade
Training date: December 6, 2001

PARTICIPANT	ORGANIZATION
Jorge Nery Lopez Vasquez	La Lima Municipality
Jose Ruben Saravia	La Lima Municipality
Doris Marlenee Perez Lazo	La Lima Municipality
Alexis Orellana Martinez	La Lima Municipality
Jenny Mariela Chavez	FUNDEMUN
Jose Rigobero Rivera	Villanueva Municipality
Julio Cesar Hernandez	Choloma Municipality
Osman O. Alvarenga. M.	Choloma Municipality
Carlos R. Castillo L.	Choloma Municipality
Jose Francisco Casco P.	Villanueva Municipality
Hector A. Cabrera	Villanueva Municipality
Olga Lara de Hubin	Choloma Municipality
Antonio Morales Flores	FHIS

Site: Island of Utila
Conducted by: Dean Wolcott, P.G., Barbara Goodrich, and Fabiola Andrade
Training Date: December 10, 2001

PARTICIPANT	ORGANIZATION
Jonell Jackson	
Joslyn J. Ponce	
Alton Cooper	Utila (Mayor Elect)
Glenn Gabourel	Island Spring
Jorge Flores	FHIS
Gilda Ordonez	Utila
Carolina Escobar	Utila

TRAINING TOPICS

The subject matter of the training sessions consisted of all relevant technical material associated with the Groundwater Level and Monitoring Program. Topics included monitoring system well selection criteria, groundwater level measuring methodology, groundwater sampling methodology, field analysis of groundwater samples, laboratory analysis of groundwater samples, quality assurance/quality control, and data interpretation.

Each training session consisted of a classroom lecture and discussion followed by a hands-on field practice session where monitoring and data collection activities were conducted at a monitoring well.

A special emphasis was placed on proper documentation of field activities and the use of designated data collection forms developed for the Program.

TRAINING MATERIALS

Training participants were provided with a copy of the Groundwater Level and Monitoring Program Field Manual. This field manual contains detailed descriptions of the activities contained in the monitoring program, copies of field data forms, pictures of specific field activities, and a list of wells in the monitoring well network for each municipality.

Materials provided in the training sessions included an electronic water level meter, Oakton field water quality kit, groundwater sample kit, water filter apparatus, and other monitoring equipment.

Water Resources Management System
Training Summary
February 12 and 14, 2002

Introduction

Brown and Caldwell conducted two training workshops in February to train representatives from each municipality on the use of the Water Resources Management System (WRMS). The WRMS is a custom database and geographic information system application that has been custom developed to use as a water resource planning tool to support the goals of this project.

Integration of the use of the WRMS with the other recommendations and programs established in this project are essential to the main project goal of providing for sustainable water resource management in the future. The WRMS has been designed to support other project programs such as the Groundwater Level and Monitoring Program (training conducted in December, 2001). The purpose of this training was to provide hands-on training and experience with the WRMS application so that the municipalities can use it to maintain and manage data and to use the tool for future decision-making.

The main goals of the training were to gain an understanding of the capabilities of the WRMS, learn how to enter and manage data, and create maps and reports from data in the database. Each workshop consisted of a one-day hands-on course and covered a system overview, how to start using the system, entering infrastructure data, accessing other resources, system administration, creating GIS basemaps, and using well prioritization tools. The following workshops were conducted:

- UNITEC Campus, San Pedro Sula, February 12, 2002;
- UNITEC Campus, Tegucigalpa, February 14, 2002.

Training Topics

Each workshop was conducted at the UNITEC computer laboratory and each participant had their own computer and a training copy of the database. The participants used a 114 page training manual that contained a detailed discussion of each function in the WRMS, theory and recommendations for best practices, and 20 individual exercises designed to provide hands-on training and practice. During the training, the following objectives were successfully accomplished by the participants:

- Learn the components of the WRMS
- Enter and edit service areas data
- Enter well information
- Store images and other electronic files
- Enter water quality samples and water levels
- Enter storage tank information
- Create reports from the database

- Learn how to access other resources (the USGS Groundwater Well Database, Municipal Water Resources Reports, etc.)
- View wells and storage tanks on a map
- Use the basic functionality of ArcView to create a map
- Display well information on a map (water level, water quality, depth, etc.)
- Overview of the well site prioritization tool

Training Participants

Training was conducted by Allan Scott of Brown and Caldwell, with assistance from Fanny Letona (ATICA), David Esponiza (ATICA), and Fabiola Andrade (Brown and Caldwell).

The following are lists of the individuals that participated in the workshops.

San Pedro Sula, February 12, 2002 participants:

Participant	Organization
Ramón Jimenéz Florez	Villanueva Municipality
José Rigobero Rivera	Villanueva Municipality
Francisco Casco	Villanueva Municipality
Marvin Pinador	Villanueva Municipality
Jackeline Reyes	La Lima Municipality
Jose Ruben Saravia	La Lima Municipality
Carlos H. Ochoa	La Lima Municipality
Doris Perez	La Lima Municipality
Julio Cesar Hernández	Choloma Municipality
Ruglio Diaz	UNITEC

Tegucigalpa, February 14, 2002 participants:

Participant	Organization
Mauricio Cruz	USAID
Carlos Verdial	USAID
Jorge Flores	FHIS
Glenn Gabourel	Utila Municipality
John Walkey	USGS

PROJECT WRAP-UP MEETINGS

USAID Groundwater Water Resources Management Project
Project Wrap-up Workshop Agenda

Introductions (All)

Project Purpose (USAID)
- History
- Objectives

Project Sequence (BC/Atica)
- Initial data gathering
- Conceptual model development
- Field Investigation
- Groundwater flow model
- Evaluation

Results and Findings (BC/Atica)
- Water requirements/demand
- Aquifer characteristics
- Groundwater quality
- Future wells
- Well head protection

Data base (BC/Atica)

Training (BC/Atica)

Computers & Equipment (USAID)

Recommendations/Summary

Break

Field visit to wells