GROUNDWATER RESOURCES MONITORING REPORT AND MANAGEMENT PLAN

Island of Utila, 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, Utila, 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 Utila, 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 Limón de la Cerca, Choloma, Villanueva, and La Lima 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

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

Julie Wright, R.G.
Arizona Registered Geologist #37120
Groundwater Modeling

Milton Sagastume
Local Project Coordinator - Honduras

PROJECT PARTICIPANTS

U.S. 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)

Jorge Flores, Honduras

Municipality of Utila

Alton Cooper, New Mayor of Utila (Elected November 2001)
Monty Cardenas, Former Mayor of Utila

Brown and Caldwell, Lead Consultant

Voytek Bajsarowicz, Walnut Creek, CA, Principal-in-Charge
Harry Brenton, Phoenix, AZ, Field Geologist
Greg Christians, Nashville, TN, Groundwater Modeling
Dana Downs, Phoenix, AZ, Report Preparation
Bob Grace, Walnut Creek, CA, Project Advisor
Jason Grant, Walnut Creek, CA, Field Engineer
Melanie Holton, Sacramento, CA, Water System Engineer
Horacio Juarez, El Paso, TX, Project Manager
Jay Lucas, Sacramento, CA, Phase 2 Field Investigation Manager
Shalom Marquardt, Sacramento, CA, Database Preparation
Jeff Nelson, Walnut Creek, CA, Project Director
Jim Oliver, Phoenix, AZ, Phase 3 Groundwater Modeling Manager
Ah'lai Phelps, Sacramento, CA, Report Preparation
Allan Scott, Sacramento, CA, Phase 4 Database Manager
Paul Selsky, Sacramento, CA, Phase 5 Report Preparation Manager
Julie Wright, Phoenix, AZ, Groundwater Modeling

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

Milton Sagastume, Local Project Coordinator
Marlon Pineda, Field Engineer

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

Terra-Dynamics Consulting, Inc. (TDC) – Electromagnetic Survey Subconsultant, Lewiston, New York, United States

David Slaine, Hydrogeologist, Lewiston, New York, United States

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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

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.

Archipelago: Any cluster of islands.

Breccias: Rock composed of sharp-angled fragments embedded in a fine-grained matrix.

Cays: Small low islands.

Conductivity: Quality or capability of transmitting and receiving. Normally used with respect to electrical conductivity.

Ephemeral: Anything short-lived.

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.

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

Infiltration: The entrance of applied water in the soil through the soil-water interface.

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

Karst: An area of limestone terrain characterized by sinks, ravines, and underground streams.

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.

Pyroclastic Flows: Composed chiefly of fragments of volcanic origin, as agglomerate, tuff, and certain other rocks; volcaniclastic. (definition for pyroclastic)

Surface Geophysical Survey: The study of specific information on the stratigraphy and structure of the local geologic environment as well as aquifer properties.

REFERENCES

Bond, Steven. 1998. *Hydrogeology of Roatan, Utila, and Guanaja, a Synoptic Survey with Recommendations for the Terms of Reference, The Bay Islands, Honduras, C.A.* Prepared for Water For People, in Support of the Bay Islands Environmental Project.

Hemmett. 1998. *2nd Ed. Mapa Geologico de Honduras, Utila, Instituto Geografico Nacional de la Secretaria de Comunicaciónes Obras Publicas y Transporte.*

Fundacion Para el Desarrollo Municipal (FUNDEMUN), Municipalidad de Utila, USAID. 2000. *Estrategia Participativa de Desarrollo Integral de Utila, Islas de la Bahia.*

Instituto Geografico Nacional, Servicio Autonomo Nacional de Acueductos y Alcantarillados, Organizacion para el Desarrollo de Ultramar, and Oficina Regional de Ciencia y Tecnologia para America Latina y el Caribe. *Mapa Hidrogeologico de la Republica de Honduras, Escala 1:500,000.*

SANAA. 1993. *Informe Tecnico No. 28. Condiciones Hidrogeológicas y la explotación de aguas subterraneas en Utila, Islas de la Bahia.*

USAID. 1999. *Terms of Reference for the Rehabilitation and Expansion of the Water Supply System and the Upgrade of the Sewerage System, Utila, Islas de la Bahia, Honduras.*

USAID. 2000. *Results Review and Resource Request, USAID/Honduras.*

U.S. Army Topographic Engineering Center. 1996. *Water Resources Areal Appraisal, Honduras.*

EXECUTIVE SUMMARY
Groundwater Resources Monitoring Report and Management Plan
Utila, 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 (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 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 Utila, Honduras.

Background

Utila is one of the three main islands of the Bay Islands archipelago located about 30 kilometers (km) (19 miles) north of the coast of mainland Honduras in the Caribbean Sea. Almost all of Utila's population lives on the eastern one-third of the island, in an area called East Harbor, also known as Utila Town. Also, a small number of residents live in a fishing village, known as Los Cayitos, off of Utila's southwestern coastline and inhabits two cays, or small islands, known as Pigeon (Lower) Cay and Jewel (Upper) Cay.

Utila is a low relief island. Geologically, the western two-thirds of the island consists of a cap of coralline limestone and carbonate sediments that is underlain by metamorphic rocks. This part of the island is characterized by low-lying areas that contain mangrove swamps and savannas with brackish surface water. The eastern third of the island consists of Holocene volcanics characterized by two hills, or relief cones. Stuart Hill (elevation 51 meters (m) (167 feet (ft))) is located approximately 2 km (1.2 miles) inland from the center of East Harbor, and Pumpkin Hill (elevation 74 m (243 ft)) is located on the northeastern coast about 6 km (3.7 miles) from East Harbor. The land between these two landmarks contains rolling hills covered in dense vegetation. The entire island is surrounded by an extensive coral reef. The climate of Utila is considered tropical, with annual precipitation ranging between 2,200 millimeters (mm) (87 inches (in)) and 2,600 mm (102 in) per year.

Description of Existing Water System and Water Demands

Four municipal wells provide the municipal water supply for East Harbor. Three of the wells pump directly into the distribution system with a combined capacity of 4 liters per second (lps) (60 gallons per minute (gpm)). Water is available from the fourth well by hand bailing. Another manual access well provides water supply for the community of Pigeon Cay. Some of the residents of Utila have constructed their own private wells to supplement the municipal water distribution system. In addition, some Utila residents use rainwater collected in cisterns for water supplies.

The East Harbor distribution system consists of one 94,635 liter (25,000 gallon) water storage tank, with one pressure zone that is gravity fed from the tank. The Utila piping system consists of approximately 3.7 km (2.3 miles) of 102 mm and 152 mm (4 in and 6 in) diameter polyvinyl chloride piping. There is no filtration or disinfection of the water before it enters the distribution system.

East Harbor had a population of approximately 6,100 residents in 2001. Based on a FUNDEMUN Study, it is estimated that the East Harbor population will increase to 12,221 by 2009 and 19,612 by 2020. The Los Cayitos community had a population of about 1,700 people in 2001. It is estimated that the Los Cayitos population will increase to 3,255 by 2009 and 4,944 by 2020. In the year 2001, there were approximately 45,177 visitors to Utila, with the average length of stay per visitor estimated to be approximately 7.4 days. Tourism is expected to increase to 106,264 visitors by 2009 and 241,150 visitors by 2020.

Brown and Caldwell's field investigations conducted for this study indicates that the municipal water system has an average annual daily water production of about 246,000 lpd (65,000 gpd). This results in a current per capita water use of 34.8 liters per capita per day) (9.2 gallons per capita per day), which includes tourists but excludes water use from private wells and rainfall harvesting. Water demands to serve East Harbor by 2020 are expected to increase to 927,000 liters per day (245,000 gallons per day) (274 acre-feet per year).

Groundwater Resources Evaluation

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

The initial conceptual hydrogeologic model stated that infiltrating precipitation could develop a fresh water lens within the coral limestone extending into the underlying volcanic units. This infiltrated precipitation is less dense than the seawater and creates a zone or lens of freshwater laying on top of the saltwater. Recharge of precipitation would flow in a radial pattern from the higher elevation areas, such as Stuart Hill, displacing seawater and potentially forming a usable potable water resource.

Based on the conceptual hydrogeologic model, the Stuart Hill area was identified as having the greatest probability of providing sustainable groundwater supplies, and thus, the field investigation was focused in this area. The primary objective of the field investigation was to evaluate if a significant lens of fresh water exists in the Stuart Hill area. The field investigation in this area consisted of conducting a surface geophysical survey, a fracture trace analysis, installation and testing of five wells, and a water quality survey.

The surface geophysical survey consisted of an electromagnetic survey to evaluate subsurface resistivity to identify the presence of fresh water. The fracture trace analysis consists of using aerial photos, maps, and field reconnaissance to identify visible fractures and faults that may provide conduits for fresh water infiltration. The results of the geophysical investigation combined with the results of the fracture trace analysis delineated a potential fresh water zone in the vicinity of Stuart Hill. Drilling locations were selected based on these findings.

From August through October 2001, Brown and Caldwell conducted a subsurface investigation that consisted of drilling five test wells. Short-term (2- to 4-hour pumping) and long-term (48-hour pumping) aquifer tests were performed on some of the test wells to evaluate the groundwater resource development potential. A small, localized zone of freshwater northeast of Stuart Hill was identified surrounding well BCUT-4. A numerical groundwater flow model was prepared to simulate limited groundwater production of this water source. Evaluation of the model results suggest that limited water production of this zone of 1.5 lps (24 gpm) is available for short-term water supply demands for less than one year of continuous pumping after which increasing salinity would make the supply unacceptable for potable water use.

Water quality surveys of the existing wells and test wells, performed by Brown and Caldwell, found that water quality on the island is generally poor with few wells producing significant quantities of water with estimated total dissolved solids concentrations of less than 1,000 milligrams per liter.

There are several potential sources of contamination to the shallow fresh water aquifer in the vicinity of Stuart Hill. These sources include cattle grazing areas and private wastewater disposal facilities.

Results of the field investigation indicate that a significant fresh water lens is not present beneath the island. The absence of a well-developed freshwater lens is believed to be due to the volcanic clay soils that inhibit the vertical recharge of precipitation. Of the 2.4 m (7.9 ft) of precipitation that Utila receives annually, it is estimated that only 2.5 percent recharges the fresh groundwater aquifer system in the vicinity of the Stuart Hill recharge area. The results of the field investigation did indicate the presence of fresh water in the coralline limestone northeast of Stuart Hill. However, the extent of this fresh water is limited and will not support substantial groundwater development above a total average annual extraction of 1 to 2 lps (20 to 30 gpm). Current annual water use by the municipal wells is estimated to be 3 lps (45 gpm). Therefore, it appears that the safe yield of the aquifer is currently exceeded, which indicates that groundwater quality may be deteriorating over time. Water quality and well yield potential for the remaining portion of the island has a very low potential for further groundwater development and would not likely support high water quality well yields greater than 0.3 to 0.6 lps (5 to 10 gpm).

Water Resources Management System

The Water Resources Management System 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 municipality and other decision-makers to sustainably manage Utila'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 that depicts the locations of the existing wells, test wells, and other key information. Geologic cross sections are presented in Figures ES-2 and ES-3. The following recommendations are made in order to address Utila's water supply:

1. Conduct a regular groundwater monitoring program consisting of monitoring groundwater levels, groundwater useage, and water quality in selected wells. For Utila, it is particularly important to establish if groundwater quality is deteriorating over time in relation to groundwater extraction rates. Collected groundwater data should be input into the database.

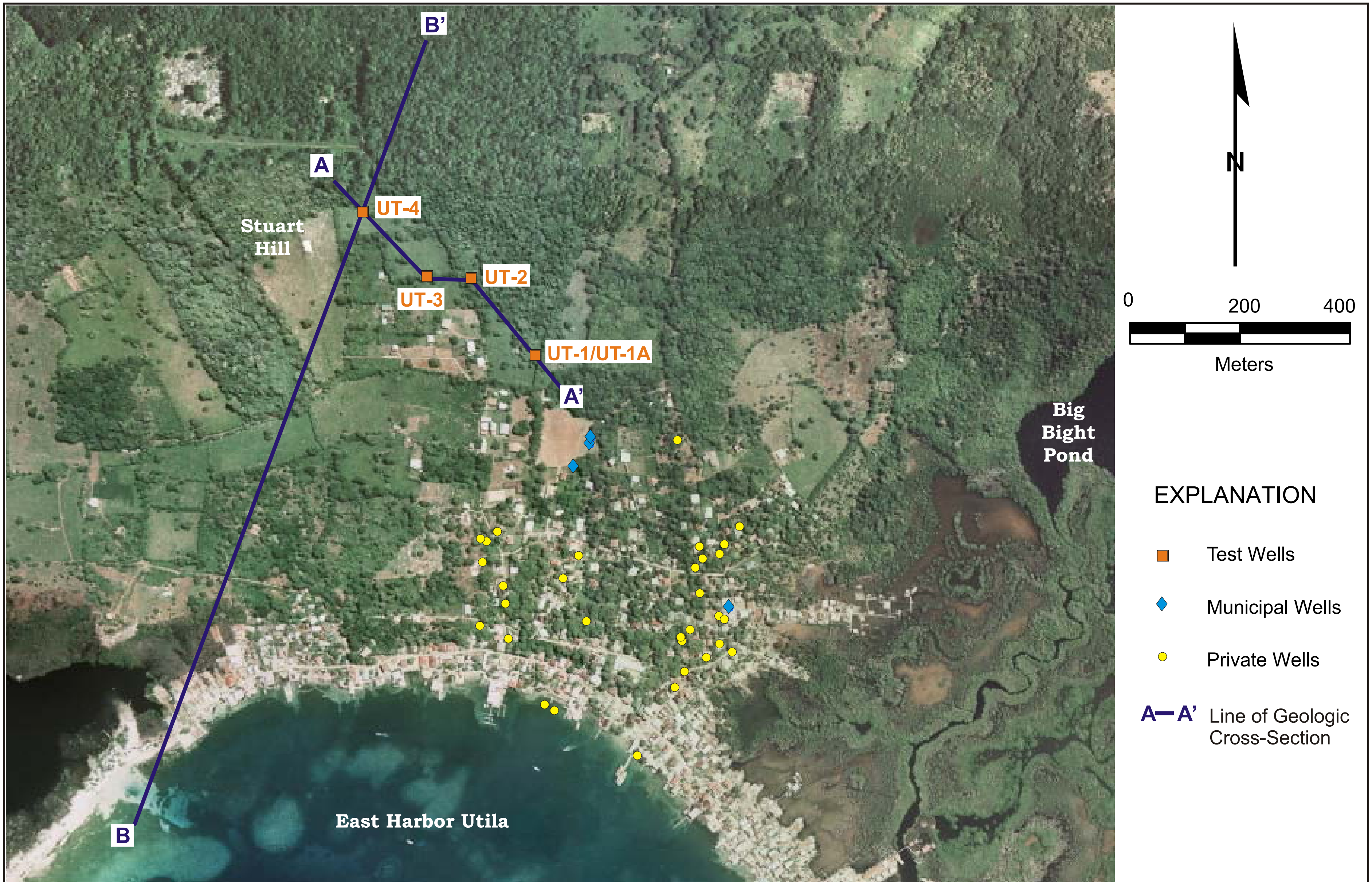
2. Establish a wellhead protection program to reduce the chance of groundwater contamination impacting water supply wells.

3. Use the database, also known as the Water Resources Management System, to input data regarding new wells and from the monitoring program.

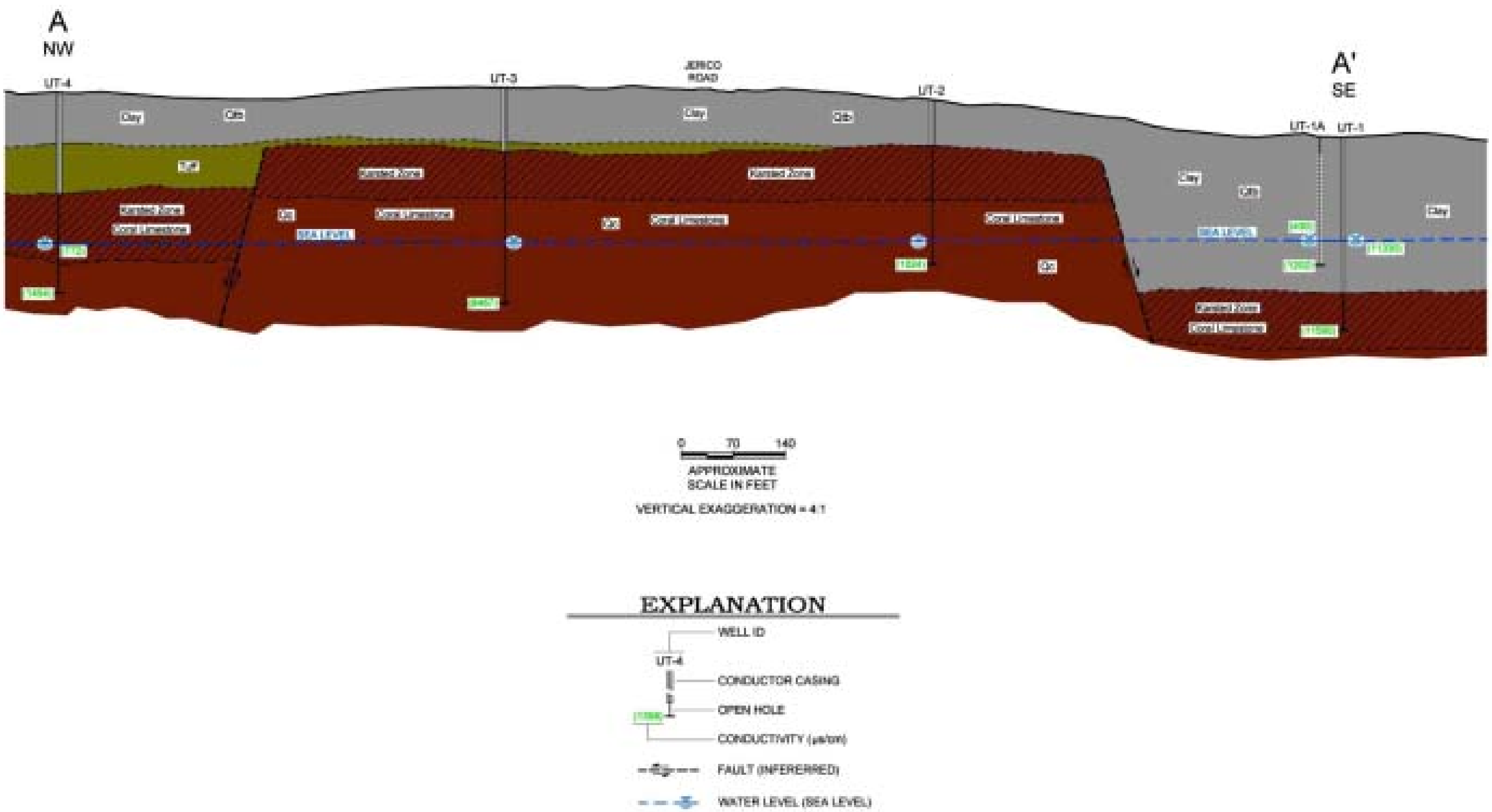
3. Ensure a functioning water utility that is financially self-sufficient by:
   a. developing a customer inventory;
   b. developing a financial plan and charge customers for water useage;
   c. having a governance structure and appropriate staff;
   d. addressing water loss from the distribution system; and
   e. investigating potential sources for grants and loans.

4. Given the restricted water supply conditions in Utila, conduct a study to evaluate water supply alternatives.

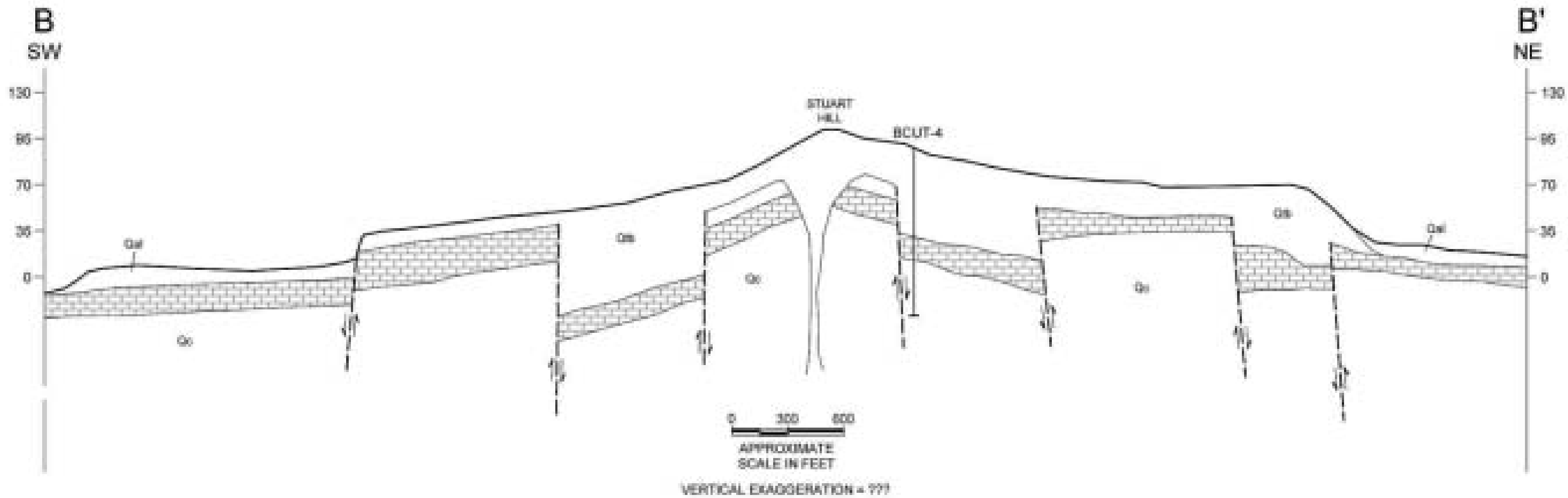
5. Since the potable groundwater resource in Utila is limited, it is recommended that the municipality limit, by municipal regulation, any increase in pumping and the construction of new wells and protect the upland recharge areas. New development should be required to utilize alternative water supply sources such as rainfall collection/cistern systems.



BROWN AND CALDWELL	DATE 6-12-02	SITE Utila Bay Islands, Honduras	FIGURE ES-1
	PROJECT 21143	TITLE Groundwater Resources Planning Map	



BROWN AND CALDWELL	DATE 6-12-02	SITE Utila Bay Islands, Honduras	FIGURE ES-2
	PROJECT 21143	TITLE Cross-Section A-A’	



EXPLANATION

BROWN AND CALDWELL	DATE 6-12-02	SITE Utila Bay Islands, Honduras	FIGURE ES-3
	PROJECT 21143	TITLE Cross-Section B-B’	

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 Nuevo Limón de la Cerca near Choluteca.

This Groundwater Resources Monitoring Report and Management Plan (Report) presents the results of the groundwater monitoring study and presents a groundwater resource management plan to help ensure the sustainable management of the groundwater resources of the Island of Utila (Utila), 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

Utila is one of the three main islands of the Bay Islands archipelago located about 30 km (18 miles) north of the coast of mainland Honduras in the Caribbean Sea, as depicted on Figure 1-1. Utila depends on groundwater as its primary source of municipal water supply. Rainfall harvesting is practiced by some residents to supplement groundwater supplies. It is anticipated that reliance on groundwater for the municipal water supply will increase as population growth continues in the future. Past studies have suggested that there is a limited fresh groundwater resource on Utila. This project was initiated by USAID due to the increasing population on Utila, the need to quantify the available groundwater resources for sustainable development in this area, the need to develop the groundwater resources while avoiding damage due to contamination and floods, and to identify and manage a sustainable water supply capable of supporting the current and future populations of Utila.

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

Sustainable improvements in family health. This objectives desired result is the rehabilitation of existing 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 represented by 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.

Figure 1-1. Site Location

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 Utila area and developed a groundwater resources management plan to help ensure a sustainable municipal water supply for the urban area of Utila. 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 the 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 USAID under contract No. 522-C-00-01-00287-00, dated March 21, 2001. The scope of work for this project defines five phases for the conduct of 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 a field investigation that included 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. 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 Utila 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 I.

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

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 presents a description of the geographic setting for Utila, as well as the climate, geology and soils, hydrogeology, land use, wastewater management, and regulatory setting.

2.1 Geographical Setting

Utila belongs to the Bay Islands archipelago, which consists of three major islands (Utila, Roatan, and Guanaja) and 65 lesser islands or cays. The archipelago extends over an area of 500 square kilometers (km) (193 square miles (mi)) and is located north of the Honduran coast in the Caribbean Sea.

Utila is roughly 13 km (8.1 miles (mi)) in length and varies between 2 and 5 km (1.2 and 3.1 mi) in width, with a land area of approximately 42 square km. Almost all of Utila's population lives on the eastern third of the island in an area called East Harbor, also known as Utila Town. Most of this population has historically resided by the coast. At present, new houses are being built inland. It is anticipated that there will be new development along the new road to the new airport.

A fishing village is located off Utila's southwestern coastline on two cays, or small islands, known as Pigeon (Lower) Cay and Jewel (Upper) Cay; this village is also known as Los Cayitos. Figure 2-1 depicts a view of the village.

2.2 Climate

The climate of Utila is considered tropical, with abundant rainfall. Utila receives between 2,200 and 2,600 millimeters (mm) (87 and 102 in) of precipitation per year, with nearly 70 percent of the rainfall occurring from September through December. Due to the project's short time frame and availability of historical precipitation data, Brown and Caldwell did not collect supplemental rainfall data. Southerly winds prevail during most of the year, but strong winds at times reverse this condition, especially during February and March. Average monthly temperatures vary between 24.5º to 28.5º Celsius (76º to 83º Fahrenheit). Table 2-1 presents monthly precipitation and temperature data for Utila, collected at the Iguana Research Station near Stuart Hill.

Figure 2-1. Village Situated on Pigeon Cay

Table 2-1. Precipitation and Temperature, 1977-2000

	Precipitation		Temperature	
	in	mm	°F	°C
January	8.6	219	76.3	24.6
February	5.8	147	77.5	25.3
March	3.5	88	79.6	26.4
April	1.2	31	80.9	27.2
May	1.6	40	81.7	27.6
June	2.0	52	82.5	28.1
July	2.4	60	81.9	27.7
August	3.1	79	82.7	28.2
September	6.0	152	83.0	28.3
October	17.2	436	80.7	27.1
November	24.2	614	79.0	26.1
December	11.6	296	76.5	24.7
Total	87.2	2,214	--	--

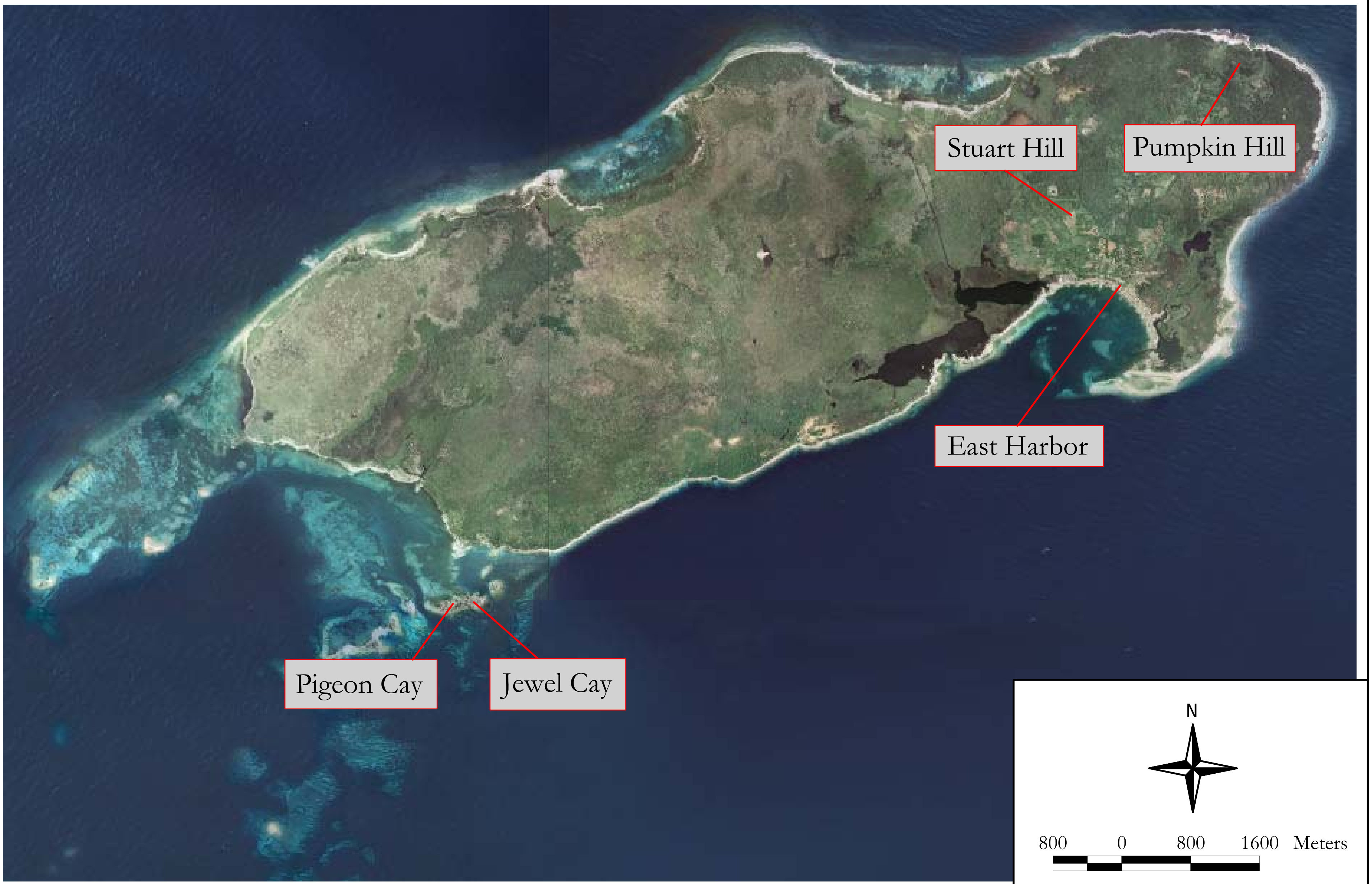
Source: Data gathered by James Gaborel at the Iguana Station, Utila, Honduras.

2.3 Geology and Soils

Geologically, the Bay Islands are located on the Caribbean plate near its boundary with the North American plate. The boundary between these plates form the Motagua Fault Zone. The Bay Islands are on the emergent crest of a narrow ridge on the south side of the Bartlett Trough formed by the tectonic movement of the plates. Utila, quite different in appearance and relief from the other Bay Islands, is a low relief island.

The geology of Utila consists primarily of Quaternary terrace deposits and swamp sediments and Quaternary volcanic material overlying Quaternary coralline limestone. The western two-thirds of the island is composed of low-lying areas that contain mangrove swamps, savannas, and brackish water. The eastern third of the island is characterized by two extinct volcanic cones, Stuart Hill located approximately 2 km (1.2 mi) inland from the center of East Harbor, and Pumpkin Hill located on the northeastern coast about 6 km (3.7 mi) from East Harbor. Pumpkin Hill is the highest point on the island at 74 meters (m) (243 feet (ft)) above sea level, and Stuart Hill is the next highest at 51 m (167 ft) above sea level. The land between these two landmarks contains rolling hills covered by dense natural vegetation, as shown in Figure 2-2. Figure 2-3 depicts an aerial view of Utila.

Figure 2-2. View from Stuart Hill looking Northwest towards Pumpkin Hill and the New Airport



BROWN AND CALDWELL	DATE 1/02/2002	SITE Utila, Bay Islands, Honduras	FIGURE 2-3
	PROJECT 21143	TITLE Bay Island of Utila	

Generally, the volcanic deposits of Stuart Hill and Pumpkin Hill are composed of highly weathered, alkali basaltic lavas altered to clay, breccias, and pyroclastic flows. In outcrop at Stuart Hill, the volcanics are characterized as relatively massive, fine-grained basaltic lava and semi-welded tuff. Locally, within the Stuart Hill study area, the tuff is intensely weathered and altered to clay, with thicknesses that range from 6 to 26 m (20 to 85 ft). At Pumpkin Hill, the volcanic deposits consist of well-stratified basaltic breccias that form the remnants of a caldera. Outcropping on the lower flanks of both Stuart Hill and Pumpkin Hill are coral limestone deposits that are believed to have been uplifted during volcanic activity (Hemmett, 1988).

The underlying coral limestone typically ranges from having dissolution cavities of varying sizes, to a massive and crystalline, fossiliferous limestone. In some areas along the eastern Utila coast, and in road cuts along the new airport road, intense dissolution cavities and karst terrain with ancient soil horizons are evident to a depth of approximately 7.6 m (25 ft) below grade. Below the karst zone, the limestone becomes massive and crystallized with abundant calcite crystals.

The island does not have any well-defined watershed basins, and there are no significant year round surface stream flows (although a few minor ephemeral streams flow during the wet season). However, some drainage areas can be delineated that drain towards the sea. These drainage areas are limited in extent and have low gradients with an average elevation of 16.0 m (52.5 ft) above sea level. The most important drainage area is by Stuart Hill, along the road that leads to the municipal dumping site.

A hand-dug canal, varying in depth from 0.6 to 3.7 m (2 to 12 ft) and in width from 1.5 to 4.6 m (5 to 15 ft), transects the island from the northwest to the southeast. According to local residents, the canal is approximately 50 years old, and was constructed to provide fishermen a shorter route to the northern coastal waters.

2.4 Hydrogeology

Fresh groundwater occurs beneath the island surface as a lens, which is recharged entirely by rainfall and constrained at its lower and lateral boundaries by saline water. The rainfall infiltrates through the soil and rock and accumulates above the denser seawater. As with many islands, the occurrence, movement, and configuration of the freshwater lenses are affected largely by the permeability of soils, fractured rock, topography, and the surrounding saline water. The upper land areas located in the eastern portion of the island are believed to have the best potential to recharge precipitation resulting in building groundwater storage and developing a freshwater lens. One of the objectives of this study is to gain a better understanding of Utila's hydrogeology. More detailed information regarding Utila's hydrogeology is presented in Chapter 4.

2.5 Land Use

Land uses on Utila consist of residential, commercial, and agricultural (some small farms with cattle, sheep, and pigs). There are no significant industrial facilities on the island. Most commercial facilities service Utila's tourism (diving) industry. Almost all of Utila's land is privately owned. Non-inhabitated areas consist of mangrove swamps, fresh water savannahs, and dense tropical forests. A new airport with a 1,500 m (4,921 ft) long paved runway was recently built in the northeast corner of the island. More detailed land use information can be found in Fundación para el Desarrollo Municipal's (FUNDEMUN) Estrategia Participativa de Desarrollo Integral de Utila, Islas de la Bahia Report (FUNDEMUN, 2000).

2.6 Summary of Past Studies

Several past studies have addressed the need to investigate Utila's groundwater resources. This section briefly summarizes these past studies.

In October 1993, Servicio Autonomo Nacional de Acueductos y Alcantarillados (SANAA) conducted a hydrogeologic study of Utila. SANAA estimated that the aquifer's recharge potential was between 25 and 40 percent of the total annual precipitation.

A water resources appraisal conducted by the United States Army Topographic Engineering Center in 1996, identified Utila as "having fresh water that was scarce or lacking" and "the groundwater on Utila occurs as a lens above the saline water" (US Army, 1996).

A hydrogeologic map of Honduras prepared in 1996 states that aquifer production on the Honduran islands is poor due to the small recharge areas. The study states that Utila is the smallest island in the sector and fresh water surface flows do not exist in the summer. Groundwater production is limited to 4 liters per second (lps) (1.1 gallons per second(gps)) (Instituto Geografico Nacional, 1996).

A 1998 study by Steven Bond for Water For People provided recommendations to conduct a water budget study for the Bay Islands. The study states that Utila's water supply is scarce and poorly understood. Long-time residents report that the water quality varies throughout the year and has steadily decreased over the past two decades (Bond, 1998).

A 2000 study conducted by FUNDEMUN presents population and tourism projections and provides a brief description of the existing water system.

A water supply improvement design prepared by Black and Veatch, an engineering firm, in 2000 located potential sites for production wells and made assumptions regarding well flow rates. This project has not yet been constructed. As discussed later in this report, there is not adequate groundwater supply to implement this design.

There is currently an ongoing program called the Environmental Management Program of the Bay Islands, known as PMAIB, that is being conducted by the Honduran government. This program is designed to the environmental quality that provides the basis for sustainable development of the Bay Islands.

2.7 Wastewater Management

An understanding of wastewater management is important because certain disposal practices can impact groundwater quality. There is no central wastewater collection and treatment system in Utila. All wastewater is discharged directly to the sea or into non-engineered, private septic systems that discharge directly into the subsurface soils. In addition, some residences and commercial establishments discharge washwater directly onto the ground, which drains along streets.

2.8 Regulatory Setting

The water system in Utila is owned by the muncipality. SANAA is an autonomous Honduran governmental entity that operates the urban water and waste water systems for Tegucigalpa and 15 other municipalities. SANAA currently provides technical support to Utila, but does not have any jurisdiction over Utila's water system.

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 Pan-American Health Organization (PAHO) provides technical support through the Ministry of Health. Some other regional organizations have been formed in Central America to share experiences in water and sanitation management.

3.0 DESCRIPTION OF EXISTING WATER SYSTEM AND WATER DEMANDS

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

3.1 Municipal Water Supply and Distribution System

Utila's primary water system is owned and operated by the municipality of Utila. The water system is supplied completely by groundwater. Some residents in East Harbor use private wells and collect rainfall as a supplementary water supply. Features and capacities of municipal and private wells, reservoirs, and the distribution system are also described in this section. Figure 3-1 depicts the locations of the main water system facilities.

3.1.1 Service Area. There are two communities located on Utila. The primary water system provides water to the community of East Harbor. The community of Los Cayitos, located on Pigeon and Jewel Cays, currently does not have a municipal water system. A well is located near Pigeon Cay on the main island.

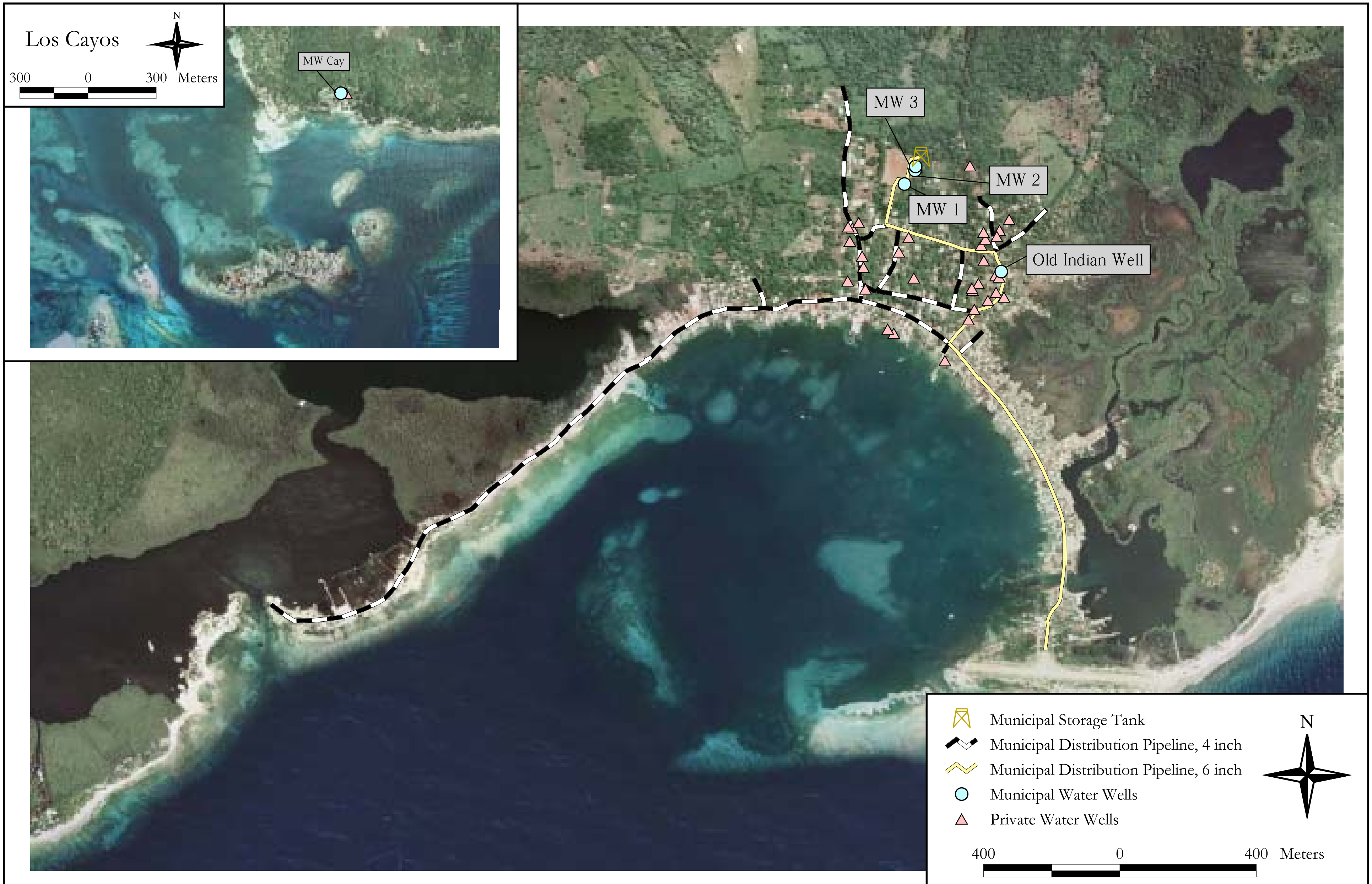
3.1.2 Water Supply Wells. Groundwater is the only source of municipal water supply. The municipal wells and private wells are described in this section. Details on the water supply wells can be found in the Water Resources Management System included with this report and described in Section 5.0.

3.1.2.1 Municipal Water Supply Wells. Four municipal wells (MW) provide the municipal water supply for East Harbor. Three of the wells are located by the soccer/baseball field and are drilled wells equipped with submersible pumps. These three wells pump to the nearby elevated storage tank that is connected to the distribution system, and they pump with a combined capacity of approximately 238.5 liters per minute (lpm) (63 gpm). A fourth well is an old hand-dug well where water is withdrawn by hand. There is no treatment including no disinfection of the well water prior to distribution. Most residents use bottled water from local private treatment plants for drinking purposes. Table 3-1 summarizes pertinent information about the existing wells. Well locations are shown on Figure 3-1, photographs of the municipal wells are shown on Figure 3-2, and the fourth municipal well is pictured on Figure 3-3.

Table 3-1. Municipal Well Information

Name	Capacity		Well depth		Depth to water		Drawdown		Remarks
	lpm	gpm	m bgs	ft bgs	m bgs	ft bgs	m	ft	
MW 1	83.3	22	16.1	53.0	13.4	44.1	0.02	0.07	Serves East Harbor
MW 2	79.5	21	16.6	54.6	14.8	48.5	0.08	0.26	Serves East Harbor
MW 3	75.7	20	17.4	57.0	14.9	48.9	0.02	0.06	Serves East Harbor
Old Indian Well			2.5	8.3	2.2	7.2			Manual access well not connected to distribution system. Hand-dug well.
MW Cay			0.8	2.5	0.4	1.4			Manual access well located in Pigeon Cay. Is not connected to distribution system.
Total	238.5	63	--	--	--	--	--	--	

lpm = liters per minute　　m bgs = meters below ground surface
gpm = gallons per minute　　ft bgs = feet below ground surface



BROWN AND CALDWELL	DATE 11/5/01	SITE Utila, Bay Islands, Honduras	FIGURE 3-1
	PROJECT 21143	TITLE Existing Water System	

Figure 3-2. Utila Municipal Wells – MW 1, MW 2, and MW 3.

The three municipal supply wells located by the soccer/baseball field are situated within 46 m (150 ft) of each other. It is estimated that the wells are at an elevation of approximately 17 m (55 ft) above sea level. Each well consists of a 305 m (12 in) diameter outer polyvinyl chloride (PVC) casing and a 31.8 mm (1¼ in) diameter inner PVC casing. The 305 m (12-in) diameter upper PVC casings are not sealed. Water is pumped from each well by an electric, one-horsepower, submersible pump. Electrical power for these pumps is provided by the island's power plant, which consists of three diesel generators that operate from 6:00 a.m. to 12:00 p.m. Water is pumped through a 31.8 mm (1¼ in) diameter PVC discharge line from each well. These three pipes converge into a 31.8 mm (1¼ in) diameter PVC well transmission line that discharges over the top of the tank's sidewall.

Figure 3-3. Old Indian Well

The wellhead for MW 1 is covered by a 0.6 m by 0.6 m (2 ft by 2 ft) wooden slab, and the wellheads for MW 2 and MW 3 are covered by a removable 0.6 m by 0.6 m (2 ft by 2 ft) square concrete slab. Inside the wellheads, the 305 mm (12-in) diameter PVC casings are not sealed, or lined, offering no protection from contaminants that could percolate from the surface.

Old Indian Well, a hand-dug manual access well, also serves East Harbor. This well does not have a pump and is not connected to the distribution system, as shown in Figure 3-3. Old Indian Well is a brick lined vault 1.5 m by 1.5 m (5 ft by 5 ft) in length and width, and 2.5 m (8.3 ft) deep. Residents collect water by dropping buckets into the well and then transferring the water into other containers to be carried home.

MW Cay, another manual access well, provides water for the community of Pigeon Cay, and is located on the southwestern side of the island. Residents typically come to the well by boat and fill containers with water by hand. Figure 3-4 depicts MW Cay.

Figure 3-4. MW Cay

3.1.2.2 Private Water Supply Wells. Many of the residents of Utila have constructed their own private wells to supplement the municipal water distribution system. It is estimated that over 100 private water supply wells provide supplemental water to residences and businesses. These wells do not pump into the municipal distribution system. No filtration or disinfection occurs prior to using the water from most private wells. Some of these wells supply water to small private treatment plants prior to being bottled to sell locally. Table 3-2 summarizes the thirty-four private wells accessible to Brown and Caldwell for monitoring. The yields of these private wells is not known.

Table 3-2. Private Well Information

	Well depth		Depth to water		
Name	m bgs	ft bgs	m bgs	ft bgs	Well owner
PW 1	8.5	28[a]	7.0	23[a]	Jernigan Cooper
PW 2	11.7	38.5	10.8	35.4	Eric Rose
PW 3	8.9	29.1	8.3	27.3	Margaret Bodden
PW 4	5.5	18[a]		[b]	Austen Bodden
PW 5	8.5	28[a]		[b]	Walter James
PW 6	9.8	32[a]		[b]	Julie Bernard
PW 7	8.8	29[a]		[b]	Dolores Cardona
PW 8	7.9	26[a]	7.3	24[a]	Cleygorn Angus
PW 9	6.7	22[a]		[b]	Charlie Ruby
PW 10	9.1	30[a]		[b]	Modesto Cooper
PW 11	3.7	12.1	2.2	7.1	George Gabourel
PW 12	7.0	23[a]		[b]	George Gabourel
PW 13	9.1	30[a]		[b]	Will Hinds
PW 14	5.5	18[a]		[b]	Tony James
PW 15	5.5	18[a]		[b]	Dona Woods
PW 16	6.1	20[a]		[b]	Lealond Wilson Howell
PW 17	7.3	24[a]		[b]	Audley Banks
PW 18	6.1	20[a]		[b]	Winey Banks
PW 19	16.3	53.5	16.0	52.6	Don Kerns
PW 20	1.2	4.0	0.8	2.5	----
PW 21		[b]		[b]	Johnnie Bodden
PW 22		[b]		[b]	Wilfield Coburn
PW 23		[b]		[b]	Wilfield Coburn
PW 24		[b]		[b]	Rosalee Lions
PW 25		[b]		[b]	Mitchell Rose
PW 26		[b]		[b]	Henry Hill
PW 27		[b]		[b]	Felix Ponce
PW 28		[b]		[b]	Mango Inn
PW 29		[b]		[b]	Johny Hinds
PW 30		[b]		[b]	Frank Spencer Morgan
PW 31		[b]		[b]	Larry Thompson
PW 32		[b]		[b]	CJ Woods
PW 33		[b]		[b]	Selvin Bodden
PW 34		[b]		[b]	Danny Hill

m bgs = meters below ground surface
ft bgs = feet below ground surface
[a] Not measured. Owner supplied information.
[b] Not known

3.1.3 Other Water Sources. Some Utila residents use rainwater collected in cisterns that are constructed adjacent to their homes. In addition, some Utilian homes pump seawater for use in toilets. Bottled water is often purchased for drinking purposes. Owners of newer houses located in the higher areas have built cisterns to collect water from the municipal distribution system.

3.1.4 Water Storage Facilities. The municipal water system currently consists of one 94,640 liter (l) (25,000 gallon (gal)) water storage tank located on a hill near the three municipal water supply wells at the soccer/baseball field. Water is pumped from the three municipal wells directly to the tank through a manifolded 31.7 mm (1 ¼-in) diameter PVC pipeline. The location of the storage tank is depicted on Figure 3-1.

In addition to the municipal water supply tank, an abandoned 136,270 to 151,420 l (36,000 to 40,000 gal) water tank is situated on Stuart Hill. This inactive tank is approximately 10 years old and is in a state of disrepair. According to local residents, the buried PVC pipeline that connected this inactive tank to the municipal system is still in place, however, Brown and Caldwell was not able to confirm the presence of this line.

3.1.5 Piping System. The East Harbor distribution system consists of one pressure zone. Water is gravity fed to the distribution system from the tank through a 102 mm (4 in) diameter PVC pipe. The Utila piping system consists of approximately 3,775 m (12,385 ft) of 102 mm and 152 mm (4 in and 6 in) diameter PVC piping. The majority of this pipe was installed less than four years ago. Most distribution pipes and house connections are uncovered and vulnerable to breakage, as depicted in Figure 3-5. System pressures range from 6.4 and 10.6 kilograms per square inch (14.2 and 23.4 pounds per square inch). The system is divided into three geographic service areas, which are manually rotated on and off throughout the day by the municipality.

Figure 3-5. Utila Water Distribution System

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 residential population and tourism, provide the basis for estimating future water requirements. This section presents a summary of demographic information, water use data, and the resulting projections of future water needs for Utila.

3.2.1 Demographics. Demographic information consisting of population, housing, tourism, commercial establishments, and water system connections are described in this section.

3.2.1.1 Population and Housing. The majority of the island's population lives on the east side of the island in East Harbor, which has a 2001 population of approximately 6,100 residents distributed throughout eleven neighborhoods. It is estimated that the population will increase to 12,221 by 2009 (FUNDEMUN). This growth represents an 8.6 percent average annual growth rate. It is assumed this high growth rate will not be maintained over the long term. Assuming for this study that growth is at only 50 percent of the projected rate, that being 4.3 percent per year after 2009, it is estimated that the East Harbor population will increase to 19,612 by 2020.

Los Cayitos has a 2001 population of about 1,695 people. It is estimated that the Los Cayitos population will increase to 3,255 in 2009 (FUNDEMUN). This growth represents a 7.6 percent growth rate. Again, assuming that growth is at only 50 percent of the projected rate or at 3.8 percent per year after 2009, it is estimated that the Los Cayitos population will increase to 4,944 by 2020. The historical and projected population by neighborhood through 2009 is shown in Table 3-3. The number of households within East Harbor and the average number of people per household in 1999 are shown in Table 3-4. This table correlates well with Table 3-3.

Table 3-3. Population by Neighborhood from 1999 through 2009

Neighborhood	1999	2000	2001	2005	2009
La Punta	1,300	1,464	1,649	2,416	3,117
Sandy Bay	706	795	895	1,312	1,725
Colamico	511	576	649	950	1,250
Mamey Lane	342	387	438	639	840
Barrio El Centro	671	755	850	1,246	1,638
Holland	114	128	144	211	278
Camponado (North and South)[a]	269	303	341	500	658
Lozano	529	596	671	983	1,293
La Loma	558	628	707	1,036	1,363
Blue Bayou	--	--	--	--	--
Los Cayitos[b]	1,500	1,500	1,695	2,475	3,255
Total	6,500	7,132	7,825	11,768	15,476

1. Source: FUNDEMUN Para el Desarrollo Municipal, Municipalidad de Utila, USAID. Estrategia Participativa de Desarrollo Integral de Utila, Islas de la Bahia, (Page 54, Table 7).
[a] The neighborhoods of Camponado South and Camponado North are combined in this table.
[b] Los Cayitos is not currently connected to the East Harbor municipal water system.

Table 3-4. East Harbor Households by Neighborhood and People per Household in 1999

Neighborhood	Households	People per household	Population
La Punta	189	6.9	1,304
Sandy Bay	105	6.7	704
Cola de Mico	152	3.4	517
Mamey Lane	75	4.6	345
Barrio El Centro	77	8.7	670
Holland	95	1.2	114
Camponado	68	4.0	272
Lozano	194	2.7	524
La Loma	27	20.7	559
Blue Bayou	--	--	--
Total	982	5.1	5,009

1. Source: FUNDEMUN Para el Desarrollo Municipal, Municipalidad de Utila, USAID. Estrategia Participativa de Desarrollo Integral de Utila, Islas de la Bahia. (Page 54, Table 7)
2. Los Cayitos is not included.

3.2.1.2 Tourism. Tourism plays a moderate role in water demands in Utila. In the year 2001, there were approximately 45,177 visitors to Utila (FUNDEMUN). The average length of stay per visitor is estimated to be approximately 7.4 days. Visitor-days represents the number of visitors each year multiplied by the average length of visit. Equivalent visitors is the number of permanent population that would be equivalent to the number of visitors. This number is generated by dividing visitor-days by 365 days per visitor. As shown in Table 3-5, tourism is expected to increase from 13,199 tourists in 1995 to 106,264 tourists by 2009 (FUNDEMUN). This represents an average annual growth rate of 15 percent per year. For this study, it is assumed that tourism will grow at a slower rate of 7.4 percent per year after 2009, and will reach 241,150 visitors by 2020. This equates to 4,889 equivalent visitors by 2020.

Table 3-5. Historical and Projected Visitors

Year	Visitors	Average length of visit, days per visitor	Visitor days[a], days	Equivalent visitors[b]
1995	13,199	7.4	97,673	268
1996	15,179	7.4	112,325	308
1997	17,456	7.4	129,174	354
1998	20,075	7.4	148,555	407
1999	23,086	7.4	170,836	468
2000	37,541	7.4	277,803	761
2001	45,177	7.4	334,310	916
2005	75,720	7.4	560,328	1,535
2009	106,264	7.4	786,354	2,154

1. Source for visitors and length of visit: FUNDEMUN Para el Desarrollo Municipal, Municipalidad de Utila, USAID. Estrategia Participativa de Desarrollo Integral de Utila, Islas de la Bahia. (Page 63, Table 11)
2. [a] Visitor days represents visitors per year multiplied by average length of visit per visitor.
3. [b] Equivalent visitors represents the permanent population that is equivalent to the number of visitors. Calculated by dividing visitor days by 365 days/visitor.

The total actual and projected Utila population, which includes both residential population and equivalent visitors is summarized in Table 3-6 and illustrated on Figure 3-6.

Table 3-6. Total Projected Population

Year	Residential population		Equivalent tourists	Total population
	East Harbor	Los Cayitos		
1999	5,000	1,500	468	6,968
2000	5,632	1,500	761	7,893
2001	6,130	1,695	916	8,741
2005	9,293	2,475	1,535	13,303
2009	12,221	3,255	2,154	17,630
2015	15,818	4,089	3,368	23,275
2020	19,612	4,944	4,889	29,445

Note: Based on FUNDEMUN estimates through 2009 and Brown and Caldwell estimated growth rate from 2009 to 2020.

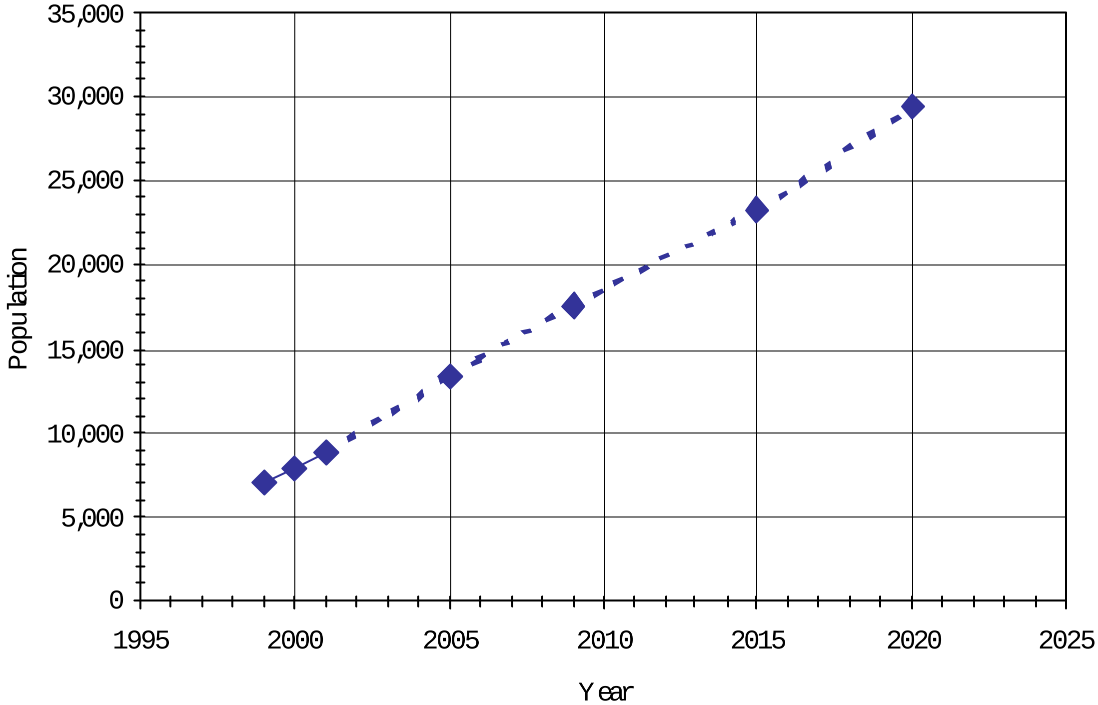


Figure 3-6. Historical and Projected Total Water Service Population

3.2.1.3 Commercial Establishments. An inventory of the number of commercial establishments by business type that are located in the urban area of the East Harbor are shown in Table 3-7. The majority of commercial and governmental activities are located in the El Centro neighborhood. The remaining neighborhoods are predominantly residential with few commercial establishments (FUNDEMUN).

Table 3-7. Commercial Establishments

Type	Quantity	Type	Quantity
Travel agency	2	Dive schools	11
Bars	10	Stores (Ferreterias)	3
Real estate agency	3	Gas stations	2
Boutiques	4	Hotels	23
Rental homes	26	Fruit stands	19
Cafeterias	3	Resorts	2
Movie theaters	2	Restaurants	26
Dining room restaurants	4	Solares Baldios	12
Cuarterias	14	Stores	6
Dance clubs	2	Others	18
Fish Market	1	Total	193

Source: FUNDEMUN Para el Desarrollo Municipal, Municipalidad de Utila, USAID. Estrategia Participativa de Desarrollo Integral de Utila, Islas de la Bahia (Page 19, Table 1).

3.2.1.4 Connections. There are 160 active connections in the East Harbor municipal water system (FUNDEMUN). The number of active connections by neighborhood is shown in Table 3-8. The number of water system connections is less than the number of commercial establishments and households in Utila. It has not been confirmed, but it is assumed that the number of registered active connections is less than the total number of establishments and households due to the lack of a strict municipal control on making connections to the system.

Table 3-8. Active Municipal Connections in 2000 by Neighborhood

Type	Quantity
La Punta	36
Sandy Bay	32
Cola mico	--
Mamey Lane	13
Barrio el Centro	18
Holland	9
Camponado	4
Lozano	11
La Loma	16
Blue Bayou	--
Cola de Mico	21
Total	160

Source: FUNDEMUN Para el Desarrollo Municipal, Municipalidad de Utila, USAID. Estrategia Participativa de Desarrollo Integral de Utila, Islas de la Bahia. (Page 39, Table 5)

3.2.2 Historical Water Use. Water production is the volume of water measured at the source, which includes all water delivered to customers, as well as unaccounted-for water. This section describes daily water production, maximum day demand, and unaccounted-for water.

Daily water production at MW 1, 2, and 3 is not known because water flow from the wellhead is not metered. Daily water production is estimated to be 246,050 liters per day (lpd) (65,000 gallons per day (gpd)), as described in Section 3.2.3.

Daily demand fluctuates throughout the year based primarily on seasonal climate changes. Water demands are higher in the dry seasons and less in the wet season. System water production facilities should be sized to meet the demand on the maximum day of the year, not just for the average day. The maximum day peaking factor, which is defined as the one day of the highest water use during a 1-year period, divided by the annual average water use, is estimated to be 1.5 for the purposes of this study. Since water production is not metered, the actual maximum day demand is not known.

Unaccounted-for water use includes lost water due to system leaks and unauthorized connections. Since Utila's system is not metered, data are unavailable for determining the percent of unaccounted-for water.

3.2.3 Unit Water Use. Unit water use factors expressed as liters per capita (or person) per day (lpcd) (gallons per capita per day (gpcd)) are developed to estimate future water needs based on the residential population and tourism projections discussed previously. The projected residential population is combined with equivalent visitors and coupled with a unit water use factor per person to estimate future water needs.

The FUNDEMUN report states that per capita water use in Utila is 83 lpcd (22 gpcd). Brown and Caldwell's field investigations conducted for this study indicate a per capita water use of 35 lpd (9.2 gpcd). This is based on three wells pumping 75 liters per minute (lpm) (20 gallons per minute (gpm)) each for 18 hours (245,295 lpd (64,800 gpd)/7,046 people) and factors in the East Harbor population and tourists. This does not factor in the water pumped by private wells, which would slightly increase the per capita water use. The Terms of Reference (TOR) for a separate USAID project in Utila assumed a unit water use factor of 227 lpcd (60 gpcd) and recommends "four wells producing 9 lps (144 gpm) each would be needed to support the Utila island area and two wells producing 3 lps (50 gpm) would be needed to support the Cayos area" (USAID, 1999) for a total of 43 lps (676 gpm). Brown and Caldwell believes the TOR's estimate to be high. For the purposes of this study, it is assumed that per capita water use is 38 lpcd (10 gpcd).

3.2.4 Projected Water Demands. Water demands through the year 2020 were estimated based on a unit water use factor of 38 lpcd (10 gpcd) and the residential population and equivalent tourist projections (see Table 3-6). These water demand projections for East Harbor are shown in Table 3-9 and illustrated on Figure 3-7. Annual water demands are expected to increase from 246,000 lpd (65,000 gpd) (73 acre-feet per year (ac-ft/yr)) in 2001 to 927,000 lpd (245,000 gpd) (274 ac-ft/yr) in 2020. Impacts to water use due to any conservation measures implemented in the future are not reflected in the projected water demands shown below.

Table 3-9. Projected Water Demands

	Annual average			Maximum day[a]	
Year	ac-ft/yr	lpd	gpd	lpd	gpd
2000	73	246,000	65,000	371,000	98,000
2005	121	409,000	108,000	613,000	162,000
2009	161	545,000	144,000	818,000	216,000
2015	215	727,000	192,000	1,080,000	288,000
2020	274	927,000	245,000	1,393,000	368,000

[a]Maximum day projected water demand based on assumed 1.5 maximum day peaking factor.
Note: Demands for East Harbor only.

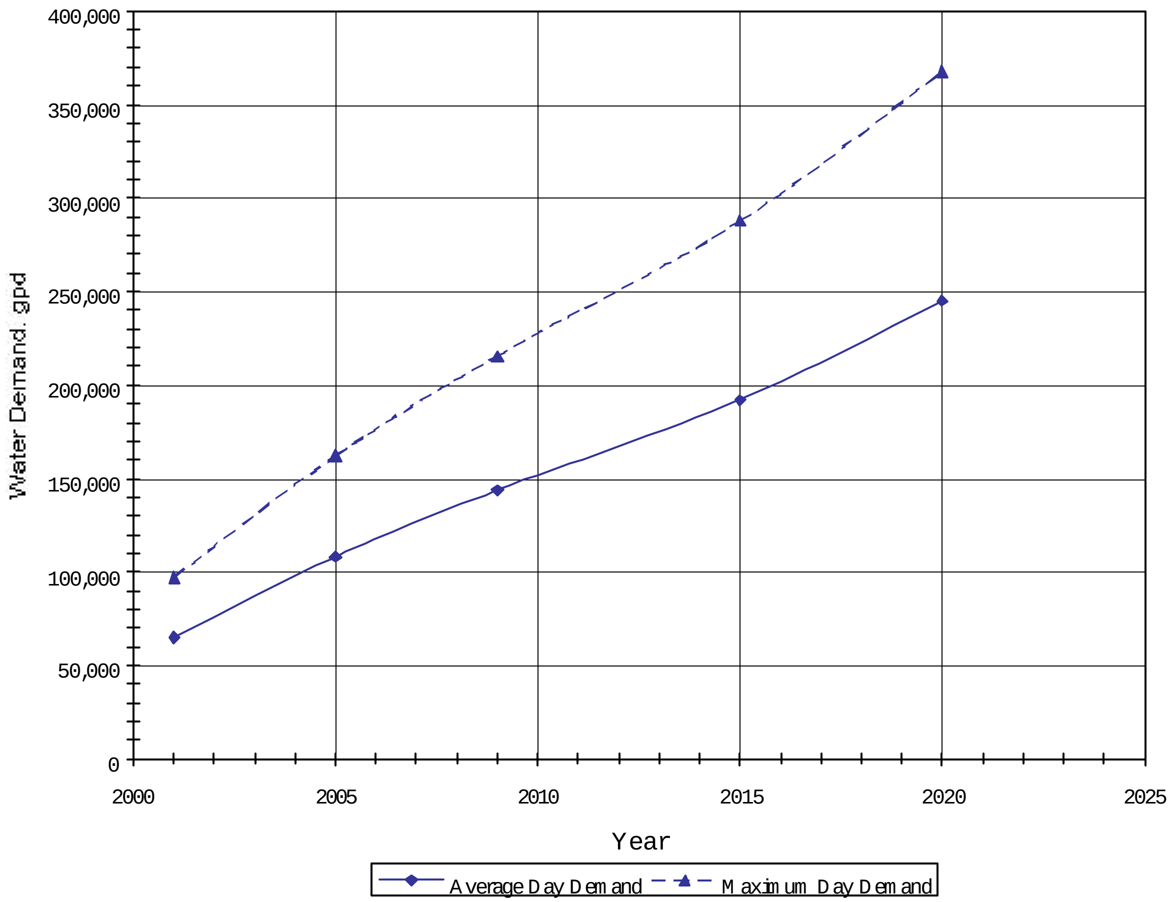


Figure 3-7. East Harbor Projected Water Demands

4.0 GROUNDWATER RESOURCE EVALUATION

The groundwater resource evaluation for Utila 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 three 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 Utila. Training in groundwater monitoring techniques was conducted for local staff, as described in Appendix G.

4.1 Conceptual Hydrogeologic Model

The initial conceptual model of Utila was developed as part of this study with the understanding that infiltrating precipitation could develop a fresh water lens within the coral limestone extending into the underlying volcanic units. This infiltrating precipitation would be less dense than the seawater and create a zone or lens of freshwater on top of the underlying seawater. Recharge of precipitation through the surface soils to the coral limestone would flow in a radial pattern from areas of higher elevation on the island (i.e., Stuart Hill and Pumpkin Hill) displacing seawater and potentially forming a usable potable water resource. The key driving force to maintain the zone of freshwater would be the continual flux of water through the groundwater system from areas of recharge in the hills to areas of discharge along the beaches. The sustainability of using this groundwater would be dependent on the proper management of the groundwater withdrawals to minimize disruption of the freshwater/seawater interface. The initial conceptual model is presented in Appendix A.

4.2 Field Investigation Program

Based on the conceptual model, the Stuart Hill area was selected as having the greatest probability of providing sustainable groundwater supplies, and thus, the field investigation was focused in this area. This area is characterized, as broad rolling hills comprised of breccia basalt, which is vegetated as pasture land and dense vegetation. These factors give rise to the potential for significant recharge and thus the possibility of sustainable groundwater supplies. As a result, the primary objective of the field investigation was to determine whether a significant lens of fresh water exists beneath the Stuart Hill area. The field investigation in this area consisted of the performance of a geophysical survey, a fracture trace analysis, installation and testing of five wells, a water quality survey, and a field reconnaissance of the island. This section summarizes the findings of these field investigations. Appendix C presents the field investigation results in greater detail.

4.2.1 Geophysical Survey. Based on a review of island hydrogeology, the area with the highest likelihood of identifying a significant fresh water lens was in the region of Stuart Hill where land is mainly used for pasture. To evaluate this potential, a large-scale geophysical survey to help identify fresh water was performed. The geophysical survey consisted of an electromagnetic (EM) survey to evaluate subsurface resistivity. In general, because the electrical conductivity of fresh water is lower than saline water, the reciprocal (resistivity) should be higher in areas where fresh water is present in the shallow aquifer system. However, the EM survey is limited to identifying the presence of fresh water and does not quantify the volume of freshwater, or the long-term sustainability.

Multiple EM resistivity measurements were made around the Stuart Hill area and were evaluated to produce resistivity contours. The results of the geophysical survey indicated a topographically high ridge, which trends in a west-to-east direction across the study area. The enlarged vadose zone associated with the ridge will contribute to lower terrain conductivity observed in this area. Also, a possible zone of low specific conductance groundwater. During data acquisition, it was observed that there was an absence of expressions of surface water runoff (stream beds, gullies, etc.) on both the north and south sides of the ridge and associated down-slope regions. The absence of such features may indicate a zone of more porous soil/rock. Finally, a contrast in rock type that may exhibit lower terrain conductivity than the surrounding rock-type.

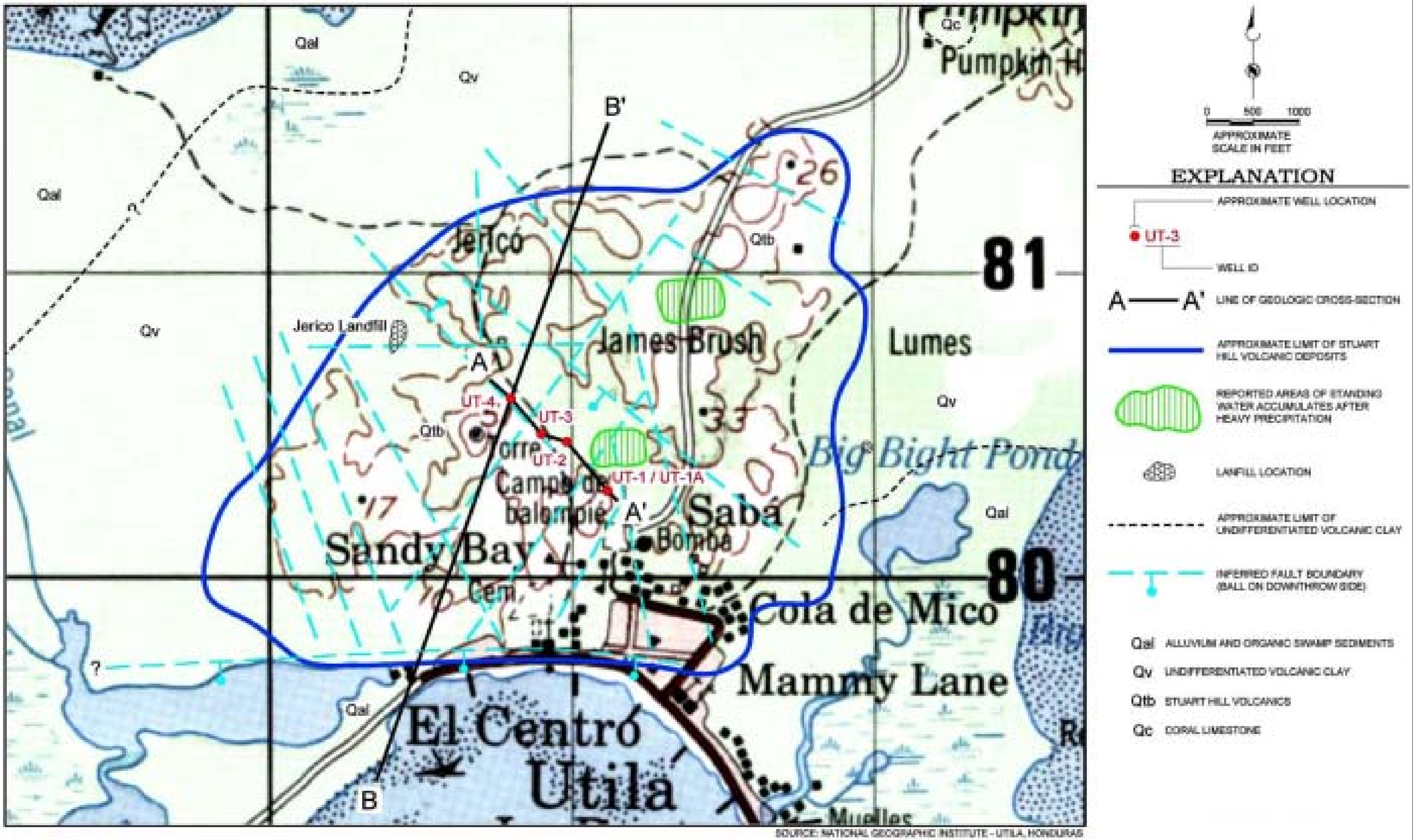
The results of the geophysical investigation identified a potential fresh water zone in the vicinity of Stuart Hill and drilling locations were selected to correlate with these findings. The geophysical survey report is included in Appendix B.

Once the geophysical survey was made, it was decided to locate the test wells within this area. Since this land is privately owned, well location was limited to areas where landowners were willing to give permission. In addition, the access for a drilling rig was limited. Taking into account all these aspects, BCUT-1 and BCUT-2 were located in Morgan's property by the road which goes to Jerico, in the central part of the target area.

4.2.2 Fracture Trace Analysis. In the upland areas, Brown and Caldwell performed an additional geologic evaluation to assess the potential for identifying areas of where the secondary permeability of the coral limestone aquifer may be enhanced due to an increased fracture density. To identify fracture sets and faults that may provide hydrologic conduits for fresh water infiltration and migration, a lineation survey was conducted using air photos and topographic maps of the eastern third of the island. Because Utila is covered by dense jungle flora, only a limited field reconnaissance mapping survey was conducted to identify the surface representations of suspected fracture locations.

In general, fracture sets were noted trending northeast (040°) and southwest (300°) and are believed to be the surface trace of high angle normal faults within the coralline limestone, with vertical displacement between 10- and 30-m, as depicted on Figure 4-1.

By comparison of the results of the fracture trace analysis with the geophysical survey, it was believed proposed well locations (BCUT-3 and BCUT-4) would have the best opportunity to locate a significant fresh water lens within the coral limestone. The combination of upland areas that receive increased precipitation and high secondary permeability of the coral limestone would promote the development of a freshwater lens. In addition, BCUT-3 and BCUT-4 were located along the same fracture lineament to evaluate the interconnectedness of the fracture network. For a long-term sustainable supply, it is necessary for the limestone fractures to be interconnected to develop a larger water resource.



BROWN AND CALDWELL	DATE 2-12-02	SITE Utila Bay Islands, Honduras	FIGURE 4-1
	PROJECT 21143	TITLE Stuart Hill and Surrounding Area	

4.2.3 Well Installation. From August through October 2001, Brown and Caldwell conducted the Phase II drilling investigation. The Phase II field investigation included the drilling of five test wells (BCUT-1, BCUT-1A, BCUT-2, BCUT-3, and BCUT-4) in the Stuart Hill study area to determine the presence, thickness, and quality of fresh water. The wells were located based on the results of the geophysical survey and fracture trace analysis. The well locations are depicted in Figure 4-1. Figure 4-2 depicts the drilling of one of the test wells. All wells were designed to be keyed approximately 1.5 m (5 ft) into competent bedrock, and completed with PVC surface casing and grouted with cement to the surface. These borings were located to provide a good lithological description to understand the geological setting and to allow for aquifer testing. In addition, a topographical survey was performed to determine the elevations of the test wells. Appendix C describes each of the wells in greater detail.

Figure 4-2. Well Installation

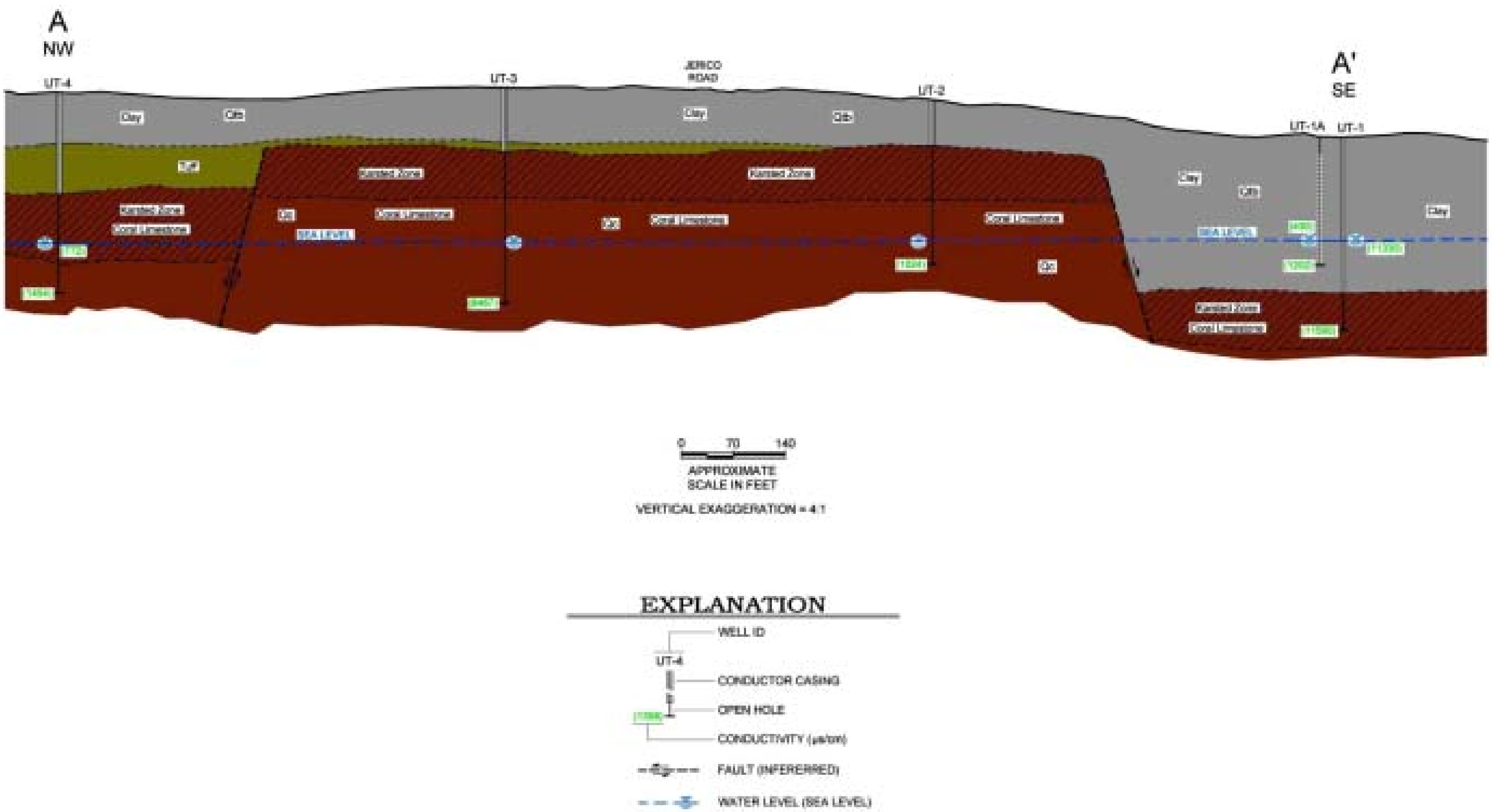
All boreholes were drilled using reverse circulation air/water/mud rotary methods by Servicios de Perforación, S. de R. L. de C. Y. (SERPE), of Tegucigalpa, Honduras, C.A. Drill cuttings in each borehole were collected every 3 m (10 ft) for lithologic control. A summary of the well construction specifications is presented in Table 4-1. A copy of the lithologic logs and well schematic diagrams are presented in Appendix C. Figure 4-3 and Figure 4-4 depict the geologic cross-sections through the area.

With the exception of well BCUT-1A, all boreholes were completed with PVC surface conductor casing extending through the volcanic clay, with open borehole to depth in the underlying coral limestone. BCUT-1A was completed as a monitoring well.

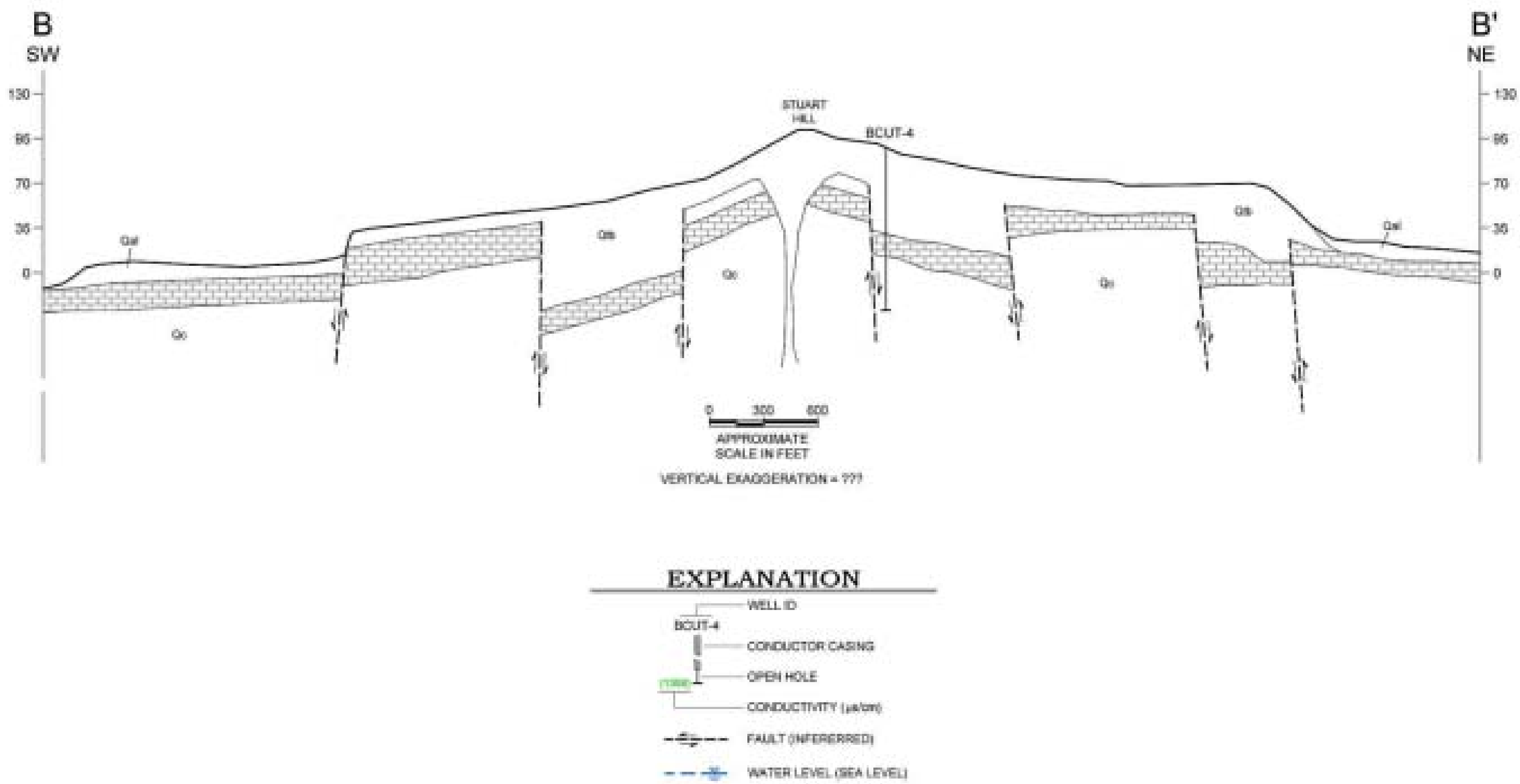
Table 4-1. Summary of Well Construction Specifications

Well ID	Total depth, m	Well diameter, cm	Blank casing interval, m	Uncased interval, m	Depth to water, m	Surface elevation, m	Date completed
BCUT-1	32.0	15.24	0-26	26-32	17.84	17.30	9-3-01
BCUT-1A	21.3	7.62	0-1.5*	1.5-21.3*	16.75	17.30	9-20-01
BCUT-2	26.8	15.24	0-7.6	10.6-26.8	24.21	23.90	9-10-01
BCUT-3	36.3	15.24	0-10.6	10.6-36.3	26.64	26.14	10-4-01
BCUT-4	36.3	15.24	0-16.7	16.7-36.3	26.72	25.3	9-28-01

*= 3-inch PVC casing and screen, 0.020" slot



BROWN AND CALDWELL	DATE 2-12-02	SITE Utila Bay Islands, Honduras	FIGURE 4-3
	PROJECT 21143	TITLE Cross-Section A-A'	



BROWN AND CALDWELL	DATE 2-12-02	SITE Utila Bay Islands, Honduras	FIGURE 4-4
	PROJECT 21143	TITLE Cross-Section B-B'	

Water quality profiles were completed on each well using a YSI 650 XLS water parameter to determine conductivity (microSiemens per centimeter (µS/cm)), pH, temperature (°C), and, dissolved oxygen (mg/L) of the water column. The results of this task are shown in Appendix C.

4.2.4 Aquifer Testing. Short term and long-term aquifer tests were performed on selected monitoring wells to evaluate the water resource development potential. Very limited tests were performed in Wells BCUT-1 and BCUT-2 because water quality deteriorated very rapidly after the onset of pumping. A bailer test of BCUT-1A indicated that freshwater was present within the surficial volcanic clay; however, well yields would likely be less than 18.9 lpm (5 gpm). Additionally, the well yield of BCUT-3 was estimated to be too low for further testing based on similar bailer draw down testing.

A 48-hour aquifer test was performed on Well BCUT-4. BCUT-4 was selected for the long-term pumping test because information regarding the geology of this area indicated the potential for significant well yield and total dissolved solids (TDS) concentrations were generally below 500 mg/L. During the test, the well maintained a flow rate of 151 lpm (40 gpm) for 48 hours with TDS less than 1,000 mg/L. Less than 0.15 m (0.5 ft) of drawdown was noted in BCUT-4 during pumping, however, TDS concentrations slowly increased during the test. A summary of the aquifer tests is presented in Appendix C.

4.2.5 Water Quality Survey. A water quality survey was conducted for some existing wells and the test wells installed for this study. Table 4-2 presents a summary of the water quality data. Only some of the constituents with drinking water standards were included in the survey.

Table 4-2. Summary of Well Analytical Results

Analytical constituent	Drinking water standard[b]	BCUT-1	BCUT-1A	BCUT-2	BCUT-3	BCUT-4
Conductivity	us/cm [e]	11,330-11,590	415-1,202	782-1,024	810-8,467	772-1,454
pH	--	6.55-6.8	6.18-6.77	6.89-6.92	6.83-6.96	6.88-7.04
Arsenic	0.01 mg/l (P)[d]	--[c]	--[c]	--[c]	--[c]	<0.005
Zinc	3 mg/l	--[c]	--[c]	--[c]	--[c]	0.0773
Pesticides	(range)[a] mg/l	--[c]	--[c]	--[c]	--[c]	None detected
Herbicides	(range)[a] mg/l	--[c]	--[c]	--[c]	--[c]	None detected
Volatile Organics	(range)[a] ug/l	--[c]	--[c]	--[c]	--[c]	None detected

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] Drinking water standard varies by individual constituent.
[b] 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.
[c] Lab reports not available/not tested for this constituent.
[d] (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.
[e] No drinking water standard.

Water quality surveys of existing wells performed by Brown and Caldwell found that water quality on the island is generally poor with few wells producing significant quantities of water with estimated TDS concentrations less than 1,000 mg/L. The existing wells (MW 1, MW 2, and MW 3) producing the higher quality water are likely deriving water from limited perched aquifer zones within the surficial volcanic clays above the coral limestone. The average TDS concentration from the existing municipal water supply wells is approximately 1,100 mg/L. Conductivity measurements from wells in the Pumpkin Hill area found that TDS concentrations ranged from 1,300 mg/L to 9,152 mg/L. The lowest TDS values were measured in the Stuart Hill area and correlated well with the results of the geophysical survey. Figure 4-5 depicts a map of the conductivity measurements.

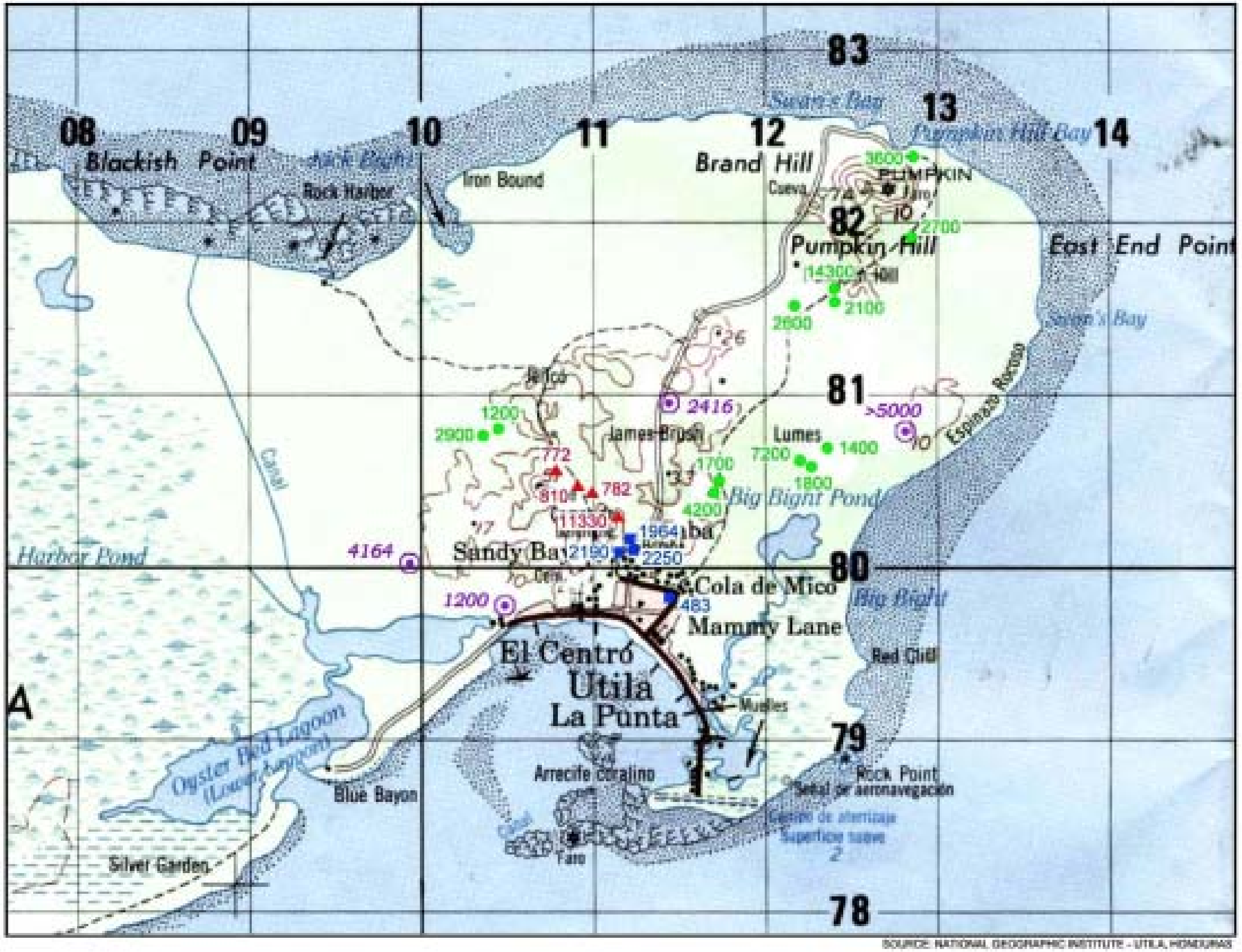
Normal drinking water has a TDS range of 300 to 800 mg/L. Seawater has a TDS of approximately 32,000 mg/L. The recommended limit for TDS by the WHO is 500 mg/L, with a maximum of 1,500 mg/L. The degree of saltwater intrusion or salinity can be measured in terms of electrical conductance or TDS. TDS is proportional to electrical conductance and conductance is approximately 1.6 times greater than TDS concentration.

A water quality survey of existing hand-dug wells and springs outside the East Harbor area indicated relatively poor groundwater, with few wells indicated conductivity measurements less than 1,000 μS/cm. Generally, the hand-dug wells are 1.2 to 1.5 m (4 to 5 ft) square with varying depth of 1.2 to 2.7 m (4 to 9 ft). Most of the wells visited are currently being used for livestock watering and agricultural irrigation on a low scale. Four springs were identified, with conductivity measurements ranging from 1,200 to >5,000 μS/cm. A summary of the water parameter measurements is presented in Appendix C.

One groundwater sample was collected from well BCUT-4 and submitted to SPL Laboratories, in Houston Texas, for analyses for several selected volatile organic compounds, chlorinated herbicides, organochlorine pesticides, and metals. Analytical results indicate that no volatile organic compounds, herbicides, or pesticides were detected. Other than zinc reported at a concentration of 0.0773 mg/L, no other metals were detected at concentrations above laboratory reporting limits or above drinking water standards. The water quality test results are included in Appendix C.

4.2.6 Other Investigation Activities. Additionally, Big Bight Pond and the major canal were investigated for the potential of fresh groundwater water recharging to these surface water bodies, which would provide evidence of a potential freshwater lens in the vicinity of these areas. There was no evidence of fresh surface or groundwater water entering either of these locations, nor was there any change in vegetation from a mangrove swamp, which could indicate a change in water quality. Nine locations throughout the canal, CA 1 through CA 9, and several within Big Bight Pond, primarily on the western shoreline, were sampled for conductivity. The readings at each of the locations were greater than the maximum scale of the meter, indicating that fresh water was not contributing to canal flow.

4.2.7 Field Investigation Results. In summary, the well investigation indicates that the shallow subsurface is comprised of a low permeability, volcanic clay-dominated soil that overlies a coralline limestone. This low permeability volcanic clay, which is visually pervasive on the majority of the island, is believed to limit vertical infiltration of precipitation. Beneath the clay soil is a coral limestone unit that possesses highly variable permeability, depending on the degree of fracturing or



0 1000 2000
APPROXIMATE SCALE IN FEET

EXPLANATION

782 — APPROXIMATE BC-UT WELL LOCATION; TOP OF WATER CONDUCTIVITY (µs/cm)

3600 — APPROXIMATE HAND-DUG WELL LOCATION; TOP OF WATER CONDUCTIVITY (µs/cm)

483 — APPROXIMATE MUNICIPAL WELL LOCATION; TOP OF WATER CONDUCTIVITY (µs/cm)

4164 — APPROXIMATE SPRING LOCATION; TOP OF WATER CONDUCTIVITY (µs/cm)

BROWN AND CALDWELL	DATE 2-12-02	SITE Utila Bay Islands, Honduras	FIGURE 4-5
	PROJECT 21143	TITLE Conductivity Map	

solution cavities. The results of a hydrogeologic study conducted by SANAA in 1993 indicated that the recharge potential of the aquifer in Utila was between 25 to 40 percent of total annual precipitation. The results of this field investigation indicate the weathered volcanic clay soils impede percolation of precipitation to the freshwater lens much more than previously thought. Of the 2.4 m (7.9 ft) of precipitation that falls on the island of Utila each year, it is estimated that only 2.5 percent recharges the fresh groundwater aquifer system.

Fresh groundwater beneath Utila occurs as lenses bounded by saline intrusive from the surrounding Caribbean Sea, and is recharged from annual precipitation during the wet season from October through January. The occurrence and movement of groundwater and the limits of the fresh water lens, is constrained by topography and subsurface geology. The water level elevations in BCUT-1 through BCUT-4 were calculated to be comparable to mean sea level elevation. These elevations correspond to 26 m (85 ft) below grade in the vicinity of BCUT-4 and to 16 m (52 ft) below grade in the lower lying areas in the vicinity of wells BCUT-1 and 1A.

Two basin areas that collect water during the rainy season were identified by local residents. One basin is located in the Stuart Hill study area and the other near Pumpkin Hill (Figure 4-1). However, the volcanic clay impedes significant infiltration in these areas into the underlying aquifer, most being lost to evaporation. Throughout the field investigation, field water quality parameter measurements were collected at various times to determine tidal influences to groundwater levels and conductivity values. Hydrographs indicate a slight variation with water levels and quality over time, however there does not appear to be a significant influence from tidal forces (Appendix C).

In general, field conductivity measurements collected from the test wells and existing water supply wells show decreasing water quality with depth. The evaluation of the lithology, water level elevations, and water quality measurements support that the amount of precipitation recharge is limited, that fracture flow within the limestone is likely inhibited by the presence of clays, and that a significant fresh water lens is not likely present in the lower elevation portions of the island.

4.3 Results of Numeric Groundwater Model

The objective of the numerical groundwater model for the island was to assess the sustainability of future groundwater supply development to meet the needs of forecasted population growth. The numerical model was developed from information derived from previous studies performed on the island and recent field investigations. Results of the field investigation conducted for this project show that saline water underlies a thin lens of freshwater beneath the eastern portion of the island. A small-localized zone of freshwater northeast of Stuart Hill was identified surrounding well BCUT-4. A numerical groundwater flow model was prepared to simulate limited groundwater production of this water source. The development of the groundwater flow model focused on evaluating the sustainability of the limited area of fresh water as a means to meet short-term water supply demands. The model simulated pumping from one well at a rate of 90 lpm (24 gpm) for one year.

Evaluation of the model results suggest that limited water production of this zone is potentially available for short-term water supply demands for less than one year of continuous pumping. After this amount of time, pumping would result in creation of vertical gradients that will result in water quality degradation. These results are based on numerous simplifying assumptions that may increase or decrease the available water supply. Additionally, the simulations assumed a continuous withdrawal of water 24 hours a day. It is likely that sustainable withdrawals could be extended by limiting the amount of pumping per day or season. A detailed explanation of the model development and calibration is presented in Appendix D.

4.4 Potential Contamination Sources

There are several potential sources of contamination to the shallow fresh water aquifer in the vicinity of Stuart Hill. A large pasture for cattle grazing is located along the eastern flank of the hill. Storm runoff carrying concentrations of coliform could migrate from the surface, through the fractured and karst limestone to the freshwater below. Similarly, many of the homes in this immediate area possess septic systems that likely discharge leachate to the shallow subsurface. Further downgradient, toward the shoreline, most of the homes and small businesses in this area do not possess adequate wastewater disposal facilities, and wastewater is discharged to the surface drainages.

4.5 Summary of Findings

Results of the investigation indicate that a significant fresh water lens is not present beneath the island. The absence of a well-developed freshwater lens is believed to be due to the volcanic clay soils that inhibit the vertical recharge of precipitation. The results of the BCUT-4 test indicate the presence of fresh water in the coralline limestone northwest of Stuart Hill. However, the extent of this fresh water is likely limited and will not support substantial groundwater development above 75 to 113 lpm (20 to 30 gpm). Water quality and well yield potential for the remaining portion of the island has a very low potential for further groundwater development and would likely be unable to support high water quality well yields greater than 18 to 37 lpm (5 to 10 gpm). It is not known how much groundwater is being used in the western part of Utila. It is unknown if the quality of the water from the existing municipal wells at current extraction rates will deteriorate over time, as measured by TDS or conductivity. Therefore, it is important that a groundwater monitoring program consisting of measuring groundwater levels, extraction volumes, and conductivity be continued. A monitoring program manual is included Appendix G. The training conducted in groundwater monitoring for this project is described in Appendix I.

Traditional water supply systems that utilize large primary groundwater pumping centers connected to a centralized water distribution network are not expected to be successful on Utila. Installation of high production wells screened in the coral limestone will likely promote continuing seawater migration into shallow aquifers and reduce water quality below potable standards. Future water development on the island of Utila would require an innovative approach to maximize use of precipitation runoff, water conservation, water treatment, growth control, and low impact groundwater withdrawals.

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 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 in our water resource management plan. The system is briefly described in this section and is described in more detail in the Water Resources Management System Users Guide (Appendix E). The training that was conducted in the use of the WRMS is described in Appendix H. 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 is shared back and forth 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 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.

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 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.

Although the fresh water resources of Utila are limited, there should be a control on its use by both municipality and private owners. The purpose is to avoid overexplotation and deterioration of water quality due to drastic saline intrusion. Monitoring data should be registered periodically. The WRMS represents a tool to compare present and future characteristics of water resources.

5.3 Utila Data

Table 5-1 summarizes mapping information collected on Utila. This data is included for review in the WRMS. There are 24 wells with information collected. One well, BC-UT4, has water quality information in the WRMS.

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

Table 5-1. Utila GIS Data Dictionary

File name	File Type	Description	Date	Source	Scale of Source Data
Utila island boundary.shp	shape	Polygon of island shape. Traced over scanned image of island – NAD 27.		Scanned Topo image	
Utila base map nad 27.img	image	Scanned image of Utila. Shows names of island locations, contours, rivers, roads, lakes, Cays, other detail. Very light scan. Shows coordinate lines. NAD 27.			
Utila distribution network.img	image	Scanned image of Utila. Shows names of island locations, contours, rivers, roads, lakes, Cays, other detail. Bright/dark scan. Shows coordinate lines. NAD 27. East Harbor circled showing pipelines.			
New_utilautm.tif	image	Scanned image of Utila. Shows names of island locations, contours, rivers, roads, lakes, Cays, other detail. Darker scan (not bright) scan. Shows coordinate lines. NAD 27.			
1_utila1.tif	image	Aerial photo of island			1 meter pixel
1_utila2.tif	image	Aerial photo of island			1 meter pixel
1_utila3.tif	image	Aerial photo of island			1 meter pixel
Utila rivers.shp	shape	Utila rivers traced from scanned topo image.			
Utila-vect-1of1.shp	shape	Vector contour file, purchased from Intec Americas		INTEC Americas	30 meter, one arc-second
Utila lakes.shp	shape	Traced polygon of lakes on Utila			
Utila-grid-av	grid	Grid file based on vector contour file of Utila. Converted using arc-info.			30 meter, one arc-second
Utilamap.tif	image	Scanned topo image. Very light. Do not think it is NAD 27.			
Utilia_wells_usgs.shp	shape	Points – wells based on USGS info, mostly private wells			
Utila_wells_bc.shp	shape	Points – wells based on BC info, springs municipal wells.			
Utila_geo.shp	shape	Points – geo points containing northing/easting and grid info.			
Utila_dump_new.shp	shape	Points - BC info on new land fill, north and south.			

File name	File Type	Description	Date	Source	Scale of Source Data
Utila_canal_geo.shp.shp	shape	Points along the canal.			
Utila_airport.shp	shape	4 points along the "new airport cleared" area.			
Utila_springs.shp	shape	2 spring points			
Utila_proposedwells.shp	shape	3 points, proposed well locations by BC.			
Utila_geostations.shp	shape	Geo stations, some overlapping Utila_geo.shp file. Many new geo stations, too.			
Utila_geo_contour_vert_dipole.shp	shape	Lines in same area as geo points.			
Utila_geo_contour_horz_dipole.shp	shape	Lines in same area as geo points.			
Pipenet6.shp	shape	Existing pipeline – 6 inches		CAD files	
Pipenet.shp	shape	Existing pipeline – 4 inches		CAD files	

6.0 RECOMMENDED GROUNDWATER RESOURCES MANAGEMENT PLAN

This chapter presents recommendations to ensure the sustainability of a potable water supply for Utila. Recommendations include the implementation of a groundwater monitoring program, the protection of wellhead and recharge areas, the maintenance and use of the Water Resources Management System (WRMS) and project database developed by Brown and Caldwell, establishment of a water management utility, additional studies for increasing water supply, and optimizing groundwater pumping to ensure a sustainable groundwater supply.

6.1 Implementation of a Groundwater Monitoring Program

An important component of managing the current water supply on Utila is the development and maintenance of a regular groundwater monitoring program. A regular monitoring program enables the tracking of fluctuations in groundwater quality and useage over time, as well as seasonal and long-term fluctuations in available water supply. Tracking these trends is important for assessing changes in water supply availability, and for planning and developing future water supply sources. Data collected doing groundwater monitoring events should be input in the groundwater database developed by Brown and Caldwell for Utila. The WRMS, also developed by Brown and Caldwell, is a tool that the municipality can use to review and analyze the groundwater monitoring data as described above.

A successful groundwater monitoring program has several components that are essential to support and enhance the effort of tracking data over time. These components include well selection, groundwater level data collection, water sample collection, analysis of water samples, and review, compilation and understanding of the water chemistry results. It is suggested that the municipal wells and the test wells be included in the monitoring program. It is particularly important for Utila to obtain the groundwater production level and conductivity data to be able to establish the long term trends over time. Brown and Caldwell recommends that the following wells be included in the groundwater monitoring program: Municipal wells MW-1, MW-2, MW-3, The Old Indian Well, and MW Cay and the wells installed by Brown and Caldwell named BCUT-1, BCUT-1A, BCUT-2, BCUT-3, and BCUT-4.

The groundwater monitoring program should include measurements of the groundwater levels and elevations, groundwater production rates, measurements of conductivity and pH, and the collection of samples for analysis for salinity, total dissolved solids, coliform bacteria, and selected metals. Information regarding the steps necessary to complete a monitoring program are outlined in the document titled Groundwater Level and Monitoring Program, Field Manual, December 2001, as presented in Appendix G. 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. This training is described in Appendix I.

6.2 Development of a Wellhead Protection Plan

The purpose of wellhead protection is to protect the groundwater resource from surface contamination such as both total and fecal coliform, pesticides, and other harmful chemicals that are used and discharged to the ground surface. Development of a wellhead protection plan for Utila consists of five key steps that are described in Appendix H. The control measures included as part of a wellhead protection plan 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.

6.3 Utilization of the Water Resources Management System

Brown and Caldwell developed a Water Resources Management System (WRMS) to store, manage, and analyze water resources related data gathered and generated for this project. To ensure the ongoing usefulness of this tool, it is important that this database be regularly updated with the data collected as part of the Groundwater Monitoring Program. The following recommendations are provided as a guide to using the WRMS as a tool for sustainable water resource management:

1. Groundwater sampling and water level monitoring should be performed as suggested in Groundwater Level and Monitoring Program Field Manual. Sampling results should be entered into the WRMS as described in Section 2.4.3.8 in the Water Resource Management System Users Guide. Water level results should be entered in as described in Section 2.4.3.9. These data should be consistently entered in order to provide up-to-date information for assessing water quality and aquifer characteristics.

2. Table 6-1 presents the reports and maps that may be generated as needed to evaluate new water quality and water level data:

Table 6-1. WRMS Reports and Maps

Report/Map Name	Application	Users Guide Reference
Hits Report	Run this report to view positive detections for selected wells	2.4.4
Water Level Report	Run this report to view the water level history of selected wells	2.4.4
Analyte Trend Report	Run this report to view the sampling history for selected wells and selected analytes	2.4.4
Well Classification Map – Water Level	Create this map to show the latest water level measurements for wells	2.4.5.10
Well Classification Map – Water Quality Parameters	Create this map to show the highest detections for a selected water quality parameter and plot them against a regulatory limit.	2.4.5.10

3. Predicted population growth and per capita water consumption data should be evaluated annually based on the latest information available. Updates can be made to the municipality growth and consumption screen as described in Section 2.4.3.1 in the Users Guide. New growth and consumption trends can be printed using the Municipal Growth Report as described in Section 2.4.4.

4. Use the Well Summary Report (described in Section 2.4.4) and Well Classification Map (described in Section 2.4.5.10) as necessary to quickly compare well depths, screen settings, pump rates, and hours of operation.

5. Print out Well Construction, Well Equipment, Well Operations, and Storage Tank Reports as needed for handy reference.

6. Annually update the Infrastructure GIS data layers to maintain current base map data. Please see 'USING ARCVIEW GIS' users guide that is provided with the WRMS for more details on how to do this.

7. Enter new wells and storage tanks into the system as they are completed in order to maintain the most up-to-date information available.

6.4 Water Utility Management

An important aspect of ensuring a sustainable water supply is having a functioning water utility with an official, dedicated board of directors or other organizational structure. The water utility should be responsible for properly managing, operating, and maintaining the water supply system. An important consideration in successful management of the water utility is financial self-sufficiency.

Several recommendations for creating a water utility are presented below:

1. Verify that a complete list of all water system customers is available. If not, prepare a list of all customers that includes descriptive information for each customer. This information would include name, address, service line size, and type of customer (residential, commercial, etc.). Both the PMAIB study and FUNDEMUN report contain valuable information for helping to establish a water utility;

2. develop a financial plan for the water utility that establishes budget needs and defines a fair and reasonable rate structure. Ensure that users are charged for and pay for water supply. Water rates will be a function of ability of the water supply system to provide reliable water;

3. evaluate the extent of water loss from the distribution system and repair leaks;

4. the water utility should have adequate staff that is trained on a regular basis to address operational and maintenance needs. The appropriate staffing needs for Utila should be defined; and

5. investigate possible sources of grant and loan financing to help conduct a study of water supply alternatives and to improve and expand the water system.

6.5 Recommended Additional Studies

Innovative approaches for obtaining water supply from sources other than groundwater are needed. Alternative water supply sources such as rainfall harvesting with roof and cistern systems, catchment of stormwater, reservoirs, infiltration and recharge galleries, desalination of sea-water, conservation programs, population growth management and other appropriate methods should be evaluated for technical and economic feasibility, prior to re-design. It is recommended that alternative water supply systems utilize simple technology, be highly efficient, low cost, and be easily maintainable with spare parts being readily available within the country. It is recommended that a study be conducted to evaluate water supply alternatives. Charging fees for using the municipal groundwater supply will encourage the use of rainfall collection and cistern systems. Alternatively, an incentive program for utilization of rainfall harvesting systems may also result in less reliance on the limited groundwater resource. Possible water supply alternatives include the following:

6.5.1 Rainfall Capture from Roof Top Systems. Additional supplies could be developed during precipitation events by capturing and storing rainfall runoff from rooftops. Use of this water would decrease demand on groundwater supplies and allow recovery of water levels and water quality during the wet seasons. It is recommended that the municipality require that all new houses and commercial buildings install a rainfall capture system.

The system could include a roof gutter collection system piped to a cistern. The design challenges associated with the system are bypass of the first flush of rainwater to improve water quality, connection to residential plumbing and evaluating individual, or cluster cistern storage systems. Rainfall distribution may limit effectiveness due to short high intensity rainfall events.

6.5.2 Aquifer Storage and Recovery. Aquifer storage and recovery (ASR) is becoming a popular alternative to provide a cost-effective alternative to constructed water storage structures. In addition, experience with ASR in coastal aquifers has shown that high quality water can be recharged in saline aquifers, stored for later use and withdrawn with an acceptable amount of water quality degradation. In Utila, ASR would involve using shallow wells to recharge precipitation during the rainy season and withdraw the water during dry periods to supplement the overall water supply. During field investigations, it was noted that after precipitation events, certain upland areas would receive runoff from larger drainage areas. In these areas, significant pooling or ponding of water was observed. The ponding is likely the result of the low permeability surficial clays in these areas. ASR wells could be constructed in these drainage areas to promote recharge of rainwater beneath the clay to the coral limestone. During dry seasons, the same ASR wells could be pumped to supply potable water. The primary disadvantage to this system is that it is untested on Utila. A feasibility study followed by pilot scale testing would be the next step to evaluate the potential of this alternative.

6.5.3 Desalinization of Water. Desalinization of groundwater is another potential method to develop additional water supplies. It is recommended that all new developments for tourism consider this solution as a source of water. The cost of membrane treatment has decreased dramatically over recent years and many coastal communities are finding desalinization a viable alternative. However, desalinization has very high power and maintenance demands that would make large-scale development on the island difficult. Desalinization is more likely a viable option for large hotel or resort development.

6.5.4 Low Flow Gallery Pumping. Large individual pumping wells will cause higher drawdown and greater potential for saltwater intrusion. An alternative to a single high production well, is multiple smaller wells placed over a larger geographic area to disperse the impact of well drawdowns. This may be a viable alternative to develop sustainable water supplies from the surficial clays. The disadvantages to this type of pumping is the need for a large land area, high infrastructure requirements in terms of pumps and pipes, and high potential for surface contamination to adversely impact water quality, septic or run-off for example. Again, a feasibility study followed by a pilot scale test are recommended as a next step.

6.5.5 Low Flow Wells. Any future additional well constructed to provide water supply should be equipped only with small pumps because of the low yield of the aquifer. It is recommended the use of pumps powered with solar energy be considered.

6.5.6 Shipping Water from Mainland. This partial solution could be considered, for public or private use.

6.6 Control of Groundwater Pumping and Recharge Area Land Use

Since the potable groundwater resource in Utila is limited, there should be control of its use by both the municipal and private well owners. The purpose would be to avoid overpumping of groundwater and resulting deterioration of water quality due to saline intrusion. It is recommended that the municipality limit any increase in groundwater pumping, limit the construction of new wells, and protect the upland areas that are covered with dense vegetation that represent potential groundwater recharge areas through rainfall infiltration. These controls should be incorporated into the municipal regulations.

6.7 Regulate Population Growth

As the groundwater resource on Utila is being fully exploited, measures to restrict development of the Island should also be considered. Regulations requiring all new developments to rely solely on rainfall collection/cistern systems, desalinization of seawater, and/or importation of water from off-Island sources should be considered for all new developments.

APPENDIX A

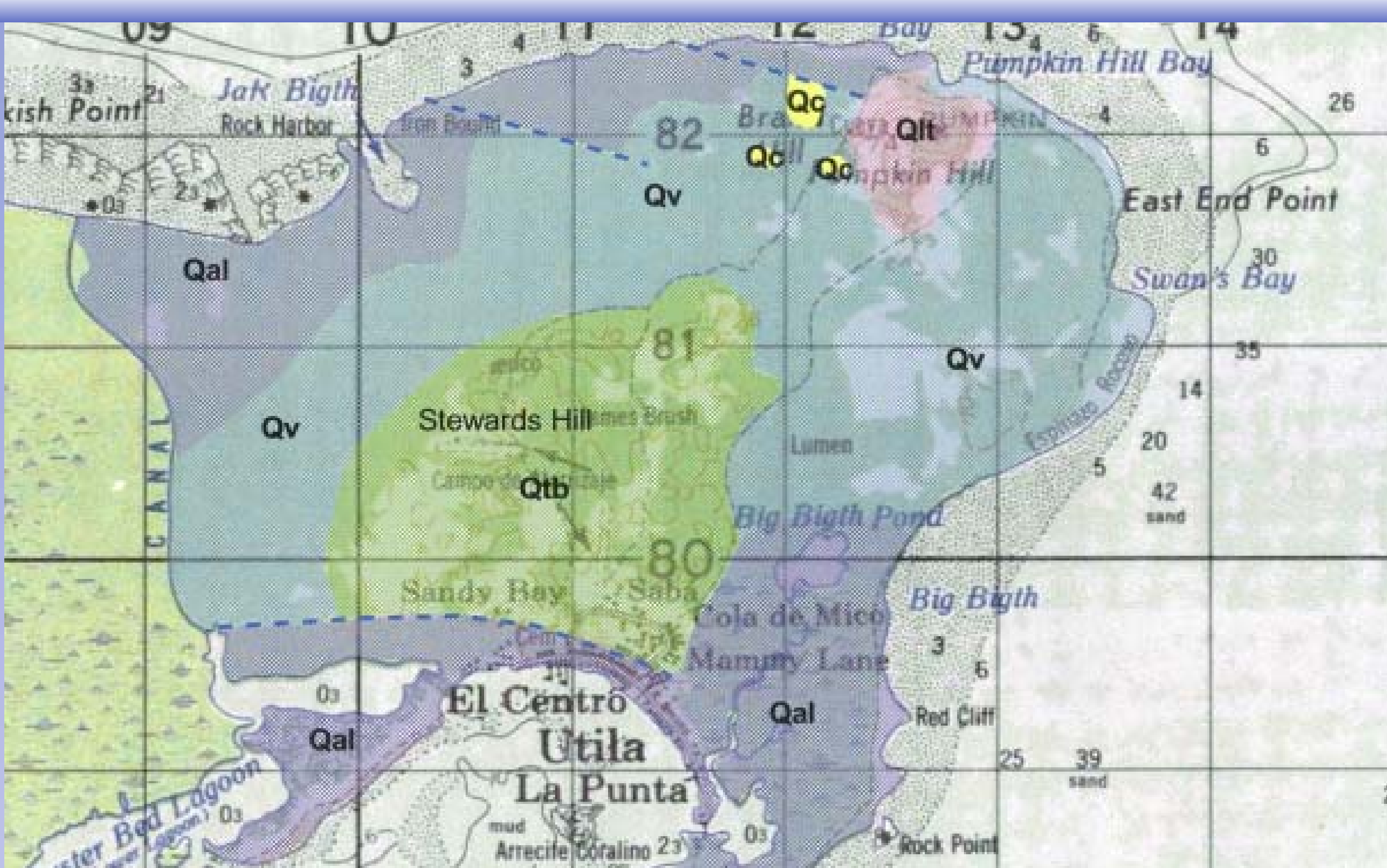
Conceptual Model and Rationale for Phase II Field Investigation

(Revised: February 2002)

Conceptual Model Update

CONCEPTUAL MODEL AND RATIONALE FOR PHASE II FIELD INVESTIGATION

Island of Utila, Republic of Honduras, C. A.



August 2001

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 presents the hydrogeological conceptual model for the Island of Utila developed as part of Phase I for the Honduras Groundwater Monitoring Study. This preliminary conceptual model presents the results of the data review and field reconnaissance, as well as the rational for conducting the Phase II field investigation. The project background, water resources needs, geologic setting, identified data gaps, and recommended areas for field investigation and activities are described herein.

BACKGROUND

The purpose of the Honduras Groundwater Monitoring project is to evaluate the sustainable yield of the potable water supply and develop a water resources management plan for Isla de la Utila to ensure sustainable water resources for municipal water supply. This project is funded by the US Agency for International Development (USAID).

Isla de la Utila (Utila) is one of the three major islands making up the Bay Islands group located north of the Honduran coast in the Caribbean Sea, and is located approximately 18 miles north of the City of La Ceiba. Utila is roughly 8 miles long and varies between 1 and 3 miles in width. The total land area of the island is approximately 16 square miles. Almost all of Utila's population lives in the eastern third of the island, in an area called East Harbor. Approximately 6,000 permanent residents live in East Harbor. Utila also is a popular tourist destination for vacationers, sports fishermen, backpackers and SCUBA divers, with about 12 dive shops located within 1 mile of each other. The island attracts approximately 1,500 to 1,800 visitors each month. Additionally, a fishing village is located off Utila's southeastern coastlined on two cays, or small islands named Pigeon (Lower) Cay and Jewel (Upper) Cay; these Cays are home to approximately 1,000 residents. Population projections predict that Utila's permanent resident population could expand to 25,000 inhabitants within the next 20 years.

EXISTING WATER RESOURCES

Utila relies on groundwater for the majority of its water supply. It is anticipated that reliance on groundwater for municipal water supply will increase as population growth continues in the future.

The current municipal water supply system consists of one 25,000 gallon elevated water storage tank, three groundwater supply wells and a water distribution network consisting of approximately 312,380 feet of 4-inch polyvinyl chloride (PVC) piping. This water supply system is situated on the eastern third of the island and connects to approximately 700 homes, businesses and restaurants. The system is divided into three systems servicing ten neighborhoods, which are turned on and off throughout the day by the municipality.

Water is supplied from three wells, known as Well 1, 2 and 3, situated adjacent to the island's soccer/baseball field and are all within 150 feet of each other. The wells consist of a 8-inch outer PVC casing and a 1 1/4-inch inner PVC casing. Water is pumped from each well by a 1 horsepower (hp) submersible pump into a 1-1/4 inch PVC pipe that feeds a 25,000 gallon elevated water tank. Electrical power for these pumps is provided by the island's power plant, which consists of three diesel generators; currently, the power plant operates for 18 hours a day from 6 a.m. to 12 a.m.

FUTURE WATER NEEDS

The Island of Utila has experienced steady growth in permanent residents and tourists in recent years. Since most of the wells lack water production meters, the amount of water used by the island cannot be precisely quantified. Water demand projections and the resulting need for additional wells will be assessed later in this study.

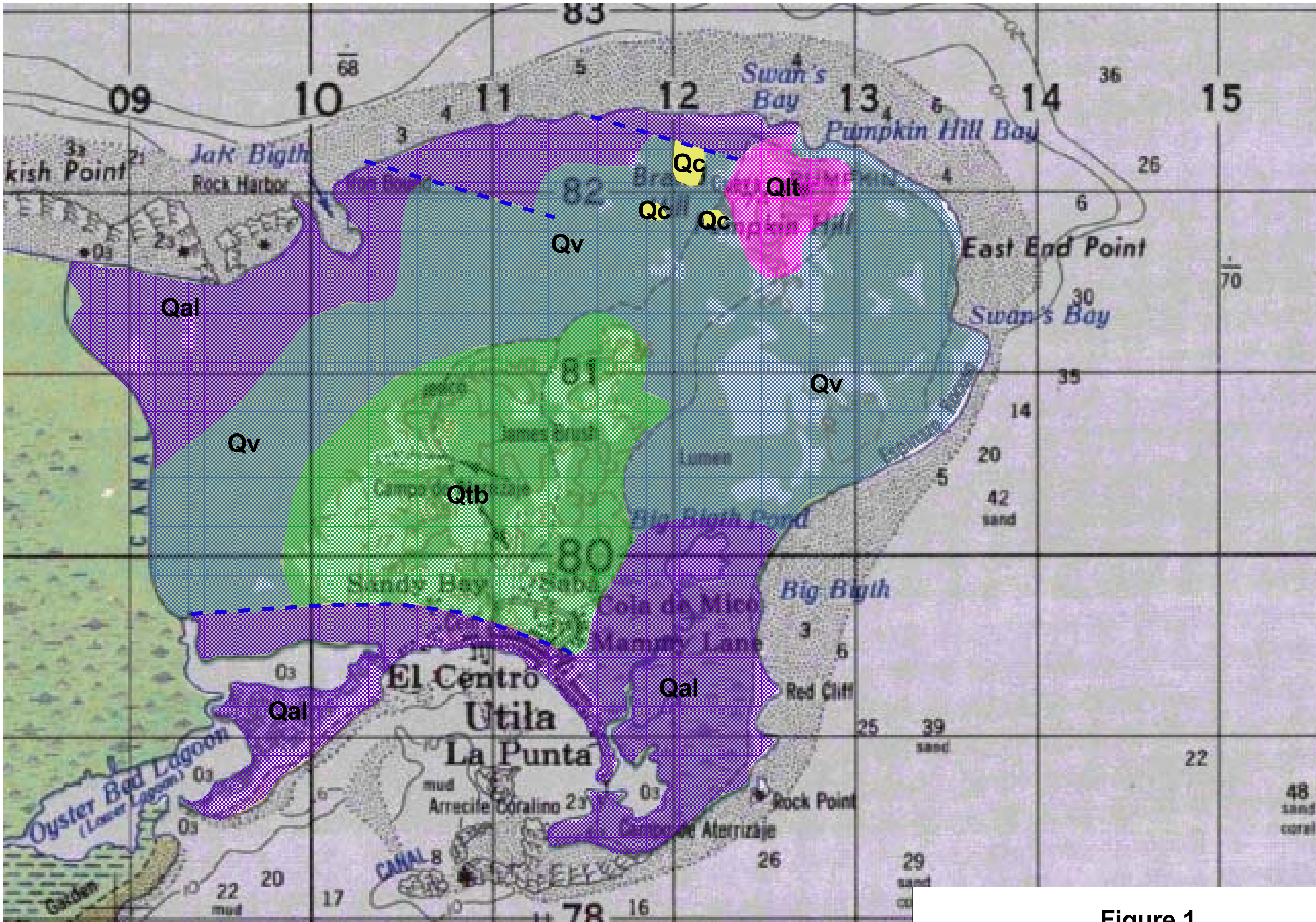
RATIONALE FOR WATER RESOURCE EXPANSION

The objective of this water resource investigation is to locate sustainable groundwater supplies that can be economically utilized. Economical groundwater supplies are supplies that would be close to existing water system infrastructure with acceptable water quality and yield that meets anticipated supply needs.

GEOLOGICAL SETTING

Utila belongs to the Bay Islands archipelago, which consists of three main islands and approximately 65 keys and extends over an area of 500 square kilometers. The Bay Islands archipelago is home to a vast coral reef system. Geologically, the Bay Islands are on the emergent crest of a narrow ridge on the side of the Bartlett Trough. The low relief of Utila is different in appearance and relief from the other Bay Islands. The geology of Utila consists primarily of volcanics at the east end of the island, and a cap of coralline limestone and carbonated sediments forming swamps and lagoons to the west, which is underlain by metamorphic rocks similar to those of western Roatan. A generalized geologic map is present in Figure 1.

The western two-thirds of the island are low-lying areas that contain mangrove swamps and savannas. These low-lying areas are primarily composed of exposed historic reefs and brackish marsh deposits. The eastern third of the island is characterized by the presence of two hills: (1) Stuart Hill located approximately one mile inland from the center of East Harbor: and (2) Pumpkin Hill located on the northeastern coast about 4 miles from East Harbor (Figure 1). Stuart Hill is characterized as a historic cinder cone remnant that is composed of basaltic breccia. Pumpkin Hill is the highest point on the island at approximately 243 feet above sea level (ASL) and is composed of stratified calcareous basalts. Numerous historic limestone reefs have been observed on the flanks of both Stuart and Pumpkin hills. The land surrounding and between these two landmarks contains rolling hills covered in dense jungle. These areas are characterized as alkali basaltic lava flows. Along the margins of these basalt areas are low-lying Quaternary alluvium containing mangrove swamps and savannas. Additionally, the entire island is surrounded by an extensive coral reef. This reef is as shallow as a few feet in some places, and its edges contain underwater walls extending to over 2,000 feet below sea level on some places. One unique feature on the island is a canal connecting the island's north and south coasts. The canal was hand-dug as a means to create a shorter route between the two coastlines to assist the fishing community. According to residents, the canal is approximately 50 years old, and varies in depth from 2 to 12 feet and in width from 5 to 15 feet.



Qal Alluvial Sediments
Qv Basalt
Qtb Breccia Basalt
Qc Limestone, Historic Reef
Qlt Stratified Basalt

Figure 1

Generalized Geology of the Eastern Portion of Utila

HYDROGEOLOGICAL SETTING

Beneath the island surface, fresh groundwater occurs as a lens, which is recharged entirely by rainfall and is constrained at its lower and lateral boundaries by saline groundwater. Although, rainfall data is limited, Utila receives approximately 87 to 102 inches of precipitation per year with nearly 70 percent of the rainfall occurring from September through December. In October 1993, Servicio Autonomo Nacional de Acueductos y Alcantarillados (SANAA) conducted a hydrogeologic study of Utila. SANAA estimated that the aquifer's recharge potential was between 25 and 40 percent of the total annual precipitation. The occurrence and movement of groundwater and the configuration of the freshwater lens is affected in part by the island's geology, topography, and the surrounding sea. Figure 2 presents a conceptual hydrogeologic cross-section of Utila.

In general, groundwater in the low-lying areas (less than 16 feet ASL) are considered be brackish and unuseable as groundwater supplies. The upper land areas located in the eastern portion of the island receive recharge, and have the potential to build groundwater storage and develop a freshwater lens.

Currently groundwater is being pumped from 3 municipal wells located near the soccer field (See Figure 3), which is located approximately 1,000 meters to the north of the village. The total depth of Well 1 was measured at 54 feet below ground surface (bgs), and the total depths of Wells 2 and 3 were both measured at 59 feet bgs. The elevations of the wellheads have been estimated to be approximately 45 feet ASL. In Wells 2 and 3, depth-to-water was measured at 48 feet bgs, while in Well 1 depth-to-water was measured at 46 feet bgs. This corresponds to 11 feet of water in the bottom of Wells 2 and 3, and 8 feet of water in the bottom of Well 1. Temperature, electric conductivity (EC) and pH were measured from grab groundwater samples collected from the three wells. For Wells 1, 2 and 3, temperature was measured at 27.7°C, 30.4°C and 28.8°C, respectively; EC was measured at 2,080 micromhos/cm (µmhos/cm), 2,040 µmhos/cm, and 2,070 µmhos/cm, respectively; and pH was measured at 7.20, 7.04 and 7.05, respectively. The elevated electrical conductivity suggest that that the freshwater lens in this area is relatively thin and impacted by saline water. In addition, the grab groundwater samples were analyzed for nitrate and nitrite. Nitrite was not detected in any of the three wells, while the samples from Well 1 and 3 contained 1 part per million (ppm) nitrate and the sample from Well 2 contained 2 ppm nitrate.

BC field staff has also identified and monitored 34 private water supply wells, PW 1 through PW 34 (Figure 3) on the Island of Utila. Data collected from these wells included: total depth, depth-to-water (dynamic water level), pH, temperature, electric conductivity, nitrate and nitrite concentrations, UTM coordinates and approximate age. A summary of the information collected for these wells is presented in Table 1. Water samples taken from the island's wells produced conductivity measurements ranging from 200 to 2,450 microsiemens per centimeter (µS/cm). A preliminary review of the data suggests that low conductivity groundwater is present in certain vicinities of the populated section of the island. However, this area also contains numerous septic tanks, which have the potential to contaminate the shallow groundwater. In some cases, the septic tanks are as close as 10 feet from the private wells. Water samples obtained from the island's private wells produced nitrate concentrations ranging up to 50 parts per million (ppm) which exceeds the World Health Organization (WHO) drinking water standard of 10 ppm for nitrate; the elevated

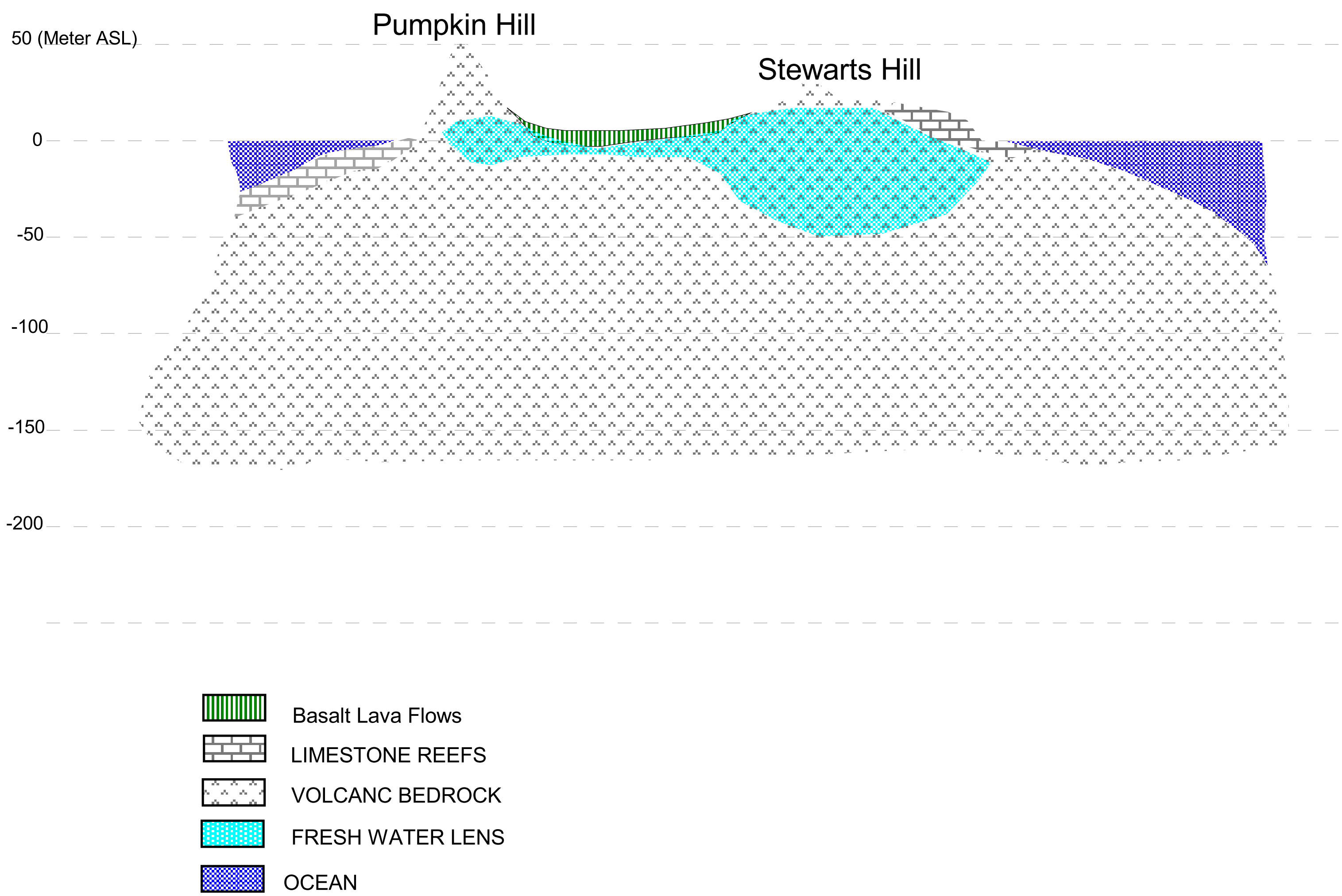


FIGURE 2

CONCEPTUAL GEOLOGIC CROSS-SECTION

UTILA

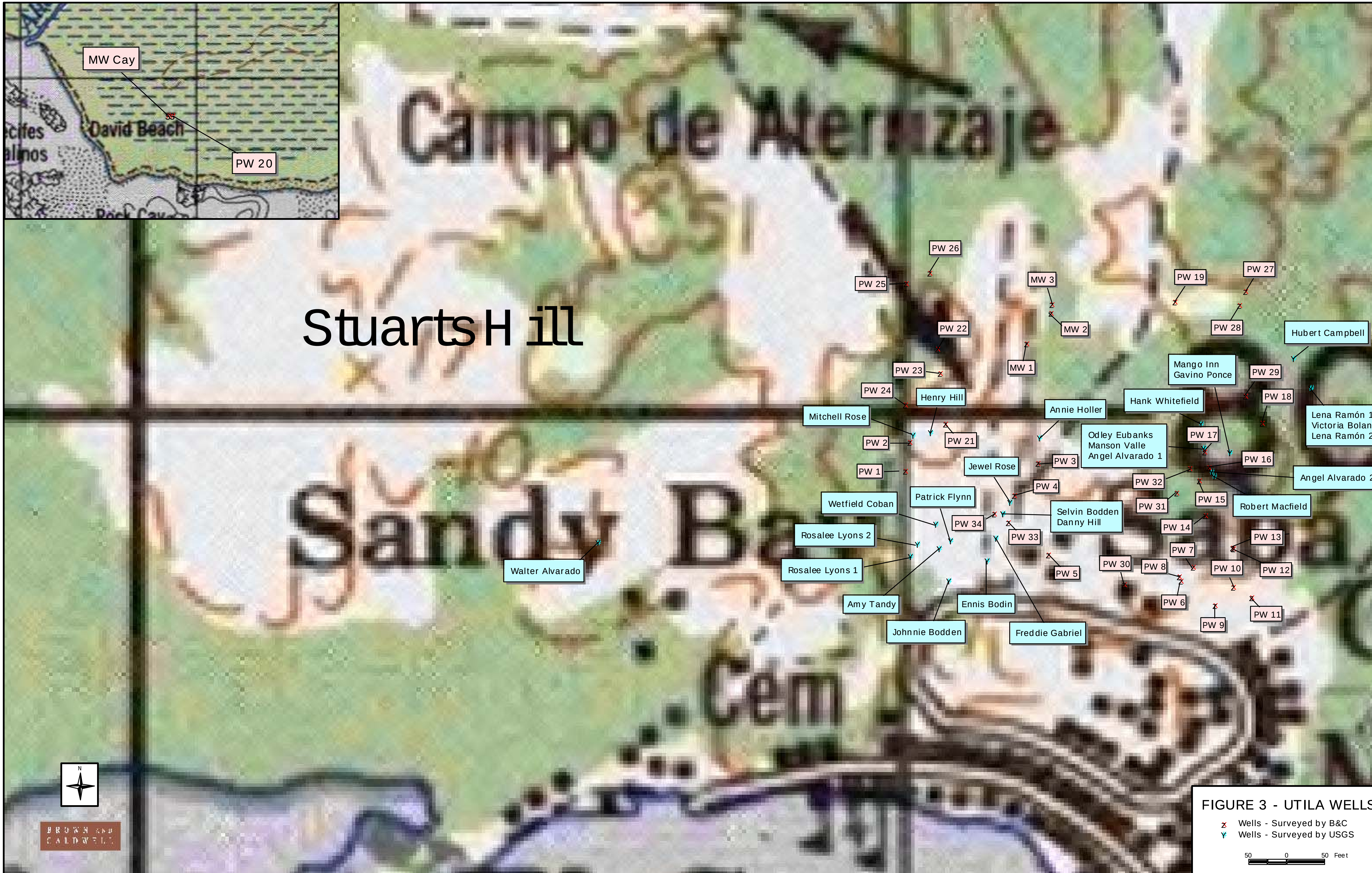


FIGURE 3 - UTILA WELLS

concentrations of nitrates may be the result of the proximity of the septic tanks and leach fields to these wells. Additionally, the majority of the private wells are believed to be completed in perched water zones, with limited production potential.

To increase understanding of the potential groundwater supply, BC subcontracted with Terra-Dynamics Consulting, Inc., to conduct a surface geophysical survey. The surface geophysical survey was conducted from June 22 through June 25, 2001, with a Geonics EM 34 Terrain Conductivity Meter (EM 34). The EM 34 measures the conductivity of a subsurface at depths up to 60 m bgs, or approximately 200 feet bgs. A total of 98 locations, GEO 1 through GEO 98, were included in this survey (Figure 4). The basic premise for the survey was that, areas of lower conductivity are an indication of the presence of a potential freshwater lens at depth. The results of this survey are presented on Figures 5 and 6. The area of low terrain conductivity is depicted within the 35 millimho/m contour interval for the vertical dipole data and the 25 millimho/m contour interval for the horizontal dipole data. These areas suggest that the breccia basalt associated with Stuart Hill is a potential source of fresh water. The surface geophysics report is included in Appendix B.

Additionally, Big Bight Pond and the major canal were investigated for the potential of fresh groundwater water recharging to these surface water bodies, which would provide evidence of a potential freshwater lens in the vicinity of these areas. There was no evidence of fresh surface or groundwater water entering either of these locations, nor was there any change in vegetation from a mangrove swamp, which could indicate a change in water quality. Nine locations throughout the canal, CA 1 through CA 9, and several within Big Bight Pond, primarily on the western shoreline, were sampled for conductivity. The readings at each of the locations were greater than the maximum scale of the meter, indicating that fresh water was not contributing to canal flow.

Based on a review of the available data, a significant lens of fresh groundwater is believed to exist in the Stuart Hill area. This area is characterized, as broad rolling hills comprised of breccia basalt, which is vegetated as pasture land and jungle. These factors give rise to the potential for significant recharge and the possibility of sustainable groundwater supplies.

RECOMMENDED AREAS FOR FIELD INVESTIGATION

Based on a review of the available data for Utila, the Stuart Hill area has been identified as having the highest probability of providing sustainable groundwater. As a result, it is recommended that the breccia basalts underlying this area be further investigated by drilling.

DATA GAPS

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

- There are an insufficient number of monitoring wells to verify the lateral and vertical extent of the suspected groundwater lens in the Stuart Hill area.
- Additional information is required to evaluate safe groundwater yields and to assess the influence of groundwater pumping on the freshwater/saltwater interface.

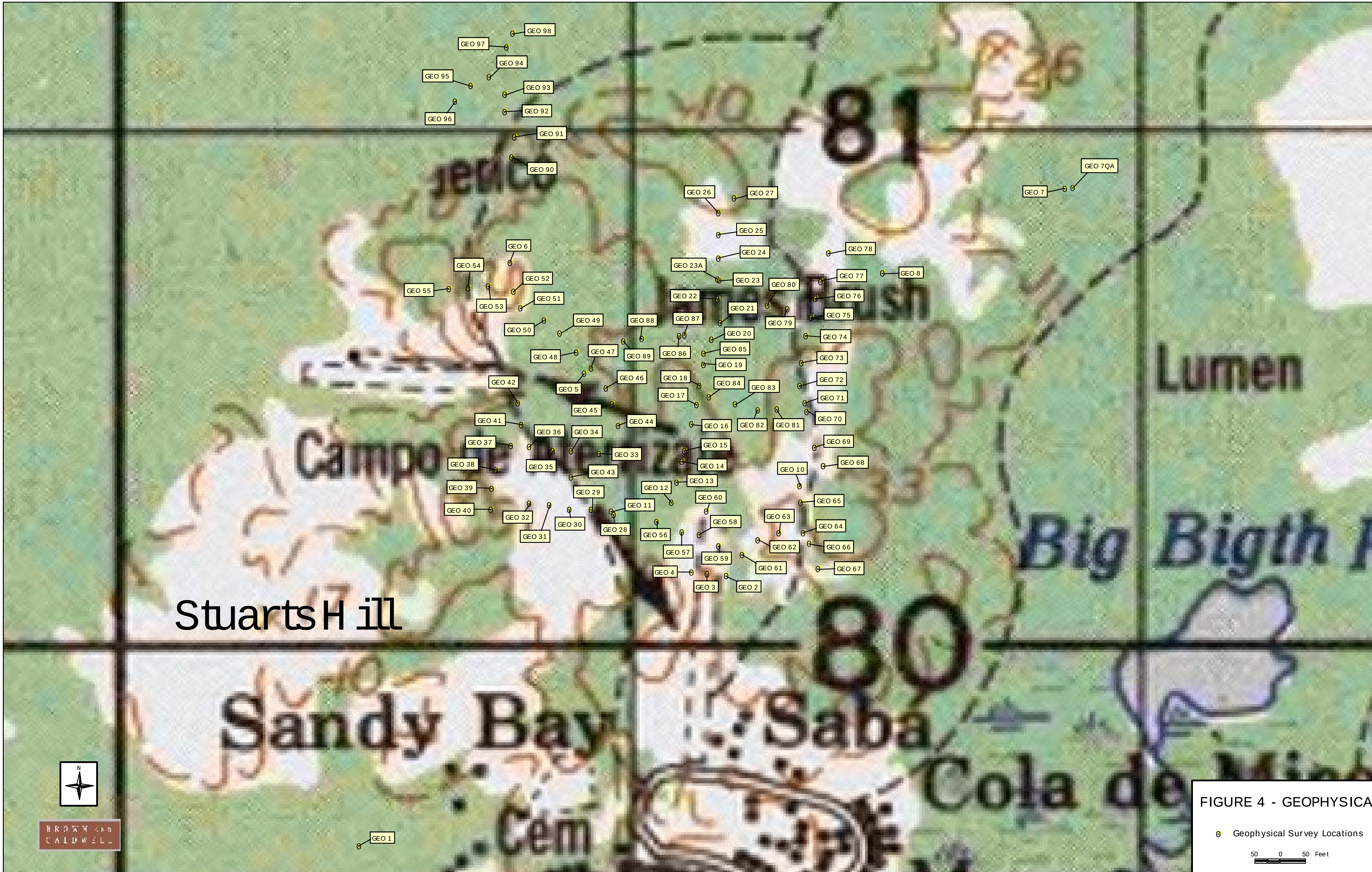


FIGURE 4 - GEOPHYSICAL
Geophysical Survey Locations
50 0 50 Feet
N
BROWN AND CALDWELL
Stuarts Hill
Sandy Bay
Saba
Lumen
Big Bigth
Cola de
Cem
81
80
GEO 98
GEO 97
GEO 94
GEO 95
GEO 93
GEO 92
GEO 96
GEO 91
GEO 90
GEO 26
GEO 27
GEO 7QA
GEO 7
GEO 25
GEO 24
GEO 78
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GEO 54
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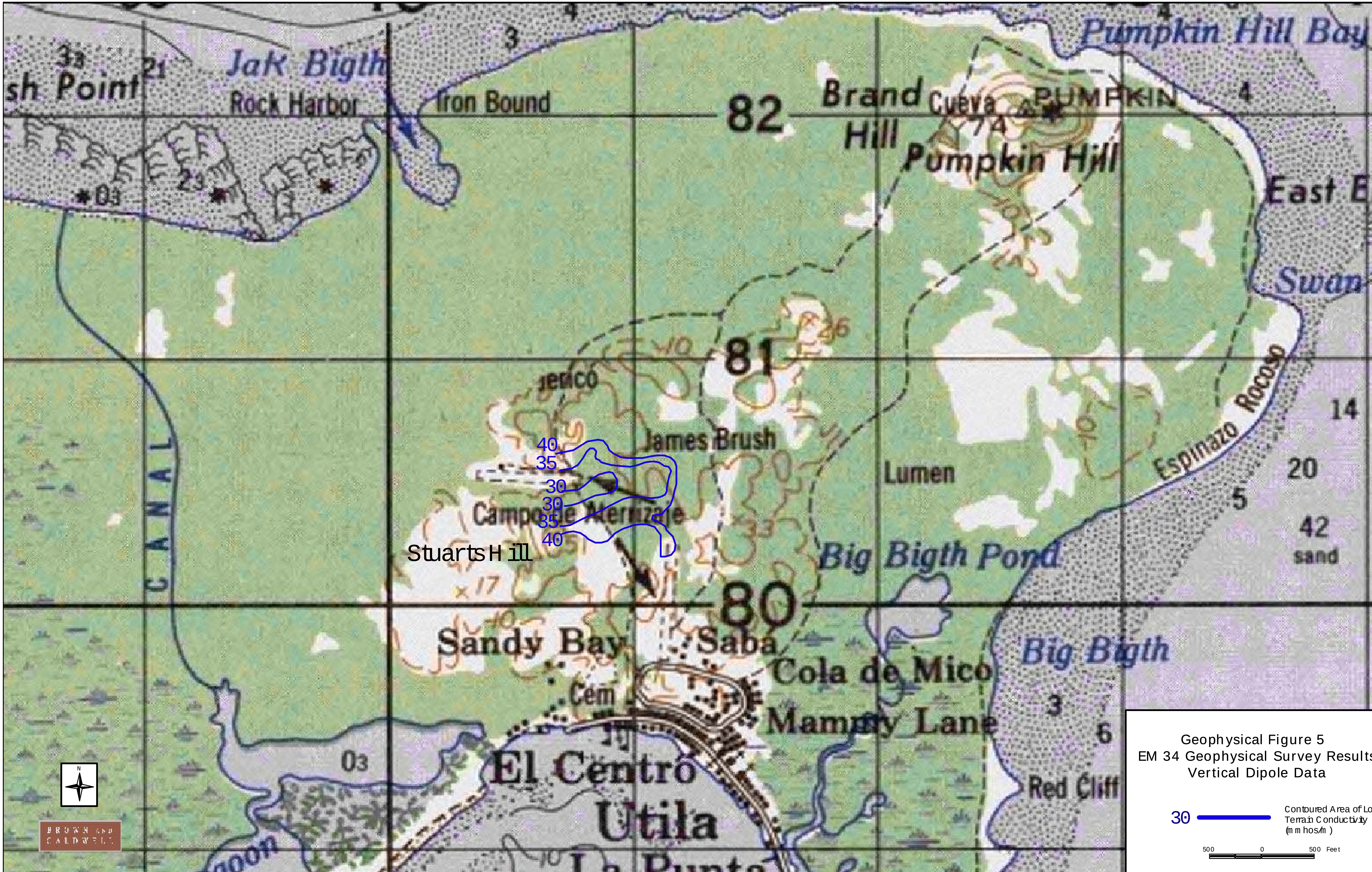
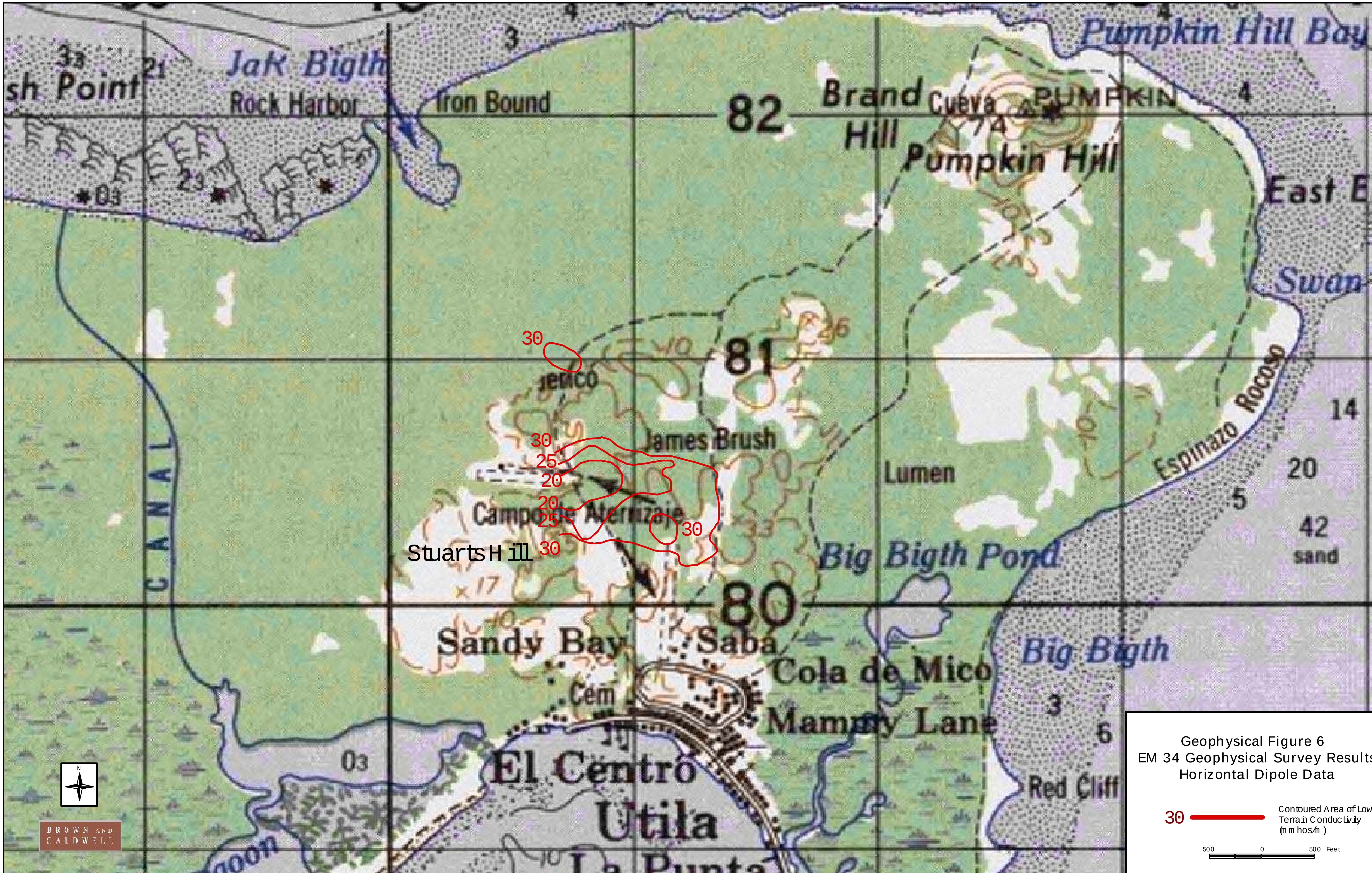


Geophysical Figure 5
EM 34 Geophysical Survey Results
Vertical Dipole Data



Geophysical Figure 6
EM 34 Geophysical Survey Results
Horizontal Dipole Data

RECOMMENDED FIELD ACTIVITIES

Test and Monitoring Wells

BC recommends that 3 wells (BCUT-1, BCUT-2, and BCUT-3) be installed to evaluate the Stuart Hill area (See Figure 7). These wells are located within the area of low terrain conductivity. Each well will be completed with a PVC surface casing that will be keyed approximately 5 feet into competent bedrock, and then cement-grouted to the surface. The based of each well will be extended to a depth of approximately 200 feet, or until the freshwater/saltwater interface is identified.

Geophysical Surveys

Down-hole geophysics will be conducted on each of the boreholes installed during this evaluation. The geophysical suite will include resistivity, spontaneous potential, gamma, caliber, and temperature measurements. Additionally, a downhole conductivity meter will be used to aid in assessing the freshwater/saltwater interface.

Aquifer Tests

A low flow constant rate and recovery test will be conducted on each of the newly installed test wells to estimate specific capacity, transmissivity and safe yields. The aquifer tests will also provide information regarding how pumping influences the freshwater/saltwater interface.

The aquifer tests will be conducted over a 72-hour period. During this testing period, 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. Additionally, the potential movement of the freshwater/saltwater interface will be monitored throughout the duration of the test.

Water Quality Sampling

Each well will be tested for the follow parameters:

- Total dissolved solids
- Specific conductance
- PH as $CaCO_3$
- Acidity
- Alkalinity as $CaCO_3$
- Nitrate/Nitrite
- Coliforms
- Chloride
- TAL metals (arsenic, barium, cadmium, chromium, fluoride iron, lead, manganese, mercury, nickel, selenium, silver, sodium, and zinc)

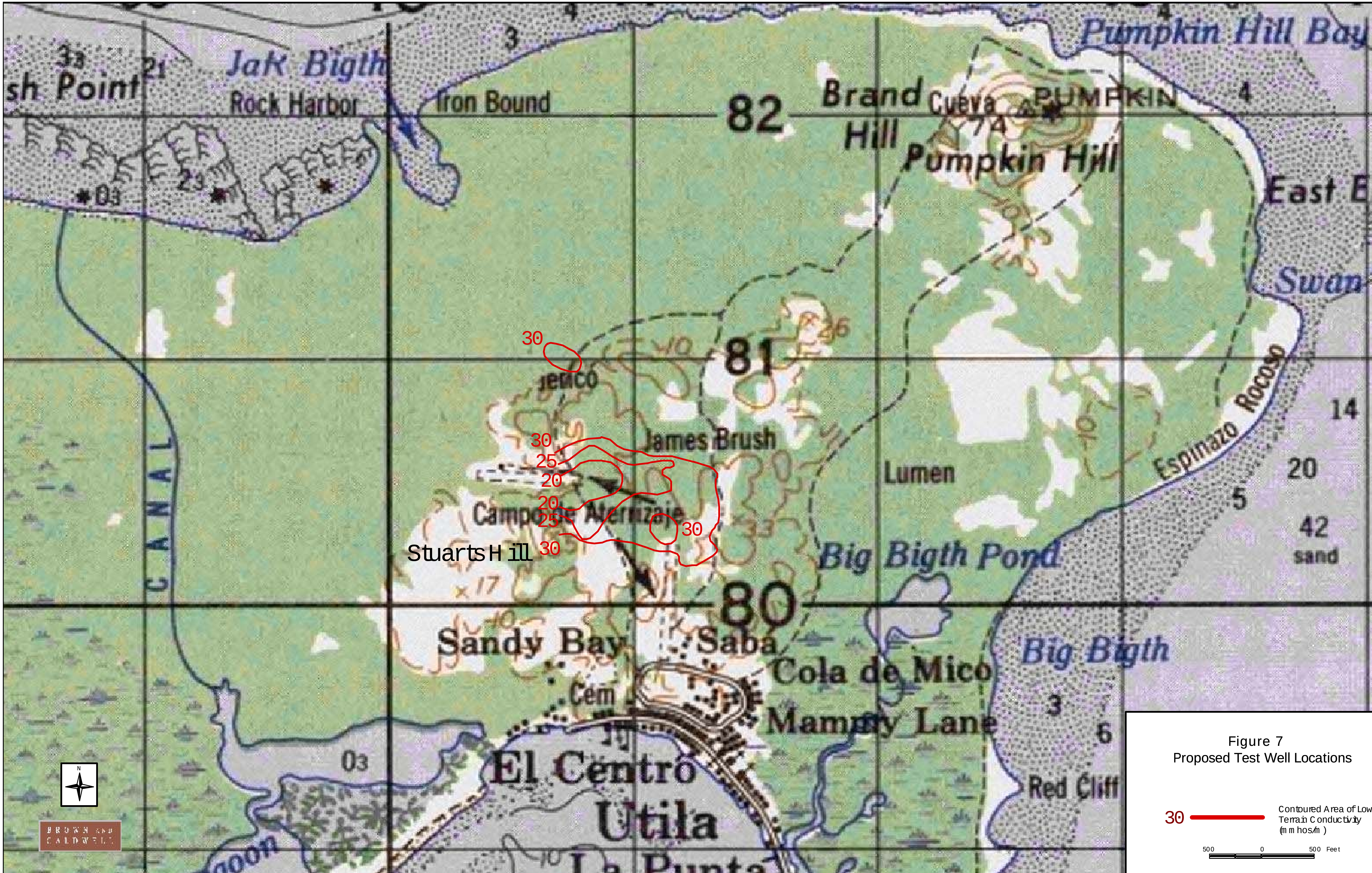


Figure 7
Proposed Test Well Locations

ANTICIPATED FIELD RESULTS

The anticipated field results are as follows:

- Verification of the existence of the suspected fresh water lens in the Stuart Hill area.
- Evaluation of the lateral and vertical extent of the suspected freshwater lens.
- Information on the influence of pumping on the freshwater/saltwater interface.
- Estimates of specific capacity and aquifer transmissisity.
- Quantify groundwater quality.

Conceptual Model Update

Utila, Honduras

1.0 INTRODUCTION

Brown and Caldwell has recently completed the field investigation portion of a water resource investigation for the Island of Utila (Utila). The purpose of the water resource study is to develop a management plan to ensure a sustainable water resource for current and future island residents.

Utila is one of the three major islands making up the Bay Islands group located north of the Honduran coast in the Caribbean Sea, and approximately 18 miles north of the City of La Ceiba. Utila is roughly 8 miles long and varies between 1 and 3 miles in width. The total land area of the island is approximately 16 square miles. Almost all of Utila's population lives in the eastern third of the island, in an area called East Harbor. Approximately 5,600 permanent residents live here in East Harbor. Population projections predict that Utila's permanent resident population could expand to 25,000 inhabitants within the next 20 years.

The current municipal water supply system consists four wells supplying a single 25,000 gallon elevated water storage tank. This system is situated on the eastern third of the island and connects to approximately 700 homes, businesses and restaurants. Three of the four existing wells, known as Well 1, 2 and 3, situated adjacent to the island's soccer/baseball field and are all within 150 feet of each other. The fourth well is a shallow well (approximately 20 feet deep) and located in East Harbor. Electrical power for the well pumps is provided by the island's power plant, which consists of three diesel generators that operate from 6 a.m. to 12 a.m.

Evaluation of existing water supplies indicates that per capita water consumption is very low and in the range of 13 to 18 gallons per capita per day (gpcd). This per capita consumption is well below gpcd estimates for the mainland of 40 gpcd. It is unlikely that water conservation efforts could be implemented to lessen the per capita water consumption, and it is likely that per capita consumption will increase as the island develops more amenities with increasing population. Therefore, the existing water system marginally meets the existing population and has a low potential to support short-term growth with out new supply development.

The main water resource issue on the island is decreasing water quality. Because of the island hydrogeology, limited fresh water supplies are available and over production of fresh water will result in intrusion of saltwater into fresh water aquifers. The degree of saltwater intrusion or salinity can be expressed in terms of electrical conductance or total dissolved solids (TDS). Electrical conductance is measured in micromohs per centimeter and TDS is measured in parts per million. TDS is proportional to electrical conductance and conductance is approximately 1.6 times greater than TDS concentration. Normal drinking water has a TDS range of 300 to 800 ppm. Seawater has a TDS of approximately 32,000 ppm. The recommended limit for TDS by the World Heath Organization (WHO) is 500 ppm, with a maximum of 1500 ppm. The current average TDS concentration of the existing Utila municipal supply wells is 1100 ppm. Based on previous measurements, TDS concentrations have been steadily increased in these wells over recent years.

2.0 SUMMARY OF INITIAL CONCEPTUAL MODEL

Based on previous studies, the initial conceptual model of Utila was developed based on the understanding that infiltrating precipitation could develop a fresh water lens within the coral limestone extending into the underlying volcanic units. This infiltration of precipitation would be less dense than the seawater and create a zone or lens of freshwater. Recharge of precipitation through the surface soils to the coral limestone would flow in a radial pattern from areas of higher elevation on the island (i.e., Stewart's Hill and Pumpkin Hill) displacing seawater and forming a usable potable water resource. The key driving force to maintain the zone of freshwater would be the continual flux of water through the groundwater system from areas of recharge in the hills to areas of discharge along the beaches. The sustainability of using this groundwater would be dependent on the proper management of the groundwater withdrawals to minimize disruption of the freshwater/seawater interface.

3.0 PRELIMINARY INVESTIGATIONS FINDINGS

Brown and Caldwell investigations to date have included a geophysical survey, water quality survey, fracture trace analysis and installation of four monitoring wells.

3.1 Geophysical Survey

Based on review of island hydrogeology, the area for the highest likelihood of identifying a significant fresh water lens was in the region of Stewart's Hill. To evaluate this potential, a large-scale geophysical survey to identify fresh water was performed. The geophysical survey consisted of an electromagnetic (EM) survey to evaluate subsurface resistivity. In general, because the electrical conductivity of fresh water is lower than saline water the reciprocal (resistivity) should be higher in areas where fresh water is present in the shallow aquifer system. However, the EM survey is limited to identifying the presence of fresh water and does quantify the volume of freshwater, or the long-term sustainability. Multiple EM resistivity measurements were made around the Stewart's Hill area and were evaluated to produce resistivity contours. The results of geophysical investigation found a potential fresh water zone in the vicinity of Stewart's Hill and drilling locations were selected to correlate with these findings.

3.2 Well Installation

Five wells (BCUT-1 through BCUT-4) were installed as part of the field investigation. The well locations are all in the vicinity of Stewart's Hill and generally extend in a line starting near the soccer fields and extending northwest towards the landfill. The preliminary results of the well investigation indicate that the shallow lithology is comprised of a low permeability clay dominated soil that overlies a coral limestone. The low permeability volcanic clay, which is visually pervasive on the majority of the island, is believed to limit vertical infiltration of precipitation. Beneath the clay soil is a coral limestone unit that has highly variable permeability depending on the degree of fracturing or solution cavities. These fractures or cavities represent a secondary matrix permeability that is orders of magnitude greater that the primary permeability of the limestone. The degree of fracturing is greater near the contact of the coral limestone and decreases with depth. The first well that was drilled (BCUT-1) encountered a large void within the coral limestone; however, well BCUT-2 encountered competent limestone with low permeability. A third well was installed in the volcanic clay above the coral limestone (BCUT1A), and results from this well indicate that water level elevations are slightly higher than in the coral limestone. Well BCUT-3 encountered a thin volcanic tuff unit between the clay and limestone. Northwest of Stewart's Hill, BCUT-4 encountered approximately 50 feet of volcanic tuff above the limestone. Water level elevations in BCUT-1 through BCUT-4 are calculated to be comparable to mean sea level elevation. Water quality has been evaluated by measuring the electrical conductivity of the well water. The electrical conductivity measurements correlate the concentration of total dissolved solids (TDS) in the aquifer. In general, conductivity measurements collected from the new wells and existing water supply wells show decreasing water quality depth. The evaluation of the lithology, water level elevations and water quality measurements support that amount of precipitation recharge is limited and significant fresh water lens is not likely present in the lower elevation portions of the island.

3.3 Water Quality Survey

Additional surveys of existing wells performed by Brown and Caldwell have found that water quality on the island is generally poor with few wells producing significant quantities of water with estimated TDS concentrations less than 1000ppm. The existing wells producing the higher quality water are likely deriving water from limited perched aquifer zones within the surficial clays above the coral limestone. The average TDS concentration from the existing municipal water supply wells is approximately 1100 ppm. Conductivity measurements from wells in the Pumpkin Hill area found that TDS concentrations ranged 1300 ppm to 9,152 ppm. The lowest TDS values were measured in the Stewart's Hill area and correlated well with the results of the geophysical survey.

3.4 Fracture Trace Analysis

In the upland areas, Brown and Caldwell has performed additional geologic evaluation to assess the potential for identifying areas of where the secondary permeability of the coral limestone aquifer may be enhanced due to an increased fracture density. Using fracture trace analysis, Brown and Caldwell has identified potential areas of increased fractures. Overlying the fracture trace analysis with the results of the geophysical survey indicates that the location for proposed well locations be relocated from the original positions to optimize the possibility of identifying a significant fresh water lens within the fracture network.

Comparison of the results of the fracture trace analysis with the geophysical survey, the well locations (BCUT-3 and BCUT-4) would have the best opportunity to locate a significant fresh water lens within the coral limestone. The combination of upland areas that receive increased precipitation, and high secondary permeability of the coral limestone would promote the development of a freshwater lens. In addition, BCUT-3 and BCUT-4 were located along the same fracture lineament to evaluate the interconnectedness of the fracture network. For a long-term sustainable supply it will be necessary for the limestone fractures to be interconnected to develop a larger water resource.

3.5 Aquifer Testing

Short term and long-term aquifer tests were performed on selected monitoring wells to evaluate the water resource development potential. Very limited tests were performed in Wells BCUT-1 and BCUT-2 because water quality deteriorated very rapidly after the onset of pumping. A bailer test of BCUT-1A indicated that freshwater was present within the surficial clay; however, well yields would likely be less than 5 gallons per minute (gpm). Well yield of BCUT-3 was estimated to be too low for further testing based on bailer drawdown testing. A 48-hour aquifer test was performed on Well BCUT-4. BCUT-4 was selected for the long-term pumping test because drilling information indicated the potential for significant well yield and TDS concentrations were generally below 500 ppm. During the test, the well maintained a flow rate of 40 gpm for 48 hours will and a TDS less than 1000 ppm. Less than 0.5 feet of drawdown was noted in BCUT-4 during pumping, however, TDS concentrations slowly increased during the test.

4.0 SUMMARY OF FINDINGS TO DATE

Preliminary results of the investigation indicate that a significant fresh water lens is not present beneath the island. The absence of a well-developed freshwater lens is believed to be due to the surficial clay soils that inhibit the vertical recharge of precipitation. The results of the BCUT-4 test indicate the presence of fresh water in the coral limestone northwest of Stewart's Hill. However, the extent of this fresh water is likely limited and will not support substantial groundwater development above 20 to 30 gpm. Water quality and well yield potential for the remaining portion of the island has a very low potential for further groundwater development and would likely be unable to support high water quality well yields greater than 5 to 10 gpm.

Traditional water supply systems that utilize large primary pumping centers connected a centralized water distribution network are not expected to be successful on Utila. Installation of high production wells screened in the coral limestone will likely promote continuing seawater migration into shallow aquifers and reduce water quality below potable standards. Future water development on the island of Utila will require an innovative approach to maximize use of precipitation runoff, water conservation, water treatment, growth control and low impact groundwater withdrawals.

5.0 PRELIMINARY WATER SUPPLY RECOMMENDATIONS

Preliminary results of the investigation show that there is potential to expand the current water supply for the island to meet existing water demands and some short-term (1 to 3 years) growth if per capita water use is restricted to current levels. Based on the groundwater investigation results, it is unlikely that long-term water supplies to meet projected growth can be developed from existing groundwater supplies. Increasing water demand will likely need to be addressed with alternative sources of potable water. An essential element in the success of alternative water supply development will be ease of maintenance and low power requirements. Based on the results of the investigation, possible water supply alternatives include the following:

5.1 Rainfall Capture from Roof Top Systems

Additional supplies could be developed during precipitation events by capturing and storing rainfall runoff from roof tops. Use of this water would decrease demand on groundwater supplies and allow recovery of water levels and water quality during the wet seasons. The system would include a roof gutter collection system piped to a cistern. The design challenges associated with the system are bypass of the first flush of rainwater to improve water quality, connection to residential plumbing and evaluating individual, or cluster cistern storage systems. Rainfall distribution may limit effectiveness due to short high intensisty rainfall events

5.2 Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is becoming a popular alternative to provide a cost-effective alternative to constructed water storage structures. In addition, experience with ASR in coastal aquifers has shown that high quality water can be recharged in saline aquifers, stored for later use and withdrawn with an acceptable amount of water quality degradation. In Utila, ASR would involve using shallow wells to recharge precipitation during the rainy season and withdraw the water during dry periods to supplement the overall water supply. During field investigations, it was noted that after precipitation events, certain upland areas would receive runoff from larger drainage areas. In these areas, significant pooling or ponding of water was observed. The ponding is likely the result of the low permeability surficial clays. ASR wells could be constructed in these drainage areas to promote recharge of rainwater beneath the clay to the coral limestone. During dry seasons, the same ASR wells could be pumped to supply potable water. The primary disadvantage to this system is that it is untested. Without pilot scale testing, it will be difficult to quantify water supply potential.

5.3 Desalinization of Water

Desalinization of groundwater is a potential method to develop additional water supplies. The cost of membrane treatment has decreased dramatically over recent years and many coastal communities are finding desalinization a viable alternative. However, desalinization has very high power and maintenance demands that would make large scale development on the island difficult. Desalinization is more likely a viable option for large hotel or resort development.

5.4 Low Flow Gallery Pumping

Large individual pumping wells will cause higher drawdown and greater potential for saltwater intrusion. An alternative to a single high production well, is multiple smaller wells placed over a larger geographic area to disperse the impact of well drawdowns. This may be a viable alternative to develop sustainable water supplies from the surficial clays. The disadvantages to this type of pumping is the need a large land area, high infrastructure requirements in terms of pumps and pipes, and high potential for surface contamination (i.e., septic or runoff) to adversely impact water quality.

APPENDIX B

Geophysical Survey Results

Geophysical Survey Results, Island of Utila, Honduras

Prepared for:

Brown and Caldwell
201 North Civic Drive, Suite 15
Walnut Creek, CA 94596-3864301 USA

Prepared by:

Terra-Dynamics Consulting, Inc.
155 Portage Road
Lewiston, NY 14092 USA
(716) 754-9439

August, 2001

TDC **Terra-Dynamics Consulting, Inc.**
155 Portage Road, Lewiston, NY 14092

August 1, 2001
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Mr. Jeff Nelson
Principal-in-Charge
Brown and Caldwell
201 North Civic Drive, Suite 15
Walnut Creek, CA 94596-3864

Re: EM-34 Electromagnetic Geophysical Survey Results, Island of Utila, Honduras
USAID Geophysical Surveys - Honduras,
Brown and Caldwell Contract 522-C-00.0100287-00

Dear Mr. Nelson:

Introduction

Terra-Dynamics Consulting, Inc. was retained by Brown and Caldwell to provide geophysical support to a USAID groundwater exploration project in Honduras. Staff from Terra-Dynamics were in Honduras between June 13 to 25, 2001. During that time, an electromagnetic survey was initiated to map areas least effected by saline groundwater intrusion on the island of Utila. The following sections describe the purpose of the geophysical survey along with descriptions of the methodologies and survey results.

Purpose and Objectives

The purpose of the study was to provide geophysical support to Brown and Caldwell's USAID project.

The objectives of the geophysical study on Utila were as follows:

1. Review geologic and hydrogeologic information pertaining to the potential for groundwater supply on the island of Utila;

2. Initiate the electromagnetic (EM) geophysical survey on the island of Utila;

3. Train staff from the Honduran engineering firm – Atica on EM mapping techniques; and

4. Provide a letter report on the findings of the EM survey along with recommendations for future candidate groundwater exploration drilling locations.

716-754-9439 **Fax: 716-754-1632** **www.terra-dynamics.com**

Principles of the EM Technique in Groundwater Exploration

Frequency domain EM methods measure the terrain conductivity of the subsurface. A transmitter produces a time varying EM primary field which, on penetrating the ground, induces a voltage which causes a current to flow in a conducting subsurface. The subsurface currents in turn create a secondary EM field which is measured by the receiver. The ratio of the secondary field to the primary field is proportional to the ground currents and therefore the ground (or terrain) conductivity.

In groundwater-based explorations, the soil and rock matrices are assumed to be electrical insulators and electrical flow is therefore, through the groundwater. Major factors affecting electrical or terrain conductivity are (i) the conductivity of the groundwater, (ii) the degree of saturation, (iii) grain size or porosity, (iv) temperature, and (v) the presence of clays with moderate to high cation exchange capacity.

The conductivity or specific conductance of the groundwater is a direct function of the total dissolved content (TDS) of the groundwater. Sea water contains elevated concentrations of TDS and hence exhibits very high specific conductance, generally in excess of 19,000 micomhos/cm. Conversely, potable or fresh groundwater exhibits low specific conductance (generally less than 1,000 micromhos/cm) because of a low TDS content. Based on the assumption that the above referenced factors (ii) through (v) are constant, a terrain conductivity survey near a sea shore will map the zones of saline groundwater intrusion in the subsurface.

Methodology

The Geonics EM-34 Terrain Conductivity Meter was employed on the island of Utila to map contrasts between the saline and the potentially fresh groundwater. Two persons are required to perform a survey. The device consists of a transmitter coil and a receiver coil that can be operated in the horizontal dipole mode (coils perpendicular to the earth' surface) or the vertical dipole mode (coils parallel to the earth's surface). The depth of penetration is a function of the inter-coil spacing and the dipole mode as described below.

The EM-34 device can map the conductivity contrasts in the subsurface to the following varying depths depending on the intercoil spacing and dipole mode:

- 10 meter intercoil spacing, horizontal dipole mode: surface to 7.5 m (25 feet);
  vertical dipole mode: surface to 15 m (50 feet);
- 20 meter intercoil spacing, horizontal dipole mode: surface to 15 m (50 feet);
  vertical dipole mode: surface to 30 m (100 feet);
- 40 meter intercoil spacing, horizontal dipole mode: surface to 30 m (100 feet);
  vertical dipole mode: surface to 60 m (200 feet);

All survey station points were referenced to a GPS waypoint.

Limitations

EM conductivity measurements can be influenced by man-made objects, which can create anomalously high or low responses. Examples of objects that can create interference with EM data acquisition are as follows: (i) electrical transmission lines, (ii) chain link fences, (iii) buried metallic utilities, (iv) electrical generators and (v) reinforced concrete. Based on field observations during data acquisition, the following data points were not utilized when assessing survey results due to the presence of one or more of these objects: Stations Geo33 through Geo36; Geo43; Geo67 through Geo71; Geo81 through Geo83; and Geo86.

Feasibility Survey

The EM-34 was employed in the 10, 20 and 40 m intercoil spacings at a variety of locations across the island at the start of the survey. The rational for this assessment was to evaluate the feasibility of the EM-34 at mapping saline groundwater in the subsurface and to determine the optimum intercoil spacing for surveying purposes. The beach area was first mapped to assess direct impact of salt water. Terrain conductivities in excess of 300 millimhos/m were observed.

The subsurface beneath the soccer field recreational area was also mapped at various intercoil spacings. The soccer field is adjacent to the island's potable communal water supply wells that produce groundwater of acceptable quality. This area produced moderately high terrain conductivity values (Stations Geo2 though 5 – Table 1).

The area of an observed west-to-east trending topographically high ridge was also mapped. This topographic ridge was assumed to act as a groundwater flow divide, directing groundwater in both southerly and northerly directions. This ridge area produced a low conductivity response (Station Geo6 – Table 1). It should be noted that this area is anticipated to have the thickest vadose zone which will also contribute to the low terrain conductivity response.

Further mapping was also performed along the access road to the new airport landing strip (Stations Geo 7 through 10 – Table 1).

Feasibility Survey Assessment
A total of 10 stations were visited during the feasibility assessment and the terrain conductivity of the subsurface was measured in the three intercoil spacings available for the EM-34 device. Based on surface topography, field observations and varying terrain conductivity responses at these diverse locations, it was determined that the 40 m intercoil spacing would provide the optimum depth of exploration for mapping the subsurface on the island of Utlila. Approximate depths of exploration of 60 and 30 m would be provided in the vertical and horizontal dipole modes, respectively.

TDC

Survey Results

Contoured terrain conductivity data for the vertical and horizontal dipole modes are presented on Figures 1 and 2, respectively. The area of low terrain conductivity is depicted within the 35 millimho/m contour interval for the vertical dipole data and the 25 millimho/m contour interval for the horizontal dipole data.

The area exhibiting a low conductivity response is similar on both Figures 1 and 2. The following are the factors (or combination of factors) that most likely contribute to the observed low conductivity response in this area:

1. The aforementioned topographically high ridge that trends in a west-to-east direction across the study area. The enlarged vadose zone associated with the ridge will contribute to lower terrain conductivity observed in this area.
2. A possible zone of low specific conductance groundwater. During data acquisition, it was observed that there was an absence of expressions of surface water runoff (stream beds, gullies, etc.) on both the north and south sides of the ridge and associated down-slope regions. The absence of such features may indicate a zone of more porous soil/rock.
3. A contrast in rock type that may exhibit lower terrain conductivity than the surrounding rock-type.

Recommendations For Candidate Test Well Locations

The areas within, and close to, the 35 millimho/m contour interval and the 25 millimho/m contour interval on Figures 1 and 2, respectively, are recommended for further investigation. Additional data collected for the purpose of the groundwater supply project should also be considered in this evaluation of candidate drilling locations. This could include, but may not be limited to, (i) reconnaissance information of existing groundwater quality and quantity data, (ii) aerial photographs, (iii) geologic maps, (iv) topographic maps, and (v) previously published reports.

We trust this information is sufficient for your present needs. If you have any questions, please do not hesitate to contact the undersigned at 716-754-9439.

Yours truly,

TERRA-DYNAMICS CONSULTING, INC.

David. D. Slaine, P.G.
Hydrogeologist

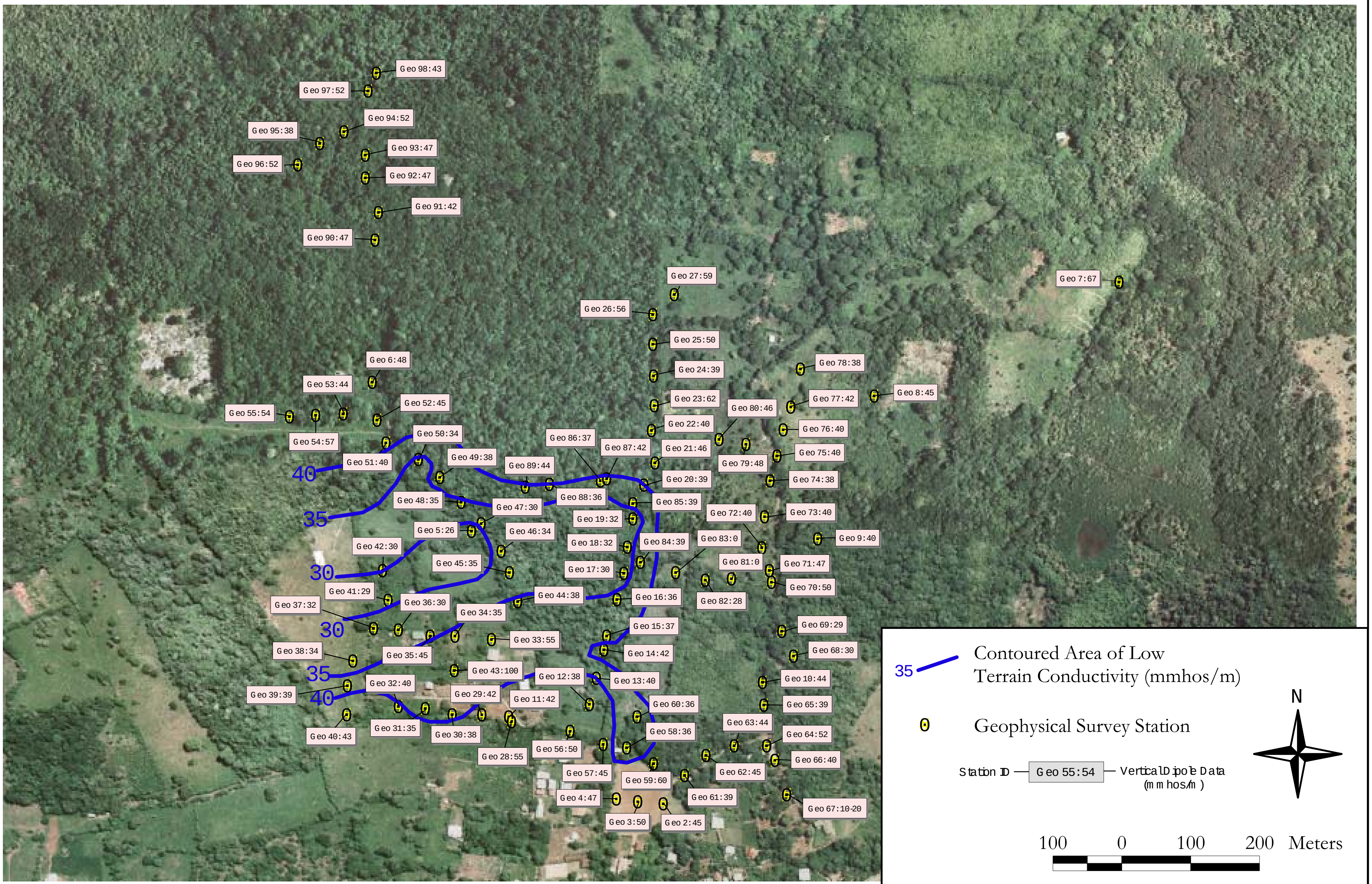
Suumary of EM 34 Geophysical Data Collected on the Bay Island of Utila, Honduras

Table 1 - EM34 DATA

Station No.	Date	UTM Grid	Easting (WGS 84)	Northing (WGS 84)	Vertical Dipole (mmhos/m)	Horizontal Dipole (mmhos/m)
Geo 2	23-Jun-01	16Q	511187	1780131	45	40
Geo 3	23-Jun-01	16Q	511150	1780134	50	39
Geo 4	23-Jun-01	16Q	511119	1780138	47	34
Geo 5	23-Jun-01	16Q	510909	1780526	26	18
Geo 6	23-Jun-01	16Q	510765	1780742	48	30
Geo 7	23-Jun-01	16Q	511848	1780887	67	120
Geo 8	23-Jun-01	16Q	511493	1780722	45	42
Geo 9	23-Jun-01	16Q	511411	1780515	40	38
Geo 10	23-Jun-01	16Q	511331	1780307	44	27
Geo 11	24-Jun-01	16Q	510963	1780257	42	30
Geo 12	24-Jun-01	16Q	511080	1780275	38	30
Geo 13	24-Jun-01	16Q	511090	1780313	40	32
Geo 14	24-Jun-01	16Q	511101	1780354	42	32
Geo 15	24-Jun-01	16Q	511105	1780374	37	30
Geo 16	24-Jun-01	16Q	511120	1780427	36	30
Geo 17	24-Jun-01	16Q	511130	1780465	30	25
Geo 18	24-Jun-01	16Q	511135	1780503	32	22
Geo 19	24-Jun-01	16Q	511143	1780544	32	30
Geo 20	24-Jun-01	16Q	511159	1780593	39	33
Geo 21	24-Jun-01	16Q	511175	1780625	46	40
Geo 22	24-Jun-01	16Q	511170	1780672	40	40
Geo 23	24-Jun-01	16Q	511174	1780708	62	38
Geo 24	24-Jun-01	16Q	511173	1780751	39	32
Geo 25	24-Jun-01	16Q	511172	1780797	50	37
Geo 26	24-Jun-01	16Q	511172	1780840	56	52
Geo 27	24-Jun-01	16Q	511203	1780869	59	38
Geo 28	30-Jun-01	16Q	510967	1780250	55	30
Geo 29	30-Jun-01	16Q	510924	1780260	42	30
Geo 30	30-Jun-01	16Q	510881	1780260	38	26
Geo 31	30-Jun-01	16Q	510842	1780269	35	24
Geo 32	30-Jun-01	16Q	510803	1780272	40	23
Geo 33	30-Jun-01	16Q	510938	1780369	55	110
Geo 34	30-Jun-01	16Q	510885	1780374	35	110
Geo 35	30-Jun-01	16Q	510849	1780374	45	150
Geo 36	30-Jun-01	16Q	510803	1780383	30	11
Geo 37	30-Jun-01	16Q	510767	1780385	32	20
Geo 38	30-Jun-01	16Q	510737	1780338	34	25
Geo 39	30-Jun-01	16Q	510729	1780302	39	29
Geo 40	30-Jun-01	16Q	510728	1780260	43	33
Geo 41	30-Jun-01	16Q	510788	1780426	29	18
Geo 42	30-Jun-01	16Q	510780	1780469	30	15
Geo 43	30-Jun-01	16Q	510884	1780324	100	48
Geo 44	30-Jun-01	16Q	510976	1780424	38	27
Geo 45	30-Jun-01	16Q	510964	1780466	35	23
Geo 46	30-Jun-01	16Q	510952	1780497	34	20
Geo 47	30-Jun-01	16Q	510923	1780537	30	18
Geo 48	30-Jun-01	16Q	510894	1780568	35	16
Geo 49	30-Jun-01	16Q	510863	1780604	38	24
Geo 50	30-Jun-01	16Q	510832	1780630	34	22
Geo 51	30-Jun-01	16Q	510785	1780654	40	27
Geo 52	30-Jun-01	16Q	510772	1780687	45	32
Geo 53	30-Jun-01	16Q	510723	1780696	44	36
Geo 54	30-Jun-01	16Q	510683	1780694	57	40
Geo 55	30-Jun-01	16Q	510645	1780692	54	48
Geo 56	30-Jun-01	16Q	511052	1780236	50	30
Geo 57	30-Jun-01	16Q	511100	1780217	45	30
Geo 58	30-Jun-01	16Q	511134	1780212	36	30
Geo 59	30-Jun-01	16Q	511173	1780189	60	40
Geo 60	30-Jun-01	16Q	511149	1780257	36	32
Geo 61	30-Jun-01	16Q	511218	1780172	39	24
Geo 62	30-Jun-01	16Q	511249	1780201	45	30
Geo 63	30-Jun-01	16Q	511290	1780215	44	28
Geo 64	30-Jun-01	16Q	511337	1780215	52	30
Geo 65	30-Jun-01	16Q	511333	1780274	39	35
Geo 66	30-Jun-01	16Q	511349	1780194	40	230
Geo 67	30-Jun-01	16Q	511366	1780144	10-20	215

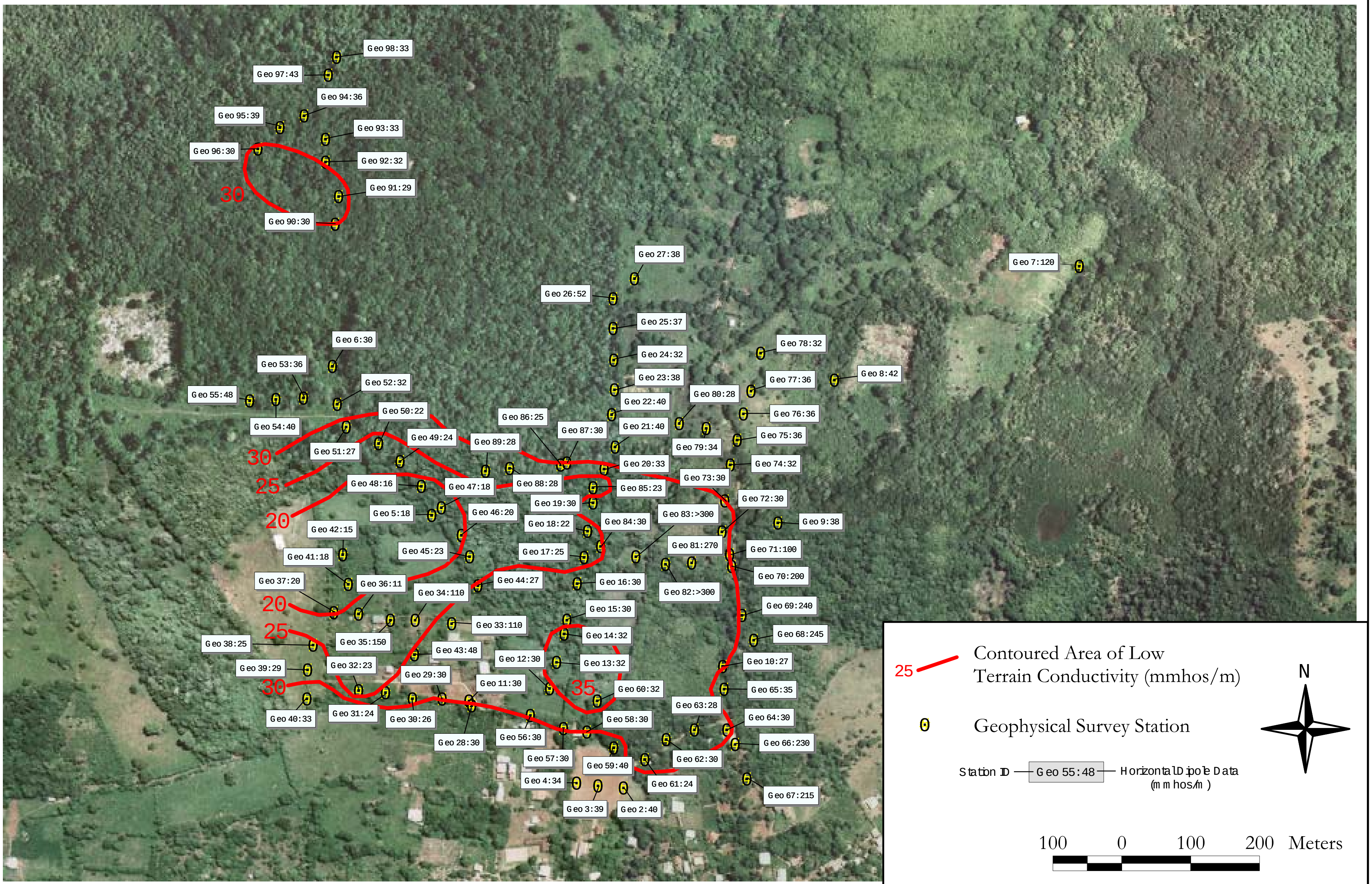
Suumary of EM 34 Geophysical Data Collected on
the Bay Island of Utila, Honduras

Station No.	Date	UTM Grid	Easting (WGS 84)	Northing (WGS 84)	Vertical Dipole (mmhos/m)	Horizontal Dipole (mmhos/m)
Geo 68	30-Jun-01	16Q	511376	1780345	30	245
Geo 69	30-Jun-01	16Q	511359	1780381	29	240
Geo 70	30-Jun-01	16Q	511344	1780452	50	200
Geo 71	30-Jun-01	16Q	511341	1780469	47	100
Geo 72	30-Jun-01	16Q	511330	1780502	40	30
Geo 73	30-Jun-01	16Q	511334	1780547	40	30
Geo 74	30-Jun-01	16Q	511342	1780599	38	32
Geo 75	30-Jun-01	16Q	511352	1780635	40	36
Geo 76	30-Jun-01	16Q	511361	1780673	40	36
Geo 77	30-Jun-01	16Q	511372	1780706	42	36
Geo 78	30-Jun-01	16Q	511386	1780761	38	32
Geo 79	30-Jun-01	16Q	511307	1780652	48	34
Geo 80	30-Jun-01	16Q	511268	1780659	46	28
Geo 81	30-Jun-01	16Q	511286	1780457	0	270
Geo 82	30-Jun-01	16Q	511248	1780455	28	>300
Geo 83	30-Jun-01	16Q	511205	1780466	0	>300
Geo 84	30-Jun-01	16Q	511154	1780481	39	30
Geo 85	30-Jun-01	16Q	511143	1780566	39	23
Geo 86	30-Jun-01	16Q	511096	1780599	37	25
Geo 87	30-Jun-01	16Q	511105	1780602	42	30
Geo 88	30-Jun-01	16Q	511022	1780594	36	28
Geo 89	30-Jun-01	16Q	510987	1780590	44	28
Geo 90	30-Jun-01	16Q	510769	1780948	47	30
Geo 91	30-Jun-01	16Q	510774	1780988	42	29
Geo 92	30-Jun-01	16Q	510755	1781038	47	32
Geo 93	30-Jun-01	16Q	510755	1781071	47	33
Geo 94	30-Jun-01	16Q	510724	1781105	52	36
Geo 95	30-Jun-01	16Q	510689	1781088	38	39
Geo 96	30-Jun-01	16Q	510657	1781057	52	30
Geo 97	30-Jun-01	16Q	510759	1781164	52	43
Geo 98	30-Jun-01	16Q	510771	1781190	43	33



BROWN AND CALDWELL

DATE	SITE	FIGURE
1/17/2002	Utila, Bay Islands, Honduras	1
PROJECT	TITLE	
21143	EM 34 Geophysical Survey Results Vertical Dipole Data	



BROWN AND CALDWELL

DATE	SITE	FIGURE
1/17/2002	Utila, Bay Islands, Honduras	2
PROJECT	TITLE	
21143	EM 34 Geophysical Survey Results Horizontal Dipole Data	

APPENDIX C

Phase II Field Investigation Results

PHASE II FIELD INVESTIGATION RESULTS

Utila, Honduras

June 2002

FIELD INVESTIGATION

From August through October 2001 Brown and Caldwell conducted the Phase II field investigation. Based on the shallow geophysical survey, the Phase II field investigation included the drilling of five test wells (BCUT-1, BCUT-1A, BCUT-2, BCUT-3, and BCUT-4) in the Stuart Hill Study Area to determine the presence, thickness, and quality of fresh water. All boreholes were drilled using reverse circulation air/water/mud rotary methods by Servicios de Perforacion, S. de R. L. de C. Y. (SERPE), of Tegucigalpa, Honduras, C.A. With the exception of well BCUT-1A, all boreholes were completed with PVC surface conductor casing extending through the volcanic clay and are uncased into the underlying coral limestone. Additionally, water quality profiles were completed on each well using a YSI 650 XLS water parameter to determine conductivity (µS/cm), pH, Temperature (ºC), and, dissolved oxygen (mg/L) of the water column. Drill cuttings from each borehole were collected every 5 feet and were described lithologically every 10 feet. A summary of the well construction specifications is presented in Table C-1. A copy of the lithologic logs and well schematic diagrams are presented in Figures C-1 to C-5.

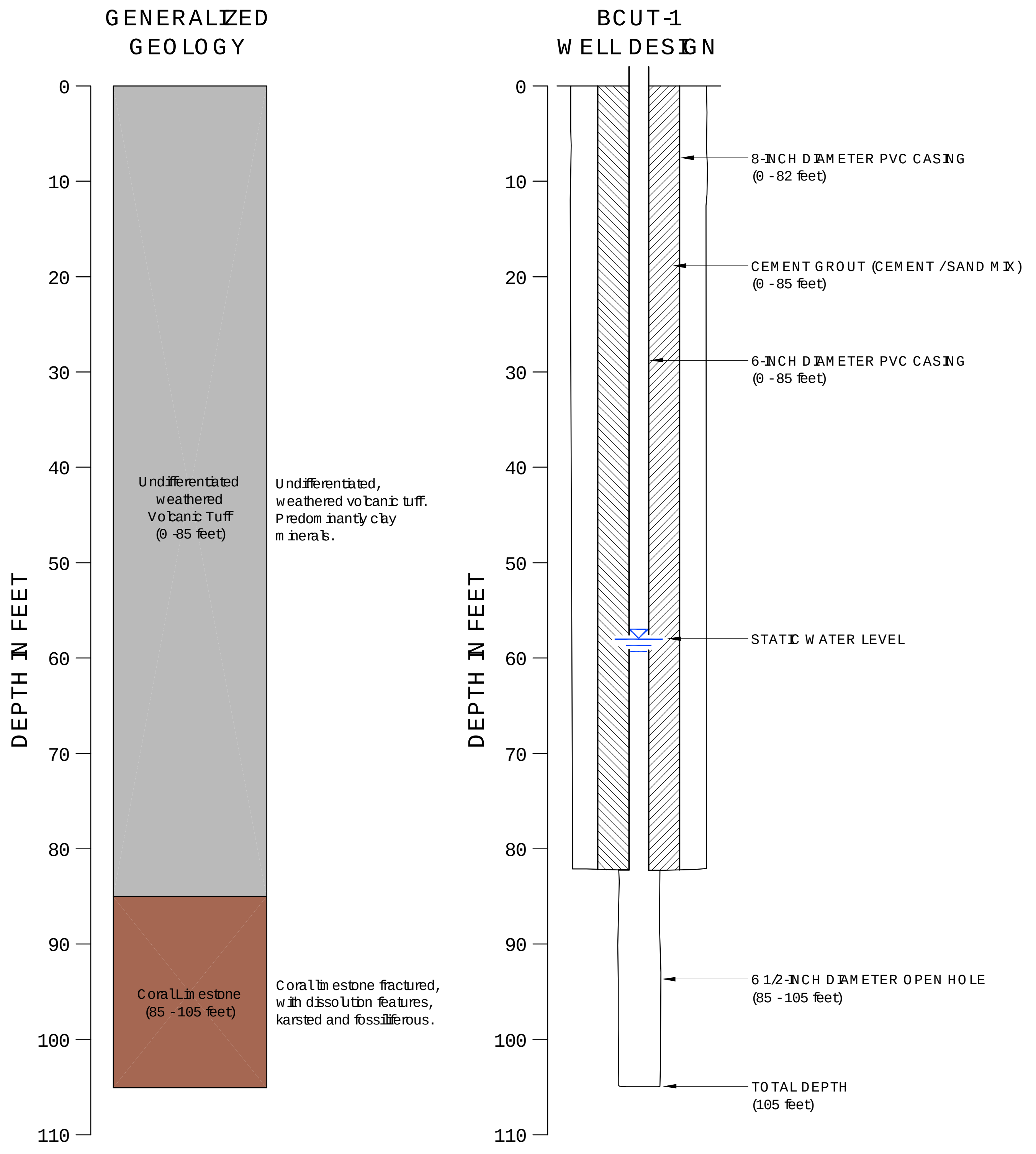
Groundwater levels in the Stuart Hill study area are approximately equivalent to sea level and range from 26 meters below grade in the vicinity of BCUT-4, to 16 meters below grade in the lower lying areas in the vicinity of BCUT-1 and 1A. Throughout the field investigation, water parameter measurements were collected at various times to determine tidal influences to groundwater levels and conductivity values. A summary of the depth to water versus conductivity measurements are presented in Figures C-6 through C-10 and Table C-2. Depth to water versus time measurements are presented in Figures C-11 to C-15.

An additional hydrogeologic evaluation survey conducted on hand-dug wells and springs outside the East Harbor Village area indicated relatively poor groundwater, with few wells indicated conductivity measurements less than 1,000 µS/cm. Generally, the hand dug wells are four to five feet square with varying depth, cased with wood two to six feet through the volcanic clay, and extend, uncased, two to three feet into the under lying coral limestone. Most of the wells visited are currently being used for livestock watering and agricultural irrigation. Four springs were identified, with conductivity measurements ranging from 1,200 to >5000 µS/cm. A summary of the water parameter measurements is presented in Table C-3.

Table C-1. Summary of Well Construction Specifications

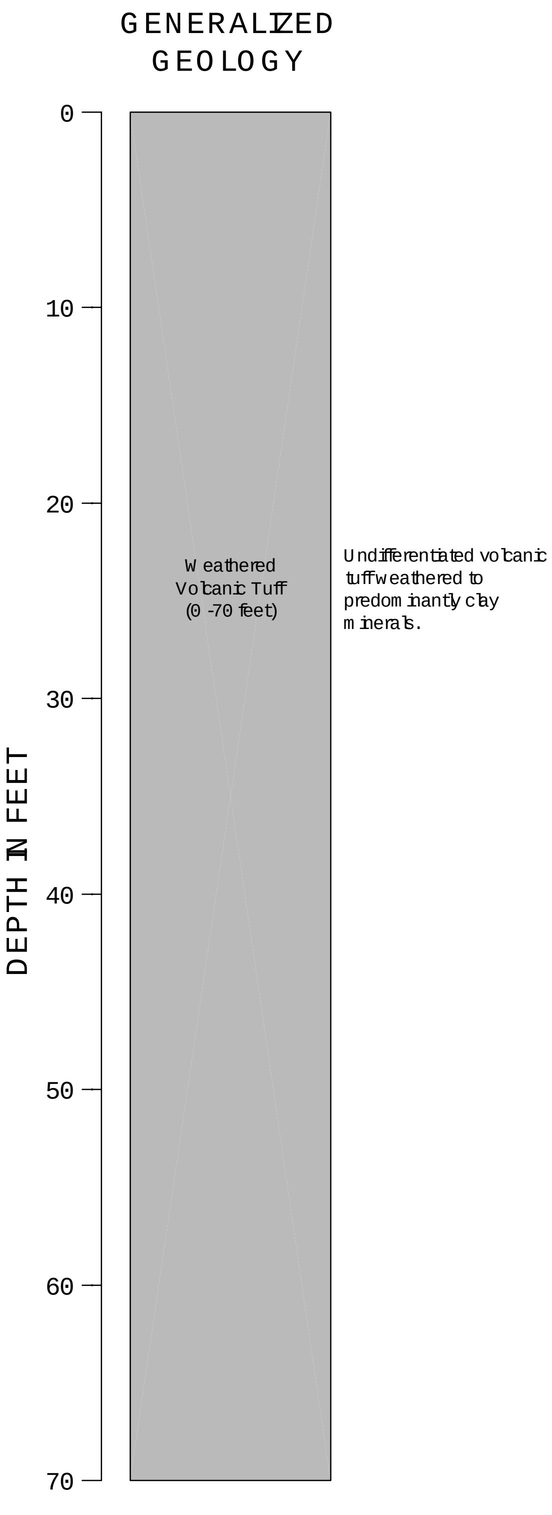
Well ID	Total Depth (m)	Well Dia (cm)	Blank Casing Interval (m)	Uncased Interval (m)	DTW (m)	Surface Elevation (m)	Date Completed
BCUT-1	32.0	15.24	0-26	26-32	17.84	17.30	9-3-01
BCUT-1A	21.3	7.62	0-1.5**	1.5-21.3**	16.75	17.30	9-20-01
BCUT-2	26.8	15.24	0-7.6	10.6-26.8	24.21	23.90	9-10-01
BCUT-3	36.3	15.24	0-10.6	10.6-36.3	26.64	26.14	10-4-01
BCUT-4	36.3	15.24	0-16.7	16.7-36.3	26.72	25.3	9-28-01

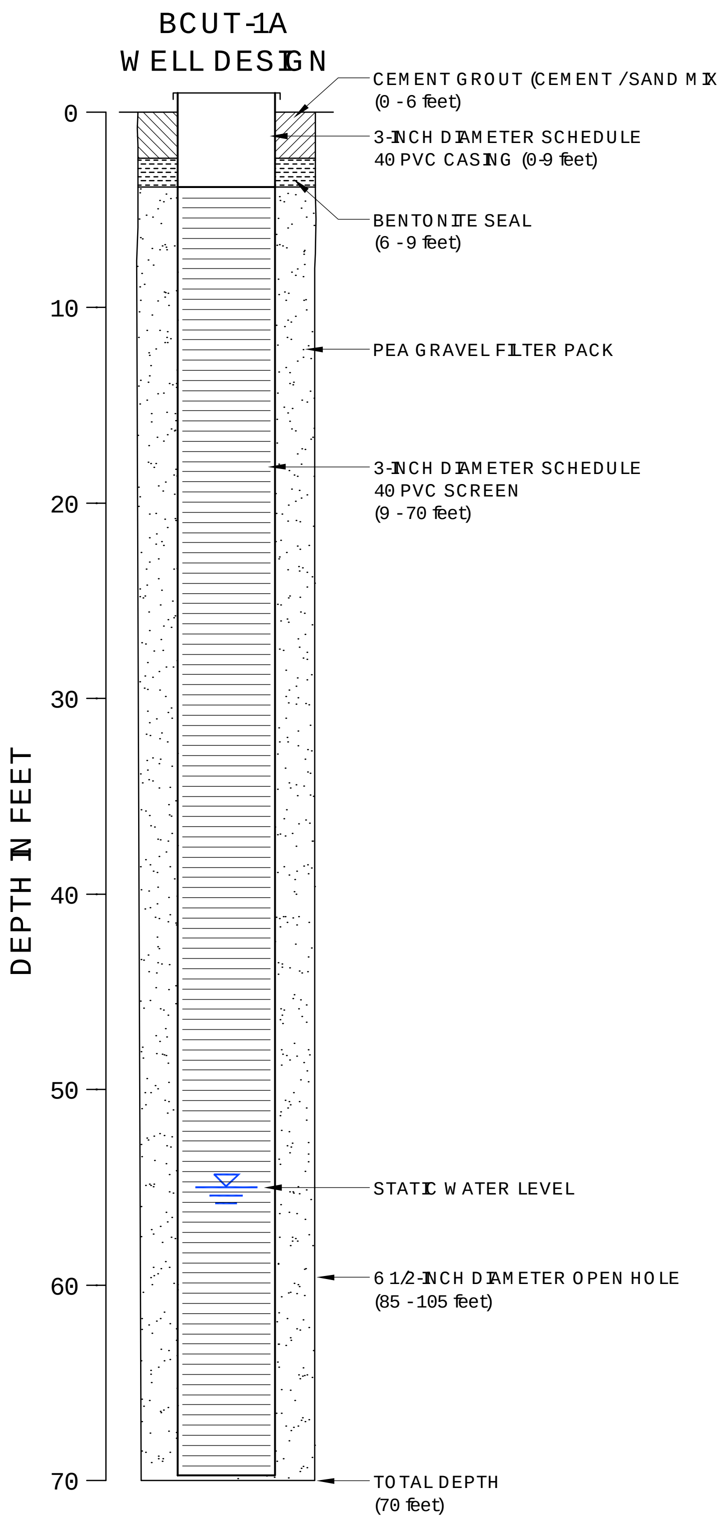
** = 3-inch PVC casing and screen, 0.020" slot



BROWN AND CALDWELL

Figure C-1
TEST WELL BCUT-1
ISLA DE UTILA, HONDURAS





BROWN AND CALDWELL

Figure C-2

TEST WELL BCUT-1A

ISLA DE UTILA, HONDURAS

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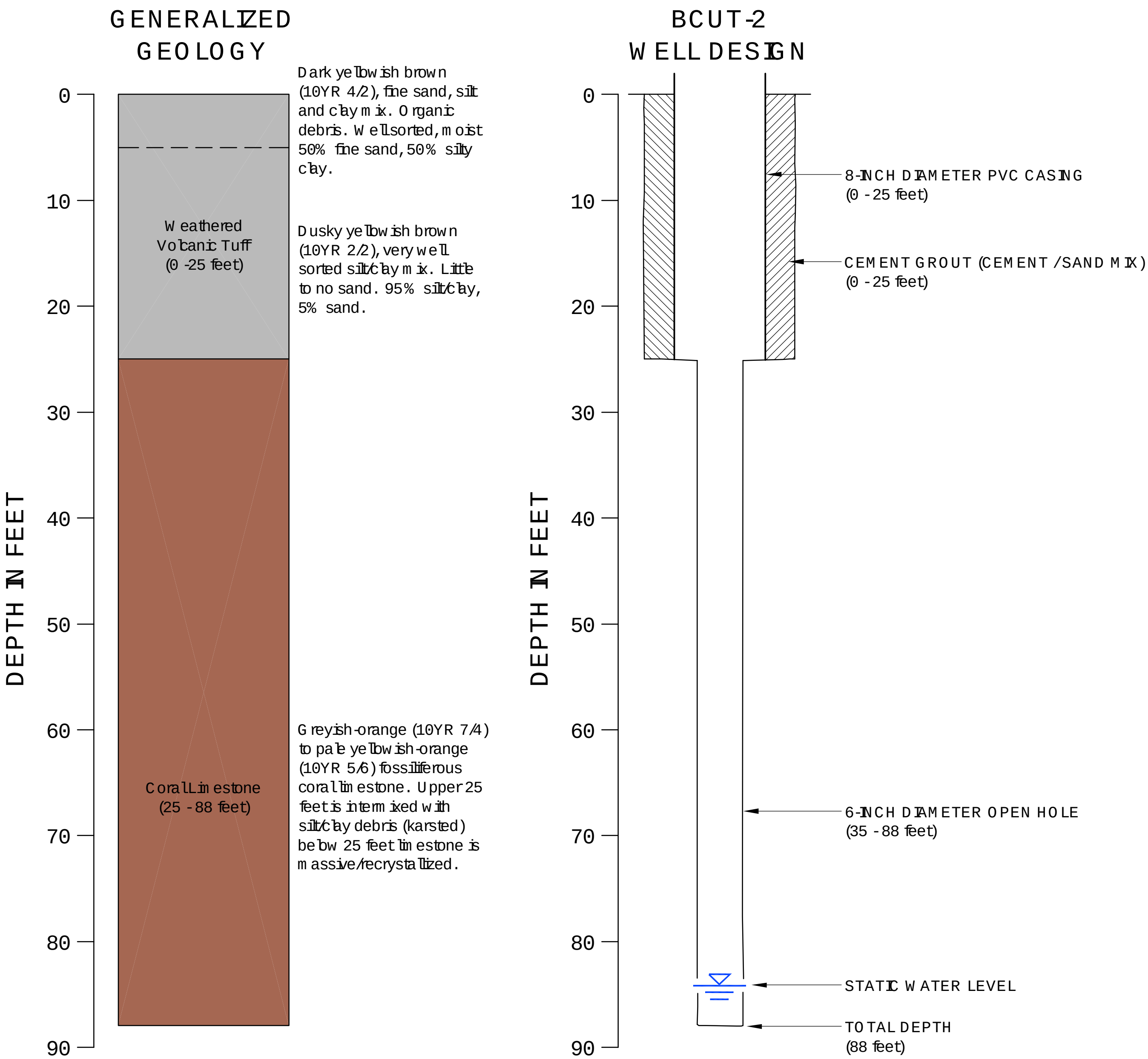
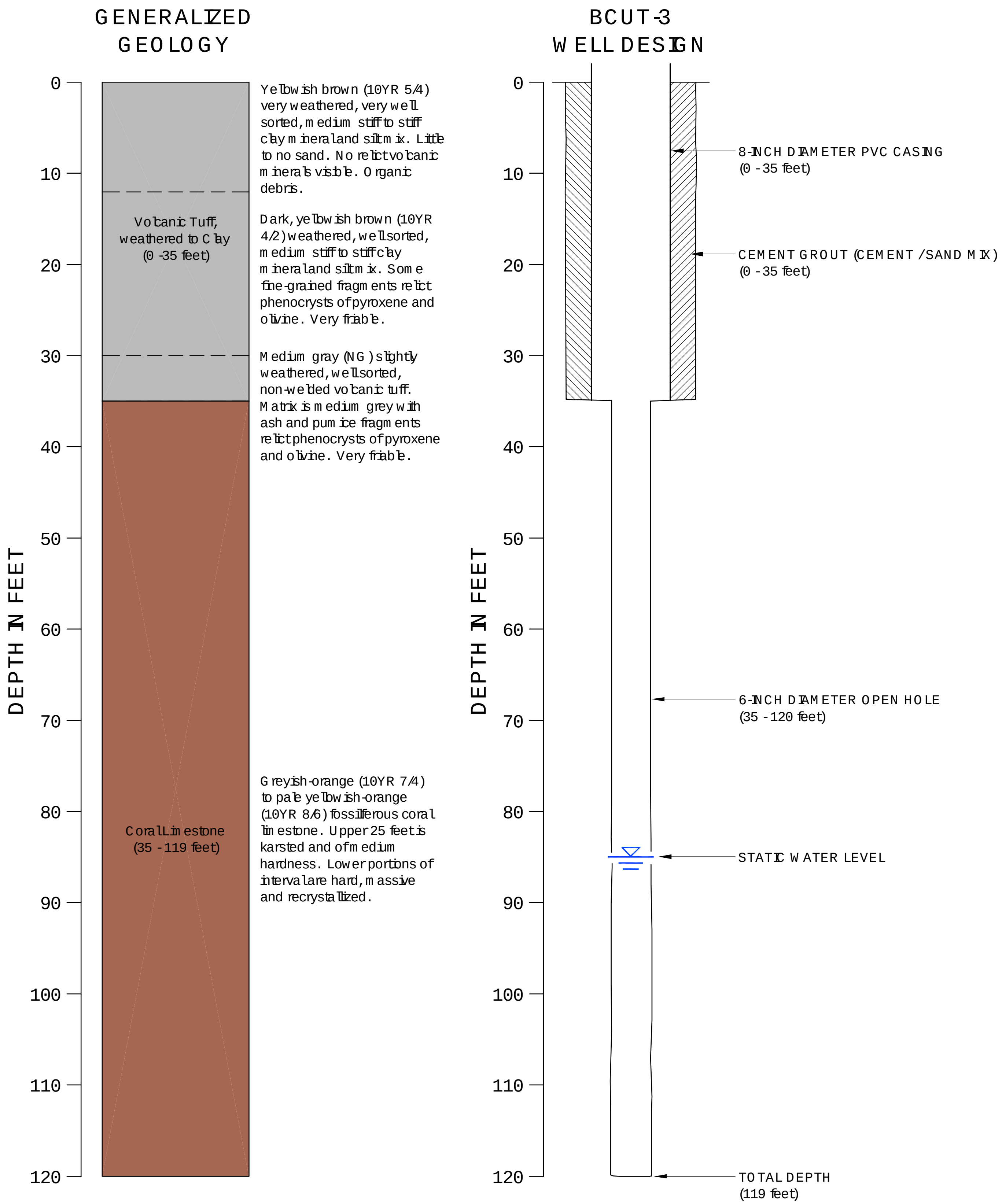


BROWN AND CALDWELL

Figure C-3

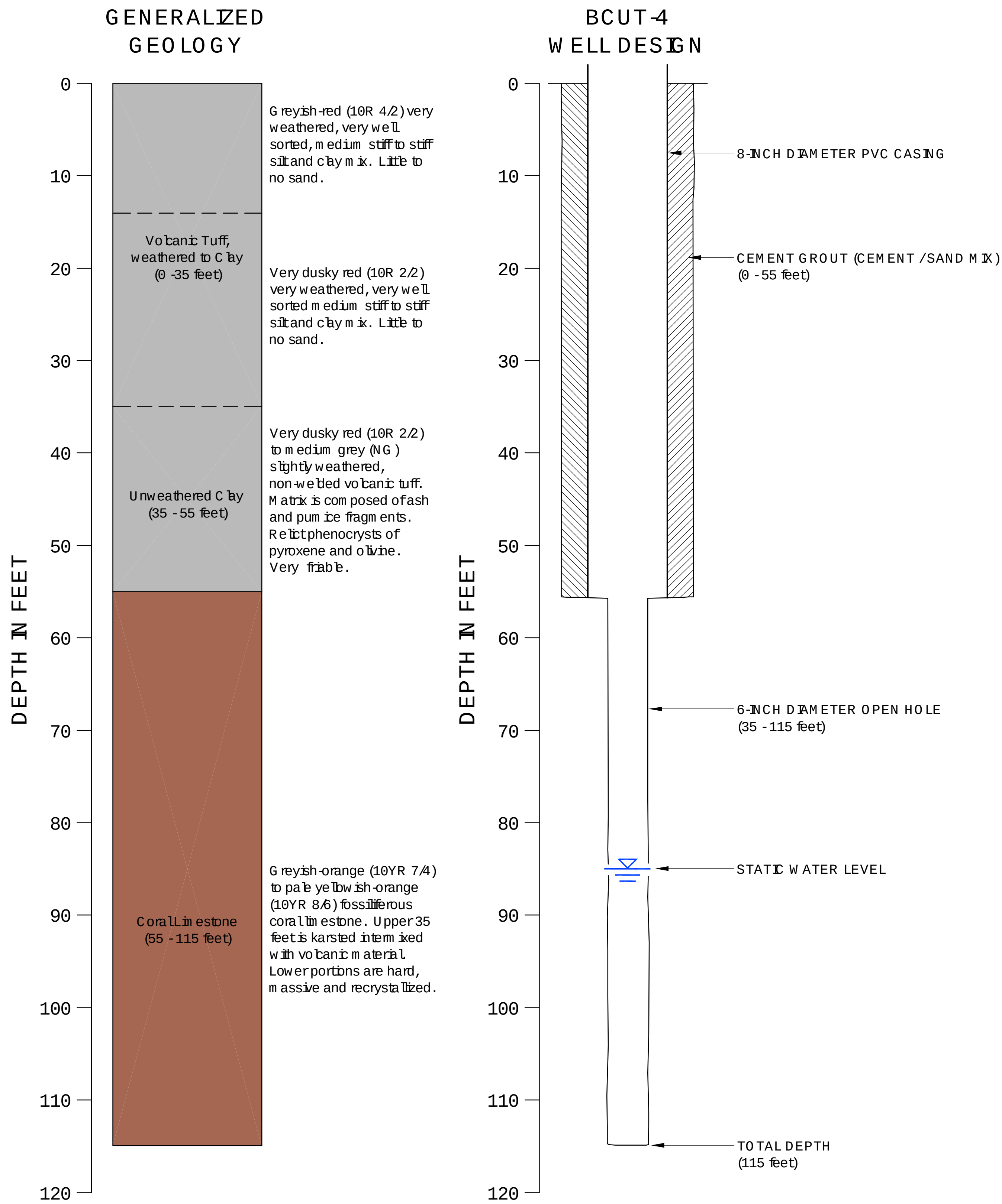
TEST WELL BCUT-2

ISLA DE UTILA, HONDURAS



BROWN AND CALDWELL

Figure C-4
TEST WELL BCUT-3
ISLA DE UTILA, HONDURAS



BROWN AND CALDWELL

Figure C-5

TEST WELL BCUT-4

ISLA DE UTILA, HONDURAS

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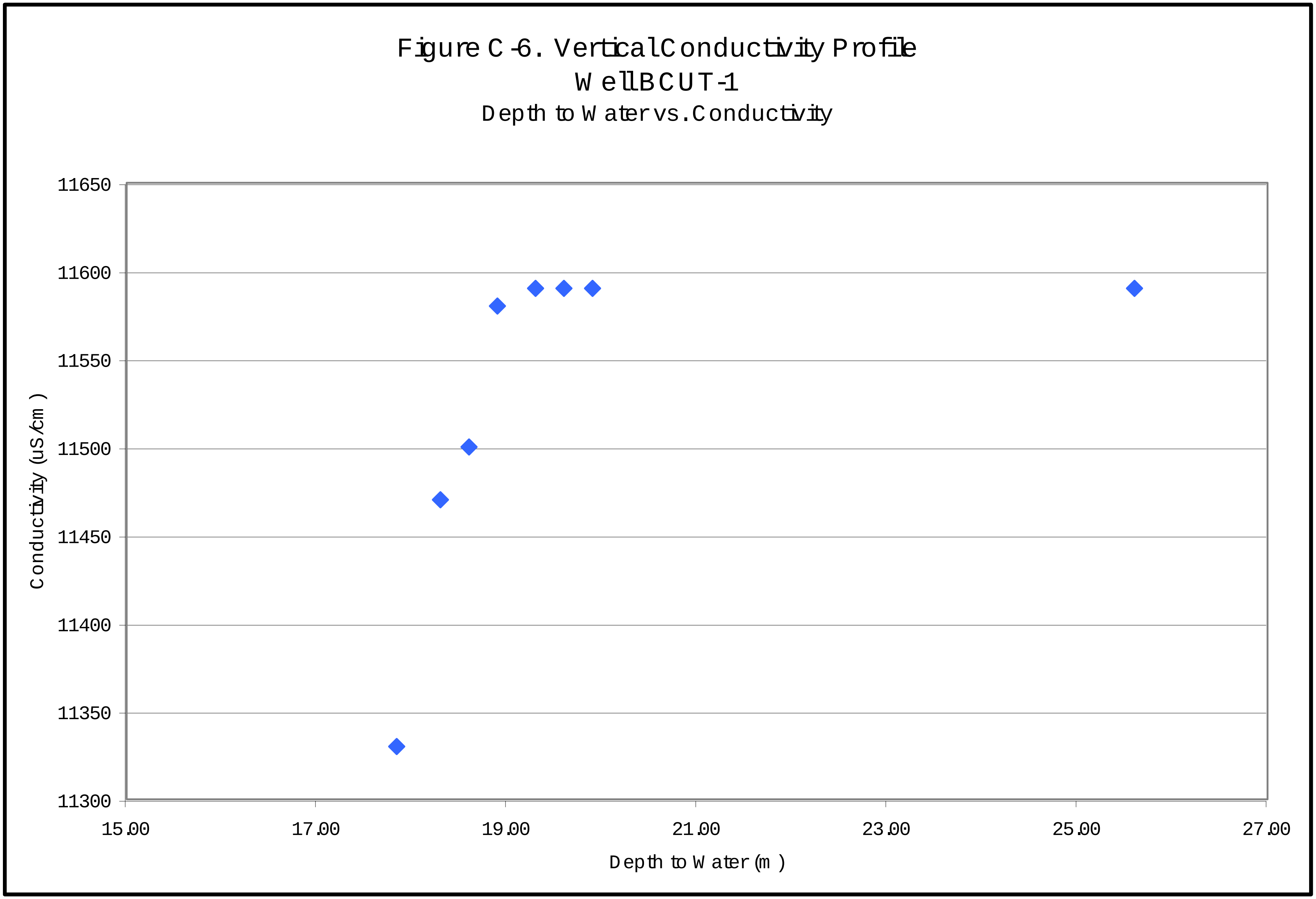


Figure C-6. Vertical Conductivity Profile
Well BCUT-1
Depth to Water vs. Conductivity
Conductivity (uS/cm)
11650
11600
11550
11500
11450
11400
11350
11300
15.00
17.00
19.00
21.00
23.00
25.00
27.00
Depth to Water (m)

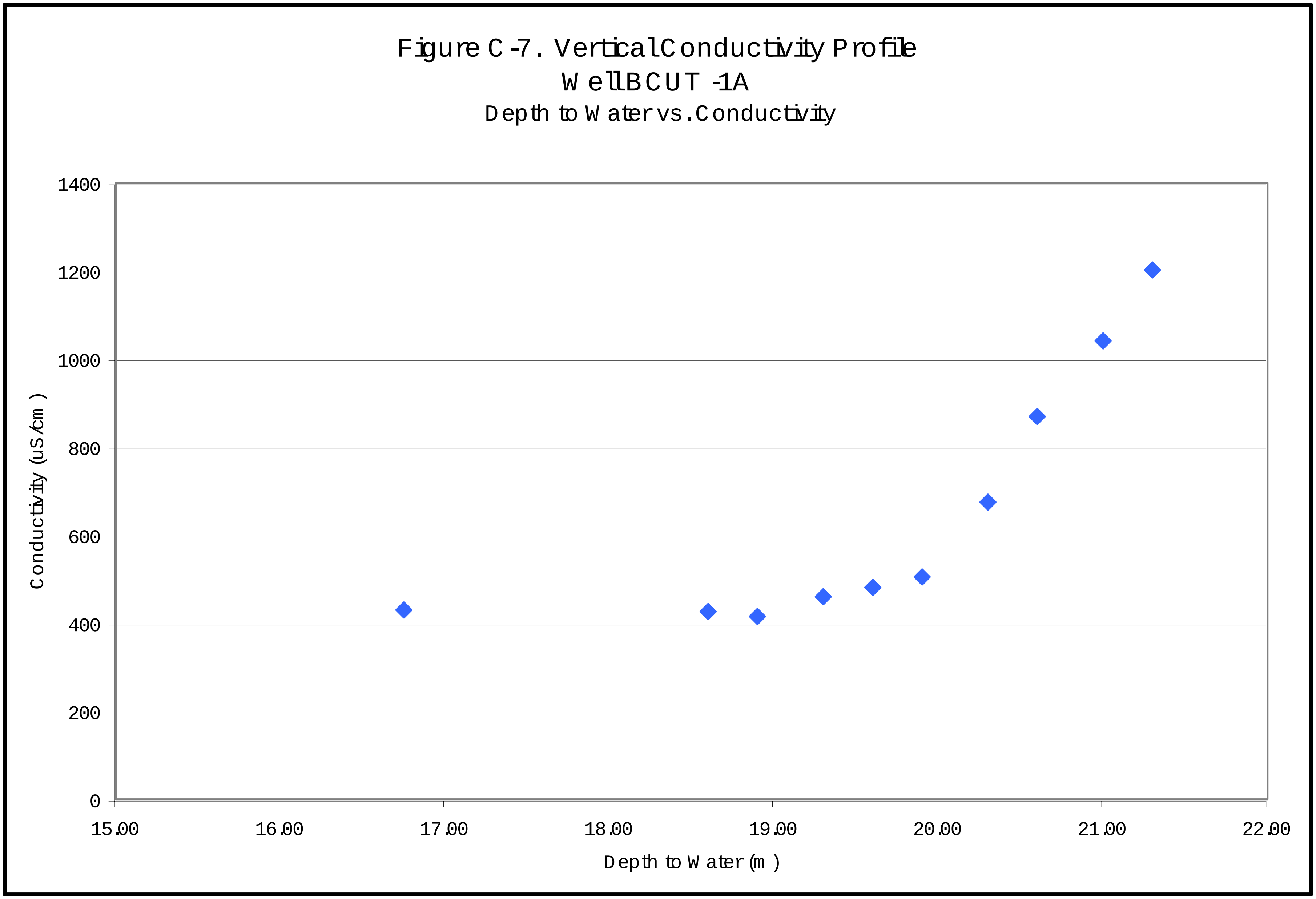


Figure C-7. Vertical Conductivity Profile
Well BCUT-1A
Depth to Water vs. Conductivity
Conductivity (uS/cm)
1400
1200
1000
800
600
400
200
0
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
Depth to Water (m)

Figure C-8. Vertical Conductivity Profile
Well BCUT-2
Depth to Water vs. Conductivity

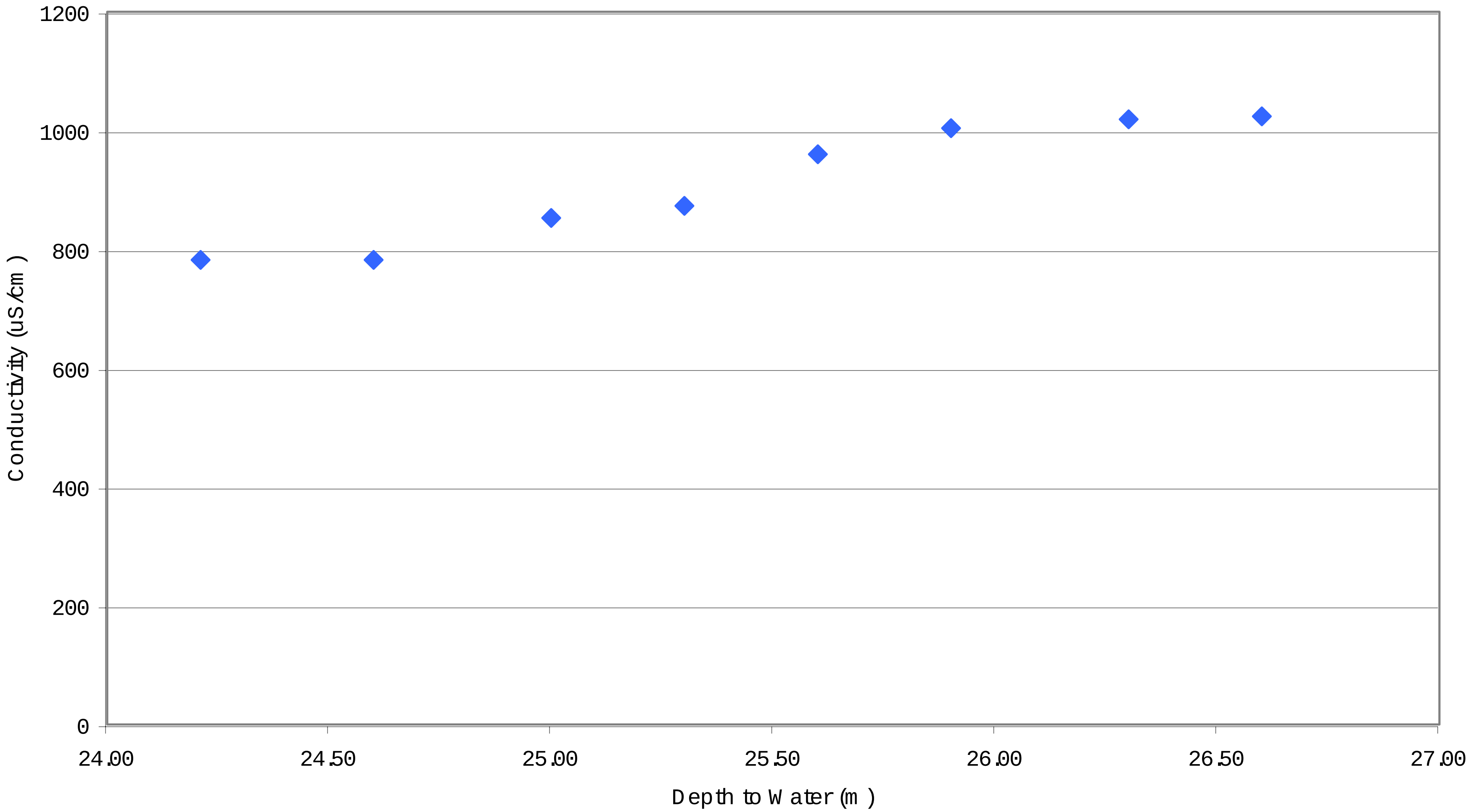
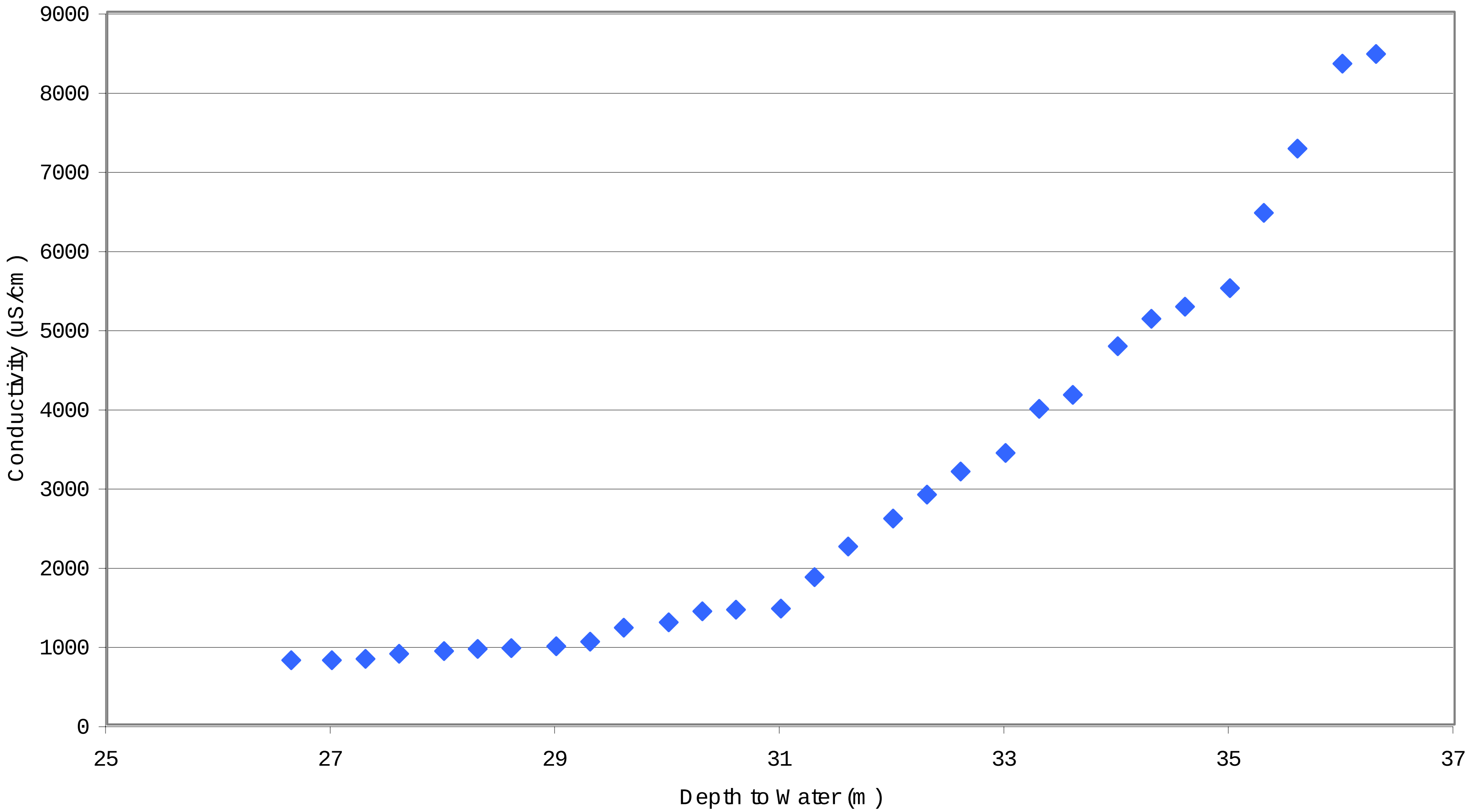


Figure C-9. Vertical Conductivity Profile
Well BCUT-3
Depth to Water vs. Conductivity



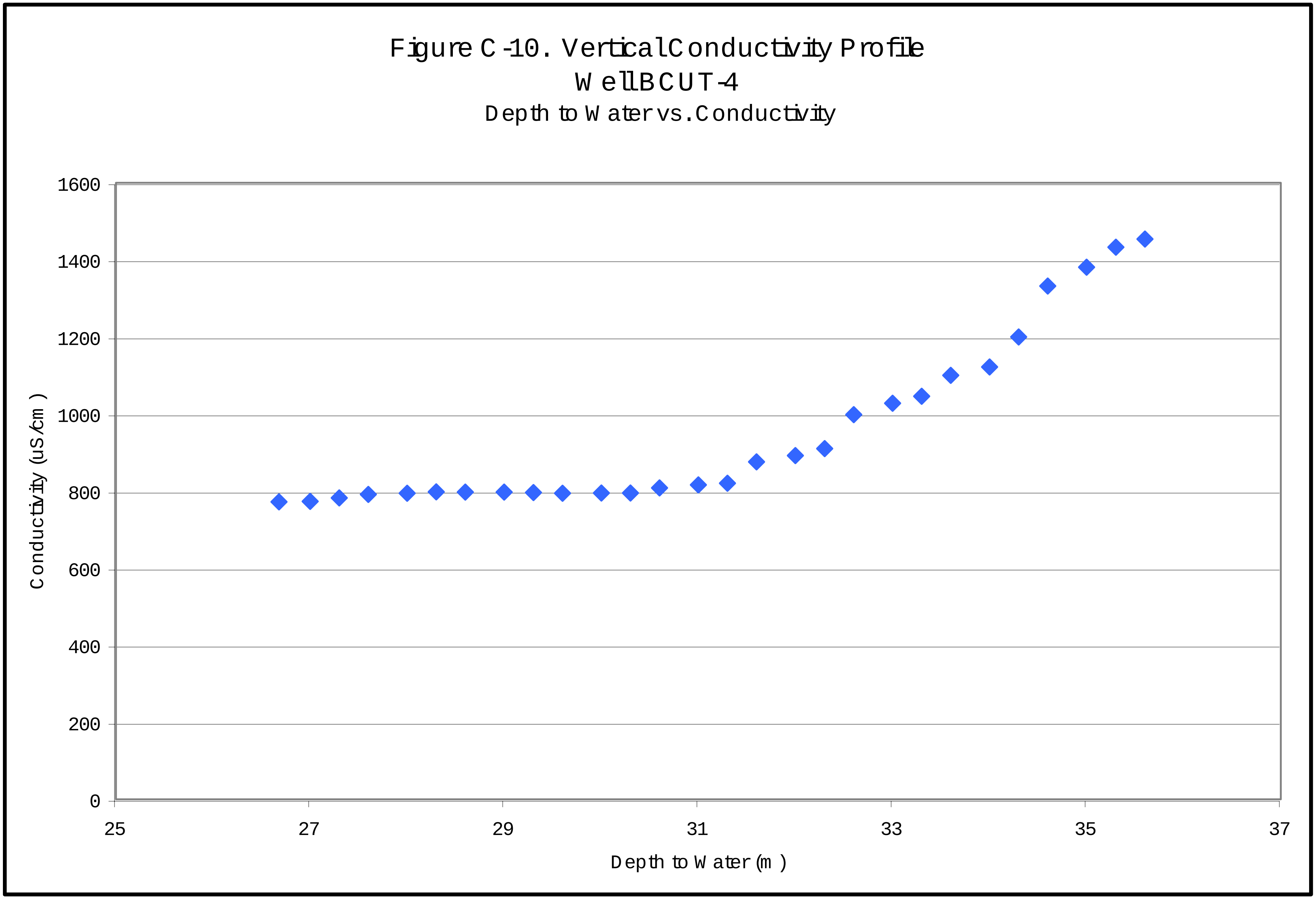


Figure C-10. Vertical Conductivity Profile
Well BCUT-4
Depth to Water vs. Conductivity
Conductivity (uS/cm)
0
200
400
600
800
1000
1200
1400
1600
25
27
29
31
33
35
37
Depth to Water (m)

Table C-2. Conductivity Profiles
YSI 650 XLS Water Parameter Meter

BCUT-1
DTW = 17.84 m (TOC)
Total Depth = 25.6 m (TOC)
September 29, 2001

Time (hr)	Depth (m)	Cond (uS/cm)	T (C)	pH	DO (mg/l)
1320	17.84	11330	27.69	6.80	2.58
1322	18.30	11470	27.64	6.67	1.39
1324	18.60	11500	27.57	6.58	1.09
1326	18.90	11580	27.54	6.56	1.10
1329	19.30	11590	27.54	6.56	1.22
1331	19.60	11590	27.52	6.55	1.40
1333	19.90	11590	27.52	6.55	1.64
1335	25.60	11590	27.52	6.55	1.92

BCUT-1A
DTW = 16.75 m (TOC)
Total Depth = 21.3 m (TOC)
September 29, 2001

Time (hr)	Depth (m)	Cond (uS/cm)	T (C)	pH	DO (mg/l)
1248	16.75	430	27.70	6.77	1.80
1250	18.60	426	27.70	6.51	1.20
1252	18.90	415	27.63	6.38	1.09
1255	19.30	460	27.57	6.31	0.98
1258	19.60	481	27.55	6.30	0.88
1303	19.90	5.5	27.56	6.31	1.03
1307	20.30	675	27.56	6.28	1.03
1311	20.60	869	27.55	6.18	1.13
1315	21.00	1041	27.54	6.23	1.18
1320	21.30	1202	27.53	6.33	1.24

BCUT-2
DTW= 24.21 m (TOC)
Total Depth = 26.6 m (TOC)
September 29, 2001

Time (hr)	Depth (m)	Cond (uS/cm)	T (C)	pH	DO (mg/l)
1200	24.21	782	27.48	6.91	4.01
1202	24.60	782	27.37	6.87	3.92
1205	25.00	853	27.33	6.86	3.43
1208	25.30	873	27.31	6.86	3.43
1210	25.60	960	27.29	6.88	2.78
1213	25.90	1004	27.29	6.90	2.28
1215	26.30	1019	27.29	6.91	2.10
1218	26.60	1024	27.28	6.92	1.98

Table C-2. Conductivity Profiles
YSI 650 XLS Water Parameter Meter
(Continued)

BCUT-3
DTW = 26.64 m (TOC)
Total Depth = 36.3 m (TOC)
October 5, 2001

Time (hr)	Depth (m)	Cond (uS/cm)	T (C)	pH	DO (mg/l)
1340	26.64	810	27.39	6.96	5.07
1343	27.00	811	27.46	6.89	5.08
1346	27.30	829	27.43	6.83	5.05
1350	27.60	894	27.44	6.83	5.15
1355	28.00	926	27.44	6.83	5.18
1358	28.30	953	27.44	6.83	5.28
1402	28.60	964	27.44	6.83	5.30
1405	29.00	988	27.44	6.84	5.41
1408	29.30	1047	27.44	6.84	5.54
1412	29.60	1223	27.43	6.84	6.00
1415	30.00	1290	27.43	6.84	6.10
1420	30.30	1430	27.42	6.85	6.56
1425	30.60	1451	27.41	6.87	6.64
1428	31.00	1462	27.41	6.87	6.64
1430	31.30	1862	27.39	6.87	7.52
1433	31.60	2249	27.38	6.89	8.19
1436	32.00	2600	27.37	6.89	8.49
1439	32.30	2901	27.36	6.90	8.64
1442	32.60	3193	27.35	6.90	8.96
1445	33.00	3429	27.35	6.91	9.12
1448	33.30	3986	27.34	6.90	9.05
1452	33.60	4163	27.33	6.92	8.86
1455	34.00	4776	27.32	6.93	8.76
1458	34.30	5122	27.32	6.93	8.83
1500	34.60	5276	27.31	6.94	8.85
1505	35.00	5510	27.31	6.95	8.88
1508	35.30	6460	27.30	6.92	8.46
1510	35.60	7273	27.30	6.94	8.92
1515	36.00	8346	27.30	6.92	8.69
1520	36.30	8467	27.30	6.93	8.58

Table C-2. Conductivity Profiles
YSI 650 XLS Water Parameter Meter
(Continued)

BCUT-4
DTW = 26.68 m (TOC)
Total Depth = 35.6 m (TOC)
October 5, 2001

Time (hr)	Depth (m)	Cond (uS/cm)	T (C)	pH	DO (mg/l)
1209	26.68	772	27.57	6.91	6.94
1212	27.00	773	27.41	6.89	6.82
1215	27.30	782	27.37	6.88	6.83
1220	27.60	791	27.33	6.88	6.84
1225	28.00	794	27.32	6.89	6.76
1230	28.30	798	27.32	6.89	6.70
1233	28.60	797	27.30	6.90	6.52
1236	29.00	797	27.30	6.91	6.34
1240	29.30	796	27.29	6.92	6.22
1245	29.60	794	27.29	6.92	6.22
1248	30.00	795	27.29	6.93	6.14
1255	30.30	795	27.29	6.93	6.14
1300	30.60	808	27.28	6.93	6.08
1303	31.00	816	27.28	6.93	6.12
1306	31.30	820	27.28	6.94	6.24
1309	31.60	876	27.26	6.93	6.24
1311	32.00	892	27.26	6.93	6.00
1313	32.30	910	27.26	6.94	6.32
1316	32.60	998	27.25	6.97	6.80
1319	33.00	1028	27.25	7.00	7.04
1322	33.30	1046	27.27	7.02	7.13
1326	33.60	1100	27.24	7.03	7.25
1328	34.00	1122	27.24	7.04	7.19
1331	34.30	1200	27.23	7.02	6.99
1333	34.60	1332	27.22	7.02	6.86
1336	35.00	1381	27.22	7.02	6.89
1339	35.30	1433	27.22	7.02	6.68
1342	35.60	1454	27.22	7.02	6.63

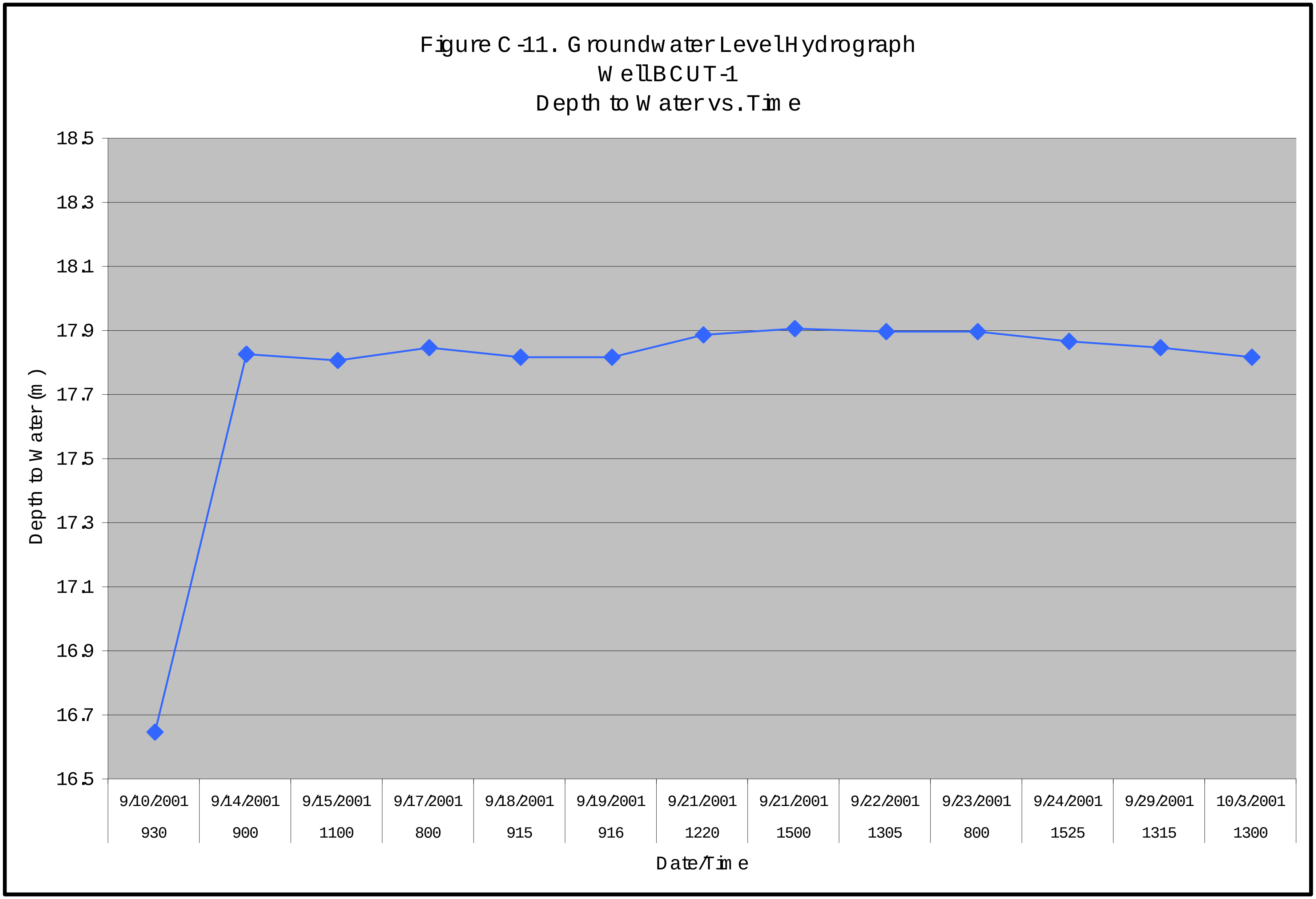


Figure C-11. Groundwater Level Hydrograph
Well BCUT-1
Depth to Water vs. Time
Depth to Water (m)
18.5
18.3
18.1
17.9
17.7
17.5
17.3
17.1
16.9
16.7
16.5
9/10/2001 930
9/14/2001 900
9/15/2001 1100
9/17/2001 800
9/18/2001 915
9/19/2001 916
9/21/2001 1220
9/21/2001 1500
9/22/2001 1305
9/23/2001 800
9/24/2001 1525
9/29/2001 1315
10/3/2001 1300
Date/Time

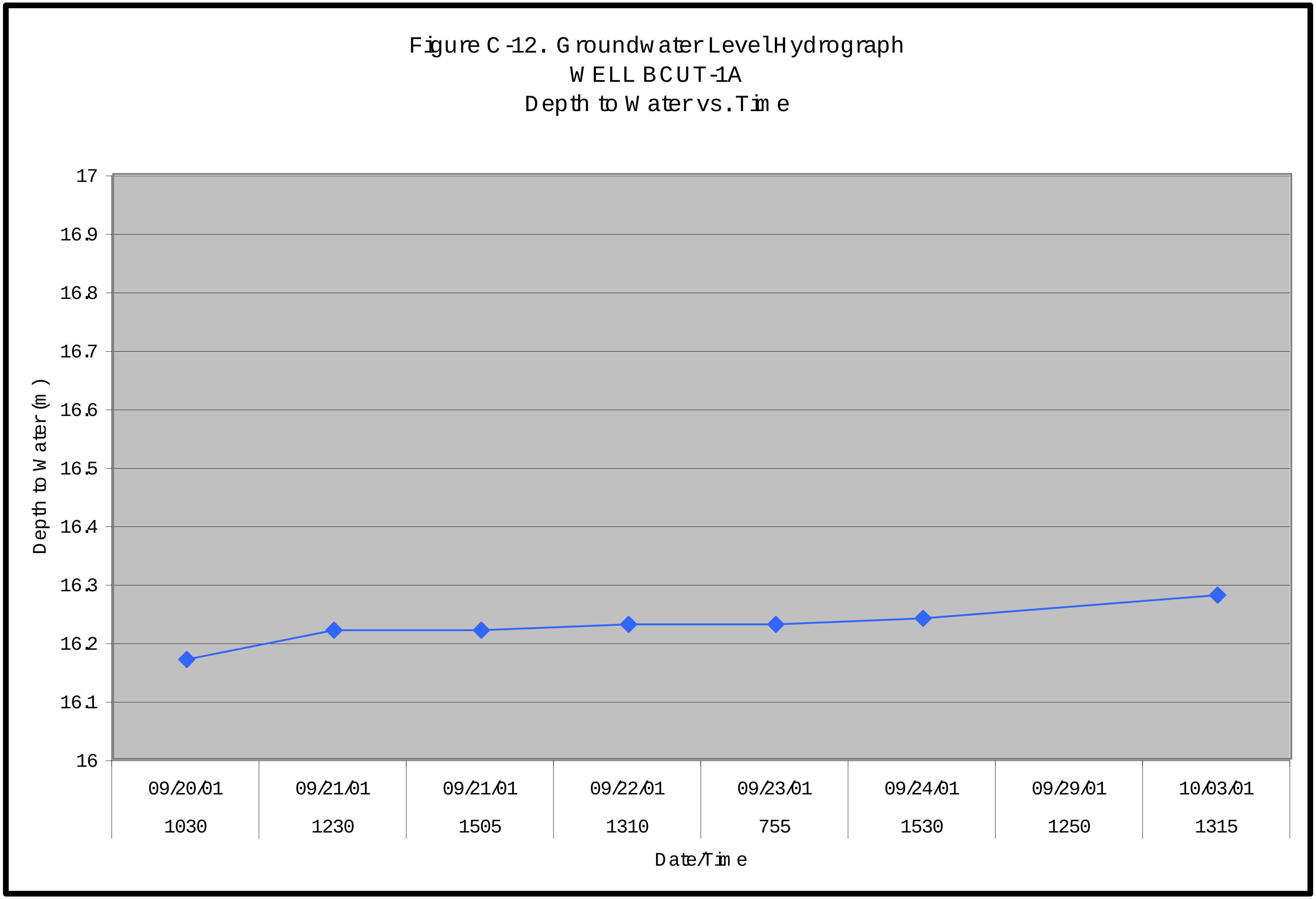
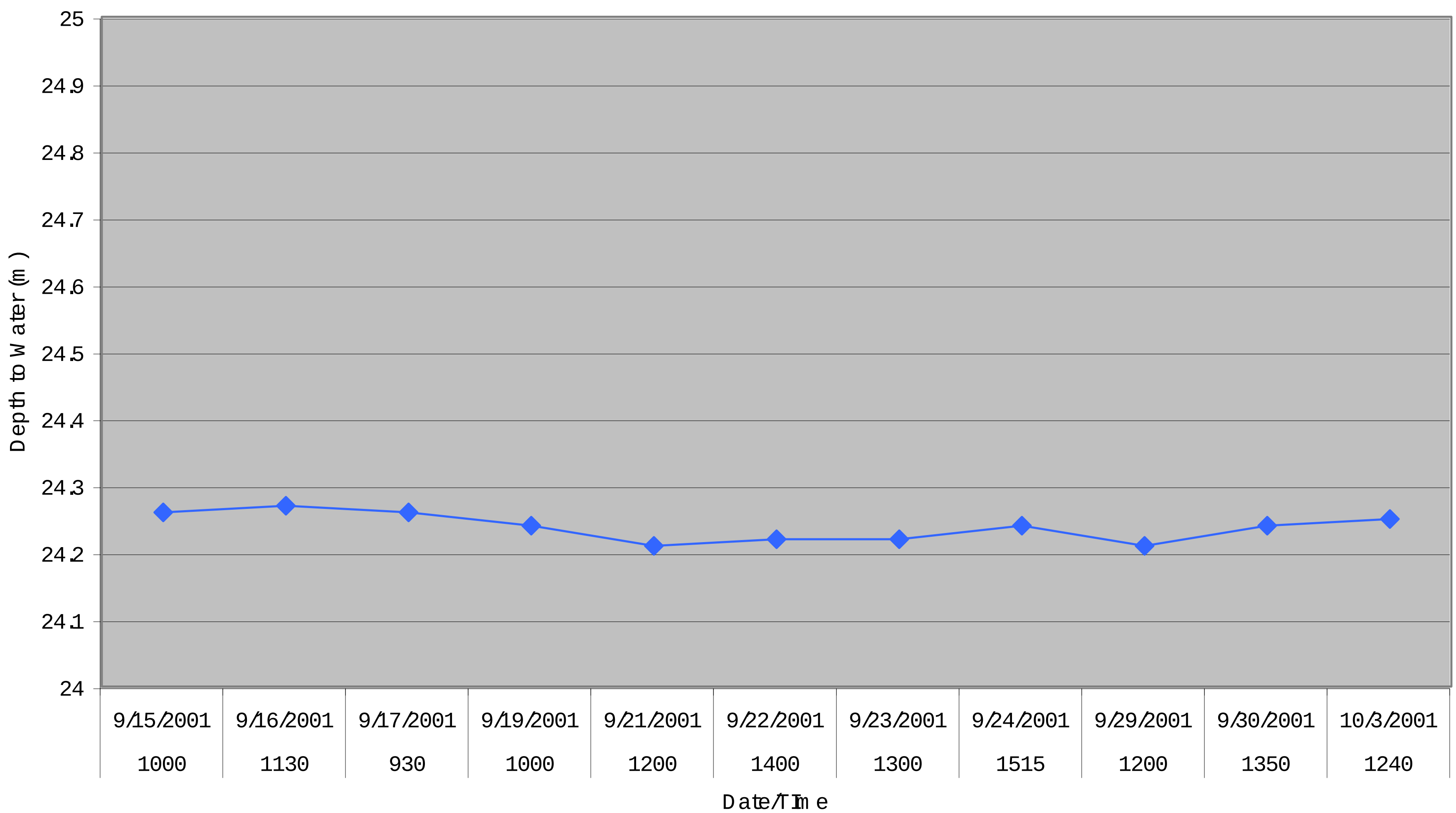


Figure C-12. Groundwater Level Hydrograph
WELL BCUT-1A
Depth to Water vs. Time
Depth to Water (m)
17
16.9
16.8
16.7
16.6
16.5
16.4
16.3
16.2
16.1
16
09/20/01 1030
09/21/01 1230
09/21/01 1505
09/22/01 1310
09/23/01 755
09/24/01 1530
09/29/01 1250
10/03/01 1315
Date/Time

Figure C-13. Groundwater Level Hydrograph
WELL BCUT-2
Depth to Water vs. Time



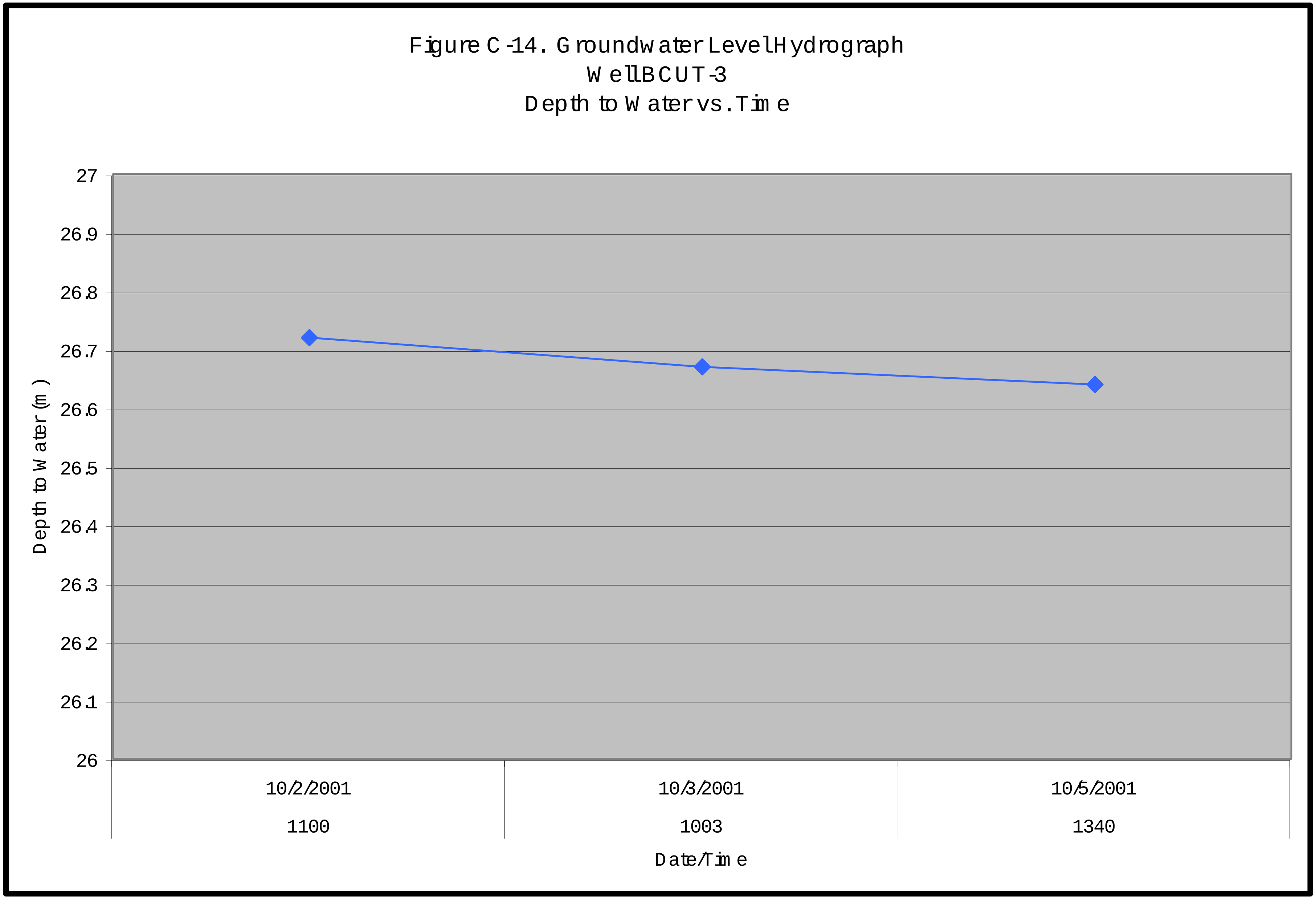


Figure C-14. Groundwater Level Hydrograph
Well BCUT-3
Depth to Water vs. Time
27
26.9
26.8
26.7
26.6
26.5
26.4
26.3
26.2
26.1
26
Depth to Water (m)
10/2/2001
1100
10/3/2001
1003
10/5/2001
1340
Date/Time

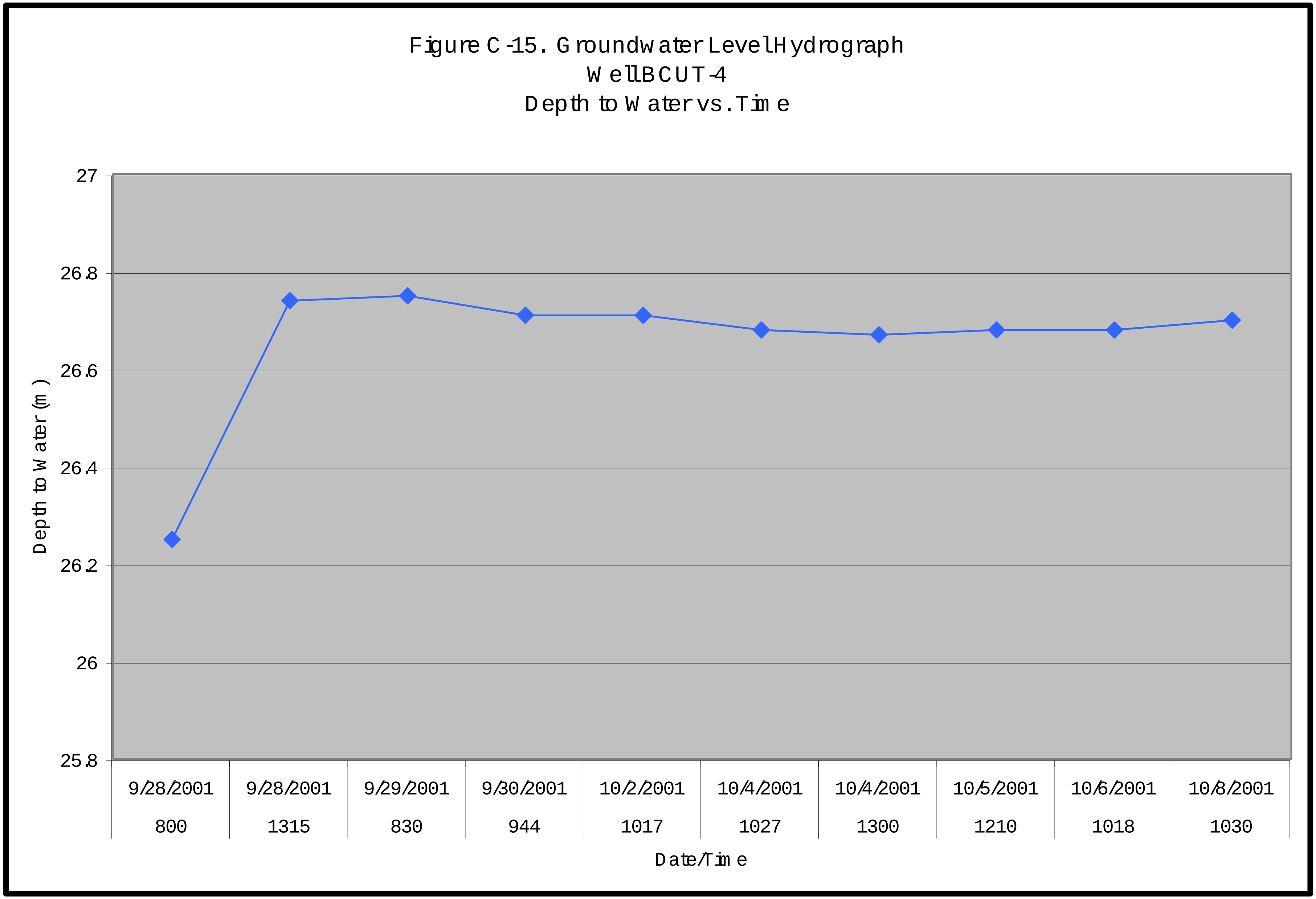


Figure C-15. Groundwater Level Hydrograph
Well BCUT-4
Depth to Water vs. Time
27
26.8
26.6
26.4
26.2
26
25.8
Depth to Water (m)
9/28/2001 800
9/28/2001 1315
9/29/2001 830
9/30/2001 944
10/2/2001 1017
10/4/2001 1027
10/4/2001 1300
10/5/2001 1210
10/6/2001 1018
10/8/2001 1030
Date/Time

Table C-3. Springs and Hand Dug Wells, Water Level Measurements and Water Quality

Well ID	Well Depth (m)	Stick up (m)	DTW (m)	T (C)	DO (mg/l)	pH	Cond	Northing (m)	Easting (m)	Date
BCUT-1	32	0.6	17.84	27.69	2.58	6.8	11330	1780290	511096	10/9/2001
BCUT-1A	21.3	0.51	16.75	27.7	1.8	6.77	430	1780446	510900	10/9/2001
BCUT-2	26.8	0.7	24.21	27.36	3.38	6.9	799	1780428	510980	10/9/2001
BCUT-3	35	0.38	26.64	27.39	5.07	6.96	810	1780446	510900	10/9/2001
BCUT-4	36.3	0.49	26.72	27.57	6.94	6.91	772	1780550	510783	10/9/2001
Jerico #1	3.18	0.55	2.54	28.44	2.08	7.31	2907	1780706	510386	9/6/2001
Jerico #2	2.44	2.03	0.62	28.33	3.2	7.28	1244	1780658	510837	9/6/2001
Jerico #3	2.3	0.25	1.95	29.07	1.62	6.74	671	1780835	510417	9/6/2001
P Morgan #1	2.18	0.51	1.31	29.91	1.66	7.14	1135	1780806	511799	9/6/2001
P Morgan #2	2.5	0.57	1.55	28.46	2.47	7.14	779	1780476	511708	9/7/2001
H. Bodden #1	3.38	0.69	1.88	28.69	1.11	7.08	1680	1780478	511711	9/7/2001
G. Gabriel #1	3.05	0.54	2.61	29.85	4.01	7.13	1846	1780673	512355	9/7/2001
G. Gabriel #2	2.46	0.6	2.46	29.34	1.25	7.45	1383	1780692	512371	9/9/2001
I Bush #1	2.35	0.3	1.79	30.85	1.83	7.23	3163	1780586	512242	9/9/2001
I Bush #2	1.64	0.32	1.18	31.77	2.37	7.27	7208	1780603	512193	9/9/2001
I Bushg #3	1.75	0.43	1.3	29.05	1.34	7.35	3511	1780706	512231	9/9/2001
J. Gabriel #1	2.6	0.77	1.87	28.57	1.73	7.15	5674	1780702	511224	9/9/2001
A Banks #1	3.44	0.63	3.33	28.87	3.72	7.73	2594	1780496	512177	9/10/2001
P Morgan #3	4.04	0.72	3.67	28.89	1.17	7.29	2108	1781538	512407	9/10/2001
J. Jackson #1	2.77	0	2	28.83	3.87	7.16	14340	1781569	512406	9/10/2001
J. Jackson #2	3.28	0.71	1.99	28.53	2.67	7.13	2747	1781906	512848	9/10/2001
J. Jackson #3	4.57	0.77	3.83	28.89	2.56	7.41	3567	1782347	512887	9/10/2001
Well in Bush	6.1	0.64	5.51	NM	NM	NM	>5000	1780817	511698	9/2/2001
Loomis #1	2.05	0.65	1.04	NM	NM	NM	1000	1781944	512135	9/2/2001
Loomis #2	1.02	0.24	0.42	NM	NM	NM	1400	1781486	511641	9/2/2001
Loomis #3	1.8	0.64	1.16	NM	NM	NM	1600	1781482	511592	9/3/2001
I Bodden #1	2.32	0.8	2.02	NM	NM	NM	750	1780285	511100	9/3/2001
R. Celaya #1	1.3	1.13	0.53	NM	NM	NM	4350	1779811	510307	9/3/2001
R. Celaya #2	2.38	0.3	1.75	NM	NM	NM	1100	1779841	510313	9/3/2001
R. Celaya #3	3.43	0.41	2.43	NM	NM	NM	3400	1779878	510350	9/3/2001
Middle Path Spr	NA	NA	NA	28.17	4.21	7.15	4164	1780008	509924	9/4/2001
L. Jackson Spr	NA	NA	NA	NM	NM	NM	1200	1779811	510479	9/4/2001
P. Flyn Spr	NA	NA	NA	30.57	3.49	7.4	2416	1780977	511857	9/4/2001
Byran's Cave	NA	NA	NA	NM	NM	NM	>5000	1780828	512817	9/4/2001

Well BCUT-1

Well BCUT-1 was drilled using air and water to a total depth of 32 meters (105 ft) below grade and completed within karsted limestone. Above the limestone, volcanic clay was encountered from the surface to approximately 26 meters (85 ft) below grade and sealed. During drilling, two voids were reported at 26.8 meters (88ft) and 30 meters (98.5 ft) within the karsted zone followed by significant sloughing and caving of clay up to a depth of 85 feet below grade. As such, to prevent further caving, 6-inch PVC casing was installed to provide an additional seal. However, even with the added seal, clay and silt continued to cave from the Karsted zone up to 25.6 meters (84 ft). Because water parameter measurements indicated a nonstratified water column within the well and conductivity measurements ranged from 11,330 to 11,590 μS/cm, no additional remedies were applied to prevent clay and silt from caving. A summary of the conductivity measurements is presented in Figure C-6 and Table C-2.

Well BCUT-1A

To determine the difference in hydraulic head between the volcanic clay and the coral limestone, well BCUT-1A was drilled to a total depth of 21.3 m below grade using and completely within volcanic clay. The well was installed using 3-inch PVC casing screened from 1.5 to 21.3 meters below grade. Blank casing was installed from the surface to 1.5 meters. From September through October, depth to water measurements averaged 16.72 meters below grade. Water parameter measurements indicated a stratified, but thin, fresh water lens with conductivity measurements that ranged from 430 to 1202 μS/cm. A summary of the conductivity measurements is presented in Figure C-7 and Table C-2.

Well BCUT-2

Well BCUT-2 was drilled using air, water, and mud to a total depth of 26.8 meters below grade and completely within coral limestone. Volcanic clay was encountered from the surface to approximately 7.6 meters below grade and sealed off using 8-inch PVC casing. From 7.6 to approximately 18.3 meters, drillers observations reported soft rock with rapid drill rates. Below 18.3 meters, the limestone became very hard and massive with slower drilling rates. From September through October, depth to water measurements averaged 24.2 meters below grade within impermeable limestone. Water parameter measurements indicated a stratified very thin fresh water lens with conductivity measurements that ranged from 782 to 1024 μS/cm. A summary of the conductivity measurements is presented in Figure C-8 and Table C-2.

Well BCUT-3

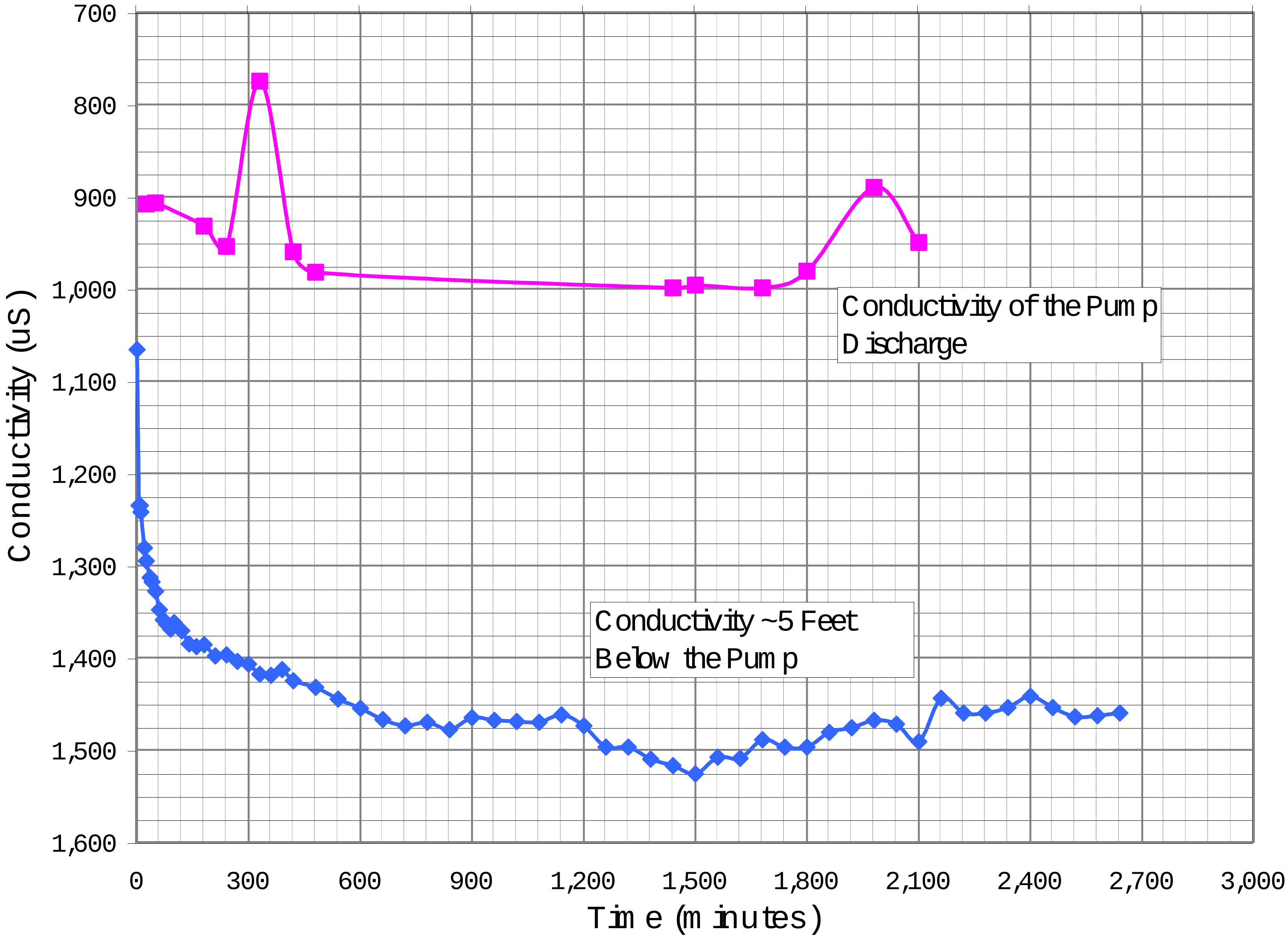
Exploratory well BCUT-3 was drilled into the coral limestone, using air and water, to a total depth of 35.0 m (115ft) below grade. Volcanic clay s was encountered from the surface to approximately 10.6 meters below grade. Basal portions 9.1 to 10.6 m (30 to 35 feet) below grade the volcanics became less weathered to a nonwelded tuff. From 10.6 (30 ft) to 22.8 meters (75 ft) below grade, drilling rates were moderate in semihard limestone. Below 22.8 m (75 ft), drilling rates were slower. From September through October, depth to water measurements averaged 26.14 meters below grade within massive limestone. After 24 hours, water parameter measurements indicated a stratified water column with a very thin fresh water lens. Conductivity measurements ranged from 810 to 8467 μS/cm (Figure C-9 and Table C-2).

Well BCUT-4

Exploratory well BCUT-4 was drilled using air and water to a total depth of 36.3 meters below grade. Volcanic clay s was encountered from the surface to approximately 16.7-m (55-ft) meters below grade. Basal portions became less weathered to a nonwelded tuff. From 16.7m (55 ft) to 27.4 m (90 ft) below grade, drilling rates were moderate in relatively soft limestone. Below 27.4 meters (90 ft), drilling rates were slower. From September through October, depth to water measurements averaged 25.3 meters below grade within soft limestone. After 24 hours, water parameter measurements indicated a stratified water column with a relatively thin fresh water lens. Conductivity measurements ranged from 772 to 1454 μS/cm. A summary of the conductivity measurements is presented in Figure C-10 and Table C-2.

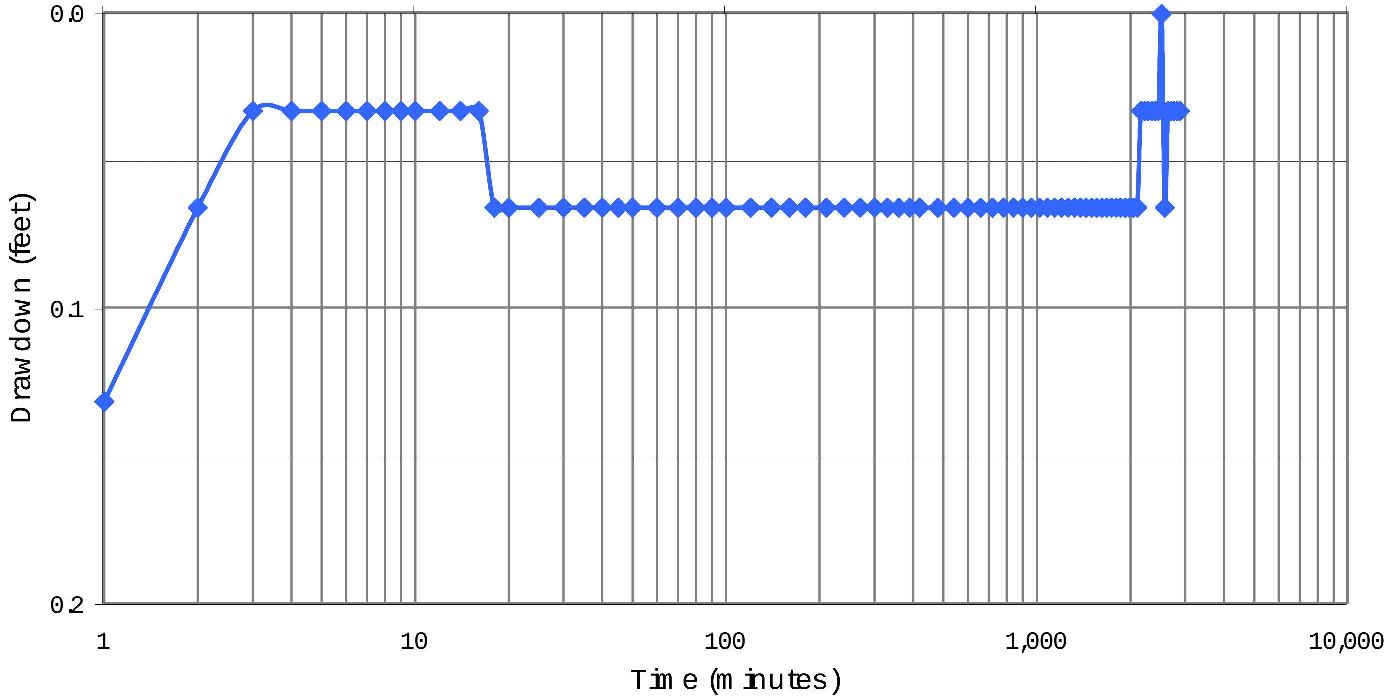
Initial low flow, short duration step pumping tests were conducted on test well BCUT-4 to determine drawdown and water quality with pumping over time using a 0.5-hp submersible pump. Since the behavior of the aquifer under high volume pumping rates was unknown and the thickness of the fresh water lens is relatively thin, pumping started 2 gpm and continued incrementally at 5 gpm, 10 gpm, and 13,gpm. Results of the tests indicated virtually no drawdown during pumping conditions and conductivity measurements only slightly increased. Based on results of the initial test, a second long term pumping test was conducted on well BCUT-4. The aquifer test data and analysis is presented in Figures C-16 to C-18 and Tables C-4 to C-8.

Upon completion of the pumping test, one groundwater sample was collected from well BCUT-4 for analysis of chlorinated herbicides, dissolved mercury, total metals, OC pesticides, and VOCs. Analytical results indicated detectable zinc at concentrations below the WHO. A copy of the laboratory report is included with this appendix.



BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BC UT-4	Figure C-16 COOPER-JACOB PLOT

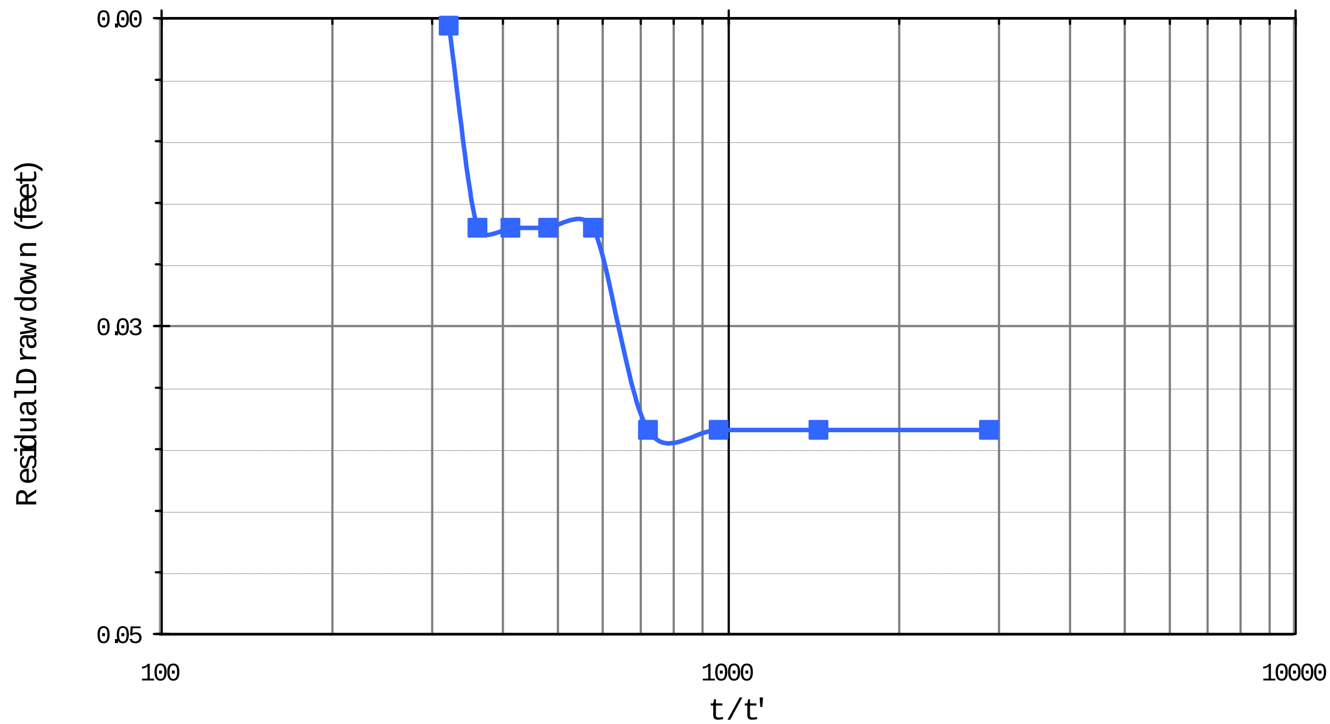
P:\Gen\GW_RES\Honduras\Utila\Pump Test Data\BC UT-4 PUMP TEST ANALYSIS1.xls\Conductivity Plot



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)/( )
T ~ gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BCUT-4	Figure C-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)(40)/( )
T ~ gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BC UT-4	FIGURE C-18 THEIS RECOVERY PLOT

P:\Gen\GW_RES\Honduras\Utila\Pump Test Data\BC UT-4 PUMP TEST ANALYSIS1.xls\Theis Recovery

Table C-4. Prueba Escalonada
Pozo #4
(Page 1 of 2)

FECHA: 11de Octubre 2,001
BOMBA: 3 HP
COMPANY PERFORMING TEST: SERPE

HORA	NIVEL DE AGUA M	CONDUCTIVIDAD	P.H.	OXIGENO DISUELTO M3/L	TEMPERATURA ºC	GPM	PRESION PSI
8:00	26.71	1,045	6.93	4.26	27.24	15	16
8:01	26.71		6.93	4.26	27.24	15	16
8:02	26.71		6.93	4.26	27.24	15	16
8:03	26.72		6.93	4.26	27.24	15	16
8:04	26.72		6.93	4.26	27.24	15	16
8:05	26.72		6.93	4.26	27.24	15	16
8:06	26.72		6.93	4.26	27.24	15	16
8:07	26.72		6.93	4.26	27.24	15	16
8:08	26.72		6.93	4.26	27.24	15	16
8:09	26.72		6.93	4.26	27.24	15	16
8:10	26.72	1,173	6.92	4.24	27.22	15	16
8:12	26.72		6.92	4.24	27.22	15	16
8:14	26.72		6.92	4.24	27.22	15	16
8:16	26.72		6.92	4.24	27.22	15	16
8:18	26.72		6.92	4.24	27.22	15	16
8:20	26.72	1,183	6.92	4.24	27.22	15	16
8:25	26.72		6.92	4.24	27.22	15	16
8:30	26.72		6.92	4.13	27.22	15	16
8:35	26.72		6.92	4.13	27.22	15	16
8:40	26.72	1,172	6.92	4.22	27.22	15	16
8:45	26.72		6.92	4.22	27.22	15	16
8:50	26.72	1,168	6.91	4.16	27.22	15	16
8:55	26.72		6.91	4.16	27.22	15	16
9:00	26.72	1,163	6.91	4.15	27.22	30	12
9:01	26.72		6.91	4.15	27.22	30	12
9:02	26.73		6.91	4.15	27.22	30	12
9:03	26.73		6.91	4.15	27.22	30	12
9:04	26.73		6.91	4.15	27.22	30	12
9:05	26.73	1,185	6.90	4.18	27.22	30	12
9:06	26.73		6.90	4.18	27.22	30	12
9:07	26.73		6.90	4.18	27.22	30	12
9:08	26.73		6.90	4.18	27.22	30	12
9:09	26.73		6.90	4.18	27.22	30	12
9:10	26.73	1,201	6.90	4.17	27.22	30	12
9:12	26.73		6.90	4.17	27.22	30	12
9:14	26.73		6.90	4.17	27.22	30	12
9:16	26.73		6.90	4.17	27.22	30	12
9:18	26.73	1,209	6.90	4.17	27.22	30	12
9:20	26.73	1,210	6.90	4.29	27.22	30	12
9:25	26.73	1218	6.89	4.29	27.22	30	12
9:30	26.73	1224	6.89	4.18	27.22	30	12
9:35	26.73		6.89	4.18	27.22	30	12
9:40	26.73	1237	6.89	4.26	27.22	30	12
9:45	26.73		6.89	4.26	27.22	30	12
9:50	26.73	1240	6.89	4.25	27.22	30	12
9:55	26.73		6.89	4.25	27.22	30	12
10:00	26.73	1253	6.89	4.22	27.22	30	12
10:01	26.73		6.89	4.22	27.22	45	7
10:02	26.73		6.89	4.22	27.22	45	7
10:03	26.73		6.89	4.22	27.22	45	7
10:04	26.73		6.89	4.22	27.22	45	7
10:05	26.73	1266	6.89	4.32	27.22	45	7
10:06	26.73		6.89	4.32	27.22	45	7
10:07	26.73		6.89	4.32	27.22	45	7
10:08	26.73		6.89	4.32	27.22	45	7
10:09	26.73		6.89	4.32	27.22	45	7
10:10	26.73	1279	6.89	4.35	27.22	45	7
10:12	26.73		6.89	4.35	27.22	45	7
10:14	26.73		6.89	4.35	27.22	45	7
10:16	26.73		6.89	4.35	27.22	45	7
10:18	26.73		6.89	4.35	27.22	45	7
10:20	26.73	1293	6.89	4.37	27.22	45	7
10:25	26.73		6.89	4.37	27.22	45	7
10:30	26.73	1308	6.89	4.35	27.22	45	7
10:35	26.73		6.89	4.35	27.22	45	7
10:40	26.73	1315	6.88	4.35	27.22	45	7
10:45	26.73		6.88	4.35	27.22	45	7
10:50	26.73	1324	6.88	4.33	27.22	45	7
10:55	26.73		6.88	4.33	27.22	45	7
11:00	26.73	1330	6.88	4.33	27.22	45	7

Table C-4. Prueba Escalonada
Pozo #4

FECHA: 11de Octubre 2,001
BOMBA: 3 HP
COMPANY PERFORMING TEST: SERPE

HORA	NIVEL DE AGUA M	CONDUCTIVIDAD	P.H.	OXIGENO DISUELTO M3/L	TEMPERATURA ºC	GPM	PRESION PSI
11:01	26.73		6.88	4.33	27.22	55	0
11:02	26.73		6.88	4.33	27.22	55	0
11:03	26.73		6.88	4.33	27.22	55	0
11:04	26.73		6.88	4.33	27.22	55	0
11:05	26.73	1348	6.88	4.49	27.22	55	0
11:06	26.73		6.88	4.49	27.22	55	0
11:07	26.73		6.88	4.49	27.22	55	0
11:08	26.73		6.88	4.49	27.22	55	0
11:09	26.73		6.88	4.49	27.22	55	0
11:10	26.73	1365	6.88	4.40	27.22	55	0
11:12	26.73		6.88	4.40	27.22	55	0
11:14	26.73		6.88	4.40	27.22	55	0
11:16	26.73		6.88	4.40	27.22	55	0
11:18	26.73		6.88	4.40	27.22	55	0
11:20	26.735	1383	6.88	4.40	27.22	55	0
11:25	26.735		6.88	4.40	27.22	55	0
11:30	26.735	1397	6.88	4.41	27.22	55	0
11:35	26.735		6.88	4.41	27.22	55	0
11:40	26.735	1410	6.88	4.41	27.22	55	0
11:45	26.735	1412	6.88	4.41	27.22	55	0
11:50	26.735	1414	6.88	4.41	27.22	55	0
11:55	26.735	1424	6.88	4.41	27.22	55	0
12:00	26.735	1425	6.87	4.40	27.22	55	0

RECUPERACION

HORA	NIVEL DE AGUA M
12:00	26.735
12:01	26.72
12:02	26.72
12:03	26.72
12:04	26.72
12:05	26.72
12:06	26.72
12:07	26.715
12:08	26.715
12:09	26.715
12:10	26.715

Table C-5. Prueba Constante
Pozo #4

UTILA, ISLAS DE LA BAHIA
FECHA: 17 DE OCTUBRE DEL 2001
CAUDAL: 40 GPM
BOMBA: 3HP
PROFUNDIDAD DE LA BOMBA: 100 PIES
PROFUNDIDAD DE LA SONDA DE CONDUCTIVIDAD:105 PIES

FECHA	HORA	NIVEL DE AGUA M	CONDUCTIVIDAD SONDA	CONDUCTIVIDAD EN LA DESCARGA	P.H.	OXIGENO DISUELTO M3/L	TEMPERATURA ºC	PRESION PSI	OBSERVACION
17/10/01	7:00 AM	26.76	1,066		6.95	2.37	27.23	20	
17/10/01		26.80							
17/10/01		26.78							
17/10/01		26.77							
17/10/01		26.77							
17/10/01		26.77	1,235		6.94	3.56	27.23	20	
17/10/01		26.77	1,235			3.56	27.23	20	
17/10/01		26.77	1,235			3.56	27.23	20	
17/10/01		26.77	1,235			3.56	27.23	20	
17/10/01		26.77	1,235			3.56	27.21	20	
17/10/01	7:10	26.77	1,242		6.94	3.65	27.21	20	
17/10/01	7:12	26.77			6.94	3.65	27.21	20	
17/10/01	7:14	26.77			6.94	3.65	27.21	20	
17/10/01	7:16	26.77			6.94	3.65	27.21	18.5	
17/10/01	7:18	26.78			6.94	3.65	27.21	18.5	
17/10/01	7:20	26.78	1,281		6.97	3.63	27.21	18.5	
17/10/01	7:25	26.78	1,295	908	6.94	3.69	27.21	18.5	AGUA CLARA
17/10/01	7:30	26.78							AGUA CLARA
17/10/01	7:35	26.78	1,313		6.93	3.77	27.21	18.5	AGUA CLARA
17/10/01	7:40	26.78	1,318		6.94	3.77	27.21	18.5	AGUA CLARA
17/10/01	7:45	26.78			6.94	3.77	27.21	18.5	AGUA CLARA
17/10/01	7:50	26.78	1,328	907	6.93	3.77	27.21	18.5	AGUA CLARA
17/10/01	8:00	26.78	1,348		6.93	3.69	27.21	18	AGUA CLARA
17/10/01	8:10	26.78	1,359		6.93	3.83	27.21	18	AGUA CLARA
17/10/01	8:20	26.78	1,364		6.92	3.73	27.21	18	AGUA CLARA
17/10/01	8:30	26.78	1,369		6.93	3.82	27.21	18	AGUA CLARA
17/10/01	8:40	26.78	1,362		6.92	3.72	27.21	18	AGUA CLARA
17/10/01	9:00	26.78	1,371		6.92	3.72	27.21	18	AGUA CLARA
17/10/01	9:20	26.78	1,385		6.92	3.59	27.21	18	AGUA CLARA
17/10/01	9:40	26.78	1,388		6.92	3.48	27.21	18	AGUA CLARA
17/10/01	10:00	26.78	1,386	932	6.92	3.48	27.21	18.5	AGUA CLARA
17/10/01	10:30	26.78	1,398		6.92	3.43	27.21	18	AGUA CLARA
17/10/01	11:00	26.78	1,397	954	6.92	3.52	31.3	18	AGUA CLARA
17/10/01	11:30	26.78	1,404		6.92	3.50	31.3	17.5	AGUA CLARA
17/10/01	12:00 M	26.78	1,407		6.91	3.52	27.22	17.5	AGUA CLARA
17/10/01	12:30	26.78	1,418	775	6.91	3.62	27.22	18	AGUA CLARA
17/10/01	1:00	26.78	1,419		6.92	3.41	27.22	18	AGUA CLARA
17/10/01	1:30	26.78	1,413		6.91	3.43	27.22	17.5	AGUA CLARA
17/10/01	2:00	26.78	1,425	960	6.91	3.49	27.22	17.5	AGUA CLARA
17/10/01	3:00	26.78	1,432	982	6.58	3.54	27.22	17.5	AGUA CLARA
17/10/01	4:00	26.78	1,445		6.91	3.54	27.22	17.5	AGUA CLARA
17/10/01	5:00	26.78	1,455		6.91	3.45	27.22	17.5	AGUA CLARA
17/10/01	6:00	26.78	1,467		6.91	3.48	27.22	18.5	AGUA CLARA
17/10/01	7:00	26.78	1,474		6.91	3.53	27.22	18.5	AGUA CLARA
17/10/01	8:00	26.78	1,470		6.91	3.43	27.22	18.5	AGUA CLARA
17/10/01	9:00	26.78	1,478		6.91	3.43	27.22	18.5	AGUA CLARA
17/10/01	10:00	26.78	1,465		6.91	3.38	27.22	18.5	AGUA CLARA
17/10/01	11:00	26.78	1,468		6.91	3.4	27.22	18.5	AGUA CLARA
18/10/01	12:00	26.78	1,469		6.91	3.45	27.23	18.5	AGUA CLARA
18/10/01	1:00	26.78	1,470		6.91	3.39	27.23	18.5	AGUA CLARA
18/10/01	2:00	26.78	1,462		6.91	3.41	27.23	18.5	AGUA CLARA
18/10/01	3:00	26.78	1,474		6.91	3.45	27.23	18.5	AGUA CLARA
18/10/01	4:00	26.78	1,497		6.91	3.45	27.23	18.5	AGUA CLARA
18/10/01	5:00	26.78	1,497		6.91	3.45	27.23	19	AGUA CLARA
18/10/01	6:00	26.78	1,510		6.91	3.45	27.23	19	AGUA CLARA
18/10/01	7:00	26.78	1,517	999	6.91	3.50	27.23	18.5	AGUA CLARA
18/10/01	8:00	26.78	1,526	996	6.91	3.49	27.23	18.5	AGUA CLARA
18/10/01	9:00	26.78	1,508		6.91	3.46	27.23	18.5	AGUA CLARA
18/10/01	10:00	26.78	1,509		6.91	3.45	27.23	18.5	AGUA CLARA
18/10/01	11:00	26.78	1,489	999	6.90	3.45	27.23	18.5	AGUA CLARA
18/10/01	12:00 M	26.78	1,497		6.90	3.39	27.23	18.5	AGUA CLARA
18/10/01	1:00	26.78	1,497	981	6.91	3.37	27.23	18	AGUA CLARA
18/10/01	2:00	26.78	1,481		6.91	3.42	27.23	18	AGUA CLARA
18/10/01	3:00	26.78	1,476		6.90	3.42	27.23	18	AGUA CLARA

Table C-5. Prueba Constante
Pozo #4
(Page 2 of 2)

UTILA, ISLAS DE LA BAHIA
FECHA: 17 DE OCTUBRE DEL 2001
CAUDAL: 40 GPM
BOMBA: 3HP
PROFUNDIDAD DE LA BOMBA: 100 PIES
PROFUNDIDAD DE LA SONDA DE CONDUCTIVIDAD:105 PIES

FECHA	HORA	NIVEL DE AGUA M	CONDUCTIVIDAD SONDA	CONDUCTIVIDAD EN LA DESCARGA	P.H.	OXIGENO DISUELTO M3/L	TEMPERATURA ºC	PRESION PSI	OBSERVACION
18/10/01	4:00	26.78	1,468	890	6.91	3.49	27.23	18.5	AGUA CLARA
18/10/01	5:00	26.78	1,472		6.91	3.37	27.23	19	AGUA CLARA
18/10/01	6:00	26.78	1,491	950	6.91	3.44	27.23	19	AGUA CLARA
18/10/01	7:00	26.77	1,444		6.91	3.29	27.23	19	AGUA CLARA
18/10/01	8:00	26.77	1,460		6.91	3.43	27.23	19	AGUA CLARA
18/10/01	9:00	26.77	1,460		6.90	3.41	27.23	19	AGUA CLARA
18/10/01	10:00	26.77	1,454		6.91	3.40	27.23	19	AGUA CLARA
18/10/01	11:00	26.77	1,442		6.91	3.44	27.23	19	AGUA CLARA
19/10/01	12:00 M	26.77	1,454		6.91	3.37	27.23	19	AGUA CLARA
19/10/01	1:00	26.76	1,464		6.91	3.37	27.23	19	AGUA CLARA
19/10/01	2:00	26.78	1,463		6.91	3.38	27.23	19	AGUA CLARA
19/10/01	3:00	26.77	1,460		6.91	3.39	27.23	19.5	AGUA CLARA

RECUPERACION

FECHA	HORA	NIVEL DE AGUA M
18/10/01	4:00 AM	26.77
18/10/01	5:00 AM	26.77
18/10/01	6:00 AM	26.77
18/10/01	7:00 AM	26.77
18/10/01	7:01 AM	26.77
18/10/01	7:02 AM	26.77
19/10/01	7:03 AM	26.77
19/10/01	7:04 AM	26.77
19/10/01	7:05 AM	26.765
19/10/01	7:06 AM	26.765
19/10/01	7:07 AM	26.765
19/10/01	7:08 AM	26.765
19/10/01	7:09 AM	226.76

Table C-6. Field Parameters Pump Test at BCUT-4
(Page 1 of 2)

Note:
Pump Depth : 100 feet
Conductivity Probe Depth: 105 feet

Date	Time	Time in Minutes	Conductivity of Discharge At Land Surface	Conductivity 5-Feet Below Pump Probe	pH Probe	Dissolved Oxygen mg/L Probe	Temperature ºC Probe
17/10/01	7:00 AM	0		1,066	6.95	2.37	27.23
17/10/01		5		1,235	6.94	3.56	27.23
17/10/01		6		1,235		3.56	27.23
17/10/01		7		1,235		3.56	27.23
17/10/01		8		1,235		3.56	27.23
17/10/01		9		1,235		3.56	27.21
17/10/01	7:10	10		1,242	6.94	3.65	27.21
17/10/01	7:20	20		1,281	6.97	3.63	27.21
17/10/01	7:25	25	908	1,295	6.94	3.69	27.21
17/10/01	7:35	35		1,313	6.93	3.77	27.21
17/10/01	7:40	40		1,318	6.94	3.77	27.21
17/10/01	7:50	50	907	1,328	6.93	3.77	27.21
17/10/01	8:00	60		1,348	6.93	3.69	27.21
17/10/01	8:10	70		1,359	6.93	3.83	27.21
17/10/01	8:20	80		1,364	6.92	3.73	27.21
17/10/01	8:30	90		1,369	6.93	3.82	27.21
17/10/01	8:40	100		1,362	6.92	3.72	27.21
17/10/01	9:00	120		1,371	6.92	3.72	27.21
17/10/01	9:20	140		1,385	6.92	3.59	27.21
17/10/01	9:40	160		1,388	6.92	3.48	27.21
17/10/01	10:00	180	932	1,386	6.92	3.48	27.21
17/10/01	10:30	210		1,398	6.92	3.43	27.21
17/10/01	11:00	240	954	1,397	6.92	3.52	31.3
17/10/01	11:30	270		1,404	6.92	3.50	31.3
17/10/01	12:00 M	300		1,407	6.91	3.52	27.22
17/10/01	12:30	330	775	1,418	6.91	3.62	27.22
17/10/01	1:00	360		1,419	6.92	3.41	27.22
17/10/01	1:30	390		1,413	6.91	3.43	27.22
17/10/01	2:00	420	960	1,425	6.91	3.49	27.22
17/10/01	3:00	480	982	1,432	6.58	3.54	27.22
17/10/01	4:00	540		1,445	6.91	3.54	27.22
17/10/01	5:00	600		1,455	6.91	3.45	27.22
17/10/01	6:00	660		1,467	6.91	3.48	27.22
17/10/01	7:00	720		1,474	6.91	3.53	27.22
17/10/01	8:00	780		1,470	6.91	3.43	27.22
17/10/01	9:00	840		1,478	6.91	3.43	27.22
17/10/01	10:00	900		1,465	6.91	3.38	27.22
17/10/01	11:00	960		1,468	6.91	3.4	27.22
18/10/01	12:00	1,020		1,469	6.91	3.45	27.23
18/10/01	1:00	1,080		1,470	6.91	3.39	27.23
18/10/01	2:00	1,140		1,462	6.91	3.41	27.23
18/10/01	3:00	1,200		1,474	6.91	3.45	27.23
18/10/01	4:00	1,260		1,497	6.91	3.45	27.23
18/10/01	5:00	1,320		1,497	6.91	3.45	27.23
18/10/01	6:00	1,380		1,510	6.91	3.45	27.23
18/10/01	7:00	1,440	999	1,517	6.91	3.50	27.23
18/10/01	8:00	1,500	996	1,526	6.91	3.49	27.23
18/10/01	9:00	1,560		1,508	6.91	3.46	27.23
18/10/01	10:00	1,620		1,509	6.91	3.45	27.23

Table C-6. Field Parameters Pump Test at BCUT-4

Note:
Pump Depth : 100 feet
Conductivity Probe Depth: 105 feet

Date	Time	Time in Minutes	Conductivity of Discharge At Land Surface	Conductivity 5-Feet Below Pump Probe	pH Probe	Dissolved Oxygen mg/L Probe	Temperature ºC Probe
18/10/01	11:00	1,680	999	1,489	6.90	3.45	27.23
18/10/01	12:00 M	1,740		1,497	6.90	3.39	27.23
18/10/01	1:00	1,800	981	1,497	6.91	3.37	27.23
18/10/01	2:00	1,860		1,481	6.91	3.42	27.23
18/10/01	3:00	1,920		1,476	6.90	3.42	27.23
18/10/01	4:00	1,980	890	1,468	6.91	3.49	27.23
18/10/01	5:00	2,040		1,472	6.91	3.37	27.23
18/10/01	6:00	2,100	950	1,491	6.91	3.44	27.23
18/10/01	11:00	60		1,442	6.91	3.44	27.23
19/10/01	12:00 M	120		1,454	6.91	3.37	27.23
19/10/01	1:00	180		1,464	6.91	3.37	27.23
19/10/01	2:00	240		1,463	6.91	3.38	27.23
19/10/01	3:00	300		1,460	6.91	3.39	27.23

Table C-7. Aquifer Test Data at BCUT-4
Constant Rate Discharge Test Performed on October 17 to 19, 2001
(Page 1 of 2)

Test Time t, minutes	Sounder Reading	Corr	Water Level meters	Drawdown meters	Water Level feet	Drawdown feet
0	26.76	-0.53	26.23	19.34	86.06	0.00
1	26.80	-0.53	26.27	0.04	86.19	0.13
2	26.78	-0.53	26.25	0.02	86.13	0.07
3	26.77	-0.53	26.24	0.01	86.09	0.03
4	26.77	-0.53	26.24	0.01	86.09	0.03
5	26.77	-0.53	26.24	0.01	86.09	0.03
6	26.77	-0.53	26.24	0.01	86.09	0.03
7	26.77	-0.53	26.24	0.01	86.09	0.03
8	26.77	-0.53	26.24	0.01	86.09	0.03
9	26.77	-0.53	26.24	0.01	86.09	0.03
10	26.77	-0.53	26.24	0.01	86.09	0.03
12	26.77	-0.53	26.24	0.01	86.09	0.03
14	26.77	-0.53	26.24	0.01	86.09	0.03
16	26.77	-0.53	26.24	0.01	86.09	0.03
18	26.78	-0.53	26.25	0.02	86.13	0.07
20	26.78	-0.53	26.25	0.02	86.13	0.07
25	26.78	-0.53	26.25	0.02	86.13	0.07
30	26.78	-0.53	26.25	0.02	86.13	0.07
35	26.78	-0.53	26.25	0.02	86.13	0.07
40	26.78	-0.53	26.25	0.02	86.13	0.07
45	26.78	-0.53	26.25	0.02	86.13	0.07
50	26.78	-0.53	26.25	0.02	86.13	0.07
60	26.78	-0.53	26.25	0.02	86.13	0.07
70	26.78	-0.53	26.25	0.02	86.13	0.07
80	26.78	-0.53	26.25	0.02	86.13	0.07
90	26.78	-0.53	26.25	0.02	86.13	0.07
100	26.78	-0.53	26.25	0.02	86.13	0.07
120	26.78	-0.53	26.25	0.02	86.13	0.07
140	26.78	-0.53	26.25	0.02	86.13	0.07
160	26.78	-0.53	26.25	0.02	86.13	0.07
180	26.78	-0.53	26.25	0.02	86.13	0.07
210	26.78	-0.53	26.25	0.02	86.13	0.07
240	26.78	-0.53	26.25	0.02	86.13	0.07
270	26.78	-0.53	26.25	0.02	86.13	0.07
300	26.78	-0.53	26.25	0.02	86.13	0.07
330	26.78	-0.53	26.25	0.02	86.13	0.07
360	26.78	-0.53	26.25	0.02	86.13	0.07
390	26.78	-0.53	26.25	0.02	86.13	0.07
420	26.78	-0.53	26.25	0.02	86.13	0.07
480	26.78	-0.53	26.25	0.02	86.13	0.07
540	26.78	-0.53	26.25	0.02	86.13	0.07
600	26.78	-0.53	26.25	0.02	86.13	0.07
660	26.78	-0.53	26.25	0.02	86.13	0.07
720	26.78	-0.53	26.25	0.02	86.13	0.07
780	26.78	-0.53	26.25	0.02	86.13	0.07
840	26.78	-0.53	26.25	0.02	86.13	0.07
900	26.78	-0.53	26.25	0.02	86.13	0.07

Table C-7. Aquifer Test Data at BCUT-4
Constant Rate Discharge Test Performed on October 17 to 19, 2001
(Page 2 of 2)

Test Time t, minutes	Sounder Reading	Corr	Water Level meters	Drawdown meters	Water Level feet	Drawdown feet
960	26.78	-0.53	26.25	0.02	86.13	0.07
1,020	26.78	-0.53	26.25	0.02	86.13	0.07
1,080	26.78	-0.53	26.25	0.02	86.13	0.07
1,140	26.78	-0.53	26.25	0.02	86.13	0.07
1,200	26.78	-0.53	26.25	0.02	86.13	0.07
1,260	26.78	-0.53	26.25	0.02	86.13	0.07
1,320	26.78	-0.53	26.25	0.02	86.13	0.07
1,380	26.78	-0.53	26.25	0.02	86.13	0.07
1,440	26.78	-0.53	26.25	0.02	86.13	0.07
1,500	26.78	-0.53	26.25	0.02	86.13	0.07
1,560	26.78	-0.53	26.25	0.02	86.13	0.07
1,620	26.78	-0.53	26.25	0.02	86.13	0.07
1,680	26.78	-0.53	26.25	0.02	86.13	0.07
1,740	26.78	-0.53	26.25	0.02	86.13	0.07
1,800	26.78	-0.53	26.25	0.02	86.13	0.07
1,860	26.78	-0.53	26.25	0.02	86.13	0.07
1,920	26.78	-0.53	26.25	0.02	86.13	0.07
1,980	26.78	-0.53	26.25	0.02	86.13	0.07
2,040	26.78	-0.53	26.25	0.02	86.13	0.07
2,100	26.78	-0.53	26.25	0.02	86.13	0.07
2,160	26.77	-0.53	26.24	0.01	86.09	0.03
2,220	26.77	-0.53	26.24	0.01	86.09	0.03
2,280	26.77	-0.53	26.24	0.01	86.09	0.03
2,340	26.77	-0.53	26.24	0.01	86.09	0.03
2,400	26.77	-0.53	26.24	0.01	86.09	0.03
2,460	26.77	-0.53	26.24	0.01	86.09	0.03
2,520	26.76	-0.53	26.23	0.00	86.06	0.00
2,580	26.78	-0.53	26.25	0.02	86.13	0.07
2,640	26.77	-0.53	26.24	0.01	86.09	0.03
2,700	26.77	-0.53	26.24	0.01	86.09	0.03
2,760	26.77	-0.53	26.24	0.01	86.09	0.03
2,820	26.77	-0.53	26.24	0.01	86.09	0.03
2,880	26.77	-0.53	26.24	0.01	86.09	0.03

Table C-8. Aquifer Test Data
Recovery Test Performed on October 19, 2001
(Page 1 of 1)

Test Time t, minutes	Step Time t', minutes	t/t'	Sounder Reading	Corr	Water Level meters	Drawdown meters	Water Level feet	Drawdown feet
2881	1	2881	26.77	-0.53	26.24	0.01	86.09	0.03
2882	2	1441	26.77	-0.53	26.24	0.01	86.09	0.03
2883	3	961	26.77	-0.53	26.24	0.01	86.09	0.03
2884	4	721	26.77	-0.53	26.24	0.01	86.09	0.03
2885	5	577	26.765	-0.53	26.24	0.00	86.08	0.02
2886	6	481	26.765	-0.53	26.24	0.00	86.08	0.02
2887	7	412.4285714	26.765	-0.53	26.24	0.00	86.08	0.02
2888	8	361	26.765	-0.53	26.24	0.00	86.08	0.02
2889	9	321	26.76	-0.53	26.23	0.00	86.06	0.00

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

Brown & Caldwell

Certificate of Analysis Number:

01100856

Report To:	Brown & Caldwell Barbara Goodrich 201 North Civic Drive Suite 200 Walnut Creek CA 94596-3864 ph: (925) 210-9010 fax: (925) 937-9026	Project Name:	GW Study-USAID 21365.253
		Site:	Bay Island of Utila
		Site Address:	
		PO Number:	
		State:	Client Specified
		State Cert. No.:	
Fax To:	fax:	Date Reported:	

Client Sample ID	Lab Sample ID	Matrix	Date Collected	Date Received	COC ID	HOLD
BC-UT-04 (#1)	01100856-01	Water	10/18/01 4:00:00 PM	10/22/01 10:00:00 AM	097946	☐

11/7/01

Sonia West
Senior Project Manager

Date

Joel Grice
Laboratory Director

Ted Yen
Quality Assurance Officer

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

Client Sample ID: BC-UT-04 (#1) Collected: 10/18/01 4:00:00 SPL Sample ID: 01100856-01

Site: Bay Island of Utila

Analyses/Method	Result		Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORINATED HERBICIDES BY METHOD 8151A				MCL	SW 8151A		Units: ug/L		
2,4,5-T	ND		1		1		10/30/01 2:12	AR	884833
2,4,5-TP (Silvex)	ND		1		1		10/30/01 2:12	AR	884833
2,4-D	ND		1		1		10/30/01 2:12	AR	884833
2,4-DB	ND		1		1		10/30/01 2:12	AR	884833
Dalapon	ND		1		1		10/30/01 2:12	AR	884833
Dicamba	ND		1		1		10/30/01 2:12	AR	884833
Dichloroprop	ND		1		1		10/30/01 2:12	AR	884833
Dinoseb	ND		1		1		10/30/01 2:12	AR	884833
MCPA	ND		25		1		10/30/01 2:12	AR	884833
MCPP	ND		25		1		10/30/01 2:12	AR	884833
Surr: DCAA	100	%	19-162		1		10/30/01 2:12	AR	884833

Run ID/Seq #: HP_M_011030C-884833

Prep Method	Prep Date	Prep Initials
SW 3510B	10/24/2001 14:47	J_L

Analyses/Method	Result		Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED				MCL	SW 7470A		Units: mg/L		
Mercury	ND		0.0002		1		11/01/01 11:33	R_T	889067

Run ID/Seq #: HGL_011101C-889067

Prep Method	Prep Date	Prep Initials
SW 7470A	11/01/2001 9:30	R_T

Analyses/Method	Result		Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
METALS BY METHOD 6010B, DISSOLVED				MCL	SW 6010B		Units: mg/L		
Antimony	ND		0.005		1		11/05/01 12:14	NS	893676
Arsenic	ND		0.005		1		11/05/01 12:14	NS	893676
Lead	ND		0.005		1		11/05/01 12:14	NS	893676
Selenium	ND		0.005		1		11/05/01 12:14	NS	893676
Cadmium	ND		0.005		1		11/02/01 20:42	EG	892258
Chromium	ND		0.01		1		11/02/01 20:42	EG	892258
Nickel	ND		0.02		1		11/02/01 20:42	EG	892258
Silver	ND		0.01		1		11/02/01 20:42	EG	892258
Zinc	0.0773		0.02		1		11/02/01 20:42	EG	892258

Run ID/Seq #: TJA_011102D-892258

Prep Method	Prep Date	Prep Initials
SW 3005	10/26/2001 21:00	MME

Run ID/Seq #: TJAT_011105A-893676

Prep Method	Prep Date	Prep Initials
SW 3005	10/26/2001 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

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

Client Sample ID: BC-UT-04 (#1) Collected: 10/18/01 4:00:00 SPL Sample ID: 01100856-01

Site: Bay Island of Utila

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
ORGANOCHLORINE PESTICIDES BY METHOD 8081A			MCL	SW 8081		Units: ug/L		
4,4´-DDD	ND		0.1	1		10/27/01 19:03	SG	882885
4,4´-DDE	ND		0.1	1		10/27/01 19:03	SG	882885
4,4´-DDT	ND		0.1	1		10/27/01 19:03	SG	882885
Aldrin	ND		0.05	1		10/27/01 19:03	SG	882885
alpha-BHC	ND		0.05	1		10/27/01 19:03	SG	882885
alpha-Chlordane	ND		0.05	1		10/27/01 19:03	SG	882885
beta-BHC	ND		0.05	1		10/27/01 19:03	SG	882885
Chlordane	ND		0.5	1		10/27/01 19:03	SG	882885
delta-BHC	ND		0.05	1		10/27/01 19:03	SG	882885
Dieldrin	ND		0.1	1		10/27/01 19:03	SG	882885
Endosulfan I	ND		0.05	1		10/27/01 19:03	SG	882885
Endosulfan II	ND		0.1	1		10/27/01 19:03	SG	882885
Endosulfan sulfate	ND		0.1	1		10/27/01 19:03	SG	882885
Endrin	ND		0.1	1		10/27/01 19:03	SG	882885
Endrin aldehyde	ND		0.1	1		10/27/01 19:03	SG	882885
Endrin ketone	ND		0.1	1		10/27/01 19:03	SG	882885
gamma-BHC	ND		0.05	1		10/27/01 19:03	SG	882885
gamma-Chlordane	ND		0.05	1		10/27/01 19:03	SG	882885
Heptachlor	ND		0.05	1		10/27/01 19:03	SG	882885
Heptachlor epoxide	ND		0.05	1		10/27/01 19:03	SG	882885
Methoxychlor	ND		0.5	1		10/27/01 19:03	SG	882885
Toxaphene	ND		1	1		10/27/01 19:03	SG	882885
Surr: Decachlorobiphenyl	42.2	%	40-150	1		10/27/01 19:03	SG	882885
Surr: Tetrachloro-m-xylene	37.5	%	39-106	1	*	10/27/01 19:03	SG	882885

Run ID/Seq #: VARA_011029D-882885

Prep Method	Prep Date	Prep Initials
SW 3510B	10/23/2001 11:54	KL

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: BC-UT-04 (#1) Collected: 10/18/01 4:00:00 SPL Sample ID: 01100856-01

Site: Bay Island of Utila

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
VOLATILE ORGANICS BY METHOD 8260B			MCL	SW 8260B		Units: ug/L		
1,1,1,2-Tetrachloroethane	ND	5		1		10/25/01 13:11	JN	883653
1,1,1-Trichloroethane	ND	5		1		10/25/01 13:11	JN	883653
1,1,2,2-Tetrachloroethane	ND	5		1		10/25/01 13:11	JN	883653
1,1,2-Trichloroethane	ND	5		1		10/25/01 13:11	JN	883653
1,1-Dichloroethane	ND	5		1		10/25/01 13:11	JN	883653
1,1-Dichloroethene	ND	5		1		10/25/01 13:11	JN	883653
1,1-Dichloropropene	ND	5		1		10/25/01 13:11	JN	883653
1,2,3-Trichlorobenzene	ND	5		1		10/25/01 13:11	JN	883653
1,2,3-Trichloropropane	ND	5		1		10/25/01 13:11	JN	883653
1,2,4-Trichlorobenzene	ND	5		1		10/25/01 13:11	JN	883653
1,2,4-Trimethylbenzene	ND	5		1		10/25/01 13:11	JN	883653
1,2-Dibromo-3-chloropropane	ND	5		1		10/25/01 13:11	JN	883653
1,2-Dibromoethane	ND	5		1		10/25/01 13:11	JN	883653
1,2-Dichlorobenzene	ND	5		1		10/25/01 13:11	JN	883653
1,2-Dichloroethane	ND	5		1		10/25/01 13:11	JN	883653
1,2-Dichloropropane	ND	5		1		10/25/01 13:11	JN	883653
1,3,5-Trimethylbenzene	ND	5		1		10/25/01 13:11	JN	883653
1,3-Dichlorobenzene	ND	5		1		10/25/01 13:11	JN	883653
1,3-Dichloropropane	ND	5		1		10/25/01 13:11	JN	883653
1,4-Dichlorobenzene	ND	5		1		10/25/01 13:11	JN	883653
2,2-Dichloropropane	ND	5		1		10/25/01 13:11	JN	883653
2-Butanone	ND	20		1		10/25/01 13:11	JN	883653
2-Chloroethylvinylether	ND	10		1		10/25/01 13:11	JN	883653
2-Chlorotoluene	ND	5		1		10/25/01 13:11	JN	883653
2-Hexanone	ND	10		1		10/25/01 13:11	JN	883653
4-Chlorotoluene	ND	5		1		10/25/01 13:11	JN	883653
4-Isopropyltoluene	ND	5		1		10/25/01 13:11	JN	883653
4-Methyl-2-pentanone	ND	10		1		10/25/01 13:11	JN	883653
Acetone	ND	100		1		10/25/01 13:11	JN	883653
Acrylonitrile	ND	50		1		10/25/01 13:11	JN	883653
Benzene	ND	5		1		10/25/01 13:11	JN	883653
Bromobenzene	ND	5		1		10/25/01 13:11	JN	883653
Bromochloromethane	ND	5		1		10/25/01 13:11	JN	883653
Bromodichloromethane	ND	5		1		10/25/01 13:11	JN	883653
Bromoform	ND	5		1		10/25/01 13:11	JN	883653
Bromomethane	ND	10		1		10/25/01 13:11	JN	883653
Carbon disulfide	ND	5		1		10/25/01 13:11	JN	883653
Carbon tetrachloride	ND	5		1		10/25/01 13:11	JN	883653
Chlorobenzene	ND	5		1		10/25/01 13:11	JN	883653

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

11/7/01 4:51:08 PM

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

Client Sample ID: BC-UT-04 (#1) Collected: 10/18/01 4:00:00 SPL Sample ID: 01100856-01

Site: Bay Island of Utila

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
Chloroethane	ND		10	1		10/25/01 13:11	JN	883653
Chloroform	ND		5	1		10/25/01 13:11	JN	883653
Chloromethane	ND		10	1		10/25/01 13:11	JN	883653
cis-1,3-Dichloropropene	ND		5	1		10/25/01 13:11	JN	883653
Dibromochloromethane	ND		5	1		10/25/01 13:11	JN	883653
Dibromomethane	ND		5	1		10/25/01 13:11	JN	883653
Dichlorodifluoromethane	ND		10	1		10/25/01 13:11	JN	883653
Ethylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Hexachlorobutadiene	ND		5	1		10/25/01 13:11	JN	883653
Isopropylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Methyl tert-butyl ether	ND		5	1		10/25/01 13:11	JN	883653
Methylene chloride	ND		5	1		10/25/01 13:11	JN	883653
n-Butylbenzene	ND		5	1		10/25/01 13:11	JN	883653
n-Propylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Naphthalene	ND		5	1		10/25/01 13:11	JN	883653
sec-Butylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Styrene	ND		5	1		10/25/01 13:11	JN	883653
tert-Butylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Tetrachloroethene	ND		5	1		10/25/01 13:11	JN	883653
Toluene	ND		5	1		10/25/01 13:11	JN	883653
trans-1,3-Dichloropropene	ND		5	1		10/25/01 13:11	JN	883653
Trichloroethene	ND		5	1		10/25/01 13:11	JN	883653
Trichlorofluoromethane	ND		5	1		10/25/01 13:11	JN	883653
Vinyl acetate	ND		10	1		10/25/01 13:11	JN	883653
Vinyl chloride	ND		10	1		10/25/01 13:11	JN	883653
cis-1,2-Dichloroethene	ND		5	1		10/25/01 13:11	JN	883653
m,p-Xylene	ND		5	1		10/25/01 13:11	JN	883653
o-Xylene	ND		5	1		10/25/01 13:11	JN	883653
trans-1,2-Dichloroethene	ND		5	1		10/25/01 13:11	JN	883653
1,2-Dichloroethene (total)	ND		5	1		10/25/01 13:11	JN	883653
Xylenes,Total	ND		5	1		10/25/01 13:11	JN	883653
Surr: 1,2-Dichloroethane-d4	108	%	62-130	1		10/25/01 13:11	JN	883653
Surr: 4-Bromofluorobenzene	78.0	%	70-130	1		10/25/01 13:11	JN	883653
Surr: Toluene-d8	92.0	%	74-122	1		10/25/01 13:11	JN	883653

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

11/7/01 4:51:08 PM

JORDANLAB
Laboratorio de Analisis Industrial
Agua Potable, Residual é 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
Muestra # 1157, ~~BC-UT DA # 3~~
Fecha de Ingreso: 19/10/01
Fecha Toma de Muestra: 18/10/01, Hora: 4:00pm

	Norma Nacional				
Parametros	Unidades	Recomendado	Max. Admisib	Metodo &	Resultados
Acidez Total	mg/l			2310-B	66
Alcalinidad Total	mg/l $CaCO_3$			2320-B	253
Dureza Total	mg/l $CaCO_3$	400		2340-C	328
Conductividad	us/cm	400		25100-B	1036
Bicarbonato (HCO_3)	mg/l			2320-B	253
Calcio	mg/l $CaCO_3$	100		3500-Ca D	110.4
Magnesio	mg/l $CaCO_3$	30	50	3500-Mg E	12.5
Hierro Total	mg/l		0.3	3500-Fe-D	<0.03
Manganeso Total	mg/l	0.01	0.5	3500-Mn C	<0.03
Fluor	mg/l		0.7-1.5	4500-F D	0.3
Cloruros	mg/l	25	250	4500-Cl-B	143
Sulfatos	mg/l	25	250	4500-SO4	8.2
Nitritos	mg/l		1	4500-NO2-B	<0.01
Nitratos	mg/l	25	50	4500-NO3-B	3.41

Norma Nacional: Decreto No.084 del 31de Julio de 1995
& Basados en Standard Methods for the Examination of Water and Wastewater 20 Edition.

JORDANLAB LABORATORIO DE ANALISIS INDUSTRIAL

LIC. LILIA J. DE RIVERA
JORDANLAB

San Pedro Sula, 19 de Octubre del 2,001

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

Client Sample ID BC-UT-04 (#1) **Collected:** 10/18/01 4:00:00 **SPL Sample ID:** 01100856-01

Site: **Bay Island of Utila**

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
CHLORINATED HERBICIDES BY METHOD 8151A			**MCL**	**SW8151A**		**Units: ug/L**		
2,4,5-T	ND		1	1		10/30/01 2:12	AR	884833
2,4,5-TP (Silvex)	ND		1	1		10/30/01 2:12	AR	884833
2,4-D	ND		1	1		10/30/01 2:12	AR	884833
2,4-DB	ND		1	1		10/30/01 2:12	AR	884833
Dalapon	ND		1	1		10/30/01 2:12	AR	884833
Dicamba	ND		1	1		10/30/01 2:12	AR	884833
Dichloroprop	ND		1	1		10/30/01 2:12	AR	884833
Dinoseb	ND		1	1		10/30/01 2:12	AR	884833
MCPA	ND		25	1		10/30/01 2:12	AR	884833
MCPP	ND		25	1		10/30/01 2:12	AR	884833
Surr: DCAA	100	%	19-162	1		10/30/01 2:12	AR	884833

Prep Method	Prep Date	Prep Initials
SW3510B	10/24/2001 14:47	J_L

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED		**MCL**	**SW7470A**		**Units: mg/L**		
Mercury	ND	0.0002	1		11/01/01 11:33	R_T	889067

Prep Method	Prep Date	Prep Initials
SW7470A	11/01/2001 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		11/05/01 12:14	NS	893676
Arsenic	ND	0.005	1		11/05/01 12:14	NS	893676
Lead	ND	0.005	1		11/05/01 12:14	NS	893676
Selenium	ND	0.005	1		11/05/01 12:14	NS	893676
Cadmium	ND	0.005	1		11/02/01 20:42	EG	892258
Chromium	ND	0.01	1		11/02/01 20:42	EG	892258
Nickel	ND	0.02	1		11/02/01 20:42	EG	892258
Silver	ND	0.01	1		11/02/01 20:42	EG	892258
Zinc	0.0773	0.02	1		11/02/01 20:42	EG	892258

Prep Method	Prep Date	Prep Initials
SW3005A	10/26/2001 21:00	MME

Qualifiers:

ND/U - Not Detected at the Reporting Limit
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>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 BC-UT-04 (#1) **Collected:** 10/18/01 4:00:00 **SPL Sample ID:** 01100856-01

Site: Bay Island of Utila

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
ORGANOCHLORINE PESTICIDES BY METHOD 8081A			**MCL**		**SW8081**	**Units: ug/L**		
4,4´-DDD	ND		0.1	1		10/27/01 19:03	SG	882885
4,4´-DDE	ND		0.1	1		10/27/01 19:03	SG	882885
4,4´-DDT	ND		0.1	1		10/27/01 19:03	SG	882885
Aldrin	ND		0.05	1		10/27/01 19:03	SG	882885
alpha-BHC	ND		0.05	1		10/27/01 19:03	SG	882885
alpha-Chlordane	ND		0.05	1		10/27/01 19:03	SG	882885
beta-BHC	ND		0.05	1		10/27/01 19:03	SG	882885
Chlordane	ND		0.5	1		10/27/01 19:03	SG	882885
delta-BHC	ND		0.05	1		10/27/01 19:03	SG	882885
Dieldrin	ND		0.1	1		10/27/01 19:03	SG	882885
Endosulfan I	ND		0.05	1		10/27/01 19:03	SG	882885
Endosulfan II	ND		0.1	1		10/27/01 19:03	SG	882885
Endosulfan sulfate	ND		0.1	1		10/27/01 19:03	SG	882885
Endrin	ND		0.1	1		10/27/01 19:03	SG	882885
Endrin aldehyde	ND		0.1	1		10/27/01 19:03	SG	882885
Endrin ketone	ND		0.1	1		10/27/01 19:03	SG	882885
gamma-BHC	ND		0.05	1		10/27/01 19:03	SG	882885
gamma-Chlordane	ND		0.05	1		10/27/01 19:03	SG	882885
Heptachlor	ND		0.05	1		10/27/01 19:03	SG	882885
Heptachlor epoxide	ND		0.05	1		10/27/01 19:03	SG	882885
Methoxychlor	ND		0.5	1		10/27/01 19:03	SG	882885
Toxaphene	ND		1	1		10/27/01 19:03	SG	882885
Surr: Decachlorobiphenyl	42.2	%	40-150	1		10/27/01 19:03	SG	882885
Surr: Tetrachloro-m-xylene	37.5	%	39-106	1	*	10/27/01 19:03	SG	882885

Prep Method	Prep Date	Prep Initials
SW3510B	10/23/2001 11:54	KL

Qualifiers:

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>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 BC-UT-04 (#1) **Collected:** 10/18/01 4:00:00 **SPL Sample ID:** 01100856-01

Site: Bay Island of Utila

Analyses/Method	Result	Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
VOLATILE ORGANICS BY METHOD 8260B		**MCL**	**SW8260B**		**Units: ug/L**		
1,1,1,2-Tetrachloroethane	ND	5	1		10/25/01 13:11	JN	883653
1,1,1-Trichloroethane	ND	5	1		10/25/01 13:11	JN	883653
1,1,2,2-Tetrachloroethane	ND	5	1		10/25/01 13:11	JN	883653
1,1,2-Trichloroethane	ND	5	1		10/25/01 13:11	JN	883653
1,1-Dichloroethane	ND	5	1		10/25/01 13:11	JN	883653
1,1-Dichloroethene	ND	5	1		10/25/01 13:11	JN	883653
1,1-Dichloropropene	ND	5	1		10/25/01 13:11	JN	883653
1,2,3-Trichlorobenzene	ND	5	1		10/25/01 13:11	JN	883653
1,2,3-Trichloropropane	ND	5	1		10/25/01 13:11	JN	883653
1,2,4-Trichlorobenzene	ND	5	1		10/25/01 13:11	JN	883653
1,2,4-Trimethylbenzene	ND	5	1		10/25/01 13:11	JN	883653
1,2-Dibromo-3-chloropropane	ND	5	1		10/25/01 13:11	JN	883653
1,2-Dibromoethane	ND	5	1		10/25/01 13:11	JN	883653
1,2-Dichlorobenzene	ND	5	1		10/25/01 13:11	JN	883653
1,2-Dichloroethane	ND	5	1		10/25/01 13:11	JN	883653
1,2-Dichloropropane	ND	5	1		10/25/01 13:11	JN	883653
1,3,5-Trimethylbenzene	ND	5	1		10/25/01 13:11	JN	883653
1,3-Dichlorobenzene	ND	5	1		10/25/01 13:11	JN	883653
1,3-Dichloropropane	ND	5	1		10/25/01 13:11	JN	883653
1,4-Dichlorobenzene	ND	5	1		10/25/01 13:11	JN	883653
2,2-Dichloropropane	ND	5	1		10/25/01 13:11	JN	883653
2-Butanone	ND	20	1		10/25/01 13:11	JN	883653
2-Chloroethyl vinyl ether	ND	10	1		10/25/01 13:11	JN	883653
2-Chlorotoluene	ND	5	1		10/25/01 13:11	JN	883653
2-Hexanone	ND	10	1		10/25/01 13:11	JN	883653
4-Chlorotoluene	ND	5	1		10/25/01 13:11	JN	883653
4-Isopropyltoluene	ND	5	1		10/25/01 13:11	JN	883653
4-Methyl-2-pentanone	ND	10	1		10/25/01 13:11	JN	883653
Acetone	ND	100	1		10/25/01 13:11	JN	883653
Acrylonitrile	ND	50	1		10/25/01 13:11	JN	883653
Benzene	ND	5	1		10/25/01 13:11	JN	883653
Bromobenzene	ND	5	1		10/25/01 13:11	JN	883653
Bromochloromethane	ND	5	1		10/25/01 13:11	JN	883653
Bromodichloromethane	ND	5	1		10/25/01 13:11	JN	883653
Bromoform	ND	5	1		10/25/01 13:11	JN	883653
Bromomethane	ND	10	1		10/25/01 13:11	JN	883653
Carbon disulfide	ND	5	1		10/25/01 13:11	JN	883653
Carbon tetrachloride	ND	5	1		10/25/01 13:11	JN	883653
Chlorobenzene	ND	5	1		10/25/01 13:11	JN	883653
Chloroethane	ND	10	1		10/25/01 13:11	JN	883653

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 BC-UT-04 (#1) **Collected:** 10/18/01 4:00:00 **SPL Sample ID:** 01100856-01

Site: Bay Island of Utila

Analyses/Method	Result		Rep.Limit	Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
Chloroform	ND		5	1		10/25/01 13:11	JN	883653
Chloromethane	ND		10	1		10/25/01 13:11	JN	883653
cis-1,3-Dichloropropene	ND		5	1		10/25/01 13:11	JN	883653
Dibromochloromethane	ND		5	1		10/25/01 13:11	JN	883653
Dibromomethane	ND		5	1		10/25/01 13:11	JN	883653
Dichlorodifluoromethane	ND		10	1		10/25/01 13:11	JN	883653
Ethylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Hexachlorobutadiene	ND		5	1		10/25/01 13:11	JN	883653
Isopropylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Methyl tert-butyl ether	ND		5	1		10/25/01 13:11	JN	883653
Methylene chloride	ND		5	1		10/25/01 13:11	JN	883653
n-Butylbenzene	ND		5	1		10/25/01 13:11	JN	883653
n-Propylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Naphthalene	ND		5	1		10/25/01 13:11	JN	883653
sec-Butylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Styrene	ND		5	1		10/25/01 13:11	JN	883653
tert-Butylbenzene	ND		5	1		10/25/01 13:11	JN	883653
Tetrachloroethene	ND		5	1		10/25/01 13:11	JN	883653
Toluene	ND		5	1		10/25/01 13:11	JN	883653
trans-1,3-Dichloropropene	ND		5	1		10/25/01 13:11	JN	883653
Trichloroethene	ND		5	1		10/25/01 13:11	JN	883653
Trichlorofluoromethane	ND		5	1		10/25/01 13:11	JN	883653
Vinyl acetate	ND		10	1		10/25/01 13:11	JN	883653
Vinyl chloride	ND		10	1		10/25/01 13:11	JN	883653
cis-1,2-Dichloroethene	ND		5	1		10/25/01 13:11	JN	883653
m,p-Xylene	ND		5	1		10/25/01 13:11	JN	883653
o-Xylene	ND		5	1		10/25/01 13:11	JN	883653
trans-1,2-Dichloroethene	ND		5	1		10/25/01 13:11	JN	883653
1,2-Dichloroethene (total)	ND		5	1		10/25/01 13:11	JN	883653
Xylenes,Total	ND		5	1		10/25/01 13:11	JN	883653
Surr: 1,2-Dichloroethane-d4	108	%	62-130	1		10/25/01 13:11	JN	883653
Surr: 4-Bromofluorobenzene	78.0	%	70-130	1		10/25/01 13:11	JN	883653
Surr: Toluene-d8	92.0	%	74-122	1		10/25/01 13:11	JN	883653

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

Client: SPL, Inc.
Proj. Name:
Proj. Number: 162734

Acculabs Work Order: G01100429
Received Date: 10/25/2001

Field Sample ID	Acculabs ID	Test	Matrix	Analyte	Result +/-CSU	MDC	Report Units	Report Basis	Qual Flag	Date Analyzed	Batch Id
01100856-01C	G01100429-01A	Gross Alpha/Beta	Aqueous	Alpha	-3.2 +/- 1.8	6.0	pCi/L	total	U	11/19/2001	GP00134
01100856-01C	G01100429-01A	Gross Alpha/Beta	Aqueous	Beta	3.0 +/- 2.0	4.0	pCi/L	total	U	11/19/2001	GP00134

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: 11/21/2001 02:25:48 PM
Printed: 11/21/2001 02:25:48 PM

APPENDIX D

East Harbor Groundwater Flow Model

EAST HARBOR GROUNDWATER FLOW MODEL

Utila, Honduras

June 2002

1.0 PURPOSE AND OBJECTIVE

The purpose and objective of the numerical groundwater flow model for East Harbor, Utila, was to assess the sustainability of future groundwater supply development to meet the needs of forecasted population growth. Based on the water resource evaluation of the island, further groundwater development is limited to a localized zone of fresh water northeast of Stuart Hill near well BCUT-4. The numerical groundwater flow model was prepared to simulate limited groundwater production of this potential water source.

2.0 MODEL ASSUMPTIONS AND APPROACH

Field investigations conducted on the island indicated that surficial clays likely limit infiltration of fresh water from precipitation. This low infiltration has resulted in a poorly developed fresh water lens that is constrained to selected portions of the island. Groundwater resource development is further complicated by the hydrogeologic properties of the producing aquifer. The main water production aquifer is a coral limestone with highly variable hydraulic conductivity due to secondary dissolution cavities associated with karst development.

Current water production areas near East Harbor are already over developed based on decreasing water quality trends over recent years. Conductivity measurements show increasing salinity concentrations due to groundwater withdrawal rates exceeding natural recharge that results in sea water intrusion. Therefore, predictive model simulations of sustainability of the resources of all of East Harbor were unnecessary due to observed groundwater overdraft conditions at existing well sites.

The approach to the model development was to develop predictive simulations of sustainable groundwater development near the fresh water resource identified near well BCUT-4. Limited data were available near well BCUT-4, and simplifying assumptions and a streamlined approach were used to facilitate the development of the mathematical groundwater model. A summary of the model assumptions is as follows:

- The aquifer system on the island of Utila is transient and unconfined.
- Tidal influences are negligible.
- Seasonal precipitation and recharge can be normalized to daily averages.
- Groundwater flow through the coral limestone can be simulated as a porous media.
- Hydraulic head is assumed to range from 0.2 meters above sea level to 0.15 meters below sea level. Head change across the region is 0.35 meters (approximately 1 foot).
- The local zone of fresh water northeast of Stuart Hill is largely associated with an uplifted fault block, and is of limited areal extent.
- Highly transmissive zones within the karsted limestone are associated with regional fracture trends and are a local phenomena.

3.0 CONCEPTUAL WATER BUDGET

A conceptual water budget for the fresh water aquifer system in the East Harbor region of the island of Utila was calculated to provide constraints for mathematical modeling. The conceptual budget is based on previous investigations, field data collection, and anecdotal information from long-term residents.

On the island of Utila, inflow to the aquifer system consists mainly of recharge from precipitation, with a small component of return flow from water useage. Fresh groundwater is removed from the system via (1) municipal and private well pumping, and (2) discharge to the ocean.

3.1 Inflow

Estimated precipitation on the island of Utila ranges from 2.2 to 2.6 meters per year (87 to 102 inches per year. An average value of 2.4 meters (95 inches) was used for water budget calculations.

The island of Utila is approximately 42 square kilometers (km2), 80 percent of which is represented by mangrove swamp. The region of interest in East Harbor consists of solid land and is approximately 2 km2 in area. A significant portionof this region is covered by a thick layer of clay, which restricts the recharge potential. Beneath the clay soil is a coral limestone unit that possesses highly variable permeability, depending on the degree of fracturing or solution cavities. The results of a hydrogeologic study conducted by SANAA (Servicio Autonomo Nacional de Acueductos y Alcantarillados) in 1993 indicated that the recharge potential of the aquifer in Utila was between 25-40 percent of total annual precipitation. However, the results of this field investigation indicate the weathered volcanic clay soils impede percolation of precipitation to the freshwater lens. Of the 2.4 meters of precipitation that falls on the island of Utila each year, it is estimated that only 2.5 percent recharges the fresh groundwater aquifer system. In the vicinity of Stuart Hill and Pumpkin Hill recharge may be enhanced; however, significant outcrops of permeable rock units do not exist. Within the area of interest, recharge is therefore calculated to be 90,000 cubic meters per year (m3/year), corresponding to a flux rate of 0.06 meters per year.

Controlled disposal of gray water (i.e., dishwater, wash water) and wastewater is non-regulated in East Harbor. The major portion of this wastewater is discharged to the ocean; however, it is assumed that a small portion of East Harbor's total water consumption recharges the aquifer as return flow. For budgeting purposes, 5 percent of total water consumption is estimated to return to the aquifer.

3.2 Outflow

Three municipal wells pump fresh groundwater for use by residents. In addition to municipal pumping, private wells are used to supply private homes. Because an official estimate of total pumping from private wells is not available, rough estimates based on total consumption were made for the purpose of estimating the water budget.

Total daily water use is estimated to be 89,600 gpd (339 m^3/day). A portion of the daily water demand is provided by storage of rainfall. The consumption of fresh groundwater is therefore less than the 89,600 gpd estimated by per capita consumption. In the rainy season, it is likely that a high percentage of the water demand is met via rainfall. It is estimated that 20 percent of the water demand is met by non-groundwater sources, resulting in total groundwater withdrawals of approximately 71,680 gpd (271 m^3/day).

Discharge of fresh groundwater to the ocean was calculated based on 1,500 meters of shoreline, 0.5 meters depth, estimated hydraulic conductivity of 100 meter per day, and a gradient of 0.0004. Discharge to the ocean using this method is estimated to be approximately 30 m^3/day.

Table D-1 below is the annualized, conceptual fresh groundwater budget for the East Harbor region of the island of Utila. For reference, the budget is also given in gallons per minute (gpm).

Table D-1. Conceptual Fresh Groundwater Budget

IN	M³ Per Year	Gallons Per Minute
Recharge	90,000	45
Return flow	5,000	
Total	**95,000**	**48**
OUT		
Municipal pumping	55,100	28
Private well pumping	43,800	22
Discharge to ocean	11,000	5
Total	**109,900**	**55**
IN – OUT (change in storage)	**-14,900**	**-7**

Based on these estimates, there is a yearly deficit of 14,900 m^3 or approximately 7 gpm, indicating that fresh groundwater supplies are being withdrawn from storage. As a result, saline water moves in to replace the fresh water lens, adversely affecting water quality. The fresh groundwater system recovers slightly during the winter rainy season; however, the overall budget deficit persists. Decreasing water quality trends in the current water supply wells supports this water budget.

4.0 MODEL DESIGN

MODFLOW™, a modular, three-dimensional, finite difference groundwater flow model developed by McDonald and Harbaugh (1988) was used to simulate hydraulic heads for the East Harbor model. MODPATH (Pollock, 1994) was used for particle tracking to depict the movement of groundwater into pumping wells. Groundwater Vistas (Environmental Simulations, Inc., 1997) was used as a pre- and post-processor for the MODFLOW™ and MODPATH™ simulations.

The finite difference grid designed for the East Harbor model is shown on Figure D-1. The grid cells are a uniform 20 meters, with 60 rows and 65 columns. The model area is thus 1,200 meters by 1,300 meters, centered on East Harbor. The y-direction of the finite difference grid is aligned with the major direction of groundwater flow, which is to the south toward the harbor.

BROWN AND CALDWELL

Figure D-1
FINITE DIFFERENCE GRID OF MODEL DOMAIN
EAST HARBOR GROUNDWATER MODEL
ISLA DE UTILA, HONDURAS

The model was vertically discretized into three layers. Thickness of the layers, from top to bottom, is 3 meters, 8 meters, and 6 meters. The top of the model is 1 meter above sea level. The bottom of the model is 16 meters below sea level.

Layer 1 generally represents the karsted coral limestone, the uppermost aquifer unit depicted on the cross section in Figure 4-2 (Chapter 4) (cross-section through BCUT1-4), and the most transmissive portion of the aquifer. The karsted limestone has good water-producing potential due to secondary porosity. However, based on data from Brown and Caldwell's drilling program, the transmissivity of this unit is highly variable. The drilling and geophysical data indicate that a potential water-producing zone is localized in the region adjacent to Stuart Hill.

Layers 2 and 3 generally represent the coral limestone identified in the drilling program and described as being non-karsted and massive. Fresh groundwater is assumed to exist in layers 1 and 2 in the vicinity of Stuart Hill. With distance from this upland, layer 2 becomes increasingly saline. Layer 3 is simulated as the portion of the aquifer that contains water too saline for pumping, and is included in the model design in order to assess vertical migration of saltwater into proposed pumping wells.

4.1 MODEL INPUTS

Table 2 is a summary of input parameters for the groundwater model of East Harbor. These estimates are based on the lithologic logs from wells BCUT-1 through BCUT-4, cross sections (Figures 4-2 and 4-3 (Chapter 4)), and the pumping test performed in BCUT-4. Where data are not available for Site-specific parameter estimation, generalized parameters from similar aquifer systems are utilized. Vertical conductance (the term "VCONT" in MODFLOW™) is calculated within the pre-processor based on vertical hydraulic conductivity and thickness of the layers.

Table D-2. Hydrogeologic Parameters for East Harbor Groundwater Model

Hydrogeologic Parameter	Estimated Value
Precipitation	2.4 meters per year
Recharge from precipitation	0.00016 to 0.00018 meters per day (approximately 2.5% of precipitation)
Solver	PCG2
Convergence criteria	0.01 meters
Layer 1	
Horizontal hydraulic conductivity	0.1 to 1,500 meters per day
Vertical hydraulic conductivity	0.01 to 150 meters per day
Storage coefficient	0.0001 to 0.001
Specific yield	0.05 to 0.3
Thickness	3 meters
Layer 2	
Horizontal hydraulic conductivity	0.1 to 10 meters per day
Vertical hydraulic conductivity	0.01 to 1 meter per day
Storage coefficient	0.0001
Specific yield	0.05
Thickness	8 meters
Layer 3	
Horizontal hydraulic conductivity	0.1 to 10 meters per day
Vertical hydraulic conductivity	0.01 to 1 meter per day
Storage coefficient	0.0001
Specific yield	0.05
Thickness	6 meters

Hydraulic conductivity values are estimates based on the drilling program and the results of the constant rate aquifer test in well BCUT-4. At a pumping rate of 40 gpm, drawdown was less than 0.1 meter for a 48-hour period. Similar results were not obtained in wells BCUT-1 through BCUT-3, which is consistent with geophysical data suggesting a localized water-producing zone near Stuart Hill, in the vicinity of well BCUT-4. Preliminary model runs were performed to simulate the results of the aquifer test in order to estimate the hydraulic conductivity in the vicinity of well BCUT-4. Based on these simulations, a plausible estimate for the hydraulic conductivity of the karsted limestone in this region is 1,500 meters per day (m/day). Hydraulic conductivity of the moderately transmissive coral limestone is estimated to be 100 m/day, an order of magnitude lower than the water-producing zone near Stuart Hill. The coral limestone is estimated to have a hydraulic conductivity of 10 m/day. The Stuart Hill volcanics are assumed to be relatively impermeable, with a hydraulic conductivity of 0.1 m/day.

Figure D-2 shows the hydraulic conductivity zones used for layer 1. Three hydraulic conductivity zones are used to depict variations in the permeability of the rock units: (1) the Stuart Hill volcanics, (2) moderately transmissive karsted coral limestone, and (3) highly transmissive karsted coral limestone.

Figure D-3 depicts the hydraulic conductivity zones for layers 2 and 3. Hydraulic parameters in layers 2 and 3 are identical and generally represent coral limestone with a small zone of low permeability volcanics at Stuart Hill.

4.2 Boundary Conditions

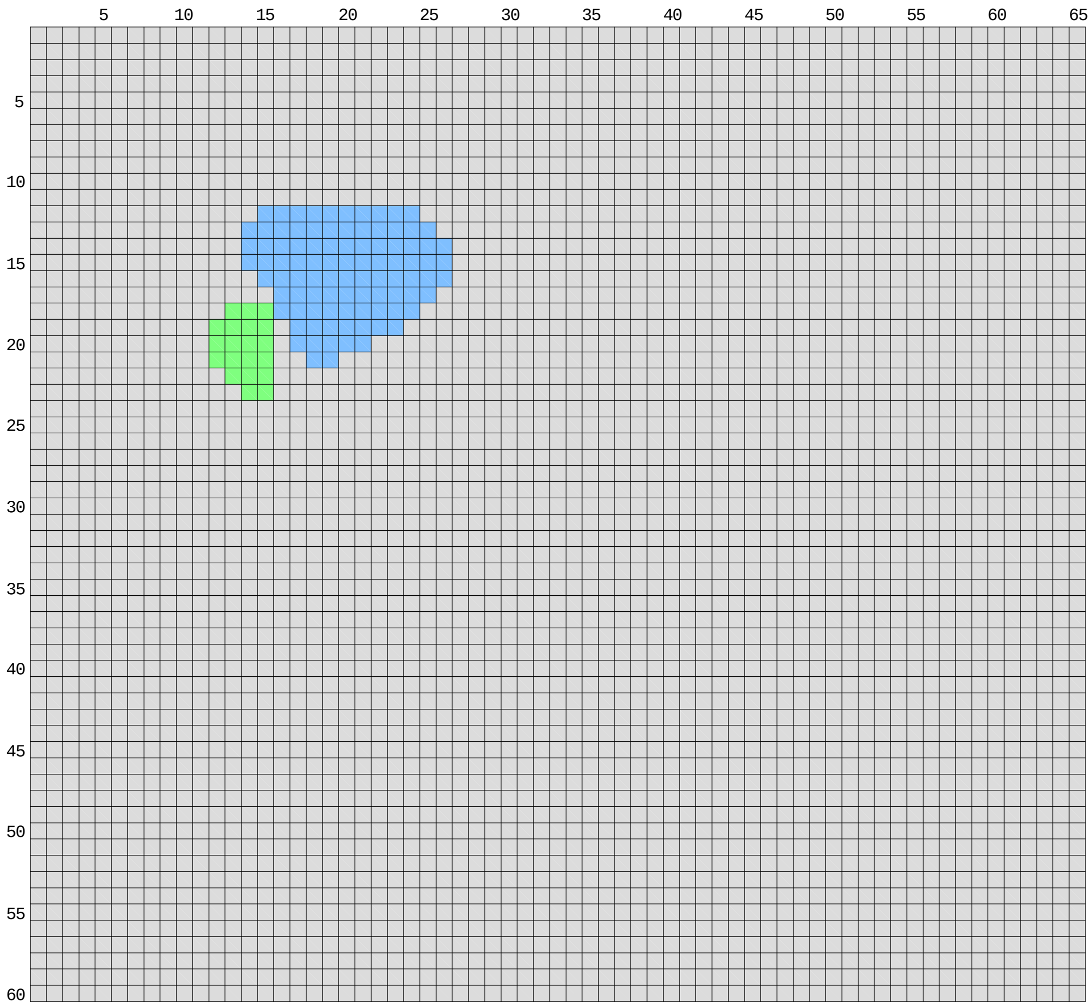
Consistent with the conceptual water budget for the aquifer system, the influx of fresh water into the aquifer was simulated with areal recharge to the water table. Slightly higher recharge is simulated in the general vicinity of Stuart Hill. Recharge into layer 1 is 259 m^3/day (94,535 m^3/year). Downgradient, the harbor is simulated with constant head cells, ranging from 0 to 0.15 meters below sea level. Figure D-4 presents boundary conditions used in the groundwater model.

4.3 Calibration

The paucity of data available for the island of Utila precluded a rigorous calibration and sensitivity analysis. The groundwater model was roughly calibrated to:

- Conceptual budget inflows, and
- A generalized, low-gradient flow regime consistent with observations during field data collection

The aquifer system in East Harbor is transient. A generalized, low-gradient flow regime was utilized for starting heads for purposes of assessing the potential for groundwater production near Stuart Hill. The starting heads for the predictive simulations are shown on Figure D-5.



EXPLANATION

LAYER 1
HYDRAULIC CONDUCTIVITY ZONES

STUART HILL VOLCANICS	0.10 meters/day
KARSTED LIMESTONE	100 meters/day
HIGHLY PERMEABLE KARSTED LIMESTONE	1500 meters/day

BROWN AND CALDWELL

Figure D-2

HYDRAULIC CONDUCTIVITY ZONES FOR LAYER 1

EAST HARBOR GROUNDWATER MODEL
ISLA DE UTILA, HONDURAS

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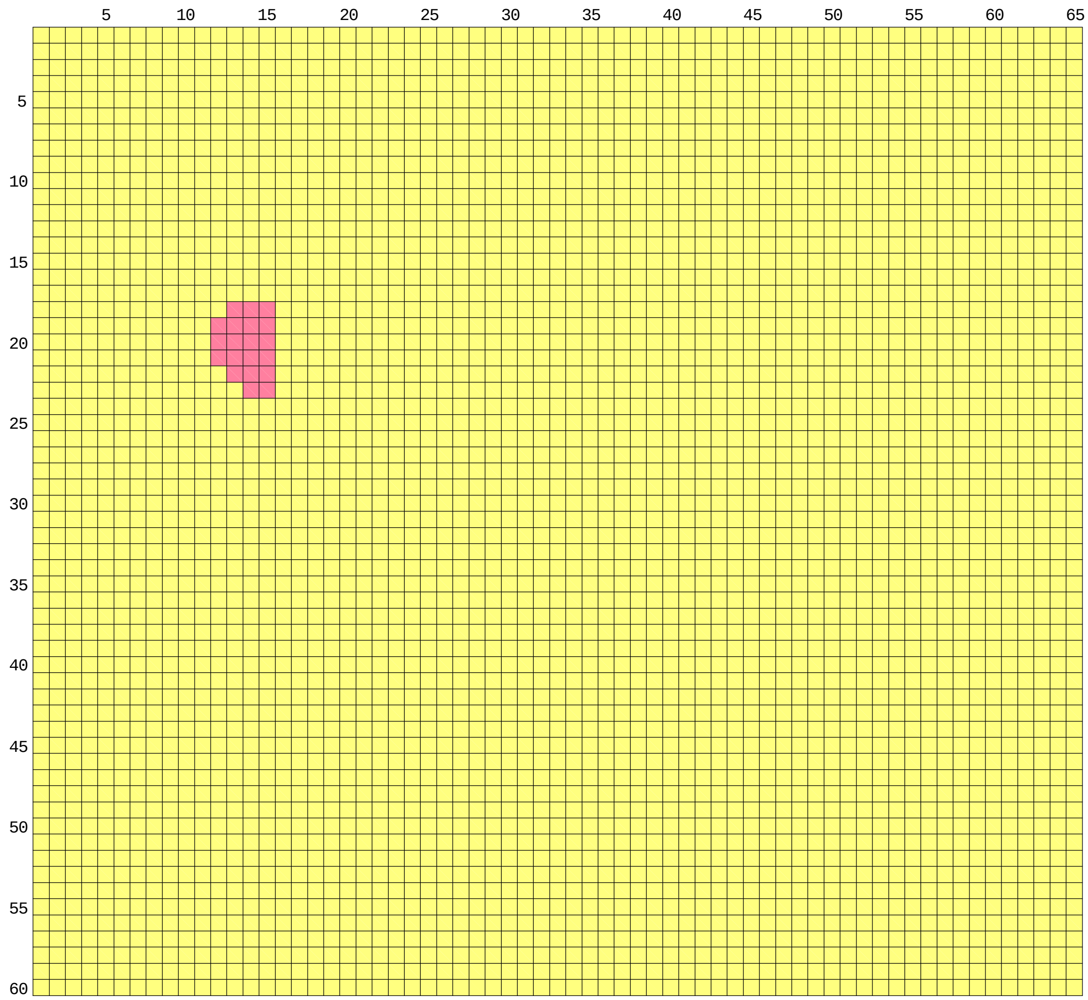


EXPLANATION

LAYERS 2 AND 3
HYDRAULIC CONDUCTIVITY ZONES

STUART HILL VOLCANICS — 0.10 meters/day

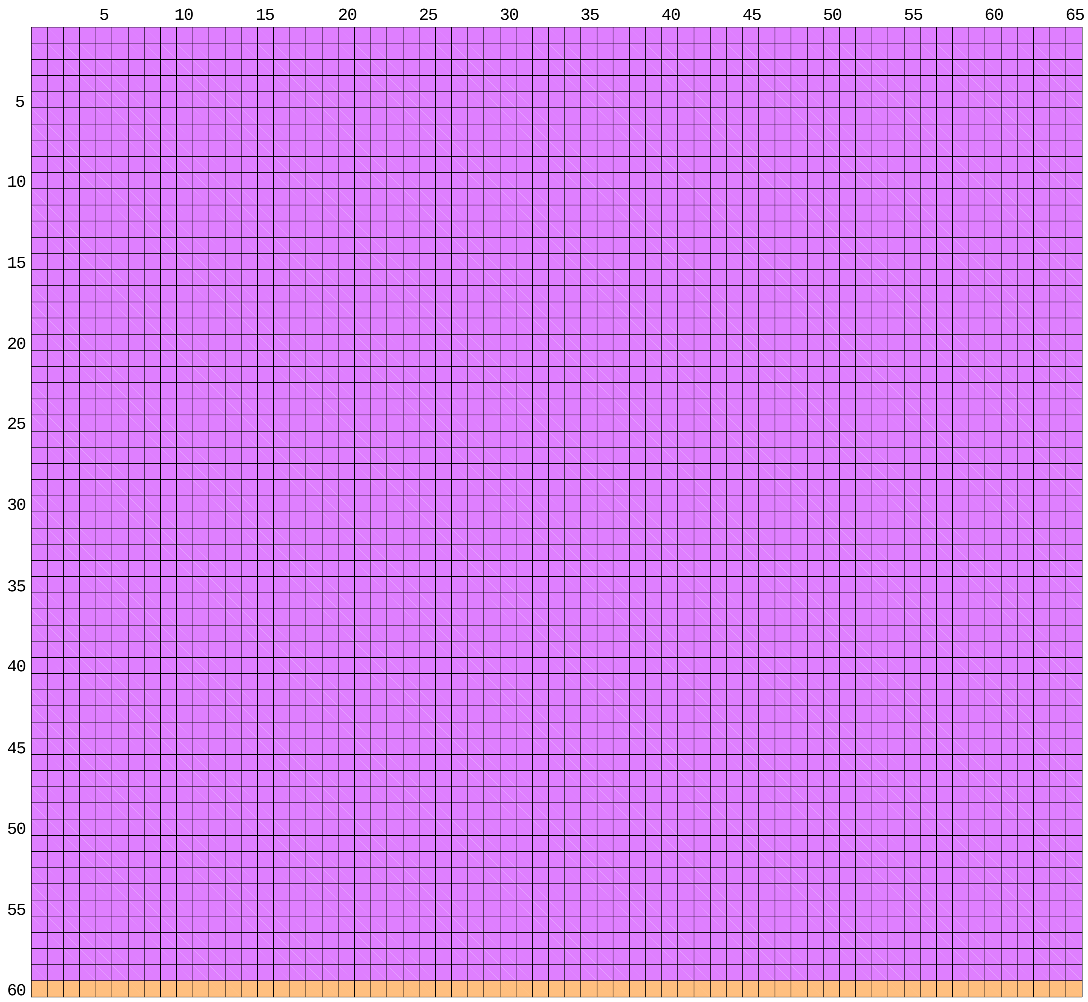
CORAL LIMESTONE — 10 meters/day

Figure D-3

HYDRAULIC CONDUCTIVITY ZONES FOR LAYERS 2 AND 3

EAST HARBOR GROUNDWATER MODEL
ISLA DE UTILA, HONDURAS

BROWN AND CALDWELL



EXPLANATION

BOUNDARY CONDITIONS

CONSTANT HEAD (LAYERS 1 THRU 3)

RECHARGE (LAYER 1)
TOTAL IN FLOW : 259 m^3/day

BROWN AND CALDWELL

Figure D-4

BOUNDARY CONDITIONS

EAST HARBOR GROUNDWATER MODEL
ISLA DE UTILA, HONDURAS

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BROWN AND CALDWELL

Figure D-5
INITIAL WATER LEVEL
ELEVATIONS FOR PREDICTIVE SIMULATIONS
EAST HARBOR GROUNDWATER MODEL
ISLA DE UTILA, HONDURAS

4.4 Predictive Simulations

The objective of the numerical groundwater model for East Harbor was to assess the sustainability of future groundwater supply development to meet the needs of forecasted population growth. The focus of predictive simulations was the small, localized zone of fresh groundwater northeast of Stuart Hill in the vicinity of well BCUT-4. To evaluate the sustainability of this limited area of fresh water as a means to meet short-term water supply demands, pumping from one well at a rate of 24 gpm (131 m^3/day) for 1 year was simulated. The pumping well was simulated in both layers 1 and 2, the equivalent of a 11-meter screened interval. Municipal wells and private wells were not simulated. The model results were assessed using model-calculated hydraulic head, drawdown, and volumetric water budgets.

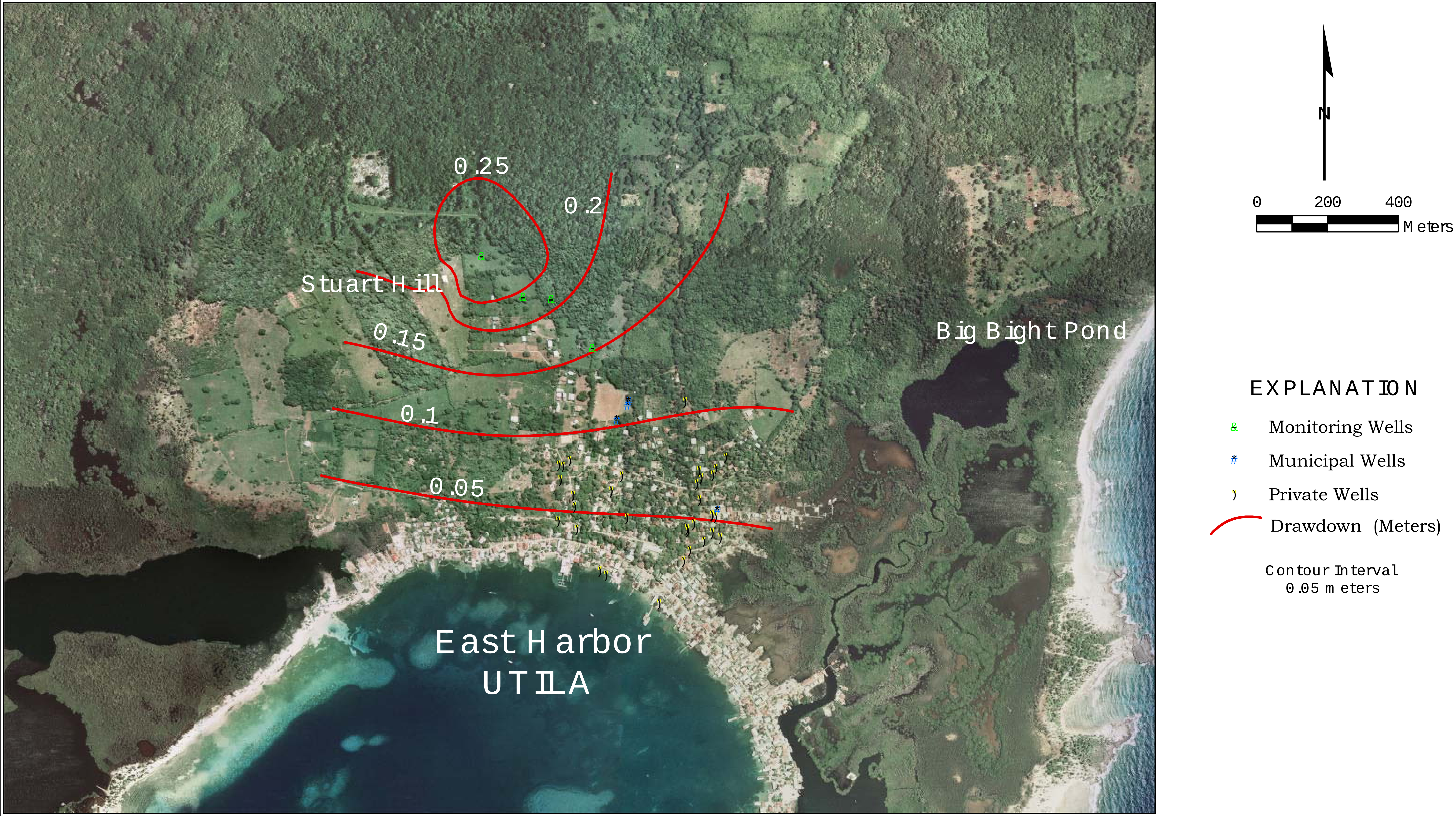
Prior to running simulations, the volume of fresh groundwater that is potentially available northeast of Stuart Hill was calculated based on the estimated volume of aquifer (155,000 m^3) and the estimated specific yield of the karsted coral limestone (0.3). Total volume of groundwater available in this local region based on this analysis is 46,500 m^3. At a rate of 131 m^3/day (24 gpm), the maximum period of pumping that could be sustained in this region is slightly less than 1 year (355 days). For the purposes of assessing sustainability, 1 year of pumping represents the maximum potential yield; factoring in the impacts on the hydraulic gradient, the overall water budget for East Harbor, and the associated drawdown will decrease this estimate. For perspective, it is important to note that the proposed new well pumping at 24 gpm represents a 50-percent increase in groundwater withdrawals from current levels, considerable increasing the budget deficit (Table D-1).

Model simulations were run to assess changes in gradient, hydraulic head, and the water budget in an attempt to quantify the impacts of the proposed pumping well. Results of the simulations are summarized below:

- Based on the model-calculated water budget, the increased water deficit caused by additional pumping may promote water quality degradation within 180 days. Groundwater withdrawn from the proposed well comes from three water sources: (1) approximately 30 percent from a reduction in the amount of fresh water available to discharge to the ocean, (2) 30 percent from capture of recharge, and (3) 40 percent from a reduction in aquifer storage. Reducing the amount of fresh water discharge to the ocean allows salt water to migrate upward. Depleting aquifer storage in a system where the fresh water lens is negligible also encourages intrusion of salt water, both laterally and vertically, as more saline water moves in to replace the fresh water. Capture of recharge is the only renewable source of water for the well.

- Figure D-6 shows drawdown after 180 days of pumping at 24 gpm (131 m3/day). The stress of pumping propagates downgradient (toward the harbor), depleting the fresh water system and impacting other wells in the region. Fresh water begins to be replaced by salt water as the horizontal and vertical gradients are impacted.

- The aquifer system never reaches a new steady state condition. Drawdown in the pumping well and drawdown within the fresh water lens steadily increases throughout the simulation. Figure D-7 is a hydrograph of water levels within the pumping well.



BROWN AND CALDWELL

Figure D-6
DRAWDOWN AFTER 180 DAYS OF PUMPING
EAST HARBOR GROUNDWATER MODEL
ISLA DE UTILA, HONDURAS

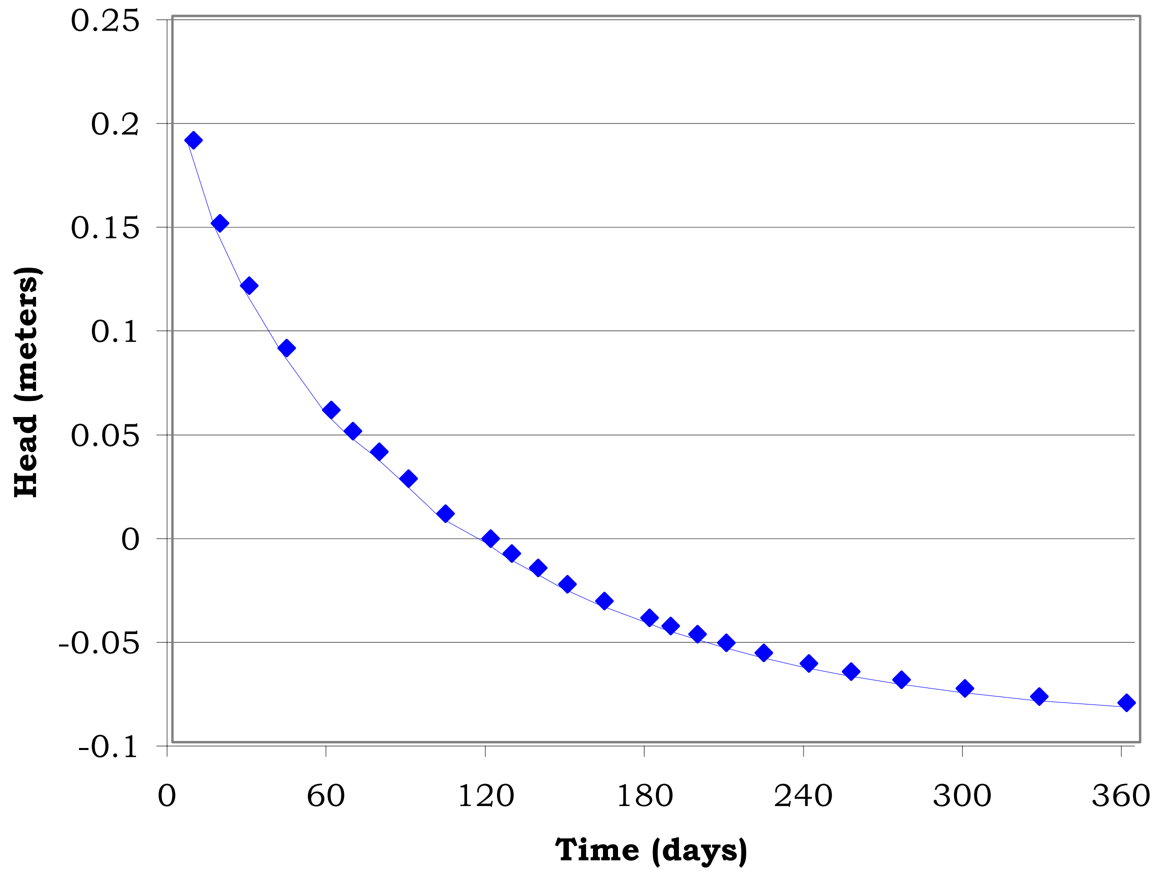


Figure D-7
HYDROGRAPH OF WATER LEVELS IN WELL BCUT-4
EAST HARBOR GROUNDWATER MODEL
ISLA DE UTILA, HONDURAS

BROWN AND CALDWELL

- Particle tracking was performed using MODPATH™ to assess the vertical movement of saline groundwater from layer 3 into the pumping well. Groundwater from layer 3 moved into the well within the first 40 days of pumping, and based on an analysis of cell by cell flows, accounted for approximately 9 percent of the water pumped from the well.

Evaluation of the model results suggest that limited water production of the localized fresh water zone is potentially available for short-term water supply demands for less than 1 year of continuous pumping. It is anticipated that the salinity of the pumped water will increase with time. Although it is not possible to stipulate an exact time when the salinity in the pumping well will increase to unacceptable levels, the impacts of pumping on the flow regime and the analysis of the water budget suggest that a range from 180 days to 1 year be used for planning purposes.

5.0 REFERENCES

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.

Pollock, D. W., 1989. *Documentation of Computer Programs to Complete and Display Pathlines using Results from the U.S. Geological Survey Modular Three-Dimensional Ground-water Model*, United States Geological Survey Open File Report 89-381.

Environmental Simulations, Inc., 1997. *Groundwater Vistas*.

APPENDIX E

Water Resources Management System Users Guide

WATER RESOURCES MANAGEMENT SYSTEM USER'S GUIDE

Utila, 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.

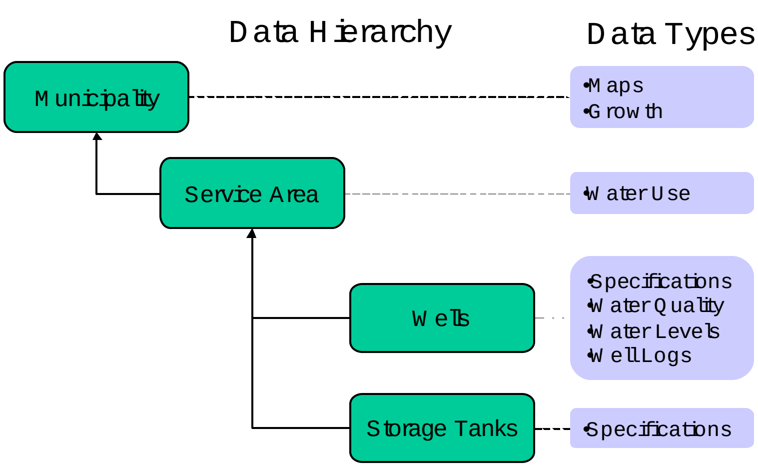

Figure 2-1. Data Organization

[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.

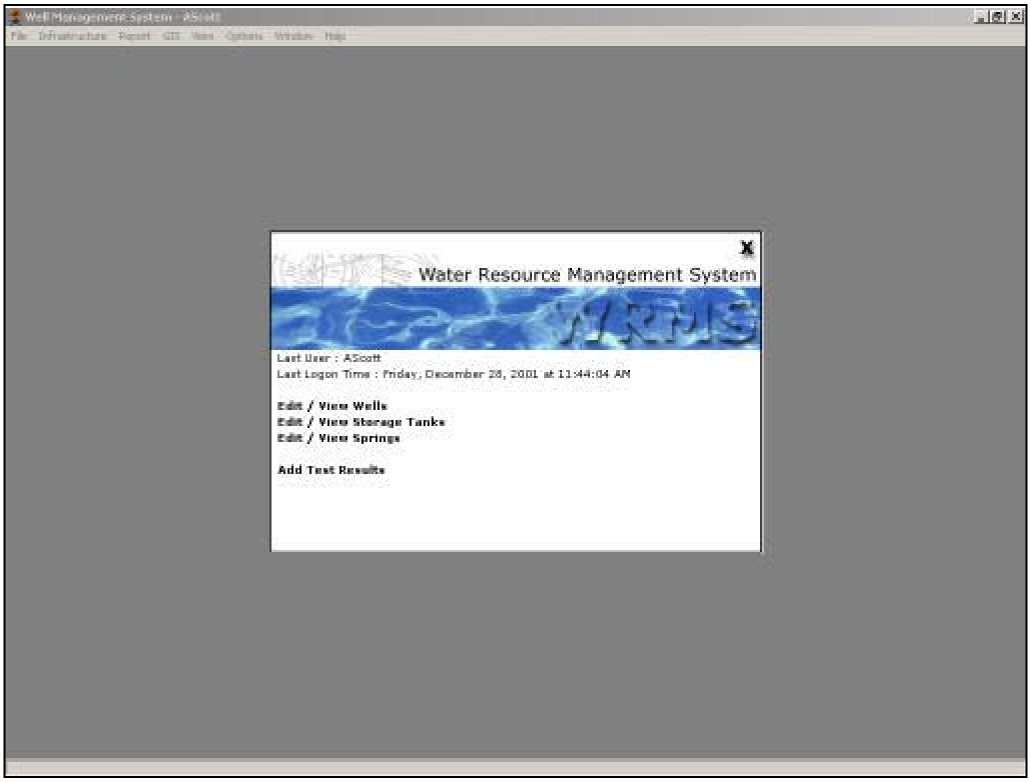

Figure 2-2. Startup Screen

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.

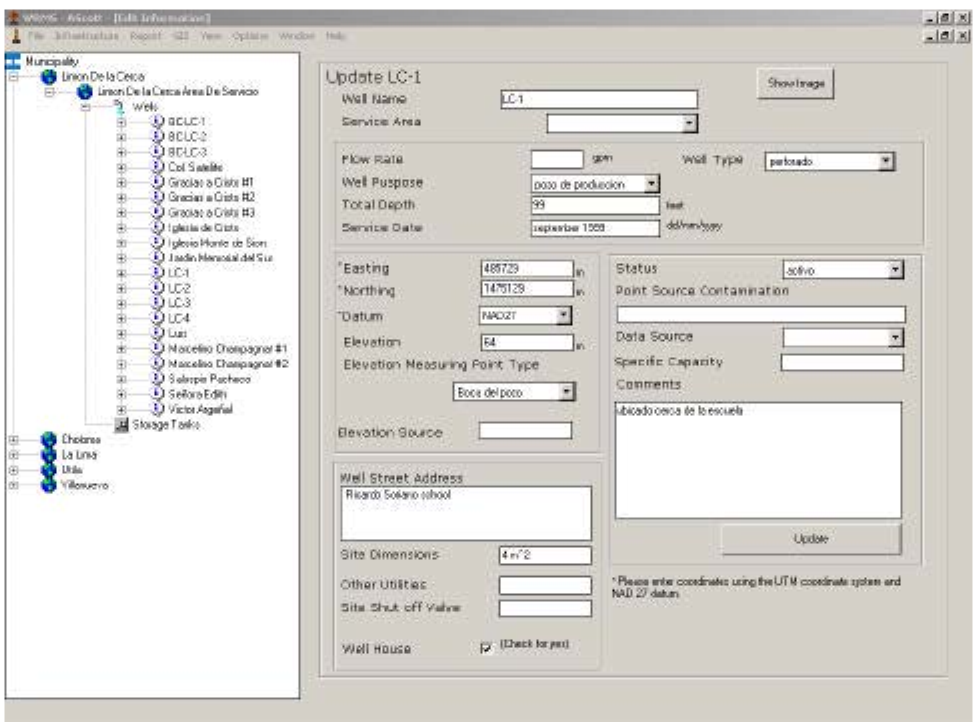

Figure 2-3. Interface Terms

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.

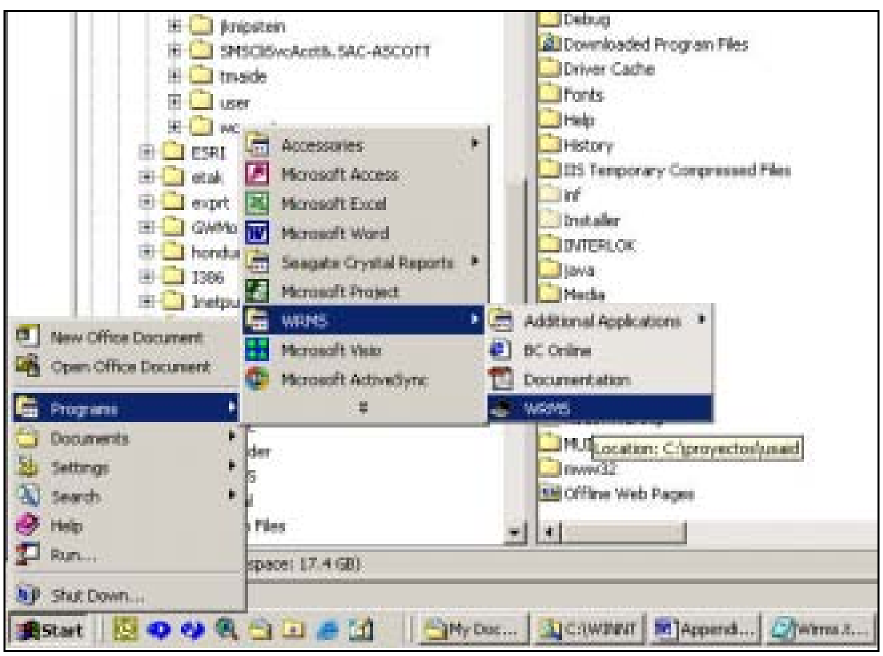

Figure 2-4. Starting the WRMS

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**.

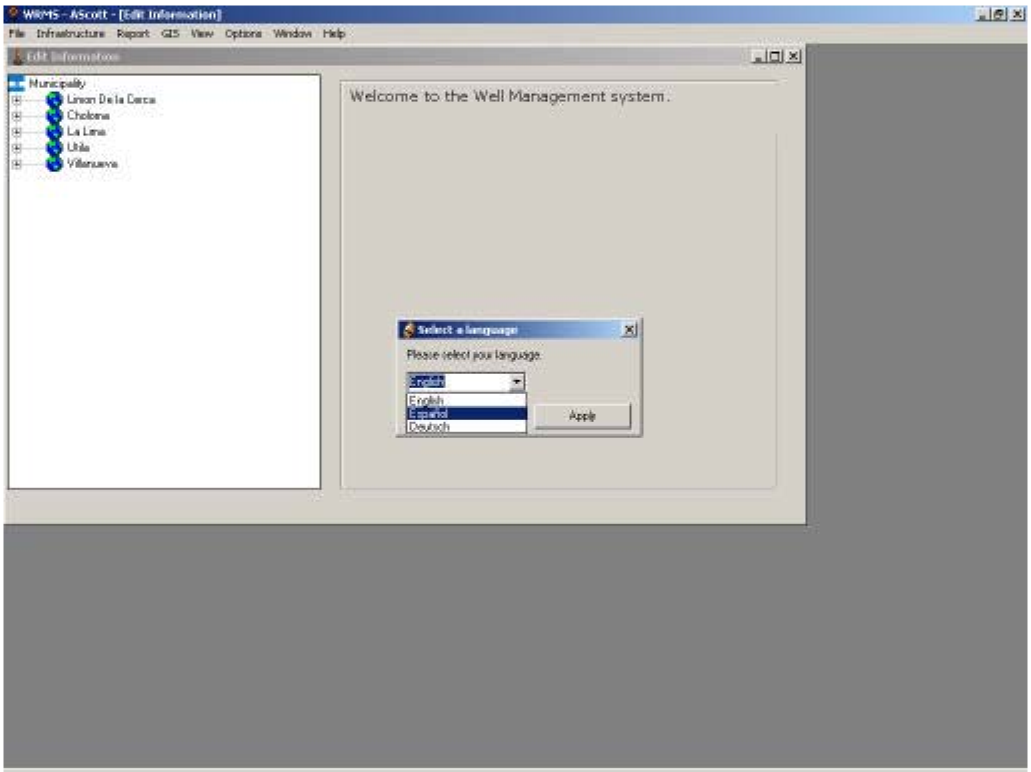

Figure 2-5. Changing the Language

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.

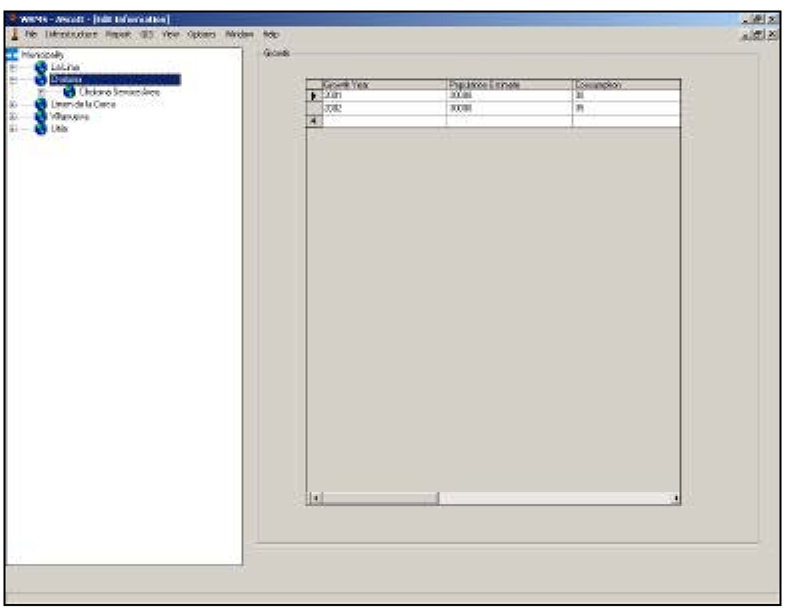

Figure 2-6. Predicted Growth Data Screen

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**.

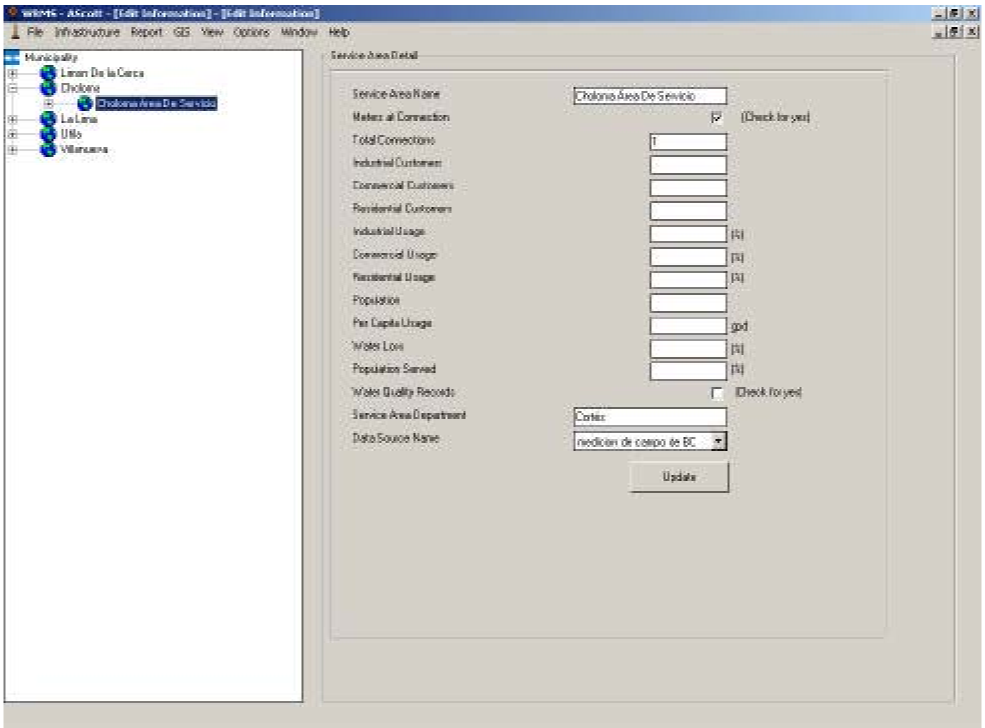

Figure 2-7. Service Area Data Screen

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.

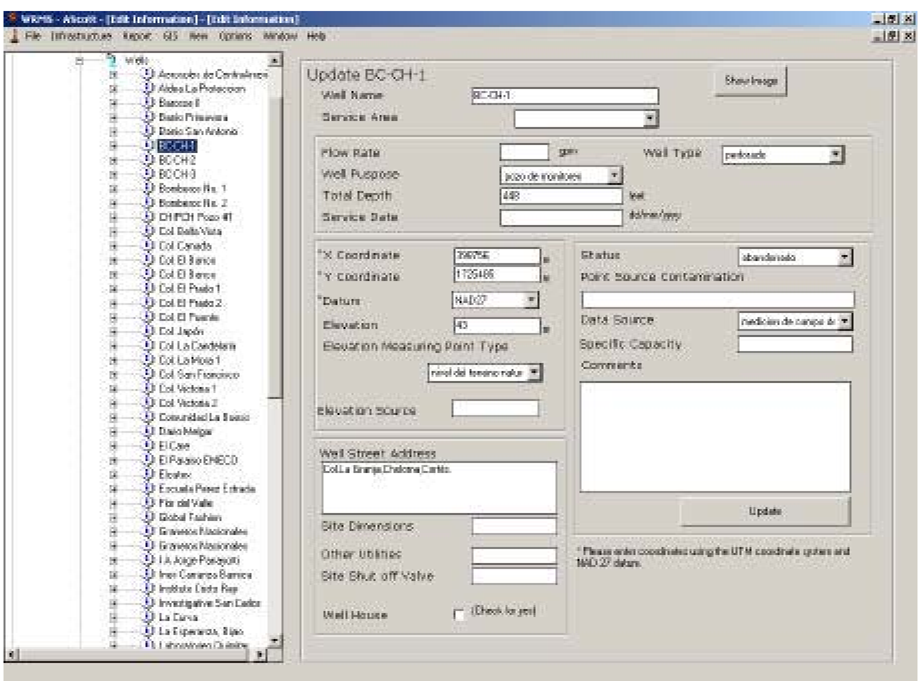

Figure 2-8. Well General Information

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.

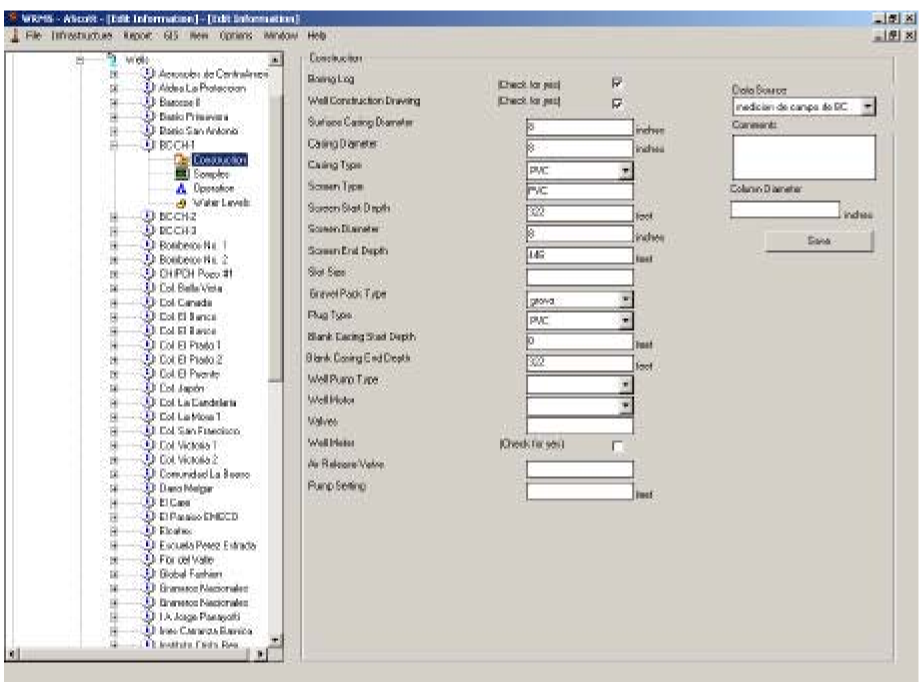

Figure 2-9. Well Construction Details Screen

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.

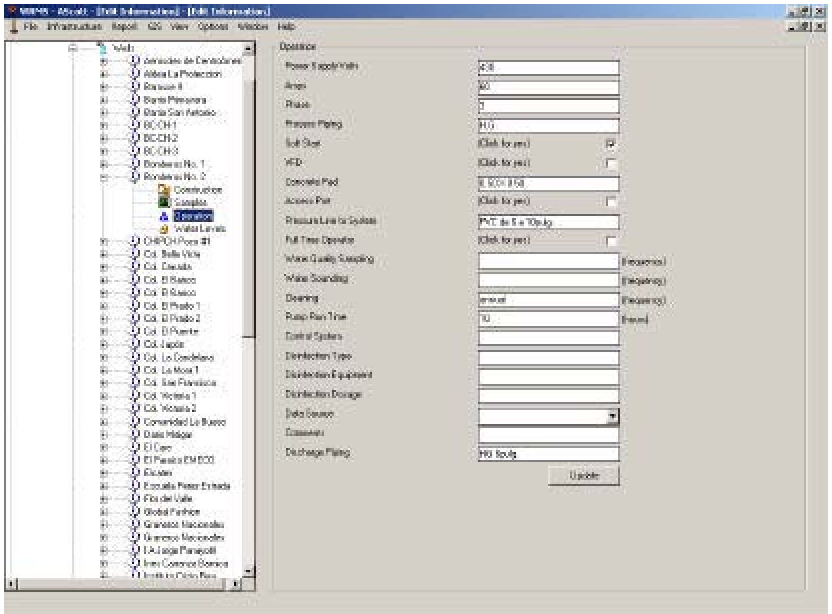

Figure 2-10. Well Operation Data Screen

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.

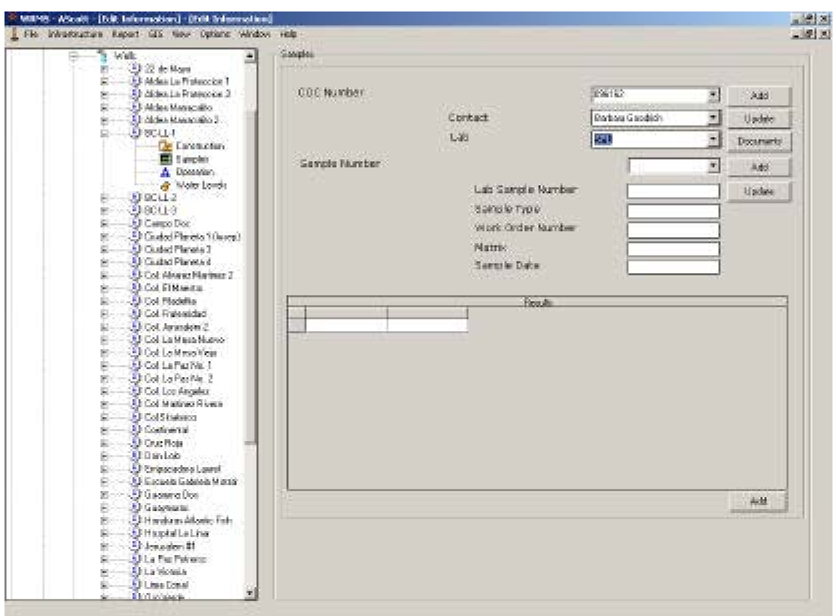

Figure 2-11. Initial Form for Water Quality Samples

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.

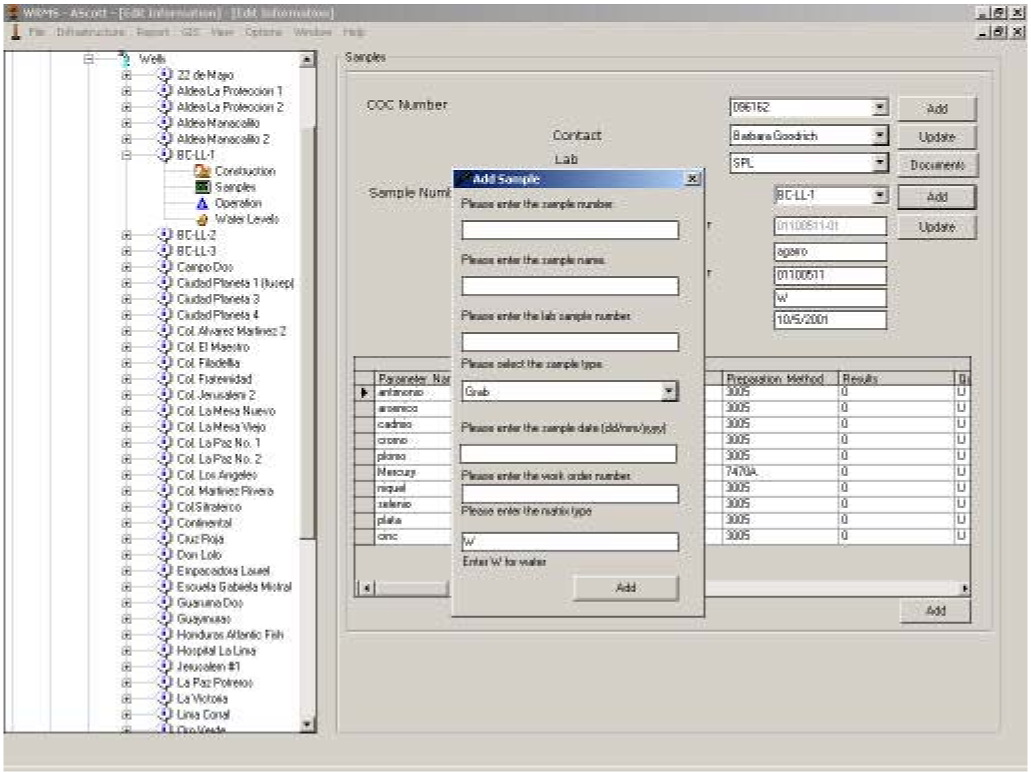

Figure 2-12. Sample Data Entry Screen

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.

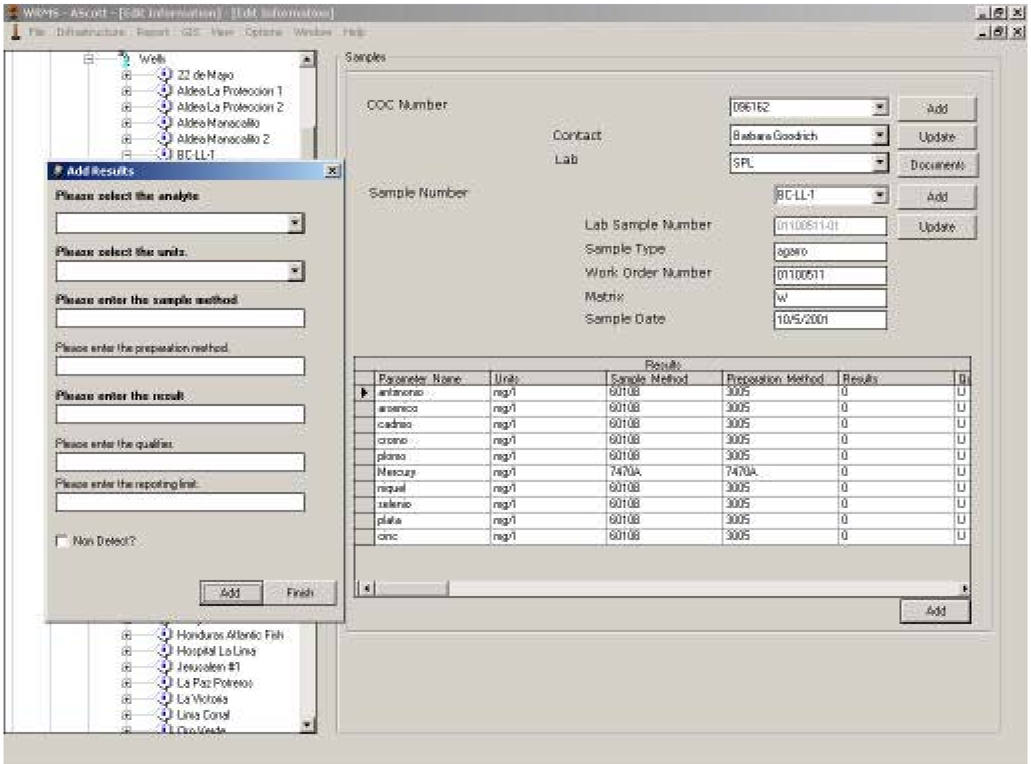

Figure 2-13. Analytical Results Data Entry Screen

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.

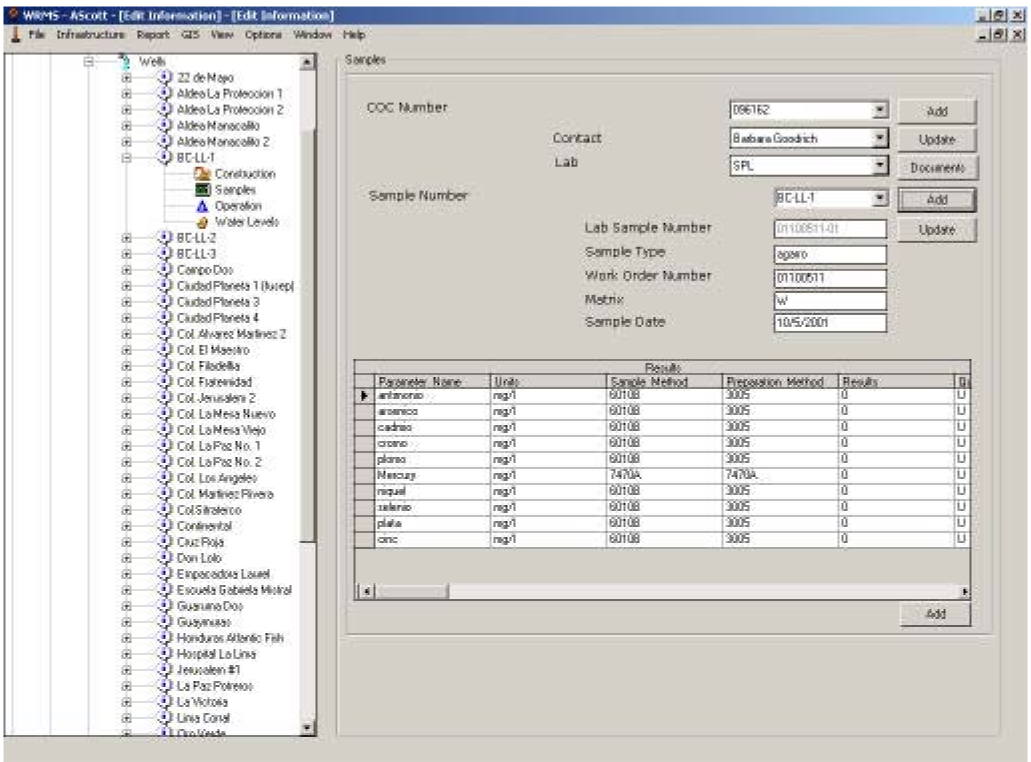

Figure 2-14. Analytical Results Table

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 <u>Water Levels.</u> 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.

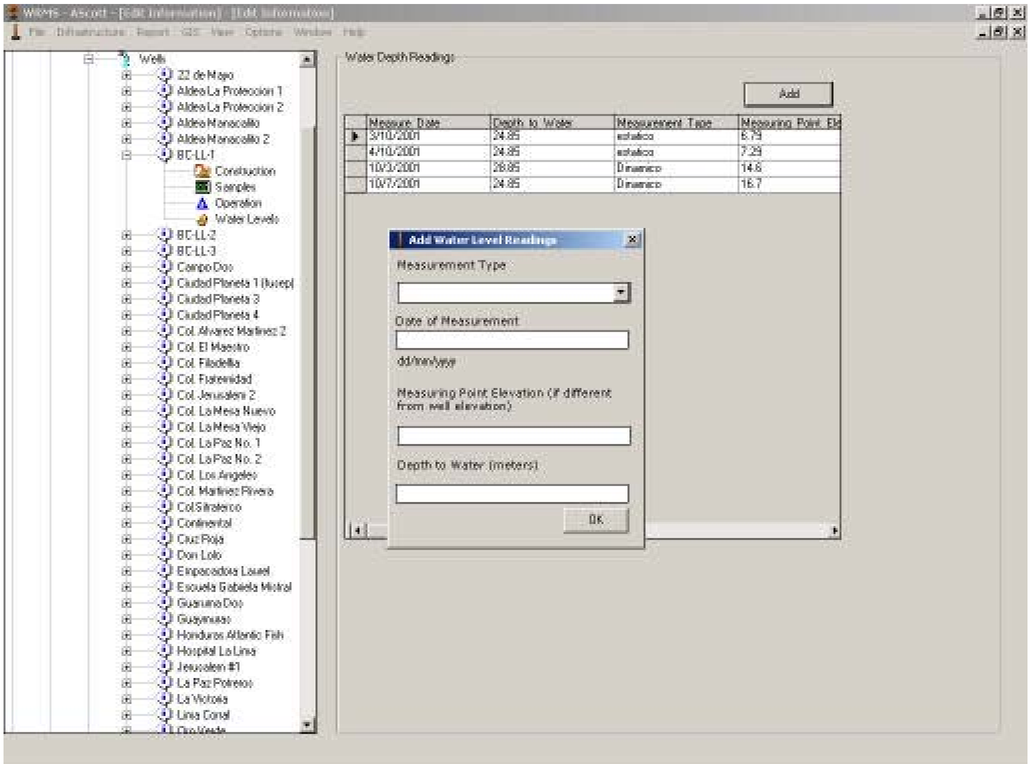

Figure 2-15. Water Level Measurement Data Entry Form

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.

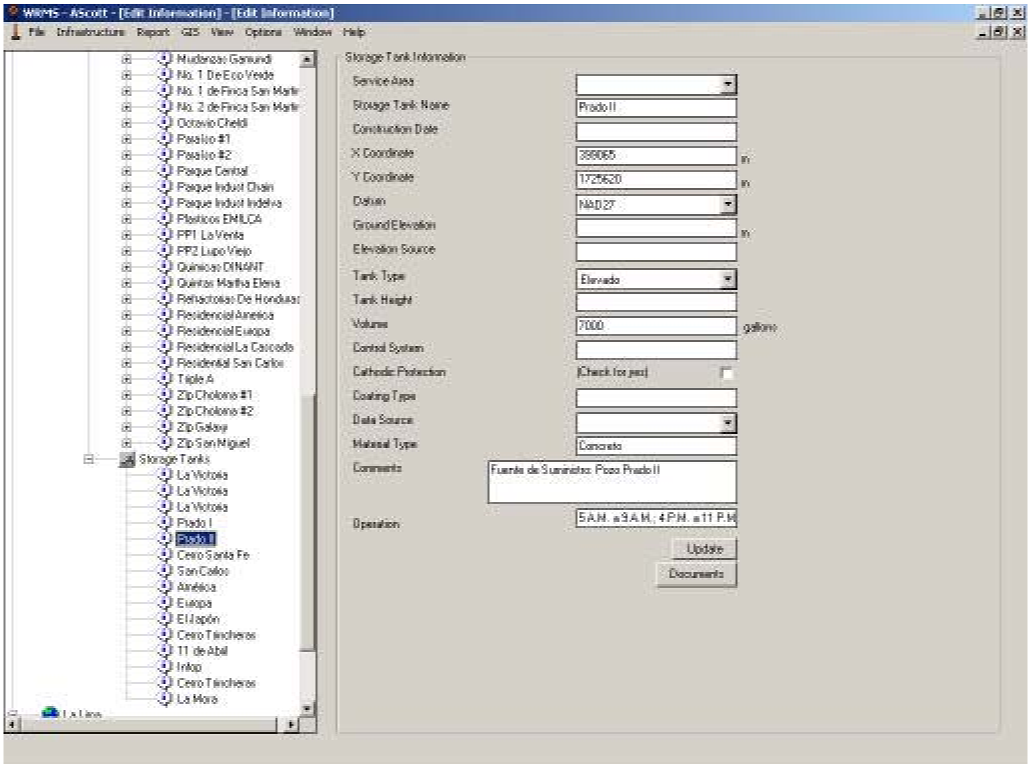

Figure 2-16. Storage Tank Data Entry Screen

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:

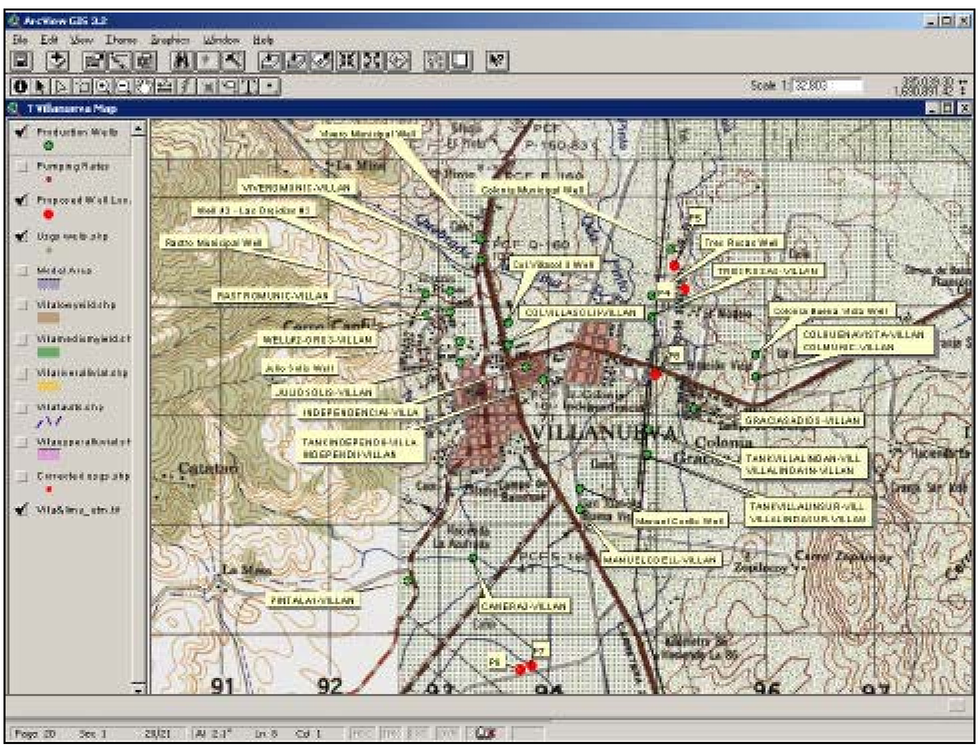

Figure 2-17. ArcView® Interface

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.

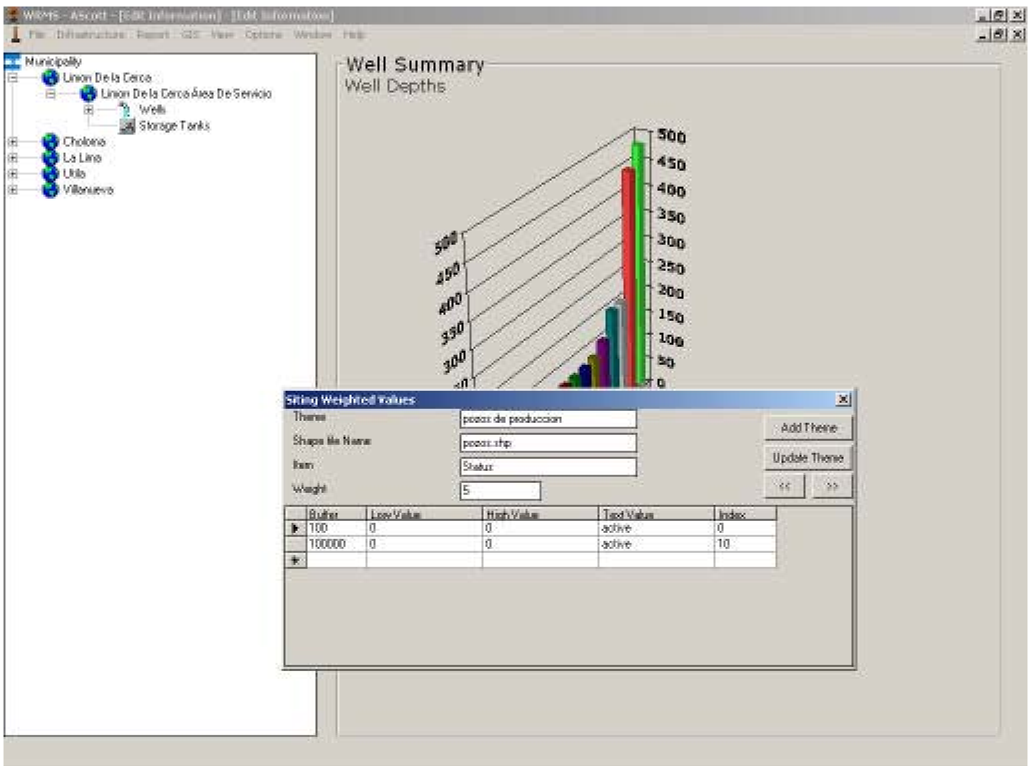

Figure 2-18. Well Siting Criterion Data Entry Screen

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

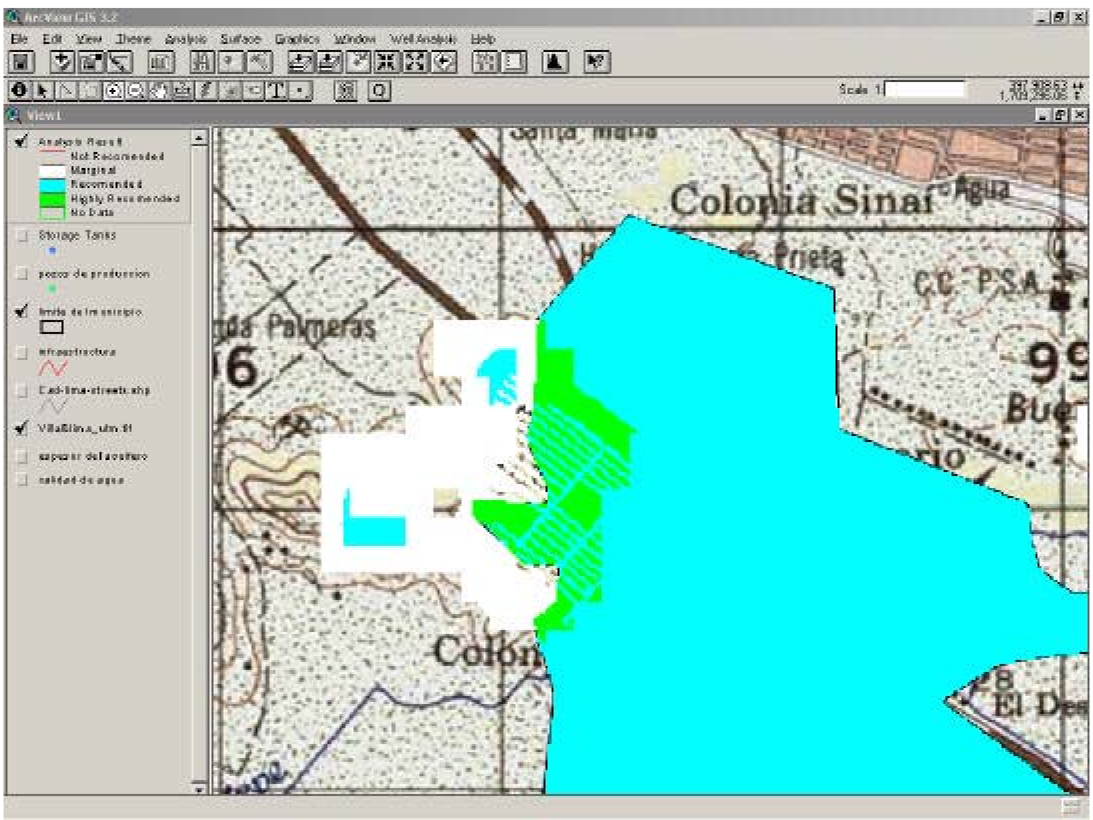

Figure 2-19. Well Site Prioritization Results

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 .

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.

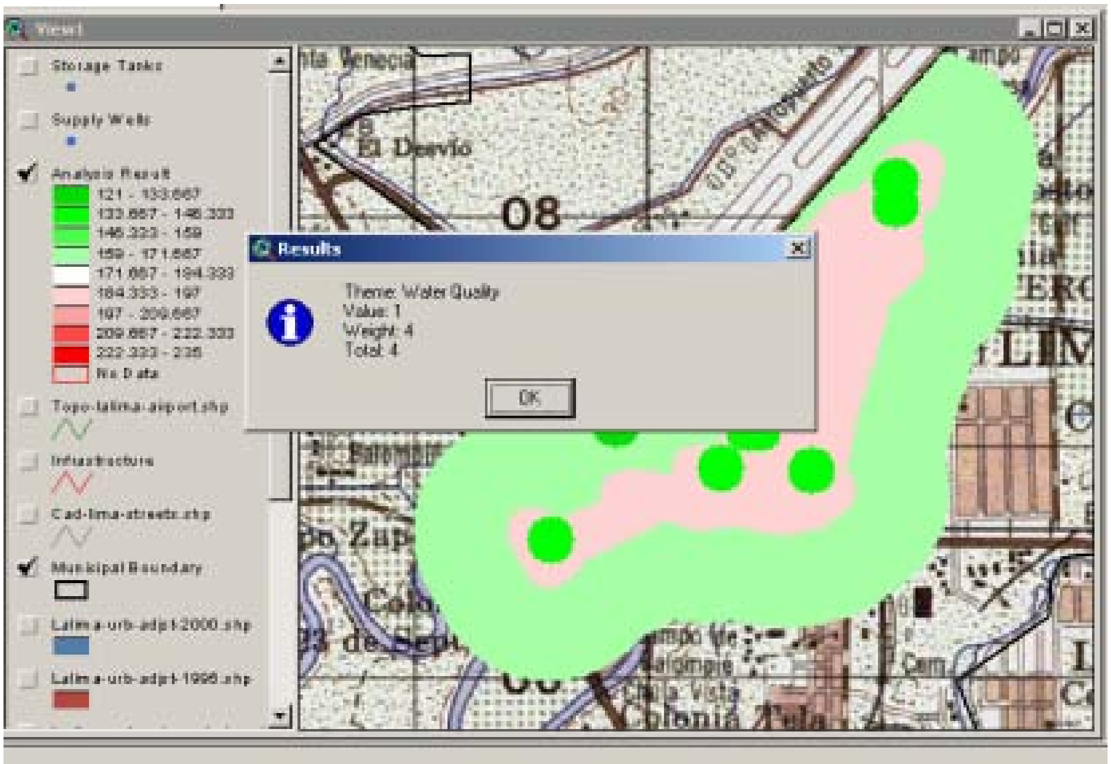

Figure 2-20. Using the Query Tool for Exploring the Siting Analysis

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.

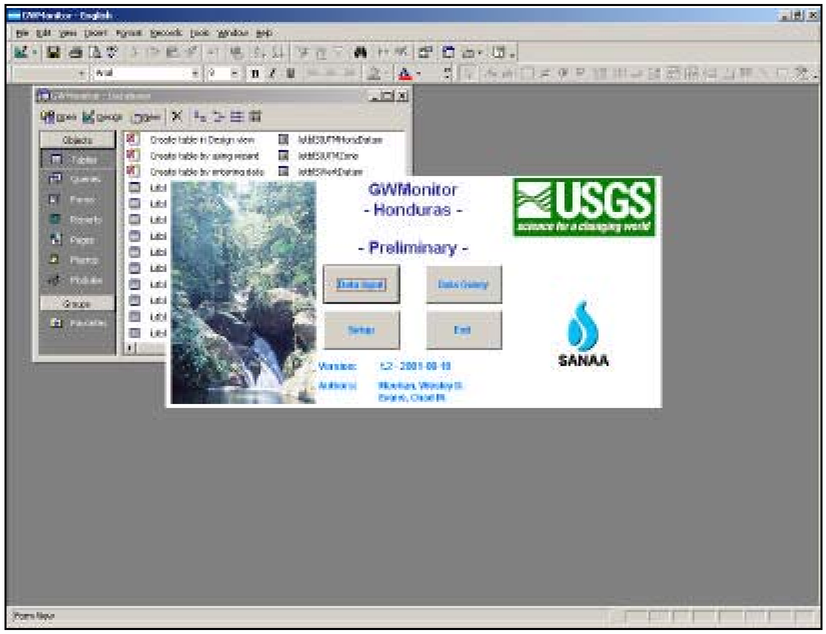

Figure 2-21. GW Monitor; the USGS Wells Database for Honduras

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.

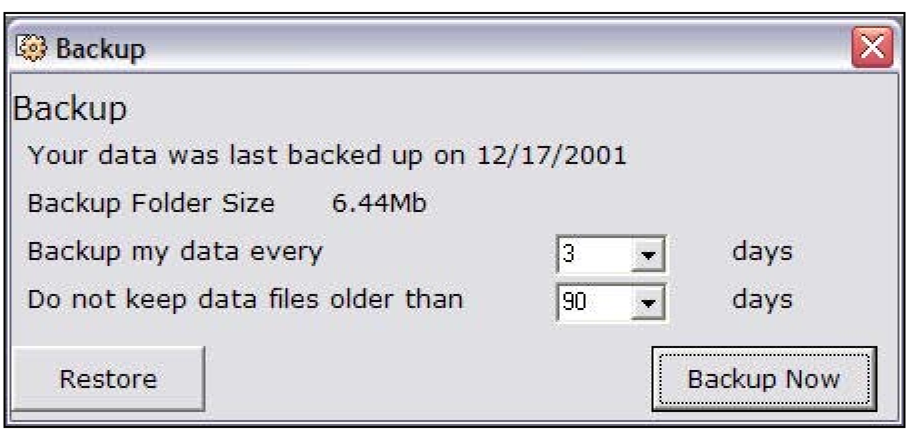

Figure 3-1. Backup and Restore Information

3.3.1.1 How to Backup Your Data. 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 How to Restore Your Data.

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.

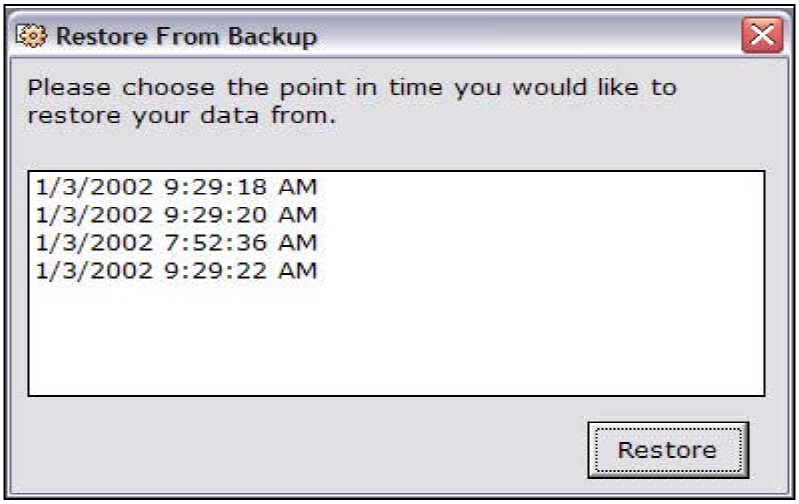

Figure 3-3. Restore from Selection of Backups

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.

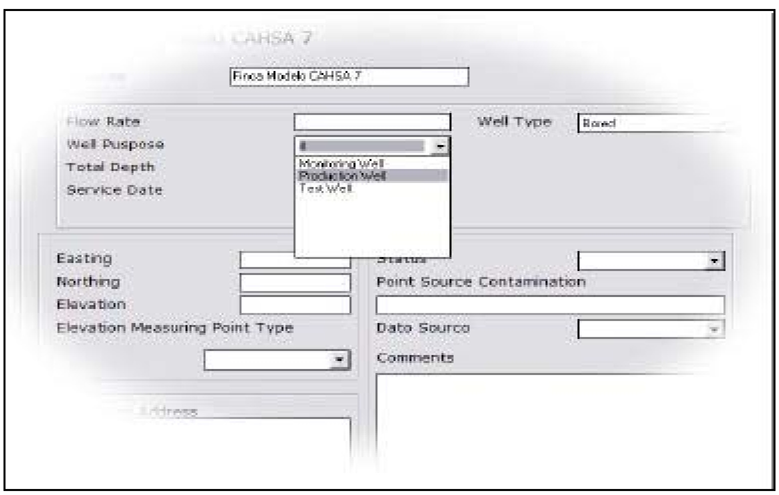

Figure 3-4. Well Purpose Drop-Down Menu Populated with Valid Values

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

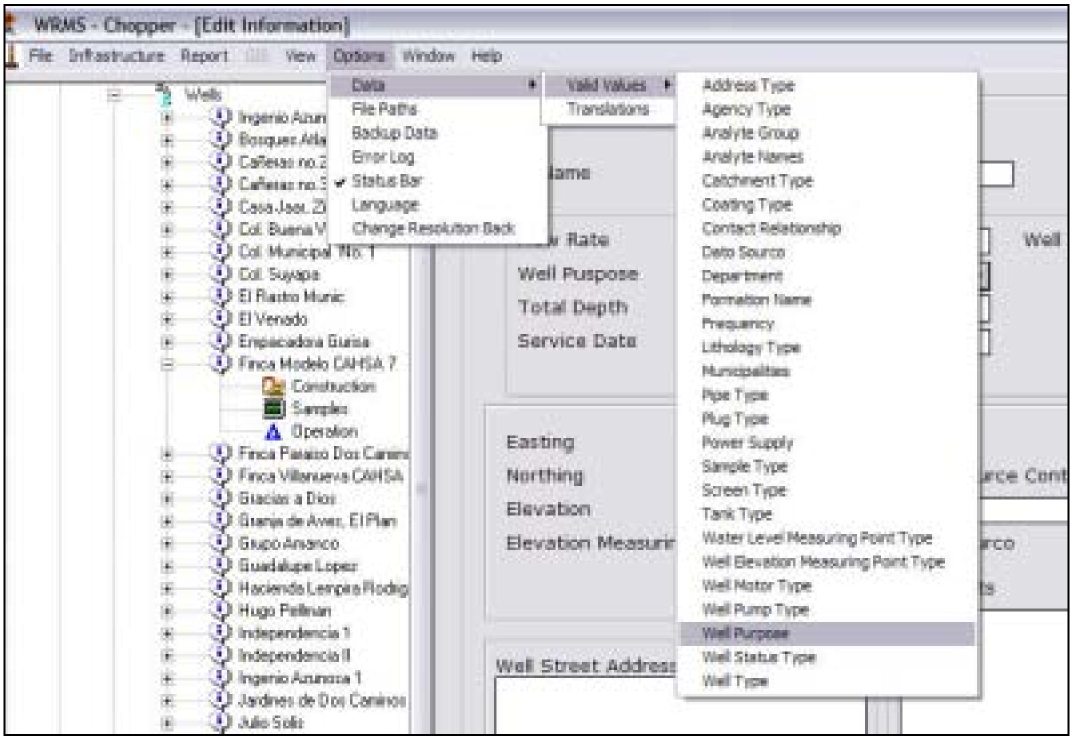

Figure 3-5. Valid Values Menu

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**.

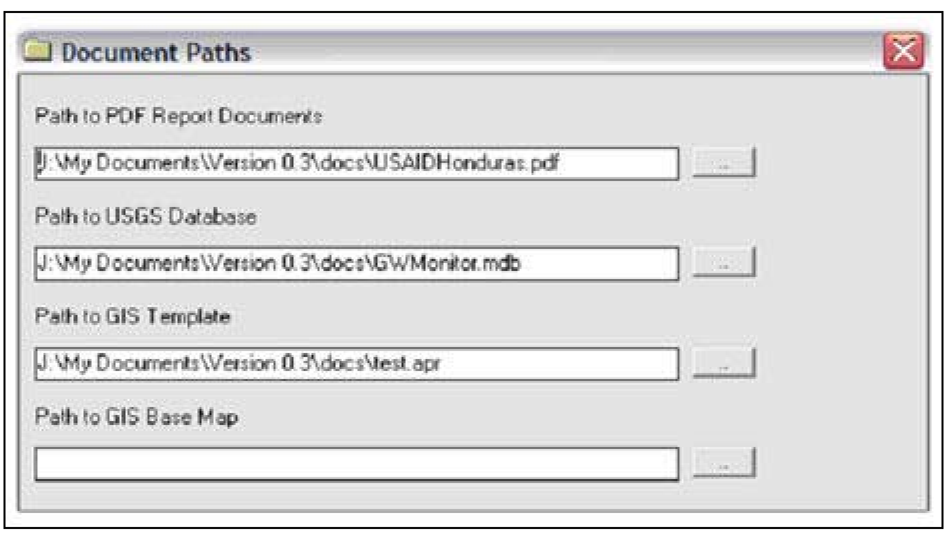

Figure 3-6. File Paths

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.

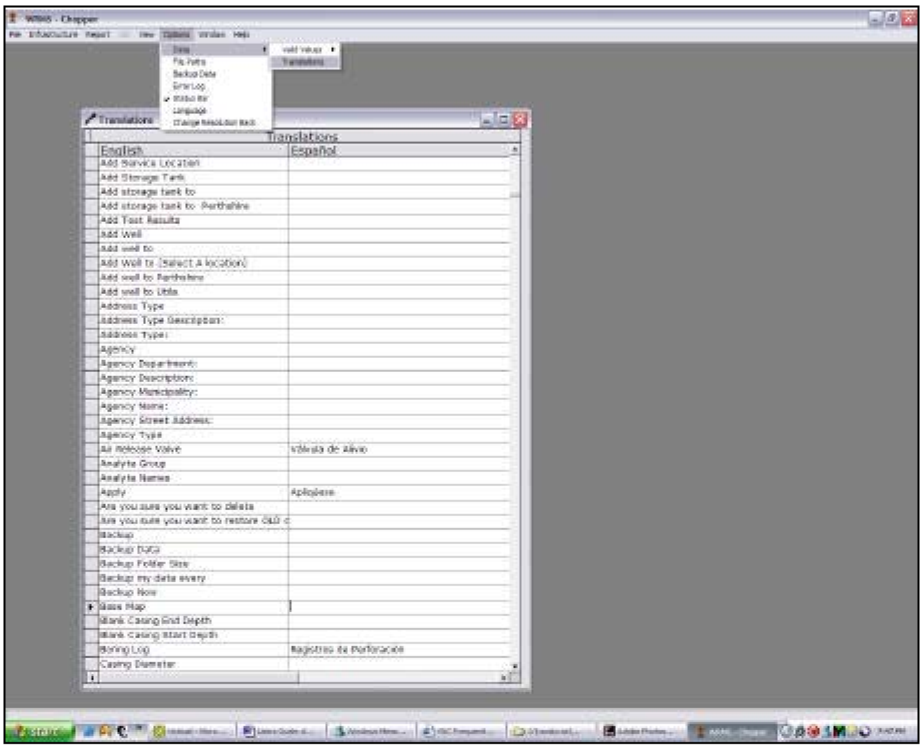

Figure 3-7. Translations Screen

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 F

Brown and Caldwell's Trip Reports

Brown and Caldwell's Trip Report

Utila, Honduras

May 24 through June 1, 2001

Introduction

A field investigation was conducted on the Island of Utila May 24 through June 1, 2001. The purpose of this trip was to collect information regarding the island's present water distribution systems and to identify possible locations for the installation of new groundwater supply and monitoring wells. Two Brown and Caldwell representatives, Jeff Nelson, Principal–in-Charge of the project and Task Manager, Jason Grant, visited the island. In addition, Brown and Caldwell held an informal meeting on May 31, 2001, to present their project to the community. Below is a summary of the information gathered during this visit.

Background

Utila is one of the three major islands making up the Bay Islands group located north of the Honduran coast in the Caribbean Sea, and approximately 18 miles north of the City of La Ceiba (Figure 1). Utila is roughly 8 miles long and varies between 1 and 3 miles in width. The total land area of the island is approximately 16 square miles. Almost all of Utila's population lives in the eastern third of the island, in an area called East Harbor. Approximately 6,000 permanent residents live here in East Harbor. Utila also is a popular tourist destination for vacationers, sports fishermen, backpackers and SCUBA divers, with 12 dive shops located within 1 mile of each other. The island attracts approximately 1,500 to 1,800 visitors each month. Additionally, a fishing village is located off Utila's southeastern coastline. The village is located on two cays, or small islands. Pigeon (Lower) Cay and Jewel (Upper) Cay are home to approximately 1,000 residents. Population projections predict that Utila's permanent resident population could expand to 25,000 inhabitants within the next 20 years. (The previous population statistics were obtained from information presented to Brown and Caldwell by the United States Agency for International Development (USAID).)

Based on geologic and topographical maps and field observations, Utila is primarily composed of limestone, a sandy silt, and volcanic rock/soil. The western two-thirds of the island is low-lying areas that contain mangrove swamps and savannas. The eastern third of the island contains two hills, Stewarts Hill located approximately one mile inland from the center of East Harbor, and Pumpkin Hill located on the northeastern coast about 4 miles from East Harbor (Figure 2). Pumpkin Hill is the highest point on the island at 243 feet above sea level (ASL), with Stewarts Hill being the second highest at 167 feet ASL. The land between these two landmarks contains rolling hills covered in dense jungle. Additionally, the entire island is surrounded by an extensive coral reef. This reef is as shallow as a few feet in some places, and its edges contain underwater walls extending to over 2,000 feet below sea level. One unique feature on the island is a canal connecting the island's north and south coasts. The canal was hand-dug as a means to create a shorter route between the two coastlines to assist the fishing community. According to locals, the canal is approximately 50 years old, and varies in depth from 2 to 12 feet and in width from 5 to 15 feet.

Currently, USAID is sponsoring three municipal projects on Utila. The groundwater project being development by Brown and Caldwell, the design and construction of a new water distribution system, and the design and construction of a new landfill for the island. The landfill and distribution systems have already been designed by the engineering consulting firm Black and Veatch. One of Brown and Caldwell's objectives for this groundwater project is to identify appropriate locations for water wells to supply the new water distribution system.

Municipal Water Distribution System

The current municipal water supply system consists of one 25,000 gallon elevated water storage tank, three groundwater wells and approximately 3,775 meters of 4-inch polyvinyl chloride (PVC) piping. This system is situated on the eastern third of the island and connects to approximately 700 homes, businesses and restaurants. The minimum and maximum hydrostatic pressure in the system is 14.2 and 23.4 pounds per square inch (psi), respectively. The system is divided into three sections, which are turned on and off throughout the day by the municipality. The island does not have a fire department, thus no hydrants or fire fighting demands are present within the system. Fires are fought with bucket brigades using seawater.

The three wells, known as Well 1, 2 and 3, are situated adjacent to the island's soccer/baseball field and are all within 150 feet of each other (Figure 3). Mr. Henry Brown of French Harbor, Roatan, constructed these wells about 20 years ago. The wells consist of a 12-inch outer PVC casing and a 1 1/4-inch inner PVC casing. The PVC casings are not screened and the walls of the wells are not lined; the well heads are unprotected and are basically open holes. There are no known construction records of these wells and the original diameter of the boreholes are unknown due to the well walls caving in over time. Water is pumped from each well by a 1 horsepower (hp) submersible pump. Water is pumped up through a 1 1/4-inch PVC discharge line from each well. These three pipes converge into a 1/1/4 inch PVC well transmission that feeds up into the bottom of the 25,000 gallon elevated water tank through a check valve. Water is gravity feed to the distribution system from the tank through a 4-inch PVC pipe. There is no filtration or disinfection of the water before entering the distribution system. It takes from 8 to 11 hours to fill the tank, and 1.5 to 3 hours to drain the tank. Additionally, according to a report prepared by Mr. Steve Bond for the organization Water for the People, the each wells average production rate is 38,000 to 40,000 gal/day. Electrical power for these pumps is provided by the island's power plant, which consists of three diesel generators that operate from 6 a.m. to 12 a.m.

Well Characteristics

The total depth of Well 1 was measured at 54 feet below ground surface (bgs), and the total depths of Wells 2 and 3 were both measured at 59 feet bgs; these wells are the deepest known wells to have been drilled on Utila. The elevations of the wellheads have not been surveyed, however, based on available topographic data, it is estimated that the wells are all between approximately 80 and 100 feet ASL. Brown and Caldwell is making arrangements to survey the well head elevations. In Wells 2 and 3, depth-to-water was measured at 48 feet bgs, while in Well 1 depth-to-water was measured at 46 feet bgs. This corresponds to 11 feet of water in the bottom of Wells 2 and 3, and 8 feet of water in the bottom of Well 1. Based on the assumption that the base of these wells are between 80 and 100 ft ASL, the groundwater table is approximately 30 to 50 feet ASL in this area. In order to perform these measurements, a drop tube was installed to avoid entangling the electric water level meter in the pump and associated electrical wiring.

The well heads for Wells 2 and 3 are covered by a removable 2 foot by 2 foot square concrete slab, and Well 1 is covered by a 2 foot by 2 foot wooden slab. Inside the well heads, the 12-inch PVC casing is not sealed, thereby offering no well head protection.

Temperature, electric conductivity (EC) and pH were measured from grab groundwater samples collected from the three wells. For Wells 1, 2 and 3, temperature was measured at 27.7°C, 30.4°C and 28.8°C, respectively; EC was measured at 2,080 micromhos/cm (μmhos/cm), 2,040 μmhos/cm, and 2,070 μmhos/cm, respectively; and pH was measured at 7.20, 7.04 and 7.05, respectively. In addition, nitrate and nitrite were measured in each of the grab groundwater samples. Nitrite was not detected in any of the three wells, while the samples from Well 1 and 3 contained 1 part per million (ppm) nitrate and the sample from Well 2 contained 2 ppm nitrate. In order to perform these measurements, the municipality installed sample valves on each of the 1 1/4-inch PVC pipes that discharges from its associated well.

During the measurement of the water levels in these three wells, it was discovered that the pumps within the wells were only situated one foot into the water column. Because of the placement of these pumps, the municipality assumed that the wells were running dry during operations, not realizing they had approximately 8 to 11 feet of a water column to draw from. Upon Brown and Caldwell discovering this, we recommended to the municipality to lower the pumps approximately 5 feet. Once the pumps were lowered, the water supply increased and the distribution of water to the community improved. This was the first time in the last 4.5 years that the position of the pumps had been adjusted.

The community also collects water from on open well called the Old Indian Well (Figure 3). This well is a brick lined vault 5 feet by feet in length and width, and 10 feet deep. During the time of this visit, 1.3 feet of water was measured in the bottom of the well. Residents collect water by dropping buckets into the well and then transferring the water into other containers to be carried home. A grab groundwater sample was collected and analyzed from this well. This sample resulted in a pH of 5.79, an EC of 398 μmhos/cm, temperature of 28°C, 0 ppm nitrites and 2 ppm nitrates. The elevation of the top of this well is estimated between 10 and 30 feet ASL.

In addition to the municipal water supply tank described above, an abandoned 36,000 to 40,000 gallon water tank (dimensions estimated to be between 25 and 30 feet in diameter and 8 feet deep) is situated on Stewarts Hill. This tank is presently inactive and in need of repair. The tank was built approximately 10 years ago to increase the community's water supply. However, the wells that were constructed to feed this tank were improperly located and became unusable due to poor water quality (high salinity) within 1 year. The PVC pipeline that connected this tank to the municipal system is still in place.

Private Water Supply Systems

Many of the residents of Utila have constructed their own private wells to supplement the municipal water distribution system. Approximately 75 homes and businesses have constructed their own wells. These wells are all hand dug to a depth of approximately 25 to 30 feet bgs, until approximately five feet of standing water is present within the hole. A 12-inch PVC casing is placed within the hole and is rested upon a large rock. Rocks are then placed in a conical manner up the hole, around the 12-inch PVC casing. This conical structure is sealed with concrete and soil is backfilled on top of the concrete. A 1- to 2-inch PVC casing and 0.5 to 1 hp submersible pump is placed within the 12-inch PVC casing. Usually a well house is constructed at the surface of the well. No filtration or disinfection occurs prior to using the water from these private wells. To develop these wells for use, the well driller will pump out the turbid water until a visually clear effluent is produced.

During this visit, one of these private wells, owned by Mr. Jernigan Cooper, was sampled and analyzed (Figure 3). The groundwater sample resulted in a pH of 6.91, an EC of 1,950 μmhos/cm, a temperature of 26.1°C, 0 ppm nitrites and 2 ppm nitrates. The well was constructed to 28 feet bgs and is depth-to-water is believed to be 23 feet bgs. A confirmation water level measurement could not be taken at this time. The well head elevation of this well is estimate to be between 30 and 60 feet ASL.

The private hand dug wells are constructed in one of two different subsurface formations, being either limestone or sand. According to a local Utilian Mr. Jem Williams, the wells constructed in sand produce better water quality for a longer period of time than the wells constructed in limestone. No known construction records exist for these wells.

The private wells constructed can either feed one or several homes, depending on the owner's prerogative. In addition, a local Utilian, Edwin Williams, has constructed his own water distribution system using three wells in supplying water to approximately 30 homes. Mr. Williams uses a combination of vanilla and Clorox to clean his wells every three months. In addition, he offers to clean his customers' tanks with sodium bicarbonate, vanilla and Clorox once a month. During the proposed schedule visit of June 17, Brown and Caldwell will collect data regarding the operation of Mr. Williams distribution system, including well locations, elevations, depths, and production rates.

Utilians have also constructed numerous cisterns adjacent to their homes for the collection of rainwater during the rainy season.

The water distributed in the municipal system from private wells, or collected in cisterns is primarily used for domestic or utility purposes, which include cooking, cleaning and the bathrooms. In addition, many Utilian homes pump seawater to be used in toilets. Bottled water is generally purchased for drinking purposes. There are two island distributors of bottled water, and bottled water is imported from the mainland.

Surface Waters

During this visit, Brown and Caldwell did identify one surface spring and was told of the existence of others (Figure 3). A water sample collected from this spring produced the following results: pH 7.02, 2,450 μmhos/cm EC, 32.6°C, 0 ppm nitrite and 0 ppm nitrate. In addition, underwater caves are reported to be located on the eastern coastline of the island and a freshwater undersea spring is reported to be located on southeastern coastline. During the next visit, additional data will be collected on other surface springs, and an attempt will be made to collect a water sample from the undersea spring to verify that freshwater is entering the ocean.

Aquifer Issues

The primary concern regarding groundwater quality on Utila is salt-water intrusion. On islands, due to fresh water being less dense than salt water, the fresh water aquifer exists as a "lens" on top of the salt water. The boundary between these two waters is called the salt water/fresh water interface. When the rate of groundwater water being replenished through rainfall equals the rate of groundwater being extracted by wells or lost through other environmental factors, the environment is in equilibrium. However, when fresh water is being pumped out the aquifer at rates greater than can be replenished by rainfall, the freshwater/saltwater interface begins to grow further inland and salt-water intrusion occurs. The movement of the interface is felt greatest in the coastal region of islands.

In order to evaluate the salt water content of a well, EC is measured. In general, the total dissolved solids (TDS) concentration of water is generally 60% of the EC. The higher the EC, or TDS, the more salty a water is becoming. The EC of salt water is typically 50,000 μmhos/cm, while rainwater is typically 2 to 100 μmhos/cm. The average EC of Utila's three municipal wells is 2,060 μmhos/cm, or approximately 1,240 ppm TDS. Thus, there appears to be an adverse impact of the groundwater due to the elevated TDS concentration. The United States Environmental Protection Agency (USEPA) secondary drinking water regulation for TDS is 500 ppm. (http://www.epa.gov/safewater/mcl.html#d_dbps)

A preliminary evaluation of the results of the water levels within Utila's three municipal wells suggests the possibility of a large supply of groundwater yet to be harvested. As previously stated, the elevation of the water table at these wells was approximately 30 to 50 ft ASL. Groundwater theory suggests that in an island's subsurface, for every foot the fresh water table is above sea level, 20 to 40 feet of freshwater exists below seal level. Thus, the possibility exists for freshwater to extend over 1,000 ft below sea level.

In October 1993, Servicio Autonomo Nacional de Acueductos y Alcantarillados (SANAA) conducted a hydrogeologic study of Utila. Through this study, SANAA estimated that the aquifer's recharge potential was between 25 and 40 percent of the total annual precipitation, which was assumed to be 2,000 mm/year. Using the more conservative estimate of 25 percent recharge potential, or 500 mm/year, it was calculated that the aquifer has a potential annual recharge volume of 1,250,000 cubic meters. This report also stated that Utila's aquifer is limited to approximately 2.5 square kilometers.

Preliminary Proposed Drilling Locations

According to Utilian local, Mr. Shelby Williams, when a watershed leads to a lowlands that contains red mangroves, the most salt tolerant of all mangroves, wells drilled in that watershed produce brackish water. However, if a watershed leads to cat-tails, wells drilled in that watershed produce high-quality freshwater.

The northwestern and western watershed of Stewarts Hill lead towards red mangrove, while its eastern and northeastern water lead towards cat-tails. With a few rolling hills, the potential exists for excellent well locations in the area northeast of Stewarts Hill (Figure 2); however, this area is occupied by a dense jungle with limited access. This area could possibly serve as future drilling locations once Utila's road system is expanded. In addition, the new water supply system being funded by USAID includes a 250,000-gallon water tank to be located on Stewarts Hill.

Given the geographical constraints and the configuration of the water distribution system, it is likely that the area between Stewarts Hill and the soccer field, southeast of Stewarts Hill, will be a primary target for either monitoring or water supply wells (Figure 2). Several land owners in the vicinity have given a verbal agreement to allow access to the property to drill. This location is ideal because the municipal distribution network is located close by and the abandoned water tank is also nearby.

Additional Studies Being Performed

There are or have been a few other environmental studies on Utila. Presently, the organization Programa de Maneja Ambiental de las Islas de la Bahia (PMAIB) is preparing to release the results of their 2 year investigation on Guanaja, Roatan and Utila. The study predominantly focused on the salt-water ecosystem surrounding these islands and found the primary concern is the eutrophication of areas of the coral reef surrounding Utila. A major cause of the eutrophication is the raw sewage entering the ocean due to the absence of a wastewater treatment facility on the island. In addition, PMAIB produced some excellent aerial photos of the island. PMAIB also produced Catastro (land-use) maps of Utila, which Ingeniera Gracia Lopez of FUNDEMUM is presently revising. These maps could prove helpful in identifying well locations and land ownership of possible drilling locations. Brown and Caldwell has also asked Ingeniero Carlos Flores of USAID to request copies of these aerial photos and catastro maps from PMAIB.

Other organizations that have conducted studies on Utila include the USGS, which surveyed the locations of 38 wells, and SANAA, which conducted a hydrogeologic study of the island in 1993. In addition, Mr. James Gaborel, a local Utilian has collected rainfall data for the last 23 years. From his data, Utila has received an average rainfall of 87 inches, or 2,214 mm. In addition, the average yearly temperature of Utila is 81°F, or 27°C. Another Utilian, Shelby Williams, has created the Bay Island Conservation Association (BICA) is an effort to form an environmental watch-dog group for the island. Mr. Williams has been successful in ensuring that developers take into consideration environmental impacts of their projects and has begun requiring environmental impact studies (EISs).

Community Meeting

On Thursday, May 31, Brown and Caldwell and USAID staff were invited by the Mayor of Utila, Monty Cardenas, to hold a community meeting and present the scope of work and project objectives for Brown and Caldwell's groundwater study. Speakers at the meeting included Mayor Cardenas, Carlos Flores (USAID), Jeff Nelson and Jason Grant (Brown Caldwell). Approximately 40 members of the community attended. Private well owners in attendance were asked to place their name on a list of wells to be tested and surveyed by Brown and Caldwell during the next trip. Additionally, Mayor Cardenas was asked to select two members of his staff to be trained by Brown and Caldwell in project sustainability aspects. Mayor Cardenas was also going to ask the two next mayoral candidates, Alton Cooper and Kelsey Cooper, to select two members of their future staff to be trained.

Proposed Scope of Work for Next Trip

Brown and Caldwell anticipates to perform the follow items during the next trip to Utila:

- Sample the private water wells identified on the list being compiled at City Hall and look for additional wells not yet identified.
- Survey the well head elevations for all wells included in this study.
- Identify and obtain permission from landowners of possible future drilling locations.
- Initiate training local personnel on procedures and equipment to sample water supply wells.
- Explore for areas that contain freshwater springs and underwater springs where fresh water is entering the ocean.
- Conduct surface geophysics to assist in identifying drilling locations.

BROWN AND CALDWELL'S TRIP REPORT

Utila, Honduras

June/July 2001

Introduction

This trip report will present a summary of additional field activities conducted by Brown and Caldwell representatives on the Bay Island of Utila during June and July 2001. These activities included: locating and sampling additional water supply wells, conducting a surface geophysical survey and a topographical survey, surveying the island for fresh water discharges and springs, and training local personal in the use of field sampling techniques and equipment. In addition, a meeting was held regarding issues surrounding the pending GIS/database system being created for Utila. Summaries of these activities, as well as a discussion into other relevant project issues, are presented below.

Water Supply Wells

Brown and Caldwell has identified a total of five municipal water supply wells, MW 1, MW 2, MW 3, the Old Indian Well, and MW Cay, and 34 private water supply wells, PW 1 through PW 34 (Figures 2 and 3) on the Island of Utila. Data collected from these wells included: total depth, depth-to-water (dynamic water level), pH, temperature, electric conductivity, nitrate and nitrite concentrations, UTM coordinates and approximate age. A summary of the information collected is presented in Table 1. Please note the data collected from some wells was limited due to the lack of availability of the information and obstacles encountered in the field.

The primary analytical measurement concerning Utila is the electric conductivity (EC) of groundwater. In general, EC is used as an indicator for total dissolved solids (TDS) concentration; TDS is approximately 60 percent of the EC. Water samples taken from the island's wells produced EC measurements ranging from 201 to 2,450 microsiemens per centimeter (μS/cm). A preliminary review of the data suggests that low EC groundwater is present in certain vicinities of the populated section of the island. However, this area also contains numerous septic tanks, which leach into the groundwater directly below. In some cases, the septic tanks are as close as 10 feet to the private wells. Water samples obtained from the island's wells produced nitrate concentrations ranging up to 50 parts per million (ppm). The United Sates Environmental Protection Agency (EPA) national primary drinking water regulation for nitrate is 10 ppm. (http://www.epa.gov/safewater/mcl.html#d_dbps)

Surface Geophysical Survey

Brown and Caldwell subcontracted with Mr. David Slaine, P.G., of Terra-Dynamics Consulting, Inc., to conduct a surface geophysical survey. Mr. Slaine visited Utila from June 22 through June 25, 2001, with a Geonics EM 34 Terrain Conductivity Meter (EM 34). The EM 34 measures the conductivity of a subsurface at depths up to 60 m bgs, or approximately 200 feet bgs. Areas of low conductivity would be candidate drilling locations. During this trip, Mr. Slaine trained Brown and Caldwell's Honduran team member, Ing. Milton Sagastume of ATICA, in the use of the EM 34. Ing. Sagastume completed the surface geophysical survey on June 29 through July 2, 2001. A total of 99 locations, GEO 1 through GEO 98, were included in this survey (Figures 2 and 4). During both trips, local Utilian Mr. Jem Williams assisted the field team. A report being prepared by Mr. Slaine regarding the findings of this geophysical survey is pending.

Topographical Survey

A topographical survey of various locations on the island, including several well heads, was conducted by Mr. Reinaldo Velasquez on June 29 through July 2, 2001. The topographical data is still in the process of being analyzed. However, one measurement of immediate interest is the elevation of the baseball/soccer field in which the three municipal wells are located. Mr. Renaldo surveyed this field to be approximately 13.8 meters above sea level (ASL), or 45.3 feet ASL. Based on the measured dynamic water levels of approximately 48 feet below ground surface (bgs), the groundwater table at the baseball/soccer field is approximately 3 feet below sea level.

Fresh Water Springs

Two areas of the island were investigated for the evidence of surface seepage of fresh water, the island's major canal and Big Bigth Pond (Figure 6). There was no evidence of fresh surface water entering either of these locations, nor was there any change in vegetation from a mangrove swamp, which could indicate a change in water quality. Nine locations throughout the canal, CA 1 through CA 9, and several within Big Bigth Pond, primarily on the western shoreline, were sampled for EC. However, these waters had a greater EC than the field meter could measure; the Oakton pH/Con 10 Meter can measure EC up 19.99 mS/cm.

Through conversations with local Utilian, Mr. Glenn Gabourel, it was discovered that a fresh water spring exists on the eastern coastline, which discharges under the ocean surface. The approximate location of this underwater spring is depicted on Figure 7, Spring 2. According to Mr. Gabourel, he has felt and seen fresh water mixing with sea water at this location. Also, a change in the type of coral reef is apparent, thus indicating a possible change in water conditions. Additionally, several other local Utilians have mentioned fresh water discharging under the ocean surface from the southeastern/eastern coastline of the island.

Geology

Additional geologic information was gathered through a conversation with local Utilian Mr. Harry Jackson. Mr. Jackson has drilled several wells on the island, three of which are located just north of the baseball/soccer field, in the vicinity that Brown and Caldwell is interested in investigating. These wells are drilled to between 60 and 80 feet bgs and could probably be utilized during the pending aquifer tests. In addition, Mr. Jackson has drilled a well 238 feet bgs. The head of this well is slightly above sea level, approximately 3 to 4 feet ASL, and is located near the southeastern coastline of Utila, approximately 100 m from the shoreline. According to Mr. Jackson, while drilling this well, a 9- to 10-foot-thick bedrock layer was encountered at approximately 150 feet bgs. Underneath this bedrock was a layer a smooth, shiny black pebbles, which Mr. Jackson said resembled river rocks, or rocks that had been smoothed by running water. It is Mr. Jackson's belief that an aquifer of fresh water exists below the bedrock, within the layer of black pebbles. This well remains as an open hole; however, this well was never entirely cased, and thus portions of the well walls could have caved in. Depth-to-water within this well is approximately 1 to 2 feet bgs.

Training and GIS/Database Meeting

On Tuesday, June 26, 2001, Brown and Caldwell task manager, Mr. Jason Grant, trained four local Utilians in groundwater monitoring techniques and equipment. These four Utilians, Mr. Hernan Escabar, Ms. Carolina Vindel Riettie, Mr. Nun Josué Lobo Pagoada, and Mr. Glenn Gabourel, were selected by Mr. Alton Cooper because he felt they would be excellent members of his municipal staff, should Mr. Cooper win the next mayorship, and because these individuals were genuinely interested in working on water issues for the island.

The training was divided into two parts, a classroom presentation/discussion and hands-on fieldwork. In the classroom presentation/discussion, these four individuals were trained in using an electric water level meter, using and reading nitrate/nitrite strips, and calibrating and reading a pH/EC/temperature meter. In the second part of this training, the four individuals were taken to the baseball/soccer field to measure water samples obtained from the three municipal wells, MW 1, MW 2 and MW 3. Initially, they were taught to place a drop tube into the well and take a depth-to-water measurement using the electric water level meter. They were also taught to use the electric water level meter to feel the bottom of the well, thus getting a total depth measurement. Then after obtaining a water sample from the well, each individual demonstrated the proper use and techniques in taking the analytical measurements of pH, EC, temperature, nitrate and nitrite. In addition, the individuals repeated these procedures on the Old Indian Well.

On Saturday, July 14, 2001, Brown and Caldwell database/GIS manager Mr. Allan Scott met with representatives of the municipality of Utila to provide an introduction to the data management system being developed. Attendees of this meeting were Mr. Monty Cárdenas, Mr. Alton Cooper, Ms. Carolina Vindel Riettie, Mr. Nun Josué Lobo Pagoada, and Mr. Kelly Alexander Marpel Ayala. Please refer to "Municipal Data Management System Briefings", prepared by Mr. Scott, for more information.

Project Issues

One major issue with regards to drilling on Utila is going to be receiving the land-owner's permission. The use of private land for public purposes has become a tricky issue, especially since the construction of the new airport, which has also created some mistrust by the Utilians in their municipal government. In order to mitigate this situation, Brown and Caldwell has begun asking permission of several land owners for the possibility of entering their land. Assisting Brown and Caldwell with this task are Mr. Alton Cooper, Mr. Jem Williams and Mr. Monty Cárdenas, the mayor of Utila. Several of these land owners have already given verbal permission, including Mr. Frank Morgan who owns the majority of the land Brown and Caldwell is interesting in investigating. In order to solidify this agreement, it will be necessary to show these land owners the exact location Brown and Caldwell desires to drill. It will then be the land owner's decision if this location is acceptable or if it should be moved to a more appropriate location. Once an agreement on the drilling locations has been reached, the land owner will sign a right-of-entry agreement with the municipality. Brown and Caldwell is in the process of drafting the right-of-entry agreement.

To date, no measurements have been taken regarding the volume of water being pumped from any of the islands' wells, nor on the water consumption patterns of the island. To quantify these parameters, it is suggested that a targeted metering program be undertaken. This program would include placing a water meter on each of the three municipal wells' pipelines. In addition, Mr. Alton Cooper and Mr. Monty Cárdenas have identified five to ten major private wells that distribute to restaurants and hotels, probably pumping more than 1,000 gallons per day (gpd). The remaining minor private wells primarily distribute water to single homes and might average a pumping rate of 100 to 200 gpd. Information regarding the pumping patterns of the major private wells could be acquired by selectively metering them with either an in-line meter or an ultrasonic meter.

To quantify the water consumption patterns of the community, two approaches should be taken. First, a 72-hour monitoring test of the municipal 25,000-gallon water tank should be performed. This test would entail taking water level measurements within the tank on an hourly basis for 72 hours. Then computations would be performed to calculate the total water volume distributed to the system, as well as graphs produced of the municipal water consumption patterns. The second approach would entail interviewing different members of the community who pump from their own private well to personal water tanks. Information obtained from these interviews could include the amount of water pumped on a daily and/or weekly basis, the frequency and duration of pumping, the volume of the personal holding tanks and the number of household members. This data would yield information regarding the average volume of water being pumped by the minor private wells, as well as give more accurate data regarding per capita water consumption on the island.

Table 1
Summary of Well Information
Bay Island of Utila, Honduras

Well ID	Well Owner	Grid	Easting (UTM WGS 84)	Northing (UTM WGS 84)	pH	Electric Conductivity (mS/cm)	Temperature (^oC)	Nitrate (ppm)	Nitrite (ppm)	Well Depth (ft bgs)	Depth-to-Water (ft bgs)	Approximate Age of Well (yrs)
MW 1	Municipaility	16Q	511164	1780085	7.12	2,190	29.7	2	0	53.0	44.1	20
MW 2	Municipaility	16Q	511195	1780125	7.11	2,250	30.5	1	0	54.6	48.5	20
MW 3	Municipaility	16Q	511197	1780137	6.98	1,964	30.0	1	0	57.0	48.9	20
Old Indian Well	Municipaility	16Q	511454	1779832	5.76	483	29.6	2	0	8.3	7.2	284
MW Cay	Municipaility	16Q	503868	1776774	7.00	746	31.0	----	----	2.5	1.4	5
PW 1	Jernigan Cooper	16Q	511005	1779919	6.91	1,950	26.1	2	0	28*	23*	3
PW 2	Eric Rose	16Q	511011	1779956	6.72	1,280	29.4	5	0	38.5	35.4	----
PW 3	Margaret Bodden	16Q	511178	1779929	6.80	783	30.6	5	0	29.1	27.3	----
PW 4	Austen Bodden	16Q	511148	1779887	7.23	554	33.2	0	0	18*	----	35
PW 5	Walter James	16Q	511192	1779810	5.86	415	29.5	----	----	28*	----	35
PW 6	Julie Bernard	16Q	511365	1779775	5.30	620	31.0	0	0	32*	----	15
PW 7	Dolores Cardona	16Q	511381	1779794	6.49	314	28.9	0.5	0	29*	----	6
PW 8	Cleygorn Angus	16Q	511363	1779781	5.98	201	30.1	2	0	26*	24*	34
PW 9	Charlie Ruby	16Q	511410	1779744	4.48	2,230	29.2	10	0	22*	----	2
PW 10	Modesto Cooper	16Q	511434	1779768	4.88	1,835	30.8	50	0	30*	----	>70
PW 11	George Gabourel	16Q	511457	1779754	4.38	663	28.8	5	0	12.1	7.1	22
PW 12	George Gabourel	16Q	511434	1779817	6.00	371	29.4	1	0	23*	----	21
PW 13	Will Hinds	16Q	511432	1779819	5.84	222	28.4	2	0	30*	----	30
PW 14	Tony James	16Q	511397	1779861	5.28	338	29.0	1	0	18*	----	18
PW 15	Dona Woods	16Q	511389	1779906	7.10	485	30.0	1	0	18*	----	18
PW 16	Lealond Wilson Howell	16Q	511402	1779924	6.17	635	29.5	----	----	20*	----	1
PW 17	Audley Banks	16Q	511396	1779944	6.76	935	31.6	4	0	24*	----	5
PW 18	Winey Banks	16Q	511471	1779982	6.76	935	31.6	0	0	20*	----	6
PW 19	Don Kerns	16Q	511357	1780140	7.50	1,754	30.2	1	0	53.5	52.6	3
PW 20	----	16Q	503892	1776772	9.70	296	29.8	----	----	4.0	2.5	0
Spring 1	----	16Q	509923	1780005	7.02	2,450	32.6	0	0	----	----	----

Notes:
UTM WGS 84 = Universal Tranverse Mercator World Geoditic System 1984 Datum
µS/cm = microsiemens per centimeter
^oC = degrees Celsius
ppm = parts per million
ft bgs = feet below ground surface
yrs = years
* = Not measured, owner supplied information

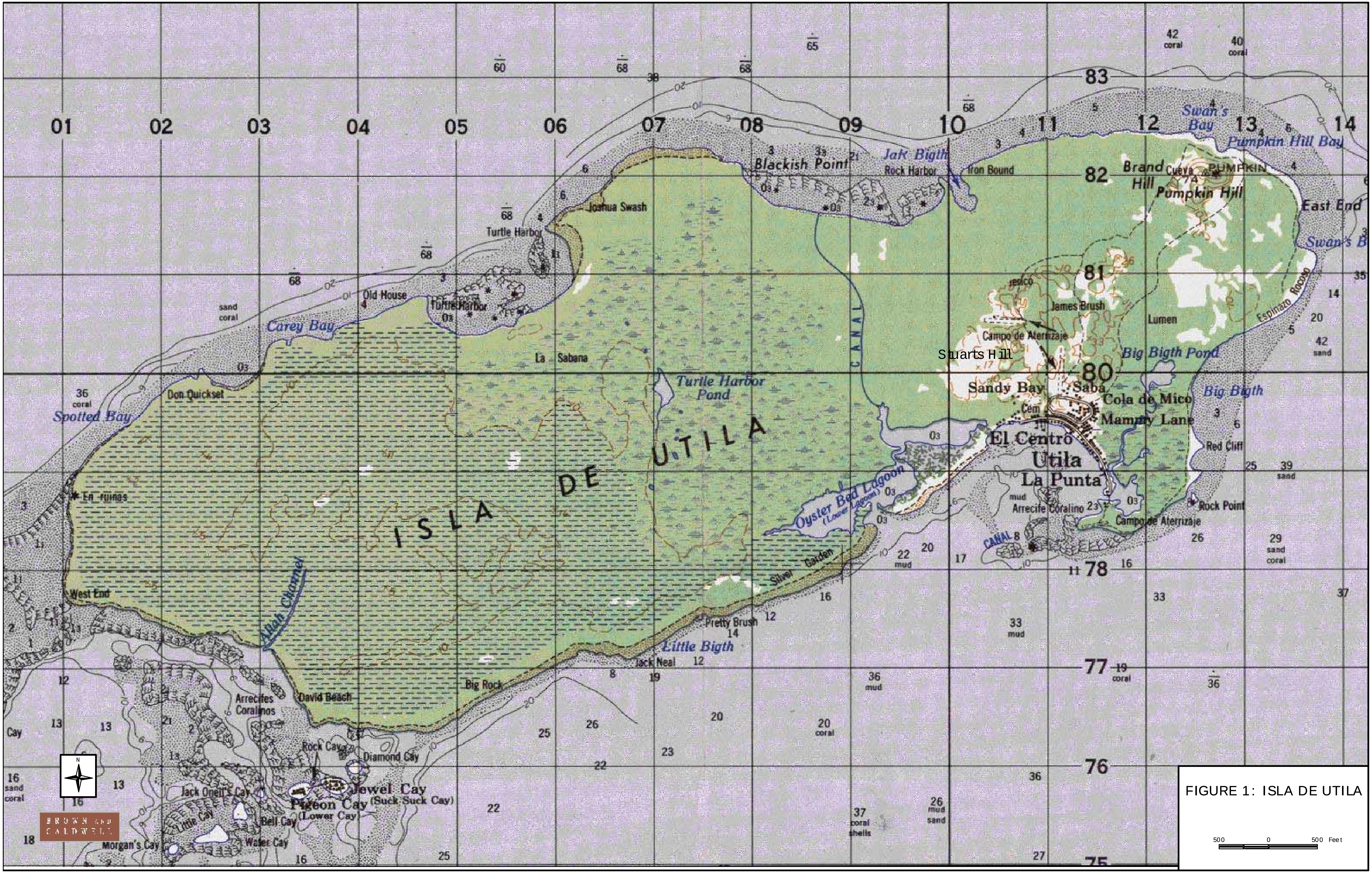

FIGURE 1: ISLA DE UTILA

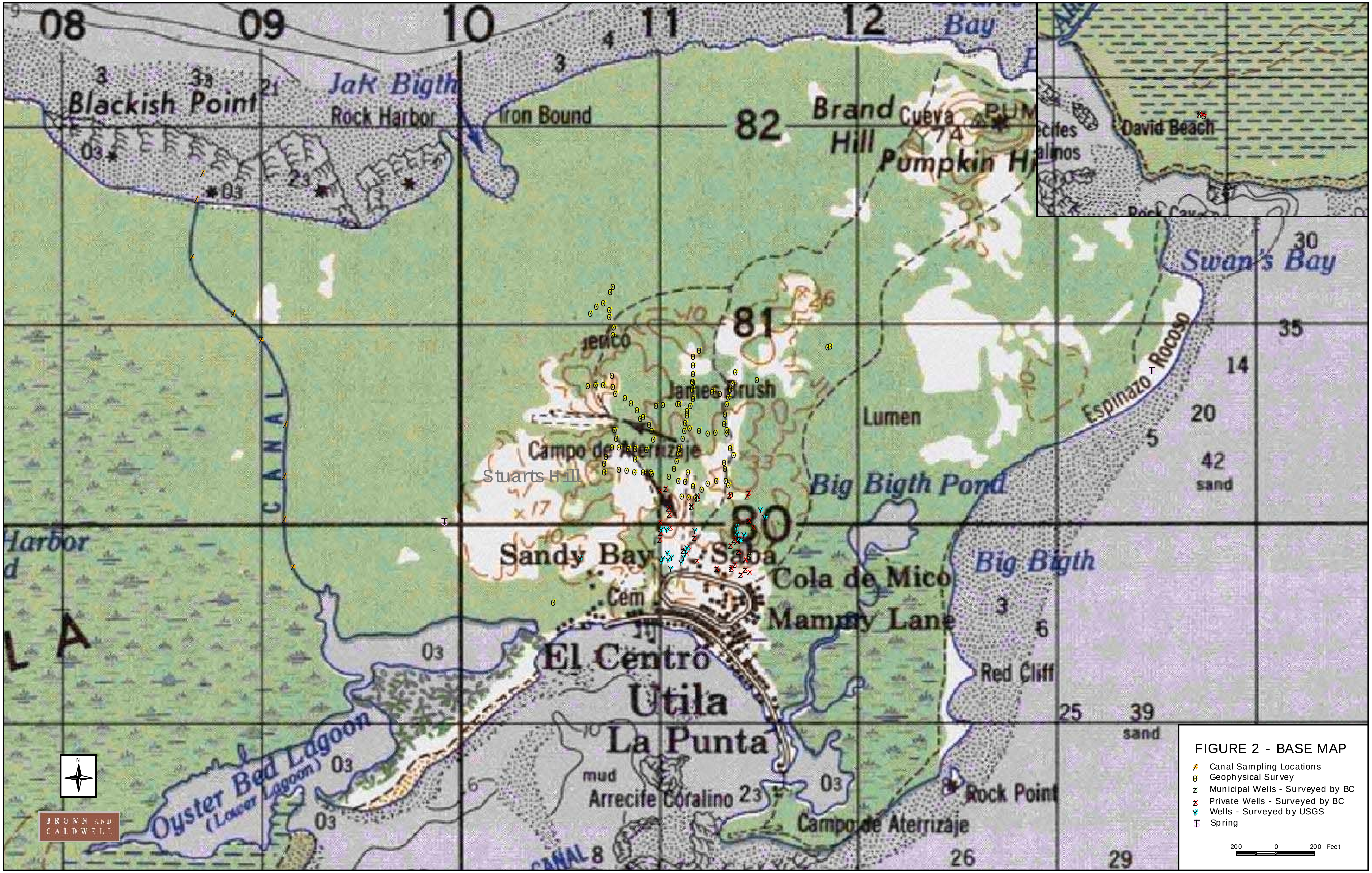

FIGURE 2 - BASE MAP

- Canal Sampling Locations
- Geophysical Survey
- Municipal Wells - Surveyed by BC
- Private Wells - Surveyed by BC
- Wells - Surveyed by USGS
- Spring

200 0 200 Feet

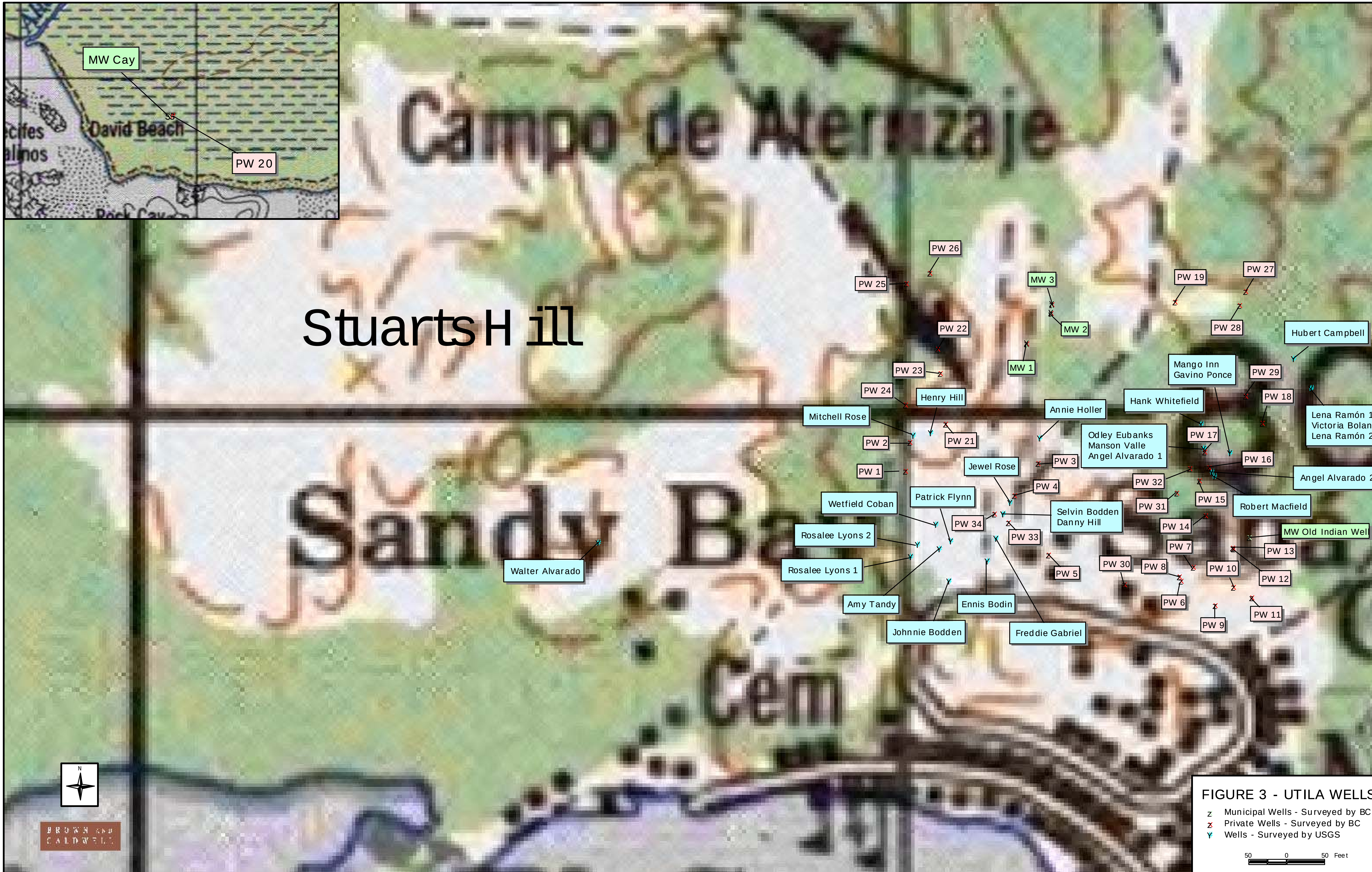

FIGURE 3 - UTILA WELLS


GEO 98
GEO 97
GEO 94
GEO 95
GEO 93
GEO 92
GEO 96
GEO 91
GEO 90
GEO 26
GEO 27
GEO 7
GEO 25
GEO 78
GEO 24
GEO 6
GEO 54
GEO 52
GEO 23
GEO 77
GEO 8
GEO 80
GEO 55
GEO 22
GEO 76
GEO 51
GEO 53
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GEO 38
GEO 14
GEO 68
GEO 35
GEO 10
GEO 43
GEO 13
GEO 39
GEO 12
GEO 29
GEO 60
GEO 65
GEO 11
GEO 40
GEO 32
GEO 63
GEO 30
GEO 58
GEO 64
GEO 28
GEO 31
GEO 56
GEO 62
GEO 66
GEO 57
GEO 59
GEO 61
GEO 67
GEO 4
GEO 3
GEO 2
81
80
Lum
Big
Big
Stuarts Hill
N
FIGURE 4 - GEOPHYSICAL
Geophysical Survey Locations
40 0 40 Feet

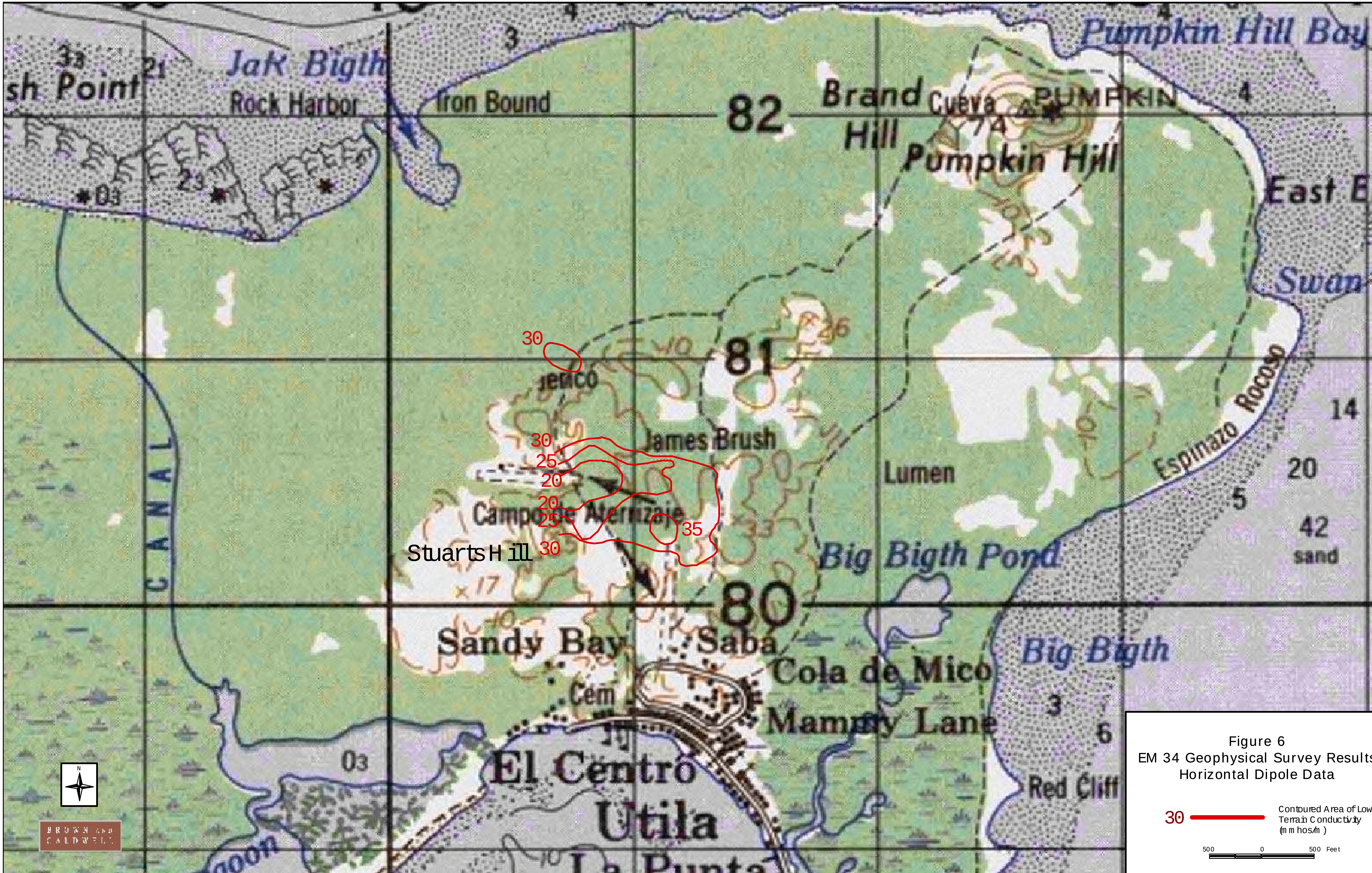

Figure 6
EM 34 Geophysical Survey Results
Horizontal Dipole Data

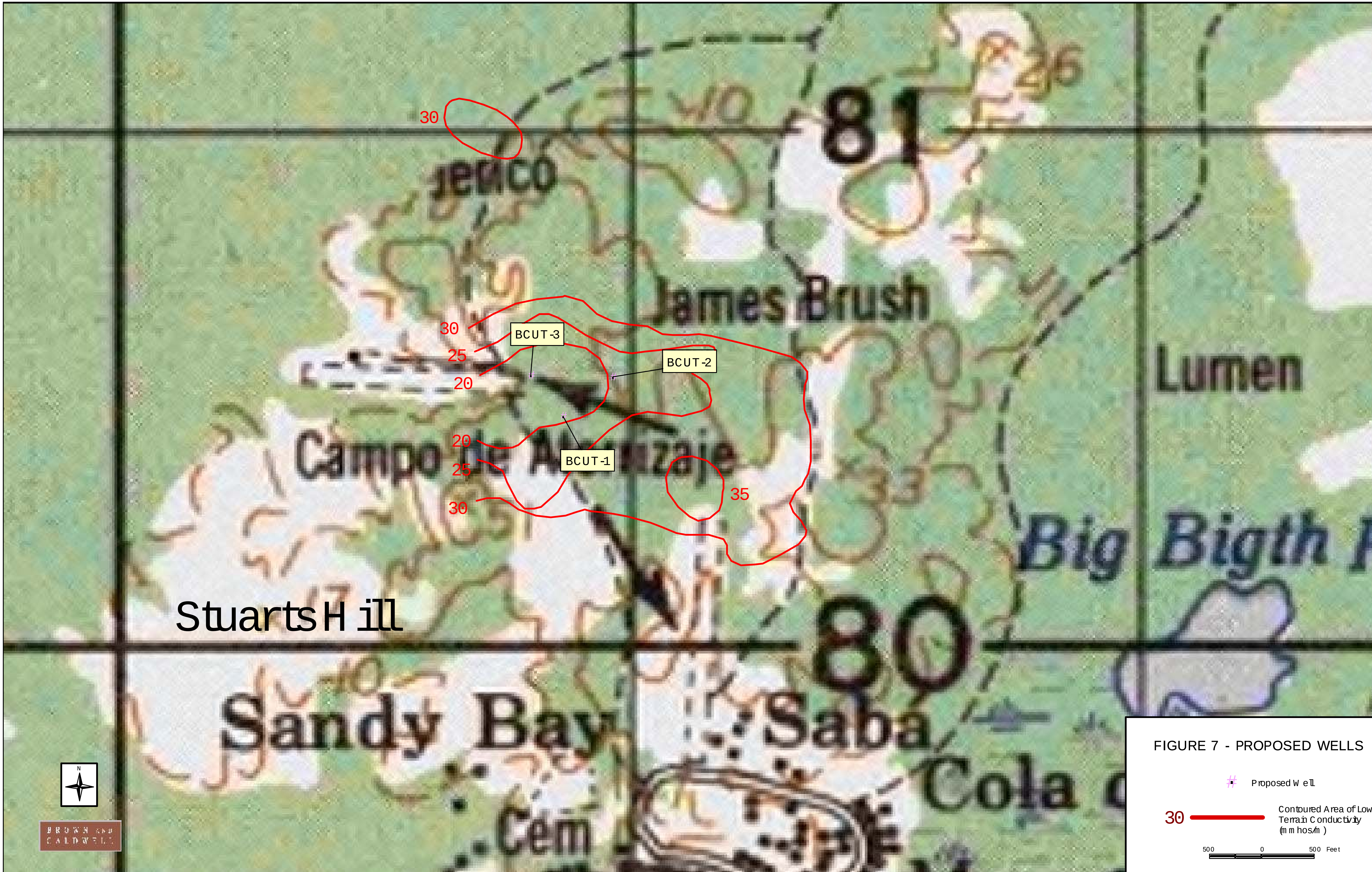

FIGURE 7 - PROPOSED WELLS

Proposed Well

30 Contoured Area of Low Terrain Conductivity (mmhos/m)

500 0 500 Feet

APPENDIX G

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.	Total a, Total ß	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 Barnica 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.	Totala, Totalß	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 (msnm)	Elevación Nivel de Referencia (msnm)	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: 1?4520

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:	date	time	4. Received by:
5. Relinquished by:	date	time	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

Before leaving for the field:

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

In the field:

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 H

Wellhead Protection Plan

WELLHEAD PROTECTION PLAN

Utila, Honduras

June 2002

INTRODUCTION

An important component in protecting the groundwater quality used for public water supply in Utila 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 the municipal regulation to ensure controls on water use and protect the area covered with dense vegetation, which represents potential groundwater recharge areas through rainfall infiltration.

Groundwater may become contaminated through natural sources as well as 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 Utila 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 protection of a well water supply must be delineated. The results of the field investigation demonstrated that the areas all around and including Stuart Hill functions as a recharge area for the freshwater aquifer. The combination of upland areas that receive increased precipitation and high secondary permeability of the coral limestone has promoted the development of a freshwater lens. Results of the model indicate that this fresh water lens flows to the south, towards the East Harbor.

Based on this information, a base map should be developed which 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 which illustrate the radius of influence (even if estimated) for every pumping residential and municipal water supply well, the location of aquifers and aquifer recharge zones, the watershed in which the aquifers are located, wetlands, lakes and flood zones which may affect recharge, and potentiometric surface information which 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, that is, 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 Utila, 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. To begin, 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 industrial waste areas. The inventory should also include agricultural sources such as crops where pesticides and insecticides may have been used, and animal feedlots, livestock waste disposal areas, and agricultural drainage ditches and canals. Finally, 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 sources 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 and 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 achievable 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 to parkland, 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 taking a number of groundwater samples on a regular basis, performing laboratory tests to detect various contaminants. Regular testing will identify problems quickly. The further the monitoring wells are located from the pumping well, the earlier problems can be identified and the 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 I

Training and Workshops

TRAINING AND WORKSHOPS

Utila, 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[illegible]
Paul Selsky	Brown & Caldwell	
Alicia Villar Landa	PRIMHOR	239-41-14/41-8[illegible]
Maurice James	U.S. Army Corps of Engineers	991-9189
Mauricio Cruz	USAID	236-9320 (479[illegible]
Carlos Verdial	USAID	236-9320 (40[illegible]
Juan Benito Guevara	Alcaldía Choloma	882-7771
John Walker	USGS	9928312
Olman O. Rivera	USACE - USAID	995-74-79
Jason Grant	Brown and Caldwell	925-210-2383
Mario A Cabrera	Fundemun	
César H. Mondragón	Fundemun	882-4298
Ricardo Valle L	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[illegible]
ARGELIA SALGADO	USAID (a.salgado@usaid/gov)	236-9320 (4663
Jeff Nelson	Brown & Caldwell jnelson@browncald.com	988-5927 (cell)
Francisco Juan	Gerente DIMUSEE	552 5811
Jorge Flores	FHIS	2348619 / 99 633
Isidro Alberto Mondragon	Fundemun	882-429[illegible]
HORACIO JUAREZ	BROWN & Caldwell	(915) 545-44[illegible] / 188-59[illegible]

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

USAID

BROWN AND CALDWELL

No.	Nombre	Empresa/Corporación	Teléfono	E-mail
1	Jonas Flores	FHIS/USAID	992 6334	Jorgeflores@optinet.hn.
2	Carlos R. Kendel	USAID		Ckendel@usaid.gov
3	Ruben C. Rosales	COE	334-990-3193	ruben.c.rosales@sam.usarmy.mil
4	Antonio Morales Flores	FHIS/USAID	980-2090	02.
5	Jose Francisco Casco	Municipalidad Villanueva	226-7269	670-04-45
6	Ramon Jimenez Flores	Municip. de Villanueva	670-04-45	
7	Hector A Cabrera	MUNIC. de Villanueva	6704084	
8	Javier Reyes	MUNIC. de Villanueva	670-4445	
9	Rigoberto Rivera C	Municip. de Villanueva	670-58-80	
10	Ruben - Saravia	Municip. de Lima	668.29.00	
11	Silvia Fernandez	Alcaldia La Lima	991-6547	AIFzelaya@
12	Monterey Cardenas	Municipalidad de Utila	425-3293	—
13	Juan Ramon Mejia A.	Municipalidad Choloma	669.39.22	— " —
14	Reudo Urdamo	Municipalidad de Choloma	669 5372	
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. Duron	FUNDEMUN	232 1846	Fundemu1 @hondotel.hn
19	Jenny Chavez	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	alejo...@...ach.com
31	Marlon Yingda	Atica	558-7751	...@Brwncald.com
32	Horacio Juarez	Brown & Caldwell		HJuarez@BRWNCALd.com • Cell Honduras 988-5937 • CELL USA (915)588-031
33	Fabiola Andrade M.	Brown & Caldwell	980-1906	@9562005@hotmal.com • Tele USA (915)545-44
34	Nely R. Lemus	ATICA	558-1751	— o — • Tele HOND 558-7751
35	Aurora Rodriguez	Municipalidad La Lima	668-2400	Edlolima@hotmail.com.
36	José Evaristo Ecada F.	Municipalidad La Lima	668-26-01	
37	Doris Marlena Pérez Lazo	Municipalidad La Lima	668-26-01	
38	Mario Ramón Jiménez Soto		6512735	

USAID

BROWN AND CALDWELL

Lista de Invitados

22 de Mayo 2001

No.	Nombre	Empresa/Corporación	Teléfono	E-mail
	German Wilfredo Henriquez	Municipalidad Roma	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

<u>VILLANUEVA MUNICIPALITY 670-4788/670-4445</u>

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

<u>LA LIMA MUNICIPALITY 668-2400/668-2601</u>

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

<u>CHOLOMA MUNICIPALITY 669-3322/6693223</u>

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

<u>LIMON DE LA CERCA 882-5079/ 882-5011</u>

1. Actilio Alvarez (Técnico DIMUSED)
2. Manuel Mejía (Técnico DIMUSED) (no)
3. Juan Benito Guevara (Alcalde Municipal) (no)

<u>FUNDEMUN</u>

1. Ing. Mario Alberto Garcia
2. Ing. Jenny Chávez (Choloma, Villanueva) 984-1577
3. Ing. Jose Tulio Gómez (La Lima) 647-3136

<u>COE</u>

1. Rueben Rosales

<u>UTILA MUNINICIPALITY 425-3255</u>

1. Monterrey Cárdenas (Alcalde Municipal)

<u>UNITEC</u>

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	[signature]
Leon. Saravia	Municipalidad	Jefe S. P	668-24-00			[signature]
Jorge Nery Lopez	Munic - La Lima	Asistente - Catastro	668-24-00			[signature]
Ramón Jiménez Flores	Munic. de Villanueva	Obras Públicas	670-44-45	670-44-04		[signature]
Victor M. Leiva	PRIMHUR	Gerente Regional	550-40-06	550-40-06		[signature]
Noemi Carrasco	CHF	Oficial Técnico	2325758	idem		[signature]
Yaudia Enamorado	ASP	Jefe Control Calidad	556-8955	556-9084		[signature]
Marlon Pineda	Atica	Supervisor	558-17-51	558-18-04		[signature]
Julio B. Alvarez	DIMUSEB chol.	Técnico Mantenimiento	983 4055			[signature]
Antonio Morales Flores	FHIS	Supervisor Proy	980-2090	276-7264		[signature]
Dania Andrade	B&C	Secretaria	557-1176	980-1906	a95620os@Hotmail.com	[signature]
Vojtek Bajsarowicz	B&C	VP	557-1176		VBAJSAROWICZ@BROWNCALD.COM	[signature]
Horacio Juarez	BC		557-1176		HJuarez@brown	[signature]
Jay Lucas	BC	Geologist	557-1176		jlucas@brwncald.com	[signature]
Paul Selsky	BC		557-1176		pselsky@browncald.com	[signature]
Jeff Nelson	BC	Ingeniero	557-1176		jnelson@browncald.com	[signature]

LISTA ASISTENTES

11 de Julio 2001

HOTEL PRINCESS, SAN PEDRO SULA

NOMBRE	EMPRESA	CARGO	TELEFONO	FAX	E-MAIL	FIRMA
Gerardo Trochez	SANAA	Coordinador de hidrogeologia	220-6506	237-8552	rtrochez@yahoo.com	
Interby Cárdenas	Munic- Utila	Alcalde Municip	4253293	4253255		
Marley Howell	Utila Lodge Resort	Secretary	425-3143	425-3209	marleyhowell@hotmail.com	
Alton Cooper	Alton's Dive Center	Owner/Dueño	425-3337	425-3108	altons@hondutel.hn	
Juan O. Alvarenga	Munic. Choloma	Jefe Obras y Serv.	669-3223	669-1774	colvarenga@hotmail.com	
José Francisco Caceo	Municip. Villanueva	Gerente Obras y Ser	P. 670-4445	670-4404		
Gracia M. López	FUNDEMUN	Consultora	557-8078	557-8078	graciaml@yahoo.com	
Aurora Rodríguez	Muni - La Lima	Asist. de Ing.	668-2800		ae06@latinmail.com	
Doris H. Pérez L.	Municipalidad La Lima	Ingeniero Municipal	668-26-01	668-26-01		
Jorge Nery Lopez	Municipalidad La Lima	Asist. - Dept. Catastro	668-24-00	668-26-01		
Ruben Samaya	Municipalidad Lima	Jefe Serv. Pub.	668-24.00	668-26-01		
Julio César Hernández	Municipalidad Choloma	Asesor Tecnico	669-32-23	669-17-74	—	
Victor M. Leva	PRIMHUR	Gerente Regional	552-4590	554-40-04		
Jenny M. Chávez	FUNDEMUN	Asesora	566-16-23			
José Julio Gómez	FUNDEMUN	Consultor	556-8292	556-8292	jgomez@yahoo.com	
Milton Sagastume	ATICA	Gerente General	558-17-51	558-18-04	atica@hn2.com	
Carlos R. Vardin	USAID	Ingeniero Proyecto	236-9320	238-2812	[illegible]@usaid.gov	
Mauricio Cruz	USAID	Oficial de Proyectos	236-9320	238-2812	mcruz@usaid.gov	

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