PEER REVIEWED

The Springs of Bohol Province Philippines

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Abstract

Bohol Province, in the central part of the Philippines, is blessed with numerous springs that issue from carbonate, volcanic, and crystalline rock aquifer systems. There are over 2,000 documented springs in the province or approximately 1 spring for every 2 km². These springs are vital to the livelihood of the province. They serve to supply drinking water to many of its residents, irrigate many hectares of cropland, provide important baseflow to all of the river systems in the province, and comprise an important future water resource for the province that requires quantification and management.

Introduction

In the spring of 2001, we conducted a project to assess the feasibility of utilizing ground water as a sustainable source of public water supply for ten municipalities in the Province of Bohol in the central part of the Philippines. Our client, a private water utility, was investigating the potential to be the bulk water supplier to these ten municipalities near the capital city of Tagbilaran. Eight of the municipalities are located on the main island of Bohol, and two on nearby Panglao Island with an area of 91 km².

Our principal assignment was to:

- Inventory current sources of water supply (wells and springs) to the 10 municipalities and develop recommendations for future usage;
- Evaluate the sustainability of the underlying aquifer systems for long term supply until the year 2020 and identify potential development constraints;
- Develop recommendations for a Phase 2 ground-water exploration program; and
- Outline preliminary development costs to meet the projected year 2005 water demand.

Our study and analysis showed that on the mainland island of Bohol, there is an abundance of developable ground water from either wells or springs to meet present and long term future demands. On Panglao Island, where growth is projected to increase substantially, the ground-water resource is more limited and development should be carefully planned and executed.

The Province

Bohol Province is located between the Islands of Cebu and Leyte (Fig. 1) and consists of the main island of Bohol which has an area of about 4,000 km² surrounded by many smaller

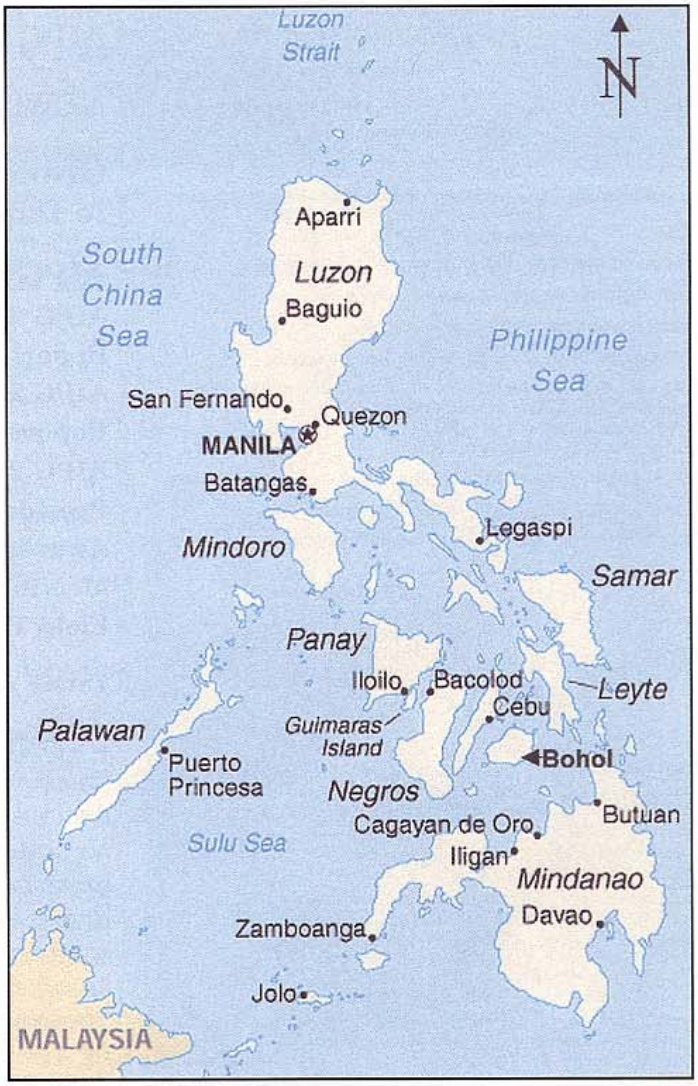

Figure 1. Location Map

Photo 1. Church in Loboc Municipality

Photo 2. Chocolate Hills

islands with a total area of 200 km^2. The Province is home to many historical towns and churches dating back to the 15th century.

The province has a population of approximately 1,140,000. The 10 municipalities that were assessed are located within 25 km from the capital city of Tagbilaran, and their current population is approximately 182,000.

The province lies at 10 degrees north latitude and the climate is tropical and wet. Mean annual rainfall ranges from 1,500 mm to 2,200 mm in the province. The highest rainfall occurs at the higher elevations in the eastern part of the province and decreases to the west.

The province has beautiful rolling topography including the Chocolate Hills which are located in the west-central portion of the province in the vicinity of the municipality of Carmen. Their name describes the rich green grass that covers these hills most of the year and turns chocolate brown during the drier summer months. There are over 1,000 of these residual tropical karst hills referred to as Haycock Hills in Bohol. In the karst area of Yugoslavia such hills are referred to as Hums, and in Puerto Rica as Haystack or Pepino Hills.

Bohol Province is famous for its diving sites and sitings of whales, sharks, and dolphins. The province also is home to the one of the earth's smallest and oldest mammals, the Tarsier Monkey, which is the size of a human fist.

For hydrogeologists, the province is home to many large capacity springs, some of which were developed for drinking water more than 100 years ago. The springs serve many purposes in the province. Some are utilized for drinking-water supply and also as a gathering spot for doing laundry and sharing stories. Others are utilized for the irrigation of rice paddy and other crops. Many springs serve to provide base flow to the river and stream systems in the Province. Several springs, such as Uhan Spring in Cortes Municipality, form the headwaters of small to medium size river systems. The river valleys, wherein the major springs lie, are lush and tropical.

Hydrogeologic Framework

The province is underlain by a variety of unconsolidated and consolidated sedimentary, igneous, and metamorphic rock units ranging in age from pre-Cretaceous (basement complex) to Recent (alluvium). More than 70 percent of the province is underlain by sedimentary rocks and most of the project area (Fig. 2: Project Area Map) is underlain by the Maribojoc Limestone, a prolific carbonate rock aquifer system. The Maribojoc is a transgressive reefal limestone of Upper Pliocene–Pleistocene Age. It is "usually soft and porous and light cream to pinkish in color on fresh surfaces and dirty white to gray when weathered" (FAO, 1987). In the project area, the Maribojoc is characterized by gently undulating to rolling topography, and two plateaus with average elevations of about 50 and 30 meters above mean sea level. The area is criss crossed by numerous karst depressions (dolines).

The Maribojoc Limestone exhibits numerous sinkholes, caves, and caverns and the hydraulic conductivity of this aquifer system can be very high where there are extensive fracture and solution openings. Dissolution in these rocks has produced secondary permeability, which results in locally high yielding wells and springs. Well yields are quite variable for a given area and can range over several orders of magnitude. Run-off occurs only during periods of very intensive rainfall; otherwise most rainfall directly recharges the underlying carbonate rock aquifer systems.

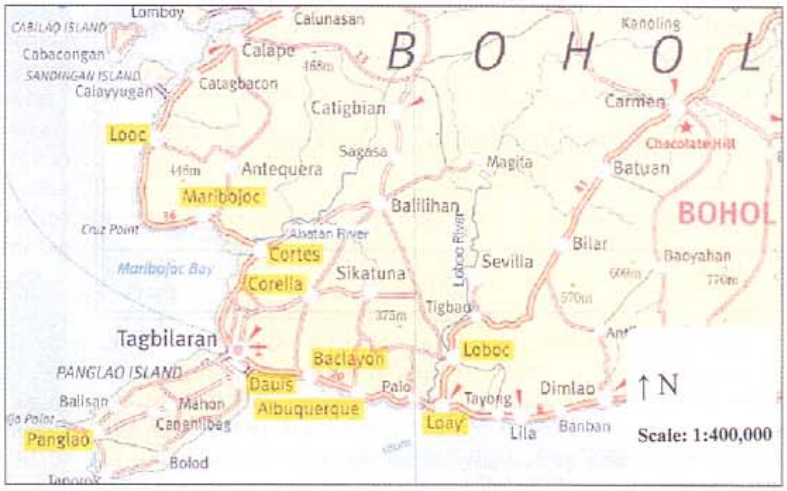

Figure 2. Project Area.
Source: Periuplus Editions (HK) Ltd.

Photo 3. Bilibili Spring in Cortes Municipality

Photo 4. Kansaon Spring in Maribojoc Municipality

Recent pumping test data provided by the Bohol Water Utilities, Inc. for five production wells in the Municipality of Corella indicate a range in specific capacity from 0.39 liters per second per meter (lps/m) to 8.0 lps/m. Calculated transmissivities were in the range from 0.00086 to 0.01 meters squared per second (m^2/sec) for these five wells in the Maribojoc Limestone or from 6,000 to 70,000 gallons per day per foot (gpd/ft) indicating an aquifer of moderate transmissivity.

The five tested production wells have yields in the range from 33 to 135 cubic meters per hour (m^3/hr). In areas where karst features have produced significant secondary permeability, well yields of up to 150 m^3/hr (1 million gallons per day) and higher are possible.

There were no data with respect to well yields and aquifer hydraulic characteristics for the hydrogeologic units in the province other than the five pumping tests in Corella Municipality. Water quality data likewise were sparse. An earlier study by the Food and Agricultural Organization of the United Nations (FAO) documented yield and field water quality data for selected springs in the province (FAO, 1987).

The river valleys draining the carbonate rock areas are characterized by many large capacity springs that provide base flow to the stream and river systems draining these areas. Table 1 provides a summary of maximum, mean and minimum flows for the Loboc River expressed in millimeters per year. The Loboc is the largest river system in the project area.

Table 1: Loboc River Flow Data (FAO, 1987)

Annual Flow Volume in millimeters			Drainage Area (km^2)
Max	Mean	Min.	
1386	967	642	618

The Loboc River drains a total area of about 618 km^2 (Fig. 2) and the river is largely spring fed with spring discharges up to 580 liters per second (lps) and higher. The FAO study noted that "because of the general lack of surface runoff in the karstic limestone, practically all of the flow of the Loboc is from ground water." This is supported by flow records which show a small variability of Loboc River flows from wet to dry seasons. The mean flow of 967 millimeters is approximately 50% of mean annual rainfall in the river basin, which suggests that half of the rainfall serves to recharge the ground water systems in this drainage basin. The FAO study indicated that the Abatan River (drainage area of 368 km^2) also has constant streamflow with "minimal variations during peak dry season, indicating that most of the flow is from ground water."

The Springs

There are over 2,000 documented springs in the province or about 1 spring for every 2 km^2. This comprises quite a dense network of springs. These springs are vital to the livelihood of the province. They serve to supply drinking water to many of its residents, irrigate many hectares of cropland, provide important baseflow to all of the river systems in the province, and comprise an important future water resource for the province that requires quantification and management. Photos 3 and 4 show the Bilibili and Kansaon Springs in Cortes and Maribojoc Municipalities.

The United Nations Development Program (UNDP) surveyed and listed 2,250 springs in the province. Table 2 presents a range of spring discharge rates for the different geologic formations in the province (UNDP, January 1999). The greatest number of springs (835) are found to discharge from the Carmen Formation, a shale and sandstone unit; and the second largest number (776 springs) issue from the Maribojoc Limestone Formation. The reported discharge information for these springs is very approximate and a more detailed study of spring yields, quality, and usage is needed and will greatly assist in future planning efforts in the province. Of the inventoried springs, 205 were reported to be dry at times and only exhibit flow during rainy periods.

The springs show the highest discharge in the sedimentary rock aquifer units, particularly in the Maribojoc and Sierra Bullones Limestones and in the shale and sandstone rocks of the Carmen Formation. The volcanic and metamorphic rock units show fewer springs (except for the Ubay Volcanics) and generally lower discharge rates. The upper range of spring yields for the limestone units is underestimated as the authors have measured spring yields up to 580 lps issuing from the Maribojoc Limestone in the dry season.

Table 2: Summary of Spring Discharge by Geologic Formation (UNDP Survey 1999)

Geologic Formation	Number of Springs with Measured Discharge Rate	Total Number of Springs	Range in Discharge Rate (approximate)(liters per second (lps))
Quaternary Alluvium	48	63	0.0013 - 19.0
Maribojoc Limestone	676	776	0.001 - 126.0
Sr. Bullones Limestone	211	292	0.003 – 31.0
Ilihan Plug	–	–	–
Carmen Formation	729	835	0.003 - 50.0
Wahig Limestone	6	13	0.008 - 0.16
Jagna Andesite	5	7	0.0043 - 4.0
Talibon Diorite	13	20	0.007 - 1.0
Ubay Volcanics	137	159	0.001 - 20.0
Pillow Basalt	–	–	–
Amphibolite Schist	11	16	0.06 - 3.33
Boctol Serpentinite	40	52	0.063 - 6.67
Unknown Formation	–	17	–
TOTAL	**1,876**	**2,250**	

Photo 5. Loboc and Abatan River Valleys

Photo 6. Abatan River Valley

Representative water samples were collected from three Maribojoc Limestone spring sources including Uhan Spring in Cortes, Gimilian Spring in Loboc, and Saudis Spring in Maribojoc for a partial physical and chemical analyses by the Metro Cebu Water District Laboratory. The analytical results are presented in Table 3.

Table 3: Laboratory Analytical Results for Samples from Maribojoc Limestone Springs

Parameter	Uhan Spring, Cortes	Gimilian Spring, Loboc	Saudis Spring, Maribojoc
(mg/l)			
Chloride	9	6	10
Calcium	54	78	53
Hardness	155	355	138
Iron	<0.02	<0.02	<0.02
Magnesium	4.86	39.02	1.21
Chromium	<0.02	<0.02	<0.02
Total Dissolved Solids	265	272	254
Total Solids	305	332	314
Turbidity (NTU)	0.8	0.03	0.07

Spring water quality showed TDS and chloride levels within a tight range (TDS from 254 to 272 mg/l and chloride from 8 to 10 mg/l). Hardness ranged from 138 to 355 mg/l. The constituents tested for meet World Health Organization (WHO) drinking water guidelines (WHO, 1993).

Summary

- Bohol Province in the central part of the Philippines is blessed with numerous springs that issue from carbonate, volcanic and crystalline rock aquifer systems. There are over 2,000 documented springs in the province or about 1 spring for every 2 km^2.
- These springs are vital to the livelihood of the province. They serve to supply drinking water to many of its residents, irrigate many hectares of cropland, provide important baseflow to all of the river systems in the province, and comprise an important future water resource for the province that requires quantification and management.
- Springs that issue from sedimentary rock aquifer units, particularly in the Maribojoc and Sierra Bullones Limestones and in the shale and sandstone rocks of the Carmen Formation, show the highest discharge rates. The volcanic and metamorphic rock units have fewer springs (except for the Ubay Volcanics) and generally lower discharge rates.
- The areas underlain by the Maribojoc Limestone have good potential for ground water development in all 10 municipalities that were investigated. The projected water demand for the 10 municipalities in 2005 is 23,770 m^3/day or 6.4 million gallons per day (MGD) and in the year 2020, 45,900 m^3/day or about 12.2 MGD.
- A recharge analysis, based on 10% of rainfall serving to recharge the aquifer systems, indicates a net recharge of 266,000 m^3/day over the 480 km^2 area of the 10 municipalities. The projected 2020 water demand is 17% of the natural recharge.
- Well siting and development must take into consideration: 1) the potential for salt water intrusion and/or upconing in areas within a few kilometers of the coast; and 2) the variability of well yields in the Maribojoc Limestone.
- Panglao Island with its two municipalities is being developed as a tourist destination. It can probably utilize groundwater resources generated on the island, into the first part of the 21st century. However, the development of these resources will require careful exploration, and planning to avoid/minimize over-pumping and potential upconing of saline groundwater

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Corporate membership level	Dues	Memberships
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