Water Quality Assessment of Hand Dug Wells

Summary: This report contains a study of rope pump's impact on bacterial water quality of shallow hand dug wells in Kandal Province, Cambodia. It also compares the overall water quality of hand dug wells to adjacent tube wells.

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Introduction

Thousands of wells are being drilled in Cambodia each year, with the goal of supplying safe and accessible drinking water. The availability of clean drinking water is a basic right for all peoples. Unfortunately, many of these wells offer water which is either unsafe for human consumption and/or has such poor aesthetic quality that no one will consume it. Despite the potential magnitude of this problem, very little data has been gathered to prevent the senseless poisoning of villagers and the wasting of millions of dollars constructing wells that yield water of inferior quality.

It is for this Resource Development Internatinonal (RDI) began exploring other types of water sources in areas know to have groundwater contaminated by arsenic. The impacts of arsenic on human health are well documented and removal using household level technologies has proven to be illusive. In the targeted area it was noted that a few eixsting handdug wells contained relatively little arsenic compared to adjacent tube wells.

RDI has completed an extensive drinking water quality survey of tube and hand dug wells in Kandal Province. Approximately 2,400 water samples were collected from tube wells and compared with 414 hand dug wells. Each sample was tested for 10 key parameters which include: Arsenic, Manganese, E. coli, Fluoride, Nitrate, Iron, pH, Turbidity, Chloride, and Hardness.

The work presented in this report is the first large scale comparison of water quality of handdug and adjacent tube wells conducted in Cambodia. Many of the wells were outfitted with rope pumps as part of a ‘World Bank Development Marketplace’ project in order to make the water more accessible and to further protect the source from pathogenic contamination. An investigation into the level of protection provide by these pumps is also reported.

Location and Population

Kandal Province is located in southern Cambodia. The province surrounds Phnom Penh and continues south along the Bassac and Mekong Rivers to the Vietnam border. The province covers an area of approximately 3,500 square kilometers. Figure 1 presents the location of Kandal Province in respect to the rest of Cambodia.

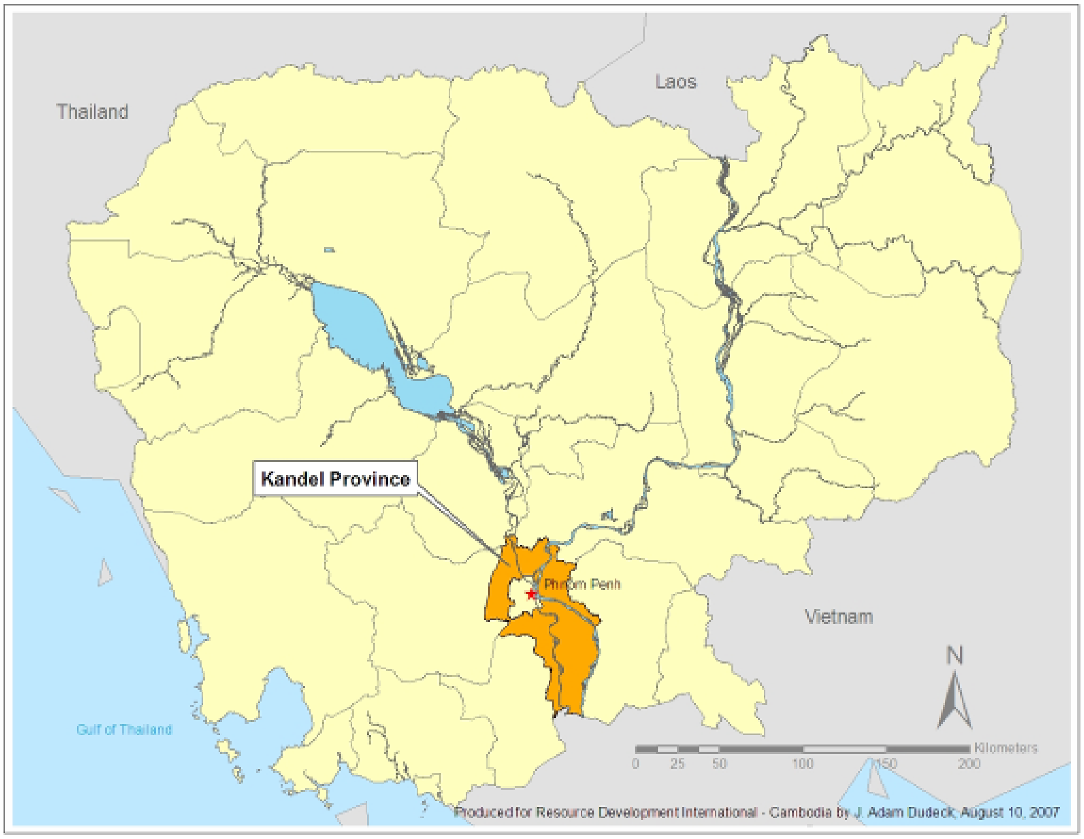

Figure 1 Provincial Map of Cambodia

The population density of Kandal Province is approximately 340 people/square kilometer, however, much of the province consists of uninhabitable wetlands and populations are highly concentrated along major roadways. Kandal Province has an estimated population of 1.2 million (2004). The province is made up of 11 districts and 147 communes.

Drinking Water in Kandal Province

Drinking water in Kandal Province is obtained from a variety of different sources, and many household treatment and storage methods are available to ensure its safety and security. Drinking water sources and methods include: tube wells (deep aquifers), open wells (shallow aquifers), rainwater harvesting, and surfical water collection. It is important to understand that an approach that is appropriate in one commune (or even a region within a commune) may not be appropriate in another. Surficial water quality, access to filtration devices, proximity to surface water, annual rainfall, and groundwater quality all impact the decision-making process involved in selecting an appropriate water source for a target community. This report focuses on tube and hand dug wells, which can provide long-lasting, clean, and reliable drinking water when implemented appropriately. Aquifers are susceptible to contamination from natural or man-made sources. As a result, wells should not be placed where known contaminations exist, and wells should be tested to confirm whether safe drinking water is being provided.

METHODOLOGY

RDI conducted a comprehensive approach to meet the drinking water guidance requirements of government and NGO communities, who annually spend millions of dollars installing and promoting tube wells in Cambodia. Water sampling teams were mobilized throughout the province to sample approximately 20 tube wells per commune, where possible and samples were also taken from hand dug wells most of which were installed by RDI. Also during this time a random selection of 4 clusteres totally 24 handdug wells were selected. A portion of these wells were outfitted with rope pumps while a control group was left undisturb. Water samples were collected over a period of six months on a biweekly basis in order to compare relative water quality of the wells. All water samples were returned to the RDI laboratory and analyzed for various health and aesthetic parameters. Standard sampling and laboratory procedures were followed throughout the process. The results of each test were hand-entered onto data sheets and subsequently digitized into an electronic database. The electronic database underwent several thorough data-checking excersises to ensure integrity and accuracy. Upon completion of the sampling and water testing stage mapping and statistical software were utilized to provide detailed analysis.
A series of 15 wells were selected at random for chorination testing and monitoring of E. coli levels over a one month period.

Sampling Methods

Field sampling teams consisted of two to three members. Water samples were collected in three bottles: a 120 mL plastic bottle, acidified with hydrochloric acid to prevent metal oxidation; a 30 mL sterilized plastic bottle used for bacterial analysis; and a 500 mL plastic bottle was used for field pH and subsequent laboratory tests.

Prior to sample collection, the well was pumped for approximately 10 minutes. This exercise ensured that the sample was representative of the aquifer and not the standing water in the well. Prior to sampling, each 500 mL bottle was conditioned with flowing well water (rinsed twice – filled and shaken). Prior to the collection of a bacterial sample, a pre-packaged cotton swab rinsed with alcohol was used to wash the samplers by hand and wipe down the outside of the bottle. The bottle was used to collect a sample from the flowing well water and was subsequently capped, labeled, and stored on ice. A second sample was taken in a 120 mL plastic bottle. The collected sample was treated with 3 drops of hydrochloric acid, capped, and labeled. A third sample was collected in a 500 mL plastic bottle and labeled. From the 500 mL bottle, water was withdrawn (using a pipette) and a pH test using a standard AgCl electrode. A GPS measurement (e-trex) was taken at every sample location using a WGS 84 Datum and UTM coordinates. Additionally, a digital photograph was taken of each well. Through the observation and the questioning of home owners, information was gathered on the color, taste, and smell of the well water, in addition to the type of well, number of families using the well, and the presence or absence of latrines and animals. If either a latrine or animal was present, its/their distance from the well was estimated. Information gathered in the field was maintained on well-specific field forms.

Chorination

Initial water samples with a volume of 120 mL were collected from 15 hand dug wells in sterile bottles after which approximately 12 liters of a 5% sodium hypochlorate solution were added to each well. Wells were allowed to set for 3 hours and then a subsequent water samples was taken. Water samples were treated with sodium thiosulfate to neutralize residual chlorine and all were tested using standard laboratory procedures. Wells were then sampled on weekly for one month.

Analytical Methods

Field samples were stored and all chemical analyses were conducted at the RDI Resource Laboratory located in Kean Svay, Cambodia. The RDI Resource Laboratory is a dedicated analytical laboratory.

Upon reaching the laboratory, the 30 mL bottles (containing bacterial samples) were transferred from ice to a refrigerator (maintained at $4^{o}C$). The other sampling bottles were stored in the laboratory at room temperature. Sample analysis was completed within several days of sample collection. Quality control analysis has shown that samples can be stored for at least four days prior to significant sample deterioration.

The majority of analytes were tested using Palintest reagents, a Palintest Photometer (model 7100), or Paqualab Photometer (ELE International). Arsenic was measured using a Hach five reagent colorimetric test kit. The tests for Fe, Mn and As were drawn from the acidified 120 mL bottles. Samples for bacterial analysis – *E. coli* and coliform – were drawn from the 30 mL bottles and tested using standard membrane filtration methodology (HiMedia rapid hicolor coliform agar or Coliscan Easygel chromogenic media). Prior to the counting of colonies, samples were incubated for 24 hours at $37^{o}C$. For the remaining analytes, water was drawn from the 500 mL collection bottle. Turbidity was tested with a Hach 2100P Turbidimeter and salinity was tested with an YSI EC 300 conductivity meter. Each instrument was routinely calibrated with up-to-date standards and manufacturer procedures were followed for the determination of all analytes.

Statistical Analysis

@RISK, a statistical software add-in for Microsoft Excel, was utilized for the statistical analysis portion of the study.

Results

To compare the water quality of open and tube wells a buffer zone of 500 meters was selected. This means that tube wells used in all analysis were within 500 meters of an open well in order to provide more accurate comparison of water quality. Table 1 shown below provides a summary of the key findings.

Open Wells (414 Samples)	Iron	Arsenic	Fluoride	Turbidity	Nitrate	Hardness	Manganese	Chloride	E. coli
Mean	3.84	14.34	1.30	27.80	2.31	340.93	0.73	304.73	1324.58
Median	1.10	0.00	0.75	5.00	0.29	288.00	0.16	355.00	160.00
% Above Cambodian Std.	70.53	7.00	10.87	50.24	0.72	64.25	55.56	67.15	76.57
Tube Wells (223 Samples)									
Mean	8.01	88.87	2.07	90.81	1.43	206.08	1.40	170.52	596.91
Median	4.56	10.00	0.70	30.20	0.22	180.00	0.12	74.00	0.00
% Above Cambodian Std.	89.24	31.84	8.97	73.09	0.00	38.12	52.47	31.84	43.05

Table 1. Open wells and adjacent tube wells water quality data

Arsenic

The data clearly shows that open wells are significantly less likely to be contaminated with arsenic. Figure 2 below compare the all tube wells exceeding the Cambodian National Standard value of 50 ppb with the adjacent open wells. While 100% selected exceed the 50 ppb standard only 10% of the adjacent open wells exceed standard.

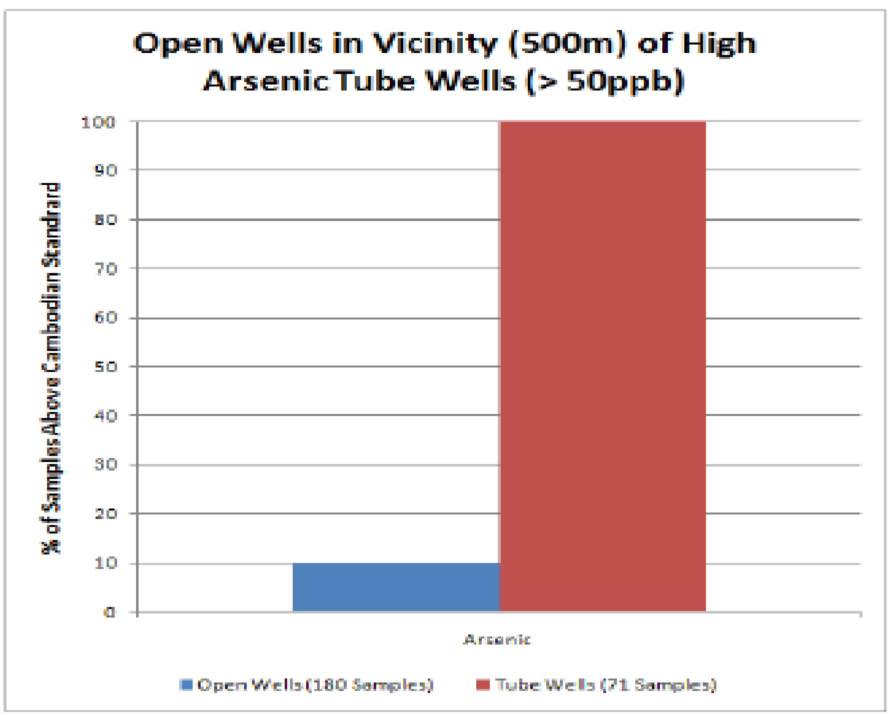

Figure 2

Figure 3 is a spatial map of arsenic concentration and location to allow one to better visualize the situation.

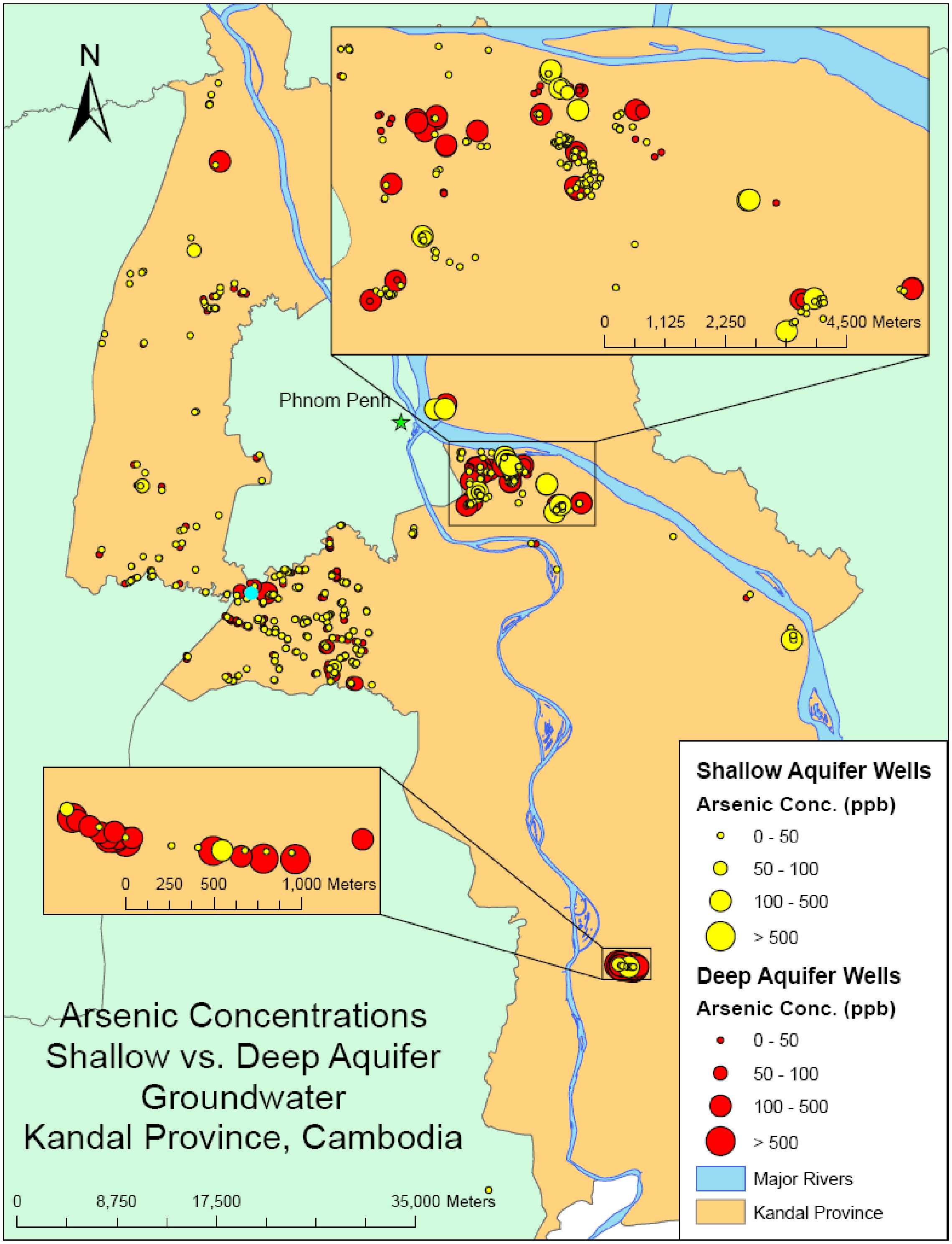

Figure 3

The information also showed a clear pattern between well depth and arsenic concentration as illustrated in Figure 4.

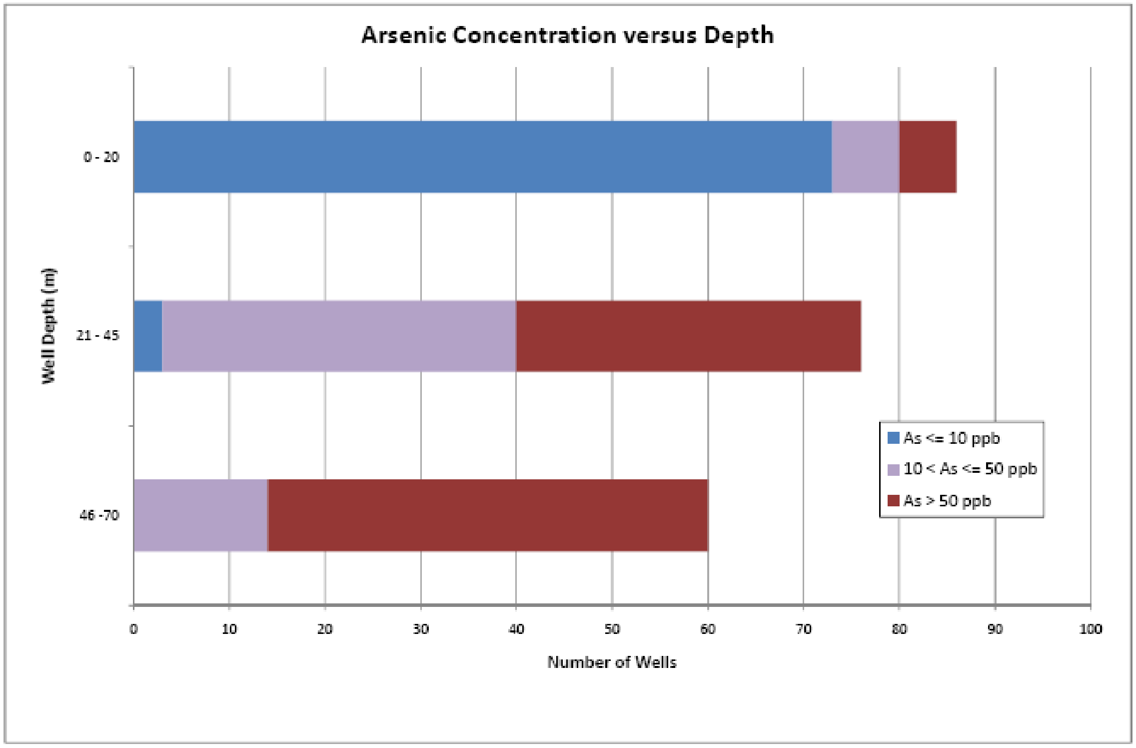

Figure 4

Fluoride

The mean value of fluoride is significantly higher in tube wells while occurrences above the standard are more common in open wells. The threat of fluoride in this area is quite small only a few wells were identified in which fluoride levels were high enough to cause skeletal fluorosis. Figure 5 is a map showing the distribution and concentration of arsenic throughout the province.

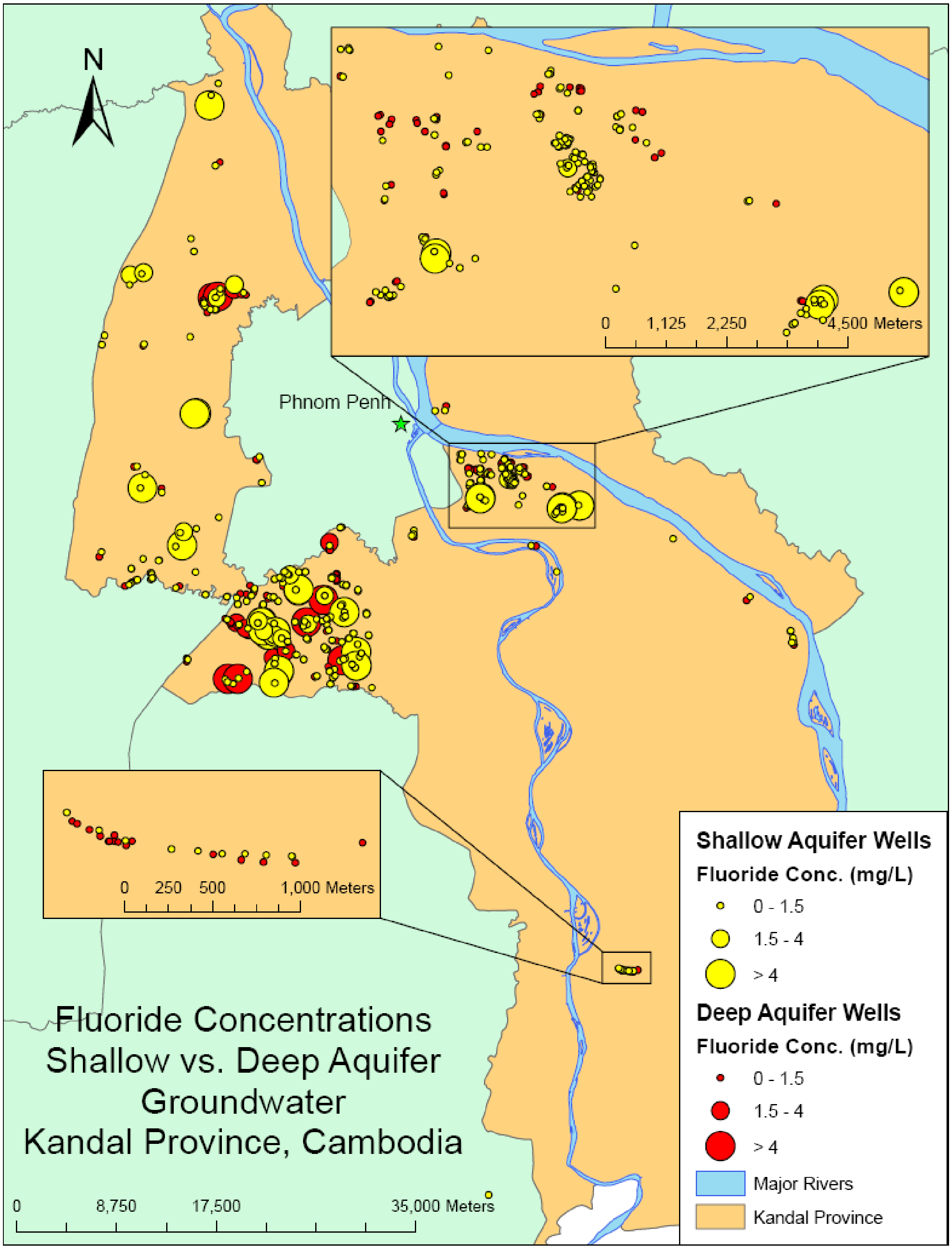

Figure 5

Nitrate

Only one exceedance was observed in the province.

Manganese

Manganese found at lower concentrations impacts the aesthetic quality of water, but at higher levels has recently been found to be a risk to human health. The data shows tube wells are more likely to contain unsafe levels of manganese. Figure 6 is a map showing the concentration and distribution of manganese in the province.

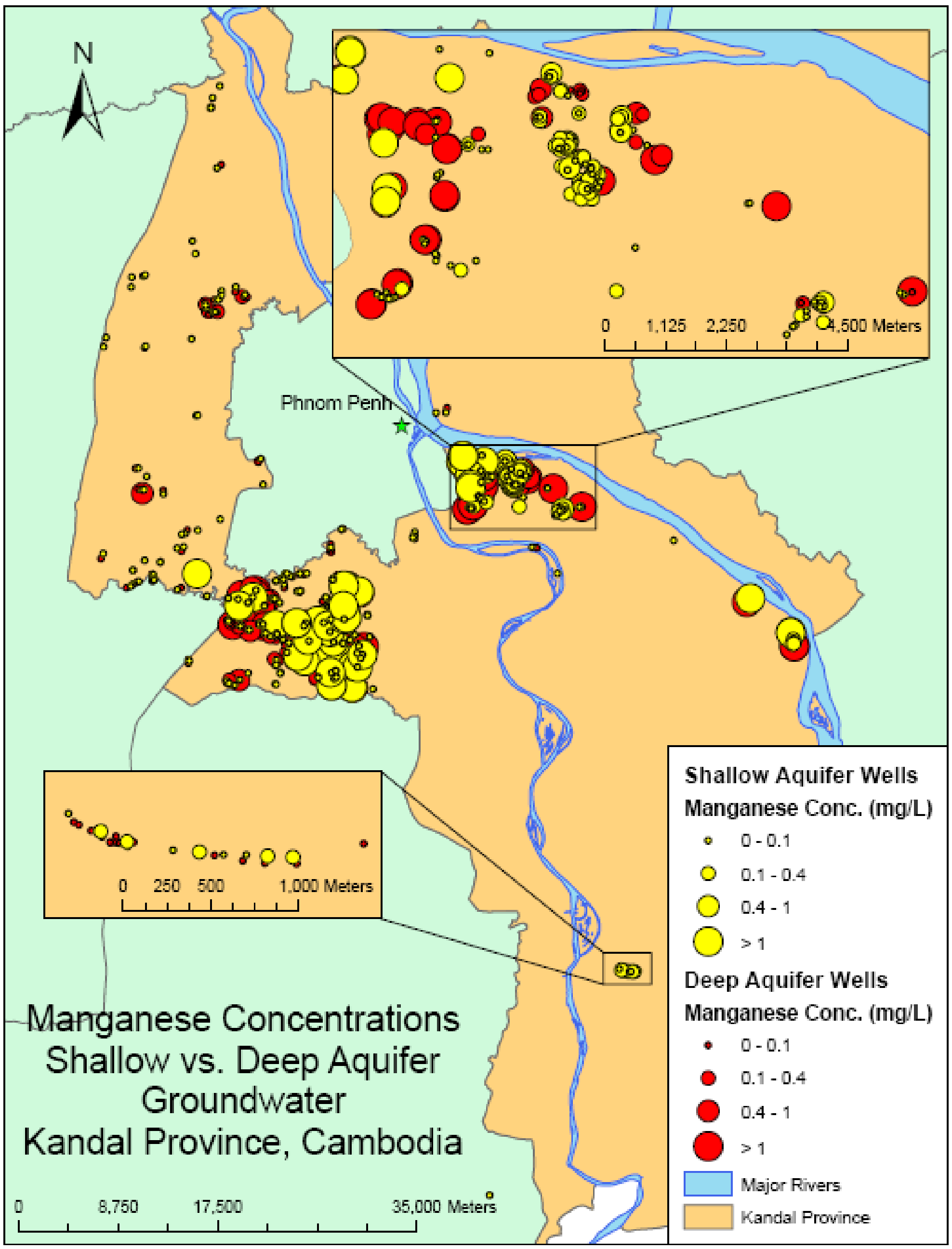

Figure 6

E. Coli

Open wells are significantly more contaminated than tube wells. The data suggest the mean value is twice as high. E. Coli is an indicator of fecal exposure and suggests open wells are more likely to contain pathogens.

Iron

The concentration of iron found in open wells is significantly lower than those found of adjacent tube wells.

Turbidity

Water collected from tubes wells was significantly more turbid than open wells. Turbidity was measured after samples were exposed to oxygen for sometime and the oxidation of iron and manganese is the most likely cause of this result.

Hardness

Open wells were significantly harder than tube wells.

Chloride

Chloride levels were higher in open wells. The levels were not high enough to impact taste significantly and therefore have little impact on the desirability of the water.

Rope Pump Protection

An order of magnitude difference was observed between hand dug wells with a rope pump compared to ones without. The mean value for rope pumps wells over the study period was 629 colonies per 100 milliliters (cfu) as compared to the unprotected well with a value of 6789 per 100 milliliters (cfu). It should be noted that these samples were collected biweekly for six consecutive months. While the standard deviation for this study was quite high all of the data was consistent.

Chlorination Study

Within one week of shock chlorination 13 of the 15 wells were found to have the same levels of E. Coli as before the treatment. By the second week all 15 had returned to their initial levels of E. coli.

Conclusions

Open wells in this study are less likely to contain unsafe levels of chemical contaminates which impact human health, but are more likely to contain pathogens. Pathogens are relatively easy to kill and can often times be introduced into drinking water during transport and storage while chemical contaminates can be quite hard to remove. Therefore one can assume that open wells are a better choice as a water source for many communities from a health prospective.

Iron is sited by communities in Kandal as the major reason for not using well water for drinking, bathing and washing clothes. The high levels of iron impacts taste, causes staining and are oftentimes is associated with strong reducing environments which caused by decaying organic matter resulting in a foul odor. As a general rule open wells contained significantly lower levels of iron making them more aesthetically pleasing.

It should also be noted that rope pumps provided a significant level of protection against bacterial contamination. This is not surprising logic dictates that the lowering of an unclean bucket into a hand dug well is a key pathway for bacteria. The rope pump greatly reduces this risk. It should be noted that shallow hand dug wells as a general rule contain significantly higher levels of bacteria compared to tube wells, but one should not assume that tube wells are free of pathogens. All water should be treated at the point of use because of unsafe transport and storage. Fortunately pathogens can easily be killed by using a variety of methods including filtration, chlorination and boiling. The source of contamination was not identified, however it is recognized that the exposed rope may be introducing bacterial contamination when this is handled by users. However it is assumed that the main contamination source is through the general environment reaching the high water table.

Chlorination proved to have little long term benefit to all wells tested and it is suggested that this method should only be used in situation were an unusual event has increased the level of contamination such as flooding, an animal dies in the well or cleaning operations are carried out (re-patching lining, people enter to remove sediment).

In Kandal province all wells should be tested before they are used for human consumption, but data from this study suggest open wells are likely to provide chemically safe and aesthetically pleasing water for villagers. Therefore open well development should be expanded through out the province coupled with proper education on how to treat the water against pathogen contamination.