# A Groundwater Quality Study in Cambodia: Data Analysis and Communication

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Resource Development International - Cambodia

# Introduction

- Prevalence of tube wells
- Pathogenic contamination
- Chemical contamination
- Historical practices
- Baseline groundwater information

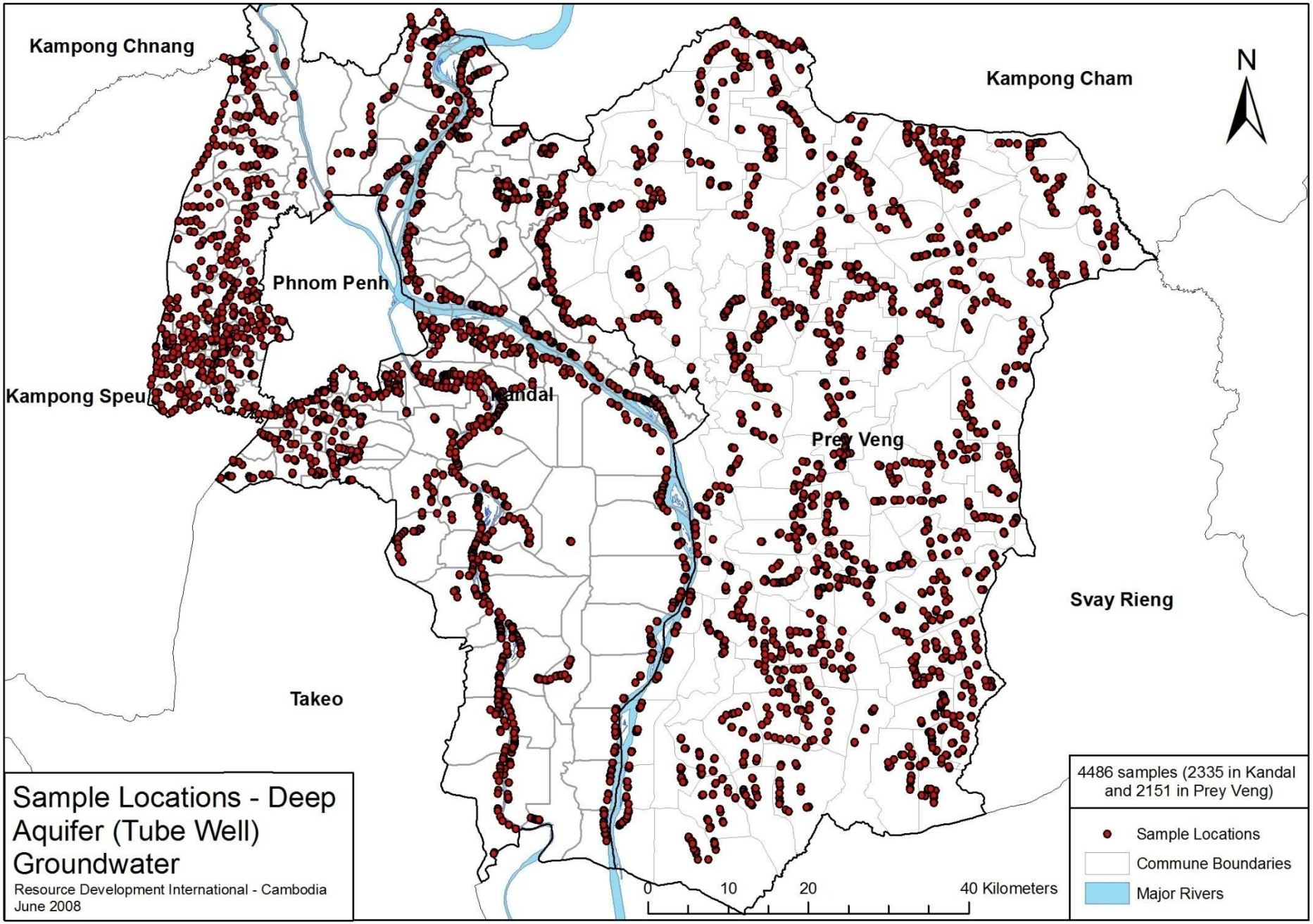
# Provincial Groundwater Quality Study

Purpose: To analyze and report groundwater quality data to decision-makers

1. Prioritize provinces
   - Risk and population
2. Sample collection
3. Water quality testing
4. Database compilation
5. Data analysis
   - Statistical and spatial methods
6. Communication and Reporting

# Study Area

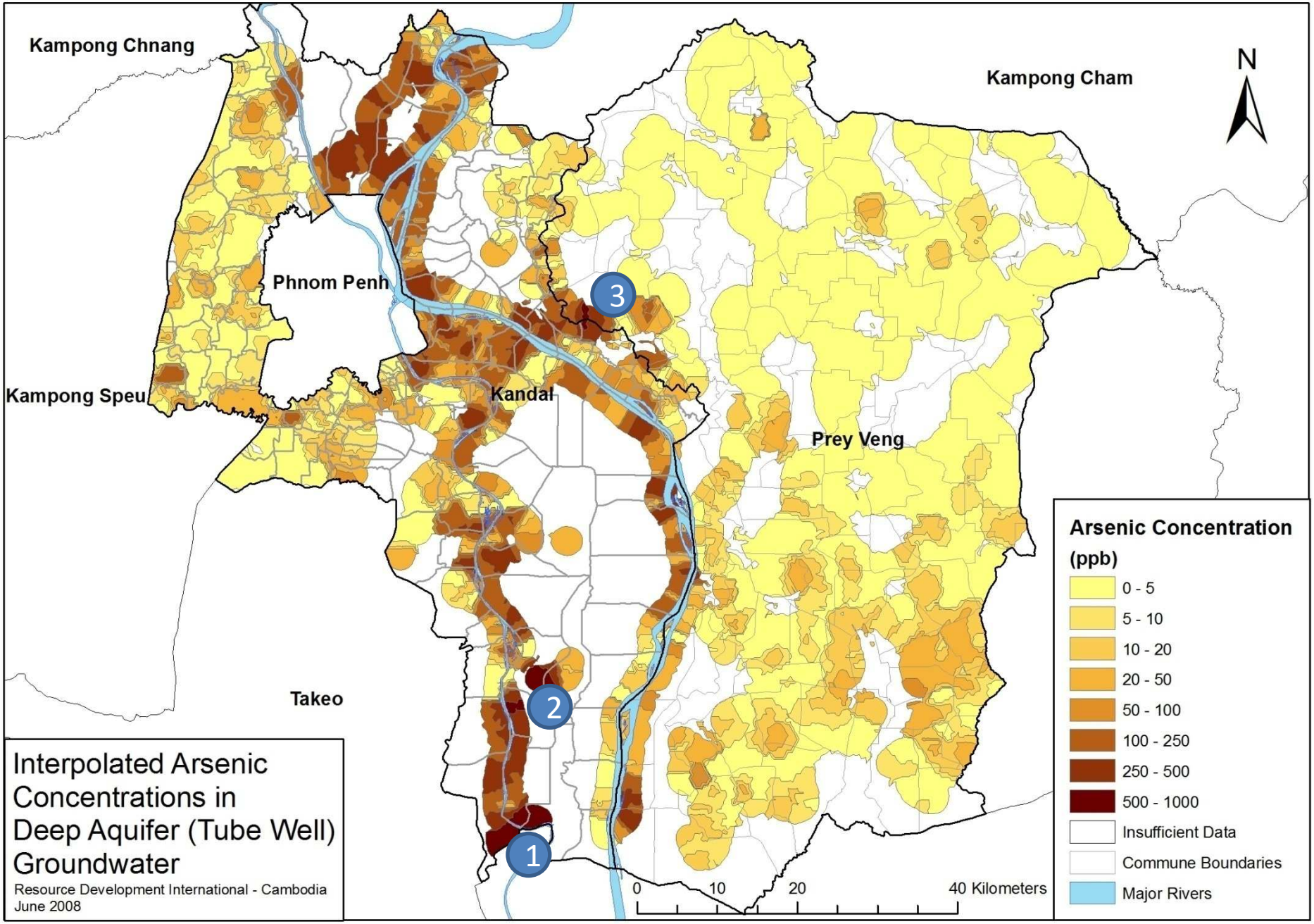

N
Kampong Cham
Phnom Penh
Kandal
Prey Veng
0 10 20 40 Kilometers
Thailand
Laos
Cambodia
Vietnam


Kampong Chnang
Kampong Cham
N
Phnom Penh
Kampong Speu
Kandal
Prey Veng
Svay Rieng
Takeo
Sample Locations - Deep Aquifer (Tube Well) Groundwater
Resource Development International - Cambodia
June 2008
0
10
20
40 Kilometers
4486 samples (2335 in Kandal and 2151 in Prey Veng)
Sample Locations
Commune Boundaries
Major Rivers

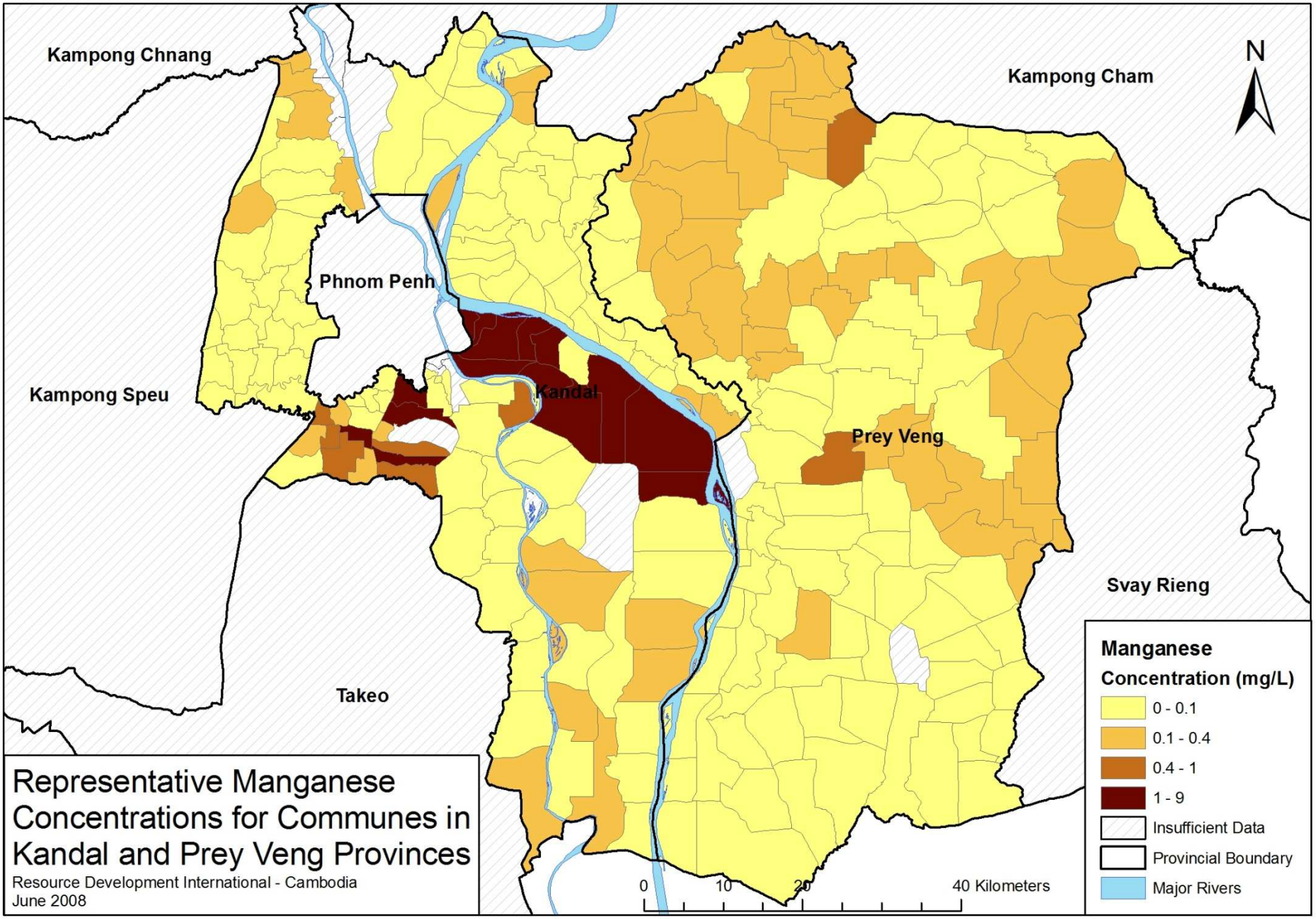
# Data Analysis

1. Spatial Analysis
    a) Interpolated concentration gradients
    b) Expected concentrations by commune
    c) Interpolated probability gradients
2. Commune groundwater quality reports
    a) Drinking water quality index
    b) Contaminants of potential concern
    c) Commune map
3. Population Impact Assessment

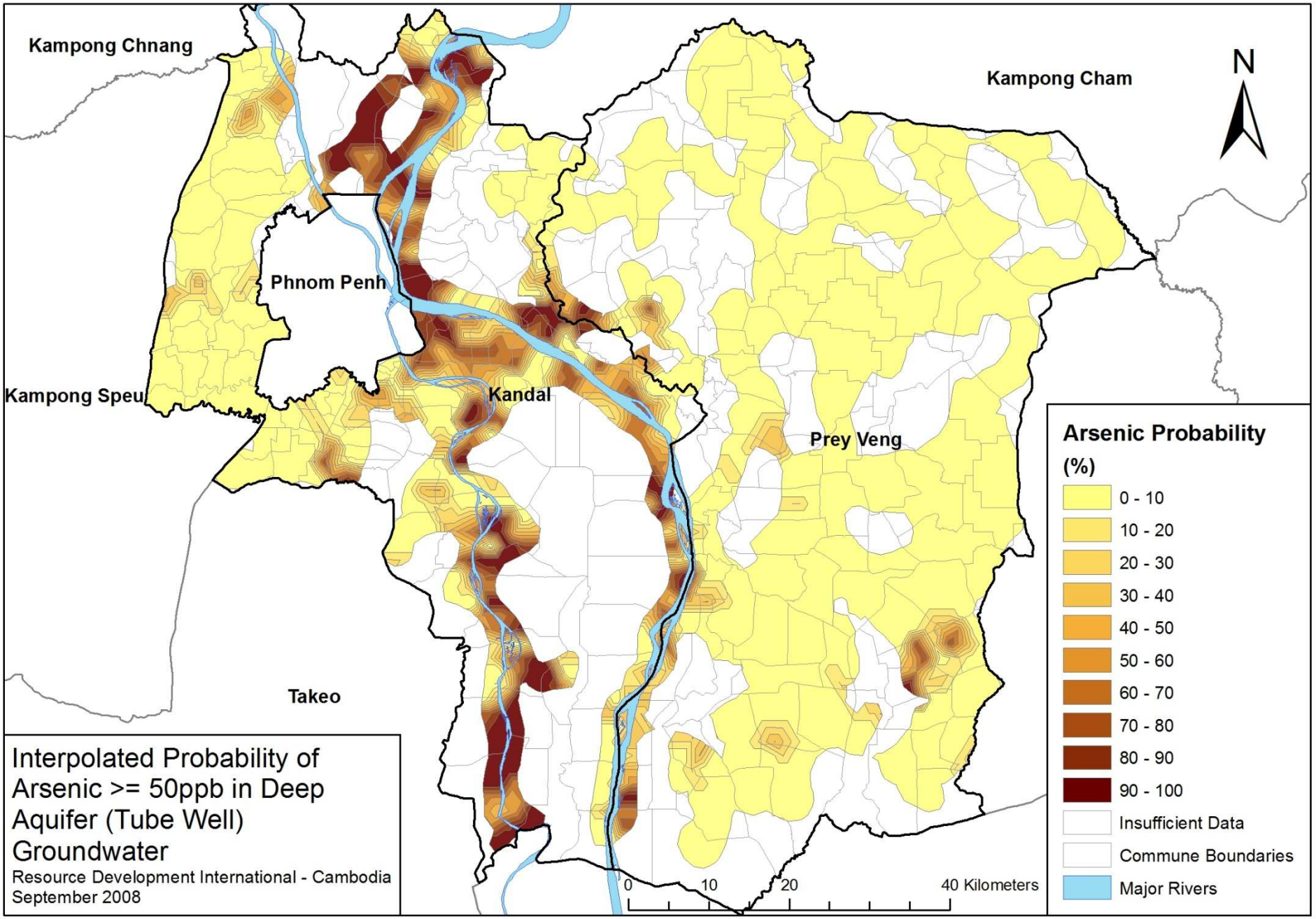
# 1a. Spatial Analysis – Concentration Gradients



# 1b. Spatial Analysis – Expected Conc. By Commune



# 1c. Spatial Analysis – Probability gradients



# 2. Commune Groundwater Quality Reports

- Drinking water quality index
  - Health and aesthetic quality
- Information on commune and samples
- Contaminants of potential concern
  - Probabilities of exceeding CDWQS
  - Health/aesthetic impacts
- Commune map
  - Location of samples
  - Colour-coded exceedances of CDWQS

# 2. Commune Groundwater Quality Report

- Drinking water quality index components
  1. Application of an appropriate statistical distribution to each parameters dataset, for each commune → Cumulative probability of exceeding water quality standards
  2. Percentage of unsafe/unacceptable wells
- DWQI is an average of these two probabilistic methods

# 2. Commune Groundwater Quality Report

| F |
|---|
| 60.00 |
| 20.00 |
| 55.00 |
| 0.75 |
| 7.00 |
| 6.50 |
| 1.05 |
| 0.60 |
| 0.85 |
| 0.95 |
| 0.85 |
| 0.75 |
| 0.70 |
| 0.60 |
| 0.65 |
| 0.80 |

- Application of distribution → 70% chance of fluoride >= 1.5 mg/L
- But only 5/16 (31%) wells unsafe

| As |
|---|
| 40 |
| 10 |
| 15 |
| 30 |
| 10 |
| 30 |
| 30 |
| 70 |
| 20 |
| 50 |
| 40 |
| 50 |
| 5 |
| 50 |
| 70 |
| 70 |

- Application of distribution → 26% chance of arsenic >= 50 ppb
- But 6/16 (38%) samples unsafe

# 2. Commune Groundwater Quality Report

| As | F | NO3 | Mn |
|---|---|---|---|
| 400 | 0.60 | 2.860 | 0.650 |
| 300 | 0.75 | 0.572 | 4.750 |
| 30 | 0.30 | 0.207 | 3.500 |
| 300 | 0.25 | 0.176 | 3.700 |
| 30 | 0.35 | 1.056 | 0.160 |
| 20 | 0.65 | 1.056 | 0.021 |
| 40 | 0.35 | 0.189 | 0.120 |
| 300 | 0.30 | 0.176 | 0.011 |
| 60 | 0.80 | 0.141 | 0.022 |
| 500 | 0.40 | 0.053 | 8.400 |
| 5 | 0.70 | 0.040 | 0.021 |
| 500 | 0.40 | 0.026 | 0.012 |
| 300 | 0.50 | 0.013 | 0.012 |
| 500 | 0.35 | 0.000 | 0.052 |
| 70 | 0.75 | 0.334 | 0.850 |
| 200 | 0.35 | 0.299 | 0.110 |
| 0 | 1.00 | 0.242 | 0.650 |
| 70 | 0.50 | 0.224 | 0.055 |
| 50 | 0.50 | 0.176 | 0.055 |

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# 2. Commune Groundwater Quality Report

- 4/19 (21%) wells are safe
- Probability of presence below standard:
  - Arsenic: 23%
  - Manganese: 37%
  - Nitrate: 100%
  - Fluoride: 100%
  - Combined: 9%
- Health-based DWQI = 15

# 2. Example Commune Report

# GROUNDWATER QUALITY ANALYSIS REPORT

## Kandal - Kaoh Thum - Kampong Kong (1F)

Kampong Kong is located in the district of Kaoh Thum. The population of this commune is approximately 11241 (2004). Groundwater sample collection occurred in November 2006 and July 2008 and consisted of the sampling of 26 tube wells throughout the commune. The attached figure presents the location of Kampong Kong within Kandal as well as groundwater sample locations and exceedances of health-impacting contaminants (when applicable).

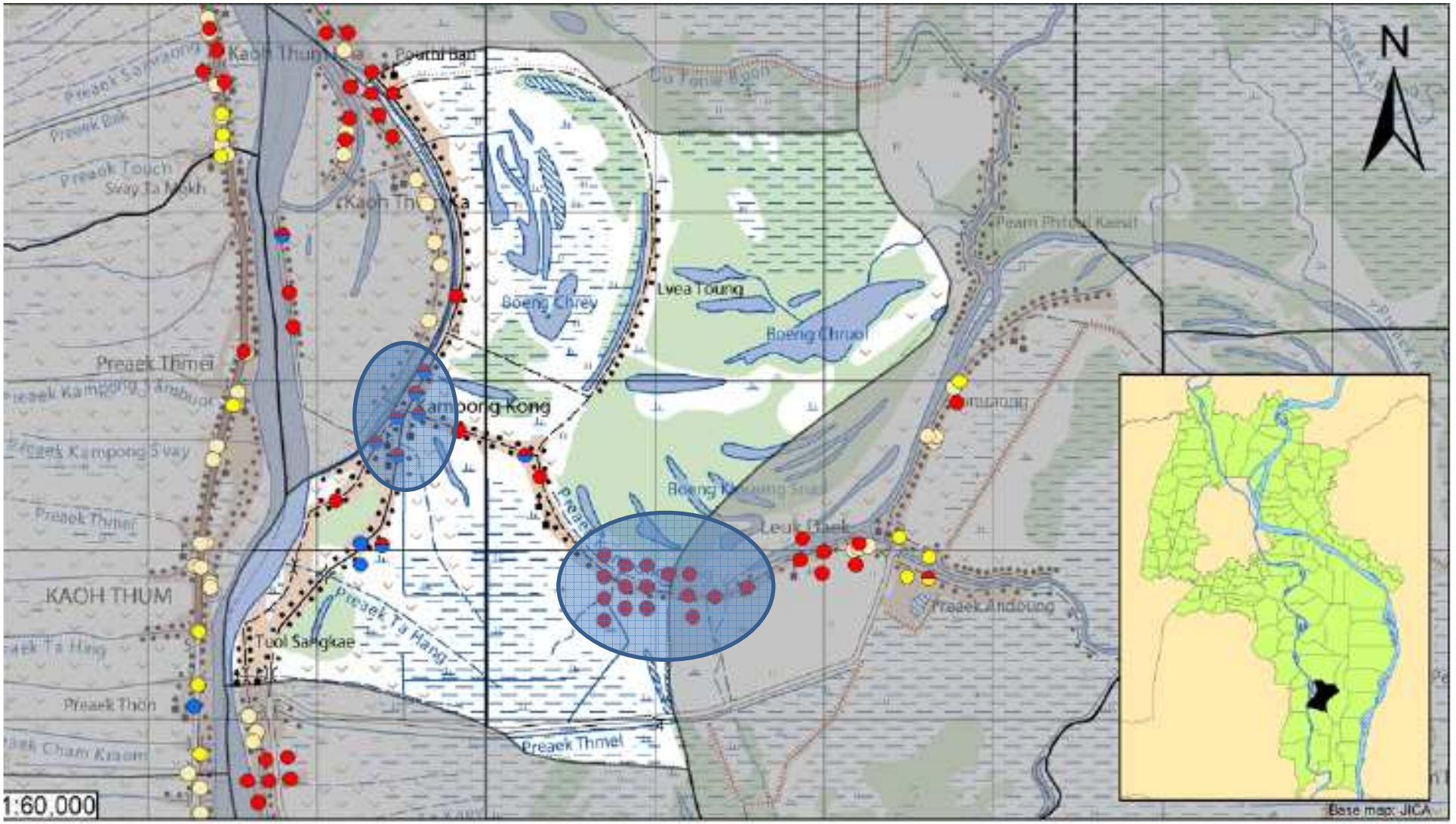
## Groundwater Quality Rating

The groundwater quality rating for Kampong Kong is 1F. Therefore, the general safety of deep aquifer groundwater is extremely poor and the aesthetic quality of the water is poor, according to the contaminants measured and samples collected. The following two sections describe all major health and aesthetic contaminants that exceeded drinking water standards in at least one sample within the commune.

## Contaminants of Potential Concern – Health

Arsenic - Elevated concentrations of Arsenic were observed within the commune. The estimated probability of encountering unacceptable concentrations of Arsenic (>50 ppb) in tube wells is 98%, based on the observed data. Long-term (5 to 10 year) exposure to elevated concentrations of Arsenic can cause arsenicosis (debilitating skin disease), increased risks of contracting cancer, as well as other negative health impacts.

Manganese - Elevated concentrations of Manganese were observed within the commune. The estimated probability of encountering unacceptable concentrations of Manganese (>0.4 mg/L) in tube wells is 42%, based on the observed data. Exposure to elevated concentrations of Manganese can cause neurological disorders. Aeration allows oxygen to enter the water and react with Manganese to form a compound which is insoluble in water. The newly formed solids will slowly settle to the bottom or can be removed more rapidly by filtration. Performing these procedures may reduce the concentration of Manganese in water but follow-up testing is recommended to ensure water quality standards are met.




Arsenic
Manganese
Fluoride
Nitrate

No Exceedance
Provincial Boundary
Commune Boundary

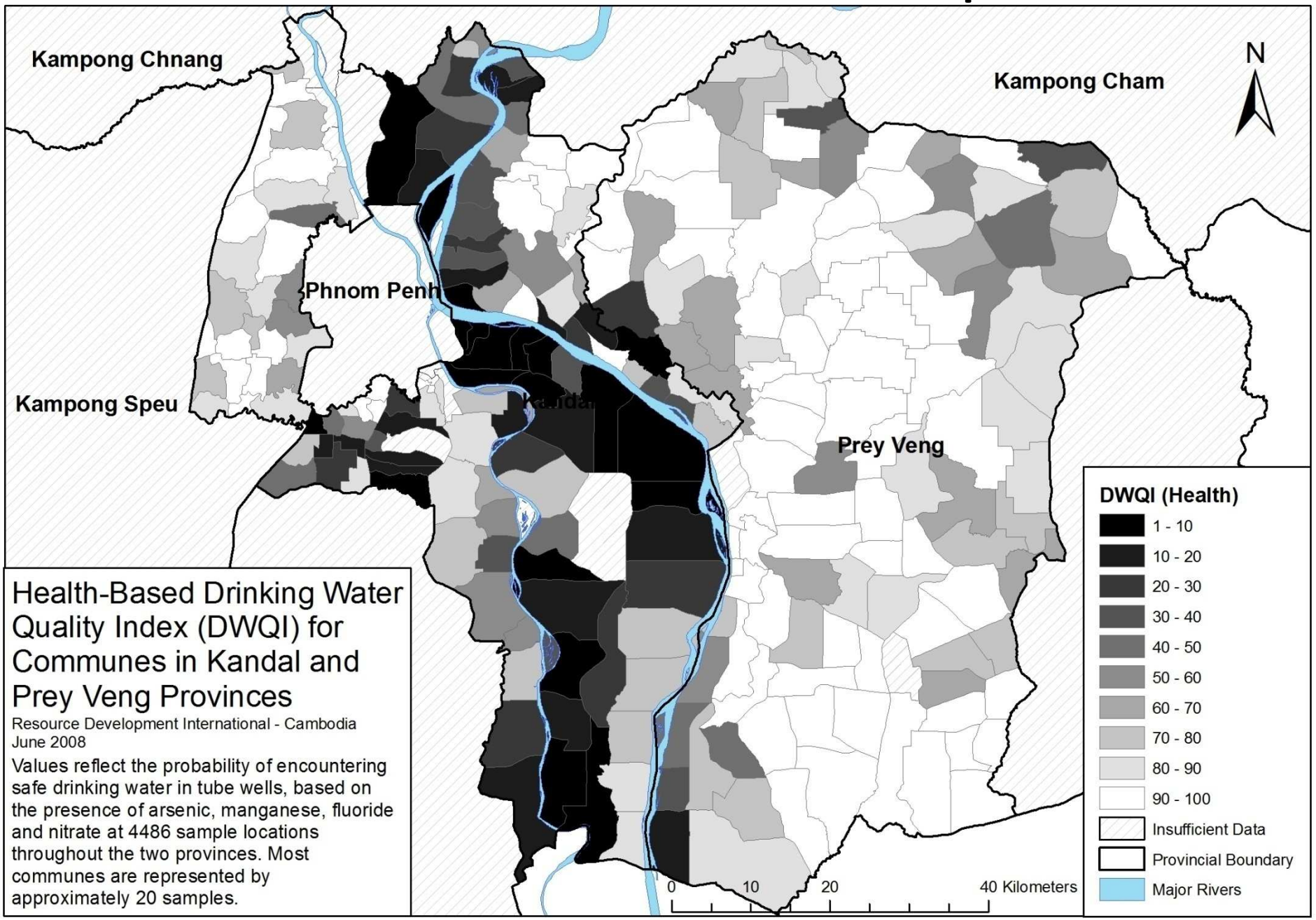
Locations exceeding the Cambodian water quality standards for major health-impacting contaminants have been colour-coded and arranged such that they do not overlap.

# Tube Well Sample Locations and Health-Based Exceedances

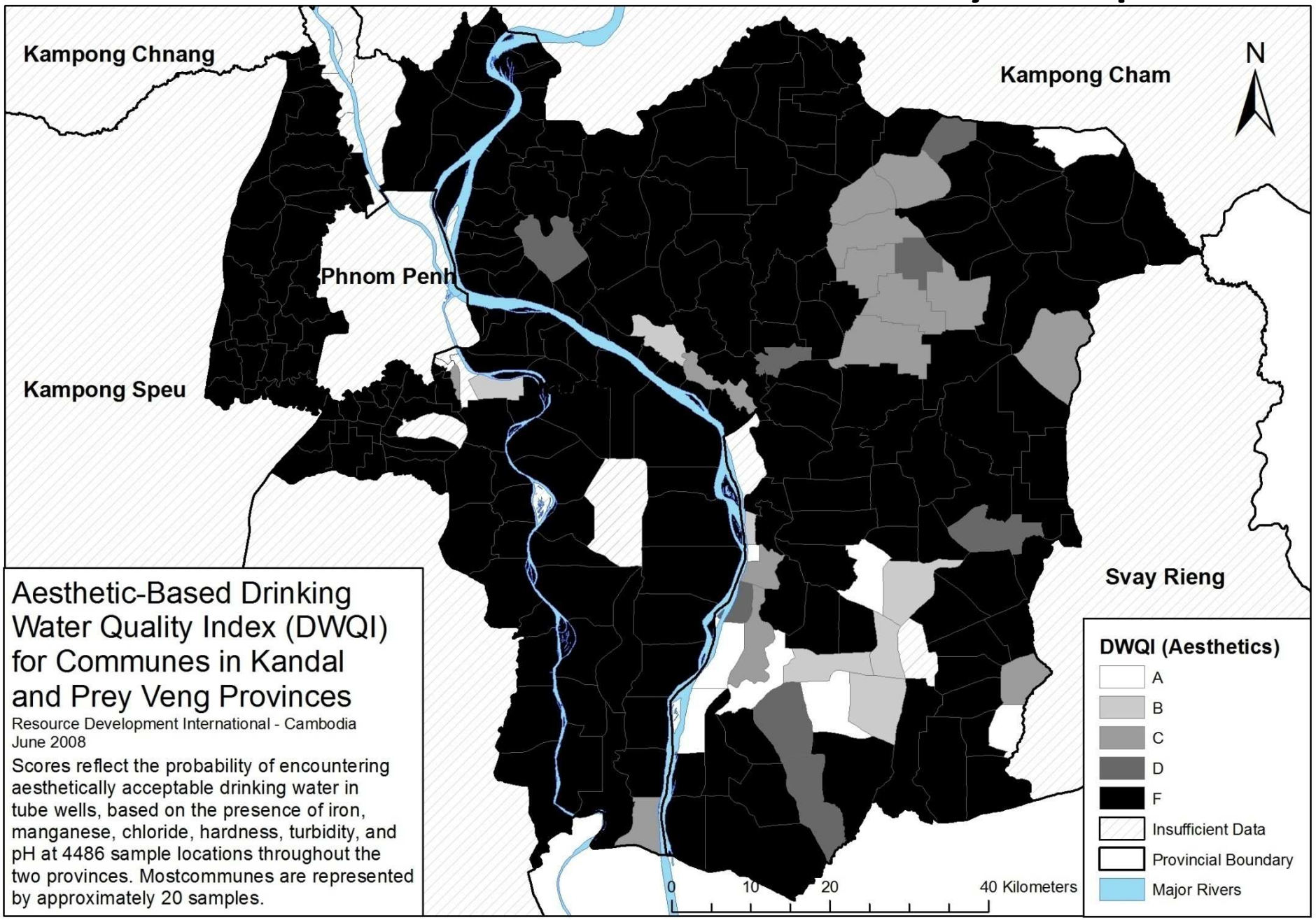
*Kampong Kong - Kaoh Thum - Kandal - Cambodia*

Resource Development International - Cambodia
www.rdic.org
June 2008

# Tube Well Hazard Map



# Tube Well Aesthetic Quality Map



# 3. Population Impact Assessment

- Purpose: To estimate the population consuming unsafe groundwater from tube wells in Kandal Province
- Inputs
  - Interpolated concentrations
  - Defined inhabited region
  - Population density at commune level

# 3. Population Impact Assessment

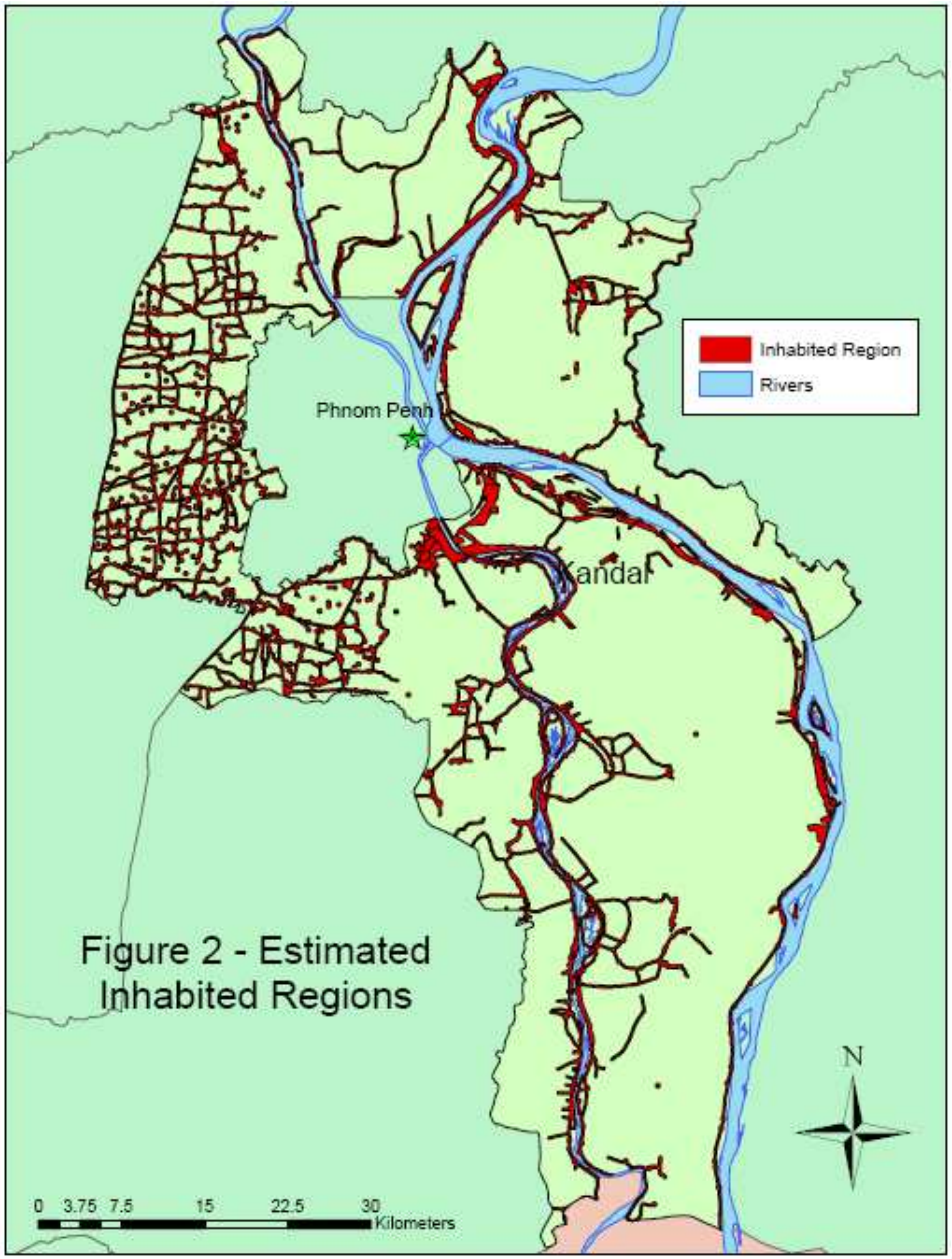
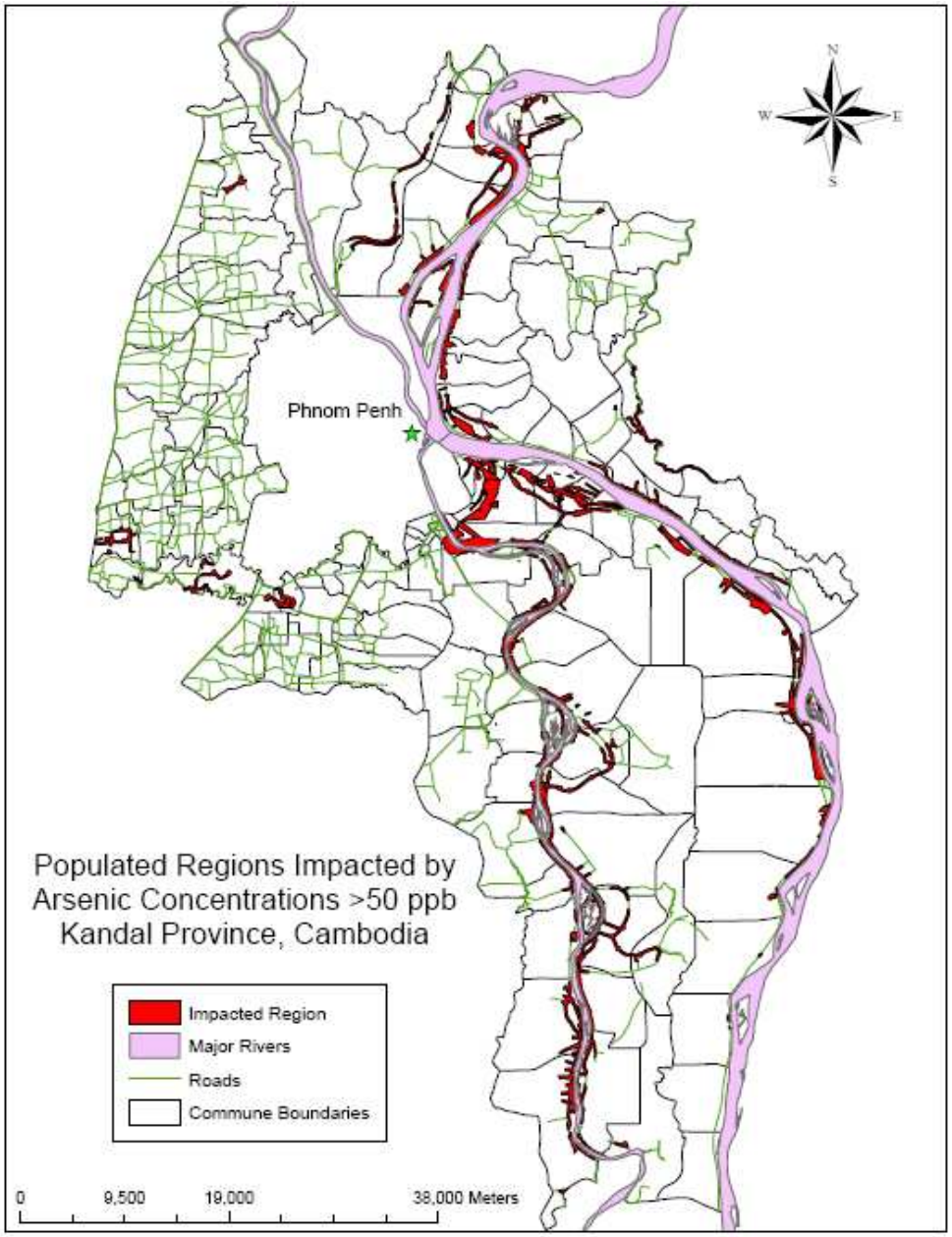



Figure 2 - Estimated Inhabited Regions



# 3. Population Impact Assessment

Summary of Impacted Populations:

| Contaminant | Water Quality Standard | Total Population | Provincial Tube Well Usage Rate[1] | Estimated Impacted Population |
|---|---|---|---|---|
| Arsenic | 50 ug/L | 380,000 | 27% | 102,600 |
| Fluoride | 1.5 mg/L | 33,000 | 27% | 8,910 |
| Manganese | 0.4 mg/L | 163,000 | 27% | 44,010 |
| Nitrate | 50 mg/L | 0 | 27% | 0 |
| All | - | 466,000 | 27% | 125,820 |

1. National Institute of Statistics (NIS) {Cambodia}, http://www.stats.nis.gov.kh/SURVEYS/cips2004/provin_cips.htm

# Sources of Error:

- Interpolated surface
- Changes in population data
- Regional fluctuations in tube well use rate
- Accuracy of inhabited region

# Alternative Drinking Water Sources

1. ‘Rope’ pumps
   - Operability
   - Pathogenic risk
   - Significantly lower chemical risk

2. Rainwater harvesting
   - Storage capability
   - Pathogenic risk
   - Preferred drinking water source

# Potential Issues

- Changes in water quality with depth
  - Typical tube well depth 20 – 50m
  - Lower arsenic in shallow (5 - 15m) aquifer
  - Relationship evident but not well studied

- Changes in water quality over time/seasons
  - Groundwater dating
  - Aquifer separation

# Conclusions

- Tube wells are a convenient and safe drinking water source in some regions of Cambodia
- Raw groundwater data can be transformed into effective baseline information for decision-makers using GIS and statistical tools
- GIS tools are a modern day necessity for analyzing, representing, and communicating spatial data

Questions?