Fight against desertification: Groundwater Artificial Recharge in Vietnam

Nguyen Thi Kim Thoa, Giuseppe Arduino, Peter Dillon, Nguyen Van Giang, Phan Thi Kim Van, Bui Tran Vuong

(1) Vietnamese Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam, Tel: 84 48 363 238, Fax: 84 48 364 696, E-mail: nkthoa@fpt.vn
(2) Hydrological/Geological Unit, UNESCO Office, Jalan Galuh (II), n. 5, Kebayoran Baru Jakarta, Indonesia. Tel: 62 21 73 99 818 Ext. 837, Fax: 62 21 72 79 6489, e-mail g.arduino@unesco.org
(3) CSIRO Land and Water, Waite Road, Urrbrae, South Australia. Email:
(4) Division of Hydrogeology and Engineering Geology for the South of Vietnam, email: buitranvuong@yahoo.com
CONTENT

1- PROJECT OBJECTIVES
2- SITE DESCRIPTION
3- EXPERIMENTAL PROGRAM
4- RESULTS
5- DISCUSSIONS
6- CONCLUSION
1- PROJECT OBJECTIVES

1. To find out appropriate methods in order to locate, design and operate an AR system in Binh Thuan, Vietnam.

2. To identify opportunities for providing water to Hong Phong subdistrict, Binh Thuan, Vietnam

3- To assess options in order to fight against desertification in Hong Phong
2- SITE DISCRIPTION

LOCATION
- 8,000 km²
- 1 million resident
  • the driest part of Vietnam
  • aver. rainfall of 1,112 mm/yr (23 mm from December to March),
  • aver. evaporation is 1800mm/year
  • 70-80% of the runoff occurs during the rainy season, only small portion of runoff is retained by surface storages, while the majority evaporates and infiltrates directly into the sand dunes

The water demand in Hong Phong was estimated to be 1700 m³/d for residents and for livestock. Large amount of water is needed for irrigation.
2- SITE DISCREPTION

TOPOGRAPHY
Three types:
- Low mountains
- Costal plains
- Costal sand dunes
## 2- SITE DISCRIPTION

### HYDROGEOLOGY

<table>
<thead>
<tr>
<th>Aquifer Type</th>
<th>Aquifer</th>
<th>Nominal Lithology</th>
<th>Geological Formation</th>
<th>Thickness (m)</th>
<th>Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holocene</td>
<td>Q3</td>
<td>Silty sand, clay sand, gravel, pebbles</td>
<td>$Q_1$, $Q_2$, $Q_3$, $Q_4$, $Q_5$, $Q_6$, $Q_7$, $Q_8$, $Q_9$</td>
<td>5 - 50</td>
<td>Low Q &lt; 0.3 l/s</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Q3, Q4</td>
<td>Pebbles, gravel, sand clay, silt, sand, clayey sand</td>
<td>$Q_1$, $Q_2$, $Q_3$, $Q_4$, $Q_5$, $Q_6$, $Q_7$, $Q_8$, $Q_9$</td>
<td>60 - 120</td>
<td>Medium 0.5 &lt; Q &lt; 2 l/s</td>
</tr>
<tr>
<td>Recent</td>
<td>Q4</td>
<td>Olivine basalt...</td>
<td>$Q_1$, $Q_2$, $Q_3$, $Q_4$, $Q_5$, $Q_6$, $Q_7$, $Q_8$, $Q_9$</td>
<td>5 - 20</td>
<td>Low Q &lt; 0.3 l/s</td>
</tr>
<tr>
<td>Jurassic</td>
<td>J1, J2</td>
<td>Sediments, sandstone and siltstone</td>
<td>$Q_1$, $Q_2$, $Q_3$, $Q_4$, $Q_5$, $Q_6$, $Q_7$, $Q_8$, $Q_9$</td>
<td>&gt; 1000</td>
<td>Low Q &lt; 0.3 l/s</td>
</tr>
</tbody>
</table>
3- EXPERIMENTAL PROGRAM

The program consists of:

- geophysical survey
- drilling
- aquifer testing
- water chemical and isotopic analyses
- tracer tests
- monitoring
- training
3- EXPERIMENTAL PROGRAM

**Geophysical survey**

- Vertical electric sounding (VES): 48 points with maximum AB=1000 m.
- VLF: along a line of 1250m with 5 m spacing.
- Ground Penetrating Radar (GPR): 10 profiles
3- EXPERIMENTAL PROGRAM

**Drilling**

<table>
<thead>
<tr>
<th>Well ID</th>
<th>KS-BN (pumping well)</th>
<th>QT-BN</th>
<th>QSI</th>
<th>QSII</th>
<th>QS3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth of well, m</td>
<td>60</td>
<td>71.0</td>
<td>34.0</td>
<td>31.5</td>
<td>79.4</td>
</tr>
<tr>
<td>Distance from pumping well (KS-BN), ri (m)</td>
<td></td>
<td>9.76</td>
<td>11</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Average yield, Q (m³/day)</td>
<td></td>
<td></td>
<td>213,408</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static water level, Hs (m)</td>
<td>4.50</td>
<td>4.83</td>
<td>2.60</td>
<td>0.80</td>
<td>8.945</td>
</tr>
<tr>
<td>Aquifer thickness D, m</td>
<td>29.96</td>
<td>31.85</td>
<td>-</td>
<td>-</td>
<td>48.835</td>
</tr>
<tr>
<td>Drawdown si (after 142 days of pumping), m</td>
<td>3.04</td>
<td>0.365</td>
<td>0.34</td>
<td>0.24</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Aquifer testing
Aquifer test had been carried out from May 27, 2005 to November 5, 2005 (over 5 months).
3- EXPERIMENTAL PROGRAM

Aquifer testing

Lake BN

QSII

Lake BN

QSI

Lake BN

KS-BN
3- EXPERIMENTAL PROGRAM

Water sampling and analyses
– 19 samples for isotope analysis.
– 116 samples for chemical analysis
– 01 samples for micro heavy metals analysis.
– 50 samples for *E.coli* analysis
– 102 samples for *Feacal Coliform*
– 83 samples for *Total coliform*,
– 50 samples for *Total aerobic bacterium*,
– 44 samples for *Clostridium-perfringer*
3- EXPERIMENTAL PROGRAM

Tracer test

- Single well techniques:
  - 2 tests under natural condition.
  - 4 tests under pumping condition.
- Multi-well tracing technique:
  - 2 tests under pumping conditions.
3- EXPERIMENTAL PROGRAM

Monitoring

• measured by manual from May 27, 2005 to October 1st, 2005
• measured by data logger (CTD) from October 1st, 2005 to now.
3- EXPERIMENTAL PROGRAM

Training

- The International Workshop on Aquifer Recharge Techniques held in HCM City in December 2004 (40 participants from 9 countries),
- The participation of Vietnamese scientists to International workshops on Managing Aquifer Recharge, held in Berlin, June 2005 and in New Delhi, September 2005,
- 2 training courses held in October 2005 for 65 master students in Vietnam.
4- RESULTS

Depth to bed rock (geophysics)
4- RESULTS

Rate and direction of groundwater flow

• Hydraulic gradient = 0.009
• Transmissivity, $k_D = 380$ m$^2$/day
• Hydraulic conductivity, $k = 11.8$ m/day
• Aquifer thickness = 30.5 m
• The amount of flow passing beneath the Lake BN (140m wide) = 453 m$^3$/day
4- RESULTS

Rate of recharge

Chloride balance:

\[ Q_{rain} \cdot C_{rain} = Q_{gw} \cdot C_{gw} \]

where:

- \( Q_{rain} \), \( Q_{gw} \) are annual rainfall and the recharge, respectively, mm/yr
- \( C_{rain} \), \( C_{gw} \): Chloride content in rainwater and groundwater, respectively, mg/l

\[ 1127 \times 5.32 = Q_{gw} \times 59.65 \]

\[ Q_{gw} = 100.5 \text{ mm/year} \]
4- RESULTS

Surface water- groundwater interaction

Pumping at 213 m$^3$/d (2.45 l/s) for over 5 months, no effect on the Lake BN is induced.
4- RESULTS

Water quality

The chloride of lake BN water varies seasonally.

NO₃⁻ content of G.W is always higher than that of lake BN water.

No relationship between pumped water and lake BN water.
4- RESULTS

Recharge areas and resident time

- Groundwater is recharged from rainwater.
- The age of groundwater is between 20 to 40 years, representing significant localised recharge.
4- RESULTS

Groundwater velocity
-under natural condition varies from 0.59 to 1.2 cm/day
-under pumping conditions ranges from 7.8 to 43.51 cm/day
5- DISCUSSIONS

- The age of groundwater is between 20 to 40 years, representing significant localised recharge.
- The flow towards, and beneath Lake BN is approximately 3.2 m$^3$/d/m, representing a considerable harvestable groundwater resource.
5- DISCUSSIONS

- At pumping rates of lower than 453 m$^3$/d (5.2 l/s), the Lake BN is not affected. This amount will meet the water supply requirements for both people and livestock as well as for irrigation of approx. 2 ha of land.
- The field site is now suitable for groundwater extraction in order to supply water to Hong Phong subdistrict.
5- DISCUSSIONS

Opportunities for providing water to Hong Phong:
1. Extract GW at well KS-BN at 453 m³/d (5.2 l/s) – NOW EXISTING.
2. POTENTIALLY: construct a well field 1 km long parallel to Lake BN in order to extract 3,200 m³/d (37 l/s) and pump Bau Trang water to Lake BN to enhance recharge and recovery.
3. Pump Lake Bau Trang water to Hong Phong directly.
5- DISCUSSIONS

4. Pump the sand dune aquifer adjacent to Bau Trang (AR through bank filtration techniques) then direct to Hong Phong.
5. Water harvesting from roofs in Hong Phong village for storage in tanks or wells.
6. Improve water harvesting at Bau Thieu.
7. Pump water from Luy River (north) for recharge at Tazon depression.
5- DISCUSSIONS

Evaluation of water supply options for Hong Phong against various criteria

<table>
<thead>
<tr>
<th></th>
<th>options</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>criteria</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of supply (m$^3$/d)</td>
<td>453</td>
<td>3200</td>
<td>large?</td>
<td>large</td>
<td>small</td>
<td>small</td>
<td>large</td>
<td></td>
</tr>
<tr>
<td>Reliability of supply</td>
<td>high</td>
<td>high</td>
<td>high?</td>
<td>high</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>high?</td>
</tr>
<tr>
<td>Cost</td>
<td>low</td>
<td>moderate</td>
<td>low</td>
<td>moderate</td>
<td>low</td>
<td>low?</td>
<td>high?</td>
<td></td>
</tr>
<tr>
<td>Robustness, maintenance, energy</td>
<td>good</td>
<td>moderate</td>
<td>good</td>
<td>moderate</td>
<td>good</td>
<td>moderate</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>Investigations completed</td>
<td>✓✓✓</td>
<td>✓</td>
<td>✓✓✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Speed to establish</td>
<td>✓✓✓</td>
<td>✓</td>
<td>✓✓✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>No environmental harm</td>
<td>✓✓✓</td>
<td>✓</td>
<td>✓✓✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ranking</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
6- CONCLUSION

1- The study is an excellent example of a well-executed hydrogeological study. These skills are essential foundations for groundwater management which will become increasingly important as Vietnam’s economy develops.
6- CONCLUSION

2- For fight against desertification in Hong Phong, it is recommended that an economic evaluation of options currently ranked 1, 2, 3 and 4 is undertaken. This would lead to a decision on whether to proceed with hydrogeological investigations at Bau Noi site, at Bau Trang pumping station site or at the Tazon depression.
6- CONCLUSION

3- It is recommended that a national master plan for managed aquifer recharge is implemented.
This project is supported by The Vietnamese Ministry of Science and Technology, the Italian Ministry for the Environment and Territory MOET, UNESCO.

Thank you for your attention

Dragon fruit in Binh Thuan

Beautiful beaches in Binh Thuan