Groundwater Resource Potential in Indonesia and their Management

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Outline

- Introduction
- Groundwater basin in Indonesia and their potency
- Groundwater exploitation
- Impacts of groundwater exploitation
- Groundwater management
- Closing remarks
Introduction

- Water, including groundwater (Gw), is indispensable for life, but its availability at a sustainable quality & quantity is threatened by many factors, mainly by climate pattern (free Gw system) & Gw abstraction (artesian Gw system).

- Since the last four decades, in the era of developing of the country, populous cities serving as centers of development for services, education, tourism and other sectors are growing in the whole of Indonesia, primarily in Java. The need for water (including Gw), therefore, is increasing correspondingly to the population & economic growth.

- As stipulated in Article 13 of Law No. 7/2004 on Water Resources which was issued by the Government of the Republic of Indonesia, management of gw resource should be based on **Groundwater Basin (GB)**.

- Detailed information on Gw potency of each GB which were identified should be provided by the central government and local governments (province, regency/city) for planning and management.

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Groundwater Basins in Indonesia and their Potency

Groundwater basin (GB) is a region which is bordered by hydrogeological boundaries where the hydrogeological processes such as recharging, flowing, and discharging of groundwater occurred.

In Indonesia, 421 groundwater basins were identified, but only a few number of the basins have been assessed in detail their gw potency (Geological Agency, 2010).
Map of Gw Basin in Banten, Jakarta, and West Java Provinces (Java Island)

Map of Gw Basin in Bali Province

16/06/2011
Gw Potency in Indonesia

Based on mean annual rainfall which were analysed by Meteorological and Geophysical Agency – MGA (1975) and recharge percentage of various aquifer formation, total gw quantity in Indonesia at unconfined aquifer system (R1) were roughly calculated \(496,217 \times 10^6 \text{ m}^3/\text{year}\), whereas at confined aquifer system (Q2) which were calculated by applying Darcy’s Law attains \(20,906 \times 10^6 \text{ m}^3/\text{year}\) (Table 1, Geological Agency, 2008).

Table 1 Recapitulation of Gw Basin in Indonesia

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Region</th>
<th>Number of GB</th>
<th>Area [Km²]</th>
<th>Free Gw (\text{Q1})</th>
<th>Confined Gw (\text{Q2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sumatera</td>
<td>65</td>
<td>272,843</td>
<td>123,528</td>
<td>6,551</td>
</tr>
<tr>
<td>2</td>
<td>Java &amp; Madura</td>
<td>80</td>
<td>81,147</td>
<td>38,851</td>
<td>2,046</td>
</tr>
<tr>
<td>3</td>
<td>Kalimantan</td>
<td>22</td>
<td>181,362</td>
<td>67,963</td>
<td>1,102</td>
</tr>
<tr>
<td>4</td>
<td>P. Sulawesi</td>
<td>91</td>
<td>37,778</td>
<td>19,694</td>
<td>550</td>
</tr>
<tr>
<td>5</td>
<td>Bali</td>
<td>8</td>
<td>4,381</td>
<td>1,577</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>West Nusa Tenggara</td>
<td>9</td>
<td>9,475</td>
<td>1,908</td>
<td>107</td>
</tr>
<tr>
<td>7</td>
<td>East Nusa Tengara</td>
<td>38</td>
<td>31,929</td>
<td>8,229</td>
<td>200</td>
</tr>
<tr>
<td>8</td>
<td>Maluku</td>
<td>68</td>
<td>25,830</td>
<td>11,943</td>
<td>1,231</td>
</tr>
<tr>
<td>9</td>
<td>Papua</td>
<td>40</td>
<td>262,870</td>
<td>222,524</td>
<td>9,098</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>421</td>
<td>907,615</td>
<td>496,217</td>
<td>20,906</td>
</tr>
</tbody>
</table>

Note:
- Gw basin in regency/city : 206 GBs
- Province border crossing Gw basin : 35 GBs
- Regency/city border crossing Gw basin : 176 GBs
- Country border crossing Gw basin : 4 GBs

16/06/2011

Groundwater Exploitation

1 Drinking Water in Rural Areas
   - \(\geq 80\%\) of the Indonesian population live in rural area.
   - Drinking water demand in rural areas \(\geq 100 \text{ L/person/day}\).
   - The utilization of groundwater (dugwells or driven wells) is roughly estimated about 70% of total water resources.

2 Drinking Water & Industrial Requirements in Urban Areas
   - Drinking water demand in urban areas \(\geq 200 \text{ L/person/day}\).
   - Less than 30% of the population in large cities (Jakarta, Bandung, Semarang, Surabaya, Medan, Ujung Pandang) used fresh water from the city water supply (the remaining still rely on Gw).
   - Qabs in Jakarta, Bandung, & Semarang areas (see figures).

3 Irrigation Water
   Gw for irrigation purpose was utilized since 1970 in Java (Yogyakarta, Est Java, & Central Java) - its use for large scale irrigation.

16/06/2011
### Total Number of Wells and Volume of Abstraction in Semarang GB

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Vol. of Abstraction in million m³</th>
<th>Number of Wells</th>
<th>Irrigated lands (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>10</td>
<td>15</td>
<td>162</td>
</tr>
<tr>
<td>1981</td>
<td>20</td>
<td>9</td>
<td>132</td>
</tr>
<tr>
<td>1982</td>
<td>30</td>
<td>7</td>
<td>91</td>
</tr>
<tr>
<td>1983</td>
<td>40</td>
<td>5</td>
<td>65</td>
</tr>
<tr>
<td>1984</td>
<td>50</td>
<td>3</td>
<td>46</td>
</tr>
<tr>
<td>1985</td>
<td>60</td>
<td>2</td>
<td>31</td>
</tr>
<tr>
<td>1986</td>
<td>70</td>
<td>1</td>
<td>22</td>
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<td>14</td>
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<tr>
<td>1988</td>
<td>90</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>1989</td>
<td>100</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1990</td>
<td>110</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1991</td>
<td>120</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1992</td>
<td>130</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1993</td>
<td>140</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1994</td>
<td>150</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1995</td>
<td>160</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1996</td>
<td>170</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1997</td>
<td>180</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1998</td>
<td>190</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1999</td>
<td>200</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2000</td>
<td>210</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2001</td>
<td>220</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2002</td>
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<td>2003</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2007</td>
<td>280</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2008</td>
<td>290</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2009</td>
<td>300</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Irrigation by Groundwater in Indonesia (Haryadi, 2009)

<table>
<thead>
<tr>
<th>Province</th>
<th>Deep Wells</th>
<th>Medium Wells</th>
<th>Shallow Wells</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of wells</td>
<td>Irrigated lands (Ha)</td>
<td>Number of wells</td>
<td>Irrigated lands (Ha)</td>
</tr>
<tr>
<td>W. Java</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>162</td>
</tr>
<tr>
<td>C. Java</td>
<td>12</td>
<td>379</td>
<td>10</td>
<td>163</td>
</tr>
<tr>
<td>E. Java</td>
<td>494</td>
<td>23.38</td>
<td>60</td>
<td>488</td>
</tr>
<tr>
<td>Yogyakarta</td>
<td>36</td>
<td>1,150</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bali</td>
<td>3</td>
<td>91</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>W. Nusa Tenggara</td>
<td>126</td>
<td>1,717</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>S. Sulawesi</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>176</td>
</tr>
<tr>
<td>C. Sulawesi</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>132</td>
</tr>
<tr>
<td>Total</td>
<td>671</td>
<td>26.71</td>
<td>119</td>
<td>1,121</td>
</tr>
</tbody>
</table>

**Note:**
- Deep wells (100-200 m) equipped with deep pumps
- Medium wells (30-100 m) equipped with centrifugal pumps
- Shallow wells (<30 m) equipped with centrifugal pumps
Impacts of Groundwater Exploitation

1 Degradation on Gw Quantity
✓ Lowering of Gw level & cone of Gw depression.
✓ Decreasing of spring discharge/underground stream.

2 Degradation on Gw Quality
✓ Increasing of Gw salinity
✓ Salt water intrusion/Gw contamination.
✓ Decreasing of Gw quality.

3 Land Subsidence
✓ Lowering of land elevation.
✓ Expansion of flooded area.
✓ Infrastructure damage.
✓ Normal consolidation and/or over Gw abstraction.
Jakarta GB

Piezometric Heads of Lower Confined Aquifer System [>140 mbbls]

Map of Piezometric Heads SEMARANG CITY

Legend:
- Contour Line of Piezometric head in 1966
- Contour Line of Piezometric head in 1983
- Contour Line of Piezometric head in 1998
- Contour Line of Piezometric head in 2007
- Road
Zone of Brackish/Salty Groundwater

Brackish/salty Gw
- Gisement under tidal influence, under tidal zone, and seawater intrusion
- Gisement under tidal influence due to seawater intrusion
- Gisement under tidal influence due to seawater intrusion, and backwater zone
- Gisement under tidal influence due to seawater intrusion, and backwater zone

Fresh Gw
- Gisement under tidal influence, under tidal zone, and seawater intrusion

Contour line of EC, in uS/Cm
- Gisement under tidal influence, under tidal zone, and seawater intrusion
- Gisement under tidal influence due to seawater intrusion
- Gisement under tidal influence due to seawater intrusion, and backwater zone

Land Subsidence phenomena in Kamal Muara area (1) and Tongkol area (2), North of Jakarta
Flooded way due to land subsidence in Cengkareng area, Tangerang

Zone of Land Subsidence in the North of Jakarta
Semarang GB, Central Java

Zone of Land Subsidence (Geological Agency, 2000-2001)

Regulations for Gw Management in Indonesia

1. Law Nr. 7 of 2004 on Water Resources.
2. Government Decree Nr. 43 of 2008 on Groundwater.
3. Presidential Decree on Gw Basin (draft, will be issued by the end of 2011).
Technical Efforts on Gw Management

Gw Inventory
1. Hydrogeological mapping scale 1:250,000 (see status in 2010).
2. Deliniation and evaluation of Gw Basin Boundaries.
3. Mapping on Gw recharge and discharge areas.
4. Assessment on Gw resource potential of the Gw Basin.
5. Establish zone of gw condition.
6. Gw modeling for urban Gw Basins.

Monitoring of Gw Quantity and Quality
(Assessment on change of Gw quantity and quality)

Gw Modeling
(Gw flow simulation model, scenario of Gw abstraction)

Gw Database and Information Management System
Monitoring of Gw Quantity and Quality

Jakarta GB

Gw Hydrographs of unconfined to confined aquifer systems in South Jakarta

Gw Hydrographs of confined aquifer systems in East Jakarta
Well Hydrograph of piezometric level in the East Bandung, 1994-2006

Zone of Gw Abstraction Controlling Bandung-Soreang GB (West Java)
Case Study: Denpasar GB, BALI

Model Aquifer System

Arah kolom

Arah baku
**STEADY STATE SIMULATION RUN**

Daerah Imbuhan AT (Gw Recharge Area)

Daerah Lepasan AT (Gw Discharge Area)

Zone transisi (horizontal flowing)

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**Cone of Gw Depresion Layer 2**

Qabs2009 = 120 x 10^6 m³/th

Daerah Gianyar (MAT > -50 mdml)

Daerah Sanur (MAT > -70 mdml)

Daerah Kuta (MAT > -70 mdml)

16/06/2011
ZONE Qabs 2009 | 2012
---|---
I.1 | 16 | -56875 | 17 | 16 | -28484 | 9
I.2 | 15 | -39942 | 12 | 15 | -15408 | 5
II | 31 | -45644 | 14 | 41 | -70175 | 21
III | 155 | -184395 | 56 | 155 | -184396 | 56
IV | 4 | -2166 | 1 | 14 | -30558 | 9
JUMLAH | 221 | -329022 | 100 | 241 | -329022 | 100

GROUNDWATER HEADS, LAYER 1
(YOUNG VOLCANIC AQUIFER SYSTEM)

Simulasi prognosis (Qabs-2012)
16/06/2011

**Daerah Kuta**
(MAT pulih dari -70 mdml menjadi -2 mdml)

**Daerah Sanur**
(MAT pulih dari -70 mdml menjadi -1 mdml)

**Daerah Badung**
(Cone of gw depresion (>18 maml)

**Jakarta GB**

**CONFIGURATION OF GROUNDWATER ABSTRACTION 1900 -2005**

**CALCULATED GW HEADS [msl]**
Closing Remarks

1. Gw has a significant role in providing water for various purposes in Indonesia (drinking water, industry, & irrigation purposes).

2. The increased rate of gw exploitation in the major cities in Indonesia had led to negative impacts on gw and on the environment surroundings (declining of gw level, salt water intrusion, and land subsidence).

3. Gw potency of each gw basin in Indonesia need to be assessed in detail (already planned for future activities).

4. Monitoring & analysis of gw conditions should be continuously performed especially in urban groundwater basins (e.g. Jakarta GB, Bandung-Soreang GB, and Semarang-Demak GB) in order to know the change of their availability.

5. Plan for future activities relating to gw management in Indonesia:
   1. Gw quantity & quality monitoring in urban gw basins (network design on gw monitoring wells, installation & expertise, budget)
   2. Gw quantification & modeling in all urban gw basins.
   3. Hydrogeological research for determining critical Gw discharge in urban Gw basins.