

PAPER • OPEN ACCESS

Urban hydrogeology in Indonesia: A highlight from Jakarta

To cite this article: R F Lubis 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **118** 012022

View the [article online](#) for updates and enhancements.

You may also like

- [Zoning groundwater potential recharge using remote sensing and GIS technique in the Red river delta plain](#)

Pham Quy Nhan, Le Viet Hung, Tran Thanh Le et al.

- [Sustainability of fresh groundwater resources in fifteen major deltas around the world](#)

J van Engelen, G H P Oude Essink and M F P Bierkens

- [Research on Establishing Tritium Concentration Model of Precipitation in Northeast of Tarim Basin Based on Factor Analysis](#)

Zhenhua Zhao, Dongqing Wang, Youliang Bai et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Urban hydrogeology in Indonesia: A highlight from Jakarta

R F Lubis¹

¹ Research Center for Geotechnology, Indonesia Institute of Sciences (LIPI)

Jl. Cisit Sangkuriang, Bandung 40135 Indonesia

E-mail: fajarlubis@geotek.lipi.go.id

Abstract. In many cities in the developing countries, groundwater is an important source of public water supply. The interaction between groundwater systems and urban environments has become an urgent challenge for many developing cities in the world, Indonesia included. Contributing factors are, but not limited to, the continuous horizontal and vertical expansion of cities, population growth, climate change, water scarcity and groundwater quality degradation. Jakarta as the capital city of Indonesia becomes a good example to study and implement urban hydrogeology. Urban hydrogeology is a science for investigating groundwater at the hydrological cycle and its change, water regime and quality within the urbanized landscape and zones of its impact. The present paper provides a review of urban groundwater studies in Jakarta in the context of urban water management, advances in hydrogeological investigation, monitoring and modelling since the city was established. The whole study emphasizes the necessity of an integrated urban groundwater management and development supporting hydrogeological techniques for urban areas.

1. Introduction

Urbanization has increasingly intensified in the last few decades and now approximately 48% of the world's population lives in urban centres. Urban areas are a focus of increasing conflict with regard to water use and water protection. More than half (54%) of the world's population and about 73% of Europeans live in cities [1]. The last century has registered significant issues related to demography, mainly concerning the increase in the overall population and demographic flow from rural areas to cities. Groundwater that represents about 30.1 % of the Earth's freshwater, is one of the most important fresh water resources for urban area [2]. In Western and Eastern Europe and in the Mediterranean region, urban aquifers contribute more than 40% to the water supply source [3]. In addition to climate change and many other influencing factors, this current status points out the necessity of an integrated urban groundwater management. This type of management must take into account all possible and relevant phenomena arising using all the latest hydrogeology investigation methods in regards to the understanding of urban hydrogeological science.

In Indonesia, urbanization also becomes one of the domain processes of city development in Indonesia. Urbanization can be referred to as a process in which an increasing proportion of an entire population lives in cities and the suburbs of cities. It has greatly accelerated conforming the rise in its population and the development of the city. In line with the development of the city in all sectors, several related problems have already caused some negative impacts to the city such as land subsidence and reduced groundwater capacity [4].



The fundamental processes that affect urban hydrogeology are not essentially different from those of rural environments. There are, however, differences relating to time and space scales [5]. Moreover, a number of new problems relating to groundwater and the urban environment arise can be defined as:

- Disruption of the groundwater cycle in urban areas. Rainfall infiltration is reduced, but this is counterbalanced by reductions in evapotranspiration and losses from the sewage and water distribution systems.
- Fluctuations of groundwater levels and temperature due to anthropogenic. Changes in urban patterns often lead to dramatic changes in water levels, and heat island phenomenon due to urban activities will also lead to urban subsurface warming.
- Effects on urban structures. Structures designed and built without a proper acknowledgement of groundwater are suffering seepage and flooding. Large areas in some cities are suffering subsidence and flooding.
- Groundwater contamination. Industrial spills, sewage losses, mobilization of pollutants due to fluctuation of groundwater levels and so on, lead to water pollution.

It can be said that urban hydrogeology is a science for investigating groundwater at the hydrological cycle and its change, water regime and quality within the urbanized landscape and zones of its impact. This paper describes some examples for implementing urban hydrogeology studies in cities in Jakarta, Indonesia based on many previous publications.

2. Hydrogeological investigation for negative impacts of altering the groundwater in Jakarta urban areas

Jakarta urban city areas lay in the Jakarta groundwater basin fill (Figure 1) which consists of marine Pliocene and Quaternary sand and delta sediments up to 300 m thick [6]. Based on groundwater drilling data in the form of cutting and some cores, previous works recorded a shallow groundwater group at 0-40 m, groundwater aquifer which is compressed over 40-140 m and groundwater aquifer which is compressed below 140-250 m [7]. [8]. This division of the group has been used until now. Another researcher [9] has divided 8 groups of aquifer systems forming an unconfined system (0 - 20 m) and 7 confined groundwater aquifers (20 - 300 m). The latest study conducted the distribution of aquifer system and aquitard in Jakarta groundwater basin based on the concept of hydrostratigraphy. This concept resulted 2 groups of aquifer system and aquitard system with basin base of Tertiary age sedimentary rock [10].

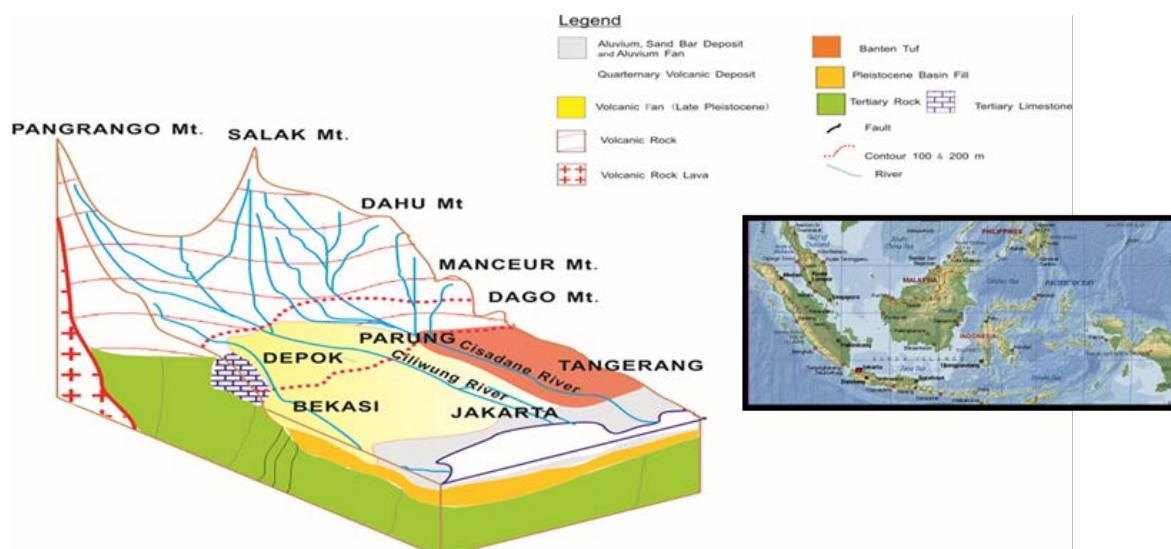


Figure 1. Jakarta city which lays in Jakarta Groundwater basin [6]

Many advances hydrogeological investigation, monitoring and modelling have already been applied to understand the current groundwater situation for the city. The results show an important artificial groundwater discharge by abstraction associated with the rapidly increasing population. In 1985, the depression area was located in the northeast of the Jakarta area and the groundwater potential was -15 m. The depression area then expanded, moving toward central Jakarta prior to moving to the northwest of the city in 2008 when it was -25 m. Note that the movement of the depression area was associated with a decline in groundwater potential, implying a disturbance in the groundwater flow system (Figure 2). The disturbance in the city of Jakarta has caused the direction of groundwater flow to go downward in the coastal areas [11], [12], [13] recently. This implies the city area has become a groundwater recharge area at the present, based on the report dated from 1848 when first groundwater well was developed in Jakarta (Fort Priens Hendrik) which also reported artesian flowing well $+2.4$ meter above the surface.

This situation is also confirmed using isotope, hydrogeological and subsurface temperature mapping techniques [14], [15] and [4] that groundwater quality in Jakarta metropolitan areas decreased due to the effects of urbanization (Figure 3). As for urban structure impact, the first reliable information about subsidence in Jakarta came from the results of leveling surveys which was followed up by GPS surveys method since December 1997. In general land subsidence in Jakarta exhibits spatial and temporal variations, with the rates of about 1 to 15 cm/year. A few locations can have the subsidence rates up to about 20-25 cm/year. It was found that the spatial and temporal variations of land subsidence depend on the corresponding variations of groundwater extraction, coupled with the characteristics of sedimentary layers and building loads above it [16].

As a result, there are 3 main stages which are crucial to understand the urban hydrogeology problem in Jakarta (Figure 4). These three main stages are: (1) Degradation of subsurface environments, land subsidence and change in reliable groundwater resources (2) Heat island effect and subsurface thermal anomalies and (3) Subsurface contaminations and loads to the coast [17].

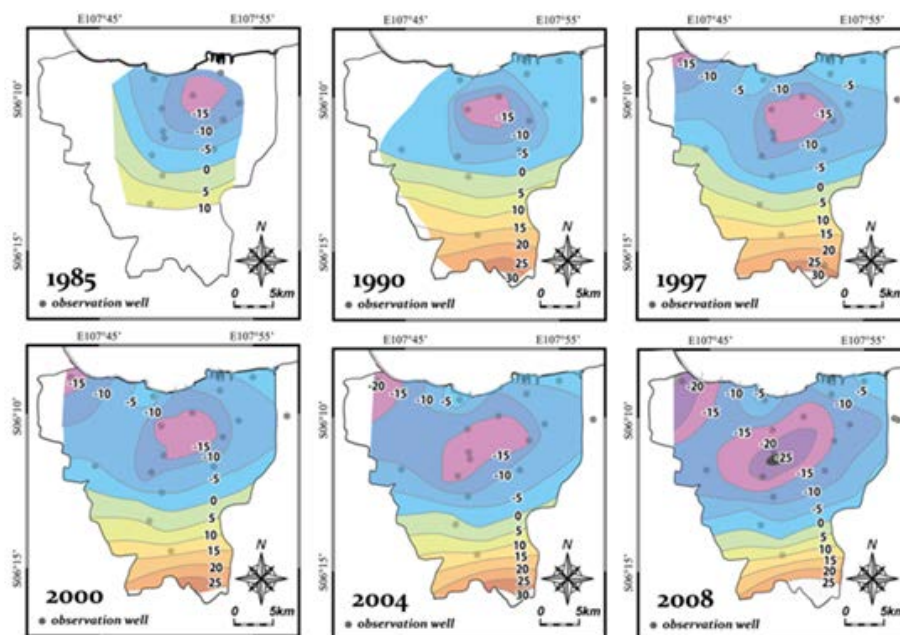


Figure 2. Changes in recharge area after groundwater overexploitation in Jakarta Basin [11,14].

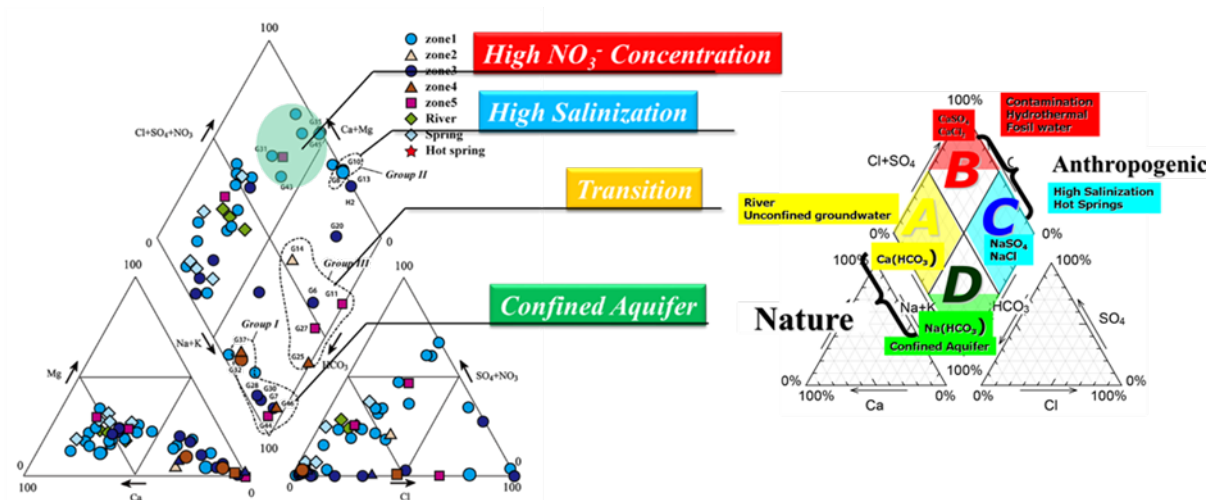


Figure 3. Groundwater quality degradation due to effect of urbanization [11,15].

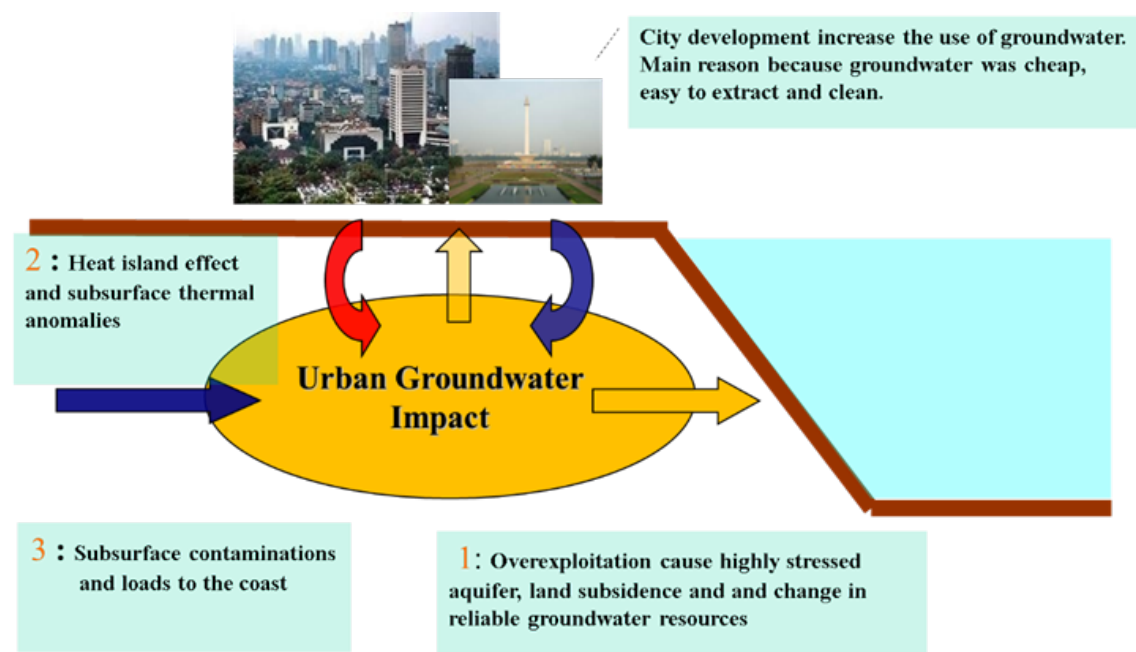


Figure 4. Three main stages urban groundwater impact related to urban subsurface impact [17].

3. Improving groundwater management in Jakarta urban areas

Studies concerning urban hydrogeology problems in Jakarta are well-documented. The urban environmental issues become emerging problems in Jakarta. Therefore, the groundwater management in Jakarta urban areas needs to be improved. One of the proposed methods was to collect existing knowledge and information from the literature and synthesize it into a Driving Forces-Pressure-State-Impact-Response (DPSIR) framework [18] as an approach using the framework of analysis. Description is given to the major issues such as excessive groundwater abstraction, land subsidence and groundwater contamination and how to respond them (Figure 5). The DPSIR framework is used to analyze the issues and problems of urban hydrogeology in Indonesia in key stages and suggestions are made to improve the groundwater management strategies in the future.

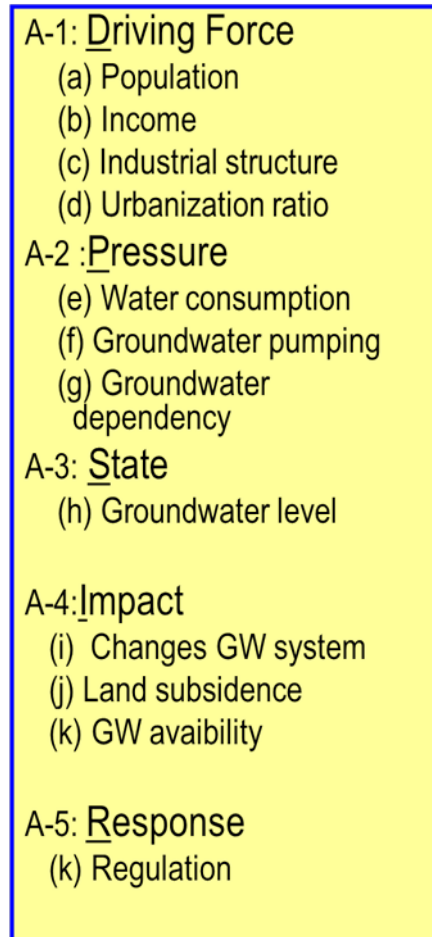


Figure 5. DPSIR Example for Jakarta Groundwater Problem analysis [18].

Acknowledgments

The authors are grateful to the Research center for Geotechnology, Indonesia Institute of Sciences (LIPI) and Research Centre for Humanity and Nature (RIHN) Japan for their funding supports. The authors acknowledge the academic suggestions for the paper provided by Prof. Dr. Robert Delinom, Sudaryanto, MT, Hendra Bakti MT (Research Center for Geotechnology, LIPI), Prof. Dr. Lambok Hutasoit (ITB), the reviewers and the editor of GCGE2017.

References

- [1] United Nations 2014 World urbanization prospects: the 2014 revision, United Nations, New York.
- [2] Shiklomanov I. 1993 *World Fresh Water Resources*, In: *Water in Crisis: a Guide to The World's Fresh Water Resources*, Gleick H. (Ed), Oxford University Press, New York, 13–14.
- [3] Wolf L., Eiswirth M and Hotzl H 2006 Assessing sewer–groundwater interaction at the city scale based on individual sewer defects and marker species distributions, *Environmental Geology*, **49**, 849-857.

- [4] Lubis R.F, Yamano M. Delinom R, Martosuparno S, Sakura Y, Goto S, Miyakoshi M and Taniguchi M, 2013. Assessment of urban groundwater heat contaminant in Jakarta, Indonesia, *Environ Earth Sci* **70**:2033–2038 DOI 10.1007/s12665-013-2712-5
- [5] Vazquez-Sune E, Carrera J, Tubau I, Sanchez-Vila X and Soler A 2010: An approach to identify urban groundwater recharge. *Hydrology Earth System Sciences* **2010;14**: 2085–97.
- [6] Turkandi, T, Sidarto, Agustyanto, D,A, Hadiwidjoyo, M (1992). Geology of the Jakarta and the Thousand Island Quadrangle Map, Jawa-Indonesia, Geological Research and Development Centre Indonesia.
- [7] Koesoemadinata, R.P., 1963; *Geologi and Under Ground Water Jakarta Artesian Basin (Northern Jawa Barat (In Indonesia Language))*, Direktorat of Geology, Bandung.
- [8] Soekardi, P. and Purbo – Hadiwidjojo, M.M., 1973; Jakarta Artesian Basin (In Indonesia Language). *Geologi Indonesia* **Vol. 2, No. 1**, 25 – 28 p, Bandung.
- [9] Assegaf A, Hendarmawan, Hutasoit L.M and Hutabarat J. 2017. Salinity of 0 – 20 m Depth Confined Aquifer Groundwater Kalideres – Cengkareng Area, West Jakarta . Indonesia *Journal of Geology and Mining* **Vol. 27, No.1**, June 2017. 15-25
- [10] Fachri, M., Djuhaeni, Hutasoit, L.M., Ramdhan, A.M. 2003. Stratigraphy and Hydrostratigraphy in Jakarta Groundwater Basin (In Indonesian language) *Buletin of Geology, Bandung Institute of Technology*, **34 (3)**; 169-189.
- [11] Kagabu M, Delinom R, Lubis R,F, Shimada J and Taniguchi, M, 2010. Groundwater Characteristic in Jakarta Area, Indonesia.. Indonesia Journal of Geology and Mining Vol. 20 No. 2 , 69 -79.
- [12] Soefner B., Hobler M., Schmidt G. 1986. Technical Cooperation with Indonesia – German Hydrogeological Advisory Group in Indonesia (CTA 40) – Vol. 8: *Jakarta Groundwater Study Final Report.*- Unpubl. Rep Directorate of Environmental Geology and Bundesanstalt für Geowissenschaften und Rohstoffe, Bandung and Hannover.
- [13] Djaeni A., Hobler M., Schmidt G., Soekardi P., Soefner B. 1986. Hydrogeological investigations in the Greater Jakarta area / Indonesia. - *Proc. Salt Water Intrusion Meeting (SWIM)*, Delft 1986: 165-176; Delft.
- [14] Onodera S.I, Saito M., Sawano M., Hosono T., Taniguchi M., Shimada J., Umezawa Y., Lubis R.F., Buapeng S., Delinom R., (2008), Effects of intensive urbanization on the intrusion of shallow groundwater into deep groundwater: Examples from Bangkok and Jakarta, *Science of the Total Environment*, **404**, 401-410.
- [15] Hosono T, Umezawa Y, Onodera S, Wang C.H, Siringan F, Buapeng S, Delinom R, Nakano T and Taniguchi M. 2009, Comparative Study on Water Quality among Asian Megacities based on Major Ion Concentration. Book title “*From Headwater to the Ocean*” Taylor and Francis Group London.p.295-300
- [16] Abidin, H.Z., H. Andreas, R. Djaja, D.Darmawa and M. Gamal 2007., Land subsidence characteristics of Jakarta between 1997 and 2005, as estimated using GPS surveys, *GPS Solutions*, Springer Verlag
- [17] Delinom R, 2015. *Jakarta Subsurface Threat, Unseen, Unthinkable and Unexpected*. LIPI Press, Indonesia 277-278.
- [18] Jago-on K, Kaneko S, Fujikura R and Taniguchi M, 2008. Urbanization and subsurface environmental issues: An attempt at DPSIR model application in Asian cities. *Science of The Total Environment* **407(9)**:3089-104.