THE EFFECTS OF GROUNDWATER ABSTRACTION ON THE GNANGARA AND JANDAKOT MOUNDS, PERTH REGION WESTERN AUSTRALIA

(Pengaruh Abstraksi Air Tanah Pada Dataran Tinggi Gnangara dan Jandakot, Wilayah Perth, Western Australia)

Baina Afkril
(Laboratorium Fisika, Fakultas MIPA, UNIPA.)

ABSTRACT

Tulisan ini merupakan hasil penelitian tentang pengaruh abstraksi permukaan air bawah tanah pada dataran tinggi Gnangara dan Jandakot di wilayah Perth, Australia Barat. Dataran tinggi Gnangara berlokasi di bagian utara wilayah Perth sedangkan Jandakot di bagian selatan. Kedua dataran tinggi tersebut adalah sumber utama air bawah tanah untuk mensuplai semua kebutuhan air di wilayah Perth, yang membentang sepanjang pantai Swan dan terdiri dari lapisan pasir, silt stone dengan bentangan silt yang tidak teratur serta lapisan lempung dengan ketebalan antara 10 -100 m. Abstraksi air tanah dilakukan perusahaan air minum dan beberapa pihak lain dan berbagai industri dan perusahaan komersial lainnya. Sementara air tanah diperlukan untuk pertanian, industri dan kebutuhan komersial lainnya.

Abstraksi yang berkepanjangan telah menimbulkan beberapa masalah terhadap kondisi air tanah di sekitar dataran tinggi Gnangara dan Jandakot. Masalah pertama adalah penutupan permukaan air tanah (water table). Selama periode 20 tahun (1974-1994) Abstraksi pada dataran tinggi Gnangara telah terjadi penurunan permukaan berkisar dari 3,0 m sampai 0,2 m. Sementara pada dataran tinggi Jandakot mengalami penurunan berkisar dari 1,5 m sampai 0,5.

Karena penggunaan pompa dan tempat lainnya seperti ektensifikasi penggunaan lahan dan perubahan iklim C (cuaca) kondisi beberapa lahan basah sekitar wilayah Perth turun secara drastis. Selama periode 1976-1985 permukaan air pada danau Western di dataran tinggi Gnangara turun sekitar 1,0 m sedangkan permukaan Danau Estern berkurang sampai 3,0 m.

Masalah kedua yang timbul akibat kegiatan abstraksi adalah peningkatan intrusi air laut pada daerah sumber air dekat pantai atau estuary. Salinitas air tanah pada dataran tinggi Gnangara adalah 130 mg/l TDS (Total Dissolved Solid), hampir mendekati nilai maximum yaitu 1200 mg/l TDS.

Key Words: Permukaan air tanah, sumber air tanah, salinitas, dan dataran tinggi Gnangara dan Jandakot

INTRODUCTION

Perth region is located in the Swan Coastal Plain that lies between the Darling Range and the Indian Ocean. Nowadays, about one million people live in the metropolitan area and the population is predicted to increase to 2 million by the year of 2020 (Board, 1994).

Perth metropolitan area is highly relying on two water sources for water supply, i.e surface water and groundwater. The surface water resources, which are known as “hills water”, are accumulated in the reservoirs along Darling Range to the South East of Perth. Meanwhile, groundwater resources are distributed below the Swan Coastal Plain.

The major sources of groundwater in the Perth Area come from water table aquifer, with small proportion from confined aquifer. Gnangara and Jandakot Mounds are the regional unconfined aquifers that are extensively abstracted to meet the need of water supply for this region. Apart of these two water table aquifers, the Perth area is also dependent on the two confined aquifers - Leederville and Yarragadee Formations.

However, the continuing growth of population of the Perth region has led to the increase demand
of water supply. Surface water, which in the past was largely used as a source of water supply, seems inadequate to serve this population growth. As a consequence, groundwater has been increasingly abstracted to meet the need of water consumption for Perth area. This then brings to the increase of groundwater abstraction. For instance, in 1975–76, the water supplied from unconfined aquifer was 18 x 10^6 m^3 (9% of total supply). This number increased to 35 x 10^6 m^3 (24% of total supply) in 1979-80 (Board, 1994).

Furthermore, Davidson (1995) revealed that during the 12-month period July to June 1992, the total water usage in the Perth area was approximately 406 x 10^6 m^3, of which 68% or about 275 x 10^6 m^3 was attained from groundwater. Of the total groundwater usage, 29% or 81 x 10^6 m^3 was abstracted by Water Authority for public water supply and 71% or 194 x 10^6 m^3 was privately utilized by Local Government, industry, agriculture, and general public. Of the groundwater for public water supply, 49% (40 x 10^6 m^3) was sucked from the unconfined superficial aquifer, 5% (4 x 10^6 m^3) from semi-confined Mirrabooka aquifer, 30% (24 x 10^6 m^3) from the shallow confined Leederville aquifer, and 16 % (13 x 10^6 m^3) from the deep Yarragadee aquifer.

The objective of this study is to provide any information related to the uses of groundwater in the Perth Metropolitan region and to identify the effects of groundwater abstraction on the Gnangara and Jandakot Mounds

GROUNDWATER RESOURCES AND USES

Gnangara Groundwater Mound

The Gnangara Mound is the largest shallow groundwater resource widely abstracted for agricultural purposes, market gardens, as well as for satisfying the public water drinking requirements for the Perth area and its future growth. It also supports a number of important wetlands, including Loch McNess, the lakes Yonderup, Joondalup, Jandabup, Nowergup, Goollelal, Gnangara, Carabooda and Mariginiup, and Coogee Springs.

The Mound covers a very large area, about 2200 km^2, extending from Perth the Swan River to the Moore River and Gingin Brook. The crest of the mound is located between Muchea and Lake Pinjar, where the water table is as high as 75 m above sea level.

At its thickest the Gnangara Mound saturates 60 m of the superficial aquifer and occupies variously between 10 % and 35 % of the total volume of sediments with the estimated storage to be 19,500 kL (Water Authority, 1995).

In the Gnangara Mound, surface run-off is very little under natural condition as a result of porous nature of the soil. The surface flow mainly occurs as a result of groundwater discharge to the surface or through drains. Precipitation, which is not returned to the atmosphere through evapotranspiration, infiltrates to the sandy soils and recharges the groundwater. The groundwater discharges to the ocean, streams, and rivers around the mound.

The water Corporation currently has authorized to operate six groundwater abstraction schemes on the Gnangara Mound, namely Pinjar, Wanneroo, Mirrabooka, Gwelup, Yanchep and Perth Coastal groundwater schemes. From these groundwater schemes, a total of 79.1 x 10^6 m^3/year is abstracted (Western Australian Planning Commission, 2001). Table 1 summarizes the existing groundwater schemes in Gnangara Mound.

Table 1 Gnangara Public Water Supply Wellfields
(Source: Western Australian Planning Commission, 2001)

Groundwater Scheme	Number of Wells (Unconfined Aquifer)	Volume of Groundwater Abstracted (m^3/year x 10^6)
Mirrabooka	34	14
Wanneroo	24	12
Gwelup	12	4.5
Pinjar	14	7.6
Perth Coastal		
Whitfords	4	9

Quinns	15	13
Eglinton	11	11
Yanchep	8	8
Total	122	79.1

The largest private user of groundwater from Gnangara Mound was Horticulture. It utilizes up to 25% of available water, mostly for vegetable production. Recreation was on the second place utilizing 13% of the available water for irrigation, parks and golf courses. The rests of available groundwater were utilized for household, stock and commercial purposes (Western Australian Planning Commission, 2001).

Jandakot Groundwater Mound

The Jandakot Mound is the smaller of the two major groundwater resources in Perth, with a water table elevation up to 27 m above sea level. The crest of the mound is located between the Jandakot airport and straddles Forrest Road.

Groundwater flow from the mound is largely westward to the sea with some northerly and north-easterly to the Swan and Canning Rivers. Groundwater losses are largely through evapotranspiration from the wetland chain on western side of the mound as well as from Forrestdale Lake on the eastern side.

Total groundwater abstraction from the central Jandakot Mound was about 24 x 10^6 m^3/year (Board, 1994). Of the total abstraction, 8 m^3/year was abstracted by the Water Authority for public water supply uses. The rest of 16 x 10^6 m^3/year was utilized by private sectors, mainly for irrigation purposes.

Leederville Aquifer

The Leederville formation is a major confined aquifer consists of interbedded sandstone and shale. It covers the Perth Metropolitan area, not including Peth City, to Fremantle.

The major recharge for the Leederville formation is leakage from water table aquifer in areas north and south-east of Perth, with a small contribution by run-off from the darling Scarp. Recharge to the Leederville aquifer was estimated to be 31 x 10^6 m^3/year (Davidson, cited in Board, 1994) which was small compared to the recharge to the superficial formation. Groundwater flow in the aquifer is towards the coast with discharge offshore, and some leakages to the deeper Yarragadee Formation.

Groundwater from the Leederville Formation is mainly abstracted by the Water Authority for public water supply purposes as well as for recreational, industrial and horticultural purposes.

Yarragadee Formation

The Yarragadee Formation is the thickest and the widest aquifer in the Perth. The formation is about 1000 m thick, mostly composed of sandstone with some shale. Annual recharge to the Yarragadee Formation was about 9 x 10^6 m^3/year, mainly by leakage from the overlying Leederville Formation. The estimated groundwater storage was about 76 x 10^6 m^3 and flows to the south-west, discharging into the ocean (Davidson, cited in Board, 1994).

EFFECTS OF GROUNDWATER ABSTRACTION

Declining Water Levels

Abstraction of groundwater will produce declining water levels around pumping areas as well as steeping of hydraulic gradients toward the areas where abstraction is occurring. The most significant effect of declining water level is abstraction conducted from water table aquifer with small part from confined aquifer.

The effects of groundwater abstraction on water levels dependent on the rate of abstraction of individual bores, as well as on the number, location and spacing of bores. Abstraction of a single bore creates a cone of depression, which radially reduces the water table around the bore. The steepness of the cone of depression depends on the hydraulic properties of aquifers. The lower the transmissivity the steeper the cone of depression of the aquifers. When two or more neighbour bores are operated in the same discharge rate, the cone of depression from individual bores will intersect each other. This phenomenon then results in increasing the drawdown of the individual bores, which correspondingly adds to the lowering of the cone of depression as well as of the water table.

Water Level Changes in Gnangara Mound

Changes in groundwater level in Gnangara Mound as a result of pumping activities have been measured for years. Yesertener (2001) interpolated measured these groundwater level changes across the Gnangara Mound through a network of 140 monitoring bores over the period 1979-1999 by Kriging griding method using Surfer 7.

Abstraction from the production bores in the superficial aquifer has produced considerably impacts on lowering water levels within a radius of 500 m. Over ten-year (1989-1999), water table in monitoring GN23 (500 m away from production bore P30) decreased up to 2 m. Similarly, water table dropped by about 1.6 m in bore GN 13 (400 m away from production W60) (Yeserterner, 2001).

Abstraction from unconfined aquifer is not the only cause of declining water level. Abstraction from shallow confined aquifer may also produce a remarkable impact on the lowering water level. Yeserterner (2001) revealed that in Gnangara Mound, abstraction from Leederville aquifer produced more significant effect on lowering water table than that from Yarragadee aquifer.

The cumulative impact of abstraction from water table and confined in Gnangara Mound extends up to 5 km from the pumping location. An example of the effect of abstraction from confined aquifer is figured out by looking at the water level changes in the monitoring bore PM6. Over 20 ten-year-period (1979 to 1999), the water level in bore PM6 has dropped by about 1.2 m, approximately 40 % of the total decline. Meanwhile, about 70 % of the groundwater level has declined as a result of abstraction from both superficial and Leederville aquifers over the period of abstraction between 1992 and 1999.

Water Level Changes in Jandakot Mound

Yeserterner (2001) revealed that the impact of groundwater abstraction in Jandakot ranged from about 1.5 m in the central area (monitoring bores JM19 and JM29) to 0.5 m in outlining areas of Jandakot GWA. In particular, groundwater level in monitoring bore JM19 (1.1 km away from the abstraction bore J380) declined about 1.2 m.

Saline Water Intrusion

Salt-water intrusion into groundwater is a problem related to the quality of the groundwater. The intrusion of salt-water occurs when an aquifer is in hydraulically connection with the ocean or an estuary that the salt-water, being denser than groundwater, forms a wedge extending inland underneath the fresh groundwater.

Pumping activities conducted near the coast or in the areas adjacent to the estuary may triggers landward movement of salt-water to create an upconing of salt-water and fresh groundwater interface. The long-term pumping will then give possibility the salt-water to reach screen of the bore and come out to the surface.

The effects of abstraction on the salinity of the groundwater in the superficial aquifer depend particularly on the location and the quantity of abstraction (Davidson, 1995). Meanwhile, the shape of the salt-water wedge and its seasonal behaviour vary considerably around the shores of the estuary (Cargeeg, 1987).

In the Perth Area, some bores have been established to observe the path of salt-water wedge. Cargeeg (1987) revealed that there was no salt-water wedge in the confined aquifer at saline water intrusion investigation bores DBN1/DBN3, BSM1/BSM2, IF10, IF11, IF13 or IF14. This possibly because the groundwater flows is sufficiently enough to resist and hold back the landward movement of salt-water. Salt-water intrusions were found in monitoring bores IF07 (at exceeding depth 18 m) and IF12 (at exceeding depth 10 m). At site IF04, which is located about 70 m from the river bank salt-water, salt-water was found at the entire thickness of the aquifer.

Furthermore, Davidson (1995) revealed that abstraction from bores in the adjacent to the ocean, Swan River estuary and Peel Inlet has caused an inland migration of the salt-water interface. At many localities, private bores for irrigation has induced inland movement of saline water from Swan River. During winter, in some areas, where there is generally no irrigation the salt-water interface recuperates almost to its original position. However, at some localities where the intensity of abstraction is high enough, the salt-water interface doesn't move backward to its winter position, but moves further inland.

Groundwater salinity in the Gnangara Mound ranged from 130 mg/L TDS (Total Dissolved Solid) near the crest to 1200 mg/L TDS near the discharge areas (Board, 1995). In the Leederville Formation, groundwater salinity ranged from 160 mg/L TDS to 10.000 mg/L TDS. Meanwhile, groundwater salinity in the Yarragadee aquifer ranged from less than 200 mg/L TDS to more than 1000 mg/L TDS (Board, 1995).

Impact on Lakes and Wetlands

Wetlands are surface express of water table. Therefore, the changes in groundwater level influence the levels of the wetlands. Lowering water table due to pumping activities will then reduce the levels of wetlands.

Generally, changes in water table are not only caused by a single parameter, but combinations of several parameters such as groundwater abstraction, changes in land use and climate changes. Over a period of 1976 to 1985, water levels in the Gnangara Mound, as a result of these combination parameters, have been declined between 1.0 m to 3.0 m. Specifically for wetlands, the water levels in the western chain lakes have been dropped by about 1.0 m, whereas in the eastern lakes the water levels have been reduced up to 3.0 m (Water Authority of Western Australia, 1986).

CONCLUSION

The Gnangara and Jandakot Mounds are the main groundwater resources in Perth Metropolitan Area, which are intensively abstracted to meet the need of water supply for this region. Abstraction conducted by Water Authority is mainly for drinking water. Meanwhile, groundwater is abstracted privately for agricultural, industrial and commercial purposes.

The long-term abstraction in the Gnangara and Jandakot Mounds has brought some problems to the properties and condition of groundwater resources around the mounds. The first problem is lowering water levels. Over a 20- year-period (1974-1999), abstraction on the Gnangara Mound has declined water levels ranged from 3.0 m to 0.2 m, while water levels on the Jandakot Mound has been decreased from 1.5 m to 0.5 m.

Due to pumping activities added by other parameters such as land use and climate changes, the levels of wetlands around the Perth Region have been decreased to certain conditions. Over a period of 1976 to 1985, water levels in the western chain lakes of the Gnangara Mound have been dropped by about 1.0 m while in the eastern lakes the water levels have been reduced up to 3.0 m

The second problem of long-term groundwater abstraction is increasing salt-water intrusion in the aquifers near the coast or estuary. Groundwater salinity in the Gnangara Mound ranged from 130 mg/L TDS (Total Dissolved Solid) near the crest to 1200 mg/L TDS near the discharge areas. In the Leederville Formation, groundwater salinity ranged from 160 mg/L TDS to 10.000 mg/L TDS. Meanwhile, groundwater salinity in the Yarragadee aquifer ranged from less than 200 mg/L TDS to more than 1000 mg/L TDS.

REFERENCES

Board, M. F. 1994. Select Committee on Metropolitan Development and Groundwater Supplies. Legislative Assembly, Western Australia.

Cargeeg, G. C., Boughton, G. N., Townley, L. R., Smith, G. R., Appleyard, S. J., and Smith, R. A. 1987. Perth Urban Water Balance Study. Volume 1 – Findings. Water Authority of Western Australia.

Davidson, W. A. 1995. Hydrogeology and Groundwater Resources of The Perth Region Western Australia, Curtin University of Technology, Perth, Western Australia.

Department of Planning and Urban Development. 1992. Jandakot Land Use and Water Management Strategy. Department of

Planning and Urban Development, Perth, Western Australia.

Research Group on Groundwater Management. 1986. Working Paper on Groundwater Management in the Jandakot Area. Western Australia Water Resources Council, June, 1986.

Research Group on Ground Water Management. 1989. The Management of Shallow Groundwater in the Perth Metropolitan Area. Final Report to the Western Australia Resources Council, February 1989.

Water And River Commission. 1997. East Gnangara Environmental Water Provisions Plan, Public Environmental Review, Perth, Western Australia.

Water Authority of Western Australia. 1986. Gnangara Mound Groundwater Resources Environmental Review and Management Programme. Water Authority of Western Australia.