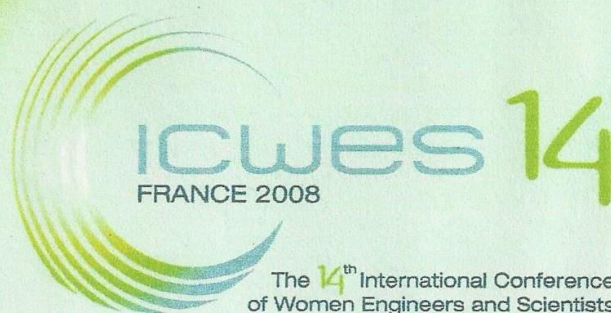


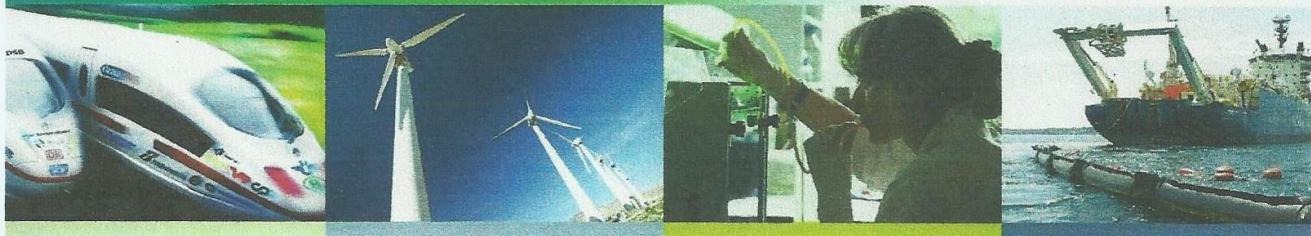
A changing world:
new opportunities for
women engineers and scientists

Proceedings



The 14th International Conference
of Women Engineers and Scientists

July 15-18, 2008
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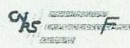
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LIST OF PAPERS

WATER AND ENVIRONMENTAL SCIENCE AND TECHNOLOGY

MOUNT MERAPI ACTIVITY 2006: ITS IMPACT ON GROUNDWATER ENVIRONMENT
Sari B. Kusumayudha

WATER IMPACT IN A GARMENT LIFE CYCLE
Anne Perwuelz, Inès Boufateh, N. Behary

**STUDY OF WATER FILTERING IN UNDER DEVELOPED AND NEED FOR USE
OF TRADITIONAL FILTERING SYSTEMS.**
Dr Hind Saidani-Scott, Dr Stephen Gundry, Dr Mike Tierney

JAPANESE EXPERIENCE DEVELOPMENT OF SMALL SCALE WATER SUPPLY
Ms.YAMAMOTO Keiko

**A PROPOSAL FOR THE WATER MANAGEMENT IN THE RIVER AMAJAC SUB
BASIN, STATE OF HIDALGO, MEXICO.**
**Vega Isuhuaylas, Griselle Felicita; Jimenez Sanchez, Leobardo; Rubiños Panta,
Enrique; Manzo Ramos, Fernando; Quispe Limaylla, Anibal; Marañon Pimentel,
Boris**

**ENVIRONMENTAL IMPACTS OF THE MAIN CONTAMINATING INDUSTRIAL AND
AGRICULTURAL UNITS ON THE ECOLOGICAL SITUATION AND SUSTAINABLE
DEVELOPMENT IN DNEPR RIVER BASIN REGION**
Anisimova Larysa 1 , Grytsan Natalia1, Kharitonov Mykola2.

GLOBAL WARMING AND LIVESTOCK PRODUCTION IN BOTSWANA
A.A.Aganga, S.J.Nsoso, U.J.Omphile, P.Malope and A.O.Aganga

ENERGY WISDOM: CLIMATE CHANGE AND FUTURE ENERGY NEEDS
Jackie Carpenter

ADVANCES IN AUTOMOTIVE POWERTRAIN AND CO2 EMISSIONS
Julie Winnard CEng, MIMechE

MOUNT MERAPI ACTIVITY 2006: ITS IMPACT ON GROUNDWATER ENVIRONMENT

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Abstract

During may to June 2006, Mount Merapi, that is located in Central Java, Indonesia has erupted. As we may know, Merapi belongs to one of the most active volcanoes on the world. It is characterized by a very specific type of eruption. Magma of Merapi is very viscous, low gas pressure, and low mobility. When the magma extrudes, it will be accumulated on the vent, forming such a dome. The dome get bigger with time until exceeding its bearing capacity. Due to new magma extrusion, triggered by such vibrations for example earthquake, lead by gravitational force, the dome or apart of it will collapse, forming nuee ardentes. Nuee ardentes occurred on 14th June 2006 was the biggest one during 2006-2007 activity period of Merapi. It reached 7 km distant to the southeast direction. A tourist object, namely Kaliadem, in the Cangkringan District was buried by pyroclastic deposits more than 3 m thick in average. Two volunteers were assassinated in the bunker. Ordinary, the primary activity of Merapi will be followed by the secondary threat, i.e. lahar. Lahar is volcanic mud flow. It is formed when pyroclastic deposits on the upper flank become wet, denser, and heavy, flowing through river valleys down slope. Lahar is very destructive to environment. There were some springs disappear, and groundwater composition change after 2006 Merapi eruption.

Key words: Mount Merapi, eruption, nuee ardentes, lahar, groundwater

Introduction

Mount Merapi, the volcano of where the research was done, administratively belongs to the Central Java Province and Yogyakarta Special Province. It is located 30 km northern of Yogyakarta city, and about 30 km western of Magelang town of Central Java (Figure 1). Although the volcano is some time dangerous, it eternally brings berkah to the surroundings by suplying sands, stones, fertile land, and beautiful scenery.

Mount Merapi belongs to the most active volcano of Indonesia, and one of the most attractive volcanoes on the world. Once in almost every 2 to 5 years Merapi increases its activity threatening surrounding environment with its phenomenal nuee ardentes and glowing clouds. In the year 2006, Mount Merapi showed its force, and erupted on 14 June burying a tourist object at Kaliadem of Cangkringan District, Sleman Region.

This paper reports the result of study on 2006 Merapi activity and how this change some environmental aspects especially for groundwater on Merapi shouthern footslopes. Methods applied to enravel the problem were field surveying, mapping, and groundwater chemistry analysis

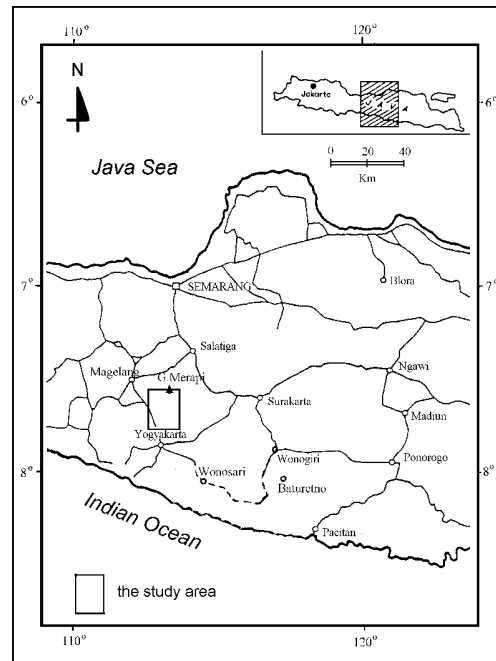


Figure 1. Map showing the location of the study area

Volcano-tectonic

Mount Merapi exists on the intersection of two volcanoc lineaments, i.e. Ungaran - Telomoyo - Merbabu - Merapi and Lawu - Merapi - Sumbing - Sundoro - Slamet. Merapi is also laid on the meeting point of Semarang fault (North – South) and Solo fault (West – east) (Laporan Tahunan P3G 1980/1981, dikutip dari Kusumayudha 1988).

Tectonic setting controls Merapi is the convergen of Eurasia Plate in the north and Indo-Australi Plate in the south since upper Pleistocene. The volcanic evolution of Merapi brought about structures that controlled the hydrogeologic system of areas located on the slopes of Mt. Merapi, including the Muntilan area and surrounding that is sited on the southwestern slope, and the Yogyakarta area and surrounding that is situated on the southern slope. At least there were four episodes of volcanic activities that significantly developed aquifer systems in the slope area of Mt. Merapi. The four volcanic episodes are Proto Merapi, Ancient Merapi, Middle Merapi, and Recent Merapi. Lava of Proto Merapi and Ancient Merapi formed impermeable bedrock. Middle Merapi deposits and Recent Merapi that predominantly consist of pyroclastics and epiclastics play as water bearing formations, each of which performed semi-confined aquifer and free aquifer. The two aquifers are separated by clayey paleo soil that was oxidized. The thickness of saturated zone of this aquifer system ranges 50 m to 100 m, and the thickness of unsaturated zone ranges from 5 m to more than 20 m. The aquifer system of Middle Merapi broughtabout several artesian wells on the southwestern slope, in the Sleman and Muntilan areas.

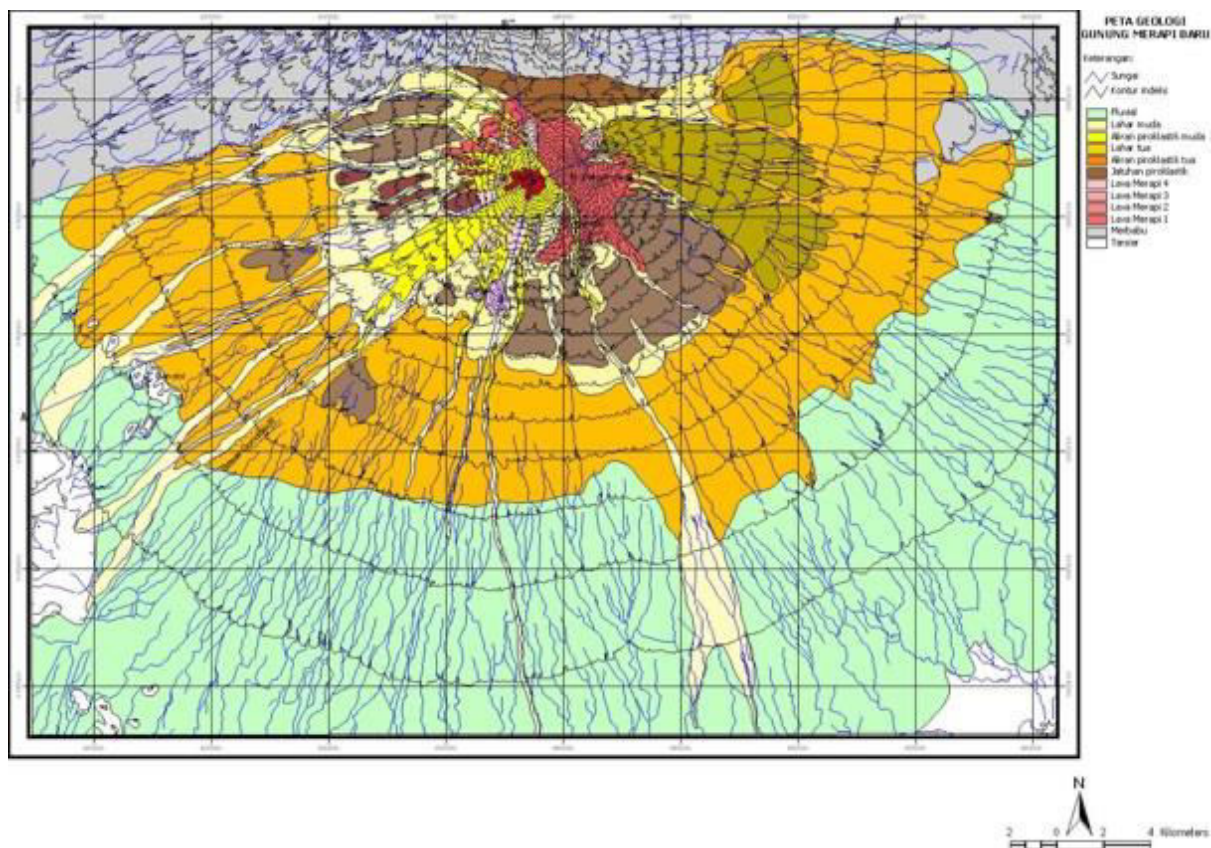


Figure 2. The geologic map of Mount Merapi

Tabel 1. Persen Komposisi Kimia Endapan Piroklastika Erupsi 1994 (Hammer, 2000)

Senyawa	Senyawa Kimia (%)						
	Smpl 1	Smpl 2	Smpl 3	Smpl 4	Smpl 5	Smpl 6	Rata-rata
SiO ₂	66.1	66.1	64.7	74.5	72.2	72.6	69.37
TiO ₂	0.53	0.54	0.5	0.62	0.47	0.52	0.53
Al ₂ O ₃	15.2	14.5	15.5	12.3	12.1	11.7	13.55
MgO	0.73	0.58	0.75	0.25	0.15	0.12	0.43
CaO	2.06	1.54	2.49	0.18	0.44	0.44	1.19
MnO	0.13	0.11	0.09	0.12	0.08	0.11	0.11
Fe O ₂	3.61	3.48	4.1	0.96	2.13	2.5	2.80
Na ₂ O	3.54	3.91	3.72	2.92	3.51	3.42	3.50
K ₂ O	5.08	5.9	5.69	5.87	6.23	6.3	5.85
Total	96.98	96.66	97.54	97.72	97.31	97.71	97.32

Hydrogeologic System

Aquifers on the southern slope of Mount Merapi can be classified into two types of free aquifer underlain by semi confined aquifer. The depth Groundwater level of the free aquifer ranges 1,5 m to 30 m deep. Piezometric level of the semi confined aquifer 15 to 5 m deep. The free aquifer is composed of the Yogyakarta Formation which is predominated by fall pyroclastic, lahar, alluvial and fluvial deposits, as sands with boulders, pebbles, granules. Semi confined aquifer comprises mostly boulders, breccia, lahar, and pyroclastic deposits of

Mature Merapi. Hydrogeologic system model of the southern slope of Merapi is shown in the Figure 3 (Sir MacDonald & Partners 1984)

Based on Cash & Wright volcanic facies model, Sleman Formation is classified into medial facies, while the Yogyakarta Formation is classified into distal facies. The basic difference between the two formations is their grain size of the deposits. Sleman Formation is predominantly composed of cobbles to boulders fragments, while Yogyakarta Formation is composed of mostly sands. The two formations are then hydrogeologically mentioned as Sleman Aquifer and Yogyakarta Aquifer respectively. On the other hand deposits of mature Merapi built semi confined aquifer generally lies under the formations mentioned before. The basement of the aquifers is lava of old and proto Merapi in the proximal and part of medial facies, and Tertiary sediments in the distal facies.

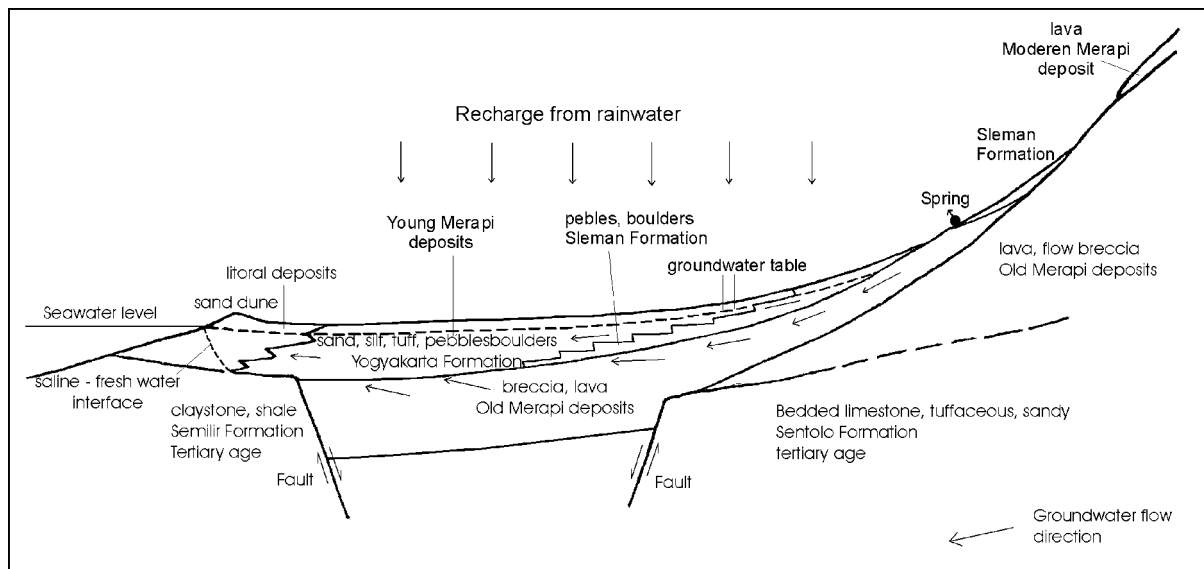


Figure 3. Hydrogeologic system conceptual model of Merapi southern slope

In general there is a clay layer in the depth of 40 m to 50 m below the surface, locally separating Yogyakarta Aquifer and the underlain deposits. This phenomenon occurs in the Sleman Formation too. The clay layer is interpreted to be formed in a reduction environment, characterized by its Fe-rich content. The thickness of the clay layer ranges from 2 m to 5 m.

Both Yogyakarta and Sleman aquifers are classified into intergranular aquifer with groundwater flow in the southward direction, controlled by hydraulic gradient and topography. In the Bantul Region, southern side of the study area, the aquifer base layer is tuffaceous calcareous sediments of Sentolo Formation and tuffaceous shale of Semilir Formation at some places.

Merapi Activity 2006 and Deposits

Results of 2006 Mount Merapi activity are sand, stone, ash deposits with various thickness, spread mostly in the area of southeastern and southern slopes of the volcano.

The deposits in the present time are taken by people as C class mining material with economic value.

There is a significant change of Merapi eruption direction. Previously since 1961 to 1994 the eruption direction was to the west. In 1994, Merapi erupted both west and southwards. In 2006 the biggest eruptions were southeastward. On 14 June 2006 A great pyroclastic flow attacked area of the surrounding River Gendol, of 7 km distant from the center of eruption. The nuee ardentes using the valley of River Gendol as the highway to flow. A tourist object, namely Kaliadem, Jambu village, in Cangkringan District was buried by more than 3 m thick of flow pyroclastic deposits. In this accident, 2 volunteers were assassinated in the bunker when they would like to avoid the nuee ardentes. The valleys of River Gendol and River Opak were then fullfilled by pyroclastic sediments, a bunker was covered, two volunteers died. Thickness of the sediments at River Gendol is 3 m average, and at River Opak is 2 m average. Estimation of volume of the deposits filling River Gendol, River Opak, Kaliadem and surroundings is 276.000 m³, while on the near summit area at elevation of 1700 m above sea level (2 km from the summit) to the edge of deposits, the volume is about 5,6 million m³. Temperature of the deposits at the depth of 30 cm to 50 cm, after 6 month deposition was still 80°C - 100°C.



Figure 4. Mount Merapi eruption (June 2006)



Paralel Nikol

Cross Nikol

Gambar 2. Sayatan Petrografis Fragmen Endapan Piroklastik di Kali Gendol

Petrologic composition of Merapi eruption 2006 is andesitic: Since rainy seasons of 2006/2007 and 2007/2008, the deposits in the River Gendol and River Opak are gravitationally flowed down as lahar. The lahar generally flow southeast direction following the river channels. Lahars not only occur in River Gendol and River Opak but also in River Boyong, River Kuning in the west part, and River Woro in the east part of the study area.

Impact on Groundwater Environment

Mount Merapi eruption in the year 2006 has much changed the environment in the study area especially in Umbulharjo and Kepuharjo villages, Cangkringan District. Many building and houses were buried by pyroclastic deposits. Plants were burnt and damaged by the glowing clouds. Cattles were disturbed, because no more fresh grass to feed. This cause many people were forced to soale their catles, or transfered to the more safe places down slopes. Land surface condition is also changed physically and chemically.



**Figure 5. Impact of Merapi eruption:
Kaliadem was buried by >3 m thick of pyroclastic flow deposits**

Tabel 2. Imbas Erupsi Merapi 2006 Terhadap Potensi Hidrogeologi

No	Location	Impact on the environment
1	Kaliadem	• A tourism object was covered by pyroclastic deposits • Buildings and houses were buried • Plants were damaged and burnt • Springs were distinct • Road flooded with lahar deposits
2	Kali Kuning	• Springs covered by lahar deposit • Pipe networking damage
4	Kec. Cangkringan	Groundwater quality degradation

Tabel 3. Concentrations of elements in groundwater pre and post 2006 eruption

Element / Parameter	Pra 2006 eruption (15 sampel) (Kusumayudha 2003)		Post 2006 eruption (19 sampel)	
	Concentration range (mg/l)	Average (mg/l)	Concentration Range (mg/l)	Average (mg/l)
Iron (Fe)	0,05 – 0,9	0,22	< 0,03 - 2,50	0,14
Calcium (Ca)	3,03 – 29,1	22,65	8,78 - 27,14	18,37
Magnesium (Mg)	0,4 – 25,71	9,73	1,03 - 23,1	10,85
Sodium (Na)	1,71 – 17,75	5,91	19 - 43	34,17
Potassium (K)	0,6 – 4,0	2,20	3 - 14	8,42
Chloride (Cl)	2,63 – 9,2	5,54	3,1 - 15,9	6,78
Sulfate (SO ₄)	1,5 – 21,9	6,42	< 2 - 30	8,83
Bicarbonate (HCO ₃)	65,6 – 198,4	113,7	66,82 - 186,07	130,83

Adapun distribusi pH, TDS dan DHL adalah sebagai tercantum di dalam Tabel 4 berikut ini.

Tabel 4. Values of pH, TDS dan EC of groundwater of Pre dan Post 2006 Eruption

Parameter	Pre 2006 Eruption (15 sampel) (Kusumayudha, 2003)		Post 2006 Eruption (19 sampel)	
	Range	Average	Range	Average
pH	6,7 – 8,3	7,2	6,2 - 7,2	6.7
TDS (mg/l)	95,25 – 143,6	109,35	107 - 204	143.947
EC μ mhos	173,6 – 326,67	180,13	171 - 316	246.95

Some groundwater sources were distinct, drinking water piping damaged by pyroclastic and lahar deposits. Hydrogeologic condition after 2006 Merapi eruption is the increase of water turbidity, TDS, EC, and some compounds such as Na, K, HCO₃, and SO₄. The increase of chemical compounds are caused by dissolution of fine grained deposits of ash and dust by rainwater that contaminated groundwater and other water body. Fine grained deposits of Merapi eruption 2006 is composed of Na₂O, K₂O, CO₂, S₂, and SO₂. On the other hand the concentration of Ca in some water samples are tend to decrease comparing to before eruption. The cause of this phenomenon is interpreted due to chemical composition of new Merapi deposits that is more acidic than the older deposits. New Merapi deposits is more rich of Na-plagioclase than Ca-plagioclase. The deposits also does not contain olivine that rich of Mg. Below is the breakdown of impact of 2006 Merapi eruption on hydrogeologic environment and potency of the study area.

Tabel 6. The changes of hydrogeologic potencies and environments as the impact of 2006 eruption

No		Change	Analysis
1	Existence of water sources	Springs disappear	Covered by lahar deposits
2	Water Quality • Iron • Calcium • Magnesium • Sodium • Potassium • Bicarbonate • Sulfate • Chloride • Ph • TDS • EC	• No significant change • Decrease • No significant change • Increase • Increase • Increase • Increase • No change • Decrease • Increase • Increase	- Chemical composition of the deposits are more acidic - The deposits are rich of ash dust, and volcanic glass that are containing Na₂O, K₂O and, gas CO₂, S₂ and SO₂. - The deposits are more acidic than those of older Merapi deposits Ash and dust pollution When TDS increase. Automatically EC will increase
3	Pipe networking	Damage	Attacked by lahar

Conclusions

This study concludes some phenomena and environmental changes as the impact of Mount Merapi eruption during its activity period of 2006 as the following:

1. Mount Merapi eruption of June 2006 had produces pyroclastic deposits 5,6 million m³ whole volume and 276,000 m³ covering arround River Gendol, River Opak and Kaliadem touristm location. Area covered by the deposits is about 80,000 m square. The deposits consits of boulders to ash and dust grain sized with andesitic composition.
2. Pyroclastic deposits of Merapi eruption 2006 created lahar in River Gendol, River Boyong, River Kuning, and River Woro, with sediments of sand to boulder grain size with andesitic composition.
3. Merapi deposits of 2006 eruption buried about 80,000 m² area with 2 – 3 m thickness. Some buildings, hauses, groundwater sources, piping networking, and degrade water quality in general. The water quality whics are change are the incrcase of turbidity, TDS, EC, conentration of Na, K, HCO₃, and SO₄. Onthe other hand, the concentration of Ca and pH decrease.

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