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SELECTING RELOCATION OF LAND USE IN HOT MUD DISASTER AREA BY APPLYING GEO-ENVIRONMENTAL EVALUATION. CASE STUDY: SIDOARJO, EAST JAVA, INDONESIA

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Abstract

Since May 29, 2006, a sea of hot mud has been gushing from the ground in Sidoarjo, East Java, 35 kilometers south of Indonesia's second largest city, Surabaya. Due to this disaster, approximately thousand of people have been forced from their homes because 600 ha of land and villages were submerged, farmland was ruined, businesses and schools closed as the mud inundated the surrounding area. Relocation of the land uses and supporting infrastructures are become important to support the human survivability and environmental sustainability in this disaster area. In order to select the suitable location for land uses and infrastructures, aspect of environmental geology must be concerned. Geo-Environmental parameters such as geological hazards and geological resources are used to select the suitable relocation area. Evaluation of the suitable land uses is conducted by applying simple overlay rating method. Result of this evaluation shows that the relocation of the land uses can be differentiated into three categories; (i) high risk land use/infrastructure, moderate risk land use/infrastructure and low risk land use/infrastructure. Each of these categories have difference map of relocation suitability, however all maps indicate that the suitable relocation area is in the west-part from the hot mud disaster area.

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1 Background

Since May 29, 2006, a sea of hot mud has been gushing from the ground in Sidoarjo, East Java, 35 kilometers south of Indonesia's second largest city, Surabaya. Due to this disaster, approximately thousand of people have been forced to go out from their homes because 600 ha of land and villages were submerged, farmland was ruined, businesses and schools closed as the mud inundated the surrounding area. The authorities response was to build containment 'basins' or 'ponds' by enclosing areas of land within earth dams, or levees. However, until now, the earth dams are not effective, during the heavy rain on the rainy season, the earth dams and ring-dykes have overflows and broken regularly, causing flooding on more land and damaging infrastructures (Pohl, 2007). Not only in the rainy season, the levees had also collapses during the dry season. Actually, the potential geo-hazard in this disaster area not only comes from the mud overflows, but also comes from the poisonous gases and subsidence which are follows the mud intrusion phenomena. Therefore, relocation of the land uses and supporting infrastructures are important to support the human survivability and environmental sustainability in this disaster area. In this paper, the evaluation is focused on the relocation of the high risk infrastructures such as railway and primary transportation roads.

2 Location of the study area

Study area is located in hot mud blast area of Sidoarjo Regency which included Porong District, Jabon District, and Tanggulangin District, East Java Province, Indonesia (see Figure 1).

3 Geo-environmental parameters

In order to achieve the objective of this research, some environmental geology parameters must be considered in the analysis and evaluation of infrastructures relocation such as (1) geology (incl. engineering characteristics and faults), (2) hydrogeology (depth to groundwater and water aggresivity), and (3) geologically hazardousness (such as distance from the mud overflows, distance from the poisonous gases and distance from the subsidence).

3.1 Geology

Morphologically, the study area can be divided into two zones of morphology: alluvium plain and hot mud plain area. The alluvium plain area consists of quarternary alluvium deposits of interbedded clay, silt and sand. The thickness of alluvium deposits is approximately more or less than 200 m. The engineering characteristics of the alluvium deposits are more or less similar (Juwarso, 2008, Sudjarwo, 2007). Therefore, this factor is assumed to be similar on the whole study area.

While as the morphological name, the hot mud plain consists of mud sediments. The hot mud sediments consists not only a mix of fine grained sediments and water but also contain some foraminifera fossil (Handoko, 2007). Even though the alluvium deposits have a Quarternary age, geological structures definitely affect this sequences (Darsoatmojo et al. 2007) with major faults and surface cracks. At least, there are two faults which found in the study area: Watukosek fault and Siring fault. In the evaluation of the infrastructure relocation, the distance from the faults become one of the important considerations. The closer the infrastructure to the faults, the higher the probability of risk if an earthquake occurrs. The geological map of the study area is shown on Figure 2.

3.2 Hydrogeology

In the alluvium deposits, groundwater is found everywhere in the study area. The depth to groundwater ranges from less than 1 m to about more than 4 m (see Figure 3). For infrastructures such as railway and roads, deeper groundwater is more presumable. Although the groundwater is commonly shallow, the salinity of shallow groundwater in this area ranges from freshwater to saline water group (see Figure 4). Saline water is an aggressive type of water that can chemically attacks concrete foundation (Prinz & Staub, 2006). Related to the salinity of shallow groundwater, fresh water condition is more appropriate for concrete foundation than saline water.

3.3 Hot mud blast hazards

The potential geohazard in this disaster area are not only comes from the hot mud overflows, but also comes from the poisonous gases (CH_4, NH_3, H_2S, and SO_2) and subsidence which are the secondary impact of hot mud gushing. Therefore, a detailed observation and mapping on the extent of primary and also secondary hazards have been conducted as shown on Figure 5, 6 and 7. Regarding the infrastructure relocation, it will be safer and better if the distance from those hazards is far enough.

4 Geo-environmental evaluation

The criteria of selection was based on the above mentioned parameters and shown in Table 1. Each parameters have rating score for the evaluation purposes. The suitable location is calculated by summing all of the parameters rating, whereas the best suitable relocation is defined based on the highest total score. Results of the evaluation can be seen in Figure 8. Based on this evaluation method, it is reasonable if the high risk infrastructures (railway and primary

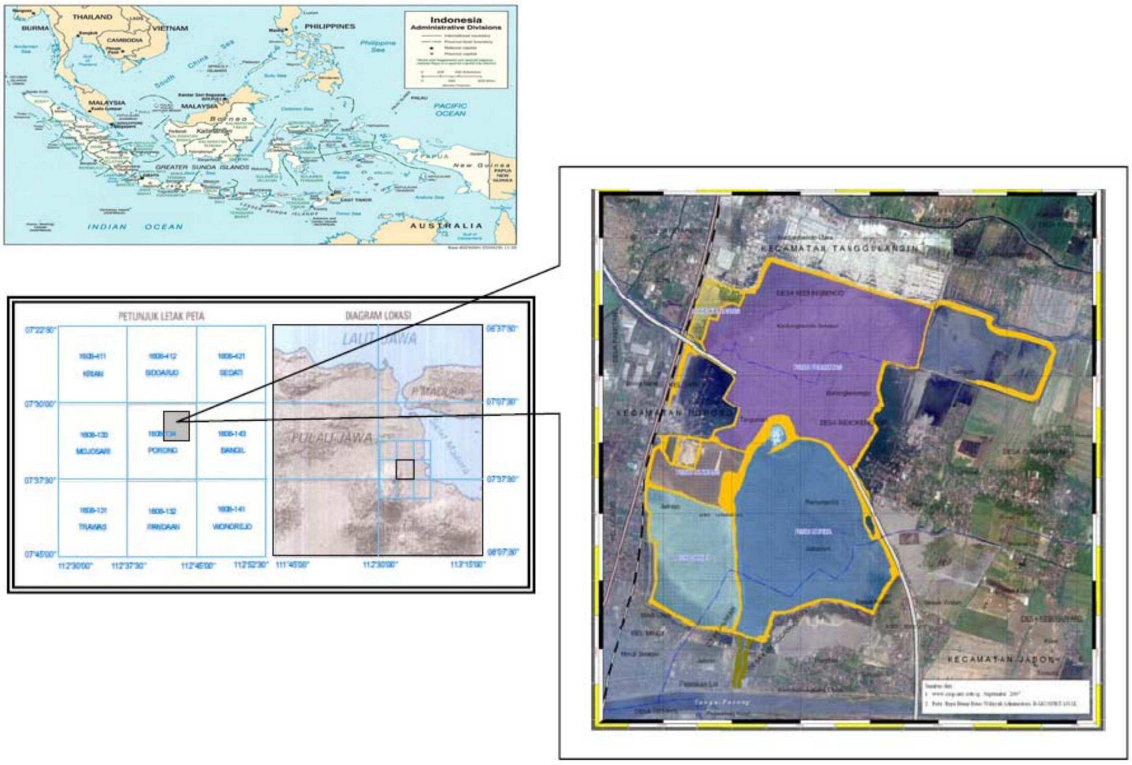

Figure 1: Location of the study area

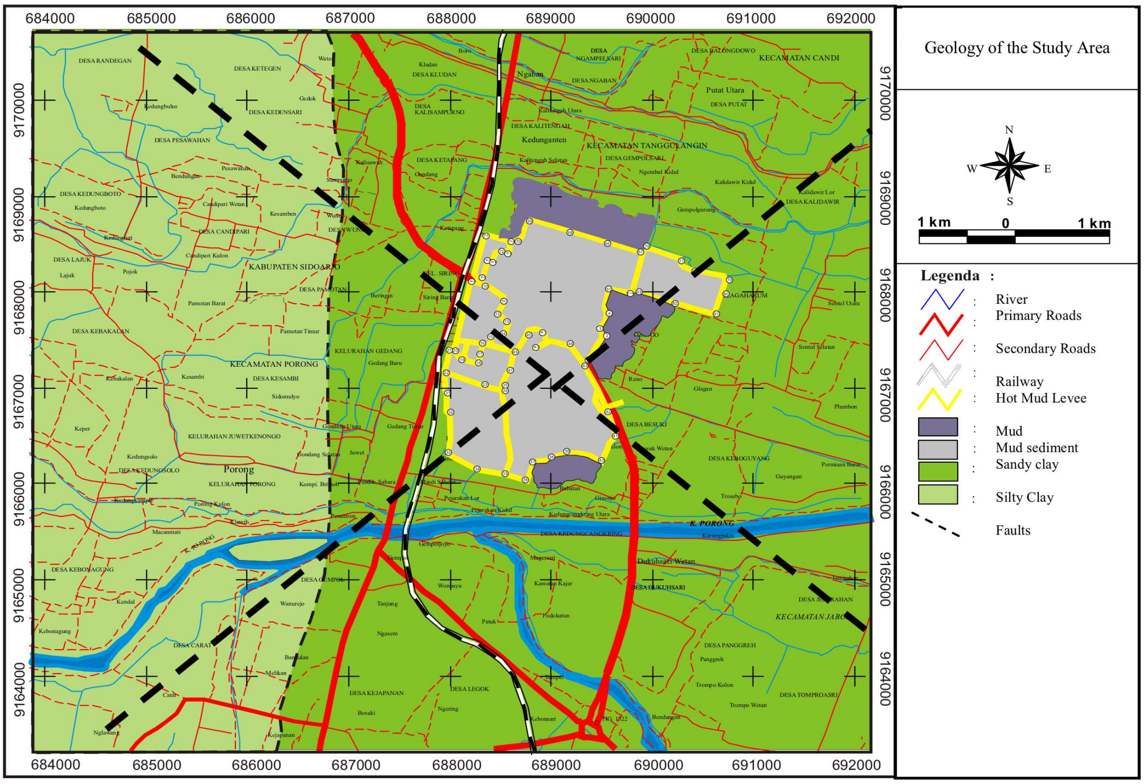

Figure 2: Geological map of the study are

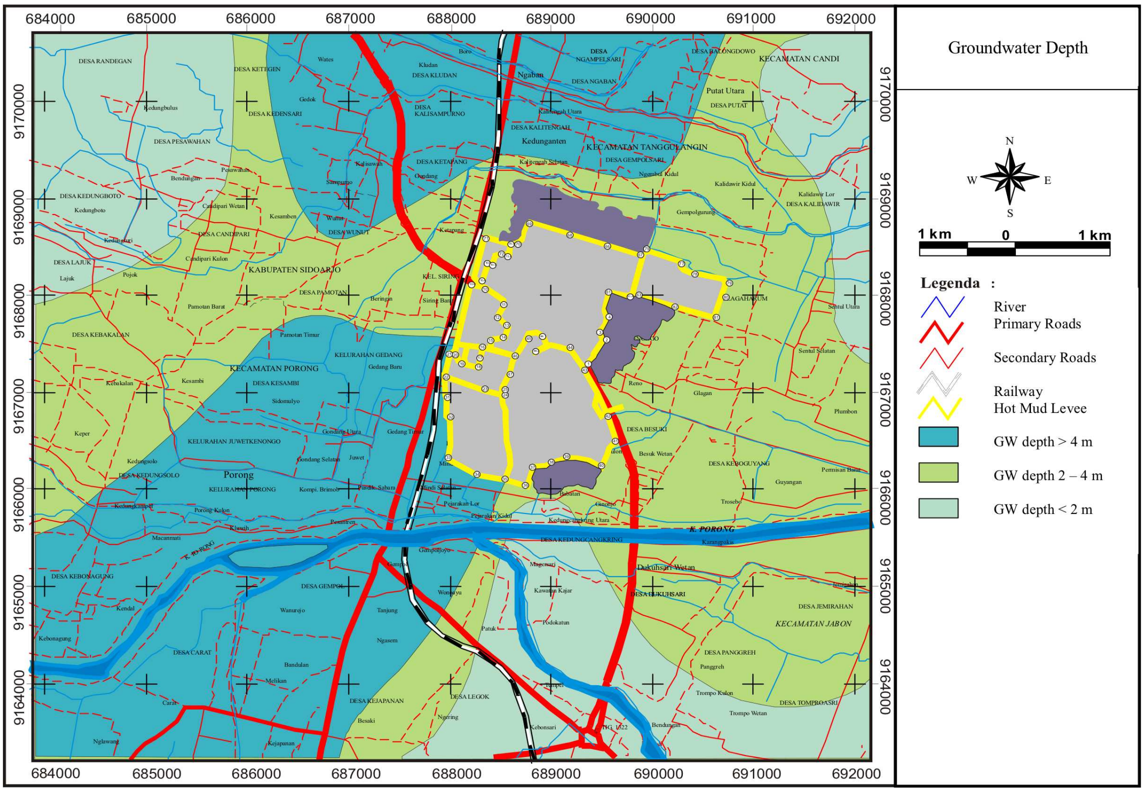

Figure 3: The depth of shallow groundwater in the study area (Syauqi, 2008)

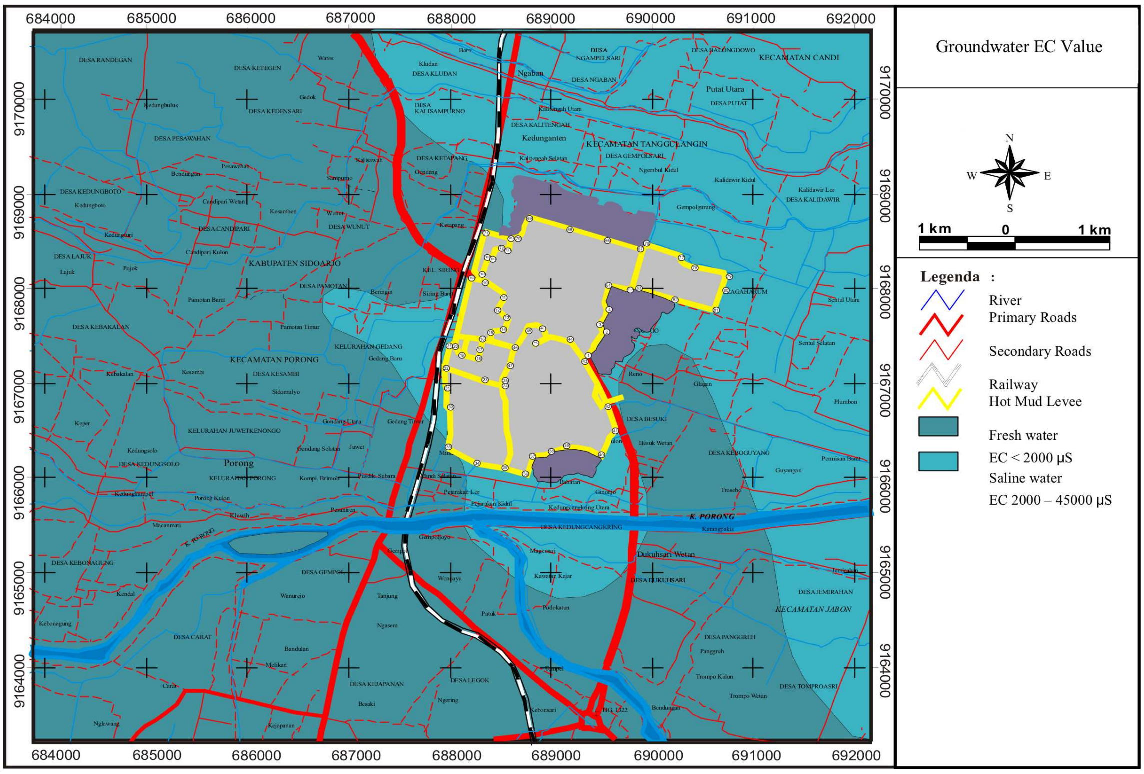

Figure 4: The EC value of shallow groundwater in the study area (Syauqi, 2008)

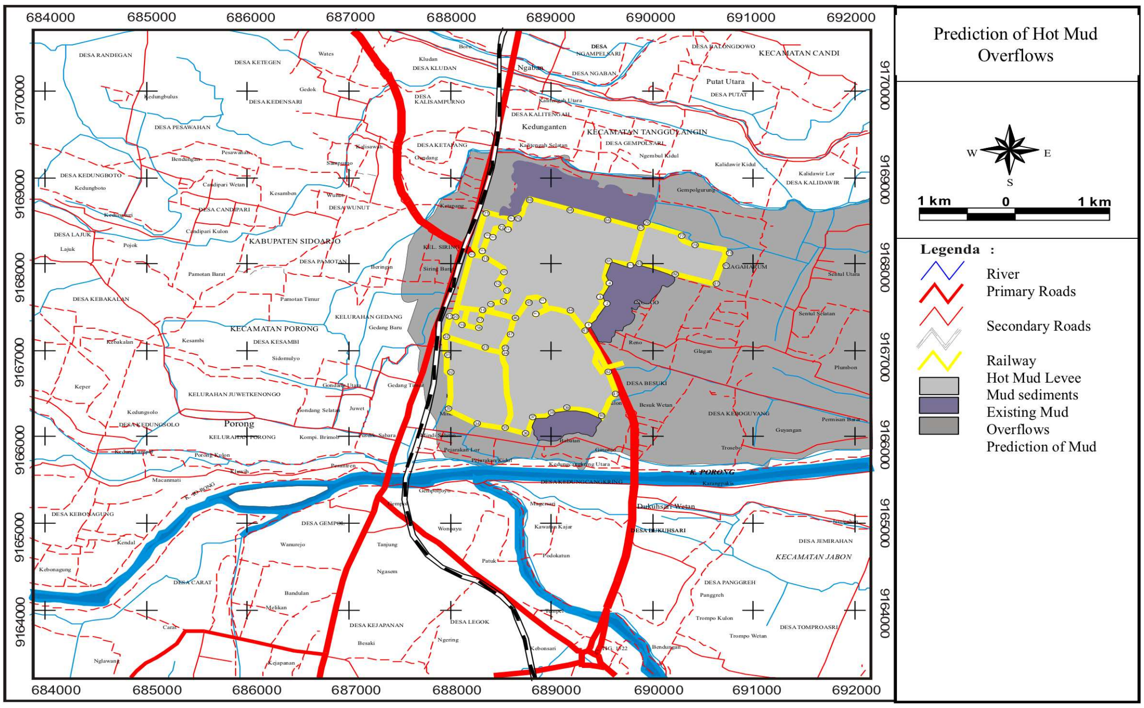

Figure 5: Hazard map of hot mud overflows in the study area (Badan Geologi, 2007)

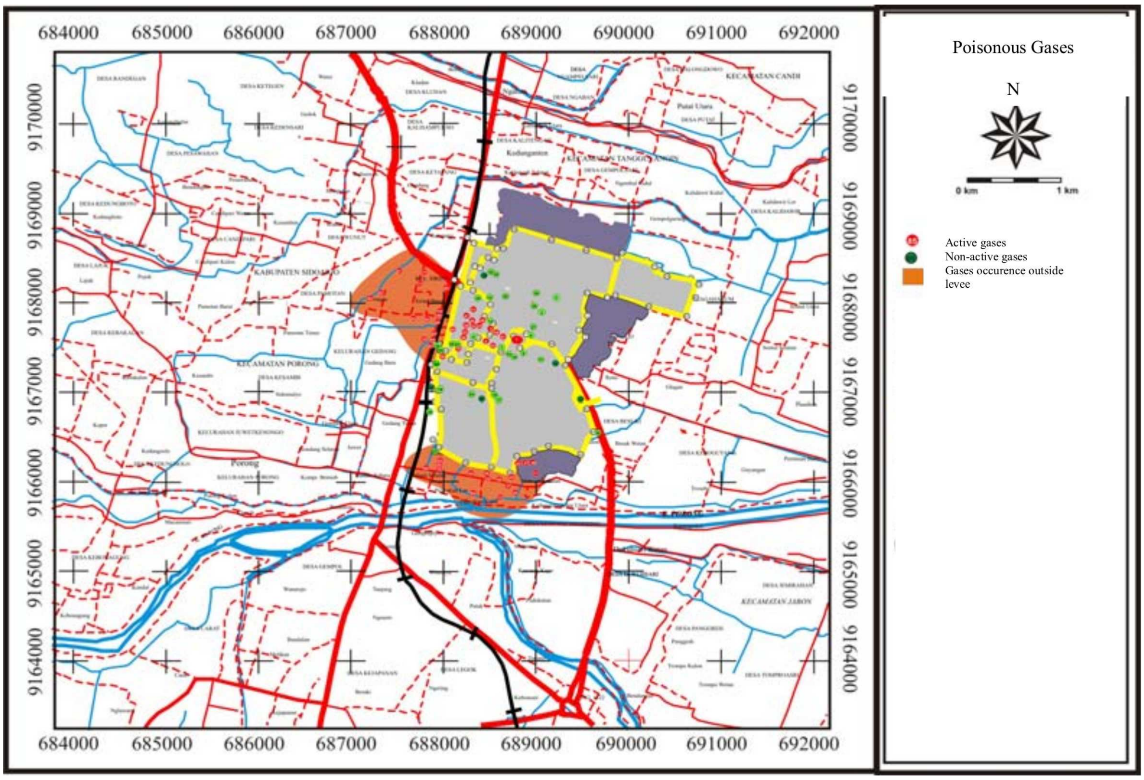

Figure 6: Location of poisonous gases occurence in the study area (Juwarso, 2008)

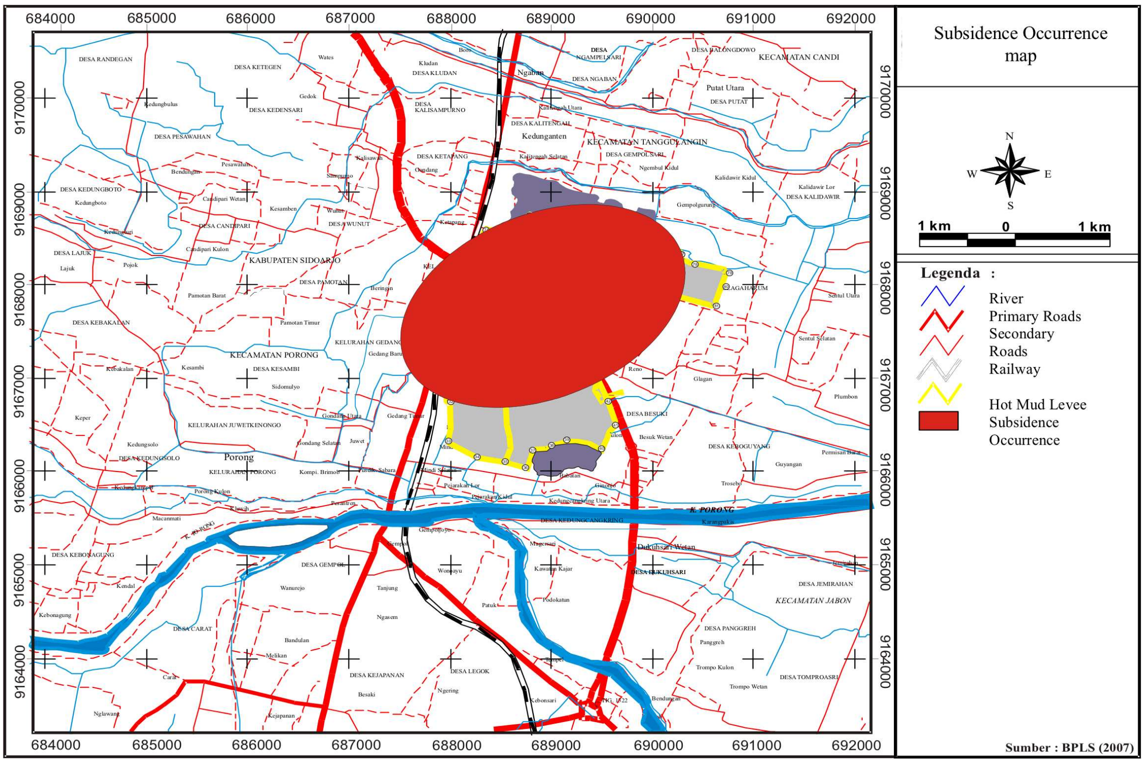

Figure 7: Subsidence hazard map in the study area (Hasanudin et al., 2007)

Table 1: Selection criteria for relocation of railway ans primary roads (high risk infrastructures) in the study area

Parameters	rating score				
	0	1	2	3	4
Eng.Geology					
Distance from faults (m)	< 100	100 - 500	500 - 1000	1000 – 1500	> 1500
Hydrogeology					
Depth to groundwater (m)	< 2		2 - 4		> 4
Groundwater salinity (µS)	> 2000				< 2000
Geo-Hazards					
Distance from mud overflows (m)	<500	500-1000	1000-1500	1500-2000	>2000
Distance from poisonous gases (m)	<200	200-400	400-600	600-800	>800
Distance from subsidence (m)	<200	200-400	400-600	600-800	>800

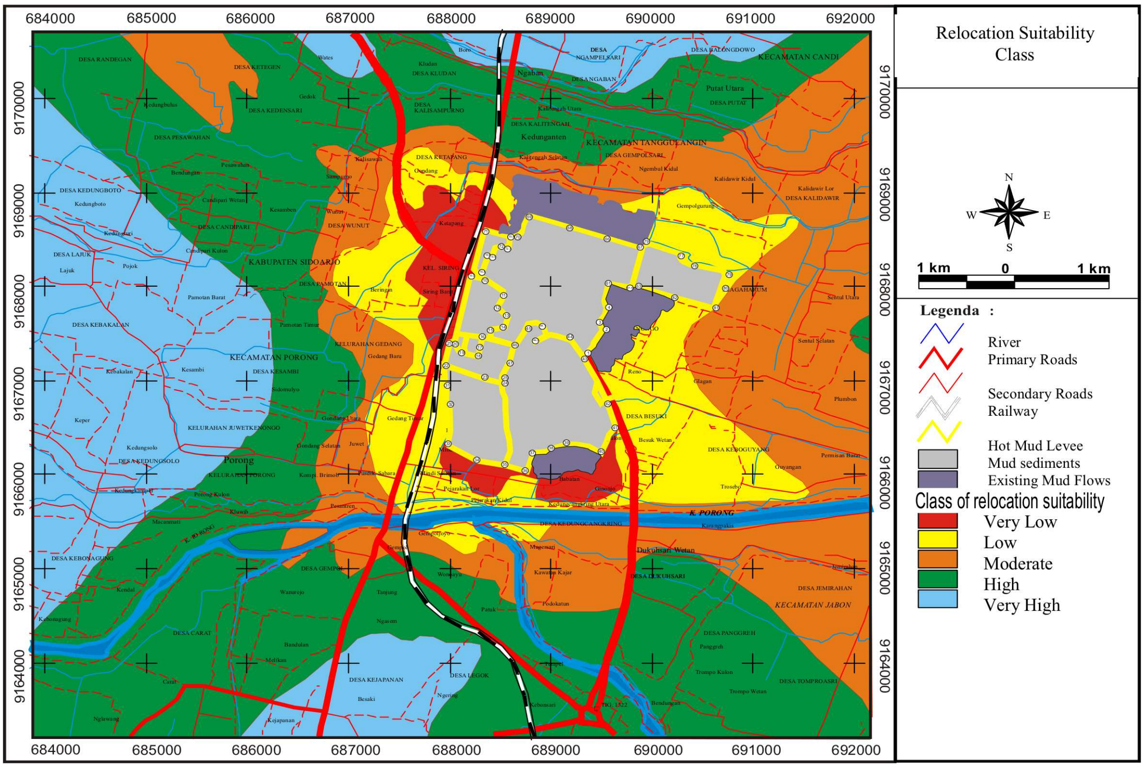

Figure 8: Suitability of infrastructures relocation in the study area

roads) affected by the hot mud blast should be relocated to the west part of the study area.

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