INTEGRATED APPROACH FOR IDENTIFICATION OF GROUNDWATER POTENTIAL ZONE IN HARD ROCK TERRAIN

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KEYWORDS: Remote Sensing; GIS; Analytic Hierarchy Process (AHP); Weighted Overlay

ABSTRACT: El Nino phenomenon in Malaysia prolonged dry seasons resulted in the decrease of surface water resources. Groundwater has been identified by the relevant authorities in Malaysia as an alternative water resource in the areas affected by the El Nino. Several studies have shown that integration of remote sensing and Geographical Information System (GIS) were able to identify groundwater potential zone in more accurate, faster and cost effective. The aim of this study is to use remote sensing and GIS to identify groundwater potential zone in hard rock aquifer at Upper part of Muar River Basin which is one of the areas affected by El-Nino event. In this study, five (5) parameters that controlled the groundwater occurrence were derived and extracted from satellite images (Landsat-8 & SPOT 6) and ancillary data. Analytical Hierarchy Process (AHP) was used to determine the weightage and score of each parameter. Weighted Overlay technique was then used to integrate these parameters in GIS environment to produce groundwater potential map. As a result, three (3) zones of groundwater potential were categorised as High (>10m^3/hour), Moderate (5-10m^3/hour) and Low (<5m^3/hour) that indicate the groundwater potential in term of yield. The map shows that 22% of the study area is in High, 23% in Moderate and 55% in Low potential zones. The yield (25m^3/h) of verification borehole drilled in the High potential zone is consistent with the groundwater potential map. This study shows that integrated approach of remote sensing and GIS is proven to be a useful tool in producing groundwater potential map. The map is needed to assist the relevant authorities in identifying an alternative water resource especially to overcome the water crisis during El-Nino event.

1. INTRODUCTION

Malaysia's water resources are mainly dependent on rainfall, which is influenced by the monsoon seasons. It has an annual average rainfall ranging from about 2,500mm in Peninsular Malaysia to 5,080mm in East Malaysia (Academy of Sciences Malaysia, 2015). In 1982-1983, 1997-1998 and 2015-2016 Malaysia experienced extensive and prolonged drought cause by very strong El- Nino phenomenon (Malaysian Meteorological Department, 2016). A recent study by Arif (2014) shows that most droughts episodes in Malaysia are associated with El Nino (Academy of Sciences Malaysia, 2016)

This phenomenon has resulted the decrease of surface water resources. According to the National Water Resources Study (NWRS) commissioned by the Ministry of Natural Resources and Environment which was completed in 2011 reported that the annual rainfall recorded in Malaysia was around 973 billion cubic meters, (BCM), of which 414 BCM was lost to the atmosphere as evapotranspiration, 496 BCM formed surface runoff and some 63 BCM contributed towards groundwater recharge. Based on this study, groundwater has been identified as an alternative to reduce the impact of the water shortage. Groundwater is defined as subsurface water that fills all the pore space of soils and geologic formations below the water table (Freeze & Cherry, 1979) while (Todd, 1980) has defined groundwater is a water occupying all the voids within a geologic stratum.

The alternative resource has been identified but then, how are going to know where is the groundwater resource. One of the technology that can be use in determine of groundwater potential zone is remote sensing. Remote sensing data from aircraft or satellite has become an increasingly valuable tool for understanding subsurface water condition (Todd, 1980). The use of remote sensing and GIS applications in groundwater studies has been widely used as reported by (Krishnamurthy, et al., 1996), (Srinivasa Rao & Jugran, 2003), (Solomon & Quiel, 2006), (Madrucci, et al., 2008), (Chowdhury, et al., 2009), (Pradhan, 2009), (Dar, et al., 2010), (Nag & Lahiri, 2011) and (Magesh, et al., 2012).

In Malaysia, the use of remote sensing and GIS applications in groundwater determination has been conducted in several areas by (Khairul, et al., 2000), (Yahya & Suratman, 2009), (Mohamad, et al., 2011), (Jabatan Mineral & Geosains Malaysia and Agensi Remote Sensing Malaysia, 2013) and (Jabatan Mineral & Geosains Malaysia and Agensi Remote Sensing Malaysia, 2014).

The aim of this study is to identify groundwater potential zone in hard rock aquifer at Upper part of Muar River Basin which have been affected by El-Nino event using remote sensing and GIS.

2. STUDY AREA

The study area is in Upper Muar River Basin with an area coverage of about 1032km^2. The area consists of eleven (11) mukims which are Ampang Tinggi, Johol, Juasseh, Kepis, Langkap, Parit Tinggi, Pilah, Seri Menanti, Terachi, Ulu Jempol and Ulu Muar. This area was chosen as a study area based on two (2) main factors i.e (i) this area is underlain by hardrock terrain which has fulfilled the study's scope; and (ii) the area was much affected during the El-Nino phenomenon occurred in 1997-1998 and 2015-2016. Study area is shown in Figure 1.

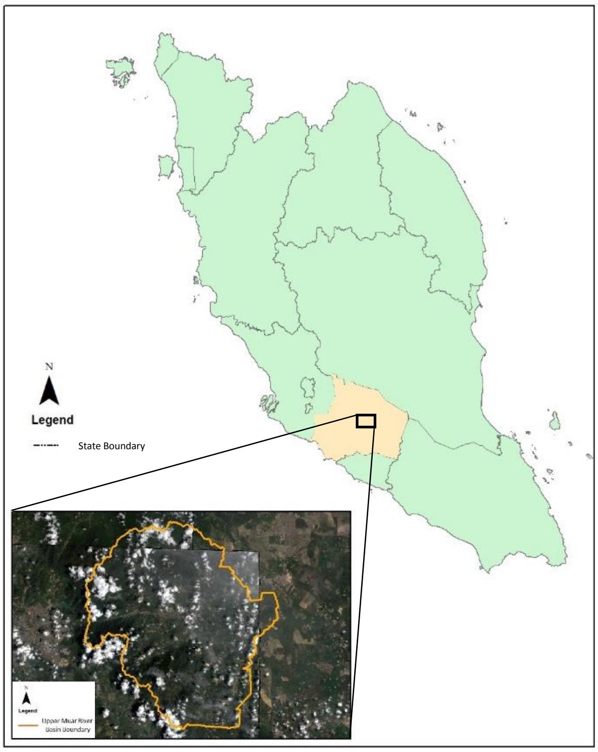

Figure 1: Location of study area, Upper Muar River Basin

3. METHODOLOGY

3.1 Data Preparation

3.1.1 Lineament Density: Straight alignment of topography shaping such as valley, ridge, straight sea shore and row of volcanos namely lineament. The obvious straightness from this feature suggest the relation with joint or fault which is sloping steep (Tjia, 1990). Lineament occurrence play a vital role in identification of groundwater potential especially in hard rock aquifer. The higher lineament density, the higher the possibility of aquifer occurrence and the infiltration rate of water (Jabatan Mineral & Geosains Malaysia and Agensi Remote Sensing Malaysia, 2014). In this study, lineament data was extracted from DEM, Landsat-8 and SPOT-6 by visual interpretation. These extracted data was then processed by GIS in order to generate the lineament density parameter and categorized to five (5) class which are more than 1.0km^2/km, 0.75 – 1.0 km^2/km, 0.5 – 0.75 km^2/km, 0.25 – 0.5 km^2/km and less than < 0.25 km^2/km. Map of lineament density for Upper Muar River Basin area is shown in Figure 2.

3.1.2 Bedrock: Bedrock give big influence to the groundwater occurrence due to different porosity and permeability characteristic. Bedrock with high percentage of porosity and high permeability is a good aquifer (Jabatan Mineral & Geosains Malaysia and Agensi Remote Sensing Malaysia, 2013). Bedrock data was extracted from Geological Map of Peninsular Malaysia (Minerals and Geoscience Department Malaysia, 1985). The bedrock of study area consist of Pilah Schist and Kepis formation (Khoo, 1998) and acid intrusive (undifferentiated). This acid intrusive exist as a part of Pluton Main range. Lithology in this study area consist of schist, metasediment and sedimentary rocks. Loganathan (1993) proposed the age of this formation is Middle Ordovician to Lower Silurian based on the similarities with the lithology found in Kuala Lumpur. These extracted bedrock then was categorized to five (5) class which are limestone, arenaceous/conglomerate, schist/gneiss, argillaceous and plutonic/chert/volcanic/pyroclastic. Bedrock map of Upper Muar River Basin is shown in Figure 3.

3.1.3 Landform: Landform is refer to any physical shape of earth surface which has physical characteristic and formed by the nature process. Landform is categorized based on relative infiltration rate of surface water into subsurface. Generally, infiltration rate for landform which topography is sloping is low compared to flat landform. This parameter was extracted from DEM and categorized to five (5) class which are low lying area, moderate lying area, undulating hills, hillcrest and side slope. Landform map of Upper Muar River Basin is shown in Figure 4.

3.1.4 Land Cover: Land cover is commonly defined as any cover of earth surface and its can be determined by analyzing satellite images (NOAA, 2016). Land cover contribute to the availability of groundwater due to it influence in water infiltration to the subsurface. Classification of land cover has been made based on land use map published by Department of Agriculture. For this study purposes, latest changes of the cover of the study area has been updated using satellite images SPOT-6. Land cover parameter was categorized to five (5) class which are permanent crop, temporary crop, water body, cleared land and urban area. Land cover map of Upper Muar River Basin is shown in Figure 5.

3.1.5 Soil Type: Soil type influence in rate of water infiltrate into the subsurface. Classification of soil type was made based on soil type map published by Department of Agriculture. This parameter classified to five (5) class which are sand, loam, clay loam, organic and clay. Soil type map of Upper Muar River Basin is shown in Figure 6.

All parameter involved have been digitized to scale 1:50,000 in GIS environment.

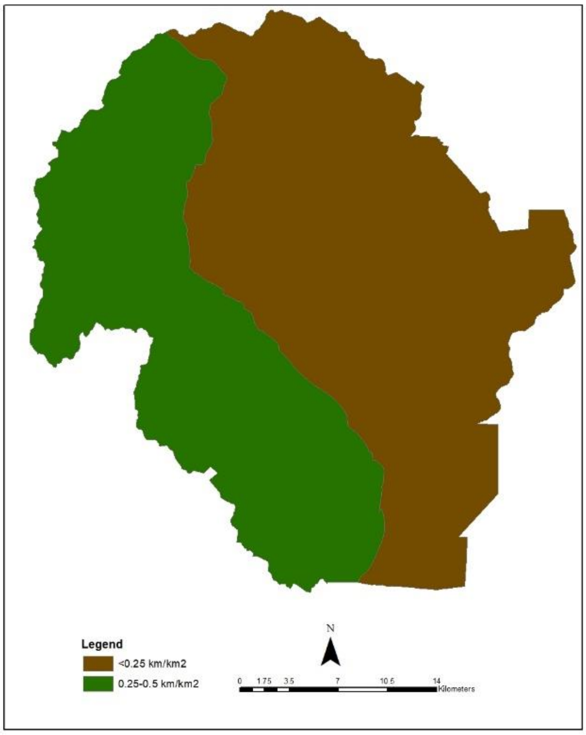

Figure 2 : Lineament density map of Upper Muar River Basin

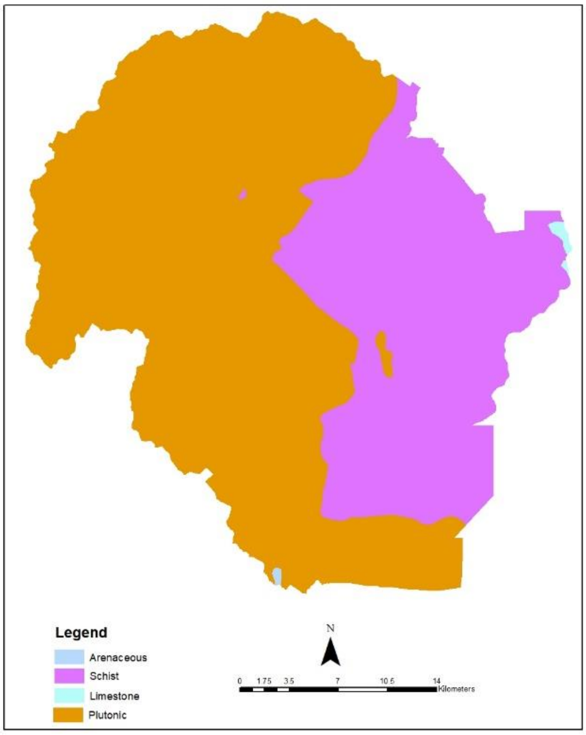

Figure 3 : Bedrock map of Upper Muar River Basin

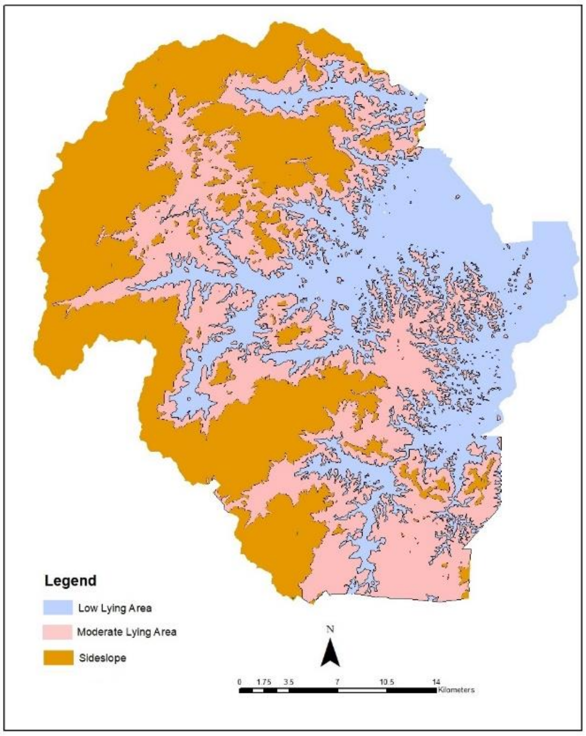

Figure 4 : Landform map of Upper Muar River Basin

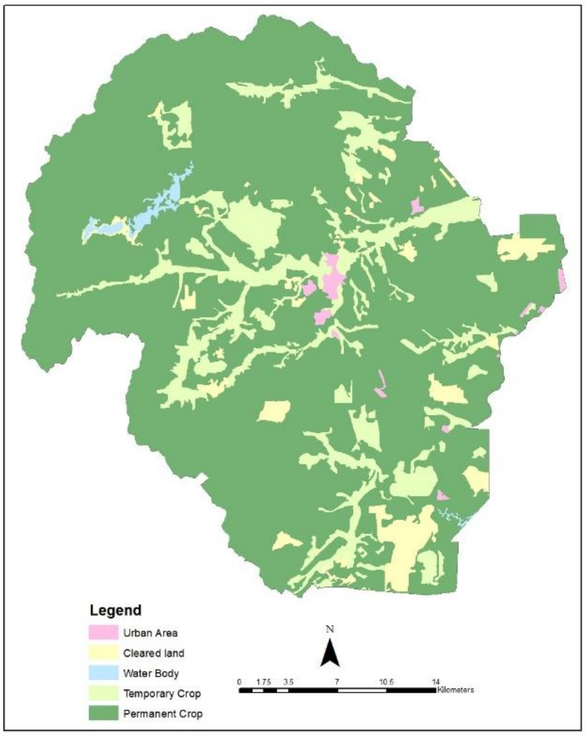

Figure 5 : Landcover map of Upper Muar River Basin

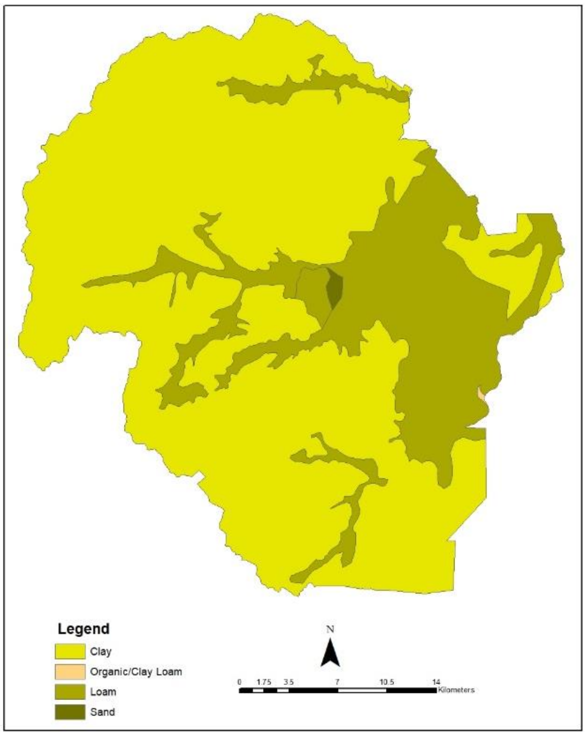

Figure 6 : Soil type map of Upper Muar River Basin

3.2 GIS Modelling

GIS software was used as a basic analysis tool for management and manipulation of spatial data (Pradhan, 2009). Lineament density, bedrock, landform, land cover and soil type were selected as an input in GIS modelling in order to generate the groundwater potential zone map based on their highly contribution to the occurrence of groundwater aquifer in hard rock terrain. Methodology in generating groundwater potential map in hard rock terrain is shown in Figure 7. These parameter were changed to raster format and resample to 30meter spatial resolution with Rectified Skew Orthomorphic (RSO) coordinate projection.

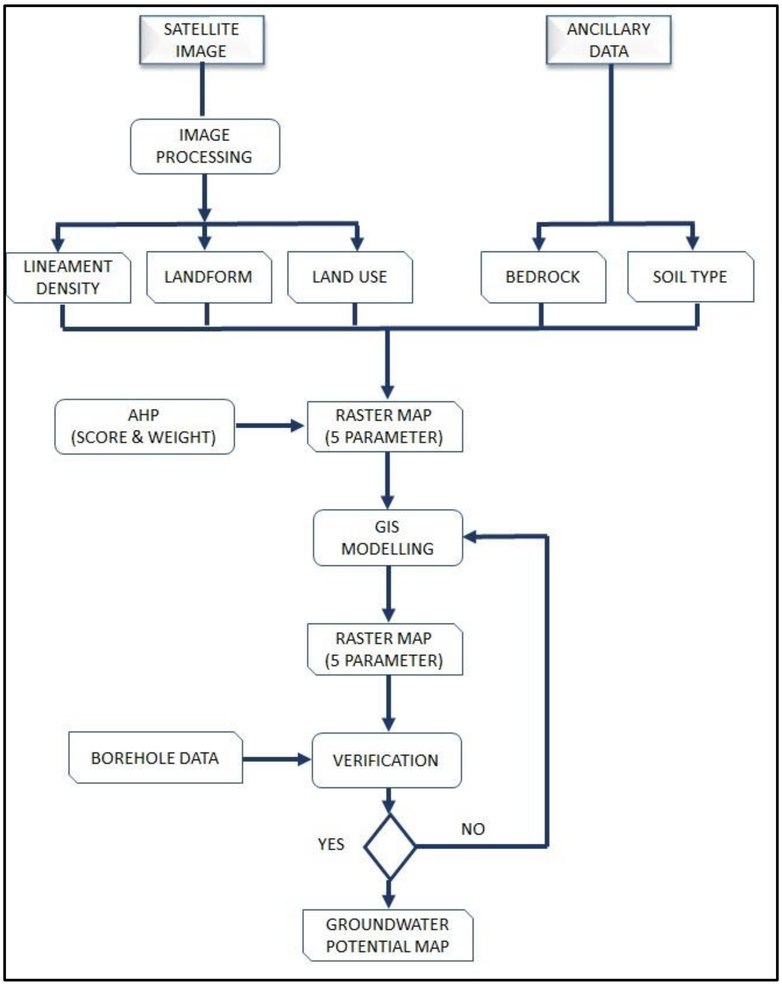

Figure 7: Methodology in generating groundwater potential map in hard rock terrain

The score and weightage for each spatial class and parameter were assigned based on Analytical Hierarchy Process (AHP). This method involves pairwise comparison in determining the relatively importance to the availability of groundwater. This relative value importance is determined by the Saaty Fundamental Scale as per Table 1 below:

Table 1: Fundamental Scale

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance of one over another
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values

After: (Saaty, 1990)

The input for the AHP analysis were driven by groundwater expert through questionnaire. It was concluded that lineament density and bedrock were the main parameters in contributing to the groundwater occurrence, therefore the weightage of these parameters are much higher than other parameters which are landform, land cover and soil type.

For bedrock parameter, score for limestone class is the highest followed by arenaceous, schist and plutonic rock. Low lying area is a landform class that most influence to water occurrence compared to moderate lying area, undulating hills, hillcrest and side slope. Based on soil type properties, sand was given the highest score compared to the others i.e., loam, clay loam, organic and clay while for land cover, permanent crop is the highest followed by temporary crop, water body, cleared land and urban area.

These parameters were integrated using Weighted Overlay model in ArcGIS software. The model was modified after Khairul, et al., 2000 and Aller et al., 1987. GIS formula used after modification and enhancement is as follows:

GWP = BdsBDw + LdsLdw + LfsLfw + LcsLcw + SpsSpw

Where:

GWP = Groundwater potential
Bd = Bedrock
Ld = Lineament density
Lf = Landform
Lc = Landcover
St = Soil type
s = Score
w = Weightage

4. RESULT AND DISCUSSION

Percentage area for each class in Upper Muar River Basin is shown in Table 2 below:

Table 2: Percentage area for each class in Upper Muar River Basin

Parameter	Class	Area (%)
Lineament Density	<0.25 km/km^2	59.0
	0.25-0.5km/km^2	41.0
Bedrock	Plutonic	65.0
	Schist	34.7
	Limestone	0.2
	Arenaceous	0.1
Landform	Side slope	35.0
	Moderate lying area	34.0
	Low lying area	31.0
Land Cover	Permanent crop	80.0
	Temporary crop	14.0
	Cleared land	4.0
	Urban area	1.0
	Water body	1.0
Soil Type	Clay	75.7
	Loam	24.0
	Sand	0.2
	Organic / Clay loam	0.1

The groundwater potential map of Upper Muar River Basin is shown in Figure 8. The area was categorised into three (3) zones namely High (>10m^3/hour), Moderate (5-10m^3/hour) and Low (<5m^3/hour) that indicate the groundwater potential in term of yield. Quantitatively, 22% of the study area was categorised as high potential covering the eastern part of the study area while 55% of the area is low zone of groundwater potential which mostly covering the western part of the study area. The other 23% is scattered mostly at central part of the map. The distribution of the zones show a good consistency with the characteristic of the assigned parameter. High potential zone is dominated by the schist bedrock, low lying area and loamy top soil which associated with highly potential of groundwater occurrence. The areas that is underlain by plutonic bedrock and clay type of soil which associated with low potential of groundwater occurrence are categorised low in the potential map.

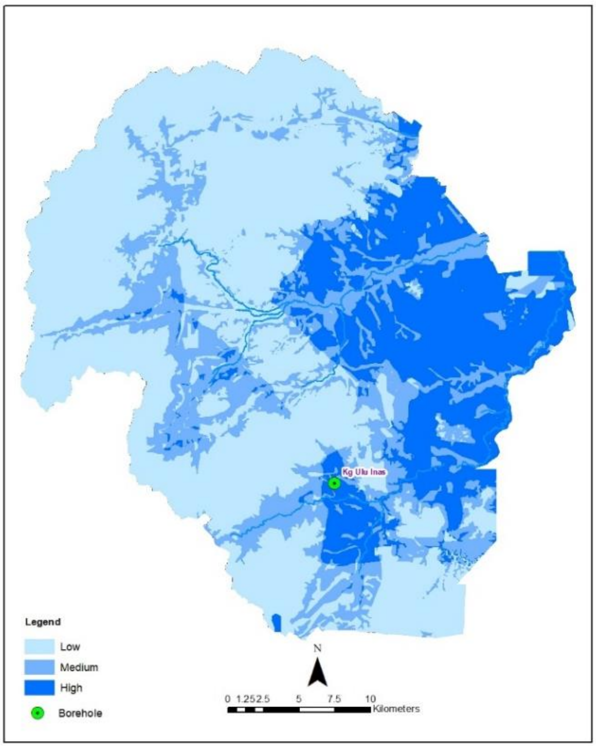

Figure 8: Groundwater potential map of Upper Muar River Basin

In this study, suitability location for borehole drilling was determined based on the potential map generated. Kg. Ulu Inas, Kuala Pilah was chosen for drilling borehole (Figure 8) because it is located in the high groundwater potential zone. The result of drilling is shown in the Table 3 and from the result, it shows that the map has a good agreement with the actual borehole data.

Table 3: Groundwater verification

Location	**Actual Borehole Yield (m^3/hour)**	**Groundwater Potential Map (m^3/hour)**	**Result**
Kg. Ulu Inas	25	>10 (High)	Match

5. CONCLUSION

In this study, upper part of Muar River Basin which is one of the areas affected by the El-Nino event was successfully been mapped using remote sensing and GIS technology. It can be concluded that integration of remote sensing and GIS technology is useful to identify groundwater potential zone in hardrock terrain in fast and accurate manner. The groundwater potential map is needed to assist the relevant authorities in identifying an alternative water resource especially to overcome the water crisis during El-Nino event.

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