THE HYDROSTRATIGRAPHIC AND GROUNDWATER FLOW MODELING OF MUKAH COAL MINING AFFECTED AREAS

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Abstract

The hydrostratigraphic and groundwater flow information within the vicinity of Mukah Coal field is important to provide a guideline in protecting the groundwater resources. The delineation of the regional aquifer–aquitard framework requires precise evaluation of the hydrostratigraphic controls and temporal patterns of groundwater flow of the study area. Possible natural contaminants include trace elements such as arsenic and selenium, radionuclides such as radon, and high concentrations of commonly occurring dissolved constituents are the possibly wash out together with spillage of removed overburden and eventually enter the groundwater aquifer. The hydrostratigrahic interpretation and the groundwater flow modeling are supported by Lithologic data analysis, wireline logging, resistivity imaging lines, and from the Ground Penetrating radar runs within the study area. The lithologic logs were obtained from 26 drill holes including drill holes for groundwater exploration and drill holes for coal exploration within the study area. A total of 8 Wirelines run for these drill also used to confirm the lithologic logs of the drill holes. Both resistivity imaging (6 runs) and Ground Penetrating Radar (6 runs) methods were used to evaluate further lithological sections of the study area. The study area is dominated by various aquifer systems, which are mostly unconfined. In several localities, this main aquifer has been locally divided into multiple layers by the presence of discontinuous aquitards (with a lateral extent of one to a few kilometers). Generally, the direction of groundwater flow is towards the central part of Mukah Coal Mining area.

i(a) Introduction

The vulnerability of the ground-water resource to sources of contamination located primarily within land surface affected by coal mining is a great concerned to the people depending on groundwater for daily usage. Because of generally low ground-water velocities, once contaminants have reached the water table, their movement to nearby surface-water discharge areas or to deeper parts of the ground-water-flow system is slow. For the same reason, once parts of an aquifer are contaminated, the time required for a return to better water-quality conditions as a result of natural processes is long, even after the original sources of contamination are no longer active. Ground-water-quality remediation projects generally are very expensive and commonly are only partly successful. In some settings, steep gradients caused by ground-water pumping can greatly increase the rate at which contaminants move to deeper ground water. The detail understanding of hydrostratigraphic and groundwater flow of the surrounding areas affected by coal mining activities is important to provide a guideline to protect the ground-water resources.

Possible natural contaminants include trace elements such as arsenic and selenium, radionuclides such as radon, and high concentrations of commonly occurring dissolved constituents are the possibly wash out together with spillage of removed overburden and eventually enter the groundwater aquifer. The common and most significant linkages in hydrology are the linkage between land-surface/water-table connection and the ground-water/surface-water connection. The intrusion of saltwater, involves movement of naturally occurring, highly saline ground water into parts of adjacent aquifers that contain less saline water. Excessive pumping of the less saline (commonly potable) ground water generally causes this movement.

i(b) Study area setting

In general, the topography of the study area is very flat maximum elevation of about 36 m above mean sea level(MSL) near Belian Mati sloping towards the Ulu Sikat area(eastern part). As the map shows, groundwater flowing west of this divide empties or discharges into the Mukah River system and groundwater flowing east of the divide empties into the Balingian River system. This groundwater contour map represents the regional groundwater flow system with the recharge area at the basin or watershed divide and the discharge area into the Mukah River and Balingian River.

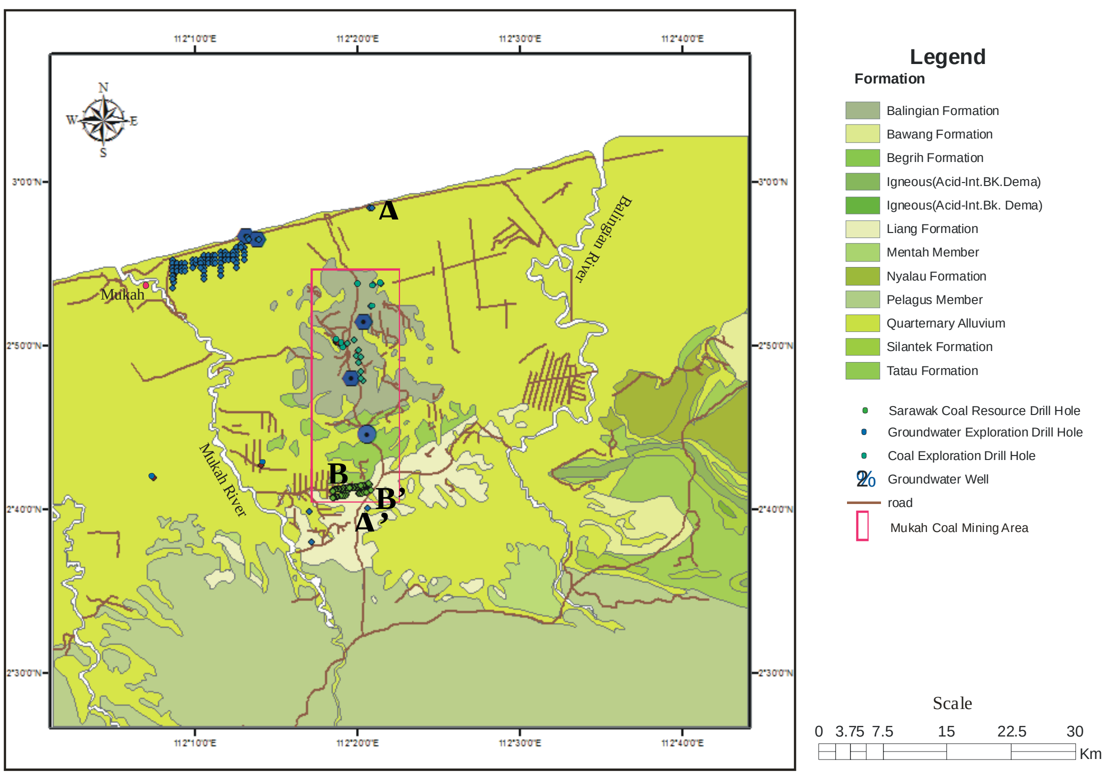

Figure 1: Location Map of Drill Holes and Formations in Mukah Coal Field

i(c) Hydrogeology

The Mukah basin groundwater system is strongly influenced by the rainfall caused by the Northeast monsoon wind. There are distinct dry seasons (June to August) and wet seasons (November to January). Annual rainfall ranges from 3067mm to 4495mm (Department of Irrigation and Drainage Sarawak, (1995-2006)). The heavy rainfalls during the monsoon period and high tide cause flood to the lower part of Mukah Coal mining area. Two major catchment areas are Mukah and Balingian catchments which dissected by their tributaries that form many subcatchment areas. These subcatchment areas are from the rivers such as Sungai Bedengan Hulu, Sungai Penipah, Sungai Bawan, Sungai Bayan, Sungai Belian Mati and Sungai Bedengan Kanan. The study is underlain by Balingian Formation, Begerih Formation and Liang Formation (Figure 1). The average thickness of sand bodies is ranging from 3.0 m to 30.0 m. The sand bodies are thickening towards the central part of the study area. The sand bodies interbedding with clay with occasionally intercalation of siltstone and occurrence of coal bed of thickness ranging from 0.60m to 4.50m are common. At the bottom of aquifer, fine sand with intercalations of clay is common and occasionally presence of fossils remains.

ii Objectives of the study

The objectives of the study were to delineate the regional aquifer–aquitard framework evaluating the hydrostratigraphic controls, and temporal patterns of groundwater flow of the study area. The understanding subbasinal scale hydrodynamics is important for evaluating the possibility of pollution movement from contaminated shallow aquifers to the as-yet uncontaminated deep aquifers and to understand the interaction between the local and regional flow systems, along with estimating and understanding the control of recharge and hydraulic parameters on the regional flow.

iii Research Methodology

The precise hydrostratigraphic study and groundwater modflow modeling require various sources of data acquisition. The hydrostratigrahic interpretation and the groundwater flow modeling are supported by Lithologic data analysis, wireline logging, resistivity imaging lines and from the Ground Penetrating radar runs within the study area. The lithologic logs, were obtained from 26 drill holes including drill holes for groundwater exploration and drill holes for coal exploration(Sia, S. G., et al,2000) within the study area. A total of 8 Wirelines run for these drill also used to confirm the lithologic logs of the drill holes. Both resistivity imaging (6 runs) and Ground Penetrating Radar (6 runs) methods were used to evaluate further lithological sections of the study area.

The lithology of the logs has been recorded at sub-meter vertical resolution and consists of four major types of unconsolidated sediment: gravel, sand, sandy clay and coal. A number of lithologs from various localities have recorded further subdivision of sands in terms of grain size (very coarse, coarse, medium, and fine). Description of the color, hardness, presence of fossils and sedimentary structures are documented.

For the purpose of this study, only the major sediment types were used. A relatively thin soil horizon with a general thickness of 2–5m covers the study area. Air photographs study is done to support the interpretation of uncovered field study area. Lineaments, escarpments, and geological structures are marked.

From a general hydrogeologic point of view, these sediments have been categorized as aquifer (sand and gravel) and aquitard (clay). The position of the sandy clay is ambiguous: it can act as either less permeable aquifer or higher-permeability aquitard. Its exact category will vary from locality to locality based on the sand/clay ratio and permeability. Also transportation of pollution plumes slow, as transmitting of groundwater water through clays layers is low due to the low hydraulic conductivity of clay (Dr. Tellam and Mr. Brook (pers.comm), Dr.Shaharin, 1987). Although the less permeable sediments like clay transmit some groundwater, they separate the overlying aquifer(s) from lower aquifer(s) by hydraulic conductivity (K) contrast. In the study area, the extent, thickness and K of these clay or aquitard layers are very important as they govern the three-dimensional flow of groundwater at the regional scale. The sediment types and hydrogeologic categories will be used interchangeably for the description of both hydrostratigraphy and groundwater flow modeling.

A total of 179 drill holes data were used to produce the 2D and 3D topographic image of the Mukah study area while 151 drill holes were used to produce 2D contour and 3D image of groundwater head. Surfer, MapInfo and modflow vistas programmes are used to predict the general flow of groundwater within Mukah coal field. The locations of the drill holes and groundwater wells are plotted on the digitized map by using Arcgis software.

In additional to the hydrostratigraphic and groundwater flow study of the Mukah coal field area, north-south, east-west cross sections, model transect at the selected lines in North-South and Northwest-Southeast direction are drawn and sequence of lithologies are indicated.

iv (a) Result & Discussion

Hydrostratigraphic units have been defined as bodies of rock with considerable lateral extent that compose a geologic framework for distinct hydrologic systems. Based on the hydraulic properties of rocks/sediments, they were supposed to be practical mapable fundamental units for describing hydrologic systems in the field.

The topographic features of Mukah coal field is as plot in Figure 2. This topographic feature represents the contour or the arrangement of the land surface including its relief and the position of its natural. The central part of mining area is higher and gently low relief towards the south as compared to the northern part.

Besides surface water, topography of the land surface also determines the general direction of groundwater flow, and it influences groundwater recharge and discharge. A recharge area is where water moves downward from a topographical high area into the zone of saturation. In other words, recharge areas replenish groundwater. A discharge area is where groundwater moves towards the surface to escape into a spring, lake, wetland, or a stream. Excavating works during the coal mining cut through shallow groundwater aquifer resulted in groundwater discharge and pumping out groundwater well is excessive. Groundwater flow system is affected.
In summary, the study area is dominated by various aquifer systems, which are mostly unconfined. In several localities, this main aquifer has been locally divided into multiple layers by the presence of discontinuous aquitards (with a lateral extent of one to a few kilometers).

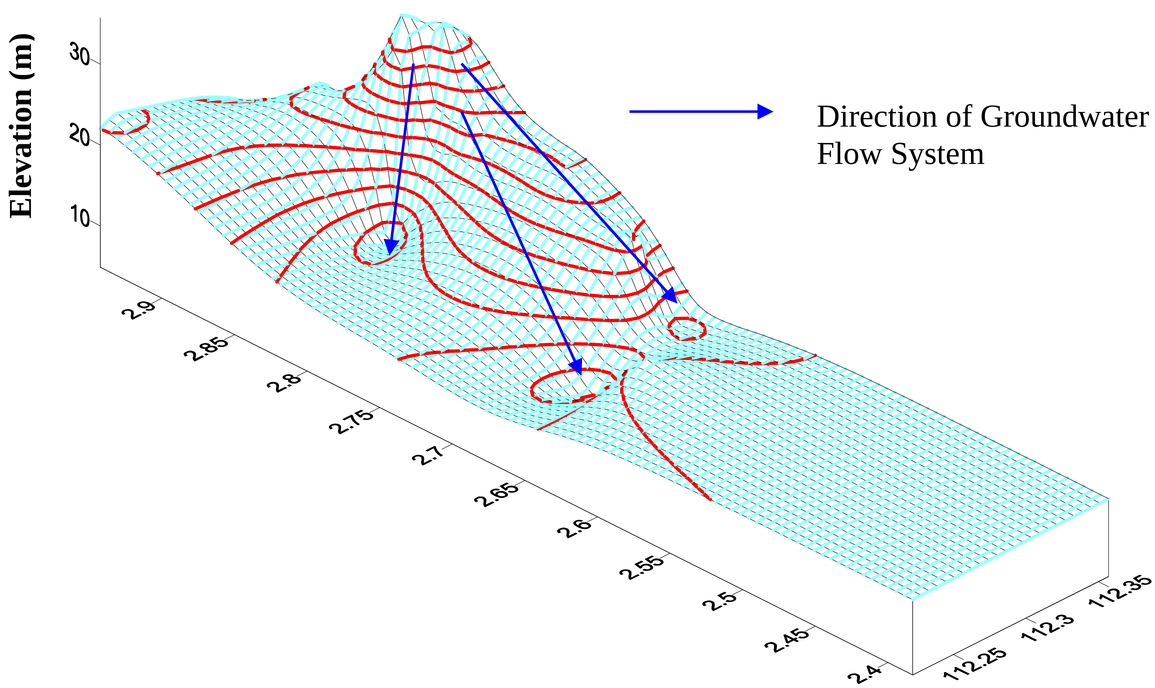

Figure 2: 3-D Topographic view of Mukah Coal Mine Area

iv(b) Groundwater flow modeling

The modeled study area is bounded in the north, west, and east by the Coastal line, Mukah River and Balingian River, respectively, and to the south by the lithologic boundary of Balingian and Bergrih formation. The study area is 35 km in length and 20 km in width. However, the total modeled area encompasses the study area along with surrounding areas as shown in Figure 1. The 3-D, constant-density groundwater flow was simulated by a block-centric, finite-difference grid model using MODFLOW (Rumbaugh, O.James and Rumbaugh, B.Douglas, 1998). Microsoft Windows® based Groundwater Vistas® (GV) version 5 (Environmental Simulations Inc., Herndon, Virgina, USA) was used as the pre and post-processor. The modeling is done in transient mode to show the continuous time-variant nature of flow under seasonal variations in recharge and abstraction rates. The unavailability of estimations of total inflow and seasonal surface water-groundwater interaction of near-absence of time-variant field data (e.g., seasonal groundwater levels and stream stage) from the study area, the construction of detailed transient models was unsuccessful. However, a very simplified groundwater flow model is developed using Surfer 3D plot (Figure 3). The lithological correlation between wells within the study area is used to support the groundwater flow prediction (Figure 4 and Figure 5) towards the central part of the mining area.

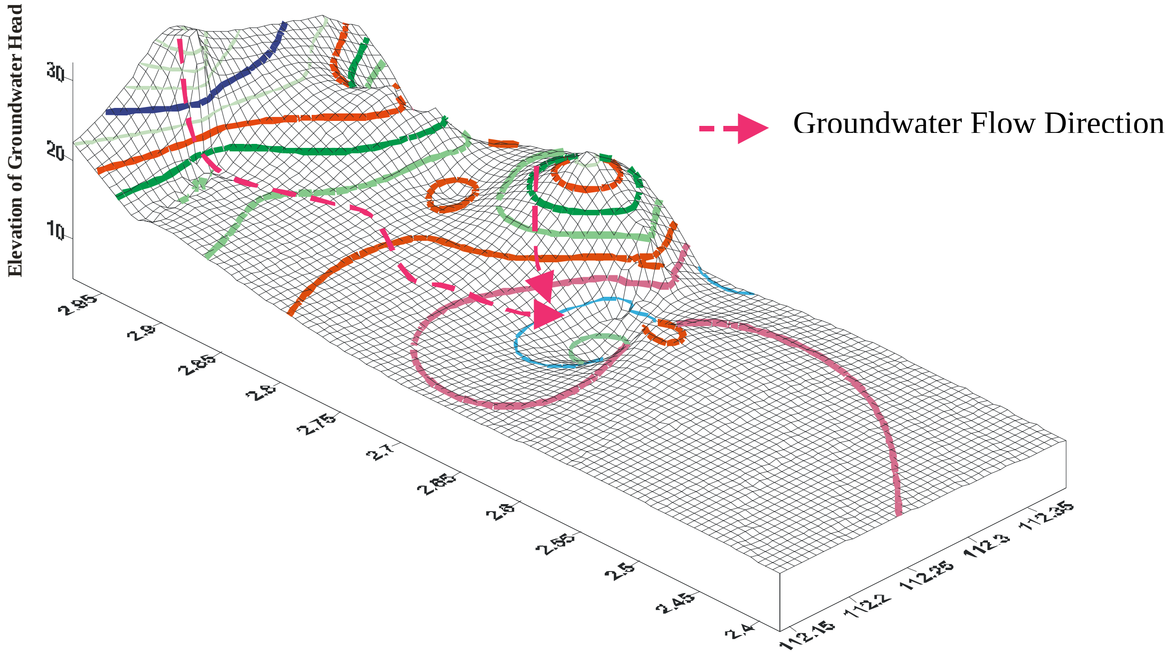

Figure 3: 3-D of Groundwater Head of Mukah Coal Mining Area

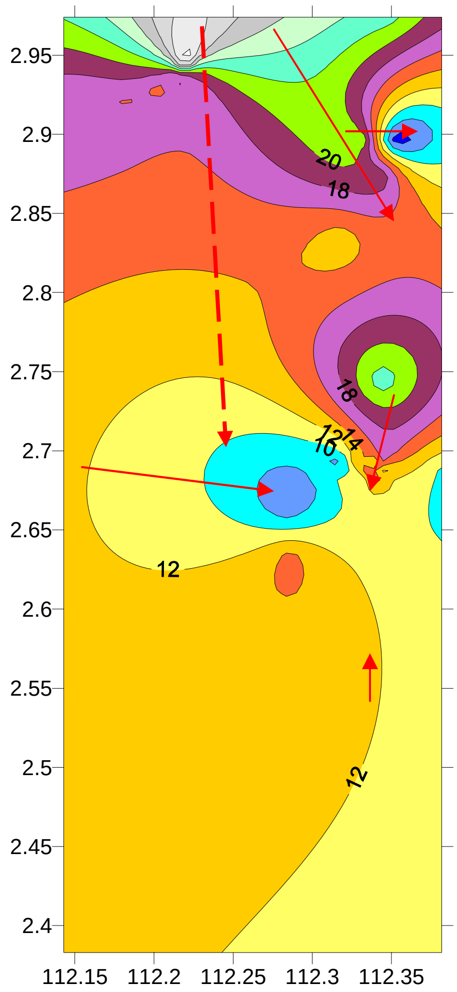

Figure 4: The Contour Map of Groundwater level(msl) in Mukah Coal field

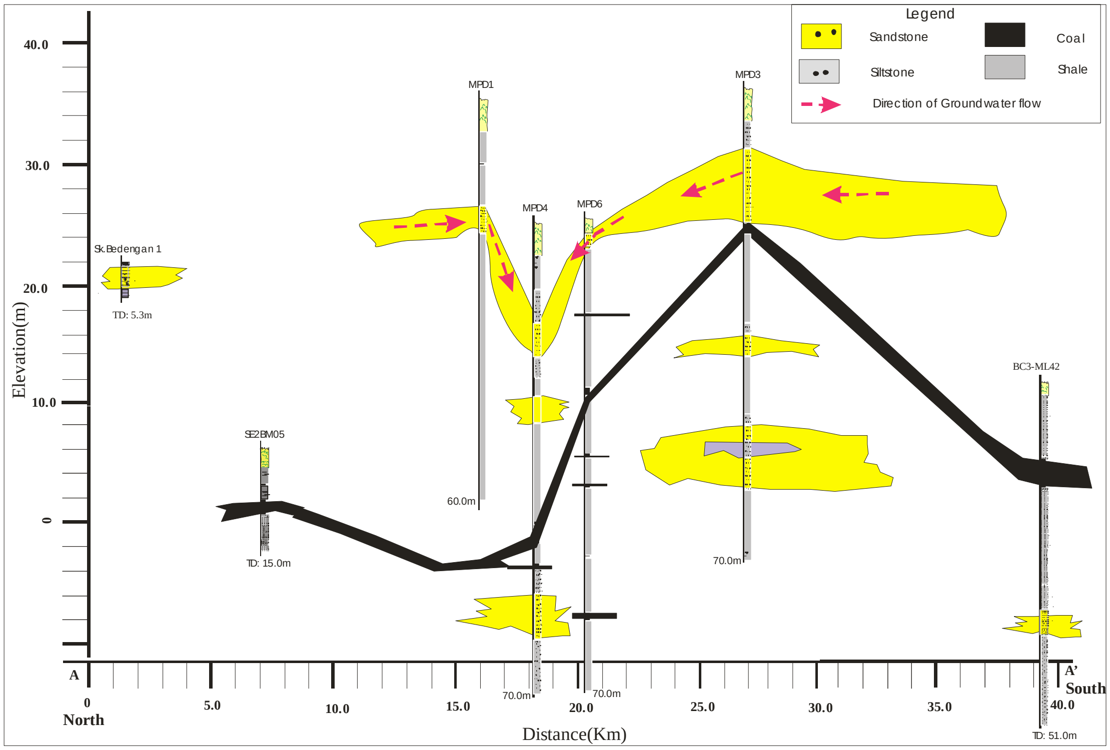

Figure 5: Model Cross Section along Transect AA' (N-S)

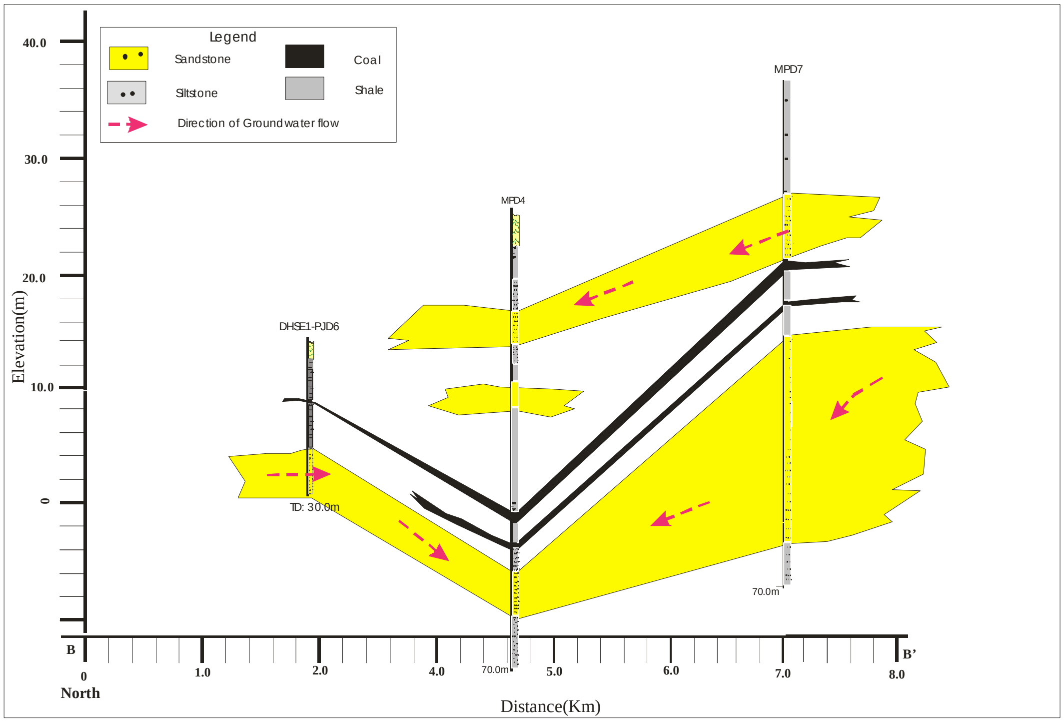

Figure 5: Model Cross Section along Transect BB' (NW-SE)

iv(c) Groundwater and Surface water Connection

The movement of water in both directions between ground-water systems and surface-water bodies influence the chemical constituents that are transported along with the moving water. Thus, contaminants in surface water can be transported into adjacent ground-water systems, and contaminants in ground water can be transported into adjacent surface-water bodies. The groundwater is a major component of stream flow, the quality of discharging groundwater potentially can affect the quality of the receiving stream in many hydrologic settings. Sungai Belian Mati, Ulu Sikat and Sungai Bedengan are the main receiving large amount of discharge from coal mining tailings. In certain proportion of stream flow is contributed by groundwater which varies greatly throughout the year. The seasonal variations can affect the groundwater quality. Reductions in the quantity of groundwater discharged to a stream as a result of pumping may have significant consequences where this discharge significantly dilutes the concentration of contaminants introduced to streams from point sources and surface runoff. In such situations, stream flow capture by pumping wells may reduce the contaminant-dilution capacity of the stream during periods of low flow below the dilution capacity assumed in setting discharge permits for the stream. Contributing areas to wells often include surface-water bodies affected by the coal mine , is being placed on surface water as a potential conduit for that transport mine pollution to groundwater wells. Possible contamination by induced infiltration of surface water adds several dimensions to the protection of ground water. These include consideration of the upstream drainage basin as part of the "contributing area" to the well and greater consideration of microbial contamination. Contaminated surface water may have a significant effect on the sustainable development of ground water near streams or on the need for treatment of ground water prior to use. Among the settings of greatest concern for contamination of ground water by streams are karst terrains where aquifers are hydraulically connected by sinkholes or other conduits that can channel river water directly into an aquifer with little or no filtration.

The contamination of seepage and groundwater by SO_4^{2-} originating from oxidation of sulphide or organically bound sulphur can last for about 10 years (Matthess, G., Oetting, R., Schultz, M., and Werner, H., 1982). These contaminants can be transported into groundwater at the speed of ranges from 0.2 meter per day to 0.8 meter per day (Kamarudin Samuding, Mohd Tadza Abd. Rahman and Juhari Yusof, 2003).

v. Significance of Finding

The hydrostratigraphic and groundwater modflow study has revealed that lithological factors influenced the flow system of groundwater and its travel time. The construction of settlement ponds in protecting of ground water contaminated by coal mining tailings through induced infiltration of surface water will be more effective.

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