Feasibility Study of Riverbed Filtration Technique at Sungai Kampar Perak by using Numerical Modelling

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Abstract. Population growth will result in the increase of water supply demand. Riverbed filtration or radial collector well technique is one of the options for increasing the water supply. Drainage Package of Visual MODFLOW was used for the riverbed filtration modelling. The modelling aimed to identify the optimum pumping rates withdrawal in order to fulfill Lembaga Air Perak requirement for additional water supply. Installation of radial collector wells in the depth of 10-12 m aquifer thickness at Sungai Kampar Perak would increase the supply of clean water for future water demand. The design of riverbed filtration technique consists of 4 m radius of collector well with depth of 10.54 m and five radials wells with 40 m length across the riverbed. Transient condition of the groundwater flow modelling result showed that the optimum pumping rate can meet the water supply requirements of about 35 MLD (35000 m³/day).

1. Introduction

Development of socio-economic will change the scenario growth of water supply. The growth of population at Kampar Perak has resulted in inadequate clean water supply [1]. Existing Sungai Kampar water treatment plant is not able to meet the increase in the clean water demand. Water supply quantity and quality can be improved by using riverbed filtration (RBeF) system [2,3]. RBeF has been look at as an alternative to the traditional use of river water for clean water supply. This is because RBeF is cheaper in treatment costs compared to the treatment of raw river water [3]. Groundwater is typically a higher quality source than surface water, and usually requires less treatment than surface waters [2]. Groundwater has gone through natural treatment process such as infiltration of precipitation and recharge from surface water sources into aquifers [2]. However, groundwater quantity is not sufficient to meet the water demand in many areas [4,5,6]. RBeF system consists of one or a series of radial well located below a river in an aquifer that have interaction between surface water and groundwater. This interaction results in potential for water extraction in large quantities [2,3]. The radial well will act as the receiver of water along screen length. The collected water flows by gravity to the collector well where it is pumped to a water treatment plant. As the water quality is already clean minimal treatment is required [7]. The aim of the study is to look at the feasibility of using RBeF as additional water supply by using numerical modelling at Kampar Perak.
2. Methodology
The study area located near Kampar town which is situated at central region of Perak state (Figure 1). Total population of central region of Perak is about 300,000 peoples [1]. The proposed site of RBeF system is near to the water intake facilities for water treatment plant of Sungai Kampar (Figure 1). The total area of study area is about 0.49 km².

The conceptual model of groundwater modelling was developed as shown in Figure 1. The regional conceptual model was developed with few assumptions on the aquifer layers and hydraulic properties [7,8]. Conceptual model considered two layers of subsurface profile which is fine sand at the first layer and combine with course sand at the bottom of the aquifer. The aquifer layer is about 10 - 13 m depth of thickness before granitic bedrock encountered. The aquifer properties parameters are shown in Table 1.

Five monitoring wells were constructed along Sungai Kampar. Heads from five monitoring wells were measured in the field and calibrate with the calculated head from numerical modelling. The study area have inactive cell around the hill and the Sungai Kampar as the active model boundaries. The numerical modelling used Visual MODFLOW with finite difference method. A continuous medium is replaced by a discrete set called nodes and various hydrogeological parameter [9]. A three-dimensional represent the site created by the Visual MODFLOW from the input data collected. For this study, the model domain was created as a 676 m by 720 m in x and y directions (Figure 2). The spacing grid node is 5.2 m each for 130 nodes in x and y directions, 5.5 m uniformly. The horizontal wells were created by using Drainage package of MODFLOW. The proposed size for the horizontal wells dimension is 0.2 m diameter and 40 m long. Central collector well having diameter of 4 m. The hydraulic conductivity value of the drain was assumed thousand times higher compared to the aquifer. Refining process of the grid were concentrated at the area to be modelled for RBeF. The proposed design of RBeF illustration is shown in Figure 3. The value of conductances used for the drain design is 309 m²/day.

![Figure 1. Location of Sungai Kampar water treatment plant](image-url)
Table 1. Hydrogeological parameters input value for groundwater modelling

| Parameter                          | Value/Sources         |
|------------------------------------|-----------------------|
| Model layers                       |                       |
| - Borehole Information             | Lembaga Air Perak [1]  |
| - Aquifer Thickness                |                       |
| - Surface Elevation                |                       |
| Hydraulic conductivity (m/s)       |                       |
| Layer 1: Fine Sand                 | Layer 1: kx,ky= 1e-4 , kz= 1e-5 [1] |
| Layer 2: Granite                   | Layer 2: kx,ky,kz = 2.765e-5 |
| Storage                            |                       |
| Layer 1: Fine Sand                 | Layer 1: Ss= 1e-5, Sy= 0.27, Eff. Por.= 0.11 |
| Layer 2: Granite                   | Total Porosity= 0.2    |
|                                    | Layer 2: Ss=3.61e-5, Sy= 0.0009, Eff. Por.=0.4 |
|                                    | Total Porosity=0.455   |
| Model boundaries                   | River, Inactive cell   |
| Conductance                        | 309 m²/day [3]         |
| Recharge Estimation from rainfall data | Rainfall= 2913 mm/year, 10% of Rainfall (LAP 2013) |
| Water Abstraction Lembaga Air Perak | Lembaga Air Perak [1]  |
| Groundwater level From             |                       |
| Monitoring well                    | Lembaga Air Perak [1]  |
| MW1, MW2, MW3, MW4, MW5            |                       |

Figure 2. Model grid area
3. Results and Discussion
The aim of model calibration at steady state condition is to minimize the value of normalized residual mean squared (nRMS) error and maximizing the correlation coefficient (r) between observed and calculated heads. Figure 4 shown the graph of calculated versus observed heads. The value of nRMS in the graph is 14.535 % which is closed to zero while the r value is 0.927. It shows that the calibration between observed head and calculated head were closed for each other.

Lembaga Air Perak (LAP) aim to produce 35MLD more of raw water for future water demand. The simulation results by using RBeF technique shown that water abstraction can fulfill LAP water requirement. Tables 2 and 3 shows the result of water head in collector well and river head at different pumping rate. The interaction between surface water and groundwater shows a good potential in
increasing the pumping rate of the well. The higher the rate of the pumping rate, the higher the water head in the collector well.

| Pumping Rate (MLD) | 10   | 20   | 30   | 35   | 40   |
|-------------------|------|------|------|------|------|
| Ground Level (m)  | 24.22| 24.22| 24.22| 24.22| 24.22|
| Initial Water Level (m) | 24.10 | 24.10 | 24.10 | 24.10 | 24.10 |
| Head (m)          | 16.00| 17.50| 18.50| 19.00| 21.00|
| Top screen (m)    | 14.72| 14.72| 14.72| 14.72| 14.72|
| Bottom screen (m) | 14.62| 14.62| 14.62| 14.62| 14.62|
| Maximum Well Head (m) | 13.69 | 13.69 | 13.69 | 13.69 | 13.69 |

Table 2. Rate of pumping and water level in the collector well

The normal condition (without pumping) of water heads in the aquifer was run in steady state condition (Figure 5). The water head in the aquifer shows consistently high heads along the river. The transient flow of groundwater with different pumping rate (Figure 6) will results in the water head decrease gradually around the radial well. Around the well, water head form circular contour (Figure 7). It shows the dropped of water head at the pumping area. The cross-section view shows the cone depression occur at the collector well and also around the radial well. The interaction between surface water and the aquifer can accommodate additional raw water supply for the Sungai Kampar water treatment plant to meet the increase in population demand.

| Pumping Rate (MLD) | Rate | Well head (m) | River Head (m) | Remarks         |
|--------------------|------|---------------|----------------|-----------------|
| 10                 | 16.00| 23.9          | Balanced water budget |
| 20                 | 17.50| 23.9          | Balanced water budget |
| 30                 | 18.50| 23.9          | Balanced water budget |
| 35                 | 19.50| 23.9          | Balanced water budget |
| 40                 | 21.00| 23.9          | Balanced water budget |

Table 3. River and well head
Figure 5. Steady state condition of water head in the aquifer where, a) plan view with b) and c) cross sections view.
Figure 6. Water head condition after pumping (transient) d) Plan view with e) and f) cross sections views
4. Conclusion
The feasibility study showed that RBeF technique at Sungai Kampar water treatment plant was successfully established by using numerical modelling (Visual MODFLOW). The steady state calibration between observed and calculated head showed good correlation and can be use in the RBeF modelling. The quantity of water produced by the RBeF was determined and the required volume needed by LAP about 35 MLD can be met. The design RBeF of 4 m diameter of collector well with 10.53 m height, and 5 units of 0.2 m of radial well diameter with 40 m length below the riverbed across the river was successfully established.

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