Progress in Engineering Application and Technology Vol. 2 No. 1 (2021) 383-393
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**PEAT**

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN: 2773-5303

# Application of Electrical Resistivity Tomography (ERT) in Designing a Tubewell Dimension, Well Screen and Pumping System of Groundwater in Northern Kelantan

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DOI: https://doi.org/10.30880/peat.2021.02.01.038
Received 13 January 2021; Accepted 01 March 2021; Available online 25 June 2021

**Abstract**: The Electrical Resistivity Tomography (ERT) measurement is used in detecting the thickness and location of the aquifer zone in North of Kelantan. This study aims to design the tubewell that discovers a location of groundwater potential using 2-D images of ERT. It consists of five locations in Northern Kelantan which are in Ketereh, Tanjung Mas, Gunong Bachok, Tok Kenali, and Pasir Tumboh. The design of a submersible pump and well screen has proceeded after knowing the condition of the underneath surface. The usage of the secondary data of ERT by M. Faizal (2016) using RES2DINV in searching the groundwater zone has helped in providing a better quality of tubewell. The suggested tubewell is designed using AutoCAD 2016. The design of the submersible pump is referred by a performance chart from the Grundfos brands namely SP 270-2L G and SP 270-3A G. Then, the well screen is designed based on the calculation of the slot opening area. Thus, the results of the maximum water yield obtained are up from 2988 $m^3$/h to 4356 $m^3$/h. Each of the components in the tubewell is considered based on the geological material, required flow rate, and capability of the pump that discovered using ERT images of 2-D.

**Keywords**: Electrical Resistivity, Groundwater Potential, Tubewell Design

## 1. Introduction

The measurement of resistivity has helped in analyzing the geological structures. The location of the aquifer zone is dissimilar due to the changes in the geological structures. Other than that, it also depends on the condition of climate, type of rock on the surface, vegetative cover, and land use in the study area. The 2-D image profiles obtained from M. Faizal (2016) show the condition of the subsurface. It displayed the subsurface properties for five locations North of Kelantan. The 2-D results produced from different study areas contain various types of geologic materials and thickness. The secondary data of the ERT is presented in Ketereh, Tanjung Mas, Gunong Bachok, Tok Kenali, and Pasir Tumboh.

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This study aimed to design the tubewell including the submersible pump and the well screen at each of the study areas. The results have shown that most of the study area was surrounded by alluvium Quaternary deposits [1][2][3][4][5]. Therefore, it is rich with the potential location for groundwater supply. The recognizing of the geology structure brings the guide for designing the suited tubewell components. It is due to the ERT which provides the required data which can help in maintaining the service of the tubewell. The result obtain for maximum water yields is depends on the pumping from the water head level and the entrance velocity of the water enter. Thus, the submersible pump and well screen for each location vary according to the depth of the aquifer.

## 2. Study Areas and Methodology

The location of the study areas is obtained from the secondary data produced by M. Faizal (2016). The latitude and longitude of the location are given, and the study areas are pinned using Google Earth. Figure 1-3 shows resistivity lines in the study areas where the ERT is applied to discover the groundwater potential. The study area comes across in the northern part of the state of Kelantan. The designed tubewell is for irrigation purposes in Ketereh and Tanjung Mas. Then, the water also is supplied for domestic purposes in the area of Gunong Bachok, Tok Kenali, and Pasir Tumboh.


**Figure 1: Resistivity lines in Ketereh and Tanjung Mas**


**Figure 2: Resistivity lines in Gunong Bachok and Tok Kenali**


**Figure 3: Resistivity lines in Pasir Tumboh**

2.1 Secondary data obtained

After determining the study areas, it is proceeded by identifying the presence of the aquifer layer using the ERT that has been done and gained as in 2-D image profiles. The 2-D images produced by M. Faizal (2016) show the layer of the soil according to the resistivity lines in the study areas. The blue color in the 2-D images is a groundwater-bearing aquifer. Then, it also consists of semi-permeable soil, weathered rock, and unsaturated soil. Figure 4-6 shows the 2-D resistivity results which revealed their types of geologic formation. The aquifer zone is quite wide and deep in the alluvium Quaternary deposits. As in Figure 5 which in Gunong Bachok area has two aquifer zone namely alluvium Quaternary deposits and granitic rock formation.

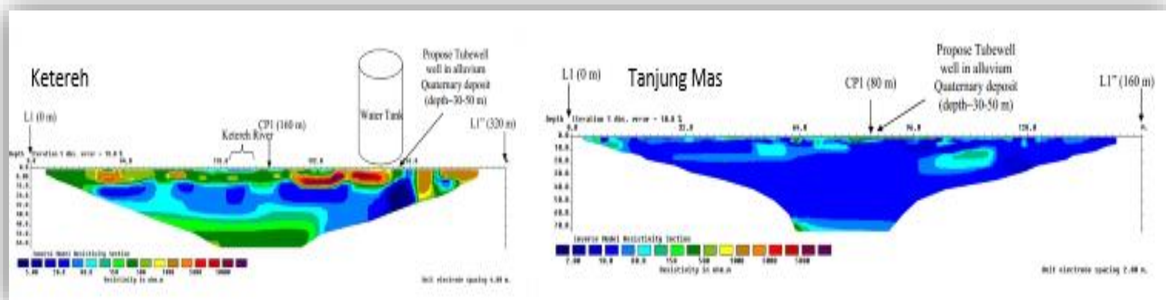


**Figure 4: The 2-D resistivity results in Ketereh and Tanjung Mas**

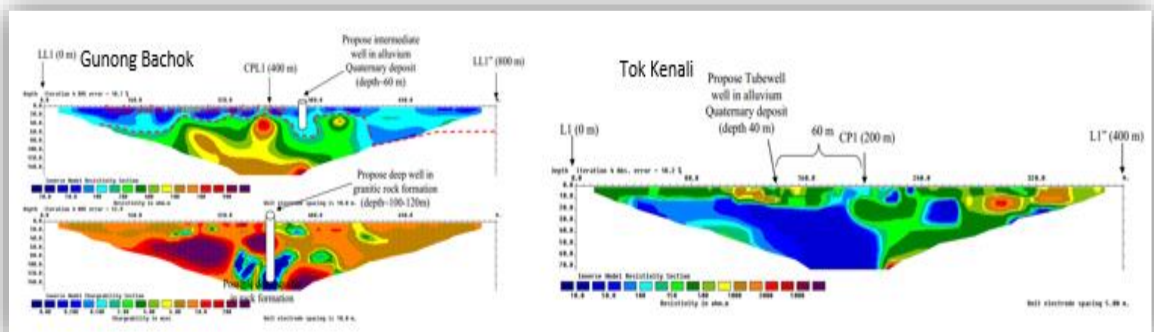


**Figure 5: The 2-D resistivity results in Gunong Bachok and Tok Kenali**

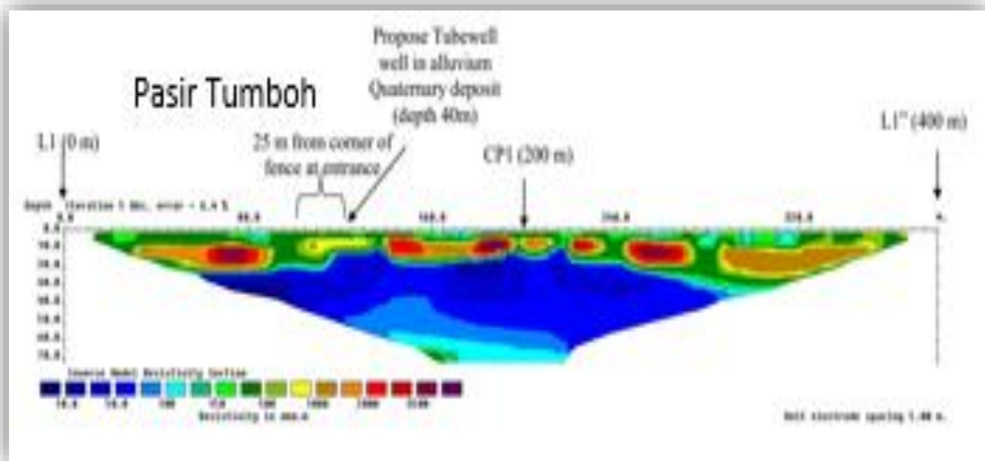


**Figure 6: The 2-D resistivity results in Pasir Tumboh**

The study area is rich with a potential location for the groundwater zone. However, the tubewell is designed at a location that has a thick aquifer zone. Therefore, each of the study areas contains vary the length of the tubewell since the depth of penetration is different. The length for the tubewell in Ketereh is suggested until at a depth of 55 m. Then, the proposed installation of the well screen begins at 30 m to 50 m. Thus, the well screen is placed at depth from 38 m with 12 m length and the setting positioned for a submersible pump is approximately 34 m from the top.

Afterward, the study area in Tanjung Mas shows the aquifer zone started from the top of the surface. The chosen location for the tubewell is at a point that is very deep than the other point. The length for the tubewell is suggested until at a depth of 55 m. It is because the proposed depth for installation of the well screen is 30 m to 50 m. Thus, the well screen is placed at depth starting from 38 m for 12 m length. The submersible pump is put in a depth of about 34 m from the surface.

The 2-D profile for Gunong Bachok consists of two geologic formations which are in alluvium Quaternary deposit and granitic rock. The proposed depth for tubewell in Quaternary deposits is 62 m. The arrangement of the good screen design is put at a depth around 48 m with 12 m length while there is no installation of a well screen in a tubewell at a granitic rock. The submersible pump is inserted at a depth of 44 m. Then, the suggested length for the tubewell in a deep aquifer rock formation is 140 m. It is due to the detection of the aquifer zone between 100 m to 120 m. Therefore, the installation of the submersible pump is planned in a depth of around 98 m.

The high potential location for groundwater zone in the study areas of Tok Kenali is selected. The length of the tubewell is 55 m. It is due to the detection for the location of the aquifer is around 40 m. Therefore, the insertion of the tubewell screen begins at a depth of 40 m with 12 m length. Then, the setting up for the submersible pump is approximately at a depth of 35 m.

The study area in Pasir Tumboh is surrounded by an alluvium Quaternary deposit. It is also revealed that the aquifer zone is about 40 m. Therefore, the length of a tubewell is proposed until a depth of 50 m. Afterward, the well screen is placed approximately 35 m with a length of 12 m. The insertion of a submersible pump is proposed at a depth of 30 m. The condition of geology for each of the study areas is figured out. Hence, the elements used for the tubewell structure are discussed.

## 3. Design Components in Tubewell

The necessary components in a tubewell are a submersible pump and well screen. Each component is designed based on the depth of groundwater level and size of the aquifer materials.

3.1 The submersible pump design

The submersible pump is selected based on the water source, the required amount of pumping flow rate, the capability of the suction head, and the dynamic total head. The suction head for the pump is seen by the ability to lift the capacity of water from the source to the discharge port. Then, the dynamic total head is the total pressure that is supplied by the pump. The location of the submersible pump is placed in the casing pipe on top of the well screen. It is made from stainless steel which protects from corrosion. It is also provided with a non-return valve which prevents from backflow of water when the pump is stopped. One of the differences between the types of submersible pumps used is from their rated head of the pump. It is considered based on the value of the aquifer zone to the groundwater table. According to the 2-D images obtained, most of the groundwater table is began at 2 m. However, the depth of the potential of groundwater discovered for each area is not the same. Therefore, the chosen pump is by their capability of the rated head. Figure 7 shows the drawing of the chosen pump.

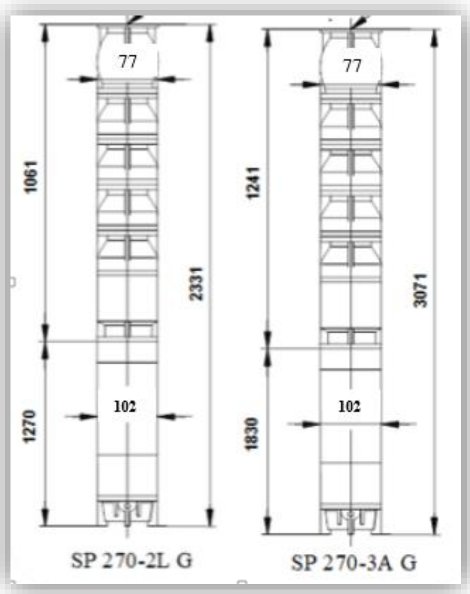


**Figure 7: The drawing of the submersible pump**

3.2 The well screen design

The installation of the well screen is to enable groundwater extraction without any material or sediments into the well and damage the components. The type of screen used is a bridge-slotted screen made from stainless steel. It is a flat sheet with a punched like a bridge and placed in staggering condition. Then, the shape of the slot opening, and the structure of the slot openings is shown in Figure 8. It is a side staggered shape in which the slot holes are covered like a bridge where the water can only enter from both sides. The size of the slot opening is determined by the gravel pack size in annular space and the velocity entrance [6]. The gravel pack is to ensure the size opening for the well screen is constant. Therefore, it is put at a location surround of well screen to avoid any fine sediments enters the screen. The gravel pack is rounded in shape with a size suggested in the range of 6 mm to 8 mm. It is because the Unified Soil Classification System (USCS)(ASTM D24887-11) categorizes it as gravel.

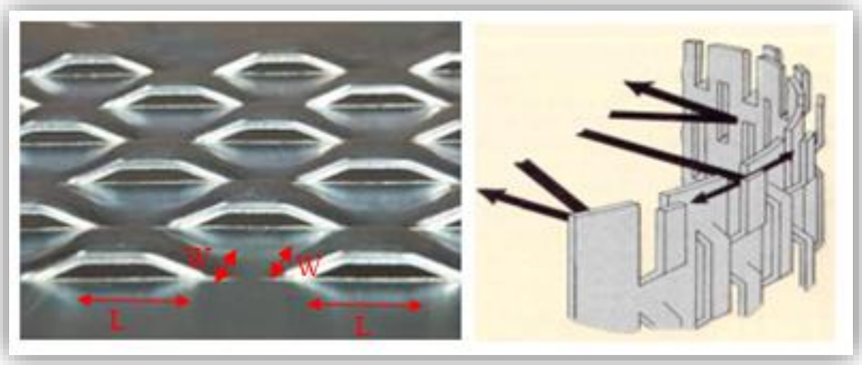


**Figure 8: The structure of the slot openings**

The required value of entrance velocity is calculated based on the American Water Works Association (AWWA) standard which is 0.03 m/s to 0.46 m/s [6]. It is determined using a formula shown as Eq. 1.

$$V = \frac{Q}{\pi D L \eta} \qquad \textit{Eq. 1}$$

Where

V is velocity entrance in-unit m/s
Q is the flow rate in unit $m^3/s$
D is screen diameter in-unit m
L is screen length in unit m
Ƞ is open area ratio in unit percentage

To get the value for the open area ratio, it is calculated using a formula shown in Eq. 2, and Figure 9 shows the defined meaning of the following formula.

$$\text{Open Area}(\%) = \frac{(2\times W\times L)-(0.43xW^2)}{2\times SP\times LP}\times 100 \qquad \textit{Eq. 2}$$

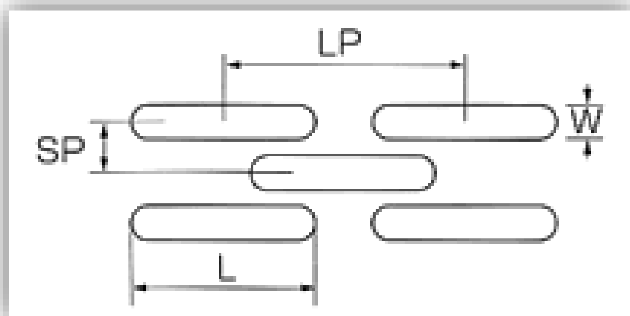


**Figure 9: The defined meaning of slot opening**

The calculation is to proceed to determine the maximum allowable discharge using formula Eq. 3.

$$Q = F\times V \qquad \textit{Eq. 3}$$

Where

Q is the maximum allowable discharge in-unit $m^3/h$
F is the overall screen area in unit $m^2$
V is velocity entrance in-unit m/s

## 4. Results and Discussion

The structure of the tubewell in Ketereh is at a pump house. Figure 10 shows the suggested design for a tubewell including the size of the slot opening for the well screen. The submersible pump used is SP 270-2L G with a pumping flow rate is around 289 $m^3/h$ which the depth of the head is 32 m. the well screen for the tubewell is put with a length of 12 m at a depth of 38 m. This is because the aquifer zone has covered until at a depth between 30 to 50. Then, the open area obtained for the well screen is 11.00 %. The width and length are 3.5 mm and 35 mm. Thus, the entrance velocity produced is 0.10 m/s and the maximum water yield is 2700 $m^3/h$.

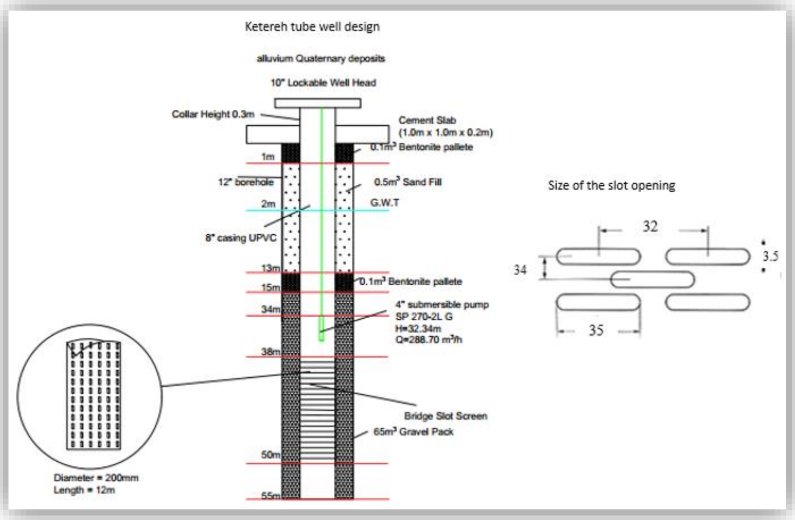


**Figure 10: The suggested design including the size of the slot opening**

The structure of the tubewell in Tanjung Mas is at a pump house. Figure 11 shows the suggested design for a tubewell including the size of the slot opening for the well screen. The submersible pump used is SP 270-2L G with a pumping flow rate is around 289 $m^3/h$ which the depth of the head is 32 m. The proposed depth is in the range of 30 m to 50 m. Thus, the well screen is placed at depth of 38 m from the surface. Then, the open area obtained for the well screen is 10.00 %. The width and length are 3.5 mm and 40 mm. Thus, the entrance velocity produced is 0.11 m/s and the maximum water yield is 2988 $m^3/h$.

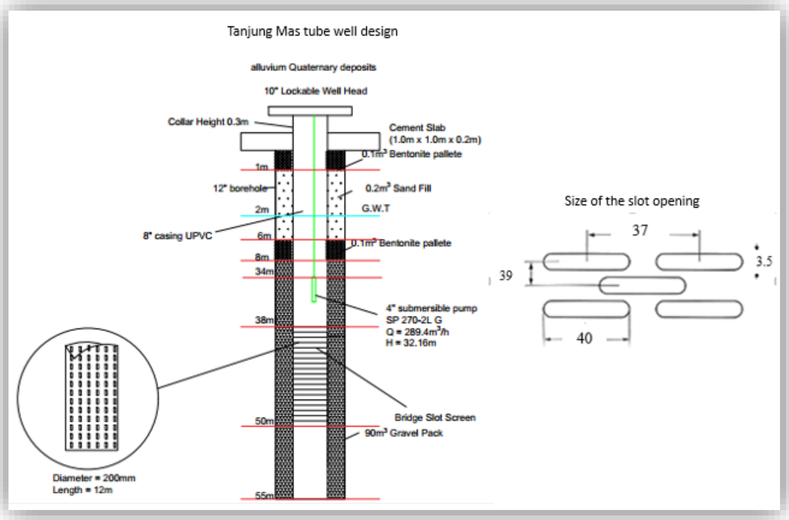


**Figure 11: The suggested design including the size of the slot opening**

The structure of the tubewell in Gunong Bachok is in the paddy field area. Figure 12 shows the suggested design for a tubewell including the size of the slot opening for the well screen. The submersible pump used is SP 270-2L G with a pumping flow rate is approximately 246 $m^3$/h which the depth of the head is around 42 m. The aquifer zone is located at depth of about 60 m where the insertion of the well screen begins from depth 48 m. Then, the open area obtained for the well screen is 7.00 %. The width and length are 3.5 mm and 50 mm. Thus, the entrance velocity produced is 0.13 m/s and the maximum water yield is 3528 $m^3$/h.

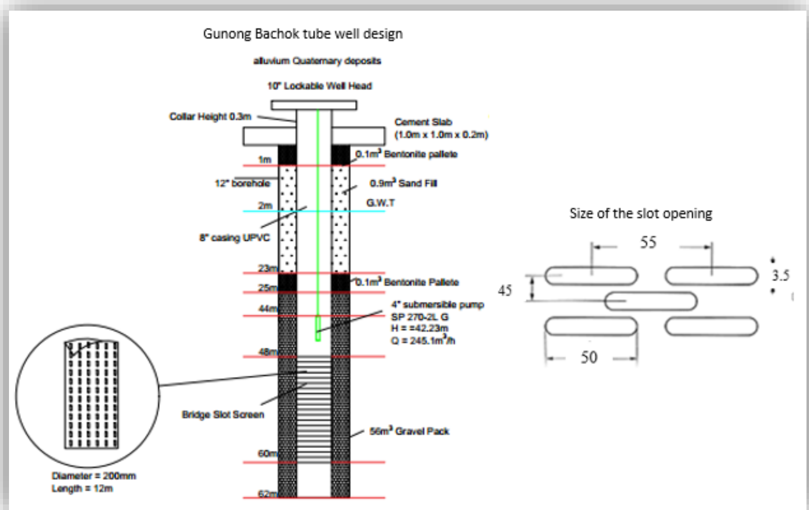


**Figure 12: The suggested design including the size of the slot opening**

The structure of the tubewell in Tok Kenali is at the water plant. Figure 13 shows the suggested design for a tubewell including the size of the slot opening for the well screen. The submersible pump used is SP 270-2L G with a pumping flow rate is approximately 285 $m^3$/h which the depth of the head is around 33 m. The well screen is placed starting from 40 m with 12 m length. This is because the aquifer zone has covered until at a depth around 50 m from the surface. Then, the open area obtained for the well screen is 7.00 %. The width and length are 3.5 mm and 57 mm. Thus, the entrance velocity produced is 0.15 m/s and the maximum water yield is 4068 $m^3$/h.

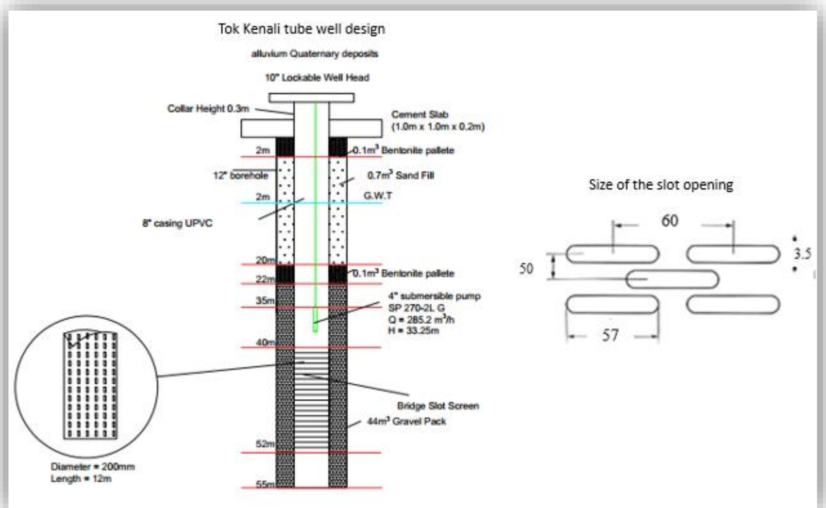


**Figure 13: The suggested design including the size of the slot opening**

The structure of the tubewell in Pasir Tumboh is at the water plant. Figure 14 shows the suggested design for a tubewell including the size of the slot opening for the well screen. The submersible pump used is SP 270-2L G with a pumping flow rate is approximately 303 $m^3/h$ which the depth of the head is around 28 m. The well screen is placed starting from 35 m with 12 m length. This is because the aquifer zone has covered until at a depth around 50 m from the surface. Then, the open area obtained for the well screen is 7.00 %. The width and length are 3.5 mm and 57 mm. Thus, the entrance velocity produced is 0.16 m/s and the maximum water yield is 4356 $m^3/h$.

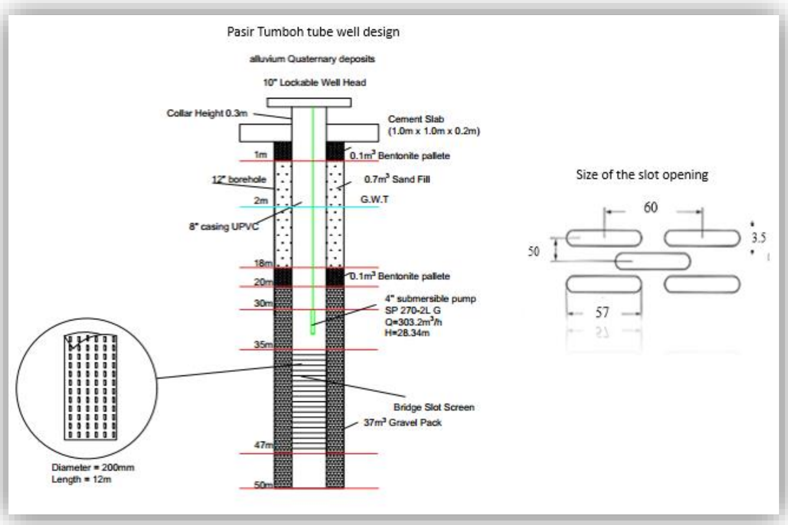


**Figure 14: The suggested design including the size of the slot opening**

4.1 Summary of the design for tubewell dimension, submersible pump, and well screen

The design of the tubewell for each location is different. Therefore, the summary for each of the locations is shown in Table 1-5.

**Table 1: Summary of design in Ketereh**

| Location | Tubewell dimension | | Submersible Pump | | Well | Screen | Max. Water Yield |
|---|---|---|---|---|---|---|---|
| Ketereh | Casing Diameter | 0.2 m | Types | SP 270 -2L G | Screen Diameter | 0.2 m | 2988 m³/h |
| | Casing Length | 55 m | Depth | 34 m | Screen Length | 12 m | |
| | Borehole diameter | 0.3 m | Head | 32 m | Slot Area (mm) | 3.5×40 | |
| | Annular space | 0.1 m | Flow rate | 289 m³/s | Velocity Entrance | 0.11 m/s | |

**Table 2: Summary of design in Tanjung Mas**

| Location | Tubewell dimension | | Submersible Pump | | Well | Screen | Max. Water Yield |
|---|---|---|---|---|---|---|---|
| Tanjung Mas | Casing Diameter | 0.2 m | Types | SP 270 -2L G | Screen Diameter | 0.2 m | 2988 m³/h |
| | Casing Length | 55 m | Depth | 34 m | Screen Length | 12 m | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Borehole diameter | 0.3 m | Head | 32 m | Slot Area (mm) | 3.5×40 | |
| | Annular space | 0.1 m | Flow rate | 289 m³/s | Velocity Entrance | 0.11 m/s | |

**Table 3: Summary of design in Gunong Bachok**

| Location | Tubewell dimension | | Submersible Pump | | Well | Screen | Max. Water Yield |
|---|---|---|---|---|---|---|---|
| Gunong Bachok | Casing Diameter | 0.2 m | Types | SP 270 -2L G | Screen Diameter | 0.2 m | 3528 m³/h |
| | Casing Length | 62 m | Depth | 44 m | Screen Length | 12 m | |
| | Borehole diameter | 0.3 m | Head | 42 m | Slot Area (mm) | 3.5×50 | |
| | Annular space | 0.1 m | Flow rate | 245 m³/s | Velocity Entrance | 0.13 m/s | |

**Table 4: Summary of design in Tok Kenali**

| Location | Tubewell dimension | | Submersible Pump | | Well | Screen | Max. Water Yield |
|---|---|---|---|---|---|---|---|
| Tok Kenali | Casing Diameter | 0.2 m | Types | SP 270 -2L G | Screen Diameter | 0.2 m | 4068 m³/h |
| | Casing Length | 55 m | Depth | 35 m | Screen Length | 12 m | |
| | Borehole diameter | 0.3 m | Head | 33 m | Slot Area (mm) | 3.5×57 | |
| | Annular space | 0.1 m | Flow rate | 285 m³/s | Velocity Entrance | 0.15 m/s | |

**Table 5: Summary of design in Pasir Tumboh**

| Location | Tubewell dimension | | Submersible Pump | | Well | Screen | Max. Water Yield |
|---|---|---|---|---|---|---|---|
| Pasir Tumboh | Casing Diameter | 0.2 m | Types | SP 270 -2L G | Screen Diameter | 0.2 m | 4356 m³/h |
| | Casing Length | 55 m | Depth | 3 m | Screen Length | 12 m | |
| | Borehole diameter | 0.3 m | Head | 28 m | Slot Area (mm) | 3.5×57 | |
| | Annular space | 0.1 m | Flow rate | 303 m³/s | Velocity Entrance | 0.16 m/s | |

## 5. Conclusion

The underground challenges have been encountered with the help of 2-D image profiles produced from ERT. In conclusion, fresh groundwater is successfully extracted based on the location discover from 2-D images of ERT. Then, the submersible pump managed to operate efficiently where it lifts the groundwater to the surface table. It is due to the pumping flow rate which depends on the height of the surface water table and groundwater table. Lastly, the well screen design can yield the maximum quantity of groundwater based on the size of the slot. Therefore, the implementation in developing groundwater must follow with Groundwater Resource Management (GWRM) system so that can obtain a safe and enough water source.

Afterward, the importance of the 2-D image profile in development is important as it can determine the ground subsurface. Thus, it has helped in monitoring the condition and types of geological materials that exist underground. Overall, the design of the tubewell can operate with a reduction in cost and time.

## Acknowledgment

The authors would like to acknowledge the Universiti Tun Hussein Onn Malaysia (UTHM) and the Faculty of Engineering Technology for the opportunity to submit this paper.

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