SITE SELECTION OF WATER RESERVOIR BASED ON WEIGHTED OVERLAY IN ARCGIS (CASE STUDY: BACHOK, KELANTAN)

N. F. A. Rahman [1,*], A.A. H. Awangku [1], V. C. Tai[1,] M. Mohammad[1], S.H. Haron[2], K. Khalid[3], M.Z.A Rasid[4] S. M. Shariff[5],

[1]Centre for Modelling and Simulation, Faculty of Engineering and Built Environment, SEGi University, Kota Damansara
[2]Faculty of Science and Technology, Universiti Kebangsaan Malaysia,UKM Bangi, Selangor, Malaysia
[3]Faculty of Civil Engineering, UiTM Pahang, Pahang
[4]Crop and Soil Science Research Centre, MARDI Serdang, Selangor
[5]Faculty of Engineering and Quantity Surveying, INTI University, Nilai, Malaysia
[*]For correspondence; Tel. + (60) 109295041, E-mail: faizaabdrahman@segi.edu.my

ABSTRACT: *There are many catchment areas in Peninsular Malaysia and eastern Malaysia that can be used as water storage. Population growth has increased the demand for water supply. To ensure a reliable and sustainable water supply for future generations, more reservoirs are be needed. Several areas in Kelantan, namely Bachok, Pasir Mas, Rantau Panjang, and Tanah Merah are expected to face water supply shortages. In this study, ArcGIS is used to identify suitable sites for new reservoirs in Bachok. The main criteria selected for this study are elevation, river, slope, and land use. The weighted Overlay (WO) method is chosen as the decision-making parameter. From the analysis, two new reservoir locations have been identified for State Government consideration. Thus, it can be concluded that the WO method is a useful tool in ArcGIS analysis for site selection of water reservoirs in the study area.*

Keywords: GIS, Malaysia, water reservoir, weighted overlay method

1. INTRODUCTION

The development of cities and population growth has increased the demand for new water reservoirs to meet the rising demand for water supply [1, 2]. Based on a report by Academic of Science Malaysia [3], Malaysia is experiencing seasonal water shortage although the effective rainfall of around 74 BCM should make the water resource four times higher than required. To ensure a reliable and sustainable water supply for future generations, more reservoirs will be needed. Therefore, the selection of suitable sites for water reservoirs is needed to fulfill the demand for water supply.

Malaysia receives a plentiful amount of rain every year. The normal yearly precipitation is 2,400 mm for Peninsular Malaysia, 3,800 mm for Sarawak, and 2,800 mm for Sabah [4]. However, several areas in Kelantan such as Bachok, Pasir Mas, Rantau Panjang, and Tanah Merah are expected to face water supply shortages [5]. This may attribute to uneven precipitation between regions and seasons, causing surface water streams and waterways to vary in water amount and speed. In creating regions where water demand is high, the surface water amid times of dry spell is inadequate to meet the needs. On the other hand during rainstorm seasons, the water supply surpasses the demand. However, due to insufficient capacity of the current stormwater management system has caused flash floods. Due to fast population growth and urbanization may cause deterioration of freshwater quality.

Geographic Information System (GIS) has been proven useful for identifying suitable locations for water reservoirs. For example, site selection of water reservoirs in Batu Pahat, Malaysia [7, 8], dam site selection in Bortala, Northwest China [19], and selection of Glade Reservoir in Colorado, U.S.A [18]. As the determination of suitable sites involves many factors such as precipitation, geological factors, land usage, cost factors, hazards, storage volume, etc. [14, 18, 19, 21], methods for decision making such as Analytic Hierarchy Process (AHP) and Weighted Sum Model (WSM) [6], Weighted Overlay Method (WOM) [7], Weighted Linear Combination (WLC) and Fuzzy Logic [9-11], Machine Learning (ML) methods such as Random Forest (RF), Gradient Boosted Tress (GBT), and Support Vector Machine (SVM) [21], are often employed.

The purpose of this paper is to identify the suitable sites for a new reservoir in Bachok, Kelantan. The remaining of the paper is organized as follows: The criteria for site selection are presented in section 2 alongside the detail of WOM, followed by the results and discussions in section 3. Lastly, section 4 concludes the study.

2. SELECTION CRITERIA AND STUDY AREA

2.1 Selection Criteria

In the present study, only four major factors are considered: 1) elevation, where higher elevation is more favorable; 2) distance from the river by river layer, where river layers nearer to rivers are preferable; 3) slope, where gradual slopes are preferable, and; 4) land use, where lands further away from residential, agricultural, and economic areas are favorable.

Digital elevation model (DEM), river network map, contour map, and land use map have been converted to shapefile (shp) format for use as input datasets in ArcGIS.

Digital Elevation Model (DEM): Definitions of priority in reclassify function for high elevation and low elevation. 10 classes are created from high elevation to low.

Rivers: Were reclassified in distance (near to far) from the other based on the river network map. Distance to river

River, ten classes were created from high to low priorities.

Slopes: Were classified due to its importance of the selection of reservoir. The slope was classified for 2 classes from low to high slope.

Land use: Was extracted from land use map for Kelantan in 2010. It has 9 categories (Residential, Forest, and others). In this study, the swamp forest area is the best place for site selection.

2.2 Study Area

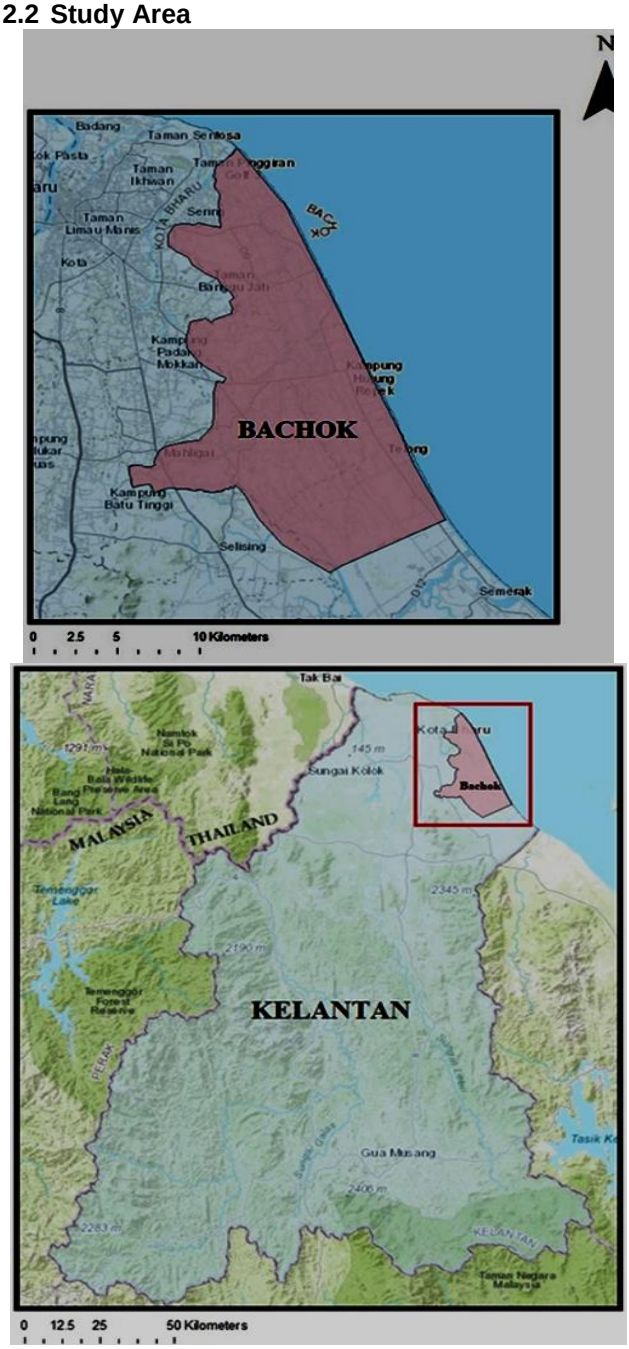

Fig (2) Location map of the study area in Kelantan state.

Bachok is one of the administrative districts in the state of Kelantan, Malaysia (Fig (2). With a total area of 280km^2 and its total population of 141,400 people, the main economy in Bachok is agriculture apart from fishing, business, and working in government and private sectors. Bachok Town is the center of administration, business, and transportation of the district. Other smaller towns are shown on the map below are famous for their wet markets and fair price groceries for the local folks. All data were converted from shapefile into raster format before using it for analysis in ArcGIS. The *Euclidean Distance* was chosen to explain the interconnection of an individual cell and its source or a set of sources using straight-line distance [9, 15]. For this study, *Natural Breaks* classes were used to distinguish related geographical aspects for data classification purposes. The following scales have been used for data classification:

1. DEM. Definitions of priority in reclassify function for high elevation and low elevation. 10 classes are created from high elevation to low.
2. River network map. 10 classes were created from high to low priorities
3. slopes. The slopes were classified into 2 classes, where slopes that are lower than 25 degress are considered moderately sloping, while more than 25 degress are considered highly sloping.
4. Landuse map. Was extracted from the Department of Agriculture Malaysia (DOA) for Kelantan state in 2010. It has 9 categories (Residential, Forest, and others).

3 WO METHOD AND ANALYSIS

WO is a method to solve multi-criteria issues for suitable site determination [16]. In general, the steps for WO are as follows [17]:

1. Evaluation scale 1 to 10, where 1 denotes the least preferable and 10 denotes the most preferable scores.
2. Set scale values. The cell values for each input raster are assigned a scale value.
3. Assign a weight to input raster based on importance. The weights must be total up to 100%.
4. Overlay the maps. The map layer was characterized into 5 sections from low suitable to high suitability by legend. Higher values indicate the respective locations are suitable for siting, result in a susceptibility map as shown in Fig (4).
5. Run the weighted overlay tool in ArcGIS (see Fig (3)), the cell value for each raster is multiplied by the weights.
6. The ideal sites for new reservoirs are the darker blue ones as shown in Fig(5) and Fig(6).

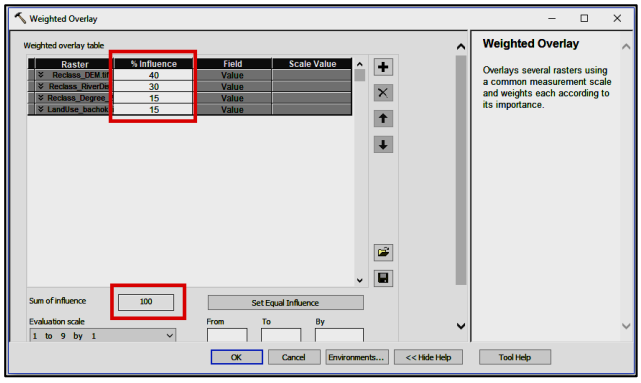

Fig (3) Weight overlay tools

The Euclidean separation yield raster contains the deliberate separation from each cell to the closest source. The distance is estimated straight from one point to the other (Euclidean separation) in the projection units of the raster, for example, feet or meters, and is figured from cell focus to cell focus. This tool can be utilized while making a reasonableness outline, information speaking to the distance from a certain

object is needed. The distances from the river is identified and these types of distance are extremely useful for site selection for the water reservoir. In this study, the swamp forest area is the best place for site selection.

The final suitability results were divided into six discrete categories according to class values 1 to 6, where class 1 is the least suitable and 6 is the most suitable area as shown in Figs (7) and (8). A total of 54 sites have been analyzed. Two candidate sites covering 4% of the total area were identified as the best suitable for a new reservoir. About 15% of the sites were found the least suitable. 48% of the sites were found to be moderately suitable, with a class value of 4.

Four criteria used in this study are not fixed factors, as it can vary from area to area depending on the weather, geology, demography, soil, etc. Therefore, these criteria can be considered for future studies.

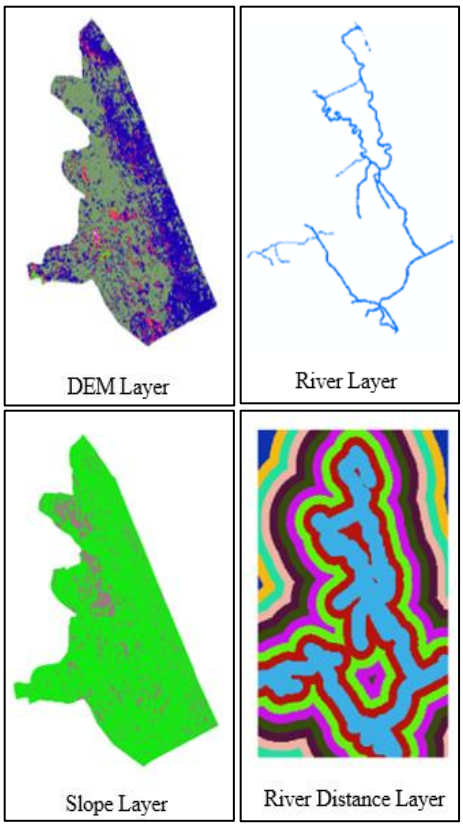

Fig (4) Susceptibility map.

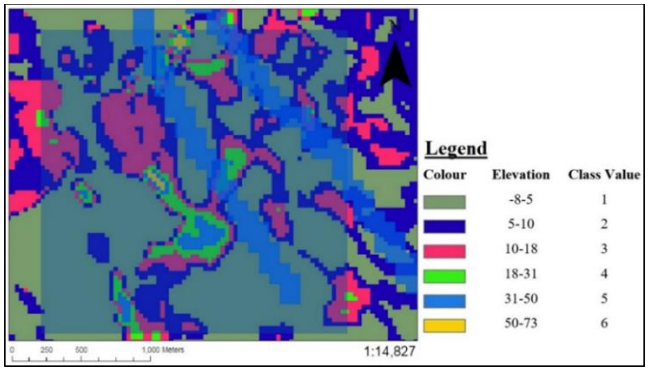

Fig (5). Optimal site selection for the water reservoir

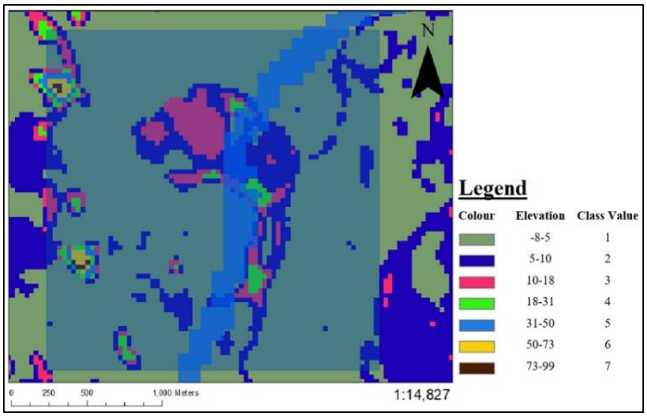

Fig (6) Selection of a suitable site for the reservoir.

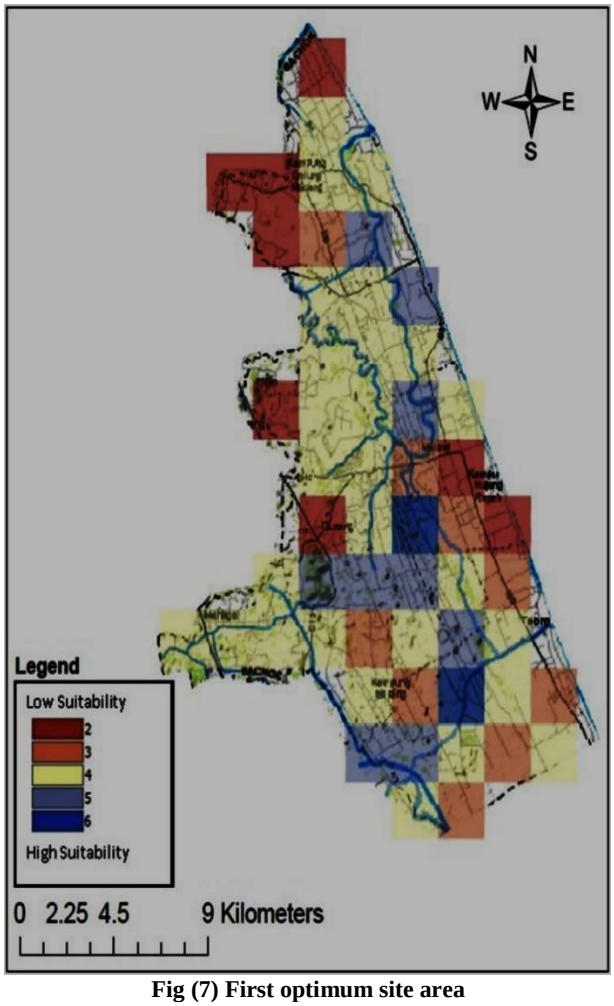

Fig (7) First optimum site area

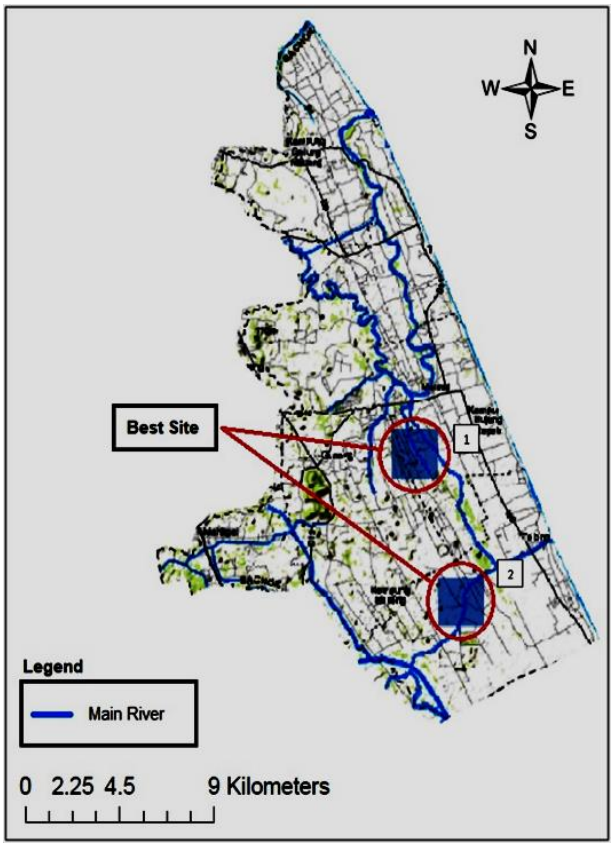

Fig (8) Second optimum site area

4 CONCLUSIONS

In this study, DEM, river network, slope, and landuse maps have been used to identify the suitable site for a new reservoir. The final location of the most suitable sites was determined by WO method.

Two areas were identified as the optimal site for reservoir location. Among the two areas, one site has a high potential chosen as the best place for reservoir due to many criteria being applied for this particular area. Which is the first area (Figure 6), where it has a larger area at high elevation and thus suitable for the gravitational dam. In addition, the proposed sites may help to overcome the water shortage in Kelantan.

With the various functions available in ArcGIS, it has been proven that ArcGIS with WO method is a practical tool to determine the selection of a site for a new reservoir.

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* For correspondence; Tel. + (60) 109295041, E-mail: faizaabdrahman@segi.edu.my