Spatial Multi-Criteria for Wetland Site Restoration: A Case Study in Senibong Johor

YF. Wahab1,2, SM. Taib2, H. Karim3, N. Baslan1

1 Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia Kuala Lumpur, Malaysia
2 School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Johor, Malaysia
3 School of Geoinformatics, Faculty of Built Environment, Universiti Teknologi Malaysia, Johor, Malaysia

*Corresponding author e-mail: yusrinfaiz@gmail.com

Abstract. Selecting sites for wetland can utilize a geographic information system (GIS) to assist in preliminary suitability analysis, in which sets of data can be quantified and aggregated to identify highly suitable wetland sites. Lunchoo River area are polluted at several points leads to the water pollution along the river and affect the source of income for Seletar people where improvement needed to avoid water pollution from becoming worse. This study focused on analyzing the land use along Lunchoo River using GIS analysis and locating the potential area for wetlands. Five sets of data were used in this suitability study, including hydrology, wetlands, soils, vegetation, and land use, all of which are key criteria for identifying suitable wetland sites. Methodology includes the creation of database, finding suitable location for the wetlands in a particular area using GIS analysis and types of wetlands suitable for particular location. Sampling location and non-point sources areas being map together with the results of water quality to show the class of water quality for each sampling station. The results of the site selection of wetland in Senibong Cove were overlay with the land use map to find whether the site selection is suitable for wetland area. Land use map is important to see the pattern around the sampling point which has high or low quality of water.

1. Introduction

Wetlands are transitional areas between land and water. The boundaries between wetlands and uplands or deep water are therefore not always distinct. Wetlands encompasses a broad range of wet environments, including marshes, bogs, swamps, wet meadows, tidal wetlands, floodplains, and ribbon (riparian) wetlands along stream channels [1]. The hydrology of wetlands is generally one of slow flows and either shallow waters or saturated substrates. The slow flows and shallow water depths allow sediments to settle as the water passes through the wetland. The slow flows also provide prolonged contact times between the water and the surfaces within the wetland. Most wetlands support a dense growth of vascular plants adapted to saturated conditions. This vegetation slows the water, creates microenvironments within the water column, and provides attachment sites for the microbial community [2].

Selecting an appropriate location can save significant costs. Site selection should consider land use and access, the availability of the land, site topography, soils, the environmental resources of the site and adjoining land, and possible effects on any neighbours [3]. The site should be located as close to the source of the wastewater as possible, and downgradient if all possible so that water can move through the system by gravity. While a wetland can be fitted to almost any site, construction costs can be prohibitively high if extensive earthmoving or expensive liners are required. A site that is well suited for a constructed wetland is one that is conveniently located to the source of the wastewater, provides adequate space, gently sloping, so that water can flow through the system by gravity, contains soils that can be sufficiently compacted to minimize seepage to groundwater and does not contain threatened or endangered species [4].
GIS is a general-purpose technology for handling geographic data in digital form [5]. The advances of GIS have grown beyond simple data management, storage, and mapping. Today, a more sophisticated means of analysis is being utilized by combining various mathematical and computer-generated models with spatial data within the GIS. Simulation models are useful tools for analysis processes and their interactions, and for development and assessment [6]. GIS used for analysis of buffer zones, which were delineated and classified from digital aerial photos, which allowed the identification of the type, width and continuity of the buffer zone [7]. [8] used GIS techniques to calculate several “distance or proximity” land-use variables to examine land-use effects on fecal coliform densities.

Water Pollution is one of the factors contributing to water crisis. Though the 70% of earth is water many parts of the earth are devoid of water because of water pollution. Thus, there is a serious need of finding a new efficient, practical and economic way of treating polluted water so that it can be used for secondary works. In big cities the waste water coming out of wash basins and kitchen sinks is found to be less dangerous and can be treated with new wetlands technology and can be reused for the secondary purposes like gardening, car washing and so on. Lunchoo river which is located in Senibong where the main river originated from Bukit Lunchoo at the north catchment and it flows passing through Coastal Highway and finally drains into Straits of Johor. The river has undergone deteriorated of water quality due to industrialization within the river. Some prevention action could be made to control the pollution in order to maintain the water quality or to improve it if possible. The potential point source that contributes to the pollution in Lunchoo river need to be mapped to locate where the source of pollutants come from. Previous research by Rafidah in 2010 [9] shown that the Lunchoo river area are polluted at several point sources and this point sources was randomly picked for the sampling station without any study from the land use details. Looking at the land use would be best to locate the suitable sampling point for the next visit. Finding suitable location for the wetlands in a particular area using GIS analysis and types of wetlands suitable for particular location is a good solution. Lunchoo river has been the source of income for Seletar people where they depend too much on this river and an improvement need to be done to avoid this water pollution from becoming worse which will affect fisherman in this area. In Johor, the use of information technology (IT) in GIS is still in the preliminary stages. On the other hand, conventional methods are still widely used, including in the management and administration. River Management Center in Lunchoo River, Johor still used conventional method where there is no digital map being used for this project. This conventional method will retard the sustainable of economic growth and no longer relevant to the current era. Therefore, this study should be done to assist Johor government in finding site selection for new wetland in Lunchoo River thus provide them with the digital map of land use as well. Use of GIS data enables user a cost effective, convenient and appropriate method of detection of wetland site interpreted in terms of raster maps [2]. The aim this study is to analyze the land use along Lunchoo River using GIS analysis. The specific objectives are:

i. To map the point sources pollution for the Lunchoo river in Senibong Cove, Johor Bahru.
ii. To propose a land use map for the Lunchoo River.
iii. To identify the most suitable location for wetland using GIS analysis.

2. Methodology
The aim of this research is to analyze the land use along Lunchoo River using GIS analysis. At the first stage, the problem statement and the scope of the study were identified. Data collection was done by gathering the primary data from the parties concerned. In data analysis, both methods are done separately and at the end both results were combined together to produce the recommended site for new wetland or the suitable site location for wetland in Senibong. Figure 1 below shows the flow chart of overall wetland site selection.
2.1. Mapping Secondary Data

2.1.1. Point Sources Pollution
In this research, the primary focus for point sources was the factories along Lunchoo River which become the most contribute factor to this point sources of water pollutant. Since industrial activities plays an important role in the economic growth within that area, it poses a serious threat to the water quality of Lunchoo River as these factories tends to release industrial discharge, hazardous waste or chemical waste directly to the river. Shahperi in 2010 [9] defines the point sources in Senibong by google earth image as shown in Figure 2.

![Point Sources Areas in Senibong](image)

2.1.2. Level of Pollution
The level of pollution in Lunchoo River is based on river water quality result where all sampling stations and parameters were considered during mapping the point sources pollution location. The highest level of
pollution was at the point W1. This will indicate the status of water quality condition in selected sampling points based on the previous study results done by Shahperi in 2010 as shown in Table 1 below.

### Table 1. River Water Quality Results

| Parameter          | W1  | W2  | W3  | W4  | W5  | W6  | W7  |
|--------------------|-----|-----|-----|-----|-----|-----|-----|
| DO (mg/L)          | 7   | 7.6 | 7   | 7.2 | 7.2 | 7   | 7.4 |
| BOD (mg/L)         | 17  | 13  | 11  | 14  | 5   | 8   | 8   |
| COD (mg/L)         | 70  | 58  | 45  | 54  | 16  | 32  | 32  |
| NH3-N (mg/L)       | 2   | 1   | 0.2 | 0.3 | 0.8 | 0.8 | 1.4 |
| TSS (mg/L)         | 22  | 69  | 42  | 126 | 28  | 28  | 26  |
| pH                 | 7.5 | 6.9 | 7.1 | 6.8 | 6.6 | 6.6 | 6.7 |
| Oil & Grease (mg/L)| <0(HO) |<0(HO)|<0(HO)|<0(HO)|<0(HO)|<0(HO)|<0(HO)|
| E.Coli (MPN/100)   | 6   | 14  | 14  | 40  | >1.6x10^6 | 48  | 35.5x10^6 |

Source: [9]

### 2.1.3. Location of Sampling Station

There were 7 total sampling stations which was chosen for monitoring water quality. Table 2 shows the description of sampling monitoring station.

### Table 2. Description of Water Monitoring Station

| Station | Description                                      | GPS Location               |
|---------|--------------------------------------------------|----------------------------|
| W1      | At the edge of prawn pond that was ruptured      | 01°29.213N, 103°50.161E    |
| W2      | Coastal Highway Bridge/ Lunchoo River             | 01°29.522N, 103°50.066E    |
| W3      | Penaga Road 18. Primechem Factory                 | 01°29.803N, 103°50.447E    |
| W4      | Plot A Housing Development (Beside Lunchoo River)| 01°30.440N, 103°49.893E    |
| W5      | Nearby TNB Pylon Industry Park Sri Plentong       | 01°30.440N, 103°49.839E    |
| W6      | Bandar Baru Permas Jaya                          | 01°30.182N, 103°49.839E    |
| W7      | Taman Perindustrian Permas Jaya (Kilang Super)    | 01°30.173N, 103°49.841E    |

Source: [9]

### 2.2. Land Use Mapping

#### 2.2.1. Developing Database

Database is a medium for storing and managing the spatial data and its attributes. This is important on developing a geographical information system. In general, before getting the results, data collection must be done and store it to make it manageable and organized. The function of developing database is to make sure that the data is not redundant, thus the storage needed can be minimized. In this study, there are three types of database design which are conceptual design, logical design and physical design. The next step in developing land use map is digitizing and updating info in the database. The current land use data was overlay together with google earth image which is 2013 updated data. The features that are not in the land use data then being digitized and inserted into the database. All the new features were included and updated based on google earth image. The data obtained from the government agencies are all in Kertau RSO Malaya Meters projection. Figure 3 below shows the database view in conceptual design of the study.
2.3. Site Selection
Site selection for wetland required some criteria with some stages of data processing. Site selection can be done without GIS, however, the details about the land and soil will be limited. After the process of site selection done and the area meet the specifications needed, the area can be classified as a suitable. If the area does not meet the specifications provided, the slope and elevation data need to be used to know how much the area needed so that the elevation of the chosen area is below 15%.

The criteria to evaluate potential wetland sites is based on the key components of GIS site suitability analyses [10]. Table 3 indicate the wetland site suitability criteria based on previous research.

| Metric Name                     | Score Range                                                                 |
|---------------------------------|-----------------------------------------------------------------------------|
| Proximity to Hydrologic Feature | 1-10, 10 being within 0.16km of hydrologic feature and 1 being 1.6km or farther from feature |
| Hydric Soils at Location        | 1 or 10, 10 being hydric soils present 1 being no hydric soils present.     |
| Vegetation Type at Location     | 1, 5, 8, or 10, 10 being grasslands, vernal pools, meadows, and other herb communities, 8 being riparian, bottomland, bog and marsh habitat, 5 being non-native vegetation, developed areas, or unvegetated habitat, and 1 being all other vegetation types. |
| Land Use at Location            | 1, 5, 8, or 10, 10 being vacant and undeveloped land, 8 being open space park and preserve, 5 being landscape open space, and 1 being all other land uses. |

The data were weighted for wetlands, vegetation types, and land uses based on the need to identify suitable wetland sites. Estuarine and marine wetland or deep water was not included since this study is not intends to identify tidal wetlands. Additionally, vegetation types were weighted based on their known ability to support hydrophytic vegetation, with grasslands, vernal pools, meadows, and other herb communities weighted the highest, vegetated areas weighted the second highest, and area with poor vegetation communities of non-natives, developed, and unvegetated areas weighted the lowest. Land use was weighted based on its potential to become a wetland site, with vacant and undeveloped land weighted the highest as these lands would be the easiest to convert to a potential wetland site, with open space park and preserve the second easiest, and landscape open space the third, while all other land uses within the country being rated the lowest. Table 4 below shows the parameters and the aspect for each parameter. The five parameters including land use, vegetation, water bodies, and soil type.
Table 4. Parameters and Aspect for Each Parameter

| Parameters       | Buffer | Moisture | Vacant – Developed | Type of Cover |
|------------------|--------|----------|--------------------|---------------|
| Land Use         | ×      | ×        | √                  | ×             |
| Vegetation       | ×      | ×        | ×                  | √             |
| Water Bodies     | √      | ×        | ×                  | ×             |
| Soil Type        | ×      | √        | ×                  | ×             |

2.3.1. Assigning Value for Each Parameter
The parameters used in this study are land use, vegetation, water body, and soil type. The values are assigned for all parameters based on the literature review.

2.3.2. Buffering Water Body
The water body needs to be buffer 160m away from all the water bodies including river, swamp, ponds and so on. Figure 5 below shows how the water bodies being buffer while Figure 6 shows the results of the buffer overlay with the land use data. The larger the distance from the water bodies, the lesser the suitability of the site selection for wetland as indicated by [10].

2.3.3. Field Calculator
Field calculator is applied based on each score for each parameter to obtain the general results. The calculation is shown in Equation 1.

2.3.4. Slope Generation
Digital Elevation Model (DEM) data for Johor is obtained from the United States Geological Survey (USGS). DEM data is a digital model which is in 3D representation of a terrain surface. This data is in geospatial file format for storing a raster-based digital elevation model. By having this data, slope for Johor can be created by using Spatial Analyst Tool in ArcGIS. The data then overlay together with study area. Figure 4 shows the slope of the study area and the data is clipped together with the study area to form the image in Figure 5.

The results of the clip data will be used for further processing. The contour interval is assigned as 5m interval which means each line represents 5 vertical feet of change between lines. The standard of the slope for the development must be below 15% according to Environmentally Friendly Drainage Manual (MSMA) and municipal approval (DID, 2012). Figure 6 shows the percent of the slope different while Figure 7 indicates the slope criteria for wetland selection or any development.
2.3.5. Specifications
The specification for any development is to protect and prevent or minimize the damage to the surroundings environment thus to promote the sustainable development. For example, the factory application, how far the distance from main road, water body, and how big the area needed in the land use industry and must be away from the residential area to avoid noise and air pollution. All these things must be considered so that the wetland constructions are parallel with the development.

3. Results and Discussion
The results in this study include the land use mapping, the map of point sources pollution location and the analysis of the site selection or potential area for wetland starting from buffering and assigning the value of the parameters, the ranking of the potential area before the final-result is achieved, and thus shows the final-result of the potential area for wetlands in Senibong area. There are some scenario cases provided to give some situation example about the site selection for wetland.

3.1. Point Sources Areas Mapping

3.1.1. Map of Sampling Location and Point Sources Pollution Areas
Map below shows the sampling monitoring station where it consists of 7 total sampling stations that was chosen randomly for monitoring water quality along Lunchoo River Basin. From the map, some of the location should not be there because the sampling station was randomly chosen without a proper study of the land use details. By having map of sampling location will help user to compare the location and plan the best location for having the monitoring station within this area along Lunchoo River basin. This map also shows the results for river water quality for each sampling station. Figure 8 shows how the sampling point station being map.

Map of the point sources pollution location indicate where the point sources of pollution comes from. The areas of point sources pollution have been revised from the exact location of industrial areas from the current land use data. Point A, B and C in the map below shows that the main areas of the point sources pollution in Lunchoo River Basin. Those in coming pollutants due to its proximity to the main drain that directly discharge to Lunchoo River, it will potentially contaminate the environment. Figure 9 below shows the map of point sources pollution areas in Senibong, Johor Bahru.
3.1.2. Land Use Map

Map of the land use in Senibong, Johor Bahru are as shown below in Figure 10. In order to complete second objective and third objective for this study, first objective map is needed to map the point sources pollution location and to apply for the site selection of wetland. Land use mapping in Senibong is needed since the development in this area is quite fast. This land use map will help Johor Government to plan the next development within the study area and thus provide them with the digital mapping. Land use map is important in this study in order to locate the potential area for wetland or else the permission from the government is needed to build the development within that area. This land use map will define the next sampling location.

Figure 8. Map of Sampling Location

Figure 9. Map of point sources pollution areas

Figure 10. Land Use Map of Senibong
3.1.3. Wetland Site Selection

Based on the parameters used in the study, which were land use, water body and soil type, the general map of the potential area for wetland in Senibong are as shown in Figure 11. The map of the general potential area is not combined with the slope map which only based on 3 parameters.

![General map of potential areas for wetland based on 3 parameters](image1)

**Figure 11.** General map of potential areas for wetland based on 3 parameters

![Site selection for wetland](image2)

**Figure 12.** Site selection for wetland

The final results of the site selection are as shown above in Figure 12 where the multi-criteria scores are the highest for the most suitable location for wetland. The yellow one for the slope needs to get permission from the government for any wetland construction or development because the slope is more than 15% according to MSMA and municipal approval. For the purple area the wetland should not be there where the area is not suitable at all for any wetland construction.
4. Conclusion
The present study is to identify the potential area for wetland in Senibong by using GIS analysis. Selection of suitable site for wetland is based on several factors. It is identified based on theme weightages and suitability score. GIS technology using the analysis of buffering, overlaying, raster calculator, generating slope from DEM data is used to select the suitable site for wetland in Senibong area based on several criteria site selection of the previous research. Based on the criteria for potential area in wetland, it also could be used for development, transportation and any other environmental site selection. Further analysis of these sites reveals that more data is necessary to conclude the most ideal wetland site in Senibong, as feasibility, a critical component of site selection, is not addressed in this study. The additional sets of data stills need to be considered to limits the number of highly suitable sites, including mapped invasive vegetation, digital elevation models to map water flows, climate data, annual precipitation, and proximity to roads and or disturbance. Economic considerations of wetland sites must be considered as well.

5. Acknowledgement
This research is fully funded by the research grant of Universiti Teknologi Malaysia. Grant Number Q.J130000.2522.20H32 and Q.J130000.3051.01M43

6. References
[1] E. A. Hunter, P. A. Raney, P. Gibbs, and D. J. Leopold, “Improving Wetland Mitigation Site Identification Through Community Distribution Modeling and a Patch-Based Ranking Scheme,” 2012.
[2] G. M. Milind, “Site selection and evaluation of constructed wetland site,” vol. 1, no. 1, pp. 222–226, 2014.
[3] J. A. Kuiper, “Modeling the Suitability of Potential Wetland Mitigation Sites with a Geographic Information System,” no. April 2004, 2015.
[4] R. P. Brooks, D. H. Wardrop, and J. A. Bishop, “Assessing Wetland Condition on a Watershed Basis in the Mid-Atlantic Region Using Synoptic Land-Cover Maps ASSESSING WETLAND CONDITION ON A WATERSHED BASIS IN THE MID-ATLANTIC REGION USING SYNOPTIC LAND-COVER MAPS The need for strategic restoration of aquatic ecosystems was strongly for integrated approaches . A more recent report by the NRC ( 2001 ) The objectives of a project conducted by the Penn State Cooperative Wetlands Center ( CWC ) were to develop , evaluate , and integrate a series,” no. May 2014, 2004.
[5] D. C. Mckinney and X. Cai, “Linking GIS and water resources management models : an object-oriented method,” vol. 17, pp. 413–425, 2002.
[6] C. He, “Integration of geographic information systems and simulation model for watershed management,” vol. 18, pp. 809–813, 2003.
[7] H. Schreier and S. Brown, “Scaling issues in watersheds assessments,” vol. 3, pp. 475–489, 2001.
[8] S. Ali et al., “Water quality assessment of Gilgit river , using fecal and total coliform as indicators Department of Environmental Sciences , Karakoram International University , Gilgit- Baltistan ,” no. January, 2014.
[9] R. Shahperi, “Prediction on water quality of point source pollution for Lunchoo River, Johor.” p. 111, 2010.
[10] Z. Liptak, “An Analysis of Wetland Restoration Site Selection for Mitigation Banking in San Diego County,” no. May, 2014.