IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Mapping of utilities risk for sewerage system asset management

To cite this article: Nurshuhada Abd Sukor *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **169** 012085

View the article online for updates and enhancements.

Related content

Mapping of utilities risk for sewerage system asset management

Nurshuhada Abd Sukor[1], Zakri Tarmidi[1], Noordyana Hassan[1], Nurul Hana Adi Maimun[2], Noorsidi Aizuddin Mat Nor[2], Nurul Syakima Mohd Yusoff[2], Nik Norasma, C. Y[3]

[1]Department of Geoinformation, Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia, 81310, Johor Bahru, Malaysia.
[2]Department of Real Estate, Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia, 81310, Johor Bahru, Malaysia.
[3]Department of Agriculture Technology, Faculty of Agriculture, Universiti Putra Malaysia, UPM Serdang,

zakritarmidi@gmail.com

Abstract. Sewerage system provide infrastructure that conveys sewage or surface runoff using sewer network. Sewerage system requires perfect infrastructure to ensure that sewage can be channelled to the sewage treatment plant safely. Meticulous asset management for sewerage system is highly recommended to avoid any risk to assets that deliver sewage. Risk assessment strategy for sewerage asset is basically will evaluate the risk factor that influences the asset to encounter the potential problem. Current risk assessment framework didn't include spatial analysis to show the locations of the assets with risk. This study focused on the production of risk map that aims to analyse potential risk for asset management of sewerage system in Majlis Perbandaran Johor Bahru Tengah (MPJBT) using spatial analysis. The spatial analysis used in this study is slope analysis and asset's analysis focusing on age sewerage assets parameter. Combination of both factors show the risks that require more attention from the sewerage system management. The results show there were 90.8% of the asset have low risk, 8.9% have medium risk and 0.3% asset have high risk. These results can be used by the sewerage assets authority to make better decision in preventions and manage risk that could happen to the sewerage assets.

1. Introduction

Development in Malaysia has increase with help of latest technologies which give positive impact to Malaysian economy [1]. The development of urban area will give impact to environment, including water, air, and plant, which lead to pollution to surrounding environment [1]. The pollution from urban development need to be manage, to reduce threat, especially for water supplies, which need to be used back for population in urban area [2]. One aspect that need to be highly manage is the 'human waste', which need proper management to reduce the impact, especially that related to health [2].

To manage 'human waste', sewerage system has been introduce, which include piping network, pumps, and force mains for the collection of wastewater, or sewage, beside runoff water from the community [3]. Sewerage system encompasses components such as receiving drains, manholes,

pumping stations, storm overflows, and screening chambers of the combined sewer or sanitary sewer. The sewerage system provides sewer's network for industrial and domestic waste, treatment to the water before discharge, and a separated network for storm runoff, before disposal into river [3]. The product from the system will be collected and transported via a network of pipelines and pump stations to a civilization treatment. Sewerage treatment needs utilities or asset manage sewage in a proper order and also responsible for processing sewage. These assets will manage sewage and make it flow into the sewage plant, before being release to water resources. One of the most important assets of managing sewerage system is the public treatment plant, where this treatment plant partially treats sewage and discharging a liquid waste that rich in organic material to the river [4]. Unmanageable sewerage system will increase the risk of public health and environmental problems, especially in urban areas [5]. To help manage sewage in Malaysia, Malaysia's Government has awarded Indah Water Konsortium (IWK), a company owned by Minister of Finance Incorporated, to develop and maintain a modern and efficient sewerage system for all Malaysians [6]. IWK [6] stated that in Malaysia, 38% of public sewage treatment plants in the country are mechanical plants. These plants operate using mechanical equipment that accelerates the sewerage break down. It is hoped that in the long-term, Malaysia's sewerage system will be made more efficient through the standardization of the types of plants used [4].

The sewerage assets were exposed to several risks in line by time so risk assessment is needed in order to reduce the risk that involved. Risk assessment commonly defined as a method for analysing the risk of system failure in a good way that gives benefit for the future. This assessment also can give the priority for resources to reduce risk in a very active way. For the recent years, risk assessment has been used in the technical industries which are suitable for sewerage system that aimed for their planning and operational goals [7]. The scope of the asset for sewerage management has evolved throughout history with changes in socioeconomic conditions and environments. Sewerage infrastructure that well planned and correctly operated can support urban sanitation and related activities [8]. Effective sewerage managements are compatible with maintaining ecosystem integrity. It's also vital for improving the environment through proper drainage and disposal of wastewater [9]. It's also good to prevent floods through a removal of drain water and preserve the received water quality to the household. The recent developments for sewerage managements also can improve the reliability and efficiency of the treatment system to treat sewage in order to meet standards and reduce the land area occupied by the treatments works through natural treatment rates in quick motion under a controlled condition. Example asset for sewerage system is shown by Chan (2015). Assets for sewerage management faces many risks that cannot be anticipated and require a more efficient way to reduce the risk. Risk analysis for asset management of sewerage by using spatial analysis can be the best method to analyse risk assets which can give negative impact to the process in the sewerage system. Some risk that often occurred is because of the age of the pipe, slope failure, pipe erosion, sewer collapse or infiltration [9].

So far, the use of spatial analysis is to determine the potential risk to the asset management of sewerage is still in its infancy and this study will be conducted to determine whether spatial analysis can provide the solution to this problem. It also aims to conserve water to be safe for the environment and the lives of human being. Bradach (2014) show the example of sewerage problem including dirty clogged pipe, including by tree root, waste and dirty water. Henceforth, in an attempt to classify the potential risk for asset of sewerage system, this study aims to examine the use of spatial analysis to analyse potential risk for asset management of sewerage system in Majlis Perbandaran Johor Bahru Tengah (MPJBT) area. MPJBT area is in Johor Bahru District, and beside the Kulai District. Some of the analysis conducted were involve both Districts.

2. Methodology
The data that used in this study consists of spatial data and attribute data. Attribute data served as the data involved to support for spatial data used for assets sewerage system. For this study, data that

involved which include spatial data and attribute data were obtained from the Indah Water Konsortium Sdn Bhd (IWK) which is main sewerage company in Malaysia.

The main spatial data obtained from IWK is asset data of sewerage system witch is the manhole and sewer line. Spatial data layers are also used in the study such as contour data, district boundary, roads, and river. Attribute data in this study is data about sewerage assets such as asset numbers, pipe diameter, year of assets and many others.

The next phase is database design and development. Database design is divided into three main types of design conceptual, logical and physical. Each design has its own way to organize data used in this study. In order to indicate the slope effect for risk of sewerage asset, slope analysis was carried out. Slope analysis is conducted to determine endangered areas with different elevation. This analysis is done as an approach to determine the effect of elevation on the risks for sewerage asset. This analysis will also be classified into several classes to define areas with different elevation and description for each class that has been done.

Slope map has been classified into 5 class to show the risk rating of elevation around study area. Table 1 act as the reference for the slope map classification. The result of slope analysis shown in Figure 1.

Table 1. Risk Rating For Slope.

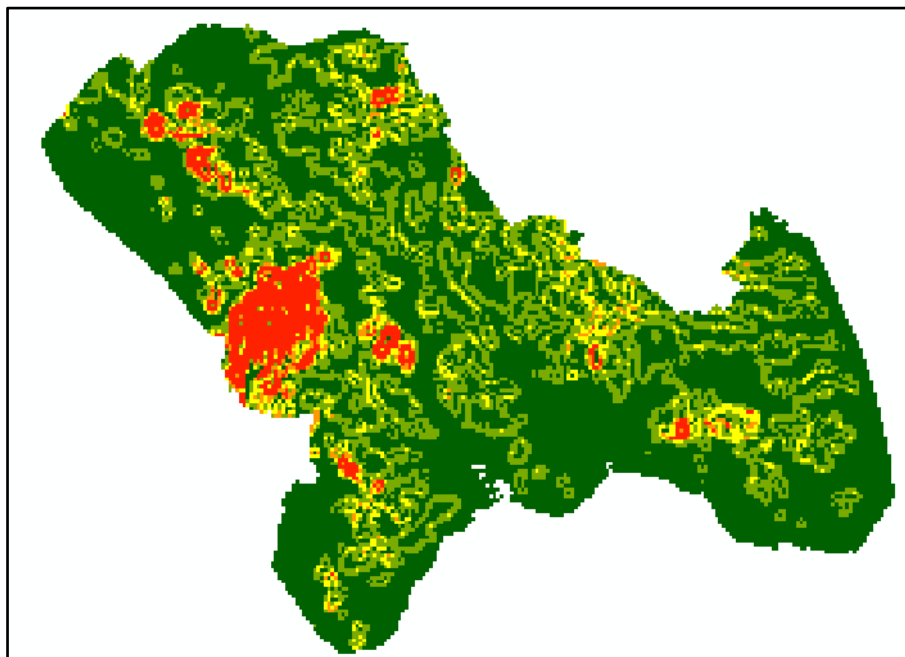| Slope class	Elevation	Description
1	0-1	Very low risk
2	1-2	Low risk
3	2-3	Moderate risk
4	3-4	High Risk
5	4-24	Very high risk

Figure 1. Slope map for Kulai and Johor Bahru District

Probability parameter is factors which were considered to significantly influence the effects generated by asset's failures were identified. The age of asset will be categorized in 4 category as shown in Table 2 in order to show the category of age asset that has potential of high risk.

Table 2. Risk Rating For Age Asset.

Age Category	Asset Year
1	1970 - 1980
2	1981 - 1990
3	1991 - 2006
4	2007 - 2014

The assets was classify into several classes, based on asset's age classification. The assets include the manhole and sewer line. Each age will be organized by the lifespan of the assets or potential assets for failure. Production of risk map for the sewerage system assets has been made with respect to risk rating matrix. Risk rating of this matrix is the computation performed by IWK for determining the risk of an asset value of the sewerage system operated and maintained under IWK care. Information obtained from the slope class and age category will be integrated to produce a risk map.

For the production of this map, the risk assessment will be based on the slope analysis and parameters of assets. After these two factors are assessed, risk map for sewerage asset is created using information from the risk assessment of these two factors. The production of risk map will combine both risk factor by using risk formulation. The matrix of these formulation shown in Table 3. After that, the rating matrix shown in Table 4.

Table 3. Calculation for Risk Rating.

Age Category / Slope Class	1	2	3	4
1	1	2	3	4
2	2	4	6	8
3	3	6	9	12
4	4	8	12	16
5	5	10	15	20

Table 4. Risk Rating Matrix.

No	Risk Category	Description
1	1-6	Low Risk
2	7-12	Medium Risk
3	13-20	High Risk

3. Results and Discussions

For the results and analysis of this study, this section discusses the results obtained through research methodologies that have been carried out. The analysis discussed in this chapter is focused on spatial analysis conducted on data relating to the study of spatial analysis.

By the end of the study produced results, risk maps are intended to identify assets that are at risk of low, medium or high risk. Risk classification of the asset sewerage system is made with reference risk rating matrix by IWK. In accordance with the rapid development of GIS technology, the use of GIS spatial analysis can produce more quality analysis and can be used for the purpose of making a good decision for dealing with risk for asset of sewerage system. Once the data is collected and processed, the data will be analysed and the result will be interpreted. There is 3 analysis has been done in this study. The mentioned analysis for this study is

      1) Probability Parameter (Age Asset)
      2) Slope Analysis
      3) Analysis for risk map

3.1 Probability Parameter (Age Asset)

Each asset has a sewerage system installed each year. Probability parameter is used to measures how likely an asset is to fail. Age for each asset is considered to be one of the factors that significantly affect the risk of sewer system assets. This study uses parameters to classify the age of the assets to the following categories of assets, failure to anticipate the sewerage system in the future. In the year of the assets are divided into 4 categories. Categories for age assets divided by the risk rating referred to the IWK. Each age category of assets is also made to obtain information about the lifespan of each asset. Therefore, the relevant parties can evaluate the assets and make statements about the assets that need to be replaced or repaired in the future.
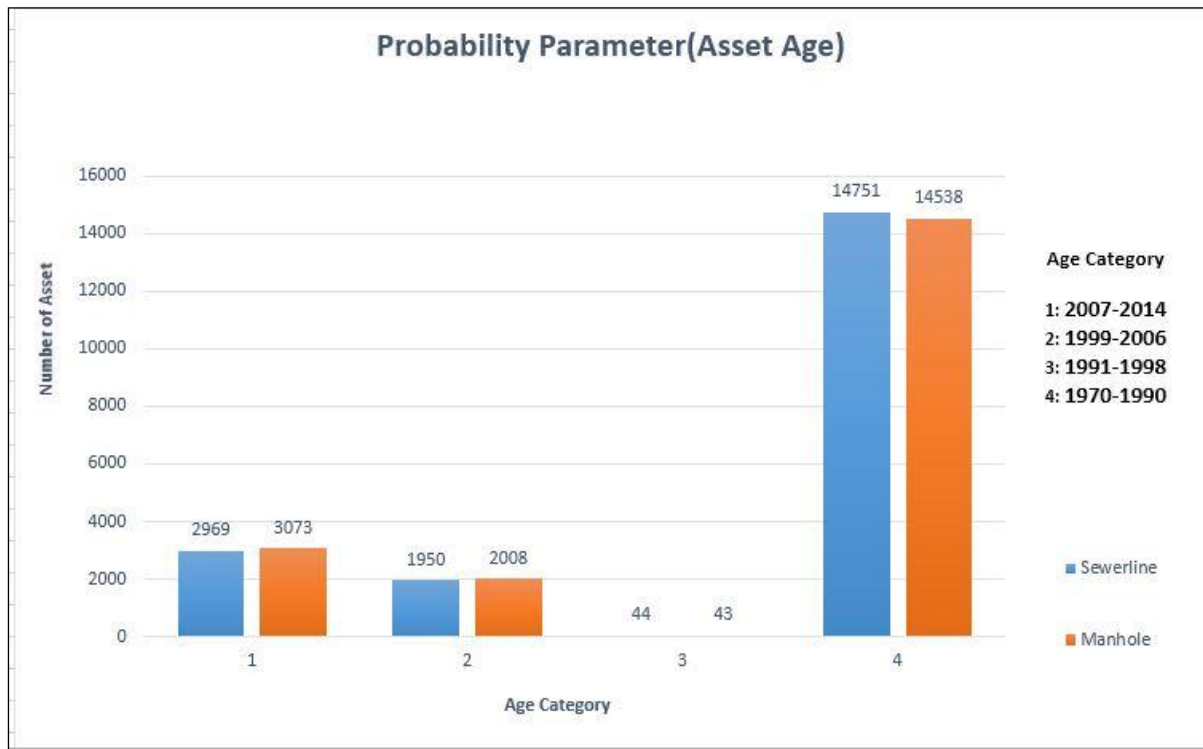

Figure 2. Graph of asset number based on probability parameter

The above graph (Figure 2) shows the number of manhole sewerage system assets and sewer line for each age category of assets. With reference to the graph, the number of higher risk assets can be determined by evaluating the life of each assets. Life expectancy for each asset can also be determined and process improvements can also be done in the future. Assets that have a long life and is mounted on a long time such as 1970 are more likely to get high risk because those assets have long been installed and need to be replaced or repaired to ensure that every item can work properly and smoothly in the future. On the other hand, the newly installed assets and have a short life such as 2014 are still classified as assets that are still in good condition and have a low risk.

3.2 Slope Analysis
Slope analysis was done to identify the steepness of the area which the sewerage assets located. Slope land is one of the important factors for risk assets as assets aunt sewerage system in accordance with a different slope. Risks arising from asset can also cause slope failure by assets such as sewage discharge pipes properly due to an improper slope and the slope is too high for the asset can also cause more potential asset at high-risk assets and cause failure.

Slope analysis was conducted to determine the different elevation of the study area. This analysis also aims to determine which are potentially at high risk or low risk. The slope analysis can be used as

a reference for management in decision making in handling assets and avoid the risk of assets arising from slope failure.
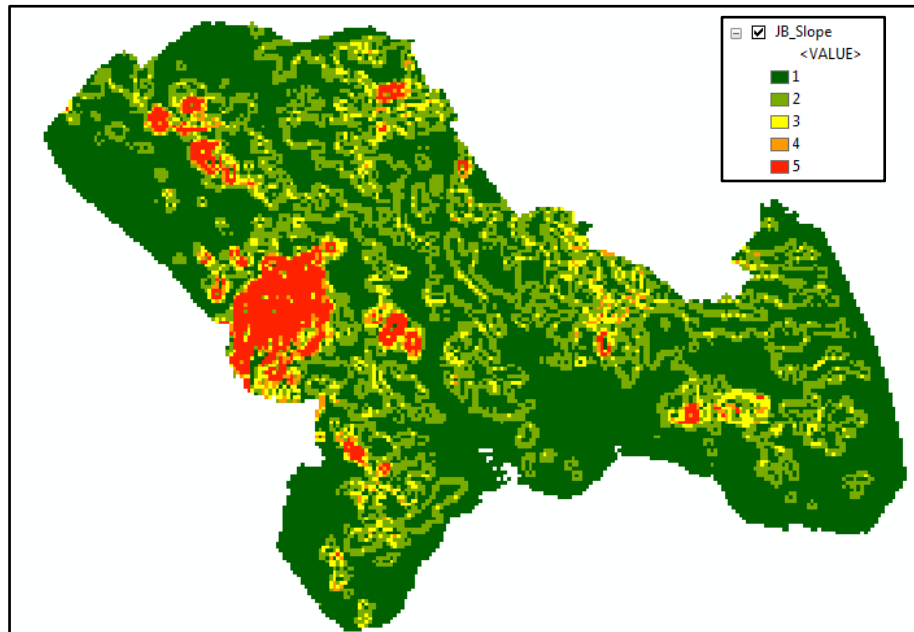

Figure 3. Slope map for study area

By referring to figure 3, the slope that has been generated and has been classified into 5 classes for showing which regions have a higher or lower elevation. Each slope class classification using ArcGIS and natural breaks classification to be used as a way for the slope in Kulai and Johor Bahru. The analysis can be made from slope map that has been produced is the study area has a slightly sloping terrain. Most of the study area has the elevation in slope classes 1 and 2 in which the elevation shows most areas in Johor Bahru and Kulai has low slope range and has less risk to sewerage asset.

Table 5. Percentage of Slope Area (km^2)

Slope class	Elevation (m)	Area of asset (km^2)	Percentage (%)
1	0-1	11105146.75	89.52
2	1-2	978073.48	7.89
3	2-3	286786.14	2.31
4	3-4	31544.21	0.25
5	4-24	3097.21	0.03
	Total	**12404647.79**	**100**

3.3 Analysis of Risk Map

Analysis of the risk map is aim to identify the assets of the sewerage system in accordance with a predetermined risk class. Based on the risk rating matrix which is made in the previous phase, risk assessment was made based on two risk factors which is slope class and age category. After making a risk assessment of these two factors, the risk map for the assets has been made. Risk maps showing assets of sewerage system in the area of MPJBT. This map using large scale which is 1: 30,000. The use of large-scale map intended to indicate clearly each asset class in terms of their risk.
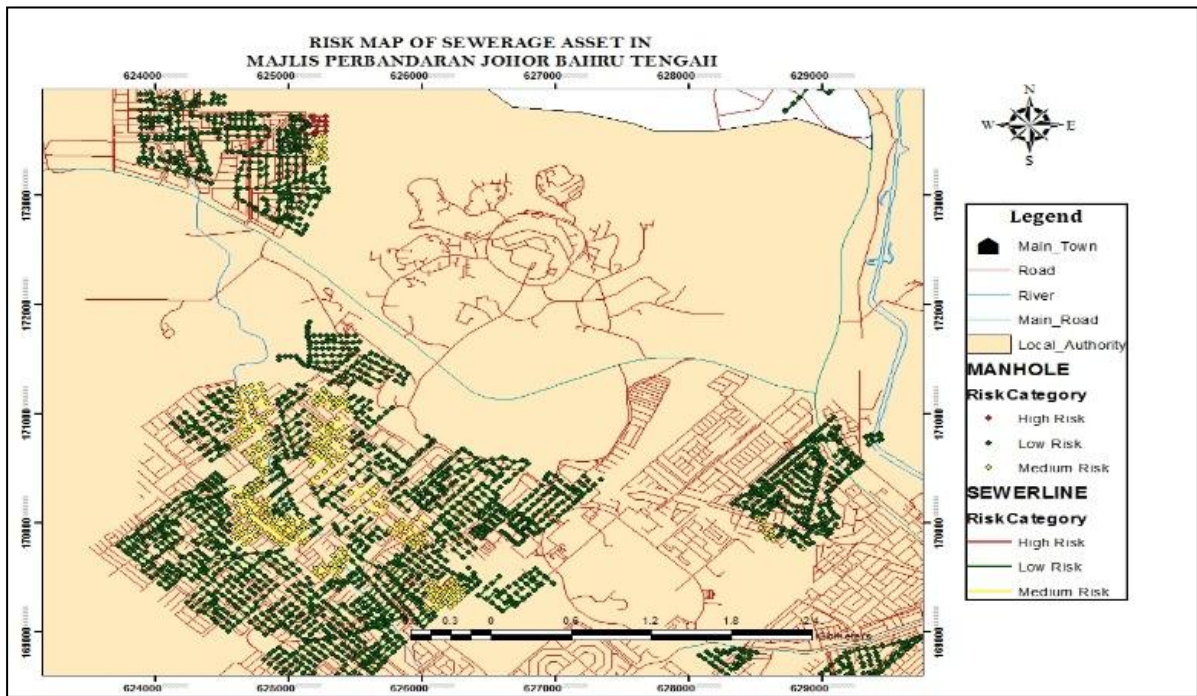
Figure 4. Risk Map for Asset of Sewerage System in MPJBT area.

Figure 4 shows the results of the risk map, with have information on the assets with high, medium and low risk. From the analysis, it's show most of the assets have a lower risk compared to high risk. However, there were some problem and limitation that occurred during this study which affect the risk assessment for asset management of sewerage system. This problem as follows:

1. The selected study area slightly sloping. Sewerage system assets data that provided by IWK is in a sloping area of Johor Bahru and Kulaijaya. Therefore, the final results of the study showed risk maps with no balanced risk class. The majority of the study area have low-risk assets as compared to medium and high-risk assets.
2. Data contour that used is not up-to-date due to budget and time limitations. This problem affect the accuracy of slope analysis which plays as important factor to determine the asset's risks.
3. The parameter that used to determine the asset risk rating is not accurate. Evaluation parameter which is age asset is not accurate to determine the asset risk. Only assumption can be made from this parameter in order to determine the risk rating for asset of sewerage system.

Table 6. Percentage of Number of Asset

No	Risk Rating	Number of Asset	Percent (%)
1	1-6	37094	90.8
2	7-12	3655	8.9
3	13-20	103	0.3
	Total	**40852**	**100**

Table 8 shows the percentage of the final results of this study, showing the percentage of assets sewerage system at high risk, medium or low. The highest percentage is low-risk assets as a percentage of assets is far more than the assets of medium and high-risk. On the other view, high-risk assets also have a percentage that is much less because of the low slope affect risk assets around the

study area. The main factors affecting the risk category also due to the elevation of the study area because of the sewerage system to drain sewage by gravity. Gravity of sewerage system is affected by the slope.

4. Conclusion

This study shows the importance of risk assessment for sewerage assets management. In this study, 2 main factor was analyse, which is slope and age factors of the sewerage assets. The result shows that there were lower risk for sewerage assets in MPJBT area, where it will reduce the cost of managing and monitoring this area. However, several improvement can be made into this study, including adding more risk factors, wider the asset area, and include other utilities assets such as water or electricity in the analysis.

As an overall conclusion, a spatial analysis for risk assessment is important to improve the management of sewerage assets, with control of the assets of the sewerage system can avoid the risk of potentially happen to the assets. Spatial analysis can facilitate the sewerage management to identified the risky assets, and make a proper decision based on their priorities.

References

[1]   Rinkesh 2012 Causes, Effects and Solutions of Air Pollution - Conserve Energy Future *Conserv. Energy Futur.* 2
[2]   Brundtland G H 1987 *Our Common Future: Report of the World Commission on Environment and Development* vol 4
[3]   Encyclopedia Britannica 2016 Britannica Online Encyclopedia *Encycl. Br.* 1–73
[4]   Ward B, Jorgensen J and Rosser S 2011 *Sewerage infrastructure asset management: an approach to encapsulate effective planning, investment optimisation, enhanced data availability and efficient solution specification Conf. Comput. Control Water Ind.*
[5]   Tibbetts J 2005 *Combined sewer systems: Down, dirty, and out of date Environ. Health Perspect.* **113**
[6]   IWK 2017 *Indah Water Portal* | Corporate Profile
[7]   Heiler D *Asset Assessment Using GIS and Infonet*
[8]   Boulos P F *Using Risk-Based GIS Modeling Software to Optimize Sewer Renewal Planning*
[9]   Alexandra A and Neto C 2015 *Asset management of sewerage systems using risk information Contribution to the quantification of failure consequences Civil Engineering*