Water Asset Inventory and Maintenance Using Geographic Information System Application

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Water asset management is a process that involves in planning, developing, distributing, handling, and monitoring water supply system to consumers from time to time. Water supply system is a system that extracts raw water and supply clean water to consumers. Therefore, to supply quality water to users, a study has been conducted. The purpose of this paper is to present the result of a study that have been conducted on some aspects of water asset planning and inventory using Geographic Information System (GIS). The main aim of the study was basically to utilize GIS technology for water asset management with particular focus on the aspect of water asset planning and inventory. The objectives of the study was to review the concept of water asset management, develop GIS database of water asset in the study area, and use GIS functionalities for the planning and inventory of water asset management. GIS application was utilized to produce results. GIS produced complete results that could be used for mapping, modeling, analysis, and query in water asset management. Therefore, water asset can be managed in easy way using GIS application.

Keywords: Water Asset management; Water Asset Database Development; GIS Application

1. Introduction

Water supply system is a system that runs a process for distributing and extracting raw water, treat and store water, and supplying clean water to consumers (Trifunovic, 2006). It is an hydraulic system that can supply fresh water from reservoir to houses through certain asset. As such, it produces facilities for collection, treatment, storage, and distribution of water in certain area. Water asset that involve in water supply include pipe, valves, distribution tanks, pumps, wells, hydrants, treatment facilities, and any other components that make up the system. Every component has its own role in transporting water in this system.

Asset management is defined as an integrative program that enables a utility to minimize the life-cycle costs of owning and operating infrastructure asset while maintaining required service levels and sustaining the infrastructure (Zheng and Xinghua, 2006). On the other hand, water asset planning is a process to plan the

asset of water that involve in supplying water to users starting from reservoir until the water can be received by users in every house. In this process, many parts are involved.

By implementing water asset planning and adaptive management, most utilities will be able to run their operation more dynamic and efficiently. Water asset planning is not only about planning the water asset in efficient way, it indirectly also has to do with the organization and financing or other utility. This element being basic condition for effectiveness and efficiency. Figure 1 showed the overall water assets that involved in water supply system in certain area.

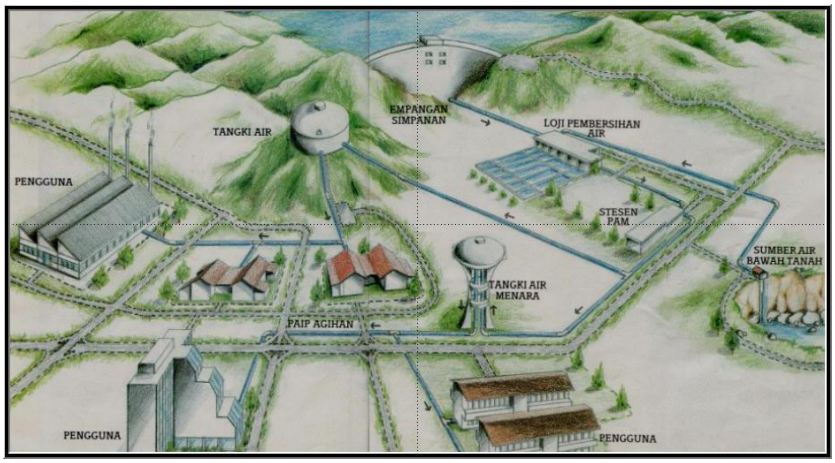

Figure 1. Water asset that involve in water supply system

GIS applications have been used in many fields. It can make decision and perform spatial analysis. In this case, GIS produce complete map that relate to water distribution system of an area. Data are stored in database that can be used to make decision. Query also is done in the database to search for any information that relates to water distribution system. Besides that, analysis can be carried out for example if pipe leakage happened. Modeling for future development also can be applied for example to locate new water distribution tank if the existing water distribution tank cannot support new development.

The purpose of this paper is to present the result of a study that have been conducted on some aspects of water asset inventory and maintenance using Geographic Information System (GIS). The main aim of the study was basically to utilize GIS technology for water asset management with particular focus on the aspect of water asset planning and inventory. The objectives of the study were to review the concept of water asset management, develop GIS database of water asset in the study area, and use GIS functionalities for the inventory and maintenance of water asset management.

2. Methodology

Methodology is a complete set of planning that need to be followed to achieve the objectives of the study. In this study, several methodology have been applied due to achieve the objectives have been decided.

2.1 *Study Area*

The study area chosen for this project is new residential area, Setia Eco Garden, located in District Johor Bahru and Mukim Pulai. This area is under the control of Majlis Perbandaran Johor Bahru Tengah (MPJBT). It cover a part of 7 363.70 hectares, which mean only 13.13 percent of MPJBT area and only 4.05 percent of Johor Bahru. Residential area that has been chosen was Setia Eco Garden at Ulu Choh – Gelang Patah. It is a new development area that was developed by Kesas Kenangan Sdn Bhd and still not has population for this moment. Figure 2 showed the study area that has been chosen.

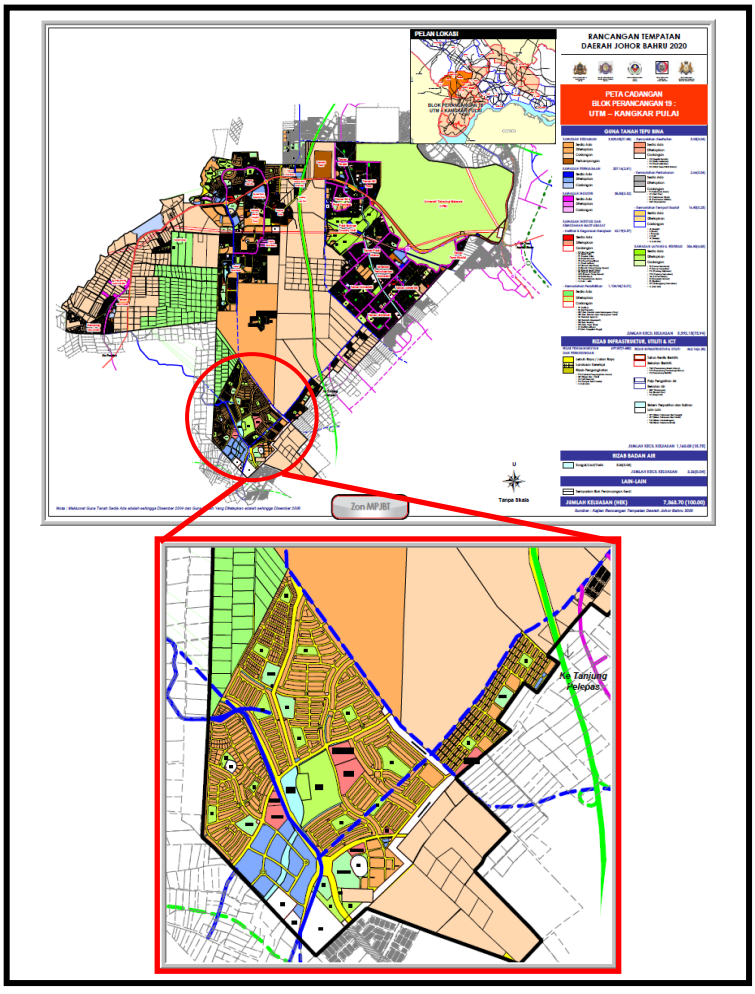

Figure 2. Study area of this project

2.2 *Water Asset Management*

The management of a water distribution system is becoming more sophisticated because the management is demanding that the operating departments not only keep the system in good repair, but do the others demand in an optimal manner. Asset Management is process of evaluating the physical assets of a utility with the goal of providing safe reliable service over the assets useful life in the most economical manner, (Richard and Cornell, 2005). Meanwhile, water asset management is a process that involves in planning, developing, distributing, handling, and maintaining water supply system to consumers from time to time. It can be classified into several types, for example water resources management, wastewater management, water treatment management, water supply management. Each categories has own asset so that the water management can be run smoothly. Water asset management is a management that focuses on water asset facilities. The focus is on the strategic aspects of developing field, providing utilities on infrastructure planning and maintenance for water assets. An effective management is one of important method so that the water supply system can work efficiently. According to Trifunovic (2006), management of water supply system is a system that treat, store, and supply water to consumers.

In this study, the focus was on how the water assets were maintained in a certain area that related to the activity occurred. This is important to make sure all the assets activity are under control of the authority and can be used for a long time. As such known the number of valve, meter, water distribution tank and hydrant in an area. Modeling of an area also can be done for prediction if any cases happen suddenly and for future development.

2.3 *Development of Database*

Development of database involves two stages which is data entry and data processing. In this stage, all data were collected, manipulated, processed, and entered into a database that had been designed. Then, data were processed to produce useful information to users. In this study, layout of water asset in study area was obtained from Syarikat Air Johor (SAJH). Unfortunately, the layout that had been given in hardcopy form. Therefore, it needed to convert the layout information into digital form by digitizing process using ArcGIS 9.3 software. Before digitizing processed was started, the layout needed to register into coordinate system using ArcGIS 9.3. Geodatic Datum Transformation System software (GDTS 4.01) was used to convert coordinate points from Certificate Plan from Cassini Old to Rectified Skew Orthomorphic (RSO) Geocentric. RSO Geocentric coordinate system was used in this project because in engineering field, coordinate system that usually used in RSO format. Since this project quite related to engineering field, RSO Geocentric coordinate system was used. Handheld GPS has been used to collect the contour point at the study area. The contour points were needed to generate elevation around study area so that the terrain could be visualized.

Development of water asset database was built before digitizing process. Data that involved in this project was water asset data included fitting, hydrant, meter, pipeline, water tank, and valve. The others data that involved were land use data, lot data, and road network data. Figure 3 showed all the data were stored in Study_Area geodatabase.

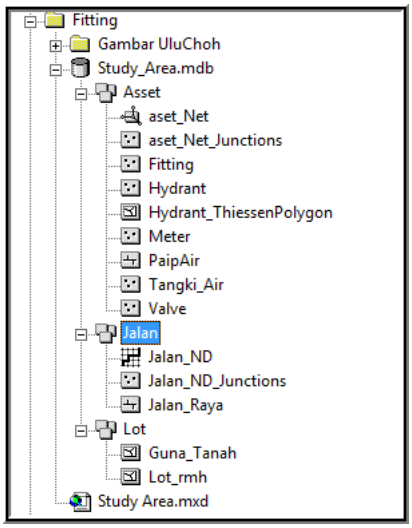

Figure 3. Structure of data in Study_Area Geodatabase

The usage of domain and subtype was applied in the database. Attribute domains are rules that describe the legal values of a field type, providing a method for enforcing data integrity. Attribute domains are used to constrain the values allowed in any particular attribute for a table or feature class. Subtype is a subset of items detailed in a feature class or objects in the table that share the same attributes. It is used in a method to classify data. Subtype allows:

a) Increase the performance of the geodatabase by representing a variety of real-world objects as a subset of features in a given feature class instead of creating new feature classes for each object.
b) Set a default value which will automatically apply when creating new features.
c) Apply coded or ranged domains to features enabling you to constrain input information to a valid set of values.
d) Create connectivity rules between other subtypes and feature classes to maintain the integrity of a network.
e) Create topology rules between other subtypes and feature classes residing in a topology.
f) Develop relationship rules between other subtypes, tables, and feature classes.
g) Create customized rules between features using written code.

Figure 4 showed the development of domain and subtype of study area database using ArcCatalog and some result after completing development of database.

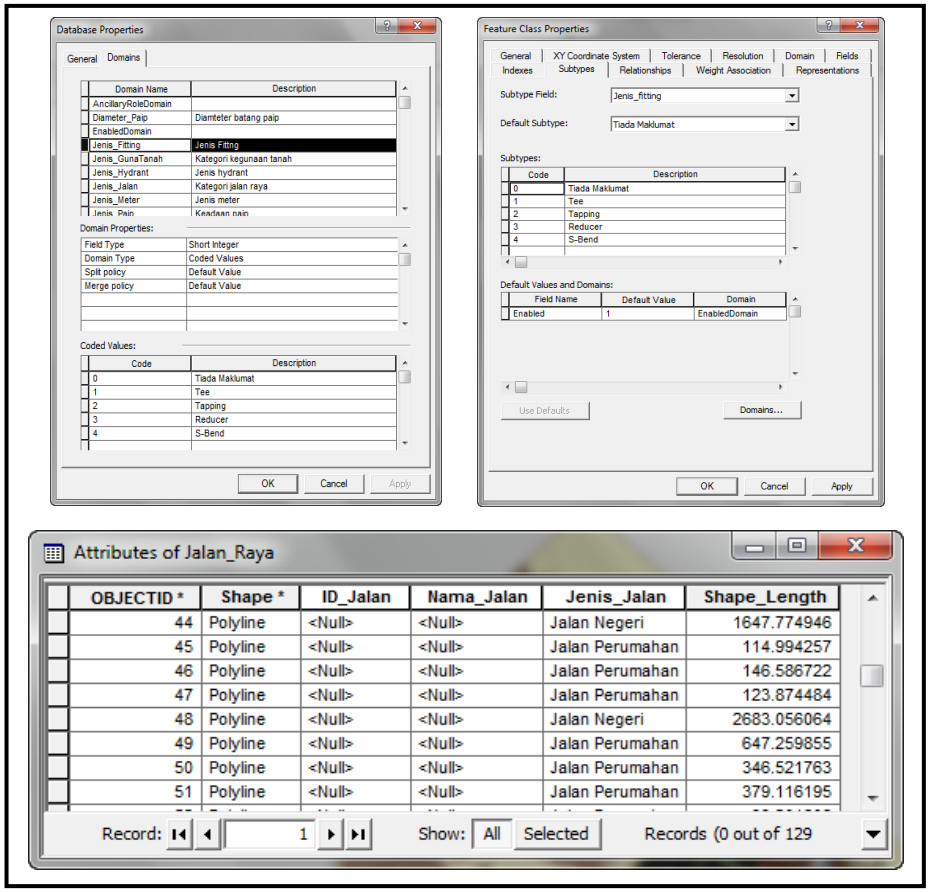

Figure 4. Creation of domain and subtype in ArcCatalog

3. Results and Analysis

After all data were stored in a database, it produced result that was planned. A complete map was produced to show the water asset network in the study area like showed in figure 5. All element of map might be included in the map like title and legend that will explained about the map.

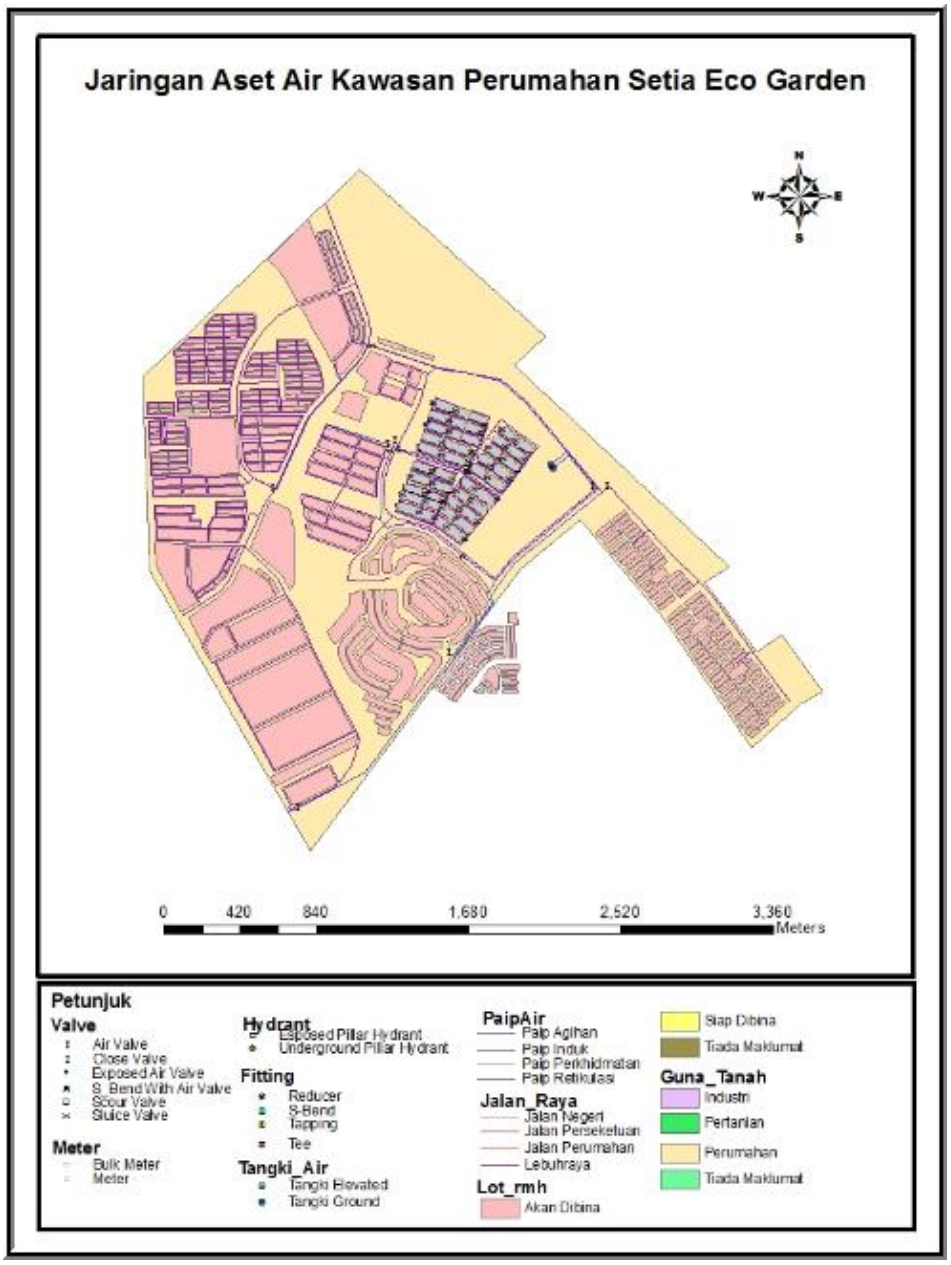

Figure 5. Map show water network in a study area

3.1 *Water Asset Inventory*

Inventory is defined as a complete list of equipment that stored or owned by someone. Inventory also known as resources that keep for current and future usage. For water asset inventory, it stored complete information about water asset in certain area for the current and future usage. In this project, all water assets have their characteristic like type, material and size. All these information have stored in database and can be shown in three forms such as database, map, and picture. To visualize real picture of water asset of the ground, it can be displayed in ArcGIS software. The real picture could be attached with the data by using HTML Popup window. Furthermore, it will show the real environment of the water asset on the ground. Figure 6(a), 6(b), 6(c), and 6(d) showed the information about water asset in study area and can be used for water asset inventory in the area.

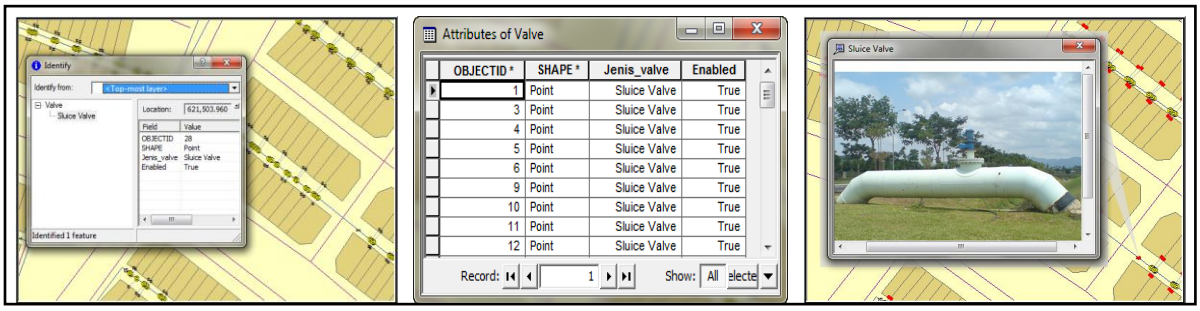

Figure 6(a). Valve

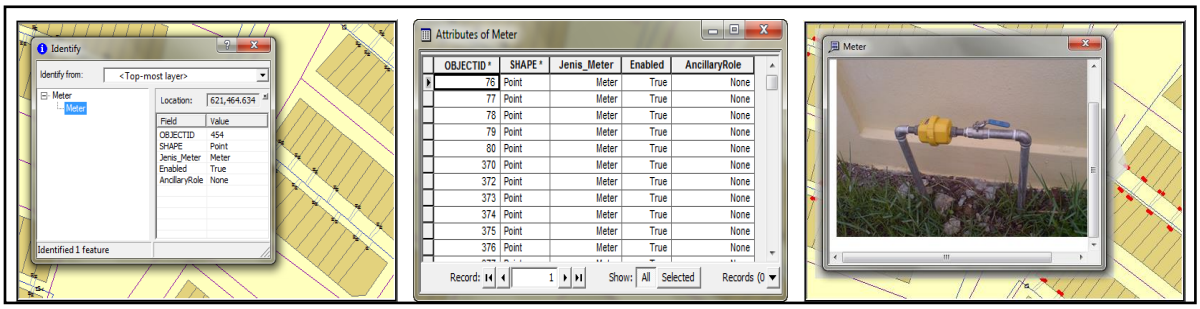

Figure 6(b). Meter

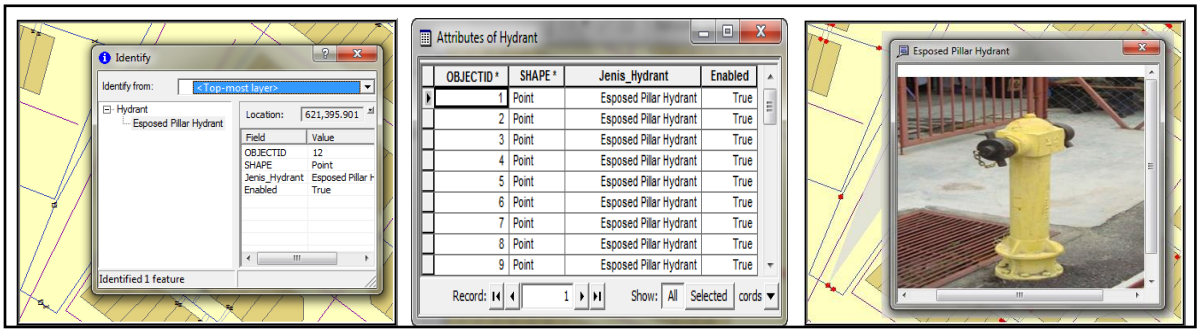

Figure 6(c). Hydrant

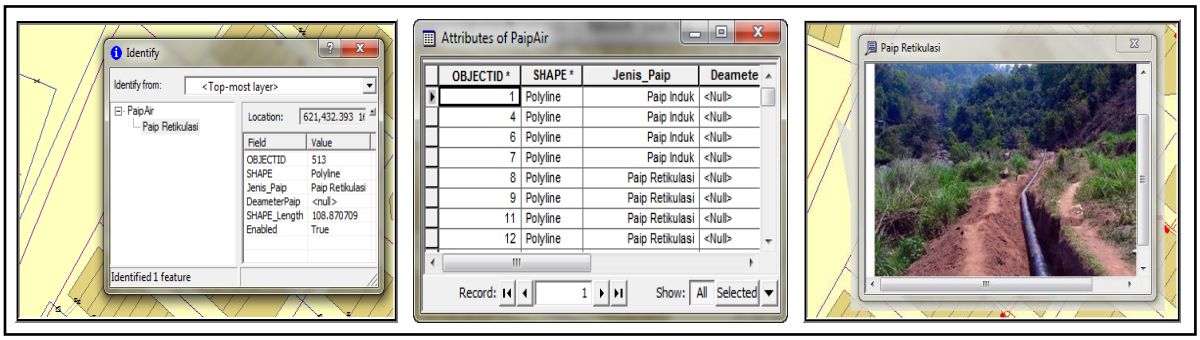

Figure 6(d). Pipeline

3.2 *Water Asset Maintenance*

Direction of water flow also can be done in this project. Figure 7 showed direction of water flow in water network in study area. Water flowed started from water distribution tank that was declared as source and flowed until meter houses that was declared as sink. This application used Utility Network Analyst Extension in ArcGIS software.

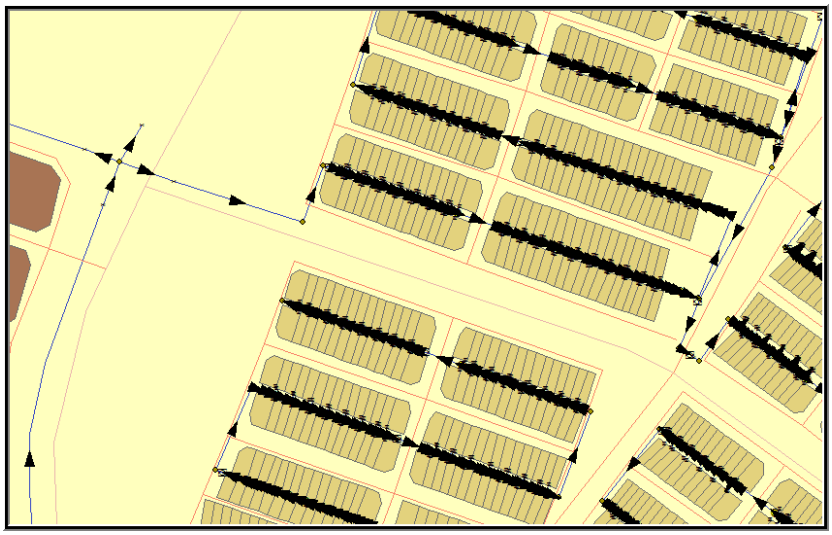

Figure 7. Direction flow of water in water network

Tracing application also has been done using Utility Network Analyst Extension in this software. This application was done to know the affected area when any pipe leakage happened in certain area. Figure 8(a) showed the valve need to close to stop the flow of water flow into the affected area and figure 8(b) showed the affected houses. The number of houses will affected could be counted by using query analyst in this software.

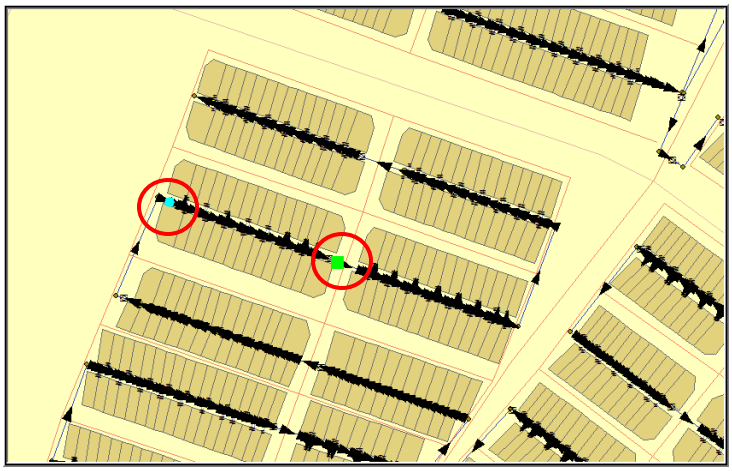

Figure 8(a). Flag (green) showed pipe leakage and valve (blue) need to close

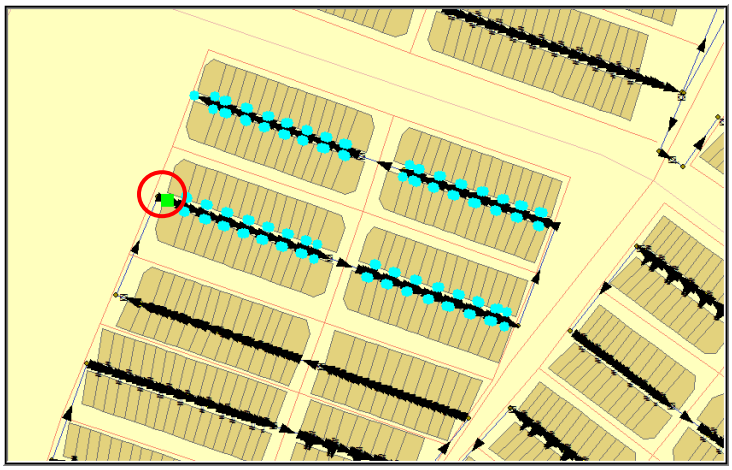

Figure 8(b). Flag (green) showed valve has been closed and meters (blue) affected

Then, query also was done to show the information of the affected houses. Attribute table was opened to show the detail of information of the affected houses. Figure 9 showed the information and the number of houses that affected with pipe leakage.

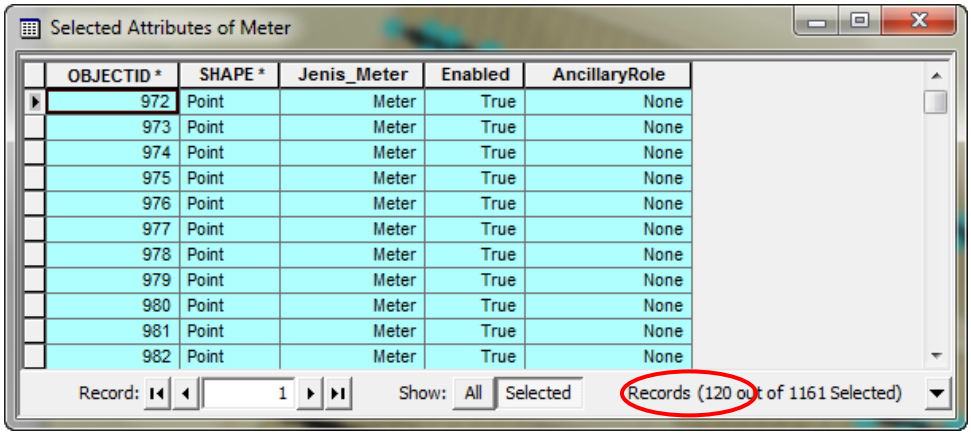

Figure 9. Show information and number of affected houses in certain area

Then, water lorry tank might be used to supply water at the affected area. When the lorry park one location, so the residents need to move to the lorry to get water. To show the nearest road that could be passed by residents, Network Analyst Extension in ArcGIS software has been used. New closest facility was used to show the nearest way. The water lorry tank was declared as facilities and houses were declared as incidents. The nearest road would showed when solve button in Network Analyst was click. Figure 10 showed the time or distance in meter when passed suggested road.

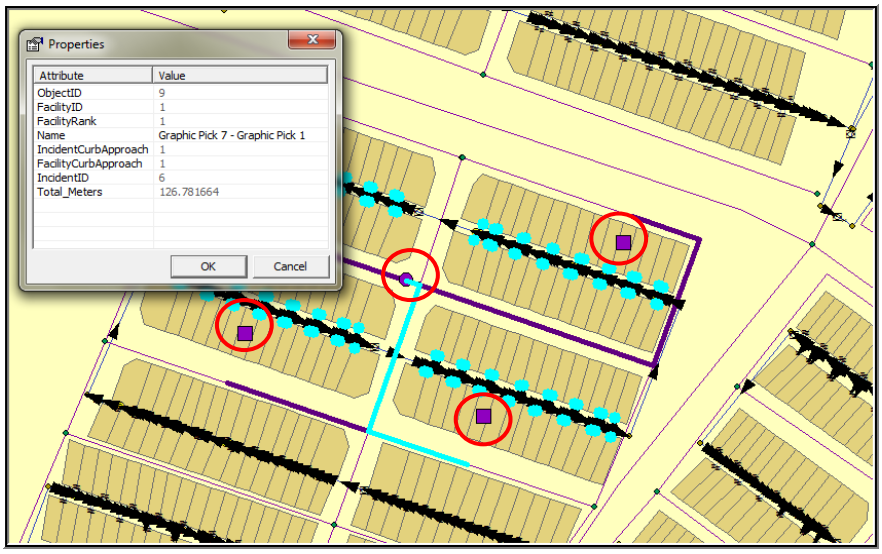

Figure 10. Circle point (purple) showed as water lorry tank and squares points (purple) showed as residents want to get the water.

Thiessen polygons define the individual regions of influence around each of a set of points such that any location within particular polygon is nearer to that polygon's point than to any other point, and therefore, have the same value,

(Heywood et al. 1998). It is relatively simple procedure that requires point coverage for input and is executed using the ArcGIS toolbox command. In this study, modeling of fire hydrant was carried out. Figure 11 showed the Thiessen polygon tool was used to generate the nearest hydrant should be found in a polygon if any fire happened in certain area.

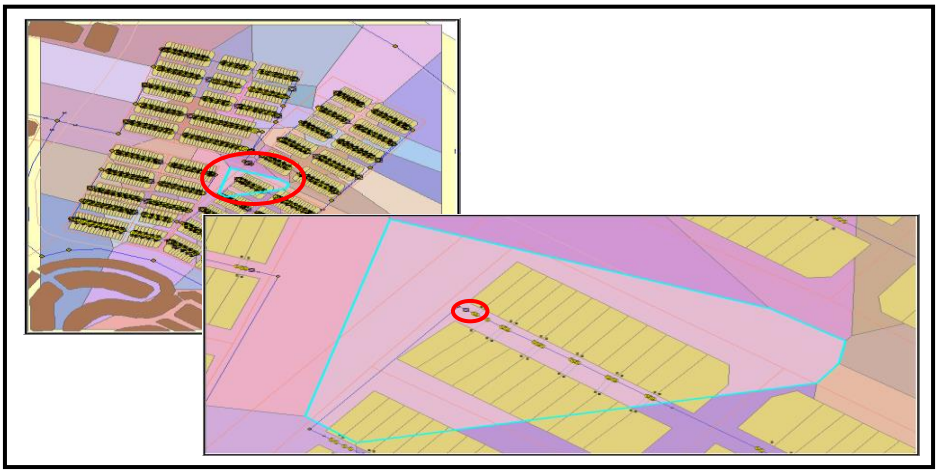

Figure 11. Generating theissen polygon in study area

Elevation of a geographic location is height above a fixed reference point and often the mean sea level (MSL). Elevation also known as geometric height is used when referring to points on the earth surface, while height is used for points above the surface. Chosen of water asset location is very important especially for water distribution tank. Characteristic needed for water distribution tank is must be built in higher area than the distribution area. Swamee and Sharma (2008) said that water resources for example water reservoir or water tank is positioned higher than in the water supply system. This is because to ensure that water pressure is high and can supply water to distribution area. Therefore, analysis on elevation of the study area has been done to know the terrain.

Figure 12 showed the terrain of the study area when generating using contour points that were collected. The elevation of the study area could be used to analyst either the location of water distribution that was built in correct location. In ArcGIS software, Profile Graph showed the elevation of earth surface in the study area. Three location have been chosen to show the elevation of the study are. From that, its showed that the location of water distribution tank was built at the higher area then residential area. Therefore, the water distribution tank was built at the correct location.

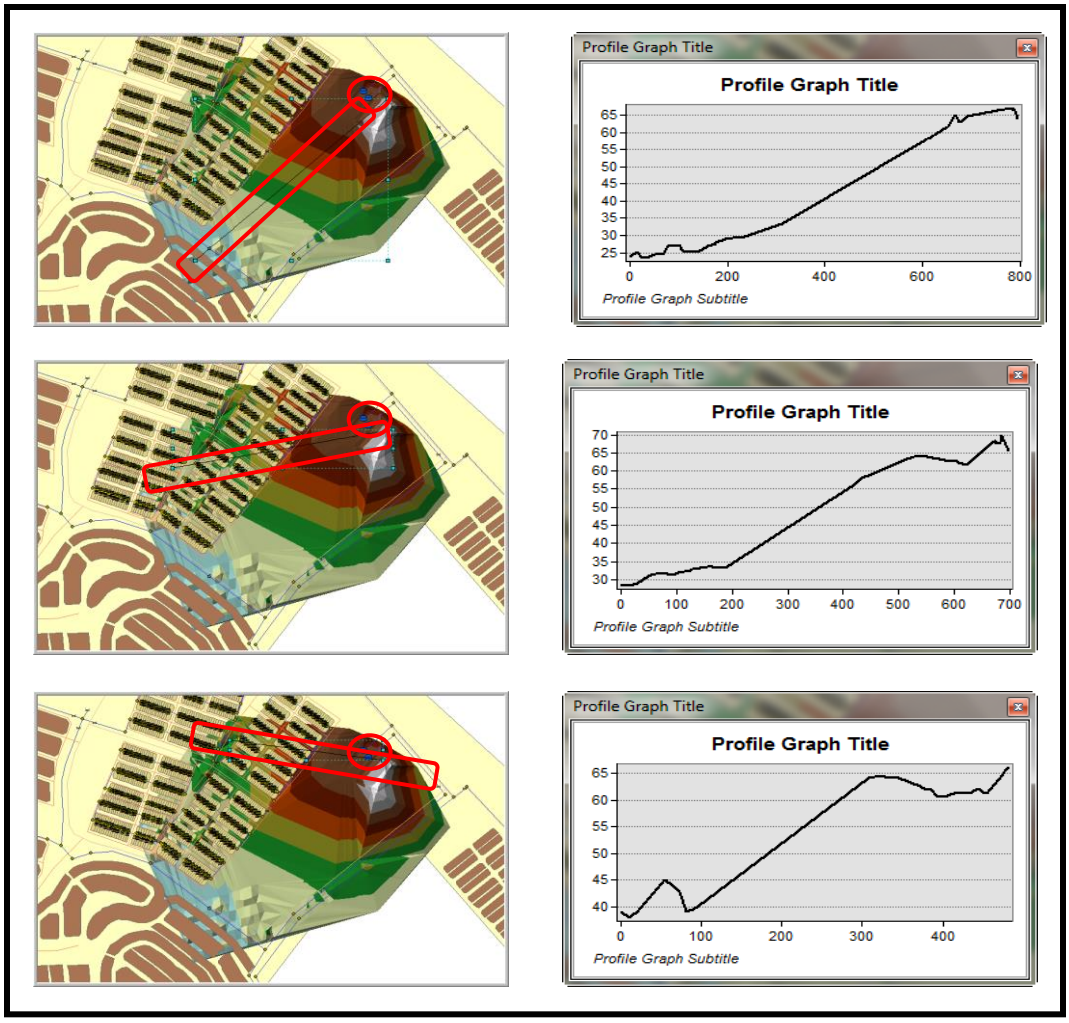

Figure 12. Water distribution tank (blue point) located at the hilly area and black line was drawn to show the elevation of the area.

4. Discussion

In water asset inventory, information of water asset and location of water asset needs to know by authority so that it can be monitor every time. To help this demand, all the water assets are shown in map that display in real coordinate system. Therefore, GIS can be used to map all the water assets in real coordinate system. GIS has capability to manage data spatial and non-spatial in one time. All the data will be stored in a database and can be displayed by users easily. The structural of database also must be done correctly. It will help the operation of database effectively and efficiently.

In management of water supply system, GIS can do modeling. Water flow direction can be modeling using GIS application so that the water flow can be detected starting from water tank until meter houses. This application will help water authority in detecting affected houses when any pipe leakage happens. It will show

the location and information of affected houses. Query also can be applied in this situation. The number of affected houses can be count easily. In fact, the number of others assets can be known exactly. Modeling of fire hydrant also can be done. It will display the nearest fire hydrant around houses if any fire burning happens suddenly. Water distribution tank is a source of water supply system some area. to make sure the water will flow from water distribution tank to houses, it need be built at the hilly area. Therefore, elevation of the area needs to visualize using GIS technology.

5. Conclusion

As the conclusion, based on the results obtained, it was found that the study has been done successfully and achieves the objectives of the study. Water asset management is very important to make sure the entire asset in good condition and can operate for a long time. Feature class can be stored in same character of feature dataset. Hence, GIS technology is the best way to manage water asset. GIS application can help authorities to store, manage, and retrieve data and process it to obtain new information easily and quickly. This application can save time and cost and to produce good result for planning and managing. Therefore, GIS is complete technology to help people in managing spatial and attribute data.

6. References

Shamsi, U. M. (2005). *GIS Application for Water, Wastewater, and Stormwater Systems*. United state of America: CRC Press.

Trifunovic, N. (2006). *Introduction to Urban Water Distribution*. Leiden: Taylor and Francis.

Zheng, Y. W. dan Xinghua, X. (2006). Asian Water. *Asset Management for Asiaan Water Utilities*. 10-12.

Syazratul Asyikin Binti Abdul Hanif (2009). *Aplikasi Sistem Maklumat Geografi (GIS) Untuk Perancangan Aset Air*. Universiti Teknologi Malaysia:Tesis Sarjana Muda.

Swamee, P. K. dan Sharma A. K. (2008). Design of Water Supply Pipe Networks. Canada: A John Wiley & Son, Inc., Publication

ESRI, last modified April 9, 2008, *An Overview of Subtype,* http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=An_overview_of_subtypes

Heywood I, Cornelius S, Carver S 1998, *An Introduction to Geographical Information Systems*. New Jersey, Prentice Hall.

Richard A. Cornell, P.E., (2005). *Water Distribution System Asset Management Needs and Nice to Have*. New Jersey. American Water Works Association.

S. Christodoulou et al. (2008). *Rehabilitation and Maintenance of Water Distribution Network Assets.* University of Cyprus.