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IDENTIFYING THE REQUIREMENTS OF WWP USING GIS AND MLR TECHNIQUE

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Abstract- Given the great importance of wastewater networks in the lives of societies and their great connection to the development of cities and the health of the person and society. The current situation of the wastewater service and its networks in Al-Kut, Iraq was studied as a case study. The areas served and unserved by wastewater services were identified and defined, using the (GIS) system for drawing the areas, calculating their areas, drawing their networks, drawing their stations, and determining the house connections through a database prepared for this purpose. The main objective of this research is to predict the number of pump stations and the length of networks needed by unserved areas. The importance of this research highlights the size of the areas that suffer from a lack of basic services, the most important of which is the wastewater service, multiple linear regression technique was used to predict the No. of pump station NOPS and length of networks *LONW* for unserved areas. The results show the two models have strong *R* are 94.3%, 98.7% and AA% are 85.49%, 81.02% respectively, this indicate the value that predicted by models are agreement with actual values.

Keywords: Geographic Information System, Lengths of Networks, Multi Linear Regression, Number of Pump Stations, Wastewater Projects.

1. INTRODUCTION

The importance of environmental problems has increased, which requires the establishment of more environmental standards. According to these standards, more restrictions are applied to the pollution resulting from the sewage of residential, commercial, and industrial units. In view of the large amount of these wastes, it is necessary to find new and highly efficient technologies for wastewater treatment [1]. Population growth is the emergence of new cultures, materials, social and economic activities, and major changes in lifestyle and consumption. Urban growth, the advancement of social and economic practices, and the improvement of lifestyle and use will inevitably lead to the production of sewage water and solid waste [2]. The wastewater projects are one of the most important elements it includes, rain and sewage systems that serve the population, communities and cities [3].

The wastewater projects are systems for collecting and transporting sewage and rain network in two ways, either by gravity or under pressure, and the collected water is delivered to treatment units or special ones by means of evaporators approved by the authorities [4, 5].

The areas of Al-Kut can be divided according to the wastewater services into served areas by an old sewage network, and it includes part of the areas of the city center of Al-Kut, which is implemented by a common system (rain and sewage) and is discharged through lifting stations directly to the Tigris River, and unserved areas that covered more than 60% of the areas and neighborhoods of the city. The main components of conventional wastewater projects include pipelines, manholes, and pumping stations. At the present time in Iraq, great efforts are devoted to improving the living conditions of a large segment of citizens who live in areas that lack basic wastewater services. GIS helps in developing a scientific database for the resource and furthermore helps in updating the data. GIS-based models assist in understanding the yearly distribution and produce a data base for future use [6]. This research aims to predict the *NOPS* and *LONW* using multiple linear regression technique in Al-Kut, Iraq.

The field survey was conducted using GIS, the data are usually stored in many layers to overcome the problem caused by handling more of information at once. The GIS has four functional system such as data entry, data storge, data analysis and result display [7].

2. GEOGRAPHIC INFORMATION SYSTEMS

GIS provides the framework for maintaining on important data and applications of the infrastructure project life cycle contain planning and design, collection of data, data analysis, construction, and operations management and maintenance. GIS provide a tool to assemble intelligent GIS applications and enhance performance of project by provide the data sources to the stakeholders [8].

Also, GIS was defined as a computational tool that able to solve problems related to spatial data. GIS technologies have the potential to solve construction problems, including update the information, planning, select the project site, soil studies, and environmental studies. GIS is an organized set of computers, such as software, personnel designed and geographic data to capture, store, data recovery, update, process, analyses and display all forms of geographically referenced information [9].

Another definition of GIS is a play pattern of computer technology with its two basic molecules (hardware and software) that allows the user to collects, stores and processes data from multiple sources, in addition to the possibility of obtaining of the results in the form of graphs, charts, tables, models, images, and scientific reports [10], [11].

3. COMPONENTS OF GEOGRAPHICAL INFORMATION SYSTEM

Each geographic information system consists of five basic components that work together to perform a specific function [12].

3.1. Data

The data divided in two types, the first is known a non-spatial data, which the data does not depend on location from the surface of the earth and can be represented by numbers or letters. The second type is known a spatial data, which the place is an influential factor in the data. Therefore, adding the shape or location of the phenomenon on the surface of the earth is essential in representing this data.

3.2. Software

GIS software is characterized by ability to store, analyses, processing data and link the graphics that represent a phenomenon with the data. There are three types of programs used in each system, which are operating, application and conversion.

3.3. Hardware

GIS include commonly used parts such as computers and uncommon used parts such as input devices scanners, numbering plates, digital recording machines, or output devices, drawing machines and plate printers that are used to perform certain functions.

3.4. Method

The methods or procedures are considered one of the most important elements because they provide objectives, plans and administrative systems for the operation and use of GIS in a way that achieves the success of the system.

3.5. Persons

It requires training the worker or employers in the field of GIS on several important computer techniques and some basic sciences, the most important of techniques such as programming, databases, networks, statistics, mathematics, and geography, etc. In order to ensure the successful use of GIS its necessary to provide the specialists in carry out all tasks of the system and technicians.

4. STUDY AREA

In this research Al-Kut was selected as a study area, its biggest city in the Wasit Governorate in Iraq, it lies about 180 KM south of Baghdad, and center of Wasit Governorate. It is located on the banks of the Tigris River. The estimated population in 2020 was 494053 capita, geographical coordinates it located WGS 1984 UTM Zone 38 N, (32° 33′) N, (45° 48′) E. The total area is 5640 KM^2. The researcher was able to obtain a satellite image from Wasit Sewerage Directorate as shown in Figure 1.

Figure 1. Basic map of Al-Kut for year 2020 [Researcher]

5. FILED SURVEY

The main objectives of field survey are to identify the serviced and unserved areas, numbers of house connections, numbers of pump stations and lengths of networks.

5.1. Create Database

The researcher created databases which deal with GIS program through a sub-program inside the system, which is ArcCatalog 10.8, where all shape files were created. In order to conduct the layer drawing, the researcher used a polygon and point shape file with a projection coordinate system (metric system) (WGS, 1984, UTM, Zone 38N). The coordinates system was selected, then the UTM folder and WGS1984 were selected, finally the researcher run about 6 or 7 times to reach (WGS 1984, UTM, ZONE38N), which represents the location of Iraq within the world's coordinates.

5.2. Layer Drawing

The layers represent a group of points and areas on the surface of earth that are required to be dealt with, which are removed from the maps, considering the independence of the layer with a set of specifications and features that differ from other layers. Each layer can be controlled, visible or hidden when there are need through the program, an addition to update the information's for any layer, the layers will be clarified with each other and will be installed on the satellite image of the city, any information can be shown on the required layer and they are given a specific color as needed [11].

The layers will be drawn using Arc Map10.8 program, and each layer is dealt with separately. The researcher divided the study area into 15 zone according to the municipal divisions, 9 served and 6 unserved, then it can be measured the areas using measure tool in ArcMap10.8 program, as shown in Figures 2 and 3.

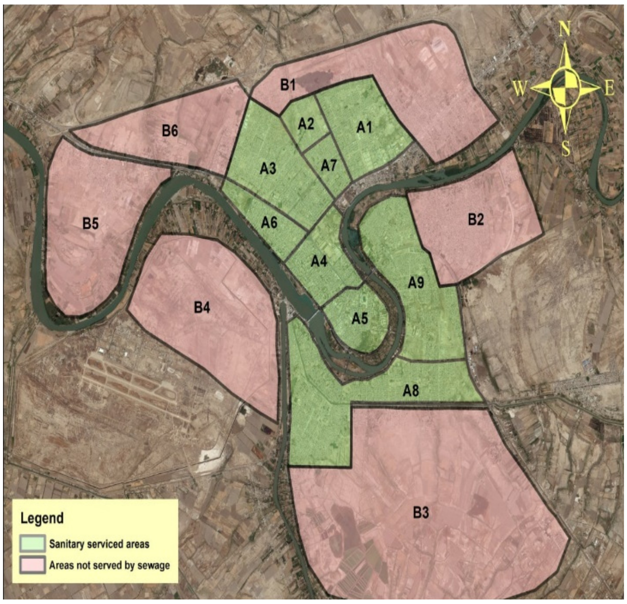

Figure 2. Municipal division map [Researcher]

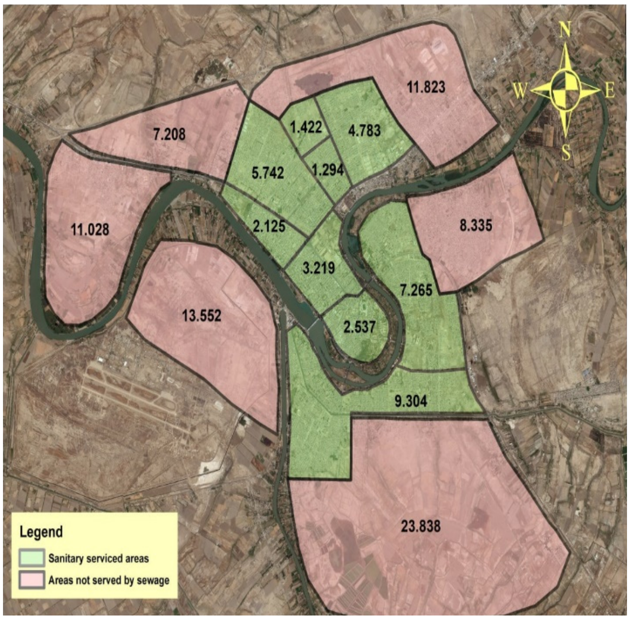

Figure 3. Area's map of study area [Researcher]

The researcher draws the location of pump stations which include rain, sewage and combined, an additional drawing the house connections and lengths of networks for each area, as shown in Figures 4, 5 and 6, respectively.

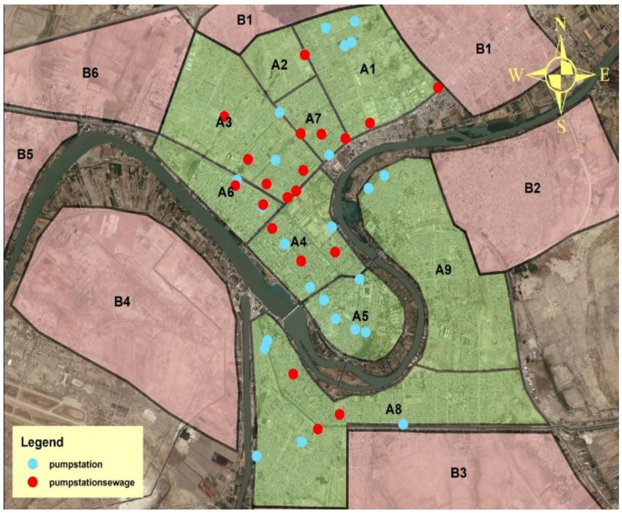

Figure 4. Location of pump station map [Researcher]

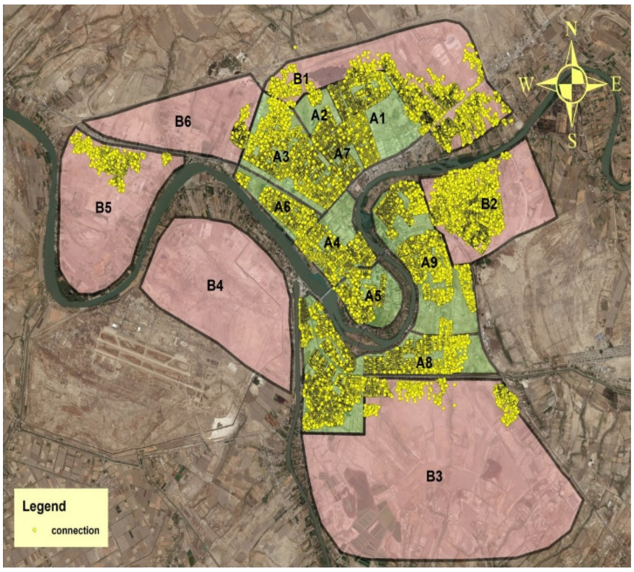

Figure 5. House connection map [Researcher]

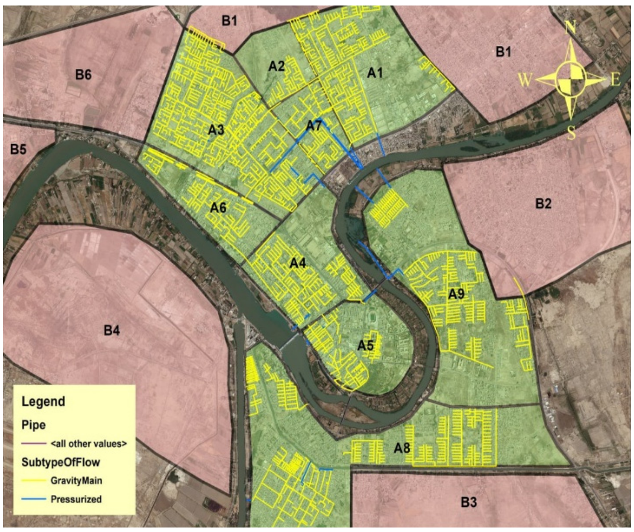

Figure 6. Length of networks map [Researcher]

6. RESULT DISPLAY

After completing the layer drawing the researcher can display the results through GIS program within table of attribute for served and unserved areas layers as shown in Tables 1 and 2, respectively, that includes areas, length of network, population, volume of pump stations, discharge, and No. of pump stations for each area.

Table 1. Attribute of served area

Cod	Area Km^2	Connections	Network	Popul.	Vol. of pump	No. of pump
A1	4.78	4088	37011	32704	750	6
A2	1.422	900	6163	7200	396	2
A3	5.74	5893	73700	47144	1200	7
A5	2.53	2790	15929	22320	725	5
A4	3.21	3188	25163	25504	730	6
A6	2.12	1945	16883	15560	500	3
A7	1.29	2378	12267	19096	709	4
A8	9.304	12713	58069	101704	1550	8
A9	7.26	6071	41672	48568	1250	2

Table 2. Attribute of unserved areas

FID	Shape	Code	Area, Km^2	Connection
1	Polygon	B_1	11.823	6657
0	Polygon	B_2	8.335	5136
5	Polygon	B_3	23.838	1297
4	Polygon	B_4	13.552	0
3	Polygon	B_5	11.028	1411
2	Polygon	B_6	7.208	874

According to the GIS outputs as shown in the tables above, the researcher identifies the independent variables such as (areas, population, volume of pump stations, discharge, and no. of manholes) and dependent variables such as (no. of pump station and length of network). The researcher checked the existence the relationship between variables, as shown in Figures 7, 8, 9 and 10, respectively.

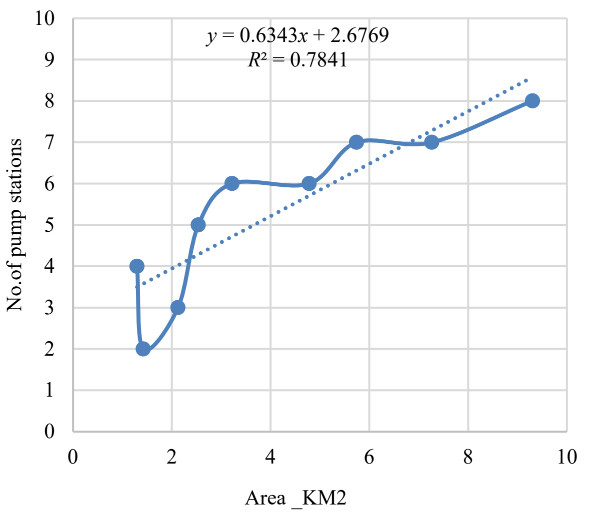

Figure 7. Relationship between no of pump and area [Researcher]

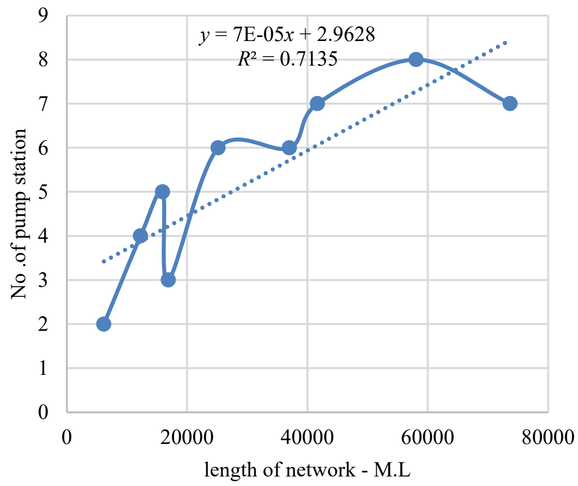

Figure 8. Relationship between no. of pump and length [Researcher]

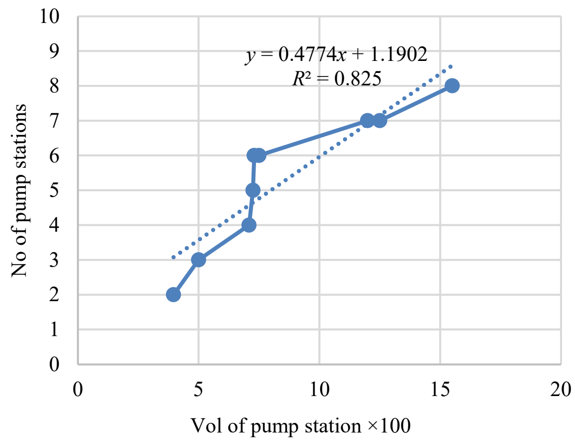

Figure 9. Relationship between No. of pump stations and vol. of pump [Researcher]

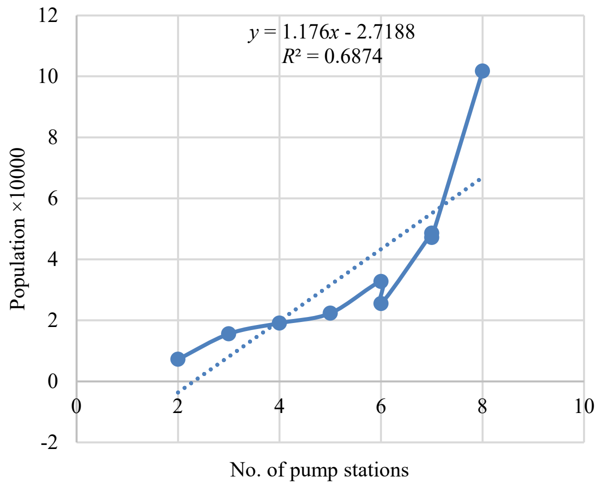

Figure 10. Relationship between no of pump and population [Researcher]

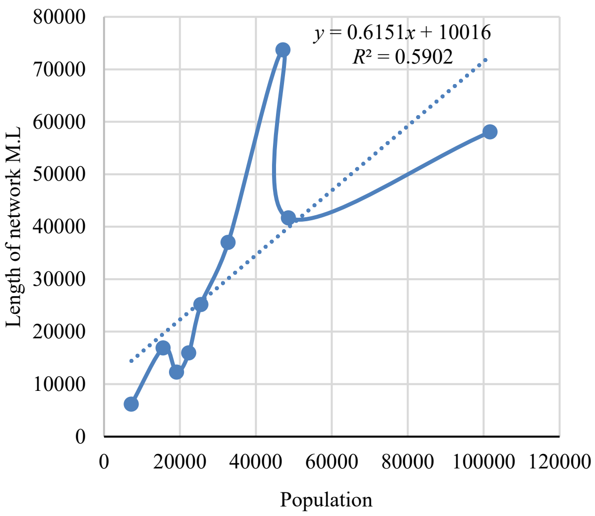

Figure 11. Relationship between *LONW* and population [Researcher]

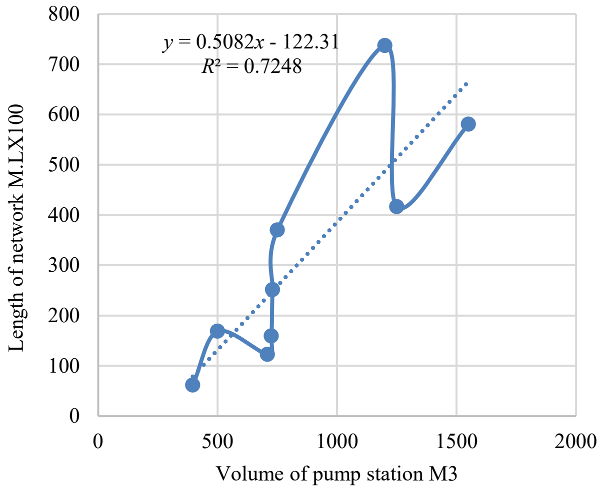

Figure 12. Relationship between *LONW* and volume [Researcher]

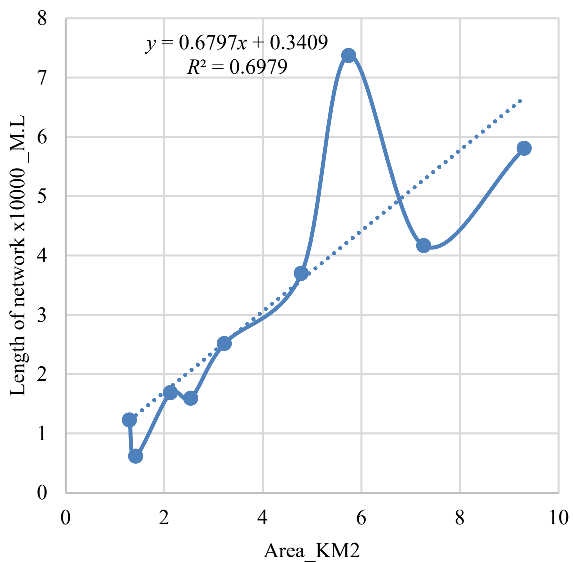

Figure 13. Relationship between *LONW* and area [Researcher]

The researcher identifies the independent variables such as (areas, population, volume of pump stations, and No. of manholes) and dependent variables such as (length of network). The researcher checked the existence of a relationship between variables, as shown in Figures 11, 12, 13 and 14, respectively.

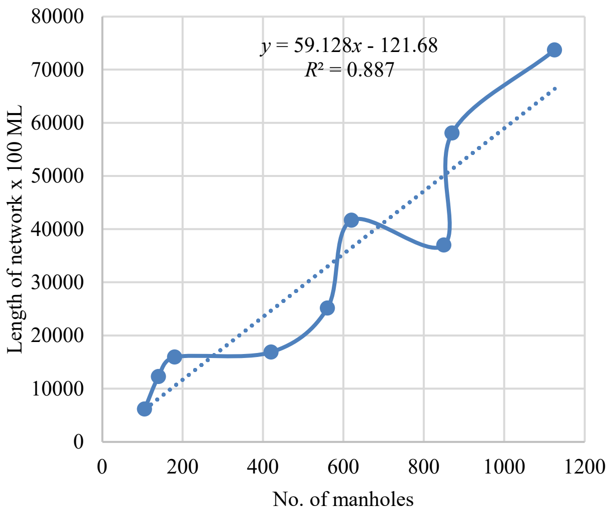

Figure 14. Relationship between LIONW and No. of manhole [Researcher]

Its concluded there are linear relationships between the variables that obtained from GIS, and these variables will be used in developing models to predict the no. of pump stations and length of the wastewater network for each unserved areas (B_1, B_2, B_3, B_4, B_5, and B_6) using statistical technique it's called multiple linear regression (*MLR*).

7. MULTIPLE LINEAR REGRESSION

The multi-linear regression MLR is one of the statistical techniques that has accuracy in values display of data to find the relationships between objects [13]. Also, the MLR define a mathematical equation that describe the relationship between two variables, and it is used to predict the past values and future values. An addition the *MLR* it is a regression of the dependent variable (Y) on many independent variables (V_1, V_2, …., V_n) [14].

The *MLR* is not one method but includes many methods that can be used to find the relationship between variables. The Equation (1) of multiple linear regression is representing as follow [15].

$$Y_i = B_0 + B_1V_1 + B_2V_2 + ... + B_nV_n \quad (1)$$

where, Y is dependent variable, V_1, V_2, ..., V_n are independent variables and B_0, B_1, …, B_n are the coefficients in the linear relationship.

The *MLR* is statistical techniques that use to find the mathematical relationship about variable such as No. of pump station and independent variables such as area, population, length of network and Vol. of pump station). After conducting the field survey and study the current situation on Al-Kut using GIS, the researcher identifies the variables are illustrated in Table 3.

Table 3. Variables of *MLR* in *NOPS* model [Researcher]

Variable	Description	Unit
V_1	Area	Km^2
V_2	Population	No. of capita
V_3	Length of network	M.L
V_4	Vol of pump station	M^3
Y_1	No. of pump stations	No. of item

7.1. Result and Discussion of No. of Pump Stations Model

The researcher was used SPSS V.20, program to analyze the data and development a predictive model of number of pump stations. The main purpose of this program is to determine the coefficients of linear regression equation. Table 4 shows the model summary, which include most important statistical output. These outputs were obtained by statistical analysis were conducted for *NOPS* model between input variables, such as V_1, V_2, V_3, V_4 and measured number of pump stations for each area (actual number). Moreover, the coefficient of correlation *R* for *NOPS* model is equal to 94.3%, which indicate a very strong correlation. An addition the coefficient of determination R^2 was 88.9 %, this indicates that the model can predict the results through the input variables

Table 4. Summary of *MLR* in *NOPS* model

Model	R%	R^2%	Adj. R^2%	Std. Error
NOPS	94.3	88.9	77.8	0.942

Table 5 explains the results of ANOVA analysis to test the significance of the regression, it funds the significate equal to 0.034 < 0.05. Therefore, the null hypothesis H0 is rejected and the alternative hypothesis Ha is accepted, this indicate the regression is significant and thus, there is an effect for independent variables on the dependent variable.

Table 5. ANOVA regression analysis of *NOPS* model

	Model	Sum of squares	*df*	Mean square	*F*	Sig.
NOPS model	Regression	28.454	4	7.113	8.024	0.034
	Residual	3.546	4	0.887		
	total	32.000	8			

Table 6 illustrates the output of *MLR* analysis, and the relative importance of Beta values influence the number of pump stations. The researcher observed that the most important variables were (V_1=0.625 and V_4=0.390).

Table 6. Result analysis of *MLR* in *NOPS* model

Model	Unstandardized coefficients		Standardized coefficients	*t*	Sig.
	B	Std. Error	Beta		
(Constant)	2.374	0.627		3.785	0.019
Area (*V*1)	0.447	0.400	0.625	1.119	0.326
Population (*V*2)	2.035E-005	0.000	0.289	0.573	0.597
Length of network (*V*3)	-1.015E-005	0.000	-0.115	-0.272	0.799
Vol. of pump station (*V*4)	2.716E-005	0.000	0.390	1.572	0.191

The *NOPS* model is given in Table 4 which formulates as the Equation (2).

$$NOPS = 2.374 - 0.447V1 + 0.0000203V2 - \\ -0.00001015V3 + 0.00002716V4 \quad (2)$$

There are many techniques and methods utilized to ensure the model agreement with the hypothesis and specifications with respect to the model concept. It involves the testing and assessment of model developed with some testing processes [16, 17]. The coefficient of correlation *R* between predict and actual No. of pump stations was determined to chick the performance of verification of the model. Table 7 indicates there is a good performance of model, because it has strong correlation 94.3% between the predicted and actual values. Figure 15 shows the *MLR* model has coefficient of determination 88.92%. Thus, the researcher concluded the values that predicted by model its agreement with actual measurements.

Table 7. Verification of *MLR* in *NOPS* model

V_1	V_2	V_3	V_4	Actual *Y*	Predicate	Error
4.783	32704	37011	39600	6	5.87884	0.12116
1.422	7200	6163	500	2	3.10737	-1.10737
5.742	47144	73700	70900	7	7.07946	-0.07946
3.219	25504	25163	72500	6	6.04634	-0.04634
2.537	22320	15929	7300	5	3.99943	1.00057
2.125	15560	16883	7500	3	3.67331	-0.67331
1.294	19096	12267	1200	4	3.24922	0.75078
9.304	101704	58069	12500	8	8.35578	-0.35578
7.265	48568	41672	15500	7	6.61024	0.38976

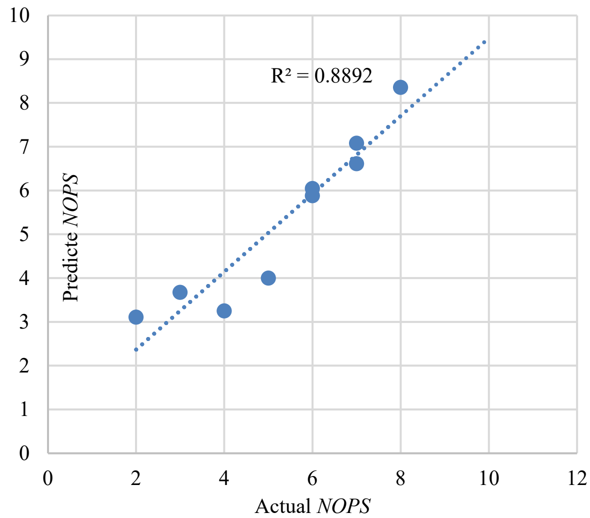

Figure 15. Comparing between predict and actual value [Researcher]

The validation of *MLR* model was checked using five statistical equations. The statistical equations used to determine the performance and accuracy of the *NOPS* model that included [18].

$$MPE = (\sum(A-E) \div A \times 100\%) \div n \quad (3)$$

$$MAPE = (\sum|A-E|) \div A \times 100\%) \div n \quad (4)$$

$$AA\% = 100\% - MAPE \quad (5)$$

where,
R is Coefficient of correlation
R^2 is Coefficient of determination

Table 8 illustrates the result of statistical equations for *NOPS* model, the *MAPE*, and Average Accuracy Percentage *AA*% were found to be 14.51% and 85.49% respectively. Therefore, the values that predicted by *MLR* are agreement with actual values.

Table 8. Validation of *MLR* in *NOPS* model

Statistical equations	Results %
MPE	-4.2
MAPE	14.51
AA	85.49
R	94.3
R^2	88.92

Also, the researcher used multiple linear regressions to determine the statistical relationship between dependent variable (e.g., length of network) and independent variables (e.g., area, No. of pump stations, population, Vol. of pump stations, and No. of manholes) as illustrated in Table 9.

Table 9. Variables of *MLR* in *LONW* model [researcher]

Variable	Description	Unit
X_1	Area	Km^2
X_2	Population	No. of capita
X_3	No of pump stations	No. of item
X_4	Vol of pump station	M^3
Z	Length of network	M.L

7.2. Result and Discussion of Length of Network Model

SPSS program V20 was used, to analyze the data and develop *LONW* model. The main purpose of this program is to determine the equation the linear regression. Table 10 shows the model summary, which include most important statistical results. These results were obtained by statistical analysis for variables. Moreover, the coefficient of correlation *R* of *LONW* model equal to 98.7%, which indicate a very strong correlation. An addition the coefficient of determination R^2 was 97.5% this shows the model can predict the results through the input variables.

Table 10. Summary of *MLR* in *LONW* model

Model	*R* %	R^2 %	Adj. R^2 %
LONW	98.7	97.5	95

Table 11 explains the results of ANOVA analysis to test the significance of the regression, it funds the significate equal to 0.002 < 0.05, therefore, the null hypothesis H0 is rejected and the alternative hypothesis Ha is accepted, this indicate the regression is significant and thus, there is an effect for independent variables on the dependent variable, and it can predict the dependent variable through these independent variables.

Table 11. ANOVA regression analysis of LONW model

	Model	*df*	Mean square	*F*	Sig.
LONW	Regression	4	1006112378.520	39.060	0.002
	Residual	4	25758236.980		
	Total	8			

Table 12 illustrates the output of *MLR* analysis, the Beta values of each variable influences length of network. The researcher observed that the most important variables were (X_3=0.754 and X_4= 0.766).

Table 12. Result analysis of *MLR* in *LONW model*

Model	Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
	B	Std. Error	Beta		
(Constant)	-17985.579	6559.303		-2.742	0.052
Area (X_1)	-2856.014	2474.381	-0.351	-1.154	0.313
Population (X_2)	-0.098	0.210	-0.122	-0.467	0.665
No. of manholes (X_3)	47.332	7.998	0.754	5.918	0.004
Vol. of pump station (X_4)	45.739	15.855	0.766	2.885	0.045

The *LONW* model can be formulating as Equation (6):

$$LONW = -17986 - 2856X1 - 0.098X2 + +47.33X3 + 45.74X4 \quad (6)$$

The coefficient of correlation *R* between predict and actual length of network was determined to chick the performance of verification of the model. Table 13 indicates there is a good performance of model, because it has strong correlation 98.7%. Figure 16 shows the *MLR* model has coefficient of determination 97.5%. Thus, the researcher concluded the values that predicted by model its agreement with actual measurements.

Table 13. Verification of *MLR* in *LONW* model [Researcher]

X_1	X_2	X_3	X_4	Actual *Z*	Predicate	Error
4.783	32704	850	750	37011	39684	-2673
1.422	7200	105	396	6163	330	5833
5.742	47144	1125	1200	73700	69128	4572
3.219	25504	560	730	25163	30216	-5053
2.537	22320	180	725	15929	14261	1668
2.125	15560	420	500	16883	17169	-286
1.294	19096	140	709	12267	15502	-3235
9.304	101704	870	1550	58069	57544	525
7.265	48568	620	1250	41672	43023	-1351

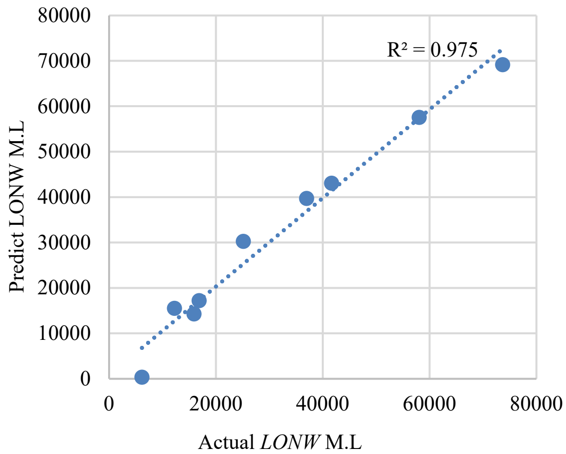

Figure 16. Comparing between predict and actual values

Table 14 illustrates the result of statistical equations [19] for *LONW* model, the *MAPE*%, and *AA*% were found to be 18.98% and 81.02% respectively. This indicates the values that predicted from *MLR* model its agreement with the actual measurements.

Table 14. Validation of *MLR* in *LONW* model

Statistical equations	Results %
MPE	5.95
MAPE	18.98
AA	81.02
R	98.7
R^2	97.5

9. CONCLUSIONS

Using the (GIS) program on the study area, the serviced and unserved areas were determined by the wastewater service. The pump stations, house connections, and wastewater networks were drawn for those areas. Linear relationships were also found between (*NOPS*) and independent variables (V_1, V_2, V_3, V_4), as well as found of relationships between (*LONW*) and independent variables. (X_1, X_2, X_3, X_4). The researcher reached to the development of two models to predict the number of pump stations and the length of networks of unserved areas by wastewater services. The models have a strong correlation coefficient, high degree of accuracy and least testing error, this indicates the values that predicted by MLR model are agreement with actual values.

NOMENCLATURE

1. Acronyms

GIS Geographic Information System

2. Symbols / Parameters

NOPS: Number of Pump Stations
LONW: Length of Networks
MLR: Multiple Linear Regression

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