THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION

INSTITUTE OF SCIENCE AND TECHNOLOGY

GIS FOR OPTIMIZING EXTENSION IN EXISTING SEWERAGE NETWORKS

CASE STUDY: KIRKUK

MASTER THESIS

Abbas I. ALI MIRDAN

THE DEPARTMENT OF INFORMATION TECHNOLOGY

THE PROGRAM OF INFORMATION TECHNOLOGY

MARCH 2017

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Supervisor: Assist. Prof. Dr. Meltem İMAMOĞLU

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Türk Hava Kurumu Üniversitesi Fen Bilimleri Enstitüsü'nün 1403660065 numaralı Yüksek Lisans öğrencisi, Abbas I. A. Mirdan belirlediği gerekli tüm şartları yerine getirdikten sonra hazırladığı GIS for Optimizing Extension in Existing Sewerage Networks, Case Study: Kirkuk, başlıklı tezini, aşağıda imzaları olan jüri önünde başarı ile sunmuştur.

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Yüksek Lisans Tezi olarak sunduğum, GIS for Optimizing Extension in Existing Sewerage Networks, Case Study: Kirkuk, tarafımdan akademik etik ve kurallara aykırı düşecek bir yardıma başvurmaksızın yazıldığını ve yararlandığım kaynakların kaynakçada gösterilenlerden oluştuğunu, bunlara atıf yapılarak yararlanılmış olduğunu belirtir ve bunu onurumla doğrularım.

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MARCH, 2017 **Abbas I. ALI MIRDAN**

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LIST OF ABBREVIATIONS

GIS : Geographic Information System [1]

GBS : Geografi Bilgi Sistemleri

SNCPC : Sewerage Network Critical Path Calculation

DEM : Digital Elevation Model

EPANET : Environmental Protection Agency Network

SWMM : Storm Water Management Model

SSOM : Sewer System Optimization Model

BIE : Bounded Implicit Enumeration

AIT : Advanced Intelligent Tape

DDDP : Discrete Differential Dynamic Programming

ESRI : Environmental Systems Research Institute

LIDAR : Light Imaging Detection and Ranging

ABSTRACT

GIS for Optimizing Extension in Existing Sewerage Networks

Case Study: Kirkuk

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Master, Department of Information Technology

Thesis Supervisor: Assist. Prof. Dr. Meltem İMAMOĞLU

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Urban areas are served with various underground infrastructures, which help in better living standards of inhabitants. One of these important infrastructures is the sewerage system. Sewer networks master plans designed for the future of 20-50 years. During this period, administrative changes may occur in some sectors (land-use change) of the urban plan of cities, for example, some low-res areas can be converted to hi-res areas, residential areas maybe become commercial centers and some abandoned lands required to convert to residential areas. That kind of changes makes the sewer master plan powerless hence requires re-design on the utility sewer networks in changing sectors, with some limits and constraints such as slope, velocity, depth, path, cost etc.

Kirkuk city, with almost flat geography, already suffering from those limitations, some authorities have experienced budget problems to overcome this situation, and some of the problems may be very difficult to solve by traditional ways.

In this thesis, the research question is; how slope, path, and cost can be, optimize easily by using GIS and programming techniques? There are several solutions for different purposes, but they address some part of the problems. We saw that our research question can be solved by combining some of the modern technologies with some software development for optimum performance in providing municipality services (sewer networks) by a simple and fast method to minimize the effort, time and the cost.

Keywords: land-use change, flat geography, Kirkuk Sewerage Network, optimization, slope, path, cost, Geographic Information System (GIS).

ÖZET

CBS KULLANARAK

MEVCUT KANALİZASYON AĞINI GENİŞLETMEK İÇİN OPTİMİZE ETMEK

Vaka İncelemesi: Kerkük

ALI MIRDAN, Abbas

Yüksek Lisans, Bilişim Teknolojileri Anabilim Dalı

Tez Danışmanı: Yrd. Doç. Dr. Meltem İMAMOĞLU

Mart 2017, 93 Sayfa

Şehir bölgelerinde çeşitli yeraltı altyapıları hizmeti verilmekte olup, gerektiği gibi hizmetler sunularak şehir sakinlerinin daha iyi yaşam standartlarına sahip olmasına katkı sağlar. Bu önemli alt yapılardan biri kanalizasyon ağı sistemidir. Kanalizasyon ağları imar planları gelecek 20-50 yıl kapsamında şehirler için tasarlanmıştır. Bu zaman süreci içerisinde, şehrin bazı sektörlerinde yönetimsel değişiklikler meydana gelebilir (arazi-kullanımı değişikliği), örneğin bazı düşük çözünürlüklü alanlar yüksek çözünürlüklü alanlara dönüştürülebilir, yerleşim yerleri ticari merkezler haline gelebilir ve bazı terkedilmiş arazilerin yerleşim yerlerine dönüştürülmesi gerekebilir. Bu tür değişiklikler kamusal hizmet ağlarının yapısı üzerinde yeniden-tasarım veya geliştirme çalışmaları yapılmasını gerektirebilir. Kanalizasyon hizmeti ağı tasarımları eğim, hız, derinlik, yol, maliyet vb. bazı kısıtlama faktörleriyle sınırlandırılmıştır.

Kerkük gibi, neredeyse düz bir coğrafyaya sahip olan şehirler, hali hazırda bu değişiklik ve sınırlamaların getirdiği sorunlar yaşamaktadırlar. Bazı yerel yönetimler bu durumun üstesinden gelebilecek bütçeye sahip olma hususunda problemlerle karşılaşmıştır ve bazı problemlerin çözülmesi zor olabilmektedir. Bu tezde, araştırma sorusu; değişen bir şehir için GBS & programlama tekniklerini kullanarak eğim, yol ve maliyet nasıl kolaylıkla optimize edilebilir? Farklı amaçlar için pek çok çözüm bulunmaktadır, ancak bunlar problemlerin bir kısmına yöneliktir. Gördük ki bizim araştırma konumuz; çaba, zaman ve maliyeti en aza indirgemek için basit ve hızlı bir metot ile belediye hizmetleri sunmakta (kanalizasyon hizmetleri) en iyi (uygun) performansı sağlamak amacı ile bazı modern teknolojileri yine bazı yazılım geliştirme çalışmalarıyla bütünleştirerek çözülebilir.

Anahtar kelimeler: arazi-kullanımı değişikliği, düz bir coğrafi yapı, Kerkük kanalizasyon ağı, optimizasyon (en iyi duruma getirmek), eğim, yol, maliyet, Geografi Bilgi Sistemleri (GBS).

CHAPTER ONE

GENERAL INTRODUCTION

1.1. Introduction

The huge rise of urban population in cities during the past years brought with it set of challenges, which in most cases require immediate solutions and also demand for future planning. To name a few; schools, hospitals, markets, public roads and rails, water availability and sewerage system. Sewerage system, which is the field of study of this thesis, is a set of underground-interconnected pipelines that terminate at bigger lines used for the effective collection and disposal of wastewater out of the city. The importance of sewerage system in urbanized areas ranged from minimizing the risks of diseases and bacterial infections through effective drainage of disposal wastewater, reduce pollution of surface and underground water, floods prevention of rainwater, and to some extent, preserving the quality of the provided water.

Over the past two decades, sewerage system management and planning rapidly grew and moved from academic research realm to developing much sophisticate computer-based informational system solutions. Geographic Information System (GIS) can be defined as "*a technological field that incorporates geographical features with tabular data in order to map, analyze, and assess real-world problems*" [1].

GIS products are developed with an easy-to-use interface enabling even the non-technical users to maneuver and to use such system. Furthermore, they traditionally accompanied with a very rich set of analysis tools required to interpret geo-information in the field of municipalities and services and present it in an elaborative form, such as maps, chart, and diagrams. Last, GIS can be integrated with another informational system to collaboratively solve the problems of design and planning accurately and quickly. As an example, sewerage GIS-based solutions help decision-maker to accurately find the optimum reach to an accurate decision related to finding sewer network layout, slope, and cost calculations. And to some extent, it can provide a prediction of expected future extensions of the designed network [2].

1.2. Problem Background

The unexpected decision in urban planning from administrative office of Kirkuk to change the land-use of some areas inside the city from one sector type to another require sewerage directorate office to establish new sewer networks for these lands and areas, and also find the optimal joint connections with the existing network. According to the city master plan, these areas were not meant to be residential areas. Therefore, it became important to study and find the optimal joint point between the new and the existing network to ensure the optimal flow of collected wastewater while trying to keep blockage risk to the minimum. Figure 1.1 shows the changing of land-use from abandon area to a residential region, the second from Green Park to a commercial mall and the third is from relics region to occupation houses. The case study of this thesis will focus on using GIS based solutions (such as MapInfo) coupled with programming techniques (MapBasic) to propose a solution model which will be used to find the optimal connection streams between the newly developed networks and the existing network in Kirkuk.

Figure 1.1 Case study areas

From researcher working experience in Kirkuk sewerage directorate office, a solution was proposed by the directorate office which suggests connecting the three new networks to its closest neighbour through joints/manholes, only to minimize the cost. But, and due to the reason that Kirkuk city topography is nearly flat, such solution is highly risky for the reasons:

1 – It does not guarantee the optimum hydraulic flow of wastewater.
2 – It does not consider the capacity limit of a neighbouring network, which might cause blockage/drainage issues in the future.

Therefore, it became important to conduct a thorough study using modern technological solutions (such as GIS) to investigate and to find the proper and the most efficient implementation of how the newly three sewerage networks (which are under development) should join the exist network around these areas.

In this study, our attention will be focused on creating and implementing a GIS-based solution to connect the three new networks to the existing neighbor networks by optimal join point. The proposed solution, SNCPC (Sewerage Network Critical Path Calculation), depends on the use of modern techniques such as Digital Elevation Model (DEM) and MapInfo to provide a real-world representation of case study topography and to formulate the proposed streams. Several factors, such as pipes diameters, slope degree, shortest path and cost are considered in formulating our model which helps in our decision-making process and minimize the effort, time.

1.3. Scope of the Study

The study scope is following this logical framework towards achieving its objectives:

- Introducing main parameters and limits governing sewer system works.
- Custom GIS applications as a new trend that proved its efficiency worldwide.
- Introducing GIS as a technology that should be integrated in sewer system more efficiently in Kirkuk.

- Describing the logic behind utilizing programming capabilities in integrating mapping and spatial features and rich databases and presentation tools in one platform and easy-to-use.
- The development as a concept for sewer sustainability.
- Discussing practical application of this development into sewer management.

1.4. Research Objectives

The overall objective of the study is to develop a new knowledge-base of sewerage network in Kirkuk according to its flat topographic using geographical information system. The study is undertaken in order to update knowledge and capacities for sustainable management of Kirkuk sewerage directorate. It will provide a new design and allow for interpretations of Kirkuk's hydrogeological; including geodatabases, maps and GIS supported management of related data. In addition to providing a wealth of new data, the program will improve the engineer's capability in the following areas: Interpretation, analysis, design and planning.

The study will outline the proposed program and the design to find the optimal slope, shortest path, and minimize the overall cost of joining newly designed networks with the existing sewer network in Kirkuk.

1.5. Anticipated Outputs

Anticipated study outputs:

- GIS model (spatially presented and previewed data).
- Thematic map of Digital Elevation Model (DEM) of study areas.
- Providing forecast tool for slope and path change of scenarios based on current trend of existing geodatabase.
- Finding the shortest path with the appropriate slope for several scenarios.

1.6. Thesis Organization

This thesis is organized as follows:

- Chapter One: Gives a general introduction about geographic information system, a background of research problem, and the objectives of this research.
- Chapter Two: Describes GIS technology in details and its applications in services and municipalities followed by a literature review related to the subject under study.
- Chapter Three: Covers the research methodology used in this research by describing research procedures in each phase of the study.
- Chapter Four: Details the results obtained from the proposed solution for the proposed problem in this thesis and discusses these results using practical methods.
- Chapter Five: Highlights the conclusion and future work of this research.

CHAPTER TWO

LITERATURE REVIEW

From our literature review, it was found that the GIS-based solution is extensively used and reviewed in the literatures. Reviewing such volume is burdensome and beyond the scope of this thesis, therefore, an elected set of related research papers to the work of this thesis will be reviewed.

2.1. Literature Review

A case study was presented by Abdelbaki in [3] describes an effective set of solutions using GIS system for the water distribution network for Chetouane region located at the north of Algeria. Chetouane area, as was described by the researcher, suffers from water scarcity and also from poor water management practices. MapInfo GIS software was employed to analyze and to identify the issues of the existing network (such as leakage and supply discontinuity) coupled with a hydraulic model (EPANET 2.0) to simulate the distribution velocity and pressures of case study area. It was indicated by the researchers that the grouping of GIS and the modeling technique provided a better analyses platform to accurately identify the issues and addresses them to local authorities.

In similar studies, Christos and Katia proposed a GIS-based solution to optimize the solid waste collection in Nikea, Athens, Greece. As described by the researchers, EU policy requires that all solid waste must be treated prior to disposal which increased the level of local services required to collect all the waste. From developing the spatial database of the study area and the use of ArcGIS Network Analyst software, the proposed optimization scenario demonstrate lowering travelling distance, collection time of solid waste from the city, and fuel consumption which lower the levels of CO_2 in the city [4]. Steele proposed a GIS-based solution for urban water systems which intended to solve two main problems, the first being generating system layout including the pipe design and crown elevations, and second, calculating the optimum slopes and pipe sizes. The proposed solution combines a heuristic model to determine the optimal layout and simulated annealing optimization procedures used to find the optimum pipe design. The proposed solution was tested on a sample scenario and it was shown that it can significantly lower costs and reduce the time required to design and compare several storm sewer networks layouts [5].

M, K and Manoj proposed a one package solution, where a GIS software SewerGEMS V8i, CAD, SWMM algorithm, and a hydraulic modelling technique are all collectively used to test the performance and for the analysis of multiple network designs for the sanitary sewer network of district 2B, Vijayapur city, India. It was shown that the proposed solution allows projects to designed and test in short time, high accuracy, and with low costs. The proposed application provides a set of useful features, such as automatic data update, automatic pipes diameter calculations, and reports, layouts and traversal cross sections of the pipe network are displayed in AutoCAD advance graphics technology [6].

An optimization method was proposed by Haghighi and Bakhshipour, where an integrated optimization model was used to make the optimization of sewer collection network to become completely unconstrained for the applied optimizer. The layout configuration for the given network is designed using loop-by-loop cutting algorithm, and then hydraulically tested to decide network parameters, such as pipes and manholes installation depths, pipes diameters, and pump specifications. The aim of the research is to focus on construction cost function and the decision variables. The model was applied to a case study, the results show that using the integrated model, the design of sewer networks becomes more efficient and systematic [7].

However, we found that GIS system was not only used for developing and optimizing sewerage networks, but also roads layouts. A GIS based solution was used to find the shortest path for the roads network in the city of Baghdad. Capturing the raster images directly from Google maps, then image segmentation algorithm is applied to extract the roads network from the raster images, then a set of morphological operators were applied to binaries and skeletonize the roads network. A dynamic GIS database was used to store all the extracted nodes and edges. Finding the optimal shortest path was determined by applying Dijkstra's algorithm [8].

However and from our literature review, it was found that a considerable research is dedicated to optimize the GIS system itself. Such that development are implemented on the GIS-based solution to optimize/propose more efficient procedures such as slopes calculations, pipes layout planning, shortest path calculations, pressure and velocity decision making, etc.

Weng and Liaw proposed a serial multi-stage multi-option system to treat branched gravity sewer system design problem. The study proposed a Sewer System Optimization Model (SSOM) using a 0-1 mixed integer optimization model coupled with an efficient screening algorithm BIE (Intelligent Bounded Implicit Enumeration). The proposed hydraulic analysis solution was implemented on a 73-manhole sewer network layout and it was shown that it is more accurate and time saving if compared with results obtained from AIT or DDDP model when applied to the same scenario [9]. Another study was published by Martínez-Solano related to developing new functions in Storm Water Management Model (SWMM). The presented modification allows the modification of network data parameters directly while performing the simulation, without the need to access any input data file. Such modification led to over 75% saving in calculations times while proving 100% of results accuracy [10].

Ben, Dragan, and Maciej focused on developing a better mathematical model to optimize the investment planning system related to sewerage management. Several mechanisms has been adopted to evaluate the cost and trade-offs of any sewer networks rehabilitations process, the proposed model uses a series of geographical information system tools integrated as a strategic decision support tool that can be used to evaluate the improvements which can be realized on the given sewer network [11].

Blumensaat, Wolfram, and Krebs presented a novel approach on how to derive and build enough information from minimum amount of data to build a hydraulic model for a sewer network. The outlined approach combines surface accumulation algorithm with hydraulic network dimensioning to derive close to reality sewer network. The proposed approached tested with different topography and state of development sewer networks and the performance is evaluated. Results analysis shows an accurate capability of reproducing the original network layout, with simulation speed improvements by a factor of 1.5 due to proposed network aggregation feature [12].

CHAPTER THREE

STUDY AREA AND THEORETICAL BACKGROUND

3.1. Introduction

Sewerage network in Kirkuk city, which collects sanitary wastewater from city's residential areas and several commercial industries, has a total length 561.967 meter. Traditionally, there are two main types of wastewater collection systems: Combined and Separate sewerage systems. The difference between the two systems can be viewed as whether the storm water (e.g. rain water) and wastewater are collected and transported separately or through using the same network lines. In Kirkuk, separate system will be adopted in designing sewerage networks for all stages.

Directorate of Kirkuk sewerage have always emphasized that the designing and construction of sewerage system must be according the use of up to date and modern technologies for collection and disposal of municipal storm water, wastewater collection, transmission, treatment and reuse.

3.2. Kirkuk-Iraq

The Republic of Iraq is located in south-west of Asia continent in the Middle East between latitudes (29° 5' and 37° 22' N) and longitudes (38° 45' and 48° 45' E); it forms the eastern frontier of the Arab countries. Turkey to the north, Iran to the east, Jordan, Syria and the Saudi to the west, and the Kuwait to the south, border it (Iran 1,458 km, Jordan 181 km, Kuwait 240 km, Saudi Arabia 814 km, Syria 605 km, Turkey 352 km). Its unique environmental, biological and social features, which are unlike anywhere else in the Arabian Peninsula, characterize the country. It has a total area of 438 317 km2, see Figure 3.1.

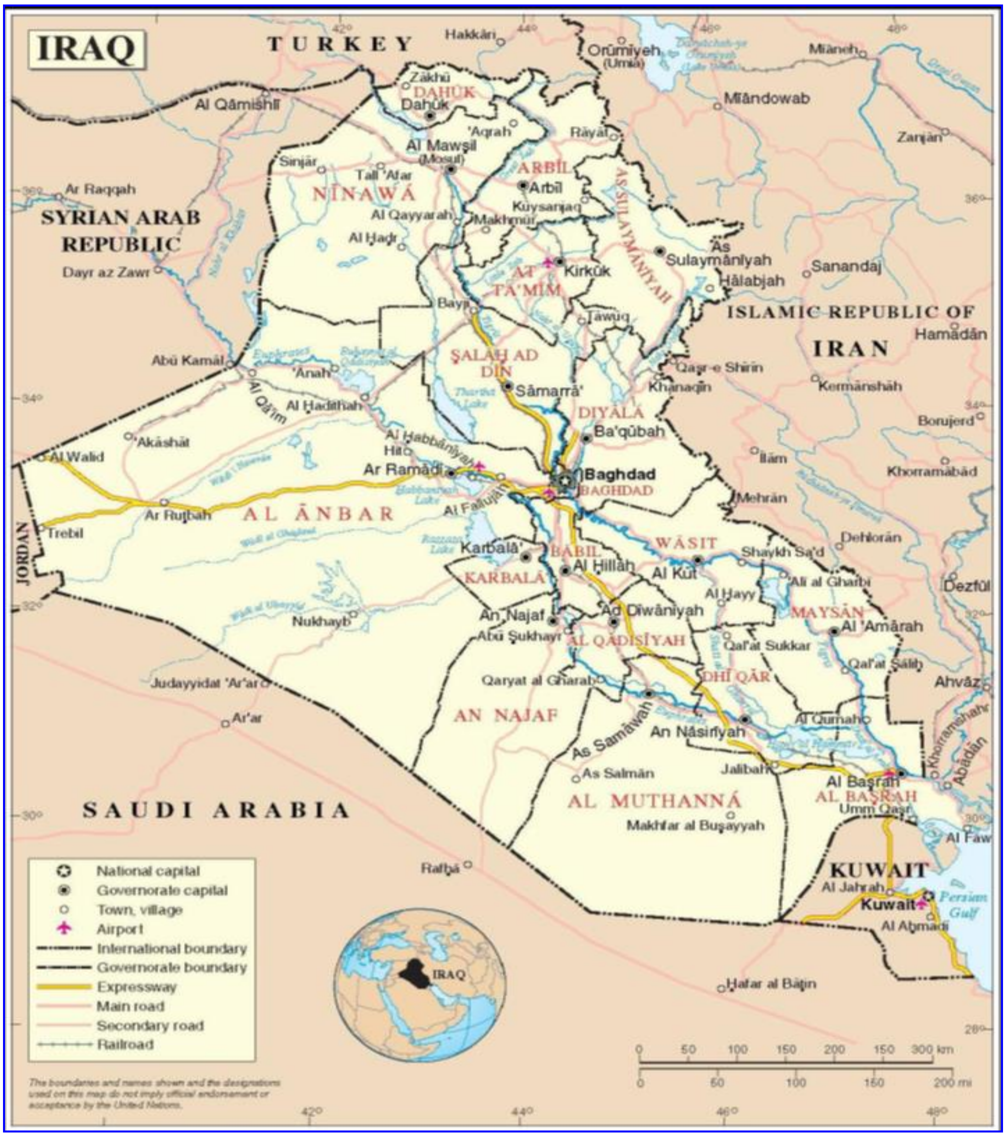


Figure 3.1 Map of Iraq [13]

Kirkuk province is situated in the north central part of Iraq and is far from the capital Baghdad about 250 km longitude and latitude coordinates of 44o 19’ and 35o 27’. Kirkuk province is surrounded by Erbil province on the north, Salah al-Din province on the south, Suleimaniyah province on the east and Mosul province on the west. Kirkuk is one of the governorates of Iraq, Inhabited by Turkmen, Kurds, Arabs and Assyrians. Kirkuk is known for its oil production, with six oil fields, the largest in Kirkuk with oil reserves that reach more than 10 billion barrels. Oil is exported through the northern oil pipeline through the Northern pipeline to the Turkish ports of Ceyhan [13], see Figure 3.2.

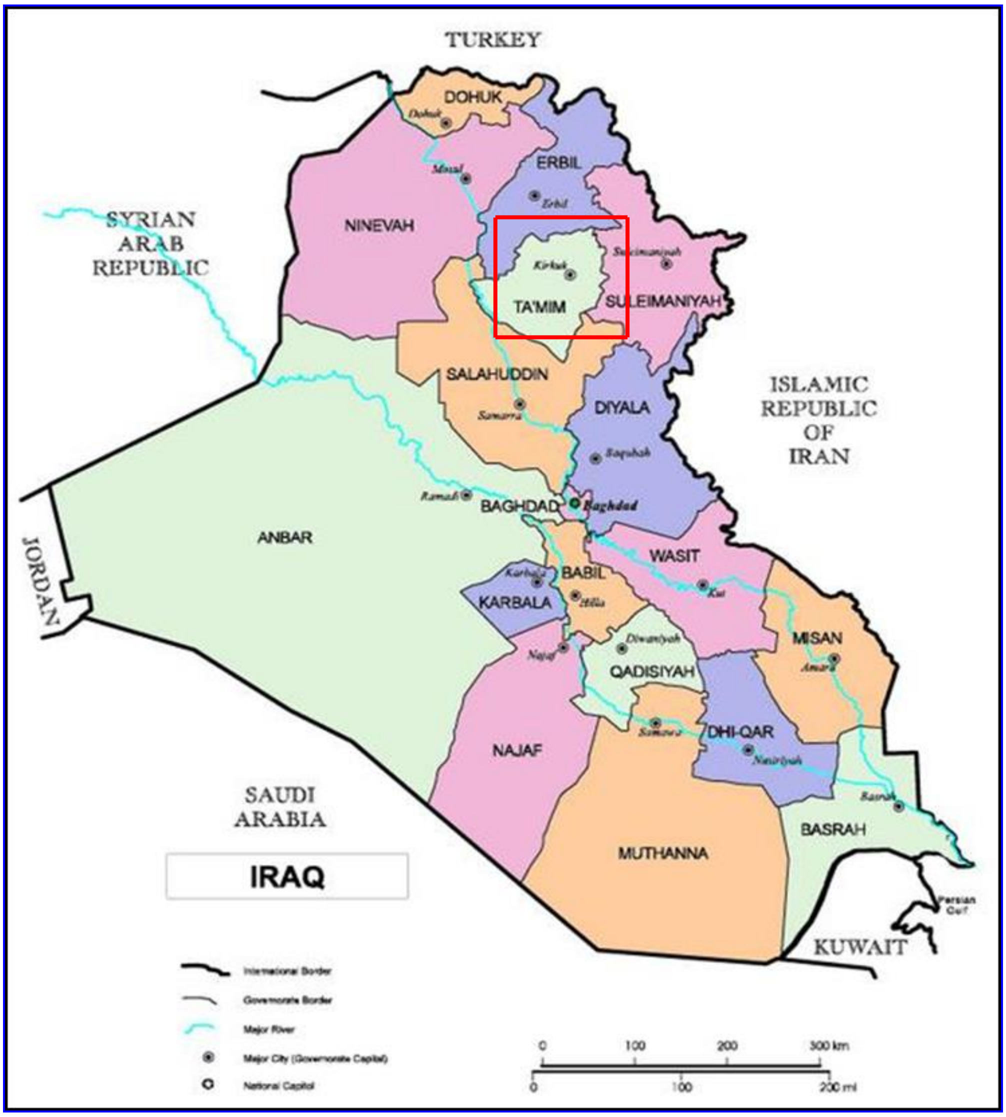


Figure 3.2 Kirkuk province in Iraq [13]

Kirkuk province is divided administratively into four districts: Kirkuk, Daquq, Dibis and Hawija. The total area of Kirkuk province is 9.679 Km2 and represents about 2.2% of the total area of Iraq. Figure 3.3 shows the location of Kirkuk city and the districts of the Kirkuk province.

Figure 3.3 Kirkuk province divisions [40]

The city of Kirkuk is one of the ancient cities with an early appearance dating back to the second millennium before Christ, where it was mentioned in Acadian literature by the name of (Eraboukha). Claiming to be the oldest site of continuous occupation in Iraq, Kirkuk sits on archaeological remains that are 5,000 years old [13]. This city has retained its importance to an economic and geographical map of Mesopotamia throughout the ages.

Now Kirkuk is the fourth largest city in Iraq as the total surface area is 128.2 sq. km and the city elevation is at 285 m to 360 m above the sea level from south to north. Kirkuk is one of the centers of the Iraqi petroleum industry, petrochemical and agriculture industries are also important aspect of Kirkuk's economy. Kirkuk is hoping to further develop its Infrastructural projects sector. Figure 3.4 shows the layout of Kirkuk city.

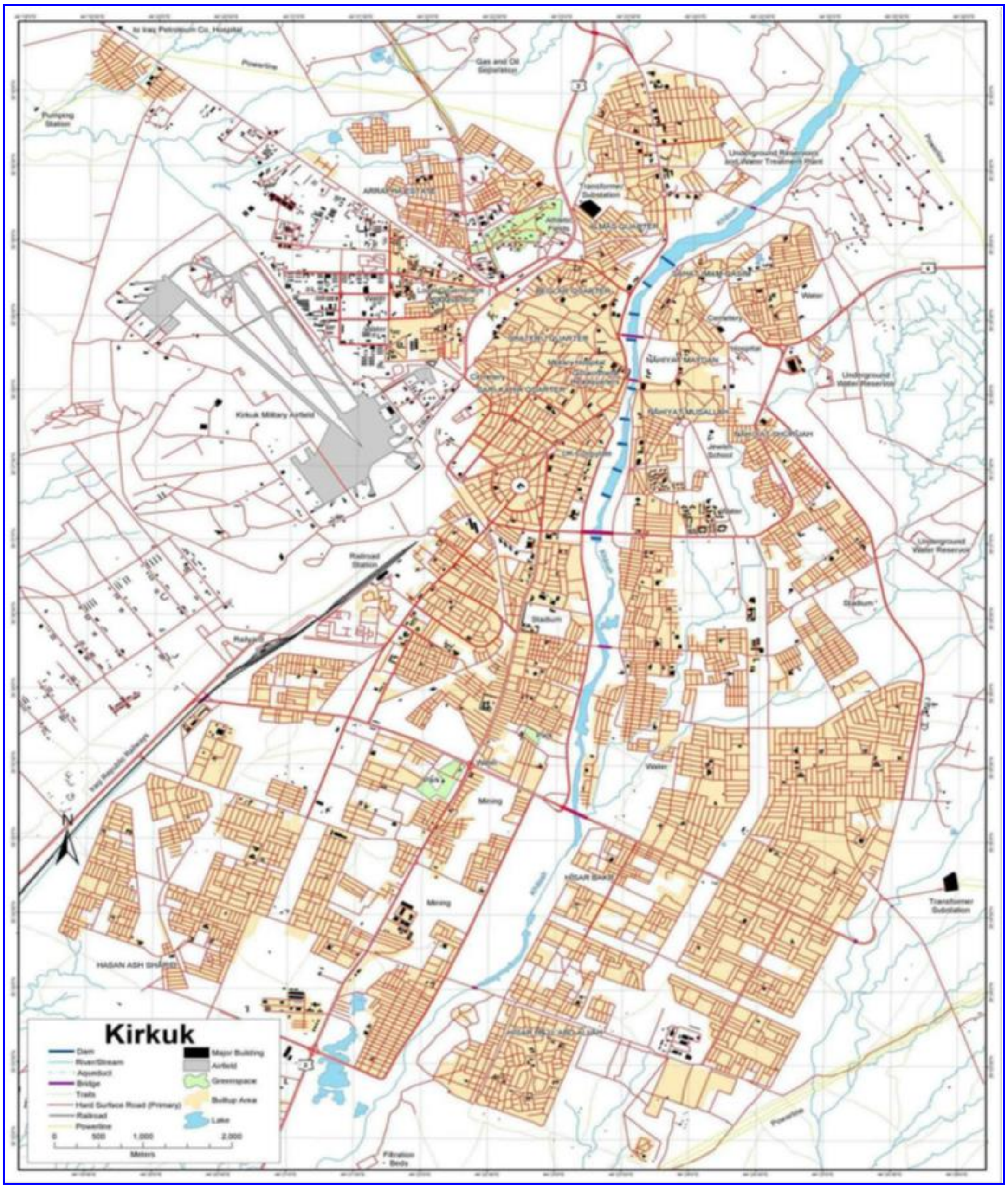


Figure 3.4 Layout for Kirkuk city [40]

3.3. Population Study

Demography studies are one of the most important bases in every municipality projects and urban facilities development. Since the existence of cities depends generally on population, and also, the existence of these studies are important in understanding and solving problems related to health planning, education, housing, and employment planning.

A population study is traditionally accomplished through the analysis of several factors, some of which might vary according to the required studies and what it is intended for. Population growth, for instance, describes the population changes over a specific geographical area over a certain period of time. Nonetheless, by simply relying on the previous population statistics cannot give an accurate estimate of future predictions of population growth. Therefore, in order to achieve a reliable prediction, other parameters should be considered to generate an accurate population growth, such parameters can include the following:

- The development of the city and its role in the region.
- Supporting factors in the growth and development of the city.
- Plans and programs affecting the future population growth.
- Economic changes which can cause unexpected fluctuations in the population changes trends.

Moreover, in the present study, Kirkuk projection population has been published by the Central organization of statistics of Iraq and has been generalized to 2041. Figure 3.5 shows the Kirkuk population projection by the Central organization of statistics of Iraq. Table 3.1 shows the Kirkuk population Projection according to the data released by the Central organization of Statistics of Iraq [14].

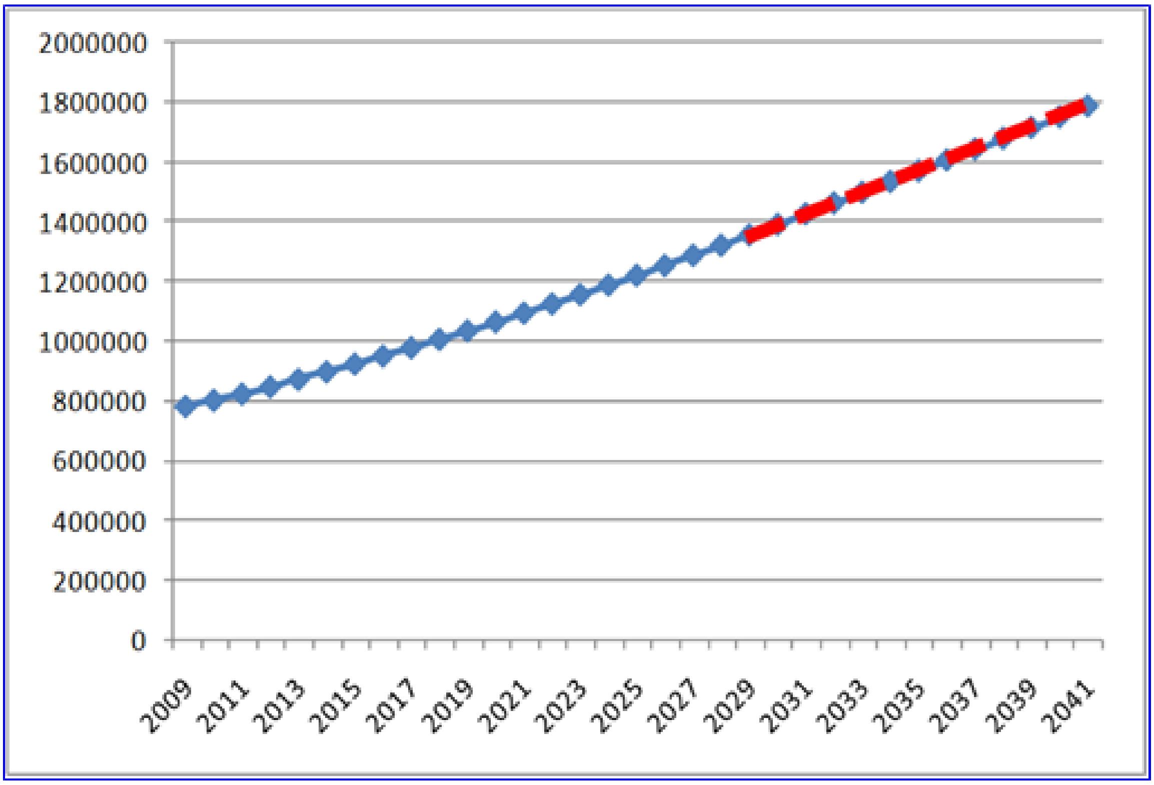


Figure 3.5 Kirkuk population projections [14]

Years	Population	Growth Rate %
2009	782143	
2010	802601	2.62
2011	823491	2.60
2012	847589	2.93
2013	872322	2.92
2014	897700	2.91
2015	923731	2.90
2016	950427	2.89
2017	977804	2.88
2018	1005863	2.87
2019	1034608	2.86
2020	1064038	2.84
2021	1093814	2.80
2022	1124248	2.78
2023	1155321	2.76
2024	1187008	2.74
2025	1219313	2.72
2026	1252220	2.70
2027	1285707	2.67
2028	1319746	2.65
2029	1354309	2.62
2030	1389425	2.59
2031	1424855	2.55
2032	1460477	2.50
2033	1496258	2.45
2034	1532169	2.40
2035	1568175	2.35
2036	1604243	2.30
2037	1640338	2.25
2038	1676425	2.20
2039	1712469	2.15
2040	1748430	2.10
2041	1784273	2.05

Table 3.1 Kirkuk population projection estimations [14]

3.4. Kirkuk GeoInformation

In this study, the data has been obtained from Kirkuk sewerage directorate office, The Iraqi ministry of municipalities and works - Kirkuk province. The described data include a detailed (as built and spatial) GIS maps and geodatabase files of existing sewerage networks of Kirkuk city which kept an up to date track of all the development occurred over the past decades. The collected data from the GIS department of Kirkuk sewerage directorate office will be used as the base to formulate the proposed solution.

Figure 3.6 shows an updated (dated: 30/8/2016) a satellite image which describes all Kirkuk city's sewerage network.

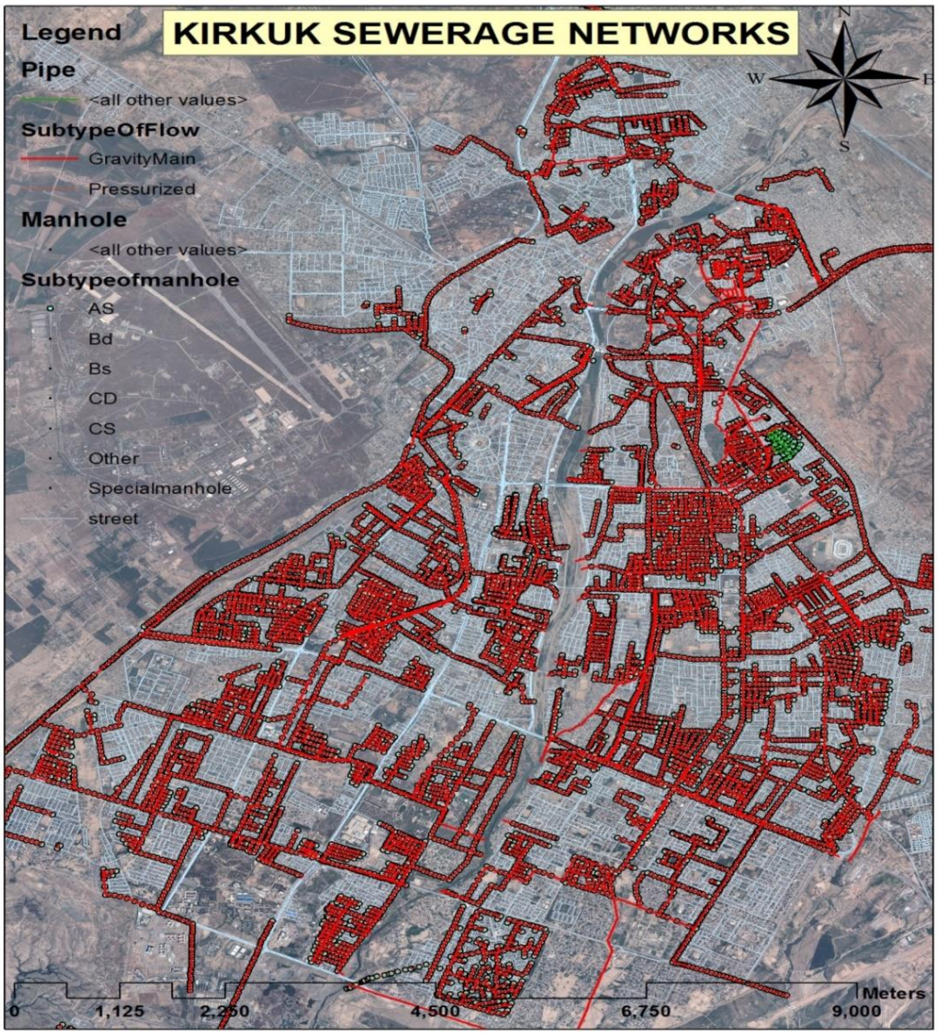


Figure 3.6 Kirkuk sewerage networks

A detailed look at three areas under study is shown in Figure 3.7, which is also obtained from the same satellite image, the first area is being an under changing from green park to a commercial mall, the second area from abandoned area to residential region and the third area from relics region to occupation region these are opted by the local government office according to the current requires which conflict with the previously installed master plan.

Figure 3.7 View of areas under study

In addition, the obtained geodatabase tables contain the sewerage system information itself, such as pipes, manholes locations, benchmarks and other sets of information layers describing, such as, pipe ID, pipe length, diameters, slope degrees and other details. As shown in Figure 3.8 and Table 3.2.

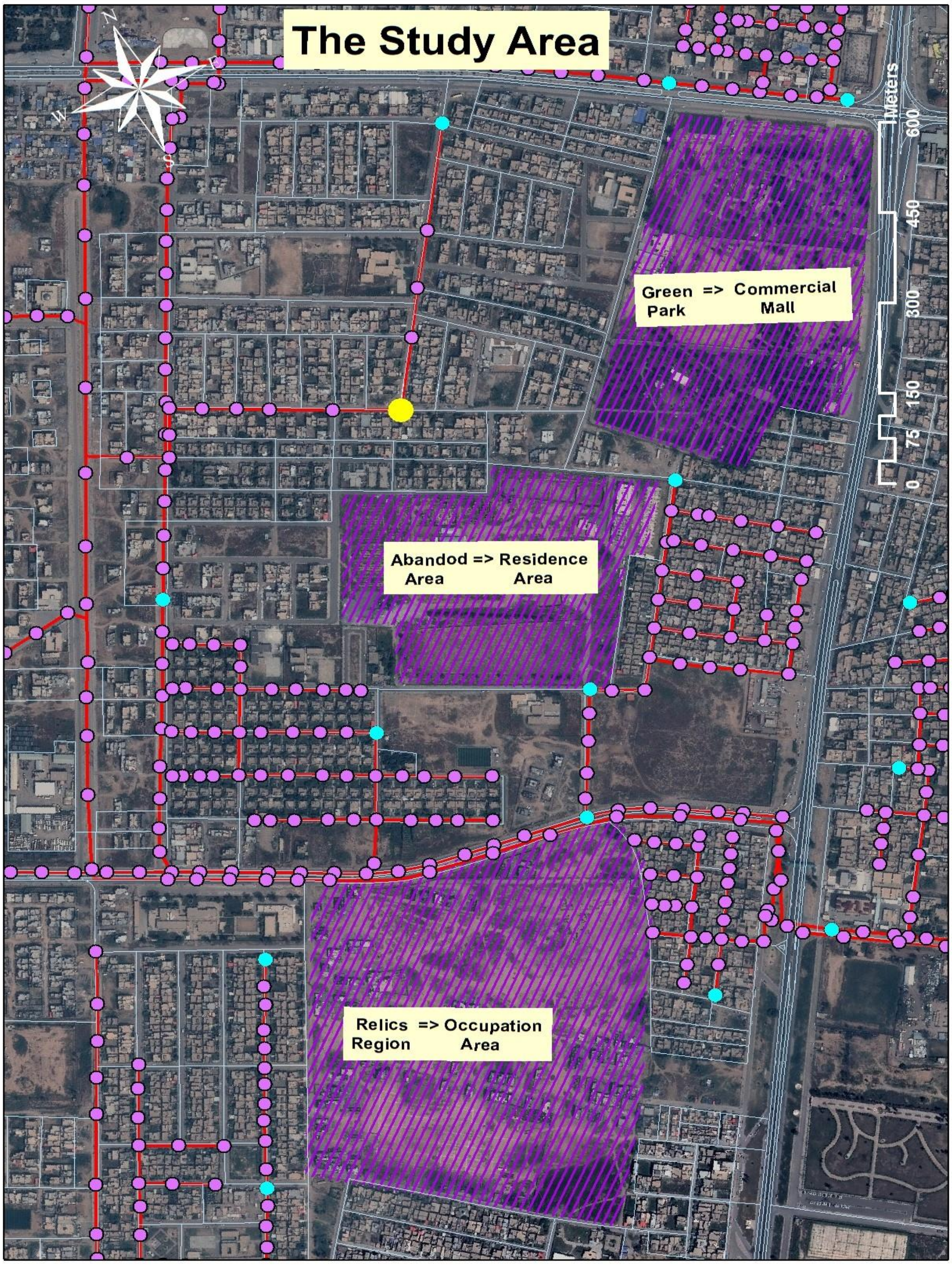


Figure 3.8 Sewerage pipe layouts

Sectornumber	ManholeID	Accessdiameter	Groundelevation	Dept	HighPipeelevatio	Invertlevel	Lifecyclestatus	Noofbond	Subtypeofmanhole	Installdate
606	58	55	90.61	1.38	90.69	90.69	Active	2	AS	02/03/2008
606	61	55	89.9	2.77	89.96	89.96	Active	2	AS	02/03/2008
606	31	55	98.63	4.2	94.43	94.43	Active	2	AS	02/03/2008
606	40	55	99.58	5.37	94.21	94.21	Active	2	AS	02/03/2008
609	46	55	98.28	4.38	93.9	93.9	Active	2	AS	02/03/2008
608	77	55	303.71	1.59	302.12	98.72	Active	2	AS	02/03/2008
608	88	55	305.62	2.03	303.59	96.45	Active	1	AS	02/03/2008
608	13	55	309.73	2.64	307.09	91.56	Active	1	AS	25/07/2011
620	256	55	403.22	2.89	400.33	400.33	Active	1	AS	01/01/1900
602	10	55	305.89	2.17	303.81	303.81	Active	1	AS	09/05/2012
602	57	55	308.45	0.9	307.55	307.55	Active	2	AS	09/05/2012
602	65	55	308.52	1.93	306.59	306.59	Active	1	AS	09/05/2012
602	23	55	313.39	4.1	309.29	309.29	Active	2	AS	06/11/2012
602	42	55	311.53	4.07	307.46	307.46	Active	2	AS	06/11/2012
602	62	55	313.96	3.89	310.07	310.07	Active	3	AS	06/11/2012
602	67	55	314.91	3.44	311.47	311.47	Active	2	AS	06/11/2012
602	71	55	317.16	3.98	313.18	313.18	Active	1	AS	06/11/2012
602	116	55	317.07	2.99	314.08	314.08	Active	2	AS	06/11/2012
602	122	55	316.67	2.2	314.47	314.47	Active	1	AS	06/11/2012
602	150	55	306.61	2.96	303.42	303.42	Active	2	AS	06/11/2012
602	153	55	306.74	2.5	304.03	304.03	Active	2	AS	06/11/2012
602	159	55	308.17	2.92	304.91	304.91	Active	2	AS	06/11/2012
611	5	55	299.47	1.57	297.9	297.9	Active	2	AS	04/02/2014
606	46	55	292.479	1.79	290.689	290.689	Active	2	AS	06/08/2013
606	36	55	292.341	1.67	290.671	290.671	Active	2	AS	06/08/2013
602	66	55	296.02	2.17	293.85	293.85	Active	2	AS	18/08/2013
602	68	55	296.27	1.49	294.78	294.78	Active	2	AS	18/08/2013

0 (27 out of 17664 Selected)

Table 3.2 Sewerage pipe fields and records

3.5. Geographic Information System (GIS)

3.5.1. What is GIS?

Geographic Information system (GIS) is an integrate system of software, hardware and data which can be dealing with geographically referenced data such as capture, manage, analyze and display this information to help the decision makers for taking the optimal one, this is the main task of GIS [15].

GIS can be used to understand, analyze, process and visualize an information in several ways to discover the patterns, relationships and trends with the maps. In addition, it is used to solve all problems related with geographically information.

3.5.2. Components of GIS

From the above definition, we can divide the GIS components as shown in Figure 3.9 [16].

- **Hardware**: are all computer physical devices which connecting as a system to used operating the GIS such as computer servers.
- **Software**: are all functions and operations in computer systems which used to store, analysis, and display geographic information.
- **Data:** is one of the important components in GIS. This data consist of geographical features (spatial data) and their attribute information (non-spatial data). Spatial data include raster data and vector data.
- **People**: people represent all technical specialists working in this system as well as end users who used this technology.
- **Methods**: it is a unique system plan which consider to modelling and operating the GIS system.

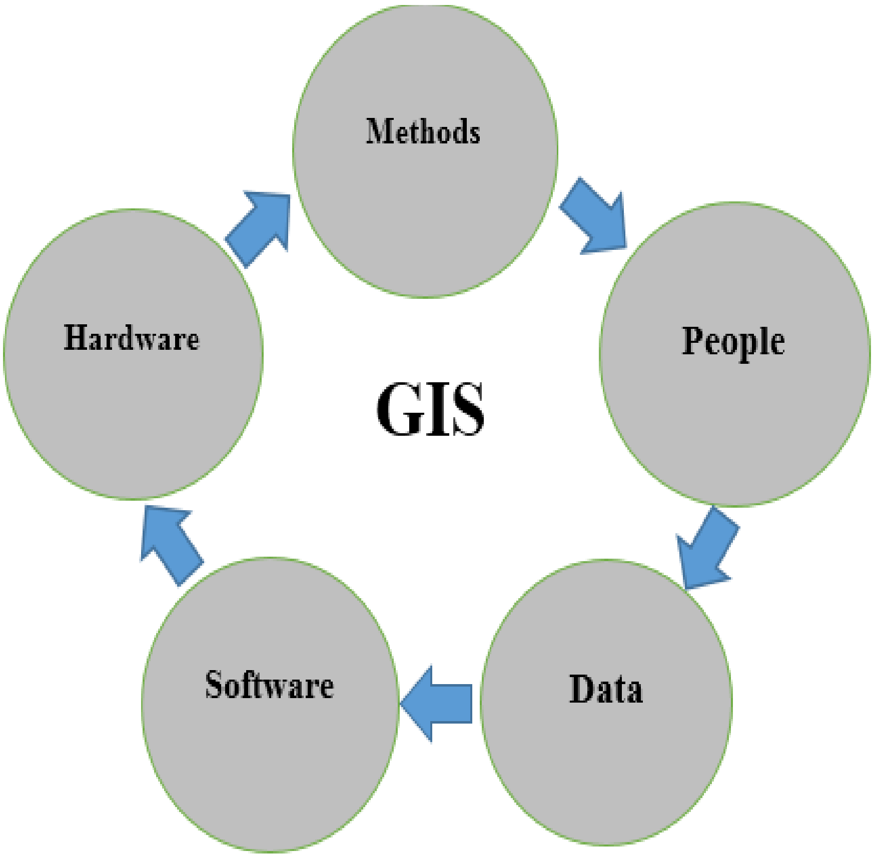


Figure 3.9 The components of GIS

3.5.3. The Characteristic of GIS

The characteristic of a GIS system is understood through the possibility of managing geographical elements - represented as points, lines and polygons, with their spatial coordinates – and their integration as tables of data, so for each graphical element is corresponded as one record in a table. Further, using the principles of the relational databases if combined with graphic functions, it is possible to connect tables and create thematic maps, perform spatial and tabular queries and preforming spatial analysis such as distance and contiguity or even to draw new layouts for any further use [17], see Figure 3.10.

GIS are powerful tools for creating geo-referenced maps and geo-databases for water, wastewater, and storm water systems. Effective waste and storm water management requires linking of specialized computer models to the GIS. Also, integration of engineering, environmental, and socioeconomic objectives into waste and storm water management can be included [18].

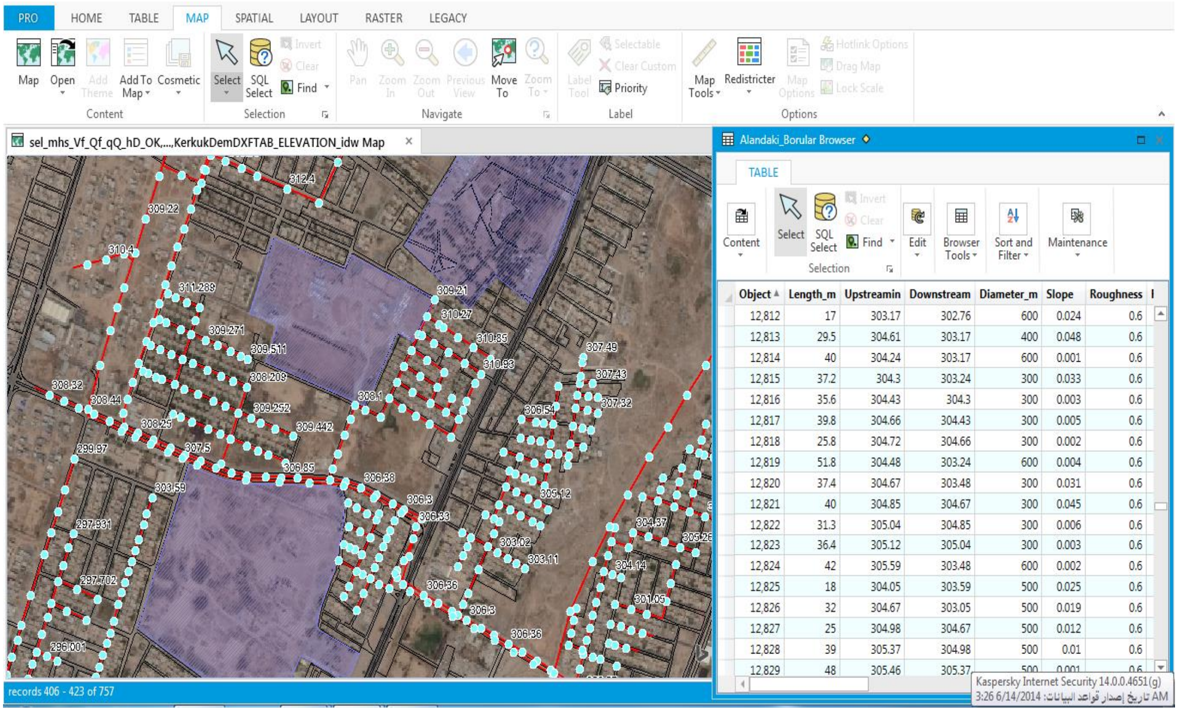


Figure 3.10: A GIS system (Info View)

Most of the physical and economic problems connected to waste and storm water are attributed to one or more of following reasons, the incorrect planning land use, insufficient attention to land drainage in urban planning, and ineffective updating of existing waste and storm water control systems.

One of the particular interest of GIS applications is the automation of infrastructure modeling and information management using modern computer-based technology and calculation techniques to build what is called intelligent infrastructures‘. However, along with the various available applications of a GIS in environmental and wastewater engineering, the readers cannot completely understand the concepts and components of any GIS system without a thorough study of what GIS systems are used for [19]. In general, GIS technology is used to answer the following questions:

- Where is... and how big is…?
- When will it...?

- How many ... are near...?
- What is the shortest path?
- How do these two relate?
- Can we combine this with data from...?
- What has changed since...?

3.5.4. GIS and Decision Making

GIS helps in Decision Support (DS) through providing all reports and documents that are related to a problem and (DS) are a sub-class of management information systems which support analysts, designers, and managers in the decision making process, see Figure 3.11. They can reflect different concepts of decision making and different decision situations. Their primary feature is harnessing computer power to aid the Digital Model (DM) to explore the problem, and increase the level of understanding about which environment decisions are to be through access to data and models appropriate to the decision. They are aimed at generating and evaluating alternative solutions in order to gain insight into the problems trade-offs between various objectives and support the decision making processes [20].

Figure 3.11 GIS and Decision Support [41]

Development involves making decisions as to the choice of a desired path to follow. Decision theory is, in and of itself, a highly complex field. Here, we take a very broad view of decision making as any situation where a decision taker has a choice between alternatives. In the simplest case may be only one alternative and the decision is to take this or not. However, in reality there are usually numerous competing options or alternatives available in any course of action and thus the decision calculus is correspondingly more complex. In contexts where decision making involves action it is important to evaluate also the implementation and results of decisions [20].

GIS has a broad range of applications. Some of the prominent examples are in urban planning, climate science, military use, emergency management, health etc. GIS uses spatially referenced data to establish trends, make detailed location-based analysis, and with the advantage of keeping information-based tracks for an over extended period of time to be used in the future.

Our environment is so complex that sometimes we make decisions with incomplete information. Yet, GIS enables us to build models which are used to describe complex environment along with its related parameters in a much simpler and easier way to increase our understanding and to help us ease the decisions making process. Visually depicted data is far easier to understand than just the raw data itself. In addition, GIS ease the interaction between various factors that the data represents through the availability of analysis tools, for example, in planning a new sanitation development project in a certain area one might need to know initially where the existing sanitation facilities, the condition of these facilities, how sustainable they are, the number of a population it serves, the number of the underserved people and the accessibility to the existing facilities, etc. [21].

3.6. Introduce the Used Technology in Sewerage Utilities

There are several procedures that have been developed and used in sewerage systems for years. But in some cases, administrators or engineers may resist using these new technologies, because they can have strange attitudes towards the new technology. That's why introducing the GIS system in this study and presenting its benefits is considered to be important factor. In addition, its important perceive the maps as visual presentations of the data instead of just graphics or pictures [22].

3.7. GIS Primary Functions in Sewerage Utilities

GIS technology can be used by each of the following wastewater utility, but there are considerable differences in the uses and relative advantages of such technology:

- **Planning**: planning the expansion of the wastewater networks system (present or future demands). A planning utility generally performs estimates of future's rid of wastewater, evaluates the sewer system utilizing these estimates, specifies the required system improvements, and structure's a long term program around these improvements.
- **Engineering**: detailed design and construction of wastewater facilities. The engineering utility within a wastewater utility is generally responsible for facility design, construction, and mapping. Unlike the planning function, engineering deals with facilities as they are actually built.
- **Operation and Maintenance**: operating and maintaining wastewater transmission and outlet facilities. These utilities work on geographically distributed facilities. The primary need on a daily basis is to manage work crews. The technology required to satisfy this need is a database application that provides work order management, work scheduling, and work history logging.

- **Administration**: managing the paperwork and costs associated with operating the wastewater system. This utility functions have been computerized and a wide variety of standard applications now exist to serve administrative needs and to integrate administrative data within a GIS.

Although, GIS system is often seen as an important technology for water and wastewater network planning, design, and optimization. It is sometimes hard to see the real benefits of GIS without well-defined objectives behind its use.

For example, expanding GIS bases requires less time and effort, which makes it more easy-to-use for researchers and engineers with no programming experience. In this way, providing spatial solutions should be area particular and simple to-use through consolidating the force of a complete GIS into an easy to use experience to the field [2]. The users can present and describes information in the form of maps and feature symbols. Such description of information combined with graphical-based analysis tools, users can obtain information about where geographic features are, what they are, and their relation to each other. GIS spatial and attribute database can be used to create reports and maps, often interactively, used in decision making process where multiple alternatives solutions can be explored and tested [23].

From the above discussion, GIS technology can be used for wastewater utility with a flexible capability to store and present geographic information. These features are complementary to applications in which are designed to solve problems of specific activities within a utility. The key requirement, prior to making any investment in technology, is to establish and maintain a long-term vision and plan while focusing on short-term benefits. A rational approach to technology investment for wastewater utilities has to focus on two critical points: database update and system modeling [24].

All in all, wastewater utilities – especially smaller ones – should adopt a slightly conservative approach to use GIS based technologies. It should be emphasized first on the utility‘s immediate needs while stressing the issues of long term investment with regards to data collection and management, and then on following a growth path towards a full GIS environment.

Although a GIS is a very potent decision-making tool, it is just a tool. There is a great temptation to rely too heavily on the computer and stop thinking. There is also a tendency to collect too much spatial data. One more layer of data is not always the answer. Therefore, be warned, and GIS will serve you well.

In additional, GIS can be utilized to execute the 4M management strategy in the field of water, storm water and wastewater. GIS integrates all types of data and applications with a geographic part into one, manageable framework. GIS offers coordinated arrangements in the ranges of arranging and designing, operation and maintenance, and finance and organization.

Likewise, with GIS the conceivable outcomes to map, monitor, model, and maintain water, wastewater, and storm water systems are perpetual by applying the force of GIS to manage them through its full potential in solving water-related problems [25].

3.8. GIS and Combination technologies in Sewerage Utilities

There are several technologies used in sewerage utilities design and implementation process, such that – for example – to calculate the demographic gravity direction or pipe slope/gradient, and more importantly, understanding the topographical heights of any area according to see level. Several modern technologies are used to extract the topographical information represented by a set of Z values are currently used, such as:

3.8.1. Hydraulic Models or DTM Digital Terrain Model

Hydraulic modelling is commonly used to analyze water pressures and identifying bottlenecks in wastewater collection system. Understanding the hydraulic nature of the sewer network system is important especially when developing master plans for sewer and wastewater networks for cities or when developing extensions to the existing network. GIS-based hydraulic modeling activity can thus help in evaluating system performance and identify improvements necessary for such parameters, such as meeting the required water pressure or reducing water-in-basement problem.

The hydraulic model represents a simulation of the natural phenomenon, the model parameters need to reflect the reality of the situation, see Figure 3.12. As a given hydraulic model begins to approximate nature, its further development often takes the path of improving the quality of its parameters. Many times, several experiments must be executed to improve the measurement level of a coefficient and thus to help supply better model predictions [9, 26].

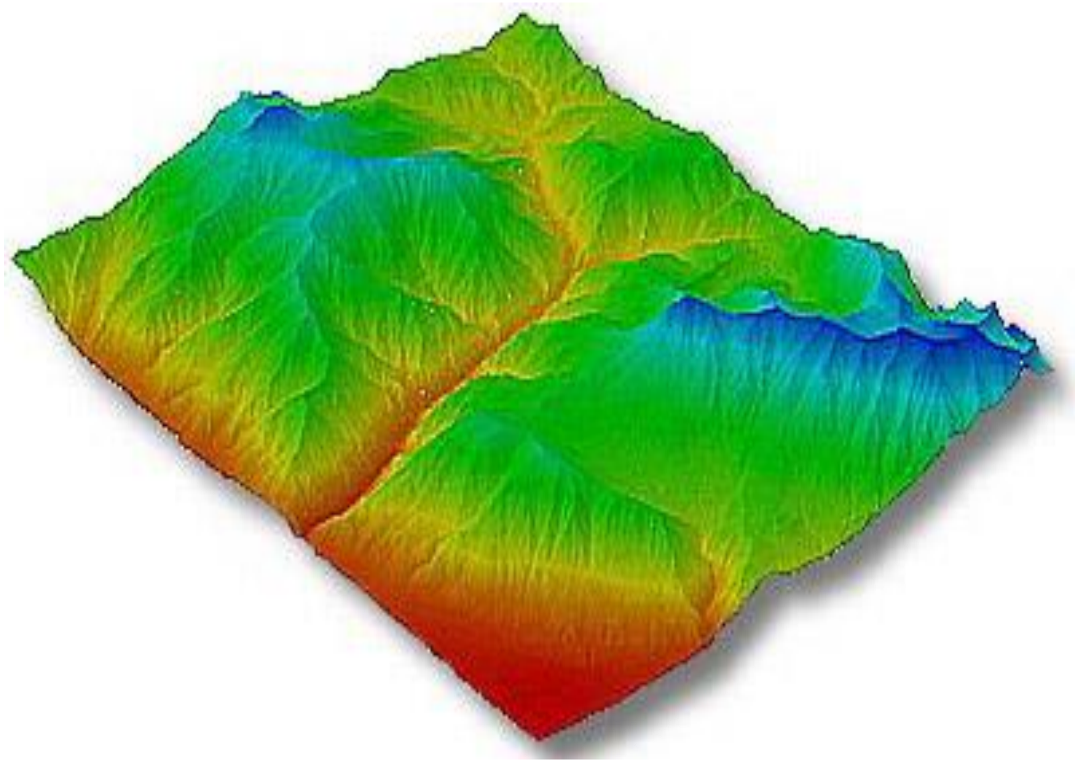


Figure 3.12 (DTM) Digital Terrain Model [42]

3.8.2. DEM Models

Digital Elevation Models (DEM), also called digital terrain models, provide a 3D representation of the real-world topography of the area under study. It describes the topographic surface of the area under study in a digital form, normally as a continuous elevation values. A DEM is a matrix where every cell value represents the elevation at the center point in the corresponding area on the earth's surface, see Figure 3.13. Normally the DEM is interpolated from a line or point data which depends on the areal extent and importance of the study. However, all DEMs models – recently – are constructed through the use of satellite information [9, 25]. DEM models can be used with various other applications, such as:

- Generating a topographical map
- Generating 3D view of the terrain surface
- Developing parameters for hydrologic models
- Determining the volume of proposed reservoirs water
- Determining landslide probability

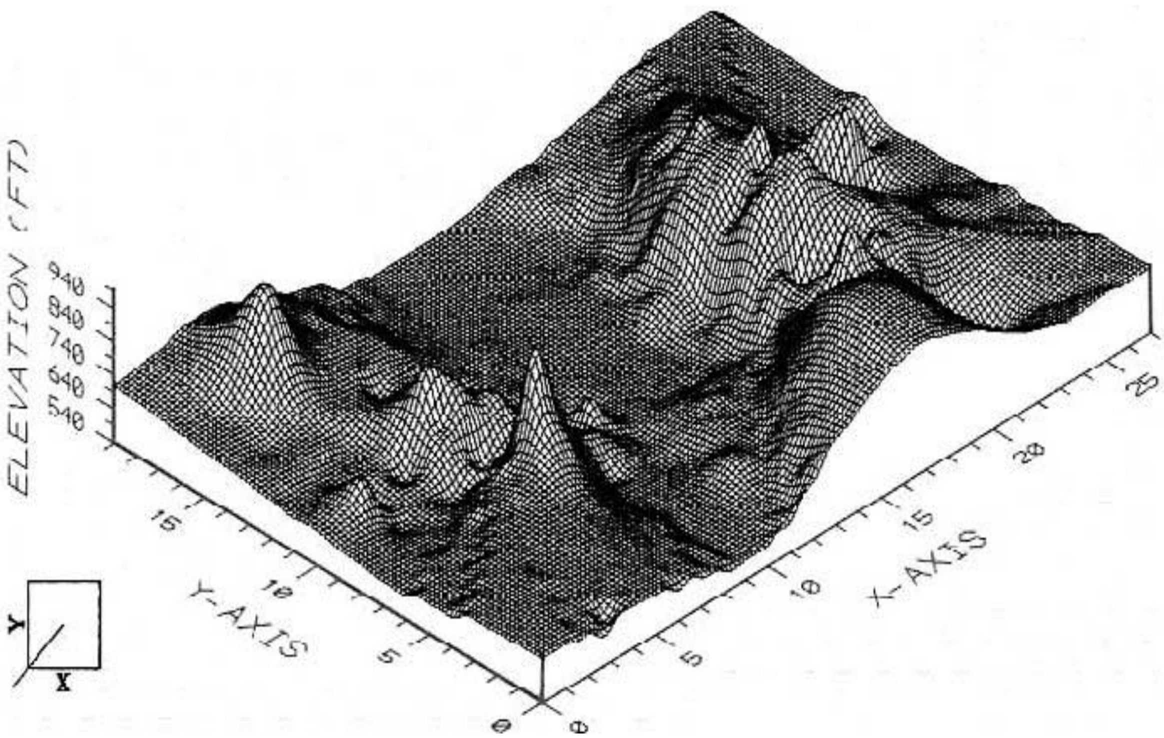


Figure 3.13 DEM Model [25]

Recently, DEM data is widely used for mapping and engineering related applications. The uses include many fields in civil engineering works, agriculture, navigation, geography and others. Another growing trend recently is the use of this product as an additional layer into GIS projects. DEM data generally comes in the form of X, Y; Z coordinates of ground surface [25, 27].

3.8.3. LIDAR Data (Light Imaging Detection and Ranging)

Unlike photogrammetric techniques, which can be time consuming and expensive for large, DEMs can be created alternatively and with accuracy levels ranging from 20 to 100 cm. Laser imaging detection and ranging (LIDAR) is a new system for measuring ground surface elevation from an airplane. The bounced laser beams off the ground can be interpreted into 3D digital models which describe the elevation of the surface with high accuracy and with time being the shortest if compared with other techniques, see Figure 3.14.

LIDAR technology, developed in the mid-1990s, comprises of a global positioning system (GPS), precision aircraft guidance, laser range finding, and high-speed computer processing collectively work together to measure geographical elevation [25].

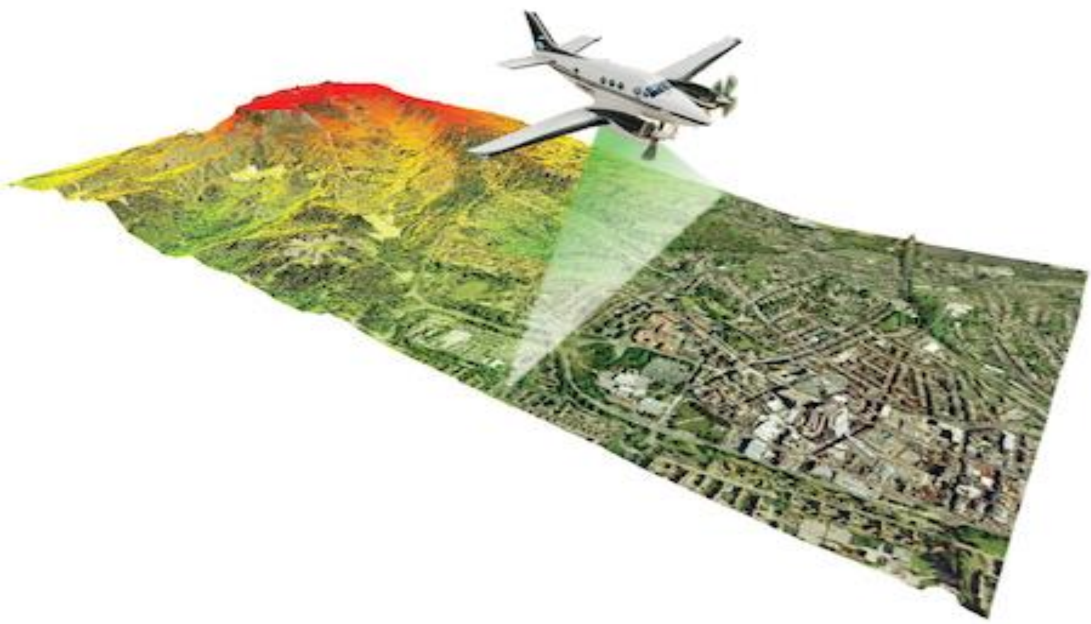


Figure 3.14: LIDAR Technology [43]

3.9. Sanitary Sewer System Design

Sanitary sewer network traditionally comprises of sewer pipes, manholes, pumping stations if necessary, and other appurtenances. Sewer networks in most of its implementations scenarios take advantage of the hydraulic nature of wastewater as to be collected from city areas to treatment plants or to disposal areas. Therefore, importance should be given when designing any sewer network system and it should conforms to several factors such as the size of population, the local topography of the planning area, pipe sizes, finding optimal slopes, and excavation depths. The difficulties of realizing optimal network layout and yet implementing the best hydraulic design can be solved but to a certain extent with the use of optimization techniques; if we consider the vast number of various layouts and alternatives faced by sewer network designers related to for example to pipes and manholes locations, optimum slope, pipes size and other appurtenances. Therefore, it was suggested that the design process of a given sewer network can optimally be accomplished if divided into two phases: (1) Selection of optimal layout, (2) Optimal hydraulic design of the network components. Determination of optimal layout might be considered the most important step in any sewer network design, as it plays the foundation for all subsequent decisions such as the hydraulic design and determining the overall cost [28]. The problem of joint layout and component size determination of a sanitary sewer network can mathematically be defined as:

$$Minimize\ \ C = \sum_{l=1}^{N} L_l K_p(d_l, E_l) + \sum_{m=1}^{M} K_m(h_m)$$

Where, C= cost function of sanitary sewer network; N= total number of sewer pipes; M= total number of manholes; L_l = the length of pipe l ($l=1,\ldots, N$); K_p = the unit cost of sewer pipe provision and installation defined as a function of its diameter (d_l) and average cover depth (E_l); and K_m = the cost of manhole construction as a function of manhole height (h_m).

3.9.1. Design Pipe Slope

Slope is the incline or gradient of a surface and is commonly expressed in a percent form. Among the three parameters which describes the terrain specifics of any geographical area (slope, aspect and altitude), slope is very important for assessing land capability, stability and irritability for environmental management purposes, and equally important for formation and management of water, wastewater, storm water, soil because of its influence on runoff, drainage, erosion and irrigation. The slope gradient of the land has great influence on selection of the drainage methods. Slope is expressed as the change in elevation over a certain distance, see Figure 3.15. In DEM data, the distance is the size of its pixel, and slope is calculated for each cell in the raster DEM image through calculating the maximum rate of change in elevation over each cell and its eight neighbors [29].

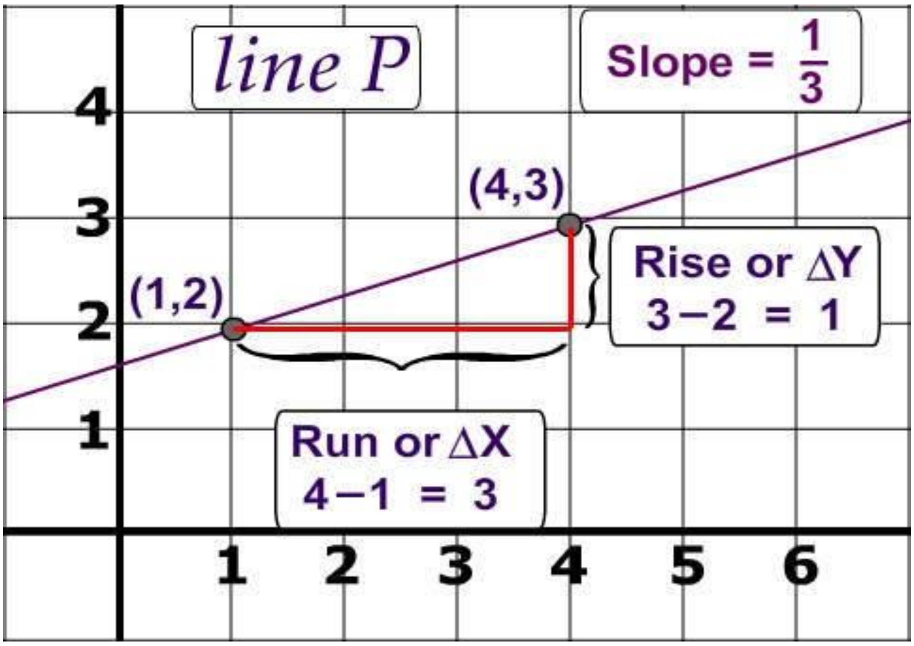


Figure 3.15 Slope gradient

Where ground slopes are comparatively flat, the slopes of pipe should be designed so that the velocity of flow will increase progressively or at least will be maintained steady. Minimum pipe slope is recommended as show in following Table 3.3.

Slope (m/1000m)	Nominal Pipe Diameter (mm)
4.00	250
3.17	315
2.50	400
2.00	500
1.67	600
1.43	700
1.25	800
1.11	900
1.00	1000
0.83	1200
0.71	1400
0.63	1600
0.56	1800
0.50	2000
0.40	2500

Table 3.3 Minimum of slope based on diameter of pipe [29]

3.9.2. Design Velocity Range

The velocity of flow of any sewer network should not exceed the maximum permissible value and also should not fall below the minimum value. Minimum value is selected in such a way that sedimentation kept as a minimum, the optimum value is considered to be at 0.60 m/s for secondary trunks and at 1.0 m/s for main trunks. While maximum velocity should be at 2.5 m/s in general. It's also important to consider designing the network in such a way prevent the risk of blockage of storm water, or at least keep the risk to the minimum [30, 32].

The accumulation of solid deposits in drains or sewers pipes plays an important factor that increases the risk of flooding, and then, the risk of pollution. Designed drains and pipes must provide sufficient shear stress to limit the buildup of solids deposits to levels that don't significantly increase this risk [30].

Among the required maintenance for any sewer network system is frequent cleansing of pipes which also can ensure blockage prevention or flooding. A self-cleansing mechanism can be achieved if the velocity of sewer water is at 0.75 m/s for branches and laterals and at 1.0 m/s for main trunk according to design department in directorate of Kirkuk sewerage. The range of velocity limitation is shown in Table 3.4

<table>
<tr><th colspan="2"></th><th>Min(m/s)</th><th>Max(m/s)</th></tr>
<tr><td rowspan="2">By gravity</td><td>Secondary Trunk</td><td>0.6</td><td>2.5</td></tr>
<tr><td>Main Trunk</td><td>1.0</td><td>2.5</td></tr>
<tr><td colspan="2">Pressurized Pipe</td><td>1.0</td><td>3.0</td></tr>
</table>

Table 3.4: Velocity Range

3.9.3. Design Equation and Hydraulic Bases

The hydraulic basis of flow in storm water collection network of cities is assumed to be of non-permanent and spatially variable type. Such simplification has been accepted so that the design of these channels can be conducted using uniform permanent flow theories (or so-called uniform flow) and regarding the maximum design flow rate at the end of the channel. Manning equation is a basic equation governing uniform flow and is appropriate for calculating the dimensions of channels [31, 32].

The cross section size of sewer pipes and channels shall be calculated according to Manning's formula. Because of its simplicity and valuable results is widely applied for uniform permanent flow, this relation is as follows:

$$Q = \frac{1}{n} S^{\frac{1}{2}} R^{\frac{2}{3}} A$$

Where:

S: Longitudinal slope of channel

A: Cross-sectional area of flow (m^2)

R: Hydraulic radius (m).

n: Manning coefficient of roughness

Q: Discharge (m^3 / s).

3.9.4. Hydrological Studies of Surface Waters (Estimating Design Discharge)

The hydrologic study of surface waters is the main approach to estimate the intensities of rainfall water which is a key important input required in storm water network design and analysis. Another important application of hydrologic study is the estimation of watersheds, which contributes to surface runoff in the city flood days that can influence the sewerage network performance [32, 33].

In addition, a third important factor that must be considered in designing surface water collection network is calculating the proposed design discharge capacity of each of the network components. Such capacity can be obtained by conducting the following hydrological studies:

- Determining the catchment area of the project.
- Determining the catchment subareas of the project.
- Selection of design return period.
- Estimating design discharge using current methods.

The study area is contained in two main watersheds; the first covers the most area of the city around Al-khasa River, and the second with an outlet in the west of Kirkuk city, which covers a small western portion of the city. GIS software is used to delineate the city watershed depending on the available DEMs from the Kirkuk city. Figure 3.16 shows the watershed contained in Kirkuk city.

Sub-watershed within the main watershed was determined according to the slope and drainage system details within the main watershed. Figure 3.16 also shows the sub-watershed overlaid on the Kirkuk city map.

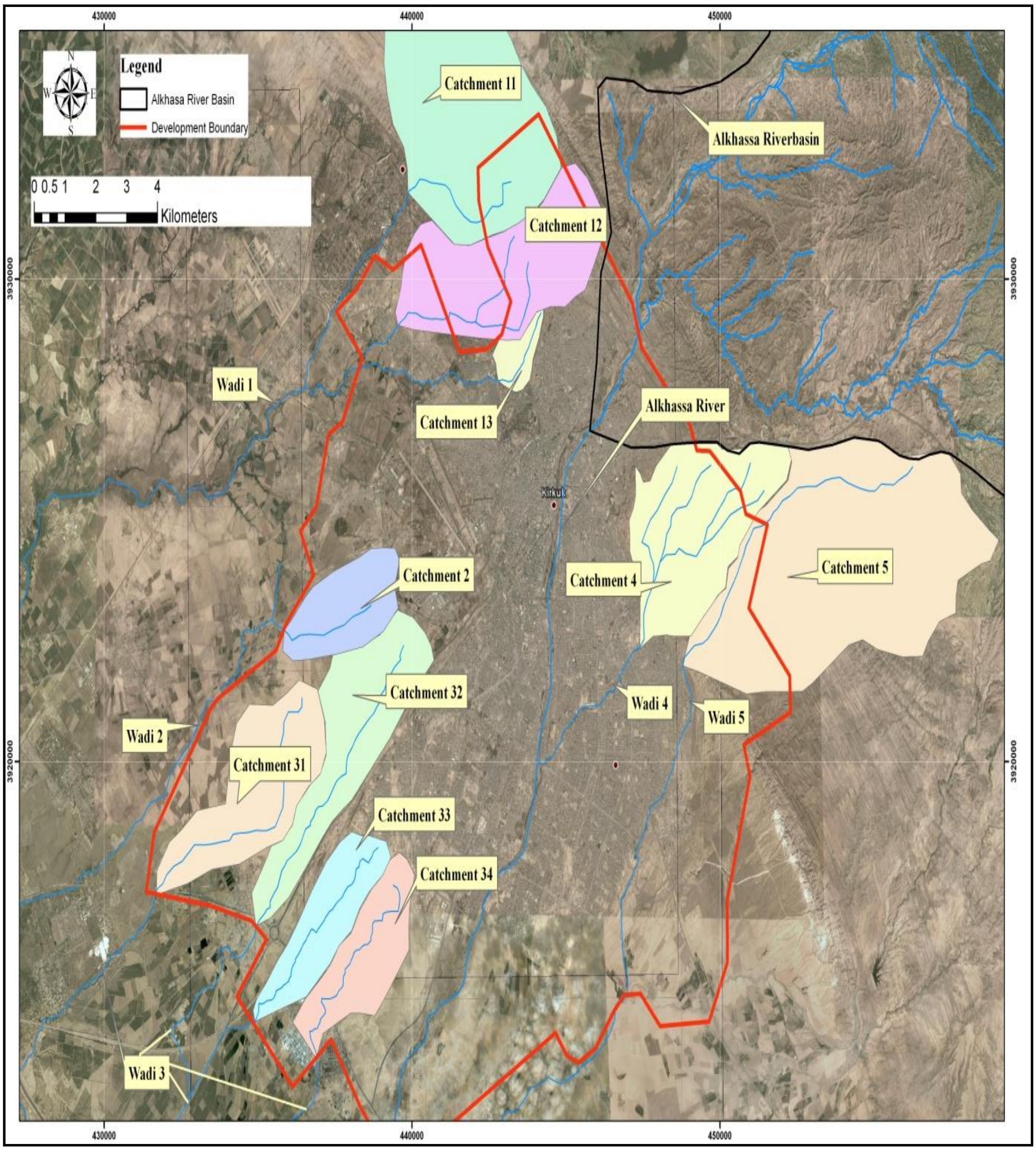


Figure 3.16 Hydrologic watershed and Sub-watershed and their coverage on the Kirkuk city [44]

3.10. GIS Applications and Software in Sewerage Utilities

Even though GIS technology began in the 1960s, GIS applications for the water industry did not evolve until the late of eighties. Water industries witnessed an extensive GIS based solutions in the early nineties for modeling, mapping, and facilities management plans. By the end of 2000, approximately 90% of the water utilities in the United States were using GIS technology in some form [25, 34]. The use of GIS as a management tool has grown since the beginning of this century with a sustainable increase in the number of users too. Utilities that are using GIS successfully have seen increased productivity and increased efficiency which saves time and money. The Environmental Systems Research Institute (ESRI) has been a significant contributor to GIS applications in the water industry. In 2009, ESRI started a Water Utility Resource Center for the utility needs of over 300,000 worldwide users [35].

3.11. Network analysis

Network analysis is a technique by which a linear path between two or more points which describes the flow path of a liquid through a specific area is to be studied. Network analysis is important and useful especially in hydrology, water resources, transportation, and other disciplines which are concerned about studying and understanding liquid flow. This flow is not limited to water but can also be applied on vehicles, utility and communication lines. Such analysis depends on different algorithms and techniques which can be organized into categories depending on network types [36], and they are:

- **Direct flow**: Flow direction of elements is determined only by the network characteristics such as geometric networks, utility networks (water and sewer).
- **Undirected flow:** Flow direction of elements not only determined by the network such as transportation networks (streets).

3.12. Buffering

Is a technique by which a boundary of known width is drawn around a point or a line feature? Some examples of point buffers may be a zone around a hazardous waste site or around a tree that is a nest of a particularly endangered bird. Examples of linear buffers may be an area around a stream to prevent logging or an area around a utility pipeline to prevent digging. A related function is generally referred to as proximity searches [37], see Figure 3.17.

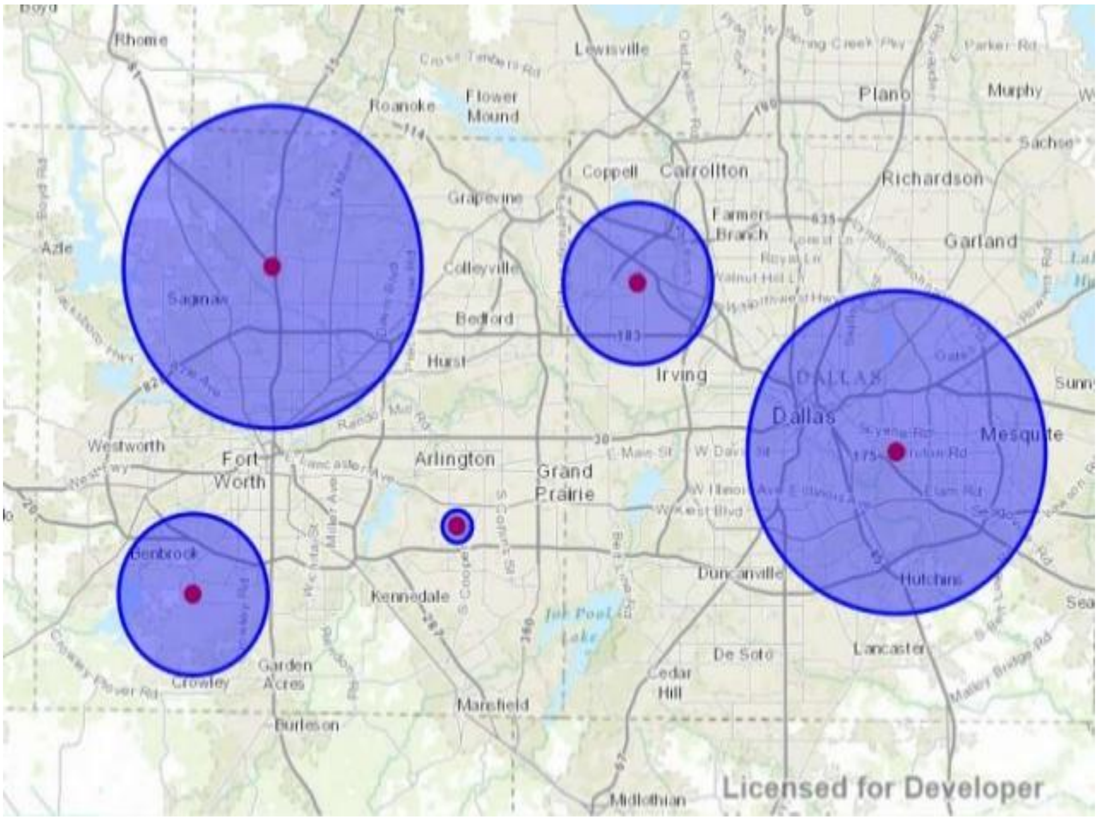


Figure 3.17 Sewer network buffering [45]

Proximity searches can be used to identify adjacencies between particular features or data classifications. For example, identifying all surrounding sewerage manholes within a specific radius from a given point of the study area. Such search can be helpful in locating potential outlet points, and then the extracted details of these nearest points (i.e. manholes) can be used for further investigations.

3.13. Planning and Modelling

The nature of behind using models is to increase our understanding or to find answers to problems which can be applied to a wide spectrum of fields and applications. For example, they can be used to gain the better understanding of a certain phenomenon, to guide further investigations of the analyzed system, to predict the spatial and temporal evolution of a system or simply as an educational tool for improved visualization of underlying processes. In environmental sciences [38], which is a highly interdisciplinary and collaborative discipline, models help to gather knowledge and to produce results that can directly be used in the context they have been elaborated for.

CHAPTER FOUR

IMPLEMENTATION METHODOLOGY

For more accurate and effective management and implementation of sewerage collection network in an area which characterized as nearly a flat region, MapInfo GIS software has been used and coupled with a Digital Elevation Model (DEM) and was applied to our case of study (see Section 1.2).

The study is based on GIS modelling and engineering techniques carried out on the proposed sewerage network system. Preliminary design for the pilot area of the integration of GIS programs, geodatabase, DEM and maps to generate the software model.

The software model of the sewerage collection network has been used as an integrated tool to be used to optimize the sewerage network management and addressing development continuity. Figure 4.1 summarizes our research and implementation methodology.

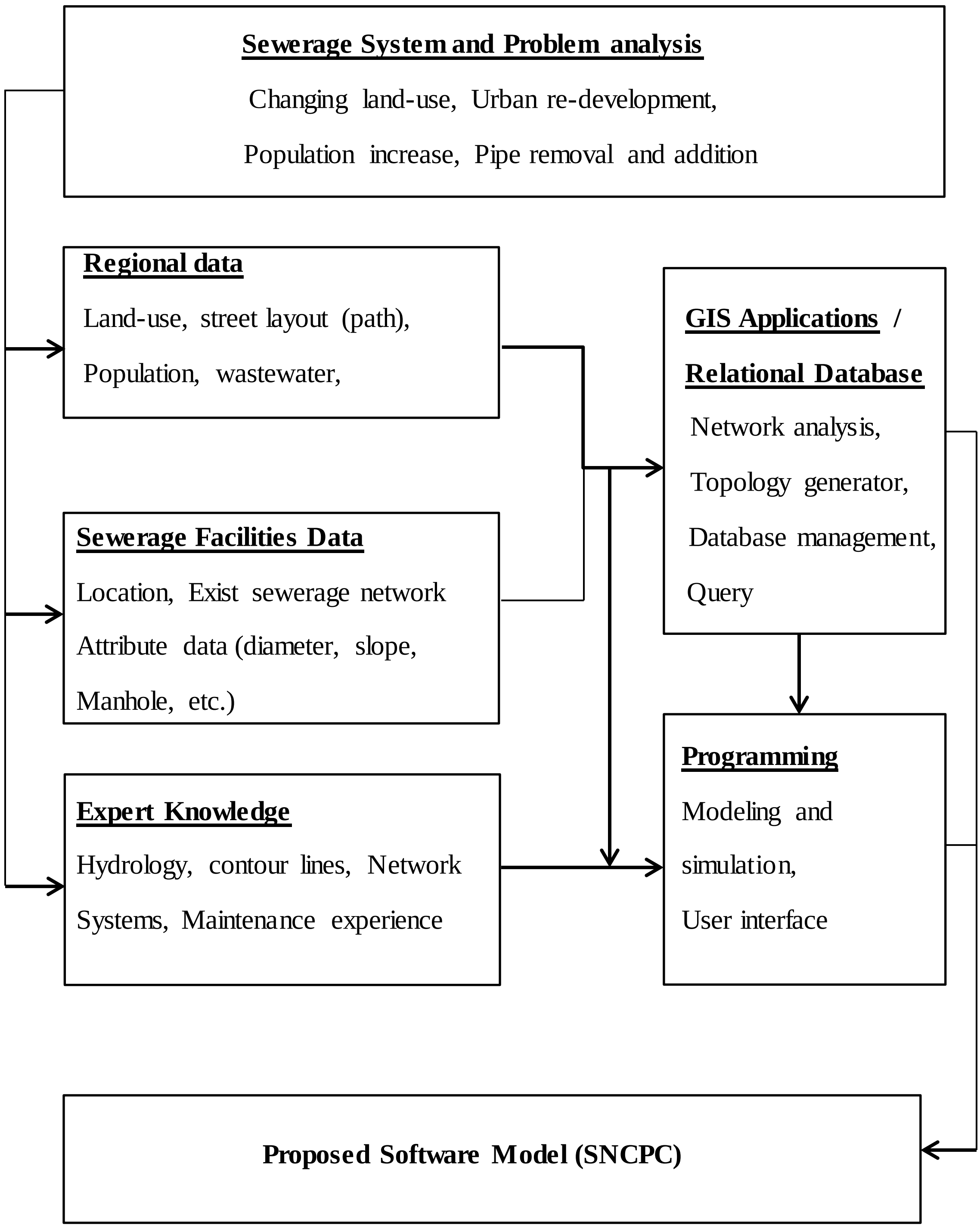


Figure 4.1 Research and implementation methodology flowchart

4.1. Software

MapInfo professional v12.0.2 [39], has been used for this work to build the SNCPC model to analyze the cartographical and spatial information of the area under study. Such information was obtained from the geodatabase file of the related area. Figure 4.2 shows the grid, streets layout and contour layer of Kirkuk city through MapInfo.

Figure 4.2 MapInfo software [39]

Further, DEM layer has been used to find the Z value of slope direction of drainage water. The set of Z values simulates the real-world terrain surface topography which explain the topographical heights according to see level. The Figure below shows the digital elevation model of Kirkuk city.

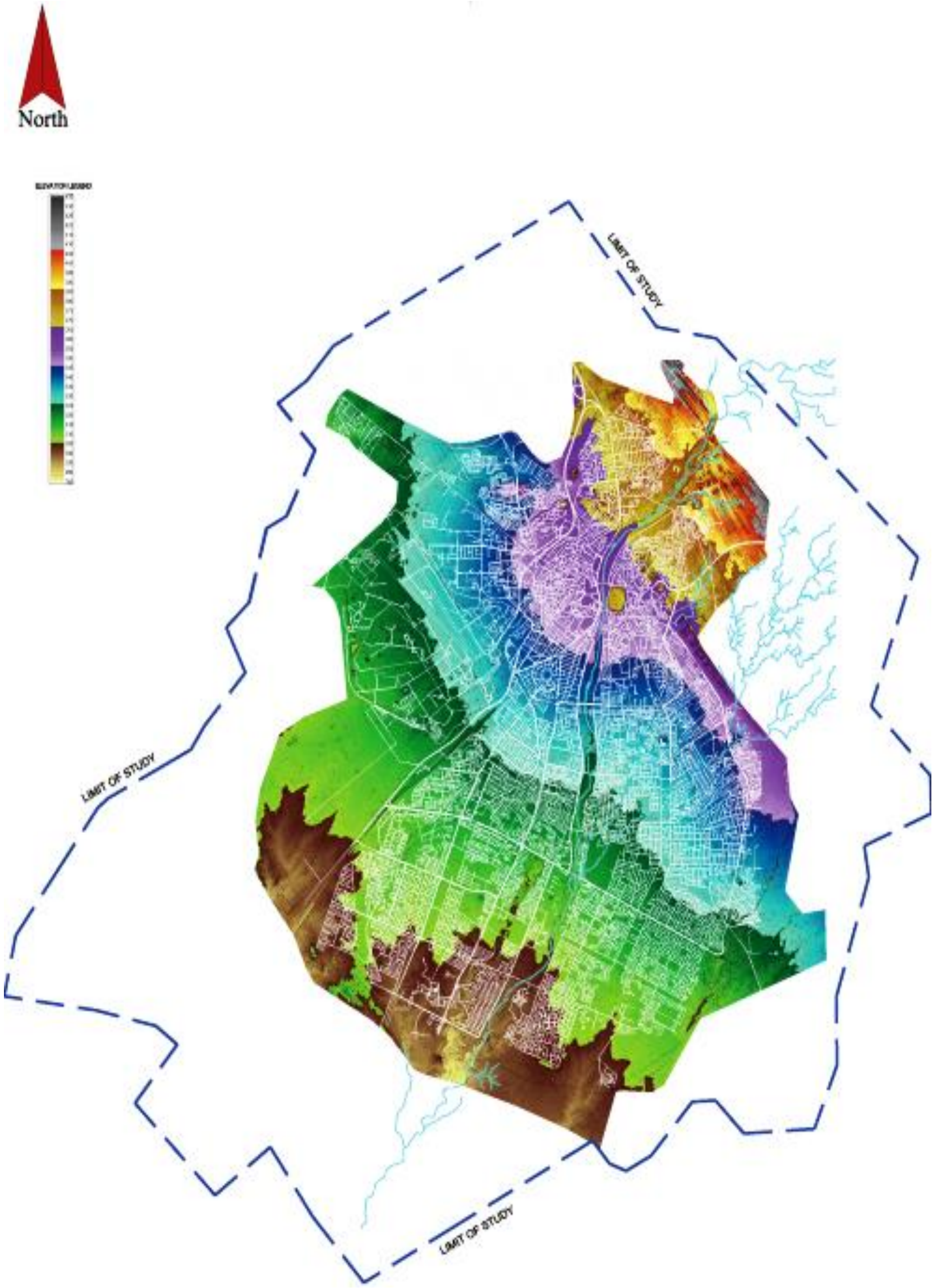


Figure 4.3 Digital Elevation Model of Kirkuk city (2013) [44]

4.2. Data

Geodatabase of Kirkuk sewerage network, updated in 30.08.2016, was used in buffering technique to identify the appropriate neighboring manholes to connect the new network with the existing city sewerage network. Table 4.1 (a and b) shows a sample data of manhole and pipe table from geodatabase of Kirkuk sewerage network.

Manhole

Sectornumber_hay	ManholeID	Depth	Invertlevel	Groundelevation	HighPipeelevation	Wallmaterial	Noofbond	Lifecyclestatus	Noofgullyconnecte	Subtypeofmanhol	Note
413	11	1.19	97.54	98.73	97.54	reinforce	2	Active	2	AS	<Null>
413	12	1.08	97.45	98.53	97.45	reinforce	2	Active	2	AS	<Null>
413	13	1.07	97.27	98.34	97.27	reinforce	2	Active	2	AS	<Null>
413	14	1.17	97.07	98.24	97.07	reinforce	2	Active	2	AS	<Null>
413	15	1.59	96.42	98.01	96.42	reinforce	2	Active	2	AS	<Null>
413	16	1.17	96.83	98	96.83	reinforce	2	Active	2	AS	<Null>
413	17	1.49	96.32	97.81	96.32	reinforce	2	Active	2	AS	<Null>
413	18	1.48	96.32	97.8	96.32	reinforce	2	Active	2	AS	<Null>
413	19	1.44	96.18	97.62	96.18	reinforce	2	Active	2	AS	<Null>
413	20	1.79	95.78	97.57	95.78	reinforce	2	Active	2	AS	<Null>
413	21	1.78	95.76	97.54	95.76	reinforce	2	Active	2	AS	<Null>
413	22	1.81	95.71	97.52	95.71	reinforce	2	Active	2	AS	<Null>
413	23	1.76	95.67	97.43	95.67	reinforce	2	Active	2	AS	<Null>
413	24	1.77	95.59	97.36	95.59	reinforce	2	Active	2	AS	<Null>
413	25	1.33	95.98	97.31	95.98	reinforce	2	Active	2	AS	<Null>
413	26	1.71	95.44	97.15	95.44	reinforce	2	Active	2	AS	<Null>
413	27	2.03	95.35	97.38	95.35	reinforce	2	Active	2	AS	<Null>
413	28	2.16	95.44	97.6	95.44	reinforce	2	Active	2	AS	<Null>
413	29	2.23	95.41	97.64	95.41	reinforce	2	Active	2	AS	<Null>
413	30	2.26	95.39	97.65	95.39	reinforce	2	Active	2	AS	<Null>
413	31	2.43	95.24	97.67	95.24	reinforce	2	Active	2	AS	<Null>
413	32	2.46	95.21	97.67	95.21	reinforce	2	Active	2	AS	<Null>
413	33	2.64	95.09	97.73	95.09	reinforce	2	Active	2	AS	<Null>
413	34	2.65	94.93	97.58	94.93	reinforce	2	Active	2	AS	<Null>
413	35	2.74	94.78	97.52	94.78	reinforce	2	Active	2	AS	<Null>
413	36	2.28	94.99	97.27	94.99	reinforce	2	Active	2	AS	<Null>
413	37	1.58	95.43	97.01	95.43	reinforce	2	Active	2	AS	<Null>
413	38	1.85	94.95	96.8	94.95	reinforce	2	Active	2	AS	<Null>

0 (0 out of 17733 Selected)

(a)

Pipe

OBJECTID	Length_m	SectorNo_Hay	UpstreamInvert_m	DownstreamInvert_m	Slope	Diameter_m	Roughnes	PipeThickness_mm	Material	InstallDate	SubtypeOfFlow	ExteriorCoating	LifeCycleStatus	PipeType	Cross	Gr
417	9.961217	318	47.25	47.2	0.005	500	0.6	14.6	PVC	02/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
2339	9.961217	318	47.25	47.2	0.005	500	0.6	14.6	PVC	02/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
53	19.20003	126	47.27	48.06	0.21	500	0.6	14.6	PVC	01/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
398	11.000003	614	47.3	47.2	0.1	600	0.6	18	PVC	04/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
425	25.200002	318	47.32	47.25	0.004	500	0.6	14.6	PVC	03/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
2347	25.200002	318	47.32	47.25	0.004	500	0.6	14.6	PVC	03/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
389	16.219169	614	47.33	47.25	0.08	600	0.6	18	PVC	28/12/2008	GravityMain	smoother	Active	Collector	Circula	clear
390	23.699992	614	47.43	47.33	0.01	600	0.6	18	PVC	30/12/2008	GravityMain	smoother	Active	Collector	Circula	clear
424	28.7	318	47.45	47.32	0.005	500	0.6	14.6	PVC	04/12/2009	GravityMain	smoother	Active	Collector	Circula	clear
2346	28.7	318	47.45	47.32	0.005	500	0.6	14.6	PVC	04/12/2009	GravityMain	smoother	Active	Collector	Circula	clear
400	17.500002	614	47.56	47.6	0.04	600	0.6	18	PVC	20/04/2009	GravityMain	smoother	Active	Collector	Circula	clear
391	27.999953	614	47.6	47.43	0.17	600	0.6	18	PVC	01/04/2009	GravityMain	smoother	Active	Collector	Circula	clear
399	30.299959	614	47.6	47.3	0.3	600	0.6	18	PVC	15/04/2009	GravityMain	smoother	Active	Collector	Circula	clear
392	17.099976	614	47.65	47.6	0.05	600	0.6	18	PVC	01/06/2009	GravityMain	smoother	Active	Collector	Circula	clear
423	34.700011	318	47.65	47.45	0.006	500	0.6	14.6	PVC	30/04/2009	GravityMain	smoother	Active	Collector	Circula	clear
2345	34.700011	318	47.65	47.45	0.006	500	0.6	14.6	PVC	30/04/2009	GravityMain	smoother	Active	Collector	Circula	clear
393	23.099971	614	47.67	47.65	0.02	600	0.6	18	PVC	01/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
401	23.600023	614	47.7	47.56	0.14	600	0.6	18	PVC	25/04/2009	GravityMain	smoother	Active	Collector	Circula	clear
394	23.449979	614	47.72	47.67	0.05	600	0.6	18	PVC	15/01/2009	GravityMain	smoother	Active	Collector	Circula	clear
395	17.300037	614	47.83	47.72	0.11	600	0.6	18	PVC	25/01/2009	GravityMain	smoother	Active	Collector	Circula	clear
396	15.600042	614	47.84	47.83	0.01	600	0.6	18	PVC	02/05/2009	GravityMain	smoother	Active	Collector	Circula	clear
422	27.49997	318	47.87	47.65	0.008	500	0.6	14.6	PVC	05/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
2344	27.49997	318	47.87	47.65	0.008	500	0.6	14.6	PVC	05/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
402	22.600041	614	47.89	47.7	0.19	600	0.6	18	PVC	05/01/2009	GravityMain	smoother	Active	Collector	Circula	clear
397	17.499983	614	47.91	47.84	0.07	600	0.6	18	PVC	15/02/2009	GravityMain	smoother	Active	Collector	Circula	clear
412	36.099958	614	47.95	47.91	0.04	600	0.6	18	PVC	28/02/2009	GravityMain	smoother	Active	Collector	Circula	clear
404	21.000014	614	47.98	47.97	0.01	600	0.6	18	PVC	05/10/2009	GravityMain	smoother	Active	Collector	Circula	clear
413	9.922837	614	48	47.95	0.05	600	0.6	18	PVC	03/05/2009	GravityMain	smoother	Active	Collector	Circula	clear
52	23.999975	126	48.06	48.17	0.11	500	0.6	14.6	PVC	01/05/2009	GravityMain	smoother	Active	Collector	Circula	clear
406	27.300018	614	48.1	48.2	0.1	600	0.6	18	PVC	22/05/2009	GravityMain	smoother	Active	Collector	Circula	clear
411	29.899971	614	48.12	48	0.12	600	0.6	18	PVC	15/03/2009	GravityMain	smoother	Active	Collector	Circula	clear
51	31.899979	126	48.17	47.82	0.35	500	0.6	14.6	PVC	01/04/2009	GravityMain	smoother	Active	Collector	Circula	clear

0 (1 out of 16868 Selected)

Pipe

(b)

Table 4.1 Geodatabase sample: (a) manhole table, (b) pipe table [46]

Kirkuk streets layer produced by GIS was used to check the degree of matching between the street layout and the path of the new line between the outlet manhole and target manholes, see Figure 4.4.

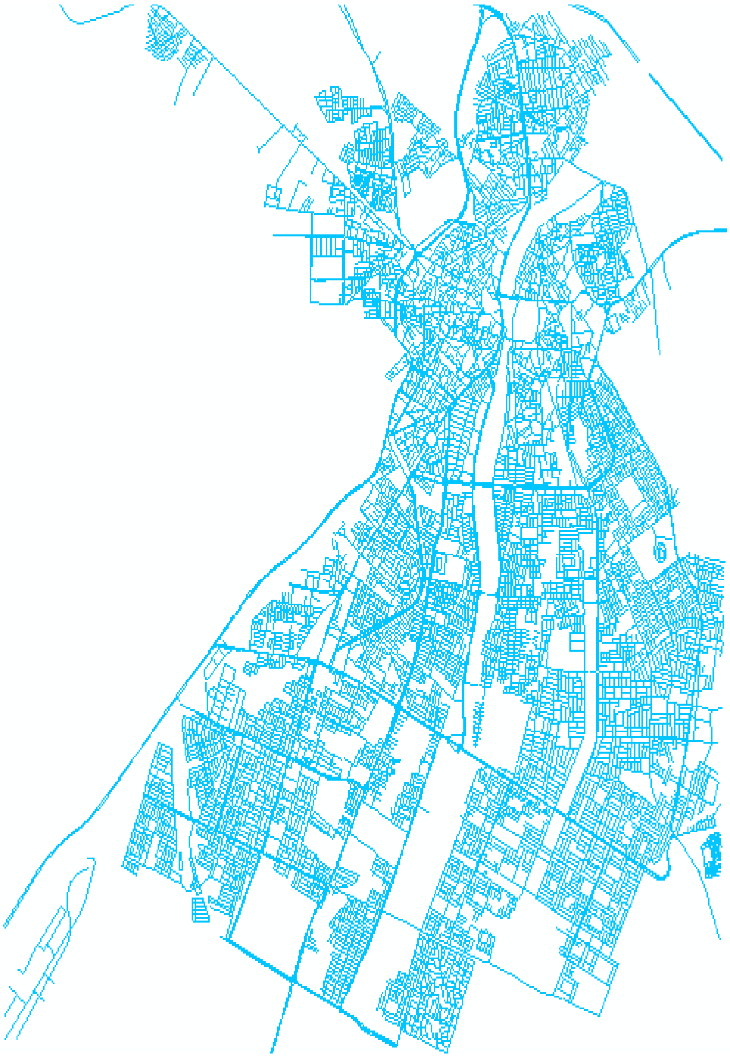


Figure 4.4 Kirkuk streets layer [44]

Kirkuk satellite raster image (Figure 4.5) 2014 used to define the area under study and to know the path of the newly designed lines represented by (x, y) coordinates.

Figure 4.5 Kirkuk satellite raster image [44]

4.3. Implementation Procedure

The following summarize the procedure steps of this study:

1. The satellite image of Kirkuk opened in MapInfo as shown in Figure 4.5.
2. The DEM layer data imported to MapInfo as shown in Figure 4.6.

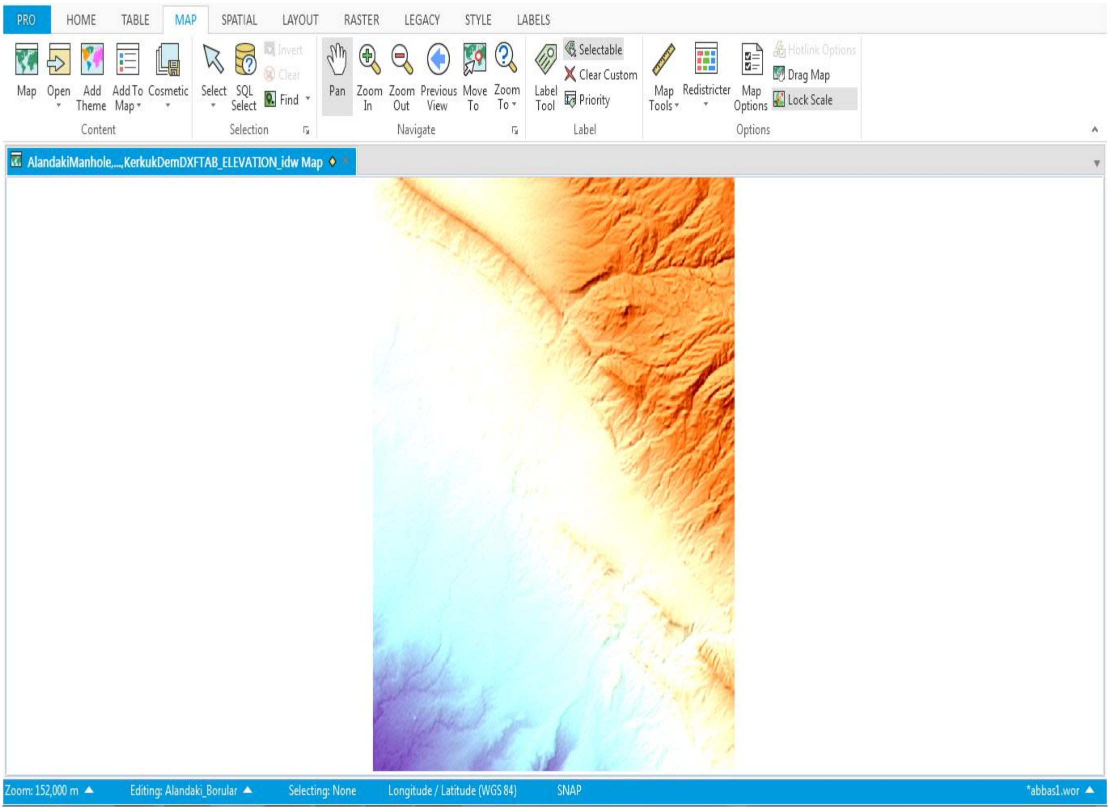


Figure 4.6 DEM layer data of area under study [44]

3. The geodatabase of sewerage network of Kirkuk city was then added to MapInfo application as shown in Figure 4.7.

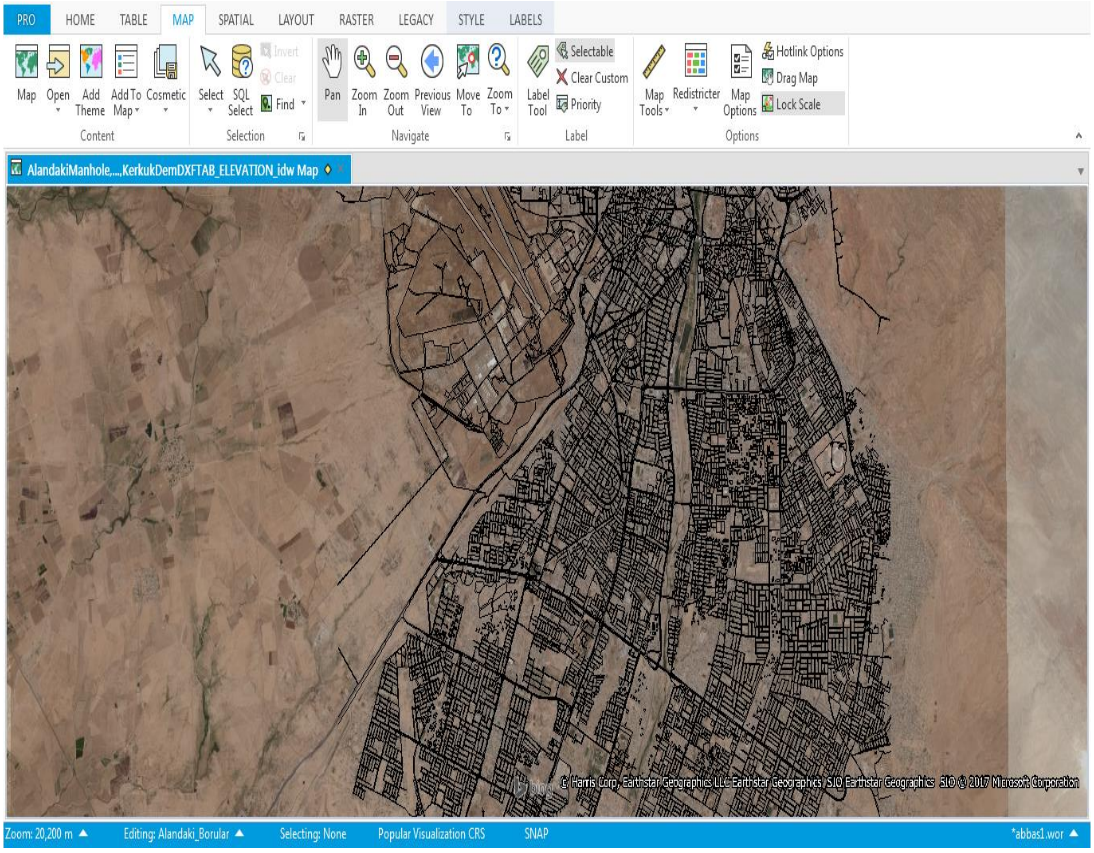


Figure 4.7 Sewerage network data of Kirkuk [44]

4. The SNCPC code is written using Map Basic instructions in MapInfo professional environment to derive the slope by extracting elevation value from the raster data of the DEM at locations of sewerage junctions or manholes, see Figure 4.8. The slope is then calculated by considering elevation difference from upstream junction to adjacent downstream junction using the Manning formula (see Section 3.7.1) (Source code: see Appendix A).

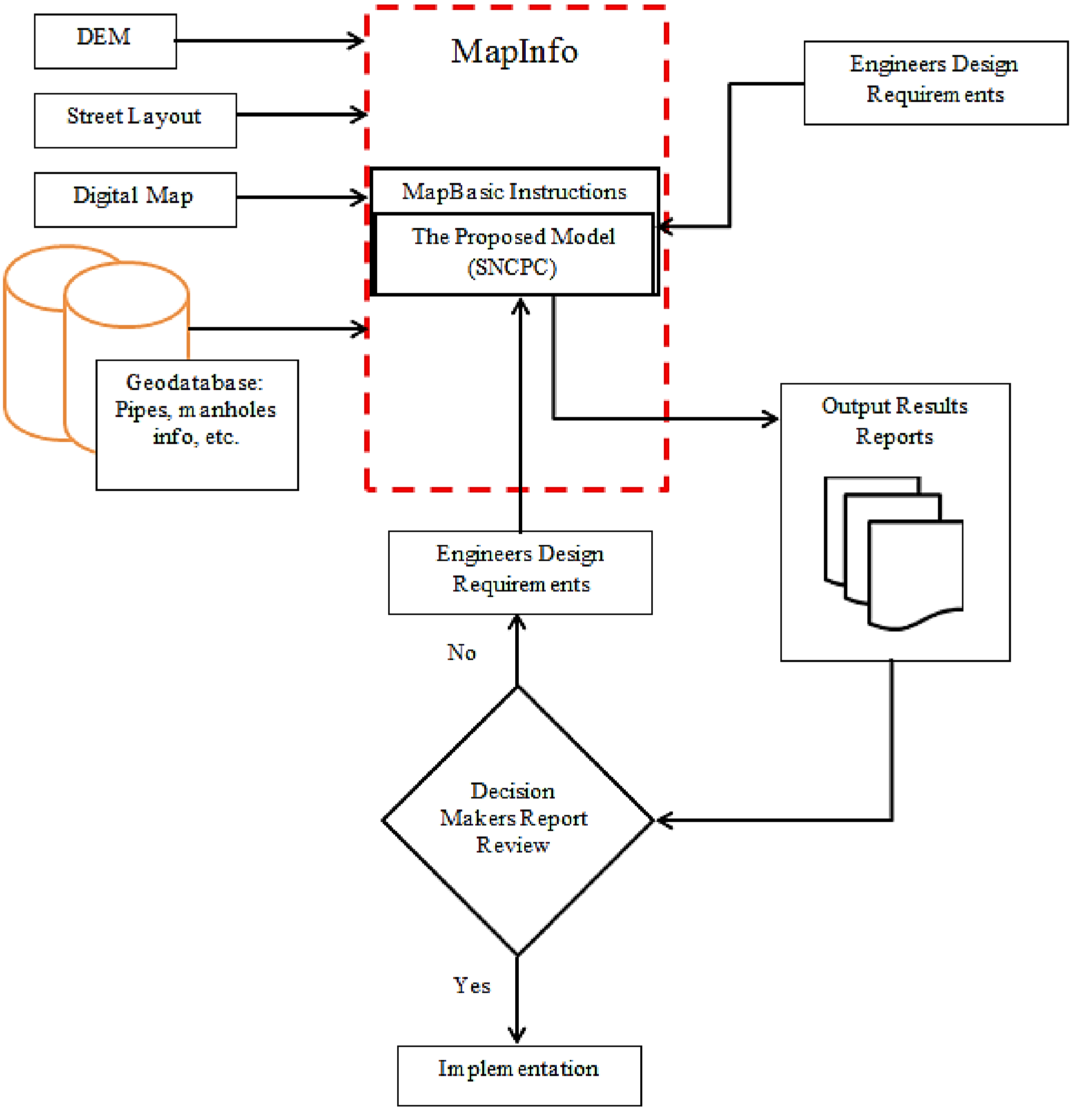


Figure 4.8 SNCPC model flowchart

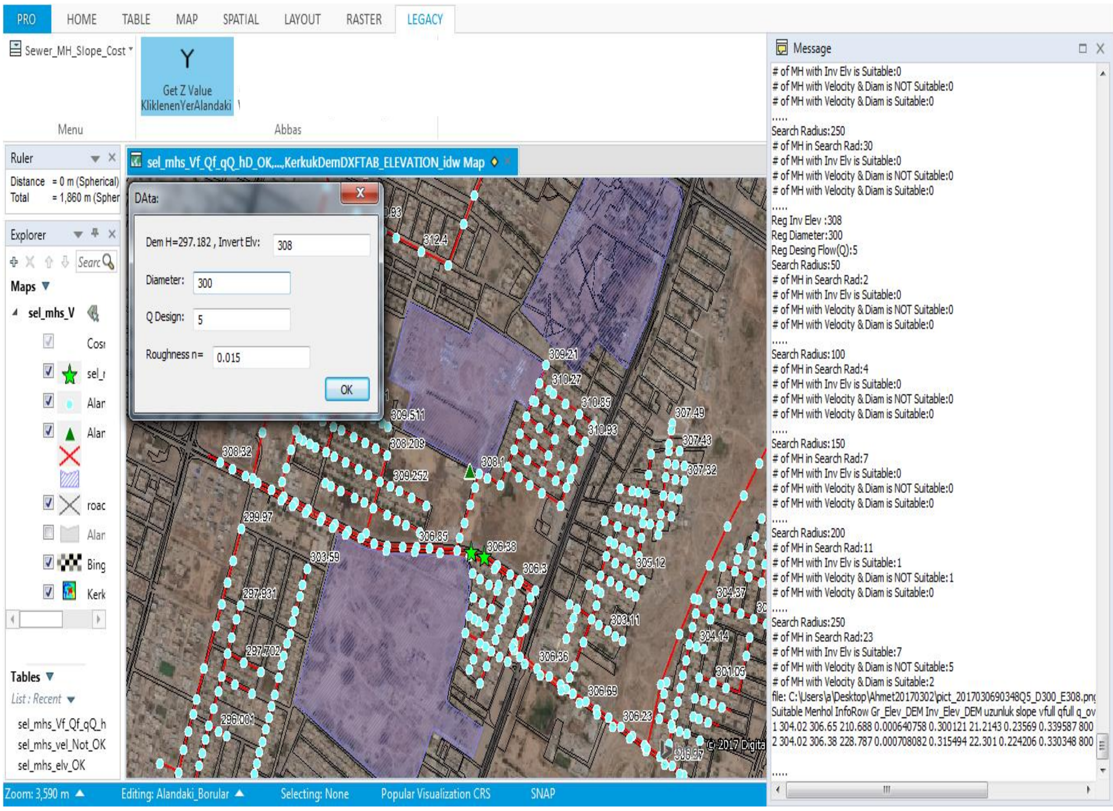


Figure 4.9 SNCPC model dialog for data entry

From the dialog shown in Figure 4.9, the SNCPC software model requires four main parameters: invert elevation (outlet manhole depth), connection pipe diameter (from outlet manhole to inlet manhole), Q-Design (describes network throughput, (Q= n^3/h), and pipe roughness. Searching for the appropriate inlet manholes is achieved through the use of buffering technique.

Buffering is the process of defining a search area by drawing a circle centered at the outlet manhole for a given radius. SNCPC model uses an automatically-incremented radius of the proposed buffer at any given outlet point, starting from 50 meter and going through 100, 150, 200, 250 meter respectively. At every stage, a list of manholes according to the given radius is buffered and compared to all the required given design parameters. The following algorithm details the SNCPC model:

```
radius = 0
for i 1 to 5 do
      radius = radius +50
     get all manholes within radius distance from geodatabase and save it in
    Buffer_list
          for each element in Buffer_list do
                 If the invert elevation of the manhole inside the buffered area is lower
than
                     invert elevation of the outlet manhole
                   Then: if the pipe diameter>= outlet manhole pipe diameter
                           Then: select it into suitable_manholes_list
          end for
          clear Buffer_list
          print suitable_manholes_list
          clear suitable_manholes_list
end for
end
```

Thereafter, and after applying the five buffering stages, a complete report is printed describes in details the number of suitable manholes found at each stage, number of not suitable manholes (drop out), along with tabulated information data of suitable manholes, as shown below:

Require Invert Elevation: 308

Require Diameter: 300

Require Design Flow (Q): 5

Search Radius: 50

# of MH in Search Rad:0

# of MH with Invert Elevation is Suitable: 0

# of MH with Velocity & Diameter is NOT suitable: 0

# of MH with Velocity & Diameter is Suitable: 0

.....

Search Radius: 100

# of MH in Search Rad:0

# of MH with Invert Elevation is Suitable: 0

# of MH with Velocity & Diameter is NOT suitable: 0

# of MH with Velocity & Diameter is Suitable: 0

.....

Search Radius: 150

# of MH in Search Rad:1

# of MH with Invert Elevation is Suitable: 1

# of MH with Velocity & Diameter is NOT suitable: 0

# of MH with Velocity & Diameter is Suitable: 1

Suitable Manhole Information.

Row	Gr_Elev	Inv_Elev	Length	slope	vfull	qfull	PipeDiam
1	303.079	307.09	116.143	0.000783516	0.331874	23.4588	400

.....

Search Radius: 200

# of MH in Search Rad:6

# of MH with Invert Elevation is Suitable:4

# of MH with Velocity & Diameter is NOT suitable: 3

# of MH with Velocity & Diameter is Suitable: 1

Suitable Manhole Information

Row	Gr_Elev	Inv_Elev	Length	slope	vfull	qfull	PipeDiam
1	303.079	307.09	116.143	0.000783516	0.331874	23.4588	400

.....

Search Radius: 250

# of MH in Search Rad:14

# of MH with Invert Elevation is Suitable: 8

# of MH with Velocity & Diameter is NOT suitable: 6

# of MH with Velocity & Diameter is Suitable: 2

Suitable Manhole Information

Row	Gr_Elev	Inv_Elev	Length	slope	vfull	qfull	PipeDiam
1	303.079	307.09	116.143	0.000783516	0.331874	23.4588	400
2	304.092	306.4	239.795	0.000667237	0.306259	21.6482	500

CHAPTER FIVE

RESULTS AND DISCUSSION

As we previously discussed in Chapter Four, the formulation of the proposed solution (SNCPC) is carried through MapInfo professional GIS software, where multiple data layers along with geodatabase file of Kirkuk sewerage network are collectively used. The case study presented in this thesis is focuses on finding the optimal connection between the newly developed sewerage networks and the existing sewerage network of Kirkuk city. Further, the optimal solution should consider the three defined criterions: optimum slope, shortest path, and minimum cost.

5.1. Implementation Results

As we mentioned in the problem background of this thesis (see Section 1.2), the results from applying SNCPC solution on the three areas of study: abandoned area, green park, and relics region, A1, A2, and A3, respectively will be presented in this chapter. For the reason that the three areas are still under-development and there are no local existing sewerage layouts, we propose three outlet manholes (MH1, MH2, MH3) for each area to demonstrate the effectiveness of the proposed model for finding the optimal solution. The model can then be reapplied on the same areas upon the completion and availability of these layouts.

The results obtained from applying the proposed model are as follow:

1 – Abandoned Area to Residential area (A1): we applied SNCPC model on the first proposed outlet manhole (A1MH1) at invert elevation 310, 300 pipe diameter, and Q-Design of 5, Table 5.1, Table 5.2, and Figure 5.1 show search results and suitable manholes information.

Buffer Radius	No. MH in Search Radius	No. of Suitable MH (Inv. Elv.)	No. of Not Suitable MH (with Velocity & Diameter).	No. of Suitable MH (with Velocity & Diameter)
50	0	0	0	0
100	0	0	0	0
150	4	3	3	0
200	3	1	1	0
250	8	6	4	2
				Total = 2

Table 5.1 Buffer search results from A1MH1

No.	Gr_Elev_DEM	Inv_Elev_DEM	Length	Slope	qfull	PipeDiam
1	304.498	308.629	202.32	0.000678	21.816	400
2	304.327	308.209	209.63	0.000854	24.496	600

Table 5.2 Suitable inlet manholes information from A1MH1

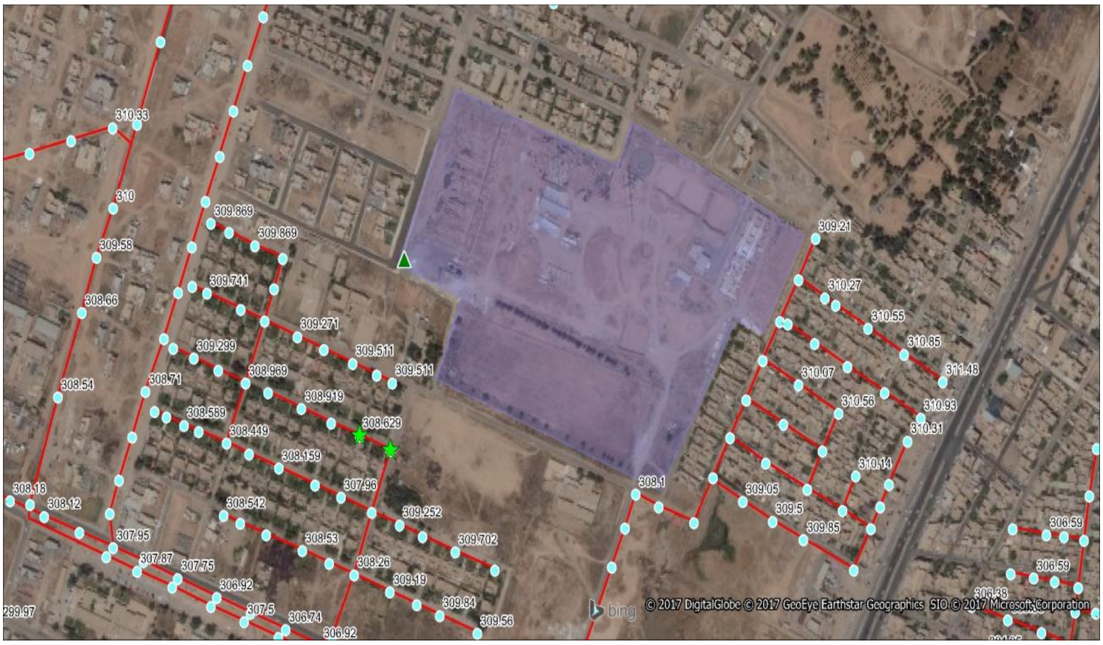


Figure 5.1 Suitable manholes from A1MH1

However, A1MH2 shows no suitable inlet manholes even at 250 meter radius at invert elevation 314, 300 pipe diameter, and Q-Design of 5. SNCPC output sample is shown as follow:

Buffer Radius	No. MH in Search Radius	No. of Suitable MH (Inv. Elv.)	No. of Not Suitable MH (with Velocity &Diameter).	No. of Suitable MH (with Velocity &Diameter)
50	0	0	0	0
100	0	0	0	0
150	0	0	0	0
200	1	1	1	0
250	0	0	0	0
				Total = 0

Table 5.3 Buffer search results from A1MH2

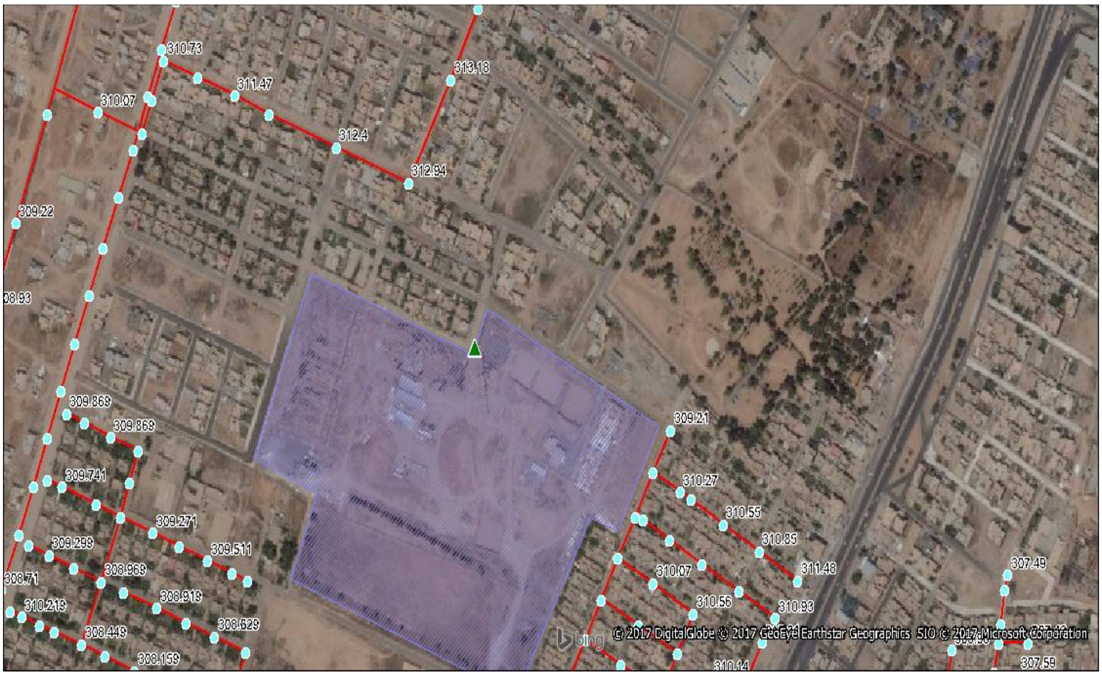


Figure 5.2 Suitable manholes from A1MH2

But A1MH3 shows eleven suitable inlet manholes, as a result, it can be considered as the best candidate outlet among the proposed three cases. The search results obtained at invert elevation 309, 300 pipe diameter, and Q-Design of 5.

Buffer Radius	No. MH in Search Radius	No. of Suitable MH (Inv. Elv.)	No. of Not Suitable MH (with Velocity &Diameter).	No. of Suitable MH (with Velocity &Diameter)
50	2	2	0	2
100	3	3	1	2
150	4	1	0	1
200	6	2	0	2
250	13	6	2	4
				Total = 11

Table 5.4 Buffer search results from A1MH3

No.	Gr_Elev_ DEM	Inv_Elev_ DEM	Length	Slope	qfull	PipeDiam
1	303.849	308.33	15.1645	0.00441822	55.7065	600
2	303.849	308.1	34.6058	0.00260072	42.7394	600
3	304.547	308.65	54.2704	0.000644919	21.2831	600
4	304.05	307.94	62.5248	0.00169533	34.5071	600
5	304.05	307.72	104.903	0.00122018	29.2747	600
6	303.854	307.6	157.145	0.000890896	25.0147	600
7	303.854	307.32	198.227	0.000847513	24.398	600
8	304.02	306.65	215.423	0.00109088	27.6802	800
9	304.02	306.38	219.942	0.00119123	28.9254	800
10	303.854	306.7	229.309	0.00100301	26.5421	800
11	304.512	305.94	240.032	0.00127483	29.9232	800

Table 5.5 Suitable inlet manholes information from A1MH3

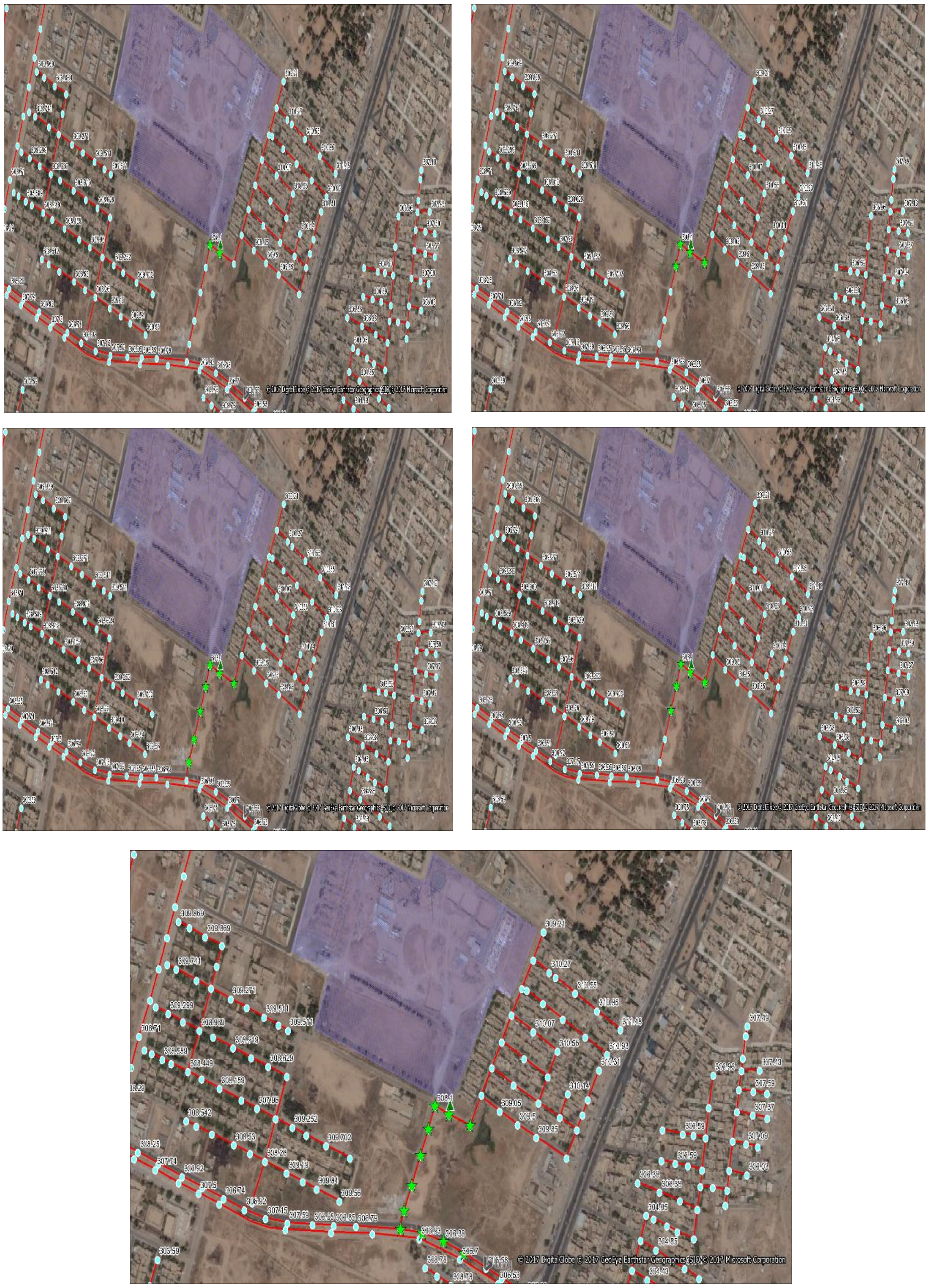


Figure 5.3 Suitable manholes from A1MH3

2 – Green land to Mall (A2): the same procedural steps are followed for the second area, but at an invert elevation of 311, 200 pipe diameters, and Q-Design value of 4. Table 5.6, Table 5.7, and Figure 5.4 show search results and suitable manholes information.

Buffer Radius	No. MH in Search Radius	No. of Suitable MH (Inv. Elv.)	No. of Not Suitable MH (with Velocity &Diameter)	No. of Suitable MH (with Velocity &Diameter)
50	0	0	0	0
100	0	0	0	0
150	0	0	0	0
200	3	0	0	0
250	7	2	0	2
				Total = 2

Table 5.6 Buffer search results from A2MH1

No	Gr_Elev_ DEM	Inv_Elev_ DEM	Length	Slope	qfull	PipeDiam
1	306.46	309.29	249.33	0.000685838	21.9479	600
2	307.33	309.21	214.816	0.000833271	24.1922	600

Table 5.7 Suitable inlet manholes information from A2MH1

Figure 5.4 Suitable manholes from A2MH1

However, A2MH2 and A2MH3 didn't show a great number of suitable results. Only one for each case. A2MH2 was calculated at an invert elevation of 314, 200 of pipe diameter, and value of 4 for Q-Design, where A2MH3 was calculated at 313, 200, and 4, respectively. The next tables and figures detail the obtained results from both cases.

Buffer Radius	No. MH in Search Radius	No. of Suitable MH (Inv. Elv.)	No. of Not Suitable MH (with Velocity &Diameter)	No. of Suitable MH (with Velocity &Diameter)
50	0	0	0	0
100	0	0	0	0
150	0	0	0	0
200	0	0	0	0
250	1	1	0	1
				Total = 1

Table 5.8 Buffer search results from A2MH2

No.	Gr_Elev_DEM	Inv_Elev_DEM	Length	Slope	qfull	PipeDiam
1	307.337	309.21	229.214	0.00209	23.5602	600

Table 5.9 Suitable inlet manholes information from A2MH2

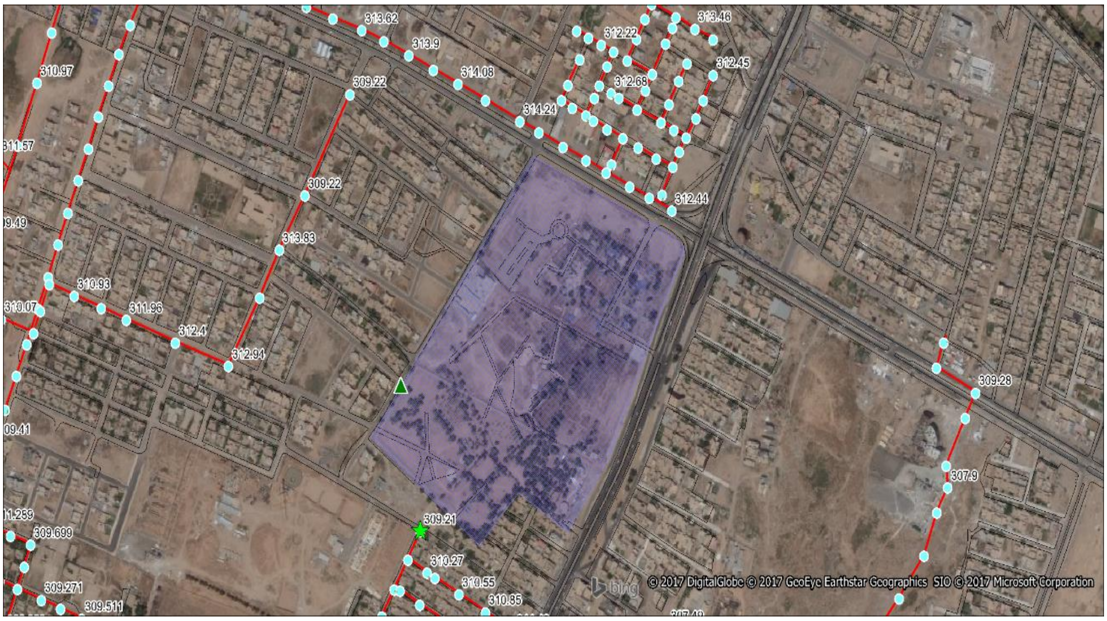


Figure 5.5 Suitable manholes from A2MH2

Buffer Radius	No. MH in Search Radius	No. of Suitable MH (Inv. Elv.)	No. of Not Suitable MH (with Velocity & Diameter)	No. of Suitable MH (with Velocity & Diameter)
50	0	0	0	0
100	1	1	1	0
150	4	3	2	1
200	6	3	3	0
250	8	2	2	0
				Total = 1

Table 5.10 Buffer search results from A2MH3

No	Gr_Elev_ DEM	Inv_Elev_ DEM	Length	Slope	qfull	PipeDiam
1	309.931	311.98	102.093	0.000999085	16.2904	400

Table 5.11 Suitable inlet manholes information from A2MH3

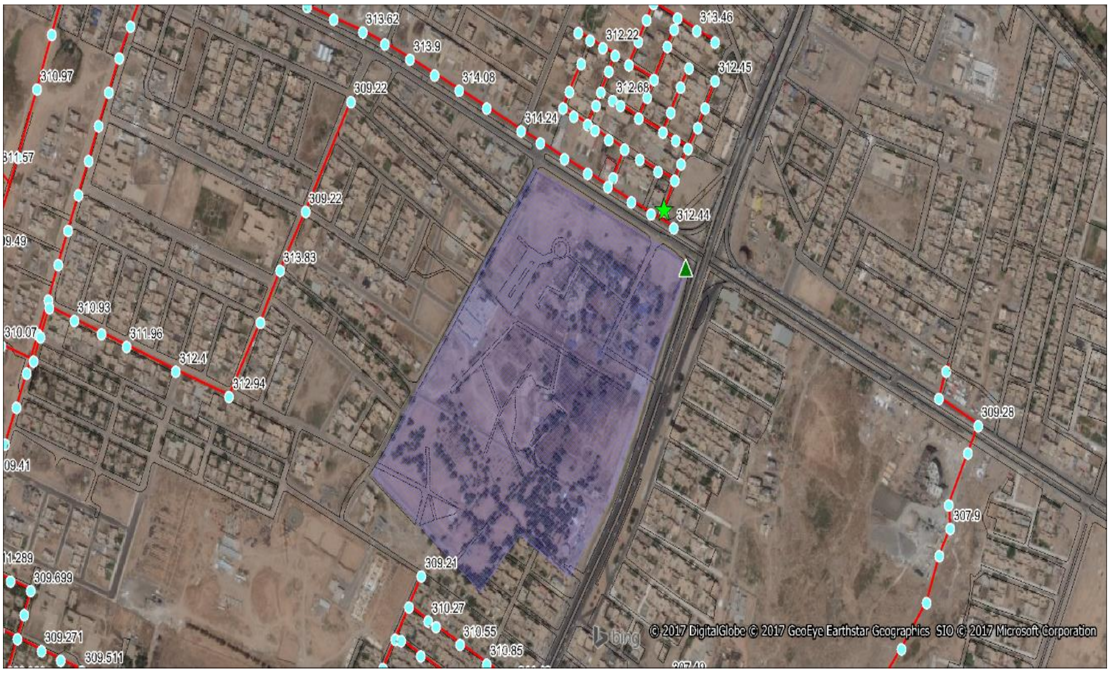


Figure 5.6 Suitable manholes from A2MH3

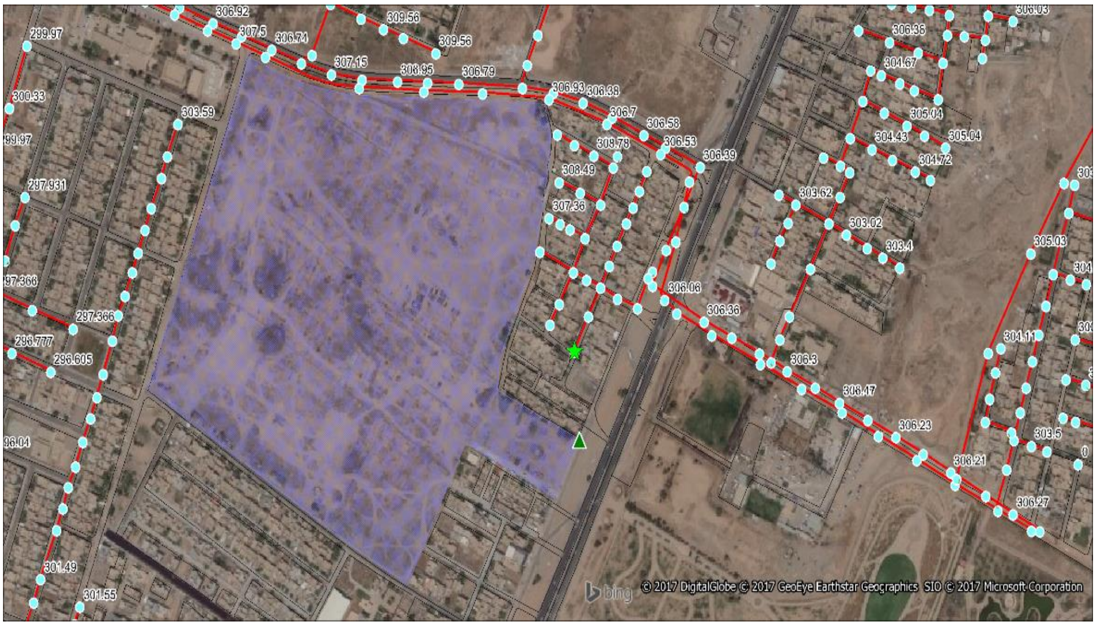
3 – Relics region to occupation houses (A3): last, we applied SNCPC at an invert elevation of 308, 500 pipe diameters, and Q-Design of 10, Table 5.12, Table 5.13, and Figure 5.7 show search results and suitable manholes information around A3MH1 outlet manhole.

Buffer Radius	No. MH in Search Radius	No. of Suitable MH (Inv. Elv.)	No. of Not Suitable MH (with Velocity &Diameter)	No. of Suitable MH (with Velocity &Diameter)
50	0	0	0	0
100	0	0	0	0
150	1	1	0	1
200	5	4	4	0
250	7	4	3	1
				Total = 2

Table 5.12 Buffer search results from A3MH1

No	Gr_Elev_DEM	Inv_Elev_DEM	Length	Slope	Qfull	PipeDiam
1	303.079	307.09	116.143	0.000783516	23.4588	600
2	304.092	306.4	239.795	0.000667237	21.6482	500

Table 5.13 Suitable inlet manholes information from A3MH1



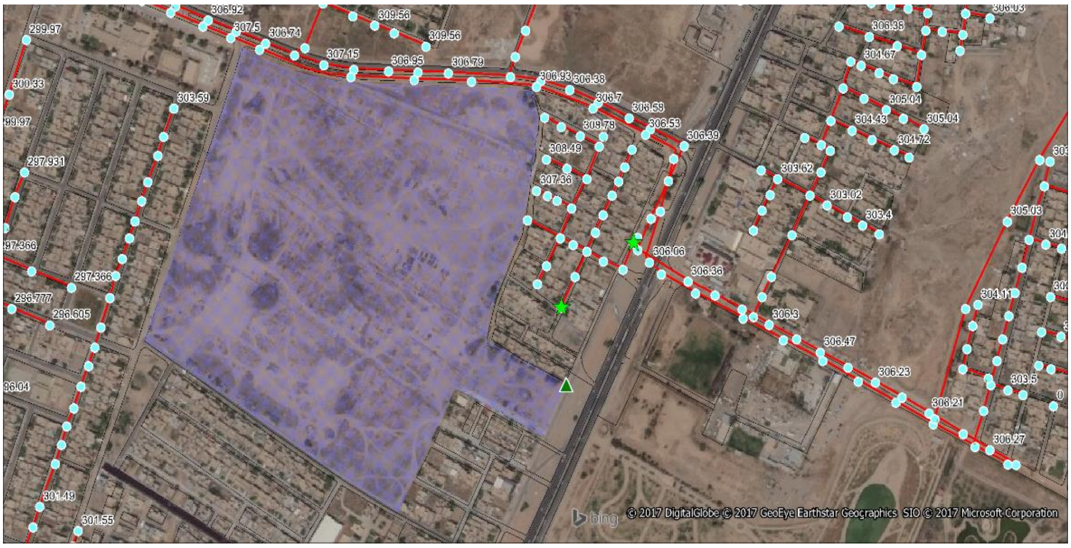


Figure 5.7 Suitable manholes from A3MH1

Then after, the second outlet manhole was also tested and it shows less result than the first proposed case outlet. A3MH2 only showed one solution calculated at invert elevation of 298, 500 pipe diameters, and Q-Design of 10. And the reason behind these poor search results can be seen as that the A3MH2 has a very low invert elevation value if compared to the surrounding manholes.

Buffer Radius	No. MH in Search Radius	No. of Suitable MH (Inv. Elv.)	No. of Not Suitable MH (with Velocity &Diameter)	No. of Suitable MH (with Velocity &Diameter)
50	0	0	0	0
100	4	0	0	0
150	4	1	1	0
200	1	1	0	1
250	7	2	2	0
				Total =1

Table 5.14 Buffer search results from A3MH2

No	Gr_Elev_ DEM	Inv_Elev_ DEM	Length	Slope	Qfull	PipeDiam
1	302.173	296.605	156.479	0.000891491	25.023	500

Table 5.15 Suitable inlet manholes information from A3MH2

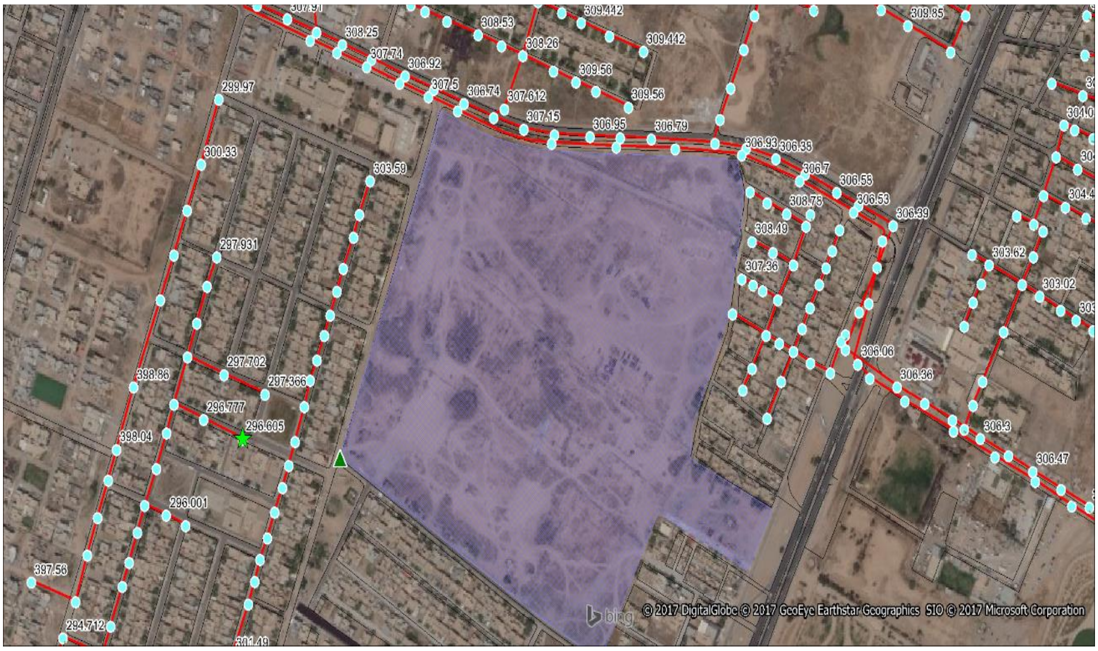


Figure 5.8 Suitable manholes from A3MH2

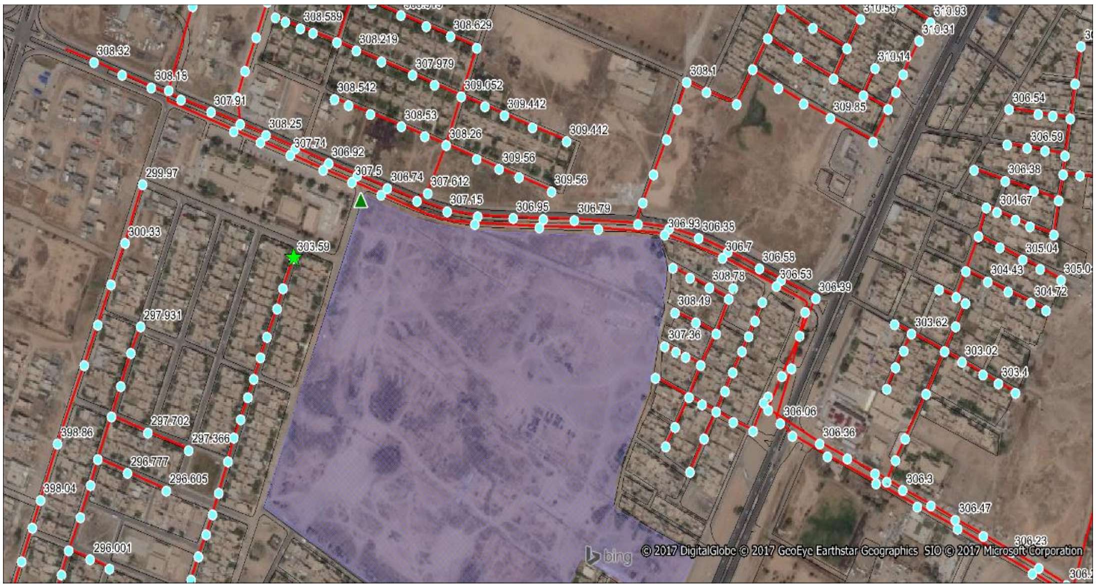
However, the proposed case of A3MH3 at invert elevation of 305, 500 pipe diameters, and Q-Design 10, shows to be more suitable as it has an appropriate invert elevation and suitable diameter when compared to the neighboring manholes. Table 5.16 shows four suitable solutions compared to two previously proposed cases.

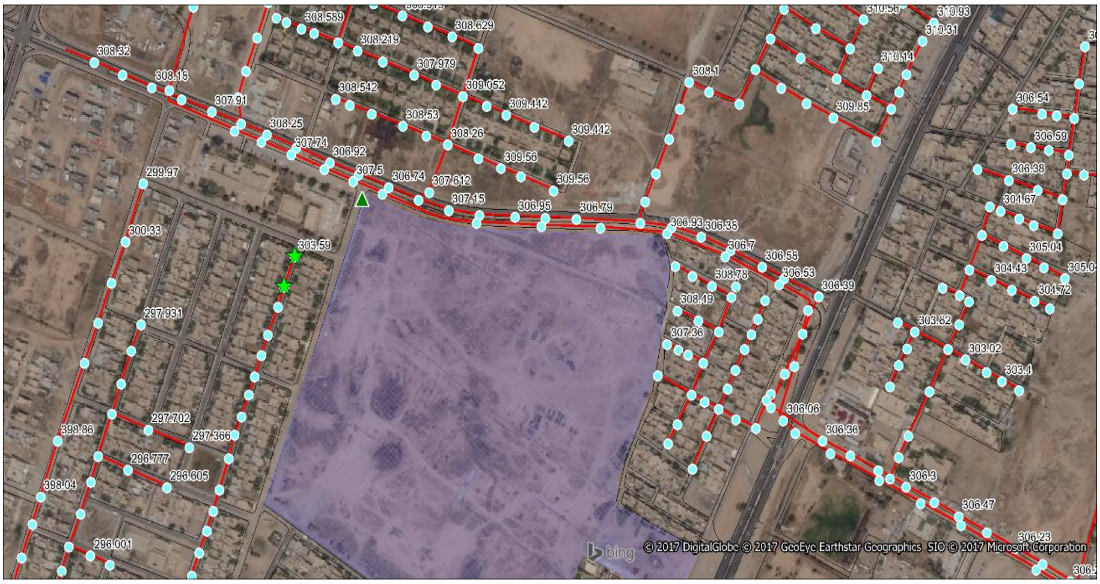
Buffer Radius	No. MH in Search Radius	No. of Suitable MH (Inv. Elv.)	No. of Not Suitable MH (with Velocity &Diameter)	No. of Suitable MH (with Velocity &Diameter)
50	4	0	0	0
100	3	0	0	0
150	10	1	0	1
200	10	1	0	1
250	12	2	0	2
				Total = 4

Table 5.16 Buffer search results from A3MH3

No	Gr_Elev_ DEM	Inv_Elev_ DEM	Length	Slope	Qfull	PipeDiam
1	303.525	303.59	133.495	0.00105622	27.237	600
2	303.525	303.12	173.717	0.00108222	27.5702	600
3	303.525	303.12	201.454	0.000933215	25.6019	600
4	303.228	302.82	243.247	0.00089621	25.0892	600

Table 5.17 Suitable inlet manholes information from A3MH3





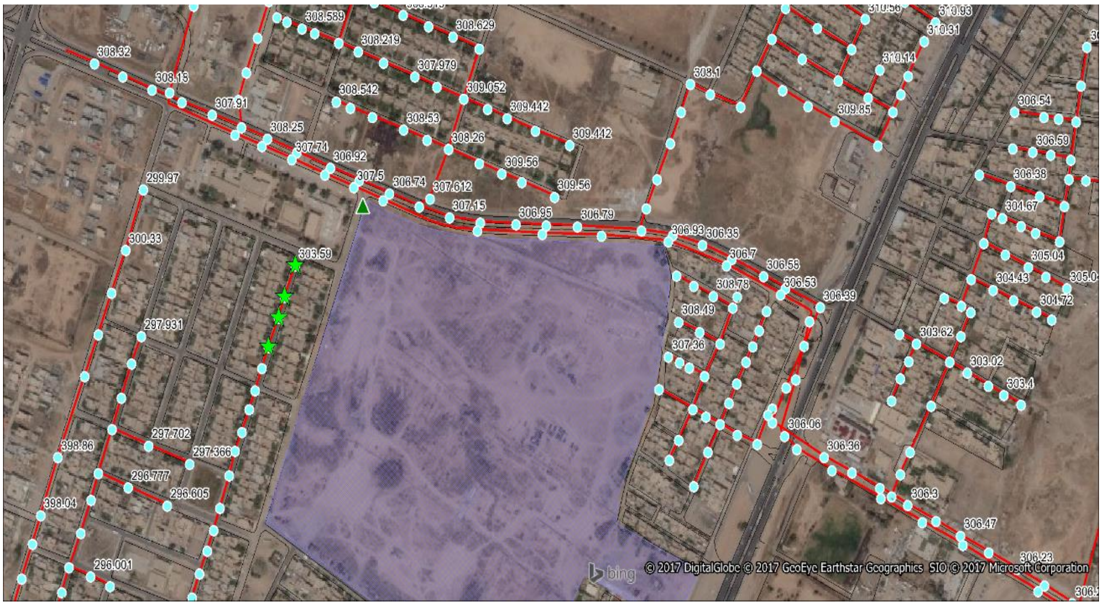


Figure 5.9 Suitable manholes from A3MH3

5.2. Discussion

From the presented results, SNCPC shows accurate results and can be applied on any area of choice. The implemented incremental-radius buffering technique proven to be time and effort saving, through report compilation where all search results is detailed and presented in tabular form at each stage. The information presented in an ascendant fashion, ordered based on the radius length, therefore, the suitable manholes found at the shortest radius (example 50, or 100) are guaranteed to have the optimal slope and shortest path, hence, ensures low cost of implementation.

From the data gathered in the results section (see Section 5.1), the optimal solutions for the three areas can be concluded as follow:

		INPUT			OUTPUT	
Area	Outlet Manhole	Invert Elevation (Outlet)	Pipe Diameter (Outlet)	Q-Design (Outlet)	Best (Inlet) Manholes Radius	(Inlet) Manhole Number (shortest path)
A1	MH1	310	300	5	250	1
	MH2	314	300	5	0	0
	MH3	309	300	5	50	1
A2	MH1	311	200	4	250	2
	MH2	314	200	4	250	1
	MH3	313	200	4	150	1
A3	MH1	308	500	10	150	1
	MH2	298	500	10	250	1
	MH3	305	500	10	150	1

Table 5.18 Optimal results of inlet manholes

CHAPTER SIX

CONCLUSION AND FUTURE WORK

The unexpected land-use change of some areas inside the city of Kirkuk require establishing new sewer networks, and find the optimal joint point between the new and the existing network to ensure the optimal flow of collected wastewater while trying to keep blockage risk to the minimum. And since these areas were not meant to be residential areas according to the city urban plan, therefore it became important to investigate an optimal solution. In this thesis, we presented and implemented a custom GIS-based application model to answer our research question of "***how slope, path, and cost can be optimize easily by using GIS and programming techniques?***"

6.1. Findings

In this thesis, we proposed and implemented SNCPC, a GIS based solution which simulates a real-world problem represented by joining the newly underdevelopment sewerage network with the existing local sewerage network of Kirkuk city. SNCPC solution simplifies the design process into a few non-expensive procedures, thus, enabling optimization of slope, path, and cost of connecting the new sewerage network. The grouping of GIS software and the proposed model will be used by managers and engineers of GIS department in sewerage directorate agency as a tool to calculate the optimal solution for any new similar project in the city of Kirkuk.

The benefits and advantages of the SNCPC can be summarized as:

1 – User-friendly interface and easy to use tool.

2 – The relationship between the ground elevation (i.e. DEM) and the parameters of sewerage network geodatabase was used by the programmed model to select the best matching joining points according to the optimal slope, as well as reduce the costs and effort.

3 - SNCPC demonstrates the ability to produce different solutions scenarios in short time (less than ten seconds for each tested case scenario) which can be used by engineers and decision makers to investigate and deliver more design alternatives.

4 - As shown in the results section (see Chapter Five) and due to the flat topography of Kirkuk city, one cannot use the traditional nearest neighbor method as mentioned in the problem background (see Section 1.2) to connect the new networks with the existing city network. However, the optimal solution must be realized through considering several factors such as initial elevation, slope, existing neighbor network capacity, and optimal path.

5 - The SNCPC solution searches all the inlet manholes located at the shortest radius and then moves to the furthest, from 50 to 250 meters in radius (see Section 4.2). Therefore, the suitable manholes found at the shortest radius (example 50, or 100) are guaranteed to have low cost of implementation.

6 - It provides better management, and minimizes expert staff requirements.

7 - Common IT system for the whole Sewer Management Department for everybody to use in a server/network environment.

6.2. Future Work

From the study presented in this thesis, we found that sewerage network optimization in general require long term exercise, more diverse studies, and continually addressing and solving rising issues in the network. We saw from the presented results that the SNCPC model optimally solved the case of this thesis; however, we think that it needs further development. Therefore, we want to propose the following future works:

1 – Including more design objectives.

2 – Improve the proposed model design efficiency.

3 – Integrating simulation models to check solutions quality.

REFERENCES

[1]. **Mark Endries, Doug Newcomb, Mark Richardson** (2015). GIS Introduction. U.S. FISH AND WILDLIFE SERVICE, National Conservation Training Center (ArcGIS 10.2.2) CSP7100, 287 pages available at: https://training.fws.gov/courses/csp/csp7100/resources/CSP7100_10132015.pdf

[2]. **SHAHAB FAZAL,** (2008).GIS BASICS. Department of Geography Aligarh Muslim University, Aligarh. Published by New Age International (P) Ltd, 350 pages, available at: https://caniban.files.wordpress.com/2011/04/gis-basics.pdf

[3]. **Abdelbaki, C., Benchaib, M. M., Benziada, S., Mahmoudi, H., & Goosen, M.** (2016). Management of a water distribution network by coupling GIS and hydraulic modeling: a case study of Chetouane in Algeria. *Applied Water Science*, 1-7. 7 pages available at: http://link.springer.com/article/10.1007/s13201-016-0416-1

[4]. **Chalkias, C. H. R. I. S. T. O. S., & Lasaridi, K. A. T. I. A.** (2009, September). Optimizing municipal solid waste collection using GIS. In *5th International Conference on Energy, Environment, Ecosystems and Sustainable Development/2nd International Conference on Landscape Architecture, Greece. In: Proceedings of Energy, Environment, Ecosystems, Development and, Landscape Architecture* (pp. 45-50). 6 pages available at: https://www.researchgate.net/profile/Christos_Chalkias/publication/266347857_Optimizing_municipal_solid_waste_collection_using_GIS/links/54b291570cf220c63cd262b0.pdf

[5]. **Steele, J. C., Mahoney, K., Karovic, O., & Mays, L. W.** (2016). Heuristic optimization model for the optimal layout and pipe design of sewer systems.

Water Resources Management, *30*(5), 1605-1620. 16 pages available at: http://link.springer.com/article/10.1007/s11269-015-1191-8

[6]. **Katti, M., Krishna, B. M., & Kumar, M.** (2015) Design of Sanitary Sewer Network for District 2B, Vijayapur city using SewerGEMS V8i Software. 6 pages available at: http://ijsetr.org/wp-content/uploads/2015/08/IJSETR-VOL-4-ISSUE-8-2766-2771.pdf

[7]. **Haghighi, A., & Bakhshipour, A. E.** (2014). Deterministic integrated optimization model for sewage collection networks using tabu search. *Journal of Water Resources Planning and Management*, *141*(1), 04014045. 11 pages available at: http://ascelibrary.org/doi/abs/10.1061/(ASCE)WR.1943-5452.0000435

[8]. **Loay.K.Abood and Ahmed.A.Shkara** (2012). Optimal Path Routing. Department of Computer Science, University of Baghdad, Baghdad, Iraq, Iraqi Journal of Science, December 2012, Vol. 53, No. 4, Pp. 1020-1024, 5 pages available at: http://www.iasj.net/iasj?func=fulltext&aId=87791

[9]. **Weng, H. T., & Liaw, S. L.** (2006). A Sewer System Optimization Hydraulic Design Model. *Journal of Environmental Informatics*, *7*(2), 66-74. 9 pages available at: http://www.iseis.org/jei/fulltext.asp?no=200600068

[10]. **Martínez-Solano, F. J., Iglesias-Rey, P. L., Saldarriaga, J. G., & Vallejo, D.** (2016). Creation of an SWMM Toolkit for Its Application in Urban Drainage Networks Optimization. *Water*, *8*(6), 259. 16 pages available at: http://www.mdpi.com/2073-4441/8/6/259/html

[11]. **Ward, B., Kawalec, M., & Savic, D.** (2014). An optimised total expenditure approach to sewerage management. 9 pages available at: https://ore.exeter.ac.uk/repository/handle/10871/17145

[12]. **Blumensaat, F., Wolfram, M., & Krebs, P.** (2012). Sewer model development under minimum data requirements. *Environmental Earth Sciences*, *65*(5), 1427-1437. 11 pages available at: http://link.springer.com/article/10.1007/s12665-011-1146-1

[13]. **Jon C Malinowski (**2001). Iraq: A Geography. DEPARTMENT OF THE ARMY UNITED STATES MILITARY ACADEMY West Point, New York 10996, 126 pages available at: http://www.usma.edu/gene/SiteAssets/SitePages/Publications/Iraq%20A%20Geography.pdf

[14]. **Central statistical organization/The Iraqi Ministry of Planning** (2016). Statistical Abstract of the Government of Kirkuk, summary for the year 2016, online website, available at: http://cosit.gov.iq/en/component/content/article/64-arabic-cat/2013-05-20-03-37-50/886-stat-summary

[15]. **Sinton, D. S., & Lund, J. J.** (2007). *Understanding place: GIS and mapping across the curriculum*. ESRI, Inc. 6 pages available at: http://esripress.esri.com/storage/esripress/images/108/understand_intro1.pdf

[16]. **Cole, I. S., Trinidad, G. S., & Chan, W. Y.** (1999). Prediction of the impact of the environment on timber components: a GIS-based approach. *Durability of Building Materials and Components 8*, *1*, 693-703. 11 pages available at: http://www.irbnet.de/daten/iconda/CIB2036.pdf

[17]. **Otto Huisman and Rolf A.**, (2009). Principles of Geographic Information Systems. An introductory textbook by The International Institute for Geo-Information Science and Earth Observation (ITC), fourth edition, 540 pages, available at: https://www.itc.nl/library/papers_2009/general/principlesgis.pdf

[18]. **Miroslav Rusko, Roman Chovanec and Dana Rošková**, (2010). An Overview of Geographic Information System and Its Role and Applicability In Environmental Monitoring and Process Modeling. Faculty Of Materials Science And Technology In Trnava Slovak, University Of Technology In Bratislava, 6

pages available at: https://www.degruyter.com/downloadpdf/j/rput.2010.18.issue-29/v10186-010-0031-1/v10186-010-0031-1.pdf

[19]. **Noorollahi, Y.** (2005). *Application of GIS and remote sensing in exploration and environmental management of Namafjall geothermal area, N-Iceland*. United Nations University. 124 pages available at: https://rafhladan.is/handle/10802/7219

[20]. **Sharifi, M.A., van den Toorn, W., Rico, A., and Emmanuel, M.** (2002) Application of GIS and multicriteria evaluation in locating sustainable boundary between the Tunari National Park and Cochabamba City (Bolivia). J. Multi-Criteria Decision Analysis, 151-164. 14 pages available at: http://onlinelibrary.wiley.com/doi/10.1002/mcda.323/pdf

[21]. **Gemelli, A., Mancini, A., Diamantini, C., & Longhi, S.** (2013). GIS-Supported Decision Making. In *GIS to Support Cost-effective Decisions on Renewable Sources* (pp. 19-32). Springer London. 14 pages available at: http://link.springer.com/chapter/10.1007/978-1-4471-5055-8_2

[22]. **Blumensaat, F., Wolfram, M., & Krebs, P.** (2012). Sewer model development under minimum data requirements. *Environmental Earth Sciences*, *65*(5), 1427-1437. 11 pages available at : http://link.springer.com/article/10.1007/s12665-011-1146-1

[23]. **Sanoff, H.** (2000). Community participation methods in design and planning.
John Wiley & Sons. 299 pages available at: https://www.amazon.com/Community-Participation-Methods-Design-Planning

[24]. **Diogo, A. F., & Graveto, V. M.** (2006). Optimal layout of sewer systems: A deterministic versus a stochastic model. *Journal of Hydraulic Engineering*,

132(9), 927-943. 17 page available at: http://ascelibrary.org/doi/abs/10.1061/(ASCE)0733-9429(2006)132:9(927)

[25]. **Shamsi, U.M**. (2005). GIS Applications for Water, Wastewater, and Storm water Systems ,CRC Press, ISBN 0-8493-2097-6, 453 pages, available at http://waterlib.ir/wp-content/uploads/edd/2016/01/GIS-Applications-for-Water-Wastewater-and-Stormwater-Systems.pdf

[26]. **Weng, H.T. and Liaw, S.L.** (2005). Establishing an optimization model for Sewer system layout with applied Genetic algorithm. Graduate Institute of Environmental Engineering, National Central University, Chungli 32054, Taiwan, 10 pages available at: http://www.iseis.org/jei/fulltext.asp?no=200500043

[27]. **MEHARI GOITOM HAILE** (2009). GIS-BASED ESTIMATION OF SEWER PROPERTIES FROM URBAN SURFACE INFORMATION, MASTER OF SCIENCE IN HYDRO SCIENCE AND ENGINEERING, 81 pages available at: https://tu-dresden.de/bu/umwelt/hydro/isi/sww/ressourcen/dateien/lehre/pdfs_abschlussarbeiten/MehariHaile_thesis_final_mod_after_submitted.pdf?lang=en

[28]. **Roger S. Bailey** (2015). Sewer Design Guide. Sewer Design Guide, City of San Diego Public Utilities Department, 9192 Topaz Way • San Diego, CA 92123, 241 pages available at: https://www.sandiego.gov/sites/default/files/legacy/mwwd/pdf/sewerdesign.pdf

[29]. **Yared Tesfaye Haile** (2014). GIS - BASED LAND SUITABILITY ASSESSMENT FOR SURFACE IRRIGATION AND MAPPING: THE CASE OF AZULE CATCHMENT, ARSI ZONE, OROMIA REGION, ETHIOPIA. In Partial Fulfillment of the Requirements for the Degree of MASTER OF SCIENCE IN IRRIGATION ENGINEERING, 117 pages available at: http://www.ijesd.org/papers/Yared's%20Thesis%202014.pdf

[30]. **Van der Hoop, G. W**. (2010). *A New Approach to Asset Management for Sewer Networks*. Delft University of Technology. 159 pages available at:

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.903.5869&rep=rep1&type=pdf

[31]. **Chambers, K., Creasey, J., & Forbes, L**. (2004). Design and operation of distribution networks. *Safe, Piped Water: Managing Microbial Quality in Piped Distribution Systems*. 32 pages available at: https://pdfs.semanticscholar.org/1b95/dad552011adcb9b54fad23914498dd32fe17.pdf

[32]. **Govers, G.** (1992). Relationship between discharge, velocity and flow area for rills eroding loose, non-layered materials. Earth surface processes and landforms, 17(5), 515-528. 14 pages available at: https://www.researchgate.net/profile/Gerard_Govers/publication/229492373_Relationship_between_discharge_velocity_and_flow_area_for_rills_eroding_loose_non-layered_materials/links/0c960534ce653cc153000000.pdf

[33]. **Petrešin, E., & Nekrep, M. P.** (2007). *C5) New approach in water distribution systems real time visualization–working example*. 8 pages available at: http://www.irbnet.de/daten/iconda/CIB6849.pdf

[34]. **Hydrologic Engineering Center,** (1993). Review of GIS Application in Hydrologic Modeling. US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, Davis, CA 59616, 24 pages, available at: http://www.hec.usace.army.mil/publications/TechnicalPapers/TP-144.pdf

[35]. **ESRI**, Water Utilities Online Website http://solutions.arcgis.com/#Water visited at 05.10.2016

[36]. **Guo, Y., Walters, G., & Savic, D.** (2008, September). Optimal design of storm sewer networks: Past, present and future. In *Proceedings of the 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK* (Vol.

31). 24 pages, available at: https://pdfs.semanticscholar.org/6fd3/c9551dbda08846efb521b0ac2eee447a0205.pdf

[37]. **T. Sutton, O. Dassau, M. Sutton,** (2009). A Gentle Introduction to GIS, sponsored by: Chief Directorate: Spatial Planning & Information, Department of Land Affairs, Eastern Cape, South Africa, 133 pages, available at: http://download.osgeo.org/qgis/doc/manual/qgis-1.0.0_a-gentle-gis-introduction_en.pdf

[38]. **Solvi, A. M.** (2006). *Modelling the sewer-treatment-urban river system in view of the EU Water Framework Directive*. PhD thesis, Ghent University, Belgium. 221 pages, available at: http://biomath.ugent.be/publications/download/solviannemarie_phd.pdf

[39]. **MapInfo Professional** (2013). USER GUIDE version 12.0, 598 pages, available at:http://reference1.mapinfo.com/software/mapinfo_pro/english/12.0/MapInfoProfessionalUserGuide.pdf

[40]. Ministry of Municipalities and Public works, Urban Planning General Directorate office. http://www.mmpw.gov.iq/PageViewer.aspx?id=33&tId=4aa9728f-aec6-4db6-9b8a-7bf9f7d33b80. Visited at 9/3/2017.

[41]. GIS, Design, and Evolving technology, available at http://www.esri.com/news/arcnews/fall09articles/gis-design-and.html. Visited in 9/3/2017.

[42]. Introduction to WMS 7 software. Available at http://www.scisoftware.com/products/wms_details/wms_details.html. Visited at 9/3/2017.

[43]. GeoConnexion, available at https://www.geoconnexion.com/news/optech-to-deliver-state-of-the-art-airborne-lidar-and-thermal-imaging-solut/, visited at 9/3/2017.

[44]. Geographical Information System Center, Kirkuk. Obtained at 10/6/2016.

[45]. https://www.slideshare.net/DEVANGKAPADIA/query-and-network-analysis-in-gis. Visited at 9/3/2017.

[46]. Kirkuk Sewerage Directorate Office. Obtained at 15/5/2016.

APPENDIX A

SNCPC Model Code

The following below show program codes taken from MapInfo, Mapbasic integrated mapping Application.

```
include "mapbasic.def"

include "ReadGridValue.mb"

dim GRDX , GRDY ,z as float

dim elv,buf,x,y as float

dim xe,ye,ze as float

dim oe,onew,o as object

dim devamet as logical

dim mDia ,pDia,mhno as smallint


Create menu "Sewer_MH_Slope_Cost" as

        "Get Z Value Alan" calling KliklenenYerAlandaki,

        "Get Z Value" calling KliklenenYer,

        "Draw Manhole and Pipe" calling KlikleBoruMHCizYukGir ,

        "Calculate Cost of MH and Pipe" calling CostCalculationPipe ,

        "(-",
```

```
        "OtomatikGr_Elev_Gir  " calling  OtomatikGr_Elev_Gir,
        "(-",
        "Close"   calling  closeprog

sub OtomatikGr_Elev_Gir
dim k as integer
if selectioninfo(3)  = 0 then exit sub end if
select * from selection into sel1
for k = 1 to tableinfo(sel1,8)
if k mod 500 = 1 then print k + " / " + TAbleinfo(sel1,8)  + " " + time(24)  end if
 fetch rec k from sel1
        o = sel1.obj
        x=centroidx(o)
        y=centroidy(o)
if GetZetValue(X  , Y , Z , "" , frontwindow())  then
        update sel1 set gr_elev_dem  = z where rowid = k
end if
Next
End sub

dialog title "DAta:"
control statictext title "Dem H="+ z +" , Invert Elv:"  position 10,10
        control edittext value (z-1.15) into elv
```

```
control statictext title "Diameter:" position 10,30
        control edittext value 150 into cap
control statictext title "Q Design:" position 10,50
        control edittext value 5 into Qq
control statictext title "Roughness n=" position 10,70
        control edittext value 0.015 into nR
'control statictext title "uzun" position 10,90
'       control edittext value 24.5 into LL
        control okbutton
if not commandinfo(1) then exit sub end if
'       select * from sel_mhs where Inv_Elev < elv into sel_mhs_elv_OK
        select * from sel_mhs where Inv_Elev < (elv-
1000/cap*Objectlen(Createline(centroidx(obj),centroidy(obj),x,y),"m")/1000) into
sel_mhs_elv_OK
        update sel_mhs_elv_OK set
        Uzunluk=Objectlen(Createline(centroidx(obj),centroidy(obj),x,y),"m")
        update sel_mhs_elv_OK set Slope = Maximum( (z-
gr_elev)/uzunluk/10,(elv-inv_Elev)/ Uzunluk/10) '
Objectlen(Createline(centroidx(obj),centroidy(obj),x,y),"m")'/100
        update sel_mhs_elv_OK set vfull = (cap/4000)^(2/3)*(slope^.5/nR)
        update sel_mhs_elv_OK set Qfull=Vfull*1000*3.14159*((cap/1000)^2 )/4
        update sel_mhs_elv_OK set q_over_Q =qq/ Qfull
        update sel_mhs_elv_OK set h_over_D = (0.7543*(q_over_Q)^0.5522)
select * from sel_mhs_elv_OK where ( q_over_Q<0.85 and h_over_D <0.8 and
Vfull<3 and Vfull>0.3) order by uzunluk into sel_mhs_Vf_Qf_qQ_hD_OK
```

```
        browse * from selection
select * from sel_mhs_elv_OK   where not ( q_over_Q<0.85 and h_over_D <0.8 and Vfull<3  and  Vfull>0.3)  into  sel_mhs_vel_Not_OK
        browse * from selection
' from sel_mhs_elv_OK  where  (Qq/4000)^(2/3)*(elv-Inv_elev)^(0.5)/nR  into sel_mhs_Vel_OK
select * from sel_mhs  where mh_top  < elv  into  sel_mhs_elv_OK
        browse * from selection


        o = createpoint(x,y)
        o = Buffer(o,100,buf,  "m")
        select * from tm where obj intersects o into sel_mhs
'       browse * from selection
dim cap ,qq ,nR,ll  as float
dialog title "DAta:"
control statictext title "Dem H="+ z +" , Invert Elv:" position 10,10
        control edittext value (z-1.15) into elv
control statictext title "Diameter:" position 10,30
        control edittext value 150 into cap
control statictext title "Q Design:" position 10,50
        control edittext value 5 into Qq
control statictext title "Roughness n=" position 10,70
        control edittext value 0.015 into nR
'control statictext title "uzun" position 10,90
```

```
'         control edittext  value  24.5 into  LL

          control okbutton

if not commandinfo(1)  then exit sub end if

'         select * from sel_mhs  where Inv_Elev  < elv into sel_mhs_elv_OK

          select * from sel_mhs  where Inv_Elev  < (elv-
1000/cap*Objectlen(Createline(centroidx(obj),centroidy(obj),x,y),"m")/1000)  into
sel_mhs_elv_OK

          update sel_mhs_elv_OK  set
          Uzunluk=Objectlen(Createline(centroidx(obj),centroidy(obj),x,y),"m")

          update sel_mhs_elv_OK  set   Slope = Maximum(  (z-
gr_elev)/uzunluk/10,(elv-inv_Elev)/  Uzunluk/10)  '
Objectlen(Createline(centroidx(obj),centroidy(obj),x,y),"m")'/100

          update sel_mhs_elv_OK  set   vfull  = (cap/4000)^(2/3)*(slope^.5/nR)

          update sel_mhs_elv_OK  set   Qfull=Vfull*1000*3.14159*((cap/1000)^2  )/4

          update sel_mhs_elv_OK  set   q_over_Q  =qq/ Qfull

          update sel_mhs_elv_OK  set   h_over_D  = (0.7543*(q_over_Q)^0.5522)


select * from sel_mhs_elv_OK   where ( q_over_Q<0.85 and h_over_D  <0.8 and
Vfull<3  and  Vfull>0.3)  order by uzunluk  into  sel_mhs_Vf_Qf_qQ_hD_OK

          browse * from selection

elect * from sel_mhs_elv_OK   where  not ( q_over_Q<0.85 and h_over_D  <0.8 and
Vfull<3  and  Vfull>0.3)  into  sel_mhs_vel_Not_OK

          browse * from selection

exit  sub
```

```
' from sel_mhs_elv_OK where (Qq/4000)^(2/3)*(elv-Inv_elev)^(0.5)/nR into sel_mhs_Vel_OK

'       select * from sel_mhs where mh_top < elv into sel_mhs_elv_OK

        browse * from selection


Add Map Layer sel_mhs

Set Map Layer 1 Display Global Zoom (0, 100000) Units "m" Off Editable Off Selectable On Global Line (2,2,0) Global Pen (1,2,255) Global Brush (1,16777215,16777215) Global Symbol (33,8388608,12,"MapInfo Symbols",256,0) Global Font ("Arial TUR",0,9,0) Label Line Arrow Position Right Font ("Arial TUR",0,9,0) Pen (1,2,0) With MH_ID Parallel On

Add Map Layer sel_mhs_elv_OK

Set Map Layer 1 Display Global Zoom (0, 100000) Units "m" Off Editable Off Selectable On Global Line (2,2,0) Global Pen (1,2,255) Global Brush (1,16777215,16777215) Global Symbol (35,32768,15,"MapInfo Symbols",256,0) Global Font ("Arial TUR",0,9,0) Label Line Arrow Position Right Font ("Arial TUR",0,9,0) Pen (1,2,0) With MH_ID Parallel On

'       select * from tp where obj intersects o into sel_pipes

end sub


dialog title "DAta:"

control statictext title "Dem H="+ z +" , Invert Elv:" position 10,10

        control edittext value (z-1.15) into elv

control statictext title "Diameter:" position 10,30

        control edittext value 150 into cap

control statictext title "Q Design:" position 10,50
```

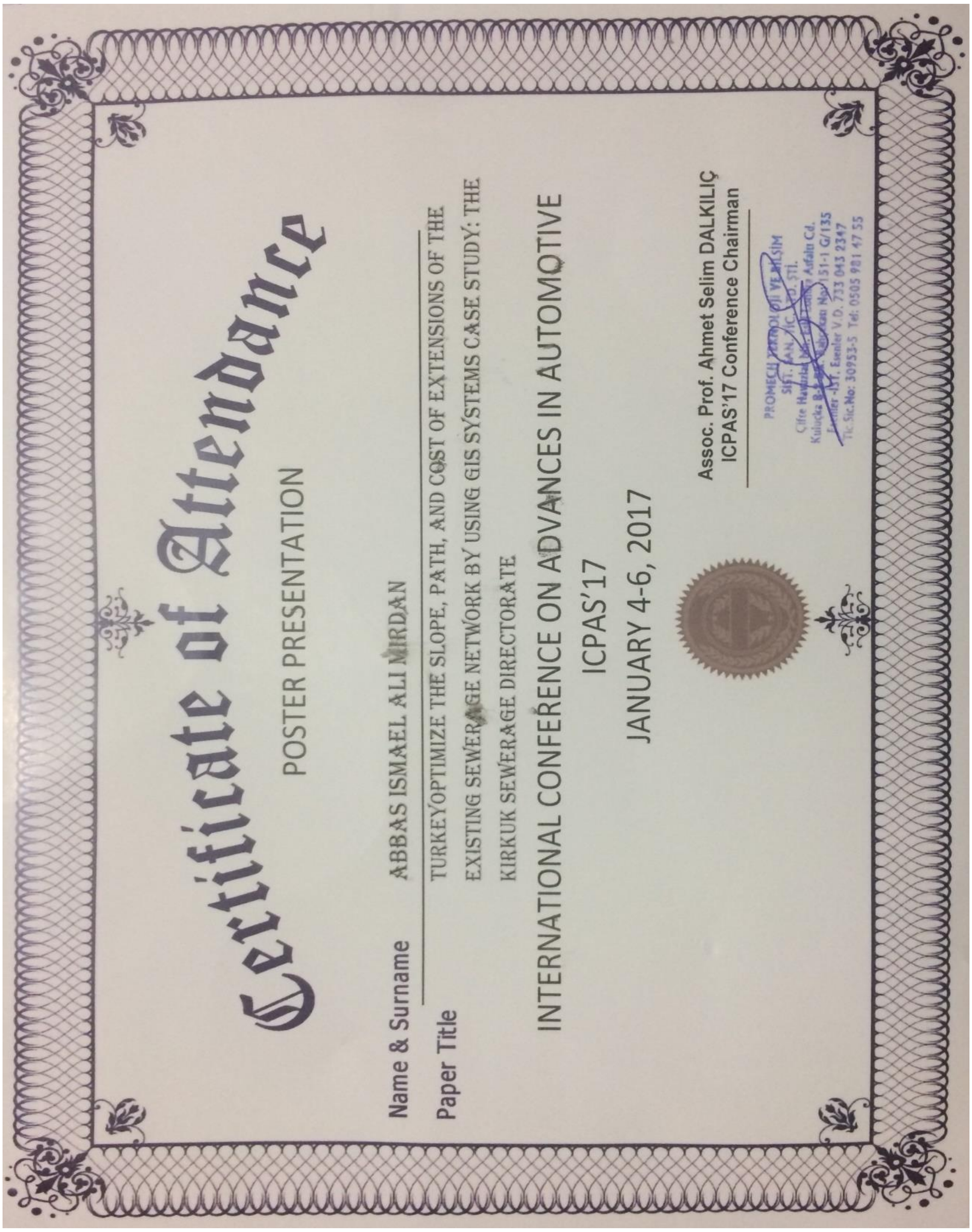
```
        control edittext value 5 into Qq
control statictext title "Roughness n=" position 10,70
        control edittext value 0.015 into nR
'control statictext title "uzun" position 10,90
'       control edittext value 24.5 into LL
        control okbutton
if not commandinfo(1) then exit sub end if
for jj = 50 to 250 step 50
buf = jj ' m
Print "Search Radius:" + jj
'exit sub

        o = createpoint(x,y)
        o = Buffer(o,100,buf, "m")
        select * from tm where obj intersects o into sel_mhs
'       browse * from selection
        update sel_mhs_elv_OK set
        Uzunluk=Objectlen(Createline(centroidx(obj),centroidy(obj),x,y),"m")
        update sel_mhs_elv_OK set Slope = Maximum( (z-
gr_elev_dem)/uzunluk/10,(elv-Inv_Elev_Dem)/ Uzunluk/10) '
Objectlen(Createline(centroidx(obj),centroidy(obj),x,y),"m")'/100
        update sel_mhs_elv_OK set vfull = (cap/4000)^(2/3)*(slope^.5/nR)
        update sel_mhs_elv_OK set Qfull=Vfull*1000*3.14159*((cap/1000)^2 )/4
        update sel_mhs_elv_OK set q_over_Q =qq/ Qfull
```

```
	update sel_mhs_elv_OK set h_over_D = (0.7543*(q_over_Q)^0.5522)
select * from sel_mhs_elv_OK where not ( q_over_Q<0.85 and h_over_D <0.8 and Vfull<3 and Vfull>0.3) or cap > bigPipeDiam into sel_mhs_vel_Not_OK
	'browse * from selection
Print "# of MH with Velocity & Diam is NOT Suitable:" + selectioninfo(3)
select * from sel_mhs_elv_OK where ( q_over_Q<0.85 and h_over_D <0.8 and Vfull<3 and Vfull>0.3) and cap <= bigPipeDiam order by uzunluk into sel_mhs_Vf_Qf_qQ_hD_OK
	'browse * from selection
Print "# of MH with Velocity & Diam is Suitable:" + selectioninfo(3)


f=applicationdirectory$()
if f not like "%\" then f = f + "\" end if
f=f + "pict_" +curdate()+ int(rnd(1)*100000)+"Q"+qq+"_D"+cap+"_E"+elv+ ".png"
'save window frontwindow() as f type "png"
Save Window frontwindow() As f Type "PNG"
'Width 11.0104 Units "in"
'Height 3.28125 Units "in"
Resolution 192
print "file: "+f
s = "Row" + chr$(9)
for k = 1 to 10
	s = s + columninfo(sel_mhs_Vf_Qf_qQ_hD_OK,"col"+k,1) + chr$(9)
next
```

```
print "Suitable Menhol Info"

print s

for k = 1 to selectioninfo(3)

        fetch rec k from sel_mhs_Vf_Qf_qQ_hD_OK

s = k + chr$(9)

dim aa as alias

for i = 1 to 10

        aa ="sel_mhs_Vf_Qf_qQ_hD_OK.col"+i

        s = s + aa + chr$(9)

next

        print s

end if

exit sub


' from sel_mhs_elv_OK where (Qq/4000)^(2/3)*(elv-Inv_Elev_Dem)^(0.5)/nR into sel_mhs_Vel_OK

'       select * from sel_mhs where mh_top < elv into sel_mhs_elv_OK

'       browse * from selection


Add Map Layer sel_mhs

Set Map Layer 1 Display Global Zoom (0, 100000) Units "m" Off Editable Off Selectable On Global Line (2,2,0) Global Pen (1,2,255) Global Brush (1,16777215,16777215) Global Symbol (33,8388608,12,"MapInfo Symbols",256,0)
```

```
Global Font ("Arial TUR",0,9,0) Label Line Arrow Position Right Font ("Arial
TUR",0,9,0) Pen (1,2,0) With MH_ID Parallel On

Add Map Layer sel_mhs_elv_OK

Set Map Layer 1 Display Global Zoom (0, 100000) Units "m" Off Editable Off
Selectable On Global Line (2,2,0) Global Pen (1,2,255) Global Brush
(1,16777215,16777215) Global Symbol (35,32768,15,"MapInfo Symbols",256,0)
Global Font ("Arial TUR",0,9,0) Label Line Arrow Position Right Font ("Arial
TUR",0,9,0) Pen (1,2,0) With MH_ID Parallel On

set map redraw on

'       select * from tp where obj intersects o into sel_pipes

end sub
```

APPENDIX B



Certificate of Attendance

POSTER PRESENTATION

Name & Surname ABBAS ISMAEL ALI MIRDAN

Paper Title TURKEYOPTIMIZE THE SLOPE, PATH, AND COST OF EXTENSIONS OF THE EXISTING SEWERAGE NETWORK BY USING GIS SYSTEMS CASE STUDY: THE KIRKUK SEWERAGE DIRECTORATE

INTERNATIONAL CONFERENCE ON ADVANCES IN AUTOMOTIVE

ICPAS'17

JANUARY 4-6, 2017

Assoc. Prof. Ahmet Selim DALKILIÇ
ICPAS'17 Conference Chairman

APPENDIX C

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: ALI MIDAN, Abbas

Nationality: Iraqi (IQ)

Date and Place of Birth: 13 February 1979, Kerkuk-Iraq

Marital Status: Married

Phone: +905366007951, +9647702191370

Email: abbas_asaf@yahoo.com

EDUCATION

Degree	**Institution**	**Year of Graduation**
B.sc.	Computer Science, Mosul University	2004
High School	Kuteybe High school, Kerkuk	1999

WORK EXPERINCE

Year	**Place**	**Enrollment**
2005-Present	Directorate of Kerkuk Sewerage	Head of GIS Department

FOREIGN LANGUAGES

Arabic, Turkish, English