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Irrigation Planning Using Geographic Information System and Remote Sensing of the Baranti Plain in Northern Iraq

Twana Abdulrahman HAMAD

DEPARTMENT OF SOIL SCIENCE AND PLANT NUTRITION

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Doktora Tezi

Kuzey Irak'taki Baranti Ovası'nın Coğrafi Bilgi Sistemi ve Uzaktan Algılama Kullanılarak Sulama Planlaması

Twana Abdulrahman HAMAD

Harran Üniversitesi
Fen Bilimleri Enstitüsü
Toprak Bilimi ve Bitki Besleme Bölümü

Danışman: Prof.Dr. Mehmet Ali ÇULLU
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Su, yeryüzündeki kurak ve yarı kurak bölgelerde yaşamın temel kaynağı olarak hayati önem taşımaktadır. Bu alanlar iklim değişikliği etkileri ile ile doğrudan karşı karşıya olduğundan yeraltı suyu kaynaklarına dikkat edilmesi gerekmektedir. Bu çalışma, Irak'ta Erbil'in yaklaşık 25 km kuzeyinde yer alan Baranti Ovası'nda yer alan 445 km2'lik bir bölgeye yayılmaktadır. Büyük Zap Nehri kuzey bölgesinden saniyede ortalama 400 m3'lük bir deşarjla akmaktadır. Bu alanda karşılaşılan zorluklara yanıt olarak Tarım ve Su Kaynakları Bakanlığı, temel verileri toplamak amacıyla Gıda ve Tarım Örgütü (FAO) ile işbirliği yapmaktadır. Bu kapsamlı veri seti, Eylül ayındaki yeraltı suyu seviyesinin izlenmesine özellikle odaklanarak 2000'den 2021'e kadar olan aylık kayıtları içermektedir. Farklı lokasyonlarda farklılıklar olsa da bölgedeki yeraltı suyu seviyelerinde ortalama 23 metre düşüş kaydedilmiştir. Bölgedeki özel kuyularda değişen derecelerde tükenme dikkati çekmektedir. Örneğin Ganj Gowra kuyusu 19,65 metre, Garda Chal kuyusu 10,4 metre, Jadida Zab kuyusu 35,39 metre, Sebirani Gowra kuyusu 15,87 metre, Qafar köyü kuyusu 11,74 metre ve Jjnikan Ababakr köyü kuyusu 18,2 metre düştüş gösterirken, Kawar Goski köyündeki kuyu 53,15 metrelik keskin bir düşüş yaşamıştır. Ayrıca bölgedeki kentsel büyüme %7,8 artarken, kuyu sayısı 2006'da 257'den 2021'de 627'ye yükselmiştir. Yeraltı suyundaki azalmanın önlenmesi ve çiftçilerin tarlaları için sulamanın kolaylaştırılması gibi zorlukların üstesinden gelmek amacıyla üç olasılık test edilmiştir. Birincisi gölet yapımı, ikincisi suyun borularla dağıtılması, üçüncüsü ise beton kanalların inşası olarak düşünülmüştür. İkinci ve üçüncü adımlar ovaya su taşıma aracı olarak Büyük Zap Nehri'ne varlığına dayanmaktadır. İlk yol, depolama kapasitesi 5,7 milyon metreküp olan 15 gölet inşa etmektir. Bu çok düşük bir sulama miktarı olsa bile bölgedeki yeraltı suyunun iyileştirilmesine önemli katkı yapacaktır. İkinci yol ise suyun borular aracılığıyla dağıtılması aşamasıdır. Bölgedeki tarım arazisinin yüzde 65'ini sulayabilecek kapasiteye sahip olmakla birlikte pahalıve yönetilmesi zor görünmektedir. Üçüncü yol ise beton kanalların tarım arazilerinin %68'ini sulama kapasitesine sahip olması ve daha düşük maliyetle yönetilmesinin daha kolay olmasıdır. Son olarak yapay beton kanalların inşası, bölgeyi canlandırmak ve çiftçilerin karşılaştığı zorlukları çözmek için en etkili çözüm olarak ortaya çıkmaktadır. Proje, 30.000 hektardan fazla araziyi sulama kapasitesine sahip ve 1.200'den fazla çiftçiye fayda sağlama özelliğine sahiptir. 600'den fazla kuyunun sulama amaçlı kullanımının durdurulması ve potansiyel olarak yeraltı suyu seviyelerinin yılda yaklaşık 2,5 m artması beklenmektedir. Araştırmada, yeraltı suyunun tükenmesine çözüm bulmak için kanalların kurulmasını, yağmur suyu hasadını, çiftçi eğitimini, modern sulama, sondaj kısıtlamalarını ve suyun desteklenmesi gerektirdiğini ortaya çıkarmıştır. Bu araştırma, sürdürülebilir su yönetimi uygulamaları ve yarı kurak bölgelerde su kaynağı projelerinin planlanması ve uygulanmasında CBS teknolojisinin entegrasyonunun önemi katkılar sağladığını göstermiştir.

ANAHTAR KELİMELER: GIS, meteoroloji istasyonu verileri.DEM, akış hesaplayıcı. kanalı aç

Abstract

Doctorate Thesis

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Twana Abdulrahman HAMAD

Harran University
Graduate School of Natural and Applied Sciences
Department of Soil Science and Plant Nutrition

Supervisor: Prof.Dr. Mehmet Ali ÇULLU
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Water is crucially important as the basic source of life on Earth in arid and semi-arid regions. These areas face the direct impacts of climate change, requiring careful attention to groundwater resources. This study focuses on the Baranti plain,The Baranti Plain is located approximately 25 km north of Erbil in Iraq and spans an area of 445 km2. The Great Zap River flows through its northern region, with an average discharge of about 400 m3 per second. In response to the challenges faced in this area, the Ministry of Agriculture and Water Resources collaborated with the Food and Agriculture Organization (FAO) to gather essential data. This comprehensive dataset included monthly records from 2000 to 2021, with a particular focus on groundwater level monitoring in September. On average, groundwater levels in the area have fallen by 23 meters overall, although there are variations in different locations. Notably, private wells within the region showed varying degrees of depletion. For example, Ganj Gowra well saw a drop of 19.65 metres, Garda Chal well decreased 10.4 metres, Jadida Zab well decreased 35.39 metres, Sebirani Gowra well saw a decrease of 15.87 meters, Qafar village well decreased 11.74 metres, and Jjnikan Ababakr village well decreased 18.2 metres 5 meters, the well at Kawar Goski village suffered a sharp decline of 53.15 metres. Additionally, urban sprawl in the region increased by 7.8%, while the number of wells rose from 257 in 2006 to 627 in 2021. To meet the challenges of groundwater depletion and irrigation facilitation for farmers' fields, three possibilities were tested. The first was the construction of ponds, the second was the distribution of water through pipes, and the third was the construction of concrete channels. while the second and third relied on the Great Zap River as a means of transporting water to the plain. The first way was to build 15 ponds with a storage capacity of 5.7 million cubic meters. This is a very low rate of irrigation that is only good for improving the groundwater in the area. The second way was to distribute water through pipes. It had the capacity to irrigate 65% of the region's agricultural land, but it was expensive and difficult to manage. The third way is that concrete canals have the capacity to irrigate 68% of the agricultural land area and are easier to manage at a lower cost. Finally, the construction of artificial concrete canals emerged as the most effective solution to rejuvenate the area and solve the challenges faced by farmers.The project has the capacity to irrigate more than 30,000 hectares of land, benefiting more than 1200 farmers. It is expected to stop the use of over 600 wells for irrigation and potentially raise groundwater levels by about 2.5 m annually. Our work revealed that addressing groundwater depletion requires installing canals, rainwater harvesting, farmer education, modern irrigation, drilling restrictions, and supporting water. This paper provides valuable insights about sustainable water management practices and the importance of integrating GIS technology in the planning and implementation of water resource projects in semi-arid regions.

KEY WORDS: GIS, weather station data. Sentinel & WorldView-3 imagery. DEM, flow calculator. Open channel

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LIST OF SYMBOLS and ABBREVIATIONS

GIMMS	Global Agricultural Monitoring System
GIS	Geographical Information Systems
RWH	Rainwater Harvesting
WAH	Water Harvesting
MICA	micro catchment
MACA	macro catchment
FW	Freshwater
FWR	Freshwater resource
RS	Remo sensing
WSHM	Watershed management
WSH	Watershed
OPCH	Open channel
DEM	Digital elevation model
IDW	Inverse distance weighted
GPS	Global Positioning System
LU	Land use
LC	land cover
GWM	Ground water monitoring
IR	Infrared
LST	Land Surface Temperature
WGS	World Geodetic System
NDVI	Normalized Vegetation Index
NIR	Near-Infrared
PRI	Photochemical Reflectance Index
RGB	Red, Green, And Blue
SAVI	Soil Adjust Vegetation Index
SRWI	Simple Ratio Water Index
SWIR	Short-Wave Infrared
TCI	Temperature Condition Index
TIFF	Tagged Image File Format
USA	United States
USGS	United States Geological Survey
UTM	Universal Transform Mercator
WGS	World Geodetic System
A	is the cross-sectional area of the trapezoidal canal
b	is the width of the bottom of the canal
B	the width of the top of the canal
H	the height water depth of the cannel
Q	flow discharge
N	the Manning roughness coefficient
R	the hydraulic radius
S	slope
V	flow velocity
Z	bank slope
D	the diameter of the circular channel
Π	is the mathematical constant pi,
ha	hectare

1. INTRODUCTION

Throughout history, rivers have held significant importance within societies, despite their constantly changing water levels and channels. As civilizations progressed, their impact on river management became increasingly influential. As a result, many rivers have experienced significant alterations, losing their once unique natural characteristics. The primary driving force behind river and flood controls has primarily been of an economic nature (Szabó, 2006).

Water is an indispensable and precious resource, especially in arid and semiarid regions where water access often sparks conflicts. Water harvesting, a traditional practice in such areas for collecting rainwater to support crop and livestock growth, is now being implemented globally as a sustainable solution to alleviate the strain on existing water sources (Prinz, 1996). Rainwater harvesting, a specific type of water harvesting, involves the collection and storage of rainwater for various purposes, including agriculture, domestic use, commercial activities, institutional needs, flood management, and replenishing groundwater levels (Mzirai, 2010; Roebuck, 2007).

Rainwater harvesting can be categorized into two types: micro catchment and macro catchment. Micro catchment focuses on preserving rainfall at its point of occurrence and utilizing the water directly within the field or designated area. Typically encompassing an area of less than 1000 m2, micro catchment methods include small semi-circle pits, strip catchment tillage, semi-circle bunds, contour bunds, and meskat-type systems (Girma, 2007; Zakaria et al., 2012). On the other hand, macro catchment involves collecting water from a larger basin area, ranging from 0.1 hectare to several thousands of hectares, which may be situated in proximity or at a distance from the intended utilization area. (Hameed, 2017).

Water is a vital resource for human survival, daily activities like agriculture, commercial activities, sanitation, and hygiene (Mokgope & Butterworth, 2001). To address the increasing demand for water, water harvesting has been practiced for centuries, with some societies relying on it to relieve pressure on overburdened water systems (Palmback, 2004). One approach to water harvesting is the use of macro catchment systems, which require storage Infrastructure and transfer systems, such as channels and natural streams, are employed to convert water storage in the utilization area (Zakaria et al., 2012).

Global freshwater resources are facing increasing strain due to factors like population growth, improved living standards, and economic development, leading to intensified competition for these resources, which are unevenly distributed across locations and seasons. Certain regions suffer from devastating floods, leading to loss of life and property, while others face the harsh reality of drought, where water becomes a scarce and valuable commodity. Furthermore, certain areas encounter heightened risks of both droughts and floods. According to the UN Water (2022).

Throughout history, Monitoring water quantity and quality is a crucial concern for societies, with competition for resources often leading to conflicts, ranging from individual disputes to international tensions. The traces of human efforts in areas such as irrigation, drainage, and urban development are evident throughout recorded history (Basra is thirsty, 2020).

In addition to its vital role in the life cycle, water also serves as a means of transportation and a valuable resource, whose availability can shape the development of different regions. The presence or scarcity of water remains a critical determinant of land utilization. Despite possessing the necessary knowledge and skills for water management, humanity has struggled to effectively steward this resource. Economic considerations have played a significant role in this challenge. The rapid economic advancements of the 19th and 20th centuries have heavily influenced water management decisions, often resulting in inadequate resource management. As professionals in watershed management, it is incumbent upon us to acknowledge this responsibility and apply our expertise to enhance water management practices (Water management: Current and future challenges and research directions, 2015).

Watershed management plays a crucial role in ensuring the sustainable allocation of resources and preserving the vital functions of a watershed, which directly impact the well-being of human, animal, and plant communities within its boundaries. It entails the study of relevant watershed characteristics and the development of plans, programs, and projects to achieve these objectives. To effectively manage all aspects of a watershed, agencies rely on the use of Geographic Information Systems (GIS), which is considered the most valuable tool available. GIS enables the control and monitoring of various aspects within a watershed, including water rights, stormwater runoff, drainage, water quality, water supply, as well as overall watershed planning and utilization (Woolley et al., 2002).

The northern region of Iraq is endowed with a rich array of water resources, encompassing various rivers, streams, springs, groundwater sources, and lakes like Dokan, Derbandikhan, and Dohuk. Precipitation in the form of rainfall and snowfall serves as a vital water source, with the climate exhibiting seasonal variations, ranging from cold and snowy winters to warm and dry summers. Average annual rainfall varies across the region, with the southern Erbil area receiving around 250 mm, while the high mountains along the northeastern border with Iran and the northern border with Turkey experience over 1200 mm (Omer, 2011). Surface water resources mainly comprise rivers and streams, with approximately 40% of the surface water originating from outside the Regional Government (KRG) region. Notable rivers include the Greater Zab, Lesser Zab, Khabur, Sirwan, and Awa Spi, all of which flow into the Tigris River within Iraq (UNDP, 2011). The Greater Zab, serving as the primary tributary of the Tigris, flows through the Erbil Governorate after originating from Wan Lake in Turkey, entering Iraq at Al-Amadieh city.

1.1. The Aim and Objective of the Study

Our primary objective in conducting this discussion is to address the challenges faced by farmers in this area, particularly the scarcity of groundwater. To tackle this issue, we employ modern technologies, including:

1. Geographic Information System (GIS) - specifically, ArcMap 10.8.
2. watershed and pond construction.
3. Epanet 2.2, a software tool for water distribution network analysis.
4. Flow Calculator software, a tool for calculating flow rates and related parameters.
5. open channel concrete
6. Weather station data for monitoring and understanding climatic conditions.

1.2. Research Questions

1. Does urban expansion and population growth affect groundwater decline?

2. Does climate change affect water shortages?

3. Does global warming affect groundwater depletion?

4. Does the topography of an area affect differences in groundwater levels?

5. Does increased demand for agricultural products affect groundwater depletion?

6. Does the type of crop plant affect groundwater depletion?

7. Does this type of irrigation method affect groundwater depletion?

1.3. Goal of thesis

This thesis aims to tackle the challenges faced by farmers in the Baranti plain, with additional benefits and purposes, including:

1. Implementing strategies to enhance groundwater levels is crucial for ensuring a sustainable and reliable water source for farming activities in the area.
2. Resolving water-related issues and improving agricultural productivity can boost farmers' income and financial stability.
3. The thesis aims to enhance local agricultural production by enhancing water availability and implementing efficient irrigation practices, thereby promoting food security and reducing external reliance.
4. The goal is to expand the area of irrigated land by optimizing water resources and addressing water scarcity, allowing farmers to cultivate larger areas.
5. Addressing water scarcity in the Baranti plain can indirectly alleviate clean water issues in the center of Erbil by reducing pressure on existing water sources.
6. Sustainable water management practices can reduce the impact of droughts on agricultural activities, ensuring resilience against changing climate conditions.
7. The goal is to decrease electricity usage and associated costs for farmers by implementing efficient irrigation systems and reducing reliance on energy-intensive methods.
8. Increasing the area of green belt: By promoting sustainable agricultural practices and creating a green belt, the thesis seeks to enhance environmental sustainability and contribute to the overall ecological balance of the region.

2. LITERATURE REVIEW

The sustainability of rainwater harvesting practices relies heavily on the effective management of river water harvesting infrastructure, which plays a crucial role in storing, treating, and distributing collected rainwater.

Climate change and human activities have disrupted the hydrologic cycle, which includes condensation, precipitation, infiltration, runoff, and evapotranspiration. Precipitation occurs when atmospheric moisture condenses and descends to the Earth's surface as rain, guided by gravity. Water from precipitation can seep into soil, flow into oceans, or evaporate back into the atmosphere. Vegetation plays a crucial role in the water cycle by releasing water vapor through transpiration. (Hunt et al., 2018).

2.1. History of water Harvesting

Throughout history, water harvesting has played a vital role in agriculture, stretching back thousands of years to the earliest days of human civilization. Water harvesting has been a crucial practice in various cultures, from basic techniques to sophisticated systems like Roman aqueducts, especially in arid and semi-arid regions where alternative water sources were scarce. (Neville and Coles, 2020). In areas such as the Middle East, Northern Africa, and Western Asia, where subsistence farming prevailed, water harvesting emerged as a lifeline for irrigation and various other purposes (Fernández-Giménez and Le Febre, 2006). While diverse methods were invented, each culture developed its own distinctive approaches to collecting or redirecting runoff for productive utilization (Prinz, 1996).

2.1.1. The Middle East

Water harvesting has been a common practice in the Middle East for thousands of years. According to Prinz (1996 The Southern Mesopotamia region, now Israel, has been practicing runoff irrigation farming since the 10th century BC, with simple structures dating back to 4,500 BC, and this practice continued throughout Roman and Byzantine rule. (Neville and Coles, 2020). Floodwater management systems have also been implemented in North Yemen, dating back to at least 1,000 BC and still in use today, producing agricultural products for up to 300,000 people . Other regions in Pakistan and Saudi Arabia have also employed floodwater systems, adapting to their specific climate and terrain . These historical water harvesting practices demonstrate the importance of sustainable water management in arid and semi-arid regions and continue to inspire modern-day water management strategies.

2.1.2 Africa

Northern Africa has a rich history of water harvesting techniques, adapted to its unique landscapes. In Libya, formerly the Roman Empire's granary, runoff irrigation was used to cultivate crops like barley, wheat, olive oil, grapes, figs, and dates, and support livestock farming like sheep, pigs, and cattle. (Prinz, 1996). This innovative agricultural system sustained a sizable, settled population for more than four centuries and yielded surplus crops (Mbilinyi et al., 2005). Additional water harvesting methods still in practice across the region encompass the "lacs collinaires" rainwater storage ponds in Algeria.

Rainwater harvesting in Tanzania has been a significant aspect of rural farming for centuries, using indigenous methods like Majaluba, Vinyungu, and Ndira for effective irrigation. (Mbilinyi et al., 2005). Additionally, the concept of "mashamba ya mbuga" has been utilized, referring to the utilization of rainwater from the neighboring highlands to cultivate water-intensive crops. These traditional approaches to water harvesting have stood the test of time, demonstrating their sustainability by aligning with local lifestyles, institutional frameworks, and social structures.

2.1.3. Western Asia

Indigenous communities in India have adapted and thrived despite water scarcity in arid regions of Asia through traditional water harvesting methods. The annual rainfall in India varies significantly, from 1000 cm in the northeast to 15 cm in desert regions, highlighting the social groups' organization around water scarcity. (Krishiworld, 2006). In the cool and arid Spiti valley of Himachal Pradesh, an elaborate network of channels known as Kuls has been ingeniously designed to capture meltwater from glaciers. and distribute it equitably among families for irrigation purposes (Rainwater Harvesting, 2002). The eldest son of a family inherits all landholdings, Within the community, various aspects are governed by the "Bada Ghars" (big houses), including farm tools, family residences, and water rights. These water rights are of utmost importance and regulated by the Bada Ghars. Other families in the community must either buy water from the Bada Ghars or offer unpaid labor as compensation. The Bada Ghars hold primary access to the stored water for irrigating their fields, while the remaining water is distributed in a hierarchical manner to each family farm, facilitating a crop rotation system. and equitable labor sharing (Rainwater Harvesting, 2002).

Additional examples of historical water harvesting techniques from India encompass the Kunds found in the Thar Desert and the bamboo irrigation method utilized in the Khasi and Jaintia hills of Meghalaya. Kunds are circular, underground tanks designed to store drinking water with a saucer-shaped catchment area and a tank in the center. These structures are built utilizing indigenous materials like lime plaster or cement. and have a depth between 3-4.5m (Rainwater Harvesting, 2002). In the bamboo irrigation method, bamboo pipes transport water to local farmers' crops at a rate of about 18-20L per minute, reducing to 20-80 drops per minute over several hundred meters (Rainwater Harvesting, 2002).

2.1.4. America

Water harvesting techniques are not limited to the Old World, as ancient civilizations in the Americas also had their own methods. The Mayans, for example, had a long history of water harvesting, as evidenced by structures such as Chultuns, which were early types of cisterns capable of holding 20 to 45 thousand litres of water. Additionally, they used Aguadas, artificial rainwater reservoirs These structures are specifically engineered to accommodate water storage ranging from 10 to 150 million liters, while Aquaditas are smaller artificial reservoirs capable of holding 100 to 50,000 liters of water (Gnadlinger, 2000). (Mbilinyi et al., 2005).

2.2. Watershed

A watershed refers to a land area where all precipitation and watercourses converge to a central outlet, which could be the mouth of a bay, the discharge point of a reservoir, or any location along a stream channel. The terms watershed, catchment, and drainage basin are sometimes used interchangeably. A watershed includes all the components that contribute to the outflow point, such as Surface waters, underground aquifers, reservoirs, flowing streams, expansive lakes, and thriving wetlands. Large watersheds consist of a range of smaller watersheds. The boundaries of a watershed are determined by the land that contributes water to the outflow point. Watersheds are critical because human activities and land use practices within a The watershed plays a direct role in influencing both the quantity and quality of available water within its boundaries. (US EPA, 2022).

A watershed, also referred to as a drainage basin or catchment area, is an essential concept in hydrology and environmental science. It represents an area of land where all the water that falls as precipitation or flows across the surface drains into a common river, stream, lake, or groundwater system. The boundaries of a watershed are determined by the topography of the land, with ridges and high points serving as natural dividers (Heathcote, 2009).

A watershed can range in size from small, localized areas to large basins that span multiple states or even countries. Regardless of their size, watersheds are crucial components of the Earth's hydrological cycle, playing a fundamental role in the movement, storage, and distribution of water. They act as natural units for water resource management and serve as the foundation for understanding and protecting water quality and quantity (Levner and Zhang., 2007).

The water cycle within a watershed begins with precipitation in the form of rain, snow, or hail. This water can take several paths: it can infiltrate into the ground and become part of the groundwater system, flow overland as surface runoff, or be intercepted by vegetation. Surface runoff collects in streams and rivers, eventually making its way to larger bodies of water such as lakes or the ocean. Groundwater moves through the soil and rock layers, feeding springs and seeping into rivers and lakes (Allan et al., 2020).

The concept of a watershed is closely linked to the idea of a river basin. A river basin encompasses the entire area drained by a river and its tributaries, including all the watersheds within its boundaries. For example, the Mississippi River basin encompasses numerous smaller watersheds, such as the Ohio River watershed and the Missouri River watershed (Teclaff, 2012).

Watersheds are dynamic systems influenced by land's physical geography, such as shape, slope, and soil composition, which affect water movement and potential flooding, erosion, and sedimentation. Climate also plays a significant role, with variations in rainfall patterns and temperature affecting water balance within a watershed (Lee et al., 2014).

Land use and human activities significantly affect a watershed's health and functionality. Agriculture, urban development, industrial activities, and deforestation can increase runoff, pollution, and habitat degradation. However, responsible land management practices like reforestation, soil conservation, and sustainable development can help maintain or restore ecological integrity. (Su et al., 2012).

Watersheds are vital ecosystem services for human well-being, serving as natural filters, providing habitat for diverse species, supporting recreational activities, and contributing to landscape aesthetics. They also serve as the primary source of freshwater for drinking, irrigation, and industrial use, making them essential for water supply. (Olsson & Folke, 2001).

In conclusion, a watershed is a dynamic and interconnected system that encompasses an area of land where all water resources drain into a common body of water. Watersheds play a critical role in the water cycle, influencing water quality, quantity, and overall ecosystem health. Understanding and effectively managing watersheds are essential for sustainable water resource management and environmental conservation (Choudhari et al ., 2018) .

2.2.1. Classification based on area.

Watersheds can also be classified into various categories based on the area they encompass, as depicted in the following (Table 2.1.).

Table 2.1. watershed classification

No	Type Of watershed	Area Covered
1	Micro Watershed	0 to 10 ha
2	Small Watershed	10 to 40 ha
3	Mini Watershed	40 to 200 ha
4	Sub Watershed	200 to 400 ha
5	Macro Watershed	400 to 1000 ha
6	River basin	above 1000 ha

2.3. Open Channel Stream

Open channel concrete is crucial in agriculture as it provides irrigation channels, drainage systems, and water conveyance structures for crops and livestock, transporting water from various sources. a reservoir, river, or well to the fields, as well as to drain excess water from the fields to prevent flooding and soil erosion.

One definition of open channel concrete in agriculture is provided by the Food and Agriculture Organization (FAO) of the United Nations, which defines it as "a concrete channel or canal used for the conveyance of water to irrigate crops or to drain excess water from fields." (FAO, 2013).

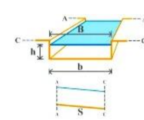
Open channels can be categorized based on their source, which can either be man-made or occur naturally.

- **Natural channels.** Open channels, ranging from small creeks to large rivers, can even be subterranean water bodies with visible surfaces. Their hydraulic characteristics often show unpredictability and irregularity due to their natural formation.
- **Artificial channels.** Human activity creates or modifies man-made open channels, such as navigation channels, irrigation canals, drainage ditches, and spillways, typically designed with regular cross-sectional shapes in engineering practice.

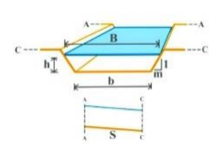
Open channels are commonly used for irrigation and can be classified based on various criteria, including shape, lining, slope, and flow regime. Here are some of the common types of open channels for irrigation:

Several types of canals are often used in agricultural irrigation.

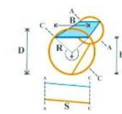
1. Rectangular channels: These channels have a rectangular cross-section and are commonly used for irrigation in flat terrain. They can be designed using the Manning's equation for open channel flow, which relates the flow rate, channel geometry, and roughness coefficient of the channel. (Chow, V. T., Open Channel Hydraulics, McGraw-Hill Education, 1959)



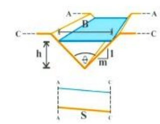
2. Trapezoidal channels: These channels have a trapezoidal cross-section and are often used in hilly areas where the slope of the land is greater. The design of trapezoidal channels can also be based on the Manning's equation or other methods, such as the standard step method. (Source: Subramanya, K., Engineering Hydrology, Tata McGraw-Hill Education, 2008)



3. Circular channels: These channels have a circular cross-section and are used for the transport of large volumes of water. They can be designed using the Hazen-Williams equation, which relates the flow rate, channel diameter, and roughness coefficient of the channel. (Source: Chow, V. T., Open Channel Hydraulics, McGraw-Hill Education, 1959)



4. Triangular channels are commonly used in civil engineering and hydrology for various applications, such as irrigation, drainage, and stormwater management. They are also used in the design of some types of spillways, which are structures used to safely discharge excess water from dams or reservoirs.



2.3.1 Advantages of channel Stream

One significant advantage of canal lining is the reduction of water loss through seepage. Unlined canals can lose up to 60% of water through seepage, while lined canals can reduce water loss to as low as 10%, thus conserving water resources (Bastiaanssen, Molden, and Makin, 2007).

Canal lining improves irrigation efficiency by reducing the volume of water required for crop irrigation. This reduction in water usage can lead to lower irrigation costs and increased crop yields (FAO, 2018).

Lining canals increase the durability of the canal by reducing erosion and wear on the canal walls and base. This results in reduced maintenance and repair needs, saving both time and financial resources. Additionally, canal lining helps restrict weed growth, further reducing maintenance costs (FAO, 2018).

Canal lining effectively controls waterlogging, mitigating the negative effects associated with it (Mahajan, 2020).

The smooth surface provided by canal lining allows for increased flow velocity, thereby increasing the canal's discharge capacity. This increased velocity can also help reduce evaporation losses (Singh et al., 2017).

Canal lining ensures the stability of the canal section, providing structural integrity and reducing the risk of erosion or collapse (Singh et al., 2017).

Lining canals can prevent sub-soil salt from coming into contact with canal water, maintaining water quality and preventing potential negative impacts on crops or the environment (Kumar, 2019). deteriorate, which, consequently, impacts the size and frequency of hydrologicaldroughts.

2.4. Previous Studies

Oweis et al. (2006) conducted global studies on water resources and harvesting to improve agricultural productivity and efficiency in dry and semi-dry areas. conducted a study focused on developing a water harvesting strategy for West Asia and North Africa, which highlighted the potential for storing over 50% of lost rainwater at a low cost. Ketsela (2007) The Munyao team used a GIS-based model in the central Rift Valley of Ethiopia to identify suitable areas for water harvesting, focusing on micro catchments. (2010) utilized remote sensing and GIS techniques to determine rainwater harvesting sites in Unguja Island, Tanzania. Mzirai et al. (2010) conducted research in the Chome-Makanya catchment of the Pangani basin in Tanzania, demonstrating the significant increase in yield production (over 120%) by utilizing harvested runoff water for supplemental irrigation during dry periods. Weerasinghe et al. (2011) developed the Geographic Water Management Potential (GWMP) The model effectively identified suitable water supply management locations in the Nile and Sao-Francisco catchments, demonstrating its effectiveness in determining rainwater harvesting sites in diverse geographic and climatic conditions. Zakaria et al. (2012) studied macro-catchment water harvesting systems in Iraq, utilizing the watershed modeling system (WMS) to estimate rainwater harvesting potential for supplemental irrigation in the region, specifically focusing on six selected macro catchments.

2.4.1. Recently Similar Project

They have implemented similar projects in several countries neighboring and surrounding Iraq. While there may be some geographical differences, the objectives remain the same. In this section, we will discuss three specific projects:

2.4.1.1 Harran plain project in Turkey

The Harran Plain Irrigation Project is a notable irrigation endeavor situated in the Şanlıurfa province of southeastern Turkey. It forms part of the broader Southeastern Anatolia Project (GAP), which aims to stimulate regional development across various sectors, including agriculture, irrigation, and rural infrastructure. The Harran Plain has long been recognized for its fertile soils and rich agricultural heritage. The irrigation project in this area seeks to enhance agricultural productivity, improve water management practices, and ensure sustainable water resources to support farming activities. (World Bank, 2005).

Covering approximately 1.8 million hectares of land, the project comprises an extensive network of irrigation systems. Within the GAP region, the Harran Plain stands out as a significant project site, characterized by abundant groundwater resources and a vast irrigated field. The Harran Plain encompasses a drainage area of 3,700 km2, a plain area of 1,500 km2, and an irrigation area spanning 476,000 hectares. These statistics underscore the scale and importance of the project in terms of agricultural development and water resource utilization (Bilgili, 2018).

The Harran Plain Irrigation Project plays a crucial role in transforming the region's agricultural landscape, enabling farmers to cultivate crops more efficiently and sustainably. By harnessing the available groundwater resources and implementing advanced irrigation techniques, the project contributes to increased agricultural productivity and economic growth in the Şanlıurfa province. It represents a significant step towards achieving the objectives of the GAP initiative and promoting overall regional development Özel, N. (2019).

2.4.1.2 Toshka Project in Egypt

The Toshka Project, also known as the New Valley Project or the Southern Egypt Development Project, stands as one of the most significant irrigation channel endeavors in Egypt. Its ambitious objective is to reclaim and cultivate vast desert areas in the southern part of the country by diverting water from the Nile River.

At the heart of the project lies the construction of the impressive Toshka Canal, also referred to as the Sheikh Zayed Canal. This extensive irrigation channel spans approximately 51 kilometers (32 miles) and features branching canals. The Mubarak Pumping Station, a crucial component of the project, facilitates the transfer of up to 1.2 million cubic meters of water per hour from Lake Nasser into the Sheikh Zayed Canal.

The Toshka Project seeks to convert around 500,000 hectares (1.2 million acres) of arid desert into fertile agricultural land. This transformation enables the cultivation of various crops, including wheat, corn, vegetables, and fruits. Additionally, the project encompasses plans for establishing new towns, developing infrastructure, and generating employment opportunities within the region.

The Toshka Project represents a significant endeavor in addressing Egypt's agricultural and developmental needs. By utilizing the Nile River's water resources and implementing advanced irrigation systems, the project aims to unlock the potential of previously uninhabitable desert areas, fostering agricultural growth, and boosting the local economy (Abdel-Aziz, 2020).

2.4.1.3 South to North water project in China

The main aim of the South-to-North Water Transfer Project in China is to address severe water scarcity and the imbalance between water-rich southern regions and water-stressed northern regions of the country (Berkoff, 2003). Spanning a considerable distance, the project consists of multiple routes covering a total length of approximately 4,400 kilometers (2,734 miles) (Nong., et al., 2020). Its primary objectives are to alleviate water shortages, support population growth, and promote economic development in the northern parts of China.

Specifically, the project aims to achieve the following goals: by diverting 44.8 billion cubic meters of water per year, it intends to increase water supply to meet the growing demand for domestic, industrial, and agricultural water needs in the target areas (Kattel, and Shang, 2019).

3. MATERIAL and METHOD

3.1. Study Area

Erbil, also known as Hawler, is the third largest city in Iraq. Located in the northern part of the country, it is one of the oldest continuously inhabited cities in the world, believed to be over 6,000 years old, and is recognised as a UNESCO World Heritage Site (UNESCO, 2010). The city has a population of approximately 1.5 million people and is home to a diverse mix of Kurds, Arabs, and other ethnic groups (Hamad, 2016).

Erbil experiences a semi-arid climate characterised by hot and dry summers and cool winters. The city's climate is influenced by its location in northern Iraq and its proximity to the Zagros Mountains. During the summer months, from June to September, Erbil can reach scorching temperatures of up to 45°C during the day, with hot and arid conditions. Nights are relatively cooler but still warm, with temperatures ranging from 20-25°C. Humidity is generally low during this time of year. In the winter months, from December to February, temperatures in Erbil can drop to around 0°C at night, while daytime temperatures range from 10–15°C. Precipitation is higher during the winter, occasionally resulting in snowfall. The shoulder seasons of spring (March to May) and autumn (October to November) are mild, offering comfortable temperatures and low humidity. During these months, the temperatures range from 15-25°C during the day and 5-15°C at night. Overall, Erbil has a dry climate with low annual precipitation, averaging around 300-400 mm per year. The ideal time to visit Erbil is during the spring and autumn months when the temperatures are milder and the weather is pleasant (Abdullah et al., 2020).

Our research site is located to the north of Erbil, approximately 25 kilometres away. It is situated between the Bahrka and Khabat districts, encompassing the renowned Baranti plain. The study area spans a total of 450 square kilometers and is bordered by two rivers: the Bastor River and the Great River. The geographic coordinates of the midpoint of our region are latitude 36.296497 and longitude 43.848955. That is shown in figure 3.1. In terms of irrigation, 76% of the land in this region relies on rainfall to nourish crops, while the remaining 24% depends on groundwater. It is worth noting that the area is equipped with over 500 irrigation wells to support agricultural endeavours.

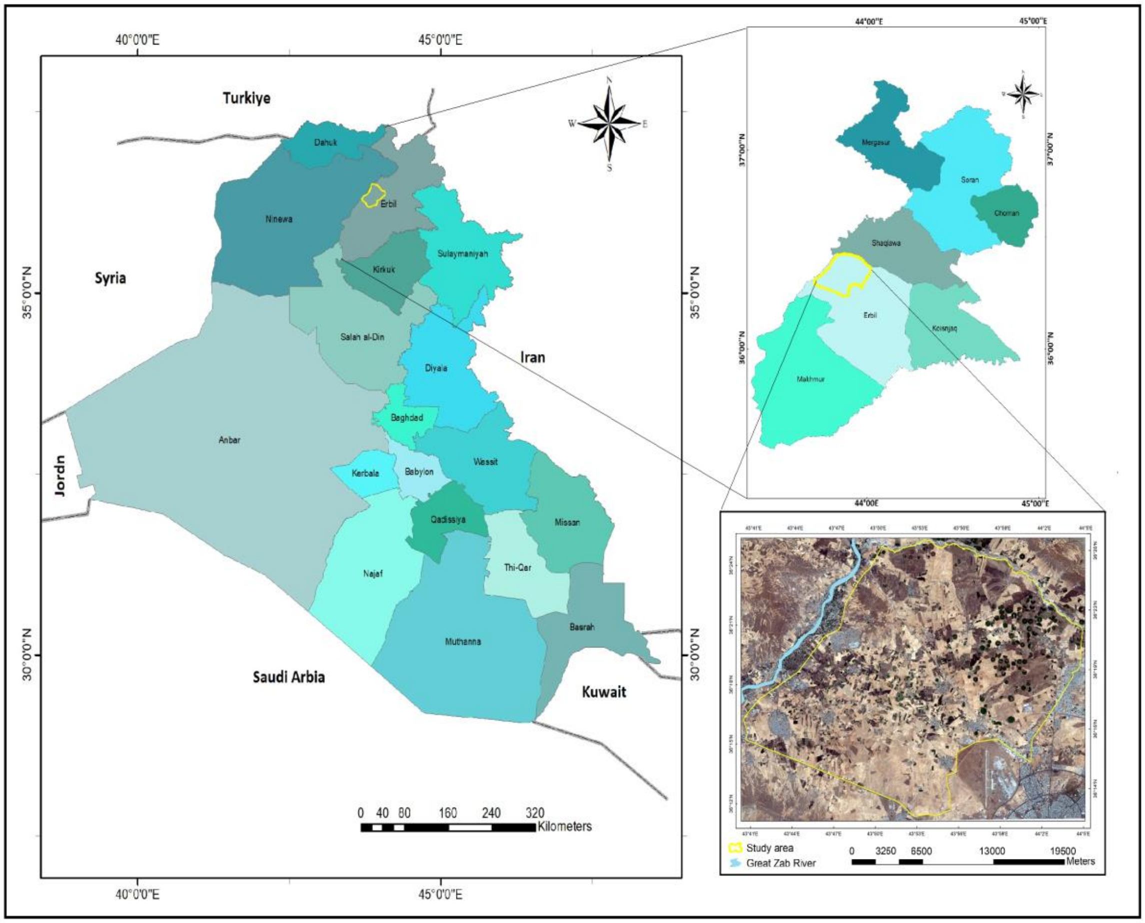


Figure 3.1. The study area delineated on the map of Iraq.

3.2. Data collection

3.2.1. Digital elevation model (DEM)

The 12.5-meter resolution digital elevation model (DEM) was obtained from the United States Geological Survey (USGS) Earth Data website (http://alaska.edu/). The data provided are rasterized and based on WGS-84 data. A DEM is a digital representation of the Earth's elevation from the surface, where each cell represents the height at a specific point on the ground. In our area, the highest recorded elevation is 513 meters above sea level, while the lowest point is 279 meters above sea level. Figure 3.2. Shows our interpretation of the area using contour lines based on the DEM.

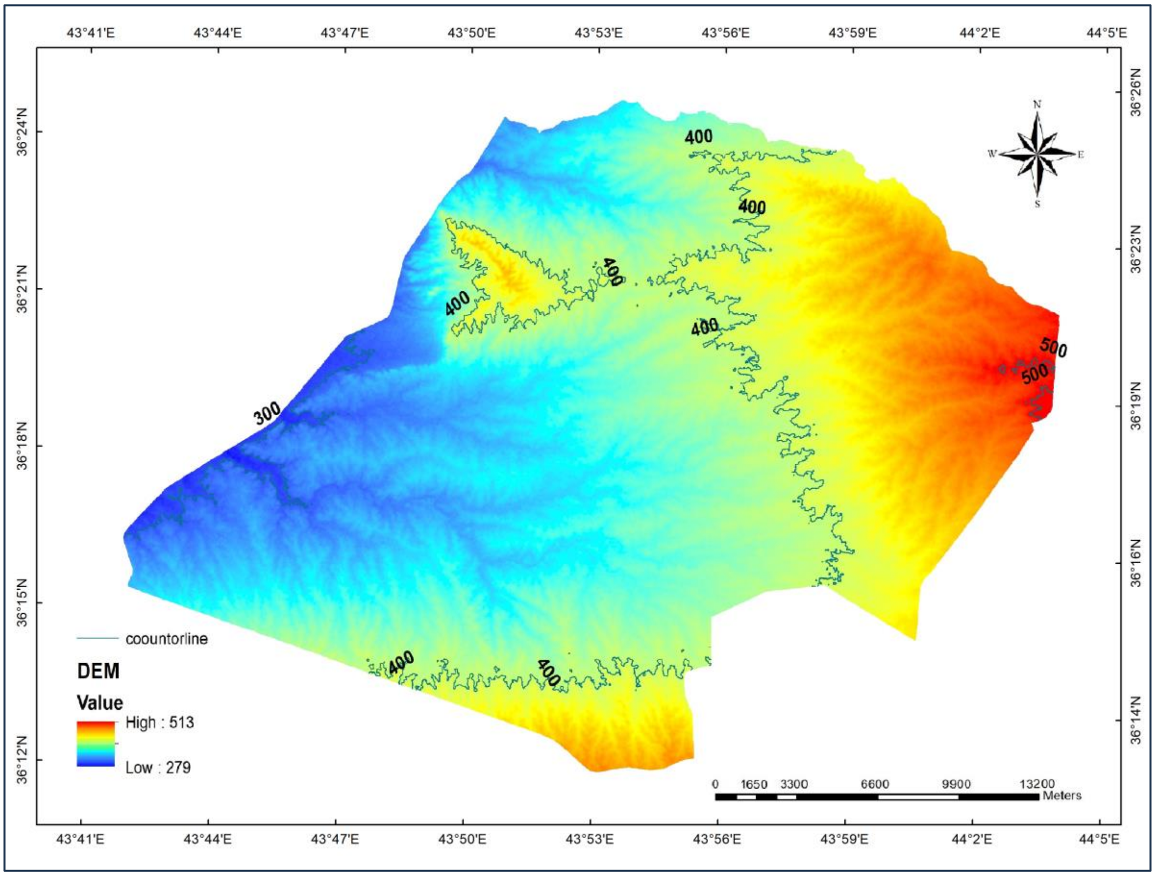


Figure 3.2. Topographic of the study area: digital elevation model with contour lines

3.2.2. Satellite Data Preparation

Satellite images play a crucial role in remote sensing, environmental monitoring, agriculture, disaster management, and urban planning. In our research, we utilized Worldview imagery from 2021 and Quick Bird imagery from 2006 for the classification of the study area. The additional imagery was acquired from the Geoland Company.

To ensure accurate spatial referencing, the images were geo-referenced to UTM Zone 38, WGS 84 coordinates. The Quick Bird image was captured on June 18, 2006. That showed in figure 3.3. while the Worldview image was captured on July 6, 2021.That showed in (Figure 3.4.).

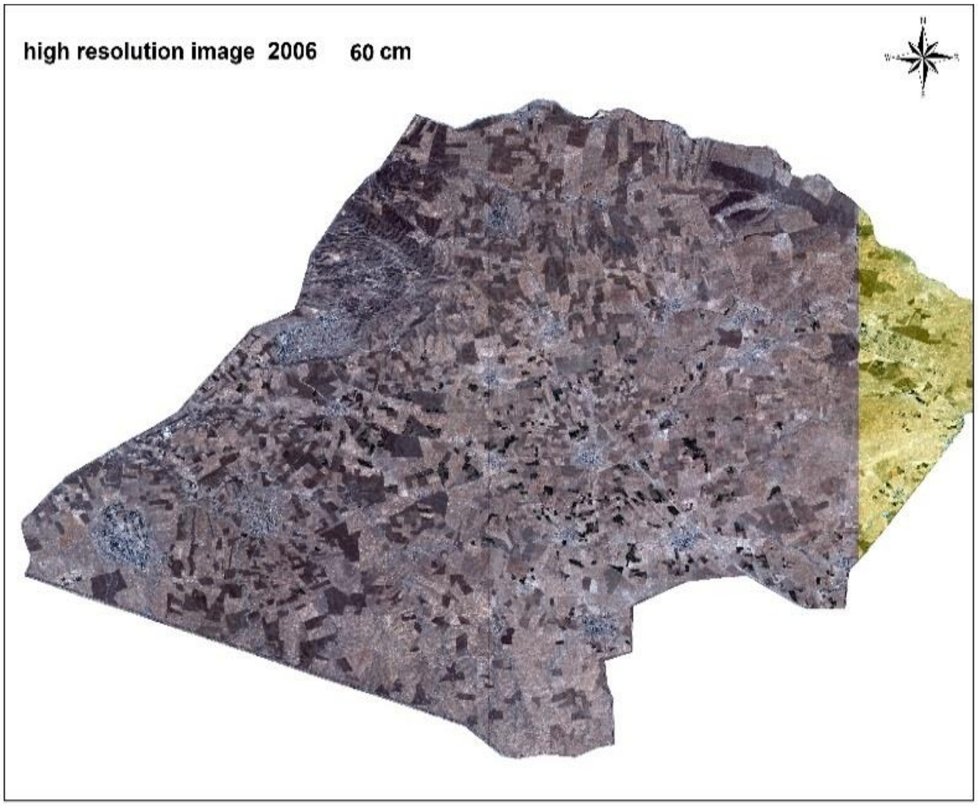


Figure 3.3. Quick Bird image 2006

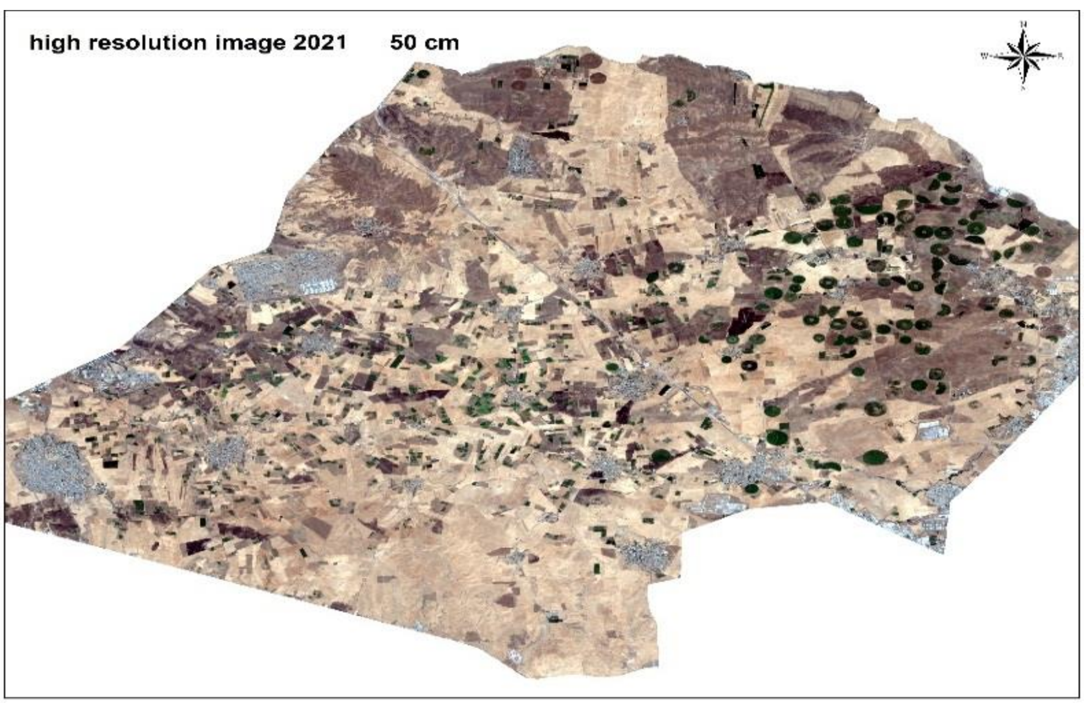


Figure 3.4. Worldview image 2021

3.2.3. Soil Texture

Khabat District falls within the Erbil Governorate, and, like any specific district, its soil texture is shaped by the local topography, climate, and historical geological events. According to the information gathered from Salahaddin University, the predominant soil textures in the region are silty loam and silty clay, as indicated in Table 1.

Table 3.1. Soil texture data in the designated study area.

No	Name of village	Latitude	Longitude	Soil texture
1	Gazna	36.278849	43.933636	silty loam
2	Jazhnikan	36.393277	43.970823	silty loam
3	Kawrgosk	36.350319	43.793304	silty loam
4	kawrgosk	36.340822	43.778883	silty clay loam
5	Bahrka	36.325947	44.01697	silty clay
6	Kawrgosk	36.319672	43.784284	silty clay loam

3.2.4. Rainfall

Precipitation data is essential for conducting various studies as it provides valuable information for making informed decisions. In our research area, we have access to data from three meteorological stations: Ainkawa, Bastora, and Khabat. These stations have been continuously recording data since 2001 under the supervision of the Erbil General Directorate of Agriculture. During our visit to the site, we were able to obtain the monthly data from these three stations.

The collected data was organized and stored, and an annual average was calculated. The summarized data is presented in table (3.2). By analyzing this data, we can gain insights into the average precipitation levels in our research area over the years

Table 3.2. Ankawa weather station monthly recording.

Years (mm)	September	October	November	December	January	February	March	April	May	June
2002-2001	4	1.4	16	94.3	87	13.7	102.5	77.5	4.2	
2003-2002		28.3	32.5	168.6	57.2	83.1	102.5	41	6.2	10.6
2004-2003		26.7	73.4	107.7	112	81.7	5.1	89.7	2.7	
2005-2004		1.7	148.3	45.3	80.1	76.8	47.8	16.8	12.2	3
2006-2005		3.5	14.8	18.5	105.1	214.2	17.6	86.5	17.5	
2007-2006		60.9	21.8	19	59	124.2	44.7	55.8	19.6	
2008-2007		1	4.2	4.6	48	58.8	58.6	4.3	0.9	
2009-2008	13.2	53	19	38	0.9	22.7	84.8	36.8		22
2010-2009	11.7	53.3	13	95.7	43.8	77.6	75.2	31.9	23.9	
2011-2010	0.7	5.9	15	42.9	128.2	40.1	33	97.5	10.1	
2012-2011		4.4	6.5	23.9	51.7	30.1	71.4	24.2	8.4	
2013-2012		14.7	52.3	89.9	169.9	59.2	20.5	30.8	52	
2014-2013			32.8	98.5	85.1	8	92.9	19.4	6.4	
2015-2014	0.8	82.8	88.5	54.7	36	40.5	43.4	16.7		
2016-2015	8	23.2	99.5	109.9	47.4	31.4	68.1	56.5		1.3
2017-2016			25.4	128.1	31.3	13.5	74.2	39.7	3.2	
2018-2017			18.3	30.7	45.7	147.2	8.8	73.2	61.8	
2019-2018		47.8	148.8	224.4	120.6	77.9	221.9	113.6	8	
2019-2020		16.4	13.5	61.7	94	69.5	131.3	28.1	17.3	
2020-2021		0.4	63.7	25.3	49.2	27.9	141	58		

Khabat weather station monthly recording

Years (mm)	September	October	November	December	January	February	March	April	May	June
2002-2001	4	0.5	10.1	54.4	63.3	21.6	116.1	58.7	1.6	
2003-2002		10.2	14.8	138.2	51.8	81.4	67	32.4	17.5	
2004-2003		10.7	74.4	82.1	79.8	73.7	6.4	59.1	3.2	
2005-2004		2.3	72	31.9	86.7	89.4	26.5	13.3	8.2	
2006-2005		0.7	19.1	24.1	88.1	134.6	14.6	85.2	14.1	
2007-2006		34	5.8	15.4	35.9	103.7	25.1	59.9	11.7	
2008-2007		0.2	0.3	2.4	33.5	39.1	46.6	0.9	1.5	
2009-2008	7.7	47.1	18.1	19.4	0.3	21.4	42.6	32.9		
2010-2009	6	18	6	81	34	48.6	36.8	21.3	13.7	
2011-2010		5.6	10	66.5	87.2	35.6	9.3	79.9	4	
2012-2011		2.5	14	14.5	28.2	17.8	44.5	4.5	0.7	
2013-2012		23.2	64.2	97.6	130.7	45.6	27.2	17	16.8	
2014-2013		10	38.6	95.4	22.9	2	97.7	8.2	3.3	
2015-2014		65.9	77.5	69.1	21.1	33.4	55.2	7.8		
2016-2015	12.9	31.9	86.3	68.9	77.5	55.1	39.7	32.6	1.9	
2017-2016		0.5	25.7	89.8	30.1	6.7	47.1	41.5	0.7	
2018-2017			14.4	28.5	39.7	88.2	13	73.1	41.6	
2019-2018		35.1	158.4	200.1	81.6	73.6	217.5	122.4	14.1	
2019-2020		23.7	7.1	100.1	99.9	57.6	136.4	23.6	13.6	
2020-2021			42.8	33.7	79.4	24				

Bastora weather station monthly recording

Years (mm)	September	October	November	December	January	February	March	April	May	June
2004-2003			55	88.2	153.5	113.6	9	72.8	13.8	
2005-2004		1.6	103.5	24.5	96.4	59.9	47.8	15	11.5	
2006-2005		6.9	16.4	18.6	75.4	153.7	15.5	66.7	13.5	
2007-2006		59.4	22.9	15.3	35.5	83.6	31.1	40.2	10.5	
2008-2007			12.6	10	27.9	50.3	35.2	0.4	1.7	
2009-2008	4.9	20.4	7.8	26.1	1.1	14.3	56.4	27	2.3	
2010-2009	4.7	30.4	10.4	102.1	51.3	81.4	80.9	44	39.9	
2011-2010	0.7	3.4	12	41.3	107.4	51.4	35	86.1	15.3	
2012-2011		11.4	13.7	27	73.7	55.8	96.3	21.7	21.5	
2013-2012		50	44.6	144.1	259.6	93.4	29.9	23.1	17.5	
2014-2013		1.4	34.1	123.5	130.2	6.7	114.7	20.8	3.2	
2015-2014		165.5	136.3	61.5	52	48.1	95.7	29.2	4.6	
2016-2015	12.5	98.9	103.7	131.8	71.8	61.9	110.2	61.4	1.1	
2017-2016		0.4	21	128.9	46.6	25.2	89.8	53.4	13.2	
2018-2017			44.5	28.9	93.7	170.9	14.3	99.1	98.2	
2019-2018		58.6	110.2	215.6	138.3	116.7	208	134.7	15.3	
2019-2020		49.5	58.5	67.6	107.1	75.9	131.7	48.3	21.3	
2020-2021			65.4	35.3	76.2	40.2				

3.2.5. Groundwater Monitoring Data

Groundwater monitoring is a crucial process that involves the continuous measurement and analysis of groundwater quality and quantity at a specific location. Monitoring projects plays a significant role in assessing the impact of groundwater on health and agriculture, particularly in semi-arid regions. In these regions, where climate changes are frequent, monitoring groundwater becomes even more important.

In our study area, which is situated in the northern region of Erbil and represents the final segment of a semi-arid area, the government annually monitors 82 wells for both groundwater quality and quantity. These monitoring efforts are complemented by monthly supplies of data, as outlined.Within this network of wells, seven specific wells in our study area have been monitored since 2001 as presented in Table (3.3). Namely (Gainj gawra , Grda chal , jadida zab , jazhnikan ababakr , kawer gosk , qafar , sebirany gawra) After conducting our analysis, we selected September as the focal month for further investigation, as it experiences peak loads on the wells.

Additionally, we conducted a field visit to the area to gather more data. During this visit, we were able to record information from 25 additional wells, as presented in Table (3.4). To analyze and visualize the data, we utilized a Geographic Information System (GIS) and employed interpolation tools, (IDW) with the formula (3.1), to interpolate the data from a total of 32 wells.

$$z_p = \frac{\sum_{i=1}^{n}\left(\frac{z_i}{d_i^p}\right)}{\sum_{i=1}^{n}\left(\frac{1}{d_i^p}\right)} \tag{3.1}$$

Using this interpolated dataset, we identified the highest and lowest groundwater levels in the study area and divided it into five distinct zones. This zoning approach allows for a comprehensive understanding of the groundwater distribution and variability within the area.

Table 3.3. Groundwater monitoring by government

NO	NAME village	2001		2021	
		Depth	Date	Depth	Date
1	Gainj gawra	29.55	sep/2001	49.2	sep/2021
2	Grda chal	25	sep/2001	35.4	sep/2021
3	jadida zab	39.41	sep/2001	74.8	sep/2021
4	jazhnikan ababakr	21.9	sep/2001	40.15	sep/2021
5	kawer gosk	31.85	sep/2001	85	sep/2021
6	qafar	43.36	sep/2001	55.1	sep/2021
7	sebirany gawra	42.13	sep/2001	58	sep/2021

Table 3.4. Groundwater monitoring by site visit

No	Name_Water Well	Water level depth		Water level depth	
1	sarkawr harkyi 3	2005	60	2021	75
2	sarkawr harkyi 1	2014	90	2021	107
3	shakholan	2017	90	2021	112
4	barhoshtr	2011	90	2021	108
5	kewrgosk	2009	50	2021	89
6	jazhnekame fandyi	2009	29	2021	44
7	Grda chal	2001	22	2021	35
8	jazhnekane fandyi 3	2010	35	2021	50
9	Kawer gosk	2001	31	2021	82
10	jazhnekane fandyi 2	1987	46	2021	61
11	berhoshtr	2010	77	2021	96
12	grd araq	2013	50	2021	68
13	saedan	2008	51	2021	77
14	ashokan	1980	50	2021	69
15	dara ban	1983	28	2021	53
16	grd araq	2012	31	2021	48
17	mam choxan	2008	29	2021	53
18	tobzawa	2005	52	2021	85
19	smayilawa	2013	61	2021	89
20	grd jotear	2008	44	2021	63
21	tobzawa	2003	49	2021	79
22	Sebirany	2005	37	2021	56
23	smayilawa	2004	50	2021	75
24	jdida zab	2006	41	2021	71
25	Sebirany gawra	2001	42.6	2021	58

3.2.6. Soft Wear Used.

- Arc Map 10.8.2
- ERDAS IMAGINE software.
- GPS-S70G GNSS RTK - Stonex
- Pipeline flow calculator software.
- Open channel flow calculator application
- Drone

3.3. Methodology

3.3.1. Land use and land cover classification

Land use and land cover classification is the process of categorizing the Earth's surface into different types of land cover and land use classes. It relies on remote sensing technologies, including satellite imagery, aerial photographs, and LiDAR data, to identify and map these classes. The classification process involves assigning each pixel or polygon in the image to a specific land cover or land use class based on its spectral, spatial, and temporal characteristics. The accuracy of the classification depends on various factors, such as data quality, the choice of classification algorithm, and the expertise of the analyst (Bekalo, 2009; Mohammad, 2021).

In our study area, we conducted a land use and land cover classification using high-resolution satellite images like Quick Bird and Worldview-3. Our main objective was to identify the distribution of green areas and urban areas. We employed a polygon-based classification approach, eliminating the need for post-processing. Although this method is more challenging, it allowed us to achieve a high-quality result.

The study area was divided into five primary classes: Urban, Crop, Vegetation, Water, Barren Land, and Hill Zone. These classes represent the various land cover and land use types present in the area.

3.3.2. Slope

Slope can also have important ecological and environmental effects, as it affects factors such as soil erosion, runoff, and plant growth. For example, steep slopes may be prone to soil erosion and landslides, while gentle slopes may be more favorable for vegetation growth and biodiversity. (Hamad, T. 2016)

Slope is based on the analysis of many things you want to do, from building cities, planting agriculture, flooding, or erosion. For these reasons, we have paid great attention to the slope of the region. We have divided it into four zones according to the classification (FAO).

To calculate distance in ArcMap, you first need to have a digital elevation model (DEM) of your study area, which can be obtained from a variety of sources such as lidar, radar, or satellite imagery. Once you have the DEM, you can use the Slope tool in the Spatial Analyzer toolbox to create a raster layer that shows the slope values for each cell in the DEM.

Follow these steps to use the Slope tool in ArcMap:

1. Open ArcMap and add the DEM layer to your map.
2. Open the Spatial Analyst toolbox by clicking the Arc Toolbox button and navigating to Spatial Analyst Tools > Surface.
3. Click the Slope tool to open its dialog box.
4. In the input raster field, select the DEM layer for which you want to calculate slope.
5. Select the output measurement unit for the range values (e.g. degrees, percent).
6. Select the output cell size and resampling method.

Specify the name and location of the output raster.

3.3.3. Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a commonly used remote sensing index that assesses the greenness and density of vegetation. NDVI values range from -1 to 1, with higher values indicating greater vegetation density and greenery. Mean NDVI refers to the average NDVI value calculated over a specific time period or area, providing an indication of overall vegetation productivity and health.

In our study area, we obtained Landsat-8 satellite imagery for the years 2021 and 2013, specifically for the month of September. This imagery was acquired to detect changes in vegetation over time. Remote sensing techniques were employed, utilizing both the red and near-infrared bands of the Landsat-8 sensor.

By analyzing the red and near-infrared bands, we can calculate the NDVI for each pixel in the images. The formula to compute NDVI is as follows:

$$NDVI = (NIR - Red) / (NIR + Red) \quad (3.2)$$

Where NIR represents the pixel value in the near-infrared band and Red represents the pixel value in the red band. The resulting NDVI values range from -1 to 1, with higher values indicating healthier and denser vegetation.

By comparing the mean NDVI values obtained from the Landsat-8 imagery for 2021 and 2013, we can assess changes in vegetation over time in our study area. This analysis provides valuable insights into vegetation dynamics, such as growth, decline, or changes in density, which can be further interpreted in terms of ecological and environmental factors affecting the area.

3.3.4. Watershed Delineation

A watershed, also known as a drainage basin or catchment, is indeed an area of land that collects and channels all precipitation and surface water into a common outlet such as a river, lake, or ocean. The boundaries of a watershed are determined by the highest elevations or ridge lines that encircle it. These ridges divide the area into separate subbasins or smaller watersheds, each contributing water to the main outlet.

To accurately identify and delineate watersheds, a Digital Elevation Model (DEM) is commonly used. A DEM is a digital representation of the Earth's surface topography, which provides elevation data for different locations. Geographic Information Systems

(GIS) software can utilize the DEM to perform various analyses, including watershed delineation.

By employing GIS tools and a DEM, you can easily determine the location and extent of watersheds. This information is crucial for understanding the flow of water within an area and managing water resources effectively.

Once the watersheds have been identified, you express an interest in locating several ponds within the area. These ponds would serve multiple purposes, such as irrigation for crops and groundwater replenishment. Constructing ponds can help capture and store water, reducing reliance on well water and providing a sustainable water source for agricultural activities. The specific locations for these ponds would be determined based on factors such as topography, water availability, and the needs of the crops being cultivated.

In summary, utilizing a DEM and GIS software allows for accurate identification of watersheds, providing valuable information for water resource management. Additionally, the construction of ponds within the watershed area can contribute to sustainable agriculture and groundwater recharge.

To determine the watershed in ArcMap 10.8, you can follow these general steps:

1. Start by opening ArcMap 10.8 and load your digital elevation model (DEM) data into the software. Make sure your DEM is in a suitable format, such as a raster file.

2. Once your DEM is loaded, go to the "Spatial Analyst" toolbar, and make sure it is enabled. If not, you can enable it by going to "Customize" > "Toolbars" > "Spatial Analyst".

3. In the Spatial Analyst toolbar, click on the "Hydrology" dropdown menu and select "Fill" to remove any sinks or depressions in the DEM. This step ensures that water can flow consistently across the terrain.

4. After filling the sinks, click on the "Flow Direction" tool in the Spatial Analyst toolbar. This tool calculates the flow direction of water across the DEM based on the

steepest downhill path.

5. Next, use the "Flow Accumulation" tool from the Spatial Analyst toolbar to calculate the accumulated flow of water in each cell. This will help identify stream networks and potential watershed boundaries.

6. Once the flow accumulation is calculated, you can set a threshold value to determine the delineation of the watershed. Higher threshold values will result in larger watersheds, while lower values will produce smaller watersheds.

7. To delineate the watershed, use the "Watershed" tool from the Spatial Analyst toolbar. This tool uses the flow direction and flow accumulation data to identify the boundaries of the watershed for a specific outlet point.

8. Specify the outlet point for the watershed by either clicking on the cell in the DEM or providing the coordinates manually.

9. After running the Watershed tool, the resulting watershed will be displayed as a new raster layer in the ArcMap table of contents.

10. You can further refine and analyze the watershed by using other tools and functions available in ArcMap, such as extracting the watershed boundaries.

3.3.5. Pipeline Network Project

Pipeline irrigation is a system for irrigating crops or transporting water. It involves the use of pipes to deliver water from a spring or pond directly to the fields through a large network of pipes. This method of irrigation is often used for large agricultural areas or for the transportation of water between cities. To do this, we need to find a suitable location first before starting work. Then, with the help of the EPANET 2.2, software, we started designing the water distribution to the farmers to find the pipe diameter, length, roughness, height, connection, pump, valves, and reservoirs. It calculates flow rates, pressures, velocities, and head losses at various points in the network. As shown in Figure 3.5.

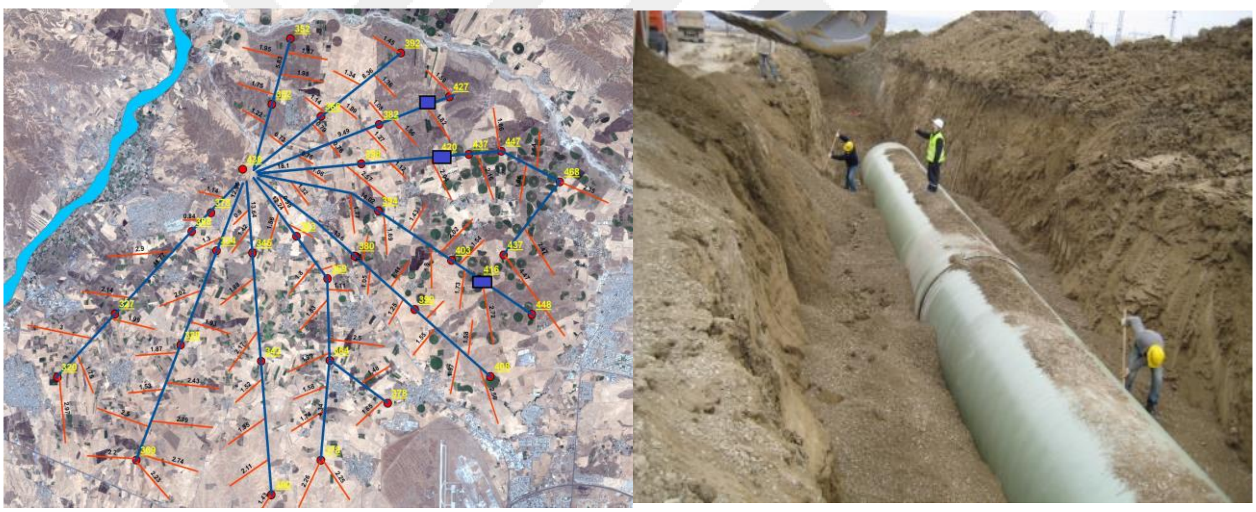


Figure 3.5. Pipeline network sample

3.3.5.1. Epanet 2.2 Software

EPANET is a widely used software package for modelling water distribution networks. It is free, open-source software developed by the U.S. Environmental Protection Agency (EPA). This software allows users to simulate the behaviour of water in a distribution network and provides various tools for analysing and optimising network performance. Hydraulic modelling: EPANET can simulate the hydraulic behaviour of complex pipe networks, taking into account factors such as pipe diameter, length, roughness, height, joints, pumps, valves, and reservoirs. It calculates the flow rate, pressure, velocity, and head loss at different points of the grid shown figure 3.6.

EPANET, a software tool used to model water distribution systems, uses the following units of measure:

1. Length: metres (m) or feet (feet)
2. Diameter: millimetre (mm), centimetre (cm), inch (inch), or foot (feet).
3. Flow rate: litres per second (L/s), gallons per minute (GPM), cubic metres per hour (m3/h), or cubic feet per minute (CFM)
4. Pressure: metre head (m), pounds per square inch (psi), kilopascals (kPa), or bar (bar)
5. Height: metres (m) or feet (feet)
6. Water quality parameters: parts per million (ppm) or milligrammes per litre (mg/L)

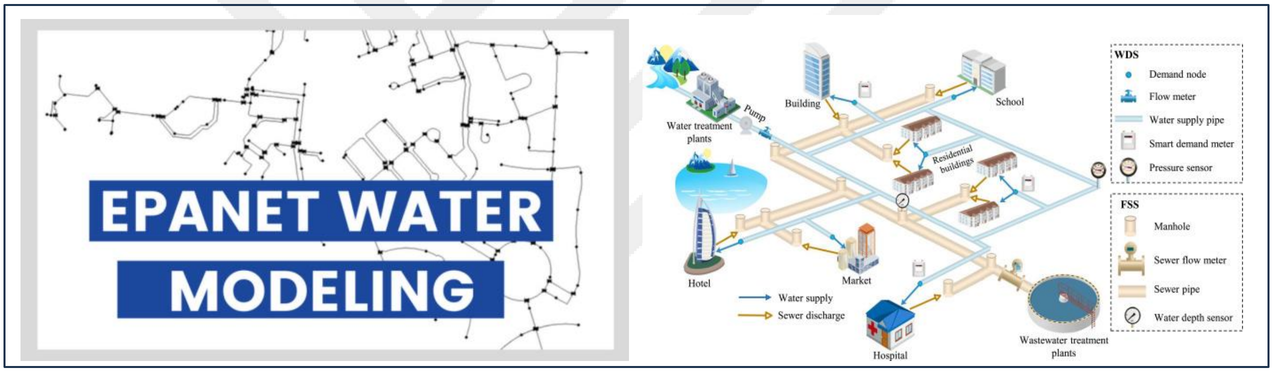


Figure 3.6. Epanet software image view

3.3.6 Open Channel Stream

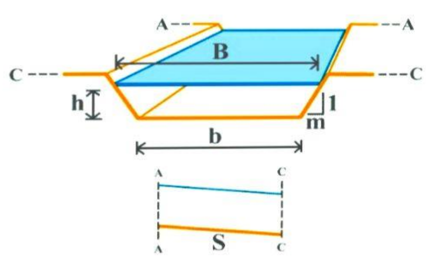
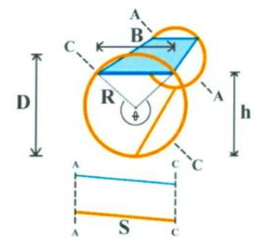
Open channel concrete plays a vital role in agriculture, providing irrigation canals, drainage systems, and water conveyance structures for crops and livestock. These canals serve the purpose of transferring water from various sources like reservoirs, rivers, or wells to fields, as well as draining excess water to prevent flooding and soil erosion.

In our discussions, the open channel takes precedence. Before commencing the design process, it is crucial to gather certain information about the location. This includes determining the availability of a water source, assessing the favorable altitude for canal construction, and verifying if the requested water quantity from farmers is within the capacity of the water source. To obtain this information, we conducted field visits to engage with farmers and gather data on their irrigation practices, focusing particularly on crops such as wheat and barley.

To determine the optimal location for the concrete channels and assess the area's slope, we utilized a Digital Elevation Model (DEM) map and Geographic Information System (GIS) software to aid in our design process. By employing these tools and incorporating relevant equations found in Table 3.5, which help determine key parameters such as discharge, flow velocity, side slope, area, and water depth, we were able to design the most suitable irrigation system for the area. This approach allowed us to reduce reliance on well water and ensure an efficient and effective irrigation solution. Figure 3.5 provided essential data for making informed design decisions.

Figure 3.7. open channel concrete image view

Table 3.5. equation and formula open channel

parameter and formula		
	Trapezoidal channel	**Circular Channel**
area (A)	A = (b + B) * h / 2	A = (π/4) * D^2
discharge (Q)	Q = (1/n) * A * R^(2/3) * S^(1/2	Q = (π/4) * D^2 * V
flow velocity (V)	v = (1/n) * R^(2/3) * S^(1/2)	V = Q / (π/4) / D^2
bank slope (or side slope) m	m = (h/B) * (1 - (b/B))	(S) = (H / R)
top width (B)	B = b + 2 * z * h	B = 2 * R * tan(θ/2)
water depth (h)	h = A / B	h = R - (R^2 - (D/2)^2)^0.5
bottom width (b)	b = B - 2 * z * h	b = D
hydraulic radius	R = A / P	R = A / P
Wetted perimeter (P)	P = b + 2y(√(1+m^2))	P = π * R

3.3.6.1. Suitable Zone

In the second stage of open channel design, it is essential to gain familiarity with the topography and slope of the area to assess its feasibility. To accomplish this, we utilized a Digital Elevation Model (DEM) map and employed a Geographic Information System (GIS) program to analyze the area's topography. Through this analysis, we were able to identify suitable locations and determine the distance between the water source and the appropriate area.

Our primary water source for this project is the Great Zap River, which holds significant importance in Iraq and Kurdistan. The river exhibits a maximum flow rate of 800 m3 per second and a minimum flow rate of 200 m3 per second. On average, it ranges between 300 to 400 m3 per second during most months of the year.

By incorporating these flow rate values into our design considerations, we can ensure that the open channel system is capable of accommodating the varying water supply from the Great Zap River throughout different seasons and conditions.

3.3.6.2. Suitable site

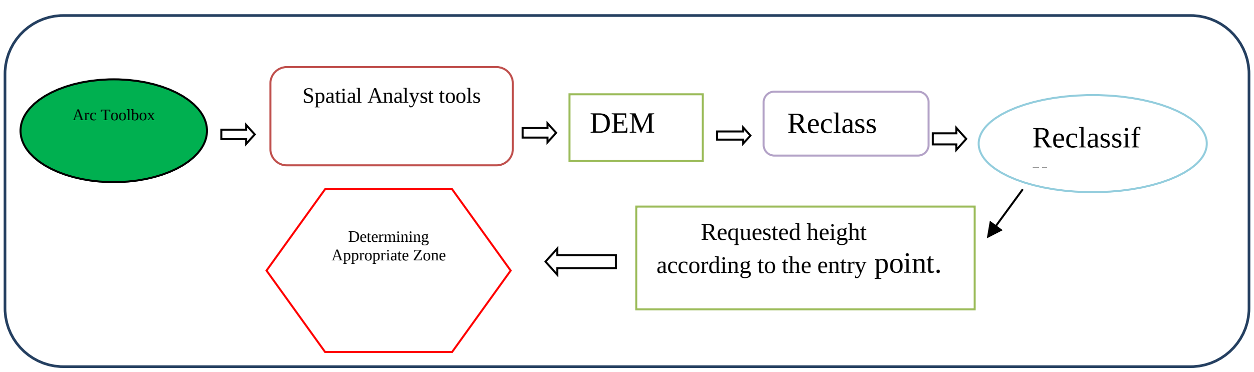
After identifying the suitable area in the initial phase, we employed a Geographic Information System (GIS) program to further analyze and divide the area. The objective was to determine the optimal locations for creating channels. To achieve this, we categorized the area into four distinct categories:

Low Suitable: This category represents areas that have limited suitability for channel creation. Factors such as soil quality, terrain, or proximity to obstacles may contribute to this classification.

Moderately Suitable: Areas falling under this category exhibit a moderate level of suitability for channel construction. They may possess certain characteristics that make them viable options, although they may have some limitations or factors that need to be considered.

Highly Suitable: These areas are deemed to be highly suitable for channel development. They possess favorable attributes, such as suitable soil conditions, favorable terrain, and minimal obstructions, which make them ideal for creating channels.

Unsuitable: This category encompasses areas that are unsuitable for channel creation. Factors such as steep slopes, poor soil quality, presence of protected or sensitive areas, or other constraints may render these areas unsuitable for the intended purpose. The following diagram & figure 3.8 shows how to find a suitable site & zone.



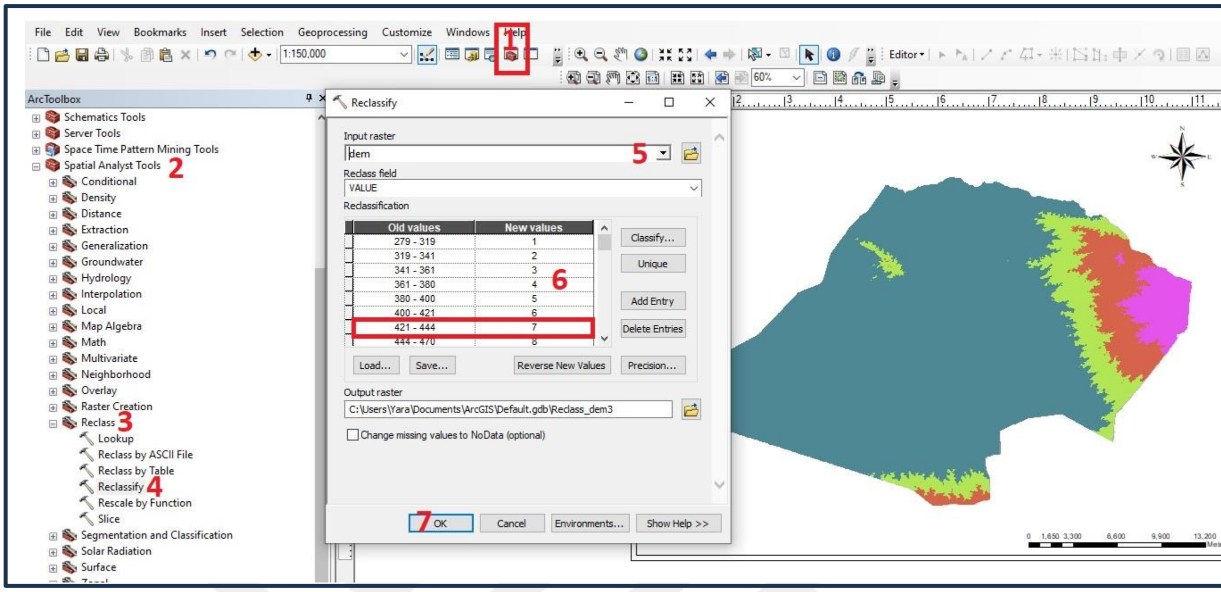
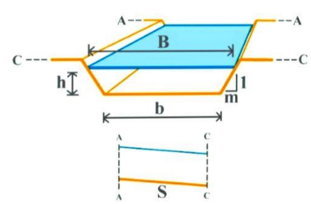


Figure 3.8. Steps on how to find a suitable site & zone.

3.3.6.3 Main Channel Stream

After designing the main canal, most of it is located in very convenient areas. It starts at an altitude of 400 m above sea level and then descends at a slope of 50 cm per kilometer. It is 130 meters above the river level, so a pump is needed to transport the water in the first stage. A minimum of 6 m^3 per second and a maximum of 9 m^3 per second are required. Considering the total land area of approximately 300 km2 and the fact that the channel is trapezoidal , According to the water required for the area, the size of the channel is as follows with a bottom width of 2 m, height of 2 m, and an upper width of 6 m. the following equations are needed to determine the velocity, discharge, channel slope, Manning coefficient, water depth, and bank slope.



Manning's Equation for Discharge (Q):

Q = (1 / n) * A * R^(2/3) * S^(1/2) **(3.3)**

Where:

- Q is the discharge.
- n is Manning's roughness coefficient (a measure of channel roughness).

- A is the cross-sectional area.
- R is the hydraulic radius.
- S is the channel slope.
-

Hydraulic Radius (R):

$$R = A / P \tag{3.4}$$

A is the cross-sectional area.

P is the wetted perimeter.

Cross-sectional Area (A):

$$A = (b1 + b2) * h / 2 \tag{3.5}$$

Where:

b1 and b2 are the lengths of the two parallel sides of the trapezoid.

h is the vertical height of the trapezoidal cross-section.

Wetted Perimeter (P):

$$P = b1 + b2 + 2 * \sqrt{h^2 + ((b2 - b1) / 2)^2} \tag{3.6}$$

Where:

b1 and b2 are the lengths of the two parallel sides of the trapezoid.

h is the vertical height of the trapezoidal cross-section.

Velocity (V):

V = (1 / n) * R^ (2/3) * S^(1/2) **(3.7)**

Where:

V is the velocity.

n is Manning's roughness coefficient (a measure of channel roughness).

R is the hydraulic radius.

S is the channel slope.

3.3.6.4 Sub-Channel Stream

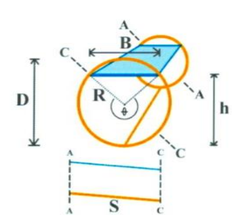
The sub-channel, located in the moderately suitable zone, originates from the highest point at an elevation of 395 meters above sea level, with a slope of 50 cm per kilometer. The base of the channel measures 1 m, and the upper part has a width of 3 m. The channel is trapezoidal, and the same formulas mentioned above can be used for calculations.

3.3.6.5 Branch Channel Stream

These branches are part of our project after the mainstream and sub-stream. These branches play an important role in transporting water to lands that are not accessible through the mainstream. These branches are circular channels with a diameter of 1 meter and a slope of 50 cm per kilometer. This type has its own equations and formulas to find velocity, discharge, area, water depth, and top width of the channel bed. Here are the following formulas to calculate these parameters.

Velocity (V): The velocity of flow within a circular channel can be determined using Manning's equation:

V = (1/n) * R^ (2/3) * S^(1/2) **(3.8)**



Where

n is the Manning's roughness coefficient.

R is the hydraulic radius.

S is the slope of the channel.

Discharge (Q):

$$\mathbf{Q = A * V} \quad \mathbf{(3.9)}$$

Where

A is the cross-sectional area of the channel.
V is the velocity of flow.

Area (A):

$$\mathbf{A = (\pi * D^2) / 4} \quad \mathbf{(3.10)}$$

Where

D is the diameter of the channel.

Water Depth (H):

$$\mathbf{H = (4 * A) / (\pi * D)} \quad \mathbf{(3.11)}$$

Where

D is the diameter of the channel.
A is the cross-sectional area of the channel.

3.3.6.6 Pumping Station

To design the pump stations for transferring water from the river into the channel, we faced a significant challenge due to the large height difference of 130 meters. To overcome this difficulty, we decided to divide the height into two sections of 65 meters each, making it more manageable.

To design the pumps for this purpose, we utilized a pump model called 300QS-125, which is capable of transferring water at a capacity of 461 liters per second to a head of 100 meters according to the table (3.6). However, since we needed to transfer water to a height of 65 meters, we had to adjust the capacity accordingly.

To convert the pump capacity to the desired 65-meter head, we can use the following equation:

Capacity1 * (Head1 / Head2) = Capacity2

Where:

Capacity1 = 461 liters per second (original capacity at a head of 100 meters)

Head1 = 100 meters (original head)

Head2 = 65 meters (desired head)

Capacity2 = adjusted capacity at the desired head

Using this equation, we can calculate the adjusted capacity as follows:

Capacity2 = Capacity1 * (Head1 / Head2)

Capacity2 = 461 * (100 / 65)

Capacity2 ≈ 708.77 liters per second

Therefore, to achieve a head of 65 meters, we would need a pump with a capacity of approximately 708.77 liters per second. This adjusted capacity would allow us to effectively transfer water from the river to the channel, accounting for the height difference, and ensuring efficient pump performance.

It requires 620 kW of electrical power for each pump. Convert this power to megawatts (MW) in the following steps

kW = kilowatts

MW=megawatts

1 kW = 1000 watt

1 MW = 1000 kW

620 / 1000 = **0.62 MW**

Each pump requires 0.62 megawatts of power to operate efficiently.

Table 3.6. the table displaying the proposed pump capacities for this project

Pump Type	Flow (Q)		H Head (m)	n Speed (rpm)	N Power(kw)		η Eff	NPSH	Pump Weight (kg)
	(m3/h)	(l/s)			Shaft power	Motor			
300QS-19	612	170	23	1450	47.3	55	81	5.5	660
	792	220	19.4		49.8		84		
	935	260	14		47.6		75		
300QS-125	850	236	140	1470	450	680	72	6.5	1580
	1250	347	125		252		81		
	1663	461	100		620		73		
300QS-125B	745	207	108	1470	313	500	70	6.5	1580
	1100	305	96		373		77		
	1458	405	77		422		72.5		
350QS-75	972	270	80	1450	268	400	79	6.5	1200
	1260	350	75		306		84		
	1440	400	65		319		80		
350QS-75A	900	250	70	1450	220	300	78	6.5	1200
	1170	325	65		247		84		
	1330	370	56		257		79		

3.3.7 Flow calculator Software for Open Channel

This software can be used to design open channels of various shapes, including trapezoids, circles, triangles, and squares. It enables quick channel design without the need for manual calculations involving velocity, discharge, channel slope, Manning coefficient, water depth, or bank slope. The software is compatible with both computers and smartphones, although it is not available for free. Its self-contained equations ensure accurate results, saving a significant amount of time and providing high precision.

The operation of this software is incredibly simple. You can effortlessly input information in the red squares, and once you've entered the necessary details, the software will generate the results. The results will be displayed in the green squares, as shown in the accompanying figure (3.9). This intuitive process ensures that you can easily input the required data and quickly obtain accurate results.

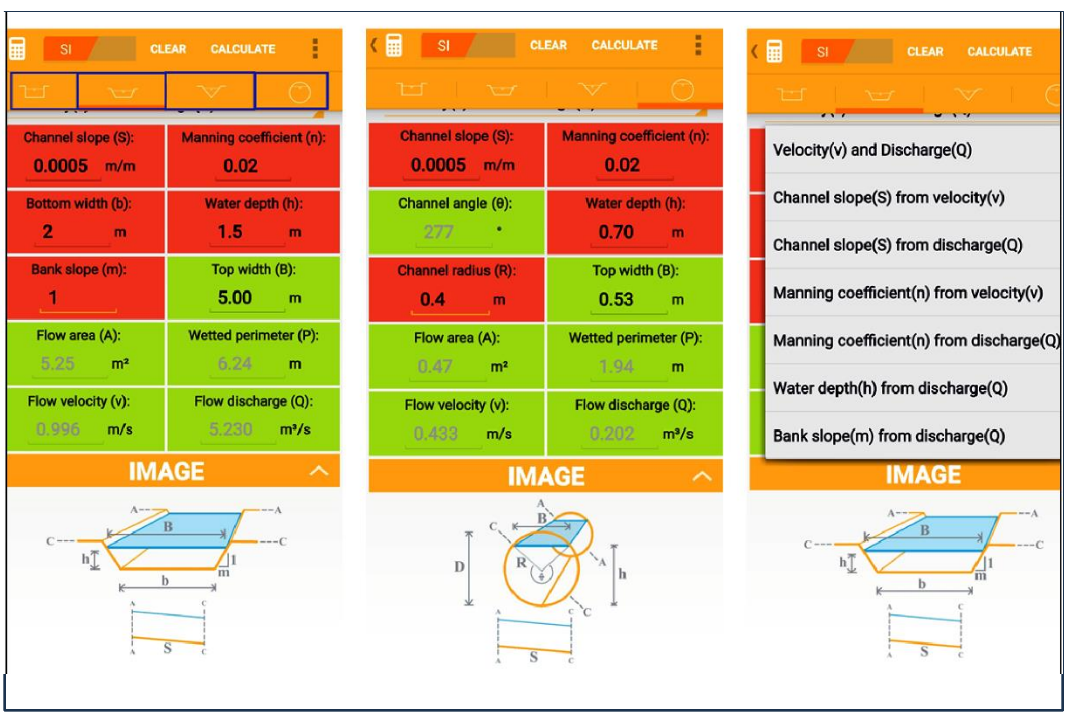


Figure 3.9. Flow calculator sample working

4. RESULTS and DISCUSSION

4.1. Results

4.1.1. Result Of Land use and Land cover classification

Land use and land cover classification are important components of any thesis because they provide crucial insights into change detection. Change detection serves as a key tool for addressing various problems. By accurately classifying land use and land cover, researchers can assess the dynamics of landscapes and understand the changes that have occurred over time. This information enables the identification of trends and patterns, facilitating informed decision-making. Therefore, land use and land cover classification play a vital role in comprehending change detection and are essential for effectively addressing research questions."

In this study, the land use in the study area was classified for the years 2006-2021. For this classification, we utilized high-resolution satellite images, specifically "Quick Bird" and "Worldview-3," which provided a resolution between 50 and 60 centimeters. We classified the land use using polygons without supervised classification, as this approach offers higher accuracy. The polygon used covered an area of 445 km2, as shown in the figure (4.1). The land use was divided into six classes: urban, crop, vegetation, water, barren land, and hill zone The urban area increased by 7.8%, while the crop area decreased by 8.3%. The vegetation area saw an increase of 4.6%, while the barren land area decreased by 2.5%. Additionally, the hilly area decreased by 1.4%, and there was a slight increase in the water area. The results were as follows table (4.1)

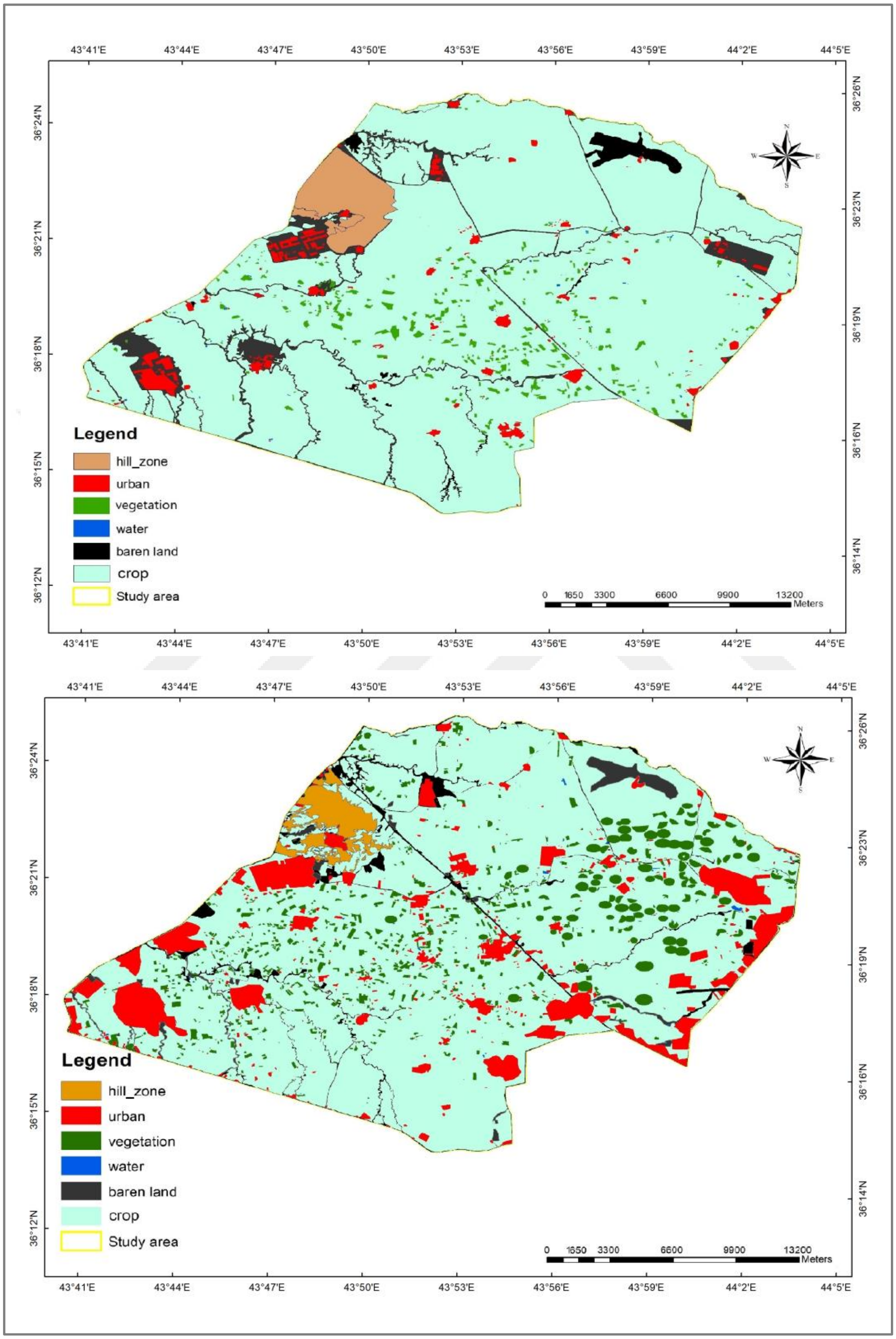


Figure 4.1. Land use and land cover classification (2006 to 2021)

Table 4.1. The results of LU and LC

Class Name	2006		2021		Change detection	
	Km^2	Area %	Km^2	Area %	Area %	
Urban	10.53	2.4	45.53	10.2	**7.8**	**Increase**
Crop	380	85.0	342.77	76.7	**8.3**	**decrease**
vegetation	8.58	1.9	29.12	6.5	**4.6**	**Increase**
Water	0.255	0.1	0.43	0.1	**0.055**	**Increase**
baren land	32	7.2	20.94	4.7	**2.5**	**decrease**
hill zone	15.69	3.5	9.22	2.1	**1.4**	**decrease**

4.1.2. Slope Result

Slope detection is one of the most important tasks for our business, as it assists us in understanding the topography of an area. By gaining knowledge about the area's topography, we can gather valuable insights, including the degree of erosion and the suitability of the land for agriculture, construction, or dam development, among other considerations. To determine the slope, we utilize a digital elevation map (DEM) and analyze it using ArcMap software. We then compare the results with according to FAO classification divided to five class, which include categories such as Flat to very gently sloping, gently sloping, Sloping, moderately steep, and steep. Our findings are presented in the following table (4.2). Depending on our region, the results

were as follows: 73% is classified as flat to very gently sloping, 25.2% as gently sloping, 1.8% as sloping, and 0.1% as moderately steep, as shown in the figure (4.2). The best site for open Chanel construction is Class Flat to very gently sloping which accounts for 73% of the study area.

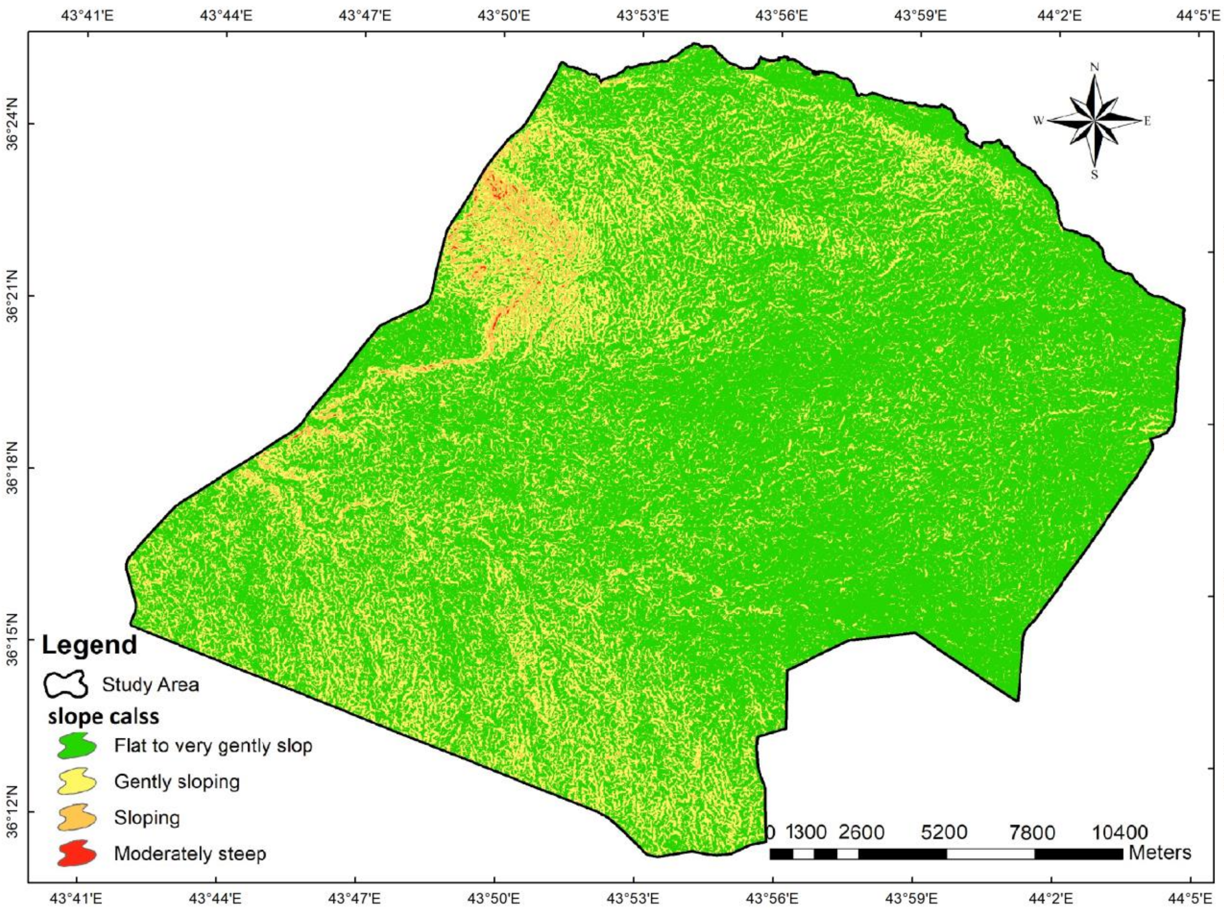


Figure 4.2. Slope Map derived from digital elevation model (DEM).

Table 4.2. Result of slope classification.

NO	slope class	Slop %	Hectare	Area %
1	Flat to very gently sloping	< 2	32634	73.0
2	Gently sloping	2 - 8	11241	25.2
3	Sloping	8 - 15	791	1.8
4	Moderately steep	15 - 30	28	0.1
5	Mountainous	> 30	0	0

4.1.3. Results of Normalized Difference Vegetation Index (NDVI)

NDVI is a crucial parameter for assessing changes in vegetation over time in relation to attraction. In this study, Landsat 8 OLI satellite images from 2013 and 2021 were utilized to calculate the NDVI. The results indicate that NDVI values for 2013 ranged between 0.4 and 0.05, while for 2021, they ranged between 0.18 and 0.50, as shown in Figure (4.3). The result map reveals that the NDVI values increased in 2021, primarily in the northeast region of the study area. This change confirms the expansion of vegetation based on the classification.

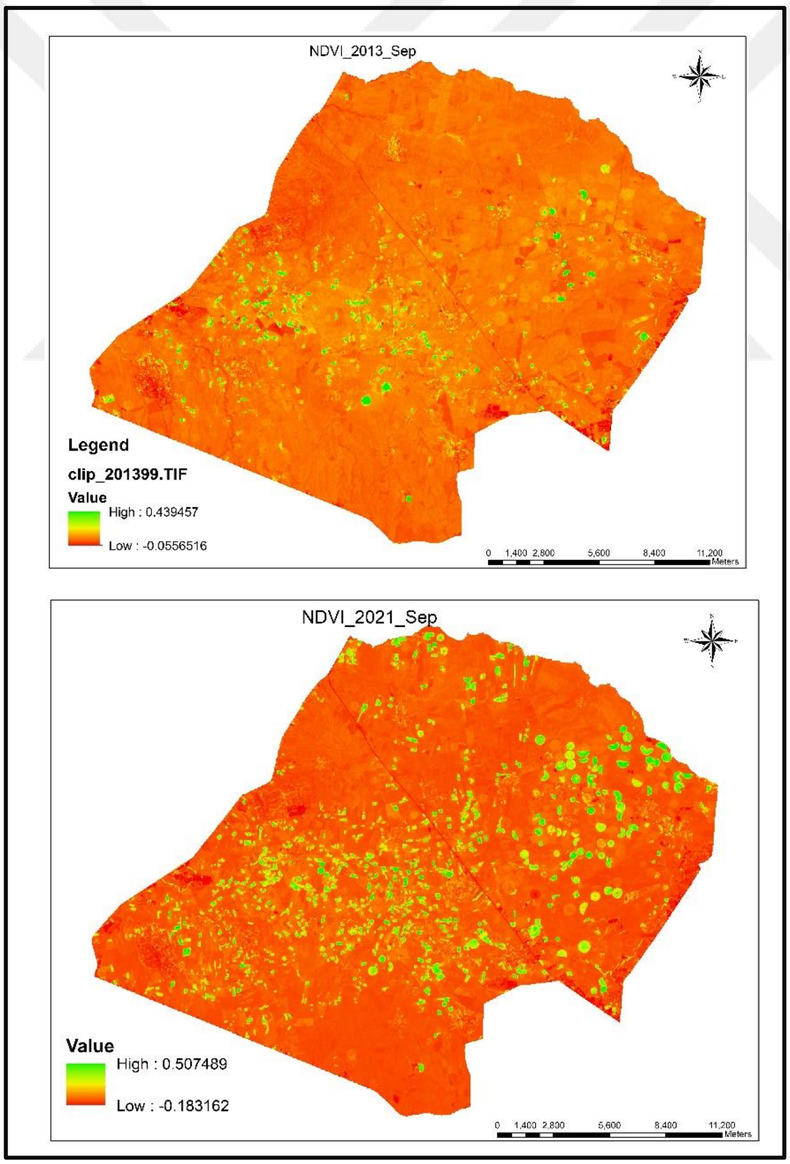


Figure 4.3. NDVI result

4.1.4. Rainfall

Precipitation data plays a vital role in conducting various studies as it provides valuable information for making informed decisions. In our research area, we have access to data from three meteorological stations: Ainkawa, Bastora, and Khabat. These stations have been consistently recording data since 2001 under the supervision of the Erbil General Directorate of Agriculture. During our site visit, we obtained the monthly precipitation data from these three stations.

We compiled the average precipitation for each 20-year period in Table (4.3). The results indicate that the Khabat station recorded 332.94 mm of precipitation, the Ankawa station recorded 412.9 mm, and the Bastora station recorded 444.1 mm. These stations experience relatively high levels of precipitation in our area.

Next, we utilized the IDW (Inverse Distance Weighting) program in ArcMap to generate a map, as depicted in Figure (4.4).

Table 4.3. Average yearly rainfall

No	Name	latitude	longitude	Average rainfall from 2001 to 2021 (mm)
1	Bastora	36.340303	44.167739	**444.1**
2	Khabat	36.27865	43.69658	**332.94**
3	Ankawa	36.247041	43.995148	**412.9**

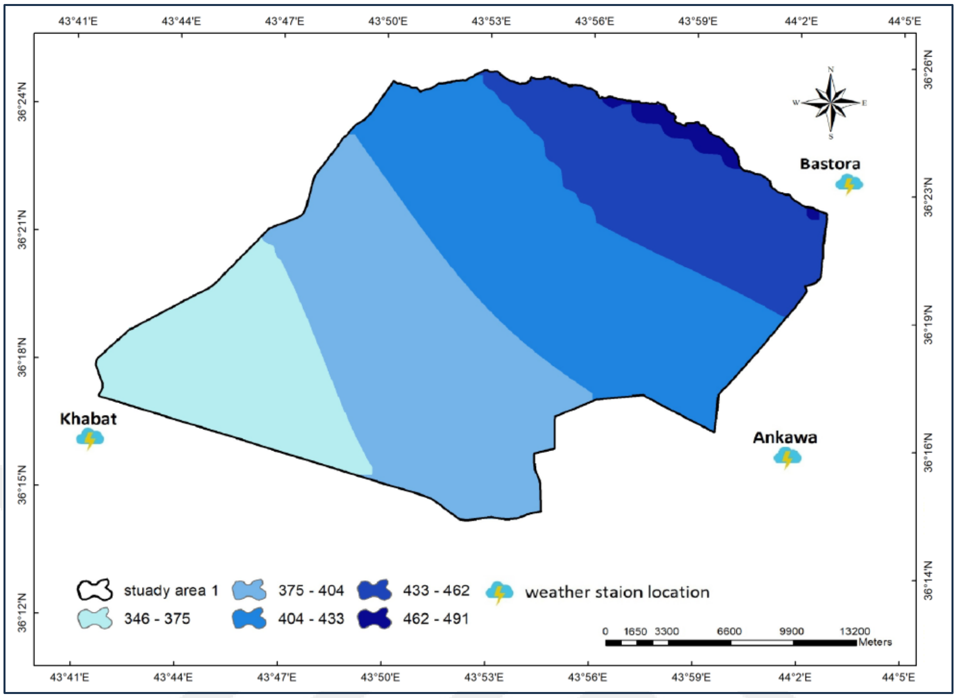


Figure 4.4. Rainfall zones and locations of the weather stations

4.1.5. Soil Texture

In this discussion, we will highlight the significance of soil texture in determining its capacity to support crop growth and its ability to absorb water, which is crucial for raising groundwater levels. By utilizing data obtained from the College of Agriculture at Salahaddin University, as presented in Table (4.4), we were able to create a study area map using ArcMap 10.8, as shown in Figure (4.5). The results revealed that an area of 241.17 km2 is covered by silty loam, 132.38 km2 is covered by silty clay, and 74.35 km2 is covered by silty clay loam, as presented in Table (4.5).

Table 4.4. Soil Texture data

No	Name of village	Latitude	Longitude	Soil texture
1	Gazna	36.278849	43.933636	silty loam
2	Jazhnikan	36.393277	43.970823	silty loam
3	Kawrgosk	36.350319	43.793304	silty loam
4	kawrgosk	36.340822	43.778883	silty clay loam
5	Bahrka	36.325947	44.01697	silty clay
6	Kawrgosk	36.319672	43.784284	silty clay loam

Table 4.5. Soil Texture Result & area

NO	Soil Texture	Area km2	area %
1	silty loam	241.2	54
2	silty clay	132.4	29.6
3	silty clay loam	74.4	16.6

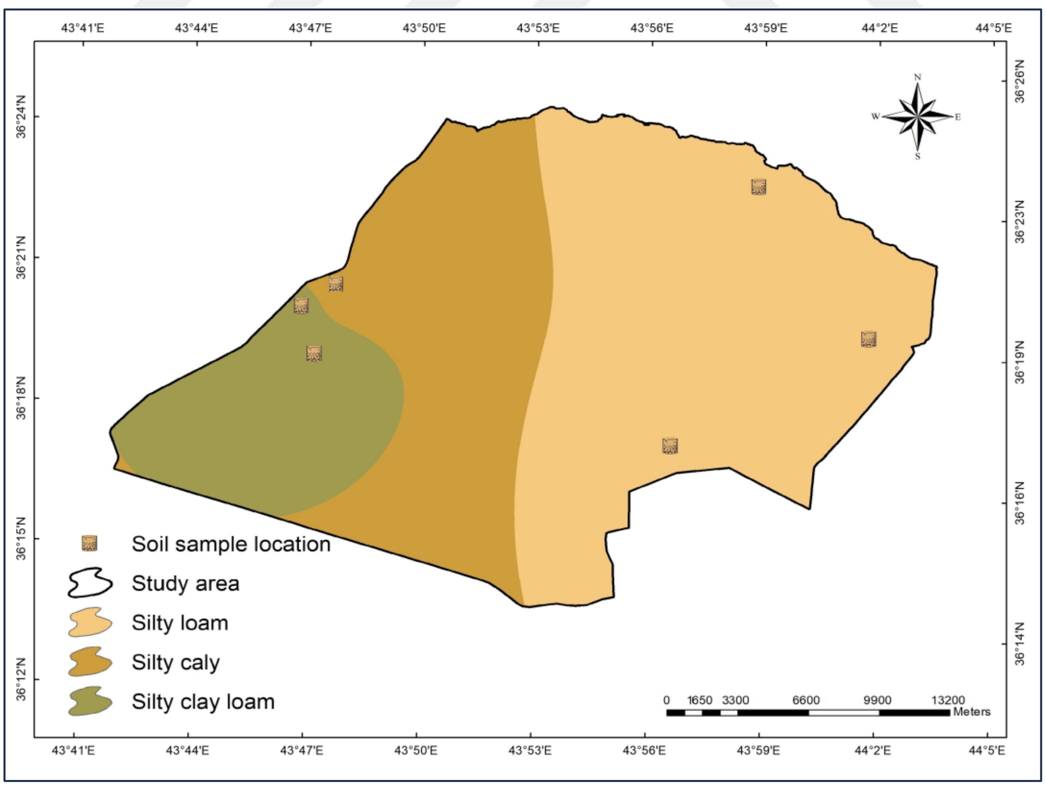


Figure 4.5. Soil Map result

4.1.6. Groundwater Monitoring result data

Groundwater monitoring involves the continuous measurement and analysis of the quality and quantity of groundwater at specific locations. Groundwater monitoring projects are highly significant as they directly impact health and agriculture, particularly in semi-arid regions where constant climate changes pose challenges. In our study area, situated in the northern region of Erbil, which represents the final part of a semi-arid zone, the government conducts annual monitoring of 82 wells to assess their quality and quantity, providing monthly reports. Among these wells, seven have been monitored in my research area since 2001. We specifically focused on the month of September, which experiences peak load on the wells, and the results are as follows: Gainj Gawra well decreased by 19.65 m, Grda Chal well decreased by 10.4 m, Jadida Zab well decreased by 35.39 m, Jazhnikan Ababakr well decreased by 18.25 m, Kawer Gosk well decreased by 53.15 m, Qafar well decreased by 11.74 m, and Sebirani Gowra well decreased by 15.87 m. These results are summarized in Table (4.6).

Furthermore, we conducted a field visit to gather additional data. During this visit, we recorded information from an additional 25 wells, as presented in Table (4.7). To analyze and visualize the collected data, we utilized a Geographic Information System (GIS) and employed interpolation tools, specifically the Inverse Distance Weighting (IDW) method to interpolate data from a total of 32 wells.

Using this interpolated dataset, we identified the highest and lowest groundwater levels within the study area and categorized it into five distinct zones. These zoning categories provide a comprehensive understanding of the distribution and variability of groundwater in the area. Blue represents a decrease of 11 to 19 meters, pink represents a decrease of 19 to 25 meters, purple represents a decrease of 25 to 31 meters, brown represents a decrease of 31 to 40 meters, and red indicates a decrease of 40 meters. The maximum decrease observed is 53 meters. See Figure (4.6).

Table 4.6. Groundwater monitoring has been done by the government.

NO	NAME village	2001		2021		Reduce Groundwater level by meter
		Depth	Date	Depth	Date	
1	Gainj gawra	29.55	sep/2001	49.2	sep/2021	**-19.65**
2	Grda chal	25	sep/2001	35.4	sep/2021	**-10.4**
3	jadida zab	39.41	sep/2001	74.8	sep/2021	**-35.39**
4	jazhnikan ababakr	21.9	sep/2001	40.15	sep/2021	**-18.25**
5	kawer gosk	31.85	sep/2001	85	sep/2021	**-53.15**
6	qafar	43.36	sep/2001	55.1	sep/2021	**-11.74**
7	sebirany gawra	42.13	sep/2001	58	sep/2021	**-15.87**

Table 4.7. Groundwater monitoring has been done by Site visit.

No	**Name_Water Well**	**Water level depth in September (Since-m)**		**Water level depth in September (Since-m)**		**Reduce Groundwater level by meter**
1	sarkawr harkyi 3	2005	60	2021	75	**-15**
2	sarkawr harkyi 1	2014	90	2021	107	**-17**
3	shakholan	2017	90	2021	112	**-22**
4	barhoshtr	2011	90	2021	108	**-18**
5	kewrgosk	2009	50	2021	89	**-39**
6	jazhnekame fandyi	2009	29	2021	44	**-15**
7	Grda chal	2001	22	2021	35	**-13**
8	jazhnekane fandyi 3	2010	35	2021	50	**-15**
9	Kawer gosk	2001	31	2021	82	**-51**
10	jazhnekane fandyi 2	1987	46	2021	61	**-15**
11	berhoshtr	2010	77	2021	96	**-19**
12	grd araq	2013	50	2021	68	**-18**
13	saedan	2008	51	2021	77	**-26**
14	ashokan	1980	50	2021	69	**-19**
15	dara ban	1983	28	2021	53	**-25**
16	grd araq	2012	31	2021	48	**-17**
17	mam choxan	2008	29	2021	53	**-24**
18	tobzawa	2005	52	2021	85	**-33**
19	smayilawa	2013	61	2021	89	**-28**
20	grd jotear	2008	44	2021	63	**-19**
21	tobzawa	2003	49	2021	79	**-30**
22	Sebirany	2005	37	2021	56	**-19**
23	smayilawa	2004	50	2021	75	**-25**
24	jdida zab	2006	41	2021	71	**-30**
25	Sebirany gawra	2001	42.6	2021	58	**-15**

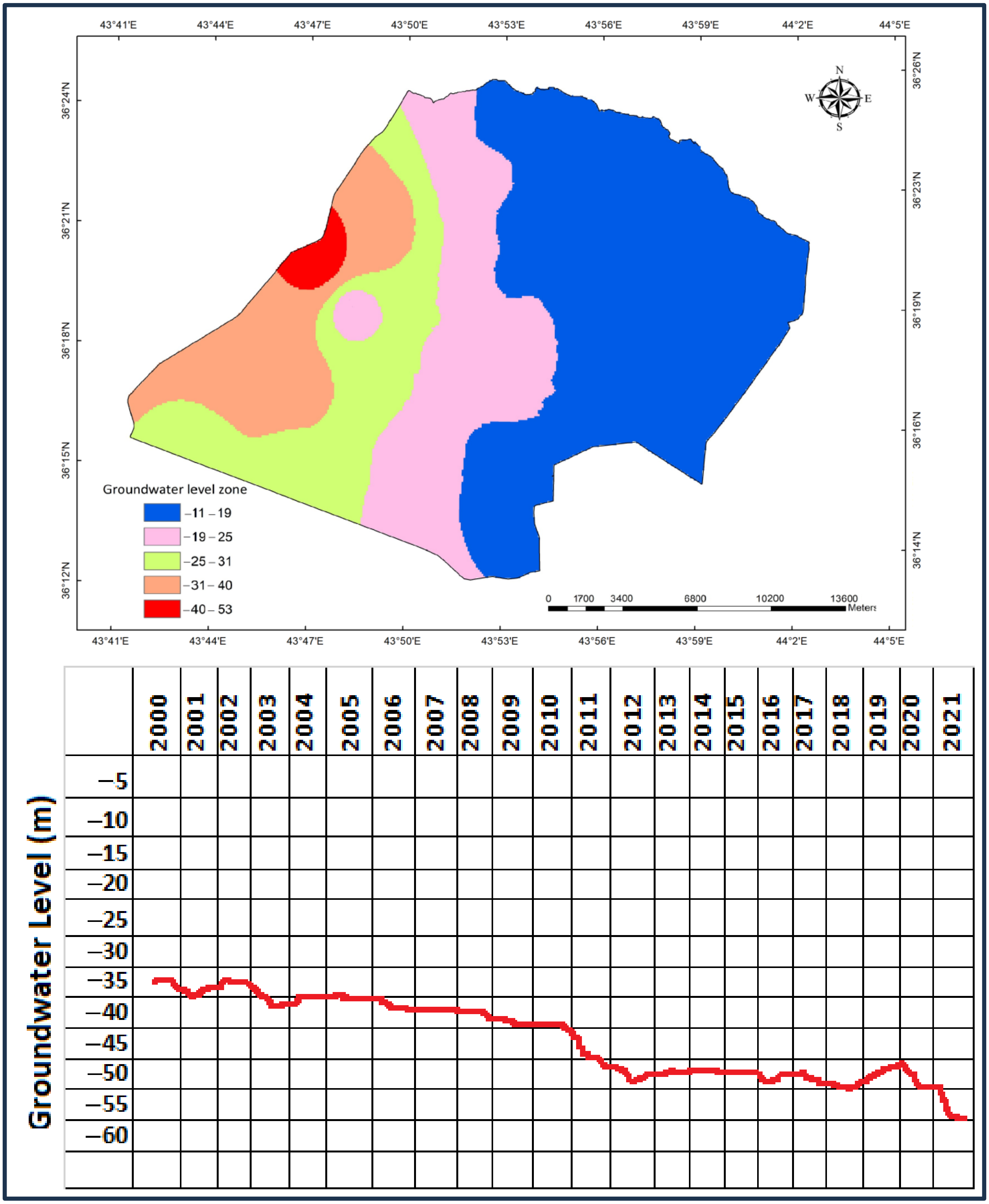


Figure 4.6. Result of Declining groundwater levels from 2000 to 2021 in the Baranati Plain

4.1.7. Result Stream Order

Stream order classification is a system used in hydrology and river network analysis to categorize and describe the hierarchical arrangement of streams within a drainage basin or watershed. It provides a means to understand the branching and connectivity of streams in a river network.

Stream ranking is determined based on stream characteristics and behavior. In this study area, we have classified them into five classes, enabling us to easily distinguish between small rivers and streams. Identifying these streams is essential for our work in identifying watersheds and locating ponds. The results of our work are shown in Figure (4.7).

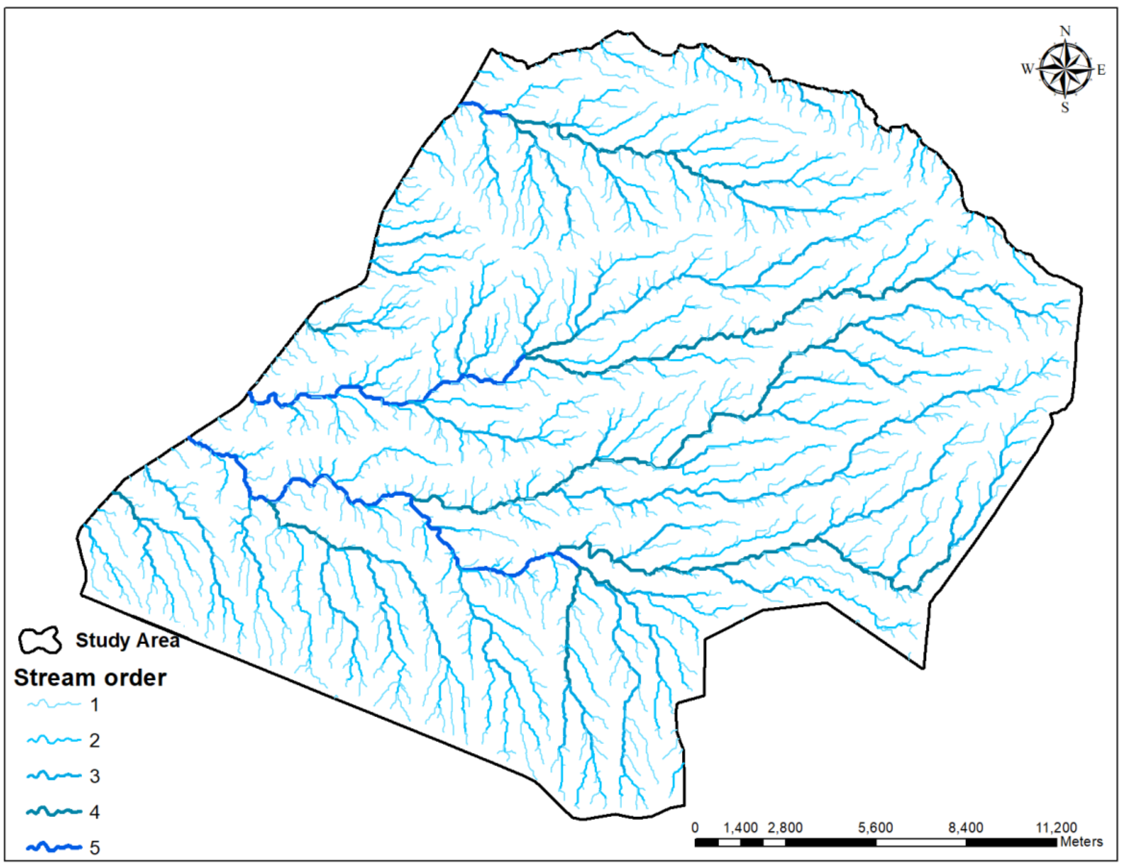


Figure 4.7. Result of Stream Order

4.1.8. Results of Watershed Delineation

A watershed, also known as a drainage basin or basin, is an area of land that drains all precipitation and surface water to a common outlet such as a river, lake, or ocean. Watershed harvesting involves the conservation of rainwater by constructing structures such as percolation tanks, farm ponds, or contour trenches along the edge of a watershed. These structures aid in capturing rainwater and replenishing groundwater levels. Therefore, in our study area and collected rainwater to raise the groundwater level for irrigation by farmers near the ponds. To accomplish this, we required rainfall data for the area and a topographical map. Subsequently, we utilized the GIS program to determine the watershed of the area, as shown in Figure (4.8), and table (4.8). which consisted of five large watersheds. With the assistance of the contour lines in the area, as depicted in Figure (4.9), we identified the location of the farm pond within each of the five large watersheds. Furthermore, we created a separate watershed for each farm to ensure that the rainfall in the area could fill these ponds, as illustrated in Figure (4.10). The resulting data is presented in Table (4.9). At the same time, we have compared it with the watershed classification.

In the first watershed, with an area of 221 km2, we identified a pond spanning 22.8 hectares, with a catchment capacity of 0.5 million cubic meters. In the second watershed, covering an area of 176.9 km2, we identified a pond spanning 65.7 hectares, with a catchment capacity of 7 million cubic meters. The third watershed, encompassing an area of 13.5 km2, contained a pond spanning 12.2 hectares, with a catchment capacity of 0.28 million cubic meters. In the fourth watershed, which covers an area of 39 km2, we identified a pond spanning 12.3 hectares, with a catchment capacity of 0.21 million cubic meters. The fifth watershed, with an area of 63 km2, featured a pond covering 8.86 hectares, with a catchment capacity of 80,000 cubic meters.

In the sixth watershed, spanning 26.5 km2, we identified a pond covering 6.32 hectares, with a catchment capacity of 52,000 thousand cubic meters. The seventh watershed, with an area of 4.3 km2, contained a pond spanning 19.68 hectares, with a catchment capacity of 550,000 cubic meters. In the eighth watershed, covering an area of 19.5 km^2, we identified a pond spanning 10.38 hectares, with a storage capacity of 187,000 cubic meters. The ninth watershed, with an area of 23.2 km^2, contained a pond spanning 12.4 hectares. In the tenth watershed, covering an area of 33 km^2, we successfully located a pond spanning 16.81 hectares, with a storage capacity of 430,000 cubic meters. It covers an area of 78 hectares and has an irrigation capacity of 100,000 cubic meters.

In the twelfth watershed, spanning 54.2 km^2, we identified a pond covering 5.35 hectares, with an irrigation capacity of 100,000 cubic meters. In the thirteenth watershed, with an area of 707 km2, we found a pond spanning 6.24 hectares. In the fourth watershed, with an area of 4.4 km^2, we were able to locate a pond spanning 3.42 hectares, with a water storage capacity of 60,000 cubic meters. Finally, in the fifteenth and final watershed, with an area of 4.8 km^2, we located a pond spanning 9.6 hectares,

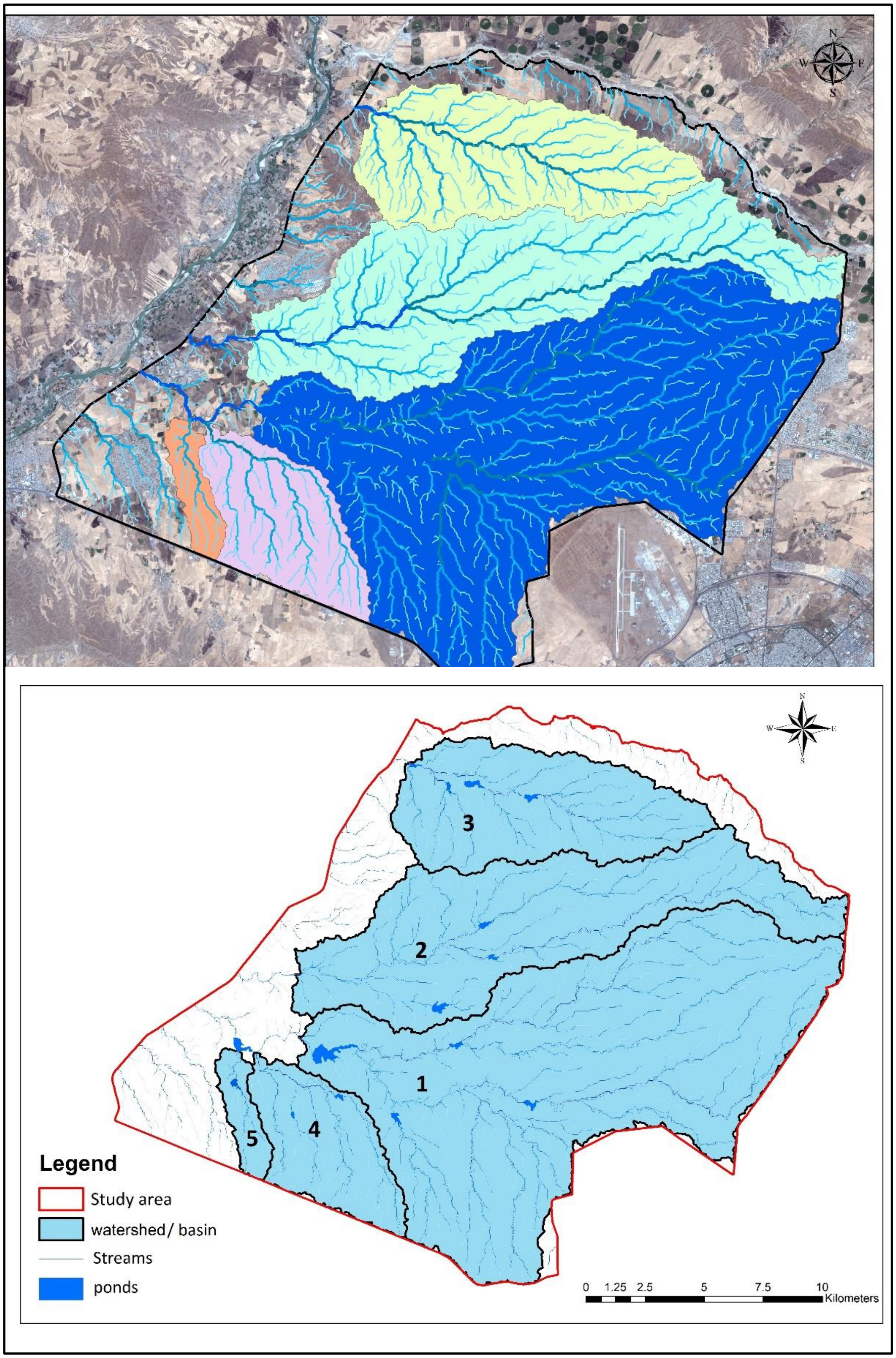


Figure 4.8. Result of five big basin watershed in Study area

Table 4.8. Average monthly rainfall inside all basin

Basin / watershed	Area km²	Hectare	Average rainfall year/ mm	total rain in this area million/m3
basin 1	180	18000	396	**71.28**
basin 2	90.4	9040	396	**35.7984**
basin 3	54.2	5420	396	**21.4632**
basin 4	28.8	2880	396	**11.4048**
basin 5	6.8	680	396	**2.6928**

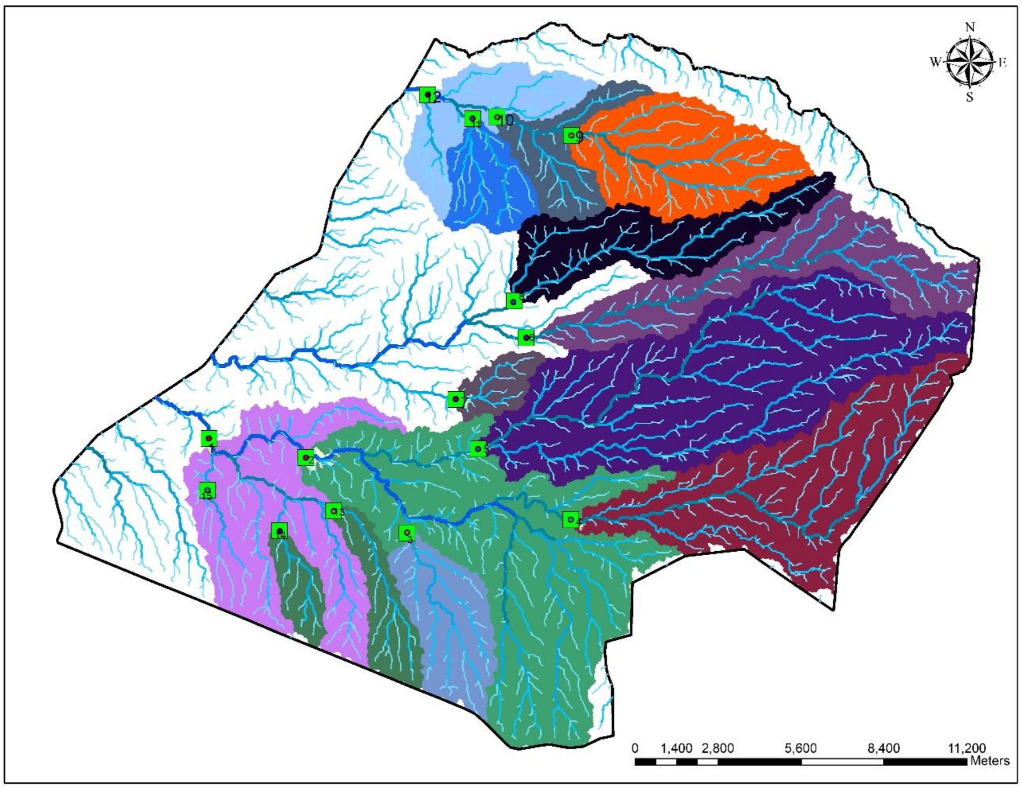


Figure 4.9. Result of 15 ponds and catchment area in Study area

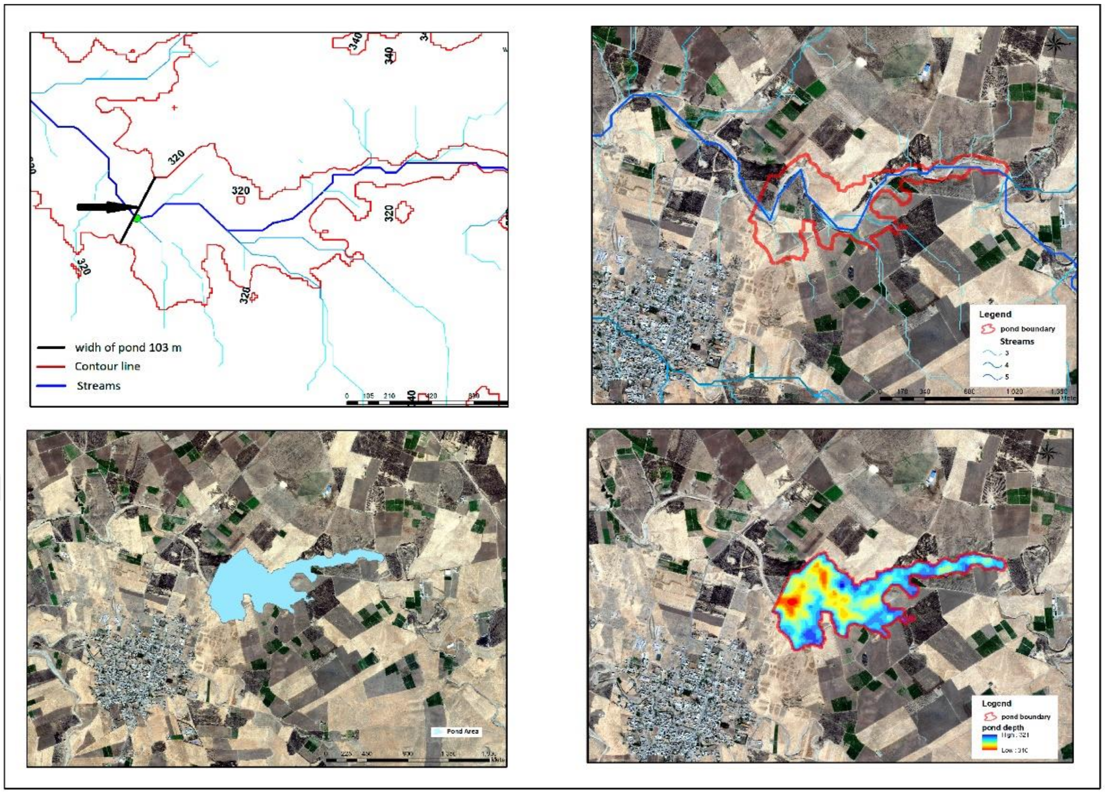


Figure 4.10. Result of One details pond in study area

Table 4.9. all details about 15 pound in study area

No	watershed area km²	Average rainfall year/ mm	total rain in this area million/m³	ponds area by hectar	ponds volume m³	watershed classification
1	221	396	87.516	22.8	500,000	small
2	176.9	396	70.0524	65.7	2,700,000	mini
3	13.5	396	5.346	12.2	280,000	small
4	39	396	15.444	12.3	210,000	small
5	63	396	24.948	8.86	80,000	micro
6	26.5	396	10.494	6.32	52,000	micro
7	4.3	396	1.7028	19.68	550,000	small
8	19.5	396	7.722	10.38	187,000	small
9	23.2	396	9.1872	12.4	246,000	small
10	33	396	13.068	16.81	430,000	small
11	8.5	396	3.366	6.78	100,000	micro
12	54.2	396	21.4632	5.35	100,000	micro
13	7.7	396	3.0492	6.24	36,000	micro
14	4.4	396	1.7424	3.42	60,000	micro
15	4.8	396	1.9008	9.6	172,000	micro

4.1.9. Results of pipeline network

To design the water distribution pipeline in the Baranti Plain, we first needed the help of the GIS and EPANET programs. Then he found a source of water, the Great River. The upside is that the location of the reservoir is crucial to the design of the job. The starting point starts at an altitude of 440 metres above sea level, which is 160 metres above the water level of the Great River, which requires a pump to transport the water. After research, we found that the land in this area requires 72 m3 of water per hectare per day to irrigate their wheat. This amount varies from place to place depending on soil type and local climate. After entering this information, the programme (EPANET) analysed the data as follows: amount of water required per second: 5355 L/sec per day; a total of 462672 m3/day is required. As shown in Figures (4.12 4.13 & 4.14) the amount of water required is determined at the endpoints and pressures. Figure 4.11 shows the design and size of the reservoir. 600 m long, 50 m wide, and 3 m high, for a total area of 90,000 m3. The water from the reservoir is distributed through 10 pipes to the Baranti Plain. The diameter of the pipes is initially 30 (inches) and eventually 9 (inches). This design can irrigate 65% of the total cropland in the area by gravity, but if we use pumps at two low-pressure locations, we can irrigate 83% of the cropland area.
We need about 215 km of pipeline to distribute the project. As detailed in Table 4.10 The minimum flow point is 50 liters per second, and the highest point is 75 liters per second. The maximum pressure in the pipes is 96 m, and the minimum is 10 m.

Table 4.10. Table of pipe diameters and lengths.

NO	pipe diameter (inches)	length / Km
1	30	48
2	25	21
3	24	5
4	22	2
5	20	10
6	15	63
7	12	27
8	10	35
10	9	4
Total length		**215 km**

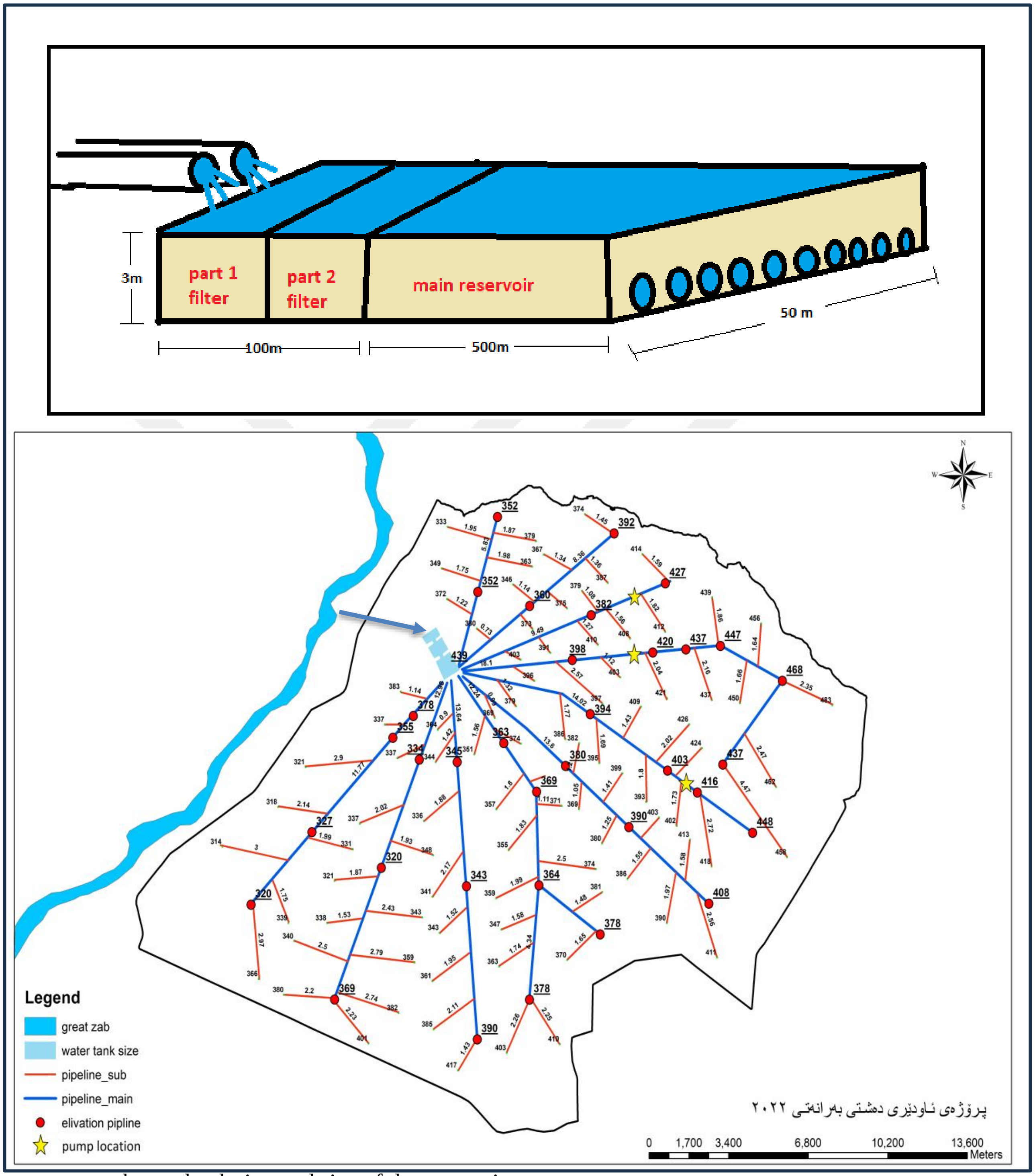


Figure 4.11. shows the design and size of the reservoir.

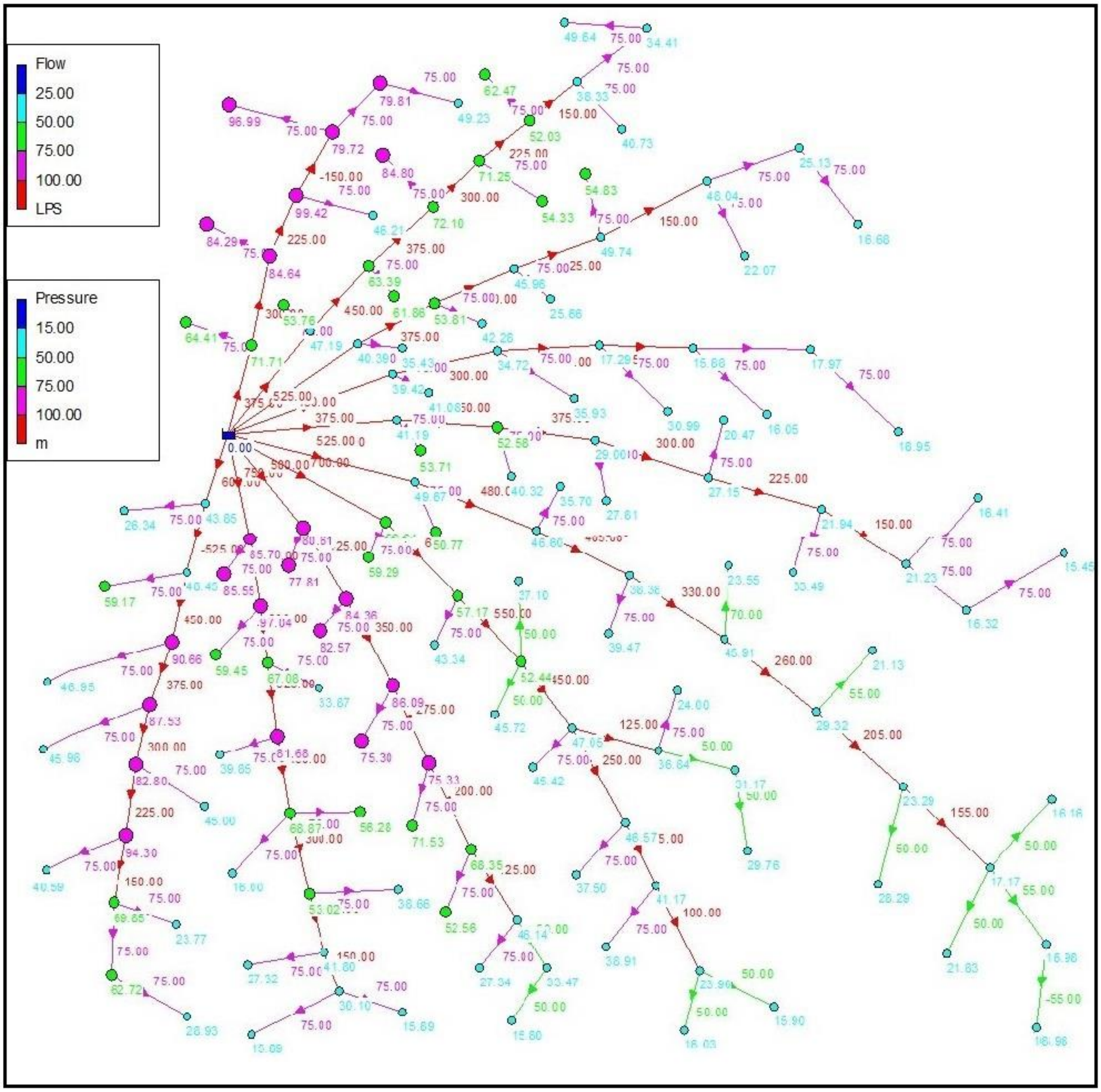


Figure 4.12. shows the Flow and pressure results.

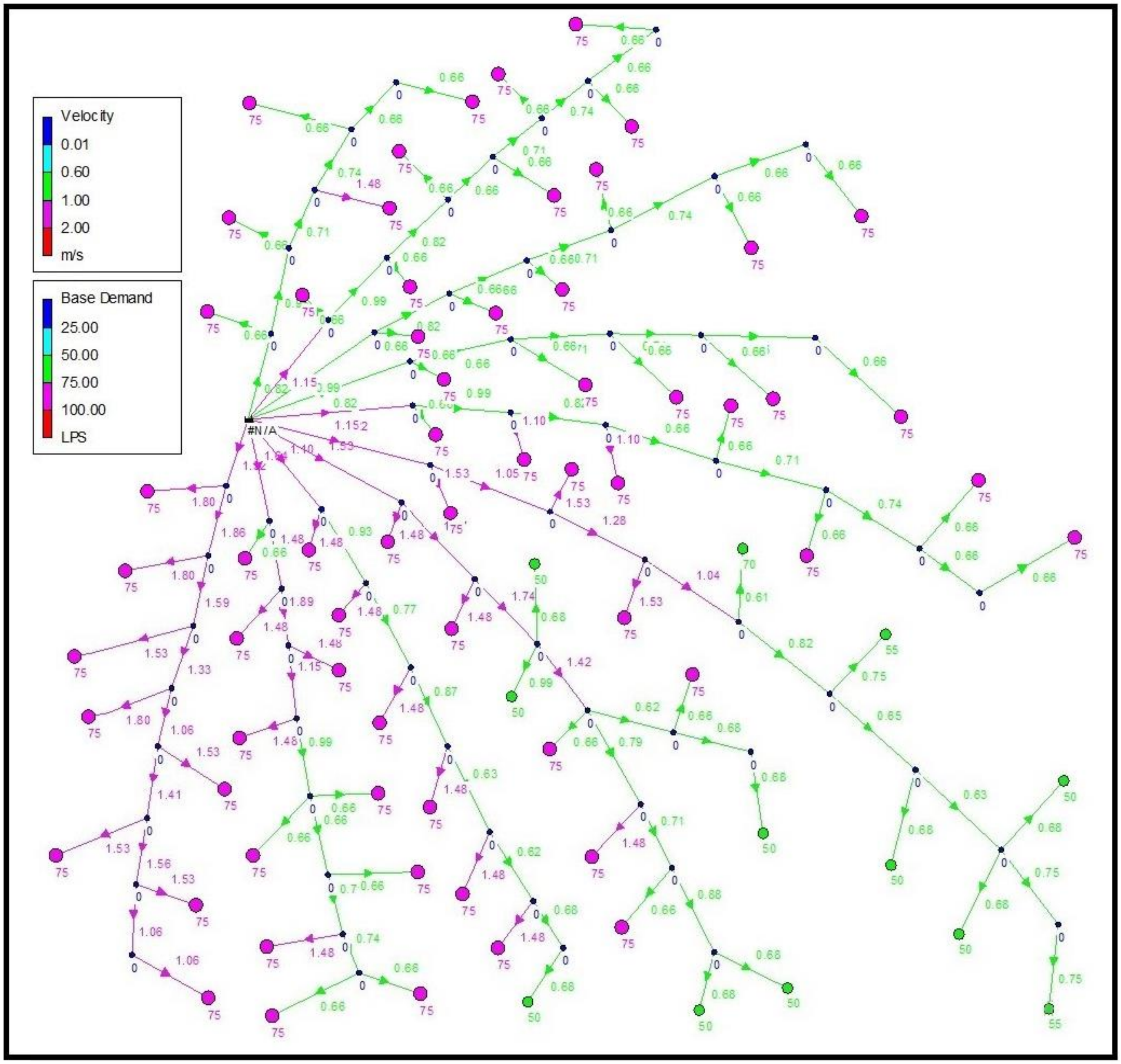


Figure 4.13. shows the velocity and base demand

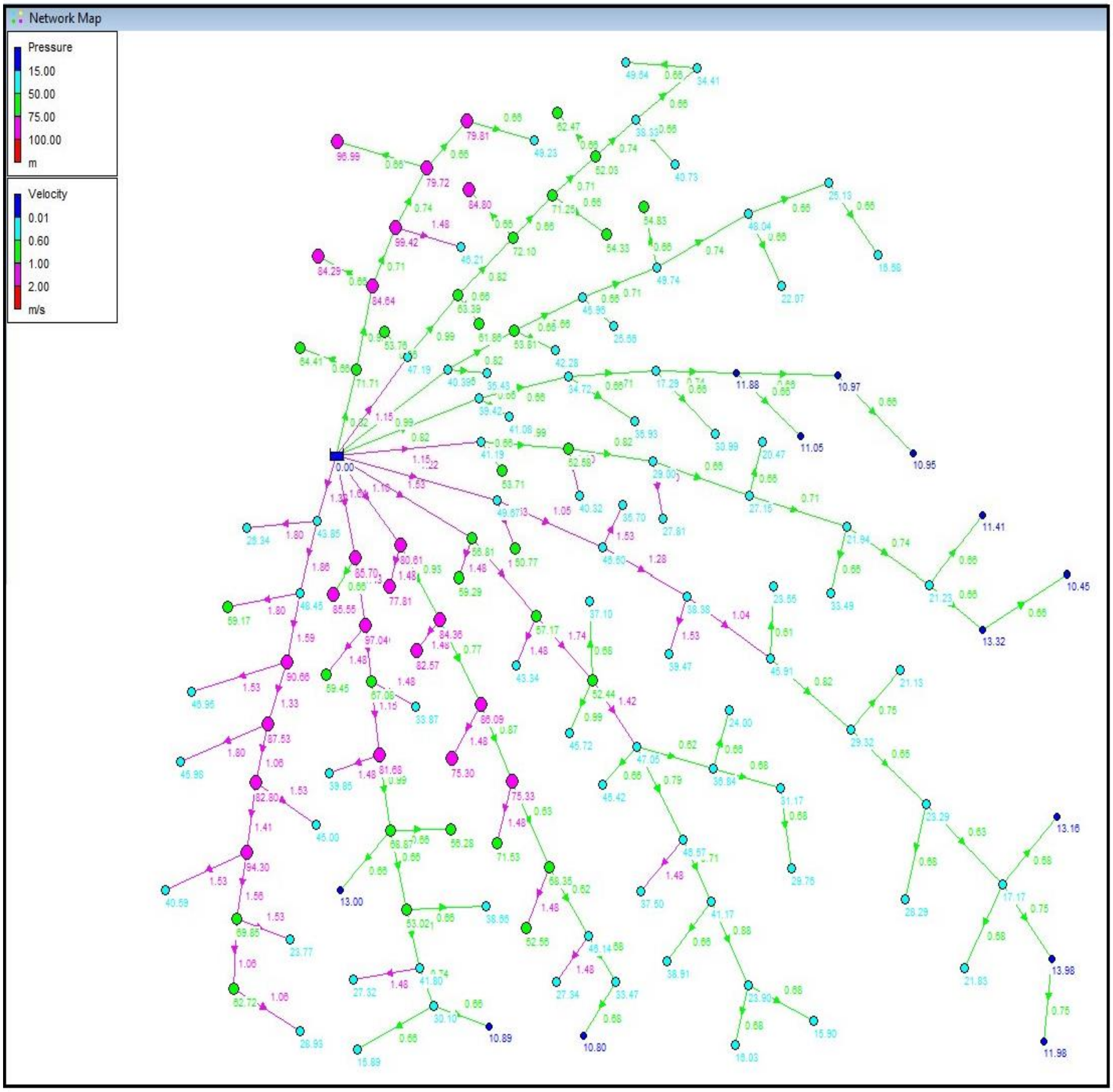


Figure 4.14. shows the pressure and velocity

4.1.10. Results of Open Channel Stream

To begin the design process for the Open Channel, there are several important factors to consider. Firstly, it is crucial to determine if there is a reliable water source available. In this case, you have identified the Great Zap River as your water source.

Next, you need to assess whether the altitude of the area is suitable for constructing the canal. This consideration is important because the elevation affects the flow of water in the channel. If the altitude is favorable, it would be conducive to proceeding with the canal construction.

Furthermore, it is essential to determine if the water requirements of the farmers can be met by the available water source. To do this, you conducted field visits to the area and spoke with the farmers about their water usage for crop irrigation, specifically for wheat and barley. By examining their wells and the volume of water they utilized for irrigation purposes, you found that the farmers required 18 m3 of water per dunam per day, equivalent to 0.20 liters per second.

It's worth noting that the specific water requirements may vary across regions due to factors such as soil type and climate conditions. Therefore, it is crucial to account for these variations when designing the Open Channel.

In the initial phase of your investigation, you established that the Great Zap River is capable of supplying the required amount of water, as determined by the farmers' water usage. This understanding provides a solid foundation for further designing and planning the Open Channel.

4.1.10.1. Result of Suitable Zone

In the second phase of the open channel design process, it is essential to gain an understanding of the topography and slope of the area to evaluate its feasibility. To accomplish this, a map with a Digital Elevation Model (DEM) was required, and a Geographic Information System (GIS) program was utilized to analyze the topography of the area.

The analysis of the topography using the GIS program allowed for the identification of suitable areas for the construction of the open channel. These areas are visually depicted in Figure (4.15). The results of the analysis indicated that it would be possible to irrigate approximately 300 square kilometers of land using gravity flow. This area corresponds to approximately 68% of the total study area.

The identification of these suitable areas is a significant step in the open channel design process as it helps determine where the channel can be constructed to maximize the coverage of irrigable land. By leveraging gravity flow, the natural slope of the terrain can be utilized to ensure efficient water delivery to the agricultural fields.

With this information at hand, further design considerations can be made to determine the specific alignment, dimensions, and necessary features for the construction of the open channel.

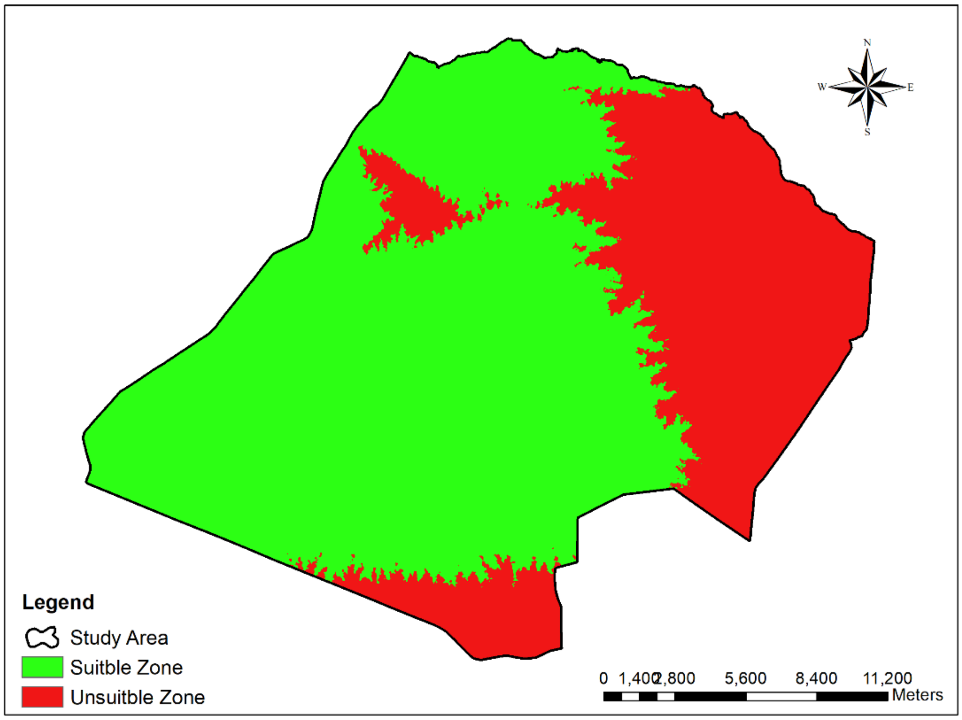


Figure 4.15. Result between suitable zone and non-suitable zone

4.1.10.2. Result of Suitable Site for Main Channel stream

After conducting an analysis of the study area, the next step involved dividing it into four zones based on the suitability of their locations for constructing the main channel stream. These zones are illustrated in Figure (4.16). The results are as follows:

- The low suitable zone covers an area of 88.8 square kilometers.
- The moderate suitable zone covers 137.6 square kilometers.
- The most suitable zone covers 75.3 square kilometers.
- The non suitable zone covers 146.2 square kilometers.

In addition to identifying the suitability zones, you also determined the distance and elevation between the starting point of the channel and the river. The distance was found to be 1.5 kilometers, while the elevation was 400 meters above sea level.

These details are crucial for the design and planning of the open channel. Understanding the distribution of suitability zones allows for the allocation of resources and efforts in constructing the main channel stream in the most appropriate areas. Furthermore, knowing the distance and elevation provides important information for determining the alignment and gradient of the channel, ensuring efficient water flow from the river to the designated areas.

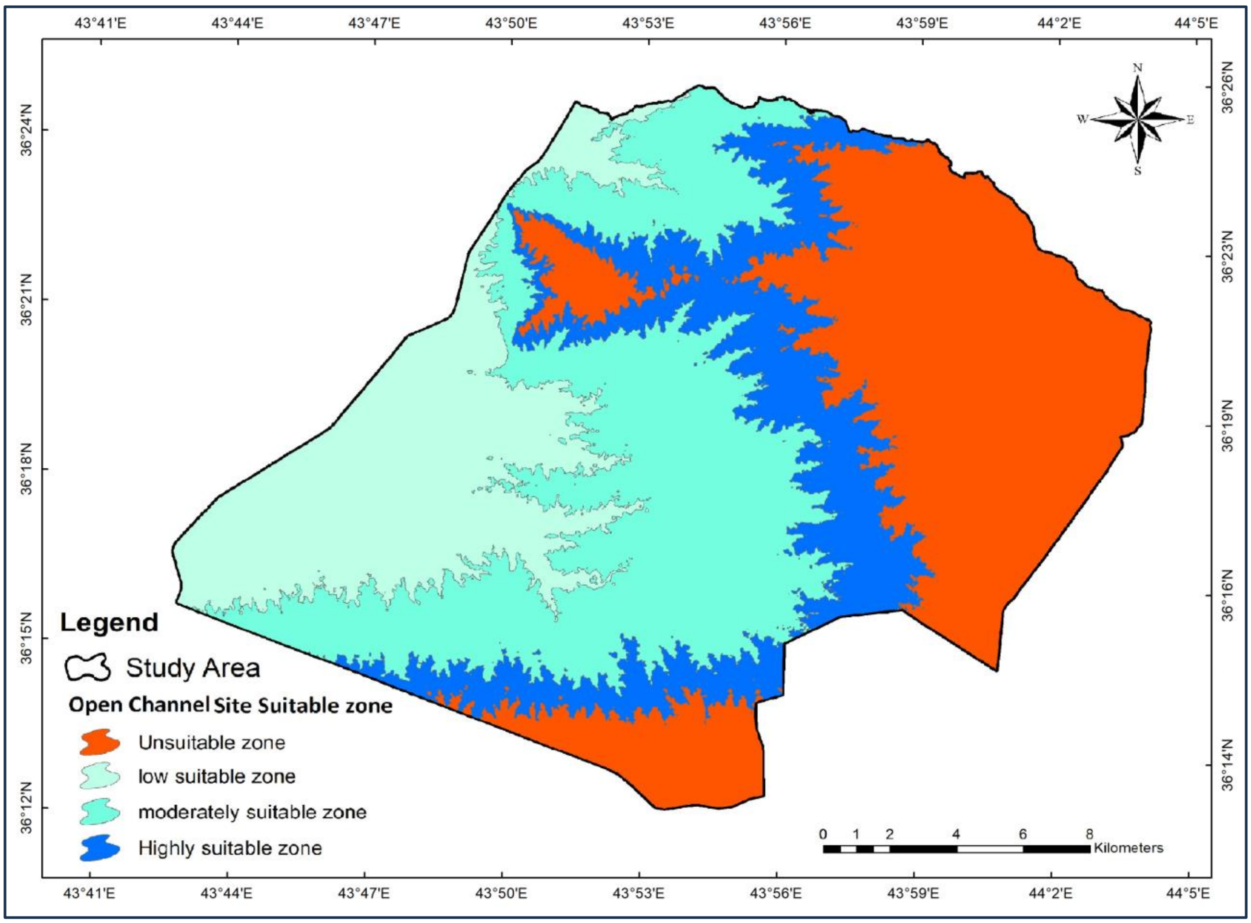


Figure 4.16. determine the most suitable site zone

4.1.10.3. Result of Main Channel stream

After designing the main channel, the majority of it falls within the highly suitable zone, as shown in Figure (4.17). The main channel consists of three interconnected channels collectively known as 'Ifraz.'

The first channel, starting from the pumping station, allows for the direct transfer of water from the river. This channel has a length of 10.5 km and extends from the intake water point to the main gate, which is located at an elevation of 400 meters.

The second part of the main channel is called 'Gazna' and spans a length of 44 km. The third channel, named 'Sarkawr Harkyi,' measures 10 km in length. Together, these three channels have a combined water capacity of 9 m^3/s.

The total length of the main channel, including the three interconnected channels, is 68.2 km. The channel has a bottom width of 2 m, a height of 2 m, and an upper width of 6 m. For more detailed information, please refer to Table (4.11) & (4.12).

The slope of the channels is maintained at 50 cm per kilometer. This slope helps ensure the efficient flow of water within the channel system. The main channel has the capacity to irrigate an area of 10,600 hectares of land.

4.1.10.4. Result of Sub-Main Channel stream

The sub-channel, situated in the moderate suitable zone, originates from the highest point at an elevation of 395 meters above sea level, as depicted in Figure (4.17). It consists of six sub-channels, listed from longest to shortest: Tobzawa, Gaenj 1, Shakholan 2, Jdeda Zab, Gaenj 2, and Shakholan 1.

The combined length of these six sub-channels is 86 km, and they maintain a slope of 50 cm per kilometer to facilitate the flow of water. The base of the sub-channel measures 1 m, while the upper part has a width of 3 m.

The water transfer capacity of the sub-channel is 1.45 m^3 per second, enabling the efficient movement of water. A summary of these details can be found in Table (4.11) & (4.12). The six sub-channels have a collective capacity to irrigate an area of 16,200 hectares of land, ensuring the distribution of water to support agricultural activities in the region.

4.1.10.5. Result of Branch Channel Stream

These branches comprise four individual branches: Sebiran with a length of 6.5 km, Daraban with a length of 6.2 km, Barhushtar with a length of 3.3 km, and Ashokan with a length of 2 km. These branches utilize a concrete pipe with a diameter of 1 meter, as specified in Table (4.11) & (4.12).

The total length of all four branches combined is 18 km. These branches maintain a slope of 50 cm per kilometer to ensure proper water flow.

The water flow rate in these branches is 0.34 m^3 per second. This flow rate, combined with the designated slope, allows for efficient water transfer within the channel system.

The capacity of these branches is to irrigate an area of 1,700 hectares of land. This ensures the availability of water resources for agricultural purposes in the designated area.

4.1.10.6. Result of Pumping Station

In this section, we will discuss the pump bases, which are divided into two bases due to the channel's height being 130 meters above the river level. Each base has a height of 65 meters. There are 13 pumps assigned to each base, specifically the 300QS-125 model. For detailed characteristics of these pumps, please refer to Table (4.13)

At the highest level, we require a total of 26 pumps. These pumps have a capacity to transport $9m^3$ of water per second. On the other hand, at the lowest level, we need 17 pumps that are capable of transporting $6m^3$ of water per second.

Moving on to the electricity requirements, the maximum demand for the pump system is 16.2 MW (megawatts), while the minimum demand is 10.54 MW. This indicates the power required to operate the entire system at its peak and lowest levels.

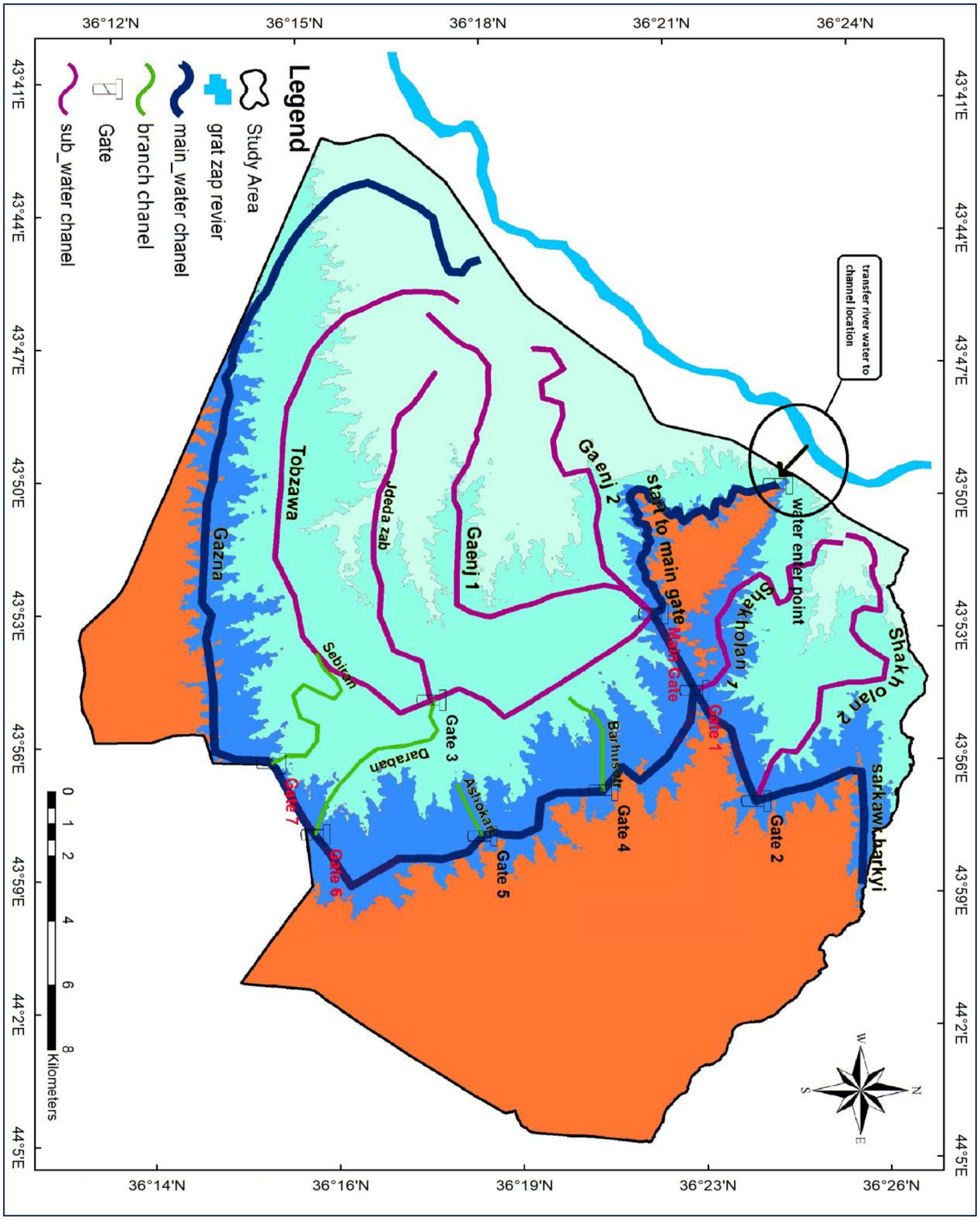


Figure 4.17. Location of channels according to suitable zone

Table 4.11. all details about open channel in my study area

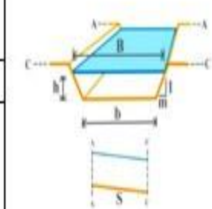
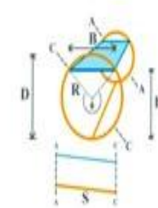
shape channel	type of channel	type of slopes	coefficients (n)	water depth (h)m	bank slope or slide slope (m)	Bottom width (b) m	channel slope m/m	Flow Discharge (Q) m3/s	Flow velocity (V) m/s	Flow area (A) m2	Top width (B) m	length of channel km	volume m3 of channel	image of channel
Trapezoidal channels	main channel	100cm/1km	0.02	2	1	2	**0.001**	**13**	**1.62**	8	6	68.2	1,088,000	
		50cm/1km	0.02	2	1	2	**0.0005**	**9**	**1.1**	8	6			
		25cm/1km	0.02	2	1	2	**0.00025**	**6.5**	**0.8**	8	6			
		10cm/1km	0.02	2	1	2	**0.0001**	**4.1**	**0.5**	8	6			
	sub channel	100cm/1km	0.02	1	1	1	**0.001**	**2**	**1**	2	3	86	172,000	
		50cm/1km	0.02	1	1	1	**0.0005**	**1.45**	**0.7**	2	3			
		25cm/1km	0.02	1	1	1	**0.00025**	**1**	**0.51**	2	3			
		10cm/1km	0.02	1	1	1	**0.0001**	**0.65**	**0.32**	2	3			
					channel angle	channel radius (R) m								
Circular channels	branch channel	100cm/1km	0.02	0.8	277	0.5	**0.001**	**0.48**	**0.7**	0.67	0.8	17	9112	
		50cm/1km	0.02	0.8	277	0.5	**0.0005**	**0.34**	**0.5**	0.67	0.8			
		25cm/1km	0.02	0.8	277	0.5	**0.00025**	**0.24**	**0.35**	0.67	0.8			
		10cm/1km	0.02	0.8	277	0.5	**0.0001**	**0.15**	**0.22**	0.67	0.8			

Table 4.12. all details about gate & name of open channel Stream

No	Gate Name	longitude	latitude	elevation	stream name	channel type	m3/s	length km
1	intake water Gate	43.8175	36.389	400	ifraz	main chanel	9	10.5
2	Main Gate	43.8628	36.3571	395	tobzawa	sub-chanel	1.45	26.7
3	Main Gate	43.8628	36.3571	395	Gaenj 1	sub-chanel	1.45	16.3
4	Main Gate	43.8628	36.3571	395	Gaenj 2	sub-chanel	1.45	10
5	Main Gate	43.8628	36.3571	395	shakholan	main chanel	9	2.6
6	Gate 1	43.8892	36.3681	393.5	sarkawr harkyi	main chanel	9	10
7	Gate 1	43.8892	36.3681	393.5	Gazna	main chanel	9	44
8	Gate 1	43.8892	36.3681	393.5	shakholan 1	sub-chanel	1.45	9.2
9	Gate 2	43.9272	36.3844	391.5	shakholan 2	sub-chanel	1.45	12.4
10	Gate 3	43.8937	36.2994	391	Jdeda zab	sub-chanel	1.45	11.3
11	Gate 4	43.9242	36.3446	391	Barhushtr	branch chanel	0.35	3.3
12	Gate 5	43.9403	36.3132	388.7	Ashokan	branch chanel	0.35	2
13	Gate 6	43.9405	36.2697	385.7	Daraban	branch chanel	0.35	6.2
14	Gate 7	43.9176	36.2592	384.5	Sebiran	branch chanel	0.35	6.5

Table 4.13. The table displays the proposed pump capacities for this project. Chosen **300QS-125**

Pump Type	**Flow (Q)**		**H Head (m)**	**n Speed (rpm)**	**Power(kw)**		**η Eff**	**NPSH**	**Pump Weight (kg)**
	(m3/h)	**(l/s)**			**Shaft power**	**Motor**			
300QS-19	612	170	23	1450	47.3	55	81	5.5	660
	792	220	19.4		49.8		84		
	935	260	14		47.6		75		
300QS-125	850	236	140	1470	450	680	72	6.5	1580
	1250	347	125		252		81		
	1663	**461**	**100**		**620**		73		
300QS-125B	745	207	108	1470	313	500	70	6.5	1580
	1100	305	96		373		77		
	1458	405	77		422		72.5		
350QS-75	972	270	80	1450	268	400	79	6.5	1200
	1260	350	75		306		84		
	1440	400	65		319		80		
350QS-75A	900	250	70	1450	220	300	78	6.5	1200
	1170	325	65		247		84		
	1330	370	56		257		79		

4.2. Discussion

It is widely recognized that groundwater levels play a crucial role in shaping the lives of people and the agricultural sector. The rapid decline in groundwater level is evident in Figure (4-6).Clearly, water levels decrease significantly each year in this area. At the highest level of 53 m from the Kewargosk well and the lowest level of 11.7 m from the Qafar well, this study was conducted to prevent this decline while diverting river water to farmers instead of using groundwater. The reasons for the decline in groundwater levels are mainly due to the expansion of towns from 10.53 km^2 to 45.5 km^2. Furthermore, vegetation has increased from 8.83 km^2 to 29.12 km^2, as shown in Table 4.1, and there are several large enterprises in the area, such as the Coca-Cola Manufacturing Company and a large oil refinery (Hamad ,Cullu ,Bilgi & Akca, 2022). The solution, for the most part, is to choose the Great Zab River. The Great Zabi River, which originates in Turkey near Lake Van and flows through central and northern Iraq, covers a basin of 40,300 km^2, of which 62% is in Iraq and 38% in Turkey (Al-Ansari,. et all ,. 2014). The river discharge experiences significant seasonal variations due to pre-rainfall and snowmelt. In winter and spring, the average flow is more than 500 m^3/sec, while in summer and autumn, it drops to 200 m^3/sec. (Ministry of Water Resources of Iraq, 2022.). Despite these changes, most water quality parameters indicate that the Greater Zabi River is within permissible levels for drinking water use and is considered safe for all crop species (Shekha, Y.A. 2016).It is known as the closest water source in our area. We tried three ways to solve the problems of the farmers on the Baranti Plain. The first rainwater harvesting in the area was 15 pounds. The average rainfall in the basin is 396 mm annually, and the average annual rainfall is 142 million cubic meters. With an area of 360.7 km^2, the total water collection of all 15 ponds is equal to 5.7 million m3 per year. The second way is to distribute the water of the Great River through a pipeline to the area by building a reservoir at the highest level and then distributing the water by gravity. About 215 km of pipelines are needed. For this purpose, from 30 inches to 9 inches, it is able to irrigate 65% of the land in the area. The third option is to build a concrete channel based on the Great River, although it requires a pump to transport the water initially. The Toshka and Harran Plain projects in Egypt and Turkey are two large projects located in arid and semi-arid areas that are similar to the Barantin Plain project in several respects. Toshka draws its water from Lake Nasser on the Nile.(Warner , 2012). Meanwhile, the Haran Plain Project gets its water from the Ataturk Dam, located on the Euphrates River (Yesilnacar., et all., 2008). In contrast, the Baranti project draws water from the Great Zab River. In the initial phase, Toshka uses 24 large pumps with a transfer capacity of 1.2 million cubic meters per hour (Sallam,. et all ,. 2014). The first phase of Baranti, meanwhile, uses 26 pumps with a ring transfer capacity of 32,400 cubic meters per hour. The initial phase of the Haran Plain has been designed using 26-kilometer-long tunnels capable of transporting 1 million cubic meters of water per hour (Thomson, K. J. 2009). The main Toshka canal extends 51 km and can irrigate an area of about 500,000 ha (El Quosy, D.E.D 2019). The main canal of the Haran Plain, which is 86 km long, has the capacity to serve about 800,000 ha .The main canal of the Baranti project stretches for 68 km and is designed to irrigate 30,000 hectares. Besides the many benefits of the agriculture sector, such as increasing GDP and local employment opportunities, it also contributes to the annual groundwater level rise exceeding 2.5 m, as illustrated in Figure (4.18). (Kahraman., et all ,. 2015). Although our area is smaller than the Haran Plain, there are more than 600 agricultural wells. When inactive, these wells contribute significantly to rising groundwater (Shekha, Y.A. 2016).

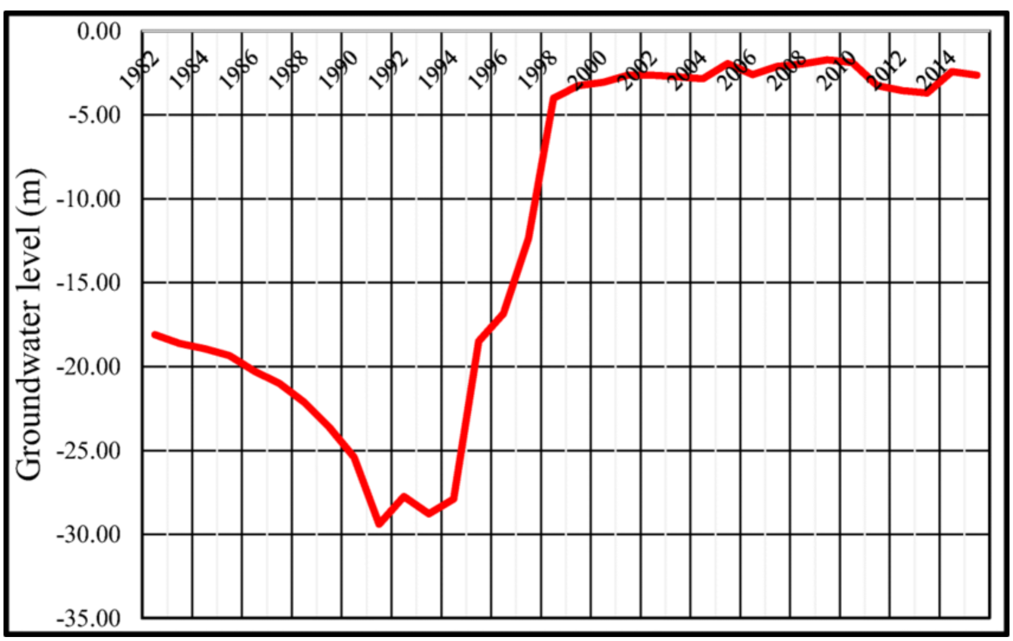


Figure (4.18) Groundwater level rise from 1982 to 2015 in the Haran Plain (DSI 2018)

5.CONCLUSION and RECOMMENDATIONS

5.1. Conclusion

In general, climate change has a direct impact on groundwater depletion in arid and semi-arid regions, and our region is not immune to these effects. This study focuses on the Baranti Plain, which is located in the northern part of the center of Erbil between Khabat and Ankawa districts. After analyzing the groundwater storage data of the region, we have found that the groundwater levels in the Baranti plain have decreased by approximately 23 meters from 2000 to 2021. However, it is important to note that this decline is not uniform across all parts of our study area, as depicted in figure 4.6. Comparatively, the northeastern part of Erbil exhibits significantly better water quality than the northwestern part. This discrepancy can be attributed to several reasons, which can be divided into two categories: natural factors and humanitarian factors.

a) **Natural Factors:**

1. Low rainfall: The area experiences limited precipitation, resulting in insufficient water resources.
2. Increased temperature: Rising temperatures lead to increased evaporation rates and water loss.
3. Low groundwater level: The available groundwater is at a decreased level, affecting access to water sources.
4. Topography of the region: The landscape and terrain of the area influence water distribution and availability.

b) **Humanitarian Factors**:

1. Increased agriculture: The expansion of agricultural activities puts additional pressure on water resources.
2. Sudden population increase: The rapid growth in population strains the existing water supply.

3. Increase in the number of irrigation and surface wells: The escalating demand for water leads to the proliferation of wells, impacting groundwater levels.
4. Type of crops planted: Certain crops require higher amounts of water, exacerbating the water scarcity issue.
5. Type of irrigation: Inefficient irrigation practices contribute to water waste.
6. Increase in the number of fishponds: The establishment of fishponds contributes to increased water demand.

To solve these problems, we used modern technologies such as Geographic Information Systems (GIS), remote sensing, and meteorological data analysis. These tools played an important role in determining the appropriate location for the construction of ponds, concrete channels, and the highest point for piped water distribution in order to raise groundwater levels in the area.

In our research, we generally preferred the first and third options, although the construction of ponds is not able to irrigate the farmers' land in this area because it can only collect 4% of rainwater, equivalent to 5.7 million m^3. This amount is too small to irrigate farmers' crops, but we can use it as a good source to increase groundwater. The third way was to build concrete channels. This project initially requires a pump to transfer water from the river into the concrete channels because the plain level is 130 m higher than the river and then slopes and disperses it throughout the area. The project has the capacity to irrigate over 30,000 hectares of land in the region, covering 68% of the total area. The transfer capacity of the channel is 32,400 m^3/hour. The length of the main channel is 68.2 km, the length of the sub-channel is 86 km, and the length of the branches is 17 km. Construction and maintenance are much easier than piped water distribution. Because water distribution by pipeline is very difficult to build and repair, Over 1200 farmers will benefit from a project that replaces over 600 irrigation wells, improving groundwater levels and increasing farming and fishing resources. It also protects the land in this area from drought. The project will also support drinking water projects in Erbil’s center during the summer season, when these wells will be stopped.

5.2. Recommendation

In order to address the problem of groundwater depletion, the study proposes several recommendations:

- Utilize surface water instead of groundwater.
- Constructing concrete channels is the most effective approach. As a result of this discussion, we have discovered.
- Construct ponds in suitable locations.
- Organize awareness courses for farmers to comprehend the risks associated with water scarcity.
- Encourage farmers to adopt new irrigation methods instead of conventional ones.
- Restrict new well drilling.
- government should subsidize crops that do not use extensive water.

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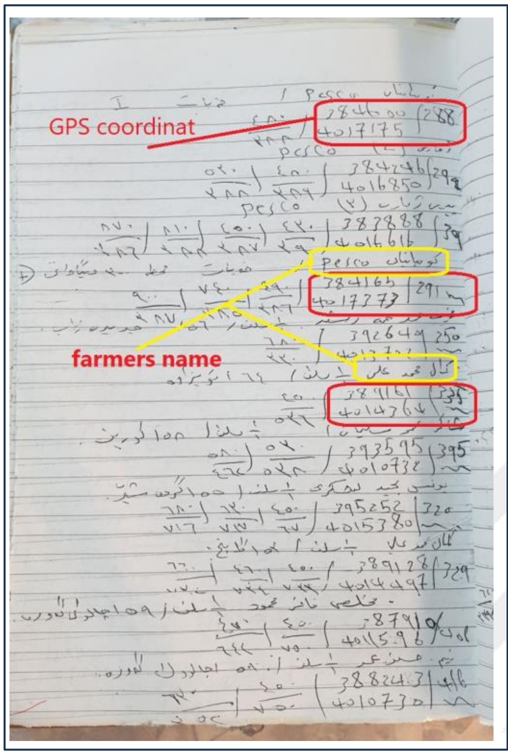
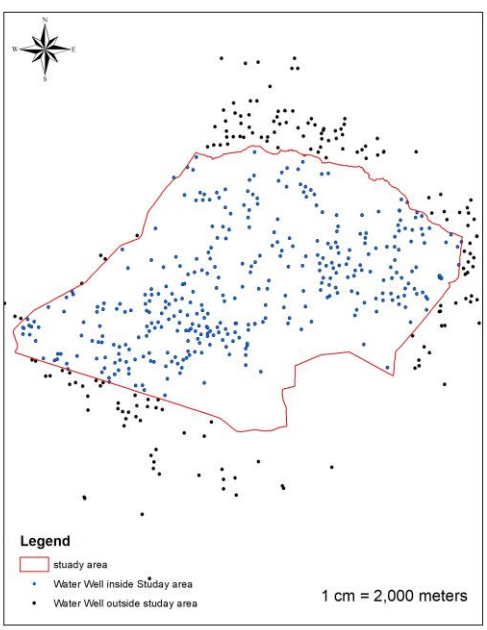
APPENDICES

Appendix 1: Field visits to measure well depths.

Appendix 2: Collect well data and convert it to Excel



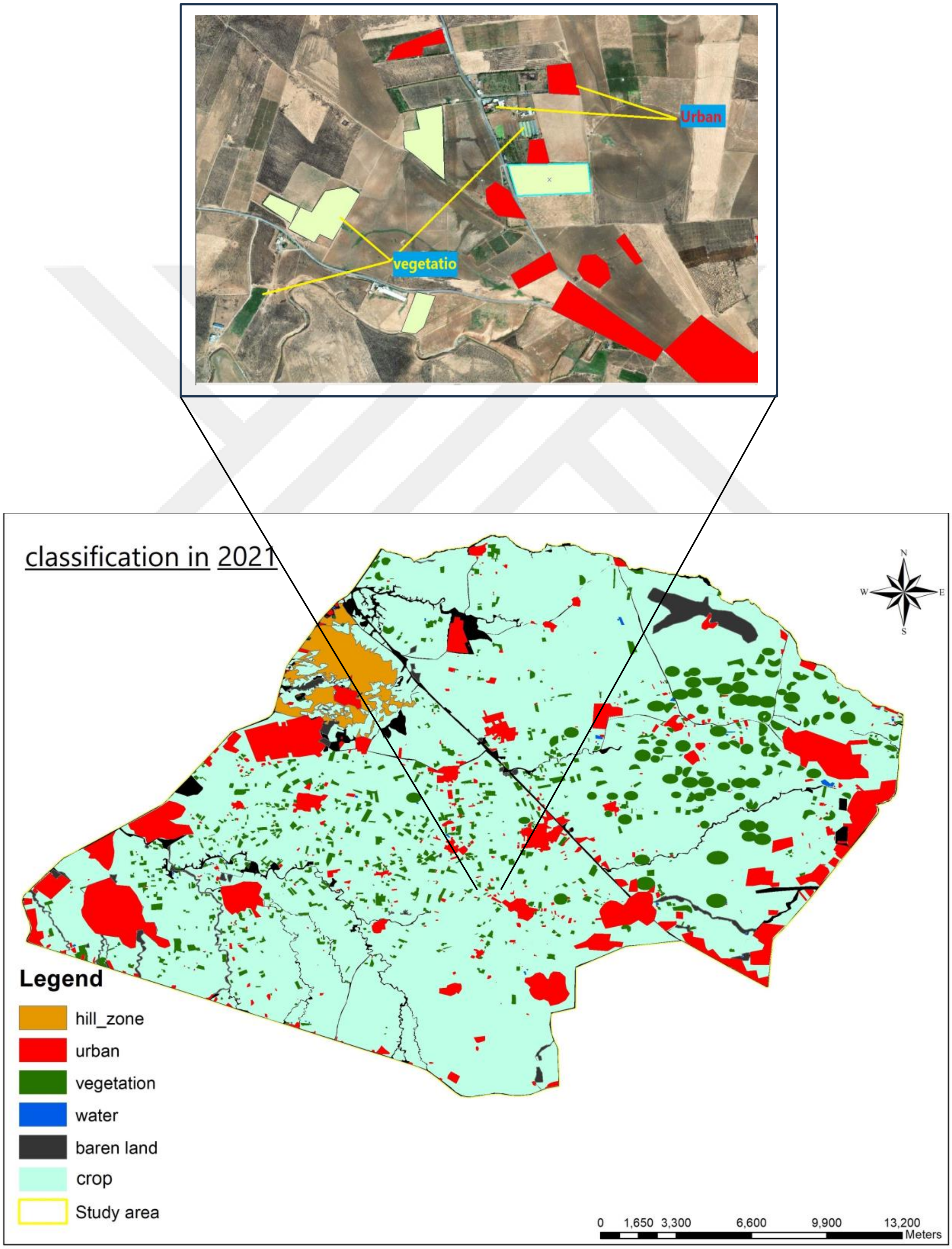


NO	village	Z	Y	X	Name	
1	شيوقرةش	275	4021268	395784	فتم عزيز نادر	1
2	جديدة زاب	300	4013062	391124	فوزية حمزة حسن	2
3	خالوان	321	4032422	400924	رسمية فرحان كريم	3
4	خالوان	241	4032757	400552	هيَشلا نيران فرحان	4
5	خالوان	297	4032153	397245	فرحان نيران فرحان	5
6	خالوان	322	4032216	398202	كريم سليمان كريم	6
7	خالوان	333	4034181	398080	نظيرة هدني سليمان	7
8	طردة شيَر	342	4013995	394366	قطب الدين عزيز	8
9	طردة شيَر	270	4013620	394099	محسن ياسين عزيز	9
10	تؤبزاوة	377	4013563	390168	ليلى عبداللة كريم	10
11	طاينج	345	4018605	390577	طولي حسين كريم	11
12	تؤبزاوة	375	4019364	392785	سمكؤ سعدي مشير	12
13	زراو	368	4015328	389278	نجيم عبدالرحمن كريم خان	13
14	كؤمثانياى كار	370	4031410	407157	كامران عبداللة صادق	14
15	كؤمثانياى كار	289	4019714	387258	ثالاوطةى كةلةك/كومثانياي كار	15
16	كؤمثانياى كار	323	40190733	387463	ثالاوطةى كةلةك/كومثانياي كار	16
17	كؤمثانياى كار	362	4019463	387341	كومثانياي كار	17
18	طاينج	320	4018897	394440	عطية عمر قادر	18
19	كاني قرذالة	463	4007499	394898	سيداد جعفر	19

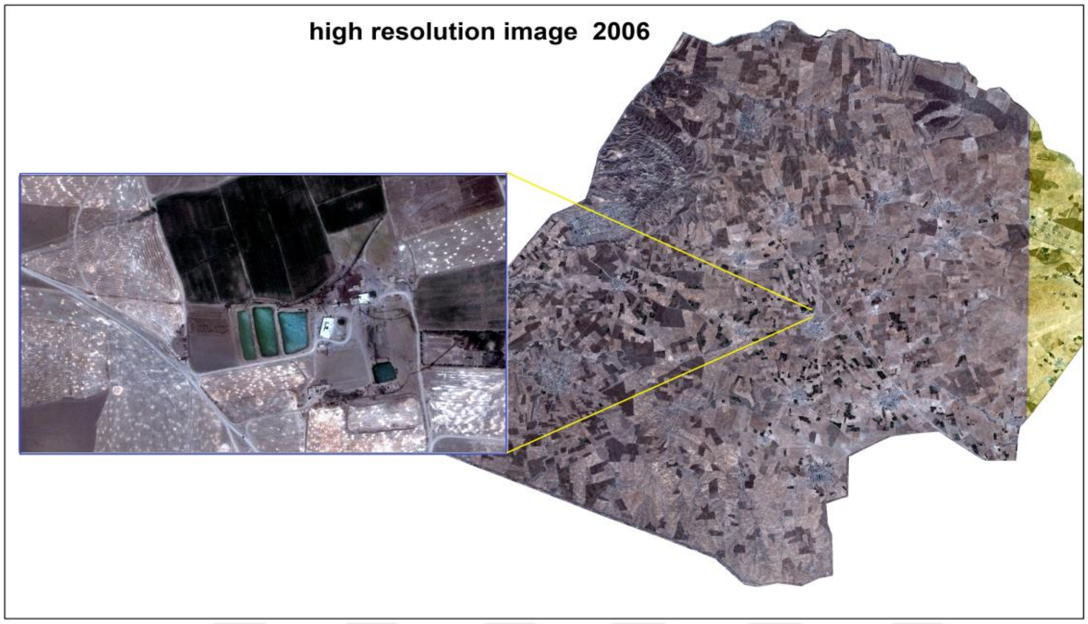
Appendix 3: Interpretation of groundwater monitoring data from 2000 to 2021 in September.

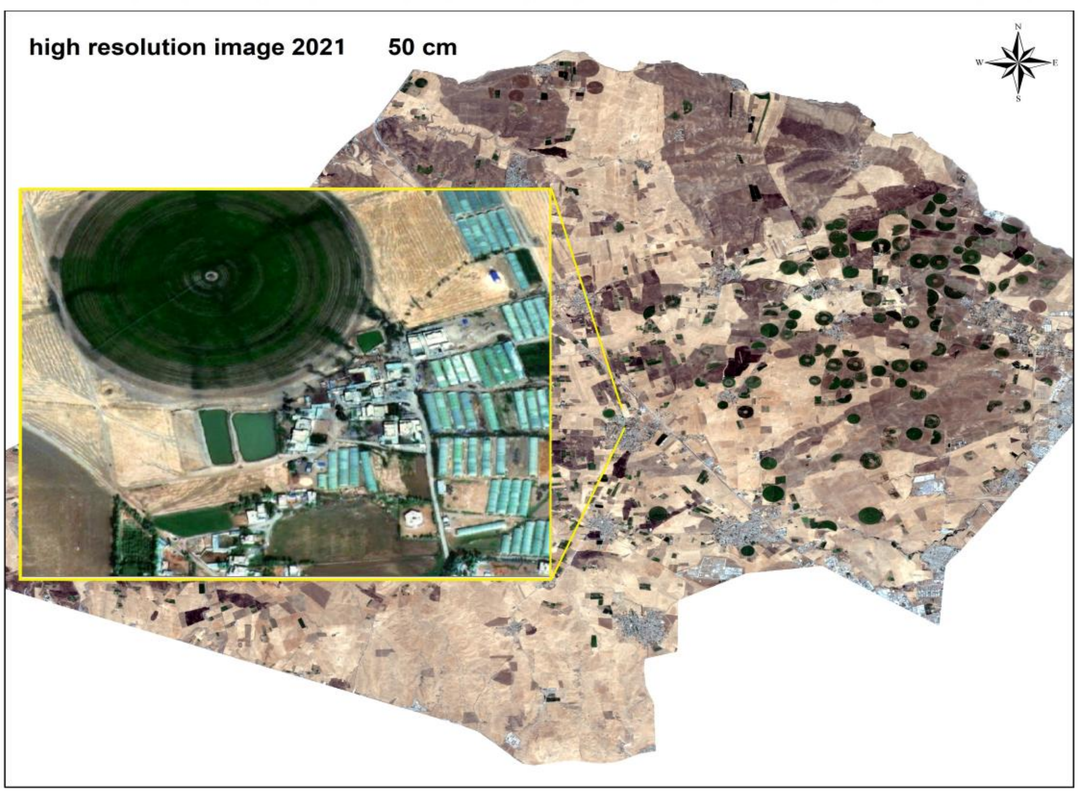
	years	گاینجی گەورە	rain	گردەجال	rain	جدیدە زاب	rain	جاژنی کان بابکر	rain	کەورگۆسک	rain	قەفەر	rain	سێبیرانی گەورە	rain
1	2000					39.41				31.85		43.36			
2	2001	29.55	340.7	25	355	39.92	340.7	21.9	355	35.46	340.7	45.5	355	42.13	365
3	2002	30.47	330.3		410	40.69	330.3	23.85	410	36.56	330.3	46.75	410	42.7	400.6
4	2003	31.23	413.3	61.91	533	41.24	413.3	22.94	533	39.52	413.3	44.9	533	42.88	530
5	2004	31.57	389.4		505.9	41.57	389.4	20.9	505.9	33.1	389.4	42.69	505.9	42.33	499
6	2005	32	330.3		360.2	42.38	330.3	20.12	360.2	33.6	330.3	42.87	360.2	43.35	432
7	2006	31.97	380.5		366.7	42.48	380.5	19.3	366.7	32.38	380.5	42.64	366.7	43.87	477.7
8	2007	32.14	291.5		300	42.32	291.5	18.52	300	31.79	291.5	42.71	300	43.55	405
9	2008	32.76	124.5		138.1	43.48	124.5	19.26	138.1	32.36	124.5	46.14	138.1	44.29	180.4
10	2009	33.68	189.5		160.3	44.57	189.5	22.61	160.3	35.83	189.5	47.63	160.3	44.51	290.4
11	2010	34.21	265.4		445.1	44.98	265.4	23.46	445.1	36.25	265.4	48.86	445.1	44.69	426.4
12	2011	34.3	288.1		340.6	47.4	288.1	28.6	340.6	66	288.1	49.8	340.6	47.8	538.4
13	2012	34.4	126.7		321.1	48.7	126.7	30.9	321.1	76.35	126.7	54.2	321.1	50.6	220.6
14	2013	37.92	422.3		662.2	47.9	422.3	31.1	662.2	55.42	422.3	53.1	662.2	51.21	489.3
15	2014	37.3	278.1		434.6	46.98	278.1	30.17	434.6	61.5	278.1	52.8	434.6	49.68	343.1
16	2015	37.9	330		592.9	48	330	31.9	592.9	55.2	330	53.55	592.9	50.35	363.4
17	2016	38.21	406		653.3	49	406	33	653.3	56.3	406	53.85	653.3	52.2	445.3
18	2017	48.9	242.1		378.5	53.7	242.1	50.3	378.5	72.1	242.1	52	378.5	60	315.4
19	2018	46	298.5	23.73	549.6	55.86	298.5	42.3	549.6	74.6	298.5	50	549.6	56.4	385.7
20	2019	41.2	902.8	37.5	997.4	50	902.8	33.7	997.4	53.35	902.8	51.46	997.4	54.9	963
21	2020	43.5	462	33	559.9	51.8	462	37.65	559.9	75.25	462	50.98	559.9	57.5	431.8
22	2021	49.2	179.9	35.4	217.1	74.8	179.9	40.15	217.1	85	179.9	55.1	217.1	58	166.5
#		-19.65		-10.4		-35.39		-18.25		-53.15		-9.6		-15.87	

Appendix 4: Sample of classification By the polygon

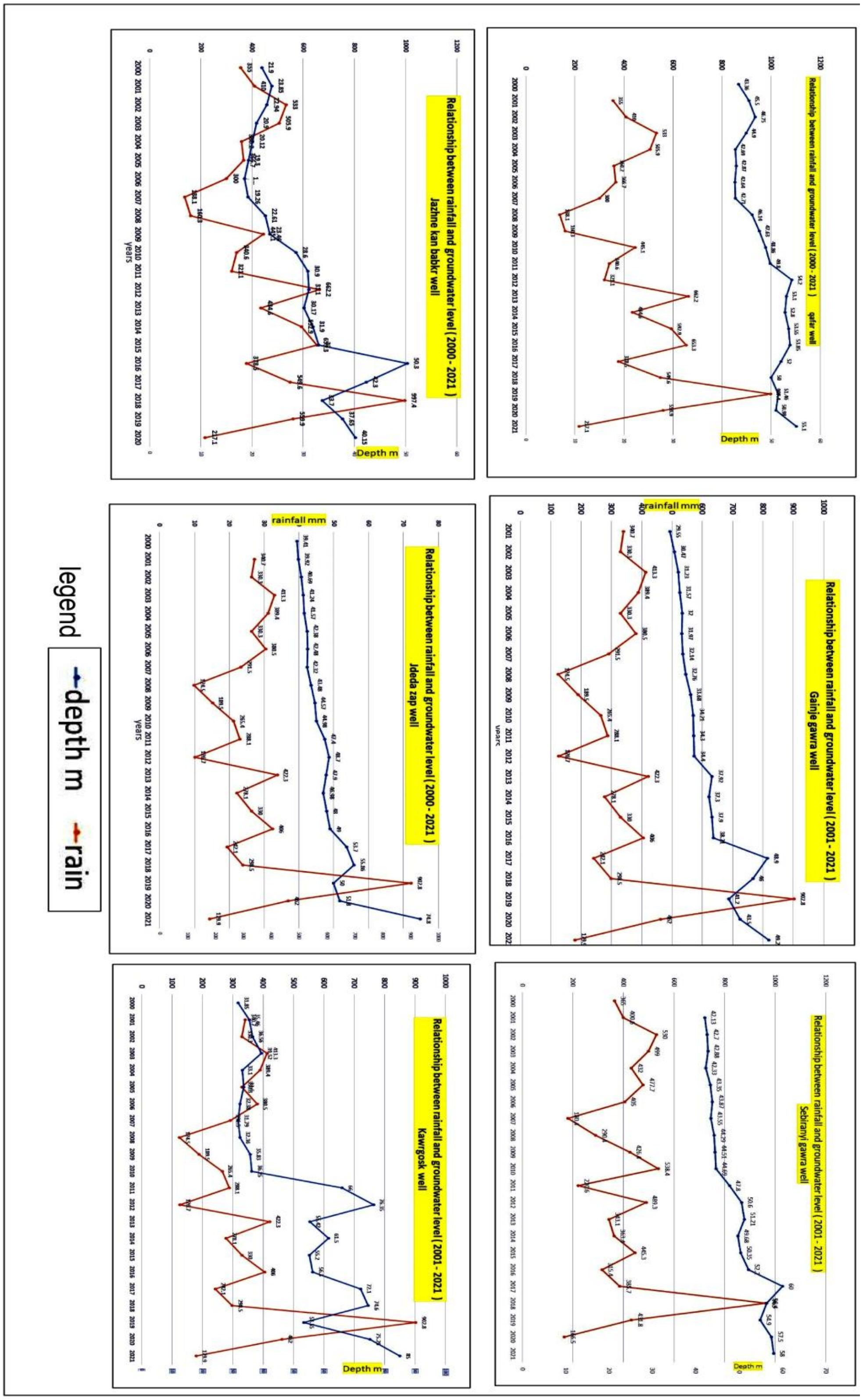


Appendix 5: Two examples in the same place but in two different years.



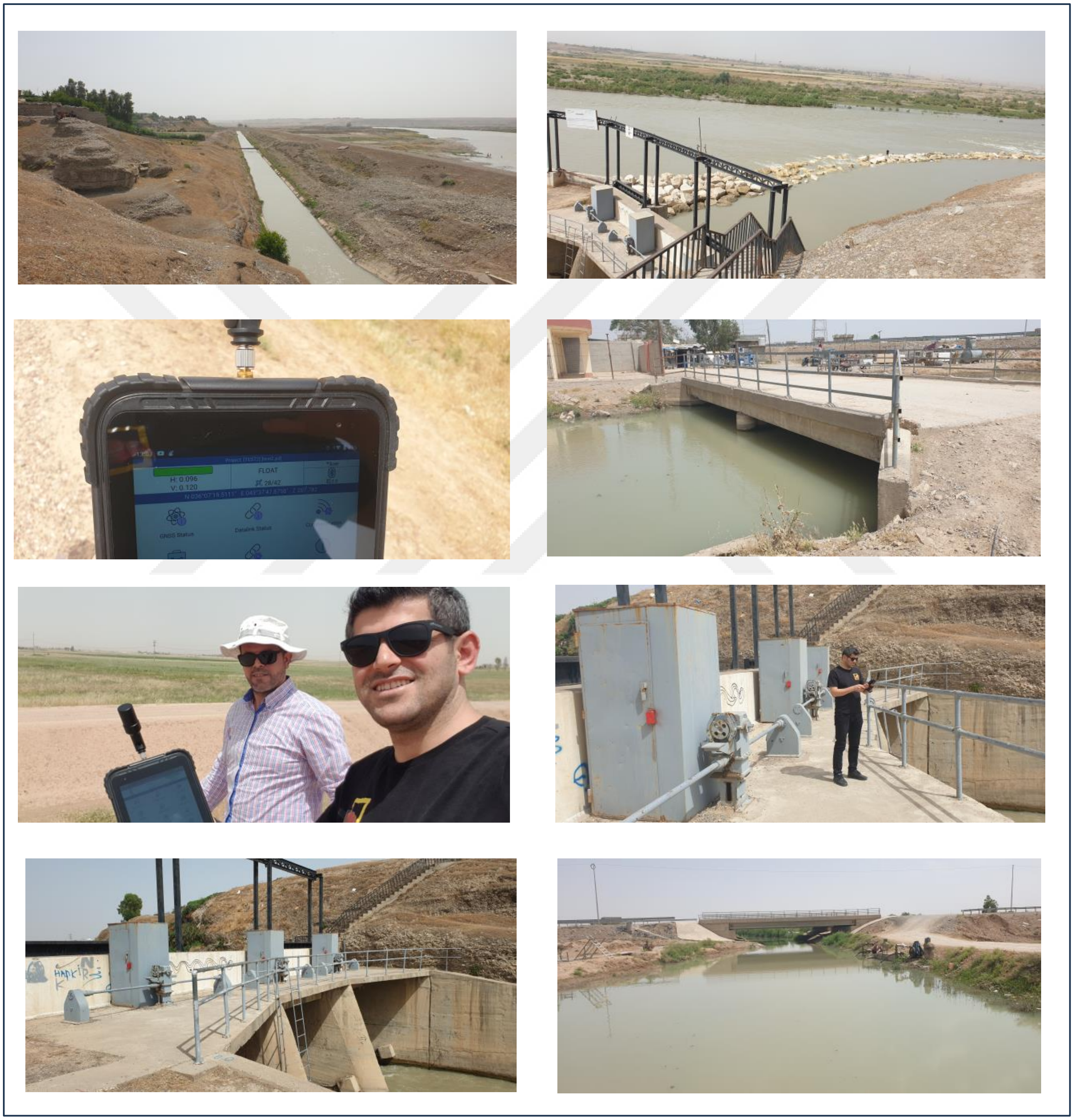


Appendix 6: Relationship between rainfall and groundwater level



Appendix 7: Photos of visiting several pump shops.

Appendix 8: Visit the Gower Concrete Channel to find out the slope. by use (GPS-S70G GNSS RTK-Stonex)



Appendix 9 : Node and Link results in pipe line network distribution by Epanet 2.2

Network Table - Links

	Length	Diameter	Flow	Velocity	Unit Headloss
	m	mm	LPS	m/s	m/km
Pipe 134	2000	230.2	75	1.8	22.28
Pipe 136	1000	230.2	75	1.8	22.28
Pipe 137	1100	230.2	75	1.8	22.28
Pipe 122	1000	250	75	1.53	14.9
Pipe 123	1000	250	75	1.53	14.9
Pipe 124	1000	250	75	1.53	14.9
Pipe 131	1750	250	75	1.53	14.9
Pipe 132	3000	250	75	1.53	14.9
Pipe 133	2000	250	75	1.53	14.9
Pipe 135	3000	250	75	1.53	14.9
Pipe 85	1900	254	75	1.48	13.79
Pipe 140	2500	254	75	1.48	13.79
Pipe 144	1800	254	75	1.48	13.79
Pipe 145	1900	254	75	1.48	13.79
Pipe 146	2000	254	75	1.48	13.79
Pipe 148	1000	254	75	1.48	13.79
Pipe 149	1000	254	75	1.48	13.79
Pipe 150	1000	254	75	1.48	13.79
Pipe 151	1000	254	75	1.48	13.79
Pipe 152	1000	254	75	1.48	13.79
Pipe 153	1000	254	75	1.48	13.79
Pipe 155	1560	254	75	1.48	13.79
Pipe 156	1800	254	75	1.48	13.79
Pipe 159	1800	254	50	0.99	6.51
Pipe 162	1600	254	75	1.48	13.79
Pipe 114	1700	295.3	75	1.1	6.62
Pipe 115	1690	295.3	75	1.1	6.62
Pipe 13	1000	300	75	1.06	6.13
Pipe 130	2900	300	75	1.06	6.13
Pipe 30	1000	305	50	0.68	2.67
Pipe 39	1000	305	50	0.68	2.67
Pipe 47	1000	305	55	0.75	3.19
Pipe 126	2200	305	-55	0.75	3.19
Pipe 127	1500	305	50	0.68	2.67

Pipe 128	1500	305	50	0.68	2.67
Pipe 129	1000	305	55	0.75	3.19
Pipe 154	1000	305	50	0.68	2.67
Pipe 157	2000	305	50	0.68	2.67
Pipe 161	1650	305	50	0.68	2.67
Pipe 164	2200	305	50	0.68	2.67
Pipe 165	2250	305	50	0.68	2.67
Pipe 5	2000	305	50	0.68	2.67
Pipe 12	1000	350	150	1.56	10.45
Pipe 3	1000	381	75	0.66	1.91
Pipe 37	1000	381	100	0.88	3.26
Pipe 55	1000	381	75	0.66	1.91
Pipe 62	1000	381	75	0.66	1.91
Pipe 74	1000	381	75	0.66	1.91
Pipe 82	1000	381	75	0.66	1.91
Pipe 83	1200	381	75	0.66	1.91
Pipe 84	1750	381	75	0.66	1.91
Pipe 86	1950	381	75	0.66	1.91
Pipe 87	1870	381	75	0.66	1.91
Pipe 88	750	381	75	0.66	1.91
Pipe 89	800	381	75	0.66	1.91
Pipe 90	1200	381	75	0.66	1.91
Pipe 91	1000	381	75	0.66	1.91
Pipe 92	1340	381	75	0.66	1.91
Pipe 93	1360	381	75	0.66	1.91
Pipe 94	1450	381	75	0.66	1.91
Pipe 95	500	381	75	0.66	1.91
Pipe 96	800	381	75	0.66	1.91
Pipe 97	1200	381	75	0.66	1.91
Pipe 98	1000	381	75	0.66	1.91
Pipe 99	1550	381	75	0.66	1.91
Pipe 100	1800	381	75	0.66	1.91
Pipe 102	700	381	75	0.66	1.91
Pipe 103	2500	381	75	0.66	1.91
Pipe 104	1200	381	75	0.66	1.91
Pipe 105	2000	381	75	0.66	1.91
Pipe 106	2100	381	75	0.66	1.91
Pipe 113	1300	381	75	0.66	1.91
Pipe 116	1400	381	75	0.66	1.91
Pipe 117	1800	381	75	0.66	1.91
Pipe 118	2000	381	75	0.66	1.91

Pipe 119	1500	381	75	0.66	1.91
Pipe 125	1400	381	70	0.61	1.68
Pipe 138	2200	381	75	0.66	1.91
Pipe 139	2200	381	75	0.66	1.91
Pipe 141	2800	381	75	0.66	1.91
Pipe 142	1500	381	75	0.66	1.91
Pipe 143	2400	381	75	0.66	1.91
Pipe 147	600	381	75	0.66	1.91
Pipe 158	1900	381	75	0.66	1.91
Pipe 160	1480	381	75	0.66	1.91
Pipe 163	1700	381	75	0.66	1.91
Pipe 11	1000	450	225	1.41	6.51
Pipe 4	1000	508	-150	0.74	1.7
Pipe 22	1000	508	150	0.74	1.7
Pipe 29	1000	508	125	0.62	1.21
Pipe 38	1000	508	125	0.62	1.21
Pipe 54	1000	508	150	0.74	1.7
Pipe 61	2000	508	150	0.74	1.7
Pipe 73	1000	508	150	0.74	1.7
Pipe 81	1000	508	150	0.74	1.7
Pipe 36	1000	560	175	0.71	1.41
Pipe 46	1000	560	155	0.63	1.12
Pipe 7	2000	600	-525	1.86	7.7
Pipe 8	1000	600	450	1.59	5.79
Pipe 9	1000	600	375	1.33	4.13
Pipe 10	1000	600	300	1.06	2.73
Pipe 1	1000	635	300	0.95	2.07
Pipe 2	1000	635	225	0.71	1.22
Pipe 16	2000	635	600	1.89	7.48
Pipe 21	1000	635	225	0.71	1.22
Pipe 27	1000	635	275	0.87	1.76
Pipe 28	1000	635	200	0.63	0.98
Pipe 33	2000	635	550	1.74	6.37
Pipe 34	1000	635	450	1.42	4.39
Pipe 35	1000	635	250	0.79	1.48
Pipe 42	2000	635	405	1.28	3.61
Pipe 43	1000	635	330	1.04	2.47
Pipe 44	1000	635	260	0.82	1.59
Pipe 45	1000	635	205	0.65	1.02
Pipe 53	1000	635	225	0.71	1.22
Pipe 60	2000	635	225	0.71	1.22

Pipe 72	1000	635	225	0.71	1.22
Pipe 80	1000	635	225	0.71	1.22
Pipe 6	2000	762	600	1.32	3.08
Pipe 14	2000	762	750	1.64	4.65
Pipe 15	2000	762	675	1.48	3.83
Pipe 18	1000	762	525	1.15	2.4
Pipe 19	1000	762	450	0.99	1.81
Pipe 20	1000	762	300	0.66	0.85
Pipe 24	2000	762	500	1.1	2.2
Pipe 25	2000	762	425	0.93	1.62
Pipe 26	2000	762	350	0.77	1.13
Pipe 31	2000	762	700	1.53	4.09
Pipe 32	2000	762	625	1.37	3.32
Pipe 40	2000	762	555	1.22	2.66
Pipe 41	2000	762	480	1.05	2.04
Pipe 48	1000	762	375	0.82	1.29
Pipe 49	2000	762	525	1.15	2.4
Pipe 50	2000	762	450	0.99	1.81
Pipe 51	2000	762	375	0.82	1.29
Pipe 52	1000	762	300	0.66	0.85
Pipe 58	2000	762	375	0.82	1.29
Pipe 59	2000	762	300	0.66	0.85
Pipe 69	2000	762	450	0.99	1.81
Pipe 70	2000	762	375	0.82	1.29
Pipe 71	1000	762	300	0.66	0.85
Pipe 76	2000	762	525	1.15	2.4
Pipe 77	1000	762	450	0.99	1.81
Pipe 78	1000	762	375	0.82	1.29
Pipe 79	1000	762	300	0.66	0.85

Network Table - Nodes

Node ID	Elevation m	Base Demand LPS	Demand LPS	Head m	Pressure m
Junc 12	305	0	0	399.3	94.3
Junc 142	314	75	75	354.59	40.59
Junc 140	318	75	75	363.98	45.98
Junc 13	319	0	0	388.85	69.85
Junc 14	320	0	0	382.72	62.72
Junc 10	321	0	0	408.53	87.53
Junc 139	321	75	75	367.95	46.95
Junc 9	322	0	0	412.66	90.66
Junc 11	323	0	0	405.8	82.8
Junc 18	324	0	0	405.68	81.68
Junc 16	326	0	0	423.04	97.04
Junc 141	331	75	75	376	45
Junc 89	333	75	75	429.99	96.99
Junc 19	335	0	0	403.87	68.87
Junc 4	336	0	0	435.42	99.42
Junc 144	336	75	75	364.93	28.93
Junc 146	336	75	75	395.45	59.45
Junc 154	336	75	75	418.57	82.57
Junc 138	337	75	75	396.17	59.17
Junc 143	339	75	75	362.77	23.77
Junc 150	340	75	75	367.32	27.32
Junc 148	341	75	75	380.85	39.85
Junc 155	341	75	75	416.3	75.3
Junc 17	341	0	0	408.08	67.08
Junc 149	343	75	75	399.28	56.28
Junc 158	343	75	75	414.53	71.53
Junc 153	344	75	75	421.81	77.81
Junc 145	344	75	75	429.55	85.55
Junc 26	344	0	0	430.09	86.09
Junc 15	345	0	0	430.7	85.7
Junc 94	345	75	75	429.8	84.8
Junc 160	347	75	75	384.5	37.5

Junc 147	348	75	75	381.87	33.87
Junc 25	348	0	0	432.36	84.36
Junc 88	349	75	75	433.29	84.29
Junc 20	350	0	0	403.02	53.02
Junc 166	351	75	75	410.29	59.29
Junc 6	352	0	0	431.81	79.81
Junc 3	352	0	0	436.64	84.64
Junc 27	353	0	0	428.33	75.33
Junc 5	354	0	0	433.72	79.72
Junc 24	355	0	0	435.61	80.61
Junc 164	355	50	50	400.72	45.72
Junc 165	357	75	75	400.34	43.34
Junc 151	359	75	75	397.66	38.66
Junc 161	359	75	75	404.42	45.42
Junc 28	359	0	0	427.35	68.35
Junc 36	360	0	0	406.57	46.57
Junc 34	360	0	0	412.44	52.44
Junc 83	360	0	0	431.25	71.25
Junc 82	360	0	0	432.1	72.1
Junc 21	360	0	0	401.8	41.8
Junc 157	361	75	75	413.56	52.56
Junc 35	361	0	0	408.05	47.05
Junc 159	363	75	75	401.91	38.91
Junc 90	363	75	75	409.21	46.21
Junc 37	364	0	0	405.17	41.17
Junc 96	365	75	75	427.47	62.47
Junc 2	367	0	0	438.71	71.71
Junc 33	368	0	0	425.17	57.17
Junc 126	369	75	75	419.77	50.77
Junc 128	369	75	75	408.47	39.47
Junc 167	370	50	50	407.1	37.1
Junc 8	370	0	0	418.45	48.45
Junc 93	370	75	75	431.86	61.86
Junc 81	370	0	0	433.39	63.39
Junc 44	370	0	0	406.84	36.84
Junc 22	370	0	0	400.1	30.1
Junc 163	370	50	50	399.76	29.76
Junc 87	372	75	75	436.41	64.41
Junc 38	373	0	0	404.17	31.17
Junc 98	374	75	75	423.64	49.64
Junc 32	375	0	0	431.81	56.81

Junc 102	375	75	75	429.83	54.83
Junc 95	375	75	75	429.33	54.33
Junc 48	375	0	0	420.91	45.91
Junc 39	378	0	0	401.9	23.9
Junc 84	378	0	0	430.03	52.03
Junc 117	379	75	75	432.71	53.71
Junc 54	379	0	0	431.58	52.58
Junc 91	379	75	75	428.23	49.23
Junc 42	380	50	50	395.9	15.9
Junc 127	380	75	75	415.7	35.7
Junc 43	380	50	50	396.03	16.03
Junc 74	380	0	0	433.81	53.81
Junc 118	380	75	75	420.32	40.32
Junc 162	380	75	75	404.01	24
Junc 92	380	75	75	433.76	53.76
Junc 31	380	75	75	395.89	15.89
Junc 29	380	0	0	426.14	46.14
Junc 23	380	75	75	395.89	15.89
Junc 76	382	0	0	431.74	49.74
Junc 77	382	0	0	430.04	48.04
Junc 137	383	75	75	409.34	26.34
Junc 46	384	0	0	430.6	46.6
Junc 45	385	0	0	434.67	49.67
Junc 156	385	75	75	412.34	27.34
Junc 97	385	75	75	425.73	40.73
Junc 47	385	0	0	423.38	38.38
Junc 152	385	75	75	401	16
Junc 132	386	50	50	414.29	28.29
Junc 75	387	0	0	432.96	45.96
Junc 80	388	0	0	435.19	47.19
Junc 30	390	0	0	423.47	33.47
Junc 133	390	55	55	406.98	16.98
Junc 100	390	75	75	432.28	42.28
Junc 49	390	0	0	419.32	29.32
Junc 85	390	0	0	428.33	38.33
Junc 7	390	0	0	433.85	43.85
Junc 121	390	75	75	423.49	33.49
Junc 41	390	50	50	411.83	21.83
Junc 119	390	75	75	417.81	27.81
Junc 86	392	0	0	426.41	34.41
Junc 53	394	0	0	435.19	41.19

Junc 50	395	0	0	418.29	23.29
Junc 106	395	75	75	436.08	41.08
Junc 129	395	70	70	418.55	23.55
Junc 107	395	75	75	430.93	35.93
Junc 131	395	55	55	416.13	21.13
Junc 73	396	0	0	436.39	40.39
Junc 52	397	0	0	413.98	16.98
Junc 134	397	50	50	413.16	16.16
Junc 62	398	0	0	437.42	39.42
Junc 99	400	75	75	435.43	35.43
Junc 51	400	0	0	417.17	17.17
Junc 55	400	0	0	429	29
Junc 108	400	75	75	430.99	30.99
Junc 63	401	0	0	435.72	34.72
Junc 56	401	0	0	428.15	27.15
Junc 78	403	0	0	428.13	25.13
Junc 58	404	0	0	425.23	21.23
Junc 40	405	50	50	420.8	15.8
Junc 122	405	75	75	421.41	16.41
Junc 123	405	75	75	420.45	15.45
Junc 110	405	75	75	423.95	18.95
Junc 120	405	75	75	425.47	20.47
Junc 103	405	75	75	427.07	22.07
Junc 57	405	0	0	426.94	21.94
Junc 101	405	75	75	430.66	25.66
Junc 59	407	0	0	423.32	16.32
Junc 104	408	75	75	424.68	16.68
Junc 66	410	0	0	427.97	17.97
Junc 109	410	75	75	426.05	16.05
Junc 65	414	0	0	429.88	15.88
Junc 64	416	0	0	433.29	17.29
Resvr 1	440	#N/A	-5355	440	0