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College of Engineering and Technology
Civil & Architecture Engineering Department

Project Title

A GIS-based DRASTIC Model For Assessing Intrinsic Groundwater Vulnerability In Bani Naim Town.

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A GIS-Based DRASTIC Model For Assessing Intrinsic Groundwater Vulnerability

In Bani Naim

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In accordance with the recommendations of the project supervisor, and the acceptance of all examining committee members, this project has been submitted to the Department of Civil and Architectural Engineering in the College of Engineering and Technology in partial fulfillment of the requirements of the department for the degree of Bachelor of Science in Engineering.

Project Supervisor **Department Chairman**

إهداء

إلى من جرع الكأس فارغاً ليسقيني قطرة حب
إلى من كلّت أنامله ليقدم لنا لحظة سعادة
إلى من حصد الأشواك عن دربي ليمهد لي طريق العلم
إلى القلب الكبير............ (والدي العزيز)

إلى من أرضعتني الحب والحنان
إلى رمز الحب وبلسم الشفاء .... (والدتي الحبيبة)

إلى القلوب الطاهرة الرقيقة والنفوس البريئة إلى رياحين حياتي
الى من يحملون في عيونهم ذكريات طفولتي وشبابي .... إخوتي وأخواتي
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(قل اعملوا فسيرى الله عملكم ورسوله والمؤمنون)
صدق الله العظيم

إلهي لا يطيب الليل إلا بشكرك ولا يطيب النهار إلا بطاعتك .. ولا تطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك .. ولا تطيب الجنة إلا برؤيتك
الله جل جلاله.......

لابد لنا ونحن نخطو خطواتنا الأخيرة في الحياة الجامعية من وقفة نعود إلى أعوام قضيناها في رحاب الجامعة مع أساتذتنا الكرام الذين قدموا لنا الكثير باذلين بذلك جهودا كبيرة في بناء جيل الغد لتبعث الأمة من جديد

وقبل أن نمضي نقدم أسمى آيات الشكر والامتنان والتقدير والمحبة إلى الذين حملوا أقدس رسالة في الحياة إلى الذين مهدوا لنا طريق العلم والمعرفة

إلى جميع أساتذتنا الأفاضل
"كن عالما فإن لم تستطع فكن متعلما ، فإن لم تستطع فأحب العلماء ،فإن لم تستطع فلا تبغضهم"
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"إن الحوت في البحر ، والطير في السماء ، ليصلون على معلم الناس الخير"

وكذلك نشكر بلدية بني نعيم وطاقمها التي لم تبخل علينا بتزويدنا بالمعلومات اللازمة ومدت لما يد العون بكل اخلاص

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We would like to express our thanks and gratitude to Allah, the Most Beneficent, the most Merciful who granted us the ability and willing to start and complete this project. We pray to his greatness to inspire us the right path to his content and to enable us to continue the work started in this project to the benefits of our country.

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Work Team

Abstract

A GIS-Based DRASTIC Model For Assessing Intrinsic Groundwater Vulnerability

In Bani Naim

Prepared By:

Ahmad Hassan **Saher Tamera**

Mohammad Deeb

Supervisor By :

Dr. Itissam Abuizia

Vulnerability assessment to delineate areas that are more susceptible to contamination from anthropogenic sources has become an important element for sensible resource management and land use planning. This contribution aims at estimating aquifer vulnerability by applying the DRASTIC model as well as utilizing sensitivity analyses to evaluate the relative importance of the model parameters for aquifer vulnerability. An additional objective is to demonstrate the combined use of the DRASTIC and geographical information system (GIS) as an effective method for groundwater pollution risk assessment. The DRASTIC model uses seven environmental parameters (Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, and hydraulic Conductivity) to characterize the hydrogeological setting and evaluate aquifer vulnerability. Net recharge parameter inflicted the largest impact on the intrinsic vulnerability of the aquifer followed by soil media, topography, vadose zone media, and hydraulic conductivity. Sensitivity analyses indicated that the removal of net recharge, soil media and topography causes large variation in vulnerability index. Moreover, net recharge and hydraulic conductivity were found to be more effective in assessing aquifer vulnerability than assumed by the DRASTIC model. The GIS technique has provided efficient environment for analyses and high capabilities of handling large spatial data. moreover this study has shown that (13%) of the total area was under the low vulnerable zone, mainly due to the presence of the higher depth of water level and high elevation (Topography). And About (66 %) of the area was low vulnerable zone .About (%19) of the area was moderate vulnerable zone which could be due to the reason that less depth of water level and high elevation. And about (2%) of the area was high. Final computed values for DRASTIC Index provide numerical range for vulnerability criteria and aquifer vulnerability analysis. For Bani Naim , the DRASTIC index value degree varied from 32 to 118 divided into four categories ; under low vulnerability (32- 42) , low vulnerability (42- 73) , under high vulnerability (73- 101), and high vulnerability (101- 118).

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List of Acronyms

Acronym	Description
GIS	Geographic Information Systems.
C	Celsius.
GW	GROUND WATER.
PH	Potential Hydrogen.
D	Depth to groundwater levels.
R	Net recharge.
T	Topography (slope).
S	Soil media.
C	Hydraulic conductivity.
A	Aquifer media.
I	Impact of vadose zone.

Chapter One

Assessment of Groundwater vulnerability to pollution using a GIS-based DRASTIC model for Bani Naim Town

1.1 Introduction

Groundwater vulnerability assessment has been a challenging task, since it highlights areas where particular attention should be given to groundwater protection. The term groundwater vulnerability includes two basic definitions: intrinsic vulnerability and specific vulnerability. The former defines the vulnerability of groundwater to contaminants taking into account only the hydrogeological properties the aquifer and its confining layer, and is independent of the nature of the contaminant. The latter takes into account both the characteristics of the contaminant and the hydrogeological properties of the confining layer and the aquifer. Vulnerability refers to the sensitivity of an aquifer system to deterioration due to an external action.

It is an intrinsic property of an aquifer system and can vary with regard to the specific natural and/or human impact. It is pointed out that vulnerability is a general concept and can be used in the assessment of impacts from floods or droughts .A vast majority of groundwater quality problems are caused by contamination, overexploitation, or combination of both. Most groundwater quality problems are difficult to detect and hard to resolve. The solutions are usually very expensive, time-consuming, and not always effective although the groundwater quality. Many techniques have been developed to assess groundwater vulnerability, including index, rating, hybrid, statistical and simulation methods [1] .

The DRASTIC method has been the most commonly used for mapping vulnerability in porous aquifers .The wide range of contamination sources is one of the many factors contributing to the complexity of groundwater protection. It is important to know the geochemistry of chemical-soil-groundwater interactions to assess the fate and impact of pollutants migration from the ground surface to the aquifer water [2] .

Pollutants travel through different hydrologic zones as they migrate through the soil to the water table. A remote sensing system has a great role in groundwater exploration because remotely sensed data provide a synoptic view of high observational density. The common current remote sensing platforms record features on the surface.

Most of the information for groundwater, as yet, has to be obtained by qualitative reasoning and semi-quantitative approaches. Remotely sensed information is often surrogate and has to be merged with geo-hydrologic data to become meaningful . reduce the water reservoirs and drawdown of groundwater in many of aquifers beside, the development of technology and expansion of urban planning, burial of industrial and urban waste is another threat the country's aquifers The normal DRASTIC model was applied to the study area with the help of GIS. DRASTIC parameters were calculated from geological data, soil and elevation contour maps, and groundwater level data of the study area. Arc Info/GIS were used to demarcate vulnerable zones based on their vulnerability index [3] .

1.2 Description of DRASTIC system method

DRASTIC system is the most widely method used to evaluate intrinsic vulnerability for a wide range of potential contaminants. It is an overlay and index model designed to produce vulnerability scores by combining several thematic maps. It was originally developed in USA under cooperative agreement between the National Water Well Association (NWWA) and the US Environmental Protection Agency (EPA) for detail hydrogeological evaluation of pollution potential [4].

The word (DRASTIC) is acronym for most important factors within the hydrogeological settings which control groundwater pollution. Hydrogeological setting is a composite description of all major geologic and hydrogeological factors which affect the groundwater movement into, Through and out of the area. These factors are depth to water, net recharge, aquifer media, soil media, topography (slope), impact of vadose zone, and hydraulic conductivity. The DRASTIC numerical ranking system contains three major parts: weights, ranges, and ratings.

Weights Each DRASTIC factor is evaluated with respect to each other to determine the relative importance of each factor. Each factor is assigned a relative weight range of 1-5 (Table 1.1) [5].

Table (1.1): Weights of the factors in the DRASTIC model use in Iraq [5]

Factor	Standerd	Pesticides
D: Depth to water	5	5
R : Net Recharge	4	4
A : Aquifer media	3	3
S : Soil media	2	5
T : Topography	1	3
I : Impact of vadose Zone	5	4
C : Hydraulic conductivity	3	2

1.3 Problem Statement

Recently, groundwater pollution due to human activities has become an increasing threat. The impact on groundwater quality can occur as a result of agriculture, domestic and industrial activities contributing to subsurface or surface disposal of sewage wastes. A major problem in urbanized areas is the collection and disposal of domestic wastewater. Because a large volume of sewage is generated in a small area, the waste cannot be adequately disposed of by conventional septic tanks and cesspools. Therefore, special disposal sites may be required to collect and dispose such wastes in heavily populated areas. The quality of groundwater is of great importance to determine its suitability for a certain use (public water supply, irrigation, industrial applications, power generation, etc.).

Groundwater likelihood to be polluted is intrinsically difficult to detect. In order to estimate the aquifer intrinsic vulnerability, detailed information is needed about the geometry, stratigraphy and hydraulic properties of the aquifer and its confining layer. Interpolating boreholes logs, laboratory tests and geophysical logging are possible ways to characterize the aquifer intrinsic vulnerability but they are expensive, time consuming and have a limited lateral extension. Remote sensing is an efficient powerful tool, which can be used to assess the groundwater vulnerability using the DRASTIC model. Many studies on DRASTIC method using GIS have been done. The DRASTIC method was modified and calibrated [6] .

applied the DRASTIC for industrialized part of Poland. With take in consideration the character of the karst aquifer for the groundwater in vulnerability.so that, the six factor was consider to find the potential contamination for the ground water in this area, these factor is depth of ground water, the lithology of unsaturated zone, net recharge, hydraulic conductivity, groundwater flow, and thickness of the aquifer [7] .

1.4 Objectives

To develop a groundwater vulnerability map for the study area through the utilization of the well-known DRASTIC model in order to define different ranges of vulnerability and to recommend future land use restrictions for each range.

1.5 Overall Methodology

DRASTIC groundwater pollution assessment is a widely used method for creating vulnerability maps using the overlay index procedure . The assessment uses seven hydro-geological parameters to create a final index in the framework of GIS. The final pollution potential index (PPI) is computed by summing the products of the ratings and weights for each of the seven factors.

$PPI = D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_r I_w + C_rC_w$ (Eq.1)

The DRASTIC acronym stands for the seven hydro-geological parameters used to determine the vulnerability of groundwater to potential contamination:

D = Depth to groundwater (The more the depth to water the less the chance for the contaminant to reach it and the vice versa).

R = Net Recharge (It is the process through which the contaminant is transported to the aquifer; the more the recharge is the more vulnerable the aquifer).

A = Aquifer media (It reflects the attenuation characteristics of the aquifer material to the mobility of the contaminant through it).

S = Soil media (The Soil water holding capacity and its influence on the contaminant travel time).

T = Topography (High degrees of slope increases runoff and erosion of surface pollutant).

I = Impact of the vadose zone (It reflects the texture of the soil in the unsaturated zone above the water table).

C = Hydraulic conductivity of the aquifer (The amount of water percolating to reach the ground water through the aquifer is influenced by the hydraulic conductivity of the soil media).

The subscripts r and w denote the rating and the weight, respectively.

Weights defined by the DRASTIC system are used for each layer to account for different land uses and to give emphasis to some layers more than others.

Groundwater vulnerability mapping procedures in this study will be carried out to incorporate the use of a GIS. A GIS is a computerized mapping and spatial data analysis system, which enables the development and analysis of spatially referenced information to describe the relationship between landscape features.

Initially, all the seven DRASTIC maps were geo-referenced, digitized, and edited to generate polygon maps. These polygon maps were classified either into ranges or into significant media types, which have an impact on pollution potential.

The range for each factor has been assigned a subjective rating, which varies between 1 and 10. The set of variables that are considered for the DRASTIC model can be grouped according to three main categories: land surface factors, unsaturated zone factors and aquifer or saturated zone factors. The aquifer media properties and the hydraulic conductivity are the critical factors identified for the saturated zone. The depth to water and the properties of the vadose zone characterize the water/contaminant path down to the saturated zone [8].

In soil and the unsaturated zone, some mechanisms may affect the contaminant concentration much more than in the saturated zone .Generally the ratings are incorporated into the GIS attribute table of specific polygon maps. The polygon maps containing the rating values were then converted into specific raster maps. Weight multipliers were then used for each raster map to balance and enhance its importance. By combining all the raster maps using the above equation, a final vulnerability map was generated, and in figure (1.1) below explain the process[9].

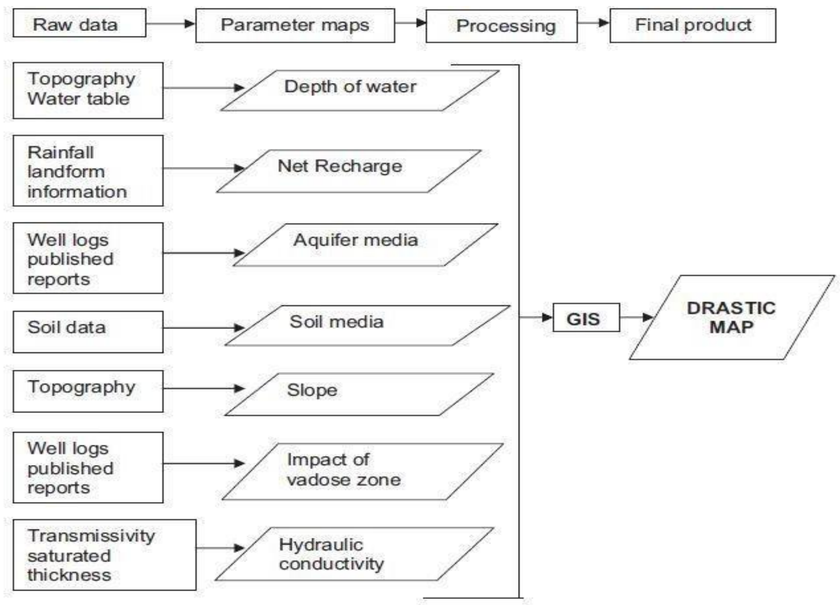


Figure (1.1): Methodology flowchart for groundwater vulnerability analysis using DRASTIC model in GIS.

1.6 Work plan

1.6.1 Data preparation

To carry out the aquifer vulnerability analysis using DRASTIC, seven thematic maps need to be prepared:-

- The Depth of water table: Depth to groundwater data were collected from borehole log information, direct measurement of water level of existing shallow tubes, and dug wells from ground surface.
- The Recharge Where Net recharge = (rainfall - evaporation) × recharge rate
- The Aquifer media : It refers to the consolidated and unconsolidated rock which serves as a water storage
- The Soil media : In general, soil pollution potential is largely affected by the type and amount of clay present, the shrink/swell potential, and the soil grain size.
- The Topography : It refers to slope of an area. Areas with low slope tend to retain water for long periods of time
- The Impact of vadose zone: This parameter represents the influence of the unsaturated zone above the water table.
- The Conductivity : Aquifer hydraulic conductivity is the ability of the aquifer formation to transmit water. It depends on the intrinsic permeability of the material and on the degree of saturation.

1.6.2 Vulnerability mapping

A new raster data file for the DRASTIC Index will be created according to Eq. 1 using the weighted sum overlay in spatial analyst tools using the 7 individual raster files which were indicated previously. An important step is to consider the parameters one by one in order to calculate their respective index values. For each parameter the rating values will be multiplied to the appropriate DRASTIC weight.

1.6.3 Sensitivity analysis

Sensitivity analysis will be applied to check the influence of rating values and weights assigned to each parameter and to assess the sensitivity of each parameter to reduce subjectivity .

Chapter Two

Lecturer Review

2.1 Case Study in Iran

2.2 Case Study in Qalqilia Governorate

2.3 Case Study in Mandala , India

2.4 Case Study in Lahor , Pakistani

2.5 Case Study in Ranchi , India

2.6 Case Study in Amasya, Turkey

2.7 Case Study in Gaza

2.1 Case Study in Iran

A sensitivity analysis of the parameters constituting the model was performed in order to evaluate the relative importance of the each DRASTIC model parameters. GIS greatly facilitated the implementation of the sensitivity analysis applied on the DRASTIC vulnerability index which otherwise could have been impractical. Appropriate methods for keeping groundwater resource sustainability in the study area have been suggested. The study area (60°25'05" to 61°225'24") E and 26°49'01" to 27°48'10") N is located in the eastern part of Jazmoorian basin. Situated in 365 km from Zahedan city, Iran, with an area of 1136km2

Result, Regarding to the drastic index, about 0.6% of the study area has no risk, 47% low vulnerability risk, 52.4% is moderately vulnerable class. The moderate vulnerability class is situated in the north, west and west south area that can be said these parts should be care and control to prevent contamination of ground water [10] .

2.2 Case Study in Qalqilia Governorate

The Palestinian city of Qalqilia, that is located in the northwest of the West Bank, has its roots and origins in the Canaaite era. The name "Qalqilia" goes back to the Roman times, where European Mediaeval sources refer to it as "Kalkelie", which is the name that is still in use (Wildlife-Palestine, 2006)

Qalqilia is situated about 12 km from the Mediterranean coast. The city's altitude ranges from 45 to 125 m above sea level, and it covers approximately 3.5 km2

The PI Method is a GIS-based approach to mapping intrinsic groundwater vulnerability with special consideration of karst aquifers. It is based on an origin-pathway-target model (Figures 5.2 and 5.3): The origin of the assumed hazard is the ground surface; the groundwater table in the uppermost aquifer is the target; the pathway includes the layers between the ground surface and the groundwater surface. Thus, the PI method can be used for resource vulnerability mapping .

extreme" vulnerability assess around sinking streams in Qalqilia governorate, "high" vulnerability is located in the middle and in the majority of eastern part of the governorate, "moderate" vulnerability is assigned in the areas of brown rendzians and pale renzians top soil, and the low vulnerability is assigned in the western part .

Extreme" vulnerability is assigned in Ramallah and Jerusalem since they have many springs which are located near the surface. These areas display highly developed karst features ."High" vulnerability is assigned given to rocks which make up the regionally important turonian/ upper cretaceous, and upper cretaceous (most of Jenin, west of Tulkarem and Qalqilia, Salfit, areas in Bethlehem and Hebron) while these rocks also display karstic features.Moderate" vulnerability is assigned to upper cretaceous (east of Tulkarem, parts in Bethlehem). These deposits are not typically used for drinking water purposes but are important sources of water for agriculture ."Low" vulnerability is assigned to parts in Hebron district [11].

2.3 Case Study in Mandala , India

The study area is situated in the India district, East Central part of Madhya Pradesh, India and covering about 325 km^2 with uneven topography, the area has a semi-arid climate with temperature of (41.3 C) and mean daily minimum of 24C. Average annual precipitation is 1182 mm

Result, GW samples were collected from different vulnerability zones of the study area for estimation of concentration of fluoride and nitrate. It has been found that 16 samples (57.14%) are contaminated by fluoride and the remaining 12 samples (42.86%) are within permissible limit (1.5 ppm). Location of high fluoride concentration is superimposed on vulnerability zones, which shows that 25% , 62% and 12.5% samples were situated in high, moderate and low vulnerable zones respectively.

Distribution of nitrate is below permissible limit in the study area, but value varies from place to place. In the high vulnerable zone, concentration of nitrate varies between 0.221 and 0.396 ppm; in the low vulnerable zone, it varies between 0.109 and 0.200 ppm and in the moderate vulnerable zone, it varies between 0.118 and 0.198 ppm. Twelve samples lie in high vulnerable zone and 11 in low vulnerable zone and 5 samples in moderate vulnerable zone [12] .

2.4 Case Study in Lahor , Pakistani

Lahore City is located between 310'-15' E and 310'- 42' N. Having an altitude ranging from 208m to 213m ASL, it is located on the alluvial plain of the left bank of Ravi River. Lahore is bordered northerly and westerly by the district of Sheikhupura, easterly by India (international border) and southerly by Kasur district with a population of over 6.5 million inhabitants in 2007, it is the Provincial Metropolis and the largest urban district of Punjab. It is also the second largest urban center of Pakistan and considered the 24th largest city in the world Lahore is characterized by large seasonal variations in temperature and rainfall. Mean annual temperature is approximately (240 C), ranging from (340 C) in June to (120 C) in January. Average annual rainfall is close to 575 mm, varying from 300 to 1200 mm (Pakistan Meteorological Department.

Result, Lahore is now one of Pakistan's most rapidly urbanizing cities, where like most cities in the developing world, urban management and development planning are far behind the pace of urbanization. Most times the impacts of urbanization are so visible on the surface that most studies simply ignore as impacts on underground resources, such as groundwater. Current research is conduced to assess aquifer vulnerability level at Lahore city by developing DRASTIC model in GIS environment. Seven hydro-geologic parameters were used to having the lowest vulnerability, and less permissible to contamination transportation, while cultivation and high water level area were L0hat north-east and east-south sides has moderated vulnerability potential and west-south part contains high vulnerability degree. Central regions were more susceptible to contamination due the variation in groundwater level. Accordingly, the importance of protecting high vulnerability area and contamination sources is crucial. Topography and aquifer media are the two hydro-geological parameters calculated using the DRASTIC which show high vulnerability degree with mean value more than 8. In terms of aquifer vulnerability, vadose zone and aquifer media represent it more precisely as these both criteria provide highest weight in vulnerability assessment compared to recharge rate, water depth, VZ impact and hydraulic conductivity, which represent low to moderate values for vulnerability[13].

2.5 Case Study in Ranchi , India

The area selected for the proposed study is Ranchi district, Ranchi district lies in the southern part of Jharkhand state and bounded by other district of Jharkhand, viz., Hazari-bagh, West Singhbhum, Gumla, Lohardaga, and East Sing-hbhum. This is also bounded by Purulia district of West Bengal. The district has a total area of 4,912 km^2 and is located between 22°450'-23°450' North latitude to 84°450'- 84°500' East longitude. The district comprises of 14 blocks .Result, A GIS-based DRASTIC model was used for computing the groundwater vulnerability to pollution index map of Ranchi district. The study area was divided into five zones (low, moderately low moderate, moderately high and high) on the basis of relative groundwater vulnerability to pollution index. Higher the value of the vulnerability index, higher is the risk of groundwater contamination. The results reveal that moderate vulnerable class covers the maximum percentage of the area (38.85 % of the total area). Moderately high vulnerability class and moderately[14] .

2.6 Case Study in Amasya, Turkey

The GMB covers a 1,060 km^2 area elevation ranging from 550 - 1,873 m. Average annual rainfall is 458 mm average annual temperature is (13.6 C) (URL-1) and the average annual potential evaporation is 680 mm . The most important body of surface water flowing through the basin is the ***Gümüşsuyu*** River, which discharges 8.5x106m3/ year. Groundwater in the basin draws from both alluvium aquifers, one being confined, (the ***Gümüşhacıköy*** aquifer) and the other unconfined (Merzifon). Agriculture is widespread in the basin, and fertilizer and pesticide application have caused groundwater contamination through leaching.

This study involved using a GIS model and the DRASTIC method for determining the vulnerability of the groundwater in the basin. The aquifer vulnerability map was prepared using depth to water, net recharge, aquifer media, soil media, topography, vadose zone impact, and hydraulic conductivity. The study area was divided into three zones according to groundwater vulnerability assessment results: low (risk index <100); middle (risk index 100–140) and high groundwater vulnerability risk (risk index >14).

Result, the DRASTIC method results should be useful in designing aquifer protection and management strategies. The DRASTIC index map indicated that overall potential for groundwater becoming polluted was low for the GMB. Low sensitivity areas lay outside the agricultural areas in the basin. The alluvium and most Pliocene sediments were used for agriculture in the GMB. The town of ***Gümüşhacıköy*** is located on an aquifer recharge area. Areas determined by the DRASTIC method should thus be given priority in research in terms of contamination. High nitrate concentrations were mainly near urban areas according to the study area's analysis High nitrate concentration was likely to be related to wastewater leakage from industrial activities, urbanization and agricultural practices [15].

2.7 Case Study in Gaza

Khanyounis Governorate is a part of the Gaza Strip, located in the south of the Gaza Stripound by Deir al Balah to the north it covers an area of about 111 km2 (about 31% of the Gaza Strip total area). According to the Palestinian Central Bureau of Statistics (PCBS, 2007), the population of Khanyounis in 2007 was 270,979 inhabitants (about 19.1% of the Gaza Strip total population).

The built-up area occupies an area of about 17.57 km2, while the agricultural lands cover an area of about 63 km2. The area is generally flat with topographic elevation ranging from mean sea level (MSL) in the west to about 100 m above MSL in the east). There is a five month period in winter (November-March) with a rainfall surplus. The rest of the year, evaporation greatly exceeds the rainfall. The annual average rainfall in the Governorate is about 300 mm. On an average there are less than 30 rainy days in the year.

In this paper, an attempt has been made to assess groundwater vulnerability to contamination in Khanyounis Governorate. This task was accomplished using DRASTIC model. Based on the vulnerability analysis and according to DRASTIC index values, it was found that about 26% and 3% of the study area is under high and very high vulnerability of groundwater contamination, respectively, while more than 43% and 27% of the study area can be classified as an area of moderate and low, respectively, vulnerability of groundwater contamination .

It is noticed that the western part of the study area was dominated by high and very high vulnerability classes, while the east of the previous part and in the south-eastern part, vulnerability to contamination is moderate. In the central and the eastern part, vulnerability to contamination is low. In these regions, pesticides which might have heavy metals or nitrate-rich groundwater should not be used in the agricultural fields and orchards, since the contaminants may easily leach into the aquifer through the vadose zone [16].

Chapter Three

Material and Methods

3.1 General

3.2 Project area

3.3 Topography

3.4 Meteorological Data

3.5 Population

3.6 Water Supply

3.1 General

In this chapter, basic data of Bani Naim town will be discussed, location of the project, Topography, meteorological data, Population data, water consumption, and supported by maps and figure, these maps illustrate the study area and it shown in figure (3.1).

3.2 Project Area

Bani Naim is a town in Hebron Governorate located seven km east of Hebron City in the southern part of the West Bank. It is bordered by Ar Rawa'in areas (مسافر بني نعيم) to the east, Sa'ir and Ash Shuyukh towns to the north, Hebron City to the west, and Yatta town to the south Bani Naim extends over a mountainous area east of Hebron shown in figure (3.2). Mountains at an elevation of 958 m above sea level. The mean annual rainfall in Bani Naim town is 369 mm, the average annual temperature is (16 C), and the average annual humidity is 61 % (ARC GIS).

3.3 Topography

The contour is a map showing the heights of the region. Where the heights in the town of Bani Naim range from about 121 m to 1000 m. The ground well is located at an altitude of 400 m to 500 m. As shown in figure (3.3), the contour period is also 20m. The geography of the town of Bani Naim can also be illustrated below in figure (3.4).

3.4 Meteorological Data

The hydrology of region depends basically on its climate, and secondary on its topography. Climate is largely dependent on geographical position of the earth surface, humidity, temperature, and wind .These factors are affecting on evaporation and transpiration. So this study will include needed data about these factors, since they play big role in the determination of water demand.

The climate of Bani Naim town tends to be cold in winter with limited amount of rain and warm in summer and relatively humid. Climate can be divided in general for two seasons:

A) Rainfall season usually start in October and reach its peak in February then decrease gradually in May month .This climate consist of three seasons winter season, and part of spring, autumn season.

B) Dry season consist of summer and part of spring, and autumn seasons. It start from May till September and sometimes continue to October month.

The climatological data presented in the following section were obtained from survey carried out by the meteorological station of Hebron city.

3.4.1 Rainfall

The relative humidity varies Almost 64% this information from Bani Naim municipality. The driest month is June, with 0 mm of rainfall. The greatest the average annual rainfall in Bani Naim town is about 450 mm per year and amount of precipitation occurs in January, with an average of 204 mm. And in table (3.1) and figure (3.5) showing rainfall from 2004 to 2015 and total of rain fall during each year

Table (3.1): Showing yearly rainfall from 2004 to 2015

YEARS	JAN	FEB	MARS	MAY	OCT	NOV	DEC	Y.TOTAL
2004-2005	98	86	44	9	4	163	49	453
2006-2007	127	94	80	13.5	13	2	87	430.5
2009-2010	111	130.5	8	0	10	49.5	54	366
2011-2012	70	78.6	15	2	2	0	60	266.6
2012-2013	133.5	179	115	0	0	28	37	492.5
2013-2014	235	73	6	5	0	28.5	49	403.5
2014-2015	2	9	114	35	0	0	311.5	475.5

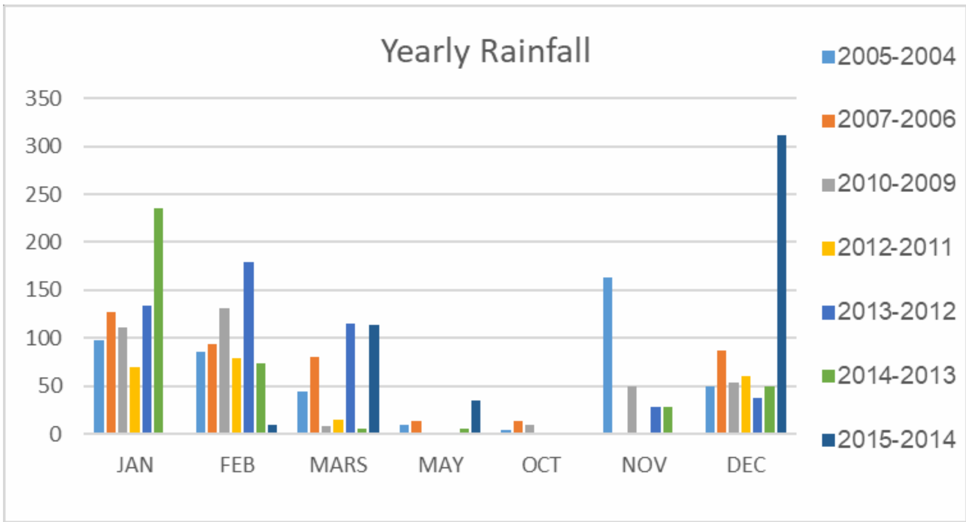


Figure (3.5): Yearly rainfall amounts for the rainy from 2004 to 2015 by column representation.

This map shows the distribution of rainfall by the study area, which is a region, Bani Naim and notes through this figure (3.6) that there is a difference in the rate of rainfall from the area to another area and the result of differences in the heights of this region and these maps show us the rate of rainfall in the study area.

3.4.2 Temperature

The temperature is characterized by considerable variation between summer and winter times. The mean temperature values a Bani Naim, The following minimum and maximum values were shown in Table (3.2) and Figure (3.7) \ (3.8) :

- The mean maximum temperature : (28) ˚C
- The mean minimum temperature : (13) ˚C

Table (3.2): Meteorological Condition at Bani Naim Town Weather Station for (2011-2016). The climatological data presented in the following section were obtained from survey carried out by the meteorological station of Hebron city.

Month	Rainfall (mm)	Maximum Temperature (˚C)	Minimum Temperature (˚C)
January	110.5	12.2	5.3
February	97.8	14.7	7.1
March	48.2	17.5	8.4
April	50.4	28	12.8
May	10.3	24.8	14.5
June	0	27.2	17.2
July	0	28.8	18.7
August	0	29.9	19
September	3.6	27.3	16.4
October	28.6	24.4	14.7
November	48.3	19.1	10.9
December	155.7	13.8	6.5

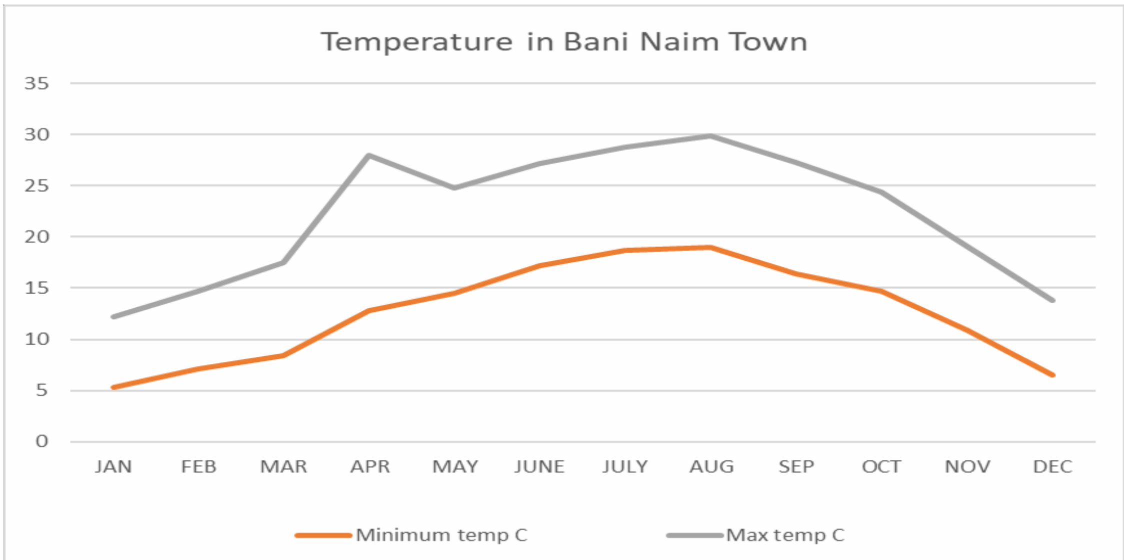


Figure (3.7): Temperature in Bani Naim Town by Linear representation.

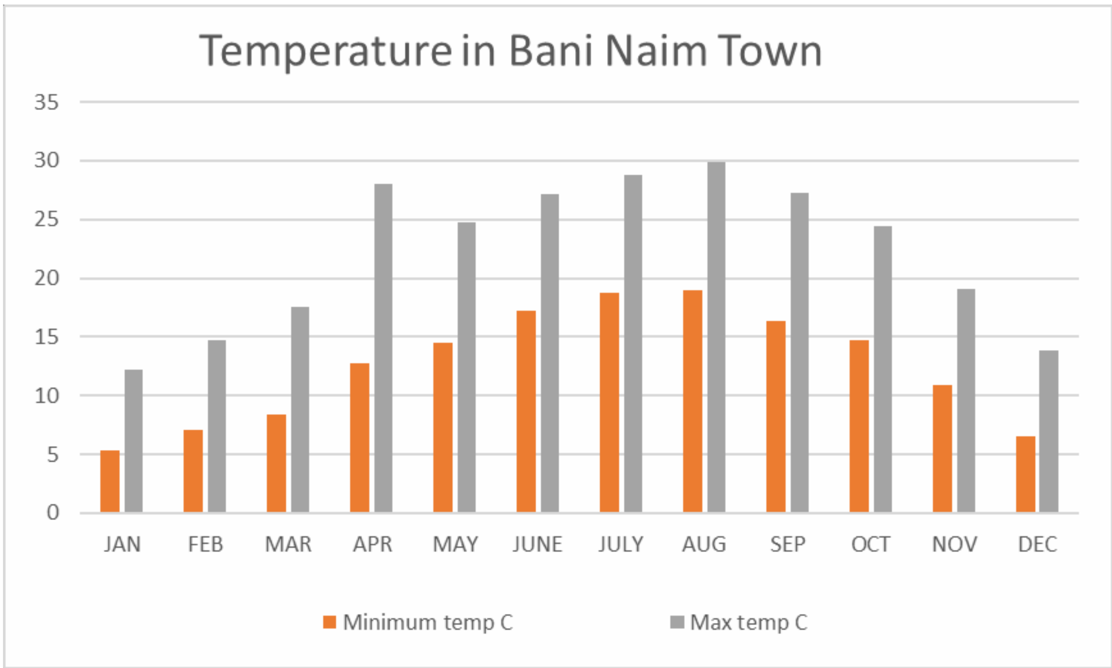


Figure (3.8): Temperature in Bani Naim Town by column representation.

3.5 Population projection

The base for the forecast is the 2017 population for Bani Naim town obtained from Municipality of Bani Naim of 29300 parsons. The annual growth rates is 2.7% which is high when compared to the rate of population growth in the West Bank (See in Table (3.3)).

To calculate the population for the coming 25 year, a geometric increase is assumed, represented by the following equation. $\mathbf{Pf = P0 * (1+ r)^{n}}$.

Where :

P : Future population.

$\mathbf{P_o}$: Current population.

n : Time perio (25 years).

r : Population growth (rate).

based on the previous data for Bani Naim town population forecast in the year 2042. Is shown in table (3.3). The data show that the population of Bani Naim town is estimated to be 57033 in year 2042.

Table(3.3): Presents the population projection up to the year 2042 to Bani Naim.

Year	**2017**	**2022**	**2027**	**2032**	**2037**	**2042**
Population(capita)	**29300**	**33475**	**38245**	**43694**	**49920**	**57033**

3.6 Water Supply

The main source of water in the town is the Israeli Water Company (MEKOROT), though alternative sources of water in the town exist, including cisterns, water tanks and springs.

The collection wells, tanks and four groundwater wells are the alternative sources of water network, and the village has a water tank with a capacity of 500 cubic meters and the water service in the town of Bani Naim of the most important problems :-

1. Lack of water and especially during the summer months.

2. Lack of access to high water due to poor pumping.

3. The water tank is unable to fill the city's need of water.

Chapter Four

Meddling Concentration And Aspect

4.1 Depth to groundwater levels (D)

4.2 Net recharge (R)

4.3 Topography (slope) (T)

4.4 Soil media (S)

4.5 Hydraulic conductivity (C)

4.6 Aquifer media (A)

4.7 Impact of vadose zone (I)

4.1 Depth to ground water levels (D)

Depth to water is one of the most important factors because it determines the thickness of material through which infiltrating water must travel before reaching the aquifer-saturated zone. Depth to water consequently impacts on the degree of interaction between the percolating contaminant and sub-surface materials (air, minerals, water) and therefore, on the degree, extent, physical and chemical attenuation, and degradation processes. In general, the aquifer potential protection increases with depth to water. The bore well data was collected from the Jal Nigam Department,. These point data were contoured by interpolating and divided into five categories i.e. 158-274 m , 274-342 m , 342-428 m , 428-518 m and 518-636 m as show in figure (4.1), Thereafter it was converted into grid to make it raster data for GIS operation. The depth-to-water table interval range, DRASTIC rating, weight, and resulting index are shown in Areas with high water tables are vulnerable because pollutants have short distances to travel before contacting the GW. So, the deeper the GW smaller the rating value .

4.2 Net recharge (R)

Net Recharge (R): Groundwater recharge or deep drainage or deep percolation is a hydrologic process where water moves downward from surface water to groundwater. Net recharge represents the annual average amount of water that infiltrates the vadose zone as shows in figure (4.2). Net recharge is an agent, which can easily transport contaminant to groundwater. Then the greater the recharge, the more vulnerable is the aquifer to contamination because its controls the volume of water available for dispersion and dilution of the contaminants in the vadose zone The main source of groundwater recharge is precipitation which percolates from the ground surface and infiltrates through the soil and the unsaturated zone to reach the aquifer. Sources of recharge may include precipitation, irrigation, and wastewater.

4.3 Topography (slope) (T)

Topography refers to the slope and slope variability of the land surface. Topography controls the likelihood of a pollutant disposed as runoff or retaining it in the area remains long enough to infiltrate show in figure (4.3). Topography is also significant from the standpoint that the gradient and direction of flow often can be inferred for water table condition from the general slope of the land. Typically, steeper slopes signify higher ground water velocity.

4.4 Soil media (S)

Soil media: Soil is commonly considered the upper weathered zone of the earth and in figure (4.4) can display the distribution of soil in study area, which averages 1.8 m or less. It has a significant impact on the amount of recharge water which can infiltrate into the ground and hence, influence the ability of a contaminant to move vertically into the vadose zone . There are seven types of soil present in the study area such as Brown desert skeletal soils, Coarse desert aalluvuum, Colluvial - Alluvial soils, desert stony land, Mediterranean brown forest soils, Rendzina soils of mountains, Terra rossa soils.

And in figure (4.5) was shown the percentage of each type soil we can understand the most if soil in study area is (Brown desert skeletal soils) it content about 54 % of study area, (Coarse desert Alluvial) it content about 9 % of study area, (Colluvial - Alluvial soils) it content about 1 % of study area (Desert stony land) 2 % of area study , (Mediterranean brown forest soils) it content about 12 % of study area, (Rendzina soils of mountains) it content about 6 % of study area and (rossa soils) it content about 16 % of study area.

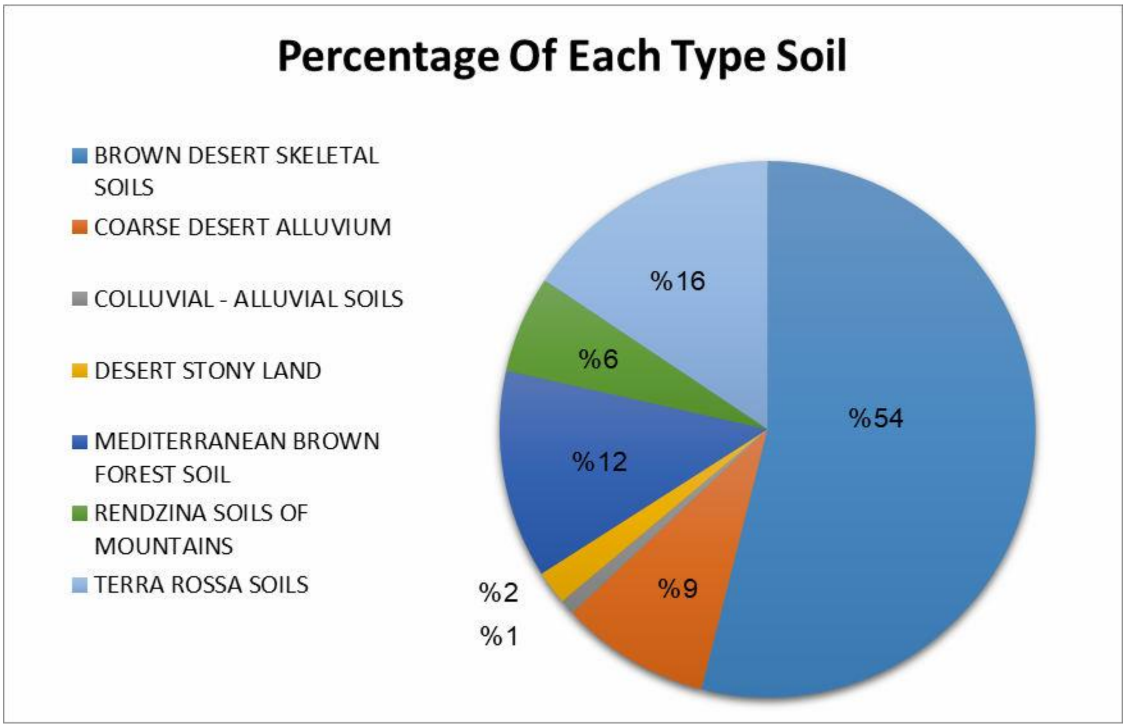


Figure (4.5): Percentage of each type soil

4.4.1 Brown desert skeletal soils

Brown earth is a type of soil , are mostly located between 35° and 55° north of the Equator. The largest expanses cover western and central Europe, the east coast of America and eastern Asia.

This soil has the ability to retain moisture. Its develop in area of deciduous woodland. The color of the soil is an indication of the amount of organic material it contains with darker soils having more organic content. Humus is plentiful in brown earths They are common in lowland areas (below 300 meter) on permeable parent material.

Rainfall totals are moderate, usually below 76 cm per year, They are well-drained fertile soils with a pH of between 5.0 and 6.5 ,which is generally permeable and non- or slightly acidic, for example clay loam and defined as being very dry [17] .

4.4.2 Coarse desert Alluvial

Alluvium (from the Latin alluvius, from alluere, "to wash against") its loose, unconsolidated (not cemented together into a solid rock) Alluvium is typically made up of a variety of materials, including fine particles of silt and clay and larger particles of sand and gravel Alluvial materials often have very thick layers (strata) of different size material this occurs over time.

The soil is porous because of its loamy (equal proportion of sand and clay) nature. Porosity and texture provide good drainage. The soils are constantly replenished by the recurrent floods. The proportion of nitrogen is generally low, proportion of Potash, phosphoric acid and alkalis are adequate and. The proportion of Iron oxide and lime vary within a wide range.

Texture and color: prairie soils The top soil is a black loam to clay loam with moderate crumb structure and pH 7.0 to 30 cm depth. The subsoil is a blocky light clay, moderately structured with pH 7.5 [18] .

4.4.3 Colluvial - Alluvial soils

Colluvium is a type of parent material that moved down slope due to gravitational forces (in some cases water may play a role in initiation of the movement). Colluvium is heterogeneous, unsorted material of all particle sizes (from boulders to clay) with relatively little abrasion to round the particles. Consequently, colluvium consists of very sharp, angular rock fragments accumulated at the base of steep slopes.

This term is also used to specifically refer to sediment deposited at the base of a hill slope by unconcentrated surface runoff or sheet erosion [19]

4.4.4 Desert stony land

Desert pavement, also called reg (in the western Sahara), serir (eastern Sahara), gibber (in Australia), or saï (central Asia) is a desert surface covered with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size. Desert varnish collects on the exposed surface rocks over time.

Several theories have been proposed for the formation of desert pavements. A common theory suggests they form through the gradual removal of sand, dust and other fine-grained material by the wind and intermittent rain, leaving the larger fragments behind. The larger fragments are shaken into place through the forces of rain, running water, wind, gravity, creep, thermal expansion and contraction, wetting and drying, frost heaving, animal traffic, and the Earth's constant microseismic vibrations [20].

4.4.5 Mediterranean brown forest soils

Mediterranean soils are soils which form under a Mediterranean climate. They are variously called Terra Rossa (on hard limestone) and Red Mediterranean Soils. Not all soils in a Mediterranean environment are, however, qualified as such because normal pedogenetic development may be hampered by erosion (rejuvenation of the profile), lack of time, lack of water or unfavorable parent material characteristics The role of climate, topography, parent material (mineralogical composition, coherence and permeability), time and human influence as soil forming factors is discussed. Pedogenesis is reviewed and three phases in a color sequence are recognized, with a major focus on soils developed over carbonaceous substrata. It is shown that the red phase corresponds to a climax development, but that as soon as environmental conditions are not optimal, this phase is not reached. The position of Mediterranean soils in the three major world classification systems is commented [21] .

4.4.6 Rendzina soils of mountains

Rendzina (or rendsina) is a soil type recognized in various soil classification systems, as well as some obsolete systems. They are humus-rich shallow soils that are usually formed from carbonate- or occasionally sulfate-rich parent material .Rendzina soils are often found in karst and mountainous regions.

Soils of this type contain a significant amount of gravel and stones, which, during ploughing, produce various sound effects (clicking, screeching, etc.), i.e. In the World Reference Base for Soil Resources, rendzina soils would be classified as lepto sols, chernozems, kastanozems, or phaeozems, depending on their specific characteristics.

Rejuvenated and remain skeletal. Rendzina soils typically develop from solid or unconsolidated rocky material that is carbonate- or sulphate-rich,Limestone is by far the most common, but others include dolomite, gypsum, marble, chalk and marlstone. Alongside physical weathering, which breaks down the structure of rocky material, chemical weathering, in particular the dissolution of carbonate, contributes to rendzina development.

Loss of soluble minerals leaves the upper part of the soil enriched in insoluble materials, particularly clay minerals [22] .

4.4.7 Terra rossa soils

Terra rossa is a type of red clay soil produced by the weathering of limestone. Under oxidizing conditions, when the soils are above the water table, iron oxide (rust) forms in the clay. This gives it a characteristic red to orange color.

Terra rossa is typically found in regions with a Mediterranean climate but can also be seen elsewhere, for example in Prince Edward Island, Canada.

There are several theories about the formation of terra . rossa The first one, traditionally accepted, states that it derives from the insoluble residue of the underlying limestone.

Under oxidizing conditions iron oxides appear, which produces the characteristic red color. Formed during the Tertiary and subjected to hot and humid periods during the Quaternary. A more recent theory is based on the geochemical composition of the soil, and suggests that these soils would have formed about 12.000 [23].

4.5 Hydraulic conductivity (C)

Aquifer hydraulic conductivity is the ability of the aquifer formation to transmit water. It depends on the intrinsic permeability of the material and on the degree of saturation. This critical factor controls the contaminant migration and dispersion from the injection point within the saturated zone and, consequently the plume concentration in the aquifer. And a hydraulic conductivity mainly depends on the aquifer, show in figure (4.6).

4.6 Aquifer media (A)

The aquifer is defined as a rock formation, which will yield sufficient quantities of water for use. The shallow aquifers occur within a depth from the earth's surface. And special map of aquifer media will be prepared in the next step of this project to explain the characteristics of these factor. In general, larger the grain-size and the more fractures or openings within the aquifers, the higher the permeability and lower the attenuation capacity; consequently the greater the pollution potential, so the coarse (saturated or unsaturated) media was assigned a high rating value compared to the fine media. Show in figure (4.7).

4.7 Impact of vadose zone (I)

The vadose zone's influence on aquifer pollution potential is essentially similar to that of soil cover, depending on its permeability, and on the attenuation characteristics of the media. The impact of vadose zone is a complex phenomenon, combining aquifer media and topographic characteristics. Movement of water within the vadose zone is studied in hydrogeology, and is of importance to contaminant transport. Impact of vadose zone was prepared from the lithological cross-sections obtained from the geophysical data and this factor will also create a map for him and work on it in the next step of the project (4.8).

CHAPTER FIVE

Vulnerability Assessment

5.1 Vulnerability assessment using the drastic method

5.2 Methodology and Data

5.1 Vulnerability assessment using the drastic method

The Concept of Groundwater Vulnerability The concept of groundwater vulnerability is based on the assumption that the physical environment may protect, to some degree, the groundwater against natural impacts, especially with regard to contaminants entering the subsurface environment. Consequently, some land areas are more vulnerable to groundwater contamination than others. The term “vulnerability to contamination” has the opposite meaning to the term “natural protection against contamination” where the two can be used alternatively. Thus, the term “vulnerability” means the sensitivity of a groundwater system to contamination. However, the term „vulnerability‟ is not restricted to groundwater but is used in a wide sense to describe the sensitivity of whatever to any kind of stress, e.g. the vulnerability of global climate to human impacts. As this chapter deals with the vulnerability of groundwater to contamination, the term is used in that sense.

The vulnerability is a relative, non-measurable and dimensionless property. Two different types of vulnerability were distinguished: intrinsic vulnerability and specific vulnerability. The intrinsic vulnerability of groundwater to contaminants takes into account the geological, hydrological and hydro geologic characteristics of an area, but it is independent of the nature of the contaminants and the contamination scenario. The specific vulnerability takes into account the properties of a particular contaminant or group of contaminants in addition to the intrinsic vulnerability of the area. The advantage of such qualitative and descriptive definitions is that the term „vulnerability‟ is often intuitively understood, particularly by decision-makers in the planning process. Vulnerability is typically displayed as maps. Vulnerability maps are means of presenting various complex hydro geologic properties in an integrated and comprehensible way.

From the parameters of drastic, a DRASTIC Index or vulnerability rating can be obtained. The higher the value of the DRASTIC Index is, the greater the vulnerability of that location of an aquifer.

The following definitions are useful:

Rating: Each range for each DRASTIC factor has been evaluated with respect to the others to determine the relative significance of each range with respect to pollution potential. The rating is from 1 to 10.

Range: Each DRASTIC factor has been divided into either ranges or significant media types which have an impact on pollution potential.

Weight: The weighting represents an attempt to define relative importance of each factor in its ability to affect pollution transport to and within the aquifer. The weight is from 1 to 5.

Table 5.1 provides the weight for each parameter. Tables 5.2 through 5.8 provide the ranges and ratings for each parameter. The rating is multiplied by the weight to get a score for the parameter.

These scores are then summarized to arrive a pollution index, called the DRASTIC index [24].

$$DI = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw$$

Where,

DI = DRASTIC Index

Dr and Dw = Rating and weight assigned to the depth to water table

Rr and Rw = Rating and weight for range of aquifer re-charge

Ar and Aw = Rating and weight assigned to Aquifer media

Sr and Sw = Rating and weight for Soil media

Tr and Tw = Rating and weight assigned to Topography

Ir and Iw = Rating and weight assigned to Vadose Zone

Cr and Cw = Rating and weight given to Hydraulic conductivity

The higher the DRASTIC index is, the greater the relative pollution potential. The DRASTIC index can be further divided into four categories :

1. High: DRASTIC index (DI) is greater than 105 and less than 130.

2. Moderate: DRASTIC index (DI) is greater than 85 and less than 104

3. Low: DRASTIC index (DI) is equal to or less than 70.

The sites with extreme, high, and moderate index values are more vulnerable to contamination and consequently need to be managed more carefully. The weights assigned are related. Therefore a site with low pollution potential may still be vulnerable to groundwater contamination while it is less when compared to the sites with high DRASTIC ratings [25].

Table (5.1): Assigned Weights for DRASTIC Parameters [25].

Feature	DRASTIC Weights
Depth to Water	5
Net Recharge	4
Aquifer Media	3
Soil Media	2
Topography	1
Impact of Vadose Zone	5
Hydraulic Conductivity	3

Table (5.2): Ranges and Rating for the Depth to Water [11].

Depth to Water (meter)	
Range	Rating
< 50	10
50 - 150	3
> 150	1

Table (5.3): Ranges and Rating for the Net Recharge [11].

Net Recharge		
Range (inch/year)	Range (mm/year)	Rating
0 - 2	0-50	1
2 - 4	50-100	3
4 - 7	100-175	6
7 - 10	175-250	8
> 10	>250	9

Table (5.4): Ranges and Rating for the Aquifer Media [11].

Aquifer Media	
Range	Rating
Cenomanian	8
Senonin	6
Turonian	10

Table (5.5): Ranges and Rating for the Soil Media [11].

Soil Media	
Range	Rating
Mediterranean brown forest soils (Clay)	1
Colluvial - Alluvial soils (Clay loam)	3
Rendzina soils of mountains (Silty loam)	4
Brown desert skeletal soils (Sandy loam)	5
Desert stony land (Sand)	9
Coarse desert Alluvial (Gravel)	10
Terra rossa soils (Thin or absence)	10

Table (5.6): Ranges and Rating for the Topography [11].

Topography	
Range (% slope)	Rating
0-2	10
2-6	9
6-12	5
12-18	3
>18	1

Table (5.7): Ranges and Rating for the Impacts of Vadose Zone [11].

Impact of Vadose Zone		
Range	Rating	Typical Rating
Clay	2-8	4
Silt/Clay	1-2	2
Sand And Gravel	2-9	10
Sandstone	4-8	6

Table (5.8): Ranges and Rating for the Hydraulic Conductivity [11].

Hydraulic Conductivity (M / day)	
Range	Rating
1-100	1
100-300	2

5.2 Methodology and Data

Groundwater vulnerability maps are designed to show areas of greatest potential for groundwater contamination on the basis of hydro geologic and anthropogenic (human) factors. The maps are developed by using computer mapping hardware and software called a Geographic Information System (GIS) to combine data layers such as soils and depth of water table. Usually, groundwater vulnerability is determined by assigning point ratings to the individual data layers and then adding the point ratings together when those layers are combined into a vulnerability map. The seven maps needed for the DRASTIC model were prepared and built using available hydro-geological data with the help of ArcGIS10.2 .

CHAPTER SIX

Result and Recommendation

6.1 Analysis of the results

In the study, an attempt has been made to assess aquifer vulnerability in Bani Naim, The task was accomplished by using the DRASTIC model. Based on the result, the vulnerable zones were classified into four zone under low, low , moderate and high vulnerable zones as figure (6.1)

The study has shown that (13%) of the total area was under the low vulnerable zone, mainly due to the presence of the higher depth of water level and high elevation (Topography). And About (66 %) of the area was low vulnerable zone .

About (%19) of the area was moderate vulnerable zone which could be due to the reason that less depth of water level and high elevation. And about (2%) of the area was high.

Final computed values for DRASTIC Index provide numerical range for vulnerability criteria and aquifer vulnerability analysis. For Bani Naim , the DRASTIC index value degree varied from 32 to 118 divided into four categories; (1)under low vulnerability (32- 42), (2) low vulnerability (42- 73), (3) under high vulnerability (73- 101), and (4) high vulnerability (101- 118). These are further shown in table (6.1) .

Table (6.1): Classification of vulnerability.

SL.No	DRASTIC Index Value	Vulneravility zone	Area in Age %
1	32 – 42	Under The Low	13%
2	42 – 73	Low	60%
3	73 – 101	Moderate	19%
4	101 – 118	High	2%

6.1 Analysis of the results:

After analyzing the results of the project, we analyzed the effect of each of the seven coefficients, so that each time one of the parameter was deleted to see how it affected the vulnerability map .

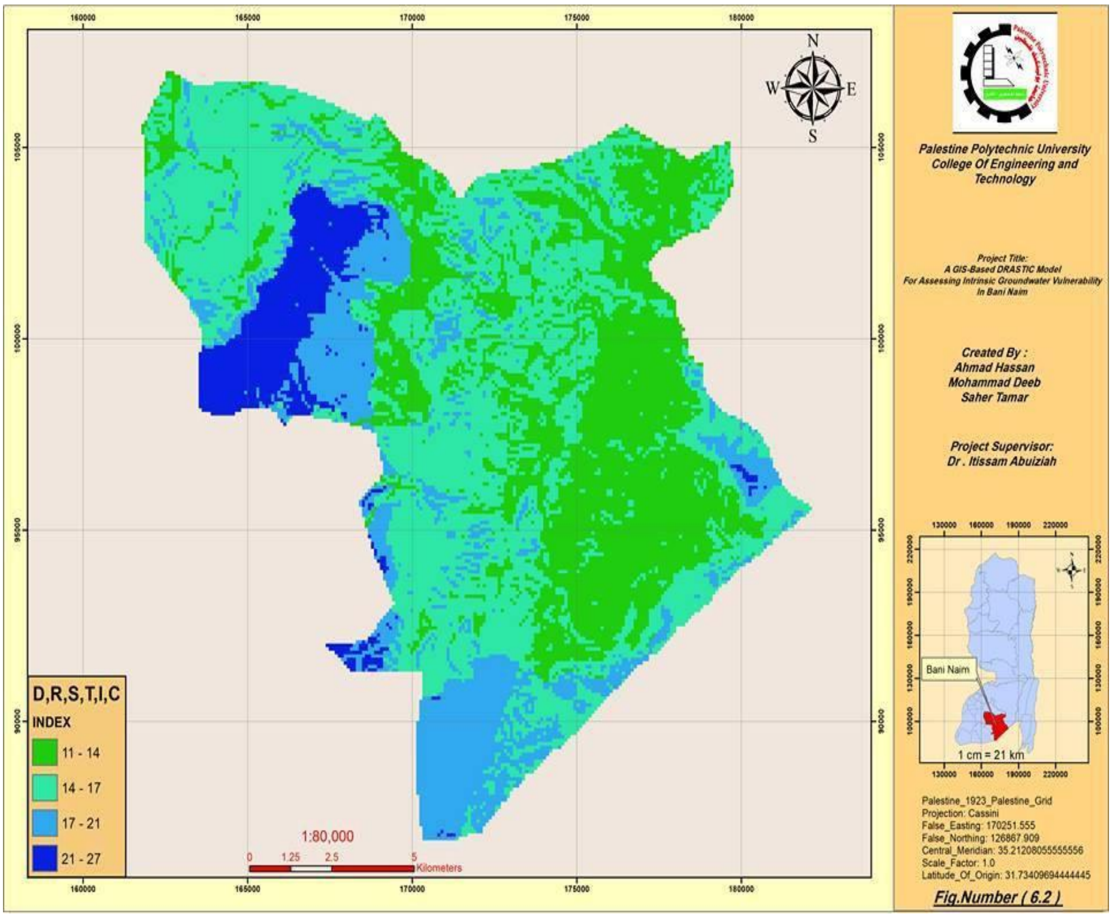
Table (6.2): Statistics of map removal sensitivity analysis.

Parameters used	Variation index (%)			
	Min	Max	Main	SD
D, R, S, T, I, C	11	27	19	4.8
D, R, S, T, C	8	23	27	4.8
D, R, T, C	5	17	11	3.74
D, R, T	3	15	9	3.74
D, R	2	10	6	2.85
R	12	32	22.4	8.9

The results of the map removal sensitivity analysis computed by removing one or more data parameters at a time are presented in Table (6.2) . The statistical analysis of the variation index (the sensitivity measure) was applied for all the cells within the model domain . Table (6.2) summarizes the variation of the vulnerability index as a result of removing only one parameter at a time.

Recharge and vadose zone media. In addition, depth to water table seems to pose a high influence on the vulnerability index. One apparent possible reason for this high sensitivity in these three parameters can be attributed to the high theoretical weight assigned to these parameters as well as the ratings.

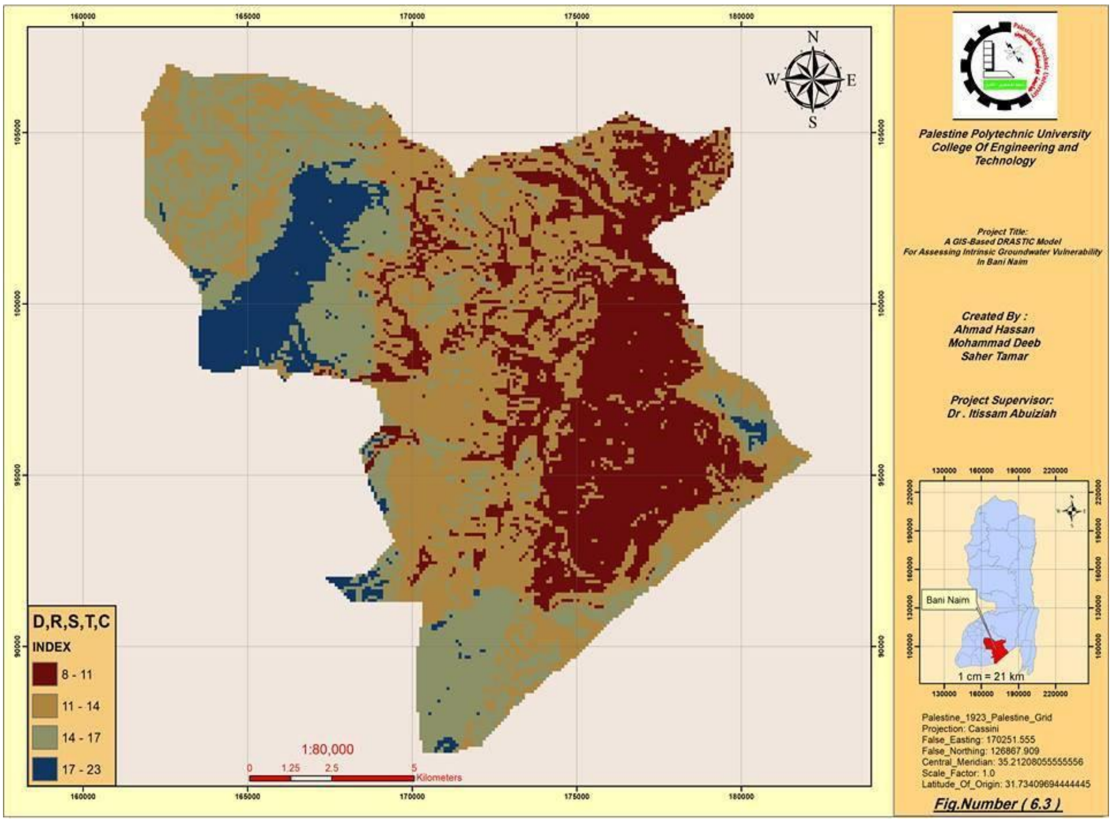
When we delete the parameter (A) ,and remain (D, R, S, T, I, C) its effect is as show in the figure(6.2).



Figure(6.2): Map when we delete the parameter (A).

Note that when removing the Aquifer media that the percentage of pollution is high and therefore Aquifer media does not affect significantly the sensitivity of water to pollution, depending on the pollution values .And give us the max index value 27 and min value is 11 .

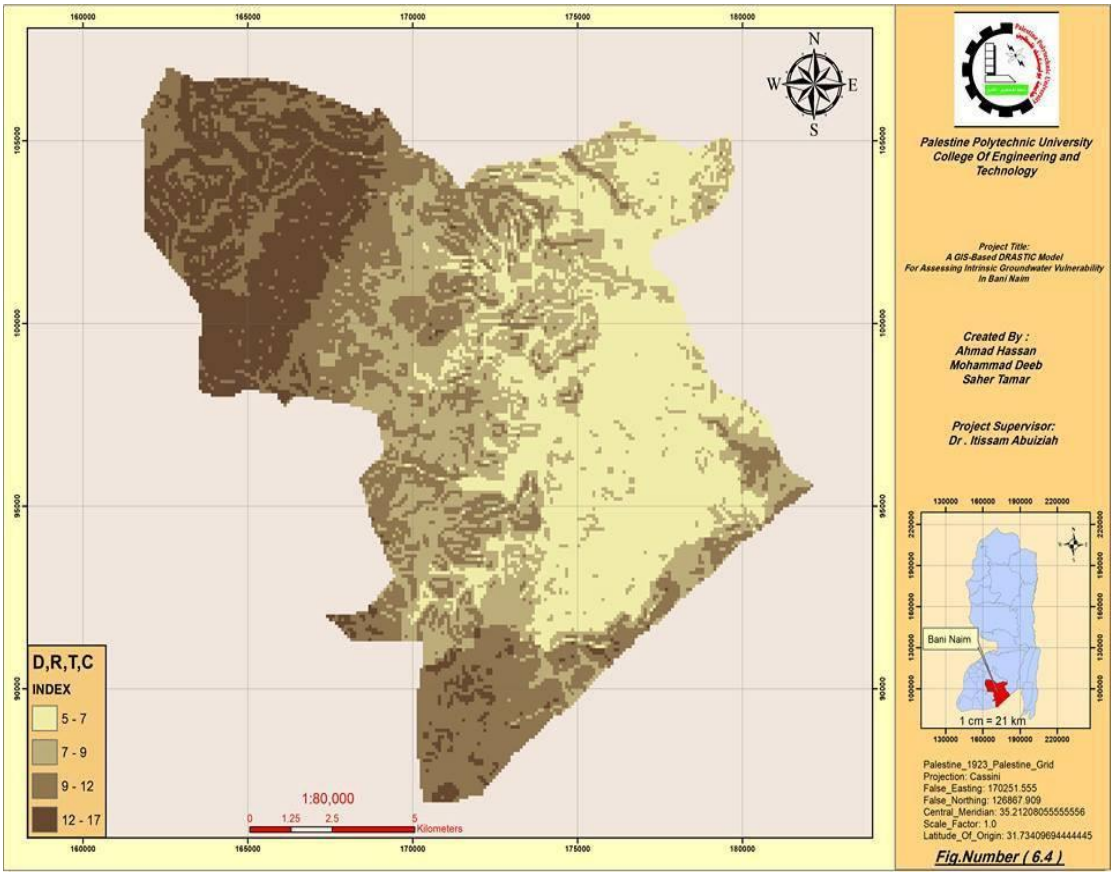
When we delete the parameters (A , I) ,and remain (D, R, S, T, C) its effect is as show in the figure(6.3).



Figure(6.3): Map when we delete the parameters (A , I).

The Aquifer media and Impact of vadose zone media decrease the sensitivity of water to pollution It was also high, and consequently the effect of Aquifer media and Impact of vadose zone media of decreased the groundwater pollution . And give us the max index value 23 and min index value is 8 .

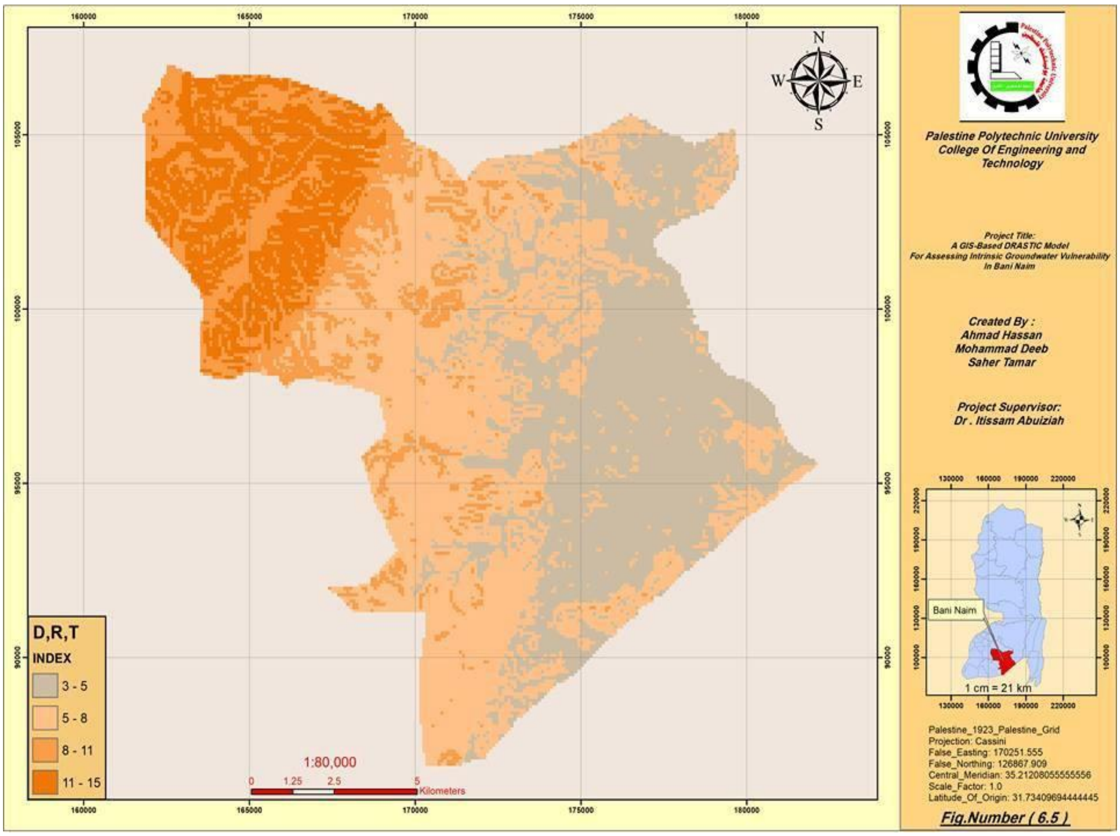
When we delete the parameters (A , I , S) ,and remain (D, R , T, C) its effect is as show in the figure(6.4).



Figure(6.4): Map when we delete the parameters (A , I , S)

When removing the Aquifer media , Impact of vadose zone media and Soil media the average of these factors on the pollution of groundwater and the sensitivity of water pollution is moderate by these factors. And give us the max index value 17 and min index value is 5 .

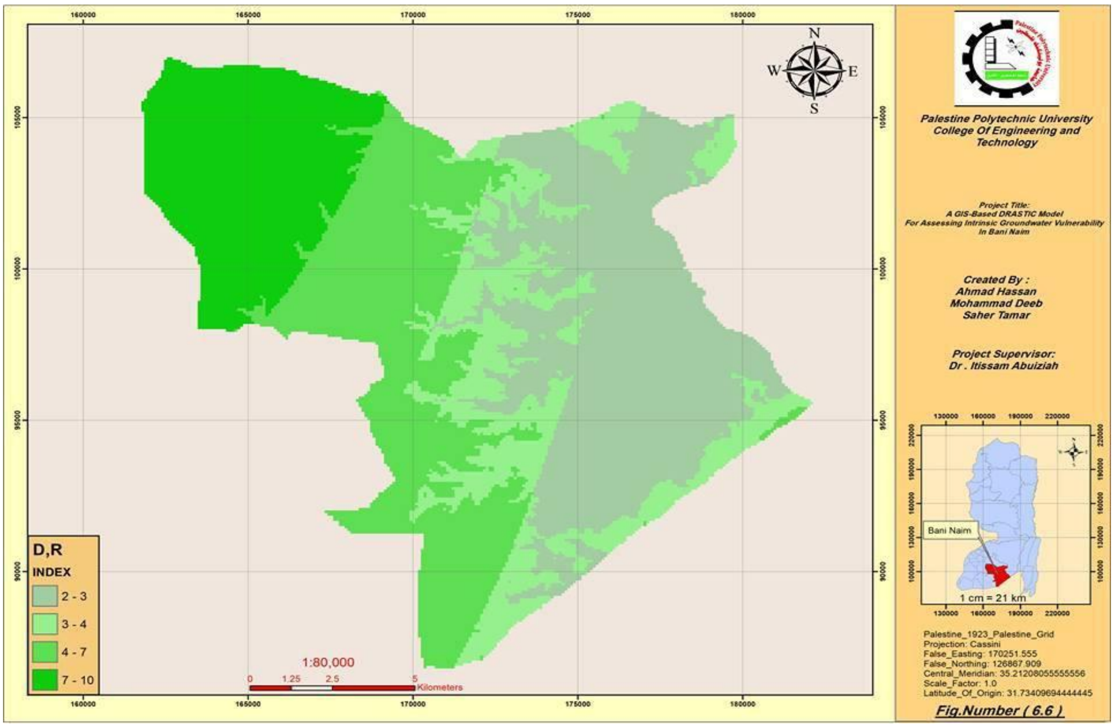
When we delete the parameters (A , I , S , C) and remain (D, R , T) its effect is as show in the figure(6.5).



Figure(6.5): Map when we delete the parameters (A , I , S , C).

when the removal of Aquifer media ,Impact of vadose zone media ,Soil media and Hydraulic conductivity , the sensitivity of water to pollution Are moderate and therefore these factors are the effect of average water pollution . And give us the max index value 15 and min index value is 3 .

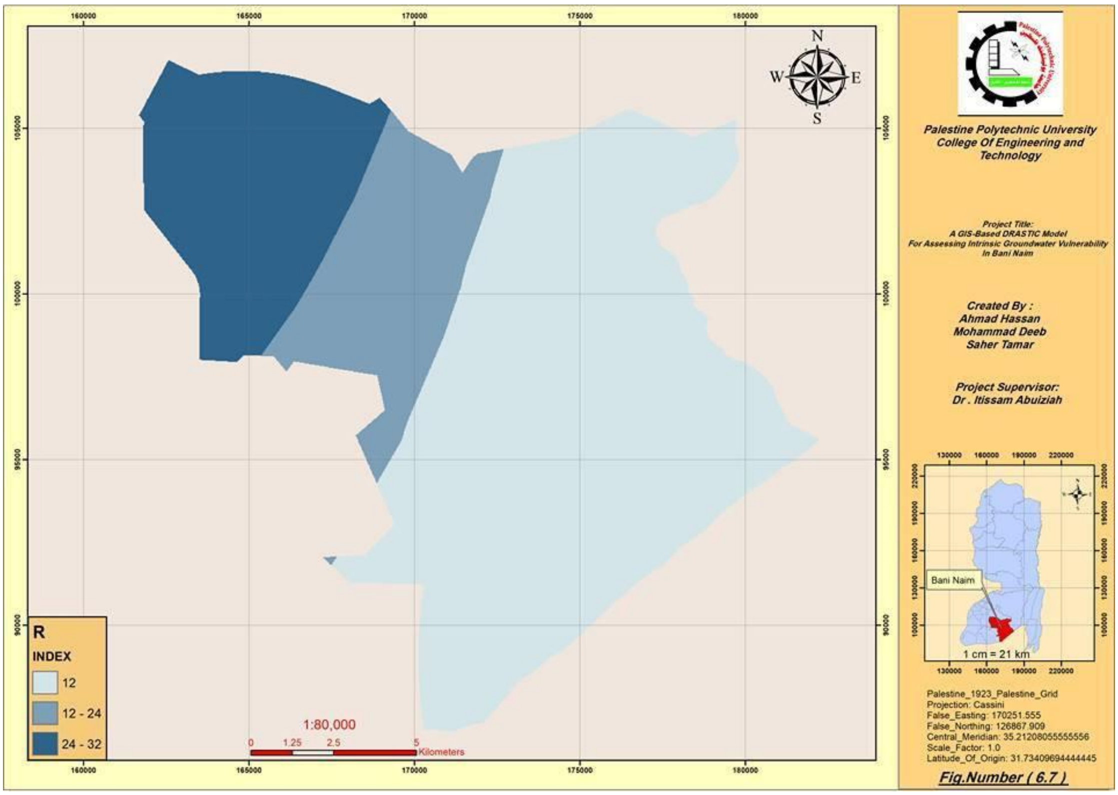
When we delete the parameters (A , I , S , C , T) and remain (D, R) its effect is as show in the figure(6.6).



Figure(6.6): Map when we delete the parameters (A , I , S , C , T) .

We note that when removing the Aquifer media ,Impact of vadose zone media ,Soil media , Hydraulic conductivity and Topography , these factors have a significant impact on the pollution of groundwater and when removed, the water sensitivity of the pollution as low as possible. And give us the max index value 10 and min index value is 2 .

When we delete the parameters (A , I , S , C , D) and remain (R) its effect is as show in the figure(6.7).



Figure(6.7): Map when we delete the parameters (A , I , S , C , T , D) .

The highest value of water pollution caused by et recharge , which significantly affects the water sensitivity of pollution . And give us the max index value 32 and min index value is 12 .

CHAPTER SEVEN

Conclusions And Recommendations

7.1 Conclusions

7.2 Recommendations

7.1 Conclusions

- Vulnerability Index divided into four categories; under low vulnerability (32-42), low vulnerability (42-73), under high vulnerability (73- 101), and high vulnerability (101- 118).

- The proportion of each of the four categories in relation to the total area (13%) was under the low vulnerable zone,(66 %) of the area was low vulnerable zone , (%19) of the area was moderate . And about (2%) of the area was high .

- The vulnerability index of Bani Naim area indicates that groundwater resources in the surrounding area are susceptible to pollution to a moderate degree .

- The vulnerability map has a range from the most vulnerable for contamination to the least vulnerable in Bani Naim .

- While working on the project and reviewing many of the previous studies, the information available helps any future research .

6.3 Recommendations

- Identification areas where there is significant risk to groundwater quality.

- Invest the results in future decision making in protecting groundwater .

- Take updated data which are required for analysis since there is a variety in data from time to another according to our special political situation.

- Improved control (physical system, water quality, and watershed attributes such as land use, demographics).

- Work on applying the study model to all underground wells in order to reduce the effects of pollution

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