Assessment of Water Pollution Indicators for the Springs and Wells of Wadi Abu al-Qamra Watershed

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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF
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PALESTINE POLYTECHNIC UNIVERSITY

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(PPU)

Hebron-Palestine

The Senior Project Entitled:

"Assessment of Water Pollution Indicators for the Springs and Wells of Wadi Abu al-Qamra Watershed"

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In accordance with the recommendations of the project supervisors, 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 Department for the degree of Bachelor of Science in Engineering.

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Hebron - Palestine

May - 2007

ABSTRACT

Assessment of Water Pollution Indicators for the Springs and Wells of Wadi Abu al-Qamra Watershed

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Water quality is a concept referring to the chemical, biological and physical characteristics of the water. The required water quality is determined by the purpose for which the water is to be used (domestic, urban, agricultural or industrial). The evaluation of the water, for any purpose, is based on the characteristics of the water, compared to a standard for that target use. By "standard" is meant the concentration of a constituent which causes no negative effect to the health of the consumer over the life of consumption (i.e. WHO).

Springs in the Hebron District are an important source of water for domestic as well as irrigation purposes. Previous investigators (Awadallah and Owaiwi, 2005) reported that the District contains springs/dug wells that discharge, annually, more than 2 million cubic meters of water. In some Palestinian communities a spring is the only source of water.

This study is of considerable importance as it will discuss in details the springs (dug wells) of Wadi Abu al-Qamra, an area located to the south of Dura City in the south-western part of the Hebron District. The Wadi discharge, in terms of springs and dug wells, besides its water quality parameters will be measured or assessed.

Our study indicated that the Wadi has 61 springs (and dug wells) which are mostly of private ownership. Also most of the available water in the area comes from dug wells rather than exposed springs. This means that people draw the water mainly by pumping. In the whole catchments, 17 and 44 wells are existing.

The GIS mapping of the project included discharge, water use, location, catchment boundary and topography, and aerial photo digitizing for the Wadi. Also it included mapping and classifying the water quality data using different criteria. The GIS mapping shows that most of the springs (dug wells) are located in the northwestern part of the Wadi catchment. Exposed springs are existing at low topographic levels and at the middle of the catchment with elevations approaching the least values over the Wadi section. The Wadi upstream is located at the northwestern area of the Wadi, while the Wadi downstream is at the southeastern part and this indicates the flow direction.

The study clearly demonstrated that, irrigation is the dominant water use. Although, drinking and other uses are available, but they are only of minor importance.

In fact, the Wadi path surrounding areas is the main irrigated arable land in Dura City and is used for vegetables production.

The discharge of the springs (dug wells), expressed as 4 classes in the GIS mapping, is mostly within the range of (1-5) and (5-10) m^3/d. Only few springs and wells were exceeding a discharge value of 15 m^3/d. The overall discharge of the Wadi's springs and dug wells is at a value of $131{,}000 m^3/year$.

In this project we measured chloride (Cl^-), Nitrate ($NO3^-$), pH, Dissolved Oxygen (DO), Electrical conductivity (EC) and salinity (SAL).

The important stage in this project, measured chloride and nitrate for different springs (wells) and used to assess pollution effects either coming from agricultural sources or sewage from residential sources. The GIS mapping of this stage showing spatial classification of the springs (and dug wells), water quality classes according to NO3 & Cl levels and acceptable/non acceptable water for drinking.

Based on our water quality results, we observed nitrate values of 212.8±129 (mg/l) (*average ± standard deviation*). The nitrate values vary from 0.5 to 431.0 mg/l for the wells/springs. This large range of nitrate value reflects the variations in the factors affecting the Wadi water quality which change along and across the Wadi.

Chloride values for the wells/springs were 98.1±54.2 mg/l and fall within the range 8.4 to 248.7 mg/l. It's clear that nitrate is more effected by land use changes rather than chloride. The electrical conductivity and TDS of the water of different wells/springs were with values of 890.9 ± 705.9 μs/cm, 770.2 ± 325.1 mg/l, respectively.

The pH values of the water of the different wells/springs were at 7.9 ± 0.5 while DO the value was mostly > 6.0 mg/l indicating aerobic water type. This is due to continuous aeration of the water stared in the water – bearing rock formation due to fractures and channels in the rocks.

The GIS mapping revealed that the most polluted springs/wells are available at the Wadi upstream and those close to residential areas. Sewage and fertilizers (manure) are the main pollution sources.

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Introduction

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Introduction

1.1 General

Water quality is a concept referring to the chemical, biological and physical characteristics of the water. Accurate and reliable water quality data are required to characterize ground water for use in resource management. Generally speaking, a certain water quality should comply with the standards of the target water use.

A spring's water quality is determined by several factors. These include the chemical composition of the water entering the aquifer, the composition and solubility of the rocks with which the water comes into contact along flow paths, the length of time the water is in contact with the rocks as it moves from recharge to discharge areas, and the mixing of fresh groundwater with residual formation water or seawater.

Land use activities in a spring's recharge basin and the up coning of poorer quality water from deeper zones due to groundwater withdrawals may also impact water quality. This study deals with the variation of water quality for the springs along Wadi Abu al-Qamrah in Dura area.

1.2 Background

Springs constitute major sources of domestic and irrigation water for many villages in the West Bank. Villages not connected to municipal water are depending on spring water on their living. Most of these springs are ignored and water losses are high such as Water losses by evaporation and percolation through the ground.

In Hebron District, there are more than 170 springs with an average discharge exceeding 0.01 liter/sec. These springs are used for domestic and irrigation purposes. Many of the springs are available in Dura area and specially in Wadi Abu al-Qamrah.

In the project area, springs are the major source of water for irrigation purpose, in which water quality should be good and suitable for agriculture use the evaluation of the water, for any purpose, is based on the characteristics of the water compared to standards for that use. Detailed information concerning water quality and related issues, for the study area, is lacking. Therefore, this study is conducted to investigate water quality of Wadi Abu al-Qamrah springs in Dura area of the Hebron District.

1.3 Previous Studies:

Adul-Jaber and Aliewi (1994-1997) carried out several studies to evaluate the water quality of springs in north and central of the West Bank. They showed that the springs, in general, are suitable for domestic purposes from the chemical point of view and can be relied on for any future development. In the study of the effect of contamination from wastewater on the shallow aquifer, they concluded that most of the springs and wells within the heavily populated areas were probably contaminated with wastewater through infiltration from septic tanks and the flowing sewage streams.

Abu Sharkh (1995) in the unpublished study for University Graduates Union evaluated the water quality of the springs of Hebron City. He concluded that most of the springs are contaminated with coliform and safe from the chemical point of view.

Abed Rabbo *et al.* (1995) presented the results of a study of the biological characteristics of the networks, cisterns, and springs in Nablus, Jenin, Qalqiliya, and

Tulkarm areas, based on coliform testing. The study showed that about one third of these water resources are free of coliform contamination and thus satisfactory for drinking, according to the World Health Organization guidelines (WHO, 1995). Abed Rabbo *et al.* (1999) presented the results of an extensive study of springs and wells throughout the West Bank. The study aimed to determine the levels of biological and chemical pollution and recommended means of improving the situation.

1.4 Problem Identification:

Most of the Wadi springs/wells have not been covered in previous studies. Also the Wadi is a major economical and income site for Dura area due to its role in the food-security of the area because its water and land are enabling the production of significant agricultural (vegetables) products.

Awadallah and Owaiwi (2005) carried out a comprehensive study on the hydrogeology and hydrochemistry of the springs and dug wells of the Hebron Districts. The study concluded that the chemical composition of the springs and dug wells are mostly coping within the standards with regard to the following parameters: pH, turbidity, EC, Cl, TDS, salinity, DO, hardness, TSS, TS, Na, K, Ca, Mg, NH_4, HCO_3, and PO_4. The study showed that polluted dug wells and springs are mostly located in the residential unsewered areas where direct contaminations from septage take place.

1.5 Objectives of the Project:

Springs, in the West Bank, are an important source of water for domestic and irrigation purposes. This project concerned with the quality of the springs water in the project area. The general objective of this study is to evaluate the water quality of springs discharging along Wadi Abu al-Qamrah in Dura area. More specifically, the main objectives of the present study may be classified as follows:-

- Determine the concentrations of chloride and nitrate in the water of different springs/dug wells in the study area. This is because both of these constituents are important to indicate agricultural or domestic sources of pollution.
- Provide an overall picture of the water quality of springs in the Wadi.
- Determine the physical characteristics of spring's water, such as pH value, electrical conductivity, total dissolved solid.
- Determine the biological characteristics of spring water using the total coliform bacteria as an indicator.
- Evaluate the suitability of the water for agricultural and domestic purposes.
- Identity the catchment's boundaries and spring location by means of the GPS
- Generate a GIS mapping and data base for the Wadi spatial data as well as water quality and hydraulic data will be used to generate multi-layer mapping by GIS program.
- Identity sources of pollution in the Wadi.
- Give suggestions and recommendations with respect to the improving of the quality, and protecting of springs water sources.

1.6 The Project Area:

The study area, named Wadi Abu al-Qamrah, is located in Dura City of the Hebron area which will known later as Wadi Abu al-Qamrah watershed. The watershed is situated between latitude 83-120 N and 138-183 E referenced on the Palestinian Grid in eastern Dura city, with an elevation ranging from 700-800 m (above Sea Level) and extended over a total area of 0.5 square kilometer. The watershed receives an average annual rainfall of 450 mm with more than 90% of the rainfall received during the winter season (November- March). The minimum and maximum temperature varies in the range of 10 °C to 25 °C. The soils of the watershed are characterized by light sandy to clay loam, and the major land use/cover patterns in the watershed are: agricultural and residential.

1.7 Work plan

Work descriptions	First Semester		2006		Second Semester			2007		
	Sep	Oct	Nov	Dec	Jan	Feb	March	April	May	June
1-Carry out site visits to the Wadi and Dura Municipality										
2-Data collection										
3- Revising literature and previous studies										
4- Identifying location points by GPS										
5- Creating GIS Data base for the Wadi										
6- Water Sampling and Testing										
7- Reporting										
8- Submitting the introduction and preparing the presentation of it										
9- Submitting the final report and preparing its presentation										

1.8 Organization of the report:

The subject matter of the project is presented in six chapters. The first chapter entitled "Introduction" outlines the subject, objectives of the project, summary about previous studies, project area, and the organization of the report. The second chapter entitled "Literature Review" explains the physical, chemical and biological characteristics of water, and quality of water required for domestic uses and irrigation. Chapter three "Fieldwork and Methods" discusses the detailed methods and tools used in this study. It discusses the used of GPS and GIS as tools for analyzing and interpreting the data. The fieldwork, the laboratory methods are also discussed there. Chapter four "Description the study Area discusses different features and characteristics of the study area". Chapter five entitled "Results" presents the spatial data and the GIS mapping achieved at this stage of the study and chapter six contains conclusions and recommendations.

CHAPTER TWO

Literature Review

CHAPTER TWO

Literature Review

2.1 Hydrological Background

The meaning of the hydrologic cycle is the circulation of water evaporated from the oceans, seas and the land surface, its transport through the atmosphere to the land and its return to the oceans via surface and atmospheric routes. Although called a cycle, the process is much more complex than a mere cycle. All kinds of short cuts and parallel processes take place.

The rate at which rain falls over an area and its duration are of importance. The rain duration equal to the time of concentration, or the time required for the water to run from the farthest part of the catchment to the point in question. This is critical, since the shorter the duration of a rainfall, the greater may be its average intensity. The greatest intensity to be expected for the critical duration therefore will produce the greatest runoff.

Of the precipitation upon a certain catchment area:

- some runs off immediately to appear in streams or flood flow
- some evaporates from land and water surfaces
- some, the snow, remains where it falls, with some evaporation, until it melts
- some, known as interception, is caught on leaves of vegetation and evaporates
- some termed infiltration, seeps into the ground. Of the infiltration:
    - a part is taken up by vegetation and transpired through the leaves

- some percolates through the soil to emerge again to form springs and streams which make up the dry weather flow
- a part is held by the capillarity of the soil
- while small portion may penetrate into deep porous underground strata.

Simply, runoff is the flow of rainwater over the surface and occurs when rainfall intensity is greater than the soil infiltration capacity. The factors that affect run-off rate are numerous and interrelated. Of these, the rainfall is most important. The total precipitation and its distribution are important since rains occurring during the growing season for vegetation. Solar radiation and its variation on the watershed will affect evaporation. The amount and type of vegetative cover affect infiltration and loss of water by evapotranspiration. The topography of the area, its degree of roughness and slope. The geology of the area, including the perviousness or imperviousness of the subterranean formations, is important. Runoff can be measured by several methods among them is the plot method.

Infiltration rates depend on several factors, the more important of which are discussed below.

Rainfall characteristics: a small rainfall may all be absorbed and produce no runoff. Heavy rains impact the soil surface by impact of the raindrops and reduce entrance and cause erosion.

Soil characteristics, the smaller the pore size in the topsoil, the smaller will be infiltration. Small soil particles, as in clay, mean small pores, while sand or gravel is at the other extreme. Mixture of fine and coarse tends to pack and reduce pore size. The Soil cover or the type of surface cover is important in several ways. It protects the soil from compaction by rain and also provides detention on the surface and thereby increases infiltration opportunity.

Infiltration capacity is defined as the maximum rate at which a given soil at a given condition can absorb rain as it rains. Thus the capacity will be equal to an observed rate of infiltration in the rainfall intensity equals or exceeds it. Runoff occurs if the rainfall intensity exceeds the infiltration capacity.

Soil moisture is the term used to water trapped in the soil by molecular attraction forces.. Soil moisture moves under the influence of the gravitational force and the force resulting from the difference in capillary action.

Evaporation can be measured by the pan method. Evapotranspiration is the total amount of water taken up by vegetation for transpiration and building of plant tissue and the evaporation of the soil moisture, during the growing of some particular crop (Awadallah and Wishahi, 2004).

The general global hydrologic cycle can simply be represented schematically as shown in Figure (2.1).

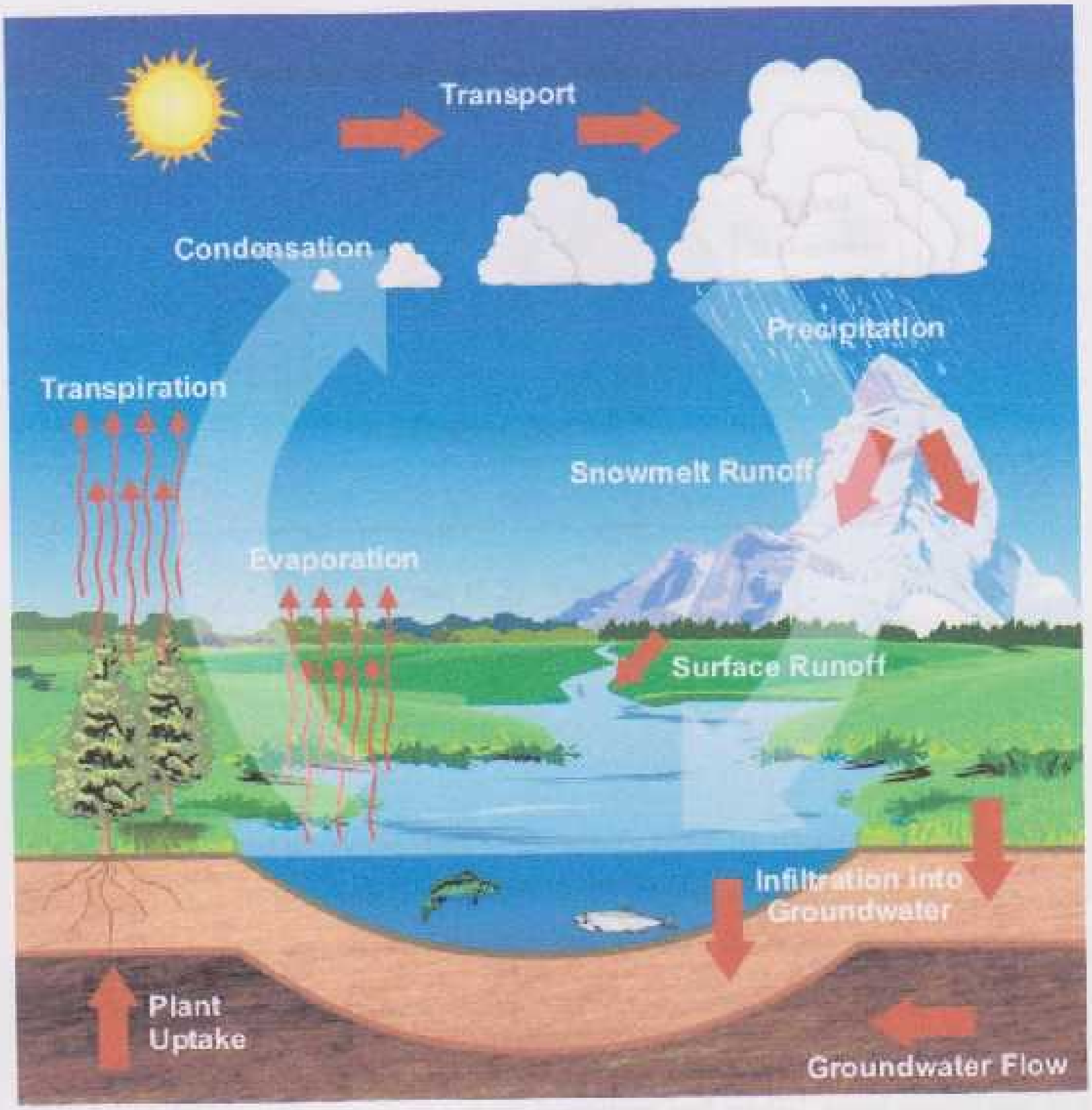


Figure (2.1): Movement of Water through the Hydrologic Cycle

Source of the figure: [45].

For the West Bank area, an overall water balance was reported by Rofe and Raffety (1965) and shows that the actual evaporation, infiltration and surface runoff represent 66.9%, 26.8% and 6.3% of the annual rainfall, respectively. These data are represented in Figure (2.2).

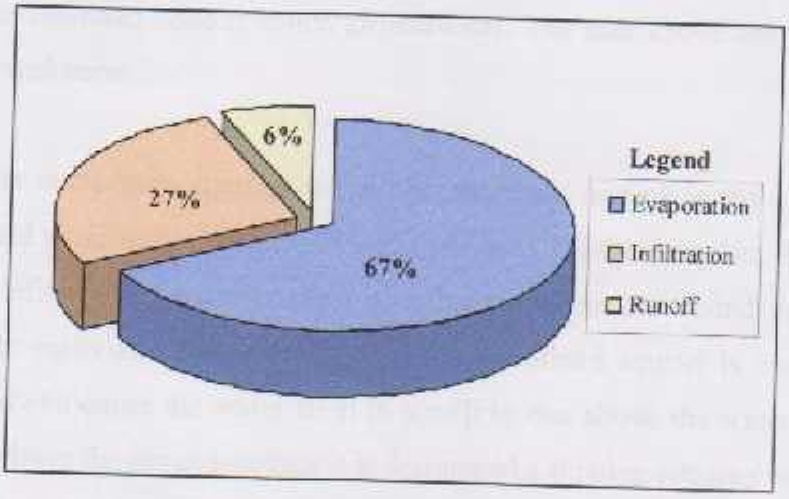


Figure (2.2): Water Balance
Source of the figure: [45].

2.2 Groundwater

It is well-known that minor amounts of the earth's water are considered as accessible-freshwater. This fresh water is either a surface-water, a groundwater or blocked in glaciers as ice. Groundwater is found in natural rock formations. These formations, called aquifers, are a vital natural resource with many uses.

World widely, groundwater is the most important and crucial water source and is a development-limiting factor.

Where water infiltrates the ground, gravity pulls the water down through the pores until it reaches a depth in the ground where all of the spaces are filled with water. At this point, the soil or rock fractures become saturated, and the water level which results is called the water table. The water table is not always at the same depth below the land surface. During periods of high precipitation, the water table can rise. Conversely, during periods of low precipitation and high evapotranspiration, the water table falls. The area below the water table is called the saturated zone, and the water in the saturated zone is called groundwater. The area above the water table is the unsaturated zone.

Groundwater is found in aquifers which consist of soil or rock in the saturated zone that can yield significant amounts of water. In an unconfined aquifer the top of the aquifer is defined by the water table. Confined aquifers are bound on the top by impermeable material, such as clay. Water in a confined aquifer is normally under pressure and can cause the water level in a well to rise above the water table. If the water rises above the ground surface it is designated a flowing artesian well.
Water moving from an aquifer and entering a stream or lake is called groundwater discharge, whereas any water entering an aquifer is called recharge **[22]**.

2.3 Springs and Shallow (hand-dug) wells:

2.3.1 Wells with focus on dug-well type:

The most common types of wells are named by the method used to construct them; i.e., drilled, jetted, driven, dug, or bored. Since constructing a well exposes the groundwater source to surface as well as subsurface contaminants, installation must be carefully done.

Dug wells (Figure 2.3) are constructed with hand or power tools, are usually 3-30 feet in diameter and less than 50 feet deep, which may result in an inadequate supply of water during dry periods. If sand mixed with clay and silt surrounds the well, a larger storage area can be provided to avoid water shortages.

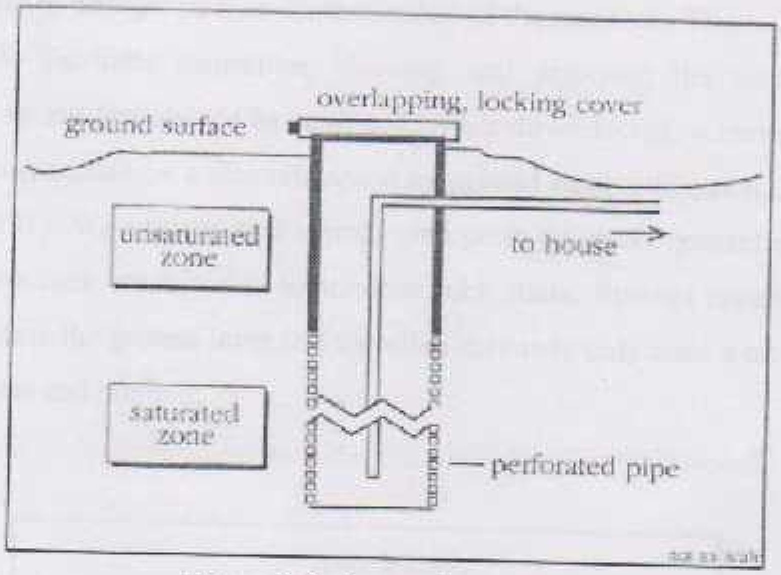


Figure 2.3: Dug well schematic diagram
Source of the figure: **[45].**

2.3.2 Springs

Typically, springs tap a shallow groundwater source with a variable flow rate (Figure 2.4). To be used as a drinking water source, two criteria must be met. First, the spring must provide adequate, good-quality water to meet household needs throughout the year. The origin of a spring is difficult to determine but ideally, better springs are those emerging from rock formations. It is desirable to ask the local health department to do a sanitary survey of the area before developing a spring. This inspection should detect any present and future health hazards in the vicinity of the spring. Protection is the second requirement for proper spring development. Since the spring's source is at a higher elevation than its outflow, protecting this source is vital.

Surface water runoff should be diverted by constructing a curtain drain or beam upstream of the spring. The area should be fenced to prevent animals from contaminating the spring source. Yearly water testing for coliform bacteria is necessary to monitor the sanitary condition of the spring. The encasement surrounding a spring should be watertight, open at the bottom, and have a heavy, overlapping lid to prevent surface contamination of the reservoir. There should be an entry point to facilitate inspection, cleaning, and emptying the spring box. In addition, the spring box should be equipped with a down-facing, screened overflow pipe and be surrounded by a concrete apron on ground sloping (Cornell Cooperative Extension, 1991). We can say that springs emerge at the rocks contact zones when fractured upper rock strata meets impervious rock strata. Springs appear when the water table meets the ground level and therefore they may only need a catch-basin to collect the water and pump it.

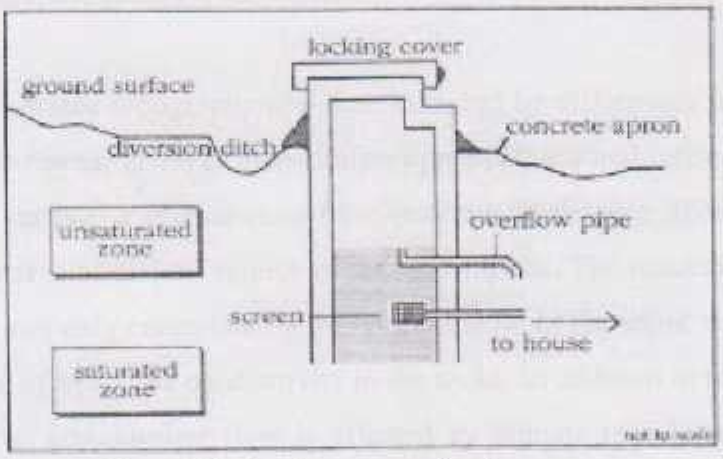


Figure 2.4: Spring schematic diagram
Source of the figure: [45].

2.3.3 Factors affecting spring/well discharge

Groundwater and surface water are not isolated components of the hydrologic system, but instead interact in a variety of physiographic and climatic landscapes. Thus, development or contamination of one commonly affects the other. Therefore, an understanding of the basic principles of interactions between groundwater and surface water (GW–SW) is needed for effective management of water resources.

In recent years, as Winter (1995) points out, studies of GW–SW interactions have expanded in scope to include studies of headwater streams, lakes, wetlands, and estuaries.

The interaction between groundwater and lakes has been studied since the 1960s because of concerns related to eutrophication as well as acid rain. To understand GW–SW interactions, it is necessary to understand the effects of what Tóth (1970) calls the "hydrogeologic environment" on groundwater flow systems – that is, the effects of topography, geology, and climate.

Differences in surface topography are often mirrored by differences in potential. As Hubbert (1940) shows, given a really uniform precipitation and infiltration rate over an undulating surface, a groundwater flow system will develop driven by a water-table surface that is a subdued replica of the land surface. The resulting groundwater flow pattern is not only controlled by the configuration of the water table but also by the distribution of hydraulic conductivity in the rocks. In addition to topographic and geologic effects, groundwater flow is affected by climate (precipitation being the source of recharge). Groundwater moves along flow paths that are organized in space and form a flow system. In nature, the available subsurface flow domain of a region with irregular topography contains multiple flow systems of different orders of magnitude and relative, nested hierarchical order. Based on their relative position in space, Tóth (1963) recognizes three distinct types of flow systems – local, intermediate, and regional – which could be superimposed on one another within a groundwater basin. Water in a local flow system flows to a nearby discharge area, such as a pond or stream. Water in a regional flow system travels a greater distance than the local flow system, and often discharges to major rivers, large lakes, or to oceans. An intermediate flow system is characterized by one or more topographic highs and lows located between its recharge and discharge areas, but, unlike the regional flow system, it does not occupy both the major topographic high and the bottom of the basin. Regional flow systems are at the top of the hierarchical organization; all other flow systems are nested within them.

Flow systems depend on both the hydrogeologic characteristics of the soil/rock material and landscape position. Zones of high permeability in the subsurface function as drains, which cause enhanced downward gradients in the material overlying the upgradient part of the high-permeability zone (Freeze and Witherspoon 1967). Areas of pronounced topographic relief tend to have dominant local flow systems, and areas of nearly flat relief tend to have dominant intermediate and regional flow systems.

In topography-controlled flow regimes, groundwater moves in systems of predictable patterns, and various identifiable natural phenomena are regularly associated with different segments of the flow systems.

2.3.4 Pumping effect on water level

In water wells, the removal of water on a continuous basis results in a drop in water level from the static (non-pumping) level to the dynamic (pumping) level. This drop in water level is a manifestation of the drop in pressure necessary to cause water to flow from and through the aquifer into the well. The pumping level is a function of the pumping rate with higher flow resulting in lower (deeper) pumping levels. The vertical distance between the pumping level and the ground surface constitutes the "lift" portion of the well pump head. The lift varies with flow, but at far less than the second power relationship of frictional resistance. The total depth of the well and the distance the pump is submerged below the water surface has no bearing upon pump head (ASHRAE Transactions, 1998)

2.4 Water Consumption for Different Uses

Water is essential for achieving sustainable development, and it is this resource that will play a large role in determining whether or not the development goals are achieved. The core concern is how to achieve equitable access and adequate water supplies, while at the same time protecting and preserving supplies and maintaining environmental security. Water is the key resource for food security, for good health, for providing clean hydroelectric energy, for protecting ecosystems and aquatic biodiversity, and for industrial development. Together these make for a complex set of relationships reflecting water demand and water supply relative to size of population and the multiplicity of end uses. While the world population increased threefold during the twentieth century, water withdrawals increased six fold. Current water withdrawal at the global level accounts for about 10 per cent of the world's total renewable water resources and of this withdrawal about half is consumed. In the next two decades, water consumption is projected to double but still remaining well below the critical ratio of water consumption to supply generally set at 40 per cent. If water consumption per capita at the global scale reaches the current level in developed countries, over 90 per cent of the available water resources would be utilized by 2025.

A person needs to consume about three liters of fresh water per day in order to maintain adequate hydration (mainly direct drinking) (Fetter, 1994). For instance, in an industrial society such as the United States, personal water consumption for all domestic uses is between 200 and 300 liters per day (Fetter, 1994). When the industrial and energy production usage is added in to the equation, fresh water usage exceeds 5,000 liters per day on a per capita basis (Fetter, 1994). Sources for fresh water include surface water such as lakes and rivers, groundwater, rain water, desalination of ocean water, and treatment and reuse of wastewater. Surface water and groundwater are the only two sources that have widespread use. Groundwater accounts for approximately 25 percent of the fresh water used for agricultural, industrial, and domestic use (Driscoll, 1986). Groundwater accounts for about 50 percent of the water used the drinking water supply in the United States (Driscoll, 1986). Groundwater is a valuable resource, which needs to be properly used and managed.

With regard to agricultural water, the use of appropriate irrigation system could raise the water use efficiency by reducing evaporation, water losses and irrigating with water quantities not exceeding the plant's water requirement. Change in the efficiency of water use, could result in a doubling of agricultural productivity per unit of water utilized. A significant problem arises in that, although there is enough water at the global level, availability does not coincide with the regional distribution of the world's population. In many tropical regions, annual rainfall occurs during a short rainy season, and most of it is lost in runoff. Table 2.1 illustrates the different water uses at global level with great variations between developing and developed countries for different water uses (i.e. domestic, agricultural and industrial).

Table2.1: Percentage of Water Resources Devoted Annually to Domestic, Industrial and Agricultural Uses for 17 Selected Countries (data of 2001-2002) [23].

Country	Domestic Use	Industrial Use	Agricultural Use	Population
Egypt	6	8	86	57,673,000
South Africa	17	11	72	40,435,000
Canada	11	80	8	29,248,000
Guatemala	9	17	74	10,322,000
Mexico	6	8	86	87,341,000
USA	12	46	42	255,020,000
Brazil	10	5	85	155,792,000
Peru	19	9	72	23,088,000
China	6	7	87	1,200,000,000
Israel	16	5	79	5,423,000
Jordan	22	3	75	4,936,000
Turkey	16	11	72	58,775,000
France	16	69	15	57,850,000
Netherlands	5	61	34	15,385,000
United Kingdom	23	73	4	57,998,400
Russia	19	62	20	148,366,00
Australia	65	2	33	17,803,000

2.5 WATER QUALITY

Water quality is a concept referring to the chemical, biological and physical characteristics of the water. The required water quality is determined by the purpose for which the water is to be used (domestic, urban, agricultural or industrial). The evaluation of the water, for any purpose, is based on the characteristics of the water compared to a standard for that use. By "standard" is meant the concentration of a constituent which causes no negative effect to the health of the consumer over the life of consumption [24]. However, local requirements, dependent on the availability of water resources, the national economy, the political situation and scientific progress, may modify these standards. The water quality short-term deviations from a standard for a specific purpose do not mean that the water is unsuitable for that purpose. Suitability here is judged by the amount and the length of the deviation time as well as by the nature of the constituent involved.

The water that is used for drinking, cooking, bathing, cleaning and in residential, institutional and public buildings is referred to as domestic water. The suitability of its quality as domestic water is judged on physical, microbiological and chemical characteristics. The physical characteristics, such as turbidity, total suspended solids, colour, odour and taste, are the first concern in the evaluation process, as they are the easiest parameters to detect. Microbiological characteristics are second, as people are more familiar with waterborne-microbiological diseases than they are with waterborne chemical diseases, detection is easy and treatment costs are comparatively low. However, though it is no less important, the need for the identification and evaluation of the chemical characteristics is not appreciated by the public, as waterborne-chemical diseases are less well-known. Also, the testing and treatment for the chemical parameters are difficult and require expensive high technology.

Potable water is water that can be used safely for domestic purposes. It must have the following characteristics:

- Its turbidity, color, odor and taste must be within acceptable and permissible limits.
- It must be free of pathogens.
- Its content of hazardous chemicals must be within permissible limits **[24]**.

More details are given in the following:

2.5.1 Physical Quality Evaluation

1. **Turbidity:** Water containing visible material in suspension is termed as turbid. Turbidity in water consists of clay, silt, finely divided organic matter, macroscopic organisms. Turbidity may result from living or dead algae or other organism. It is generally caused by soil erosion in natural waters. River water is normally most turbid when storms are most numerous. Turbidity depends on fineness and concentration of particles in the water
2. **Color:** Pure water is colorless. Color is imparted to water by material in solution or in colloidal suspension or mineral and is distinguished from turbidity which may cause an apparent color.
3. **Odor and Taste**. Pure water is odorless and tasteless but potable water while being essentially odorless is pleasant to the taste. Taste in water is generally due to presence of dissolved salts.
4. **Temperature:** Natural water is seldom below 5°C. In a water supply system, the desirable temperature is 5°C to 10°C, temperature above 25°C is not desirable.

2.5.2 Microbiological Quality Evaluation

The biological characteristics of water are very important in the evaluation of its suitability for domestic purposes, as the infectious diseases caused by pathogenic bacteria, viruses, protozoa or parasites are the most common and widespread health risk associated with drinking water. In our microbiological evaluation of the water samples, the faecal and total coliform bacteria indicators were used. An indicator organism is an organism that is universally present in high numbers in the faeces of humans and warm-blooded animals, readily detected by simple methods and not growing in natural water. Furthermore, it is important that its persistence in water and the degree of removal in treatment be similar to that of waterborne pathogens. Coliforms have been recognized as indicators for a long time, as they are easy to detect and enumerate in water (Thomann & Mueller 1982). Our evaluation is based on the WHO (1995) recommendation that the long-term count of the total and faecal coliform must be zero.

Details about different microbiological indicators for water are shown below:

1. **Total Coliforms:** As mentioned earlier Water may contain various kinds of organic life such as bacteria and microscopic organisms. Coliforms are important harmless micro-organisms which are found in the human intestine. Harmless organisms of coliform group live longer water than pathogenic bacteria. Therefore, water is safe if it is free of bacteria in it. Also coliform organisms are considered suitable indicators of pollution because they die in a short time and can be identified easily.

The quality of water for public water supply is determined by the presence or absence of total coliform. In order that the water is safe for drinking water and is free from pathogenic bacteria, it is generally necessary that no one coliform organism is present.

2. **Escherichia coliform:** The fecal coliform group includes all of the rod-shaped bacteria that are non-spore forming, Gram-Negative, lactose-fermenting in 24 hours at 44.5 °C, and which can grow with or without oxygen. Fecal coliform is a type of fecal bacteria. Another type of fecal bacteria is Fecal Streptococcus. Fecal Streptococcus is a group of bacteria normally present in large numbers in the intestinal tracts of warm-blooded animals other than humans.

Some strains of Escherichia coliforms, related to fecal coliform family, can cause intestinal illness. This is found in the digestive tract of cattle.

2.5.3 Chemical Quality Evaluation

The chemical characteristics which decide the suitability of water for domestic use are the concentrations of the various ions which can be health hazards if they exceed a certain threshold or if they can change the aesthetic quality of the water by causing an undesirable color, taste or odor or water hardness.

A comparison of the water quality of the resources studied with the WHO (1995) guidelines is the basis for evaluation, since there are no published Palestinian national standards to this date. The hardness of water is defined as its content of divalent metallic ions which react with sodium soaps to produce solid soaps or scummy residue and which react with negative ions when the water is heated in boilers to produce solid boiler scales (De Zuane, 1990). The evaluation of hardness could help in determining the need for water softening required to reduce the amount of detergents consumed, thus helping to protect the environment through the reduction of the use of nonbiodegradable detergents. It could also help in avoiding extensive scale formation (carbonate-mineral precipitation) from hard water. Total hardness is expressed as $CaCO_3$ in mg/L, which is calculated according to the following formula (Todd, 1980):

Total hardness ($CaCO_3$) = 2.497 Ca^{+2} + 4.118 Mg^{+2}

Where the Ca^{+2} and Mg^{+2} concentrations are in mg/l

The Sawyer and McCarty (1967) classification of water samples according to their total hardness is given in (Table 2.2). This classification is helpful in the evaluation of water for domestic purposes.

Table 2.2: Sawyer and McCarty (1967) classification of water, based on hardness[33].

Hardness as $CaCO_3$ mg/L	Water Type
0-75	Soft
75 - 150	Moderately hard
150-300	Hard
>300	Very hard

More details about different chemical parameters are given below:

1. **pH Value:** most water is more or less alkaline because alkaline salts are very common in the ground. Carbonates and bicarbonates of calcium, sodium and magnesium are the common impurities. Alkalinity is expressed in milligrams /liter in terms of equivalent calcium carbonate. Acidity in water is caused by carbon dioxide. It is measured in terms of calcium carbonates needed to neutralize the carbonic acid and is expressed in milligrams per litter. Alkalinity and acidity are also expressed in terms of pH. pH value of water is of importance in water treatment and industrial processes. Pure water has a pH value of 7; below 7 it is acidic and above 7 it is alkaline. Acidic water results in corrosion of pipe line.

2. **Hardness:** Hardness of water is a matter of great concern for public water supply. Hard water requires more soap before a lather is formed. Hardness is indicated by the formation of insoluble precipitate or curd, rather than lathering with soap and formation of scale in utensils. Hard water contains solution of carbonates and sulphates of calcium and magnesium, their chlorides and nitrates besides iron and aluminum. Temporary hardness, removed by boiling or addition of lime to the water,

is rendered by the presence of bicarbonates of calcium and magnesium. Permanent hardness, softened by special treatment, results from the presence in water of sulphates, chlorides and nitrates of calcium and magnesium. Hardness is expressed in mg/l by weight in terms of calcium carbonates.

3. **Electrical conductivity (EC):** The total amount of dissolved salts present in water can be easily estimated by measuring the specific conductivity of water. Specific electrical conductivity defines the conductivity of a cubic centimeter of water at a standard temperature of 25° C. The unit of conductivity is mho (1 ampere/1 volt). It is determined by a potable diomic water taster. Pure water at 25° C has a specific conductivity of 5.5 x 10-8 mho and sea water about 5×10^{-2}mho.

4. **Total Dissolved Solid (TDS):** The mineral constituents and organic materials dissolved in water constitute the total dissolved solids. The measurement of total dissolved solid in water is essential for water used in drinking, irrigation, and industrial purposes. The recommended maximum concentration for TDS is 1000 mg/l, but more than 600 mg/l is undesirable for drinking and many industrial. Classification of the drinking water quality in terms of TDS published by World Health Organization (WHO) is given in Table (2.3)

Table (2.3) Classification of the Drinking Water in Terms of the Total Dissolved Solids (TDS) **[24].**

Water Quality	Total Dissolved Solid (mg/l)
Very good	<300
Good	300 – 600
Fair	600 – 900
Poor	900 – 1200
Not acceptable	> 1200

5. **Calcium and Magnesium (Ca^{++}, Mg^{++}):** The most important divalent metallic cations in water. The major natural sources of calcium and magnesium are amphiboles, pyroxenes, dolomite, and clay minerals. The recommended maximum concentration in drinking water is 100 mg/l for calcium, and 50 mg/l for magnesium. Hardness which is caused by calcium and magnesium ions interferes with laundering of clothes by reducing the cleaning action of the soap or detergent and at high concentration produces scale in water pipes and on plumbing fixtures.

6. **Sodium and Potassium (Na^{++}, K^{+}):** The main sources of sodium and potassium are feldspars, clay minerals, and industrial waste. The recommended maximum content in drinking water is 100 mg/l for sodium, and 10 mg/l for potassium. Sodium and potassium affect the suitability of water for irrigation. High sodium concentration adversely effects the soil and plant growth. More than 50 mg/l sodium and potassium causes corrosion in boilers.

7. **Chloride (Cl^{-}):** Chief source of chloride is sedimentary rock. Excess chloride causes bad taste. Water which contains chloride with concentration between 200 - 600 mg/l can be used for domestic use. The recommended maximum concentration for chloride in drinking water is 250 mg/l.

8. **Carbonate and Bicarbonate (CO_3^{-}, HCO_3^{-}):** In general, the dissolved carbonate materials and CO_2 are the major source of carbonate and bicarbonate in water. The bicarbonate ion and carbonate ion content in water is referred to as alkalinity. Below pH of 8.3 the total alkalinity is in the form of the bicarbonate ion.

Water contains less than 500 mg/l of carbonate and bicarbonate can be used for drinking. The recommended concentration is 50 mg/l for carbonate, and 500 mg/l for bicarbonate. Water containing large amounts of bicarbonate is undesirable in many industries. The carbonate combines with calcium and magnesium to form calcium carbonate and magnesium carbonate which cause hardness.

9. **Dissolved Oxygen (DO):** The primary effect of dissolved oxygen in water is on oxidation-reduction reactions, involving iron, manganese, copper and compounds that contain nitrogen and sulphur. In certain distribution systems there may be a tendency for the level of dissolved oxygen to fall with residence time. Although such changes are normally indicative of corrosion processes, it is also possible that microbial respiration of organic material, especially in sediments and deposits, within pipes may be responsible. Thus, dissolved oxygen may decrease without a marked increase in the concentration of iron in the water. Conversely, water containing high levels of iron as a result of corrosion may show little depletion of dissolved oxygen content.

One milligram of oxygen per litter will produce 3.5 mg of ferrous iron per litter so that a large amount of iron corrosion may occur with little perceptible change in dissolved oxygen when the available oxygen in water has been depleted; anaerobic corrosion processes precede involving the activity of the sulphates-reducing bacteria that may be present.

Frequently, depletion of the level of dissolved oxygen below about 80% saturation leads to an increased incidence of consumer complaints, especially regarding taste, odor and discolored water.

10. **Nitrates and Nitrites** (NO_3, NO2): The presence of nitrites and nitrates indicates an organic contact sufficiently remote to permit some oxidizing action on organic matter. Nitrate in water is commonly reported in terms of the nitrogen equivalent, but in mineral analyses results are reported in terms of the acid radical (NO) and, as such, in ground waters it may have sanitary significance as a cause of

mathemoglobinemia. The total nitrogen in natural waters is seldom sufficient to require its removal by water-treatment processes. It has, however, been found in concentrations as high as 40 to 60 ppm in natural waters.

11. **Ammonia (NH_3):** The presence of free ammonia in water indicates the presence of undecomposed organic matter, and for potable water, its value should not exceed 0.15 mg/l. The very presence of organic nitrogen in water indicates pollution, and for potable waters, it should not exceed a value of about 0.3 mg/l.

12. **Chlorine (Cl_2):** Dissolved free chlorine is not found in natural waters. Its presence in treated water results from disinfection with chlorine and because a residual is left as a safety measure to ensure the killing of pathogenic bacteria. The customary residual is in the order of 0.1 to 0.2 ppm. Residuals up to 2 ppm are successfully carried but may result in complaints of unpleasant tastes. Chlorine must not be confused with chlorides, for they are not the same thing [24].

2.5.4 Water Quality for Agricultural Purposes

The suitability of any water for irrigation is determined by many factors. Some of these include the water quality and quantity and the soil type, as well as the type of crops irrigated. Salts in the irrigation water could negatively affect the growth of plants by changing the osmotic conditions in the root zone which would decrease or limit the water uptake (a physical effect). Some toxic constituents such as boron might influence the metabolic reactions (a chemical effect). Salts may also affect the soil by changing the soil structure, permeability and aeration, which would indirectly affect the growth of plants (Todd, 1980). The evaluation of the soluble sodium percentage, sodium adsorption ratio and the total dissolved solids / electrical conductivity plays a major role in the evaluation of the suitability of water for irrigation.

a- Soluble Sodium Percentage (SSP)

Sodium concentration is an important index in the evaluation of irrigation water as it has an influence on soil permeability.

b- Sodium Adsorption Ratio (SAR)

The expression SAR was recommended by the United States Salinity Laboratory (USSL) of the Department of Agriculture (Richard, 1954). The SAR is considered to be in direct relationship with the water adsorption by the soil. It is calculated according to the equation:

$$SAR = [Na^{+}]/\{([Ca^{2+}] + [Mg^{2+}])/2\}^{0.5}$$

The cations are expressed in milli-equivalent per liter.

2.5.5 Standards of potable (drinking water in relation to public health)

Table 2.4 shows the WHO standards for drinking water quality.

Table 2.4: World Health Organization (1995) guidelines for potable water [24].

Parameters	Permissible Limits	Source of Cause
Temp C°	12-25	Earth's temperature or chemical reaction.
pH-value	6.5-8.5	Dissolved CO2 and the organic acids.
Na (mg/L)	200	All rocks and soils, found also in sea water, brines and sewage.
Ca2 (mg/L)	75	Dissolved from all rocks and soils, but especially from limestone, dolomite and gypsum.
Mg2 (mg/L)	<125	All rocks especially carbonates.

Parameters	Permissible Limits	Source of Cause
K (mg/L)	12	Sedimentary rocks. Wastes of man and livestock.
HC03 (mg/L)	125-350	Carbonate rocks and soils. Present in sewage. Ancient brines and sea water.
Cl (mg/L)	250	Dissolved from rocks and soils. Present in sewage. Ancient brines and sea water.
SO (mg/L)	250	Dissolved from rocks and soils containing gypsum. Sulphide ores and other sulphur compounds.
NO3 (mg/L)	50	Decaying organic waterborne diseases. Legume plants. Sewage and fertilizers.
TDS(mg/L)	500-1000	
Hardness (mg/L)	500	
Fe (mg/L)	0.3	Rocks and soils.
Mn (mg/L)	0. 1-0.5	Rocks and soils, industrial water.
Zn (mg/L)	3	Industrial wastes,
Pb (mg/L)	0.01	Industry and auto fuels and par mills.
F (mg/L)	1.5	Rocks and soils
Total Coliform colqy100ml	0	Wastes and residues of warm-blooded animals.
Faecal Coliform colony/lOOml -	0	Wastes and residues of warm-blooded animals.

2.6 Water Pollution Sources

Estimates suggest that nearly 1.5 billion people lack safe drinking water and that at least 5 million deaths per year can be attributed to waterborne diseases. With over 70 percent of the planet covered by oceans, people have long acted as if these very bodies of water could serve as a limitless dumping ground for wastes. Raw sewage, garbage, and oil spills have begun to overwhelm the diluting capabilities of the oceans, and most coastal waters are now polluted. Beaches around the world are closed regularly, often because of high amounts of bacteria from sewage disposal, and marine wildlife is beginning to suffer **[24]**.

The major sources of water pollution can be classified as municipal, industrial, and agricultural:

1. Wastewater from homes and commercial establishments is a major pollution contributor for fresh water.
2. Fertilizers contain nutrients such as nitrates and phosphates. In excess levels, nutrients over stimulate the growth of aquatic plants and algae in the water and contaminate it. Excessive growth of these types of organisms consequently clogs our waterways, use up dissolved oxygen as they decompose, and block light to deeper waters.
3. Pollution is also caused when silt and other suspended solids, such as soil, wash-off plowed fields, construction and logging sites, urban areas, and eroded river banks when it rains. Pollution in the form of organic material enters waterways in many different forms as sewage, as leaves and grass clippings, or as runoff from livestock feedlots and pastures. When natural bacteria and protozoan in the water break down this organic material, they begin to use up the oxygen dissolved in the water. Many types of fish and bottom-dwelling animals cannot survive when levels of dissolved oxygen drop below two to five parts per million. When this occurs, it kills aquatic organisms in large numbers which leads to disruptions in the food chain.

4. Industry contributes significantly to water pollution. Clearing of land can lead to erosion of soil into the river. Waste and sewage generated by industry can get into the water supply, introducing large organic pollutants into the ecosystem. Many industrial and power plants use rivers, streams and lakes to dispose of waste heat. The resulting hot water can cause thermal pollution. Thermal pollution can have a disastrous effect on life in an aquatic ecosystem as temperature increases decrease the amount of oxygen in the water, thereby reducing the number of animals that can survive there. Water can become contaminated with toxic or radioactive materials from industry.

Contaminants can be broadly classified into organic, inorganic, radioactive and acid/base. Examples from each class and their potential sources are too numerous to discuss here [21].

The effects of water pollution

The effects of water pollution are varied. They include poisonous drinking water, poisonous food animals (due to these organisms having bioaccumulated toxins from the environment over their life spans), unbalanced river and lake ecosystems that can no longer support full biological diversity, deforestation from acid rain, and many other effects. These effects are, of course, specific to the various contaminants.

How can we take measures to decrease those problems?

Science and environmental engineering provide many practical solutions to minimizing the present level at which pollutants are introduced into the environment and for remediation (cleaning up) past problems. All of these solutions come with some cost (both societal and monetary). In our everyday lives, a great deal can be done to minimize pollution if we take care to recycle materials whose production creates pollution and if we act responsibly with household chemicals and their disposal **[21]**.

2.7 The Use of GPS and GIS in Water Resources Investigation

2.7.1 The Geographic Information System (GIS)

Geographic Information System (GIS) is defined by ESRI (Environmental System Research Institute) as an organized collection of computer hardware, software, geographic data, and personal designed to efficiently capture, store, update, manipulate, analysis, and display all forms a geographically referenced information. Many GIS databases consist of sets of information called layers. Each layer represents a particular type of geographic data. For example, one layer may include information on the streets in an area. Another layer may contain information on the soil in that area, while another records elevation.

The GIS can combine these layers into one image, showing how the streets, soil, water resources and elevation relate to one another. Engineers might use this image to determine whether a particular part of a street is more likely to crumble. A GIS database can include as many as 100 layers **[13]**.

When looking at a map to know more about the features represented in it, than simply where they are. For example, when looking at a map of rivers and streams, it is helpful to know their names, and hydrologists want to know a good deal more about a river than its name. Such information as the slope of the river, the roughness of its bed and banks, and the shape of its cross-section, are important in being able to define the velocity of water flow in the river.

This type of descriptive information about a geographic feature is called its attributes. Attributes can be stored as numbers or character strings in a data record. A collection of data records makes up a data table. We thus have two descriptions available of each geographic feature: their spatial location and their descriptive attributes.

A key idea of GIS is that these two descriptions are connected by associating with each geographic feature a unique identifying number that is stored both with the spatial description and with the attribute description.

A GIS is designed to accept geographic data from a variety of sources, including maps, satellite photographs, and printed text and statistics. GIS sensors can scan some of this data directly—for example, a computer operator may feed a map or photograph into the scanner, and the computer "reads" the information it contains. The GIS converts all geographical data into a digital code, which it arranges in its database. Operators program the GIS to process the information and produce the images or information they need.

The applications of a GIS are vast and continue to grow. By using a GIS, scientists can research changes in the environment; engineers can design road systems; electrical companies can manage their complex networks of power lines; governments can track the uses of land; and fire and police departments can plan emergency routes. Many private businesses have begun to use a GIS to plan and improve their services. GIS technology attempts to precisely describe the spatial environment, while hydrology attempts to describe how water and pollutant move through the environment, then the synthesis of GIS and hydrology is spatial hydrology.

The purpose of spatial hydrology is to use spatial data and functions of GIS to help in solving the problems in water management. The spatial technology currently used in spatial hydrology is ArcGis.9 software and ArcGis.9 spatial Analysis Extension. Arc View GIS is readily available to the greatest number of users, although Arc/ Info software can be employed to solve spatial hydrology problems just as effectively [13].

The substance of current spatial hydrology is devoted to spatial data development for hydrology because GIS does not have explicit provisions for time-series data and much of hydrology is concerned with time-series measurement systems.

The ArcGis.9 Spatial Analysis has several built-in functions that enable simple watershed delineation using a Digital Elevation Model (DEM). These functions have been further developed by other organization, including the Center for Research in Water Resources (CRWR).

GIS has versions, and we will make our experiments (watershed delineation, runoff) by version "ArcGis.9 ".

2.7.2 The Global Positioning System (GPS)

The Global Positioning System (GPS) is the most significant recent advance in navigation and positioning technology. GPS is an aerospace technology that uses satellites and ground equipment to determine positions any where on earth. Anyone with a small receiver can use the system at no cost. GPS has drastically changed methods of navigation and is fast becoming important in everyday life.

Advantages of GPS surveying

For hundreds of years, surveyors have relied on optical instruments and physical measuring devices (such as tape measures or chains). Optical instruments (and newer electronic distance measuring (EDM) instruments) require direct line of site from the instrument to a target.

Measuring tapes or chains require that the survey crew physically pass through all the intervening terrain to measure the distance between two points. The big advantage of GPS is that line of site does not have to be established between two stations. Thus, surveying can be done in almost all weather conditions or on opposite sides of a mountain.

Because line of sight does not have to be established between GPS stations, major cost savings can be realized in large projects involving a large number of survey teams over a limited area (say, 100 sq miles). A single GPS receiver can be set up as a reference station which can be used by any number of surveyors, each of which can be working a job. This contrasts with conventional survey equipment in which at least two people must be working the same job (one for each end).

Accuracy requirements

Control surveys are used to establish the locations of arbitrary points. These points, called control points, may then be used as reference locations for performing additional survey work. Often, the reason for performing a control survey is to place control points in locations which are physically convenient for the intended survey work. Control surveys are generally performed to a higher standard of accuracy than other types of surveys. This is necessary because any follow-on survey work must be able to count on the accuracy of the control points, GPS smart in determine accurate location of points that's needed in (CATCHMENT) and (land use) process in this research in fast time and limited efforts.

CHAPTER THREE
Fieldwork and Methodology

CHAPTER THREE

Fieldwork and Methodology

3.1 The study fieldwork and methods include the following:-

3.1.1 Visits to Dura municipality:

We visited the municipality of Dura to take information about the Wadi Abu al-Qamra such as topography map, data for water supplied and billed for Dura town other information about the demography and sanitation will be collected also.

3.1.2 Site visits for the Wadi (fieldwork)

We visited Wadi Abu al-Qamra to identify many parameters such as:

- Location of the boundary (catchment) by GPS.
- Collect data about springs as shown in the table format below.
- Taking photo for each spring

Table (3.1) Basic Details of Major Springs in Wadi Abu al-Qamra in Dura Area

Number	Common Name	Discharge Q (m3/day)	Type	Water Use	Coordinate (X , Y)	Elevation	Owner
1							
2							
3							
4							

3.1.3 The use of GIS

GIS will be used to generate:

- Map for the boundary location (catchment area).
- Map for the boundary and spring location.
- Map for Aerial photo for the Wadi.
- Map for classes of spring type (dug well or spring).
- Map for water uses for the springs/well.
- Map for classes of springs according to the discharge (Q).
- Topographic map (contour map).
- Digital elevation model for the Wadi (TIN).
- Map for classes of springs by the discharge (Q) after that by using the (digital elevation model TIN) we can get the elevation of any point in the Wadi such as elevation of springs.
- Map for spatial classification of the springs/wells (clusters).
- Map for water quality classes according to NO3 levels.
- Map for water quality classes according to Cl levels.
- Map for acceptable/nonacceptable water quality (according to NO3 and Cl levels).

3.1.4 Water Sampling and Analysis:-

A comprehensive sampling program concerning springs in Wadi Abu al-Qamra will be conducted. Our procedure in the field will be to have sampling bottles for each spring. Each bottle before filling will be sterilized in the PHG laboratory.

In the field bottles will be first rinsed with the water intended for sampling. Each bottle will be filled completely and placed in ice box. Until arrived at the laboratory.

Direct measurements were made at each site with a Mettler Toledo set of probes giving readings for temperature, electrical conductivity and PH.

All analysis will be carried out according to each instrument catalogue and according to the hand book "Standard Methods for the Examination of water and wastewater, APHA, AWWA, WEF, 1998"

3.2 Measurements

3.2.1 Measurements of Total Dissolved Solids

Name: Total Dissolved Solids

Definition: The sum of all dissolved solids in water or wastewater and an expression of water salinity in mg/l empirically related to electrical conductivity (EC) in mmhos/cm multiplied by 640.

Apparatus: Laboratory Conductivity Meter (sension7).

Method: APHA standard methods, 1995

Procedure:

To determine TDS with the sension7 meter:

1. Press the TDS key on the keypad. The instrument will display the TDS value for the currently displayed conductivity measurement.
2. The standard method to determine TDS (Total Dissolved Solids) is to evaporate the sample to dryness at 180 °C, then weigh the residue.

3. Another way to estimate TDS is by calculating the concentration of sodium chloride that would have the same conductivity as the sample at the same temperature.
4. The sension7 meter reports a sample's TDS value in mg/L of sodium chloride by comparing the sample conductivity and temperature to data stored in the meter's memory.
5. Data were obtained from empirical procedures using sodium chloride solutions.

3.2.2 Measurements of Salinity

Name: Salinity

Definition: The salinity of the soil water is related to, and often determined by; the salinity of the irrigation water.

Apparatus: Laboratory Conductivity Meter (sension7).

Method: APHA standard methods, 1995

Procedure:

1. To determine salinity with the sension7 meter, press the SAL key on the keypad. The instrument will display the salinity value for the sample being measured.
2. Salinity, a measure of the mass of dissolved salts in a given mass of solution, is used to describe seawater, natural, and industrial waters. Salinity is a relative scale based on a KCl solution. A salinity value of 35

is equivalent to a KCl solution containing 32.4356 g KCl in 1 kg of solution at 15 °C. Salinity is measured in ‰ (ppt - parts per thousand).

3. The meter calculates the salinity based on the Extended Practical Salinity Scale of 1978, as referenced in 17th edition of Standard Methods, 25200 B. The applicable range is 0 to 42‰ and -2 to 35 °C.

3.2.3 Measurements of Conductivity

Name: Conductivity

Definition: The Electrical Conductivity (EC) of water is a measure of the ability of a solution to conduct an electrical current.

Apparatus: Laboratory Conductivity Meter (sension7).

Method: APHA standard methods, 1995

Procedure:

1. Determining conductivity with the sension7 meter is easy; just press the COND key on the keypad. The instrument will display the conductivity value for the sample being measured.
2. For conductivity, place the probe into the sample and make sure the slot on the end of the probe is totally immersed. Agitate the sample with the probe for 5-10 seconds to remove bubbles that may be trapped in the slot.

3.2.4 Measurements of pH

Name: Conductivity

Definition: pH is indication of acidic or basic nature of wastewater. A solution is neutral at pH value 7.

Apparatus: Laboratory pH Meter (sension3).

Method: APHA standard methods, 1995

Procedure:

1. Place the electrode in the sample. Press READ/ENTER stabilizing.., will be displayed, along with the sample temperature and the pH or mV reading. These values may fluctuate until the system is stable.
2. If the Display Lock is enabled, Stabilizing.., will disappear and the display will "lock in" the pH or mV and sample temperature when a stable reading is reached. If the Display Lock is off, Stabilizing.., will still disappear, but the display will show the current reading and temperature and the values may fluctuate.
3. Record or store the pH and mV value.

3.2.5 Measurements of chloride

Cl; argentometric titration

Principle

In a neutral or slightly alkaline solution, potassium chromate (K_2CrO_4) can indicate the endpoint of the $AgNO_3$ titration of CR AgCl Is precipitated quantitatively before red Ag_2CrO_4 is formed.

Interference

Substances in amounts normally found in potable waters will not interfere. B(, I and CN register as equivalent Cr. Sulfide, S2032 and SO3 interfere but can be removed by treatment with H_2O_2. OiTho-P04 in excess of 25 mg/L interferes by precipitating as Ag_3PO_4. Fe in excess of 10 mg/l. interferes by masking the endpoint. A potentiometric method is suitable for coloured or turbid samples in which the colour indicated endpoint might be difficult to observe. However, a turbidity and colour can also be removed by treatment with $Al(OH)_3$.

Reagents

a) K_2CrO_4 indicator: Dissolve 12.5 g K_2CrO_4 in a little H_2O, add $AgNO_3$ solution until a definite red precipitate is formed. Let stand 12 h, filter and dilute to 250 ml.

b) $AgNO_3$ titrant: Dissolve 2.40 g $AgNO_3$ in water and dilute to 1000 ml. Store in a brown bottle. Standardize against NaCI;

1 mol Ag^+ = 1 mol Cl^-.

c) NaCI standard: Dissolve 824 mg NaCI, dried at 140° C, in water and dilute to 1000 ml. 1 ml = 0.0141 mmol Cl^-.

d) Phenolphthalein indicator: Dissolve 0.5 g in 50 ml ethanol and add 50 ml H_2O.

e) NaOH 1 M: Dissolve 4 g in 100 ml H_2O

f) H_2SO_4 0.5 M: Add 2.7 ml conc. H_2SO_4 to 100 ml H_2O.

g) H_2O_2 30%.

h) $Al(OH)_3$ suspension: Dissolve 30 g $AlK(SO_4)_2.12H_2O$ in 250 ml H_2O. Heat to 60°C and add 14 ml conc. NH_4OH slowly with stirring. Let stand about 1 h, transfer to a large bottle and wash precipitate by successive additions, with thorough mixing and decanting with water, until free from chloride. The suspension occupies a volume of approximately 250 ml.

Standardization of $AgNO_3$

1. Pipet 10.00 ml NaCl standard in an Erlenmeyer flask of 250 ml
2. Add about 90 ml H_2O; adjust to pH 7-10 if necessary
3. Add 1 ml K_2CrO_4 indicator
4. Titrate with $AgNO_3$ to pinkish yellow end point. Be consistent in endpoint recognition.

Molarity $AgNO_3$ = 0.141/ML titrant

Procedure

1. Use a 100 ml sample or a suitable portion diluted to 100 ml which contains 0.15-10mg Cl^-.
2. If the sample is highly coloured or turbid, add 3 ml $Al(OH)_3$ suspension, mix, let settle and filter. If sulfide, sulfite or thiosulfate is present, add 1 ml H_2O_2 and stir for 1 mm.
3. Adjust pH 7-10, if necessary
4. Add 1 ml K_2CrO_4 indicator
5. Titrate with $AgNO_3$; be consistent in endpoint recognition
6. Carry out a blank, a titration volume for the blank of 0.2-0.3 ml is usual.

Calculation

mg Cl^-/L = (A - B) x M x 35.45 x (1000/ ml sample), where

A= ml titration for sample

B = ml titration for blank

M = molarity of $AgNO_3$

3.2.6 Measurement of Nitrate

Determination of anions, NO3'

NO_3^- ; U.V. spectrophotometric screening method

PRINCIPLE

Use this technique only for screening samples that have low organic matter contents; i.e. uncontaminated natural waters and potable water supplies. Measurement of U.V. absorption at 220 nm enables rapid determination of N03. Because dissolved organic matter also may absorb at 220 nm and N03 does not absorb at 275 nm, a second measurement made at 275 nm may be used to correct the N03 value. The extend of this empirical correction is related to the nature and concentration of organic matter and may vary from one water to another. Acidification with I M HCI prevents interference from hydroxide or carbonate concentrations up to 1000 mg CaCO3/L.

Interference

Dissolved organic matter, surfactants, N02, $Cr6^+$, chlorite and chlorate interfere. Chloride has no effect on the determination.

Apparatus

Spectrophotometer for use at 220 and 275 nm with quartz cells of 1 cm.

Reagents

a) Standard $N03^-$: 1.00 ml=10.0 micro g N03-N.

b) HCI 1M

Calibration

1) Dilute 0; 5.00; 10.00; 15.00; 20.00 and 25.00 ml standard NO3 to 50 ml in volumetric flasks. Add 1 ml 1 M HCI and mix

2) Measure the absorbance at 220 nm and 275 nm against H2O. "Zero" the instrument for both wavelengths Remark: clean the quartz cells carefully with special tissues and use the same cell, as much as possible, for measurement of the standards and samples

3) Subtract two times the absorbance reading at 275 nm from the reading at 220 nm to obtain absorbance due to $N03^-$.

4) Plot the absorbance against micro g N03—N/50 ml and determine the mathematical expression of this line.

Procedure

1. To 50 ml clear sample, filter it necessary, or a portion diluted to 50 ml, add 1mL 1 M HCI and mix

2. Proceed as mentioned under calibration.

3. MgNO3- -N/L =

(Micro g NO3 - N in 50 ml end volume / ml sample).

CHAPTER FOUR

Study Area Description

CHAPTER FOUR

Study Area Description

4.1General Background

Focus on springs (and dug-wells) in our area is increasingly gaining more interest as a result of being located in a water-scarce country. These are complementary fresh water resources. These resources could produce a significant amount of water for different uses. The water produced from springs is mostly available at cheaper price in comparison with piped-water supply. Although many springs are public, it seems to be that a significant number of them are privately-owned. The water of theses sources are used in agriculture, animal watering and drinking. Sometimes it is transported by vehicle-tankers and sold to people living in areas where piped-water is unavailable and especially in summer times the cost of 1 cubic meter could approach $ 2-3 when sold as tankered water for remote areas.

Protection of the water quality of these resources is crucial due to their vulnerability to pollution because they are discharging from shallow water tables. Non-sanitary conditions and increased urbanization and random development are threatening the water quality and degrading it.

4.2Dura Municipal Area

4.2.1 Location

Dura Town is located 8 kilometers to the southwest of the City of Hebron. The total land area of the town is about 14,000 dunums. Dura is considered as a center of a several surrounding villages such as Khursa, Al-Tabaqa, Deir Samit, Al-Kumn, etc... It is a center for a region of population size not less than 40,000. The location map of the town is shown in Figure 4.1.

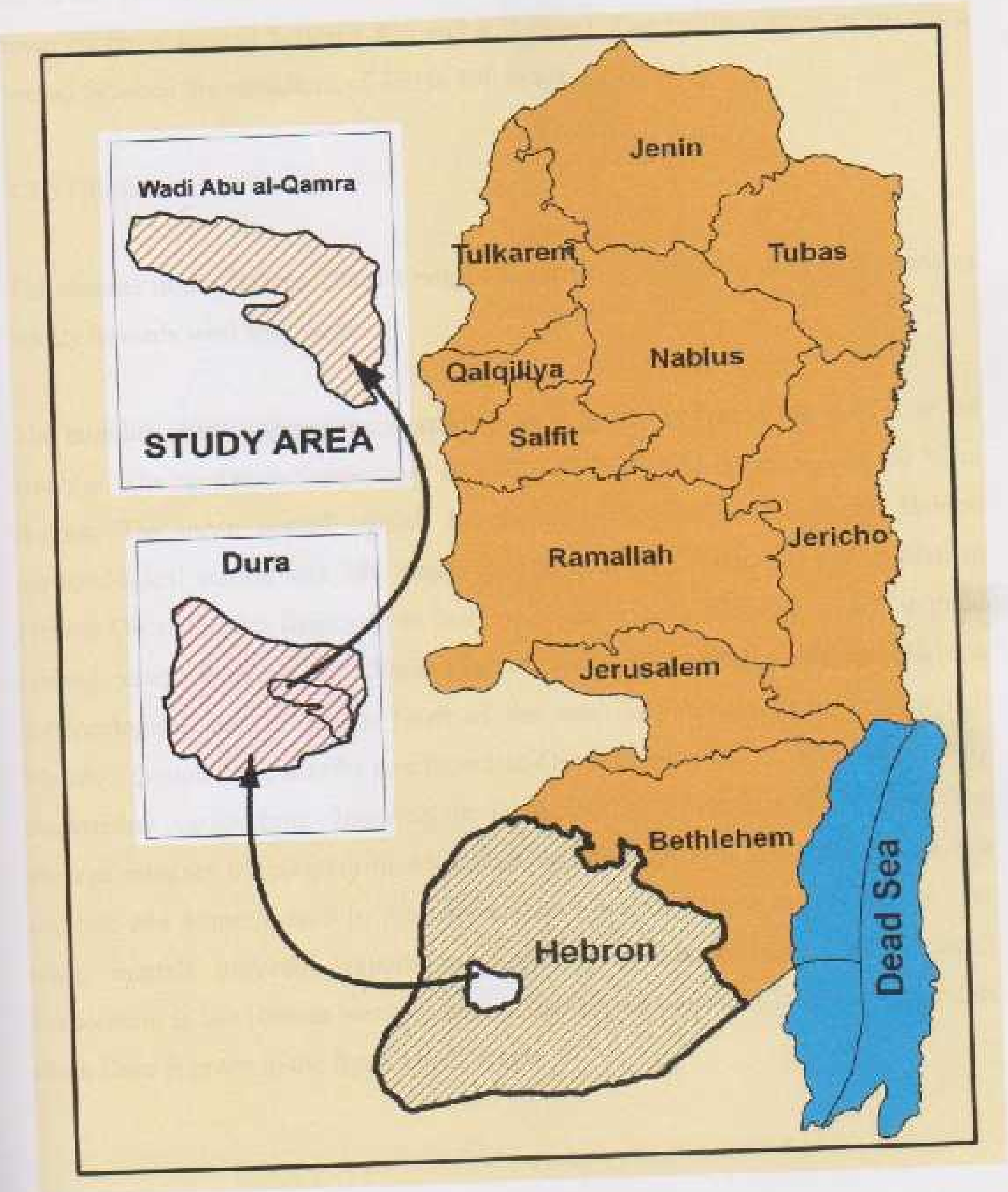


Figure 4.1 Study area

4.2.2 Topography

The area consists of mountains with steep slopes and a few plain areas located east of the town. The town is about 900 meters above mean sea level (asl). The area of the town center is located between 820 and 870 m asl. The built-up areas of the town spread between the elevations of 760 to 890 m asl.

4.2.3 Climate

The climate in the Hebron District ranges from arid to semi-arid with an increase of aridity towards west and south.

The monthly average temperature ranges from 7.5-10°C in the winter to 25°C in the summer. The minimum temperature is 3 °C in January and the maximum 40 °C in August. The mean annual rainfall for the period of 1970-1992 at the Hebron meteorological station was 588 mm/year. The quantity of mean annual rainfall in Hebron District varies from year to year, while the rainfall reaches 1027mm in good raining years, it drops to 200mm/year during the drought conditions (Hebron meteorological station, 2002). Most of the rain falls during December through March, although there may be rain from mid-October to the end of April. Mean daily evaporation varies from 2mm/day in December to 8.5mm/day in August. The average monthly evaporation in Al-Arroub weather station is 230mm/month in the summer and 80mm/month in the winter. There are only three months of the year when rainfall exceeds evaporation. Figure (4.2) shows more details about evaporation in the Hebron weather station. During the period 1975-1997. Other data about Dura is given in the figures (4.3) and (4.4)

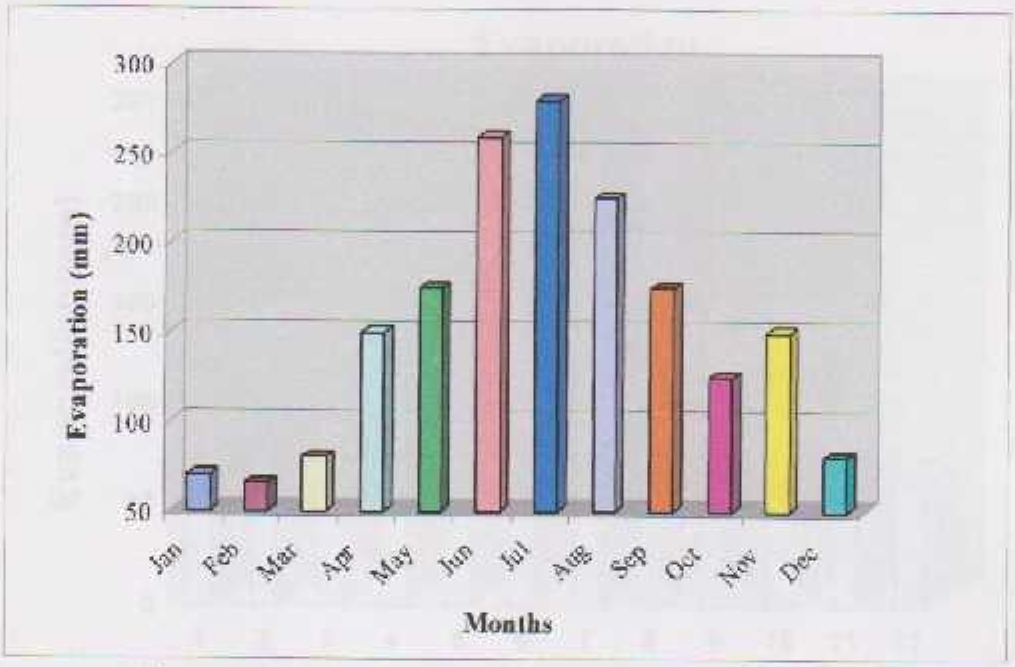


Figure (4.2): Mean Monthly Evaporation for Hebron Area
Source of the figure: **[16]**.

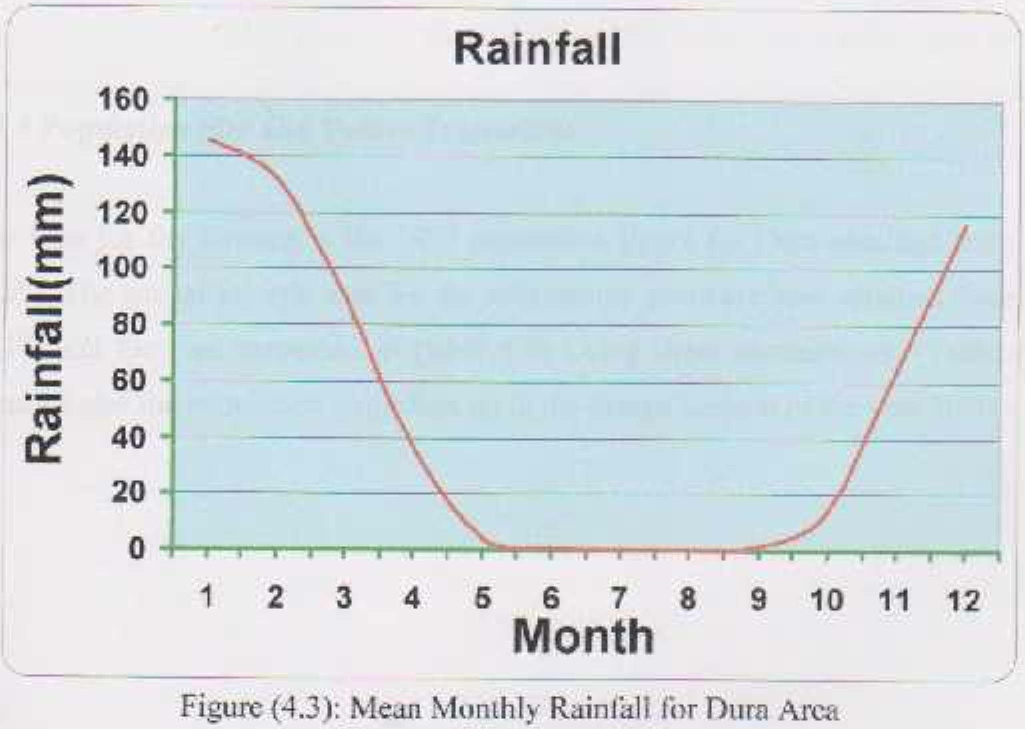


Figure (4.3): Mean Monthly Rainfall for Dura Area
Source of the figure: **[16]**.

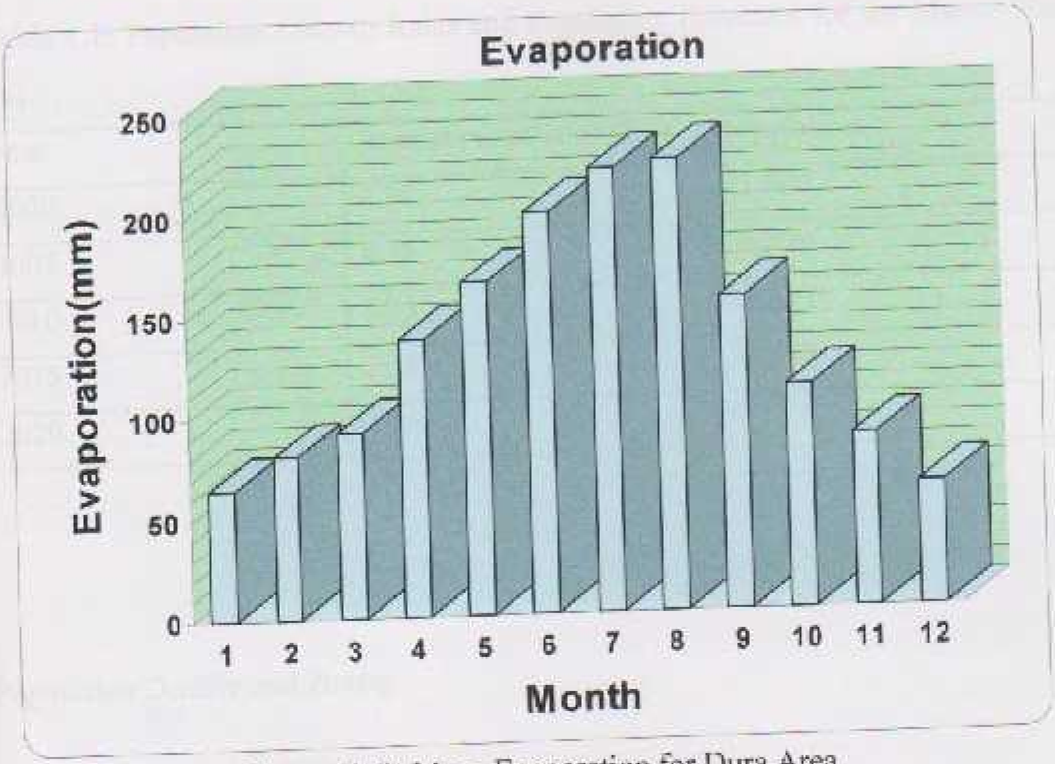


Figure (4.4): Mean Evaporation for Dura Area
Source of the figure: [16].

4.2.4 Population Size and Future Projections

The base for the forecast is the 1997 population figure for Dura obtained from the PCPS. The annual growth rates for the next twenty years are also obtained from the PCPS and they are presented in (table 4.1) Using these assumptions, (Table 4.1) presents also the population projection up to the design horizon of the year 2020.

Table 4.1: Population Growth Rates and Population Forecasts for the Master Plan [16].

year	Annual growth rate (%)	population
2000	4.56	21,800
2005	4.24	26,800
2010	3.73	32,200
2015	2.51	36,450
2020	2.26	40,750

Population Density and Zoning

According to the Engineers of the Municipality, the town of Dura is subdivided into planning zones according to the land use. The zones are residential, agricultural, commercial and industrial. In addition to the old city, the residential zones are subdivided into sub-zones A, B and C. There is an ongoing modification to the existing planning zone of 1992. The total municipal area is approximately 7,000 dunums and there is a plan to expand the municipal boundaries to become 14,000 dunums. It should be noted that the population of the old city, which represents the highest population density, will remain almost constant as it is already saturated while the other residential zones represent the attractive areas for the citizens.

4.2.5 Water Supply

Current Conditions

The main water source for Dura town is from Al-Fawwar wells, which is owned and operated by Hebron Municipality. The average water quantity which is supplied to Dura is around 400m^3/day. Table 4.2 represents the quantities of water supplied and billed for the last three years.

Table 4.2: Quantities of Water Supplied and Billed for Dura Town **[16]**.

year	Water supplied (m^3)	Water billed (m^3)	Unaccounted for water (%) (Leakage)
1996	146,036	77,353	47
1997	155,370	95,074	39
1998	138,726	89,476	36

As presented in Table 4.2, the unaccounted for water in the distribution network is about 35- 50% of the quantity of water pumped into the network.

Due to insufficient water quantities pumped into the network, the people of Dura rely on rainwater harvesting as an additional water supply source. Almost all new houses have underground cisterns built at the time of construction. It is estimated that around 70% of houses have individual cisterns with an average capacity of 40-60m^3.

The people of Dura are forced to purchase water through the water tanker during the summer season to meet their basic needs. Most of theses tanker-trailors bring water from Dura springs such as those of Wadi Abu al-Qamra.

There is no available data about the commercial and industrial water consumption for the Dura town. Main water consumers are the two stone cutting factories and the five brick plants.

On-Going and Projected Water Consumption

It is estimated that water consumption in Dura will dramatically increase during the next few years, due to several ongoing water projects, which are:
-Drilling new production wells;
-Upgrading the existing water supply system;
-Rehabilitation of the existing network; and
-Detecting network leakage as well as dealing with institutional development of water sector and tariff structures.

The Dura Municipality has projected the existing per capita water consumption at about 100L/c/d. It is estimated that the per capita water supply will be 170L/c/d including the physical losses in the year 2020. Assuming the physical losses (i.e., leakage) at about 20%, the per capita water consumption will be 136L/c/d in case new water sources for supply will be introduced. It should be noted that the figure includes commercial and industrial consumption. The water consumption for years between 1999- 2020 was interpolated from these estimates by assuming per capita water consumption will increase linearly between years 1999 and 2020. The estimated per capita water consumptions for the years 2005, 2010, 2015 and 2020 are presented in Table 4.3.

Table 4.3: projection of Per Capita Water Consumption [16].

year	Water consumption l/c/d
1999	100
2005	110
2010	119
2015	127
2020	136

4.3 Wadi Abu al-Qamra Description

4.3.1 Location

The study area, named Wadi Abu al-Qamra area, is located in Dura City of the Hebron area which known later as Wadi Abu-Qamra watershed. The watershed is situated between latitude 83-120 N and 138-183 E referenced on the Palestinian Grid in eastern Dura city, with an elevation ranging from 700-800 m asl and extended over a total area of 0.5 square kilometer. The watershed receives an average annual rainfall of 450 mm and more than 90% of the rainfall is received during the winter season (November-March). The minimum and maximum temperature varies in the range of 10 °C to 25 °C. The soils of the watershed are characterized by light sandy to clay loam with wadi gravel and wadi deposits, and the major land use categories in the watershed are mostly agricultural with some being residential in the wadi path up-hills.

4.3.2 Previous Studies on Water Quality in the Area

General background

Springs are an important, but secondary, source of water for drinking and other domestic purposes and for irrigation and other agricultural uses throughout the West Bank. Rural villages, particularly in the south-west, depend on spring water to a much greater extent than do urban dwellers.

Abdul-Jaber (1994) studied the effect of septic tanks on the water quality of the shallow local aquifer system, taking the springs of the village of Sinjil as an example. Abdul-Jaber (1995) evaluated the chemistry of some springs and groundwater wells from the central and northern parts of the West Bank. He showed that there are four water types represented in the West Bank. The most abundant type is the earth alkaline with prevailing bicarbonate, followed by the earth alkaline with increased portions of alkalis and prevailing bicarbonate, then the earth alkaline water with increased portions of alkalis and prevailing chloride and lastly the alkaline water with prevailing chloride.

Abdul-Jaber and Aliewi (1996) studied the water quality and chemistry of the springs of Nablus City, especially those used for domestic purposes. They concluded that the major springs in the city are suitable for domestic use from the chemical point of view and can be relied on for any future development.

Abdul-Jaber *et al.* (1997) studied the effect of contamination from wastewater on the shallow perched aquifer systems in the northern West Bank. They concluded that most of the springs and wells within the heavily populated areas were probably contaminated with wastewater through infiltration from septic tanks and the open conduit of raw sewage. Abdul-Jaber (in press) studied the springs and groundwater wells in the Zeimar catchment (Nablus to Tulkarm). The study showed that the water chemistry of the wells and springs is determined by the lithology of the aquifer itself and by the human activities in the recharge areas of these water resources. The springs of Nablus that lie in the western part of the city as well as the springs of Beit Wazan and Beit Umrin are heavily polluted and thus not suitable for drinking. The wells that lie along Wadi Zeimar, such as those of Anabta, Nur Shams and some of the wells of Tulkarm are polluted. This pollution is due to the infiltration of wastewater flowing in the Wadi between Nablus and Tulkarm.

Abed Rabbo *et al.* (1995) presented the results of a study of the biological characteristics of the networks, cisterns and springs in the Nablus, Jenin, Qalqiliya and Tulkarm areas, based on coliform testing. The study showed that about one third of these water resources are free of coliform contamination and thus satisfactory for drinking, according to the World Health Organization guidelines (WHO, 1995).

Abed Rabbo *el al.* (1997) in the unpublished final report for the Ford Foundation presented the results of an extensive study of springs and wells throughout the West Bank. The study aimed to determine the levels of biological and chemical pollution and recommended means of improving the situation.

The springs of Dura

This collection, which includes the springs of Dura and Taffuh, is represented in this study by 22 samples collected from 18 springs. The EC of this group ranges from 250 to 2500 (S/cm, Ca^{2+} from 14 to 225 mg/L, Cl^- from 20 to 290 mg/L and NO_3^- ranges from 4 to 500 mg/L.

The results show that all the springs of the Dura group are generally contaminated with coliform bacteria, but some are occasionally free of coliform. Thus, the springs of the Dura group are not suitable for drinking unless disinfected. Chemically, the springs of Al Baiarah and Bir Al Sharif in Dura exceed the WHO (1995) guidelines for K, N03 and Cl. The springs of Alaqa Al Foqa and Dilbi exceed the N03 permissible concentration. Thus, the water of these springs is not suitable for drinking (Table 1). Detailed heavy- metal analysis was conducted on all the samples but did not show amounts that might cause alarm.

The Sawyer and McCarty (1967) classification of water, based on total hardness, shows that the water from the majority of the springs is "hard" water. The springs of Alaqa Foqa, Qais in Abdah, Bir Al Sharif and Al Baiarah in Dura and Fir'ah in Taffuh have "very hard" water and the Al Bustan spring in Taflhih has "soft" water.

The water of the springs of the Dura group in the Hebron district ranges from excellent to permissible for irrigation purposes, based on the SSP. The water of the majority of the springs is of good SSP. The springs of Fir'ah in Taffuh, Imran, Majnuna, Kanar in Dura and Kurza are of excellent SSP. The Al Bustan spring in Taffuh is of permissible SSP. (Table 1).

The water of the springs of this group is classified into three classes, based on the ECSAR relationship. The springs of Dilbi and Kannar in Dura and Kurza and Fir'ah in Taffuh are classified as low sodium - medium salinity hazard (SI -C2) water. The springs of Allaton in Beit 'Awwa and Qais in Abdah are classified as low sodium - high salinity hazard (S i-C3) water and Bir Al Sharif in Dura is classified as low sodium - very high salinity hazard water. Many springs of the Dura group could be used for irrigation, based on the SSP and EC-SAR classification, with limitations, especially Bir Al Sharif.

Table 4.6: Major microbiological and chemical characteristics of some springs of Dura [5].

Spring	Date	SAR	SSP	TDS mg/L	EC micro-S/cm	K mg/L	Cr mg/L	NO3 mg/L	FC #./100mL	TC #/100mL
'Alaqa Foqa	25.6.96	1.6	27.8	462	1300	1.0	175.0	114.8	>1000	>1000
Qais	25.6.96	1.0	22.3	330	880	0.9	90.4	29.7	> 1000	> 1000
Al-Baiarah	11.1.96	3.0	37.1	731	247	23.0	264.5	500.0	95	> 1000
Bir Al Sharif	25.6.96	2.3	37.7	693	2270	92.7	263.0	304.2	> 1000	> 1000
Dilbi	11.1.96	0.7	23.8	197	528	8.0	40.2	31.5	0	0
Imran(No.2)	11.1.96	0.5	17.1	241	598	5.6	29.4	11.4	>1000	>1000
Karnar	11.1.96	0.5	16.6	179	448	0.8	22.5	9.5	> 1000	> 1000
Majnuna	11.1.96	0.7	18.6	236	594	2.4	37.2	35.0	>1000	>1000
Kurza	25.6.96	0.7	18.1	262	637	0.7	29.2	11.3	> 1000	> 1000
Bustan(Hawooz)	29.1.96	1.5	52.5	66	287	10.3	21.6	3.7	5	20
Fir'an	29.1.96	0.7j 17.2		303	724k	1.2	54.9	30.61 1		8

Recently, we represent here the following data tables on the public springs of the area. Some of the springs are located in the target study Wadi. Tables 4.7, 4.8, 4.9, give some data about the area's springs

Table (4.7): Hydrogiological Data about the area springs [7].

Name	Type	Locality	Formation	Discharge (m^3/day)	Saturated Thickness (m)	Depth to Water Table (m)
Al-Qharbi well	Dug Well	Dura	Hebron-Bethlehem-Jerusalem Formations	18.0	10.0	6.2
Abu Al-Khalasi	Dug Well	Dura	Hebron-Bethlehem-Jerusalem Formations	30.0	5.0	2.0
Salman/Abu Edbarah	Dug Well	Dura	Hebron-Bethlehem-Jerusalem Formations	7.5	8. 0	2.0
Al-Sharqi well	Dug Well	Dura	Hebron-Bethlehem-Jerusalem Formations	11.0	3.0	12.0
The Water canal at Wadi Abu-Alqamrah	--------	Dura/Wadi Abu-Alqamrah	Yatta	1382.0	0.0	0.0
Al-Rjoob	Spring	Dura/Wadi Abu-Alqamrah	Yatta	66.5	0.0	0.0
Al-Wad/Ehdeid	Dug Well	Dura/Wadi Abu-Alqamrah	Hebron-Bethlehem-Jerusalem Formations	27.0	0.2	2.2

A clear remark from table 4.7 is that the Wadi flow in the wet season was exceeding 1000 m^3/day which makes the Wadi water quantities as significant for use.

Table 4.8: Water Quality Data about the area springs [7].

Name	Location	pH	EC	Turbidity	DO	Hardness	TDS	TSS	TS	COD	Na+K
			uS/cm	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Al-Rjoob	Dura/Wadi Abu-Alqamrah/Dura	7.9	1001	13.7	6.17	445.06	491	82.33	573.33	13.71	100.7
Al-Wad/Ehdeid	Dura/Wadi Abu-Alqamrah/Dura	7.53	1354	3.08	5.21	749.78	570			10	130
Al-Sharqi well	Dura	8.65	1918	2.7	6.86	601.21	962	338	1300	10	157
The Water canal at Wadi Abu-Alqamrah	Dura/Wadi Abu-Alqamrah/Dura	8.4	1659	10.5	7.78	543.03	827	217	1044	10	120.4

Name	Ca	Mg	NH4	NH4_N	Cl	NO3	SO4	PO4	PO4_P	S	TC
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	coliforms/100ml
Al-Rjoob	85.5	55.47	0.15	0.11	80.76	158.51	39.59				0
Al-Wad/Ehdeid	280	11.2	0.26	0.2	127.07	250.57	51.2				
Al-Sharqi well	124.57	70.58	0.05	0.04	165.07	263.22	111.84				2
The Water canal at Wadi Abu-Alqamrah	77.73	89.73	0.13	0.1	203.08	287.05	93.22				20

Table (4.9): Water Quality Data about the area springs [7].

Name	Location	pH	EC	Turbidity	DO	Hardness	TDS	TSS	TS	COD	Na+K
			µS/cm	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Al-Qharbi well	Dura	8.3	2820.0	2.3	4.1	756.4	1150.0	476.7	1626.7	10.0	218.8
Abu Al-Khalasi	Dura	7.6	1834.0	2.9	5.3	660.8	918.0	586.0	1506.0	10.0	164.6
Salman/Abu Edbarah	Dura	7.9	543.0	6.8	6.6	562.4	1104.0	2.7	1106.7	10.0	26.4

Name	Location	Mg	NH4	NH4_N	Cl	NO3	SO4	PO4	PO4_P	S	TC
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	coliforms/100 ml
Al-Qharbi well	Dura	68.2	0.4	0.3	301.6	353.0	88.8				200
Abu Al-Khalasi	Dura	2.3	0.4	0.3	207.8	327.2	74.4				6
Salman/Abu Edbarah	Dura	30.5	0.1	0.0	114.0	163.3	66.3				12

The table above indicates nitrate levels exceeding the WHO guideline for drinking purposes.

CHAPTER FIVE

Results

CHAPTER FIVE

Results

5.1 Introduction

This chapter presents our results. The results are available as tables. GIS maps or excel charts.

5.2 Springs Data

Table (5.1) shows the data resulted from our fieldwork survey. In indicates that the Wadi has 61 spring/wells which are mostly of private ownership. Also most of the available water in the area comes from dug wells rather than exposed springs. This means that people draw the water mainly by pumping.
The table shows discharge variation from 1 to 80 m^3/d.

5.3 The GIS Mapping

Note: All the figures of GIS maps and Tables placed at the end of this chapter.

Figure 5.1 shows a map for the catchments boundary which ranged from 152750 to 155300 on X-axis (Palestinian grid coordinates) and from 99300 to 101600 on Y-axis coordinate with a total area of about 2.67 Km^2. In general the Wadi area shape is like an arc extending from southern area by a narrow width then gaining its maximum width as we move to north-southern area while it continues to the west with approximately affixed width. The curvature angle is located in the north – southern corner of the Wadi.

Figure 5.2 shows the position of springs and wells inside the catchments boundary .In fact most of them is located in the north – western part of the catchments. The map in this figure allows distinguishing the dug – well from the spring. In the whole catchments 17 springs and 44 wells are existing. The majority of the springs are available at the center of the catchments. This may be due to topographic point of view. This will make us move to see the contour map in figure 5.3 which shows that mostly low topographic levels are existing at the middle of the catchments with elevations approaching the least values over the Wadi sections. The springs are mostly abundant in the Wadi at elevations below 810 m. as Approximately the water total depth in the Wadi meets the ground level at these elevations (<810m asl).

The topographic map (figure 5.3) also gives the interpretation of the remark: why most of wells are located at the north – western part of the catchments? This topography of the area there is with elevations > 820 m. asl. This may conclude that in the parts of the Wadi where the topographic level exceeds 840 m. asl no springs or dug wells mostly exist. The water table at these ground topographic levels is becoming deeper (i.e. < 800-810 m. asl) and this means required excavation of about 40 meters or more.

Of course geology of the area, which is beyond our study, is an important factor that interferes with analyzing the topographic issues with regard to the discussion introduced here.

The map of figure 5.8 indicates the water use patterns available for the Wadi's spring and wells. It clearly demonstrates that, irrigation is the dominant water use.
Although drinking and other uses are available, but they are only of minor existence.

Figure 5.4 is showing the map of figure 5.3 placed over the aerial image. Figure 5.4 shows the Wadi gully (floor) which is the water canal in the wet weather conditions.

In fact the Wadi path surrounding area is the main irrigated arable land in the catchments.

While the catchment borders are the adjacent hilly areas. The maps in figures 5.5 and 5.6 show the digital elevation model for the area without and with springs/wells, respectively. Most of the catchment area is with elevations in the range of 800-850 with details given for each elevation interval.

The map in figure 5.7 is showing the digital elevation model for the catchment and its neighboring areas.

The Wadi upstream is located to the north- western area of the Wadi. While the down stream is at the south – eastern part.

The map of figure 5.9 illustrates the discharge of the springs/wells expressed as 4 classes (interval). Mostly the discharge of the springs and wells was within the range of (1-5) and (5-10) m^3/d. Few springs and wells were exceeding a discharge value of 15 m^3/d. The total discharge of the Wadi's springs and dug wells is 359 m^3/d.

5.4 Water Quality

Of the Wadi 61 wells/springs, we were able to sample 49 wells/springs. The remained 12 wells/springs were inaccessible for us due to closure of its gates and the absence of the owners. During laboratory analysis focus was given to testing chloride (CL^-), Nitrate ($NO3^-$), pH, Dissolved Oxygen (DO), Electrical conductivity (EC), and salinity (SAL).

Our sampling work book place during march and may /2007 .the sampling was done during non rainy week in order to avoid direct rain dilution and to give the rain water a sufficient time to get percolated and homogeneously mixed with underground water available before . Since the rainfall this year was good and exceeds 450mm, the well/springs discharge was improved some 10% in comparison with the values which we measured in the last semester. During the winter time, the Wadi shows ephemeral water course flow with duration of about 2 weeks due to well/springs overflowing. This resulted from the elevation occurred, during winter, is the saturated water level.

5.5 General Overview

Based in our water quality results, we observed nitrate values of 212.8+129 (mg/l) (average – standard deviation). The nitrate value varies from 0.5 to 431.0 mg/l for the wells/springs. This large range of nitrate value reflects the variations in the factors affecting the Wadi water quality which change along and across the Wadi.

Chloride values for the wells/springs were 98.1±54.2 mg/l and fall within the range 8.4 to 248.7 mg/l. it clear that nitrate is more effected by land use changes rather than chloride. The electrical conductivity and TDS of the water of different wells/springs were with values of 890.9 ± 705.9 Ms/cm, 770.2 ± 325.1 mg/l, respectively.

The pH values of the water of the different wells/springs were at 7.9 ± 0.5 while DO the values were mostly > 6.0 indicating of aerobic water type. This is due to continuous aeration of the water stared in the water – bearing rock formation due to fractures and channels in the rocks.

The full data set is available in table 5.2; the reader can refer also to the water quality standards table (table 5.3) for comparison purposes using different guidelines from different countries or organizations.

Table 5.3: Guidelines for drinking water [7].

Parameter	WHO	EU	The Netherlands	US/EPA	Canada	Oman	Upper limit[c]
Nitrate mg/l	50	25-50	50	45	45	45	50
Chloride	250	25	150	250	250	200-600	600
DO mg/l or %		<75%	2 mg/l				75%
pH	6.5-9.5	6.5-8.5	7-9.5		6.5-8.5	6.5-9.2	9.2
TDS mg/l	1000	1500	1000	500	500	500-1500	1500

.6 Spatial Zonation in the Wadi

rom spatial distribution point of view, the wells/springs in the Wadi fall in 4-spatial ones (Figure 5.10 and table 5.2) according to figure 5.10 the following zones are istinguish: - Zone A: located at the Wadi upstream and contains 7 wells/springs. his area is close to built-up area and is with limited agricultural area separating it om the built- up area at the Wadi start.

- Zone B: comes directly after zone A at lower ground level. This area is more affected by agricultural activities (especially that it contains green houses) but less affected by residential areas.

- Zone C: comes in the third order as we come downward the Wadi.
Unlike zones A and B which are located along the Wadi center line, Zone C is a little bit shifted close to the Wadi north embankment and is in contact with residential are there.

- Zone D: is at the farthest downstream segment of the Wadi this area neighborhood contains no housing land use pattern. Also they are mostly with very low agricultural activities. Mostly the water of this zone wells/springs is the mostly available recharge – water type due to mostly unavailability of pollution source.

5.7 Nitrate and Chloride along the Wadi

Since nitrate changes detected for different wells/springs, were high and varies from about zero to more than 400 mg/l, we should analyses carefully the factors standing behind this huge variation.

This approach of data interpretation starts with answering a main question: what are the different sources of nitrate in the Wadi? However, we can't answer this question in separation of chloride.

So that we can calculate that nitrate comes from 2 sources. One is the sewage from underground seepage of cesspits in residential areas. The other source is the fertilization of the agricultural land. While chloride main source is the sewage contamination.

Evaporation of the irrigation water is another source that concentrates salts and makes their built-up in the soil. After rainy again to underground water.
Based on what we introduced above, we will discuss in the following the different trends of different parameters of water quality.

5.7.1 Nitrate Trend

The wells/springs nitrate levels were classified as intervals with jumping value of 50. As we calculated in chapter 2, the nitrate admissible levels according to WHO is 50 mg/l.

Based on this , we observed that 13 out of 49 sampled springs (27%) were with permissible nitrate levels and are complying with drinking water guidelines . different classes of nitrate are shown on figure 5.11.

Comparing figure 5.10 with figure 5.11 (the spatial one), we can point out the following based on figure 5.10 zones:

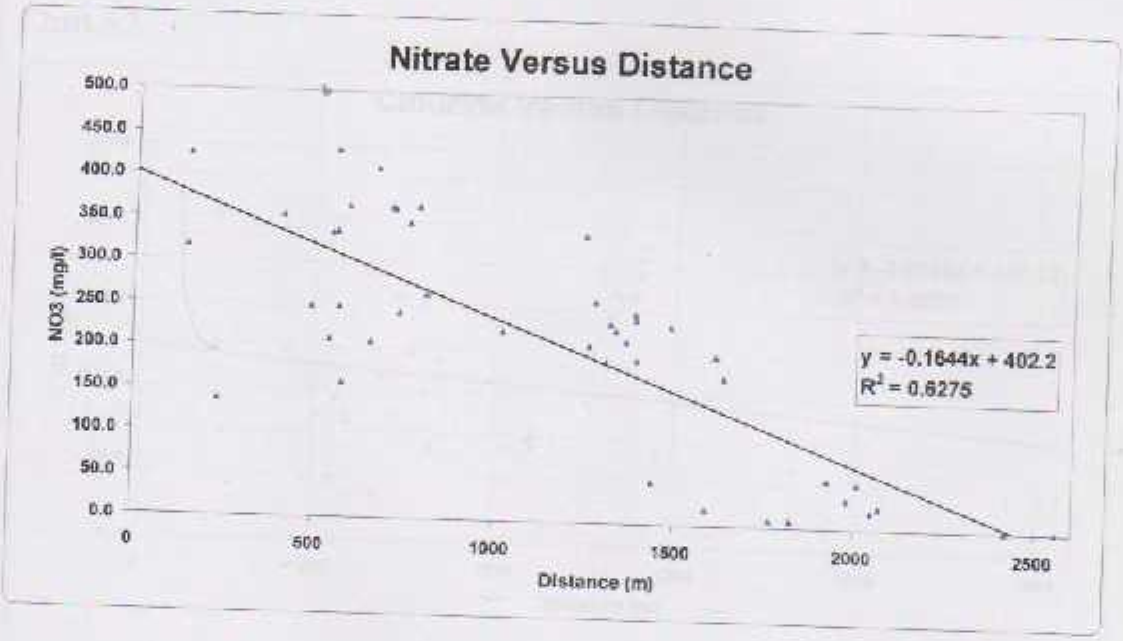
- Wells/springs following zones A, B, and C, are mostly polluted (NO_3>50 mg/l). Zones A, B are polluted from sewage and from agricultural (fertilizers) source but the agricultural pollution is the most influencing factor. However, still sewage contamination is slightly available here.

- Zone C is mostly affected by sewage contamination because it is stiked to residential area which is answered.
- Zone D springs are mostly unpolluted due to clean surrounding condition and existence at the Wadi furthest point that is considered as a clean recharge area.

Chart 5.1 shows that as we move towards the Wadi downstream nitrate concentration goes down in general.

Indicates data correlation between distance of spring location at the Wadi path and nitrate value.

Chart 5.1



5.7.2 Chloride Trend

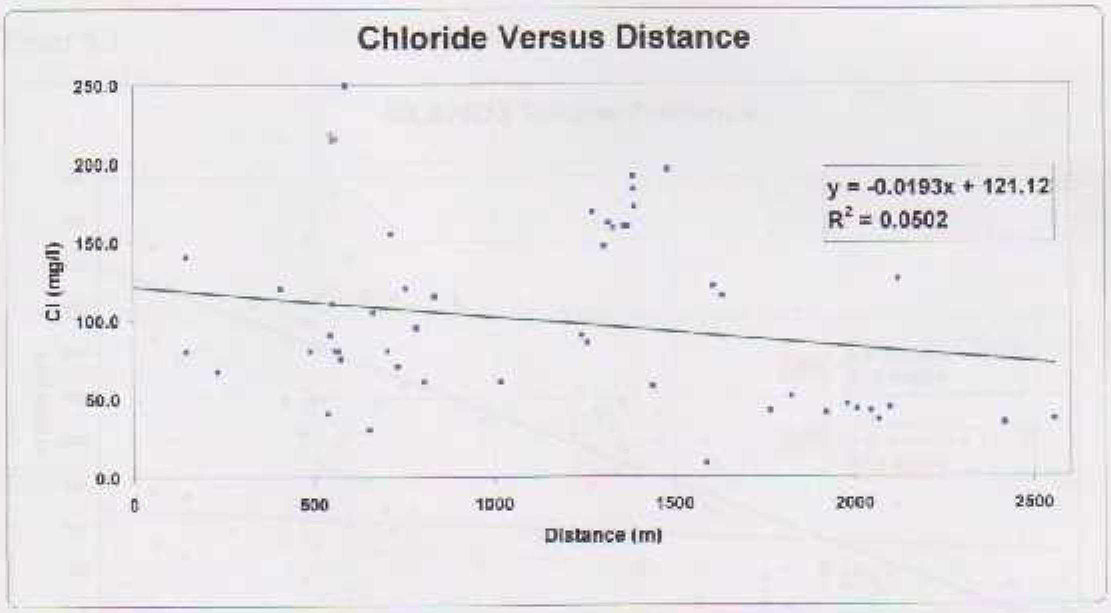
Based in figure 5.10, spatial classification and combining this with classification of chloride shown in figure 5.12 we can point out the following:

- Wells/springs of zone C which is close to residential are with the highest CL value - Wells/springs of zone A, B are showing medium chloride levels because they are at less distance from residential areas.

- Zone D, shows springs with least chloride levels as these are faraway from built up areas.

Chart 5.2 shows the variation in CL as we move downstream, however the data is with low R^2 value due to the fact that chloride comes mainly from sewage and is unlike NO3 which comes also from agricultural fertilizers.

Chart 5.2



5.7.3 Acceptability of the Water for Drinking

Figure 5.13 shows the wells/springs with acceptable water quality.
In fact, with regard to chloride, all springs are with Cl level below 250mg/l (WHO guideline). So that nitrate level is the main limiting factor in Figure 6 classification.
As it was for NO3, figure 6 shows that about (27%) of the wells/springs are with good quality.

5.8 Statistical Correlation

5.8.1 Parameter-distance correlation:

Chart 5.3 shows the trend of Cl, NO3 with distance (starting from upstream to down stream). It's clear that Nitrate is more correlated to distance (R^2 = 0.63) rather than Chloride correlation to distance (R^2 – 0.05).

Chart 5.3

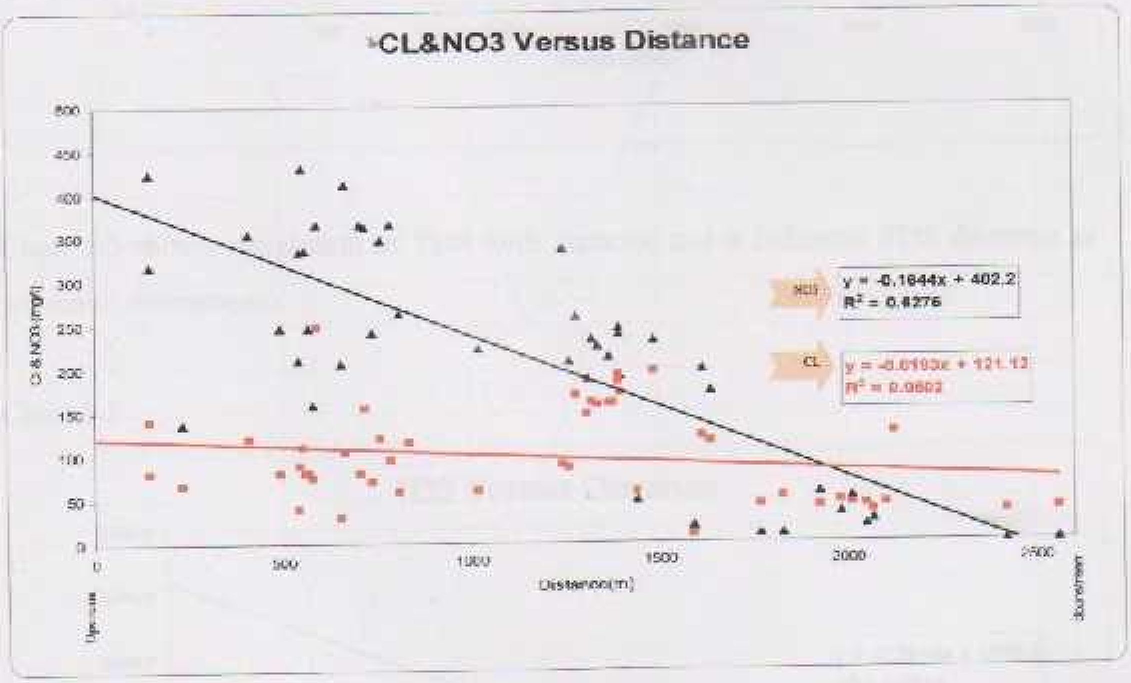


Chart 5.4 shows pH correlation to distance. Here R^2 value was 0.61 and mostly pH increases as we go downward the Wadi. This could be due to that the water of the upstream wells/springs are mostly withdrawn continuously for irrigation, while that at down stream is with less use. This higher residence or less movement of the water allow its exposure for longer time to sun light which allows algae to grow and assimilate CO2 and raise pH.

Chart 5.4

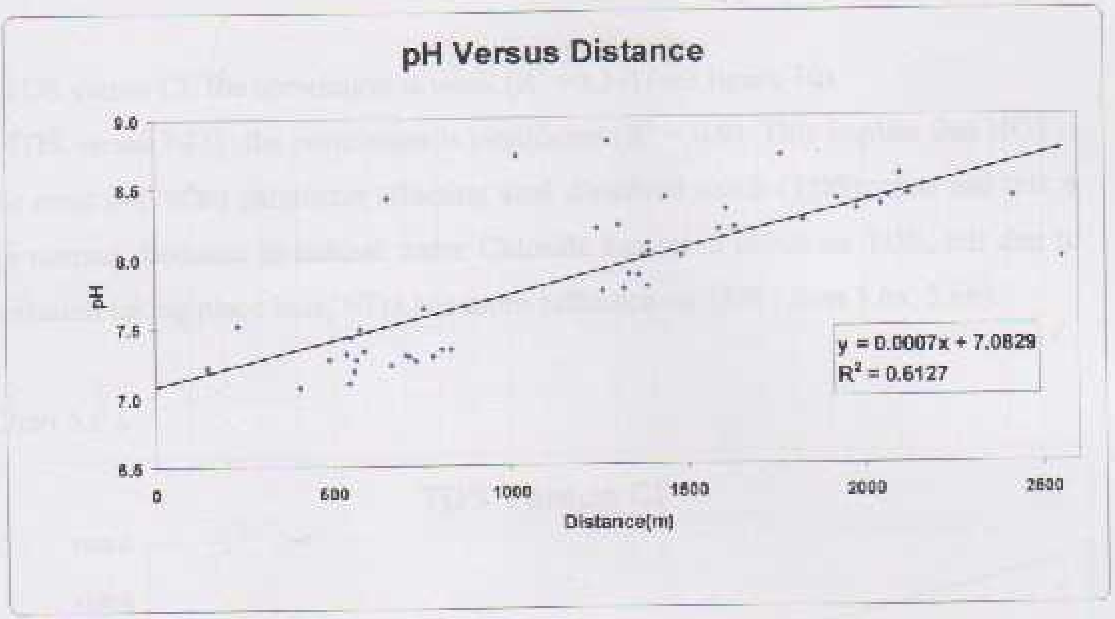
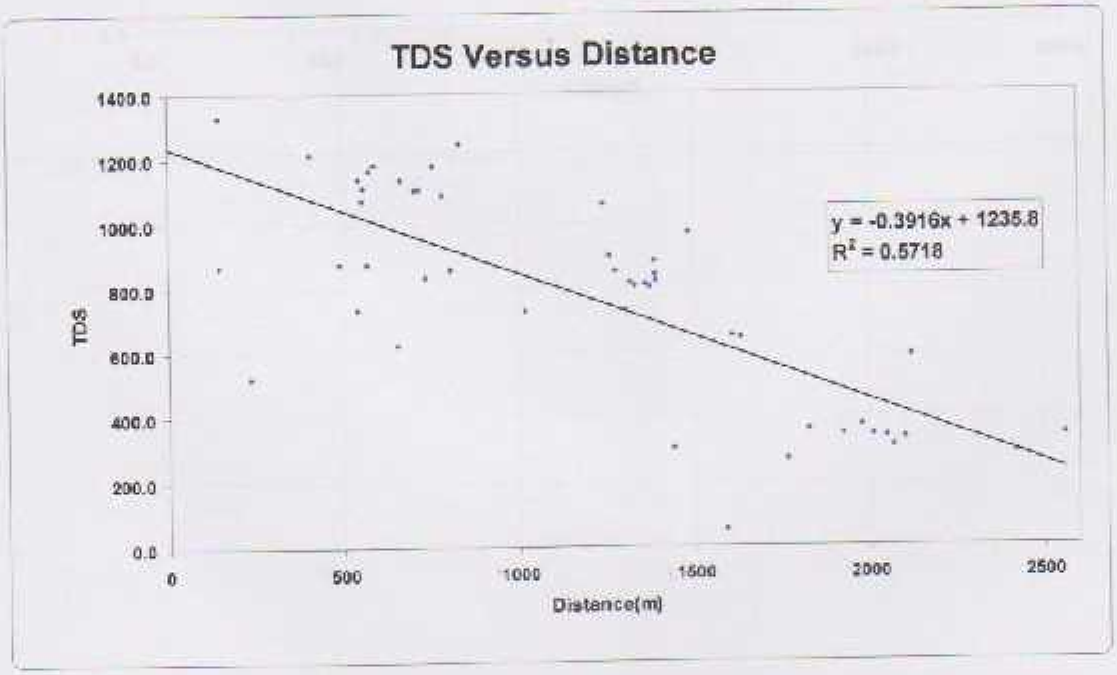


Chart 5.5 shows correlation of TDS with distance and it indicates TDS decrease as we move downstream.

Chart 5.5



5.8.2 Correlation among water quality parameters:

- TDS versus Cl: the correlation is weak (R^2 =0.34) (see figure 10).
- TDS versus NO3: the correlation is significant (R^2 = 0.9). This implies that NO3 is the most important parameter affecting total dissolved solids (TDS) value and this is up normal. Because in natural water Chloride has more effect on TDS, but due to pollution taking place here, NO3 has more influence on TDS (chart 5.6a, 5.6b).

Chart 5.6 a

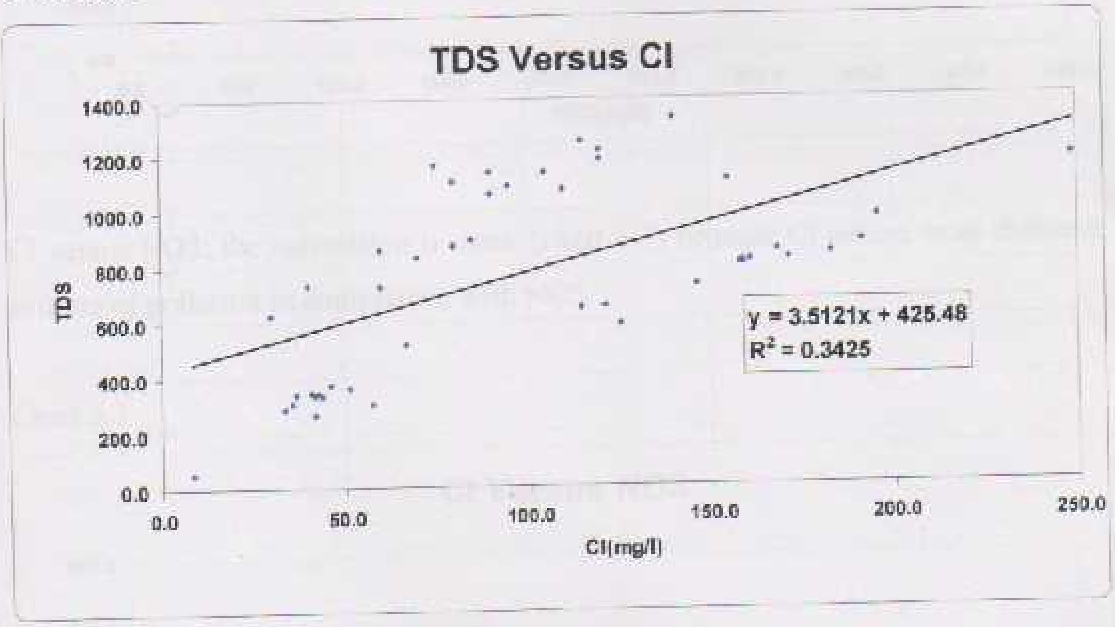
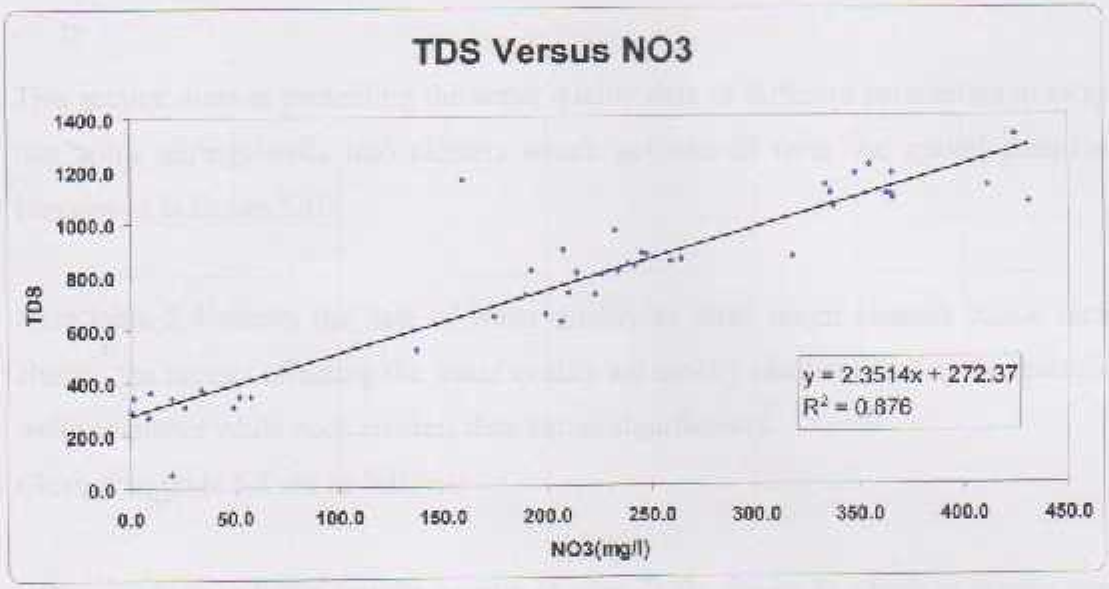
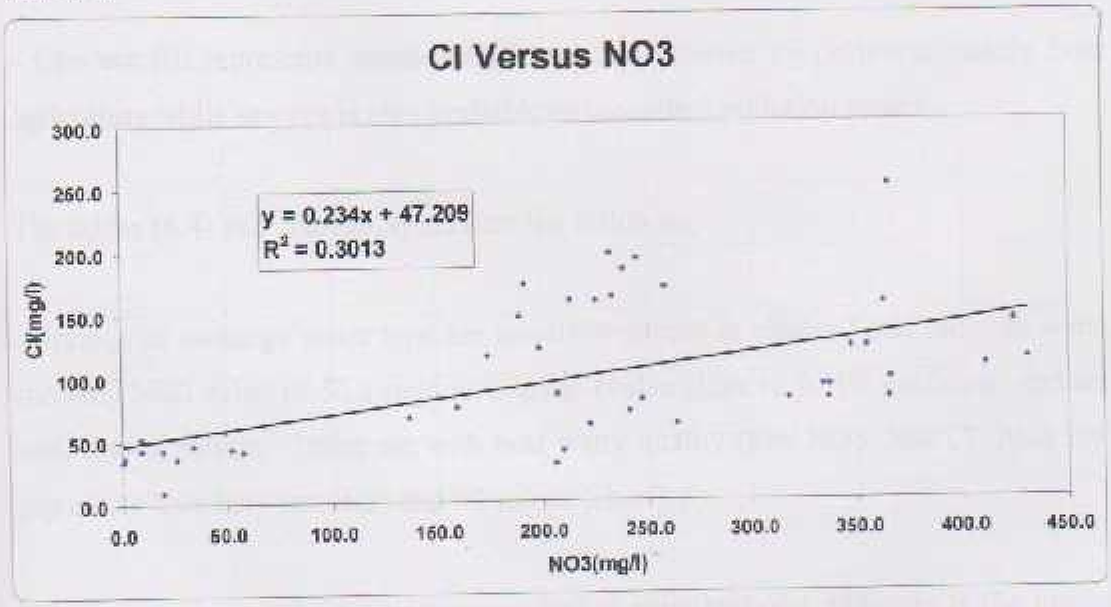


Chart 5.6 b



Cl versus NO3: the correlation is weak (chart 5.7) because Cl comes from different sources of pollution in comparison with NO3

Chart 5.7



5.9 Springs / Wells Clusters

This section aims at presenting the water quality data of different parameters in away that splits springs/wells into clusters which get benefit from the spatial zonation introduced in figure 5.10.

Here table 5.4 shows the data of water quality as three major clusters inside each cluster, the factors affecting the water quality are mostly identical among the springs/ wells available while each clusters data varies significantly.

Clusters in table 5.4 are as follows:

- Clusters I: containing springs / wells of zone D (in figure 1) which is mostly non polluted and are located in clear recharge area.

- Clusters II: contains these springs / wells of zone C which are mostly affected by pollution from sewage.

- Clusters III: represents zones A+B which are affected by pollution mainly from agriculture while sewage is also available as secondary pollution source.

The tables (5.4) and chart (5.8) indicate the following:

- Springs of recharge water type are mostly available in cluster I and are with water showing NO3 value of 50.1 mg/l as average (value close to WHO guideline) and are with lowest salinity. These are with best water quality (low NO3, low Cl).Also low gap exists here between NO3 and Cl values (chart5.8).

This is an unirrigated area with unresidential neighborhood, chloride is the lowest here (56.1 mg/l) as will as nitrate.

- Clusters II springs / wells are with elevated NO3 and Cl values with higher gap (in comparison with cluster I) existing between NO3 and Cl values.

This emphasize common source of both NO3 and Cl and is mainly sewage (chart 5.8). Nitrate is at medium value here (233.1 mg/l) while chloride is the highest.

- Clusters III shows springs / wells mostly with highest pollution the gap between Cl and NO3 is the highest indicating pollution from more than are source and no dominant source could be identified precisely. The nitrate average value here is (306.4 mg/l) and is the highest in comparison with other clusters. While chloride here is not high which indicate more pollution coming from agricultural fertilization.

Chart 5.8

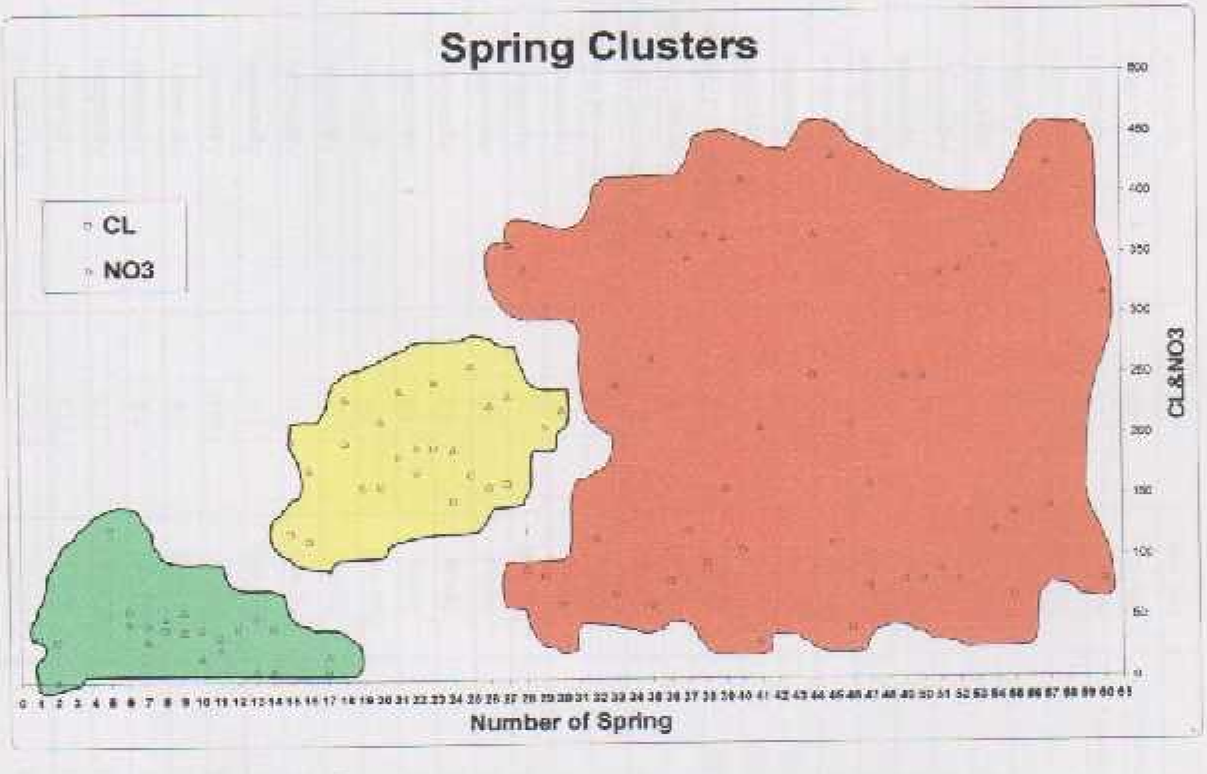


Table (5.1): The data resulted from our fieldwork survey.

NO	COMMON NAME	TYPE	DISCHARGE (m^3)	WATER USE	X (m)	Y (m)	ELEVATION (m)	OWNER
1	Ali Al-Shareef (1)	Spring	13.0	Agriculture	154689	100188	805	Ali Al-Shareef
2	Ali Al-Shareef (2)	Spring	12.0	Agriculture	154624	100298	805	Ali Al-Shareef
3	Owdeh Rjoob (1)	Dug well	5.0	Agriculture	154963	100669	799	Owdeh Rjoob
4	Owdeh Rjoob (2)	Dug well	5.0	Agriculture	154894	100720	800	Owdeh Rjoob
5	Abd Allah Owdeh	Spring	10.0	Agriculture	154836	100738	797	Abd Allah Owdeh
6	Abo Tha'er Alfar	Dug well	1.0	Agriculture	154660	100857	799	Abo Tha'er Alfar
7	Nihad Swaiti (1)	Dug well	5.0	Agriculture	154536	100696	810	Nihad Swaiti
8	Waleed Amro	Spring	11.0	Agriculture	154557	100667	811	Waleed Amro
9	A'hed Qazaz	Dug well	2.0	Agriculture	154533	100714	809	A'ahed Qazaz
10	Nihad Swaiti (2)	Spring	4.0	Agriculture	154602	100636	807	Nihad Swaiti
11	Nihad Swaiti (3)	Spring	4.0	Agriculture	154614	100625	806	Nihad Swaiti
12	Nihad Swaiti (4)	Spring	5.0	Agriculture	154616	100606	809	Nihad Swaiti
13	Ameen Abo Sba'a	Dug well	1.0	Agriculture	154457	100740	816	Ameen Abo Sba'a
14	Alhaj Khlal (1)	Spring	1.5	Agriculture	154421	100764	818	Mohammad Abd Alazeez Amro
15	Hasan Joma'a	Spring	2.0	Agriculture and Domestic use	154376	101037	806	Hasan Joma'a
16	Sa'adallah Amro	Spring	4.0	Agriculture and Domestic use	154400	101032	806	Sa'adallah Amro
17	Gazi Amro	Dug well	40.0	Agriculture and Domestic use	154348	101061	809	Gazi Amro
18	Mohammad Alseekh	Spring	2.0	Agriculture and Domestic use	154262	101091	808	Mohammad Alseekh
19	Salah Naief Hejah (1)	Spring	3.5	Agriculture	154160	101124	807	Salah Naief Hejah
20	Salah Naief Hejah (2)	Spring	1.0	Agriculture	154163	101151	809	Salah Naief Hejah
21	Ojra Hejah (1)	Dug well	2.5	Agriculture	154168	101090	804	Ojra Hejah
22	Ojra Hejah (2)	Dug well	2.5	Agriculture	154171	101084	803	Ojra Hejah
23	Ojra Hejah (3)	Dug well	2.0	Agriculture	154154	101059	804	Ojra Hejah
24	Alhaj Khlal (2)	Spring	8.0	Agriculture	154080	101111	810	Mohammad Abd Alazeez Amro
25	Alhaj Khlal (3)	Dug well	8.0	Agriculture	154050	101119	810	Mohammad Abd Alazeez Amro
26	Naief Hejah	Spring	3.0	Agriculture and Domestic use	154102	101079	809	Naief Hejah
27	Al-Namora	Dug well	4.5	Agriculture	154097	101123	810	Al-Namora Family
28	Solaiman Mohamad Amro (1)	Dug well	3.0	Agriculture	153999	101084	811	Solaiman Mohamad Amro
29	Solaiman Mohamad Amro (2)	Dug well	6.0	Agriculture	154023	101129	810	Solaiman Mohamad Amro
30	Aqel Kashoor	Dug well	2.0	Agriculture	153824	101286	820	Aqel Kashoor

NO	COMMON NAME	TYPE	DISCHARGE (m^3)	WATER USE	X (m)	Y (m)	ELEVATION (m)	OWNER
31	Omar Amro	Dug well	2.0	Agriculture	153636	101225	827	Omar Amro
32	Yasser Esser	Spring	2.0	Agriculture	153671	101361	825	Yasser Esser
33	Alhaj Aamer Alreje'e (1)	Dug well	4.0	Agriculture	153488	101156	841	Alhaj Aamer Alreje'e
34	Alhaj Aamer Alreje'e (2)	Dug well	1.0	Agriculture	153458	101155	842	Alhaj Aamer Alreje'e
35	Mohamad Abd-Alqader Abu-Sharar	Dug well	1.0	Agriculture	153563	101178	834	Mohamad Abd-Alqader Abu-Sharar
36	Majed Al-Namora	Dug well	1.0	Agriculture	153470	101257	834	Majed Al-Namora
37	Kamel Judo'a Al-Namora	Dug well	1.0	Agriculture	153520	101325	830	Kamel Jado'a Al-Namora
38	Jado'a Al-Namora	Dug well	11.0	Agriculture	153551	101274	830	Jado'a Al-Namora
39	Kamel Bader Al-Namora	Dug well	1.0	Agriculture	153483	101259	833	Kamel Bader Al-Namora
40	Mohamad Abdallah Hereebat (1)	Dug well	1.0	Agriculture	153422	101201	839	Mohamad Abdallah Hereebat
41	Mohamad Abdallah Hereebat (2)	Dug well	3.0	Agriculture and Drinking after filtration	153413	101178	840	Mohamad Abdallah Hereebat
42	Abd Alazeez Shadeed (1)	Dug well	7.0	Agriculture and Factories use	153365	101175	840	Abd Alazeez Shadeed
43	Abd Alazeez Shadeed (2)	Dug well	20.0	Agriculture and Factories use	153344	101169	840	Abd Alazeez Shadeed
44	Mohamad A'amer Alreje'e	Dug well	1.0	Agriculture	153354	101226	838	Mohamad A'amer Alreje'e
45	A'ayed Aldrabe'e (1)	Dug well	1.0	Agriculture and Drinking after filtration	153314	101179	840	A'ayed Aldrabe'e
46	A'ayed Aldrabe'e (2)	Dug well	3.0	Agriculture and Drinking after filtration	153301	101227	838	A'ayed Aldrabe'e
47	A'ayed Aldrabe'e (3)	Dug well	1.0	Agriculture and Drinking after filtration	153325	101115	846	A'ayed Aldrabe'e
48	A'ayed Aldrabe'e (4)	Dug well	1.0	Agriculture and Drinking after filtration	153293	101097	846	A'ayed Aldrabe'e
49	Eessa Shaheen (1)	Dug well	2.0	Agriculture	153314	101122	844	Eessa Shaheen
50	Eessa Shaheen (2)	Dug well	2.0	Agriculture	153251	101190	840	Eessa Shaheen
51	Eessa Shaheen (3)	Dug well	10.0	Agriculture	153312	101295	835	Eessa Shaheen
52	Marzoqa	Spring	3.0	Agriculture	153326	101300	835	Alhaj Yousef Dodeen
53	Akram Kazem Alshareef (1)	Dug well	10.0	Agriculture	153439	101360	832	Akram Kazem Alshareef
54	Alsaqieh	Dug well	80.0	Agriculture	153214	101352	832	Abd Alqader Dodeen
55	Akram Kazem Alshareef (2)	Dug well	4.5	Agriculture	152987	101201	840	Akram Kazem Alshareef
56	Ali Alawawdeh	Dug well	2.0	Agriculture	152924	101264	840	Ali Alawawdeh
57	Ekram Kazem Alshareef	Dug well	1.5	Agriculture	152930	101298	840	Ekram Kazem Alshareef
58	Taha Alawawdeh	Dug well	1.0	Agriculture	152922	101290	840	Taha Alawawdeh
59	Hesham Ehdeb	Dug well	1.5	Agriculture and Drinking after filtration	152932	101188	843	Hesham Ehdeb
60	Maher Yousef Othman Amro	Dug well	3.0	Agriculture and Drinking after filtration	152912	101227	842	Maher Yousef Othman Amro
61	Albeer Alsharqee	Dug well	3.0	Drinking	152799	101429	847	Municipality

Table 5.2

#.OF SPRING	ELEVATION (m)	DISTANCE (m)	zone	pH	DO (mg/l)	DO (%)	TDS (mg/l)	EC (µs/cm)	Sal (%)	Cl (mg/l)	NO3 (mg/l)
1	805	2557	D	8.0			339.0	696.0	0.3	36.6	1.1
2	805	2418	D	8.4	6.96	76.9	287.0	591.0	0.3	33.4	0.5
3	799	2239	D								
4	800	2179	D								
5	797	2122	D	8.4			586.0	1189.0	0.6	125.4	
6	799	1440	D	8.4			302.0	622.0	0.3	57.5	49.1
7	810	1980	D	8.3			373.0	765.0	0.4	46.0	33.7
8	811	2009	D	8.4			343.0	705.0	0.3	42.8	52.3
9	809	1924	D	8.4	6.33	70.6	345.0	708.0	0.3	40.8	57.6
10	807	2047	D	8.4			336.0	690.0	0.3	41.8	19.7
11	806	2068	D	8.4			306.0	631.0	0.3	35.5	26.2
12	809	2100	D	8.6			333.0	685.0	0.3	43.9	
13	816	1825	D	8.3			361.0	740.0	0.4	51.2	9.2
14	818	1766	D	8.7			267.0	552.0	0.3	41.8	8.9
15	806	1610	C	8.3			650.0	1314.0	0.7	121.2	199.2
16	806	1634	C	8.2			644.0	1301.0	0.7	115.0	174.1
17	809	1590	C	8.2	6.33	71.5	51.8	109.1	0.1	8.4	19.4
18	808	1485	C	8.0			968.0	1931.0	1.0	195.4	232.2
19	807	1375	C	8.0			800.0	1606.0	0.8	158.9	
20	809	1362	C	7.9			808.0	1622.0	0.8	158.9	213.9
21	804	1391	C	8.1			839.0	1683.0	0.9	182.9	238.7
22	803	1393	C	8.0			819.0	1643.0	0.8	171.4	192.1
23	804	1389	C	7.8			879.0	1760.0	0.9	191.2	245.3
24	810	1307	C	8.2			727.0	1465.0	0.7	146.3	189.4
25	810	1277	C	8.8			848.0	1700.0	0.9	168.3	259.0
26	809	1334	C	7.9			802.0	1611.0	0.8	157.8	226.0

#.OF SPRING	ELEVATION (m)	DISTANCE (m)	zone	pH	DO (mg/l)	DO (%)	TDS (mg/l)	EC (μs/cm)	Sal (%)	Cl (mg/l)	NO3 (mg/l)
27	810	1320	C	7.8			812.0	1629.0	0.8	160.9	233.5
28	811	1244	C	8.2	6.06	70.4	1057.0	2.1	1.1	90.0	337.0
29	810	1260	C	7.8			894.0	1789.0	0.9	85.0	207.4
30	820	1020	B	8.7			727.0	1464.0	0.7	60.0	222.4
31	827	844	B								
32	825	835	B	7.3			1245.0	2.6	1.3	115.0	
33	841	735	B	7.3			832.0	1667.0	0.8	70.0	241.7
34	842	703	B								
35	834	808	B	7.3			857.0	1716.0	0.9	60.0	263.9
36	834	707	B	7.3			1102.0	2.2	1.1	80.0	365.1
37	830	758	B	7.6	7.15	81.8	1179.0	2.3	1.2	120.0	347.4
38	830	784	B	7.3			1087.0	2.2	1.1	95.0	366.1
39	833	717	B	7.3			1104.0	2.2	1.1	155.0	362.8
40	839	666	B	7.2			1134.0	2.3	1.2	105.0	411.1
41	840	654	B	8.4			623.0	1262.0	0.6	30.0	206.4
42	840	603	B								
43	840	584	B								
44	838	589	B	7.3			1181.0	2.3	1.2	248.7	365.6
45	840	554	B	7.4			1070.0	2.1	101.0	110.0	431.0
46	838	540	B	7.3			732.0	1475.0	0.7	40.0	210.0
47	846	577	B	7.5			1162.0	2.3	1.2	75.0	159.4
48	846	545	B								
49	844	568	B	7.3			875.0	1752.0	0.9	80.0	247.6
50	840	491	B	7.3			875.0	1752.0	0.9	80.0	247.5
51	835	546	B	7.1			1138.0	2.3	1.2	90.0	333.7
52	835	560	B	7.2			1109.0	2.2	1.1	80.0	336.0
53	832	656	B								

#.OF SPRING	ELEVATION (m)	DISTANCE (m)	zone	pH	DO (mg/l)	DO (%)	TDS (mg/l)	EC (µs/cm)	Sal (%)	Cl (mg/l)	NO3 (mg/l)
54	832	408	B	7.1			1214.0	2.4	1.2	120.0	354.6
55	840	234	A	7.5	5.9	66.7	520.0	1059.0	0.5	66.9	136.6
56	840	149	A								
57	840	147	A	7.2			1328.0	2.6	1.4	140.0	424.5
58	840	141	A								
59	843	180	A								
60	842	146	A	7.2			867.0	1736.0	0.9	80.0	317.4
61	847	0	A								
Average				7.9			770.2	890.9		98.1	212.8
SD				0.5			325.1	705.9		54.2	129.0
var				0.3			105665.0	498337.2		2933.6	16636.5
MAX				8.8			1328.0	1931.0		248.7	431.0
MIN				7.1			51.8	2.1		8.4	0.5
Mode				8.4			727.0	2.2		80.0	#N/A
Median				7.9			819.0	740.0		85.0	226.0

Table 5.4

#.OF SPRING	pH	EC (µs/cm)	TDS (mg/l)	Sal (%)	NO3 (mg/l)	Cl (mg/l)
CLUSTER I	(Zone D)					
1	8.0	696.0	339.0	0.3	1.1	36.6
2	8.4	591.0	287.0	0.3	0.5	33.4
3						
4						
5	8.4	1189.0	586.0	0.6		125.4
6	8.4	622.0	302.0	0.3	49.1	57.5
7	8.3	765.0	373.0	0.4	33.7	46.0
8	8.4	705.0	343.0	0.3	52.3	42.8
9	8.4	708.0	345.0	0.3	57.6	40.8
10	8.4	690.0	336.0	0.3	19.7	41.8
11	8.4	631.0	306.0	0.3	26.2	35.5
12	8.6	685.0	333.0	0.3		43.9
13	8.3	740.0	361.0	0.4	9.2	51.2
14	8.7	552.0	267.0	0.3	8.9	41.8
15	8.3	1314.0	650.0	0.7	199.2	121.2
16	8.2	1301.0	644.0	0.7	174.1	115.0
17	8.2	109.1	51.8	0.1	19.4	8.4
Average	8.4	753.2	368.3	0.4	50.1	56.1
STD	0.2	308.8	154.1	0.2	63.6	35.1
VAR	0.0	95350.1	23749.0	0.0	4050.5	1228.8
Mode	8.4			0.3		41.8
Median	8.4	696.0	339.0	0.3	26.2	42.8

#.OF SPRING	pH	EC (µs/cm)	TDS (mg/l)	Sal (%)	NO3 (mg/l)	Cl (mg/l)
CLUSTER II	**(ZoneC)**					
18	8.0	1931.0	968.0	1.0	232.2	195.4
19	8.0	1606.0	800.0	0.8		158.9
20	7.9	1622.0	808.0	0.8	213.9	158.9
21	8.1	1683.0	839.0	0.9	238.7	182.9
22	8.0	1643.0	819.0	0.8	192.1	171.4
23	7.8	1760.0	879.0	0.9	245.3	191.2
24	8.2	1465.0	727.0	0.7	189.4	146.3
25	8.8	1700.0	848.0	0.9	259.0	168.3
26	7.9	1611.0	802.0	0.8	226.0	157.8
27	7.8	1629.0	812.0	0.8	233.5	160.9
28	8.2	2.1	1057.0	1.1	337.0	90.0
29	7.8	1789.0	894.0	0.9	207.4	85.0
30	8.7	1464.0	727.0	0.7	222.4	60.0
Average	8.1	1531.2	844.6	0.9	233.1	148.2
STD	0.3	476.1	90.6	0.1	38.7	42.7
VAR	0.1	226625.3	8210.8	0.0	1494.1	1822.7
Mode	#N/A	#N/A	727.0	0.8	#N/A	158.9
Median	8.0	1629.0	819.0	0.8	229.1	158.9

#.OF SPRING	pH	EC (µs/cm)	TDS (mg/l)	Sal (%)	NO3 (mg/l)	Cl (mg/l)
CLUSTER III	(Zone A+B)					
31						
32	7.3	2.6	1245.0	1.3		115.0
33	7.3	1667.0	832.0	0.8	241.7	70.0
34						
35	7.3	1716.0	857.0	0.9	263.9	60.0
36	7.3	2.2	1102.0	1.1	365.1	80.0
37	7.6	2.3	1179.0	1.2	347.4	120.0
38	7.3	2.2	1087.0	1.1	366.1	95.0
39	7.3	2.2	1104.0	1.1	362.8	155.0
40	7.2	2.3	1134.0	1.2	411.1	105.0
41	8.4	1262.0	623.0	0.6	206.4	30.0
42						
43						
44	7.3	2.3	1181.0	1.2	365.6	248.7
45	7.4	2.1	1070.0	101.0	431.0	110.0
46	7.3	1475.0	732.0	0.7	210.0	40.0
47	7.5	2.3	1162.0	1.2	159.4	75.0
48						
49	7.3	1752.0	875.0	0.9	247.6	80.0
50	7.3	1752.0	875.0	0.9	247.5	80.0
51	7.1	2.3	1138.0	1.2	333.7	90.0
52	7.2	2.2	1109.0	1.1	336.0	80.0
53						
54	7.1	2.4	1214.0	1.2	354.6	120.0
55	7.5	1059.0	520.0	0.5	136.6	66.9

#.OF SPRING	pH	EC (µs/cm)	TDS (mg/l)	Sal (%)	NO3 (mg/l)	Cl (mg/l)
56						
57	7.2	2.6	1328.0	1.4	424.5	140.0
58						
59						
60	7.2	1736.0	867.0	0.9	317.4	80.0
61						
Average	7.4	592.8	1011.1	5.8	306.4	97.2
STD	0.3	787.0	215.2	21.8	86.6	46.1
VAR	0.1	619310.3	46318.9	476.0	7501.9	2128.7
Mode	7.3	2.2	875.0	1.2	#N/A	80.0
Median	7.3	2.4	1102.0	1.1	334.9	80.0

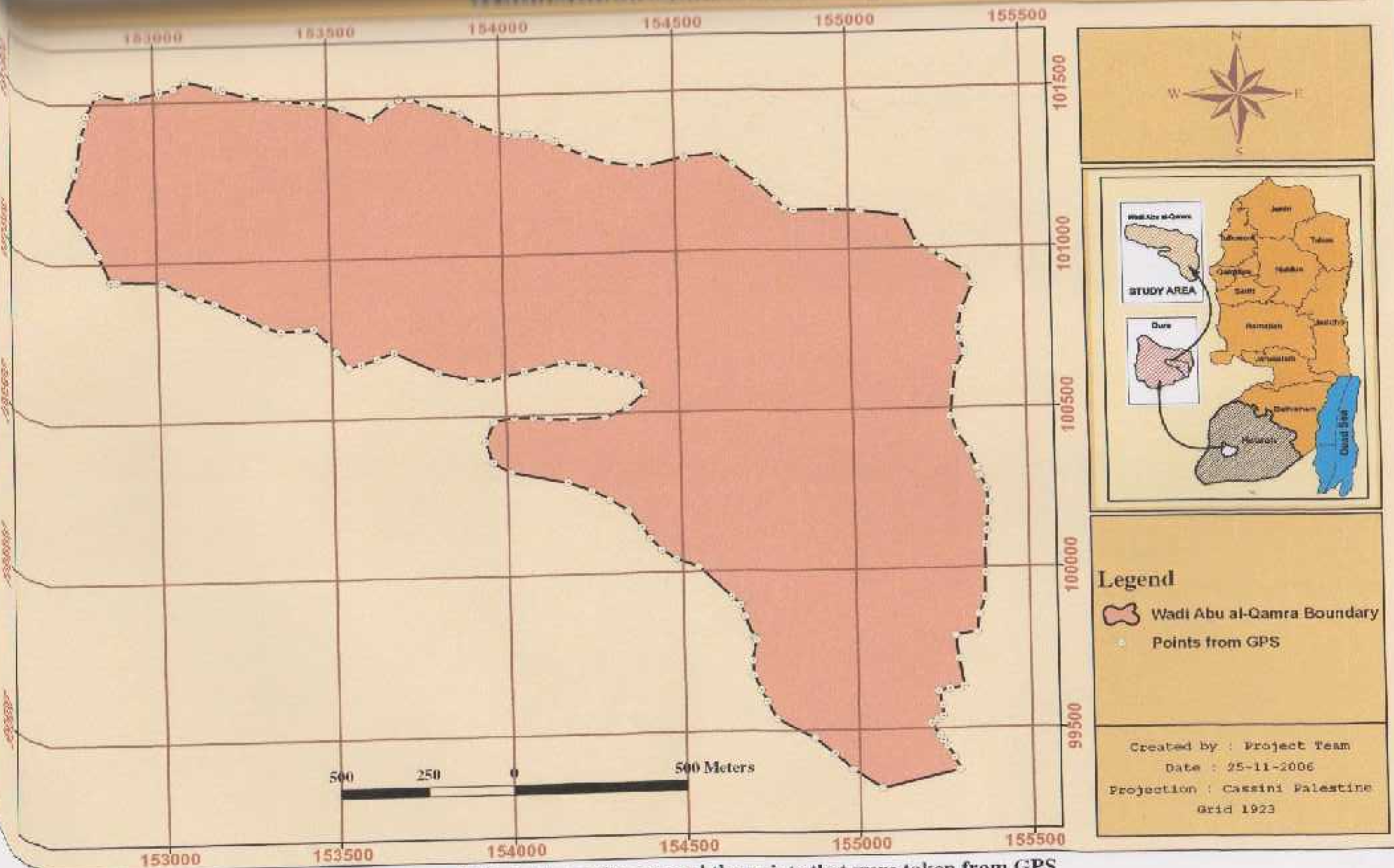


Fig. 5.1: The boundary of Wadi Abu al-Qamra and the points that were taken from GPS

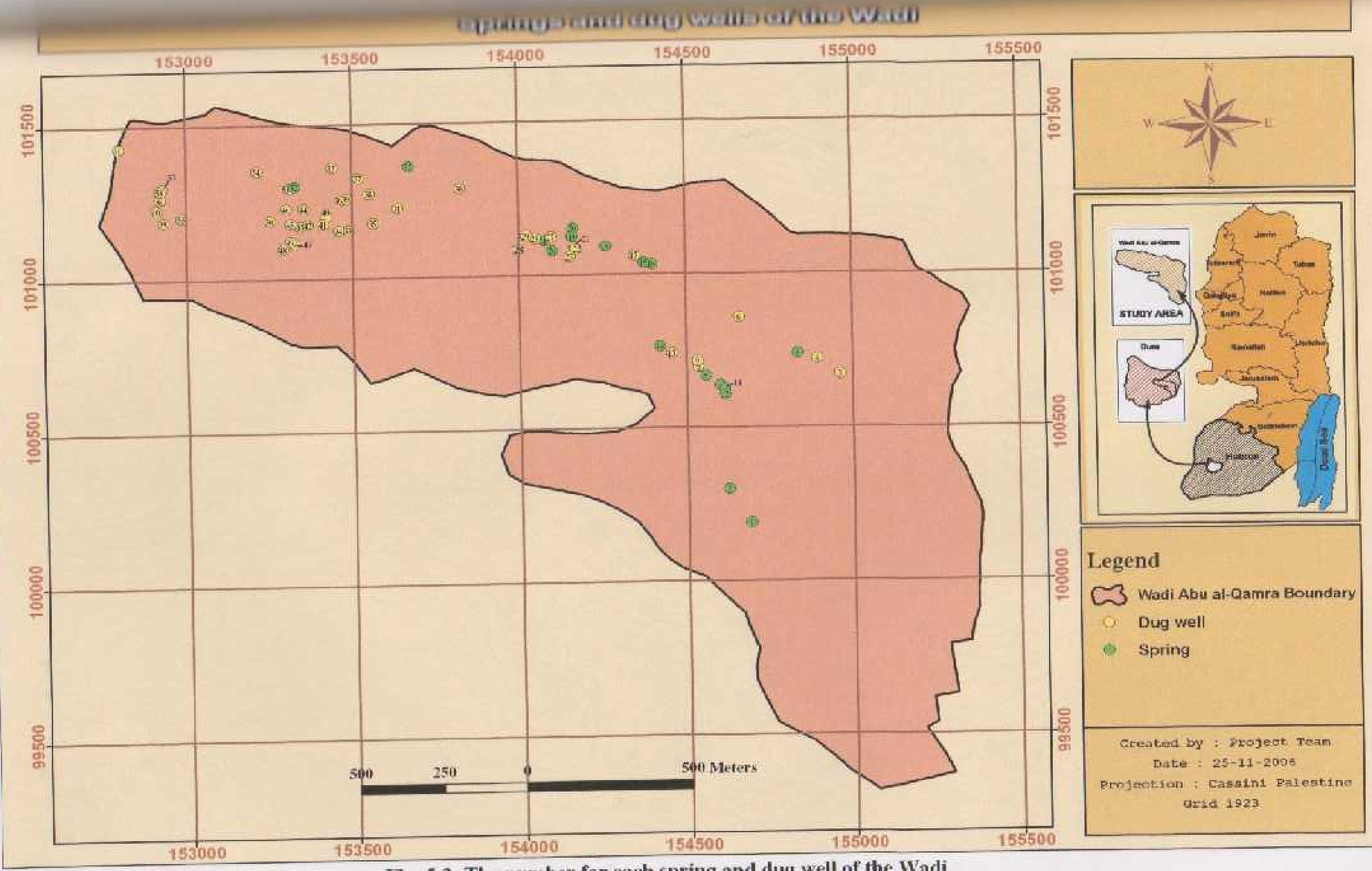


Fig. 5.2: The number for each spring and dug well of the Wadi

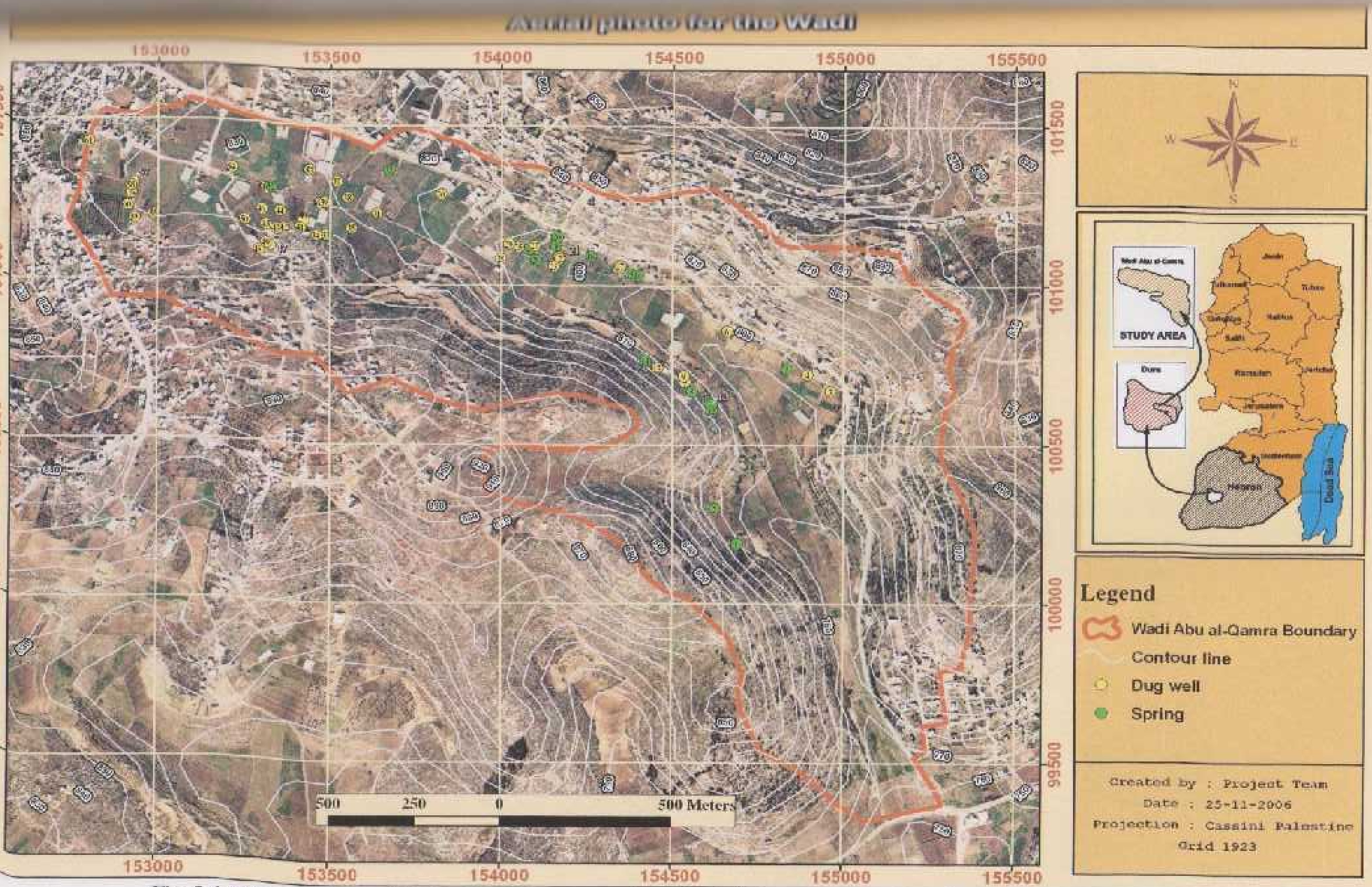


Fig. 5.4: The boundary of Wadi Abu al-Qamra, springs, dug Wells and contour lines shown on an aerial photo.

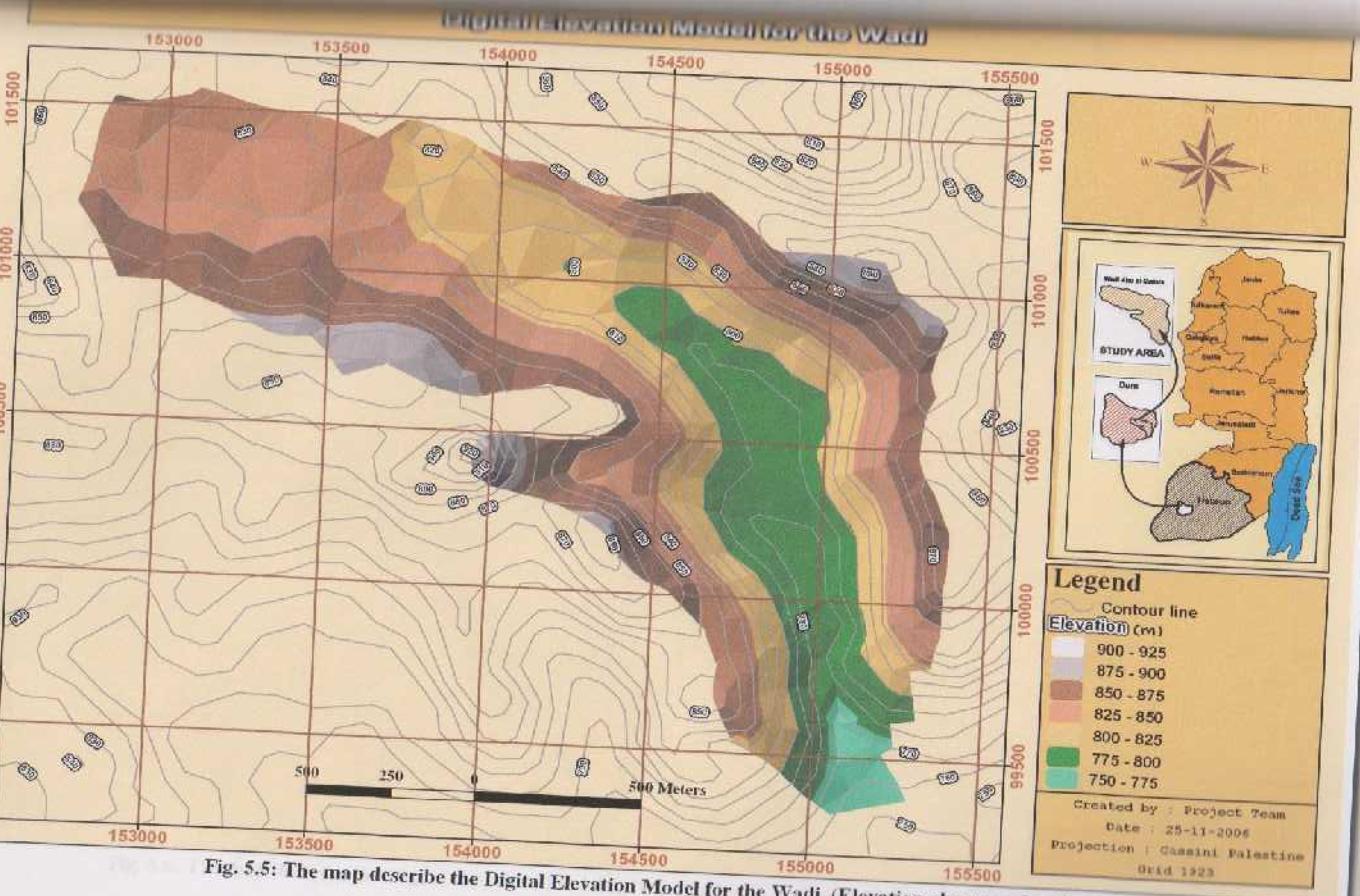


Fig. 5.5: The map describe the Digital Elevation Model for the Wadi (Elevation above sea level)

Digital Elevation Model for the Wadi with springs and dug wells

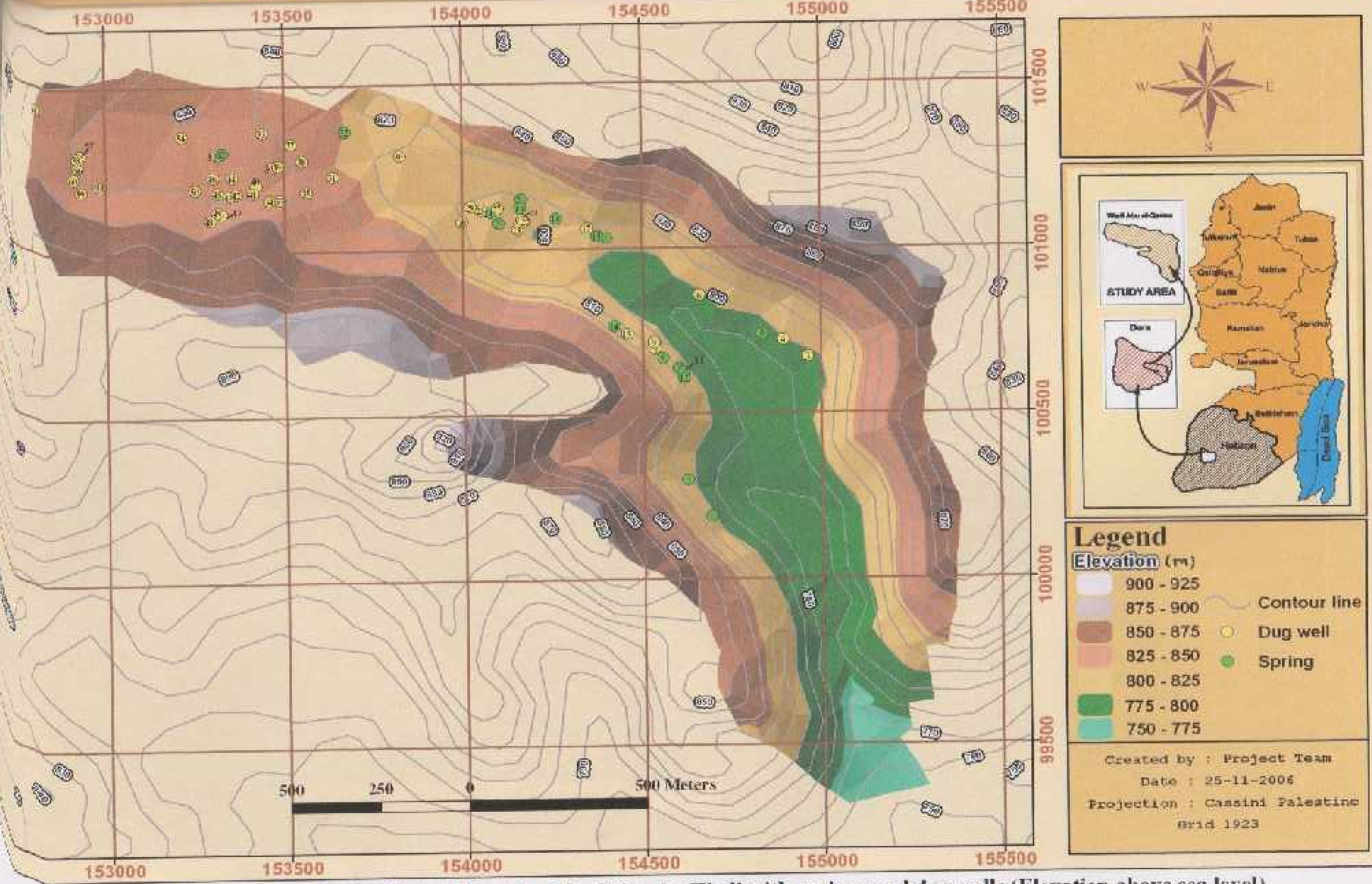


Fig. 5.6: The map describe the Digital Elevation Model for the Wadi with springs and dug wells (Elevation above sea level)

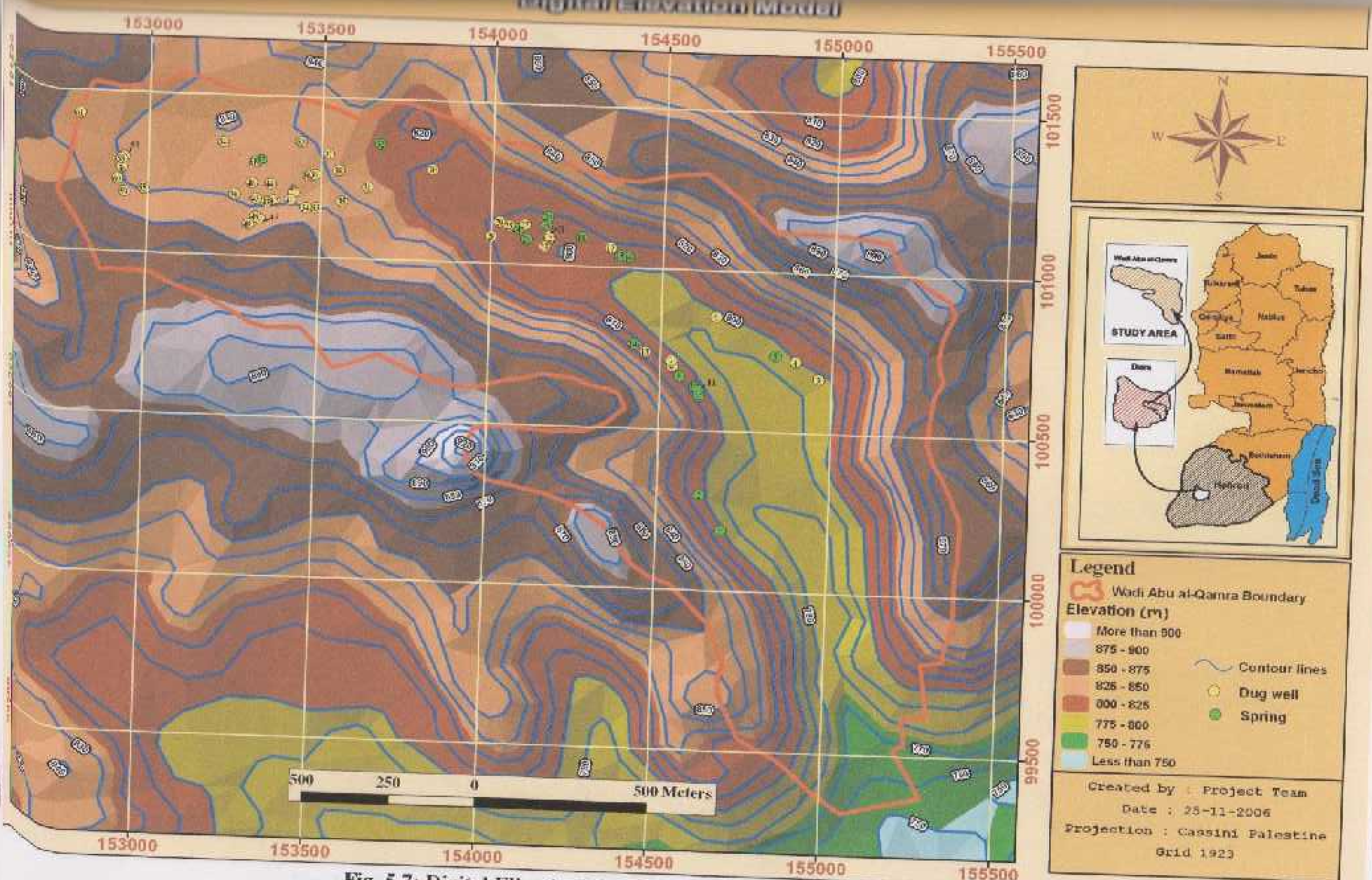


Fig. 5.7: Digital Elivation Model for the Area around the Wadi

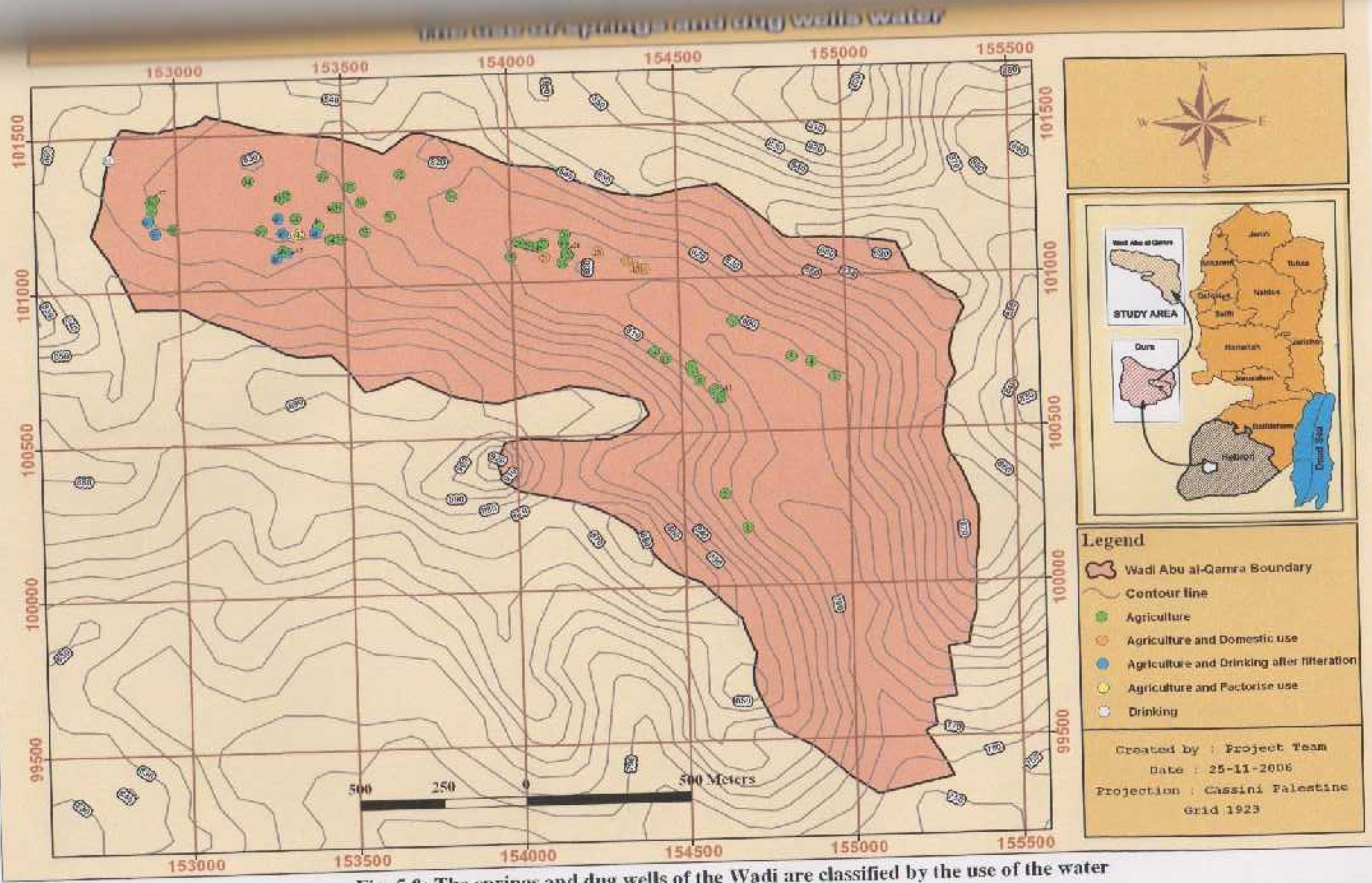


Fig. 5.8: The springs and dug wells of the Wadi are classified by the use of the water

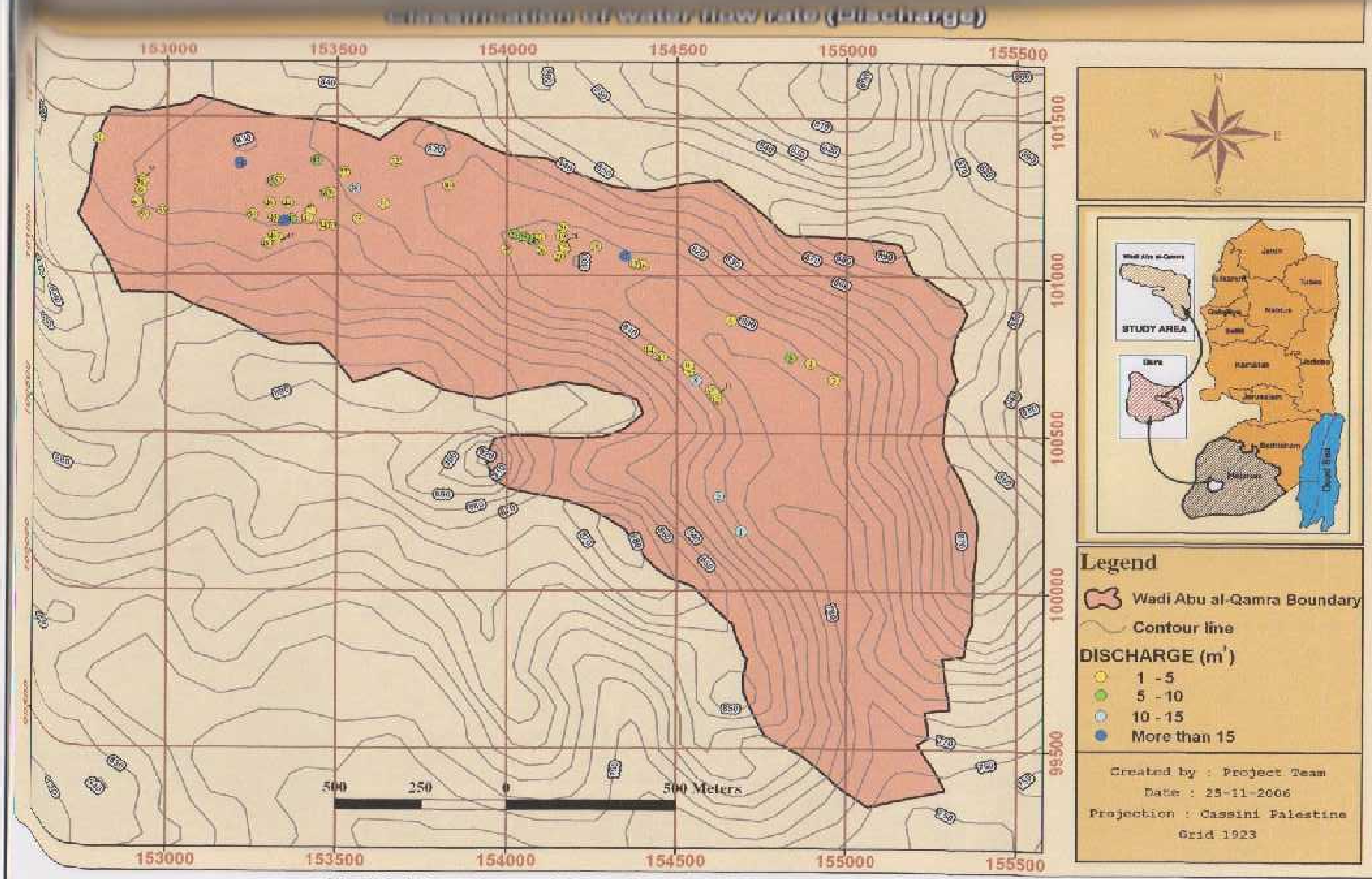


Fig. 5.9: The springs and dug wells of the Wadi are classified by discharge

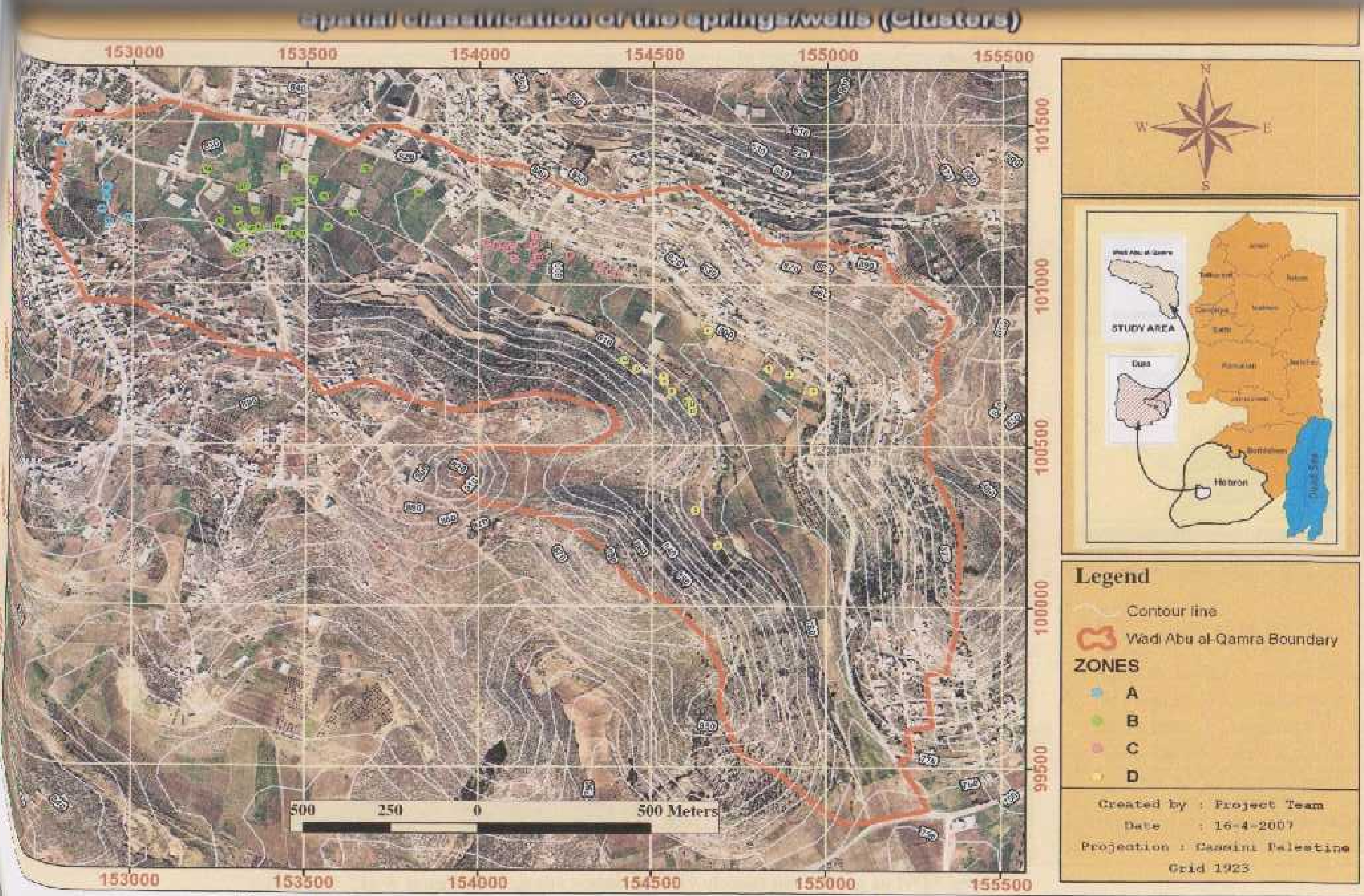


Fig. 5.10: A map showing spatial classification of the springs/wells (Clusters)

Fig. 5.11: A map showing the water quality classes according to NO3 levels

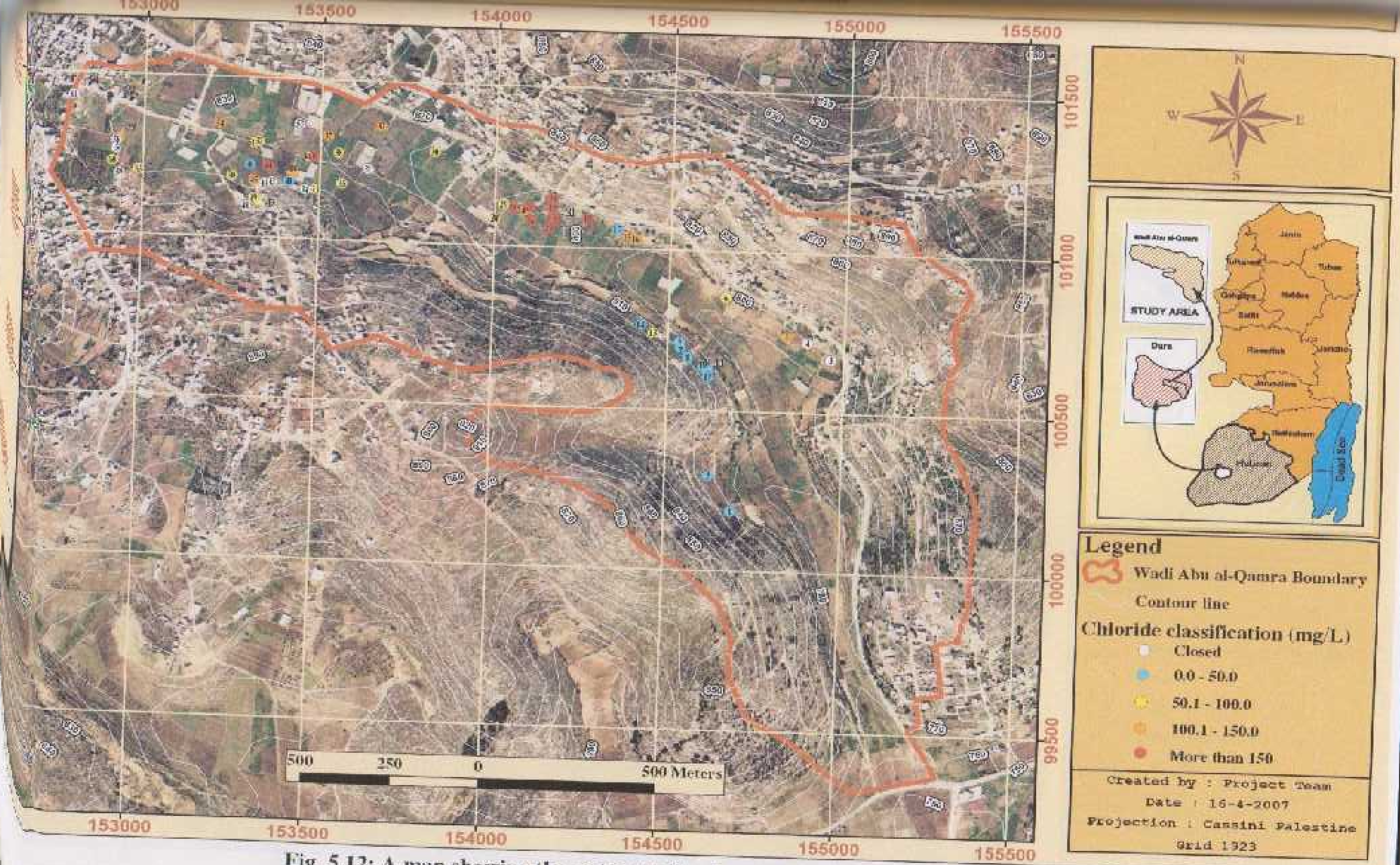


Fig. 5.12: A map showing the water quality classes according to Cl levels

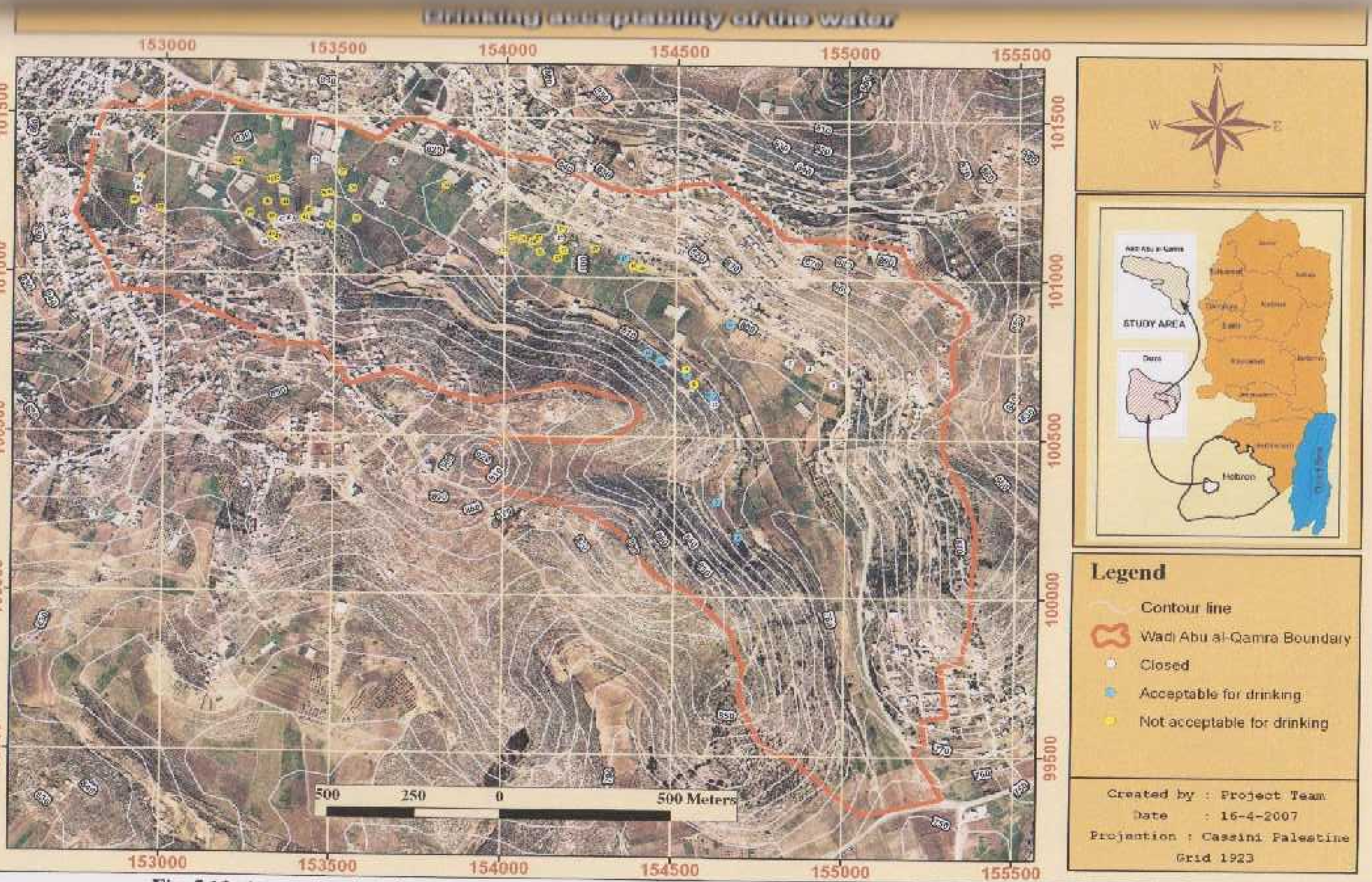


Fig. 5.13: A map showing the acceptable/nonacceptable water quality (according to NO3 and Cl levels)

CHAPTER SIX

Conclusions and Recommendations

CHAPTER SIX

Conclusions and Recommendations

6.1 Conclusions:

1. The GIS mapping revealed that, the Wadi contains 61 springs/wells concentrated mainly at its upstream and the middle.

2. The dominant water use is for irrigation purposes.

3. In this study, nitrate and chloride were used as indicators of pollution, excess nitrate levels emerges from wastewater or fertilizers (organic or chemical) while chloride comes mainly from wastewater.

4. From spatial distribution point of view , the wells/springs in the Wadi fall in 4-spatial zones:

- Zone A: located at the Wadi upstream, this area is close to built-up area and is with agricultural area separating it from the built- up area at the Wadi start.

- Zone B: comes directly after zone A at lower ground level. This area is more affected by agricultural activities (especially that it contains green houses) but less affected by residential areas.

- Zone C: comes in the third order as we come downward the Wadi.
Unlike zones A and B which are located along the Wadi center line, Zone C is a little bit shifted close to the Wadi north embankment and is in contact with residential are there.

- Zone D: is at the farthest downstream segment of the Wadi this area neighborhood contains no housing land use pattern. Also they are mostly with very low agricultural activities. Nitrate changes, detected for different wells/springs, were high and varies from about zero to more than 400 mg/l.

5. Based on the above spatial distribution, the following water quality clusters were identified:

   - Clusters I: containing springs / wells of spatial zone D which are mostly non polluted and are located in clear recharge area.
   - Clusters II: contains these springs / wells of spatial zone C which are mostly affected by pollution from sewage.
   - Clusters III: represents spatial zones A+B which are affected by pollution mainly from agriculture while sewage is also available as secondary pollution source.

6. Approximately, 27% of the springs/wells were with permissible nitrate levels (< 50 mg/l) and are complying with drinking water guidelines. These springs are good for drinking purposes.

7. No salinity problems of the water were distinguished; therefore the water could be used for irrigation without any restrictions.
8. Non-polluted springs/wells are mostly available at the Wadi downstream and are of recharge water type due to clean recharge area conditions.

9. Nitrate coming from fertilizers are mostly affecting the water quality rather than sewage.

6.2 Recommendations:

1. The Wadi should be protected from pollution sources and we suggest the following steps for that:

- Applying fertilizers should be according to the plant nutrient requirements and not exceeding that because any excess amounts will be leached to groundwater.
- Sewers and treatment plant should be installed and constructed to protect the Wadi from wastewater pollutions.
- Springs with good water quality (27% of the springs) should be used for drinking after chlorination.
- For the next five years, we suggest the formation of 500 m diameter protection zone around the Wadi as urgent solution for pollution problems of the water.

2. Better water management plans should be set for the Wadi water in order to reach a better benefit from the water. This could be done by selecting better crop or vegetable types, applying better methods of irrigation and improving marketing of the Wadi agricultural production.

3. As a precaution, all of the spring's water should receive chlorination before being dinking.

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ANNEX

ANNEX

In the following we placed photos for each spring/well

Remain: number according to data of table 5.1

1- Ali Al-Shareef (1)

2- Ali Al-Shareef (2)

3- Owdeh Rjoob (1)

4- Owdeh Rjoob (2)

5- Abd Allah Owdeh

6- Abo Tha'er Alfar

7-Nihad Swaiti (1)

8-Waleed Amro

9-A'hed Qazaz

10-Nihad Swaiti (2)

ANNEX

In the following we placed photos for each spring/well

Remain: number according to data of table 5.1

1- Ali Al-Shareef (1)

2- Ali Al-Shareef (2)

3- Owdeh Rjoob (1)

4- Owdeh Rjoob (2)

5- Abu Aligh Owdeh

6- Abu Tha'er Alfar

7-Nihad Swaiti (1)

8-Waleed Amro

9-A'hed Qazaz

10-Nihad Swaiti (2)

11-Nihad Swaiti (3)

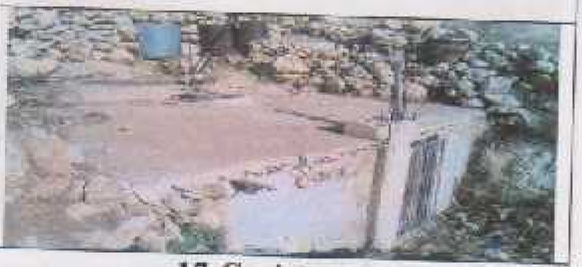
12-Nihad Swaiti (4)

13-Ameen Abo Sba'a

14-Alhaj Khlal (1)

15-Hasan Joma'a

16-Sa'adallah Amro



17-Gazi Amro

18-Mohammad Alseekh

19-Salah Naief Hejah (1)

20-Salah Naief Hejah (2)

21-Ojra Hejah (1)

22- Ojra Hejah (2)

23- Ojra Hejah (3)

24- Alhaj Khlal (2)

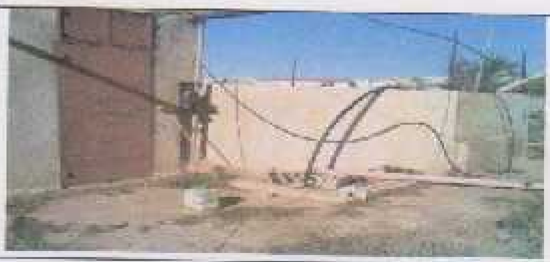
25- Alhaj Khlal (3)

26- Naief Hejah

27- Al-Namora

28- Solaiman Mohamad Amro (1)

29- Solaiman Mohamad Amro (2)



30- Aqel Kashoor

31- Omar Amro

32- Yasser Esser

33- Alhaj Aamer Alreje'e (1)

34- Alhaj Aamer Alreje'e (2)

35-Mohamad Abd-Alqader Abu-Shara

36- Majed Al-Namora

37- Kamel Jado'a Al-Namora

38- Jado'a Al-Namora

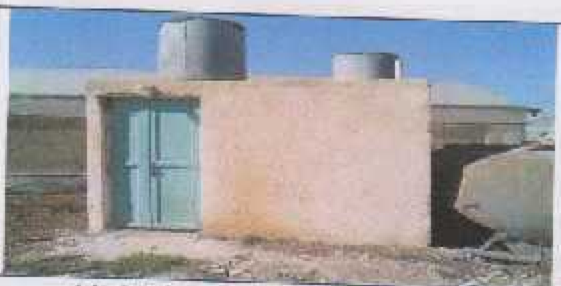
39- Kamel Bader Al-Namora

40- Mohamad Abdallah Hereebat (1)

41- Mohamad Abdallah Hereebat (2)

42- Abd Alazeez Shadeed (1)

43- Abd Alazeez Shadeed (2)



44- Mohamad A'amer Alreje'e

45- A'ayed Aldrabe'e (1)

46- A'ayed Aldrabe'e (2)

47- A'ayed Aldrabe'e (3)

48- A'ayed Aldrabe'e (4)

49- Eessa Shaheen (1)

50- Eessa Shaheen (2)

51- Eessa Shaheen (3)

52- Marzoqa

53- Akram Kazem Alshareef (1)

54- Alsaqieh

55- Akram Kazem Alshareef (2)

56- Ali Alawawdeh

57- Ekram Kazem Alshareef

58- Taha Alawawdeh

59- Hesham Ehdeb

60- Maher Yousef Othman Amro

61- Albeer Alsharqee