Environmental flow regime for Wadi Zomar

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نظام التدفق البيئي في وادي الزومر

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This thesis was prepared under the supervision of Dr. Ziad Mimi and has been approved by all members of the Examination Committee

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The findings, interpretations and conclusions expressed in this study do not necessary express the views of Birzeit University, the views of the individual members of the MSc-committee or the views of their respective employers.

Abstract

The Zomar stream has been suffering for over 50 years from a variety of domestic, agricultural and industrial pollution sources together with development pressures in the open spaces that surround the stream. Increased water-dependent development and utilization have led to significantly environmental and hydrological degradation of the Zomar stream in Palestine and its dependent ecosystems.

The aim of this study is to assess the physiochemical and microbiological quality of the stream Zomar stream through one-year long monitoring, in order to estimate the key factors and variables that play a role in the environmental flow regime of the stream which in role can be functioned to save the stream restoration process.

Three sampling stations were selected depending on the human activities and pollution sources along the stream. The water samples were examined for the presence of *coliform* bacteria and pathogens. Four species were isolated (*Escherichia coli, Pseudomonas, Enterococcus, and Klebsiella*). The spatially and temporally behavior of these species in response to the variability in hydraulic parameter and nutrients load respectively. High total and *fecal coliform* were observed in most water samples under drought conditions.

The results from this study reflect that no one indicator or simple hydrological parameter is entirely suitable for all environmental systems and pathogens, even within a common geographic setting. Much point source pollution contributes to the water stream along its path. In the base flow conditions, the amount of pollutant load varied temporally according to the amount of load from point sources along the stream, and spatially with distance from the same sources. Significant variation was observed in response to the hydrological behavior of the catchment. The data show that commonly the bacterial community in the stream is affected by two factors; the first is the cumulative rain factor in winter season, where the bacterial potential to re-enhancing its growth is limited with successes rain events along the hydrological year. The second factor is single rain event dilution where the maximum bacterial removal was noticed at the maximum flood within one rain event. High flow and frequent washout of bacteria lead to lower bacterial concentrations. The *fecal Coliform* bacteria shows a good pattern in response to variation in one storm event, where the maximum *fecal Coliform* concentrations were measured after two week of drought and directly before the rainfall events. Anbta showing highest pathogen removal (self purification) while Deir Sharaf show lowest removal (close to source

point). Anbta show the lowest bacterial community. In general, relationships between indicator bacteria and pathogens were weak, site specific, but primarily positive. This happens because distribution of bacteria or pathogens perpendicularly across the edges and centre, when wash out occurs, it occurs in the middle leaving edges without washing. Average total Coliform levels in Zomar stream were $7x10^{16}$, $4x10^{16}$, $8x10^{16}$cfu/100 ml all over the year. During discharge event this average reduced to $7x10^{14}$, $4x10^{7}$, $1x10^{14}$ cfu/100 ml showing log removal of 2, **9**, and 2.9 for all three sites, Deir Sharaf, Anbta and Tulkarem respectively. In case of FC, average concentration were $4x10^{13}$, $6x10^{12}$,$2x10^{11}$ cfu/100 ml and reduced to $5x10^{9}$,$4x10^{5}$,$2x10^{10}$ cfu/100 ml showing log removal of 3.9,**7.2**,1.

The overall assessment for the water quality in the Zomar reflects a potentially serious threat to the environment. The results emphasize the need for:

1) Regulating the seepage effluent from industries and sewage system along the stream.
2) The stream should regularly provide with sufficient treated wastewater, in term of quality and quantity that ensure its sustainability all over the year even in summer time.
3) The addition of treated wastewater to the stream should not be restricted to the beginning of the stream, but distributed on at least 3-5 points along the stream to ensure good restoration process with spatial pattern.

الخلاصة

الهدف من هذه الدراسة هو تقييم جودة الخصائص الكيميائية و الفيزيائية والبيولوجية من خلال عملية رصد مدتها سنة واحدة لوادي الزومر في الضفة الغربية - فلسطين من أجل تقييم العوامل والمتغيرات الرئيسية التي تلعب دورا هاما في نظام التدفق البيئي في الوادي.

تم اختيار ثلاث نقاط من اجل أخذ العينات اعتمادا على الأنشطة البشرية ومصادر التلوث على طول الوادي. وتم فحص عينات المياه بحثا عن وجود البكتيريا القولونية ومسببات الأمراض. وتم عزل أربعة أنواع من البكتيريا المسببة للإمراض (Escherichia coli, Pseudomonas, Enterococcus, Klebsiella). وجرى أيضا تقييم التباين المكاني والزماني للوجود البكتيري واستجابته للتغير في الخصائص الهيدروليكية للوادي و قدرته على تحميل المواد الغذائية لكل نوع بكتيري موجود في الماء، حيث تم أيضا ملاحظة تركيز عالي من البكتيريا القولونية في معظم عينات المياه .

نتائج هذه الدراسة تعكس أنه لا يوجد مؤشر واحد أو قياس هيدرولوجي بسيط تماما مناسب لجميع النظم البيئية ومسببات الأمراض ، حتى ضمن وضع جغرافي موحد. العديد من النقاط التي تشكل مصادر تلوث تسهم في تلوث التيار المائي على طول مساره. وجدت الدراسة أنه في ظروف تدفق عادية، مقدار الملوثات تتغير زمنيا طبقا لمقدار الحمولة من مصادر التلوث على طول الوادي، ومكانيا مع المسافة من المصادر نفسها.وتظهر البيانات إن التجمعات البكتيرية في العادة تتأثر في الوادي بعاملين ، الأول هو العامل التراكمي منذ بداية موسم الشتاء ، حيث إمكانات البكتيريا لإعادة تعزيز نموها محدودة مع تكرار هطول مزيد من الإمطار على طول العام. والثاني هو التخفيف من خلال التدفق المرحلي حيث لوحظ إزالة الحد الأقصى من البكتيريا الجرثومية عند وصول مستوى التدفق إلى الحد الأقصى ضمن الحالة المطرية الواحدة . ارتفاع التدفقات (من الواضح إن البكتيريا تنشأ تجمعات كبيرة في موسم الصيف) أدى إلى انخفاض تركيز البكتيريا.

أظهرت البكتيريا القولونية البرازية نمط جيد في اختلاف الاستجابة ضمن الحالة المطرية الواحدة في وقت العاصفة ، حيث تم قياس الحد الأقصى للتركيزات القولونية البرازية بعد اسبوعين من الجفاف ، ومباشرة قبل بدأ هطول الأمطار. بشكل عام ، العلاقات بين البكتيريا الدالة ، وتلك مسببات الأمراض ضعيفة ، تعتمد على الموسم(وقت أخذ العينة) ، موقع أخذ العينة ، ولكن بالمجمل تتميز بالإيجابية .يحدث هذا بسبب التوزيع العمودي للبكتيريا والجراثيم عبر الحواف والوسط ، عندما يحدث الغسل يحدث للوسط فقط . وكان معدل ازالة البكتيريا الكلية 2 ، 9 ، 2.9 لجميع المواقع الثلاثة ، دير شرف ، عنبتا وطولكرم على التوالي. في حالة البكتيريا الدالة كانت معدل الازالة 1،7.2،3.9. التقييم الشامل لجودة المياه في وادي الزومر يعكس تهديدا خطيرا للبيئة. النتائج تؤكد على الحاجة إلى :

1) تنظيم تسرب النفايات السائلة من الصناعات ونظام الصرف الصحي على طول الوادي.
2) يجب توفر تدفق منتظم للمياه العادمة المعالجة بشكل كافي ، من حيث الجودة والكمية التي تضمن استمرارية الوادي طوال العام حتى في فصل الصيف.

3) المياه العادمة المعالجة في الوادي لا ينبغي أن يقتصر على بداية الوادي ، ولكن على الأقل موزعة على 5-3 نقاط على طول الوادي.

المعايير التي تم قياسها في هذه الدراسة يجب أن تدرج في نموذج لتدفق المياه السطحية، لتحديد الجودة المطلوبة والكمية اللازمة لدعم نظام بيئي صحي كامل .

Dedication

I Dedicate My Work

To Whom I Belong;

To My Parents,

To My Wife

To My Sons

Mohammad, Mahmoud & Noor

To My Best Friends,

Ahmad Amer & Ghassan A. Daghrah

For Their Help, Support & Encouragement

All the Way Long

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My deepest gratitude goes to my family for their unflagging love and support throughout my life; this dissertation is simply impossible without them. I am indebted to my father, Mohammad Sulieman, for his care and love. As a typical father in an Arabic family, he worked educationally to support the family and spare no effort to provide the best possible environment for me to grow up and attend school. I cannot ask for more from my mother, as she is simply perfect. I have no suitable word that can fully describe her everlasting love to me. I remember many sleepless nights with her accompanying me when I suffered from asthma. I remember her constant support when I encountered difficulties and I remember, most of all, her delicious dishes. Mother, I love you. I want to express my great appreciation to my family represented by my sisters and my brothers for their patience and support throughout my study.

Words fail me to express my appreciation to my wife Sabah whose dedication, love and persistent confidence in me, has taken the load off my shoulder. I owe her for being unselfishly let her intelligence and ambitions collide with mine, in addition to; my sons Mohammad, Mahmoud and Noor. My great thanks and gratitude go to my colleagues in IEWS for their valuable comments and support. I would like to thank my colleagues from the Department of Chemistry especially from Health and Environment Center at Birzeit University; Dr. Gabi Abu Sada and Mr. Belal Amous, for their support and encouragement.

Table of Contents

List of Figures

List of Tables

List of Appendices

Abbreviations

APHA	American Public Health Association
ARIJ	Applied Research Institute Jerusalem
BOD	Biochemical Oxygen Demand (after five days)
BOD	Biological Oxygen Demand
^{o}C	Degrees Celsius
CC	Climate change
CFU	Colony-forming units
Cm	Centimeter
COD	Chemical Oxygen Demand
CV	Climate variability
DO	Dissolved Oxygen
EC	Electrical conductivity
EFR	Environmental flow requirement
FC	Fecal Coliform
GW P	Global Water Partnership
HWE	House of Water and Environment
IETC	International Environmental Technology Centre
IEWS	Institute of Environmental of Water Studies
IHP	International Hydrological Programme
ISO	International Standard Operation
IWRM	Integrated water resources management
MCM	Million Cubic Meter
MF	Membrane filtration
mg/L	Milligram per Liter
Mm	Millimeter
MOPIC	Ministry of Planning and International Cooperation
MPCs	Maximum Permissible Concentrations
mS	Millisiemens
µS/cm	Microsiemens per Centimeter
NRC	National Research Council
OPTIMA	Optimization for Sustainable Water Resources Management
PCBS	Palestinian Central Bureau of Statistics
PECDAR	Palestinian Economic Council for Development and Reconstruction
PET	Potential evapotranspiration
PHG	Palestinian Hydrology Group
PSI	Palestinian Standard Institution
PWA	Palestinian Water Authority
SUSMAQ	Sustainable Management of the West Bank and Gaza Aquifers
TC	Total Coliform
TDS	Total dissolved solids
THM	Trihalomethans
TMDL	Total Maxim um Daily Load
UNDP	United Nations Development Program

UNICEF	United Nations Children’s Fund
USEPA	U.S. Environmental Protection Agency
UV	Ultraviolet
WHO	World Health Organization
WP	wetted perimeter
WR	Water Resources

1. Chapter one: Introduction

1.1 Background

The so-called water crisis, recognized as an important issue in our times, is the result of several situations including demographic growth, water, soil and air pollution, catchment deforestation and increasing land and water-use conflicts. The effects of climatic variability and climate change on human beings and on the aquatic and terrestrial ecosystems increase this crisis. The real and apparent conflicts existing between human and ecosystem water needs have increased the need to implement an alternative model for Integrated Water Resources Management (IWRM), of wide acceptance and use on a global scale. Environmental flow, a concept from the IWRM approach, has great potential in this type of conflict resolution; and it can be implemented at the catchment level (Carvajal-Escobar, 2008).

The real and apparent conflicts between human and natural needs for water have contributed to the need for finding an alternative model for managing the resources at the world level (Barón *et al*. 2003). Since the water resources in the Middle East area is scarce, management options and optimal water allocation policies should aim at protecting the quality of these resources while making use of all the conventional and non-conventional sources (Carvajal-Escobar, 2008).

Water pollution by human activities caused serious health problems and other economic costs related to water treatment, remediation and locating a new water supply, become evident (Gasana et al, 2002). Public health protection, pathogen contamination regulation have been developed for water bodies such as streams. *Fecal Coliform* presence is typically used as an indicator for the presence of pathogen.

To maintain the healthy and sustainable development of a stream basin, the focus of water resources allocation has been put on the water supply for human needs, with little attention to the environment (Kashaigili et al, 2005). The eco hydrological approach to sustainable stream basin management and the control of biological and hydrological processes should be integrated with technical approaches (Zalewski and Wagner-Lotkowska, 2004).

Despite the lack of appropriate scientific knowledge, there remains a need to initially develop management procedures in the short term to facilitate achieving the longer-term goal of ecological sustainability. One of the challenges in achieving this goal is the development of a flow management system that mimics natural flows. Understanding the dynamics of the stream dependent ecosystems is crucial to evaluate restoration efficiency and effectiveness (Puckridge et al., 1998 and 2000; Pettit et al., 2001). Issues include the restoration of condition to clarify and measure the impact of increased water to enter and setting goals for restoration. While assessing the validity of the stream also included the monitoring of many variables, biotic and a biotic (Norris and Thoms, 1999).

The magnitude of flow event could be characterized as the minimum wetted perimeter during the event or alternatively by the event duration. The type of analysis used to characterize the temporal distribution of events should reflect the aspect of the event distribution that is important (Gordon et al, 1992). Once the flow events have been defined, relations between the hydraulic parameters (such as wetted perimeter) and discharge are derived using hydraulic surveys and modeling.

There are many main factors that control the relation between the hydraulic parameters and ecological life that maintain a healthy ecosystem. These factors and mechanism of flow with respect to different kind of biota are based on bacterial content as indicators. The presence of pathogens in one hand indicate the deterioration of life surrounded the stream, in other hand the presence of common flora and digestive Coliform bacterial in considerable amount help the system to reduce the organic pollution and restore its quality. Such balance required special hydraulic conditions that should maintain a balance relation between different kinds of biota to support a healthy system.

Zomar stream, the case study of this research, is used as drain for the sewage from the towns of Nablus, Tulkarem and the villages located at the banks of the stream. It is roughly estimated that half of the sewage load generated between Nablus and Tulkarem infiltrates into the groundwater. Besides this, the geological situation (limestone, karstic underground) provides only very little protection for the groundwater, Figure 1.1 below shows the strength in Zomar stream from 1995-2010.

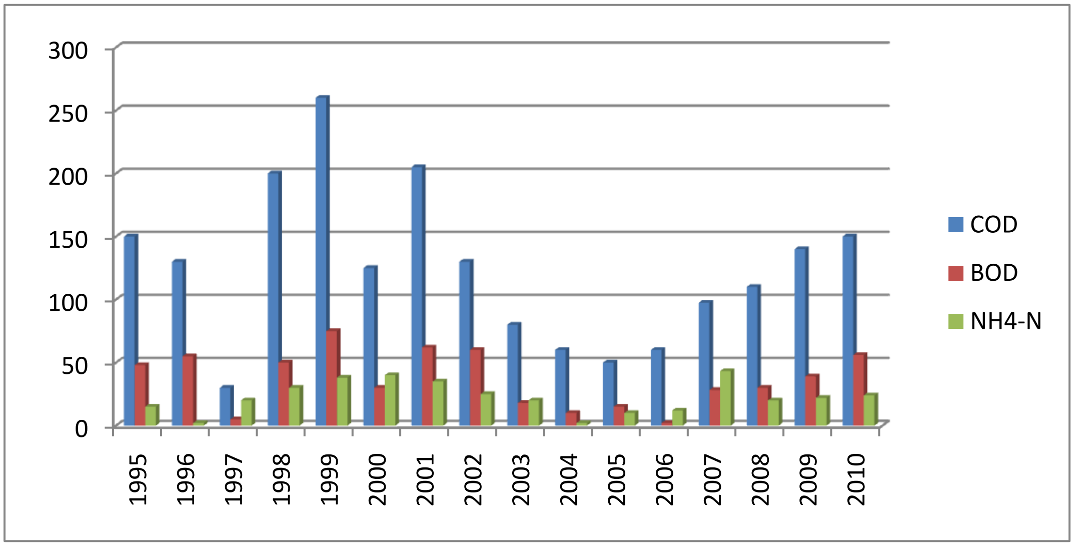


Fig 1.1: BOD, COD, NH4 average concentration in Zomar stream from 1995-2010

1.2 Statement of the Problem

For the past five decades Zomar stream has been suffering from different kind of pollution sources caused by domestic, agricultural and industrial sectors. Interestingly, around 7000 cubic meter per day of the Valley discharge come from the western part of Nablus (e.g. sewage and effluents from refugee camps, towns, Tulkarem, stone-cutting industries, landfills, leather factories and seasonal discharge from twenty-six olive oil mills) (HWE, 2006), as well as around 5 million cubic meter per year come from the domestic sector of the green line area (Abramson *et al.,* 2007).

Zomar stream must satisfy biodiversity, conservation, irrigation and restoration functions to be healthy. Stream naturally has periods of both very low (summer) and very high flows (winter). One way to achieve that is to determine the environmental flows that simulate the flows, which can occur naturally.

Zomar stream restoration is a very complex task due largely to the interactions between the physical, chemical, and biological stream components. Because of these interactions, restoring only a single component to a more natural state could have a negative effect on stream health. Pre-restoration interactions between hydrology and nutrients in the stream should be studied where wastewater effluent and a highly developed urban watershed dominated stream flow.

The Zomar stream was measured over the past twenty years. It is clear that in the years of particularly high rainfall such as 1990 to 1993, there are associated peaks in stream flow, the general trend in the data reflects a steady increase in base flow due to the increase discharge of waste water and base from the area's growing population (HWE, 2006).

Zomar stream and its catchments do several functions like recreation and biodiversity conservation which requiring a balance of environmental, social and economic considerations in determining how much water should be released for the environment.

Aquatic ecosystems are particularly sensitive to impact from unnaturally long periods of low flow will result in harmful impacts. While smaller floods are particularly important to prevent sediment build up in rocky bottomed sections of stream from damaging aquatic habitat.

The mixture of pathogenic and nonpathogenic microbes from sewage effluents, industrial processes, and agricultural activities can be a danger to bathers at a dose of the causal factors of infectious diseases and colonize a suitable location in the body growth and lead to illness (WHO, 1998).

1.3 Objectives

The following are the two objectives of the research:

- Evaluate the environmental risks of Zomar stream through studying the seasonal and annual pollutant loads, through studying representative storm water events discharges and their impact on the water quality of receiving waters.
- Develop the best scenario achieve optimum hydraulic conditions for the restoration process of Zomar stream for sustainable healthy ecosystem.

1.4 Thesis Structure

The thesis is divided into five chapters as follows:

- Chapter one is an introduction provides a general background about the subject of the thesis that describes the statement of the problem and objectives.
- Chapter two provides comprehensive literature review about Zomar Stream drainage basin and investigates previous studies.
- Chapter three deals mainly with materials and methods used to carry the study.

- Chapter four discuses the main results of   the physical, chemical, biological and hydrological parameters.
- Chapter five summarizes conclusions and recommendations.

2. Chapter two: Literature Review

2.1 Background

The process of setting environmental flow in a basin will relate to the degree of "environmental health" we wish to maintain in the basin ecosystems. The production of hydrological, chemical, socioeconomic and ecological information about the flow in question is fundamental. Environmental flows are the flows of water in streams that are necessary to keep them healthy; this concept has various key aspects. River flow has regimes to which biotic populations have adapted over millions of years; the flow regime is composed of the following elements (Stewardson and Cottingham 2002):

1) Base flow, or the volumes of water present most frequently during the dry season or rainy season
2) Yearly avenues or relatively brief discharges of large volumes of water. Other results are the renewal of water quality and flushing out of the river channel, since yearly avenues tend to restructure sediment beds in the rivers and produce seasonal fluctuations in the habitat of many benthic species.

Environmental flow assessments are directed at two main types of management response of both potential and extant impacts of altered flow regimes (Stewardson and Cottingham 2002):

(1) Proactive response, intended to maintain the hydrological regimes of undeveloped rivers as close as possible to the un-regulated condition, or at least to offer some level of protection of natural river flows and ecosystem characteristics, and

(2) Reactive response, intended to restore certain characteristics of the pre-regulation flow regime and ecosystem in developed rivers with modified/regulated flow regimes.

Both of these circumstances can be addressed using the environmental flow assessment methods currently available.

The Flow Events Method (FEM) is a new approach to developing environmental flow regimes by explicitly identifying geomorphic and biological processes affected by flow variability, the method uses the assumption that the effects of flow variations can be represented by a series of flow events, each characterized by an event magnitude. Flow events are defined using available information regarding the geomorphic or biological process of concern. Changes in flow regime are evaluated by comparing the recurrence interval of flow events with the modified and some reference flow regimes (Stewardson and Gippel, 2003).

FEM comprises 4 steps: (1) identification of ecological processes (hydraulic, geomorphic and ecological) affected by flow variations at range of spatial and temporal scales, (2) characterization of flow events (e.g. duration, magnitude) using hydraulic and hydrological analyses, (3) description of the sequence of flow events for particular processes, using a frequency analysis to derive event recurrence intervals for a range of event magnitudes, (4) setting of EF targets, by minimizing changes in natural or reference event recurrence intervals or to satisfy some constraints (e.g. maximum percent permissible change in recurrence interval for any given event magnitude) (Stewardson and Gippel, 2003). Table 2.1 contains common terms used to describe variability in river flow (Naiman et al., 2008).

Table 2.1: Common terms used to describe variability in stream flow

Magnitude	The amount of water moving past a fixed location per unit time. The larger (or smaller) the magnitude of a flood (or drought), the greater the expected physical impact.
Frequency	The number of events of a given magnitude per time interval (e.g., per year). For a given river or stream, frequency is typically related inversely to magnitude.
Duration	The period of time associated with a particular flow event. Typically expressed in terms of number of days a flood or drought lasts.
Timing	The date during the year that flood or drought occurs, often derived from long-term flow records.
Predictability	The degree to which flood or drought events are auto correlated temporally, typically on an annual cycle. Predictable events also might be correlated with other environmental signals (e.g., rainfall events, seasonal thermal extremes, photoperiod, sudden increases or decreases in flow).

Hydraulic methods relate various parameters of stream geometry to the discharge of flow. The hydraulic geometry is based on surveyed cross-sections, from which parameters such as width, depth and wetted perimeter are determined. Velocity is not usually considered in hydraulic methods (Jowett, 1997).

2.2 Previous Studies

Previous studies on Zomar Stream restoration

Abramson et al. (2010) discussed Zomar stream as the major polluted transboundary stream causes environmental degradation which often resulted in serious health and security threats to regional residents. The study assessed the Palestinian and Israeli public perceptions and preferences for stream restoration work in two transboundary watersheds: the Zomar/Alexander and the Hebron/Besor basins, in this research they utilized a survey given to a random national sample of Israelis and Palestinians over the period of February to April 2007, respondents were asked to fill out a questionnaire containing questions about river restoration, each society expressed comparable willingness to pay for restoration efforts. Results from this study indicated both populations support the improvement of their riparian environments and were willing to contribute to that goal. The study suggested further investigation should be done to determine the specific quantities of treated effluent that optimize net benefit for both watersheds.

Optima (2007) discussed Zomar stream as case study that deal with managing a cross border stream in which there was a strong interdependence between different users. The major concern in the stream was water pollution. They have conducted two economic analyses: the first one tested the 10 years long master plan of the stream between 1995 and 2005. The second economic analysis tested the stricter water quality standards which will enable more use along the stream. In order to perform the first analysis they have modeled the entire stream system from hydrological point of view; they estimated the costs associated with the master plan action which was taken in the 1995 – 2005 period and contrasted those costs with the benefits derived from that acts, where these benefits were divided into market and non-market ones.

The major conclusion was to use a mixed strategy which deals with all major pollution sources, to get a positive net benefit. This net benefit was estimated to be about $0.49 million annually. In order to perform the second economic analysis; they measured the incremental cost associated with stricter water quality standards. Those were measures at two points, namely the Turtle Bridge and the potential Peace Park. The costs associated with these stricter standards were contrasted with the benefit. This time there were only non-market benefits involved, and since it was a hypothetical scenario they used the Contingent Valuation Method (CVM) to estimate them.

Tal et al. (2006) aimed in their research to promote for Peace between Israelis and Palestinians by laying the foundations for an effective stream restoration strategy for both countries. The project covered the period from October 2004 to September 2005. They characterized the total pollution loadings into two transboundary streams whose geographic boundaries cross over the Israeli/Palestinian border (The Zomar/Alexander and Hebron/B'sor/Gaza) using the Hydrologic Simulation Program Fortran (HSPF), this allowed a more systematic assessment of intervention options affected by stream restorations and their relative cost-effectiveness.

A detailed monitoring plan was conducted that included the location of automatic monitoring stations. The characteristics of base flow and two flow events in the winter of 2005 were determined by 77 water samples that were taken from various locations and numerous time intervals in the two watersheds. These 77 water samples were also collected and analyzed for physical, biological, major components and trace elements, and sediment samples were analyzed for general trace elements and nutrients.

Previous studies on Environmental Flow Regime

Environmental flow have been increasingly recognized as a central issue in sustainable water resources management (Kashaigili et al, 2007). Environmental flow requirement (EFR) for water resources allocation requires that a certain amount of water to be purposefully left in or released into an aquatic ecosystem to maintain a condition that will support its direct and indirect use values (King et al, 2003) . Maintenance of EFR has also become one of the highest priorities of the stream basin management (Barnett et al, 2006). To assess how much of the original flow regime of a stream should continue to flow down to maintain the stream ecosystem health, besides the variability of the structures, there is also spatial variability of the ecological functions among ecosystems with deferent ecological objectives. To identify the ecological objectives for deferent ecosystems in a stream basin; regionalization of the stream system is necessary for determining the EFRs concerning deferent natural factors (e.g., hydrology and climate) and anthropocentric factors (e.g., hydraulic works). There is compatibility between the non-consumptive water requirements for deferent regions connected by the hydrological process in the basin.

Protecting and restoring stream flow regimes and hence the ecosystems they support by providing environmental flows has become a major aspect of stream basin management. There is growing awareness of the pivotal role of the flow regime (hydrology) as a key 'stream' of the ecology of streams and their associated floodplains (Richter et al.1996; Poff et al. 1997; Puckridge et al. 1998; Bunn and Arthington 2002; Naiman et al. 2002 for reviews). Every stream system has an individual or 'signature' flow regime with particular characteristics related to flow quantity and temporal attributes such as seasonal pattern of flows, timing, frequency, predictability and duration of extreme events (e.g. floods and droughts), rates of change and other aspects of flow variability (Richter et al., 1996; Poff et al., 1997; Olden and Poff, 2003). Each of these hydrological characteristics has individual as well as interactive regulatory influences on the biophysical structure and functioning of stream and floodplain ecosystems, including the physical nature of river channels, sediment regime and water quality, biological diversity/riverine biota and key ecological processes sustaining the aquatic ecosystem (Naiman et al., 2002). These processes in turn govern the ecosystem goods and services that rivers provide to humans (e.g. flood attenuation, water purification, production of fish and other foods and marketable goods).

The concept of river health is not easily defined and opinions differ on what is a "healthy river" (Marshall et al., 2001). Methods of analyzing environmental outcomes from different water policies and management options have been largely neglected until environmental problems became evident in the late 1980s and early 1990s. While this research is now in progress, a significant gap in knowledge and conflicting views on methodologies is still present (Stewardson and Cottingham, 2002).

Crabill et al. (1999) analyzed FC in water and sediment samples .They found sediment samples with up to 2200 times the FC counts of the water column. Results showed that re suspension of sediments due to agitation by recreational activities and storm events during the summer season negatively impact the water quality. Studies on the survival of bacteria indicate that sediments form an environment favorable for growth. Fecal bacteria have survived and, to a certain extent, even grown in sediments.

The microbiological context of sediments at the sediment–water interface in bathing waters is receiving increased attention (Arakel, 1995). There is evidence that fecal indicator and pathogens bacteria survive longer in sediments than in the overlying water, and it has been proposed that sediments serve as sinks of fecal bacteria with the potential pollution of bathing water more than lying (Ashbolt et al, 1993; Ghinsberg and others, 1994; Howell and others, 1996). Stream sediments have contained fecal Coliform (FC) at concentrations higher than those observed in the overlying water column. Van Donsel and Geldreich (1971) and Ashbolt et al. (1993), e.g., indicated that sediments may contain 100–1000 times the number of fecal indicator bacteria contained in the overlying water.

The main source of microbiological contamination is microorganisms from human or animal excreta, which reaches humans through contaminated water from wastewater, landfills, or wastewater treatment stations, causing serious health problems. People all over the world are estimated to suffer from water-borne diseases, and 3.4 million people die directly or indirectly from the consumption of contaminated water with bacteria and single-cell parasite, or viral pathogens (WHO / UNICEF, 2000).

Relations between bacteria and pathogens in fecally contaminated surface water will be complex and variable (Townsend, 1992; Payment et al., 2003; Yates, 2007), posing a challenge to the benefit of indicator organisms, at least, refers to the poor quality of water by pathogen.

Chemical pollution, the other type of water contamination, could be organic or inorganic. Organic chemicals include leachate (e.g., from solid waste), synthetic organic compounds, and chlorinated compounds like Trihalomethans (THM), which are associated with poisoning, cancer, liver, kidney and Central Nervous System problems (Viessman et al, 2005). Anthropogenic dry river systems are special cases of where the flow of the river had been broken, water tables have dropped sharply, and the ecosystem has responded, or is in the process of responding to the system markedly different.

2.3 Study Area

Zomar/ Alexander stream watershed spans over 556 km^2 of land and is 44 km long. It is located in the western slope of the West Bank flows from city of Nablus to the west through Anbta town and Tulkarem city down to its estuary in the Mediterranean Sea (Figure 2.1). The Alexander stream is the name given to the lower 32 kilometer section of a river running from the Mountains of the West Bank in the Palestinian authority to the coastal plain within historical Palestine. The upper, Palestinian, 22 kilometer section is known as Zomar stream and makes its way from Nablus down to the coastal plain (Brandeis, 2003).

Point pollution sources along the stream are numerous; the major pollution source is effluents that enter the stream through Zomar stream. Beginning with deposition of sewage from the western side of Nablus, the stream receives about seventy pollution sources along its route (Brandeis, 2003). These include sewage and effluents from refugee camps, towns, Tulkarem, stone-cutting industries, landfills, leather factories, etc'. For three months every year, during October through December, waste from surrounding olive press factories is added to the pollution load discharged into the stream. According to one estimate, a total quantity of 2.5-3 million cubic meters of effluents from the Palestinian territories yearly enters green line and this quantity is constantly rising (Brandeis, 2003).

2.4 Climate

The climate in the West Bank area is Mediterranean, with long hot summers and short warm winters. Autumns and springs are very short without any distinguished features. In general, the case study area (Zomar Stream) has similar conditions. The average temperature ranges between 8°C to 14°C in winter and 21.9°C to 40°C in summer; the average relative humidity varies from 39 percent in May to 84 percent in January. Humidity is at its highest in the early morning and lowest in the early afternoon (OPTIMA, 2007).

2.5 Precipitation

The mean annual rainfall in Tulkarem city is 642 mm between 1952 and 1995 (Tulkarm Agricultural Department, 1996). The amount of mean annual rainfall in the area of Tulkarem varies from year to year and rain may fall with great intensity in wet years. The rainy season in the area usually starts in October and continues through May. Almost 70% of annual rainfall occurs between December and February, while 20% of annual rainfall occurs in October and November. December and January are normally the wettest months in Tulkarem Area, rain in June and September is rare and comes to negligible amounts.

As shown in Figure 2.1 the average annual rainfall within served area ranges from 450-600 mm. The Potential Evapo Transpiration (PET) is about 100 mm during the summer, and 50-75 mm during the winter.

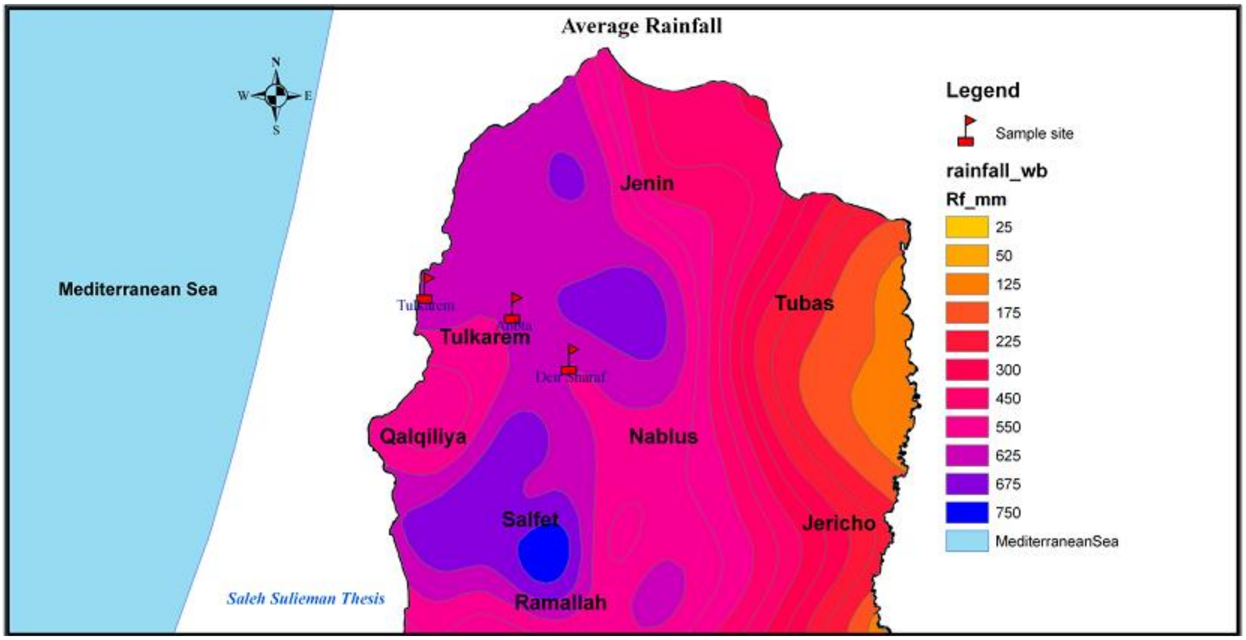


Fig 2.1: Average rainfall

Environmental flow calculations are based on long-term historical flow records, so it is important to consider the effects of climate change. Long-term projections suggest that future rainfall may be reduced and hence evaporation increase, resulting in changed stream flows.

2.6 Topography

The study area covers a wide range of different landscape and topographic features such as:

- Western part of Nablus;
- Anbta;
- Tulkarem Area;

As shown in Figure 2.2, the Topography of these areas varies between 50 to 200 m and slopes are filled with thick calcareous red-buff soils (Arabtech Jardaneh, 2008).

2.7 Geology

The geology of the study area is characterized by the presence of marine carbonate sediments such as limestone, dolomites, chalks and marls. Thus, Zomar stream suffer from major damage in the year 1927 caused by an earthquake (OPTIMA, 2007).

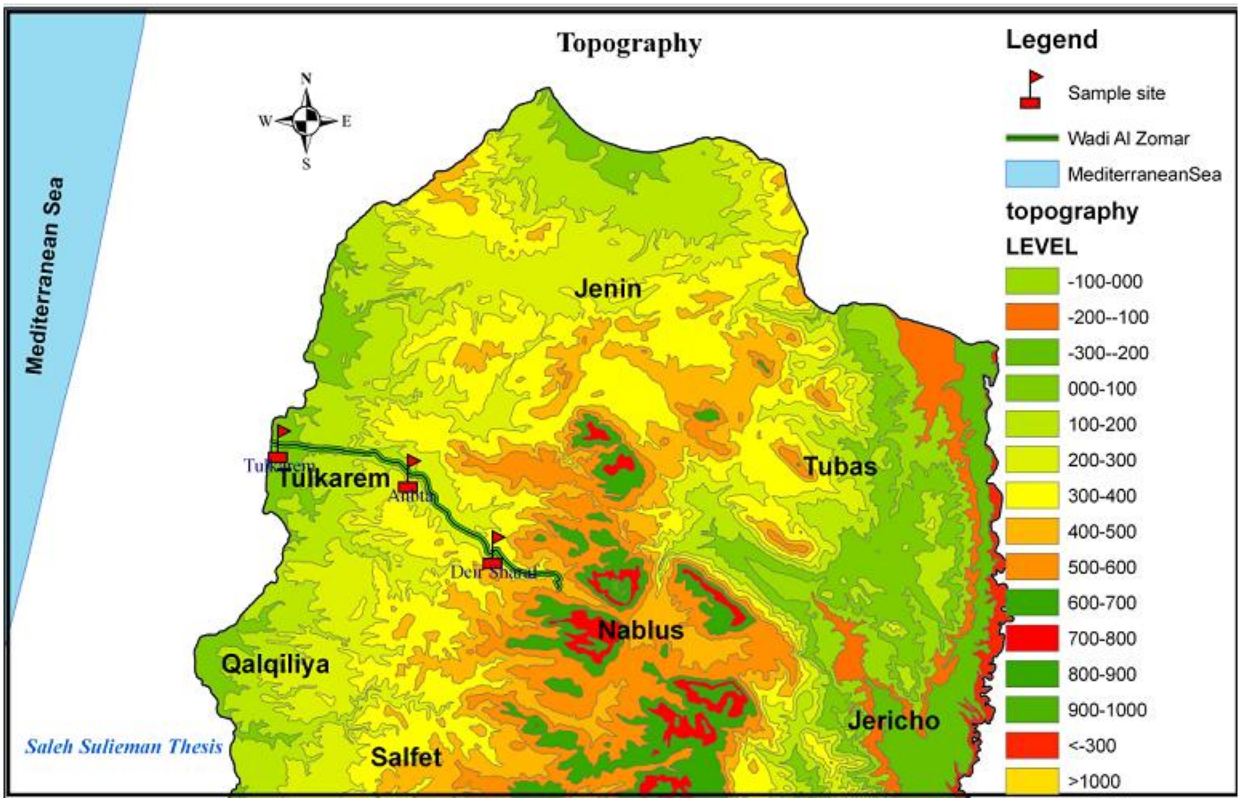


Fig.2.2: Topography of Area

2.7.1 Demography, land use change

Within the Zomar Stream Catchments, nearly 40% of the available area is dedicated to agriculture (primarily olives, but also including citrus, almonds, vegetables, wheat and barley). The built-up area covers slightly more than 5% of the catchments; forests cover about 1% of the available land, while more than half the basin area is "un-used." Although less than 10% of the total cultivated lands in the region which is included in the Palestinian authority are under irrigation (i.e. more than 90% is rain-fed), the agricultural production of this sector represents more than 50% of the total agricultural production. Vegetables and fruit trees are the most important crops in irrigated agriculture in the Palestinian part of the basin. Water scarcity, however, represents a critical constraint to further expanding, or even maintaining present irrigated areas. There are increasing demands for agricultural water use to be restricted in favour of other water consumers, such as local communities and industry. Figure 2.3 give soil classification in Zomar Stream region.

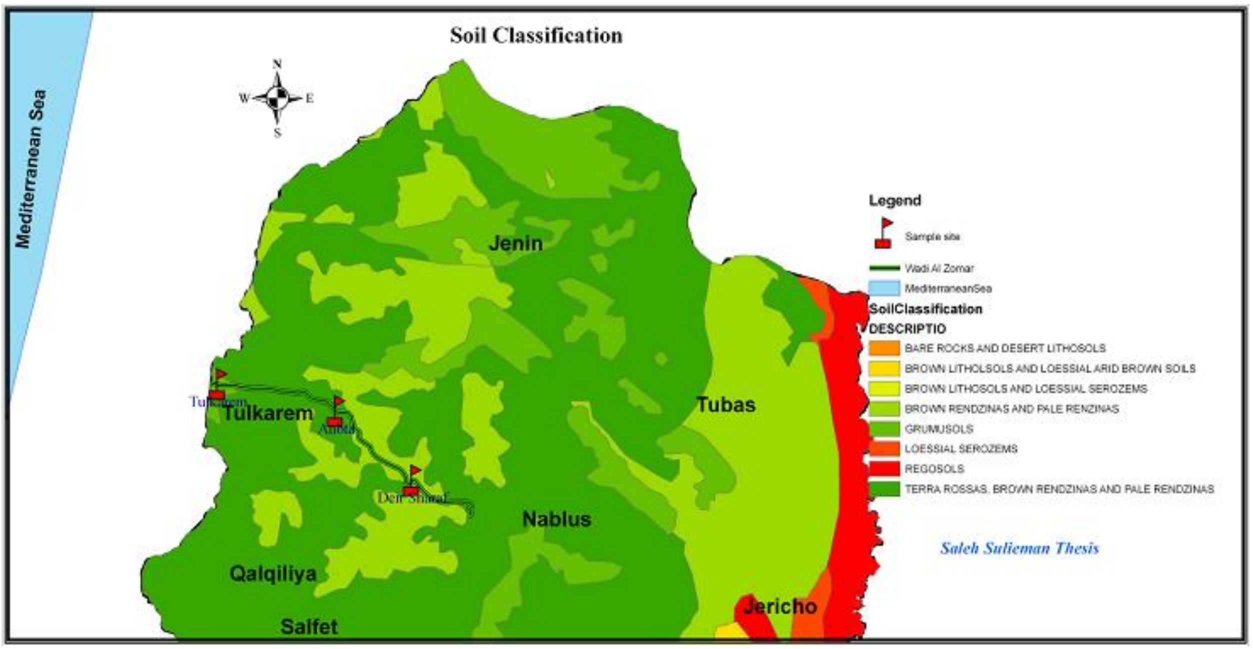


Fig.2.3: Soil Classification in the region of Zomar Stream

The land use of the watershed is divided into five categories as shown in Table 2.2, it is clear that the land utilization is dominated by the agricultural activities (both orchards and field crops) with a meaningful percentage of urban areas discharging into the watershed as well (OPTIMA, 2007).

Table 2.2: Areas of land use types within Zomar Watershed

ID	Type Name	Area (km^2)	% from Total area
1	Urban (including road system)	72.21	15.05%
2	Field Crops	142.74	29.76%
3	Orchards	173.97	36.27%
4	Shrubs	87.12	18.16%
5	Forests	3.66	0.76%
Total		**479.7**	**100.00%**

2.7.2 Hydrogeology

The main source of domestic water in the West Bank is derived from shallow and deep water bearing formations of the Mountain Aquifer. This Mountain aquifer was divided and named into three main groundwater basins based on the direction of the hydraulic drainage, namely the Western, North-Eastern and Eastern Basin (OPTIMA, 2007).

The West Bank has been classified into different sensitive areas based on the degree of sensitivity to pollution. Most of the sensitive areas are located in the north and the west of the West Bank while the south and the east are less sensitive and the area of Tulkarem is considered highly sensitive due to the shallow aquifer system where pollutants are being increasingly added to the groundwater system through various human activities and natural processes (MOPIC, 1998).

Tulkarem district lies nearly in the Western Aquifer, whereas Nablus district is located in all three aquifers. Most of the recharge areas (~80%) of the Western Aquifer are in the West Bank and the ground water flows westwards towards the Mediterranean Sea. In Tulkarem there are three major aquifers, the Cenomanian Aquifer (Lower Aquifer), Upper Cenomanian-Turonian

(Upper Aquifer) and the Eocene complexes. The Lower Aquifer is a deep confined aquifer with high water bearing capacity and productivity, due to the great thickness of up to 400 m of dolomitic limestone.

In Tulkarem the Lower Aquifer has not been explored yet as the high yielding wells, the Upper Aquifer can satisfy the required amount of water. The Upper Aquifer has generally higher water heads than the Lower Aquifer; it is exposed to pollution caused by leaking cesspits, sewage disposal in the wadis and the infiltration of chemicals released on the surface. Close to urban and agricultural areas water analyses show high levels of nitrate in most of the wells (OPTIMA, 2007).

2.8 Springs and Wells

There are 10 domestic wells and 53 irrigation wells with total available quantity of groundwater of 21.25MCM per year (PWA, 2004).The spring of Nablus district can be divided into two aquifers, Eocene aquifer system which contains 18 springs located around Nablus city. The Albian – Turonian aquifer system that contains 13 springs located in the southern and south-eastern part of this district.

2.9 Socio-economic aspect

The two main municipalities in the stream region are Tulkarem and Nablus. Tulkarem is one of a major Palestinian city with a population of ~ 95,000. Nablus is another major city with a population of ~ 120,000; Deir Sharaf and Anbta are medium-sized towns with a population of ~ 13,000.

Detailed socio-economic studies on the social uses of non-perennial rivers are scarce. The development of socio-economic matrixes, for the assessment of river uses, is, however, a significant step towards the refinement of an appropriate social methodology for the study area.

Such matrices can only benefit from similar approaches and instruments which have been developed by practitioners in the area of social impact assessments.

There are two main issues regarding the Zomar stream restoration: Water supply and Environment. Water supply: Since the stream is located in a dry area, not much water is available for people's consumption. So if the sewage in the stream is treated, people could use the water again. Environment: If the sewage is treated, the ecosystem would recover, the wildlife would improve, and the entire area would become healthy whether there is water in the stream or not.

Chapter Three: Materials and Methods

3.1 Background

The evaluation of the environmental risks for Zomar stream was assessed by carrying physiochemical and microbiological quality analysis. The key factors and variables that play role in the environmental flow regime of the stream were identified. For restoration purposes three sampling points were selected based on the human activities and pollution sources along the stream. The water samples were examined for the presence of *Coliform* bacteria and pathogens. Four species were isolated (*Escherichia coli, Pseudomonas, Enterococcus,* and *Klebsiella*). The spatially and temporally behavior of these species were investigated in response to the variability in hydraulic parameters and nutrients load respectively.

3.2 Sampling

3.2.1 Samples Location

Samples were taken from three locations as shown on Figure 3.1:

1. Deir Sharaf: This location receives high load of sewage and industrial wastes.
2. Anbta: This location was selected to evaluate its effect on self purification occurred because of the long distance between the two sampling points.
3. Tulkarem: This location was selected as far as along the Zomar stream after Tulkarem city near the green line.

These sites were identified by landmarks and by global positioning system as shown in Table 3.1

3.2.2 Samples collection

Sampling was performed according to the World Health Organization Manual for Recreational water and Beach Quality Monitoring and Assessment (1995). The samples were collected by the

Author. And analyzed at the Environmental and Water studies Institute's lab. The sampling frequency was weekly and after each raining event from three sites. Sample collection lasted from Jan 2010 to March 2010. The samples of raw wastewater were collected in sterile 2-L plastic bottles, stored at 4 °C, held in sterile boxes, and sent to the laboratory within 1–2 h of collection where they were analyzed within 6h for microbial parameters and 24hr for other chemical parameters (Hach, 1999). The measured parameters for the storm water analysis are listed in Table 3.2.

Table 3.1: Sampling site identification information

Location no.	Location title	Permanent mark	GPS location		
			X(m)	Y (m)	Elevation(m)
1	Deir Sharaf	Dam	0167517	4184694	285.9
2	Anbta	Eman school	0161563	4190108	162
3	Tulkarem	Dam	0152193	4192224	55.3

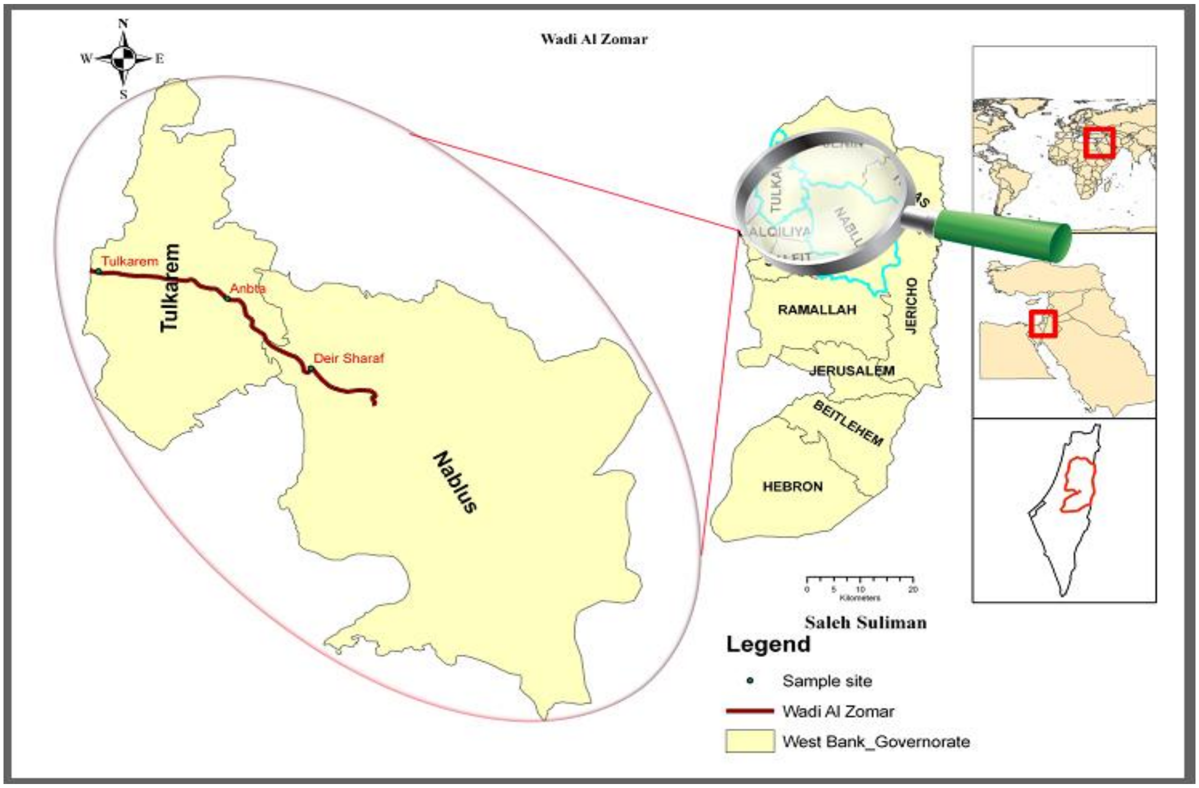


Fig.3.1: Samples' locations

Table 3.2: Methods used and water quality parameters measured for Zomar stream

Parameters measured	Instruments used for analysis	Methods of analysis	Location of analysis	Reference
pH	pH-meter 3320, Jenway	SM#4500-H+(B)(on site)	IEWS lab Onsite, Hanna pH meter	Direct measurement as manufacturer procedure APHA 1995, 19th ed.
Conductivity	Conductivity meter, 4320, Jenway	2520-B	IEWS lab Onsite, Hanna EC meter	
Total coliforms and fecal coliforms		9222-B 9221-E	IEWS lab	APHA 1995, 19th ed.
Orthophosphate	Automated ascorbic acid reduction	SM# 4500-P F	IEWS lab	APHA 1995, 19th ed.
NO_3^-	UV 300/ UV-Visible spectrophotometer/ UNICAM (λ=22 0 nm)	4500- NO_3^-	IEWS lab	APHA 1995, 19th ed.
Organic material COD BOD_5	Hach COD reactor DO meter – Oxi 197	5210-B 5220-D	IEWS lab	APHA 1995, 19th ed.
NH4-N	Nesselarization Method	4500A- NH_3	IEWS lab	APHA 1995, 19th ed.
Pathogens: *E. Shigella* *Klebsiella* *Enterococcus* *Pseudomonas*	Membrane Filter Technique	9260F 9222F 9230C 9213E	BZLC	APHA 2005, 21th ed.
Flow	Current meter	--	Certain sampling station	--

3.3 Parameters' Analysis

3.3.1 Physical parameters

pH, temperature, Total Dissolved Solids (TDS), Dissolved Oxygen (DO) and Electrical Conductivity (EC) were measured using field instruments, WTW (Germany) Inolab pH/Oxi meter.

3.3.2 Chemical parameters

BOD_5, COD, Nitrate, ammonia and orthophosphate were measured according to Standard methods (APHA, 1998).

3.3.2.1 Chemical Characteristics and measurements of Base Flow

Measurements of base flow water discharges (Q) were conducted at several stations along the Zomar stream. Stream flows were calculated using Equation 1.

$$Q = A*V \qquad (1)$$

Where:

A is the cross-section area of the stream (m^2)

V is the mean stream water velocity (m/sec).

After a cross-section area was chosen and measured, water velocities of the water columns were measured in 0.20 m intervals, using an electromagnetic flow velocity meter – (Marsh- McBirney Inc., flow-mate model 2002).

The mean velocity of a water column was measured at 60% of the depth (from the water level) (Naiman, et al, 2002, Postel, et al, 2003). The total discharge is a summation of all partial discharges from the individual intervals.

The base flow in the Zomar stream was sampled and analyzed at different occasions. The flow in Zomar stream, as expected, is primarily raw sewage discharged from the city of Nablus, which gives the water a whitish–grayish color

Literature shows that stream restoration is a lengthy process, lasting many years. It involves multipurpose activities, including the cessation of sewage discharge, cleanup of riverbeds, re-creation of flow paths, and the facilitation of the natural processes of habitat renewal (Bar-Or , 2000).

3.3.3 Biological parameters

Total and *fecal coliform* were analyzed according to 9222-B and 9221-E methods respectively (APHA, 1995). Pathogens were analyzed according to (APHA, 2005).

3.4 Sediments

Sediments were collected and analyzed according to (APHA, 2005).

3.5 Conceptual Model

Conceptual models can be viewed as qualitative or quantitative statements of hypotheses concerning the nature of ecological risks. While it is likely that all risk assessments will require a conceptual model, it is clear that the models will vary with circumstances. To predict the conceptual model for Zomar stream restoration, rain events from the beginning of winter season, and the bacterial community were predicted monthly with respect to both actual monthly rain events and cumulative amount of monthly Rainfall. All factors and variables that control the process of natural restoration for the stream, as well as, the spatial and temporal parameter that affect the whole process were assessed. Such identification of the hydrological, chemical and related biological community can help for building a new visualized model where the best optimal condition where the healthy environment is exist can be predict by adjusting different recognized key factors out of this study. In natural stream at normal condition; the factors that cause stream pollution are studied (deteriorate stream water quality), but this case deals with wastewater flow and the exception is the dilution resulted from discharge of fresh rain water in winter season as shown on Figure 3.2. So to determine the natural flow regime, identifying different parameters that control the following is needed:

- Deterioration of water quality and consequently biota.
- Dilution of wastewater that restores or save a healthy environment. This done with reference to point that achieves best condition during one rain events.

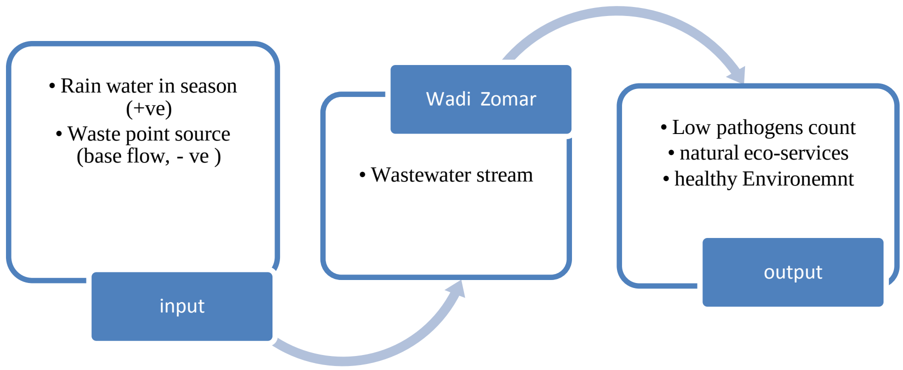


Fig.3.2: Zomar stream conceptual model

3.6 Validation and quality control

Certain measures were conducted for quality control of the measured values as follows:

- Standard calibration curves for most analyzed parameters were constructed using the appropriate concentrations that cover the range of samples concentration.
- Blank samples were used with the suitable solvent to reduce matrix effects on the analyzed parameters.

Chapter Four: Results and Discussion

4.1 General

Water samples from the three locations described in the previous chapter (Deir Sharaf, Anbta and Tulkarem) were collected in the periods from January to March 2010. The main physical, chemical, biological and hydrological results for samples from three sampling locations at different times during previous period are presented in the following sections.

4.1.1 Physical Parameters

pH, Total Dissolved Solid (TDS), Temperature, Conductivity, Salinity and Dissolved Oxygen (DO) parameters were measured at field for each location and presented in Table 4.1 below. Table 4.1 shows that temperature correlated significantly with DO in most locations and with EC in all locations. Most pH measurements were found to be in the acceptable range, 6.5–8.5 (Elmanama et al., 2006) for all locations during the whole monitoring period. Slightly lower values were obtained during the rainy season; these values started to rise at the end of the season. DO drop to alarming levels at almost all locations during certain collection periods. The average did not vary greatly but it is evident that DO was inversely related to BOD_5 which illustrates the seasonal variation in both DO and BOD_5 at all locations (Table 4.1).

Table 4.1: Physical parameters at the three sampling locations during the hydrological year 2009/2010.

Location	Sample Date	pH	TDS (mg/l)	Temp. (°C)	Conductivity (µS/cm)	Salinity (%0)	DO (mg/l)
Deir Sharaf	31.1.2010	7.35	154	19.6	307	0.6	1.3
Anbta	31.1.2010	7.55	158	19.2	312	0.6	1.7
Tulkarem	31.1.2010	7.75	463	20.7	932	0.8	1.4
Deir Sharaf	7.2.2010	7.53	470	19.8	970	0.6	1.6
Anbta	7.2.2010	7.1	612	18.6	1240	0.7	1.8
Tulkarem	7.2.2010	7.25	636	20.1	1298	0.7	1.9
Deir Sharaf	14.2.2010	7.27	545	20.0	1103	0.7	1.5
Anbta	14.2.2010	6.78	682	17.0	1380	0.9	1.4
Tulkarem	14.2.2010	7.08	783	18.5	1534	1.1	1.4
Deir Sharaf	21.2.2010	7.23	458	17.3	910	0.7	1.2
Anbta	21.2.2010	6.80	430	18.3	853	0.8	1.2
Tulkarem	21.2.2010	7.10	560	21.1	1110	1.2	1.3
Deir Sharaf	2.3.2010	7.38	388	20.1	774	0.4	2.4
Anbta	2.3.2010	7.58	257	22.7	520	0.2	7.4
Tulkarem	2.3.2010	7.22	370	21.2	750	0.6	4.0

4.1.2 Chemical Parameters

Chemical oxygen demand (COD), Biochemical oxygen demand (BOD_5), Ammonia, Orthophosphate and Nitrate were measured as presented in Table 4.2. There was a clear difference in BOD_5 levels for the three sampling locations under study. The lowest average BOD_5 scores were measured at Anbta sampling location which presents the least polluted with organic matter. Deir Sharaf and Tulkarem sampling locations had the highest BOD_5 levels. Thus, organic pollutant input to the various locations is not consistent, as indicated by the wide difference between the minimum and maximum BOD_5 values at all sampling locations. Figure 4.1 illustrate the relationship between BOD_5 and *fecal* indicators at all sampling locations. Deir Sharaf sampling location shows heavily contaminated with sewage. Ammonia correlated with BOD_5 at Deir Sharaf. Orthophosphate concentrations were highest at Tulkarem sampling location followed by Deir Sharaf sampling location (Figure 4.1). That is in addition to the wastewater outlet no significant correlation was observed between orthophosphate and any other parameter at any location.

Table 4.2: Chemical parameters (mg /L) for the three sampling location during the hydrological year 2009/2010.

Location	Sample Date	COD	BOD_5	NH_4-N	PO_4-P	NO_3
Deir Sharaf	31.1.2010	176.0	51	41.4	1.72	0.3
Anbta	31.1.2010	94.8	37	60.9	1.4	0.6
Tulkarem	31.1.2010	142.2	28	2.1	0.1	1.2
Deir Sharaf	7.2.2010	120.4	15	11.4	1.2	0.8
Anbta	7.2.2010	122.2	35	13.0	0.13	0.7
Tulkarem	7.2.2010	53.5	20	23.6	1.0	1.1
Deir Sharaf	14.2.2010	78.5	30	14.4	2.7	0.2
Anbta	14.2.2010	99.3	35	10.7	1.9	0.5
Tulkarem	14.2.2010	105.9	40	19.9	5.5	0.8
Deir Sharaf	21.2.2010	385.3	180	31.1	10.4	7.7
Anbta	21.2.2010	385.6	165	26.6	8.14	4.0
Tulkarem	21.2.2010	386	150	43.2	12.4	3.6
Deir Sharaf	2.3.2010	67.6	28	38.4	1.2	1.6
Anbta	2.3.2010	4.6	2	4.6	0.8	1.3
Tulkarem	2.3.2010	29.9	10	20.9	0.6	0.8

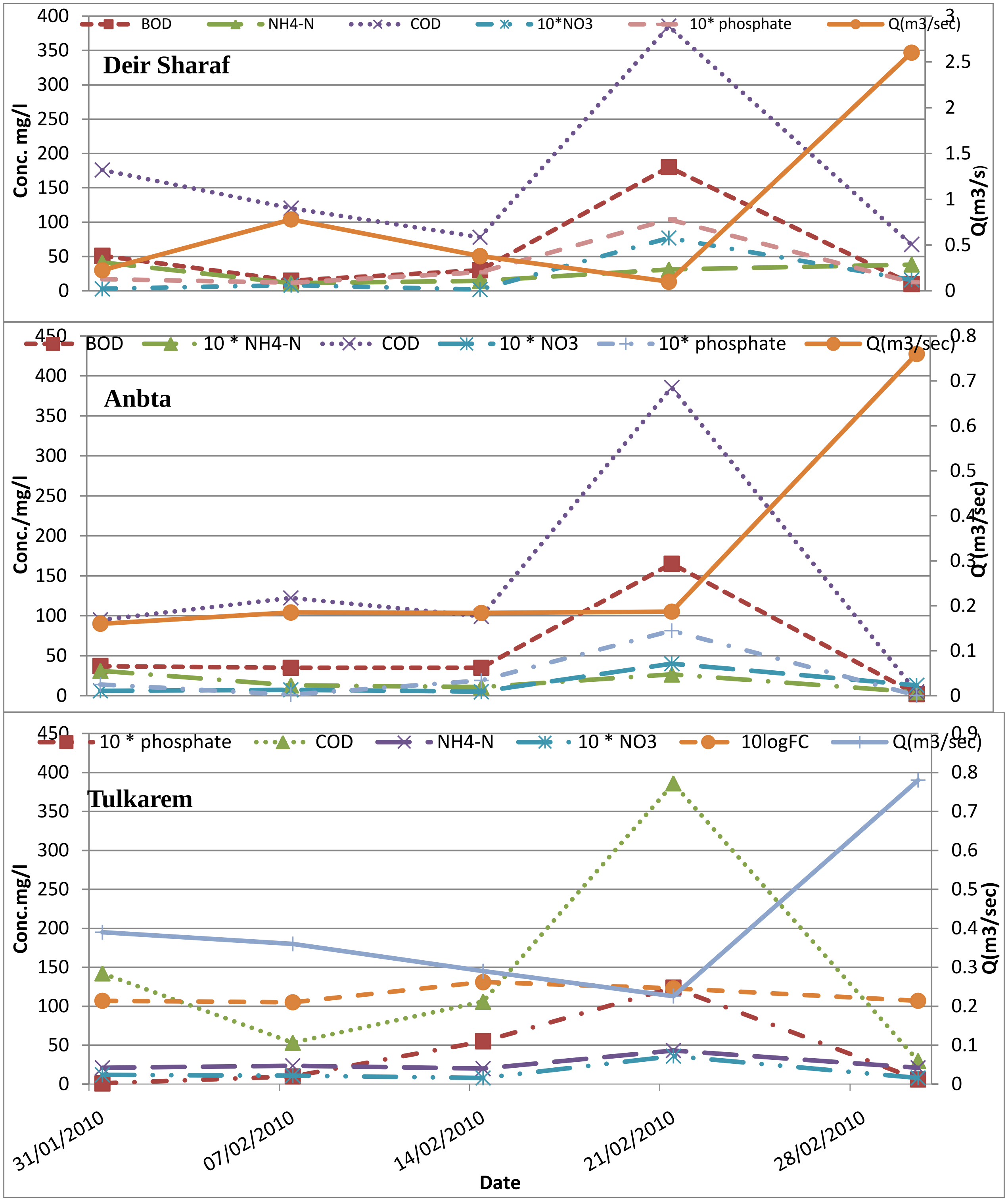


Fig.4.1: Chemical parameters and flow discharge at the three sampling locations

4.1.3 Microbiological Parameters

4.1.3.1 Bacteria

Water samples from Zomar stream were analyzed for Total Coliform (TC) and *Fecal Coliform* (FC) as shown in able 4.3. *Fecal Coliform* levels correlated significantly with BOD_5 at all sampling locations.

Table 4.3: *Total Coliform (TC)* and *Fecal Coliform (FC)* for the three sampling locations during the hydrological year 2009/2010.

Location	Sample Date	Storm event	Fecal Coliform (cfu/100ml) edge	Fecal Coliform (cfu/100ml) mid.	Total Coliform (cfu/100ml) edge	Total Coliform(cfu/100ml) mid.
Deir Sharaf	31.1.2010	End of first storm (11:30 AM)	$12*10^{9}$	$2*10^{9}$	$7*10^{14}$	$5*10^{12}$
Anbta	31.1.2010		$2*10^{10}$	$8*10^{9}$	$6*10^{14}$	$4*10^{13}$
Tulkarem	31.1.2010		$9*10^{10}$	$8*10^{9}$	$2*10^{14}$	$1*10^{13}$
Deir Sharaf	7.2.2010	End of second storm (10:30 AM)	$12*10^{10}$	$3*10^{10}$	$7*10^{16}$	$2*10^{12}$
Anbta	7.2.2010		$5*10^{10}$	$6*10^{9}$	$6*10^{14}$	$4*10^{11}$
Tulkarem	7.2.2010		$7*10^{10}$	$3*10^{10}$	$2*10^{14}$	$6*10^{10}$
Deir Sharaf	14.2.2010	14/02/2010 After one week of drought	$4*10^{12}$	$8*10^{10}$	$2*10^{6}$	$4*10^{12}$
Anbta	14.2.2010		$6*10^{12}$	$4*10^{9}$	$5*10^{14}$	$8*10^{12}$
Tulkarem	14.2.2010		$2*10^{13}$	$6*10^{10}$	$1*10^{14}$	$3*10^{12}$
Deir Sharaf	21.2.2010	After two week of drought	$4*10^{12}$	$3*10^{10}$	$7*10^{16}$	$4*10^{14}$
Anbta	21.2.2010		$8*10^{12}$	$3*10^{10}$	$4*10^{16}$	$8*10^{13}$
Tulkarem	21.2.2010		$4*10^{12}$	$2*10^{10}$	$8*10^{16}$	$2*10^{14}$
Deir Sharaf	2.3.2010	End of storm (11:30 AM)	$5*10^{9}$	$3*10^{10}$	$8*10^{14}$	$8*10^{6}$
Anbta	2.3.2010		$4*10^{12}$	$8*10^{10}$	$4*10^{7}$	$6*10^{6}$
Tulkarem	2.3.2010		$2*10^{11}$	$6*10^{10}$	$6*10^{16}$	$4*10^{15}$

4.1.3.2 Pathogens

Specific enteric pathogens *E. coli, Enterococcus, Klebsiella pneumonia, Pseudomonas aeruginosa* were isolated and measured as shown in Table 4.4. These pathogens were chosen based on the available literature, ability to cause waterborne disease, presence in surface water and available technical capacity at Palestine. Samples were taken from the mid and from the edge of the stream in order to study the effect of flow discharge on bacteria community build up.

For risk assessment of pathogens in supply stream, it was important to understand the role of hydrodynamics in determining the timescale of transport to the off-take relative to the timescale of inactivation.

The transport of pathogens overland in surface runoff is clearly responsible for event-related increases in the concentrations of in-stream waterborne pathogens in many watersheds. However, there are significant knowledge gaps concerning the precise mechanisms of pathogen transport. Pathogens considered representative of those associated with waterborne disease included human *fecal* contamination.

Studies on the survival of bacteria indicated that sediments form an environment favorable for growth (Curtis and Sloan, 2005; Jamieson et al., 2004; Characklis et al., 2005). Results showed that re suspension of sediments due to agitation by recreational activities and storm events during the summer season negatively impact the water quality. As a result, the relationship between pathogen load and sediment, settled and running loading was investigated.

Pathogen removal performance reported here covers monitoring period for the three sampling locations. The results show that in contrast to the other pathogens, *E. coli* was detected very infrequently during rain event in settled samples, and/or (re)mobilization of bacteria that had proliferated. Pathogenic bacteria count changed significantly with heavy rain caused an increase in stream flow.

Pathogen removal efficiency

Average pathogenic concentration in the stream like *E.Coli* was reduced from $1.8*10^4$, $6.2*10^4$, $1.7*10^5$ cfu/100 ml to $3.6*10^3$, $1.7*10^2$, $9.4*10^3$ showing log removal of 0.7, 2.6 and1.2, respectively. Anabta sampling location shows the highest removal (self purification) while Deir Sharaf sampling location shows the lowest removal (close to source point). Among the list of enteric pathogens, *E.Coli* was special concern due to public health.

Table 4.4: Pathogen types, presence and concentration in the sampling locations.

Sampling Site	Sampling Type	Sampling date /Pathogen Type	Events Sample Date			
			31/1/2010	15/2/2010	21/2/2010	2/3/2010
Deir Sharaf	Sediment	Escherichia coli	$4.8*10^5$	$4.8*10^7$	$1.4*10^7$	$2.7*10^5$
		Pseudomonas	$1.7*10^5$	$1.0*10^8$	$1.2*10^7$	$3.0*10^6$
		Enterococcus	$1.8*10^4$	$2.4*10^7$	$1.9*10^7$	$4.2*10^5$
		Klebsiella	$3.9*10^5$	$5.2*10^7$	$2.2*10^6$	$3.3*10^7$
	Settled	Escherichia coli	$2.7*10^5$	$2.3*10^5$	$4.9*10^4$	$3.3*10^4$
		Pseudomonas	$2.0*10^6$	$7.7*10^6$	$1.5*10^5$	$1.4*10^4$
		Enterococcus	$5.3*10^4$	$9.8*10^4$	$3.7*10^4$	$1.2*10^5$
		Klebsiella	$3.0*10^6$	$5.0*10^5$	$4.2*10^5$	$2.0*10^5$
	Running	Escherichia coli	$1.2*10^6$	$4.8*10^5$	$1.8*10^4$	$3.6*10^4$
		Pseudomonas	$3.2*10^6$	$1.8*10^6$	$7.2*10^4$	$2.5*10^5$
		Enterococcus	$9.9*10^4$	$1.0*10^5$	$3.0*10^4$	$1.4*10^5$
		Klebsiella	$2.8*10^5$	$2.8*10^6$	$1.1*10^5$	$5.5*10^6$
Anbta	Sediment	Escherichia coli	$2.0*10^5$	$8.8*10^6$	$1.4*10^5$	$1.1*10^4$
		Pseudomonas	$1.4*10^5$	$5.3*10^7$	$9.0*10^4$	$3.0*10^6$
		Enterococcus	$1.3*10^5$	$1.6*10^4$	$8.2*10^4$	$2.5*10^3$
		Klebsiella	$2.7*10^6$	$4.5*10^5$	$6.0*10^5$	$2.5*10^7$
	Settled	Escherichia coli	$1.4*10^6$	$2.4*10^5$	$5.0*10^3$	120
		Pseudomonas	$1.0*10^5$	$4.7*10^5$	$7.2*10^4$	$1.2*10^4$
		Enterococcus	$2.2*10^5$	$1.1*10^4$	$2.9*10^3$	370
		Klebsiella	$1.1*10^6$	$3.6*10^5$	$3.8*10^4$	$7.9*10^3$
	Running	Escherichia coli	$1.9*10^5$	$1.5*10^5$	$1.7*10^5$	$9.4*10^3$
		Pseudomonas	$2.5*10^5$	$3.0*10^5$	$1.0*10^5$	$7.8*10^4$
		Enterococcus	$1.1*10^4$	$1.2*10^5$	$1.3*10^5$	$1.7*10^4$
		Klebsiella	$1.9*10^5$	$3.4*10^5$	$5.5*10^4$	$8.0*10^4$

Table 4.4: Pathogen types, presence and concentration in the sampling locations./continue						
Tulkarem	Sediment	Escherichia coli	$2.0*10^5$	$8.8*10^6$	$1.4*10^5$	$1.1*10^4$
		Pseudomonas	$1.4*10^5$	$5.3*10^7$	$9.0*10^4$	$3.0*10^6$
		Enterococcus	$1.3*10^5$	$1.6*10^4$	$8.2*10^4$	$2.5*10^3$
		Klebsiella	$2.7*10^7$	$4.5*10^5$	$6.0*10^5$	$2.5*10^7$
	Settled	Escherichia coli	$1.4*10^6$	$2.4*10^5$	$5.0*10^3$	120
		Pseudomonas	$1.0*10^7$	$4.7*10^5$	$7.2*10^4$	$1.2*10^4$
		Enterococcus	$2.2*10^5$	$1.1*10^4$	$2.9*10^3$	370
		Klebsiella	$1.1*10^6$	$3.6*10^5$	$3.8*10^4$	$7.9*10^3$
	Running	Escherichia coli	$1.9*10^5$	$1.5*10^5$	$1.7*10^5$	$9.4*10^3$
		Pseudomonas	$2.5*10^5$	$3.0*10^5$	$1.0*10^5$	$7.8*10^4$
		Enterococcus	$1.1*10^4$	$1.2*10^5$	$1.3*10^5$	$1.7*10^4$
		Klebsiella	$1.9*10^5$	$3.4*10^5$	$5.5*10^4$	$8.0*10^4$

- All units are in cfu/100ml

4.1.4 Precipitation

Table 4.5 and Figure 4.2 present the precipitation at the three sampling locations.

Table 4.5: Events precipitation at three locations (PMD, 2010).

Sampling Time	Deir Sharaf Precipitation (mm)	Anbta Precipitation (mm)	Tulkarem Precipitation (mm)
31/01/2010	18	10.4	11
07/02/2010	59	34.3	36
14/02/2010	9	16.8	13.7
21/02/2010	7.5	4.5	4.6
02/03/2010	197.4	114.2	120.5

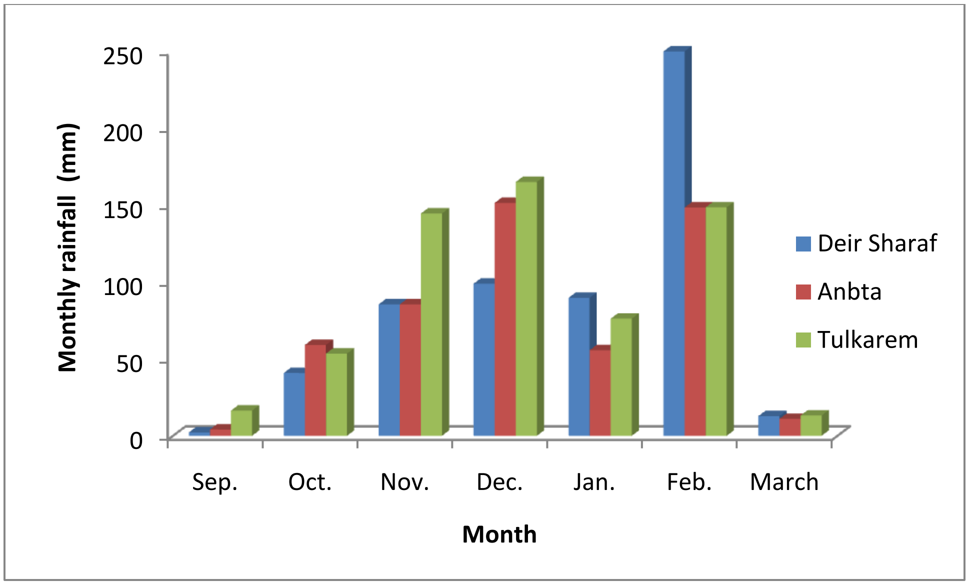


Fig.4.2: Monthly rainfall in study area for hydrological year 2009/2010

Table 4.6 illustrates the respond of *Fecal Coliform* population to monthly and cumulative precipitation at Anbta sampling location.

Table 4.6: Fecal Coliform population, monthly precipitation and cumulative precipitation at Anbta sampling location (PMD, 2010).

Month	Fecal Coliform(cfu/100ml)	monthly precipitation (mm)	cumulative precipitation (mm)
Sep.	9000000000	2.2	2.2
Oct.	100000000	40.8	43
Nov.	20000000	85.4	128.4
Dec.	5000000	98.8	227.2
Jan.	2000000	89.6	316.8
Feb.	80000	249.7	566.5
Mar.	30000	12.8	579.3

4.2 Flow event

Results for amount of discharge and Wetted perimeter (P) at each sampling location were illustrated in Table 4.7. At each sampling location the stream discharge was calculated through measuring width, depth and velocity of the stream. The wetted perimeter is the portion of the channel that is "wet". The wetted perimeter (P) is the width (W) plus twice the depth (D) that the water touches:

P= W + 2D

The greater the cross-sectional area, the greater wetted perimeter, and thus more freely flowing will the stream, because less of the water is in proximity to the frictional bed. So as hydraulic radius increases so will velocity (all other factors being equal) (Gippel et al., 1998).

Studies have shown that width and depth tend to vary regularly with stream discharge. If discharge is held constant and width decreases, then the channel should deepen by scouring. This occurs as a result of the increased velocity and transportation power which accompanies the narrowing of a channel (Gippel et al., 1998). Studies have also shown that as mean discharge of a stream increases downstream so do channel width, depth, and average current velocity (Gippel et al., 1998).

Table 4.7: Main hydrological parameters for the three sampling locations at different times during the hydrological year 2009/2010.

Location	Sample Date	Discharge (Q)(m3/sec)	wetted perimeter (m)
Deir Sharaf	31.1.2010	0.22	3.1
Anbta	31.1.2010	0.16	2.4
Tulkarem	31.1.2010	0.39	2.8
Deir Sharaf	7.2.2010	0.78	3.9
Anbta	7.2.2010	0.18	2.6
Tulkarem	7.2.2010	0.36	3.5
Deir Sharaf	14.2.2010	0.38	3.6
Anbta	14.2.2010	0.18	2.8
Tulkarem	14.2.2010	0.29	3.0
Deir Sharaf	21.2.2010	0.10	2.4
Anbta	21.2.2010	0.87	2.5
Tulkarem	21.2.2010	0.22	2.9
Deir Sharaf	2.3.2010	2.60	5.5
Anbta	2.3.2010	0.76	3.6
Tulkarem	2.3.2010	0.78	3.8

Figure 4.3 shows the flow in the Zomar stream as measured over the past forty years. It is clear that in the years of particularly high rainfall such as 1990 to 1993, there are associated peaks in stream flow, the general trend in the data reflects a steady increase in base flow due to the increase discharge of waste water and base from the area's growing population. The annual Average Flow during the past 40 years is around 12 MCM (OPTIMA, 2007).

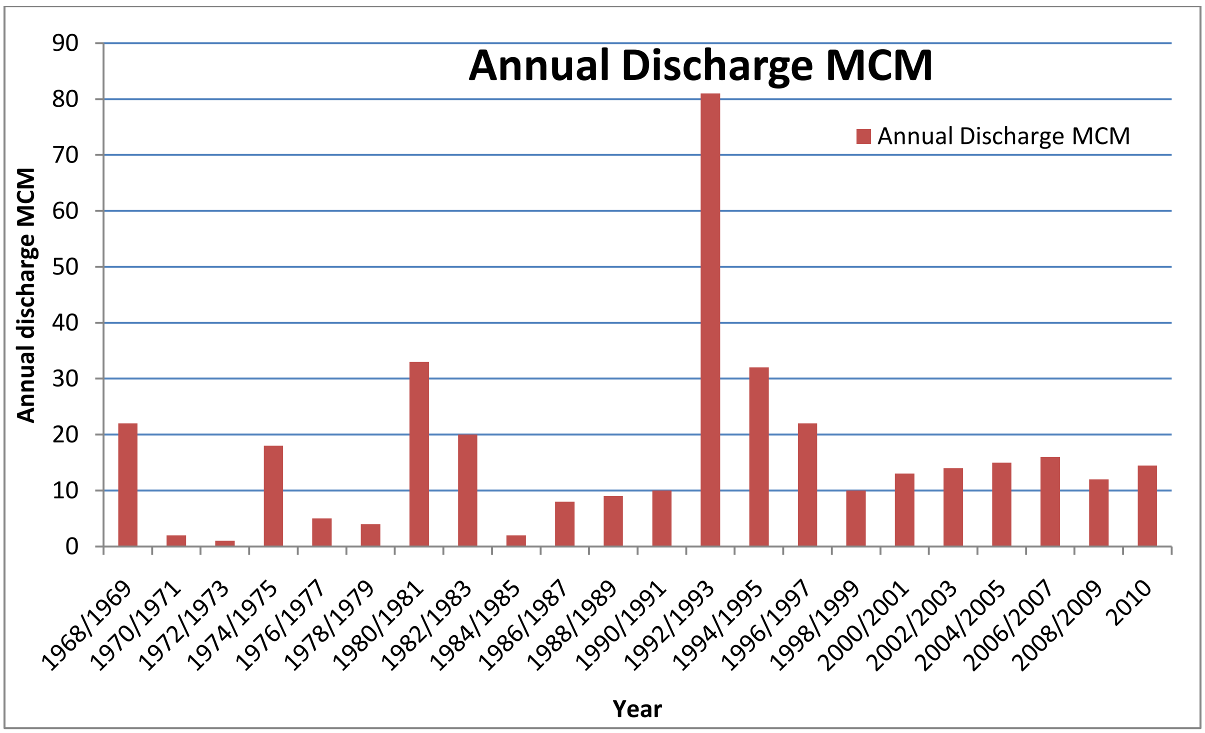


Fig.4.3: The annual discharge in Zomar Stream between 1968-2010

Bacterial communities decreased after each rain events because nutrients and colonies wash out, the bacteria lost the ability to re-build its communities again due to short draught period where the second rain event make further flush out and so on as shown in Figure 4.4.

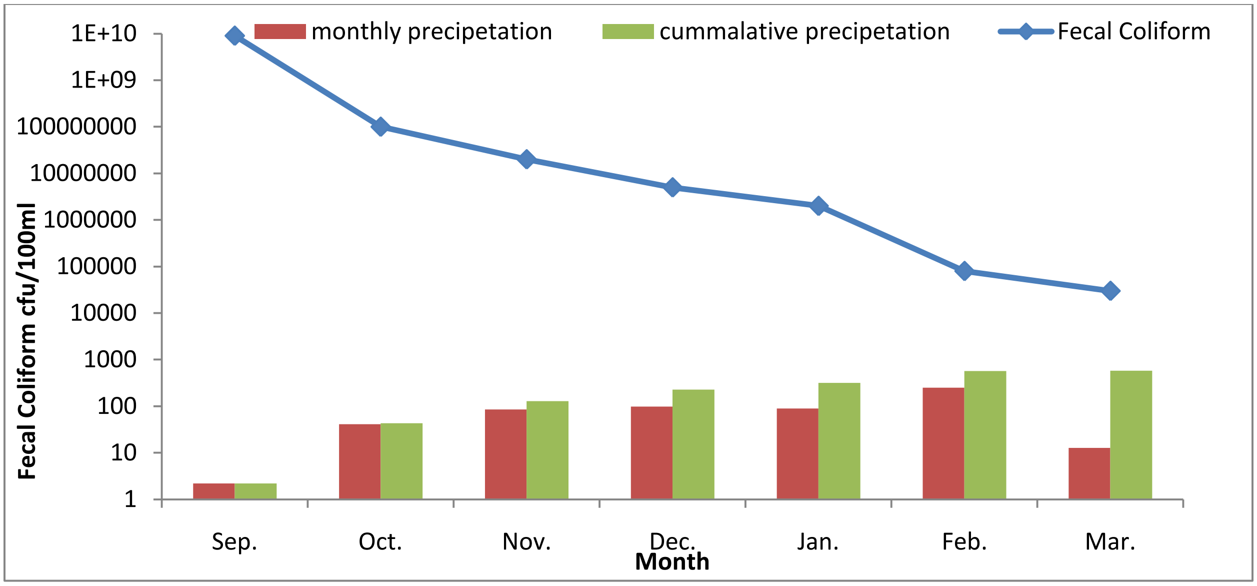


Fig.4.4: Bacterial activity and monthly and accumulative rainfall at Anbta.

Accurate prediction of pathogen counts and occurrence in Zomar stream is attractive risk assessment (USEPA, 2001; Coffey et al., 2007); Tables 4.3, 4.4 indicate that there were a broad range of concentration for indicator and pathogenic bacteria in response to hydrological results due to variance of rainfall and discharge accompanied by temporal and spatial conditions couple with limited pathogen data information. The *E. coli* load in sediment was investigated (Table 4.4, Figure 4.5, Annex A&B), as sediments were presumed to be an important mode of transport for *fecal* bacteria and pathogen to the water stream (Jamieson et al., 2004; Characklis et al., 2005).

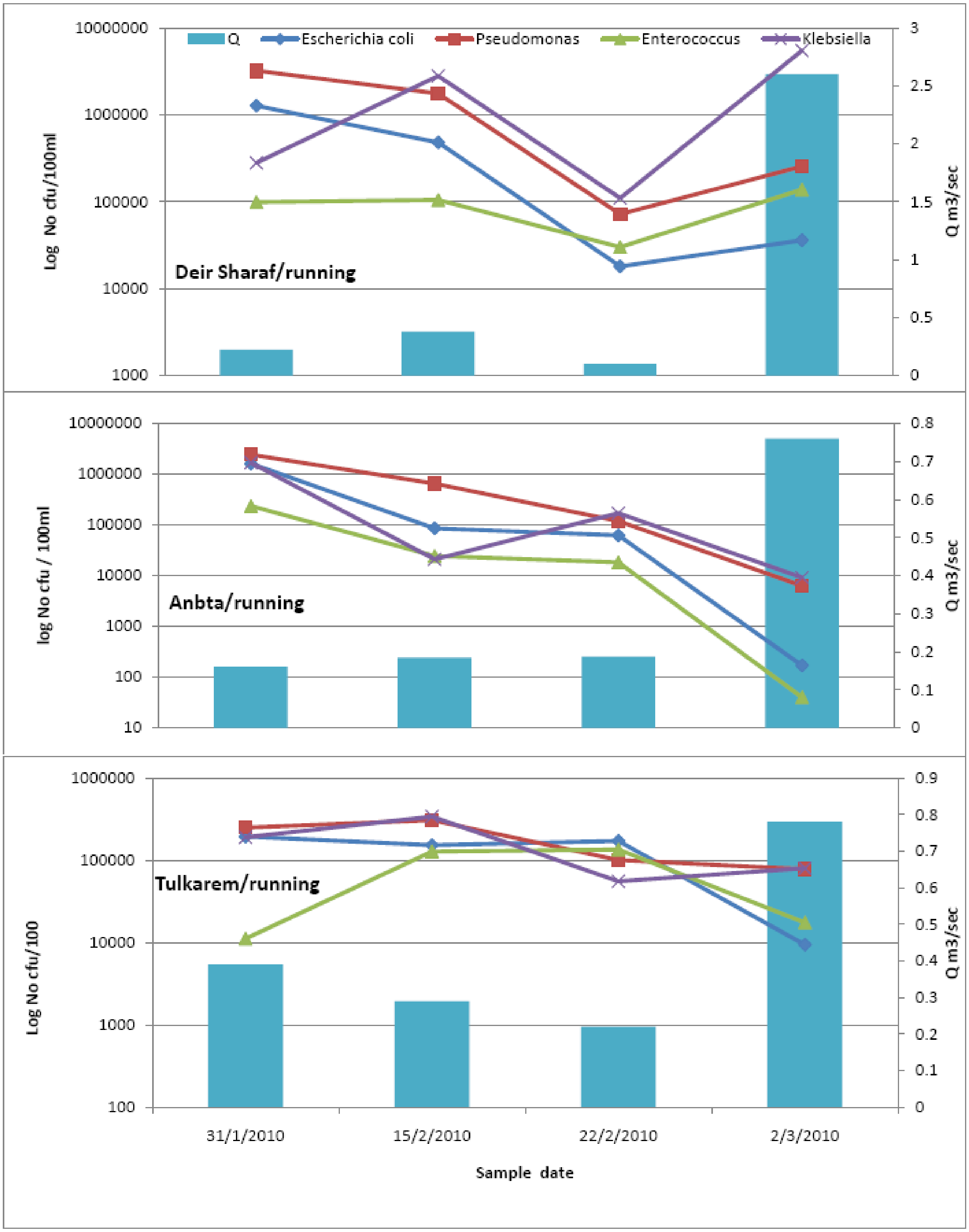


Fig.4.5: Pathogenic counts and flow discharge

Figure 4.6 shows the relation between BOD_5 and P which seems logic, however, increase in P as stream discharged increases will dilute the organic matter found in stream and thus causes decrease in stream BOD_5 (Figure 4.1) and bacterial community levels (Figure 4.7). The wetted perimeter values fluctuated where the maximum wetted perimeter for the events at the end of February in Zomar stream reaches 5.5 m at Deir Sharaf location with BOD_5 28 mg/l, and the minimum value at base flow reach 2.4 m and BOD_5 180 mg/l, Wetted perimeter shows strong negative correlation with BOD_5.

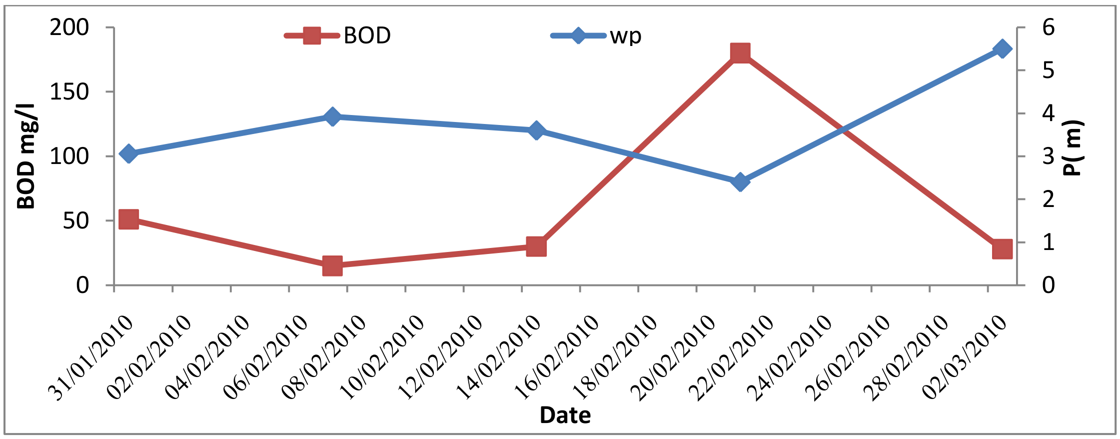


Fig.4.6. P and BOD5 at Deir Sharaf sampling location

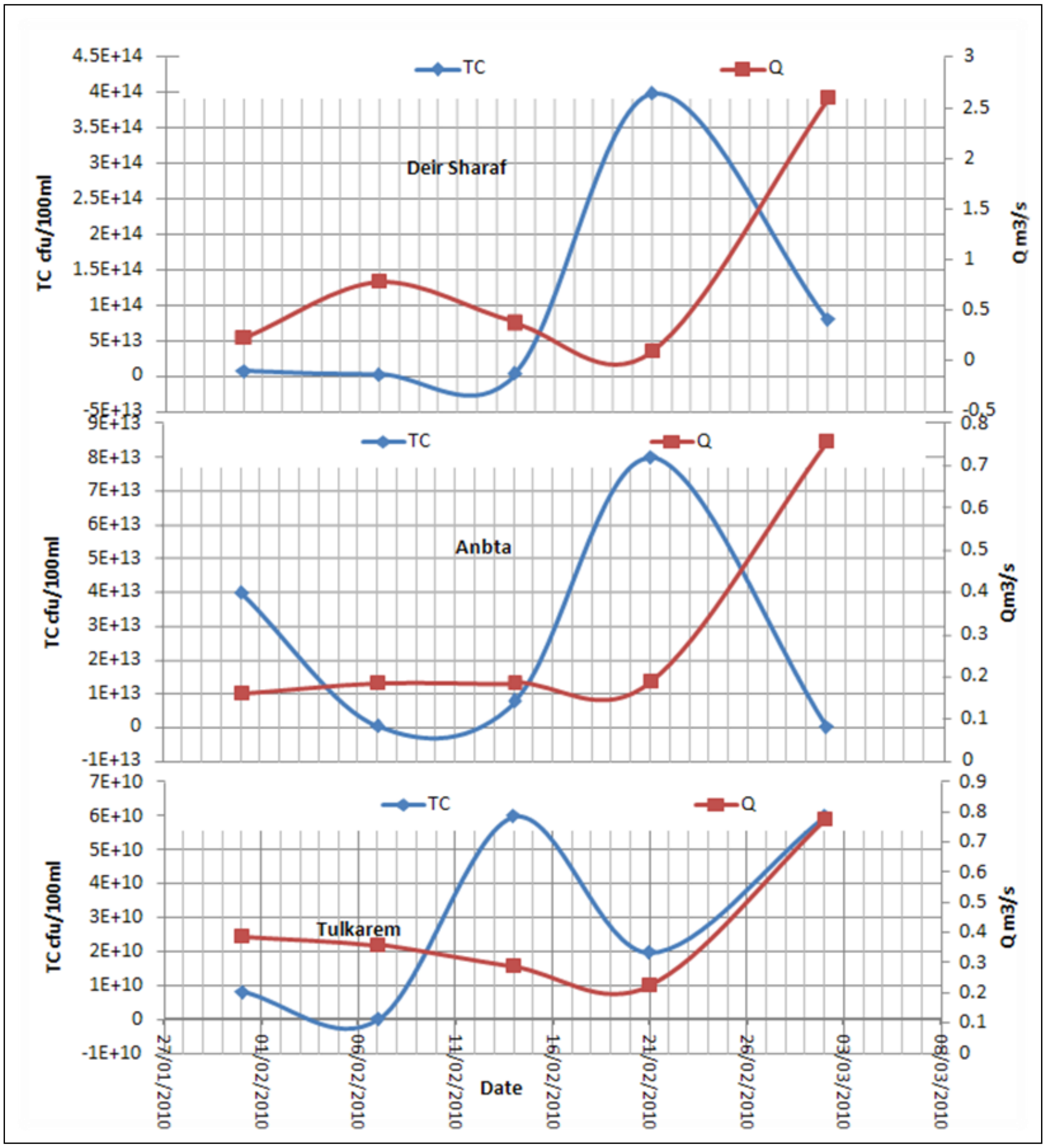


Fig.4.7: Flow discharge and Total Coliform at each sampling point

4.3 Restoration of the Zomar stream

Today, the restoration of the Zomar stream is no longer a Fairy story. Today hopes are high that implementation of the idea will indeed restore the ecology of the stream and transform it into a source of beauty and joy for residents and tourists alike.

Two central problems have plagued the stream for years: pollution from a variety of domestic, agricultural and industrial sources and development pressures in the open space surrounding the stream which threaten its potential for leisure and recreation uses.
It is no wonder, that this stream was one of the first in Palestine to be selected for restoration. There are many attempts to remove pollutants, restore landscapes and ecosystems, and develop the stream for vacation and recreation purposes.

A comprehensive master plan for the whole stream basin must be prepared participated with stakeholders. This can be done by dividing the area into planning regions, each defined by different sensitivities and features. It then defines the policy for the stream's restoration as well as some activities and projects necessary to implement this policy. The plan must characterized by comprehensive approach and aspects for restoration – ranging from environmental and landscape aspects to land-use and economic aspects.

The inevitable conflicts between seemingly opposing interests such as ecology, flood defense, economy, landscape planning and tourism should be addressed in the framework of working groups, workshops and meetings. Based on an important factor and consensus approach, a balance must be achieved between conservation, rehabilitation, restoration, and development.

To a large extent, the success of any stream restoration program is dependent on the implementation of solutions to the problems of sewage and effluent discharge. The Zomar stream is no exception. The major problem may be traced back to sources of pollution that are discharged into the stream.
The process of restoring the Zomar stream has involved both non-governmental organizations and local authorities along the stream. The communities adjacent to the stream must have taken

an active part in the stream administration and participated in all aspects of the restoration activity. The location of the Zomar stream within the heart of a densely populated area and its pioneering nature have generated a great deal of interest by the public. Public participation is essential. The restoration of a stream can become an important component of a region's vision.

4.4 Discussion

Temperature is a key environmental factor, yet the predicted rises in temperature are within the growth range of the majority of most environmental bacteria. As with most biological systems, if it gets warm then bacterial activity will increase, and bacteria will also respond to any changes in nutrient levels caused by increased inputs or reduced stream dilution. Considerable functional redundancy exists: i.e. the number of species performing the same ecological function in a community is often high, as many different bacterial species can perform the same task (e.g. denitrification). Therefore climate change may illicit a community response, but the general ecological services will remain. Regarding the processes, an increase in organic nutrients to stream may be in prospect, due to greater biological productivity from plants and algae, in response to more prolonged sunlight and warmer temperatures. The breakdown of these natural organic products, predominantly by bacteria and fungi, may lead to more O_2 consumption and CO_2 production in the stream (Figure 4.8).

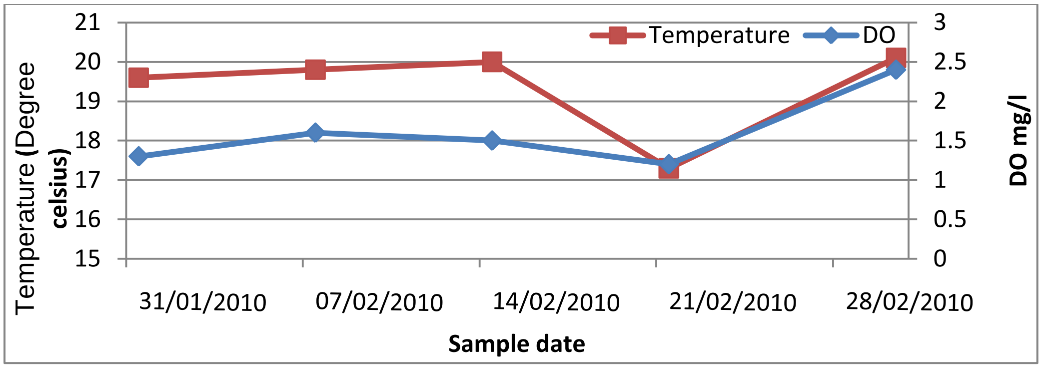


Fig.4.8: Temperature and dissolved oxygen levels in Deir Sharaf.

The drop in electric conductivity is shown by the significant correlations between pH and EC in the three sampling locations (Figure 4.9) (Schulze et al., 2001). With an average value of 7.6, this indicates that all inorganic carbon exists as bicarbonate (HCO_3^-). pH was inversely correlated at significance level to EC, TDS. These pH values might refers to the type of waste drained to the stream mainly the $CaCO_3$ from the queries located along the stream which act as buffer that prevent the high acidity resulted from sewage effluent. However these pH values fluctuated due to bacterial decay, because degradation of organic matter by bacterial will produce CO_2, thus the pH will go down. With less bacterial decay, the amount of CO_2 will be less and thus pH will go up. Thus more bacterial activity means more CO_2 production and lower pH (Schulze et al., 2001).

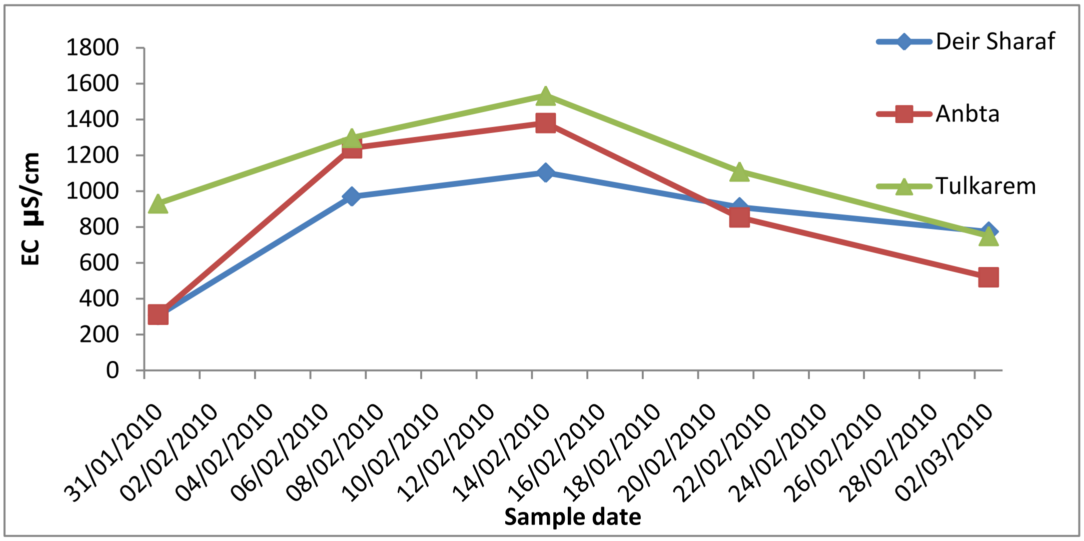


Fig.4. 9: Electric conductivity levels in all sampling locations

pH could be influenced by temperature, pressure, and the photosynthetic and respiratory activities of microorganisms (Harvey, 1955). An acidic pH (5.0) was found to be most favorable to survival of Escherichia coli (in the 5.0–9. 0 range), and sensitivity increased with the increase in pH (Carlucci and Pramer, 1960). Almost all pH values measured were within the normal range; however, all sampling locations showed higher values at some points during the monitoring period. This may be explained by algal growth and depletion of CO_2 which is conversely related to pH. pH is correlated negatively with EC, temperature, ammonia. These factors (temperature, ammonia) are important in the process of algal growth and therefore could be considered to be a factor controlling CO_2 and, consequently, affecting pH values (Figure 4.10). This finding is supported by Schulze et al. (2001). Algal blooms, which are often initiated by an overload of nutrients, can cause pH to fluctuate dramatically over a few-hour period; greatly stressing local organisms.

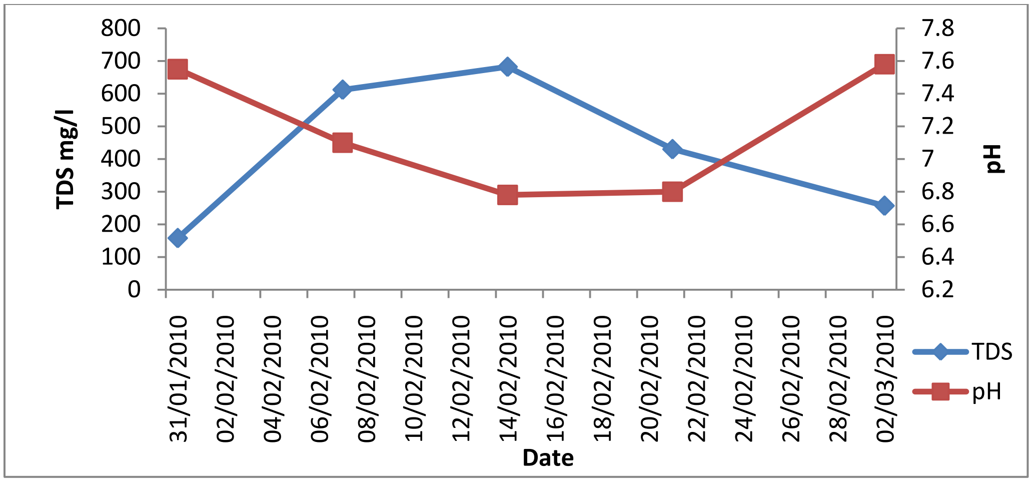
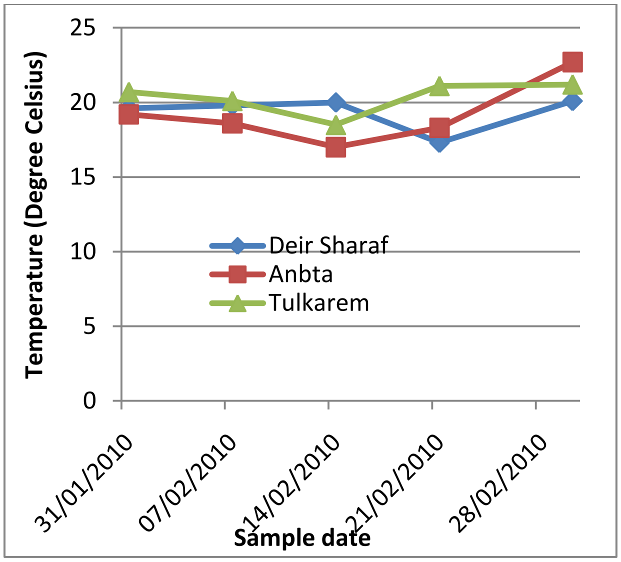
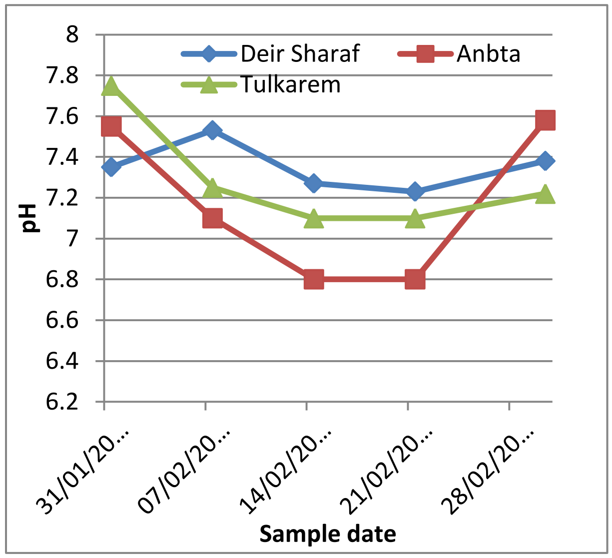


Fig.4.10: TDS and pH at Anbta sampling location

pH for sampled events was in a range typical of natural surface waters with minimum and maximum values of 6.8 and 7.8 , respectively. Increased biological activity during the warmer spring–summer period resulting in increased production of aqueous CO_2 and associated elevated acidity. Where the data is available, there appears to be some correlation between pH and temperature for the samples for a given event. This is likely to be related to diurnal variations and may be attributable to photosynthetic activity that consumes CO_2, thereby increasing pH during the day and the corresponding build up of aqueous CO_2 at night when photosynthesis is at a minimum, the pH– temperature relationship is depicted in Figure 4.11.





Figs.4.11: pH and temperature

Variation of EC with time indicates that EC, which is a measure of salt concentrations, is greatly affected by dilution process of rainfall. The positive correlation between turbidity and DO can be explained by the turbulence, which caused turbidity, increasing the chance of molecular oxygen dissolving in water. The negative correlation of DO with temperature is well documented (Bartram and Rees, 2000; Schulze et al., 2001). *Fecal Coliform* are known to be facultative an aerobes, and when present in high concentrations use oxygen. However, this finding was totally different from that of Guillen et al. (2000), in which DO was positively correlated with *fecal Coliform*. This difference in results may be attributed to other factors such as temperature and level of pollutants.

Oxygen depletion as a result of organic pollution is well known. However, eutrophication with organic nutrients can result in oxygen depletion as well. Eutrophication in running waters causes an increase in production rate. This has impact on the water quality, because primary producers play an important role in the oxygen balance of the water. Oxygen consuming processes occur during the whole day, while oxygen producing processes only take place during daylight. That is why the oxygen content fluctuate strongly over the day (Thomann and Mueller, 1987). An increase in production causes an enhanced oxygen use, especially during the night.

A higher decomposition rate can cause oxygen depletion as well, because bacteria which break-down the organic matter consume oxygen. This happens mainly within the biofilm on the river bottom of slow flowing waters (Hajda and Novotny, 1996). A combined effect of both increased production and increased decompositions rates, results in extremely low oxygen contents, because during the night no oxygen is produced and both groups, autotrophic and heterotrophic organisms will grow and consume (e.g. Caspers and Karbe, 1967). Oxygen decline can be a result of oxygen-consuming processes, bacterial carbon oxidation and nitrification.

During sampling at the first location it was noticed that the water has color change continuously due to industrial dyes activities in the region. These activities have direct impact on amount of dissolve oxygen present in water which is already low due to low solubility of oxygen in wastewater, since oxygen needed by microorganism in order to degrade organic pollutant found in stream. The DO concentration increased as we went down to second sampling point (Anbta), this happened due to turbulence and self purification along stream from Deir Sharaf to Anbta. DO increase also when going down at Tulkarem sampling point due to domestic and industrial discharges.

High values of COD indicate water pollution, which is linked to sewage effluents discharged from urban areas, industrial or agricultural practices. The input of anthropogenic contaminants (from point discharges mixing with urban and agricultural runoff) causes distinct, but variable, COD concentration peaks, responsible for increasing the concentrations in nutrients and organic carbon in the fresh surface waters of the flowing water (Figure 4.1) (Bellos and Sawidis, 2005).

As a result, the organic pollutant input to the various locations is not consistent, as indicated by the wide difference between the minimum and maximum BOD values at all locations. The above results reflect the potential of system restore under normal conditions with low pollution load and enough dilution from natural runoff which lead to high self-purification capacity along the stream path.

Variation in BOD_5 as illustrated in Figure 4.1 demonstrates relatively low levels during dry months in comparison to the wet season; during which rainfall and runoff add organic materials from land-based sources and the Zomar stream floods. This clearly indicates the possibility of rehabilitation due to the dilution and high self-purification capacity.

Nitrate levels followed a pattern similar to BOD_5 and also appear to be affected with flow discharge. The beginning of storm event, the pollution concentrations show dramatic temporal shifts, reflecting the so-called first flush effect in the stream then the concentration decrease as storm proceeding.

The eluted water from sediments samples showed an increasing in nitrate concentration, this might be refers to nitrates absorption by plants root near the edges that lead to more concentrated amount. Low nitrate in running samples was mainly due to the absence of proper time for oxidation. Figure 4.1 shows a limited Nitrification processes where a sharp decreased in the ammonia level accompanied by a more moderate increase in levels of nitrate in this part of stream begin to occur only downstream.

High concentrations of ammonia in surface waters indicated contamination from waste treatment facilities, industrial effluents or fertilizer run off. In addition to fecal contamination indication, ammonia causes odor problems and results in nitrate formation (WHO, 2004). Tulkarem sampling location had the lowest ammonia concentrations, where Deir Sharaf sampling location had the highest concentrations. This might be due to the relative ease with which marine organisms consume ammonia.

Orthophosphate concentrations were highest at Tulkarem sampling location followed by Deir Sharaf sampling location (Figure 4.1). Both locations were surrounded by agricultural areas besides sewage, which may contribute to these relatively high levels. Almost all high concentrations of orthophosphate were followed by algal blooms, as evident by visual observation of both water color (greenish) and the deposits of algae. This enforces the proposed role of phosphorus in the process of eutrophication. Orthophosphate concentrations, however, deviated little during the course of the streams flow. This change has resulted in the buildup of soil phosphorus to levels rarely encountered in the past. As a result, there is increased potential for phosphorus losses to surface water (Rodecap, 2000).

To prevent the development of biological nuisances and to control eutrophication, orthophosphate should not exceed 0.05 mg/L in a stream discharging into a reservoir, and the concentration should not exceed 0.02 mg/L within a reservoir (Environmental Protection Agency, 1986). Phosphorus retention was particularly influenced by temperature and current velocity. The phosphorus uptake rate decreased at higher current velocity as the contact between water and sediment was reduced. Restoration of most eutrophic waters requires the reduction of nonpoint inputs of P and N (Carpenter et al., 1998).

PO_4-P concentration influence more and directly with rainfall accumulation, since it decrease monthly with rainfall accumulation increase due to flush out events at the end of February and start increase with rainfall decrease to reach a concentration equal to that at the beginning (Figure 4.12).

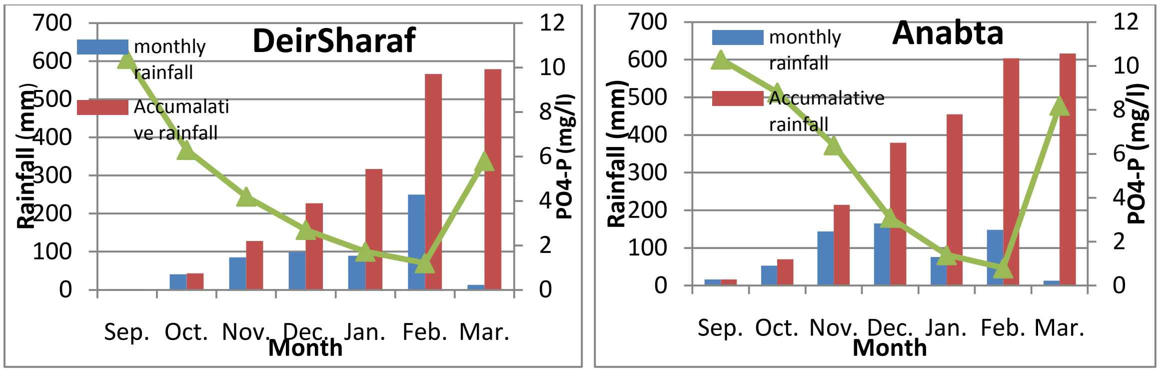


Fig.4.12: Relation between PO4-P and monthly rainfall and accumulative rainfall.

On the other hand, the nutrients load (ammonia and phosphorus) along the stream showed well correlation with the BOD_5 values and consequently the *fecal Coliform* count. The presence of reasonable amount of nutrients under normal conditions with neutral pH enhances the *fecal Coliform* growth and much other different type of natural digesters such as *Nitrosomonas* and *Nitrobacter*. The high discharge rate can reduce the ability of pathogens for competition, and as a result lowers significantly the number of pathogens as more cumulative amount of runoff washes it along the season.

The stream showed a limited self-purification mechanism that partially treats the sewage and reduces the organic load in the water. The nutrients concentration at Deir Sharaf sampling location enhance significantly the persistence of microorganisms, because this location subjected to a continuous sewage discharge with a lot of nutrient that keep the bacterial community active and lower the stream ability for self purification at this section. In contrast Anbta sampling location has different behavior since sampling point so far to sewage discharge point (Figure 4.13). The restoration process was clearly indicated in Anbta sampling location. For example, ammonia concentration decreases with discharge event, because the main source of pollutants comes from sewage point near Deir Sharaf sampling location. This promotes enough time for purification and natural bio-digestion for different kinds of organic pollutants. Tulkarem sampling location also has different behavior from other two sources, since the location of sampling location lies at the end of stream and consist the collector for different source of pollutant along the stream path. In addition to the agriculture lands around this point and the discharge from sewage system of Tulkarem district.

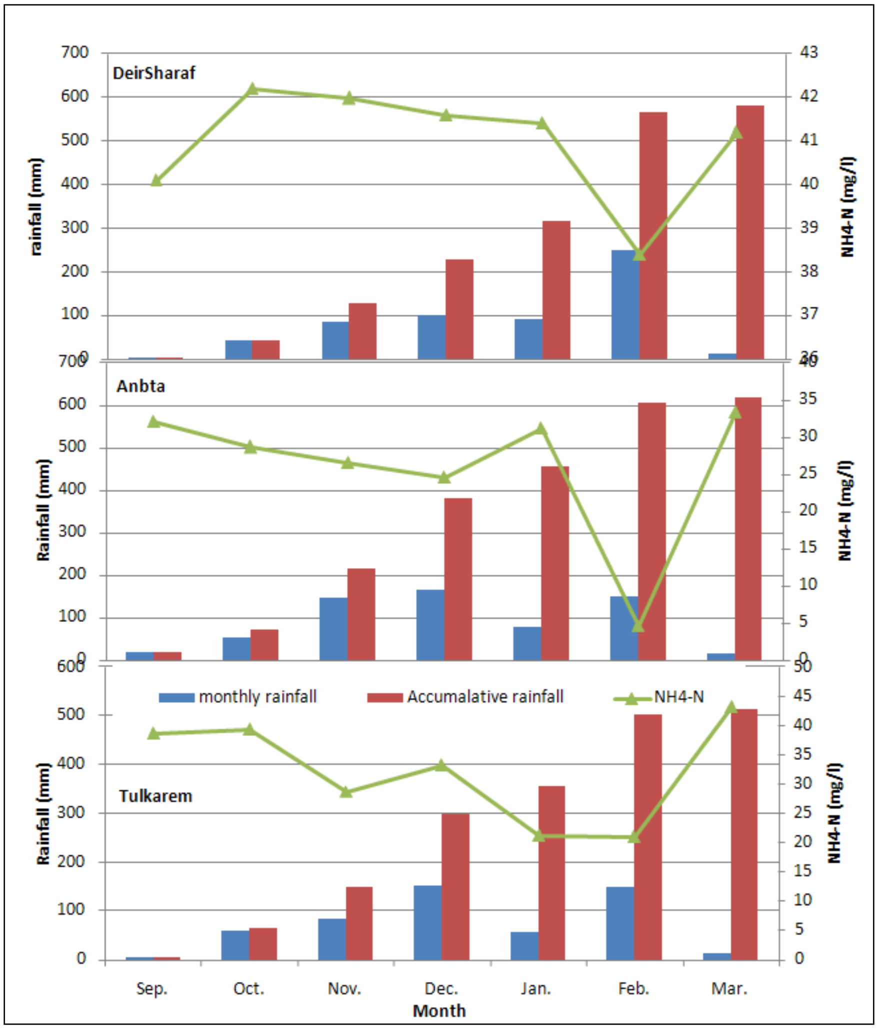


Fig.4.13: Biological activity and rainfall.

Nitrification are also seen which are reflected in Figure 4.1. A sharp decrease in the ammonia level accompanied by a more moderate increase in levels of nitrate in this part of stream begin to occur only downstream. There was an increasing in nitrate concentration in sediment samples, this because plant remove nitrogen in the form of nitrate besides leachate from stream edges. Low nitrate in running samples because there is no enough time for oxidation.

The presence of *fecal* & *total Coliform* effect negatively by amount of stream discharge, this can be clearly noticed at Anbta sampling location (Figure 4.1). The results showed that fecal indicator and pathogens bacteria survive longer in sediments than in the overlying water, and it has been proposed that sediments serve as sinks of *fecal bacteria* with the potential pollution of bathing water more than lying which agrees with previous studies (Ashbolt et al., 1993; Ghinsberg et al., 1994; Howell et al., 1996).

The ability of microorganisms, to survive in aquatic sediments implies that *fecal Coliform* detected in the water column of streams may not always indicate recent contamination but may be the result of sediment re suspension (LaLiberte et al., 1982). According to Millis (1988) and Ferguson (1994) the microbial activity in sediments is greatly encouraged by the presence of organic matter. It is possible that in nutrient- rich environments, microorganisms may survive in sediments for extended periods of time (Davies et al., 1995). Bacteria at settled can form biofilm, so it can build and grow since it has much more residence time than those in running samples. Either it was notice that the size of *Total Coliform* colony is much large, this is indicate that there are more than one kind of bacteria with different size. Sampling from mid of stream has fungi while settled sample have not, since nutrient in settled samples consumed by algae.

Total Coliform and *fecal Coliform* removal for the three sampling locations are represented graphically in Figure 4.1 and Table 4.3. It implies that there are Fate of bacteria, i.e. bacterial removal and reduction, when applied onto soil, is governed by two distinct processes— retention (filtration and/or adsorption) and die-off. Extreme acidic and alkaline pH has a direct effect on bacterial survival. A pH range of 9.0–9.5 is considered as lethal levels for pathogen survival (Pearson et al., 1987).

Figure 4.14 show that more bacterial activity means more CO_2 production and lower pH.

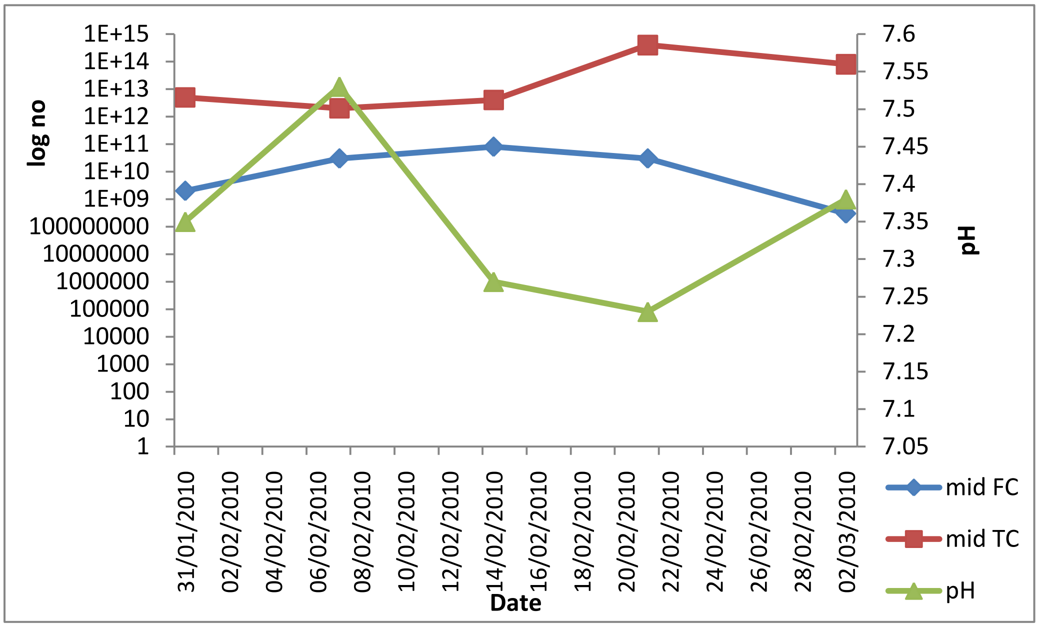


Fig. 4.14: Fecal & Total Coliform and pH

Indicator bacteria have been target variables in watershed process-based fate and transport models, and indicator organisms will likely continue to be target microorganisms in the foreseeable future (Sadeghi and Arnold, 2002; Tian et al., 2002). One constraint coupling such indicator predictions with pathogen densities or presence, outside of those already discussed, is that spatially and temporally dense pathogen–parasite data sets are limited, and model calibration–validation for these microorganisms cannot be properly conducted.

For the mid-stream samples, pathogens show decrease with rainfall events in all location except in Deir Sharaf sampling location because of nearby wastewater discharge point, where the settled and running samples show increase in all location. The results show increasing in survival *E.Coli* and to a lesser extent *Klebsiella* as wastewater discharge increase while the density of *E.Coli* declined immediately after each rain event. These results agree with study done by Lopez - Torres et al. (1988). Carlucci and Pramer (1960) suggest that the organic load improved the survival of these species. *E. coli and Enterococcus* densities were more strongly correlated to cumulative rainfall variables than the other microbiological indicators.

The resuspension of pathogens from sediment due to turbulence at the benthic boundary, attributable to internal waves or wave action of leeward shores, may present a pathogen risk not anticipated from river inflow data alone. The prolonged survival and accumulation of microorganisms in sediments, and the likelihood of their being desorbed by dilution or water turbulence indicates that sediments, as well as surface waters, should be assessed when estimating potential health risks (Figure 4.15).

The relationship between *E. coli* load and sediment loading was investigated, as sediments are presumed to be an important mode of transport for *fecal bacteria* (Jamieson et al., 2004; Characklis et al., 2005). It is apparent that the major processes affecting pathogen fate and transport in streams are the stream intrusion and inactivation by UV light and temperature.

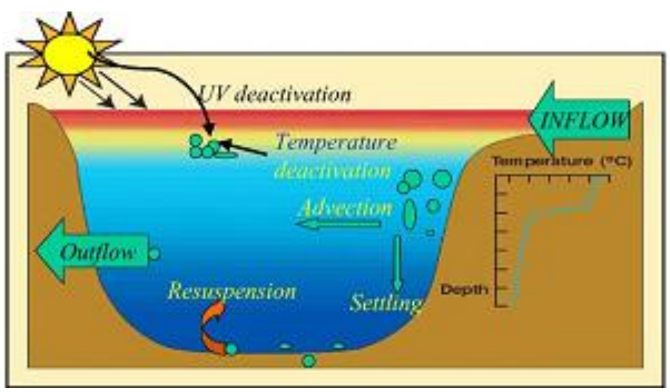


Fig. 4.15: Conceptual model of the major processes affecting pathogen fate and transport through a streams (Davies et al., 1995).

The *Coliform* and pathogens count as well show that it is directly influence by the availability of adequate nutrients supply along the stream. Figure 4.4 illustrate the relation between rainfall load and *fecal Coliform* count which reduced due to flush out bacterial colonies during and after rain event. Discharge was found to be negatively associated with indicator micro- organisms due to dilution effects (Figure 4.16). Overall, the strength and direction of hydrology–microorganism relationships appear to depend broadly on seasonal characteristics, type of microorganism, sample site disposition (e.g., stream order), upstream land use (Lyautey et al., 2007), and differences in specific hydrological loading/transport processes.

Although the considerable interval between the peak of the event and its sampling is important, perhaps more significant is the likelihood that both catchment surface and streambed stores of *fecal Coliform* bacteria may have been depleted following washout from the first event. Thus, remaining *fecal Coliform* concentrations available for flushing from either land or stream bed sources for the second event were most certainly lower leading to more subdued stream water *fecal Coliform* concentrations. The response to the third rainfall event supports this importance of the level of depletion of bacterial stores.

A high current velocity can stimulate the photosynthesis, the respiration and the nutrient uptake (Stevenson, 1984). This is explained by the higher diffusion rate of nutrients by high current velocities with continuous nutrient fluxes. On the other hand, current can have a negative effect by flushing away loosely attached algae and reducing the algal biomass (Biggs, 1996).

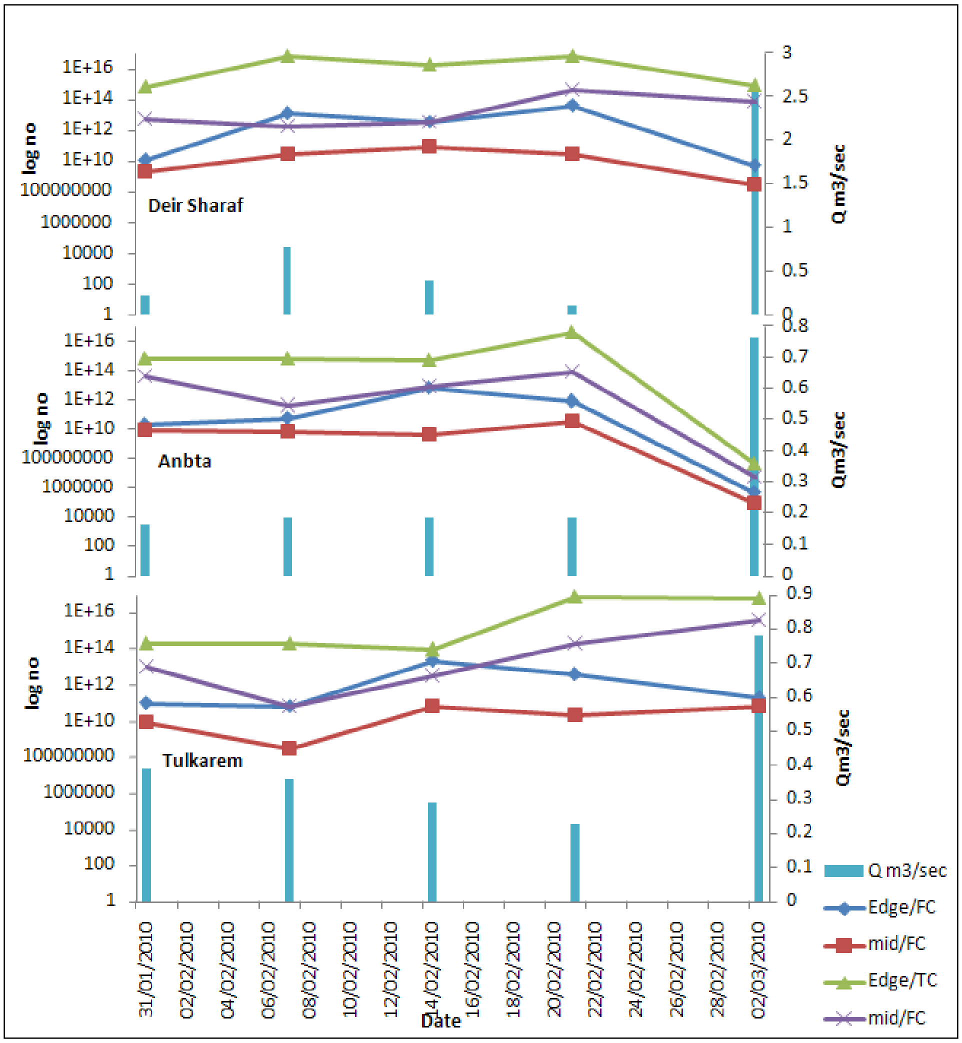


Fig.4. 16: Coliform bacteria and stream flow

The flow events in the Stream shows regular patterns all over the hydrological year except in the rainy months, where the flow fluctuated depending on the storm intensity and duration. Figure 4.17 shows the relation between precipitation amount in mm and flow amount for the same events.

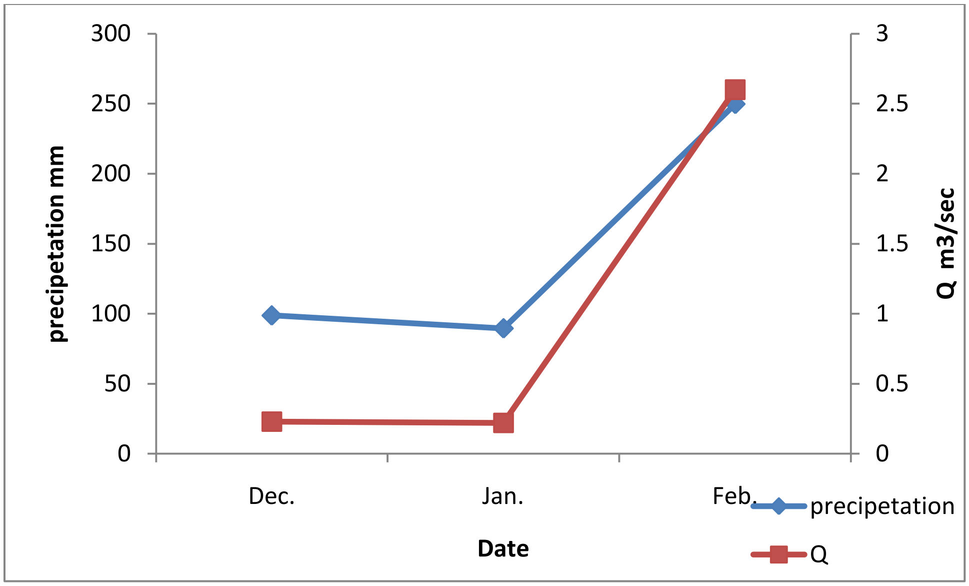


Fig. 4.17: Precipitation amount in mm and flow amount including last events (28/2-2/3/2010).

Nablus tributary, contributes the majority of the water flowing in the stream, first comprised of raw sewage and industrial effluents. Tulkarem sampling location shows the larger amount of discharge into the stream; the discharge is mostly wastewater effluent from the urban area which is drained all over the year. Several additional point sources discharge into the stream, but they are largely intermittent depending on seasonal factors. The stream draught and the peak retained relatively within less than 2 weeks. The wetted perimeter values also fluctuated where the maximum wetted perimeter for the hydrological events 28/2-2/3/2010 in Zomar stream reaches 5.5 m at Deir Sharaf sampling location, and the minimum value which is goes with the base flow line reach 2.4 m (Figure 4.18), This value become relatively constant in response to further increase of flow (Fig. 4.19). The stream dried very quickly after rain events in way that it lowers the chance for more water dilution of the waste, the amount of waste is high enough to keep the yearly average nutrients level high for the most period of the year.

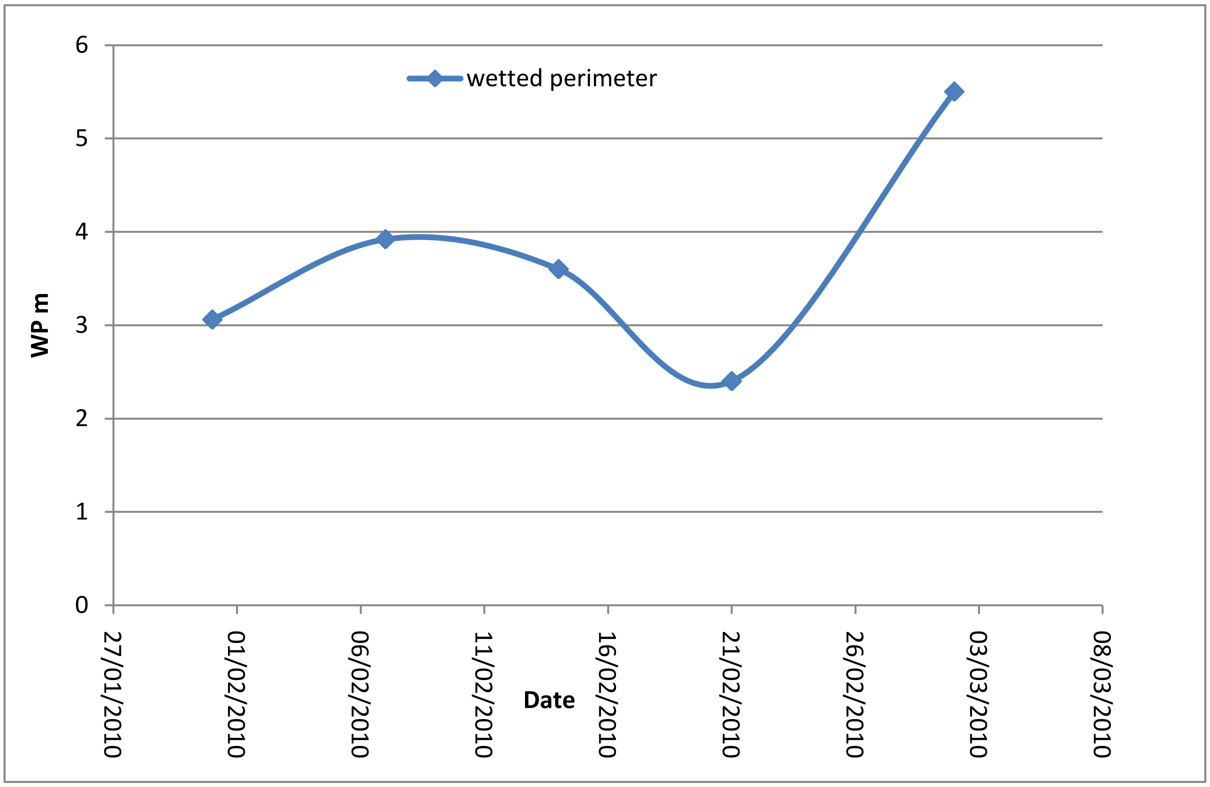


Fig. 4.18: Maximum wetted perimeter in the hydrological year 2009/2010.

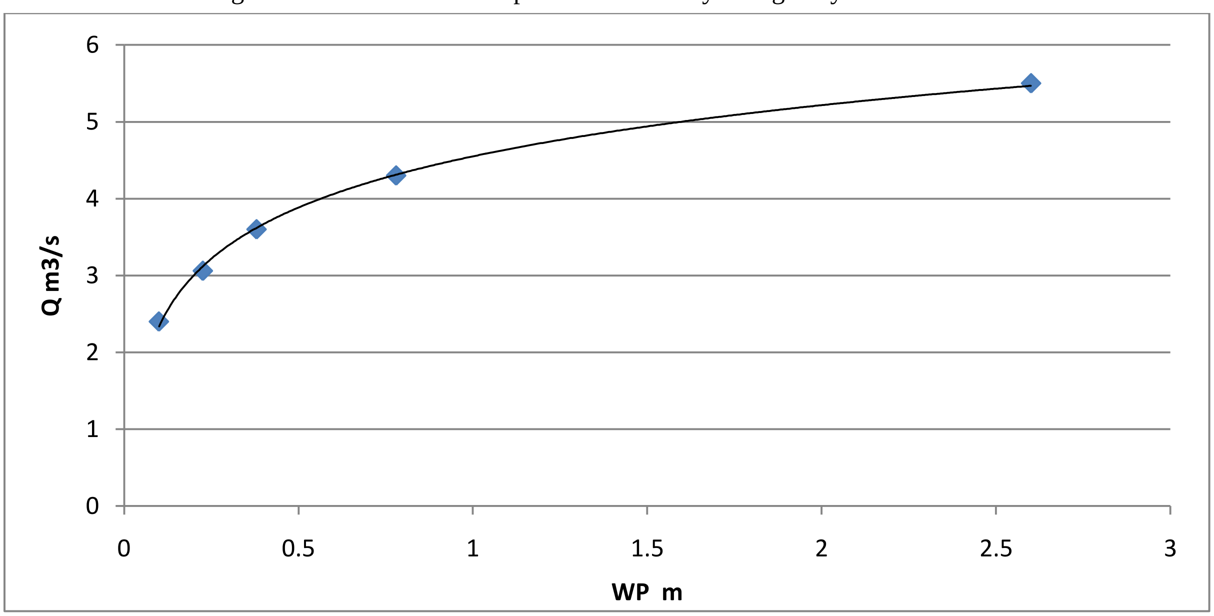
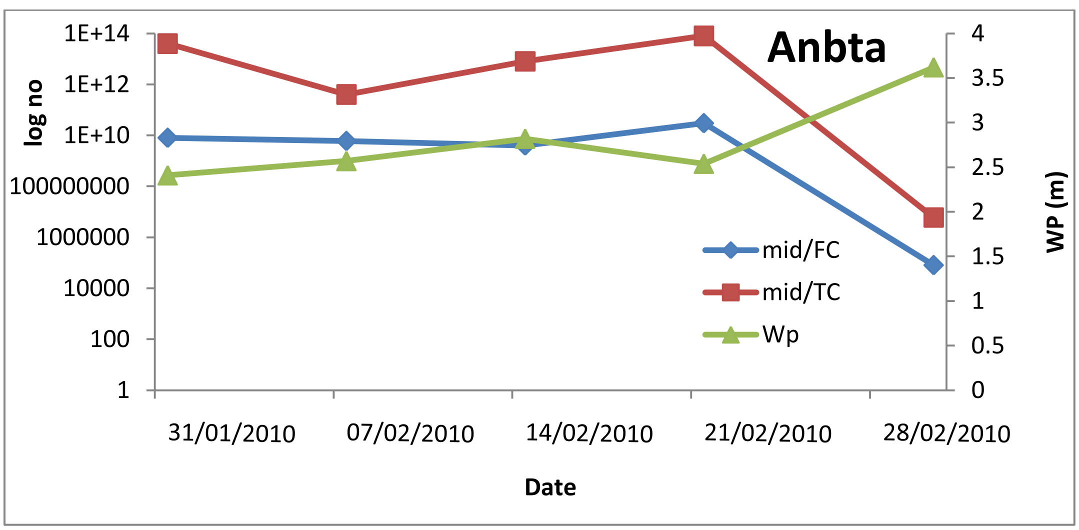


Fig. 4.19: daily discharge and wetted perimeter

Moreover, pollution loads during storm events, seem to be much higher in comparison with the pollution loads in base flow. Accordingly, the highest quantities of nutrients discharged into the stream correspond to the storm of March 25-28, 2010. This event had both the largest overall discharge and the highest peak discharge. These results can be explained by the fact that water flowing in the stream already contains nutrients. The levels of these nutrient levels differ in between the storm events. At the same time, results consistently indicate that the greater the amount of water flowing the stream, the higher the nutrient loads. This would support the existence of a cumulative effect", means that even if concentration is lower, the overall load might be higher, since more water flows through the stream. One should take into consideration that some of the loads could be attributed to re-suspended material and sediments accumulating in base flow.

For Anbta sampling location it is clear that as WP increase the bacterial community decrease and this is may be special for this location due to stream self purification because of long distance between first sampling point and this point. So the amount of organic matter will be diluted due to degradation (Figure 4.20).



0-1Fig.4.20: Bacterial growth and WP in Anbta

The results shown above indicate the importance of sustainable good quality flow to remove the pathogens, and to keep the whole system healthy. Anbta sampling location represents the model for good capacity in self purification and pathogens removal; where the optimal conditions with less additional pollutants are present. This result was confirmed by Al Sa'ed (1983) as well, his research results assured that most of the physiochemical parameters were efficiently decreased due to self purification and biodegradation processes.

Chapter Five: Conclusions and Recommendations

5.1 Conclusions

In general, many studies agree about the status of Zomar stream as a potential hazard to the whole region. In this study, the researcher tried to identify the possible factors that complicate the problem of the risky flow regime, and those factors play a role in the ability of the flow regime to be restored as healthy environment for habitat and surrounded population. As all over assessment for the above mentioned factors, the main problems triggered by the absence of sufficient good quality base flow along the year. The presence of such good quality base flow, can help in continuous nutrients and bacterial wash out. This cannot necessarily remove the whole pathogens and pollution totally, but can reduce and help in efficient removal that can reach its maximum conditions with storm water in the water time, leading finally to a good improvement on the stream water quality and consequently healthy environment in the surroundings.

The water quality results show the trend of washout response to the extreme flood conditions. The results have reflected the effect of continuous wastewater discharge on re-enhancing the bacterial growth. However, the wastewater discharge is time dependent and the bacterial presence is consequently subjected to both storm water and wastewater flow variation with time.

The study suggests that the restoration process is controlled in general by two main factors that mainly depend on the presence of sufficient base flow. Those are the role of sufficient flow in preventing the presence of bacterial rich environment, and the role of flood inundation frequency in keeping system balance all over the hydrological year by increasing the number of bacterial and nutrients flush out by flood inundation.

Environmental flow model is needed to visualize the factors affected the flow regime and pathogeneses distribution along the stream path. A new water surface model should be constructed in a manner by which it should depend on a real practical experiment for artificial discharge at different points in order to choose the best locations and best amount of discharge to keep sufficient base flow. This base flow should be kept in its minimum amount that maintains the number of hazardous waste and pathogens in its lower and environmentally acceptable status. Finally, as a result of the suggested modeling studies the amount of wastewater discharge to the stream most be treated sufficiently and re-discharge in certain points along the stream as part of the mentioned sufficient base flow. The model must be identified by the treatment level and discharge distribution locations that guarantee an equal distribution for sufficient base flow all over the stream.

In general, this study can be considered as the basic block for modeling the hydrological and biological status of the Zomar stream. Different factors that can be considered as indices for the model were well identified here as described below:

- ✓ The major point pollution source is raw sewage discharge from the cities of Nablus and Tulkarem into the Zomar stream. This source changes the fundamental nature of the ephemeral stream, converting it into a de facto sewage conduit with permanent base flow running. The Zomar stream shows a self-purification mechanism that partly treats the sewage and reduces the organic load in the water.
- ✓ As interruptible stream flow system; there are two main factors affect positively Zomar stream restoration:
    1. Discharge amount events, where one rain events were taken to study the stream flow discharge.

2. Rain frequency (accumulative) and relation of period between each event that trigger a continuous flush out and consequently the ability of bacterial community to re-build up after each event.

- Better correlation of pathogens isolation, compared with the other hydrological indicators. Total and *fecal Coliform* correlated well with the presence of pathogens.
- Anbta sampling location represents the model for good capacity in self purification and pathogens removal; where the optimal conditions with less additional pollutants are present.
- The results of this research indicate the importance of sustainable good quality flow to remove the pathogens, and to keep the whole system healthy.
- The highest pathogenic concentration including *E. coli* loading occurred in location of Deir Sharaf dominated by closing to sewage discharge source point. A location containing a cluster of residential dwellings also had substantial loading, and had the highest percentage of the total *E. coli* load occurring during base flow conditions. Average *E. coli* loading rates for the entire watershed in sediment were $1.4*10^7$ and $2.7 * 10^5$ CFU/100ml, for base flow and storm flow periods, respectively. This suggests the role of point source that complicates the problem and retards the natural eco-service in purification.

5.2 Recommendations

The results of this study indicate the necessity of:

- Creating a sustainable source for good quality runoff water all over the year, that can keep the base flow with low pollution amount and healthy eco-system that has the ability of self restoration.
- Establishing a surface flow model depending on the data obtained from this study, to visualize the role of above mentioned two mitigation parameters in the restoration process, and to suggest the best required water amount and quality to sustain a healthy flow. The model should be built through incorporating the conceptual model data in this study in proper modeling program, then the first simulation should be run, and the data set validate before providing different scenarios depending on actual reference parameters measured and behaviors for bacteria in response to chemical and physical variances. In this context, different parameters related to rain water runoff in the stream and accidental point sources of pollutants along its stream, should be modified to obtain the optimal scenario where the stream can be restored as a natural healthy environment.
- Stopping the discharge of additional waste along the stream path, as the study shows its importance in complicating the problem of retarding self restoration along the stream.
- The above two points are integrated together through constructing water treatment plants as alternative to provide and keep a good quality base flow in dry season that can support healthy environment as mentioned in the results.
- Increasing the public awareness of the issue of water scarcity, stream restoration, and pollution sources and supporting a wide range of life with healthy environment. Stakeholder’s participation should be increased to ensure public contribution in Zomar restoration.

- Further research studies are needed to develop a surface flow model depending on the data resulted from this study, and to suggest the best required water amount and quality to sustain a healthy flow.

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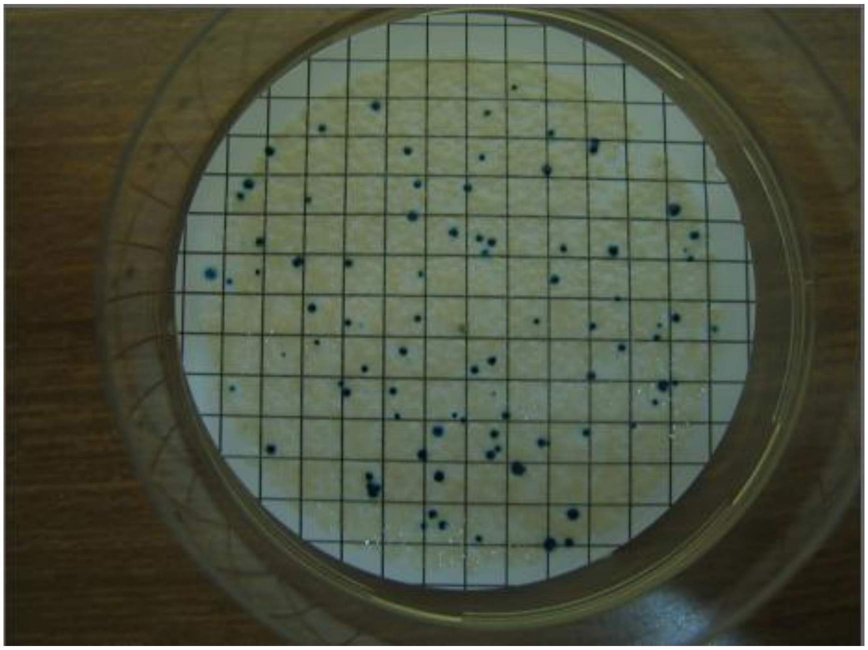
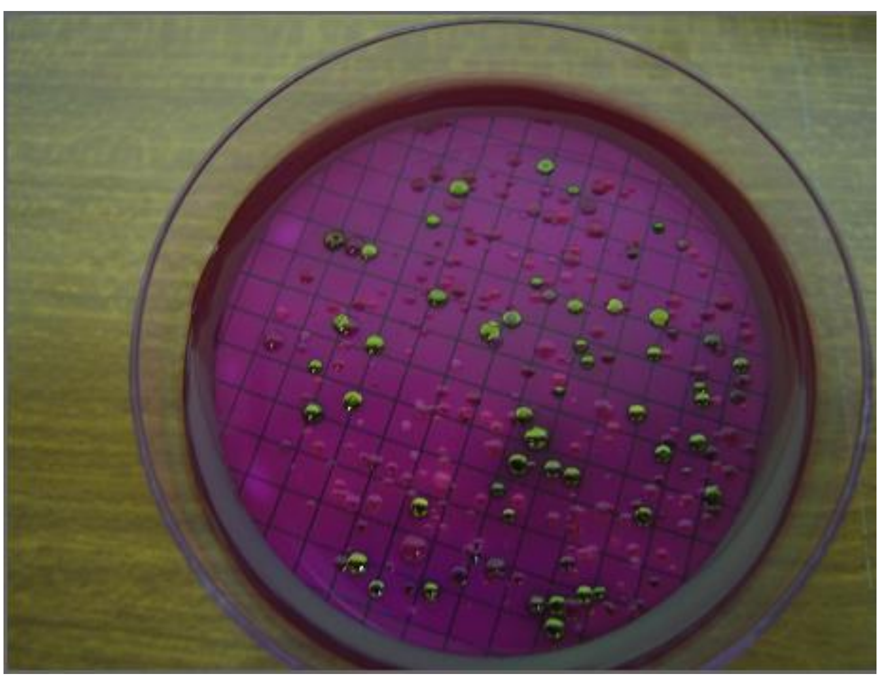
Annexes

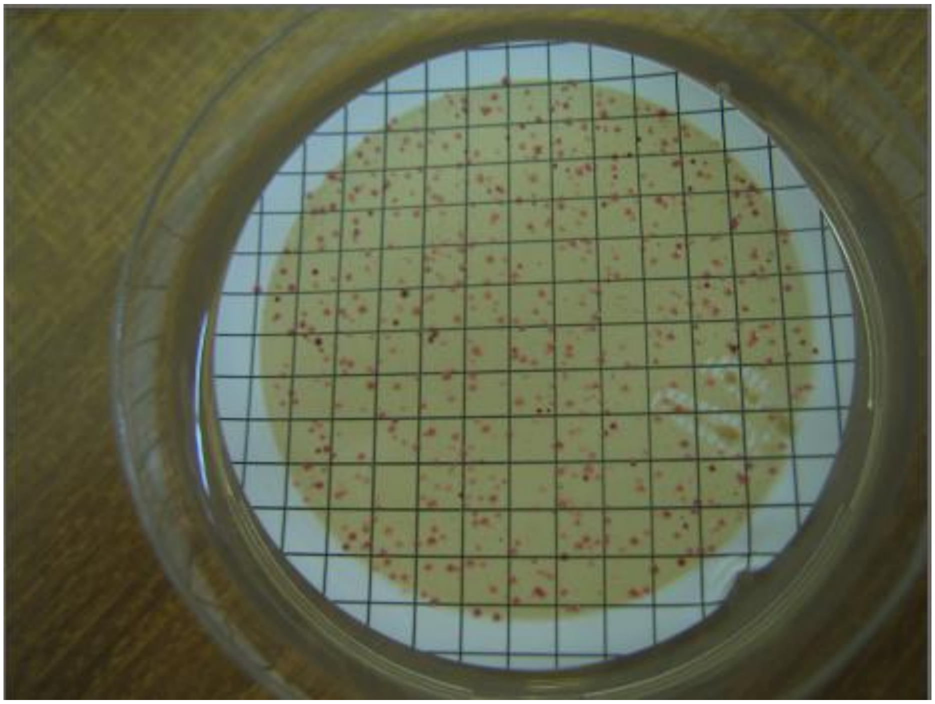
Annex A: examples on pathogen tests



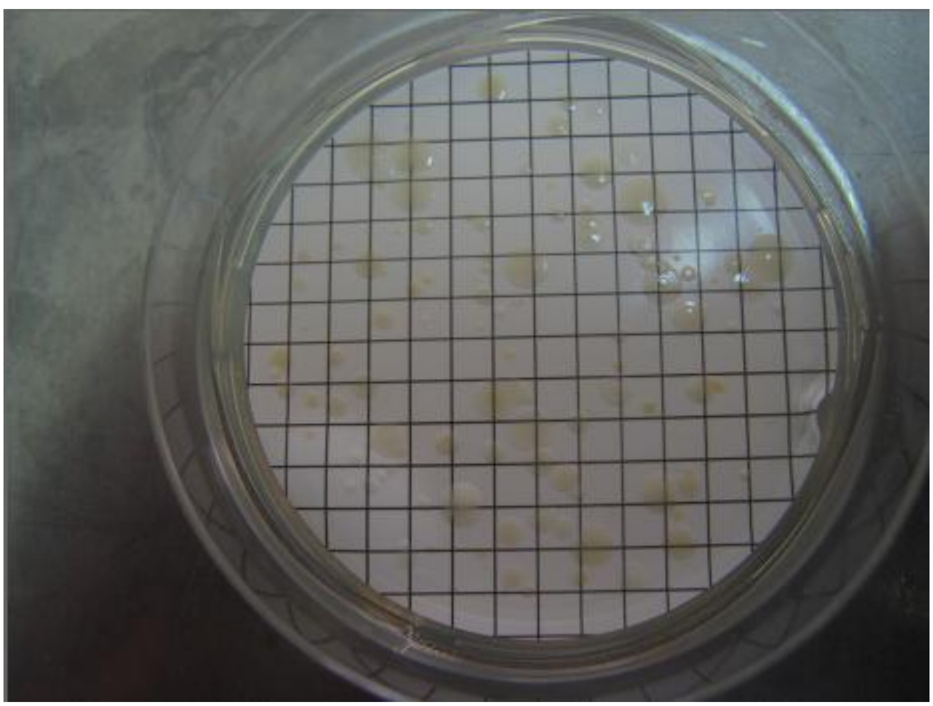
Escherichia coli



Klebsiella

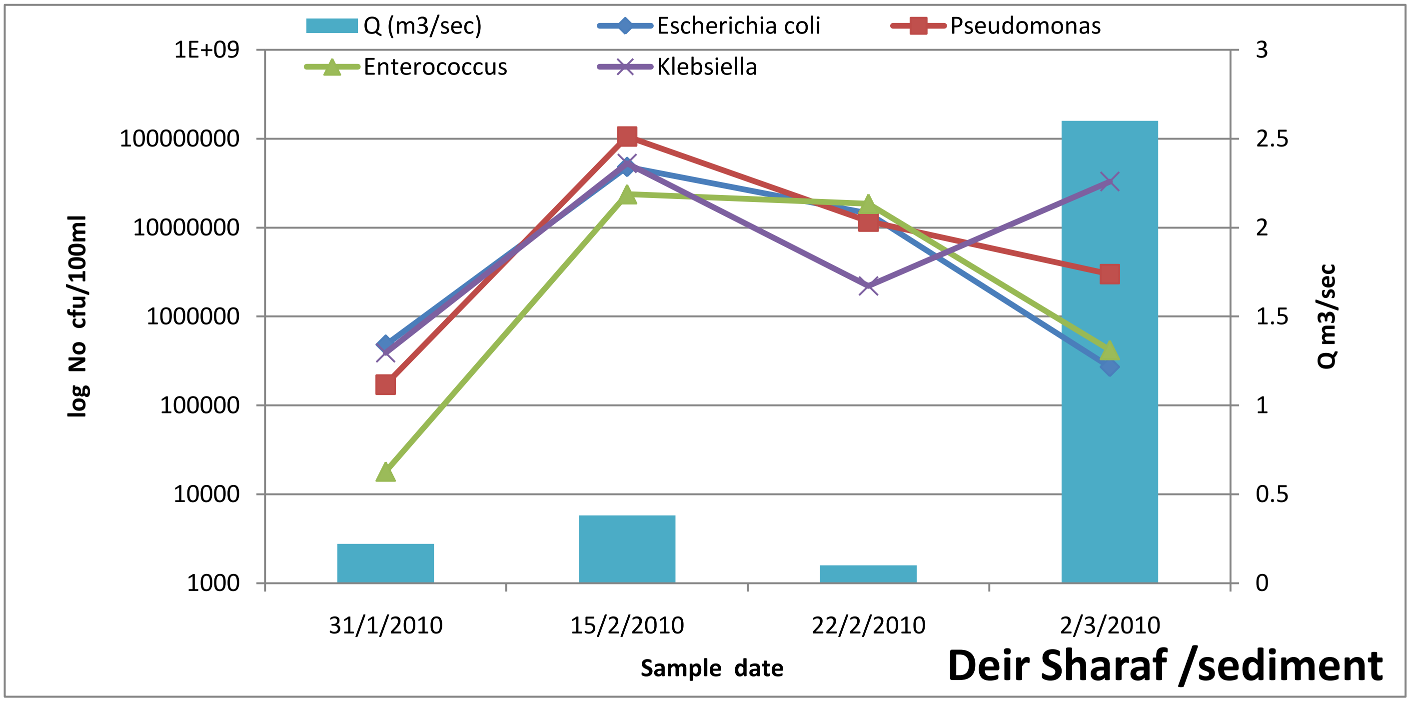


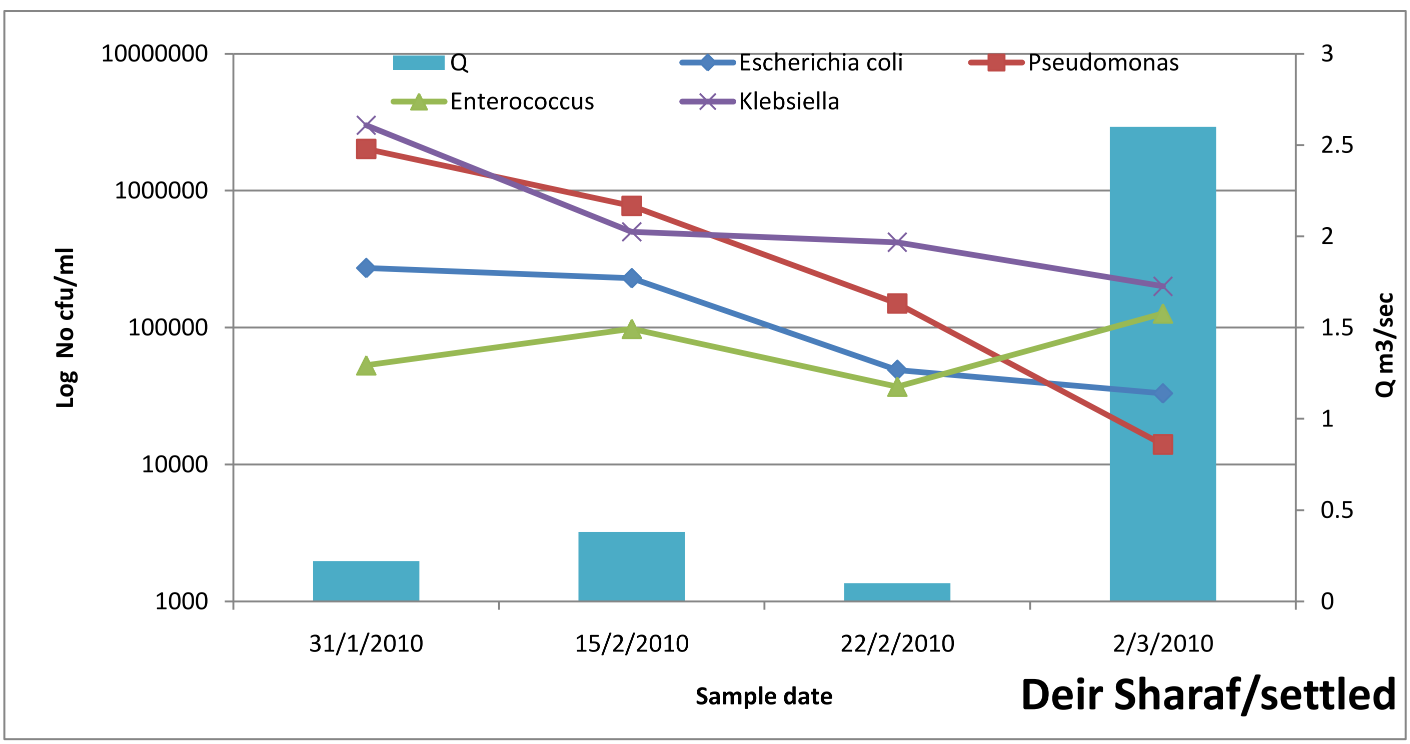
Enterococcus Fecallis

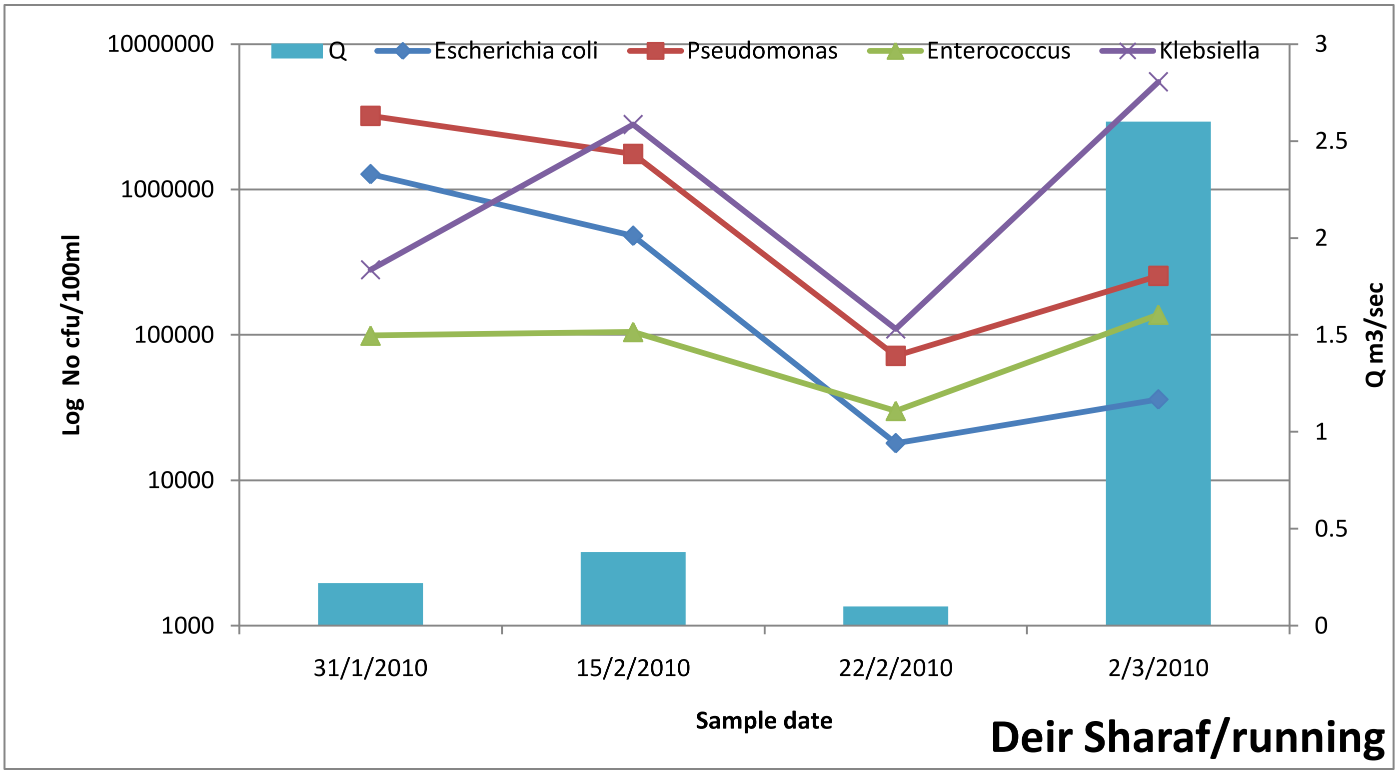


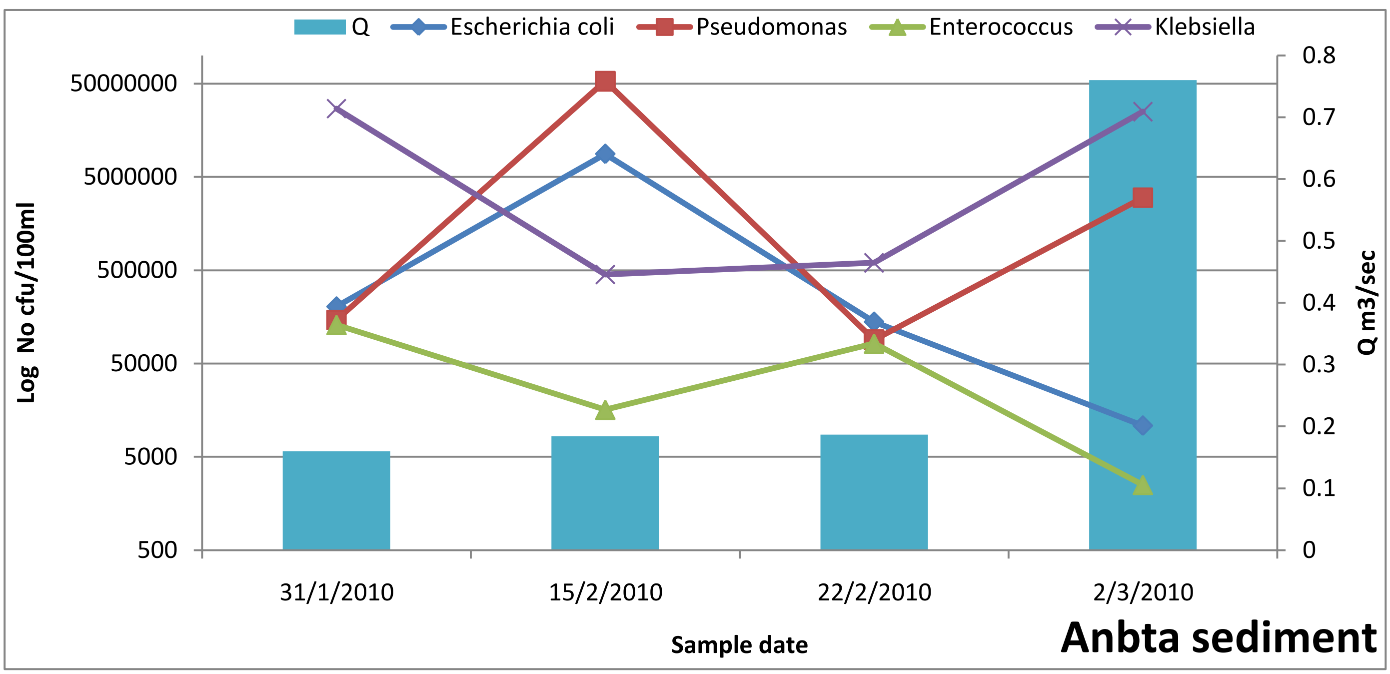
Pseudomonas aerugenosa

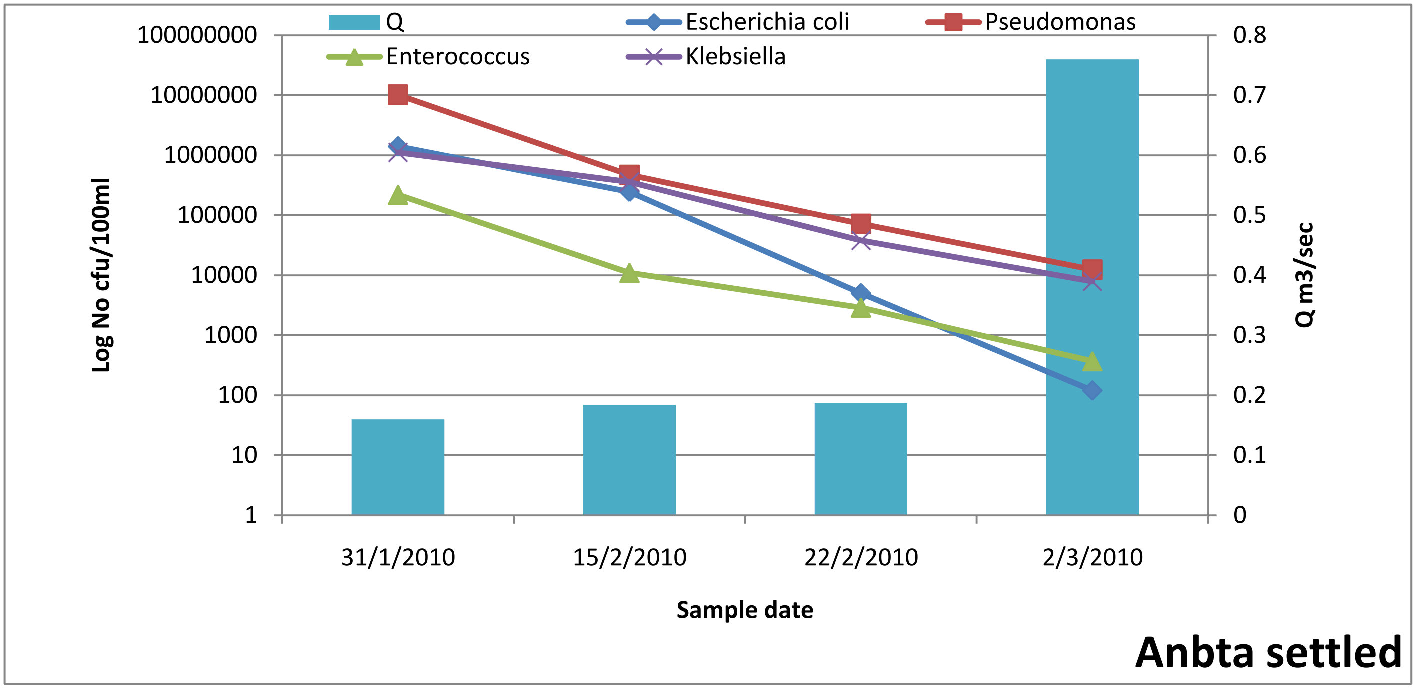
Annex B: Figures clarify the Relation between pathogenic No. And flow discharge

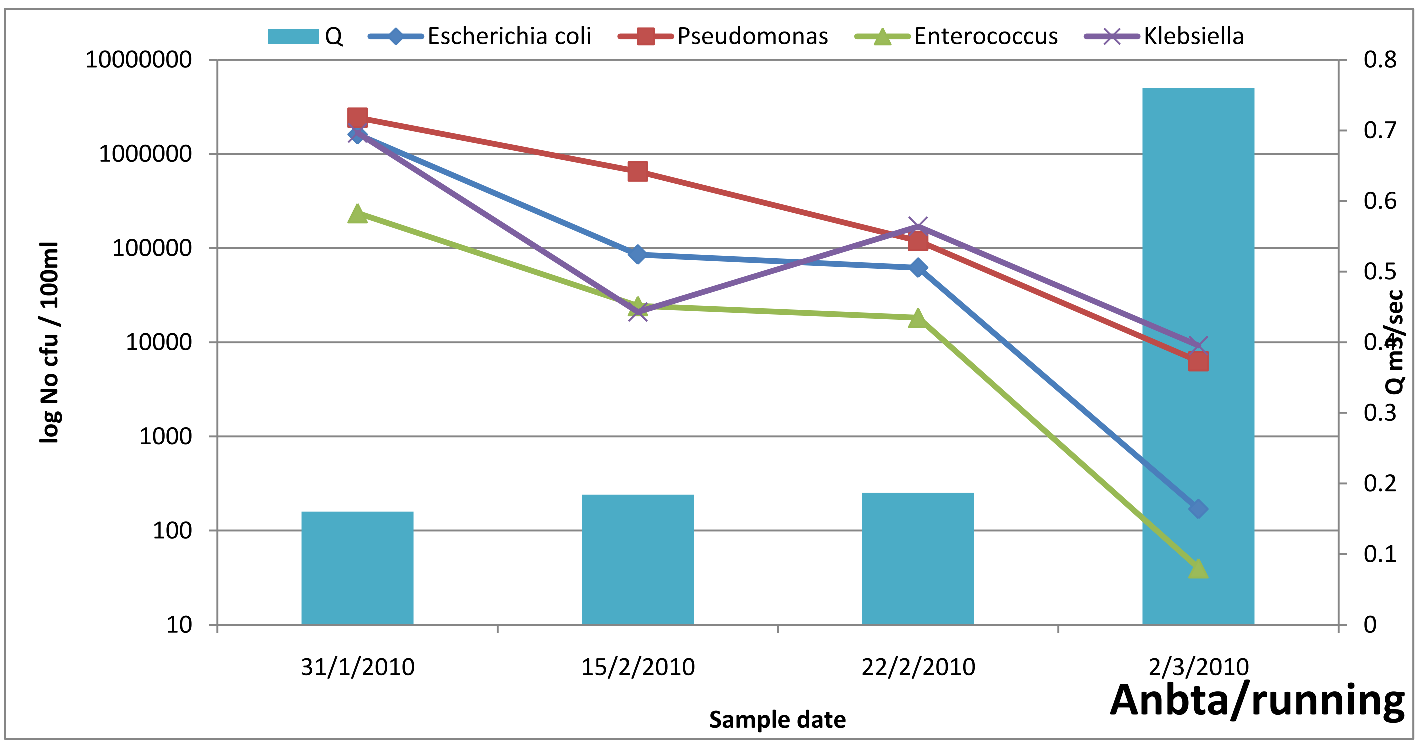


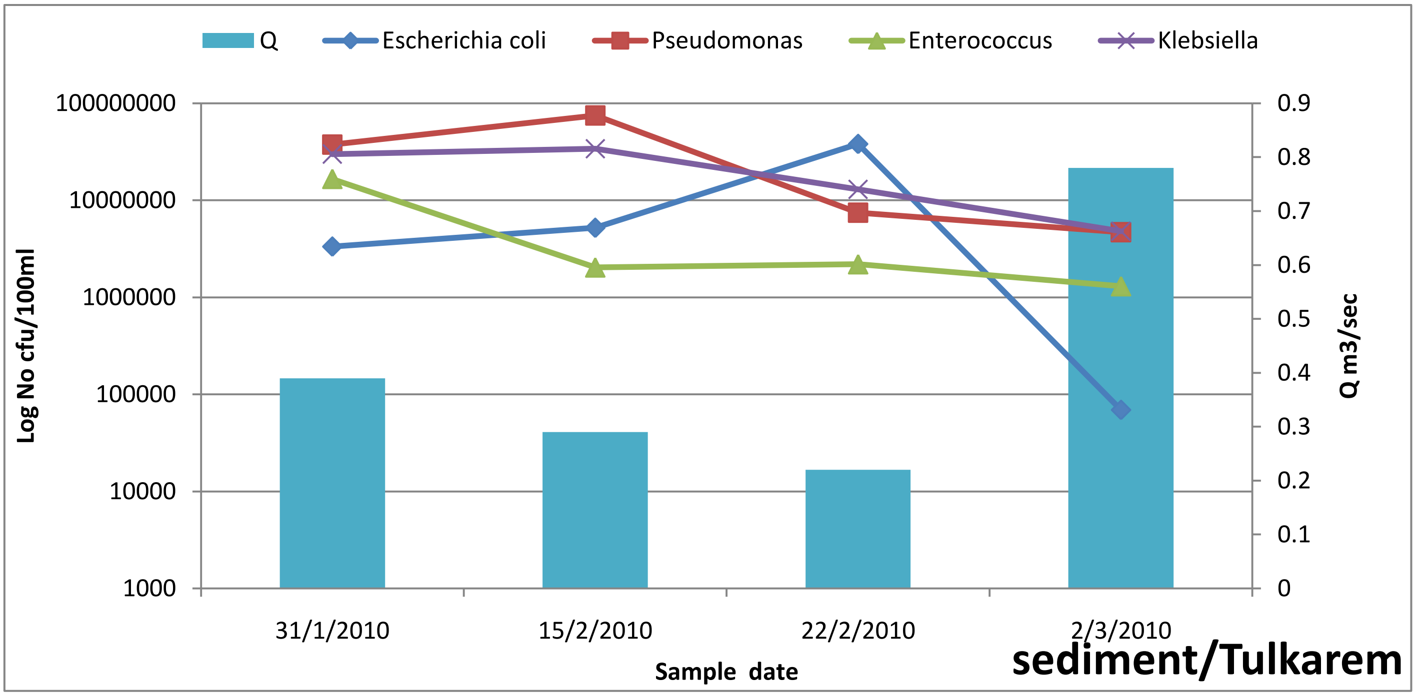


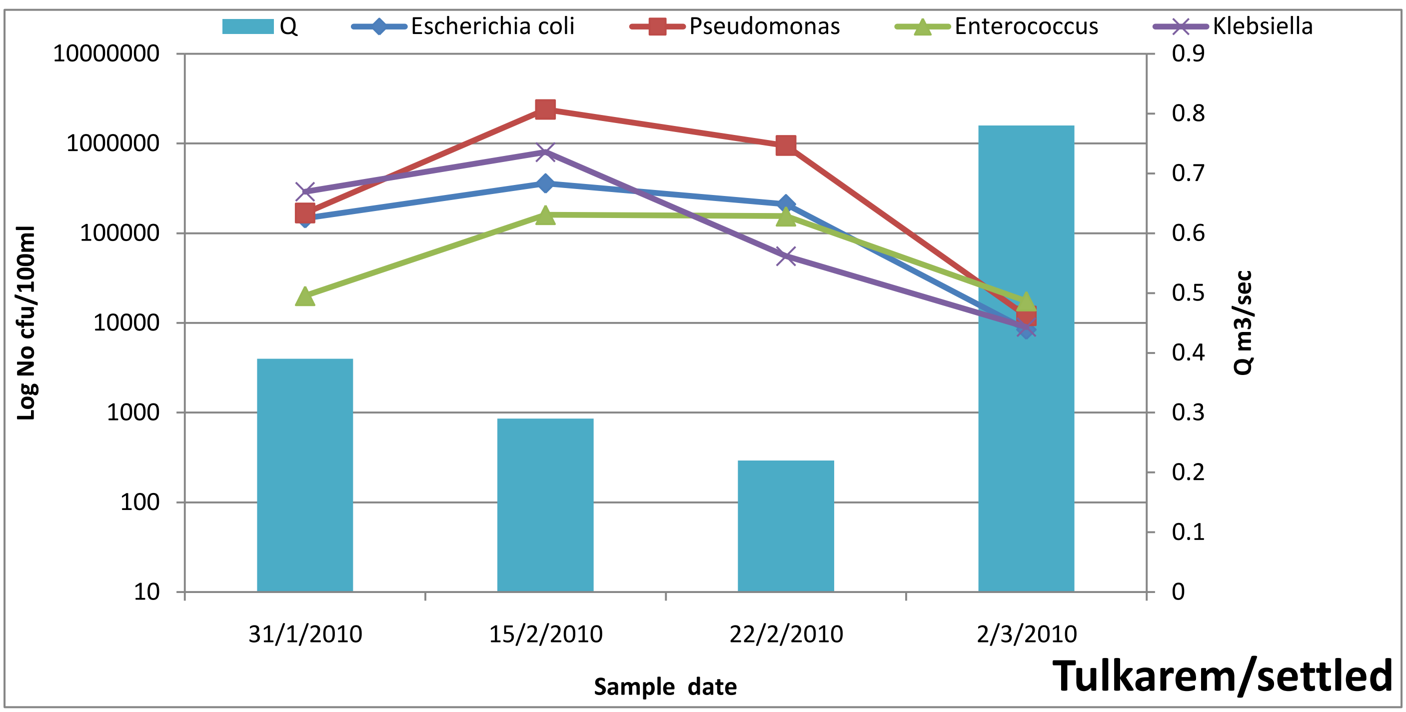

Q
Escherichia coli
Pseudomonas
Enterococcus
Klebsiella
10000000
1000000
100000
10000
1000
Log No cfu/100ml
3
2.5
2
1.5
1
0.5
0
Q m3/sec
31/1/2010
15/2/2010
22/2/2010
2/3/2010
Sample date
Deir Sharaf/running

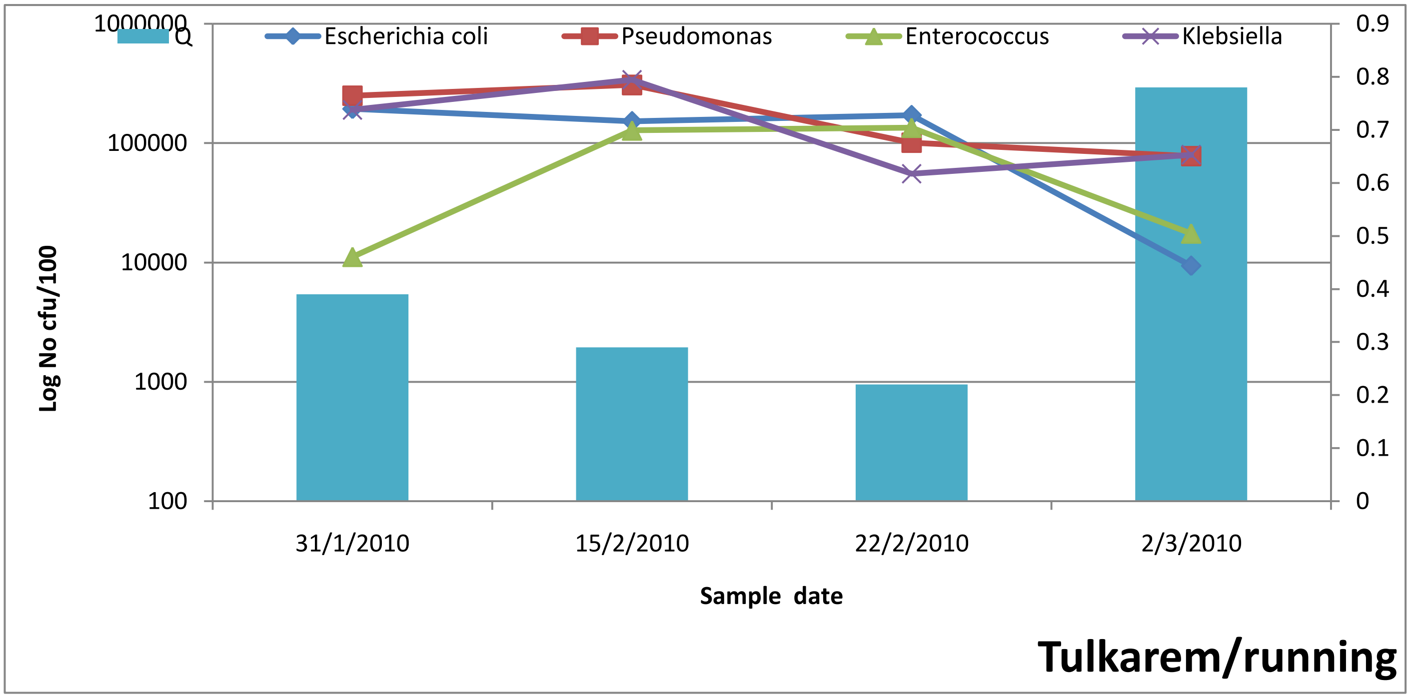

Q
Escherichia coli
Pseudomonas
Enterococcus
Klebsiella
50000000
5000000
500000
50000
5000
500
Log No cfu/100ml
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Q m3/sec
31/1/2010
15/2/2010
22/2/2010
2/3/2010
Sample date
Anbta sediment


Q
Escherichia coli
Pseudomonas
Enterococcus
Klebsiella
100000000
10000000
1000000
100000
10000
1000
100
10
1
Log No cfu/100ml
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Q m3/sec
31/1/2010
15/2/2010
22/2/2010
2/3/2010
Sample date
Anbta settled


Q
Escherichia coli
Pseudomonas
Enterococcus
Klebsiella
10000000
1000000
100000
10000
1000
100
10
log No cfu / 100ml
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Q m3/sec
31/1/2010
15/2/2010
22/2/2010
2/3/2010
Sample date
Anbta/running


Q
Escherichia coli
Pseudomonas
Enterococcus
Klebsiella
100000000
10000000
1000000
100000
10000
1000
Log No cfu/100ml
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Q m3/sec
31/1/2010
15/2/2010
22/2/2010
2/3/2010
Sample date
sediment/Tulkarem


Q
Escherichia coli
Pseudomonas
Enterococcus
Klebsiella
10000000
1000000
100000
10000
1000
100
10
Log No cfu/100ml
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Q m3/sec
31/1/2010
15/2/2010
22/2/2010
2/3/2010
Sample date
Tulkarem/settled



Q
Escherichia coli
Pseudomonas
Enterococcus
Klebsiella
1000000
100000
10000
1000
100
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Log No cfu/100
31/1/2010
15/2/2010
22/2/2010
2/3/2010
Sample date
Tulkarem/running