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Water Quality Modeling for Faria Stream

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Nuaman Mizyed

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This Thesis was defended successfully on 25/6/2013, and approved by:

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Dedication

At the end of this work I'd like to dedicate this research for my family, every one of them my mother , my brothers, and my sisters for their support through the research and through my life.

And finally I achieved what I worked hard and hoped to do, to dedicate this research to myself and to the soul of my Father.

بسم الله الرحمن الرحيم

"" أَنزَلَ مِنَ السماءِ ماءً فَسالَتْ أَوْدِيَةٌ بِقَدَرِها فَاحْتَمَلَ السيْلُ زَبَداً رابياً و مما يُوقِدونَ عليهِ في النارِ آبتغاءَ حِلْيَةٍ أو مَتَاعٍ زَبَدٌ مِثْلُهُ كَذَلِكَ يَضْرِبُ اللهُ الحَقَ و الباطِلَ فَأما الزبَدُ فَيَذْهَبُ جُفَاءً وأَما ما يَنفَعُ الناسَ فيَمْكُثُ في الأَرْضِ كَذَلِكَ يَضْرِبُ اللهُ الأَمْثَالَ""

صدق الله العظيم ((الرعد :17))

فأما الزبد فيذهب جفاء و أما ما ينفع الناس فيمكث في الأرض، دعائي لله أن يكون عملي هذا مما ينفع الناس وأنا ابتغي فيه الاخرة لا عرض الحياة الدنيا ولهذا أردت أن يكون هذا البحث صدقةً جارية عن روحي وعن روح والدي رحمه الله.

واهدي عملي هذا لعائلتي أخوتي وأخواتي وأمي العزيزة الغالية وكل من ساندني في عائلتي خلال هذا البحث، فقد كانوا عوناً لي في دراستي كما هم عونا لي في حياتي كلها، وتأييدهم كان لي دائما مصباح الأمل.

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الإقرار

أنا الموقعة أدناه مقدمة الرسالة التي تحمل العنوان :

Water Quality Modeling for Faria Stream

نمذجة نوعية المياه في وادي الفارعة

أقر بأن ما اشتملت عليه هذه الرسالة هو نتاج جهدي الخاص باستثناء ما تم الاشارة اليه حيثما ورد, و أن هذه الرسالة ككل او بأي جزء منها لم تقدم من قبل لنيل أي درجة علمية أو بحث علمي لدى أي مؤسسة علمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name:	**اسم الطالبة:**
Signature:	**التوقيع:**
Date:	**التاريخ:**

Abbreviations

A: Cross Sectional Area

a: Gauge Height of Zero Flow

amsl: Above mean Sea Level

bmsl: Below Mean Sea Level

BOD: Biochemical Oxygen Demand

BOD_o: Initial Biochemical Oxygen Demand

BOD_u: Ultimate Biochemical Oxygen Demand

BOD_5: Five-day Biochemical Oxygen Demand

C_{esc}: Escape Coefficient of Reaeration

C_t: Tracer Concentration

c: Coefficient in manning equation, for IU units equals 1, and 1.49 for UK units (ch.2).

C_s: Dissolved Oxygen Concentration at Saturation

C_a: Actual Dissolved Oxygen Concentration

CC: Climate Change

CBOD: Carbonaceous Biochemical Oxygen Demand

COD: Chemical Oxygen Demand

DO: Dissolved Oxygen

D: Oxygen Deficit

D_o: Initial Oxygen Deficit

DS: Dissolved Solids

D_{ave} : Average Water Depth

EC: Electrical Conductivity

FoEME: Friend of the Earth in Middle East

H: Water Depth or Stage Height

IPCC: Intergovernmental Panel for Climate Change

K_a: Reaeration Rate

K_d: Decay Rat of Carbon Source Organic Matters

K_n: Decay Rat of Nitrogen Source Organic Matters

K_r: Deoxygenation Rate

L: Average Biochemical Oxygen Demand Remaining.

L_o: Initial Biochemical Oxygen Demand Remaining.

LJR : Lower Jordan River

MCM/Y: Million Cubic Meters per Year

mm: Millimeter

m^3/s : Meter Cube per Second

m^3/d : Meter Cube per Day

n : Manning Roughness Coefficient

NO_3^-: Nitrate

NO_2^-: Nitrite

NBOD: Nitrogenous Biochemical Oxygen Demand

Q2E: Stream Water Quality Model QUAL2E

Q2K: Stream Water Quality Model QUAL2K

Q2Kw: Stream Water Quality Model QUAL2Kw

Q: Stream Flow in m^3/sec.

q: Injection Rate of Trace

R: Hydraulic Radius

S: Water Surface Slope

SCC: Scenario of Climate Change Effect

SFE : Streeter and Phelps Equations

SS: Suspended Solids

SOD : Sediment Oxygen Demand

t: Flow Travel Time

TDS: Total Dissolved Solids

TKN: Total Kijhledal Nitrogen

TMDL: Total Maximum Daily Load

TPC: Treatment Plant of Carbon Source Organic Matters

TSS: Total Suspended Solids

TSS: Total Suspended Solids

TTP: Tertiary Treatment Plant

α:	Rating Curve Slope
u:	Average Stream Flow Velocity
W :	Stream Width
WWT:	Waste Water Treatment
WWTP:	Waste Water Treatment Plant
WSP:	Waste Stabilization Pond
WSTR:	Waste Water Storage and Treatment Reservoir

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Abstract

Assessment and modeling of water quality is essential for ecosystem management. Faria watershed has an area of 320 km^2, its main land use is for agriculture with 70% irrigated crops. Faria stream through the watershed, is polluted mainly with untreated WW discharged from eastern Nablus and due to surface runoff from adjacent draining lands. Stream's water quality modeling is needed for stream and watershed restoration. The stream was divided into five reaches through five sampling points. At each point several field measurements were conducted for stream velocity and flow, and water samples were collected monthly from December, 2010 to May, 2012, and analyzed for pH, EC, BOD, COD, TKN, and SOD. Water quality of the stream was modeled by QUAL2Kw. Modeling of water quality along the stream was performed for three current cases. These include; summer with maximum BOD, winter with minimum flow, and critical conditions of minimum DO with minimum flow. The model was calibrated for depth, flow, velocity, travel time, DO profile and SOD using measured values. Considerable changes were detected along the stream as DO changed due to aeration in natural stream from 0.55 mg/l upstream to DO level of 5.1 and 4.8 mg/l at the following two sampling points, and also due to natural treatment in the stream, average TKN changed from 233 mg/l at upstream to about 160

mg/l at the downstream, average TDS reduced from 2000 mg/l to 500 mg/l at downstream, and TSS also reduced from average 1604 at upstream to about 266 mg/l at downstream. Withdrawals were predicted at reaches 2-3, 3-4, from Badan area to AL Malaqi Bridge, withdrawals were estimated of about 3000-3450 m^3/d and increased at summer to 8120 m^3/d at reach 2-3, Badan area.

Stream management and restoration techniques are recommended for Faria stream, this can be achieved first by the installation of WWTP at Nablus-outfall. Such solution is expected to improve stream quality by reducing SOD from 6.22 without treatment to 0.37 $gO_2/m^2/day$ after treatment, and DO profile showed enhancement along the stream as it improved after treatment, from effluent DO of 2 mg/l at upstream to about 5.56 mg/l at distance of 7.77 km and DO of 8.6 mg/l at stream end. Other management and simple structural techniques can be used for Faria stream restoration such as: Waste Water Storage and Treatment Reservoir (WSTR), improving the sanitation conditions of communities around the stream, side armoring using riprap and gabions, stream aeration by using hydraulic structures such as weirs, waterfalls or ladders, and impoundment removal. Nonstructural techniques also can be effective in Faria stream restoration and management include: planting and establishment of buffer zones and riparian zones to reduce runoff pollution, pollution control legislations and administration of fertilizers application frequency, timing and types, in addition to controlling and maintaining human activities, and land use at the watershed.

Chapter One

Introduction

Chapter One
Introduction

1.1 Background

Water is becoming an increasingly scarce source in many arid and semi-arid areas. Thus, planners consider any sources of marginal water which might be used economically and effectively to satisfy the needs of growing population.

The West Bank is located in arid to semi arid zone and thus faces water shortage [1]. Faria catchment, which located at the northeastern part of West Bank, was selected as study area for this research. This research aims to study the quality and quantity variations of Faria stream that is polluted with untreated waste water discharged from Nablus city and Faria camp.

Pollution of ecosystem has impact on the system equilibrium, and as the case at Faria stream, pollution with waste water causes health hazards directly or indirectly [2,3], in addition to risk of surface water and ground water contamination d by leakage or mixing with Faria waste water stream flow.

Waste water (WW) in its characteristics, contains all constituents added to through the use, it contains large and small suspended particles or Suspended Solids (SS), besides colloidal non settleable suspension and Dissolved Solids (DS). The waste water has in its’ constitutes heavy metals, organic and inorganic matters [4]. The organic matters consume

Dissolved Oxygen (DO) in the oxidation which will result in depletion of system's DO and cause degradation or unbalance aquiculture in that system, its effect measured and represented by terms of oxygen demand, DO for biologically degradable matters found in the waste water called (BOD), and it is classified to Nitrogenous Biochemical Oxygen Demand (NBOD) for nitrogenous organic matters oxidation, and Carbonaceous Demand (CBOD) for oxidation of carbon source organic matter [5], the chemically oxidized matters are represented by Chemical Oxygen Demand(COD). Assessment and modeling of water quality for Faria stream was done for DO, TSS, TDS, TKN, pH, Electrical Conductivity (EC), besides flow calculations to analyze and model spatial and temporal quality variations in the stream.

So, assessment and modeling of Faria stream quality is a major step needed for restoration of the stream, and allocation of waste water discharged to the stream. In other words, the research is a tool in management planning and decision making that needs to be done at the catchment level.

1.2 Research Motivation

The study area of Faria catchment, with its current conditions specifically:

- Arid and semi arid areas suffer from water scarcity, and the problem exacerbated at Faria catchment, by utilizing feasible water for irrigation.

- Using polluted water for agricultural uses, this will lead to diseases spread, and desertification of agricultural land in the catchment.
- Impact of stream pollution on biodiversity and aquatic life, and it causes degradation of the ecosystem.

The solution of these circumstances can be achieved through assessment of system variables, modeling their impacts and predicting scenarios of change.

1.3 Objectives

The objectives of the research are:

1- Assessment of Faria stream flow quantity, and quality, mainly DO, BOD, COD, TDS, TSS, pH, EC and TKN.

2- Modeling of water quality variations along the stream for summer, winter, and critical conditions that may found at the stream.

3- Studying expected scenario for management of the stream in view point of model results and possible future changes.

1.4 Study Area

1.4.1 Area Overview

Faria catchment is located in the Northeastern part of the West Bank, it has a total area of about 320 km^2. This total area accounts for about 6% of the total area of the West Bank [1]. Faria catchment extends from the ridges of Nablus Mountains down through the eastern slopes of the West Bank up to the Jordan River. It overlies through three districts of the West Bank: Nablus, Tubas and Jericho districts (**Figure 1.1**). Faria catchment is divided into three sub-catchments: upper Faria, Nablus-Badan sub-catchment, and Malaqi sub-catchment with areas of 56 km^2, 83 km^2, and 181 km^2 respectively [1,6]. It lies within the Eastern Aquifer Basin which is one of the three major groundwater aquifers forming the West Bank groundwater resources [1].

Several studies were conducted about Faria catchment including rainfall runoff modeling of the catchment [6], Runoff coefficient in relation to rainfall intensity [7], other studies for the catchment concerned with the management scenarios for water and land use in Faria as an example for arid and semi-arid catchment, this study included optimization of land use and water resources utilization for agricultural purposes in the watershed [8].

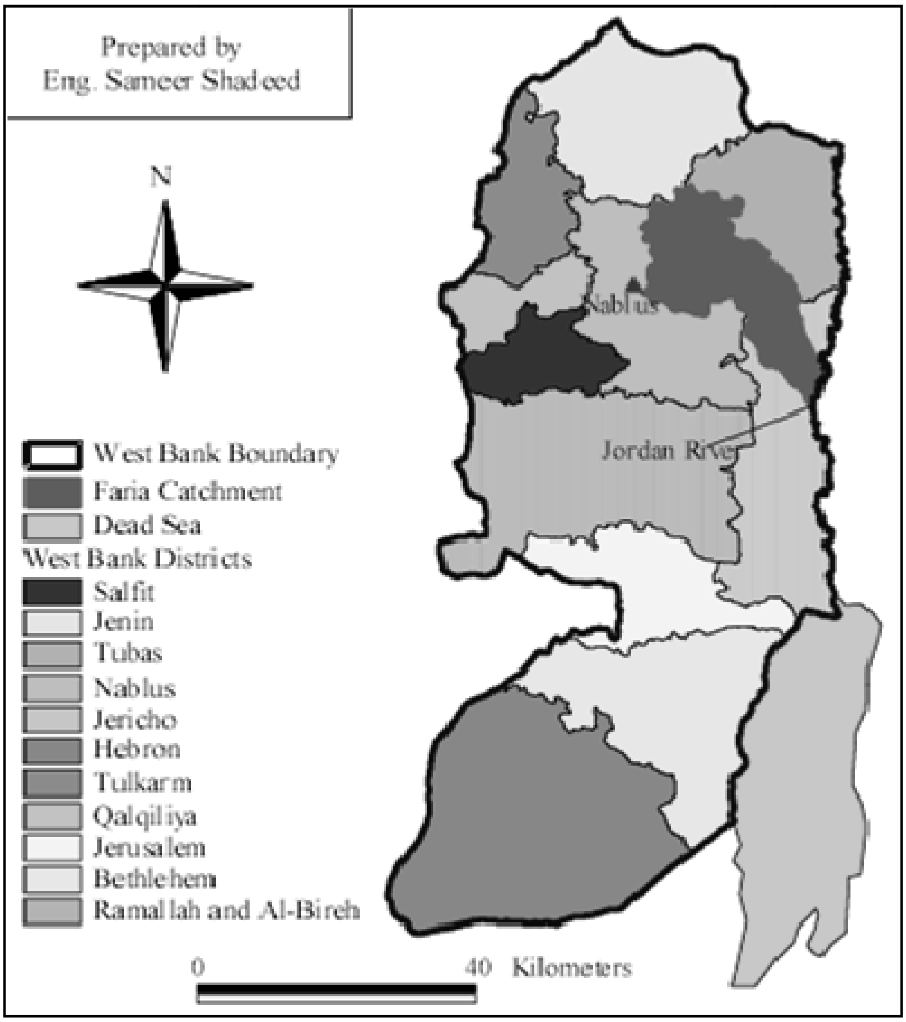


Figure (1.1): Districts Faria Catchment Overlaying in West Bank [6].

1.4.2 Climate and Landuse

Faria catchment climate is arid to semi-arid, with moderately dry hot summers and mild rainy winters for about 6 months from October to April in western parts of the catchment and a couple of months in a proximity of Jordan River [1].

Catchment temperature increases with decreasing altitudes from northern west to southern east the catchment. As the mean annual temperature ranges from 18ºC with elevation of about 900 m amsl in the upper parts of the watershed to 24 ºC in the lower parts with elevations of 350 m bmsl [1].

The Faria catchment has six rainfall stations [1,6,8]. These stations are at Nablus, Talluza, Tammun, Tubas, Beit Dajan and Faria. The Nablus station is a regular weather station in which most climatic data are measured from 1947 till now, Faria station is located at Al-Jiftlik village in the lower part of the catchment. The other four rainfall stations are located in the schools of Talluza, Tubas, Tammoun and Beit Dajan. Data from these stations covers monthly and annual rainfall for 30 to 40 years, mean, minimum and maximum rainfall values are shown in **Table (1.1)**. The annual rainfall distribution within the catchment ranges from 660 mm in the upper areas of the watershed to about 160 mm at the outlet near the Jordan River, as shown at **Figure 1.2**, the rainfall clear decreases with movement from north to south and west to east**.**

The land in the catchment is used for agriculture, irrigated agriculture constitutes about 70% of current agriculture in the areashed and it reaches about 90% in the lower parts, where the irrigated agriculture is considered as the backbone of Palestinian economy and provides about 80% of the employment in the study area [1,6,8] . The agriculture consumes about 75% of watershed’s discharged water which is 4.5-11.5 MCM/year from 62 agricultural wells and 3wells used for domestic's use.

1.4.3 Stream Characteristics

Faria valley is one of the important few valleys in West Bank, its flow is a combination of Faria catchment run off, discharges of springs in upper parts of the catchment of about 4 MCM/yr, and untreated WW of about 1 MCM/yr discharged from eastern Nablus[1]. **Figure 1.3** shows points of confluence between fresh water and WW stream flow at Badan area and Ein Shibli.

Table (1.1): Annual Rainfall at The Different Stations at Faria Watershed [1,8].

Station	Period	Rainfall (mm)		
		Mean	**Max.**	**Min.**
Faria	1952-1989	198.6	424	**30**
Nablus	1946-2003	642.6	1387.6	**315.5**
Tubas	1967-2003	415.2	889.5	**201.5**
Tammoun	1966-2003	322.3	616.1	**124.2**
Talluza	1963-2003	630.5	1303	**292.2**
Beit Dajan	1952-2003	379.1	777	**141**

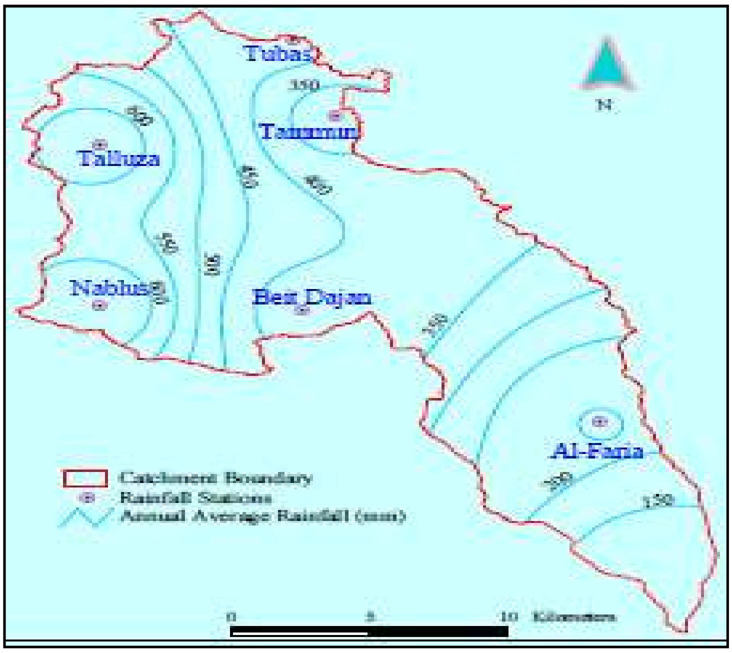


Figure (1.2): Rainfall Stations and Rainfall Distribution in Faria Catchment [6].

The stream has special characteristics of decreasing altitude of about 1.3 km in less than 30 km [1] which gives average stream slope of about 4%, so the flow can be considered moderate to rapid currents, but slow currents at upstream part with velocity of about 0.39 m/s, and velocity at downstream reaches about 0.5 m/s and 0.6 at some sampling events, this classifies the stream as modern to swift stream [9]. The streambed is mainly consists of cobbles, small rocks and gravel along the stream, where it is mixed with mud or silts at upstream. There is no plant growth through the stream, riparian plants and vegetations are scattered wild plants on both sides except the agricultural areas around the stream in the lower part and at Badan area.

(a) **(b)**

Figure (1.3): Faria Stream Flow Combination at a) Badan Springs Confluence with Nablus Waste Water. b) Waste Water Flow Mixed with Ein Shibli Spring's Discharge.

1.4.4 Sources of Pollution in the Stream

Faria stream is a combination of more than one source of water, under these circumstances, the pollution sources in Faria catchment and the stream are classified to:

- Point sources: point sources include municipal WW that is collected in a network and discharged into the stream eastern Nablus and at specific points along the stream.

- Non point sources: non point source pollution in the stream carried out by catchment runoff from land use, and road, which carries a variety of pollutants in type and quantity like volatile organic carbon, fertilizers and pesticides. Other non point pollutants include atmospheric depositions, urban runoff, and random solid waste disposal through the stream **(Figure 1.4)**.

(a) (b)

Figure (1.4): Non Point Sources of Pollution at Faria Stream from a) Animals, and b) Random Solid Waste Disposal.

Chapter Two

Literature Review

Chapter Two
Literature Review

2.1 Waste Water Characteristics

Waste water is the water that has been used by a society or a community, it contains all constituents added to through the use like faeces, urine with flushing toilet water, and all water from personal uses or food industries. Its hazard is due to the pathogens that cause human being disease when human contact happened and risk of heavy metals that can be transmitted by food chain and accumulated in human body, causing several health problems if it exceeds the allowable limits [3].

Strength of waste water classified according to BOD and COD values from weak to strong as illustrated in **Table 2.1**.

Table (2.1): Waste Water Strength in Terms of BOD_5 and COD[10]

Strength	BOD_5 (mg/l)	COD (mg/l)
Weak	<200	<400
Medium	350	700
Strong	500	1000
Very strong	>750	>1500

Aquatic system characteristics are determined by quality parameters classified to chemical, physical and biological characteristics (**Table 2.2**). These measures describe water system biodiversity and health. Physical measures include flow quantity, depth, velocity and substrate materials, which influence in stream habitat conditions and riparian biota, as stream alterations will deprive pollutants assimilation capacity of the stream, but some alterations may have good effect if it does not affect the water body considerably [9].

The chemical measures concerns with and regulate chemical compounds that are toxic to human health and aquatic life occur and have the probability to occur in the environment at harmful levels that called Priority Pollutants. They are about 129 pollutants, 13 of them are toxic metals while the remaining are organic chemicals. Water quality studies generally concern of these priority pollutants in addition to parameters describe ambient water conditions of DO, BOD, TSS, TDS and nutrients which is our attention in this research to describe natural conditions of Faria stream. The biological measurements and system biology asses the occurrence, condition and types of fish, plants, algae or other organisms in the water body, these biological indicators are almost unique environmental species that describe the qualities have to be presented in a water body, these are used to describe ecosystem health depending on biological inventory and biological potential analysis, and they serve as a benchmark for regular biological measurements [9].

2.2 Quality Parameters

The constituents of waste water will be degraded by time, with about 70% of sewage solids is organic matters and 30% is inorganic [10].

The organic matters or pollutants in a water body will consume dissolved oxygen in decomposition reaction according to the equation:

$$Organic\ Matter + O_2 \xrightarrow{\text{Microorganism}} CO_2 + H_2O \qquad [11]$$

Which will decrease the level of dissolved oxygen in the water body, this DO variations with its effect on aquatic life is illustrated in **Figure 2.1**, and DO variations classified longitudinally to decomposition zone with maximum pollutants concentration, septic zone that has critical DO level, Recovery zone, and finally Clear zone where DO level increase again until reach natural DO level before pollution [9]. This figure is called DO profile or DO sag curve **(Figure 2.2)** [5].

The biological and chemical oxygen demand (BOD and COD) measure how much is the pollution of a water body by measuring oxygen demand for degradation of the organic matters biologically, and chemically by acid and dichromate solution.

BOD Test used is generally BOD_5 that takes 5 days, and ultimate BOD (BOD_u) to measure oxygen needed for total degradation of organics, BOD_u also used to estimate the rate of reaction of the organic matter degradation, which is influenced by the temperature of the reaction, the organic matter characteristics which represent the waste water characteristics, besides the organism variety and population in the water system [12].

What is considered to say the Chemical Oxygen Demand (COD) Test can give a result in about 2 to 3 hours which is short time in comparison with BOD Test that needs days.

Due to weathering and dissolution, solid matters which found in water bodies are classified to Total Suspended Solids (TSS) and Total

Dissolved Solids (TDS). TDS determined by the solids contained in the filtrate sample, the remaining particles on the filter of filtrate sample are the TSS and it is on filter pore size of 0.45 μm to include suspended matter with microorganisms [4].

Table (2.2): Quality Assessment Measurements of Faria Stream [9].

Physical Measures	Chemical Measures
In stream characteristics	Dissolved oxygen
Size (depth and width)	pH
Flow and velocity	Suspended solids
Total volume	Sediment oxygen Demand
Reaeration rates	
Gradients, pool, riffle	
Temperature	
Sedimentation	
Riparian characteristics	
Downstream characteristics	

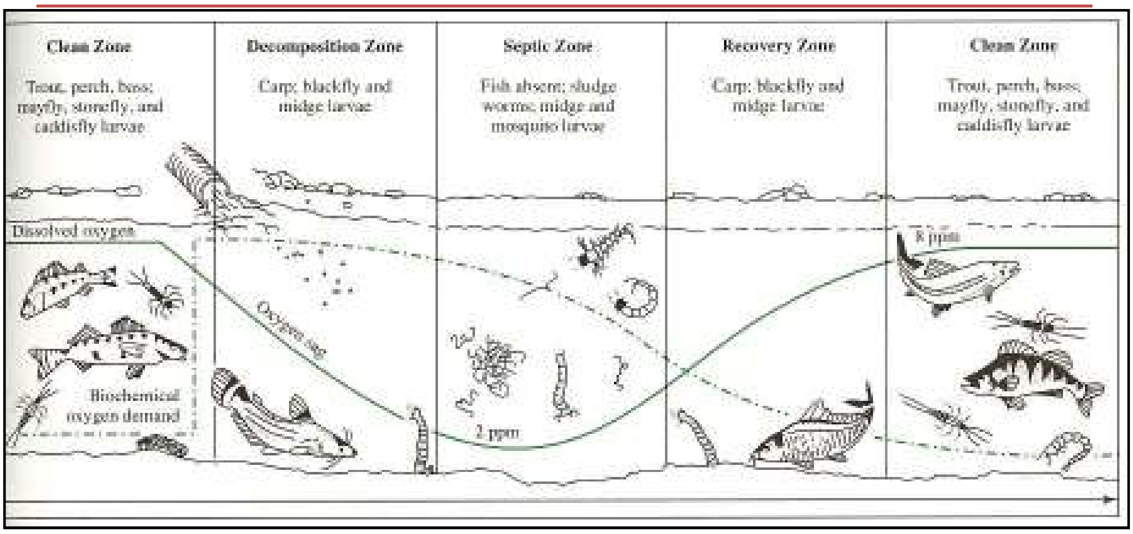


Figure (2.1): DO sag-curve and aquatic life [5].

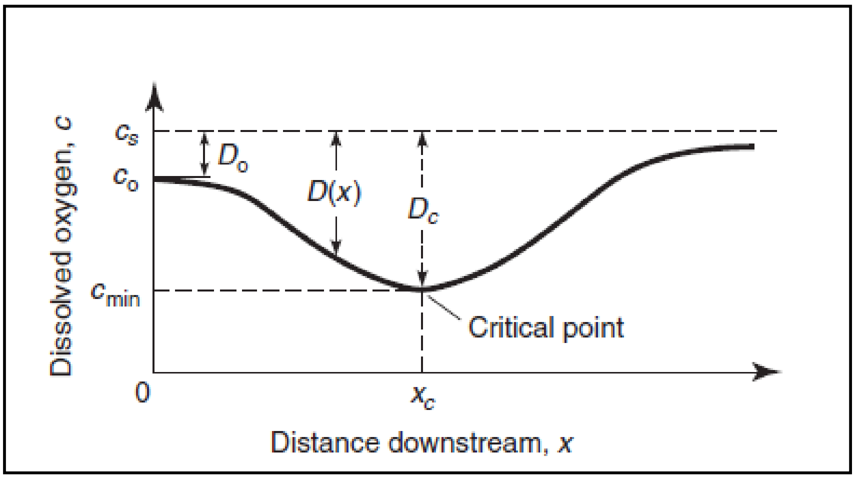


Figure (2.2): Typical DO Sag-Curve [9].

TDS gives indication about Electrical Conductivity (EC) and salinity of the water, which influence on soil fertility and crop productivity.

These parameters, describe ambient conditions of streams are the targeted parameters in our study, as a first research of water quality for Faria stream, in addition to pH, Total Kjeldahl Nitrogen (TKN) and temperature.

2.3 Modeling Principles

Modeling of water quality is simulation to the natural system in its processes and variables. It represents the relationship between variables by mathematical or empirical relations. Quality model can be any simple empirical relationship or mathematical equation developed to mass balance equation and complex software. Mass balance equation was used first in water quality modeling in order to determine waste loads that a water body can assimilate without the adverse impact on aquatic life [13], and in 1925 Streeter and Phelps equations were derived to simulate DO and BOD in rivers, since that time river modeling has been improved continuously to simulate carbonaceous and nitrogenous BOD, sediment oxygen demand, nitrogen, ammonia, nitrate, nitrite, phosphorous, and algae mass as chlorophyll a.

The Streeter and Phelps Equations (SFE), with nitrogenous BOD is given by:

$$D = \frac{K_d L_o}{K_a - K_d}\left(e^{-\frac{xKr}{u}} - e^{-\frac{xKa}{u}}\right) + D_o\, e^{-\frac{xKa}{u}} + \frac{K_n L_n}{K_a - K_n}\left(e^{-\frac{xKn}{u}} - e^{-\frac{xKa}{u}}\right) + SOD\left(1 - e^{-\frac{xKa}{u}}\right)$$

(2.1)

where :

D : oxygen deficit, it is the difference between saturation DO level and actual DO level ($D = C_s - C_o$), mass /volume.

C_s: saturation concentration of dissolved oxygen

C_a: actual concentration of dissolved oxygen.

D_o : initial oxygen deficit at time = 0, mass /volume.

K_d : carbonaceous deoxygenation rate constant, time^{-1}.

K_a : reaeration constant, time^{-1}.

L_o : ultimate carbonaceous BOD, mass/volume.

L_n : nitrogenious BOD_u , mass/volume.

K_n : nitrogenious deoxygenation rate, time^{-1}.

u : average stream velocity, length/time.

x : is the distance measured along the stream, length.

SOD: sediment oxygen demand, mass/length^2/time.

QUAL family and particularly QUAL2Kw is one of the software based on SFE, it was used for DO profile or DO sag curve modeling along Faria stream [14].

QUAL2Kw model (Q_2Kw)

QUAL2Kw model is a river and stream water quality model, it is adaptive from Q2K, which is modified version of QUAL2E model. Q2Kw model is written in Excel/VBA for simulating water quality variations.

The model is one dimensional as the channel or stream is considered well mixed vertically and laterally, steady state, non-uniform flow is simulated.

The model represents the river or stream as a series of reaches of constant hydraulic characteristics (i.e.: slope, bottom depth, velocity). Point and non point sources and withdrawals can be placed at any elements along the stream or river.

The model QUAL2kw has two features distinguished it from other softwares, sediment water fluxes for dissolve oxygen and nutrients are simulated internally, and hyporheic zone is modeled, secondly genetic algorithm for calibration of predicted output with measured data [15].

2.4 Stream Characterization for Flow Quantity and Quality

Literature covered a wide range of used methods for streams characterization, basically for flow quantity, quality measurements and calculations. These sections covered the reviewed literature for characterization methods of streams quantity and quality.

2.4.1 Sampling Allocation

Selection of sampling points is important to represent stream flow characteristics. Sampling points of historical data are preferable as they offer long data series for research program, gauge stations if found, will be chosen in order to coordinate flow condition with quality variations.

But where new sampling points are chosen it is important to be accessible as necessary for research objectives [16,17]. These sampling points have to be upstream of channel confluence, smooth, empty of aquatic growth, the section is empty of boulders, rocks with regular and stable channel bed, and a straight section of at least 50m above and below measuring point is chosen [16]. Because most water bodies are not homogeneous, great care to collection method and sampling equipment is needed for representative samples of water quality studying.

2.4.2 Flow Calculation

Flow measurements generally used to meet many purposes some of them are [17]:

- Identification and quantification pollutants sources in a watershed.
- Characterization of habitat problems in the stream channel.
- By monitoring, collection of design information for water quality, water quantity, and stream restoration projects.
- Quantity determination of pollutant loads in supporting TMDL projects or other watershed planning projects.
- Quantification of pollutant loads of some implementing projects of the watershed.

And flow measurement at Faria stream, is done as the case for identification and quantification of pollutions, in addition to stream restoration. Methods used for flow measurements are summarized by:

1. Volumetric flow measurements

Volumetric flow measurement is a direct flow measurement technique, it is the simplest and most accurate method for measuring flow [17], this method used for small flows, and it is summarized by measuring the volume and time needed to fill that volume.

2. Dilution method

Dilution method using tracer solution of known concentrations and by chemical analysis tracer dilution determined after complete mixing with river or stream flow. Tracer method needs special attention at field, special equipments, certain tracer specifications, and it consumes time [18]. Flow rate in this method measured according to the general equation [17]:

$$Q = q * \left(\frac{C_{t1} - C_{t2}}{C_{t2} - C_{to}}\right) \qquad 2.2$$

Where :

Q : stream flow,(volume/time)

C_{t1}: tracer concentration at injection, (mass/volume).

C_{t2}: final tracer concentration in the stream, (mass/volume).

C_{to}: background concentration of tracer in the stream, (mass/volume).

And q: tracer injection rate, (volume/time).

3. Stage – Discharge Relation

Flow measurements done by mathematical relation between water level and flow at natural cross section and constructed structures for that purpose (flumes and weirs).

i. Weirs and Flumes: For long term projects flumes and weirs used for flow measurements, measuring flow become easily as observing water level especially with tables prepared for that. The weirs used for flow measurements are: broad crest and sharp crest weir, the types of sharp crest weirs are V-notch weir, rectangular, and cipolletti weir. Flumes generally used where weirs are not feasible, flumes are suitable for measuring flow with sediments due to self cleaning by their high velocity in general [17].

ii. Rating Curve: rating curve is a theoretical or empirical relationship between water stage and flow discharge in natural or artificial channel [17,19], stage discharge relation is fitting in power or polynomial curve, the reliability of flow measures depend on satisfactory stage- discharge relation. Stage discharge relation is expressed in the form [19]:

$$Q = C(h - a)^{\alpha} \qquad 2.3$$

Where Q: the discharge

(h-a): the effective water depth on the control section

a: the gauge height of zero flow

h: the stage height

C: the discharge when the effective depth (h-a) equals1.

And α: the slope of rating curve, and it will confirm to the flow control type (logarithmic paper).

4. Manning Equation

This method is used for uniform flow conditions in open channels, but it may give reasonable estimate for non uniform conditions found in natural channel [17], the method needs straight reaches, with accurate slope measurement by measuring water level up and down stream cross section. Manning equation measures the velocity (u) and stream flow by the following equations [17]:

$$u = \frac{c}{n} S^{\frac{1}{2}} R^{\frac{2}{3}} \qquad 2.4$$

$$Q = \frac{c}{n} S^{\frac{1}{2}} R^{\frac{2}{3}} A \qquad 2.5$$

Where :

Q : discharge or flow rate, (volume/time)

u: average stream flow velocity, ($length^2$ /time)

A: cross sectional area, ($length^2$).

S: water surface slope, (%).

R: hydraulic radius, which is equal to cross sectional area divided by wetted perimeter (the distance under water around the cross section).

C: is coefficient for IU units equals 1, and 1.49 for UK units.

And n: manning roughness coefficient, it varies with channel characteristics and range from 0.01 for smooth concrete to 0.2 for natural weedy stream [20].

5. Velocity Area Method

Flow rate is calculated by velocity- area method, where the velocity is the direction and speed of water movement and the area is cross sectional area perpendicular to flow direction. The product of velocity and cross sectional area gives the flow as explained in **eq 2.6**.

$$Q = u_{ave} * A_{ave} \qquad 2.6$$

Where:

Q : Flow, volume per unit time.

And u_{ave} : average velocity of flow, length/ time.

A_{ave} : cross sectional area, length^2.

a. Velocity Measurement: Accurate velocity measurement is critical in velocity area method, and stream velocity vary vertically and laterally **(Figure 2.3**), bottom velocity will be slower due to water friction with rough channel bottom and sides, where higher velocity will be at the center of the channel. Dealing with this variability of stream velocity, USGS studies support several general rules [17]:

- Maximum velocity occurs at 5-25% of stream depth, this percentage increase with increasing depth.
- Mean velocity in a vertical profile is approximated by the velocity at 0.6 depths [16,17].
- Mean velocity in a vertical profile is more accurately represented by the mean of the velocities at 0.2 and 0.8 of the depth.

- The mean velocity in a vertical profile is 80- 90 % of the surface velocity, and the average of several hundred of observations is approximated as 85%.

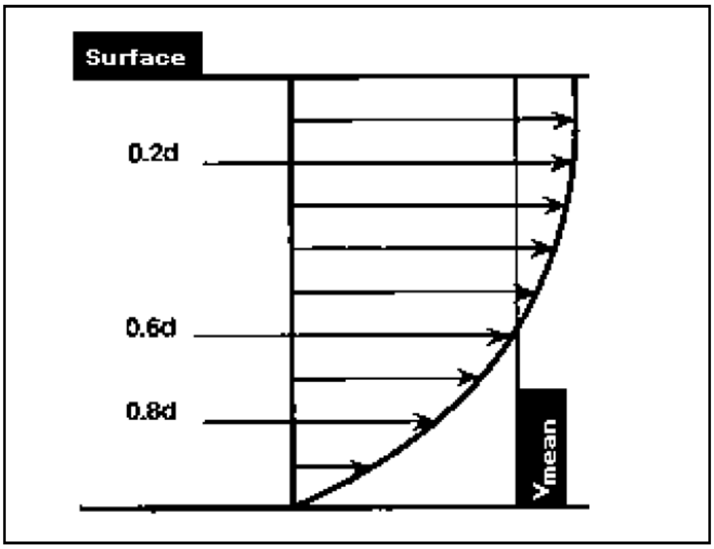


Figure (2.3): Typical River Velocity Profile with Stream Depth Percentage [16]

Many devices and methods are found for velocity measurement, **Table 2.3** summarizes the main devices and methods used for velocity measurements.

b. Cross Section Area Measurement: Cross section calculation generally is done by dividing stream cross section into subareas called subsections or increments and measuring water depth with width for each increment and the product of this cross section with average velocity gives surface flow calculation according to **eq 2.6** [17].

Table (2.3): Velocity Measurement Devices

Measuring Device	Working Principle	Characteristics
Pitot static tube	Applying Bernoulli equation for stream line meets tube tip point with zero velocity [21].	The device gives simple, rapid velocity reading, it is not suitable for dirty water as the tapping may be blocked [21].
Hot wire velocimetry	Heat transfer of heated wire, where the heat transfer is related to the velocity of flow at where the wire is placed [21].	The device may be arranged orthogonally to measure all velocity components, it is used for single point measures and where time variation of velocity of great concerns like turbulent intensities measurements and find most applications at well known structure flow [21].
Current meter	The proportionality of flow or water velocity with meter rotor angular velocity, sound propagation, and electromotive force in fluid for Deflection, Acoustic, and Electromagnetic meters respectively [22,23].	Deflection type are suitable and limited for small streams where damage hazard is minimal, acoustic type used at large rivers, this type is used when continuous velocity record is needed and electromagnetic type used for continuous record of velocity at a single point [22,23].
Float object	Velocity measuring by calculating distance and travel time needed for submerged floating object	This method gives velocity as the product of dividing certain distance by travel time for float object, the velocity measured by this method is the surface velocity of stream flow. At least the distance has to be empty and large enough to start and stop stopwatch to measure the travel time [23].

2.4.3 Kinetic Rates and Parameters

BOD data are important for waste water treatment processes (WWT), and also for natural water quality studies and applications [24], representing BOD curve will be by mathematical model of 1^{st} order reaction [25,26] explained in **eq 2.7**, which explains the remaining organic matter concentration with time:

$$L = L_o\,(1 - e^{-k_d t}) \qquad 2.7$$

BOD data from laboratory will be analyzed, to determine BOD kinetic parameters, in order to study WW characteristics and water quality modeling.

The rate constant of reaction of biologically degraded matters in WW, in addition to CBOD, NBOD and ultimate BOD can be determined from a set of BOD readings (about 20 day readings), by methods of best curve- fitting for kinetic parameters estimation, these methods are [27,25, ,4]:

1- Moment method: The method uses Moor's diagram that shows the relationship between $\sum \mathrm{BOD}/\sum \mathrm{BOD.t}$ vs. k and $\sum \mathrm{BOD}/\mathrm{L_o}$ vs. k [27], and for certain BOD time period and available readings, from Moor's diagram for $\sum \mathrm{BOD}/\sum \mathrm{BOD.t}$ value, k and $\sum \mathrm{BOD}/\mathrm{L_o}$ are determined, and L_o is calculated, where this method became widely used for the calculation of BOD constants [4] .

2- Least square method: It is based on fitting a curve of data points with sum of squares of difference between observed values and the fitted one is minimum [4,27].

3- Iteration method: the results of this method are close to least square method, using iteration method for analysis is done by assuming first BOD reading as BOD_u , and calculating k from that value of BOD_u and BOD reading value from start, and calculating BOD_u from calculated k value and BOD readings from last. Complete the iteration until all BOD reading are finished, and the final calculated values for k and BOD_u are the correct values [27].

4- Daily difference method: The method involved plotting daily BOD difference vs. time, where in this method BOD equation is difficult to be solved for parameters calculation [4].

5- Fujimoto method: An arithmetic plot of BOD_{t+1} vs. BOD_t is plotted and the intersection of the plot with line of slope 1 is approximated as BOD_u [4,27].

6- Thomas graphical method: For many years this was the most used method for kinetic parameters estimation, this slope method used a graphical approximation to evaluate BOD kinetics. Due to long period of application for this equation and it's easy to use [25,27], we used it in the research and its details are shown in the methodology of kinetic parameters determination.

2.5 Previous Studies

Many studies concern with water quality modeling taking into consideration many indicators and quality parameters in order to achieve study objectives. Here are some of related water quality studies in nearby region.

In Edrine study area at the European part of Turkey, at the border of Greece and Bulgaria [28]. Edrine area has four rivers are :Tunca, Merich, Arda and Ergene , fifteen random points or stations for collecting samples have been chosen on yearly basis during 1998-2004, to estimate and determine the water quality in that area especially to meet European water standards as Turkey is an EU candidate at 2015. Quality parameters of DO, BOD, COD, total nitrogen, sulfate, pH and group of heavy metals were estimated in the study. The DO and pH measured at field, and samples were taken to the lab for other parameters analysis, in addition to flow calculations. The results showed the lowest DO level concerns with the high values of BOD and COD, and it was for Ergene river of 3 mg/l DO and 33.146 mg/l, 133 mg/l for BOD and COD respectively.

The sulfate concentration also found to be the highest for Ergene river, and total nitrogen highest values or the peak was for Ergene river too with fluctuation of 3.7 mg/l in1998 and 17 mg/l in 2001, the other three rivers are stable around 2 mg/l. The concentrations of heavy metals of the study area for : total P, Pb, Cu, Cr, Co, Ni, Zn, Fe, Mn were calculated and the values of total P, Pb, Cu, Ni, Mn and Co are found to be relatively high in the rivers of the Thrace region. As water used for agriculture in the area, these metals can transmitted to human and accumulate by food chain, and conclude that there was need for Turkey to limit water pollution of some substances especially that poses risk to human beings [28].

Other study is annual report for ”Monitoring and Research in Lake kinneret “ or lake Tiberia, in 2004 [29], which located in the north of Jordan River at the confluence with Yarmouk River. Monitoring program during three decades aimed to fulfill sustainable water quality maintenance in the lake. The study estimated water level in the lake, meteorological and physical data of air and water surface temperature, solar radiation, humidity, wind speed and annual rainfall, it includes also chemical monitoring of pH, the profile of nitrogen concentration in hourly basic at the 5th of may, 2004, chloride, calcium, Carbon dioxide, organic carbon, dissolved oxygen, total P and soluble P in the lake, conductivity and alkalinity. The study showed the suspended matters concentration vs. particulate P in Jordan river in 2004. Also, it obtained the P concentration in river particles is 1500 mg/l. Phytoplankton populations, Chlorophyll a and primary production, zooplankton with attention to fish biodiversity and counts in the lake were also monitored. Bacterial contamination and pesticides were also estimated in types and amounts. The summary of the annual report for Tiberia Lake study was that winter has fast and intensive effect on the ecosystem of the lake, and at summer the lake was stabilized system with moderate biological activity and undesirable indications of cyanobacteria development at the summer period [29].

Another study for water quality in The Lower Jordan River (LJR), performed by the Friend of The Earth in Middle East (FoEME) in corporation with related parties of LJR [30], concerns with estimation of DO, NO_3^-, NO_2^-, NH4, chloride , total P, and fecal coliform account for water quality. It also concerned with botanical biodiversity. The study estimated macroinvertbrate diversity and the present biota in the sampling places and related them to a reference places of known flora and fauna diversity, to conclude that fresh water flow in the river has to be increased to 400-600 MCM /y according to complementary economic study for FoEME, with yearly flood to protect salinity from raising more than 750 mg/l and achieve habitat plant diversity. The study suggested many scenarios to achieve its objectives and showed each scenario with its economic applicability, advantages and disadvantages [30].

Chapter Three
Methodology

Chapter Three
Methodology

To achieve research objective of modeling stream variations, samples were collected as first step, followed by sample analysis and stream modeling. Methodology of research is shown at **Figure 3.1**.

3.1 Stream Water Sampling

3.1.1 Sampling Location

According to sample collection's recommendation mentioned at section 2.4.2, the segment of Faria stream is divided into five reaches representing confluence points and flow variations along the stream, the segment studied in the research started from stream beginning eastern of Nablus until Ein Shibli, and Sampling points (**Figure 3.2)** were located as follow:

Point 1 (Pt1) near the outfall of eastern Nablus waste water network (WW) to describe upstream conditions.

Point 2 (Pt2) is the next accessible point of the stream before stream WW is mixed with fresh water from spring's discharge at Badan area.

Point 3(Pt3) is located after WW is mixed with the springs' discharge at the same Badan area.

Point 4 (Pt4) is at AL Malaqi Bridge where the confluence of Badan and Faria branches is located.

Point 5 (Pt5) is the last sampling point at Ein Shibli for monitoring quality and quantity of remaining stream flow.

3.1.2 Sampling Frequency

Grab samples were collected from five points described in section 3.1.1, samples were collected at monthly regular intervals of about 18 months for quality and quantity monitoring through the sampling period from December, 2010 to May, 2012.

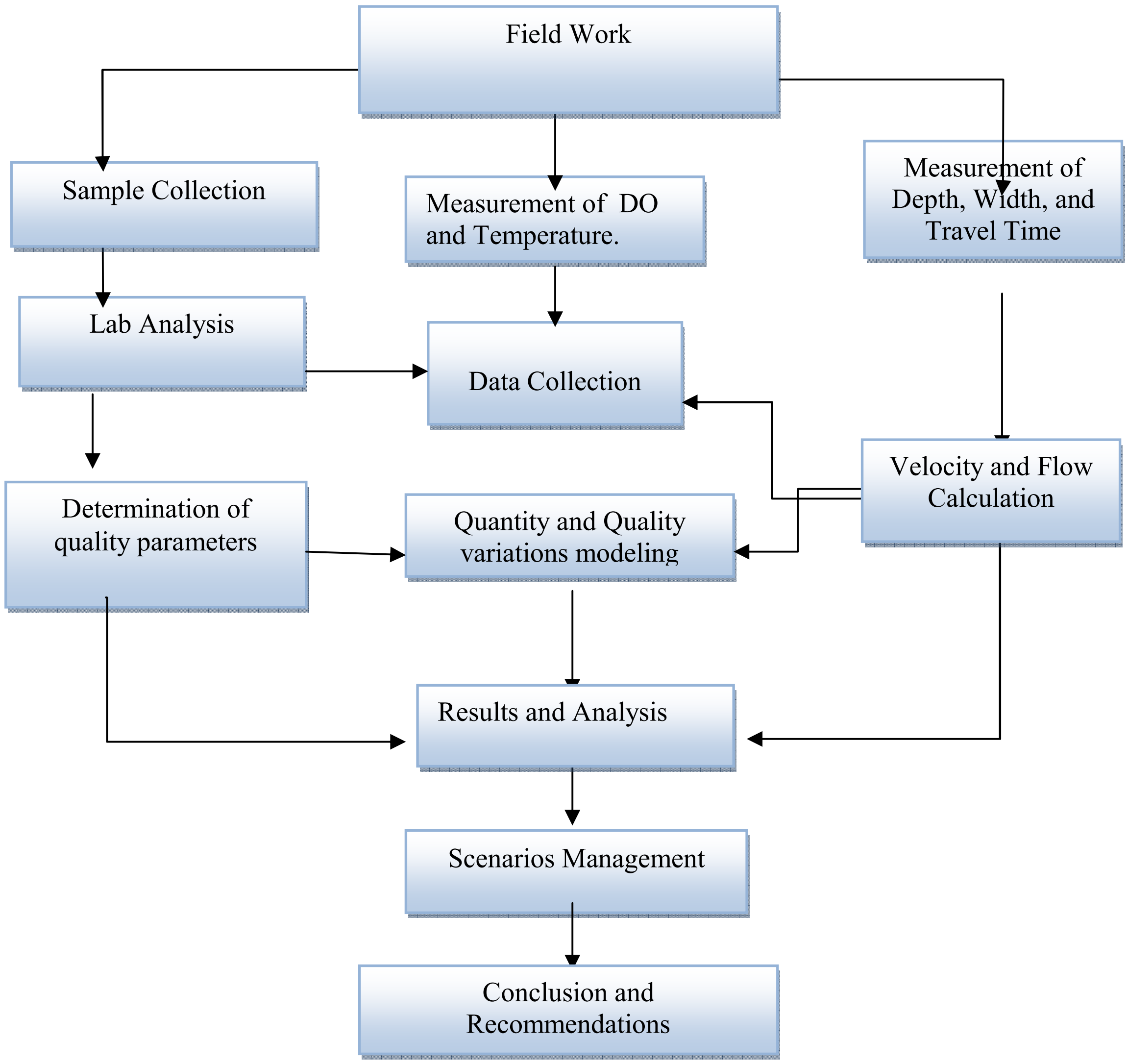


Figure (3.1): Methodology Flow Chart

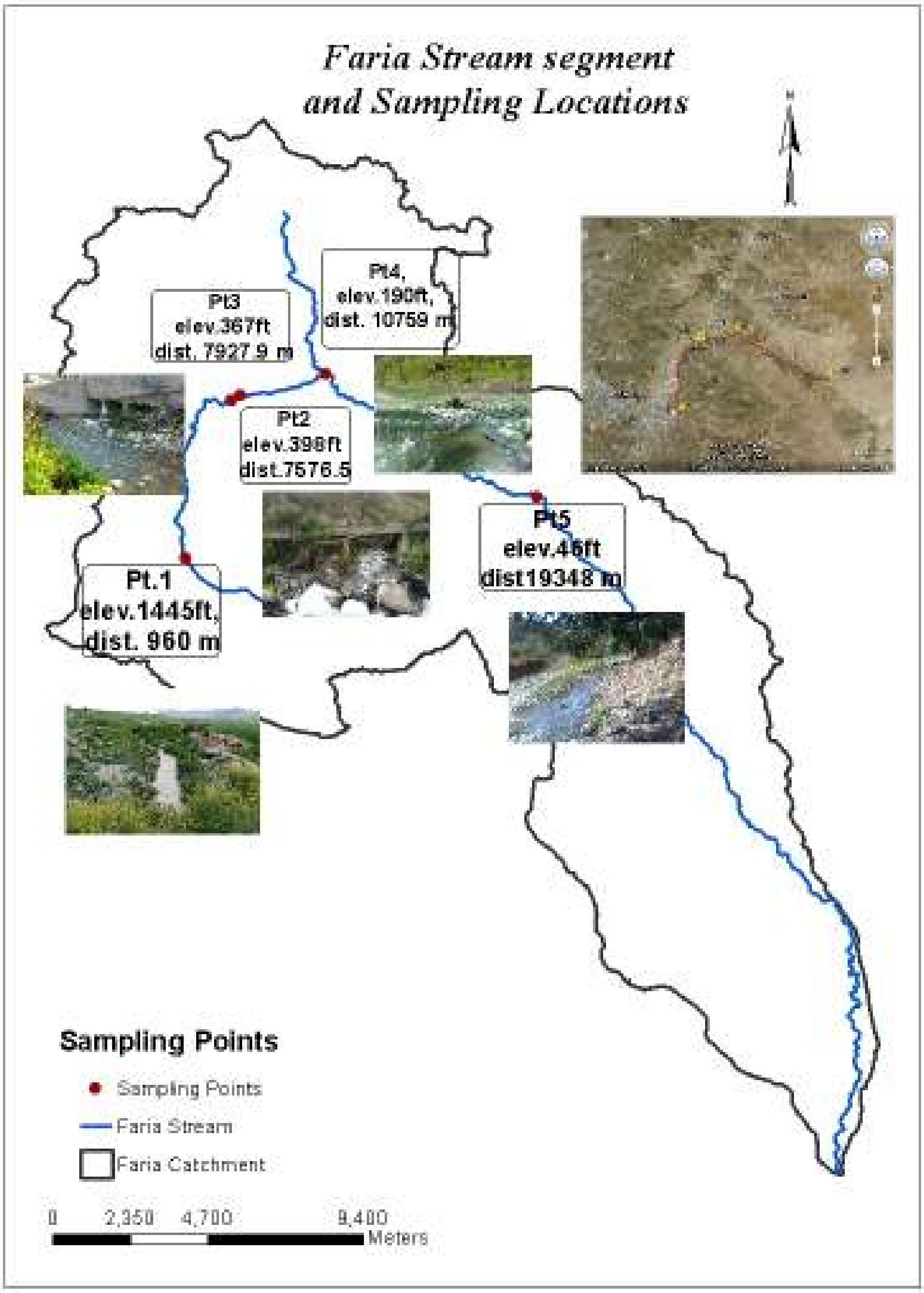


Figure (3.2): Faria Stream and Sampling Points: Location, Distance From Start Point, and Elevation.

3.2 Determination of Waste Water and Stream Characteristics

3.2.1 Flow Calculation

During the sampling events, stream's depth, width, and velocity were measured.

Velocity measurements were done by float object method (section 2.4.2).

Distance and travel time was measured for partially submerged floating object (orange or ice junk) to calculate the surface velocity of stream flow.

The velocity measured is calculated according to the eq.:

$$\text{Velocity} = \frac{\text{Distance}}{\text{Travel Time}} \qquad 3.1$$

According to USGS rules mentioned at section 2.4.2 [17,21], mean velocity equals to 85% of surface velocity is used for average stream velocity.

Faria stream flow is calculated by velocity- area method described at section 2.4.2, the product of velocity and cross sectional area gives the flow.

At Faria stream maximum width was of about 2.5 m, and small depths of less than 0.08m were found, also the apparatus used in flow measurements (tap, handmade measuring rod), it couldn't give width and depth in more details for subsections or increments, and so the depth measured along the cross section and the average depth was calculated, this average depth multiplied by the total stream width according to the equation:

$$A_{ave} = D_{ave} * W \qquad 3.2$$

Where:

A_{ave} : average cross section area, ($length^2$)

D_{ave} : average depth of water (length)

W : width of the stream (length).

And the total stream flow equals to the product of average velocity and average cross section according to **eq. 2.6**. The average flow rate, cross section, and velocity through sampling period were summarized in details in **appendix A**.

3.2.2 Waste Water Quality Parameters

Collected samples were analyzed in the Lab within 3hrs from collection for BOD, COD, where pH TDS, TSS and EC were done within 24 hrs, TKN was done during 7days of sampling date due to laboratory arrangement according to SM 4500 N_{org} A and SM 4500 N_{org} B of TKN analysis .

Test procedure in the laboratory is according to standard method, [31], in specific SM 5210B, SM 5210C for BOD_5 and BOD_u respectively, with incubation period of 20 days for BOD_u calculation.

COD test was performed according to SM 5220B Open Reflux method. Procedures of Standard methods 25 40D, 25 40C for TSS and TDS respectively were followed. Results summary are found in **appendix B.**

(a) **(b)** **(c)**

Figure (3.3): Sampling and Laboratory Analysis: a) Sampling from Faria Stream b) DO Measurements, and c) COD Test Preparation.

3.2.3 Kinetic Rate Constants and Parameters

As said before BOD data are important at waste water treatment processes (WWT), and also for natural water quality studies and applications [24], BOD curve is represented by mathematical model of 1st order reaction [25,26] as explained in **eq 2.7**.

BOD data from laboratory were analyzed, to determine BOD kinetic parameters needed for water quality modeling of the stream according to Thomas graphical method.

Thomas Graphical Method

A series of BOD data was set to use in Thomas graphical method for reaction constant (k_d, k_n) and BOD_u calculation. The method is an approximation method, it is used since many years for kinetic parameters calculation (reaction rate constants of biologically degraded matters in WW, CBOD, NBOD and ultimate BOD) [25,27,4].

It is based on the similarity with the expansion series [25]. The similarity of the term $1 - 10^{-kt}$ in the equation: $L_t = L_o - L_o e^{-kt}$ for organic matter oxidized and oxygen consumption up to time t, with the term: $2.3kt[1+(2.3/6)kt]^{-3}$.

Where it is used for calculating k, L_o as:

$$k_{10} = 2.61 * \frac{B}{A} \quad \ldots\ldots \quad 3.3$$

Where:

B: the slope of $(t/y)^{1/3}$ vs. t curve.

A: the intercept.

And change k_{10} to k_e as: $k_e = 2.302 * k_{10}$ ….. 3.4

The ultimate BOD is given by:

$$L_o = \frac{1}{2.3 * k_{10} * A^3} \quad \ldots\ldots \quad 3.5$$

And BOD_u calculated in the research by using **eq 2.7** with BOD_t value of best fit on the plotting line.

This method used also for nitrogenous BOD calculation and its rate constant, by subtracting first stage readings of BOD (first 7 days) depending on the big difference in BOD reading value due to nitrogenous

BOD effect, and using the remaining data with the same procedure explained above. The results of k, BOD_5, BOD_u, by Thomas graphical method, , and the ratio of BOD_5/ BOD_u were determined and explained in the results.

3.2.4 Sediment Oxygen Demand Measurement

Sediment Oxygen Demand (SOD) includes sediment community respiration and oxygen used for organic matter decomposition [32], SOD calculated to complete DO budget in Faria stream, as SOD can be critical sink of DO and account for half oxygen demand in some water bodies [32], with two methods of SOD measurement, in laboratory, and in situ where standard method hasn't been developed yet for SOD measurement [32], laboratory method is used in this research for SOD measurements.

Scoop was used to take grab sediment samples (2-5 cm thickness) [32,33,34] as shown at **Figure 3.4** , scoops is used for sediment samples of shallow water of less than 120-150 cm (4-5ft) depth [33], also it may have disadvantages of losing fine sediments, it is suitable for investigating recent ambient condition , recent contaminant, and sediment oxygen demand investigation [33], the procedure followed was procedure of small SOD chamber from the second edition of Rates, Constants and Kinetics Formulation in Surface Water Quality Modeling, EPA 1985 [34,35] , and from Sediment Sampling Guide and Methodology of Ohio EPA 2001, for sediment oxygen demand with two main differences [33]:

- Laboratory chamber of open surface simulating stream sites with surface reaeration, and manual stirrer is used.

- To measure DO consumption of water column and abstract that for calculating SOD, water sample replaced by tap water and the readings were SOD directly with no need for abstracting DO of water column. The disturbed samples were left to settle around 30 minutes [33,34], its area and thickness were equally and manually calculated.

Main part of SOD is a result of settling (The sediments), so it is a function of stream flow, and sediments resulting from one or two days following a storm may have negligible influence on DO level of the stream, where it takes about 40 to 50 days to decomposition and influence sediment oxygen demand [33], and so SOD measurements for November/ December of 2012 were used for summer stream simulation in addition to winter simulation due to lack of data.

The equation used for SOD measurement is [33,36,37]:

$$\text{SOD}\ {}^{\text{g}}\!\big/_{\text{m}^2}\big/_{\text{day}} = 1.44 * \left(V * \frac{S}{A}\right) \qquad \ldots.. \qquad 3.6$$

Where:

SOD: Sediment Oxygen Demand, $g/m^2/day$.

1.44: factor for conversion to $g/m^2/day$.

V: volume of sampler, liters.

A: area of sampler, m^2.

And s: slope of used DO vs. time curve .

Figure (3.4): Sediments Sampling at Faria Stream (Badan Area)

3.2.5 Reaeration Rate Constant Estimation

Atmospheric reaeration is the physical absorption of oxygen from atmosphere by flowing stream, which with biological production of oxygen by aquatic plants, it replenishes the stream with dissolved oxygen needed for aquatic community respiration and organic matter decomposition [37,38].

Reaeration rate constant (K_a at SFE) is measured by two main methods [38,39]: Direct measurements by using tracer injection method, and empirical measurement by different mathematical models based on ecosystem oxygen balance, stream characteristics (slope, depth, velocity), and stream turbulent.

Many empirical formulas for reaeration measurement depends on physical stream characteristics changes with stream characteristics , in addition to that these empirical model are more suitable for its circumstances and close conditions of velocity, slope or flow [38,39], while energy dissipation model considers renewal and mixing effect in addition to kinetic energy change, it was used here because it is most widely used for open system stream metabolism measurements [38], the reaeration rate was calculated by energy dissipation model of the equation shown below [39,40,41] :

$$K_a = C_{esc} \frac{\Delta h}{t} \quad 3.7$$

Where

K_a: base e reaeration rate constant, time^{-1}(day^{-1}).

Δh: the change of water surface elevation of stream reach, length. (ft or m).

And t: the time of flow in the reach, time (day or hour).

C_{esc}: empirical coefficient (escape coefficient), per length (ft^{-1}, m^{-1}) this empirical coefficient has calculated values of 0.09 /hr and 0.0593 /hr according to the flow in many studies [35,40,41], and it was estimated in this research according to the equation [41]:

$$\frac{D_2}{D_1} = e^{C_{esc}\Delta h} \quad 3.8$$

Where D_2, D_1 : the oxygen deficit at downstream and upstream of the reach respectively, through this relation the escape coefficient was calculated for reaches 2 to 4 of summer, and in continuous flow from reach 2 to 5, and this escape coefficient was used for K_a determination.

3.3 Data Analysis

Assessment of quality variations for Faria stream were shown and described by using Excel for parameters of: TDS, TSS, EC, pH, TKN due to lack of detailed data for modeling, in addition to flow and DO variations modeling.

Studies of modeling quality parameters are done by using different models, to choose a model, it is important that the model has good credibility, and acceptable in developing applications and design protocols. Operational models that have an available user manual and documentation, and have been used by persons other than the developer have continuous support for use [9]. Models used in water quality studying are different, some for agricultural watersheds modeling (AGNPS and CREAMS), and models for general applications like BASINS model that used QUAL2E model as part of its integrated files package with the model [9] , in addition to models used for urban drainage system (SWMM model) [9]. In stream modeling studies there is variety of models used for stream modeling (SIMCAT, TOMCAT, QUASAR, MIKE-II, ISIS, WASP models)[42], and QUAL2E model with its new versions (Q2K, Q2Kw). Model QUAL2Kw (Q2Kw) was used for Faria stream modeling, as the model processes are not simple (as SIMCAT and TOMCAT) [43] and not complex like dynamic ones [9,43] in addition to its wide application range [9].

Q2K model represents a modernized version of broad used model QUAL2E where both are based on Streeter and Phelps equation, and

QUAL2Kw for Chapra and Pelletier1987 is adapted from Q2K. The model Q2Kw is implemented in Microsoft Windows environment, it is programmed in windows macro language visual Basic VBA, and it uses excel as graphical user interface, Q2Kw is one dimensional model (i.e. well mixed channel laterally and vertically), with steady state, non uniform flow, the heat budget, temperature and water quality variables are dynamically simulated on a dial time scale [20]. Point loads and diffused loads are simulated. Q2Kw model has two features distinguished it from other softwares are that hyporheic exchange and sediment pore water quality are simulated, with option of simulating metabolism of heterotrophic bacteria in the hyporheic zone, and a genetic algorithm in the model is used to get optimum kinetic rates value and increase goodness of fit of model to meet predicted data with measured [15].

This model was used for Faria stream modeling mainly to simulate DO profile in the stream, simulation was done for: summer of maximum pollutants represented by maximum BOD reading, winter of minimum flow, and critical conditions may found for the stream of minimum DO and minimum flow along sampling period of different months, in addition to climate change effect with 10% precipitation reduction approximated at the study area was also modeled. DO level with input parameters of $CBOD_f$, NBOD, SOD, reaeration, hyporheic exchange and sediment pore water, nitrate, and organic nitrogen were the model inputs used.

Chapter Four

Results and Discussion

Chapter Four
Results and Discussion

Results of Faria stream assessment and quantity measurements are described with their variations along the stream, in addition to kinetic rates' constants. Stream modeling for three present cases of summer, winter, and critical condition of minimum DO level with minimum flow, in addition to climate change effect are detailed in the following sections.

4.1 Assessment of Stream Quality

4.1.1 Dissolved oxygen and biochemical oxygen demand with flow

To achieve better results of Faria stream quality, primary assessment is needed [44], characteristics and variations of Faria stream quality, coupling stream flow with BOD were described in this chapter. **Table 4.1** shows the average values of field and laboratory results of parameters used in the model, and **Figure 4.1** shows stream flow at sampling points coupling with BOD_5 readings, coupling figures for four points are shown. Point 5 had data for few months of winter only, because stream flow was diverted for agricultural use upstream this point, and due to that coupling flow with BOD was not possible for that point.

The results indicated that there was a decrease in BOD_5 reading with maximum stream flow at sampling points due to runoff, except at Pt1, as the flow is mainly WW with small or no runoff, and increasing flow didn't mean there is a dilution to get low BOD values, and maximum BOD’s was for one of the highest measured flow at summer season. Flow variation between seasons was clear at sampling points and less flow variation between seasons (small standard deviations) was found at Pt1 near the exit of WW network. The velocity variation along the stream had range of 0.3-0.5 m/s. These results were used to decide modeling cases for summer, winter, and the critical conditions that may be found at the stream.

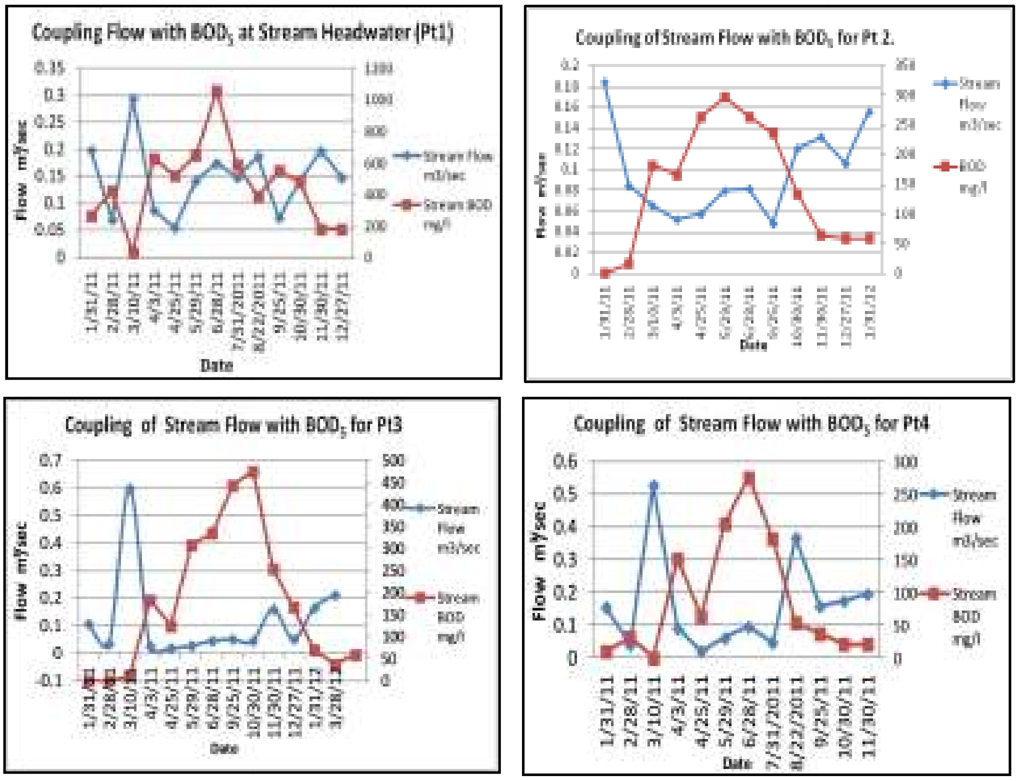


Figure (4.1): Coupling Stream Flow or Quantity with BOD_5 at Sampling Points

Table (4.1): Average Field and Laboratory Results

Sampling Location	Flow Measurement						BOD_5	
	# of Samples	Velocity m/s	Flow m^3/s	Temp. °C	DO mg/l	COD mg/l	# of Samples	Average BOD_5 mg/l
Pt1	13	0.39 ± 0.060	0.1498 ± 0.066	20.8	0.55± 1.5	1201 ± 772	9	793 ± 258
Pt2	13	0.34 ± 0.121	0.1187 ± 0.043	19.2	5.2 ± 2.08	377.6 ±232	9	282 ± 145
Pt3	13	0.55 ±0.282	0.1185 ± 0.157	19.5	4.8 ± 2.52	206 ±145	9	263± 154
Pt4	12	0.424 ±0.133	0.1599 ± 0.148	19.5	4.85 ± 2.36	275 ±358	8	224± 157
Pt5	7	0.51 ±0.328	0.1657 ± 0.207	18.5	7.13± 1.12	174 ±121	1	264

In **Table 4.1**, average DO in the stream varied from 0 at upstream to 5 mg/l at Pt2, and a decrease was noticed at Pt3 and Pt4 but it was around 4.8 mg/l, and it increased until stream end. The illustration of this DO changes, at upstream DO level is increased due to natural treatment and natural stream aeration, and DO reduction in the downstream might be resulted from the existence of diffused pollution sources in the reaches from Badan area to AL Malaqi Bridge. Spatial stream variation of temperature was not more than 2 degrees. It can be noticed from the standard deviation that high variations were found in COD and BOD_5 at upstream and appreciable decrease in their values was happened along the stream due to oxidation of organic matters by natural treatment in the stream. Instantaneous values of these variables with velocity and flow were used in stream modeling for summer, winter, and critical conditions of minimum DO with minimum stream flow.

4.1.2 Total Kjeldahl Nitrogen, Total Solids, pH and EC

Results of TKN assessment at **Figure 4.2** show that there was a considerable spatial difference in TKN due to natural treatment (i.e hydrolysis and nitrification), with average value of 233 mg/l TKN at upstream and about 160 to 180 mg/l at remaining reaches. An increase also was shown in TKN values at reaches 2-3 and 3-4, which again emphasizes the existence of pollution sources at those reaches. The temporal variations of TKN for the stream are shown in **Figures 4.3**. These Temporal variations were negligible and they had approximately equal values at each sampling points (as it is considered, the stream can be represented as steady state case), except at the date of 28th of February, 2012 TKN had higher values than the average at all Points. This might be the result of heavy rains before and through sampling and its effect on the soil, which caused runoff sediment and erosion that might carry more pollutants to the stream, especially if manure was used as fertilizer at that area, or this was due to the effect of changing sampling team at that date.

Variations of TSS and TDS are shown through **Figures 4.4** to **4.6**,

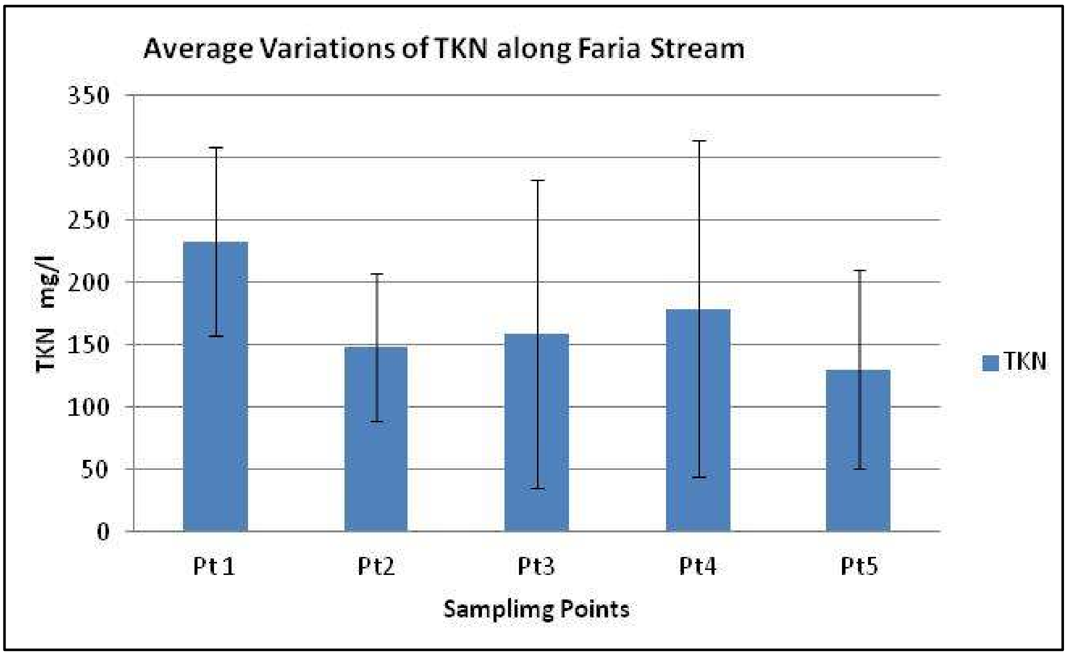


Figure (4.2): Spatial Variations of TKN along Faria Stream.

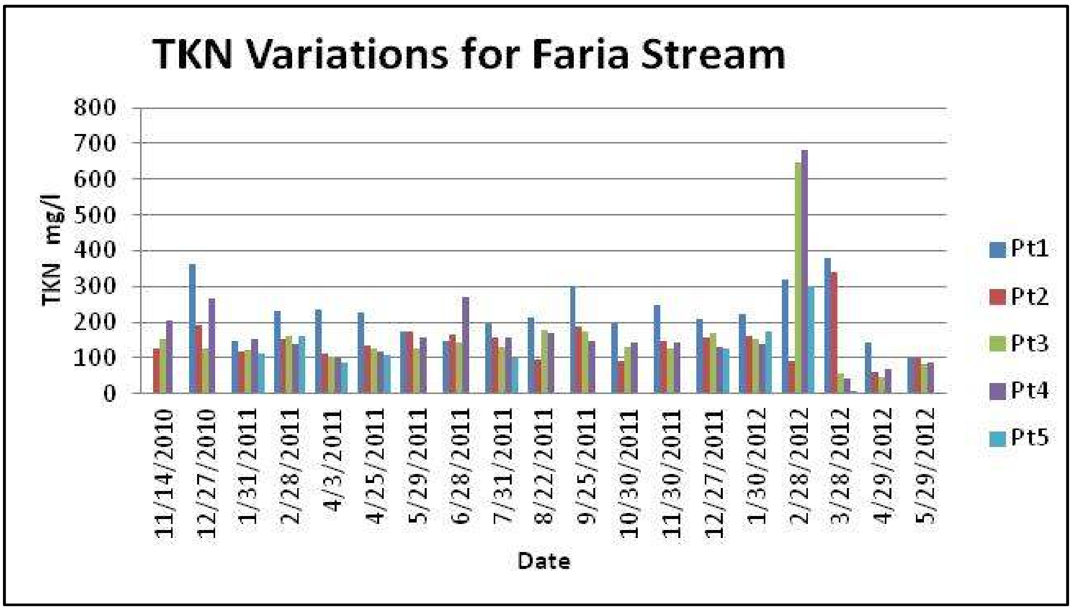


Figure (4.3): TKN Variations along Faria Stream

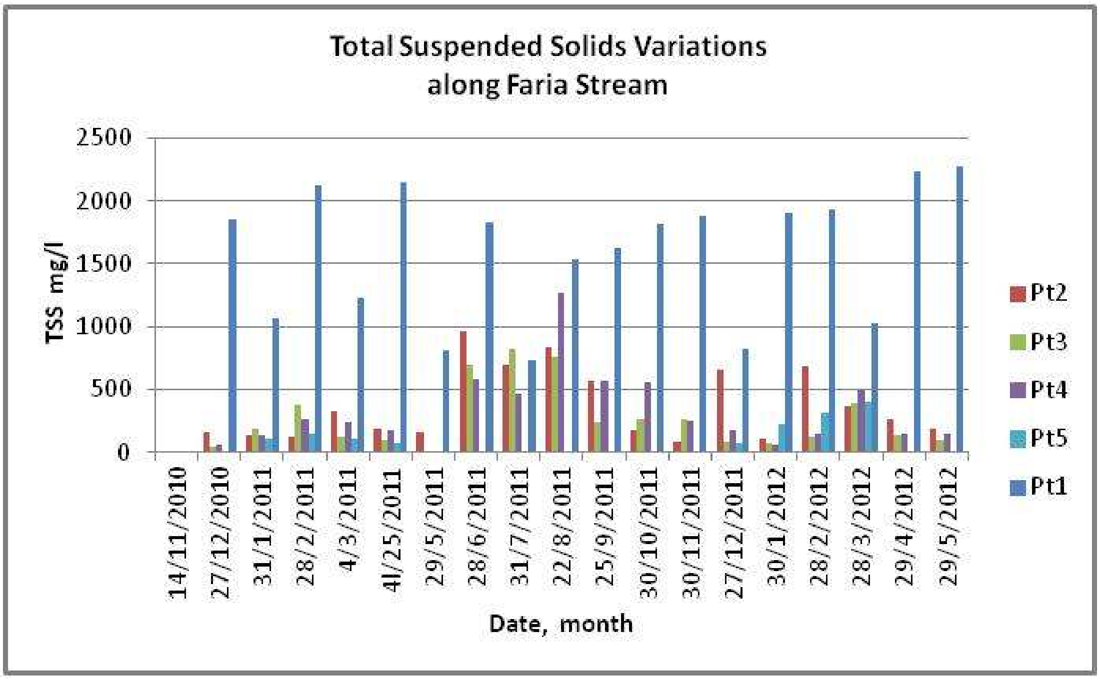


Figure (4.4): Temporal Variations of TSS along Faria Stream

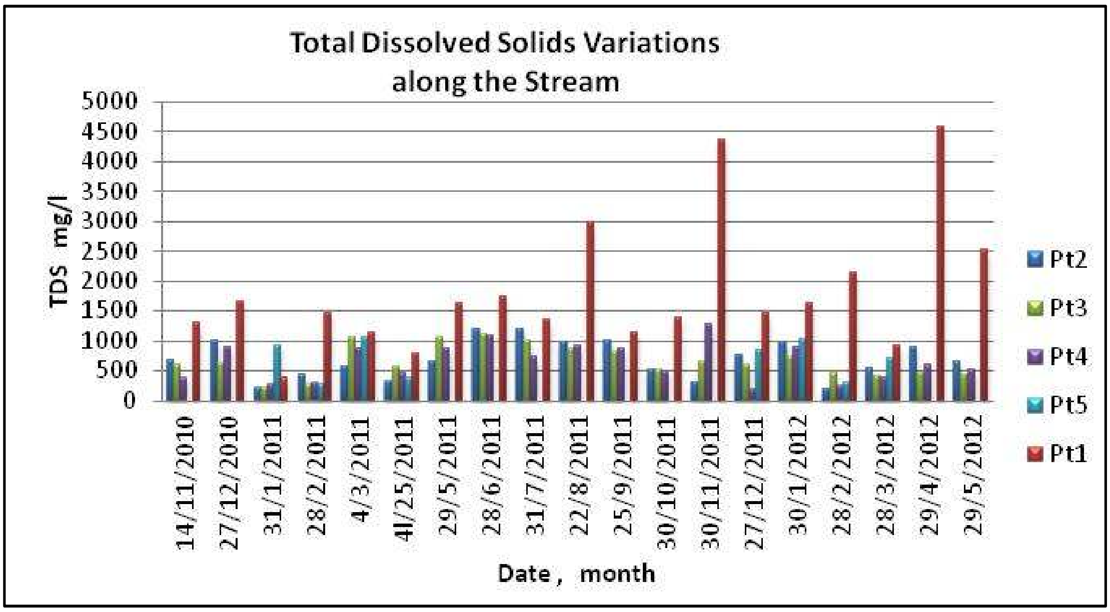


Figure (4.5): Temporal Variations of TDS along Faria Stream

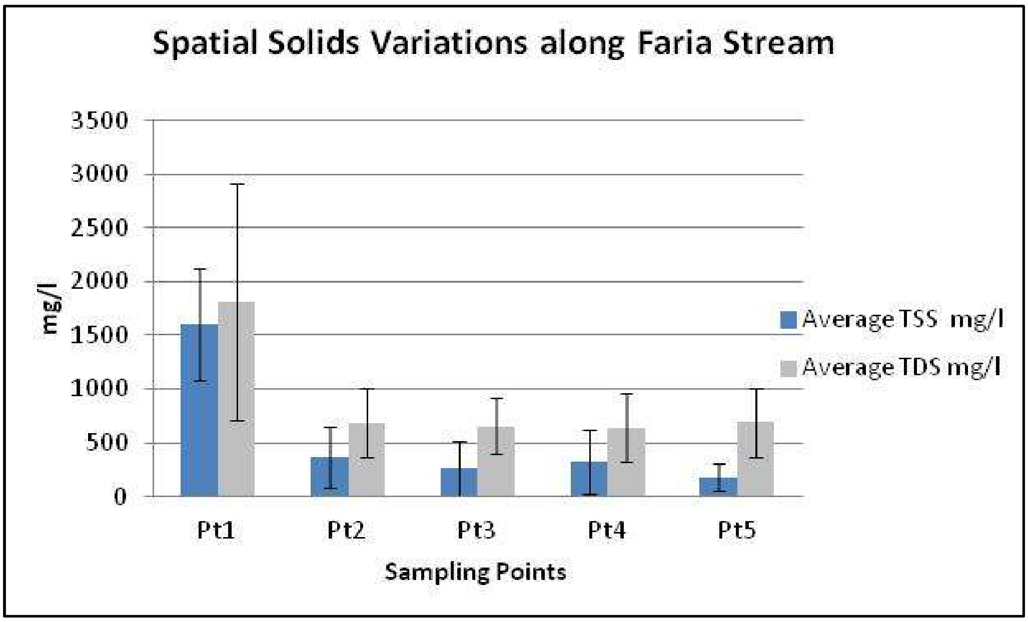


Figure (4.6): Spatial Variations of Solids along Faria Stream

The average TDS for stream varied from about 2000 mg/l at upstream to around 600 mg/l at the downstream. It is clear that five values at upstream were above 2000 mg/l which were: February, April, May of 2012, and November, August of 2011. As a value, TSS is less than TDS as shown in **Figure 4.6**. This is due to WW characteristics, and if considered in treatment, primary settling will remove TSS portion of WW considerably, TSS ranged between 1000 -2000 mg/l at upstream **(Figure 4.4)** with average value of 1603.7 mg/l (**Figure4.6)**, and it varied along the stream to 266 and 180 mg/l at downstream.

Relative to TDS, Electrical Conductivity (EC) was measured and described at **Figure 4.7**, where its average value was 4000 μs at upstream and decreased by natural reactions to 1663, 1297, 1504, 1588 μs at reaches 2 to 3 respectively, after reach 2-3 EC increased from 1297 to 1504 μs. This is consistent with increasing parameters, as said before due to pollution sources that may be found at reaches 2-3 and 3-4 and shown at **Figure 4.10**. Another point to clarify is that drainage area characteristics and land use may be the reason for increasing EC at downstream by their products of pollutants and dissolved solids. There is a mathematical relation between TDS and EC described in Met Calf and Eddy [4], and correlation of straight line for TDS vs. EC at Faria upstream is found to be as shown in **Figure 4.8**, with the equation:

$EC = 2.221\,TDS - 262$ with $r^2 = 0.89$.

multiplier of 2.221 for TDS and subtraction of 262 to get EC.

Finally pH in **Figure 4.9** from upstream to downstream varied between 7.2 to 7.7. In other words WW stream flow was approximately neutral which has to be considered in WW treatment processes.

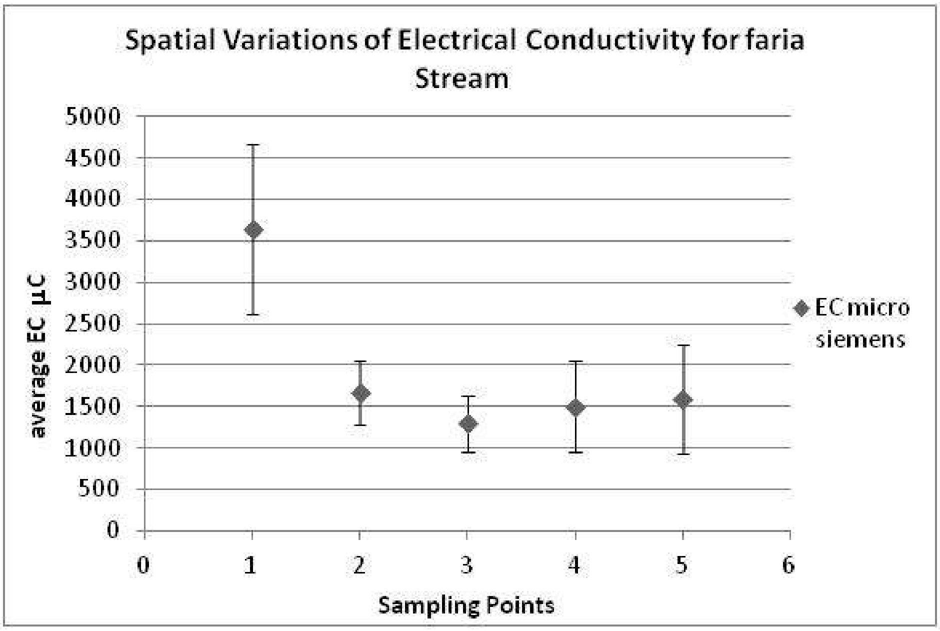


Figure (4.7): EC Variations along Faria Stream

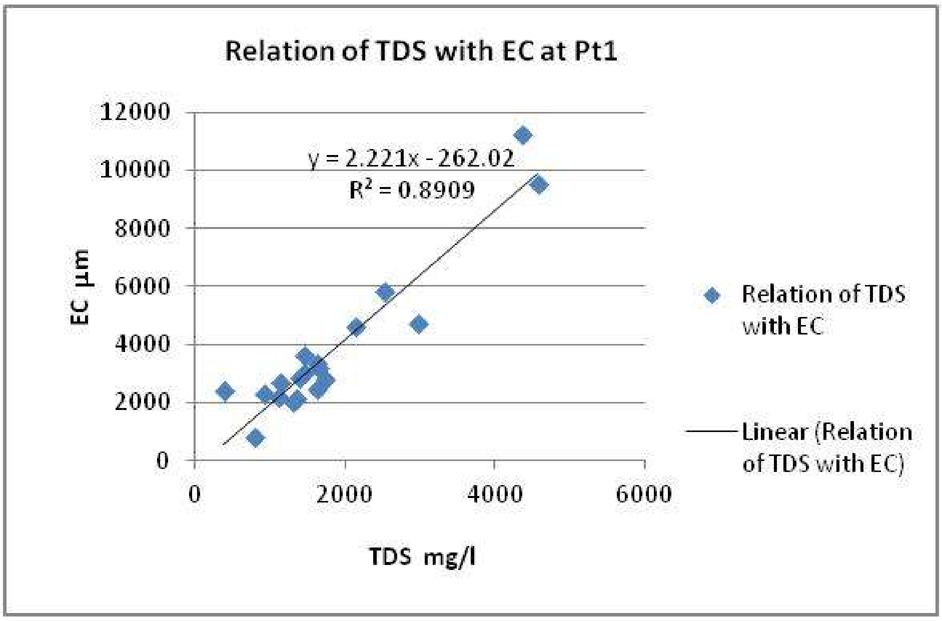


Figure (4.8): Correlation Between TDS and EC for Upstream

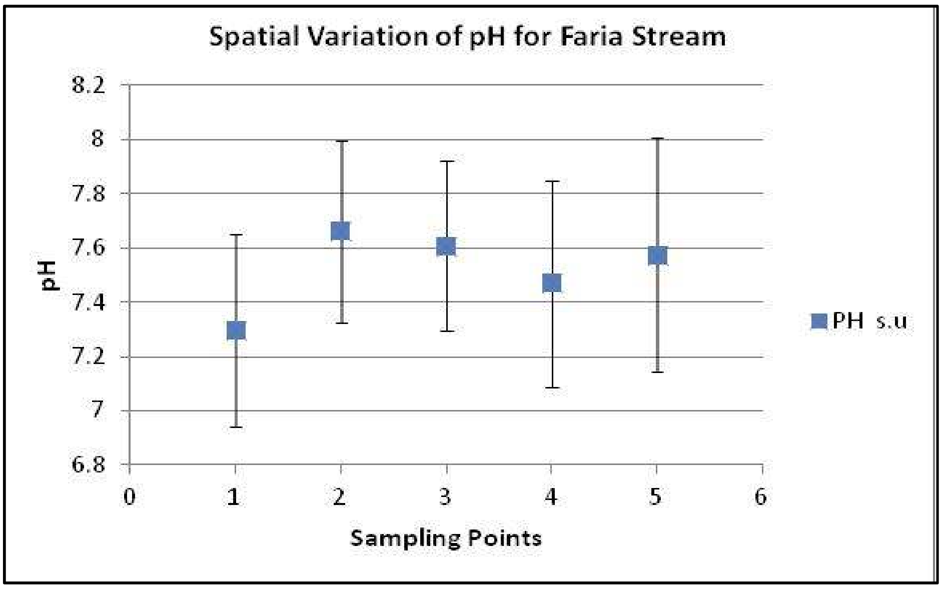


Figure (4.9): pH variations along Faria Stream

The results of Faria stream assessment for quality parameters was summarized at **Figure 4.10**. It can be seen that quality parameters (BOD, COD, TKN, TSS, TDS) decreased considerably at upstream with minor changes or increased at downstream. This change was consistent with DO level changes as shown at **Figure 4.10**, as DO increased until reach 2-3, where it decreased through reaches 2-3 and 3-4.

This emphasis the first result, as said before pollution sources may be found at reaches 2-3 and 3-4 from Badan area to AL Malaqi Bridge.

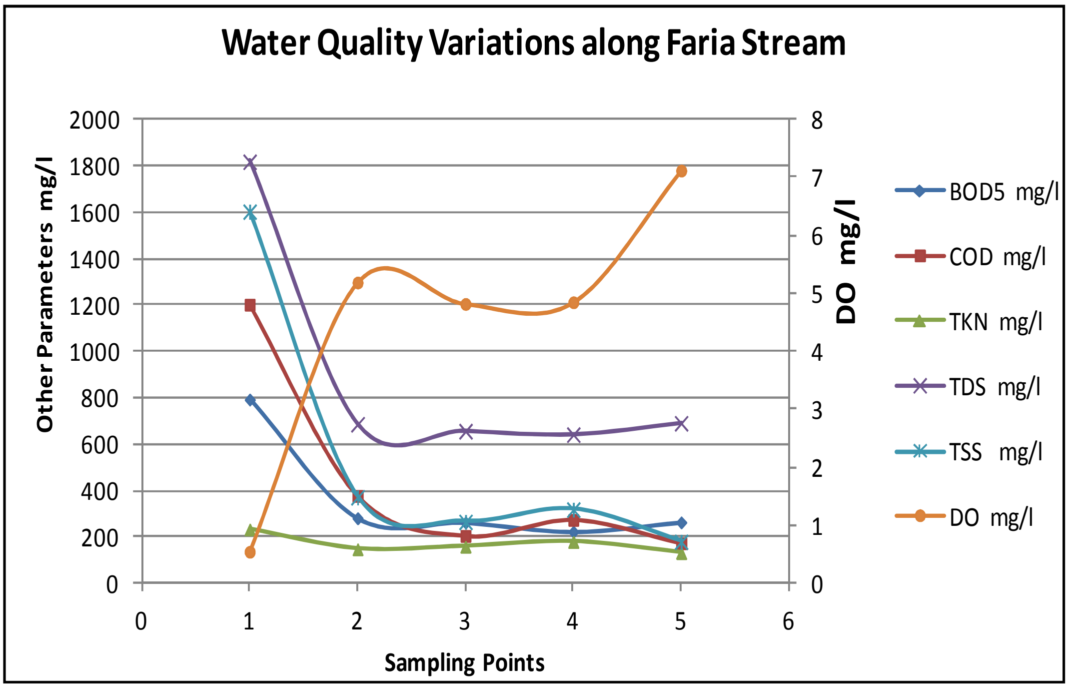


Figure (4.10): Changes of Quality Variables along Faria Stream

4.2 Rate Constants and Parameters Results

4.2.1 Rate Constants of Organic Matters' Oxidation

DO modeling for Faria stream requires to know the main processes and constants of reaction rate that affect DO level in Faria stream. The first process to be considered is oxygen consumption of organic matter oxidation and nitrification. Nitrogenous and carbonaceous rate constants of WW oxidation estimated by Thomas method, also ultimate BOD, CBOD, and NBOD were calculated. Results of rate constants and parameters are summarized in **Table 4.2**. These results showed from an experiment at point 5 that there was no flow during summer and BOD readings were failed , and due to that only one reading was used for analysis.

Results show range of nitrogenous decay rate k_n as 0.12-0.2 /day, and carbonaceous decay rate, k_d range was 0.55 – 0.68 /day which is within raw waste water rate limits (0.3-0.7 /day) [9]. The average of the ultimate BOD for upstream was 1814 mg/l with higher value of 3500 mg/l recorded for November, 2011. There was a considerable difference between upstream and downstream for BOD_u, CBOD, NBOD, and average BOD_5 had been changed from 792 mg/l to 282.2 mg/l from upstream to next sampling point by natural treatment in the stream. Values of average CBOD and NBOD were 1102 mg/l and 650 mg/l at upstream and reached about 383 and 337 mg/l at point 2 respectively. This result emphasis again that main source of pollution in Faria stream is WW from eastern Nablus at upstream and there are other diffused sources of pollution that may be found at reaches 2-3 and 3-4.

After BOD data analysis been done and the results presented in **Table 4.3**, it is clear that these results indicated that BOD_5 is equal to 0.48 of ultimate biodegradable organic matter in stream flow, and the average ratio of BOD_5 to CBOD is 0.899. Details are in **appendix C**.

Table (4.2): Average Kinetic Parameters for Faria Stream Flow

Sampling Points	Items								
	# of Exp.	BOD_5 mg/l	CBOD mg/l	NBOD mg/l	BODu mg/l	# K_d	K_d 1/day	# K_n	K_n 1/day
Pt1	10	792	1102	650	1814	9	0.55	10	0.13
Pt2	9	282	382	337	667	6	0.56	8	0.16
Pt3	9	263	379	198	560	5	0.54	6	0.20
Pt4	9	224	327	235	638	5	0.69	7	0.18
Pt5	1	264	275	224	499	1	0.62	1	0.19

Table (4.3): Ratio of BOD_5 to CBOD and BOD_u for Faria Stream Flow

Item	Sampling Point				
	Pt1	Pt2	Pt3	Pt4	Pt5
BOD_5/BOD_u	0.47153	0.51974	0.63037	0.56605	0.22556
BOD_5/CBOD	0.76480	0.93024	0.93778	0.96595	Failed

4.2.2 Sediment Oxygen Demand Estimations

Simulation results of Faria stream shown by Q2Kw model were compared to SOD ($gO_2/m^2/day$) measured by laboratory experiments.

Results of measured SOD for stream were in **Table 4.4**, calculated depending on lab experiments and data shown in **Figures 4.11-4.14**. Maximum SOD of 0.98 $gO_2/m^2/day$ was found at reach 3-4, and SOD in other reaches was in the range of 0.36 - 0.6 $gO_2/m^2/day$, with zero sediment demand of oxygen at Pt1 at upstream, due to anaerobic conditions prevailed there.

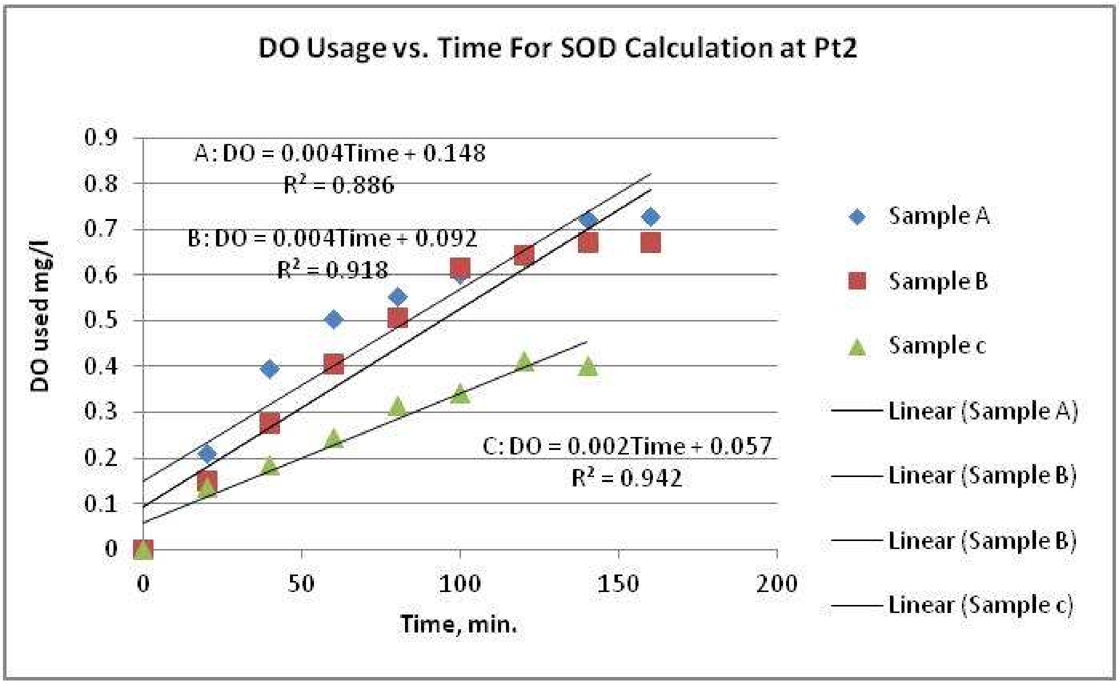


Figure (4.11): DO used vs. Time of SOD Calculation for Badan WW Flow.

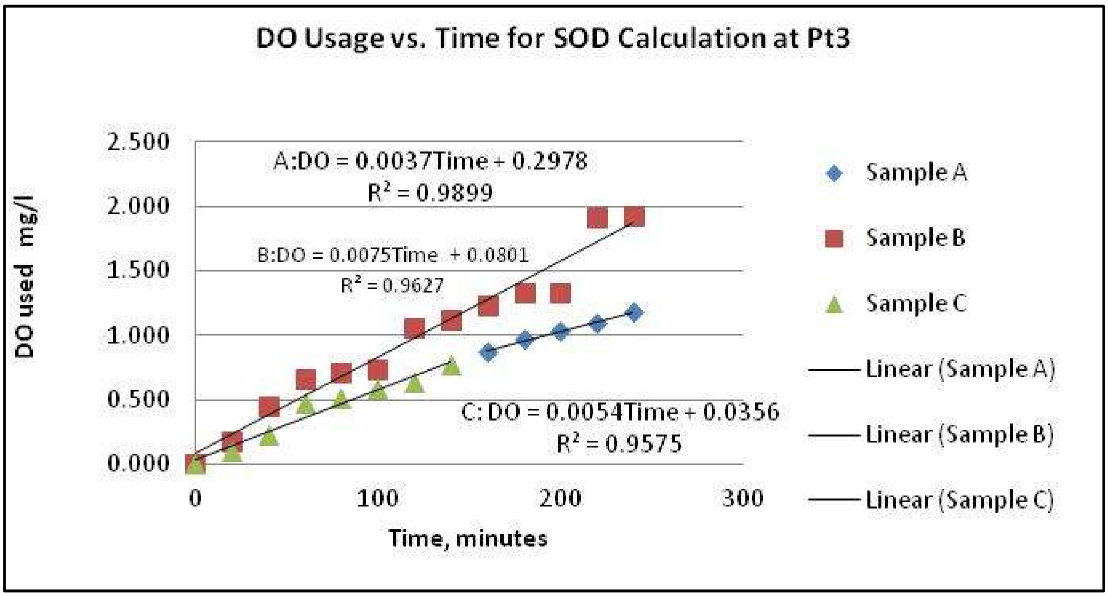


Figure (4.12): DO used vs. Time of SOD Calculation for Badan Mixed Flow .

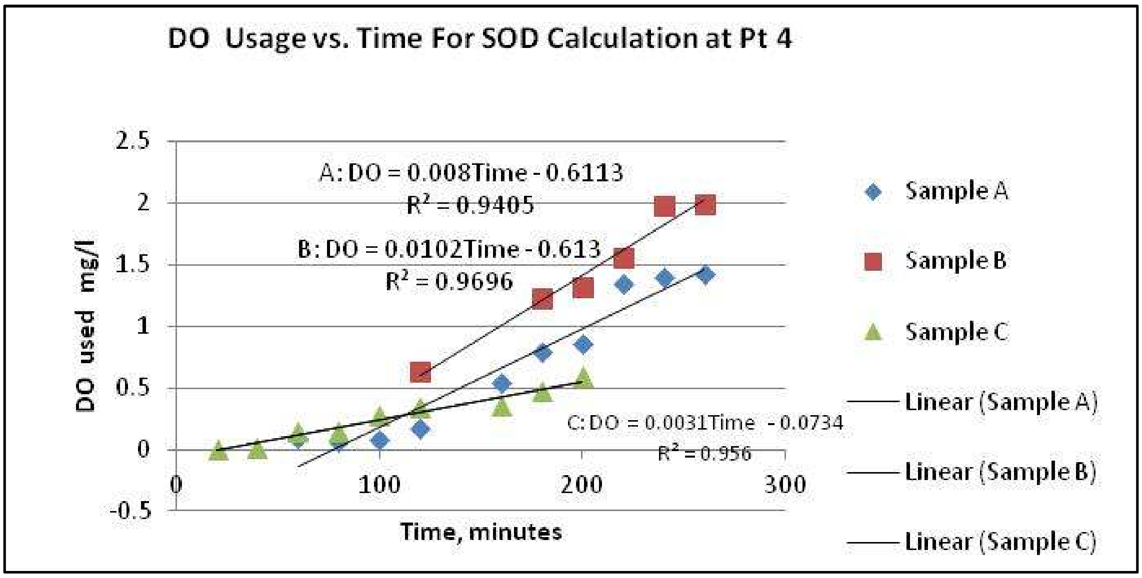


Figure (4.13): DO used vs. Time of SOD Calculation for AL Malaqi Bridge Flow.

Table (4.4): Sediment Oxygen Demand For Faria Stream

Item	Sampling Points				
	Pt1	Pt2	Pt3	Pt4	Pt5
SOD $gO_2/m^2/day$	0	0.4	0.65	0.98	0.36

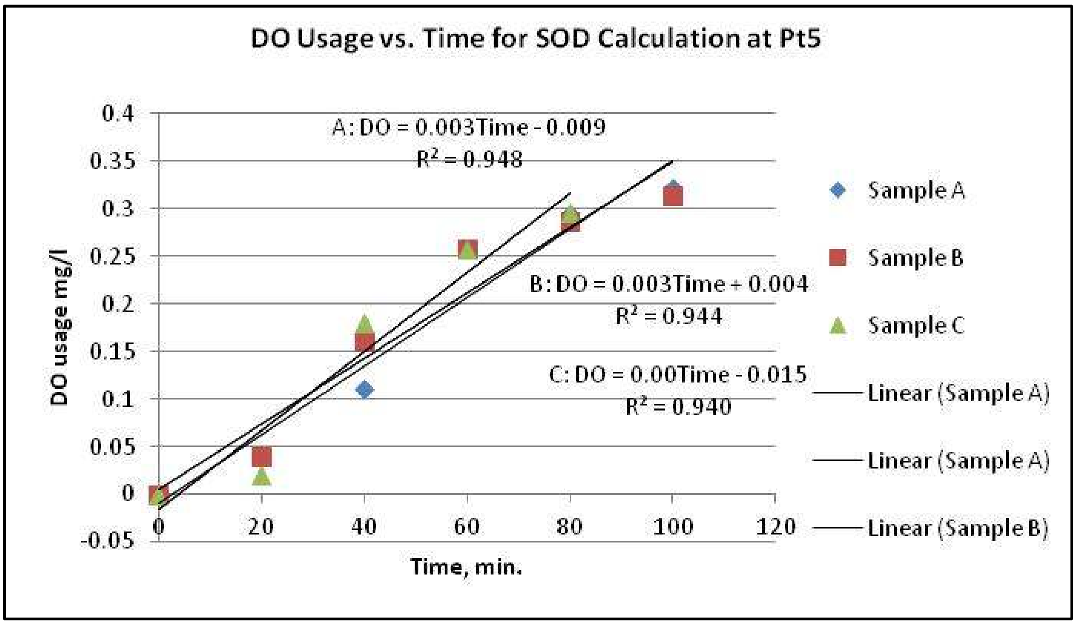


Figure (4.14): DO used vs. Time of SOD Calculation for Ein Shibli Flow.

4.2.3 Reaeration rate constant calculations

The other rate constant determined for modeling is the reaeration rate k_a,using energy dissipation model [39,40,41], keeping in mind that no reaeartion predicting model can give dependable reaeration stream capacity especially at turbulent flow conditions [45], k_a calculated is shown in **Table 4.5,** for three cases of Faria stream : June, 2011 for summer, February, 2011 for winter, and critical condition of low DO at August, with low flow along sampling period of April, 2011. These values were the initial values of stream reaeration, and model calibration was done to achieve optimum modeling results.

Table (4.5): Reaeration Rate For Faria Stream

Item	Sampling Points				
	Pt1	Pt2	Pt3	Pt4	Pt5
8/22/2011					
Δh m	318	3.96	57.04	146.86	
t_f day	0.223	0.011	0.093	0.46	
C 1/m	0.001269	0.004618	0.001345		
Temp. °C	26	24	24	24	
Ka 1/day	1.6	1.5	0.7		
6/28/2011					
Δh m	318	3.96	57.04	146.86	
t_f day	0.175	0.02	0.05	0.253	
C 1/m	0.00168	0.03414	0.00017		
Temp. °C	30	29	29	31	
Ka 1/day	2.7	5.9	1.7		
2/28/2011					
Δh m	318	3.96	57.04	146.86	
t_f day	0.21	0.01	0.099	0.361	0.56
C 1/m	0.00161	0.12662	0.00839	0.00297	
Temp. °C	17.6	14.7	14.6	14.2	16
Ka 1/day	1.9	45.12	4.3	1.1	

4.3 Stream Modeling Results

Modeling Faria stream under current conditions was carried out for three cases, summer with maximum BOD concentration, winter with minimum flow conditions, and third case of predicted critical conditions that may be found at the stream which is minimum DO level and the minimum flow along sampling period [44]. The detailed Results of the three cases are explained in the following sections. Inflow source of springs' discharges at Badan area in the model was estimated by 0.05 m^3/s by measuring flow difference at that point.

The rate constants of the model were based on the above values of deoxygenation (K_d), reaeration rate constant (K_a), sediment oxygen demand

($gO_2/m^2/day$), and CBOD is used in Q2Kw model, with research approximation of 30% of NBOD as organic nitrogen and 70% as ammonia nitrogen.

4.3.1 Summer Condition Case

Summer condition in the research was chosen to have the maximum BOD, which had a flow of 0.174 m^3/s for June, 2011, and there was no stream flow at last sampling point Pt5 in this dry season. The results of simulation were shown in **Figures 4.15-4.20**. Simulated travel time consisted with measured as shown in **Figure 4.15**. **Figure 4.16** shows simulated stream depth and depth variations along the stream, both stream depth and flow decreased from upstream toward the downstream. Simulated depth matched with measured, with little lower simulated depths than measured at reaches 1-2, 2-3, and higher at reach 3-4. There was a difference between simulated and measured velocity as shown in **Figure 4.17**, with higher simulated velocity than measured at reaches 1-3, and simulated became closer to measured at sampling point 4. As it can be clearly seen in the figure measured velocity at Pt 2 was so far from simulated, and if it is neglected there will be a more close velocity trend, but still simulated velocity higher than measured values, as a range, velocity variations along the stream were small as mentioned at section 4.1 and **Table 4.1**.

Modeling flow variations of Faria stream indicates that there was a decreasing flow from upstream towards downstream. Results indicate a match that is found between simulated and measured values as shown at **Figure 4.18** after manual model calibration. Withdrawals estimated of 0.094 m^3/s (8120 m^3/day) at reach 2-3, Badan area, and 0.03 m^3/s (2590 m^3/d) at reach 3-4, from Badan to AL Malaqi Bridge.

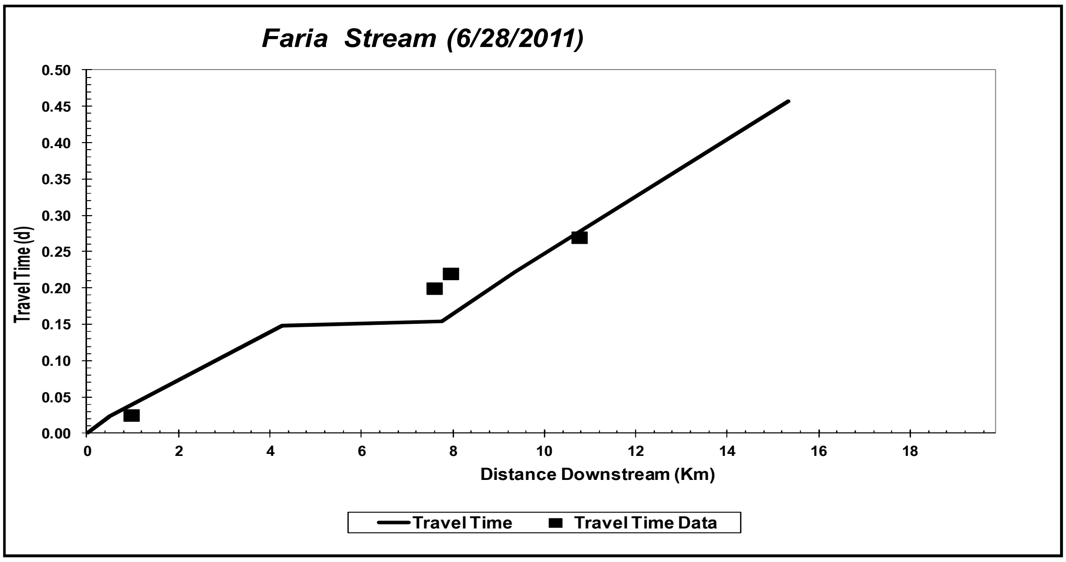


Figure (4.15): Spatial Variations of Travel Time for Faria Stream at June, 2011

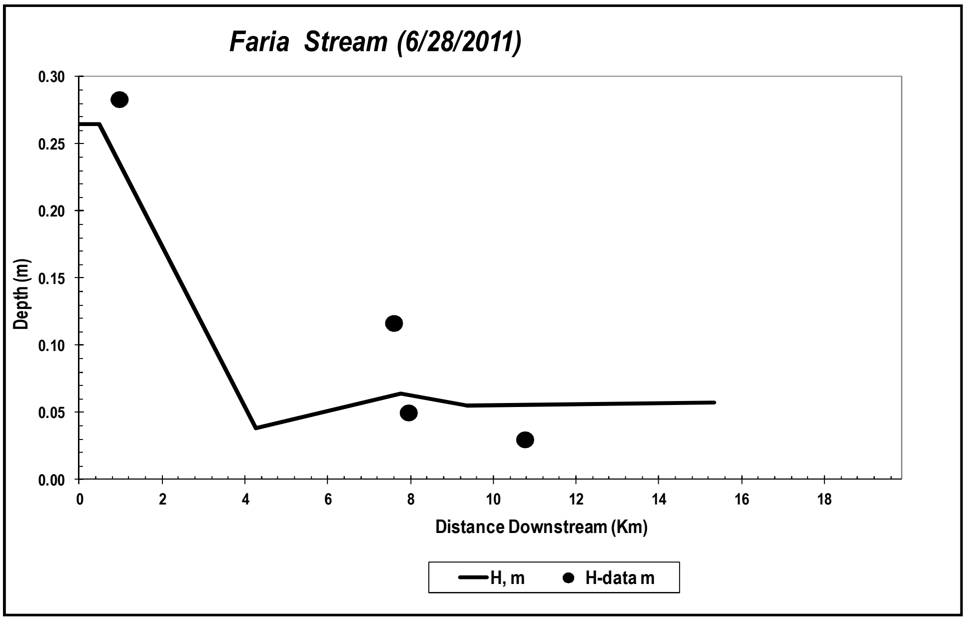


Figure (4.16): Spatial Variations of Stream Depth For June, 2011

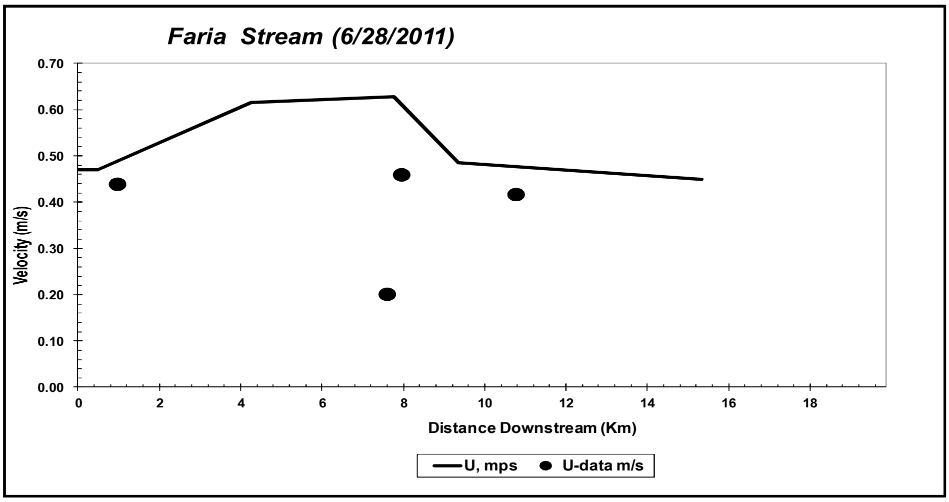


Figure (4.17): Spatial Variations of Velocity for The Stream, June, 2011.

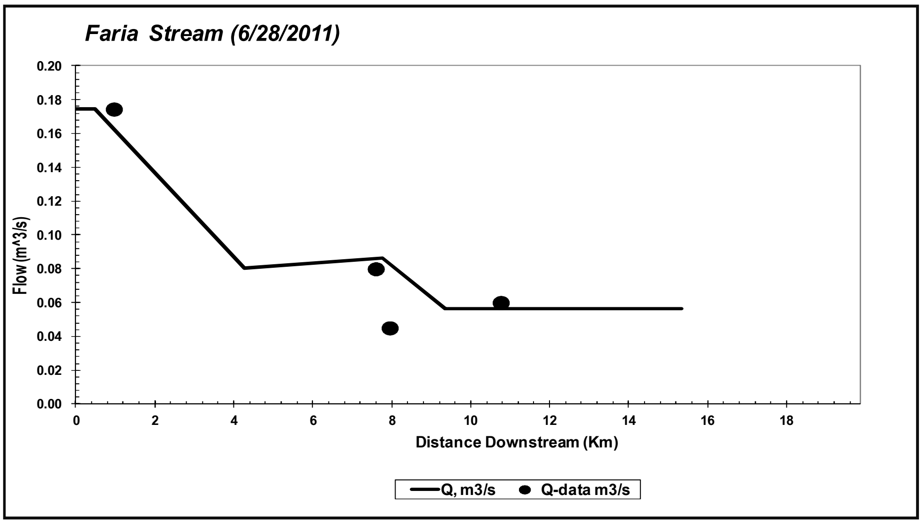


Figure (4.18): Spatial Variations of Stream Flow, June, 2011.

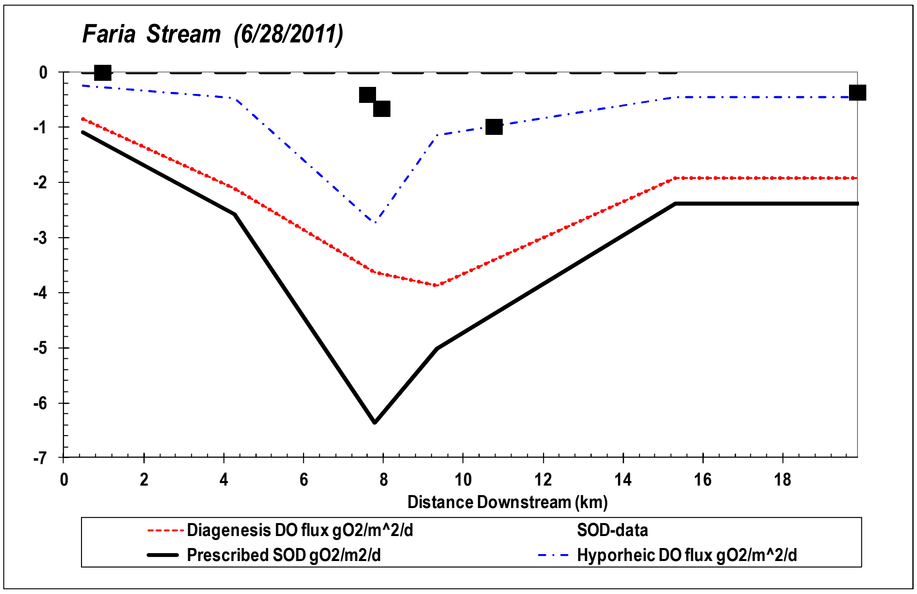


Figure (4.19): Variations of DO used For Sediments along Faria Stream, June, 2011.

The sediment oxygen demand was simulated and results are shown in **Figure 4.19.** Simulated SOD had similar trend to measured, but with shift to upstream for maximum SOD, SOD increased until reach 3-4 and after that it decreased again. The difference in value between simulated and measured is high with simulated maximum value of 6.36 $gO_2/m^2/day$ and maximum measured 0.98 $gO_2/m^2/day$.

The DO profile is shown in **Figure 4.20**, high DO deficit appears with an increase in DO level at reach 1-2, and it decreased again at reaches 2-3 and 3-4. This may be due to pollution sources at those reaches from land use, human activities or sanitation system of communities around the stream. There was also a match between measured and simulated DO level, and the highest difference between simulated DO level and measured was at reach 2-3. This difference in level of simulated DO may be due to default rates' values used in the model instead of laboratory analysis.

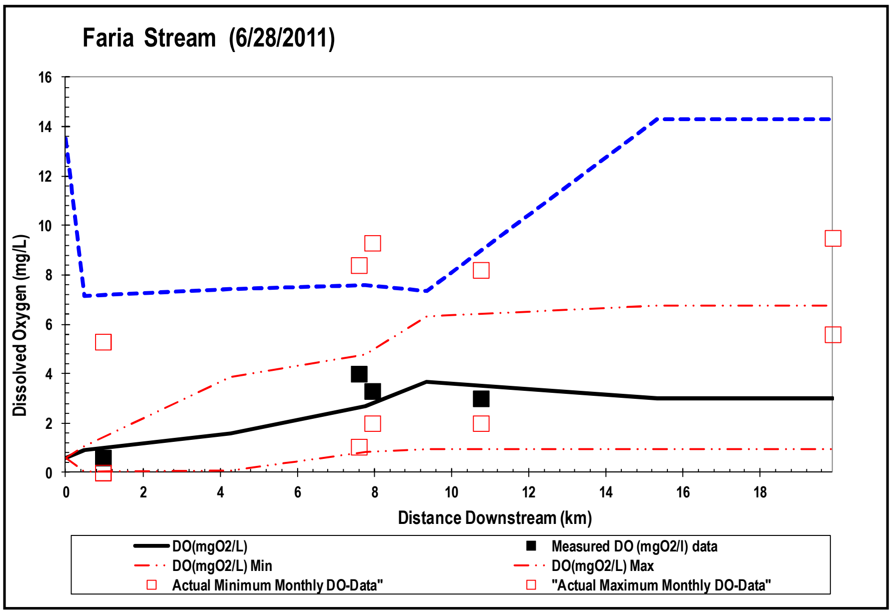


Figure (4.20): Simulated DO Profile Compared with Measured along Faria Stream for June, 2011.

4.3.2 Winter Condition Case

Winter case simulated was for February, 2011, simulation of minimum flow through winter season with value of 0.0698 m^3/s. **Figure 4.21** shows results of simulated travel time with measures. Simulated travel time started to decrease less than the measured value at reach 2-3 until stream end, for stream depth at **Figure 4.22**. The depth varied decreasingly along the stream, where simulated values matched the measured at upstream, and a difference was found at downstream as simulated depth was more than measured. Simulation for stream flow gave good fit with measured at **Figure 4.23** with withdrawals or diversions of 0.039 m^3/s at reach 2-3 and 3-4, and stream flow's change was generally stable, had no considerable decrease except the withdrawals. These withdrawals may be due to agricultural use or seepage to groundwater aquifers as it occurred during wet season. For velocity there was a difference in values between simulated and measured velocity, as the simulated velocity was considerably higher than measured along the stream with the same trend as shown in **Figure 4.24**. Little stream velocity variations along the stream as mentioned were found. A maximum difference also was found between Pt1of 0.37 m/s velocity and Pt4 of 0.29 m/s. The simulated sediment oxygen demand trend matched the measured at **Figure 4.25**, and as the case before there was a change in distance for maximum SOD as the simulated maximum SOD was of 2.96 $gO_2/m^2/day$ at reach 2-3 and maximum actual SOD was at reach 3-4, as shown in **Figure 4.25**, SOD along the stream increased until reach 3-4 and decreased again.

The difference in magnitude between simulated and measured SOD is decreased if NBOD was not applied and **Figure 4.26** shows that results, with simulated maximum SOD value of 1.37 $gO_2/m^2/day$, which is so close to measured value of 0.98 $gO_2/m^2/day$, where diagenesis and hyporheic DO flux were equal to zero.

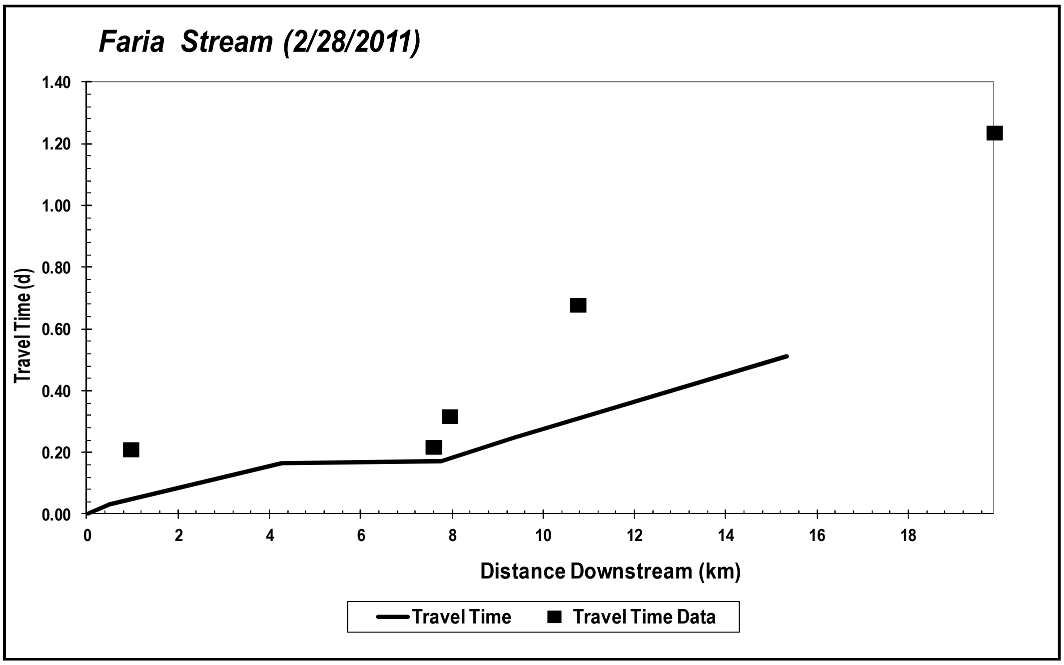


Figure (4.21): Spatial Variation of Travel Time For Faria Stream, February, 2011

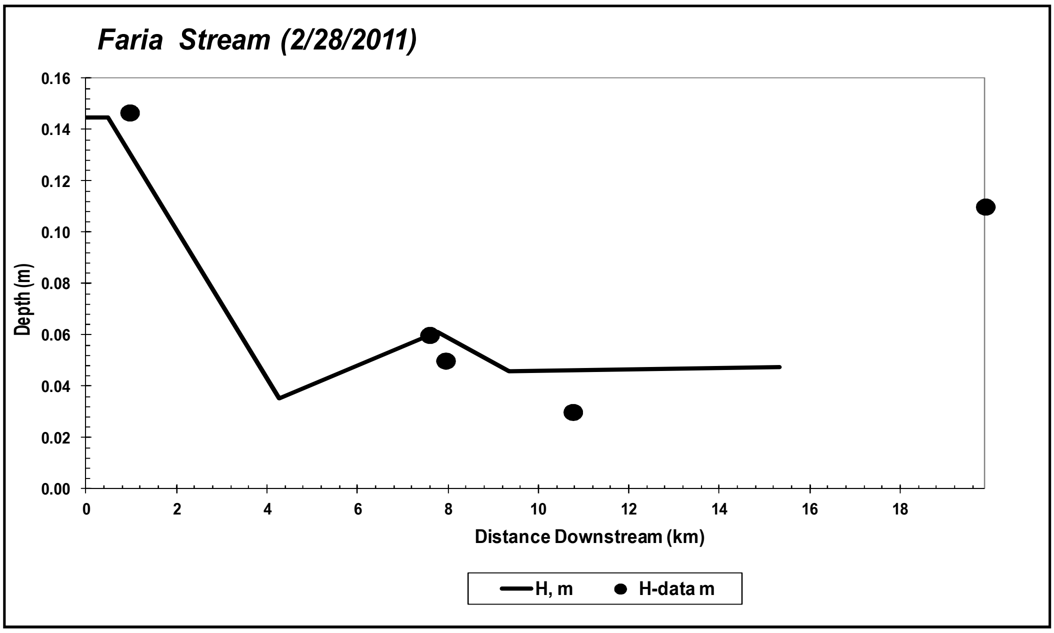


Figure (4.22): Spatial Variation of Stream Depth For February, 2011.

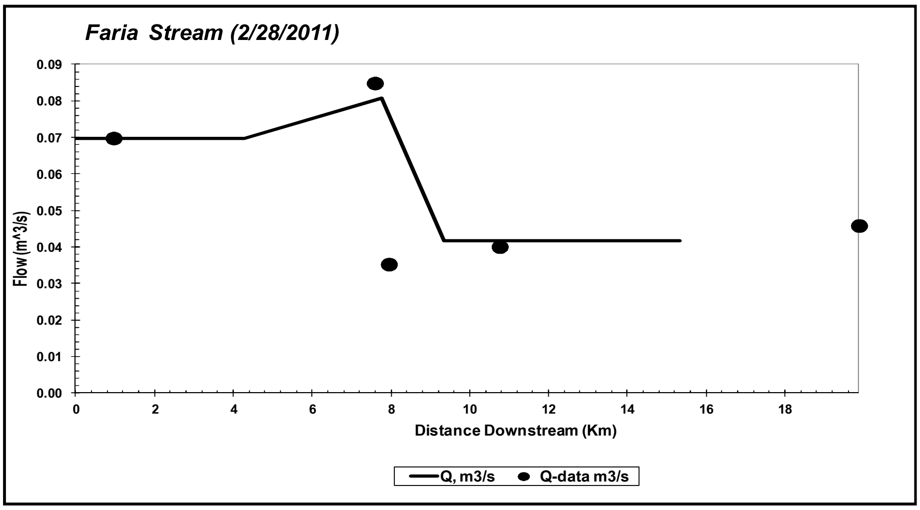


Figure (4.23): Spatial Variations of Stream Flow for February, 2011

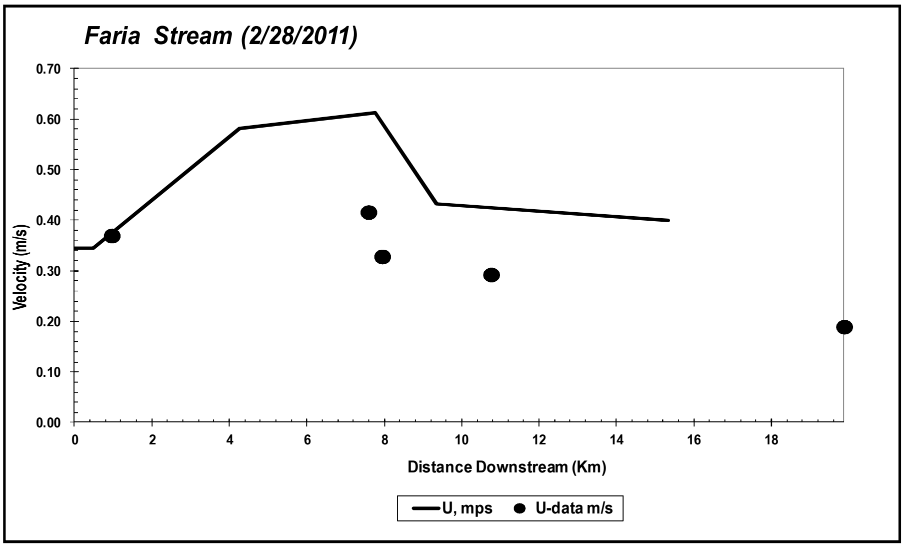


Figure (4.24): Spatial Variations of Velocity For Faria Stream, February, 2011.

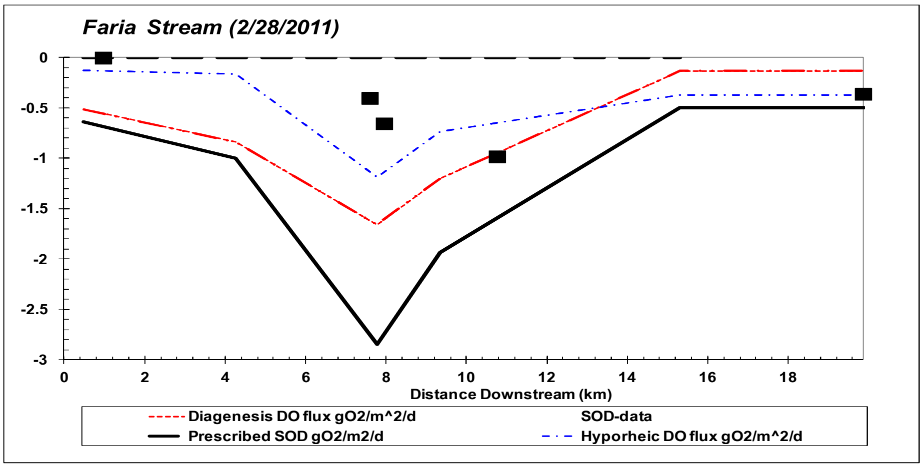


Figure (4.25): Spatial Variation of DO Used For Sediments of The Stream with Nitrogenous BOD Applications, February, 2011

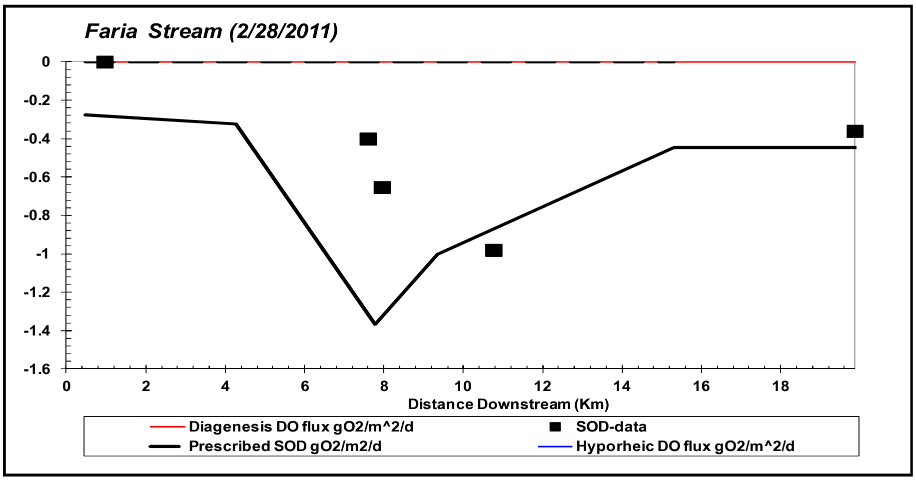


Figure (4.26): DO used For Sediment Demand along Faria Stream Without Nitrogenous BOD Applications, February, 2011.

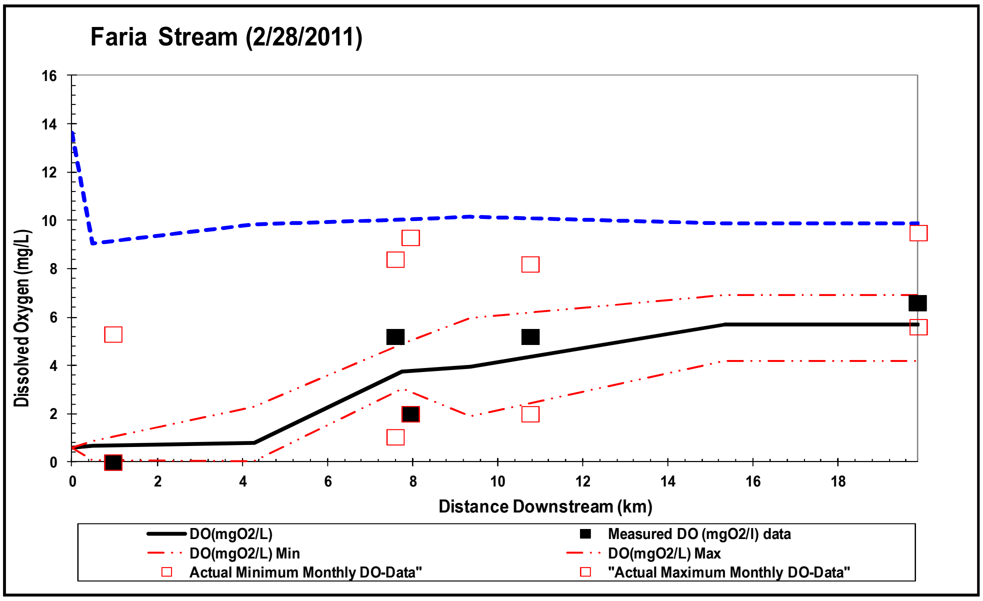


Figure (4.27): Simulated DO Profile Compared with Measured For Faria Stream with Nitrogenous BOD Application, February, 2011.

Figures 4.27, 4.28 show DO sag-curves for winter with NBOD applications and without respectively. There was a match between simulated and measured values. The difference found between measured and simulated values may be due to rates' values used in model calibration like ka for example, as they are still different from the right values in the natural stream. DO increased through reaches 1-3 of the stream, but it was approximately stable at reach 4-5 which emphasis the existence of pollution sources from land use, sanitation systems or human activities at surrounding communities of that reach.

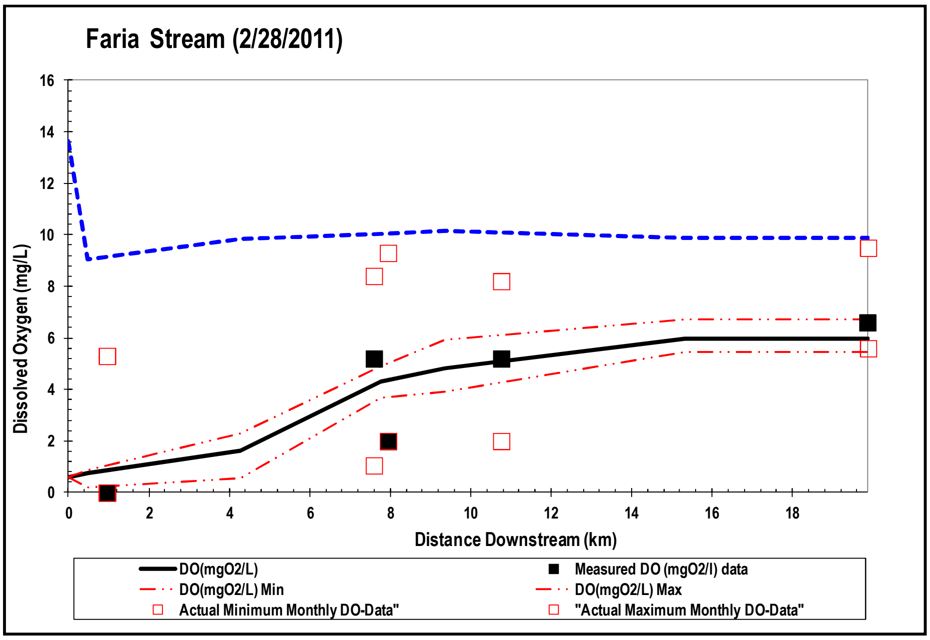


Figure (4.28): Simulated DO Profile Compared with Measured along The Stream without Nitrogenous BOD Applications, February, 2011.

4.3.3 Critical Condition Case

This scenario tries to predict critical case of Faria stream such as low flow and minimum DO, a case that was modeled by taking minimum DO level measured. Results revealed that was on August, 2011, with minimum flow through the sampling period which was on April, 2011of about 0.05525 m^3/s, at this scenario stream had no flow at the last point. This result shows spatial variations of travel time and depth as it was indicated respectively in **Figures 4.29** and **4.30**, where we have both simulated travel time and depth matched the measured along the stream, with decreasing trend of depth. The stream flow result showed withdrawals magnitude of 0.04 m^3/s(3450 m^3/d) at reach 2-3 and 3-4, with this withdrawals simulated flow match measured values as shown in **Figure 4.31** with little less simulated flow than measured at reach 3-4. The flow was approximately stable and had no changes except the withdrawals along the stream. Velocity variations were the same as before and values were equal at Pt1 simulated and measured, an increase in simulated velocity than measured was clear at stream beginning (**Figure 4.32**) but velocity decreased again close to measured velocity at Pt2 and Pt3, and it matched measured at Pt4.

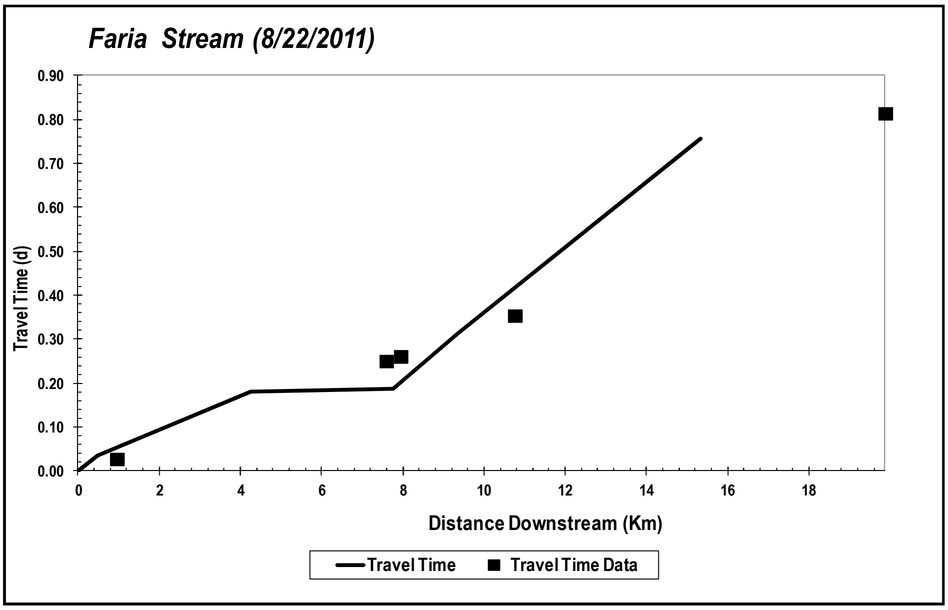


Figure (4.29): Spatial Variations of Faria Stream Travel Time for August, 2011

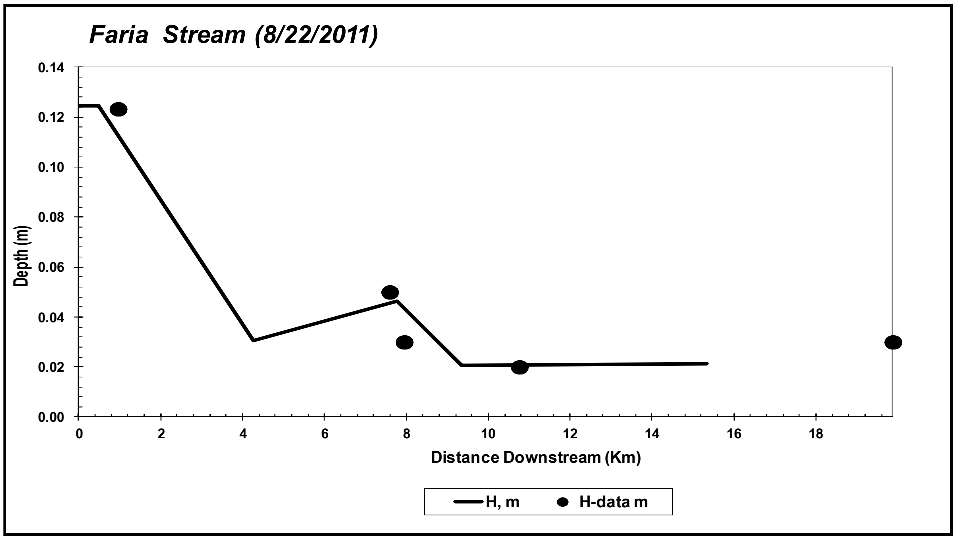


Figure (4.30): Variations of Faria Stream Depth For August, 2011

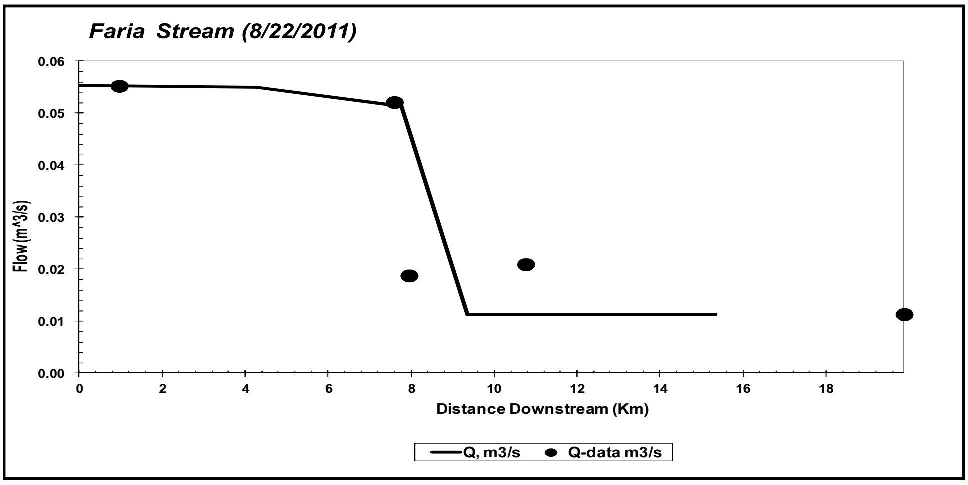


Figure (4.31): Flow Variations along The Stream For August, 2011.

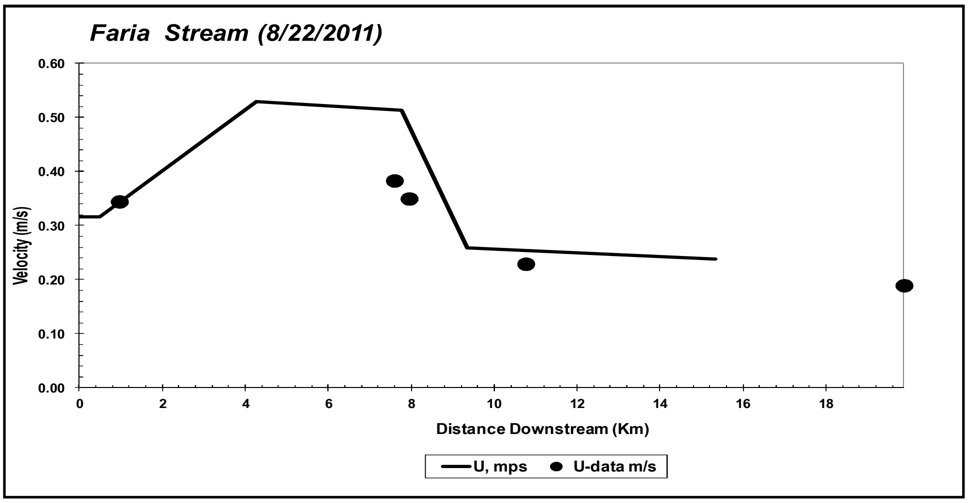


Figure (4.32): Spatial Variations of Faria Stream Velocity For August, 2011

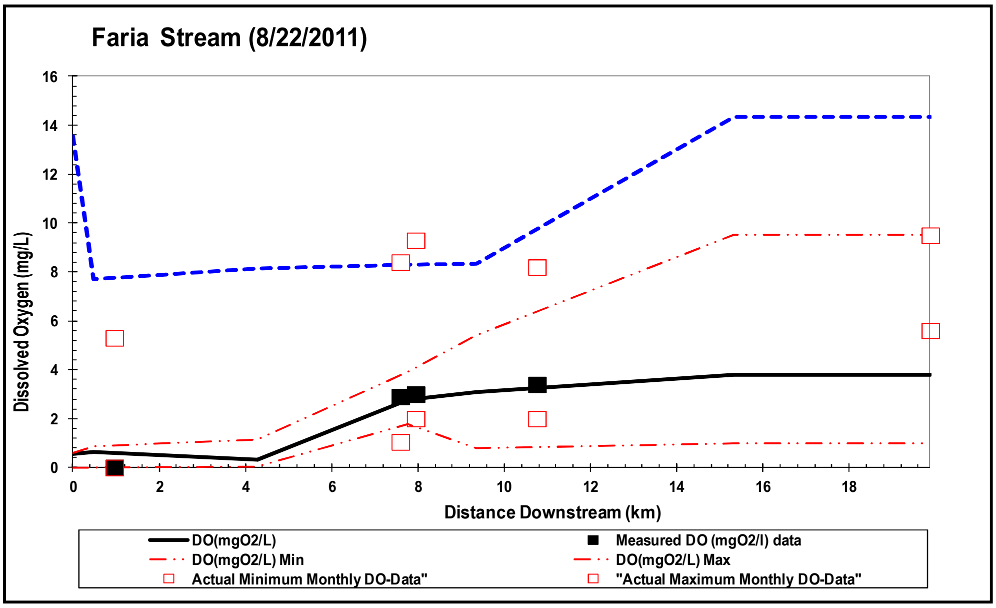


Figure (4.33): Simulated DO Profile Compared with Measured for Faria Stream, August, 2011

DO spatial change was shown at **Figure 4.33,** an increase happened in DO level at reaches 1-3, and after that change in DO level was smaller or it was stable which again emphasizes the existence of pollution sources as explained for summer and winter. The simulated DO level was within the limits of measured DO level except the last point where we did not have flow for it at this critical case, also high oxygen deficit was found at headwater. Simulated SOD of stream showed an increase in SOD until reach 3-4 and it decreased again as shown in **Figure 4.34**. Simulated SOD had the same trend of measured with shift of maximum SOD to upper reach 2-3 with maximum value of 6.22 gO_2/m^2/day which was higher than the measured of 0.98 gO_2/m^2/day.

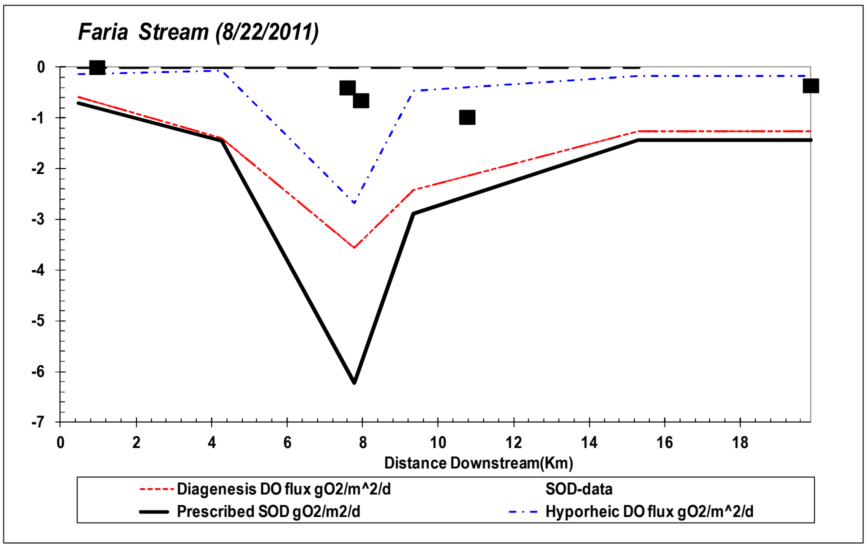


Figure (4.34): DO used for Sediment Demand along Faria Stream For August, 2011

4.3.4 Climate Change Effect Scenario

Faria watershed is located in an arid to semi arid area [1], and if climate change considerations are taken into account, the rainfall and precipitation in the watershed is predicted to decrease to around 10-20%

through the last century as shown in **Figure 4.35** [46]. Therefore if 10% precipitation reduction used in the scenario to predict Climate Change Scenario (SCC), and approximating winter stream flow, this reduction of flow will affect DO level and pollutants concentration in the stream, and so DO profile and SOD were simulated in **Figures 4.36, 4.37** respectively, and the changes for DO and SOD of SCC were negligible as no considerable difference when compared with the present winter case is shown.

Flow changes were shown in **Figures 4.38- 4.41** for flow, depth, velocity and travel time respectively. The flow and depth (**Figures 4.38, 4.39**) were close to the first results without climate change (CC) effect, and simulated velocity was larger than measured values, with close velocity values along the stream as the case without CC (**Figure 4.40**).

Simulated travel time was also less than measured as before CC effect application (**Figure 4.41)**. So depending on the results of SCC, climate change effect of flow reduction is still less than seasonal or monthly stream flow changes effect that have been shown at different seasons modeled.

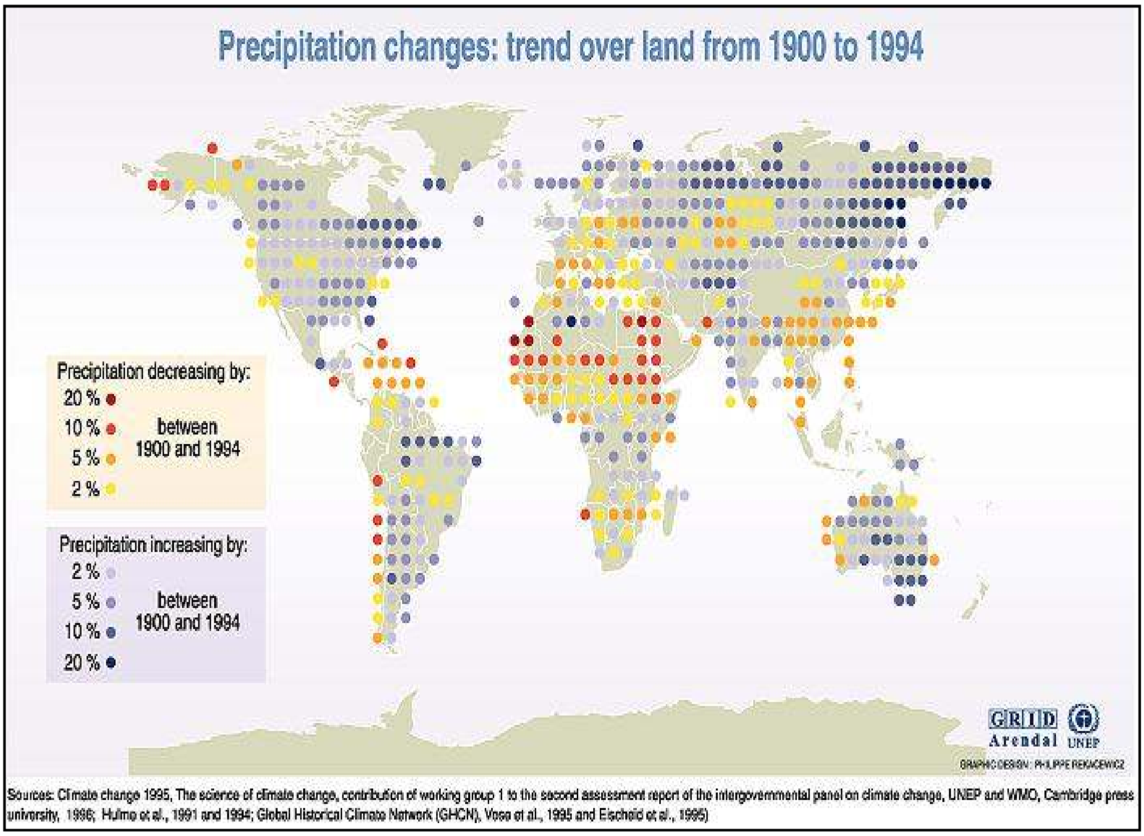


Figure (4.35): Climate Change Effect on Precipitation and Flow Reduction [46].

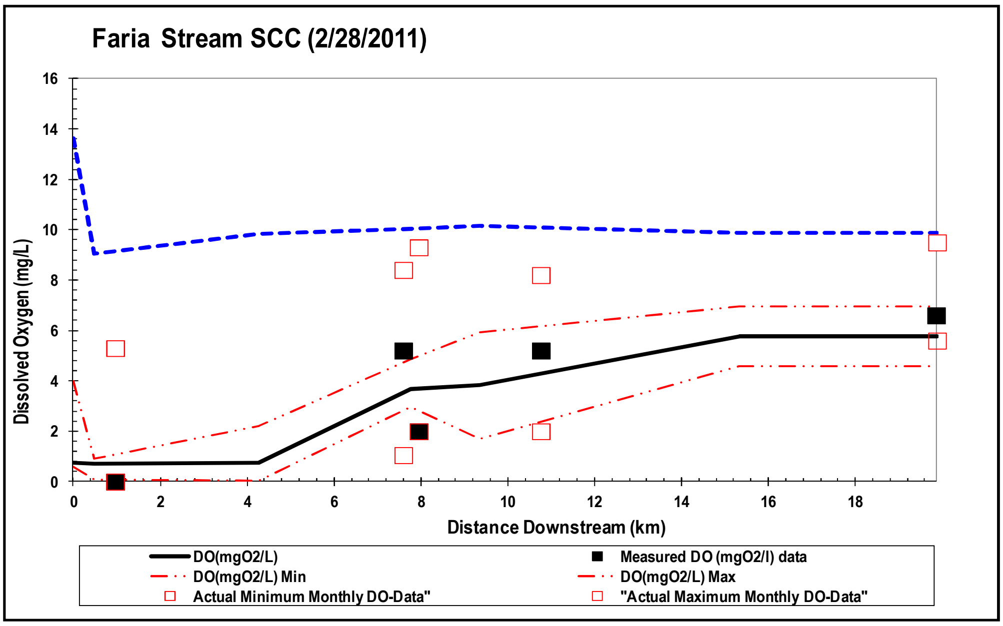


Figure (4.36): Simulated DO Profile Compared with Measured with CC Effect along Faria Stream.

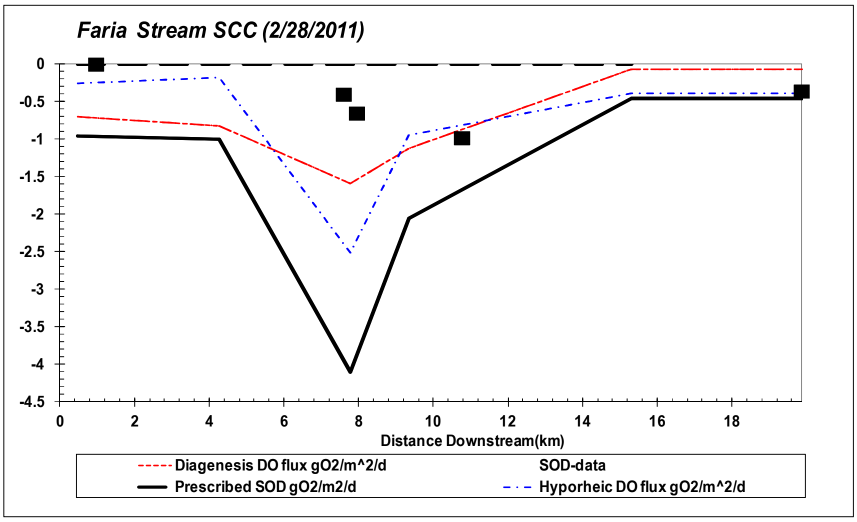


Figure (4.37): DO Used For SOD with CC Effect

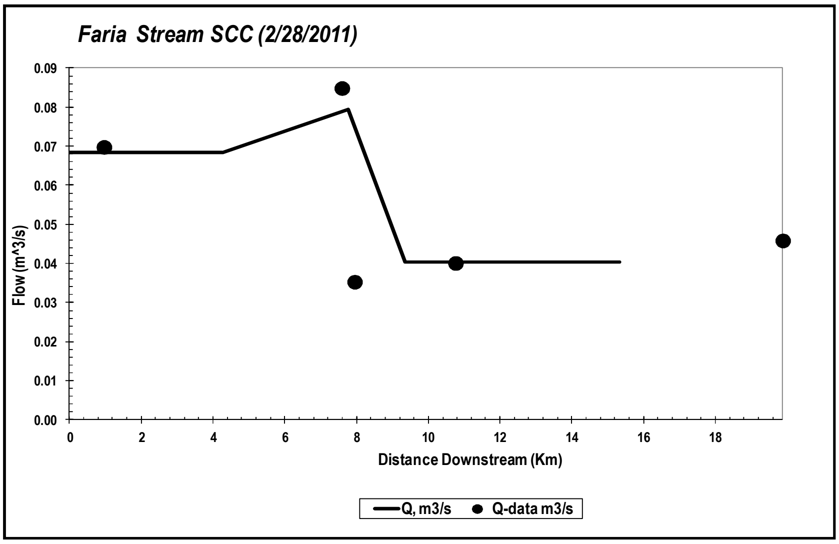


Figure (4.38): Stream Flow Variations with CC Effect.

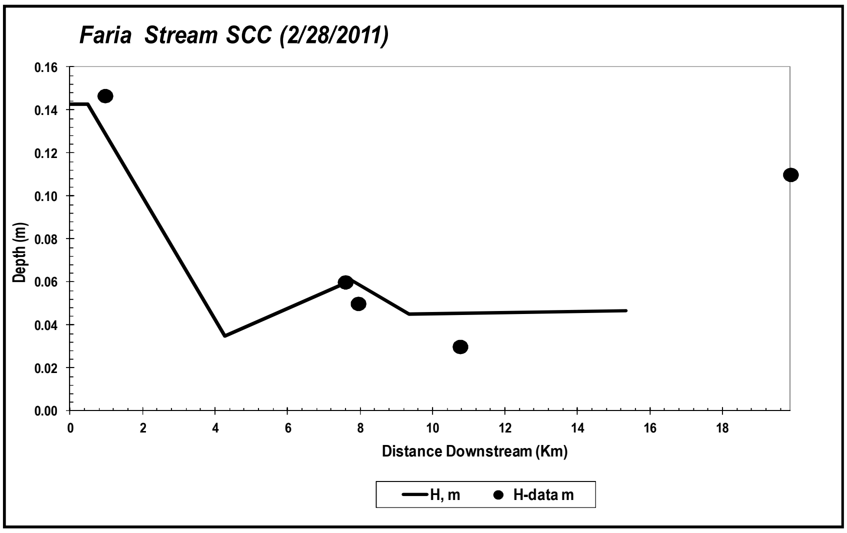


Figure (4.39): Simulated Stream Depth With CC Effect

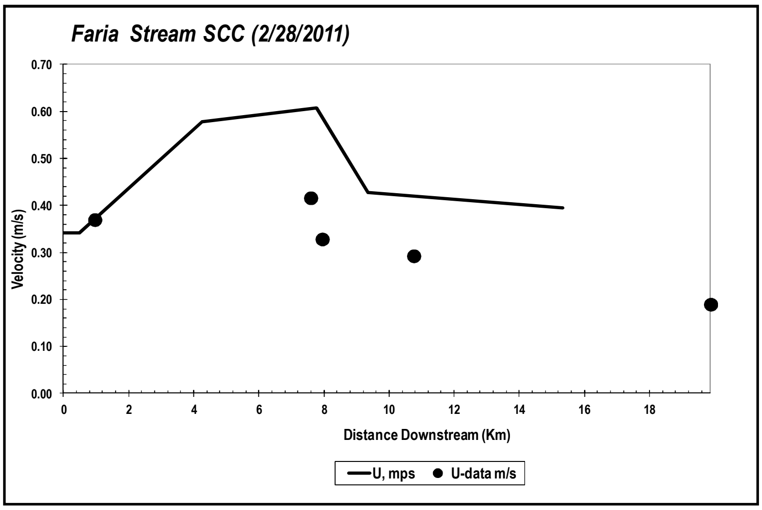


Figure (4.40): Simulated Stream Velocity With CC Effect

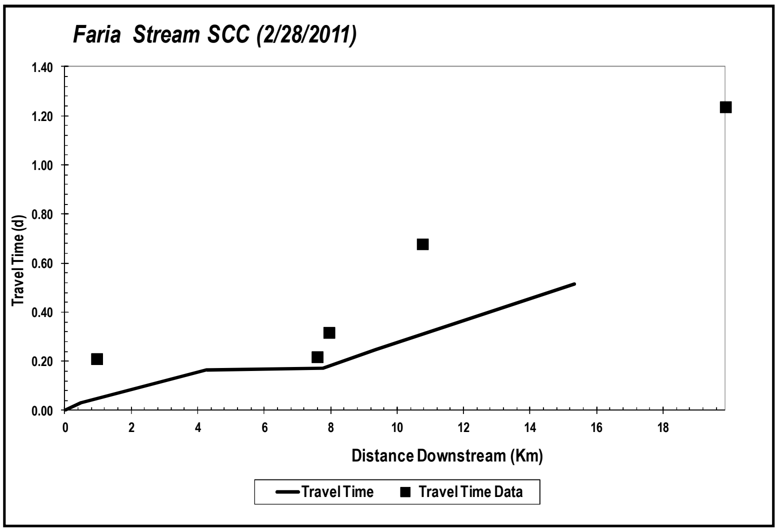


Figure (4.41): Simulated Travel Time For The Stream With CC Effect

4.4 Discussion

Assessment of water quality for Faria stream indicates that untreated WW discharged at upstream is the main source for pollution as results of the measured quality parameters revealed. For example BOD_5 was in the range of 1060 – 500 mg/l along the stream, average BOD_u of 1814 mg/l, and average COD of 1200 mg/l at upstream, they decreased at downstream to 366 mg/l for COD, and around 667 mg/l for BOD_u. Parameters' average values that measured for TKN, TSS and TDS were high at upstream or reach 1. A significant decrease also was shown at the downstream, with average TKN of 233 mg/l at upstream, and TDS varied through sampling period of 1500- 2000 mg/l with five readings more than 2000 mg/l for February, April, May of 2012, November, August of 2011, and it reached 600mg/l in downstream. TSS had stable level at upstream of about 1604 mg/l and decreased along the stream to about 266 mg/l.

The increase in quality parameters with decreasing DO level happened at reaches 2-3 and 3-4 from Badan area to Malaqi Bridge may be due to diffused pollution sources at the reaches. pH range along the stream was 7.2-7.7, average EC was 4000 μs at upstream and it was reduced to about 1500-1000 μs at downstream by natural treatment, with relation between EC and TDS at upstream is shown in the equation:

$EC = 2.221\,TDS - 262$, $r^2 = 0.89$.

As quality indicator, increasing flow was consistent with low BOD at downstream, but no such relation can be indicated at upstream as the flow is WW only, and the increasing flow did not mean that there was dilution.

Modeling for the stream was done for: summer, winter, and critical conditions of minimum DO level with minimum flow. There was a match between measured values and modeling results of the flow, depth, and travel time. Spatial variations of depth and flow were decreasing from upstream to the downstream. Simulated velocity had little difference from measured, and withdrawals were approximated at reaches 2-3 and 3-4 of about 0.039-0.04 m^3/s except at summer it reached 0.094 m^3/s at reach 2-3, and 0.03 m^3/s at reach 3-4. DO profile for the three cases had the same trend, it increased at upstream considerably, and at downstream DO increased slightly or there was decrease. The reason for that may refer to the pollution sources found at reaches 2-3 and 3=4, from Badan area to AL Malaqi Bridge. Causes of this pollution may refer to factors like activities of the surrounding communities or from land use. Simulated SOD had the same trend of measured but higher in value as the least simulated point of SOD in winter was 2.98 $gO_2/m^2/day$ and measured was 0.98 $gO_2/m^2/day$. NBOD not applied for winter case gave close results of SOD of 1.37 $gO_2/m^2/day$, which is more close to measured value. Modeling CC by 10% precipitation reduction was done and no considerable quality or flow variations were happened due to that.

Chapter Five

Stream Restoration and Management

Chapter Five
Stream Restoration and Management

Faria stream suffers from pollution due to untreated waste water discharged from eastern Nablus, land use and animal feedlots, and random solid waste disposal around the stream. These factors cause unbalanced stream flora and fauna and influence stream uses' choices.

Restoration and management techniques to achieve healthy stream, flow are capable to use for agriculture as management choice at the watershed. This can be achieved by structural techniques including: installation of WWTP at upstream. In addition, using Waste Water Storage and Treatment Reservoir (WSTR) to achieve Palestinian guidelines of restricted agriculture [47,48], side armoring by gabions or riprap for side stability , stream reaeration and impoundment removal, and useful nonstructural techniques include: planting buffer zones for diffused pollution reduction, side stability and shading stream, Further more, other nonstructural techniques of pollution control activities like improving sanitation conditions of surrounding communities and land use regulations can be employed.

5.1 Structural Techniques

These techniques require types of physical alterations of stream channel, and may include alterations to existing structures of dams or weirs. Structural techniques for Faria stream restoration and management may include simple structural techniques and more improved structural techniques like installation of WWTP and establishing waste water storage and treatment reservoir as follow.

5.1.1 Alternatives of Waste Water Treatment

Untreated waste water discharged at Faria stream is the main source of stream pollution, and the first restoration technique needed is the installation of WWTP.

We used Q2Kw model as a management tool to predict treatment effect particularly on stream DO profile as well as SOD along the stream.

To predict the worst scenario for Faria stream, modeling was done for the critical case as it has minimum DO level. Main expected scenarios of treatment are the establishment of Secondary Treatment Plant (TPC), and Tertiary Treatment (TTP). The details for each scenario are shown in the following section.

5.1.1.1 Secondary Treatment of Nablus WW

Secondary treatment addresses mainly the removal of CBOD. WWTP' effluent according to Palestinian guidelines for treated WW reuse for agricultural sector [47,48]. The BOD limits of 20 mg/l was used in the model, and DO level was modeled applying treatment plant of carbonaceous BOD (**TPC**) effect. Deoxygenation rate for treated WW range is 0.1-0.35 [9], and the value of 0.2 within the range was considered. Results for TPC are shown in **Figure 5.1** for sediment demand of oxygen that was changed significantly from about 6.22 to 0.37 gO_2/m^2/day after treatment. **Figure 5.2** describes the effect of TPC on DO level where DO changed after treatment from 2 mg/l to about 5.56 mg/l at distance of 7.77 km from upstream which is suitable for fish and most aquatic life[12,15]. Treatment effect will reduce SS by at least 70%. In addition to disinfection and any other treatment technique like WSTR this will make the flow more suitable for restricted agriculture.

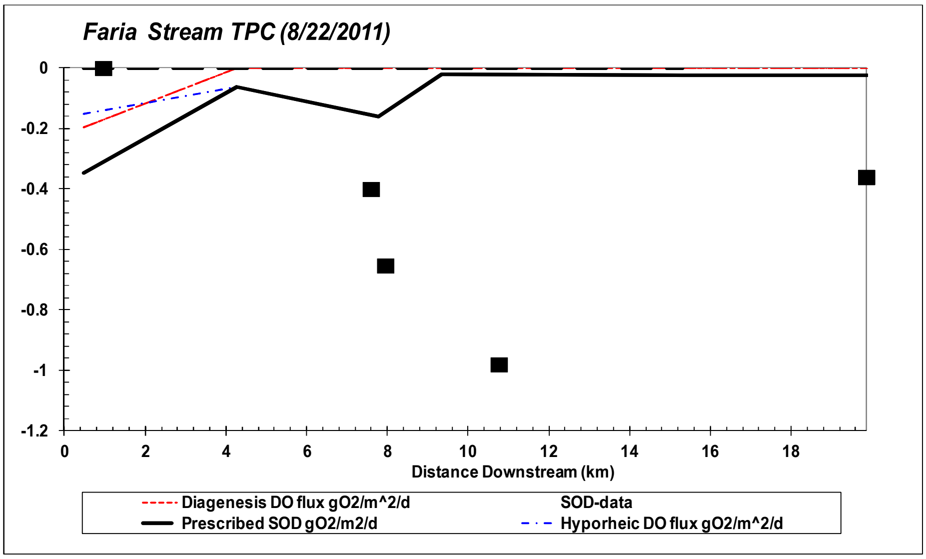


Figure (5.1): Sediment Demand of Oxygen of Faria Stream with Secondary Treatment.

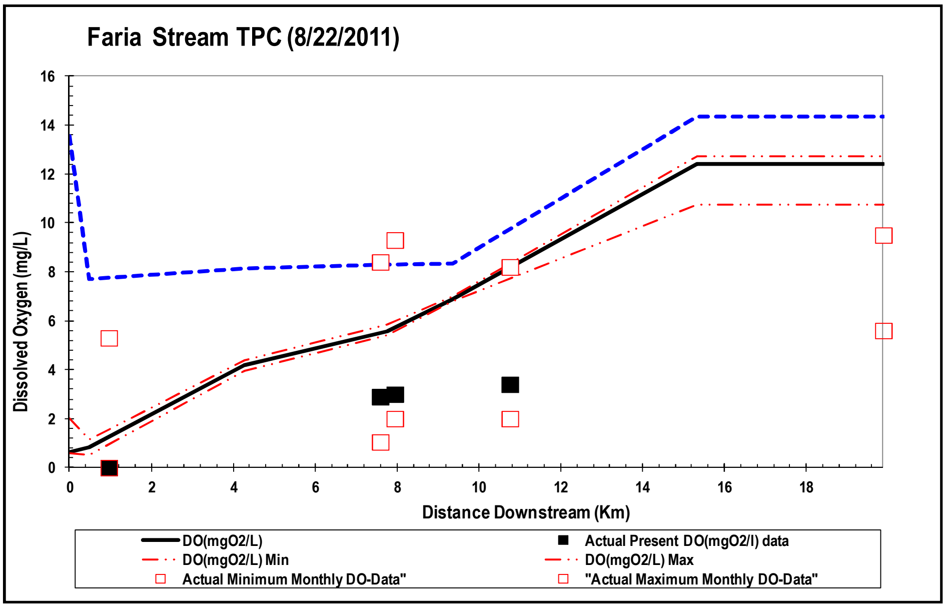


Figure (5.2): Simulated DO Profile For TPC Compared with Present DO Level along Faria Stream

5.1.1.2 Tertiary Treatment for Nablus WW

Tertiary treatment of WW for carbonaceous and nitrogenous BOD is the next choice modeled for WWTP installation. Results of Tertiary Treatment Plant scenario (TTP) are shown in **Figures 5.3** and **5.4** for DO level and SOD respectively, and it supports the result that carbonaceous compounds in WW are the main sources of pollution at the stream because results of TTP DO and SOD are very close to that of TPC.

After treatment, DO level varied from 2 mg/l effluent to 5.56 mg/l after about 7.77 km of stream length and 8.6 mg/l at stream end, with this DO changes, the stream will be suitable for different flora and fauna species [15,12] and due to these expected changes NBOD treatment has to be taken into considerations. Considerable change happened for sediment demand of oxygen (**Figure 5.4)** and its result is approximately similar to TPC, with its maximum simulated value of 0.37 gO_2/m^2/day close to present measured one (0.98 gO_2/m^2/day).

As stated before for TPC, restoration technique of WWTP has important effect on stream water quality as shown from DO and SOD variations along the stream. In addition to treatment effect on TSS and fecal coliform that make stream flow more suitable for agricultural use.

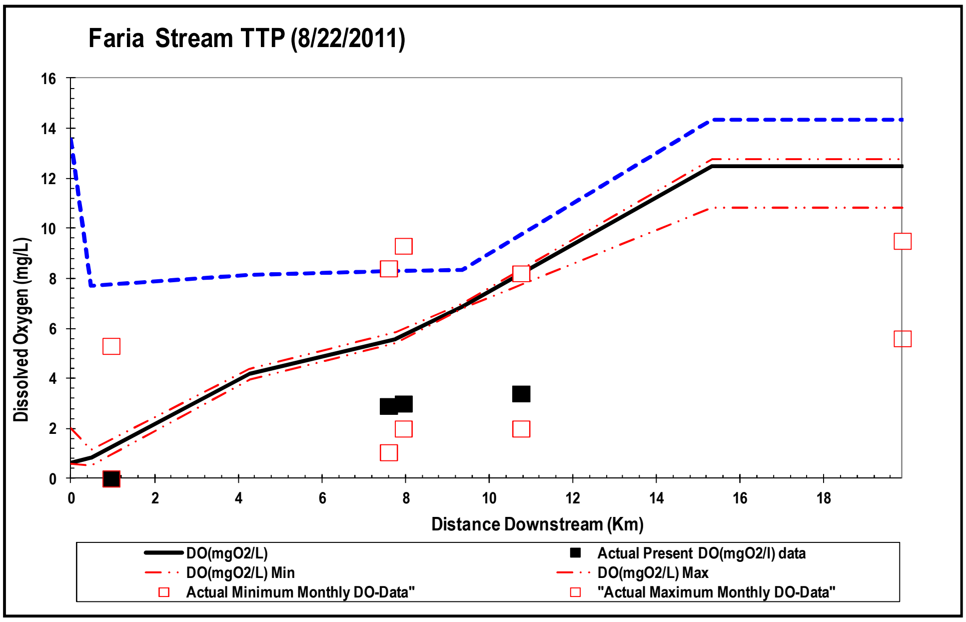


Figure (5.3): Simulated DO Profile With Tertiary Treatment Compared with Present DO Level along The stream

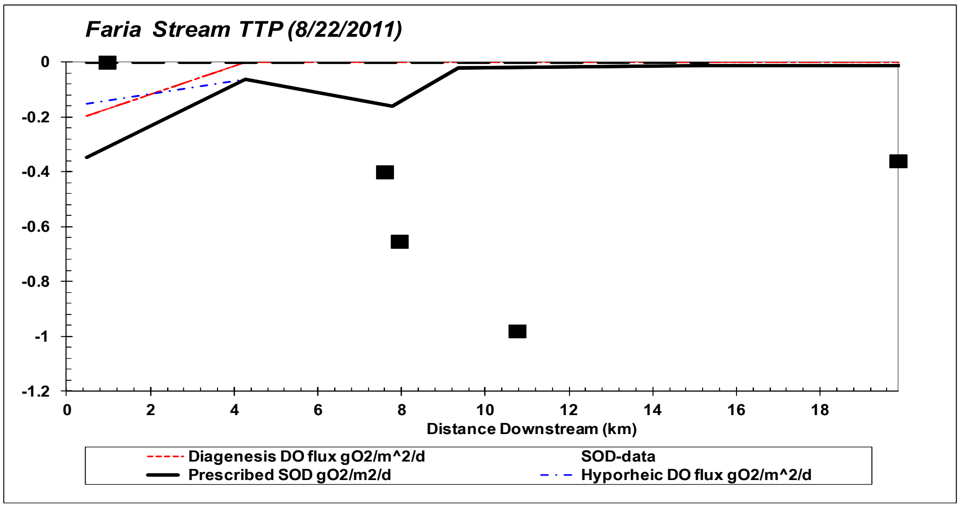


Figure (5.4): DO Used for Sediment Demand along Faria Stream

5.1.2 Simple Structural Management Technique

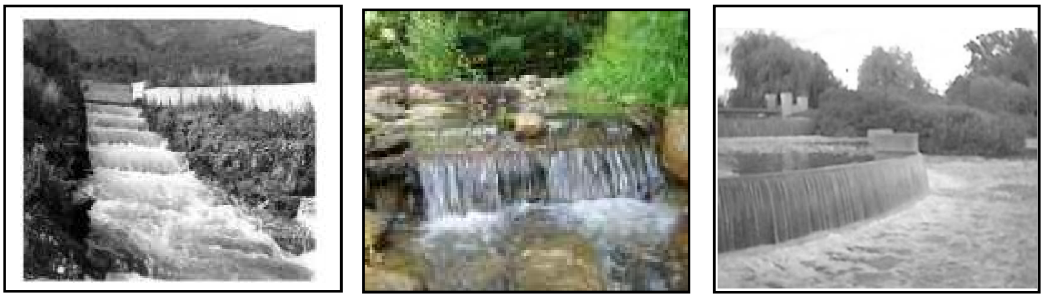
In addition to WWTP installation, there are other different alternatives of structural techniques that can help in Faria stream restoration and management especially after WWTP, and these alternatives include:

i. Waste Water Storage and Treatment Reservoir (WSTR): WSTR maximizes the potential of WW reuse for crop irrigation, and if sequential batch- fed WSTR in parallel is used after anaerobic Waste Stabilization Pond (WSP), its effluent can be used for unrestricted irrigation [10], and in achieving Palestinian microbiological quality guidelines for treated WW of ≤1 eggs/liter of human intestinal nematode [10,47], WSTR is of low cost compare to other treatment facilities, and its volume depends on management regulations and effluent use at irrigation seasons [10].

ii. Bank Armoring Techniques: applying this techniques helps to prevent banks erosion where it is needed at Faria stream, using rock or any available construction materials for side stability like using riprap, gabions which already have been used at reach 4-5 of Faria stream, after AL Malaqi Bridge and at Ein Shibli.

Figure (5.5): Side Armoring by Gabions used at Reach 4-5 of Faria Stream (Near Aqrabania Entrance)

iii. Stream Aeration: using waterfalls in Faria stream will be a reaeration technique for increasing DO level, and for nitrification that may reduce cost of WWTP, ladders, riffle and pools formations (**Figure 5.6**) [49] are also simple and easy to implement due to stream geometry as shown in **Figure 5.7**, and they are not expensive techniques to be used for Faria stream reaeration.



(a) (b) (c)

Figure (5.6): Typical in Stream Aeration Techniques: (a) Ladders [49], (b) Waterfalls, (c) Side-Stream Aeration [9].

iv. Removal of Impoundments: restoration and cleaning stream channel from pollutants by removing impoundments, wastes and obstacles that may be found in Faria stream [50] that will improve stream flow quality.

Figure (5.7): Suitability of Faria Stream Geometry for Aeration By Waterfalls and Riffles at 2.3km from WW Network Exit (Distance by Google Earth).

5.2 Nonstructural Techniques

Nonstructural techniques can be used at Faria stream for restoration, typically they include administrative and legislative procedures to limit or regulate nearby area activities, and thus expected nonstructural techniques for Faria stream include:

i. Buffer Zones: planting trees, shrubs, and herbaceous vegetations on Faria stream banks will create buffer zones. These buffer zones and riparian reforestation at downstream of Faria stream at reaches 2-3, 3-4 and 4-5, from Badan area to Ein Shibli will protect pollutants of runoff and prevent soil erosion in addition to shading stream. It is important for reforestation zones to consider native species of plants with soil suitability, slope, width, and maintenance requirements [51,52,9].

ii. Pollution Prevention Activities: regulating activities in riparian area and watershed through regulating fertilizer frequency, fertilizer types, timing, and quantities will help control pollution in Faria stream, as it is located at agricultural area, and stable or decreased DO level in some instances was measured at reaches 3-4 and 4-5 due to pollution sources. In addition to using fences for pollution control activity like protecting buffer zones from livestock and humans, and improving sanitation systems at surrounding communities which may be the reason for pollutants sources especially at Badan and AL Malaqi area.

iii. Land use regulations: regulation and prevention of potentially destructive land use at Faria watershed, like regulating construction practices, and area management planning that may cause stream flow degradation.

Chapter Six

Conclusion and Recommendations

Chapter Six
Conclusion and Recommendations

6.1 Conclusion

At the end of the research, after assessment and modeling of Faria stream quality, modeling possible future changes for stream restoration and WW treatment, main findings we have can be summarized as:

- Assessment of water quality for Faria stream indicates that untreated WW discharged at the upstream is the main source of pollution, as it was shown by very high values of quality parameters at the upstream, which causes stream degradation. Other sources of pollution may be found at downstream reaches 2-3 and 3-4, from Badan area to AL Malaqi Bridge, which can be illustrated due to human activities and sanitation conditions of stream‘s surrounding communities, or due to land use, that cause stable and in some instances decreased DO level.

- At downstream with increasing flow, BOD concentration decreased, but at upstream increased flow was not consistent with BOD reduction. This is because the increased flow at upstream is mainly WW, and increasing flow does not mean that there was dilution to get low BOD values.

- Modeling Faria stream for summer, winter, and critical conditions of minimum flow and minimum DO level gave good results compared with measured ones for flow, velocity, depth, and travel time. The results of DO profile showed increased DO level at reach 1, upstream, and after that the change in DO level was slight, or it decreased as shown at average change of DO figure.

- Modeling results indicate that there was withdrawal concluded at reaches 2-3 and 3-4 from Badan to AL Malaqi Bridge, withdrawals approximated of 0.039-0.04 m^3/sec all the year and this withdrawals increased in summer season to 0.094 m^3/sec. Illustration of these withdrawals may be resulted from agricultural use in the area or it may be due to seepage to lower soil layers and groundwater aquifers as this withdrawal was found even at winter and rainy months.

- Management and restoration of Faria stream to improve stream's water quality can be done by structural and nonstructural techniques. Restoration of WW stream flow is recommended to start by WWTP installation eastern Nablus, and modeling possible treatment alternatives gave results of increased DO level considerably. The results were close for both secondary and tertiary treatment. DO level after treatment started with DO of 2 mg/l according to Palestinian guidelines [47], and it reached about 5.56 mg/l at distance of 7.77 km from stream beginning, and 8.6 mg/l at stream end, this is suitable for most aquatic life, sediment demand of oxygen was also influenced considerably with both treatment choices.

- Other effective structural techniques can be applied for Faria stream to make use of its flow for agriculture is WSTR, which is not expensive treatment technique to achieve biological standards of ≤ 1 nematodes egg/liter. Other structural techniques may improve stream flow quality are: side armoring, stream reaeration, and impoundment removal.

- Effective nonstructural techniques have to be considered including: Buffer zones establishment, Pollution control activity of improving sanitation conditions at communities around the stream, and regulating fertilizer timing, types, frequency and quantity, in addition to Land use regulation.

6.2 Recommendations

The research recommended the following to achieve stream restoration and improve stream flow quality and uses:

- Installation of WWTP at upstream is recommended, treatment effect will change stream water quality, and make it more healthy for aquatic life. The effluent will be suitable for agricultural use and for achieving microbiological Palestinian guidelines especially if sequential batch-fed WSTR are used in parallel after anaerobic pond [10].

- More assessment efforts are needed at reaches 3-4 and 4-5, from Badan area to AL Malaqi Bridge, to determine quantity and quality of pollution sources if found, and investigate withdrawals at those reaches.

- More studies are needed to complete modeling stream variables and to simulate related parameters and rate constants for Faria stream especially that parameters related to agricultural use' guidelines of microbiology, detritus, hydrolysis rates, nitrification and denitrification.

- Management techniques have to take continuous monitoring program into consideration, to provide monitoring of stream environmental changes in aquatic life, or fish growing and transmitting pollutants to human being, and monitoring hydrologic changes. **Figure 6.1** below is an example of considerable hydrological changes at stream flow through sampling period that has to be taken into consideration in stream management and restoration.

Figure (6.1): Variation of Flow at Sampling Pt5, Ein Shibli, between: April 2011, Septemper 2011, and December 2012 Respectively.

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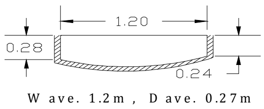
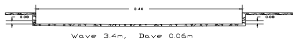
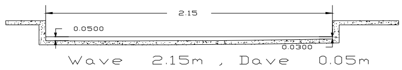
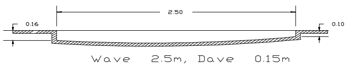
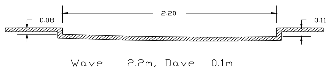
Appendices

Appendix A : Flow measurements and Calculations

A.1 Sampling Points

Sampling Points: The Distance Starting From Stream Began, Elevation, and Cross Sections

Sampling Point	Distance along stream (km)	Elevation above MSL. (ft.)	Stream Cross Section (m^2)
Pt1	0.960	1445	
Pt2	7.592	398	
Pt3	7.946	354	
Pt4	10.759	190	
Pt5	19.88	-280	

A.2 Data of Velocity Calculation:

2.1 Travel Time Measurements in seconds.

Abbreviations used:

NA: Not Available due to Field conditions

NM: Not measured at this Date

NT: Measure Not Taken due to other reason.

Date	Pt1	Pt2	Pt3	Pt4	Pt5
Jan/31/11	53	47	41	NT	NM
Feb/28/11	72.3	47	77.7	NT	157
Mar/10/11	72.3	na	18.3	NT	33.3
Apr/3/11	87.3	79	64.5	NT	33.3
Apr/25/11	74	51	85	NT	157
May/29/11	58	92	105	NT	NM
Jun/28/11	58	97	64	57.5	NM
Sep/25/11	62.5	76	83	35.7	NM
Oct/30/11	62	68.5	62	48	NM
Nov/30/11	66.5	63.5	45	35	NM
Dec/27/11	58.7	30.3	58.5	31	64
Jan/30/12	61.5	56	NA	28	52.3
Mar/28/12	90	65	50	31.5	85

2.2 Travel Distance Measurements in meter.

Date	Pt1	Pt2	Pt3	Pt4	Pt5
Jan/31/11	30	23	30	NM	35
Feb/28/11	30	23	30	NM	35
Mar/10/11	30	23	30	NM	35
Apr/3/11	30	23	30	NM	35
Apr/25/11	30	23	35	NM	35
May/29/11	30	23	35	NM	NM
Jun/28/11	30	23	35	20	NM
Sep/25/11	30	23	35	20	NM
Oct/30/11	30	23	35	20	NM
Nov/30/11	30	23	35	15	NM
Dec/27/11	30	23	35	15	35
Jan/30/12	30	23	35	15	35
Mar/28/12	30	23	35	15	35

A.3 Data of Flow calculation:

Pt1:					
Date	**Depth m**	**Width m**	**Cross Section m^2**	**Velocity m/sec**	**Flow m^3/sec**
Jan/31/11	0.27	1.55	0.413	0.481	0.1988
Feb/28/11	0.147	1.35	0.198	0.3695	0.0698
Mar/10/11	0.59	1.35	0.797	0.3695	0.2944
Apr/3/11	0.21	1.4	0.299	0.283	0.0872
Apr/25/11	0.12	1.3	0.160	0.3446	0.0553
May/29/11	0.23	1.4	0.322	0.4396	0.1416
Jun/28/11	0.28	1.4	0.397	0.4396	0.1744
Sep/25/11	0.227	1.6	0.363	0.432	0.148
Oct/30/11	0.317	1.6	0.507	0.4113	0.1867
Nov/30/11	0.193	1	0.193	0.3835	0.0738
Dec/27/11	0.27	1.2	0.324	0.4347	0.141
Jan/31/12	0.367	1.3	0.477	0.4146	0.1976
Mar/28/12	0.347	1.5	0.52	0.283	0.147

Pt2:					
Date	**Depth m**	**Width m**	**Cross Section m^2**	**Velocity m/sec**	**Flow m^3/sec**
Jan/31/11	0.13	3.4	0.442	0.416	0.1838
Feb/28/11	0.06	3.4	0.204	0.4159	0.0848
Mar/10/11	NA	3.4	NA	NA	NA
Apr/3/11	0.078	3.4	0.264	0.2475	0.0652
Apr/25/11	0.05	3.4	0.136	0.383	0.0521
May/29/11	0.08	3.4	0.272	0.213	0.0578
Jun/28/11	0.117	3.4	0.397	0.2015	0.0799
Sep/25/11	0.093	3.4	0.317	0.2724	0.0816
Oct/30/11	0.05	3.4	0.17	0.2854	0.0485
Nov/30/11	0.115	3.4	0.391	0.3079	0.1204
Dec/27/11	0.06	3.4	0.204	0.6445	0.1315
Jan/31/12	0.295	3.3	0.974	0.3491	0.1066
Mar/28/12	0.163	3.3	0.578	0.3008	0.1564

Pt3:					
Date	**Depth m**	**Width m**	**Cross Section m^2**	**Velocity m/sec**	**Flow m^3/sec**
Jan/31/11	0.08	2.15	0.172	0.6219	0.107
Feb/28/11	0.05	2.15	0.107	0.3283	0.0353
Mar/10/11	0.2	2.15	0.43	1.3909	0.5981
Apr/3/11	0.03	2.15	0.065	0.3954	0.0255
Apr/25/11	0.025	2.15	0.054	0.35	0.0188
May/29/11	0.045	2.15	0.097	0.2833	0.0274
Jun/28/11	0.045	2.15	0.097	0.6563	0.045
Sep/25/11	0.067	2.15	0.143	0.3795	0.0514
Oct/30/11	0.04	2.15	0.093	0.4798	0.0447
Nov/30/11	0.107	2.15	0.229	0.6611	0.1598
Dec/27/11	0.047	2.15	0.100	0.5086	0.051
Jan/31/12	0.18	1.8	0.33	0.5	0.165
Mar/28/12	0.198	1.8	0.3555	0.595	0.2115

Pt4:					
Date	**Depth m**	**Width m**	**Cross Section m^2**	**Velocity m/sec**	**Flow m^3/sec**
Jan/31/11	0.07	4.57	0.320	0.4864	0.1556
Feb/28/11	0.03	4.57	0.137	0.2925	0.0401
Mar/10/11	0.15	4.57	0.686	0.7683	0.5267
Apr/3/11	0.05	4.57	0.229	0.3974	0.0908
Apr/25/11	0.02	4.57	0.091	0.2294	0.021
May/29/11	0.13	0.7	0.093	NA	NA
Jun/28/11	0.147	0.7	0.103	0.4174	0.0607
Sep/25/11	0.22	0.7	0.154	0.5047	0.0954
Oct/30/11	0.19	0.7	0.133	0.3542	0.0471
Nov/30/11	0.1325	7.6	1.01	0.3643	0.3668
Dec/27/11	0.153	2.5	0.38	0.4113	0.1577
Jan/31/12	0.153	2.5	0.38	0.4554	0.1745
Mar/28/12	0.23	2.1	0.48	0.4048	0.1955

*** Pt5:**					
Date	**Depth m**	**Width m**	**Cross Section m^2**	**Velocity m/sec**	**Flow m^3/sec**
Jan/31/11	0.25	1.5	0.375	NM	NM
Feb/28/11	0.11	2.2	0.242	0.1895	0.0459
Mar/10/11	0.257	2.8	0.719	0.8925	0.6414
Apr/3/11	0.06	2	0.12	0.8925	0.1071
Apr/25/11	0.03	2	0.06	0.1895	0.0114
Dec/27/11	0.34	2.2	0.22	0.4648	0.1023
Jan/31/12	0.13	2	0.267	0.5685	0.1516
Mar/28/12	0.13	2.2	0.286	0.35	0.1001

*The data for this point are for flowing period in 2011 and 2012, as there was no flow at this point at summer seasons from April to November.

Appendix B: Results of Laboratory Analysis

Laboratory Analysis Results for TDS, TSS, EC, TKN, and COD in mg/ l, EC in (μs), and pH in standard unit.

Pt1						
Date	**TDS mg/l**	**TSS mg/l**	**pH s.u**	**EC μs**	**COD mg/l**	**TKN mg/l**
14/11/2010	1299	NA	7.6	2030	1120	NA
27/12/2010	1660	1860	7.1	3175	1306	364.6
31/1/2011	380	1060	6.9	2390	688	149.4
28/2/2011	1467	2120	7.5	3630	933	233
4/3/2011	1136	1232	8	2680	Failed	236.8
4/25/2011	790	2150	7.4	2780	600	225
29/5/2011	1632	808	7.4	2450	1040	174.5
28/6/2011	1743	1833	7.3	2800	3072	149.6
31/7/2011	1350	733	7.26	2150	888	194.5
22/8/2011	2967	1533	7.5	4700	Failed	214
25/9/2011	1125	1625	7.48	2210	1120	300.8
30/10/2011	1392	1816	6.84	2830	1493	198.2
30/11/2011	4367	1883	6.7	11250	2816	249.6
27/12/2011	1450	825	6.9	3020	1120	208.8
30/1/2012	1633	1900	7.2	3340	696	221
28/2/2012	2133	1933	7.3	4640	NA	318
28/3/2012	913	1033	8	2310	850	382
29/4/2012	4580	2240	6.8	9500	1970.7	143
29/5/2012	2527	2280	7.4	5850	1653	101.4

Pt2						
Date	TDS mg/l	TSS mg/l	pH s.u	EC µs	COD mg/l	TKN mg/l
14/11/2010	675	NA	6.9	1055	32	127.8
27/12/2010	995	156	7.4	1555	933	191.7
31/1/2011	216	140	7.4	557	90.7	116.7
28/2/2011	433	126.7	7.4	1506	213.3	150.3
3/4/2011	568	328	7.5	2180	560	112.8
25/4/2011	316	188	7.4	1675	181.3	136
29/5/2011	664	156	8	2140	399.6	174.5
28/6/2011	1183	958	7.7	1617	589.4	164.6
31/7/2011	1196	692	8.11	2000	464	154.6
22/8/2011	972	836	8.24	1532	463.1	96.9
25/9/2011	996	572	8	1890	270	188.7
30/10/2011	504	176	7.6	1683	320	91
30/11/2011	312	88	7.5	1730	704	147.7
27/12/2011	760	656	7.8	1880	336	157.9
30/1/2012	984	108	7.6	1880	277	162
28/2/2012	204	688	7.7	564	NA	92.2
28/3/2012	536	368	7.5	1225	142.7	339
29/4/2012	900	268	7.9	1702	442.8	59.9
29/5/2012	640	188	8.1	1419	133	101.4

Pt3						
Date	TDS mg/l	TSS mg/l	pH s.u	EC µs	COD mg/l	TKN mg/l
14/11/2010	585.6	NA	7.4	915	112	150.3
27/12/2010	636	52	7.38	1204	208	124
31/1/2011	228	192	7.43	536	80	121.4
28/2/2011	266.7	380	7.2	908	138.7	161.6
3/4/2011	1068	124	7.55	1330	Failed	105.2
25/4/2011	580	96	7.7	1189	234.7	125.6
29/5/2011	1044	12	8.17	1420	345.6	124.7
28/6/2011	1100	691.7	7.5	1564	589.4	144.6
31/7/2011	1012	828	8.1	1910	Failed	129.7
22/8/2011	872	764	8.18	1618	Failed	178.5
25/9/2011	820	236	7.9	1538	Failed	173.4
30/10/2011	504	264	7.42	898	197	128.6
30/11/2011	664	260	7.4	1514	296	127
27/12/2011	600	80	7.6	1571	224	168
30/1/2012	736	68	7.53	1565	120	151
28/2/2012	460	120	7.3	1030	NA	645.3
28/3/2012	410	392	7.44	790	105	55.5
29/4/2012	460	140	7.7	947	167.4	46
29/5/2012	440	92	8.1	966	85	83

Pt4						
Date	**TDS mg/l**	**TSS mg/l**	**pH s.u**	**EC µs**	**COD mg/l**	**TKN mg/l**
14/11/2010	370	NA	6.5	578	NA	203
27/12/2010	900	54	7.33	1345	69	266.8
31/1/2011	264	140	7.35	502	48	154.1
28/2/2011	287	266.7	7.41	1203	133	139.1
3/4/2011	864	236	6.8	1890	144	97.7
25/4/2011	460	168	7.35	1180	112	115.13
29/5/2011	876	14	8.06	1960	160	154.6
28/6/2011	1091	583	7.4	1198	291.6	269.3
31/7/2011	732	472	7.8	2640	96	154.6
22/8/2011	908	1272	7.86	1744	634.7	168.3
25/9/2011	864	564	7.78	1600	1417.4	147.9
30/10/2011	492	552	7.52	1506	181	144.6
30/11/2011	1280	244	7.53	2430	186.7	142.6
27/12/2011	180	176	7.63	1388	208	132.4
30/1/2012	888	60	7.41	1529	144	140.1
28/2/2012	232	152	7.47	1192	152	682.1
28/3/2012	392	488	7.6	448	NA	43.2
29/4/2012	584	152	7.75	1055	137	69.2
29/5/2012	528	152	7.93	1115	210.6	87.6

Pt5						
Date	**TDS mg/l**	**TSS mg/l**	**pH s.u**	**EC µs**	**COD mg/l**	**TKN mg/l**
14/11/2010	SNT	SNT	SNT	SNT	SNT	SNT
27/12/2010	SNT	SNT	SNT	SNT	SNT	SNT
31/1/2011	928	104	7.2	571	160	112
28/2/2011	280	153	7.4	1033	432	161.6
3/4/2011	1044	104	7.6	820	192	86.4
4/25/2011	380	72	6.8	790	Failed	110
29/5/2011	SNT	SNT	SNT	SNT	SNT	SNT
28/6/2011	SNT	SNT	SNT	SNT	SNT	SNT
31/7/2011	SNT	SNT	SNT	SNT	SNT	SNT
22/8/2011	SNT	SNT	SNT	SNT	SNT	SNT
25/9/2011	SNT	SNT	SNT	SNT	SNT	SNT
30/10/2011	SNT	SNT	SNT	SNT	SNT	SNT
30/11/2011	SNT	SNT	SNT	SNT	SNT	SNT
27/12/2011	848	72	7.7	1787	155	127.3
30/1/2012	1020	220	6.9	1970	69	172.5
28/2/2012	308	320	7.3	1374	NA	299.6
28/3/2012	716	400	7.2	1358	100	6.16
29/4/2012	SNT	SNT	SNT	SNT	SNT	SNT
29/5/2012	SNT	SNT	SNT	SNT	SNT	SNT

Abbreviations:

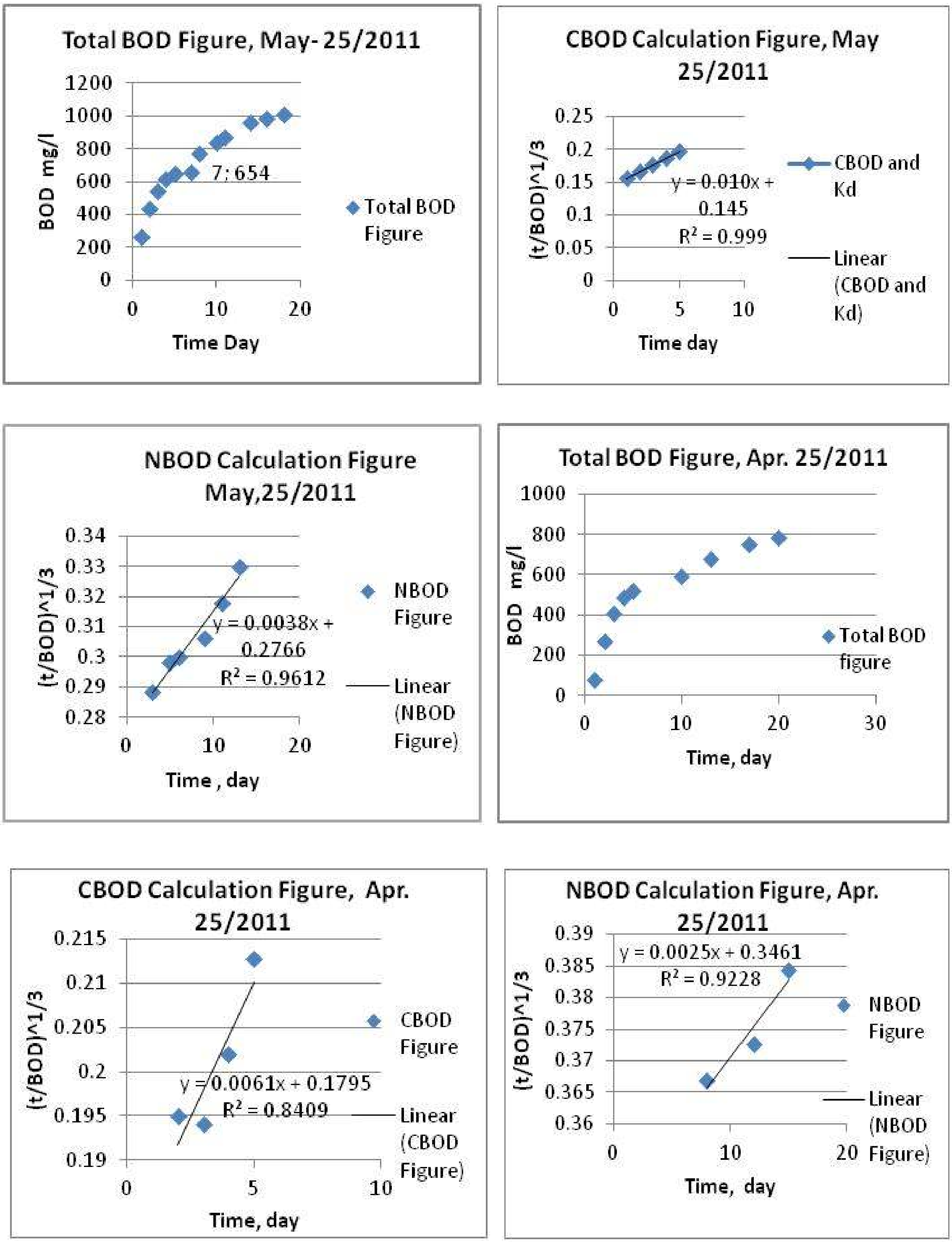
NA : Not Available Reading.

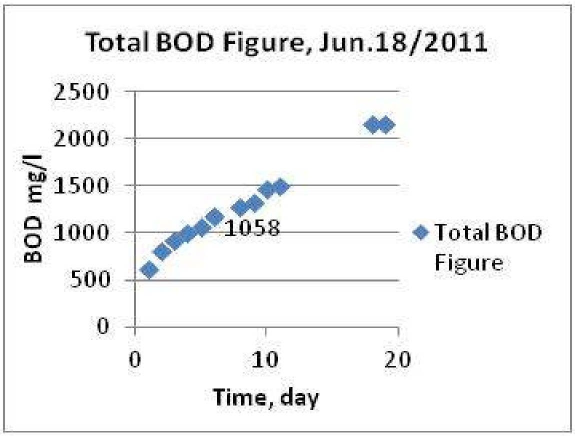
SNT: Sample Not Taken.

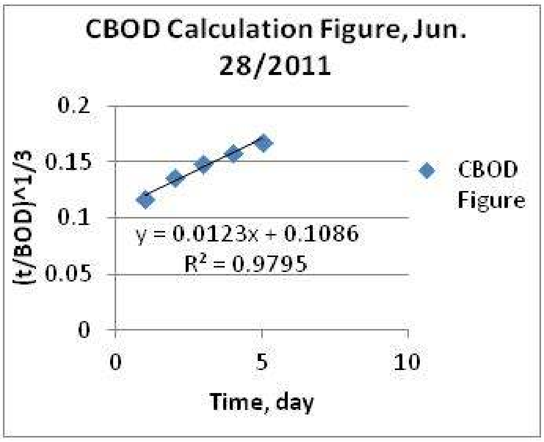
Appendix C: Kinetic Parameters Calculation and Results

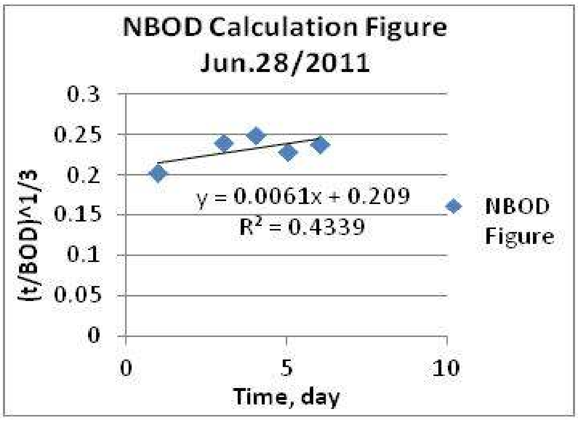
C.1 Figures for Kinetic Rate Constants and Parameters Calculation by using Thomas Graphical Method:

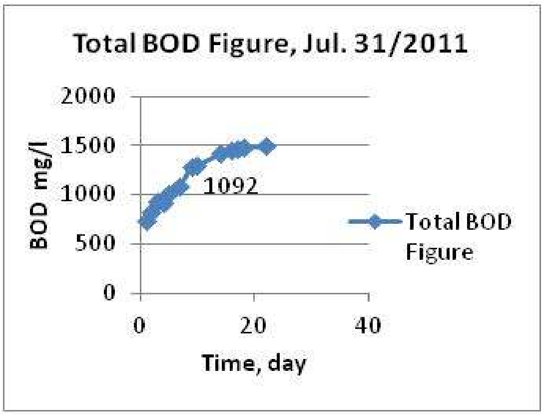
Figure 1: Kinetics Rates Figures for Sampling Point 1

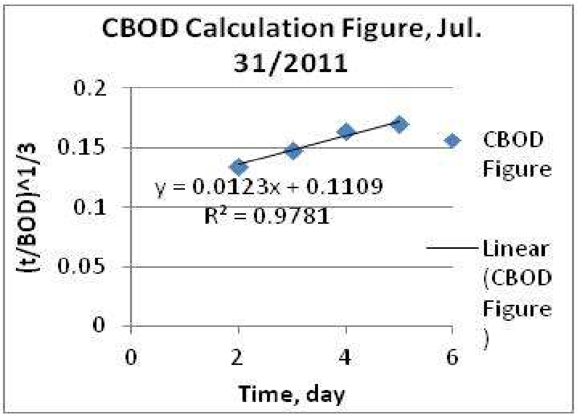


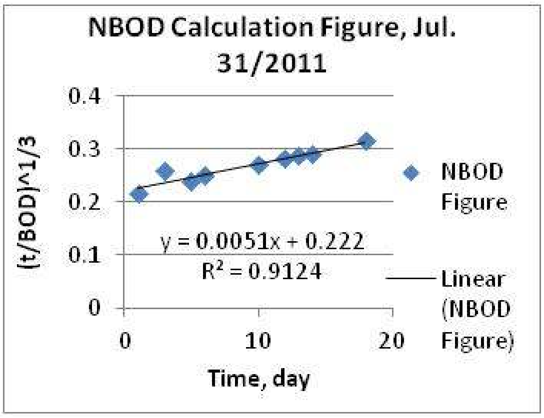

Total BOD Figure, Jun.18/2011
BOD mg/l
2500
2000
1500
1000
500
0
1058
Total BOD Figure
0
10
20
Time, day

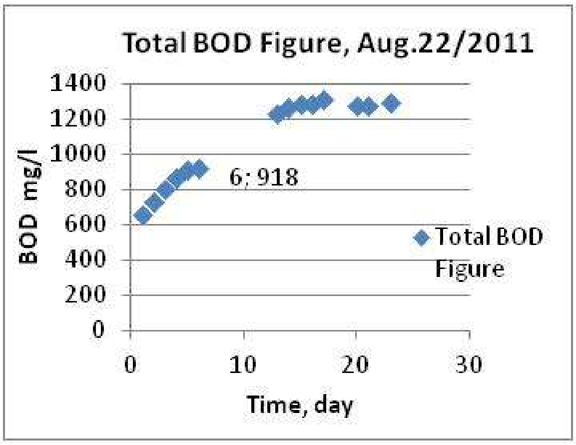

CBOD Calculation Figure, Jun. 28/2011
(t/BOD)^1/3
0.2
0.15
0.1
0.05
0
y = 0.0123x + 0.1086
R² = 0.9795
CBOD Figure
0
5
10
Time, day

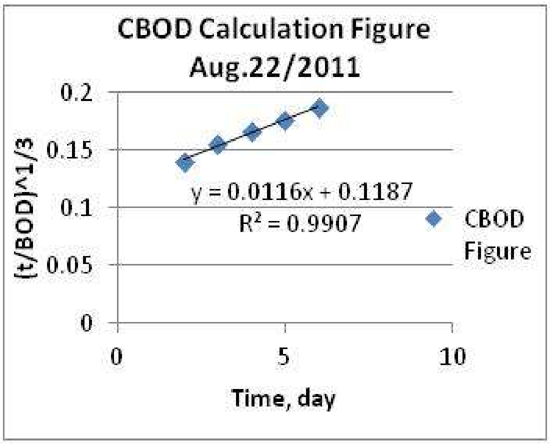

NBOD Calculation Figure Jun.28/2011
(t/BOD)^1/3
0.3
0.25
0.2
0.15
0.1
0.05
0
y = 0.0061x + 0.209
R² = 0.4339
NBOD Figure
0
5
10
Time, day

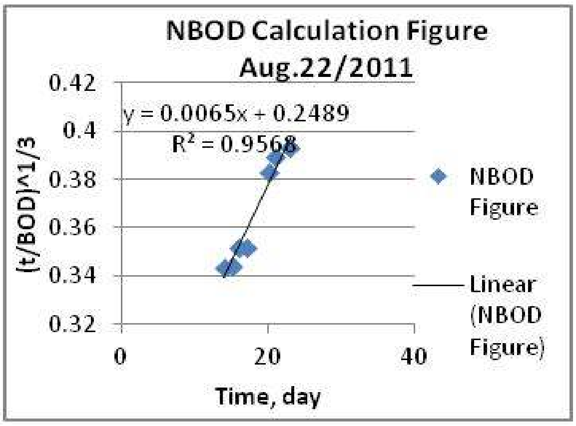

Total BOD Figure, Jul. 31/2011
BOD mg/l
2000
1500
1000
500
0
1092
Total BOD Figure
0
20
40
Time, day

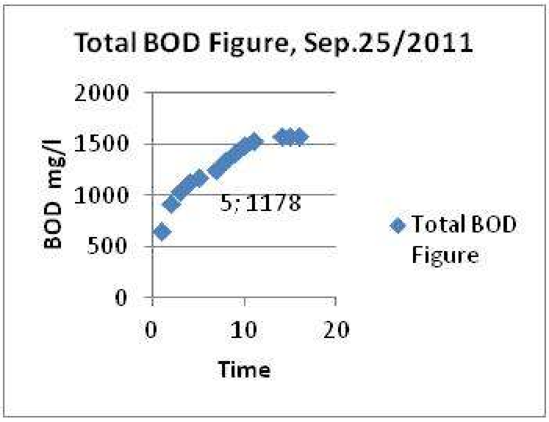

CBOD Calculation Figure, Jul. 31/2011
(t/BOD)^1/3
0.2
0.15
0.1
0.05
0
y = 0.0123x + 0.1109
R² = 0.9781
CBOD Figure
Linear (CBOD Figure)
0
2
4
6
Time, day

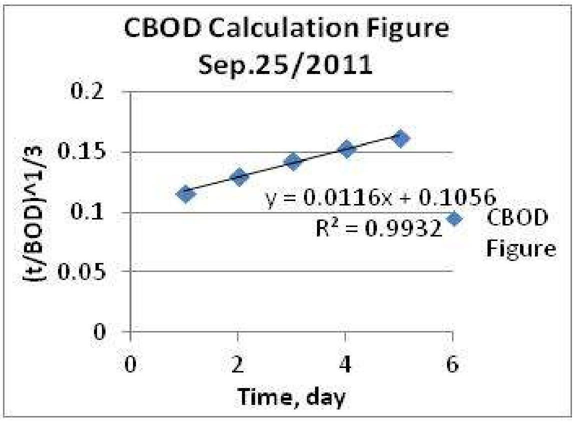

NBOD Calculation Figure, Jul. 31/2011
(t/BOD)^1/3
0.4
0.3
0.2
0.1
0
y = 0.0051x + 0.222
R² = 0.9124
NBOD Figure
Linear (NBOD Figure)
0
10
20
Time, day

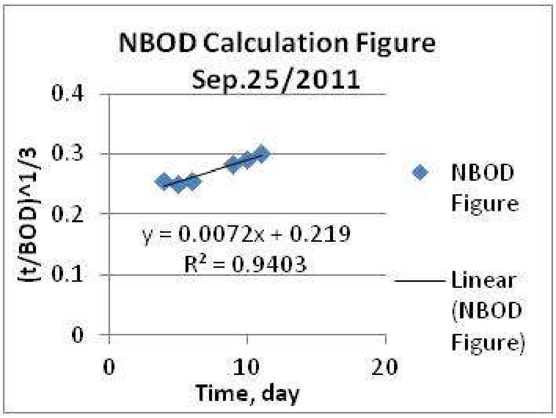

Total BOD Figure, Aug.22/2011
BOD mg/l
1400
1200
1000
800
600
400
200
0
6; 918
Total BOD Figure
0
10
20
30
Time, day

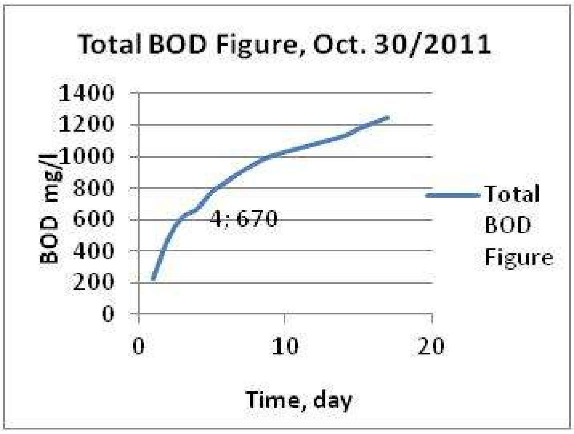

CBOD Calculation Figure Aug.22/2011
(t/BOD)^1/3
0.2
0.15
0.1
0.05
0
y = 0.0116x + 0.1187
R² = 0.9907
CBOD Figure
0
5
10
Time, day

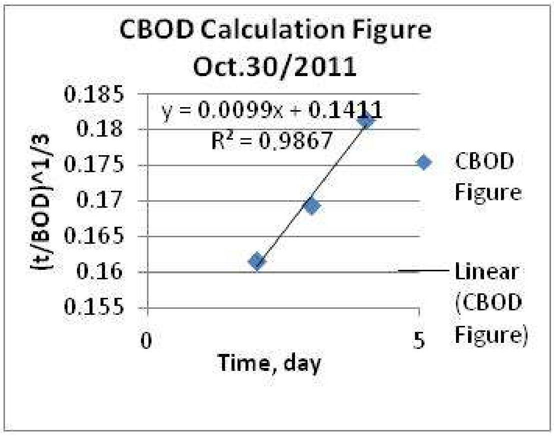

NBOD Calculation Figure
Aug.22/2011
y = 0.0065x + 0.2489
R² = 0.9568
(t/BOD)^1/3
0.42
0.4
0.38
0.36
0.34
0.32
0
20
40
Time, day
NBOD Figure
Linear (NBOD Figure)

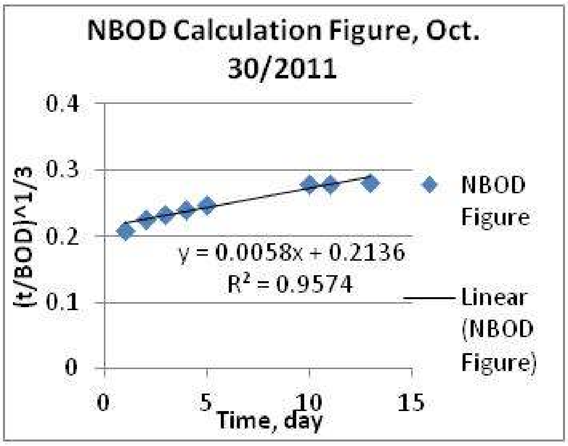

Total BOD Figure, Sep.25/2011
BOD mg/l
2000
1500
1000
500
0
5; 1178
0
10
20
Time
Total BOD Figure

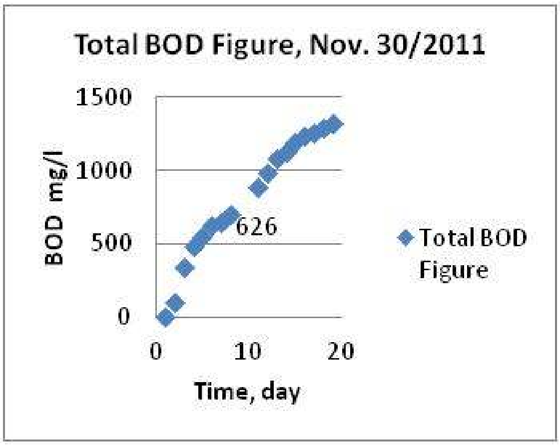

CBOD Calculation Figure
Sep.25/2011
(t/BOD)^1/3
0.2
0.15
0.1
0.05
0
y = 0.0116x + 0.1056
R² = 0.9932
0
2
4
6
Time, day
CBOD Figure

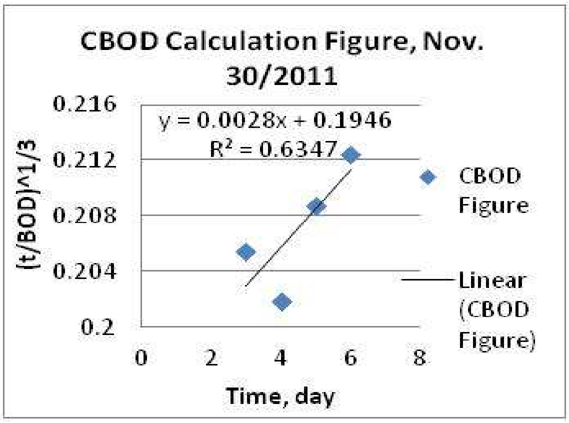

NBOD Calculation Figure
Sep.25/2011
(t/BOD)^1/3
0.4
0.3
0.2
0.1
0
y = 0.0072x + 0.219
R² = 0.9403
0
10
20
Time, day
NBOD Figure
Linear (NBOD Figure)

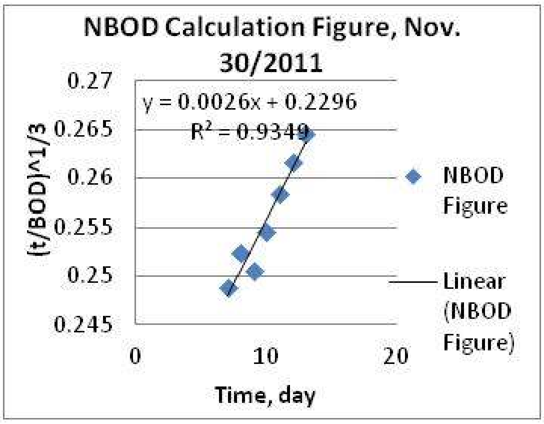

Total BOD Figure, Oct. 30/2011
BOD mg/l
1400
1200
1000
800
600
400
200
0
4; 670
0
10
20
Time, day
Total BOD Figure

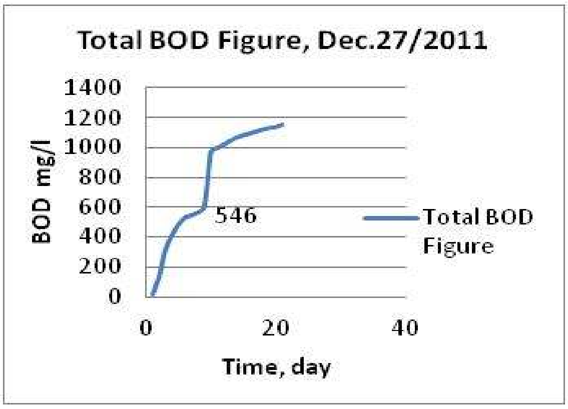

CBOD Calculation Figure
Oct.30/2011
(t/BOD)^1/3
0.185
0.18
0.175
0.17
0.165
0.16
0.155
y = 0.0099x + 0.1411
R² = 0.9867
0
5
Time, day
CBOD Figure
Linear (CBOD Figure)

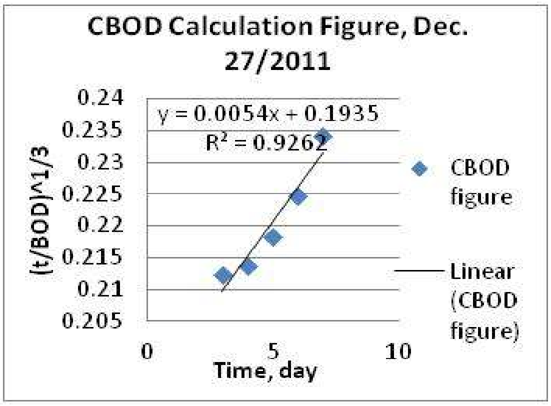

NBOD Calculation Figure, Oct. 30/2011
(t/BOD)^1/3
0.4
0.3
0.2
0.1
0
y = 0.0058x + 0.2136
R² = 0.9574
0
5
10
15
Time, day
NBOD Figure
Linear (NBOD Figure)

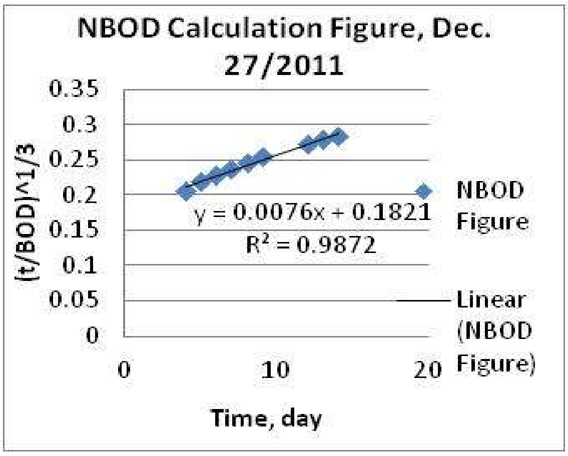

Total BOD Figure, Nov. 30/2011
BOD mg/l
1500
1000
500
0
626
0
10
20
Time, day
Total BOD Figure

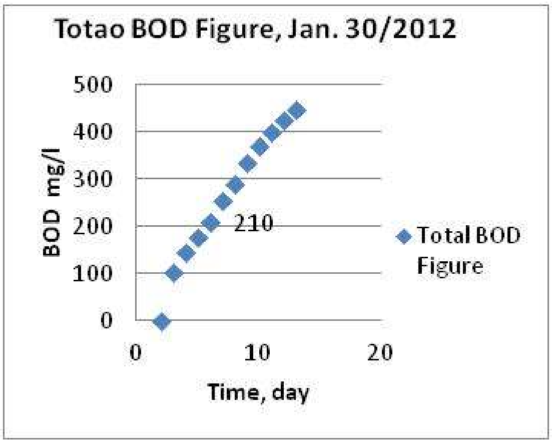

CBOD Calculation Figure, Nov. 30/2011
y = 0.0028x + 0.1946
R² = 0.6347
(t/BOD)^1/3
0.216
0.212
0.208
0.204
0.2
0
2
4
6
8
Time, day
CBOD Figure
Linear (CBOD Figure)


NBOD Calculation Figure, Nov. 30/2011
y = 0.0026x + 0.2296
R² = 0.9349
(t/BOD)^1/3
0.27
0.265
0.26
0.255
0.25
0.245
0
10
20
Time, day
NBOD Figure
Linear (NBOD Figure)


Total BOD Figure, Dec.27/2011
BOD mg/l
1400
1200
1000
800
600
400
200
0
546
0
20
40
Time, day
Total BOD Figure


CBOD Calculation Figure, Dec. 27/2011
y = 0.0054x + 0.1935
R² = 0.9262
(t/BOD)^1/3
0.24
0.235
0.23
0.225
0.22
0.215
0.21
0.205
0
5
10
Time, day
CBOD figure
Linear (CBOD figure)


NBOD Calculation Figure, Dec. 27/2011
y = 0.0076x + 0.1821
R² = 0.9872
(t/BOD)^1/3
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
Time, day
NBOD Figure
Linear (NBOD Figure)


Totao BOD Figure, Jan. 30/2012
BOD mg/l
500
400
300
200
100
0
210
0
10
20
Time, day
Total BOD Figure

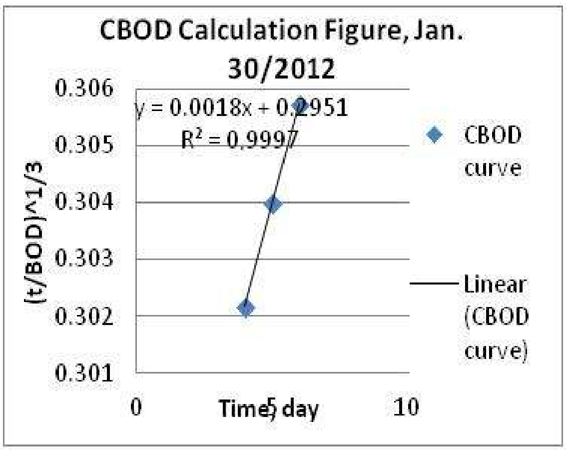
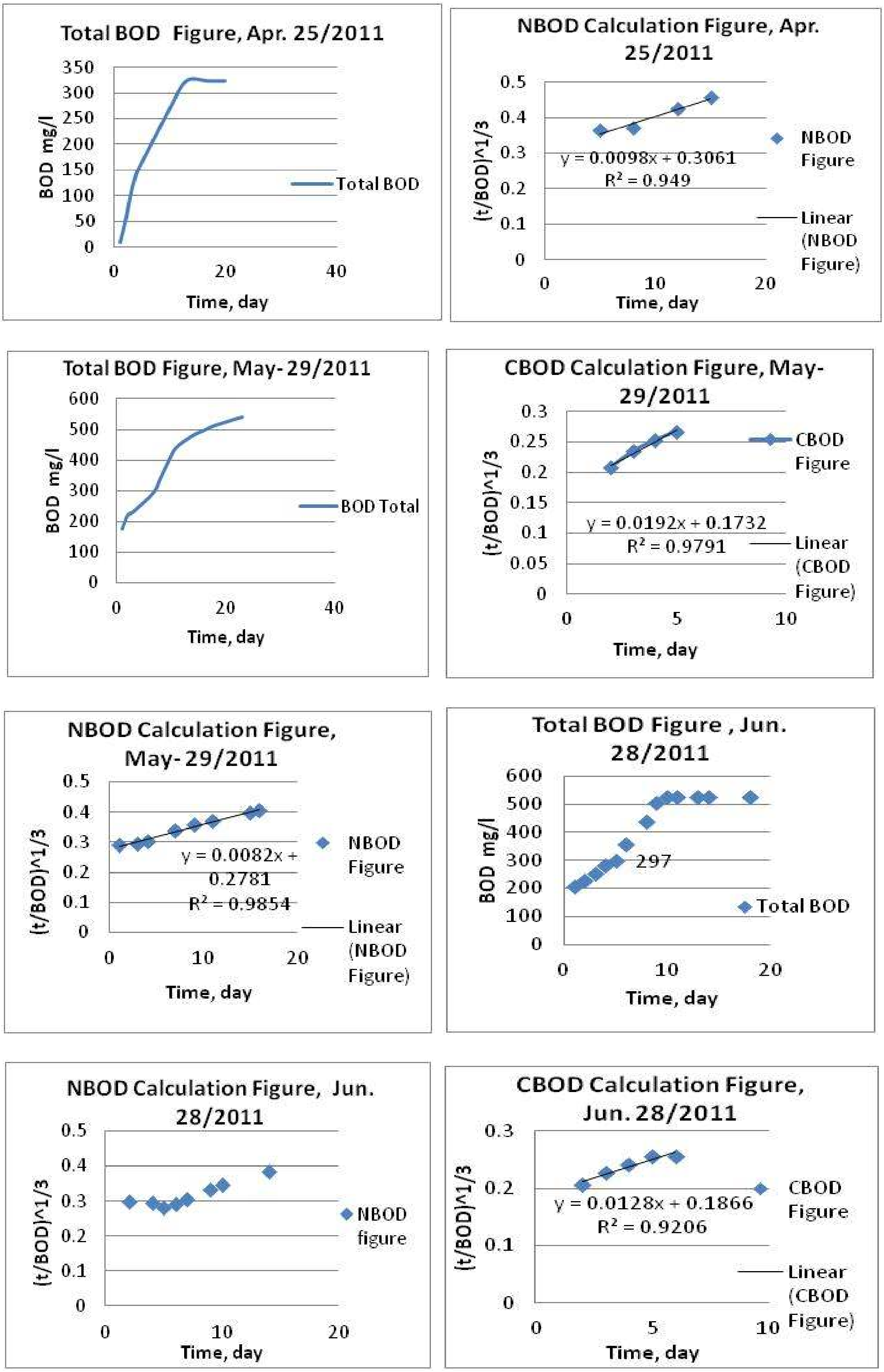
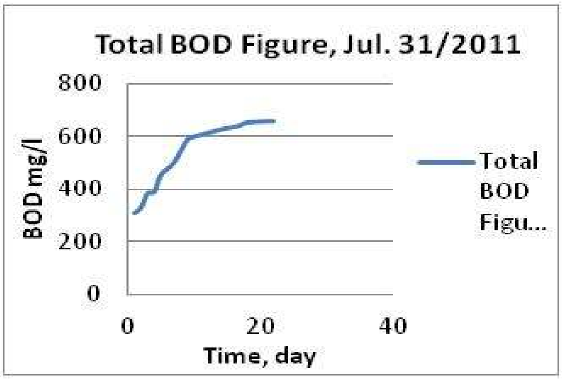
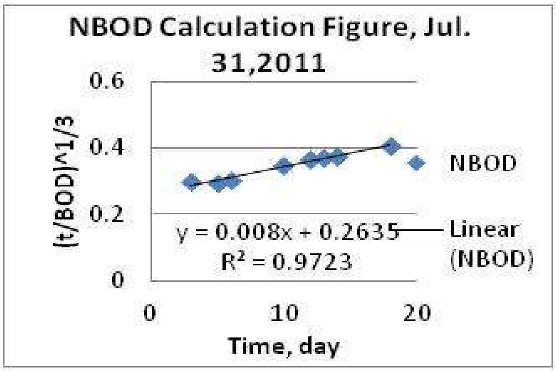
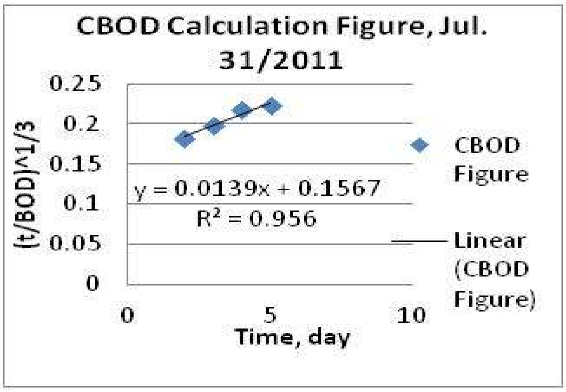

CBOD Calculation Figure, Jan. 30/2012
y = 0.0018x + 0.2951
R² = 0.9997
(t/BOD)^1/3
0.306
0.305
0.304
0.303
0.302
0.301
0
5
10
Time, day
CBOD curve
Linear (CBOD curve)

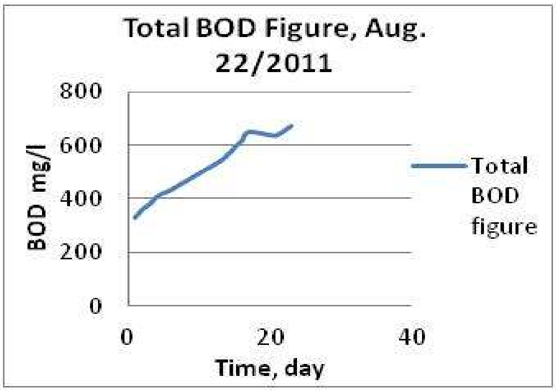
Figure 2: Kinetics Rates Figures for Sampling Point 2

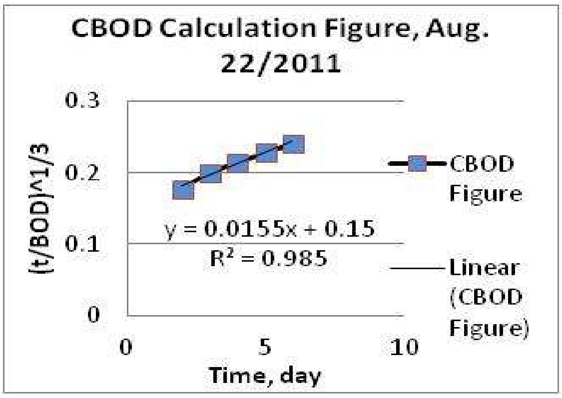


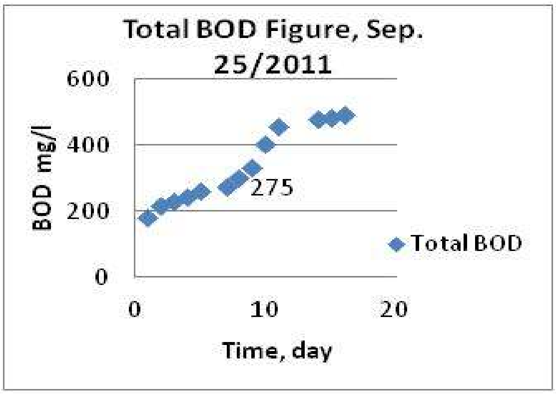

Total BOD Figure, Jul. 31/2011
BOD mg/l
800
600
400
200
0
0
20
40
Time, day
Total BOD Figu...

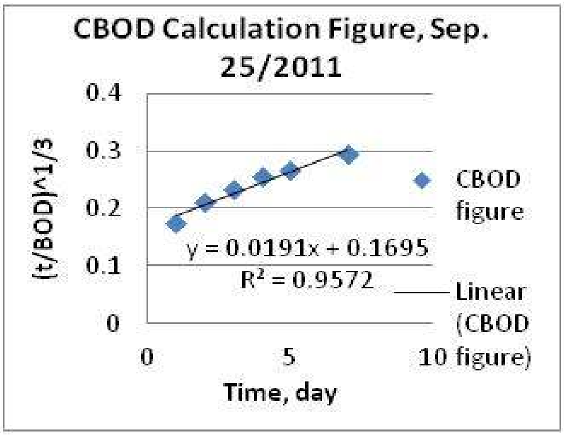

NBOD Calculation Figure, Jul. 31,2011
(t/BOD)^1/3
0.6
0.4
0.2
0
0
10
20
Time, day
y = 0.008x + 0.2635
R² = 0.9723
NBOD
Linear (NBOD)

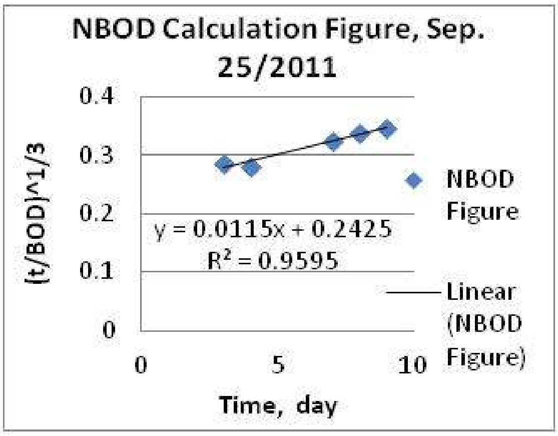

CBOD Calculation Figure, Jul. 31/2011
(t/BOD)^1/3
0.25
0.2
0.15
0.1
0.05
0
0
5
10
Time, day
y = 0.0139x + 0.1567
R² = 0.956
CBOD Figure
Linear (CBOD Figure)

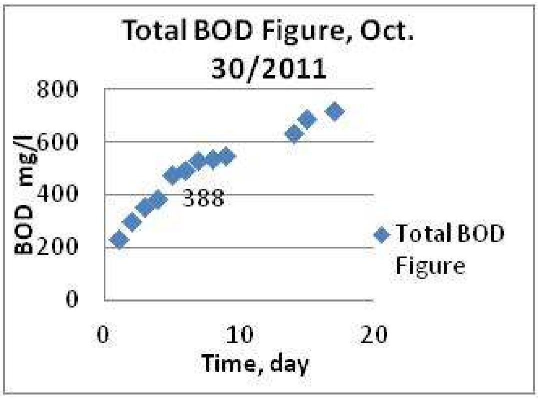

Total BOD Figure, Aug. 22/2011
BOD mg/l
800
600
400
200
0
0
20
40
Time, day
Total BOD figure

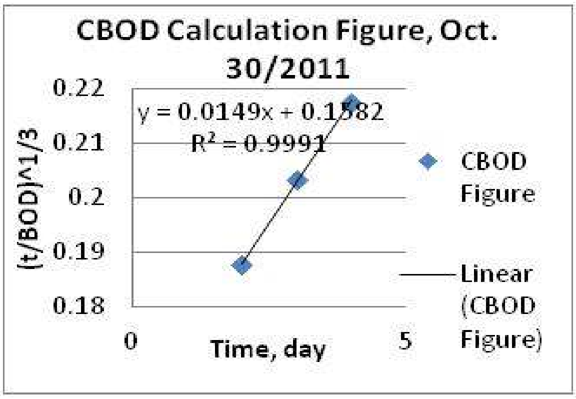

CBOD Calculation Figure, Aug. 22/2011
(t/BOD)^1/3
0.3
0.2
0.1
0
0
5
10
Time, day
y = 0.0155x + 0.15
R² = 0.985
CBOD Figure
Linear (CBOD Figure)

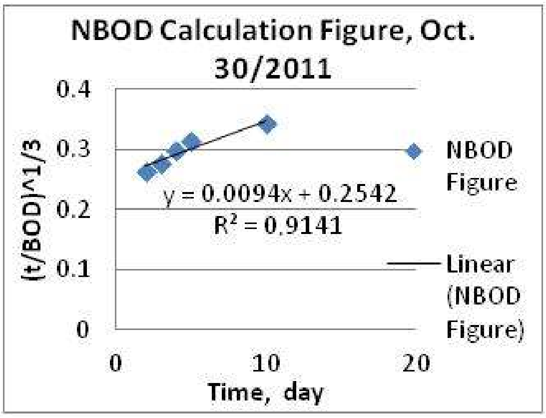

Total BOD Figure, Sep. 25/2011
BOD mg/l
600
400
200
0
0
10
20
Time, day
275
Total BOD

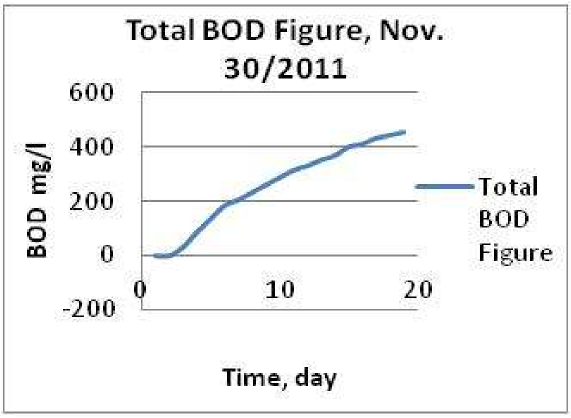

CBOD Calculation Figure, Sep. 25/2011
(t/BOD)^1/3
0.4
0.3
0.2
0.1
0
0
5
10
Time, day
y = 0.0191x + 0.1695
R² = 0.9572
CBOD figure
Linear (CBOD figure)

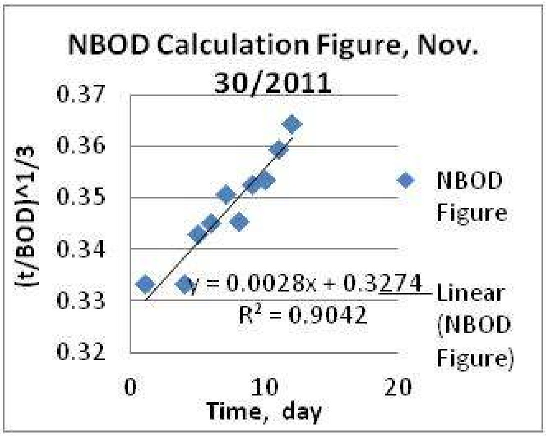

NBOD Calculation Figure, Sep. 25/2011
(t/BOD)^1/3
0.4
0.3
0.2
0.1
0
0
5
10
Time, day
y = 0.0115x + 0.2425
R² = 0.9595
NBOD Figure
Linear (NBOD Figure)

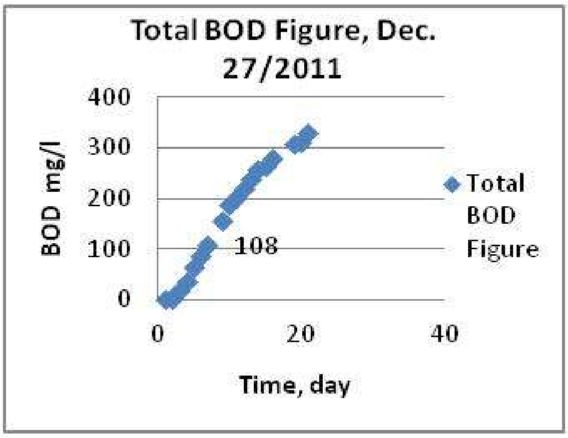

Total BOD Figure, Oct. 30/2011
BOD mg/l
800
600
400
200
0
388
0
10
20
Time, day
Total BOD Figure


CBOD Calculation Figure, Oct. 30/2011
(t/BOD)^1/3
0.22
0.21
0.2
0.19
0.18
y = 0.0149x + 0.1582
R² = 0.9991
0
5
Time, day
CBOD Figure
Linear (CBOD Figure)


NBOD Calculation Figure, Oct. 30/2011
(t/BOD)^1/3
0.4
0.3
0.2
0.1
0
y = 0.0094x + 0.2542
R² = 0.9141
0
10
20
Time, day
NBOD Figure
Linear (NBOD Figure)


Total BOD Figure, Nov. 30/2011
BOD mg/l
600
400
200
0
-200
0
10
20
Time, day
Total BOD Figure


NBOD Calculation Figure, Nov. 30/2011
(t/BOD)^1/3
0.37
0.36
0.35
0.34
0.33
0.32
y = 0.0028x + 0.3274
R² = 0.9042
0
10
20
Time, day
NBOD Figure
Linear (NBOD Figure)


Total BOD Figure, Dec. 27/2011
BOD mg/l
400
300
200
100
0
108
0
20
40
Time, day
Total BOD Figure

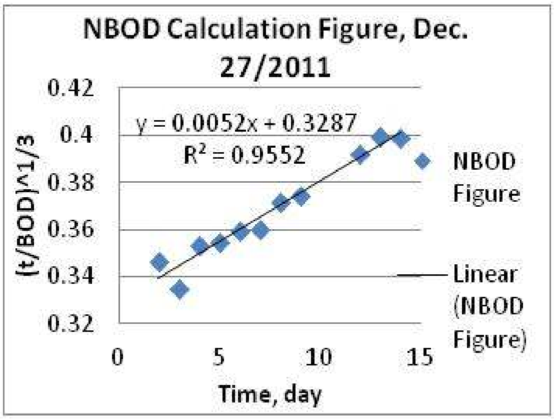
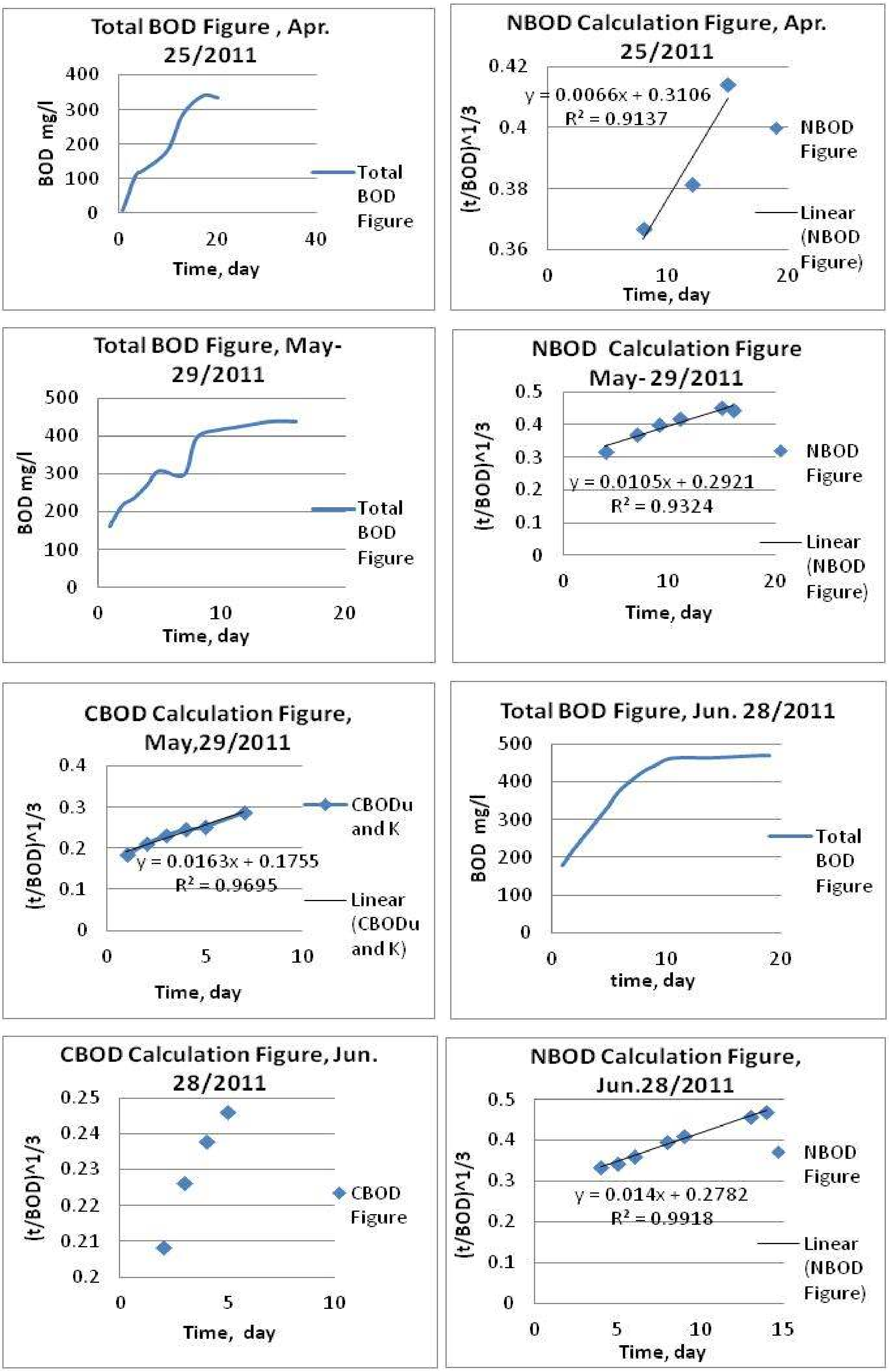
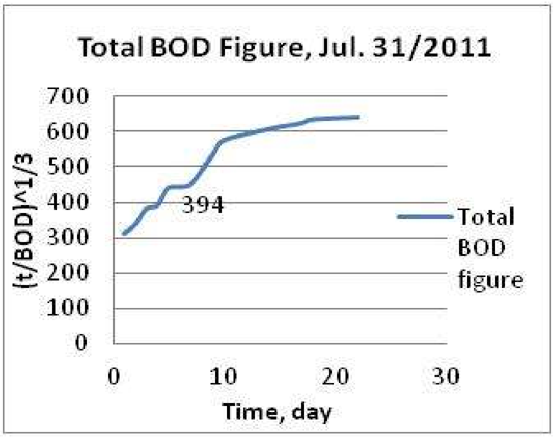
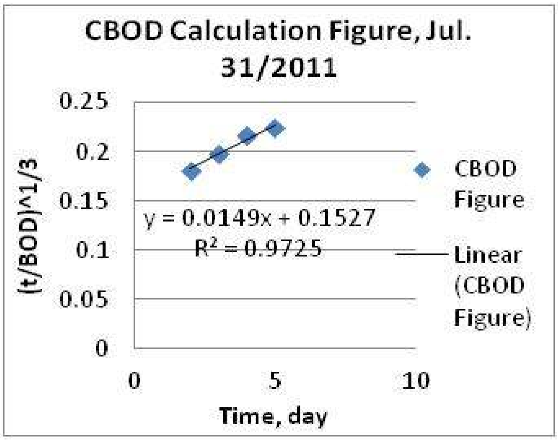
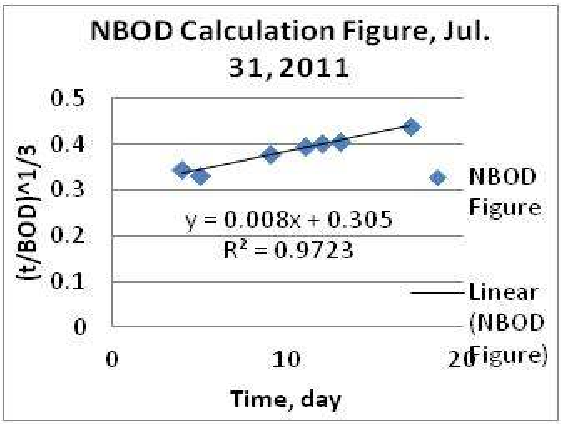

NBOD Calculation Figure, Dec. 27/2011
(t/BOD)^1/3
0.42
0.4
0.38
0.36
0.34
0.32
y = 0.0052x + 0.3287
R² = 0.9552
0
5
10
15
Time, day
NBOD Figure
Linear (NBOD Figure)

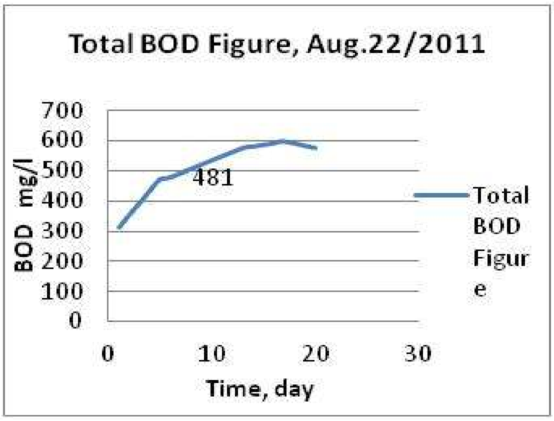
Figure 3: Kinetics Rates Figures for Sampling Point 3.

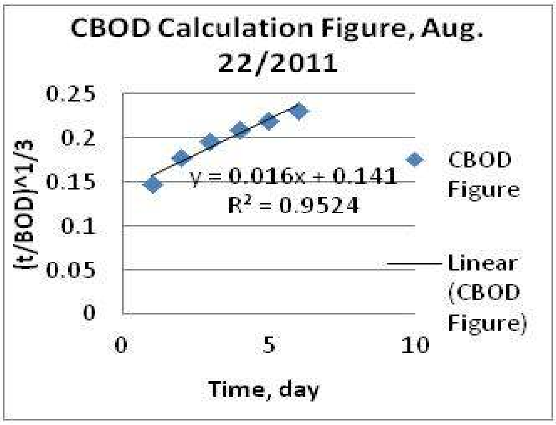


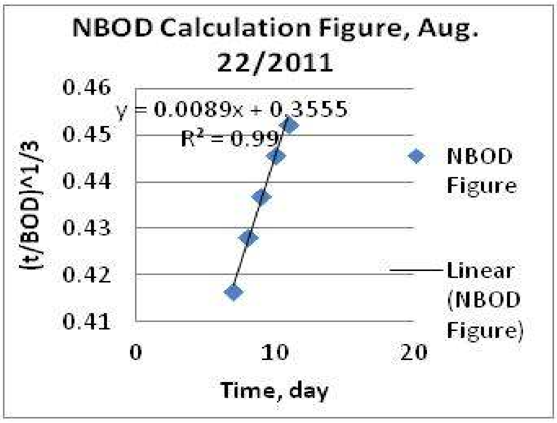

Total BOD Figure, Jul. 31/2011
(t/BOD)^1/3
700
600
500
400
300
200
100
0
394
Total BOD figure
0
10
20
30
Time, day

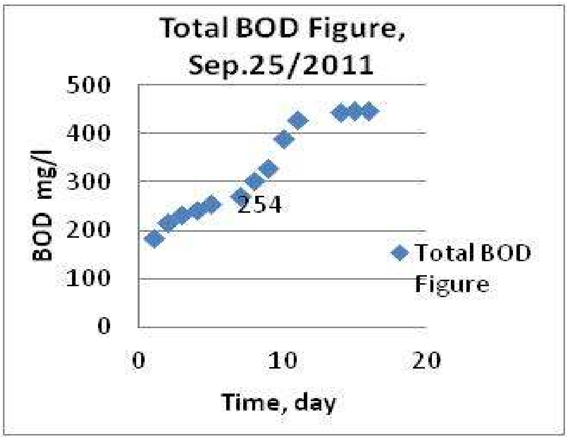

CBOD Calculation Figure, Jul. 31/2011
(t/BOD)^1/3
0.25
0.2
0.15
0.1
0.05
0
y = 0.0149x + 0.1527
R² = 0.9725
CBOD Figure
Linear (CBOD Figure)
0
5
10
Time, day

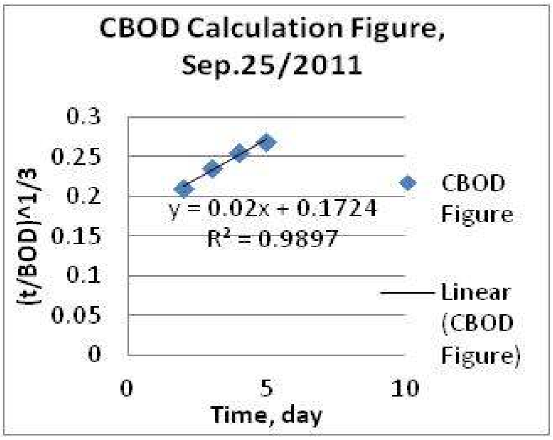

NBOD Calculation Figure, Jul. 31,2011
(t/BOD)^1/3
0.5
0.4
0.3
0.2
0.1
0
y = 0.008x + 0.305
R² = 0.9723
NBOD Figure
Linear (NBOD Figure)
0
10
20
Time, day

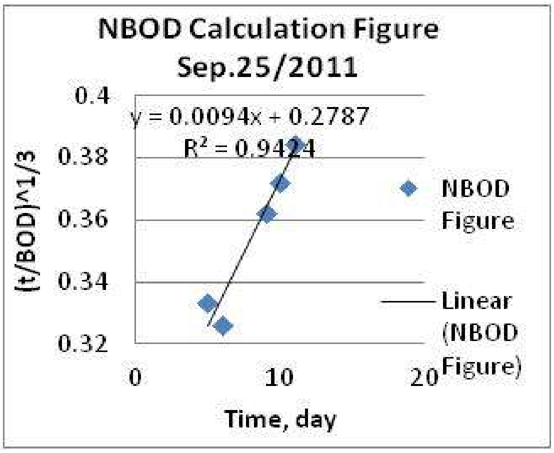

Total BOD Figure, Aug.22/2011
BOD mg/l
700
600
500
400
300
200
100
0
481
Total BOD Figure
0
10
20
30
Time, day

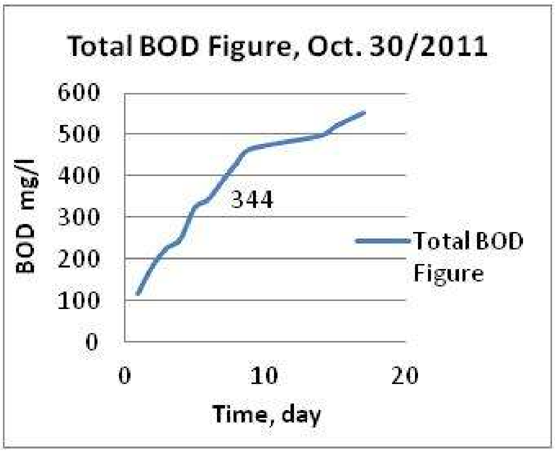

CBOD Calculation Figure, Aug. 22/2011
(t/BOD)^1/3
0.25
0.2
0.15
0.1
0.05
0
y = 0.016x + 0.141
R² = 0.9524
CBOD Figure
Linear (CBOD Figure)
0
5
10
Time, day

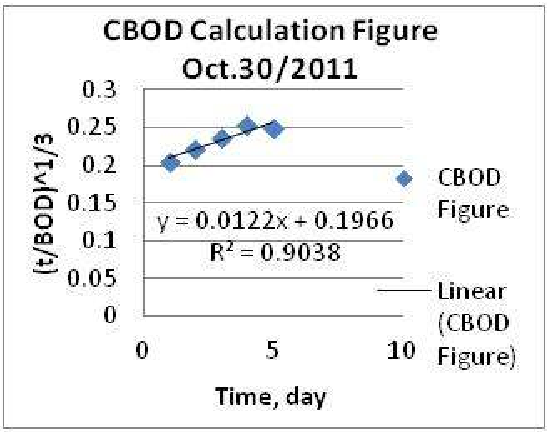

NBOD Calculation Figure, Aug. 22/2011
(t/BOD)^1/3
0.46
0.45
0.44
0.43
0.42
0.41
y = 0.0089x + 0.3555
R² = 0.99
NBOD Figure
Linear (NBOD Figure)
0
10
20
Time, day

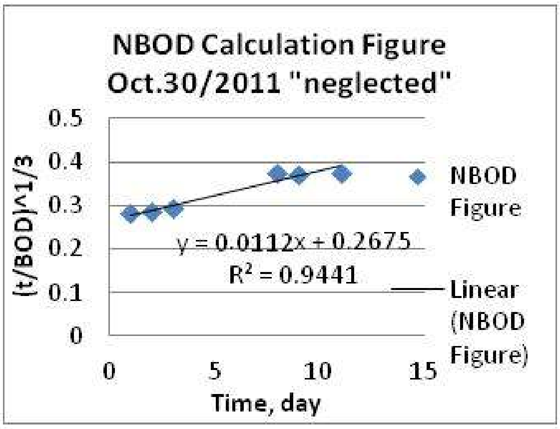

Total BOD Figure, Sep.25/2011
BOD mg/l
500
400
300
200
100
0
254
Total BOD Figure
0
10
20
Time, day

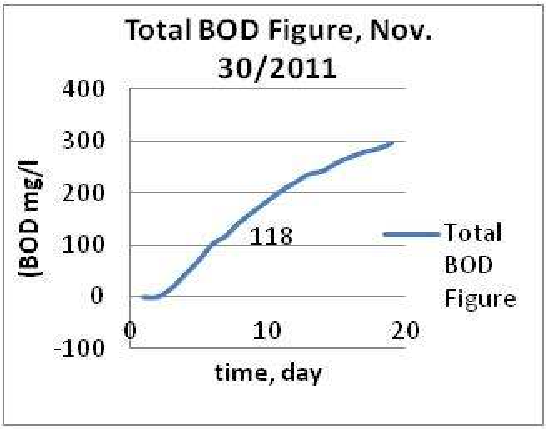

CBOD Calculation Figure, Sep.25/2011
(t/BOD)^1/3
0.3
0.25
0.2
0.15
0.1
0.05
0
y = 0.02x + 0.1724
R² = 0.9897
CBOD Figure
Linear (CBOD Figure)
0
5
10
Time, day


NBOD Calculation Figure Sep.25/2011
y = 0.0094x + 0.2787
R² = 0.9424
(t/BOD)^1/3
Time, day
NBOD Figure
Linear (NBOD Figure)


Total BOD Figure, Oct. 30/2011
344
BOD mg/l
Time, day
Total BOD Figure


CBOD Calculation Figure Oct.30/2011
y = 0.0122x + 0.1966
R² = 0.9038
(t/BOD)^1/3
Time, day
CBOD Figure
Linear (CBOD Figure)


NBOD Calculation Figure Oct.30/2011 "neglected"
y = 0.0112x + 0.2675
R² = 0.9441
(t/BOD)^1/3
Time, day
NBOD Figure
Linear (NBOD Figure)


Total BOD Figure, Nov. 30/2011
118
(BOD mg/l
time, day
Total BOD Figure

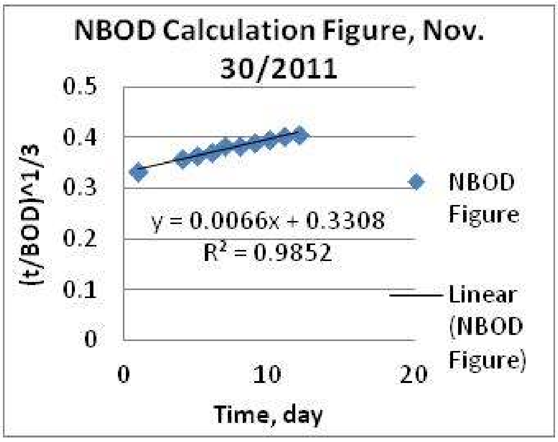
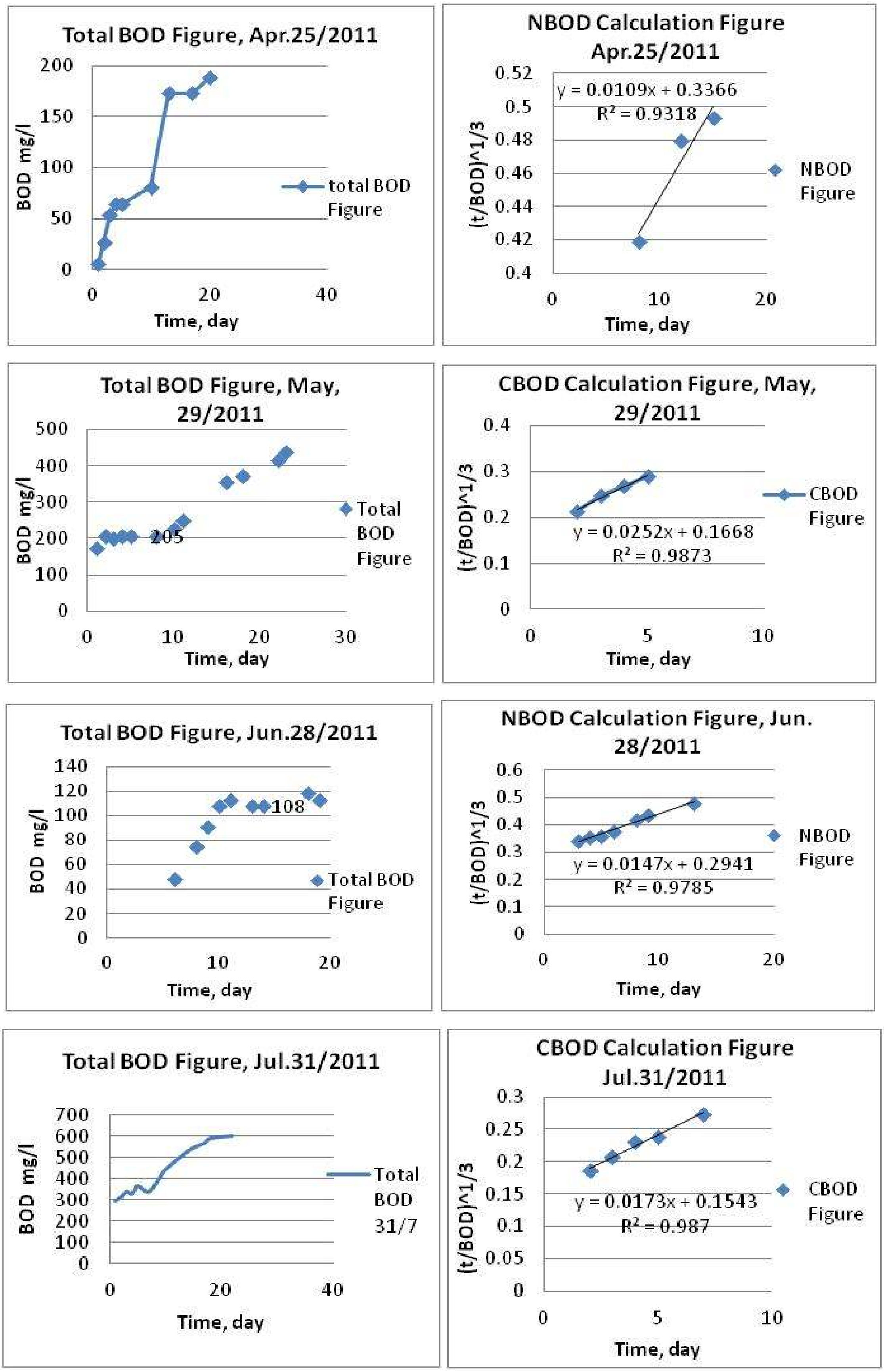
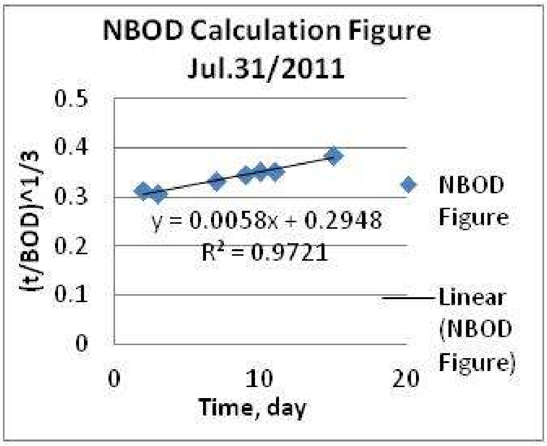
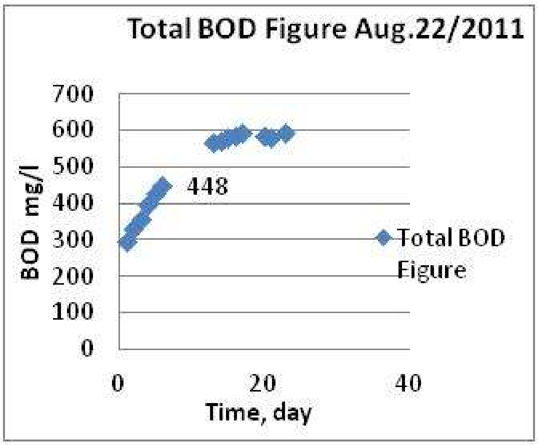
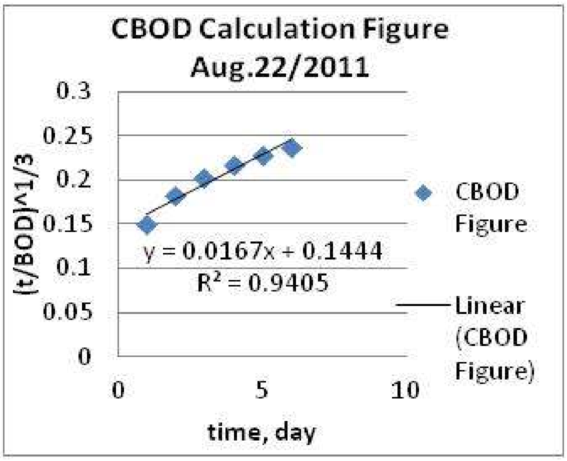

NBOD Calculation Figure, Nov. 30/2011
y = 0.0066x + 0.3308
R² = 0.9852
(t/BOD)^1/3
Time, day
NBOD Figure
Linear (NBOD Figure)

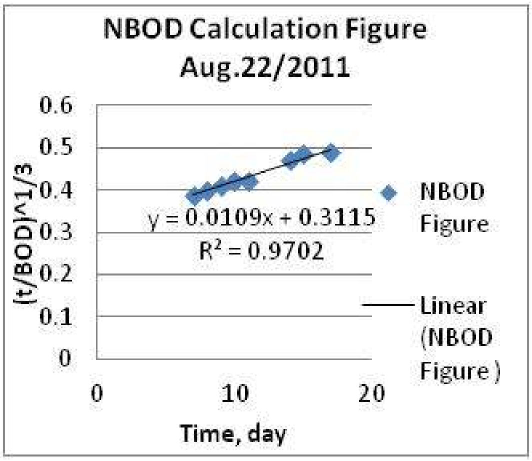
Figure 4: Kinetic rates Figures for Sampling Point 4.

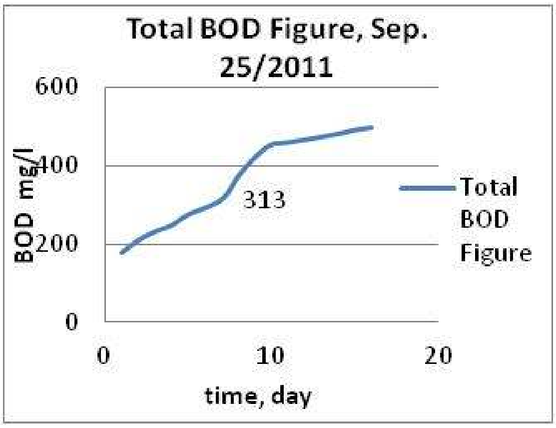


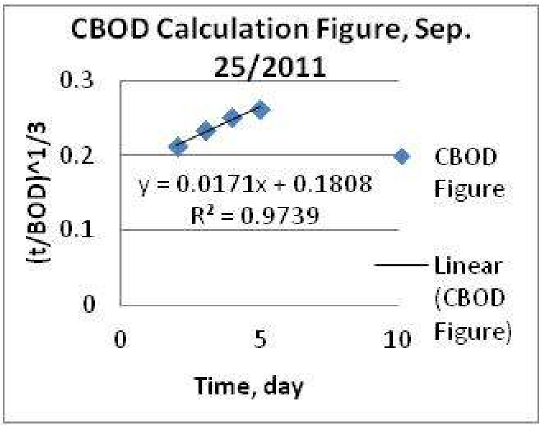

NBOD Calculation Figure Jul.31/2011
0.5
0.4
0.3
0.2
0.1
0
(t/BOD)^1/3
y = 0.0058x + 0.2948
R² = 0.9721
0
10
20
Time, day
NBOD Figure
Linear (NBOD Figure)

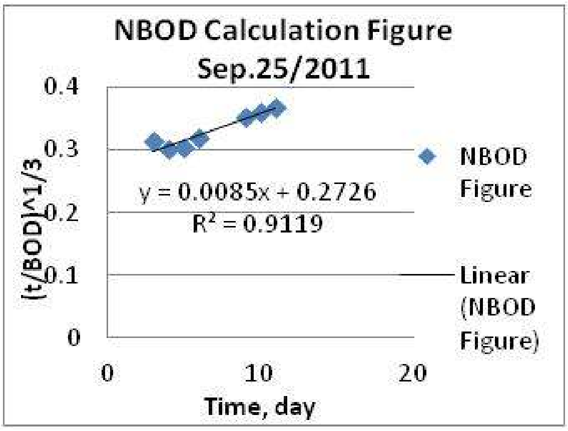

Total BOD Figure Aug.22/2011
700
600
500
400
300
200
100
0
BOD mg/l
448
0
20
40
Time, day
Total BOD Figure

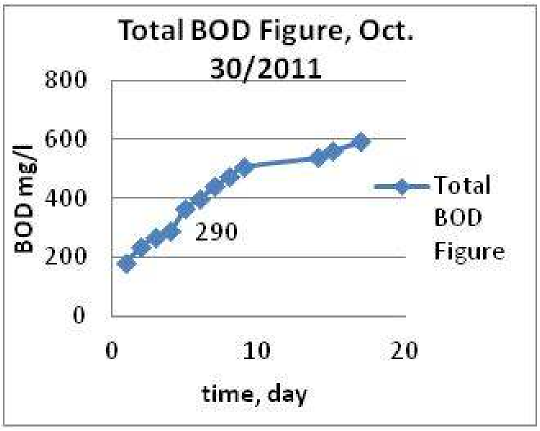

CBOD Calculation Figure Aug.22/2011
0.3
0.25
0.2
0.15
0.1
0.05
0
(t/BOD)^1/3
y = 0.0167x + 0.1444
R² = 0.9405
0
5
10
time, day
CBOD Figure
Linear (CBOD Figure)


NBOD Calculation Figure Aug.22/2011
0.6
0.5
0.4
0.3
0.2
0.1
0
(t/BOD)^1/3
y = 0.0109x + 0.3115
R² = 0.9702
0
10
20
Time, day
NBOD Figure
Linear (NBOD Figure)


Total BOD Figure, Sep. 25/2011
600
400
200
0
BOD mg/l
313
0
10
20
time, day
Total BOD Figure


CBOD Calculation Figure, Sep. 25/2011
0.3
0.2
0.1
0
(t/BOD)^1/3
y = 0.0171x + 0.1808
R² = 0.9739
0
5
10
Time, day
CBOD Figure
Linear (CBOD Figure)


NBOD Calculation Figure Sep.25/2011
0.4
0.3
0.2
0.1
0
(t/BOD)^1/3
y = 0.0085x + 0.2726
R² = 0.9119
0
10
20
Time, day
NBOD Figure
Linear (NBOD Figure)


Total BOD Figure, Oct. 30/2011
800
600
400
200
0
BOD mg/l
290
0
10
20
time, day
Total BOD Figure

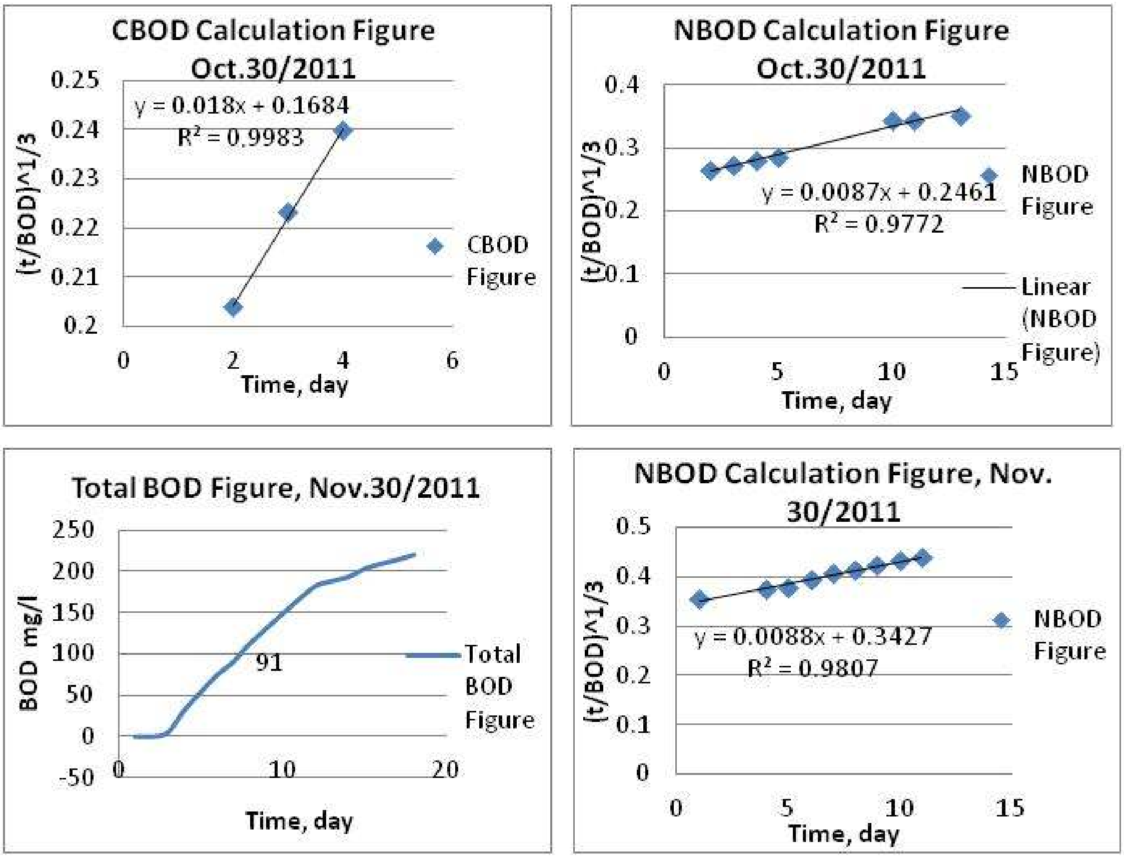
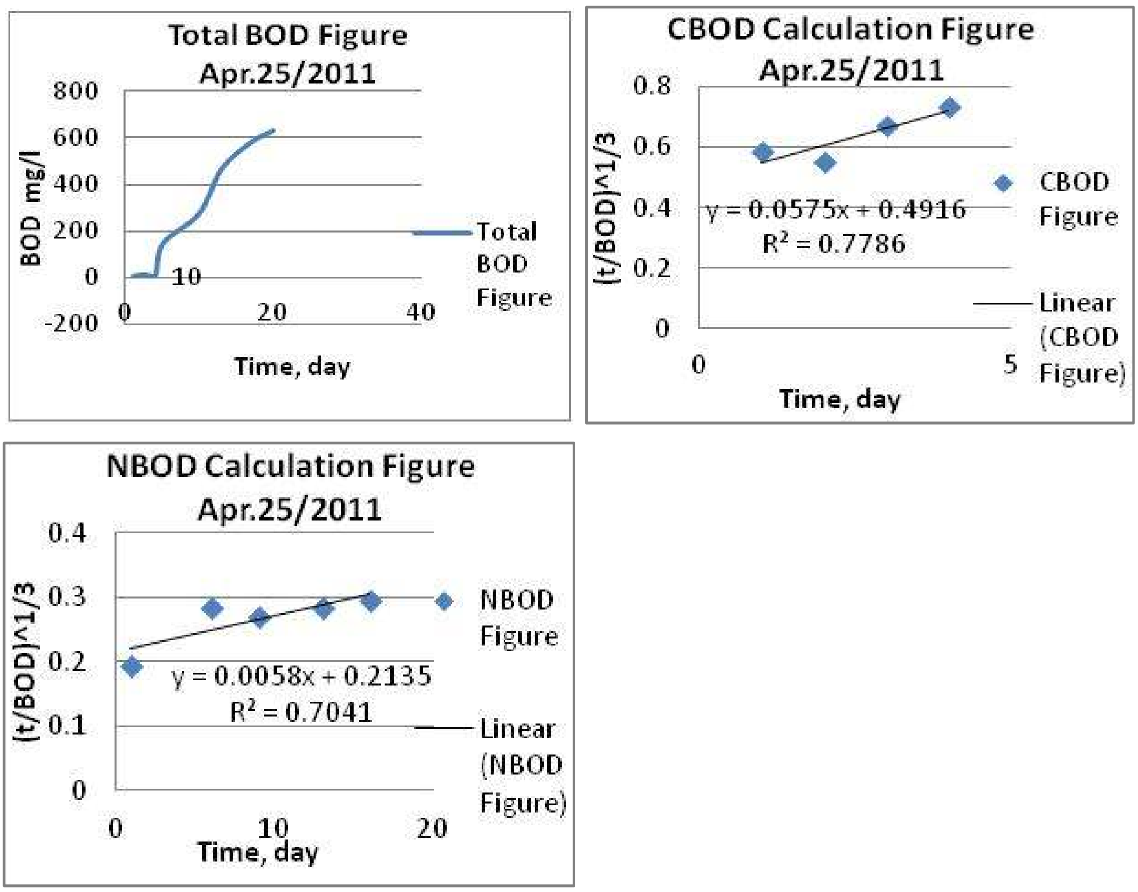


Figure 5: Kinetic rates Figures For Sampling Point 5.



C.2 Kinetic Parameters' Results.

Sampling Date	Sampling Points and Parameters in mg/l							
	Sampling Point 1				Sampling Point 2			
	BOD_5	CBOD	NBOD	BODu	BOD_5	CBOD	NBOD	BODu
Mar.10/2011			91					
Apr.25/2011	519	904	668	1572	167	failed	178	failed
May29/2011	648	761	678	1439	264	269	286	555.6
Jun.28/2011	1058	1061	689	1750	297	357	332	689
Jul.31/2011	1016	1092	680	1773	454	493	332	825
Aug.22/2011	908	967	407.8	1375	421	443	failed	failed
Sep.25/2011	1178	1282	480.3	1762	264	273	238	511.
Oct.30/2011	778	901	684	1585	474	461	297	757.6
Nov.30/2011	550	2065	1455	3520	135	failed	728	failed
Dec.27/2011	481	884	668	1552	64	failed	305	failed

Sampling Date	Sampling Points and Parameters in mg/l							
	Sampling Point 3				Sampling Point 4			
	BOD_5	CBOD	NBOD	BODu	BOD_5	CBOD	NBOD	BODu
Mar.10/2011								
Apr.25/2011	124	Failed	267.5	failed	64	failed	143.3	failed
May29/2011	308	324	162	494	205	211	failed	failed
Jun.28/2011	335	376	154	530	failed	failed	142	failed
Jul.31/2011	443	473	220	693	367	394	370.	764
Aug.22/2011	475	491	153	645	427	443	157.7	600.4
Sep.25/2011	254	265	229	493	275	277	258.7	535.3
Oct.30/2011	322	349	157	507	364	316	335.6	651.4
Nov.30/2011	70	failed	247.5	failed	54	failed	failed	failed
Dec.27/2011	37	failed	failed	failed	37	failed	failed	failed

Sampling Date	Sampling Points and Parameters in mg/l							
	Sampling Point 5							
	BOD_5	CBOD	NBOD	BODu	BOD_5	CBOD	NBOD	BODu
Mar.10/2011	failed	failed	failed					
Apr.25/2011	145	11.4	631.5	643				
Jul.31/2011	291	279.7	88.6	368.3				
Aug.22/2011	302	329.7	6.4	336				
Nov.30/2011	failed	failed	failed					
Dec.27/2011	failed	failed	failed					

Research Obstacles

Flow Measurement:

The use of manmade equipment for depth measurement could n’t give detailed measurements of increments’ depth for cross sections and the results is approximation of a cross section depth, besides big rocks and garbages that slow or stop floating object at some times. These reasons may consider error sources in flow measurements and getting inaccurate results which can n’t be useful in modeling results comparison.

BOD Test:

What is worth to say here is, the incubator of BOD bottles was without stirrer used through the research. These circumstances were constant or the same for all experiments through the sampling period and analysis.


Faria Stream, October 2012.
By : Afaf Alawneh, Modeling of Water
Quality and Quantity For Faria Stream.

جامعة النجاح الوطنية
كلية الدراسات العليا

نمذجة نوعية المياه في وادي الفارعة

إعداد
عفاف تيسير علاونة

إشراف
د. نعمان مزيد
د. عبد الفتاح حسن

قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة المياه والبيئة بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.
2013م

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الملخص

الدراسات التي تعنى بنوعية المياه تعتبر أحدى الأدوات التي تستخدم لإدارة المصادر المائية من حيث تقييم الوضع الحالي لتلك المصادر المائية ومدى اختلافها عن معايير جودة المياه إن وجدت، وتحديد المعالجة المطلوبة لمصدر أو للجسم المائي المعني بالدراسة، وهذا الحال في منطقة الفارعة ووادي الفارعة الذي يقع تحت تأثير التلوث الناتج من ضخ المياه العادمة الغير معالجة من شرق مدينة نابلس بالإضافة إلى التلوث الناتج عن استخدامات الأراضي في منطقة الفارعة كان ذلك السبب في اختياره للدراسة في هذا البحث. إذ يهدف البحث إلى تحديد وتقييم الوضع الحالي لواد الفارعة ونمذجته باستخدام (QUAL2Kw model) وتوقع التغييرات المحتملة على الوادي وطرق الإدارة وإعادة التأهيل للوادي.

بتقييم الوضع الحالي لوادي الفارعة نتج أن المياه العادمة التي تتدفق أو تُضَخْ من شرق مدينة نابلس هي الملوث الأساسي والرئيسي للوادي نتيجة القيم العالية المقاسة لمعدل المعايير الدالة على نوعية المياه فكان TDS = 2000 TSS = 1614 , TKN = 233 ملغم/لتر.

كذلك قراءات الأكسجين المذاب بالماء DO = 0.34 في أعلى الوادي وقراءات ال BOD التي تعبر عن كمية الأكسجين اللازم لتحلل الملوثات العضوية في الوادي، وحدث تغيير واضح وكبير على هذه القيم خلال المجرى نتيجة عمليات التحلل الطبيعية التي تحدث، وتم نمذجة هذا الوضع للوادي في ثلاث حالات: فصل الصيف بأخذ أكبر تلوث يحدث وأكبر قيمة للملوثات في الوادي معبر عنها بال BOD، والحالة الثانية لفصل الشتاء بأخذ أقل تدفق بالمجرى minimum flow إذ يكون مصاحب لأقل تخفيف أو dilution minimum ، والحالة الثالثة

التي تم نمذجتها هي وضع اقل DO إذا صادف مع أقل تدفق minimum flow لوادي الفارعة، وهنالك توافق بين القيم الحقيقية ونتائج النمذجة في قياسات التدفق flow و ال DO, كذلك ظهر توافق في الاتجاه المعبر عن حاجة الرواسب للأكسجين Sediment Oxygen Demand (SOD) بالرغم من الاختلاف بالقيم.

أدارة وإعادة تأهيل وادي الفارعة ممكنة باستخدام وسائل مختلفة :

- إجراءات أو تقنيات إنشائية تحدث تغيير فيزيائي في مجرى الوادي و تضم: انشاء محطة معالجة للمياه العادمة في اعلى الوادي تم نمذجتها لتعطي قراءات DO من 2 ملغم/لتر بعد المعالجة مباشرة ألى حوالي 5.56 ملغم/لتر بعد جريان ما يقارب 7.77 كم, حتى يصل DO في نهاية الوادي إلى 8.6 ملغم/لتر و التي تؤثر بشكل كبير على نوعية المياه في الوادي إذ تصبح ظروف الوادي مناسبة لشتى انواع الحياه المائية, و غذا تم مراعاة الارشادات والمعايير الفلسطينية فيما يتعلق بالمسببات المرضية (fecal coliform and pathogens) يصبح التدفق بالوادي مناسباً للاستخدامات الزراعية حسب الارشادات الفلسطينية المحددة لذلك. من الاجراءات التي تساعد على تاهيل اوادي أيضاً: منع انجراف حواف الوادي باستخدام الأسلال الحجرية و الرصفات حسب الواد الانشائية المتوفرة لذلك إذ توجد هذه الاجراءات وتستخدم في الجزء السفلي من الوادي قرب عين شبلة , كذلك التهوية للتدفق باستخدام ال ladders and waterfalls التي ترفع نسبة ال DO مما يضمن ظروف و نوع افضل للمياه, بالاضافة ألى تنظيف قناة الوادي من الاوساخ والنفايات و ازالة العوائق التي تتشكل نتيجة الامطار و الفيضانات.

- إجراءات و تقنيات غير انشائية اذ تضم بالغالب إجراءات إدارية و تنظيمية دون تغيير فعلي لمجرى الوادي او النهر مثل: زراعة منطقة حماية حول صفاف الوادي لتثبيت التربة ومنع الانجراف و التظليل على مياه الوادي بالاضافة إلى انها تعمل كضبط للفيضانات وتقليل نسبة الجريان السطحي الرواسب التي يحملها, من الوسائل الاخرى التي تساعد في تحسين نوعية المياه في وادي الفارعة أيضاً تحديد ما يسبب التلوث في منطقة الفارعة

والوادي كتحديد نوع كمية السماد المستخدم كذلك تحديد أوقات اضافته هذا كله يساعد في تخفيف التلوث والسيطرة عليه، كذلك تحسين ظروف الصرف الصحي للمناطق المحيطة بالوادي, وتنظيم الاستخدامات الموجودة في المنطقة التي قد تؤدي إلى تدهور في نوعية المياه واقتراح البدائل وطرق الوقاية الممكنة لتقليل تلوث مياه وادي الفارعة.