PREDICTION ON WATER QUALITY OF POINT SOURCE POLLUTION FOR LUNCHOO RIVER, JOHOR

RAFIDAH BINTI SHAHPERI

A project report submitted in fulfillment of
the requirement for the award of the degree of
Master of Engineering (Civil - Hydraulic and Hydrology)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

NOVEMBER, 2010

Dedicated to…

My beloved ayah, mak for giving me infinite love, support, care and blessing

Friends and lectures…

"Thank for your encouragement and advices"

ACKNOWLEDGEMENTS

In the name of ALLAH, THE MOST GRACIOUS AND THE DISPANCER OF GRACE, I would like to deeply praise for the blessing and blissfulness for allowing me passing all of this moment and accomplished this report in time and presentably.

In particular, I wish to express my deep appreciation to my research supervisor Dr Mohd Fadhil b. Md. Din and Dr. Zulhilmi Ismail for his continual guidance and encouragement during the preparation of this research thesis.

My sincere thanks also goes to my beloved and faithful friends whom had always be side in any situation that I faced. To Mohamed Nazri b Bajuri, thank you very much for the help, support and courage.

I deeply express my appreciation to my beloved parents, and to all of my ever-loving family for their love, care, support, great patience and everything and to all people who had rendered help in making this project success.

May Allah reward them for all the kindness and sincere.

ABSTRACT

The growth in population and expansion in urbanization, industrialization and irrigated agriculture are imposing growing demands and pressure on water resources, besides contributing to raise water pollution. As a case in point, Lunchoo River was initiated to be the contribution of water quality deterioration with regional consequences on the aquatic ecosystem and on the health of the downstream sub-basin's user group. Thus, a balance strike between those developments and a good quality of life that has to be considered in the complex relationship between water quality and quantity on one hand and human health and well being on the other. In this study, a limitation on point sources pollutant and low flow condition are accounted for industrialization sectors within Lunchoo River catchment boundary. Approached of Mass Balance concepts are put into practice in order to analyze the situation. However, an understanding of the existing river characteristic and waste stream characteristic is deemed necessary to determine the background level of pollutant. Output generated from this study is important because it is a vital key toward an optimal management of its resources. Then, comparison between the current standard limit or guideline and the result achieved will determine the stage of pollutant. Therefore, the outcome of this study will determine the water quality of Lunchoo River and it is one of the initiative to ensure the water quality and environment been properly manage at Lunchoo River, as it is the most important sources of raw water to satisfy the clean water supply demand for the entire Johore State and also Singapore.

.

ABSTRAK

Pertumbuhan penduduk dan pemesatan pembangunan dalam sektor perbandaran, pengindustrian dan pengairan pertanian telah menyebabkan peningkatan permintaan yang mendadak dan seterusnya member impak kepada bekalan sumber air bersih selain menyumbang kepada peningkatan pencemaran sungai. Dalam kajian ini, Sungai Lunchoo telah dikenalpasti sebagai satu contoh terbaik yang merujuk kepada kemerosotan kualiti air akibat yang memberi impak kepada ekosistem akuatik setempat dan pada juga kesihatan bagi kumpulan pengguna di hilir sungai terutamanya. Jesteru itu,perlu ada keseimbangan antara pembangunan dan satu kualiti hidup baik yang perlu dipraktiskan dalam hubungan kompleks antara kualiti air dan kuantitinya dan pada masa yang sama kesihatan dan kesejahteraan manusia dapat di capai. Dalam kajian ini, had telah ditetapkan adalah merujuk pada pencemaran sumber bertitik dan keadaan aliran rendah adalah dikira bagi kawasan pengindustrian di Sungai Lunchoo. Kaedah yang menggunapakai konsep Mass Balance dipraktikkan sebagai medium untuk menganalisis data. Walaubagaimanapun , perlu adanya kefahaman yang mendalam terhadap kriteria sediaada sungai dan juga sisa aliran dari kawasan industri yang mana ia amat diperlukan dalam menentukan aras pencemaran sungai tersebut. Hasil dari kajian ini adalah penting kerana ia adalah satu kunci ke arah satu pengurusan optimum terhadap sumber-sumbernya. Kemudiannya, perbandingan antara had standard semasa atau garis panduan dan keputusan yang diperolehi dilakukan yang mana ia akan menentukan pencemaran sungai tersebut. Seterusnya, hasil kajian ini dapat menentukan kualiti air Sungai Lunchoo dan ia merupakan satu inisiatif dalam memastikan kualiti air dan persekitaran dapat diurus dengan sewajarnya sementelah ianya merupakan sumber penting air mentah dalam memastikan permintaan bekalan air bersih untuk seluruh Johor dan juga Singapura dapat dipenuhi.

TABLE OF CONTENTS

CHAPTER		PAGE
	THESIS TITLE	
	DECLARATION SHEET	i
	DEDICATION	ii
	ACKNOWLEDGEMENTS	iii
	ABSTRACT	iv
	ABSTRAK	v
	TABLE OF CONTENTS	vi
	LIST OF FIGURES	x
	LIST OF TABLES	xi
	LIST OF SYMBOLS AND ABREVIATIONS	xiv
	LIST OF APPENDICES	xvi
CHAPTER I	**INTRODUCTION**	
1.1	Introduction	1
1.2	Background of Study	3
1.3	Problem Statement	3
1.4	Aims of Study	6
1.5	Objectives of Study	7

1.6 Scope of Study 7
1.7 Limitation of Study 7
1.8 Significant of Study 8

CHAPTER II LITERATURE REVIEW

2.1 Introduction 9
2.2 Water pollution 9
2.2.1 Point Sources Pollution 10
2.2.2 Non Point Source Pollution 12
2.3 Water Quality 14
2.3.1 Water Quality Parameter 15
2.4 Low Flow Information 18
2.5 Prediction on Water Quality Parameter 19
2.6 Water Quality Analysis 22

CHAPTER III RESEARCH METHODOLOGY

3.1 Introduction 23
3.2 Study Area 23
3.2.1 Surrounding Land Use 25
3.3 Water Quality Monitoring 27
3.3.1 Sampling Station 27
3.3.3 River Monitoring Result 28
3.4 Mass Balance Concept 28
3.5 Dissolved Oxygen Sag Equation 31
3.5.1 Temperature Effect 31

3.5.2 Reaeration Coefficient 32
3.5.3 Rate of Deoxygenation, kd 32
3.5.4 Oxygen Deficit, Da 33
3.5.5 Saturation of DO 33
3.5.6 Critical Point 33

CHAPTER IV ANALYSIS AND RESULT

4.1 Introduction 35
4.2 River Characteristic 35
4.2.1 Low Flow Analysis 36
4.2.2 River Quality 38
4.2.3 River Concentration and Loads 39
4.2.4 Area of Estimation 41
4.2.5 Peak flow analysis using Rational Method 42
4.3 Wastewater Characteristic 46
4.3.1 Population Equivalent 46
4.3.2 BOD Expected Concentration 51
4.3.3 TSS Expected Concentration 55
4.4 Mass Balance Analysis 64
4.4.1 DO Sag Equation Result 66

CHAPTER V DISCUSSIONS AND RECOMMENDATIONS

5.1 Introduction 68
5.2 Option 1: Extended Aeration (EA) Tank 68
5.3 Option 2: Detention Pond 73

5.3.1 Estimation on Peak Discharge, Qp 73
5.3.2 Calculation 75

CHAPTER VI CONCLUSIONS 79

REFERENCES 81

APPENDICES 84

LIST OF FIGURES

No	Title	Page
1.1	Lunchoo River waterways	4
1.2	Main Point Sources Pollution areas in Lunchoo River Basin	6
3.1	Lunchoo River Catchment Boundary	25
3.2	Surrounding Development for Lunchoo River	26
4.1	Low flow results correspond to 7Q10	38
4.2	Subcatchment of Lunchoo River	42
4.3	Runoff Coefficients and Rainfall Intensity for Urban Catchments	45

LIST OF TABLES

No	Title	Page
1.1	Point Sources Pollution	5
2.1	DOE Water Quality Classification Based on Water Quality Index	20
2.2	Interim National Water Quality Standards for Malaysia	20
2.3	Sub index Parameters to calculate DOE-WQI	21
3.1	Areas nearby the proposed Site	26
3.2	Description of Water Monitoring Station	27
3.3	Current River Water Quality Results during Low Tide	28
3.4	Velocity Assumption base on Bottom Substrate of River	32
4.1	Minimum for 7-Day Average Rainfall Intensity for 10 years Record	36
4.2	Minimum flowrate Discharge for 10 years record data	37
4.3	Results for Cumulative Probability of Occurrence and Recurrence Interval	37
4.4	Water Quality Index Result during Low Tide	39
4.5	BOD total load for Lunchoo River per day	40
4.6	TSS total load for Lunchoo River per day	40
4.7	Runoff Coefficient for Rational Formula	43
4.8	Typical per capita unit loads	48
4.9	Population equivalents of wastewater from some industries	48
4.10	Typical Ranges of TSS Mean Concentrations of conventional and several classic nonconventional pollutants in wastewater from selected point sources categories	50
4.11	BOD Concentration at Taman Perindustrian Seri Plentong	52

4.12(a)	BOD Concentration at Taman Perindustrian Kota Puteri	52
4.12(b)	BOD Concentration at Taman Perindustrian Kota Puteri (Cont.)	53
4.13	BOD Concentration at Jalan Bukit 1,2,3 and Bukit Lunchoo	54
4.14	BOD Average Concentration after set Up Target for Industries at Jalan Bukit 1,2,3 and Bukit Lunchoo	55
4.15	Estimation on the components of TSS in wastewater for point sources	56
4.16	TSS PE for Industrial at Taman Perindustrian Seri Plentong	56
4.17	TSS PE for Industrial at Jalan Bukit 1,2,3 and Bukit Lunchoo	57
4.18(a)	TSS PE for Industrial at Taman Perindustrian Kota Puteri	57
4.18(b)	TSS PE for Industrial at Taman Perindustrian Kota Puteri (Cont.)	58
4.19(a)	TSS Average Concentration for Industrial at Taman Perindustrian Seri Plentong	59
4.19(b)	TSS Average Concentration after Set up Target for Industries at Taman Perindustrian Seri Plentong (Cont.)	60
4.20(a)	TSS Average Concentration for Industrial at Jalan Bukit 1,2,3 and Bukit Lunchoo	60
4.20(b)	TSS Average Concentration after Set up Target for Industrial at Jalan Bukit 1,2,3 and Bukit Lunchoo (Cont.)	61
4.21(a)	TSS Average Concentration for Industrial at Taman Perindustrian Kota Puteri	61
4.21(b)	TSS Average Concentration after Set up Target for Industrial at Taman Perindustrian Kota Puteri (Cont.)	63
4.22	Mass Loading for BOD effluent	65
4.23	BOD Concentration for Lunchoo River effluent	65
4.24	Mass Loading for TSS final effluent	65
4.25	TSS Concentration for Lunchoo River effluent	66
4.26(a)	River Characteristic for Lunchoo River	66
4.26(b)	Sewerage Characteristic for Lunchoo River	66
4.27	Initial Deficit for Dissolved Oxygen	67

4.28	Initial Ultimate for BOD	67
4.29	Critical Condition for Lunchoo River	67
5.1(a)	BOD Concentration for Industrial area Jalan Bukit 1,2,3 and Bukit Lunchoo	70
5.1(b)	BOD Concentration for Industrial area Jalan Bukit 1,2,3 and Bukit Lunchoo (Cont.)	71
5.2(a)	TSS Concentration for Industrial area Taman Perindustrian Seri Plentong	71
5.2(b)	TSS Concentration for Industrial area Taman Perindustrian Seri Plentong (Cont.)	71
5.3(a)	TSS Concentration for Industrial area at Jalan Bukit 1,2,3 and Bukit Lunchoo	71
5.3(b)	TSS Concentration for Industrial area at Jalan Bukit 1,2,3 and Bukit Lunchoo (Cont.)	71
5.4(a)	TSS Concentration for Industrial area at Taman Perindustrian Kota Puteri	72
5.4(b)	TSS Concentration for Industrial area at Taman Perindustrian Kota Puteri (Cont.)	72
5.5	Coefficients for the IDF Equations for Johor State	76

LIST OF SYMBOLS AND ABREVIATIONS

BOD	Biochemical Oxygen Demand
TSS	Total Suspended Solid
DO	Dissolved Oxygen
COD	Chemical Oxygen Demand
AN	Ammoniacal Nitrogen
CO_2	Carbon Dioxide
SO_4	Sulphate
NO_3	Nitrate
p	Probability
m	Rank
T	Recurrence Interval
WQI	Water Quality Index
DOE	Department of Environmental
INWQS	Interim National Water Quality Standards for Malaysia
NH_3-N	Ammoniacal Nitrogen
C	Concentration
m	Mass
V	Volume
W	Load of Constituent
K_u	Conversion Unit
Q	Flow Rate
C_r	River Concentration
Q_r	River Flow Rate
C_{ww}	Waste water Concentration
Q_{ww}	Waste water Flowrate

Q_{out}	Flow rate Out
∀	Volume of stream
K_s	Settling Rate Constant
L_w	Ultimate BOD of the wastewater
K_T	Reaction rate at temperature
T	Temperature
K_r	Reaeration Coefficient
K_d	Rate of Deoxygenation
D_a	Oxygen Deficit
DO_S	Saturation of DO
t_c	Critical Point
I	Intensity
A	Area
PE	Population Equivalent
EA	Extended Aeration Tank
HRT	Hydraulic Retention Time
Q_p	Peak Discharge

LIST OF APPENDICES

No	Title	Page
A	Rainfall Pattern from Year 1998-2009 at Site 1730082	84
B	Average 7-Days Low Flow Determination (2000-2009)	99
C	Industries nearby Lunchoo River	108

CHAPTER 1

INTRODUCTION

1.1 Introduction

Throughout history, human beings have not had a good record in dealing with pollution. It seems that almost every day there is another story about pollution of one form or another, in the food we eat, the water we drink and the air we breathe. For most cases, water pollution (rivers, lakes, oceans) are becomes the most concern and well talks. River pollution for instance, has historically recognized to be one the consequences of human civilization. In many ways, rivers are sources of life, providing water supply for the people, irrigation for agriculture, as a means of transportation, a source of food in fisheries, hydro-electric power, and water use for industries. As the world's population increases, those water consumption and pollution will also increase. Pollution of our rivers is attributed to point and non-point sources originate mainly from land-based sources. Major land-based pollution activities identified are urban settlements, agricultural run-offs, illegal coastal settlements, industrial discharges and sewerage and animal husbandry.

However, the water situation for some parts of the country has changed from one relative's abundance to one of scarcity. The growth in population and expansion in urbanization, industrialization and irrigated agriculture are imposing growing demands and pressure on water resources, besides contributing to raise water pollution., Thus, a balance strike between those developments and a good

quality of life that has to be considered in the complex relationship between water quality and quantity on one hand and human health and well being on the other. In fact, an understanding of the existing of the river water quality is deemed necessary to determine the background level of pollutant. As a case in point, Lunchoo River was initiated to be the contribution of water quality deterioration with regional consequences on the aquatic ecosystem and on the health of the downstream sub-basin's user group. Focusing on point source pollution, industrialization was identified to be the main contributing factor of water quality deterioration. Thus, a concept of mass balance approach was employed to determine and predict the existing point source pollution in a way of water quality analysis. It is an approach that is commonly used as the indirect method to study source contributions of pollutant loads into the receiving water bodies. This approach is also useful especially when there are distinct dry and wet seasons as existent in the tropical countries (Hema and Muthulagi, 2009).

More precisely, a mass balance model is an accounting device to ensure that differences between inputs and outputs during any particular interval of time, within any particular volume in space, are equal to the net sum of the production, retention, and decay processes within the volume (Robert, 1996). The approach provides a rational basis for setting load reduction targets and priorities, as well as management and regulatory policy. However, mass balance modeling cannot make absolutely precise and accurate predictions; the concept remains sound and has been thoroughly field validated. The expense of the higher level models is primarily incurred due to greatly increased resolution of ambient monitoring and analysis.

1.2 Background of Study

This study was concerned on the determination of point source pollution which emitted directly into Lunchoo River. Those industrial discharge and construction of new coastal highway are said to be the major sources of point source pollutant. However, since construction of new coastal highway is just a temporary pollution source, industrial discharge is become the major of concern. Study area

description can be found in Chapter 3 of this report. During this study, processes involved are site visit, data collections, data interpretations and data analysis.

1.3 Problem Statement

Lunchoo main river originated from Bukit Lunchoo at the north cathment and it flows from vegetable farm areas, passing through Coastal Highway which is still under construction and finally drains into Straits of Johor which approximately 8km east of Tambak Johor. As far to be concerned, Lunchoo River (Figure 1.1) is an estuary area which is under influnced of the tidal from Selat Tebrau which varies in response to the interaction of fresh water flow, friction, and tidal mixing for the upstream and downstream physical structure. Refering to the deteriorated of water quality prior to the industrialization within Lunchoo River surrounding area, an understanding of the existing river water quality is deemed necessary to determine the background level of pollutant. Some prevention action could be made to control the pollution by the aims of maintaining its river water quality status or if possible improved its water quality. Those potential point source pollutants are described as follow;

a) Industrial Discharge

   As industrial increasing economic status, it is also contribute to point source pollution in variety ways. Chemicals, toxins, garbage, cleaning product, disease-causing agents and so on flow into rivers, lakes, oceans and end up in drinking water. It has causes health problems and even death for humans, animals, and all aquatic life. In fact, it has also rendered several recreational streams and lakes completely contaminated and usable by people surround. Unfortunately, these long term effects will leave water to be unusable and the worst, safe drinking water will be in short supply. Regarding the purposes project, some of potential industrial that discharge point sources pollution into Lunchoo River are described in Table 1.1.

b) Construction of Coastal Highway

The Johor Bahru East Coast Highway or Johor Bahru-Pasir Gudang Highway is a new highway which is still under construction. This project started on 2008 and expected to be finished on 2011. Contaminant to the surrounding Lunchoo River water body was potentially construction activities. However, the impact is only temporary. Once project is finished, those pollutions from particular activities will vanish.

Figure 1.1: Lunchoo River waterways

Table 1.1: Point Sources Pollution

Source Pollution	**Location**
Industrial Discharge	*Taman Perindustrian Seri Plentong* Super Food Technology Sdn. Bhd Universal Cable (M) Berhad Far East Plywood Sankyu Itls Wheatland Evergreen Chemical *Taman Perindustrian Kota Puteri* JB Progress Fabricator & Eng. Sdn. Bhd. Big Fabrication Sdn. Bhd. Alpha Interocean Sdn. Bhd. Ah Ang Auto *Jalan Bukit 1,2 and 3* (Sewerage Treatment Plant) *Lebuhraya Pasir Gudang* Shop lots and Petrol Stations
Construction of coastal highway	*Johor Bahru East Coast Highway or Johor Bahru-Pasir Gudang Highway*

Those in coming pollutants due to its proximity to the main drain that directly discharge to Lunchoo River; it will potentially contaminated the environment. Hence, it is very difficult to incorporate the effects of all these factors in any single calculation. Therefore, a mass balance analysis to capable in determination and prediction on the water quality of point sources pollutions was applied in this study. Figure 1.2 shows the point sources pollution areas in Lunchoo River Basin.

Figure 1.2: Main Point Sources Pollution areas in Lunchoo River Basin

1.4 Aims of Study

This study aims to investigate the contribution point sources pollution and to analyze the data over a part of point source pollution within Lunchoo River waterways. This study also means to provide some useful information for the mitigation measure in reducing pollution as well as to improve the water quality along this river.

1.5 Objectives of Study

The objectives of this study are as follow:

a) To address in general the industrialization that contributes point sources pollution along Lunchoo River water ways.
b) To predict the impact towards contamination of certain constituents on point sources pollution using Mass Balance Analysis;
c) To provide strategies and formulation of a plan of action to improve the river water quality.

1.6 Scope of Study

Once problems are address in this study, data collection was deemed necessary for further analysis. Highlighting point source industries that emit pollutant along Lunchoo River catchment areas, a significance formulation approaching to the study are employed. Those results will be compared to the available guideline or standard. Meanwhile, there are also being use the adaption of appropriate analytical techniques and results from previous study to establish a level of predictive accuracy necessary for water quality determination.

1.7 Limitation of Study

Due to time restraint and data constraint, limitations in this study are;

i. Focusing on point source pollutant from industrial discharge only
ii. Low Flow design criteria
iii. Only certain parameter will be investigate using Mass Balance Approach (BOD,TSS,DO)
iv. The study only covered area surrounding the river for about 7.5 $km^{2.}$
v. Catchment will divide into 3 sub basin, namely as;

a. Taman Perindustrian Seri Plentong
b. Taman Perindustrian Kota Puteri
c. Taman Perindustrian at Jalan Bukit 1,2,3 and Bukit Lunchoo

1.8 Significant of Study

Analysis on the water quality of baseline study for Lunchoo River is necessary to predict the level of pollutant as well as to develop better water resource management plan of this river. This study is a primary action and the best measure to ensure a sustainable water resources and environment in this area. Output generated from certain water quality constituents will verify the pollutant stage of the river as well as the direction, manipulation, and control of the river system is possible. However, an understanding of using mass balance analysis is a vital key toward an optimal management of its resources. Therefore, this study is one of the initiative to ensure the water quality and environment been properly manage at Lunchoo River, as it is the most important sources of raw water to satisfy the clean water supply demand for the entire Johor State and also Singapore.

REFERENCES

American Society of Civil Engineers (1982). Design and Construction of Sanitary and Storm Sewers, ASCE-WPCF Manual 9, ASCE, New York.

Duda, A. M. (1993). Addressing Nonpoint Sources of Water Pollution; Must Become an International Priority. Water Science and Technology 28, 3–5.

D'Arcy, B.J., J.B. Ellis, R.C. Ferrier, A.S. Jenkins, and R. Dils (2000). Diffuse Pollution Impacts, Terence Dalton Publishers, Lavenham Press, Lavenham, Suffolk England.

Frank Rendell (1999). Water and Wastewater project development, Thomas Thelford, Heron Quay, London

Frank R.Spellman (2004). Water and Wastewater Treatment Plant Operators, CRS Press, Boca Raton Florida

Gaffney, M. (1988). Non point Pollution; An Economical Solution to an unconventional Problem, in Political, Institutional, and Fiscal Alternatives for Non point Pollution Abatement Programs (V.Novotny,ed.), Marquette University Press, Milwaukee, Wisconsin.

Hann, R. W. (1972). Fundamental Aspects of Water Quality Management, Technomic Publication, Connecticut.

James Shortle, Richard, D. Horan and David G. Abler (1998). Research Issues in Nonpoint Pollution Control, Environmental and Resource Economics 11(3–4): 571–585, Kluwer Academic Publishers. Printed in the Netherlands.

Krenkel, P., and V. Novotny (1980). Water Quality Management, Academic Press, Orlando,Florida.

Masters, G. M. (1998). Introduction to Environmental Engineering and Science Second Edition, Prentice-Hall International Inc. Upper Saddle River, New Jersey.

Metcalf and Eddy (1991). Wastewater Engineering, Treatment, Disposal and Reuse, Mc Graw Hill Companies, Printed in Singapore.

Metcalf and Eddy (2003). Wastewater Engineering, Treatment and Reuse. Mc Graw Hill Companies

Nadiya Yap (2006). Water Quality of Batu Pahat River, on-line undergraduate Thesis of Civil Engineering Faculty, Universiti Teknologi Malaysia, Skudai.

Novotny, V., and H.Olem (1994). Water Quality: Prevention, Identification, and Management of Diffuse Pollution, Van Nostrand Reinhold, New York.

O'Connor, D.J., and W.E. Dobbins ((1958). Mechanism of Reaeration in Natural Stream, American Society of Civil Engineer Transactions, 153:641.

R.Parker, N.Morris, F.N Fair, S.C Batia (2008). Waste-Water Engineering. CBS Publishers and Distrubutors, New Delhi India.

Robert F. Beltran, 1996. Preliminary Management Summary of Great Lake Monitoring, A publication of the Green Bay/Fox River Mass Balance Study Management Committee, U.S. Environmental Protection Agency, Great Lakes National Program Office.

Rump, H.H., and Krist, H. (1992). Laboratory Manual for the Examination of Water, Waste Water and Soil: 2nd Edition. VCH, New York.

S.Hema, S.Muthalagi, 2009. Mass Balance Approach for Assessment of Pollution Load in the Tamiraparani River. International Journal of ChemTech Research, ISSN : 0974-4290 ,Vol.1, No.2, pp 385-389

Suppiah Samsudin (2009). Lecture material on Surface Water Hydrology, MAB6013, Chapter 13, Water Quality Estimation. Faculty of Civil Engineering, University Technology Malaysia Skudai.

Vladimir Novotny (2003). Water Quality, Second Edition Diffuse Pollution and Watershed Management, John Wiley & Sons, Inc.,Hoboken,New Jersey.