Spatial Model for Water Quality Changes of Urban Canals and Associated Land Use Pattern in Colombo City

By

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I certify that the above statement made by the candidate is true and that this thesis is suitable for submission to the University for the purpose of evaluation.

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List of Abbreviations

ANOVA	Analysis of Variance
BOD	Biological Oxygen Demand
CAD	Computer-Aided Drafting
COD	Chemical Oxygen Demand
CR	Cumulative Rainfall
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DP	Dissolved Phosphorus
DSD	Divisional Secretary's Divisions
DTM	Digital Terrain Model
EPL	Environmental Protection Licenses
FC	Faecal Coliform
GCFC&EIP	Greater Colombo Flood Control & Environmental Improvement Project
GIS	Geographic Information System
GND	Grama Niladhari Divisions
IDW	Inverse Distance Weighted
INWQS	Interim National Water Quality Standard
LMR	Little Miami River
LULC	Land Use/Land Cover
LUT	Land Use Types
NBOD	Nitrogenous Biological Oxygen Demand
NPS	Nonpoint Source Pollution
PD	Population Density
SLLR&DC	Sri Lanka Land Reclamation & Development Corporation
SMCL	Secondary Maximum Contaminant Level
StDev	Standard Deviation
STORET	Storage and Retrieval
SWAT	Soil and Water Assessment Tool
TDS	Total Dissolved Solids
TIN	Triangulated Irregular Networks
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TR	Total Residue
TSS	Total Suspended Solid
WQ	Water Quality
WQI	Water Quality Index

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"It is good to have an end to journey toward; but it is the journey that matters, in the end."
–Ernest Hemingway

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ABSTRACT

Studying of the complex relationship between surface water quality and land-use patterns in different regions under various spatial scales is a prime importance to explore effective methods for mitigating the water pollution. The focus of this study was to use a GIS based approach together with statistical analysis to examine the plausible and complex relationships to water quality of the canals in Colombo urban area with rainfall of climatic seasons, land use types, and population density. The data on land use, monthly rainfall, population density and water quality from 2003 to 2009 were collected from Department of Survey, Department of Meteorology, Department of Census & Statistics and SLLR&DC respectively. Parametric and Nonparametric statistical analysis techniques were used to analyse the relationship of land-use categories, rainfall and population density with water quality attributes namely pH value, Conductivity, Turbidity, Temperature, Dissolved Oxygen, Ammonia, Nitrate, Phosphate, COD, BOD and Salinity percentage. Majority of the selected water quality parameters except Dissolved Oxygen and BOD were in the permissible ranges of the general water quality standards in Sri Lanka. The seasonal mean values of COD, BOD, Turbidity and Conductivity remarkably vary at six sub-watersheds and they are statistically significant. The investigation reveals that the quality of canal water at these locations is found to be polluted with domestic pollutants and not suitable for the domestic purposes without any treatment. There is a strong significant difference within the mean values of Conductivity, COD, BOD and Salinity% according to the climatic seasons. The mean differences of COD, Conductivity, and Salinity% occur with the effect of third season (second inter-monsoon) and the second season (first monsoon) is affected for the mean difference of BOD. However, there are no significant mean differences of seasons on Turbidity, Ammonia and Dissolved Oxygen. Three out of eleven water quality attributes; Temperature, COD and Salinity% are significantly correlated with seasons. The correlation coefficients are -0.570, -0.225 and -0.216. It

presents a higher negative correlation between the Temperature and climatic seasons. It is found that there is no any relationship between the water quality and the population density. A significant regression model could be drawn to predict the surface water quality in Colombo city using one water quality indicator (BOD) which may suggest point sources contribute more pollutants than non-point sources.

Chapter 1

1 INTRODUCTION

1.1 Background

Waterfronts are assets that enhance the quality of built-environment in urban areas. They are used as public and recreational spaces in many cities around the world. Colombo has environmental assets in the form of a sea front, a lake and a canal network. Among the water bodies in Sri Lanka the canal system in Colombo is unique. Earlier, it was meant for some water drainage and inland transportation. But today most of the cities and towns in Sri Lanka often turn their back to water bodies (Bandaranayake, 2000).

The canal system which is in and around Colombo-Sri Jayawardanapura area is currently in such an environmentally deteriorated condition due to rapid development and urbanization of the area. The quality of water and habitat in most of the areas are influenced by industrial and public effluent discharge to the canal system. Low- income shanty dwellers and squatters have encroached the canal banks, and some places have become dumping grounds.

Therefore, the most common environmental problem in a canal ecosystem is the deterioration of water quality due to point and non-point source pollution. This is associated with foul smells and unpleasant appearance of dark and gloomy water. They easily become breeding grounds for disease carrying parasites. As a result public health of those who live near by the canals and use water therein are threatened by water borne diseases. Dumping of solid waste and unauthorized encroachments resulted silting and narrowing of canals. The combined effect of these disturbances results poor drainage capacity of canals.

But, very little attempt has been made to utilize the potential of canals in enhancing the quality of environment of the city until recent times. According to the UDA (1993) cited by Fernando (1994), the data collected by the Central Environmental Authority

during a period of 23 months (from March 1991 to February 1993) has shown that St. Sebastian canal, which is a branch of the Colombo canal system, had recorded high turbidity, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values, richer in nutrients; reduction of nitrate into nitrite and ammonia (due to eutrophication), high concentrations of metals and faecal coliform (Perera, Wattavidanage & Nilakarawasam, 2012). They revealed that there is an unhealthy condition of the canal system for living beings. Also it has been severely affected on well being of the community live around the canal system.

The canal network has already been rehabilitated under externally funded projects. But it is observed that the rehabilitated canal network is fast falling back to its previous state of stagnation and pollution due to non-utilization of improved canals and banks (Perera, 2003). As a result clogging and polluting of canal system and its effects upon urban life and health has become a critical environmental issue. Even though the Sri Lanka Land Reclamation & Development Corporation (SLLR&DC) annually spend millions of rupees to maintain and keep the canal system in order, the canals continue to pollute and clog resulting environmental problems particularly floods. This has become a major problem in the city, which raises the necessity of improving and utilizing the canal system. On the other hand the people living in Colombo and its vicinity are looking for places for recreation. Therefore, many authorities have considered the improvement of the quality of the canals in Colombo (Bandaranayake, 2000).

1.2 Problem Statement

Contamination of urban water bodies, specially canal system is serious issue in Colombo area, because, most canals in Colombo area has very slow flow rate and runs through highly populated and industrial/commercial areas. Many factors are responsible for contamination of these canals such as, sounding land use, population density, flow rate, climatic condition (rainfall and temperature), nature of canal network, and spatial distribution of pollutant sites/point etc. Pattern, of the spatial distribution of pollutant contamination of canals, severity and relations to source of pollutant sites and nature of canal network are complex environmental phenomena. However, use of Geographic

Information System (GIS) techniques for solving such multi-factorial problem is more efficient and effective methods. Thus, in this research aims to analyze pollutant contamination of some canals in Colombo urban area using GIS techniques.

1.3 General Objective

The objective of this study is to use a GIS based approach together with statistical analysis techniques to examine the plausible and complex relationships to surface water quality of the canals in Colombo urban area with Climatic seasons, Land use types, Rainfall and Population density.

1.3.1 Specific Objectives

- To examine the water quality indicators to assess the water quality in urban canal system of Colombo city.
- To investigate water quality changes according to the land use types, rainfall and population density.
- To predict a model which best described the water quality changes with rainfall, land use types and population density.

1.4 Significance of the Study

Land use and land cover information are important for land use planning and resource management. Using or relying on ground surveys and sampling alone requires man power, expenditure and time. Recent developments in GIS technologies indicate that, if these methods are carefully combined with reliable ground based data, it is possible to compile detailed inventories and to monitor water quality in surface water bodies. Such analyses include the relationships between changes in canal water and socio-economic development factors. Therefore, GISs can be used for more detailed analysis of water quality changes in the study area.

The GIS software that will be used in this study is ArcGIS Version 10.1. ArcGIS provides a scalable framework for implementing GIS for varieties of environmental application. The hydrology function in ArcGIS provides methods for describing the hydrologic characteristic of a surface. For example in this study, by using an elevation raster data set as an input, it is possible to model where water will flow, create watersheds and stream networks.

Generally, Water Quality Index (WQI) and Interim National Water Quality Standard (INWQS) are used to determine the classification and pollutant status of particular water bodies. Dumping of solid waste and encroachment by shanties will cause several adverse effects to the environment; therefore the water quality of the canal is very much useful in planning the best management practices in this study area. Therefore, this study is conducted to determine the water quality associated changes of the water bodies within the study area.

The integration of Geographical Information System to evaluate the water quality of the study area will give the better information access regarding to the quality of the water bodies. GIS helps identify and map critical areas of land use and reveal trends that affect water quality.

1.5 Study Area

Colombo-Sri Jayawardanapura (Diyawanna Oya) canal network is a manmade canal system which is located on the left bank of the lower valley of Kelani Ganga. It is situated in the western province, Colombo district of Sri Lanka, latitudes 6° 56' 12" N - 6° 50' 28" N and longitudes 79° 51' 5"E - 79° 58' 30"E. Main catchment areas of the canal system are the low-lying marshlands known as Kolonnawa, Heen Ela and Kotte marsh. The canal system is important as major flood detention zones in the city of Colombo (CEA, 1995). Total area of the marsh is around 400ha. The canals and streams, inter connected and situated in the study area are Kirillapone Canal, Wellawatte Canal, Dehiwala Canal and Diyawanna Oya. The canal system has 3 outfalls to the sea namely Mutwal, Wellawatte and Dehiwala. Mutwal has an

underground tunnel system and other two are open drains. The average depth of these canals is about 1.5 meters. It may vary seasonally due to heavy sedimentation of silts and bank erosion in the rainy season and it was frequently clogged with floating weeds & dumps (polythene, plastics & domestic wastes). It has been found that 43.5% of the families in the study area dump their household garbage into the marsh (CEA, 1995).

I selected this area for the present study which is covering an extensive area of the Colombo canal network. Study area is shown in Figure 1.1 (p.6).

The water quality data for this study was collected from 6 locations of about 15 km along the canal system. Six sites namely, Kimbulawala, Pelawatte, Sri Jayawardanapura Mawatha, Nawala, Wellawatte and Dehiwala were selected to collect water samples (Figure 1.1). These locations have been selected in order to represent the different land use characteristics to understand the variability of water quality with the inherent characteristics of different land uses.