NUTRIENS DYANAMICS OF SHALLOW LAKES;

A CASE STUDY OF NUWARAWEWA IN ANURADHAPURA, SRI LANKA.

by

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DECLERATION

The work described in this thesis carried out by me at the Department of Geology, Faculty of Science, University of Peradeniya under the supervision of Dr. R.L.R.Chandrajith and Prof. M.Rupasinghe. A report on this has not been submitted to another university for another degree.

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Affectionately Dedicated

To My Parents and Teachers

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ABSTRACT

Lakes are considered as natural resources and in environmental literature, it is a common property resource, accessible to everyone. Therefore lakes face special pollution problems. Most notably, they serve as sink of pollution arising and from upstream as lakeside activities including industrial discharges, municipal waste and agricultural drainage. Therefore many of the lake studies are applied to measuring of water quality parameters of lakes.

Nuwarawewa is a major water body in the Anuradhapura district. It has specific ecological and sociological characteristics. Therefore a preliminary survey on the some chemical and biological quality of Nuwarawewa was carried out in order to construct a baseline for further studies. Some chemical parameters (Nitrate, Phosphate, Total Dissolved Solids and pH) and biological parameters (Plankton and Biological Oxygen Demand) were measured by using standard methods.

When comparing analytical results and previous records, the increase of some nutrient particularly nitrate and phosphate were observed. Biological Oxygen Demand and plankton counts were also increased in catchments (North-East) side sampling points.

There is no sufficient evidence to categorize Nuwarawewa as highly polluted lake. However change of water quality parameters over time suggests an increasing tendency of pollution. Further disposal of waste and other pollutants may create a problematic situation in future and a proper management plan is required to control and protect the lake.

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ABBREVIATIONS

asl	above sea level
BC	Before Christ
BOD	Biological Oxygen Demand
DGM	Deputy General Manager
DO	Dissolved Oxygen
NE	North East
NWS & DB	National Water Supplies and Drainage Board
ppb	parts per billion
ppm	parts per million
TDS	Total Dissolved Solid
WHO	World Health Organization
WCP	Wetland Conservation Project
WSR	Wetland Site Report

CHAPTER 1

INTRODUCTION

Water is the most abundant liquid on the planet (Earth) and essential to the survival of every living thing. Human bodies are made up of 65% - 75% water by weight, and although individuals only need 1.5-2 liters of water daily, they could survive only a few days if completely deprived of it (Jogenson and Vollenweider, 1988).

Fresh water ecosystem occupies a relatively small potion of the surface of the earth in comparison to the marine ecosystem. 97.6% of water is in oceans, out of 71% of the surface water of the earth.

However population of the world continuous to grow with increased rapidity, clean water for drinking is becoming ever more scarce. The amount of fresh water available on the planet for drinking, bathing and agriculture is quite small, which is less than 1% of the total. Most communities get their drinking water from surface water sources or from groundwater. Surface water is the water that remains on the surface of the land and does not percolate though the soil. Rivers, streams, reservoirs and lakes are all surface waters. Surface water is replenished by rainfall. Groundwater is most purified by a percolation process, but groundwater usage is a difficult task because it is trapped in underground rock layers. Therefore surface water is a major source of fresh water for human use.

The lakes are the most valuable bodies at the surface. The, lakes with it is clear-cut boundary, is one of the best- defined natural ecosystems on the Earth. Lakes are different to one another according to their environmental condition such as physical, chemical and biological parameters. Human activities also influence the changing of lake conditions. Lakes are fulfilled human needs. It provides resources and services. Lakes are important sources of drinking water. They are sources of water for washing, agriculture and energy production (Tomar, 1999). They provide a mode of transportation and an opportunity for recreation. Further lakes are provided habitats for aquatic fauna and flora. Some species of biota are restricted for only one lake.

Some lakes are subjected to periodic flooding, serve as nurseries for many revering fish species and that provides the principle source of protein for people.

Lakes can be divided into two groups, namely the deep lake and shallow lake. Sri Lanka mainly has shallow lakes, which were constructed by man.

Sri Lanka is a tropical country where rainfall gets periodically depending on monsoon wind. Therefore lakes were constructed for collected rainwater, mainly for agriculture and for other human requirements. Most lakes were constructed in the dry zone because this zone needs much water for agriculture activities.

Nuwarawewa (wewa = tank in singhala) is a shallow and is one of the largest tank in the Anuradhapura District. It provides drinking water for people and also supplies water for agriculture purposes. Nuwarawewa is situated very closed to the Anuradhapura town. Paddy fields and other agricultural lands surround the lake. The fertilizer, which is added to these lands, washed away and can be contaminate the Nuwarawewa ecosystem.

Change of nutrient level in the lake affects both fauna and flora of a water body. It also has detrimental effects on water quality, making it unsuitable for human use. Sometimes it might even lead to toxicity. On the long run, the whole ecosystem can be collapsed.

Nuwarawewa is a water resource for many people, which supplies water for agriculture and commercial use. However it is also a dump of waste, which release from human activities. Upto now no detail investigation has been carried out to evaluate the nutrient content of the Nuwarawewa. There for this study is aiming to study the nutrient dynamics of the lake.

1.1 Aim of the study

The Nuwarawewa is located 206 km north-east of Colombo, in the North Central Province. The lake is also situated within the mid catchments of the Malwatu Oya river and closed to the ancient city of Anuradhapura.

As water body located in an urban area, Nuwarawewa is often subjected to pollution through point and diffuses sources.

For this study the Nuwarawewa in Anuradhapura were selected and several physio-chemical parameters were analyzed to obtain the current level of pollution. pH, TDS, NO_3, PO^{3-}_4, BOD and planktons of the lake were studied during this study.

CHAPTER 2

Physico-chemical characteristics of lakes.

2.1 Lake formation

Fresh water in the Earth mainly divided into two groups, as standing water and flowing water. Lakes, ponds, reservoirs, marshes are included in standing (lentic) water whereas streams, rivers etc., are belongs to flowing (lotic) water.

The lakes are part of the standing water and with its' clear cut boundary, is one of the best-defined natural ecosystem on the earth.

The water-filled depressions in the earth surface designated as lakes and have arisen in very different ways. The tectonic lakes, which formed primarily by the tectonic activities of the earth. This type of lakes consists of several largest, deepest, and oldest lakes on the earth. Much more common lakes are the basin formed secondary by deposition of loose materials or by excavation. The create lakes extinct on volcanoes. The dam lakes have arisen as a result of the damming of a valley by the moraine of a Pleistocene glacier flowing in the main valley or by a mountain slide. Excavation basins may have originated through caving of caverns in the earth crust. These basins are also called "removal basins" (Rattner, 1961).

Lakes were builds by people in the world, which are mostly located into tropical countries, which supplies water for numerous of uses.

2.2 Lake Morphology and Stratification

The well – lit surface water comprised the euphotic zone, their lower limit at the compensation point. Below this is the profounder zone. The large amount of energy absorbed by water for heat the water body. Therefore very little penetrates to deep, resulting a thermal stratification. Due to stratification a warm upper layer, (epilimnion), may form, which floating on a cooler lower volume (the hypolimnion) (Fig. 2.1). The transitional zone, often abrupt, is the metalimnion, though the sharp temperature gradient across this zone called the thormocline (Open University of Sri Lanka, 1996).

Thermal stratification is the most important physical event in lake's annual cycle and dominates most aspects of the lake structure.

In shallow lakes the typical stratification may not be seen. Although there is some form of temperature variation can be formed. In such water bodies temporary thormocline may be present between 2-3 m during the daytime, which disperse at night (Barnes and Manu, 1980).

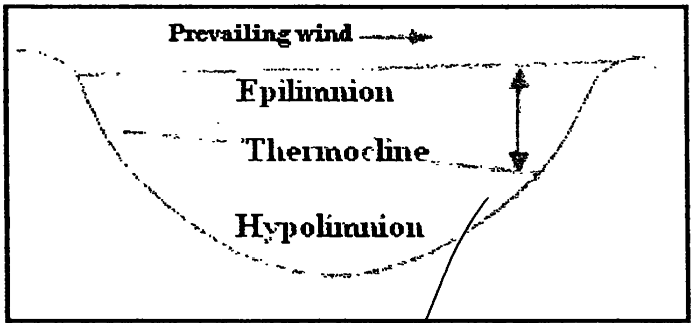

Figure 2.1 Stratification of Lake
(Source; Open University of Sri Lanka, 1996)

2.3 Abiotic Characteristics of Surface Water Bodies

Aquatic water bodies contain a variety of dissolved and suspended constituents. These are either abiotic or biotic substances. Abiotic substances are consisting of solids and other materials.

2.3.1 pH

pH can be defined as a logarithm of the reciprocal of hydrogen ion activity of a solution and is mathematically expressed as;

$$pH = - \log [H^+].$$

Where $[H^-]$ is the amount of hydrogen ions in moles per liter of the solution. The pH of most natural water in the rang of 4-9. Much more often they are in the rang of 6-8. The majority of natural water has a somewhat alkaline, because of the presence of carbonate and bicarbonate (Kegly and Andrews, 1998). In swamps and bogs, the water is acidic where pH is ranging from 4-6. In stratified lakes pH may drop with the depth. This condition is common in deep-water bodies in tropics. pH in lakes fluctuates daily due to the fluctuations of CO_2^-,as a results of photosynthesis and respiration (Barnes and Manu, 1980).

2.3.2 Total dissolved solids (TDS)

Total dissolved solids (TDS) is a measurement of the total quantity of chemical parameter dissolved in water. It is measured in Siemens per centimeter (S/cm). Water conductivity also is measured by the TDS of water bodies. TDS less than 50 µS/cm do not contain many dissolved solids. Comparatively seawater has higher TDS level than fresh water bodies. TDS changed with geomorphology characteristics of catchments areas (Ruttner, 1961).

2.3.3 Nitrate and other N-salts in lakes

Nitrate is a one of the important chemical constituents found in water bodies. It exists in three forms in water,

1. Uncombined N – from atmosphere and denitrifying bacteria.
2. Organic N compounds – Ammonium acids, Phospholipids, and Urea.
3. Inorganic N compounds – Nitrates, Nitrites and Ammonia

Out of all these forms nitrate, nitrite and ammonia are very useful to planktons in water. The decaying organic matter gives off ammonium salts. They converted to nitrite and finally to nitrate by the microorganisms. This is the most common and biologically available form of combined inorganic nitrogen in lakes (Tomar, 1999).

Ammonia is the important form of N for plant growth. Ammonia in water is taken up by plankton and other aquatic plants. It differs from NO_3^- in terms of both toxicity and mobility. In most lakes and reservoirs, ammonia is generally well bellow 0.1mg/l. Therefore most toxic effect of it on animals is due to pollution. It can become harmful to animals and, plants at elevated pH levels when toxic ammonium converted to hydride forms (Tomar, 1999).

The rate of supply of N- salts into a water body is intimately connected with land use practice of the water shade. NO_3^- ions move easily through soil and are quickly lost from the land due to natural changes such as floods, fire and artificial clearing etc. According to the presence of N content and other nutrients the lake can be classified in to different (Table 2.1).

2.1 Table. Classification of lakes according to nutrient content (Sources; Open University of Sri Lanka, 1996)

Tropic status.	Approximate N concentration (mg/l).
Oligotrophic	0.5
Mesotrophic	1.0
Eutrophic	1.5
Hypereutrophic	3.5

2.3.4 Phosphate in lakes water

Phosphorus in water present in several soluble and particulate forms, including organically bound P, inorganic polyphosphates and inorganic orthophosphates. Plants can only absorb dissolved inorganic phosphates. Inorganic soluble P is very low and cycled very rapidly in the water bodies.

Since P is one of the essential for plant, aquatic plants rapidly take up as soon as it appears in the water (Open University of Sri Lanka, 1996)

P enters a lake via rainfall, from upstream lakes, sewage, and industrial effluents and from surrounding lands. P is much more rapidly lost from it is and ecosystem than N, because it reacts with sediments and other chemical in the water. In such ways, it is making unavailable to plants (Open University of Sri Lanka, 1996). Nitrate compounds and phosphate compounds are cycled into water bodies as Figure 2.2.

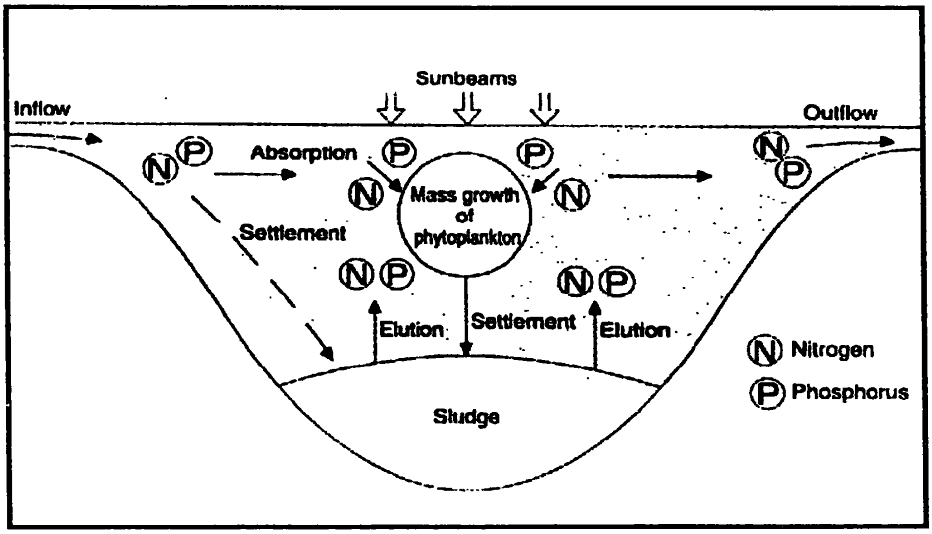

Figure 2.2 P and N dynamics of lakes. (Source; Hashimoto, 1995).

2.3.5.Oxygen

Dissolved Oxygen is one of the important parameter of lakes and other water bodies. Dissolved Oxygen (DO) is obviously essential to the metabolism of all aerobic aquatic organisms. Hence, the solubility and dynamics of oxygen distribution in a water body is the basis to the understanding of the distribution, behavior and growth of aquatic organisms (Wetzel, 1983).

The main source of DO is from the atmosphere and the photosynthesis processes of green plants. Air contains 20.95% of oxygen, which is moderately soluble in water and mainly absorbed by direct diffusion and agitation of the surface water, which formed by wind action and turbulence. The amount of oxygen dissolved in water depends on the exposed surface area, water temperature and salinity (Wetzel, 1983).

2.4 Biotic Characteristics of Lakes

Biotic portion of the lake is consists of aquatic fauna, flora and plankton. Plankton is only discussed in this section.

Planktons are floating or weakly swimming organisms whose movements are more or less dependent on currents. Plankton is important components of aquatic systems. In large lakes and reservoirs the plankton are major primary and secondary links in the tropic relationship (Open University of Sri Lanka, 1996).

By definition, the plankton includes all those organisms suspended in the water, although their size range does extend trough several scale of magnitude. This has been utilized to form size-based classification systems (Open University of Sri Lanka, 1996).

Some planktons are very small and can pass through even the finest plankton nets. Such plankton forms are refereed as planktons. The larger forms, which are retained by the plankton nets, are designated as net planktons (Wetzel, 1983).

Dussart's classification of both the fresh and marine water plankton is given below (Open University of Sri Lanka, 1996)

- Ultra nannoplankton – below 2 μ : largely bacteria
- Nannoplankton – 2-20 μ Algae and zooplankton
- Micro plankton – 200-2000 μ : large zooplankton
- Mega plankton – above 2000 μ zooplankton

The plankton is composed of mainly of an animal component (zooplankton) and a plant component (phytoplankton) (Open University of Sri Lanka, 1996).

Plankton is required to aquatic bodies. But those are highly grown with excess amount of nutrient in lake water (Wetzel, 1983).

2.5 Eutrophication

Oligotrophic lakes have few nutrients, which can sustain only to a small biomass. These lakes are considered as "young" lakes. However nutrients and silt are added into a lake by natural processes such as wind erosion or leaching by rainwater. With all these changes, the lake passes to the middle age (mesotrophic) and finally becomes an "old" lake, which is termed eutrophic. Eutrophic is the term given to the process of aging of a lake. In other words it is actually a process of enrichment nutrient in the water body. The most important nutrients that cause eutrophication are phosphate, nitrate and ammonia.

When eutrophication process in a lake occurs through hundreds of thousands of years, is called "natural eutrophication" (Schiemer, 1983).

Due to human settlements in the drainage basin and the associated clearing of forests and development of farms, causes to the natural eutrophication process. The involvement of man also adds artificial and undesirable nutrient fertilizers, sewage detergents, and animal feaces to lake. This phenomenon is known as cultural eutrophication (Schiemer, 1983).

2.6 Characteristics of Nuwarawewa

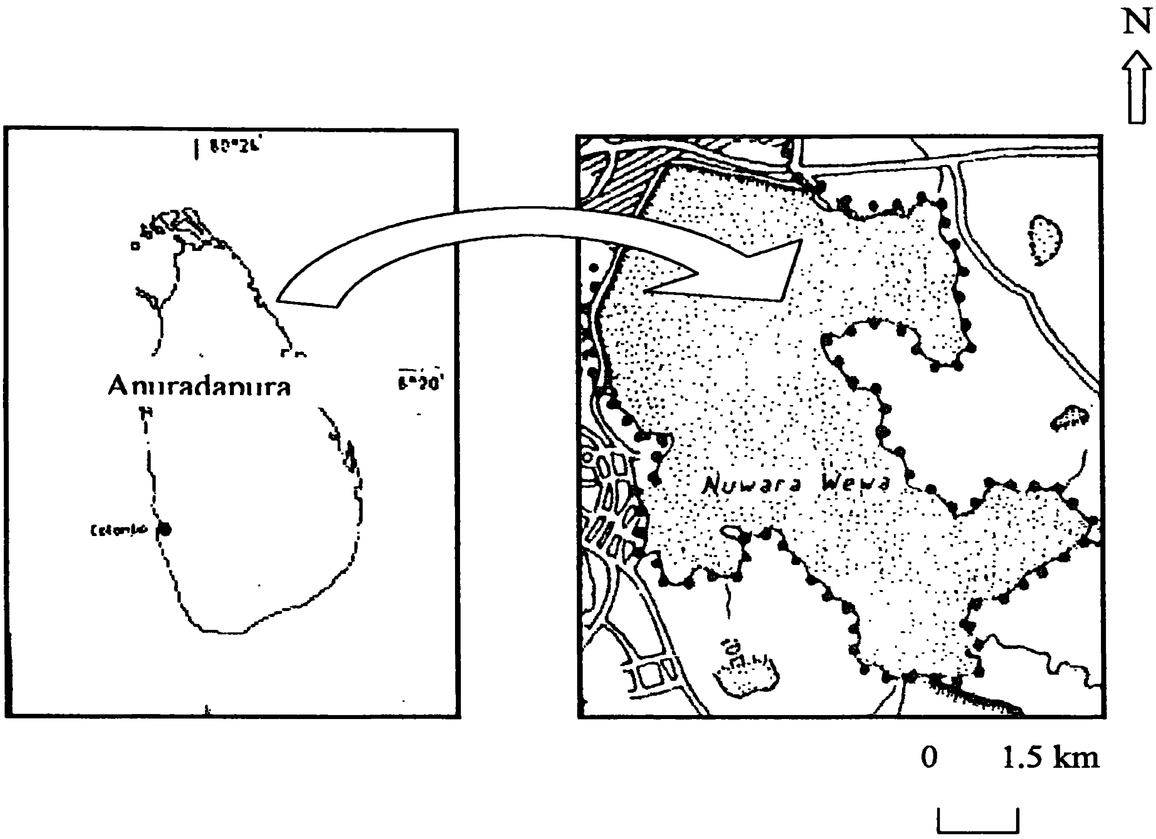

Figure 2.3 Location of Nuwarawewa at Anuradhapura (Sources; Wetland site report, 1994).

Anuradhapura is a one of the earliest kingdom in Sri Lanka, which has hundreds of large and small tanks. The King of Wattagamini Abhaya constructed the Nuwarawewa in 1st Century A.D. The tank provides water for the dwellers in the city of Anuradhapura. The catchments area of the tank is 83.2 km^2 and the capacity of the tank is 4266 hector meter. The average depth of the tank is 6.9 m.

The Nuwarawewa area is located 206 km north-east of Colombo, in the North Central Province. The site is also situated within the mid catchments of the Malwatu Oya and closed to the old town of Anuradhapura (Fig 2.3).

The dry zone of Sri Lanka consist thousands of lakes, which were constructed for the storing water for agricultural activities. These tanks often form a series of successive water bodies along small water a source, which is called a "Cascadian system". The advantage of such a system is that excess water from a tank along with the water used in the commanding area is captured by the next down stream tanks and thus is put to use again in the command area of the second tank. In this way water is continuously "recycled" (De Silva, 2003).

2.6.1 Geography of Nuwarawewa

Anuradhapura is situated in the lowest peneplain, that constitutes the iland having an elevation ranging between 90 to 115 m asl. Anuradhapura situated in dry zone and with in 1,250- 1500 mm mean annual rainfall and has 2 to 5 months of drought each year. The main rainy season is during the North- East monsoon (November- January) (Wetland site report, 1994).

Mean monthly temperature of Anuradhapura during the years 1968-1992 was 27.9^0 C with a lowest value of 25.4^0 C observed in January and a highest of $29.4\ ^0$ C in April. Mean daily temperature varies as much as $9\ ^0$ C during the westerly winds in May to September. Mean monthly relative humidity varies from 60% (March) to 80% (December) (Wetland site report, 1994).

The study area contains reddish- brown earth and low humic glay soil, which is typical to the northern low lands region. Some alluvial soils also are found in river valleys (Moorman and Panabokke, 1961).

2.6.2 Ecological characteristic of Nuwarawewa

In terms of "Agro-ecological" classification, the Anuradhapura area is situated within the Dry Zone. More specifically concerned with the study area, the natural vegetation cover can further be subdivided into aquatic vegetation types associated with the tanks and the river (i.e. Phytoplankton and floating submerged and emergent plants) and the upland woodland vegetation. The pytoplankton biomass of the reservoirs of the study area is dominated by Cynophyceae (blue- green algae) and Synedra is the commonest. Rotifera dominates the zooplankton biomass of the tank with species from the genus

Brachionus being the most common. Larvae of Cpepod (nauplii), shrimps water fleas and water mites make up the rest of the zooplankton fauna. Invertebrate fauna are also founded in Nuwarawewa area. It is dominated the insects and their larvae (water bugs, lake flies, mosquitoes and dragon flies). The snail *Melanoides turberculata* is also a very common benthic invertebrate in tanks (Wetland site report, 1994).

Fifty-three fish species have been recorded in the Dry Zone of Sri Lanka (Pethiyagoda, 1991), species at least 36 were found in the Anuradhapura area (Wetland site report, 1994). Two fish species found in the dry zone (including Anuradhapura study area), namely *Puntius ticto* (Tic-tac-toe Barb) and *Labeo porcellus* (Orange - fin Labeo), are not recorded in the wet zone. With regard to fish species, the introduced Tilapia (*Orwochromis mossambicus*) is the commonest fish in the tank. *Amblypharyngodon melettinus* (Silver carplet) and *Puntius vittatus* (Silver barb) are also very common. Prior to 1990, the tank had been stocked periodically with several major carp (*Cyprinid*) species such *as Aristrichthys nobilis* (Big head carp), *catla catla* (Catla), *Cirrhinus mrigala* (Mrigal), *Ctenopharyngodon idella* (Grass carp), *Cyprinus carpio* (common carp) and *Labe, rohita* (Rohu). Nuwarawewa area has recorded more than hundred of bird species according to Wetland Site Report in 1994. Out of this 5 species are endemic (Wetland site report, 1994).

2.6.3 Utilization of Nuwarawewa

Since the Anuradhapura District is predominately agricultural, most part of the Nuwarawewa sarrounding is used for agricultural purposes, mainly for growing of rice cultivation. More than half of population is employed directly related to agriculture. However the total fraction of the population engaged in agricultural pursuits appears to be more than 70%. Shifting cultivation (chena) is practiced as a second source of income by 3.9% of the farmer population (Wetland site report, 1994).

The main agricultural crop, paddy is cultivated in two seasons, as in other parts of the country. The major season, Maha is during the rainy period from October to January.

The Yala season (May to September) depends mainly on irrigated water from reservoirs. The important cash crop that are grown on the area are chilly (*Capsicum annum*). Vegetables such as brinjal, tomato, cucurbits and cereal crops such as corn and kurakkan (*Eleusine coracana*) are grown in mind cropping system. The Nuwarawewa is provided water for 1000 hector meters to cultivate rice in both Yala, Maha and also for other cash crops. The tank has four sluice doors opening to the four irrigation canals. The main canals divided into smaller drains, which irrigate paddy fields and other croplands (Wetland site report, 1994).

Nuwarawewa is one of the largest sources of drinking water for the Anuradhapura urban area. The National Water Supplies and Drainage Board extracts 1.5 hector liter per day as drinking water, which provides to 8180 families. In addition to that 1176 government offices and commercial establishments consume tank water. Today about 88000 people depend on tank water. During the festival season pilgrims also use the tank for different purposes. Thousands of cattle and other animals also consume tank water daily.

The Nuwarawewa is one of the main income sources for families living around the tank. Some families directly depend on the reservoir by fishing. Within the study area about 3% of the population is employed in animal farming.

The fishery in the Nuwarawewa is done using traditional nature. The major species found in the tank is exotic Thilapia (*Oreochrmis mossambicus*). Important indigenous species are pearl spot (*Etroplus suratensis*), Suakehead (*Channa striata*) and Catfish (*Mystus keletius*). The composition of an average catch in Nuwarawewa is given in table 3.1(Wetland site report, 1994).

Table2.2 Composition by weight of the fish catches in the Nuwarawewa (Sources; Wetland site report, 1994).

SPECIES	COMMON NAME	Percentage (%)
Oriochromis mossambicus	Java Thilapiya	60
Etroplus suratensis	Pearl Spot	6
Channa striata	Striped Snake Head	3
Puntius sarana	Olive Barb	2
Puntius dorsalis	Long-snouted Barb	1
Lebeo dussumieri	(Comman Labeo)	< 1
Mystus keletius	Yellow Catfish	< 1
Glossogobius giuris	Bar-eyed Gobi	< 1
Other Species	------------------	< 25

Nuwarawewa has 43 operational fiber glass and wooden out-rigger fishing crafts (Wetland site report, 1994).

The study area including Nuwarawewa is the focal point of both local and foreign tourism due to its cultural heritage. The sacred area, declared as cultural heritage has a worldwide attention. Almost all tourists also come to Sri Lanka visit Anuradhapura to appreciate the ancient monuments. The area will remain at highest tourist value in the country for many more years.

2.7 Threats to the Nuwarawewa

Water is a universal solvent and hence dissolves most naturally occurring substances as well as those produced by human activities. Pure water is not available in nature because surface water absorbs particulates, CO_2 and other gasses and mixes with silt and inorganic matters in the environment. But mixing of substances in excess amount can cause threats to water bodies.

The Nuwarawewa is situated very close to the Anuradhapura town and many hotels, guesthouses, army and a air force camp are situated around the tank. Effluents from these sources are threat to the tank water. Many effluent outlets are opened to the tank water.

Yoda Ela is one of the main water sources, which provided water from Nachchaduwa tank to Nuwarawewa. This main canal is about 19 km long. There are many paddy fields beside the canal. The manure and agro-chemicals used for cultivation, drains to canals. People also use the stream water (Yodha Ela and their sub canals) for bathing and washing. The pollutants such as oil, detergents and soap also added to the lake and its drainages. In addition to that, some people wash their vehicles from streams and from the tank, adding petroleum contaminants.

Most of the farmers around the Nuwarawewa in keep cattle for economical profits. Animal shades do not proper disposal system for cow-dung and swages. These pollutants also flow into the tank through various drains causing excessive pollution. The local and foreign tourists visiting the Anuradhapura are substantially added many pollutants to the tanks especially during the festival season in June. The use of open places as toilets during festival season also causes a pollution problem.

CHAPTER 3

Material and Methods

A field visit was made to the tank for preliminary studies. During this visits sampling points were identified. In addition to that zonation of the lacustrine vegetation and land-use patterns in the periphery of the lake were studied. Possible source of pollution were identified and other necessary information were gathered with personal communication with people living near and around the Lake. Samples were collected only from the north part of the Nuwarawewa because south part of the lake was dried with the excising drought condition.

3.1 Sampling Procedure

Totally 27 water samples were collected from Nuwarawewa from which 21 water samples were taken from the surface of the tank. Depth samples were carried out in three locations. Figure 3.1 illustrates the sampling location of the Nuwarawewa.

Water samples were collected in pre-cleaned polyethylene containers, soaking over night in dilute HNO_3 and rinsed several times with distilled water. In the field, these bottles were further rinsed with the water to be collected prior to the collection. Sampling bottles were filled up to the mouth of the bottles in order to prevent the formation of the headspace. Several Samples were collected for the determination of plankton and BOD. Figure 3.2 illustrates the sampling location for plankton and BOD determination. All samples were kept cool and dark place. 5% formalin was added only to plankton samples for preservation of planktons. pH and TDS measurements were taken immediately in the field. Other measurements were made in the laboratory.

3.2 Determination of chemical and biological parameters in water

The chemical and biological analysis of water was carried out in the field and analytical laboratory of Environmental Engineering at University of Peradeniya; Department of Agriculture Engineering of University of Peradeniya and Open University, Nawala. All analysis was carried out using standard methods for the examination of water and wastewater.

3.2.1 Nitrate (NO_3^-)

Nitrate is considered to be nutrient, essential for plant growth. Nitrate from natural sources is attributed to the oxidation of nitrogen of the air by bacteria and to the decomposition of organic material in the soil. Fertilizes may add nitrate directly to water (Weerasooriya, 1986). For the determination of the nitrate concentration in water, Hach DR-2010 Spectrophotometer was used. Nitra Var 5 nitrate regent powder pillow was used as a color development regent in this methods and the content was measured at 500nm.

3.2.2 Phosphate (PO_4^{3-})

Phosphate is also considered as nutrient and essential for plant growth. Phosphate is not found in the atmosphere. Natural constituents of Phosphate are bacteria decomposition of organic material. Fertilizers also consist of phosphate. Phosphate concentration was measured directly by using Hach DR-2010 spectrophotometer at 890nm. Phos Var 3 phosphate regent powder pillow was used as a color development regent.

3.2.3 pH

The pH of the water indicates the intensity of the acid or alkaline condition of water. pH of water was measured directly in field, by using Hanna pocket pH meter.

3.2.4 Total Dissolved Solids (TDS)

The total amount of dissolved chemical species in water is called total dissolved solids, which is a good general measure of the concentration of ionic substances in water. TDS of water samples were determined at the sampling site by Using TDScan –4, TDS meter.

3.2.5 Biochemical Oxygen Demand

The Biochemical Oxygen Demand (BOD) of a water samples is measurement of the concentration of biodegradable organic matter in water. The utilization of organic matter in water by microorganisms requires oxygen for the biochemical metabolic process. BOD of water samples was measured by using BOD_5 titrometric method (Silva *et al.*, 1996). Initial BOD values were taken into the 24 hours within sampling. Second BOD values were taken by samples, which are incubated under 25 ° C after 5 days. After that those values are calculated by using the following equation.

$$BOD_5\ mg/l = [(D1-D2) - (B1-B2)\ f] \times D$$

Where;

D1 = DO of diluted sample immediately after preparation (mg/l)

D2 = DO of diluted sample after 5 days incubation at 25 o C (mg/l)

D = Dilution factor

B1 = DO of seed control before incubation (mg/l)

B2 = DO of seed control after incubation (mg/l)

f = % seed in diluted sample

3.2.6 Plankton

Plankton counts are a biological parameter. The diversity and composition of planktons are an indicator of the quality of water (Fernando, 1990). Plankton species (especially zooplankton) were identified using an Olympus microscope. Planktons were stained with Rose Bengol stain and counts were made using Sedgwick rafter.

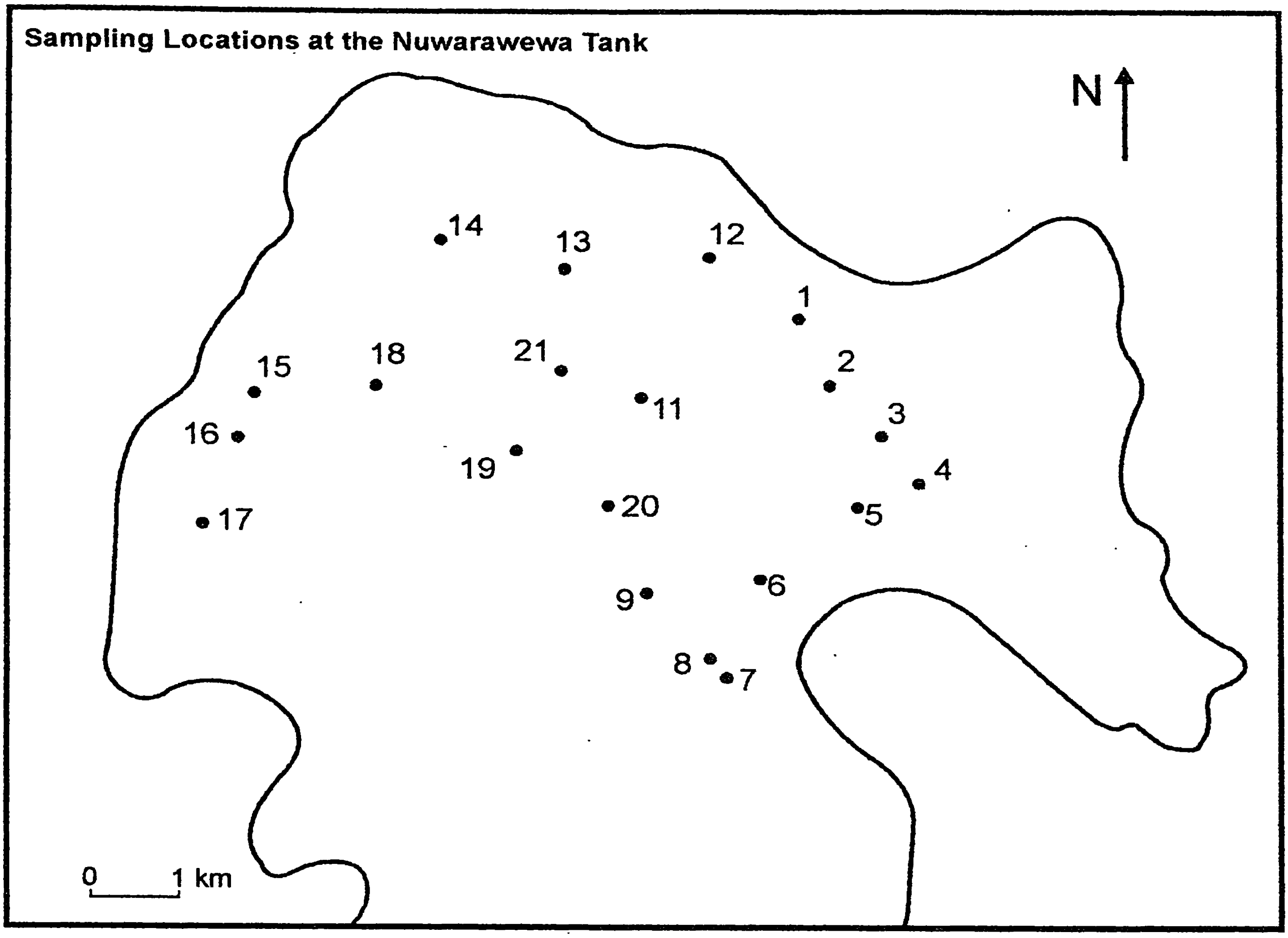

Figure 3.1 Sampling location at Nuwarawewa for the determination of nitrate, phosphate, TDS and pH.

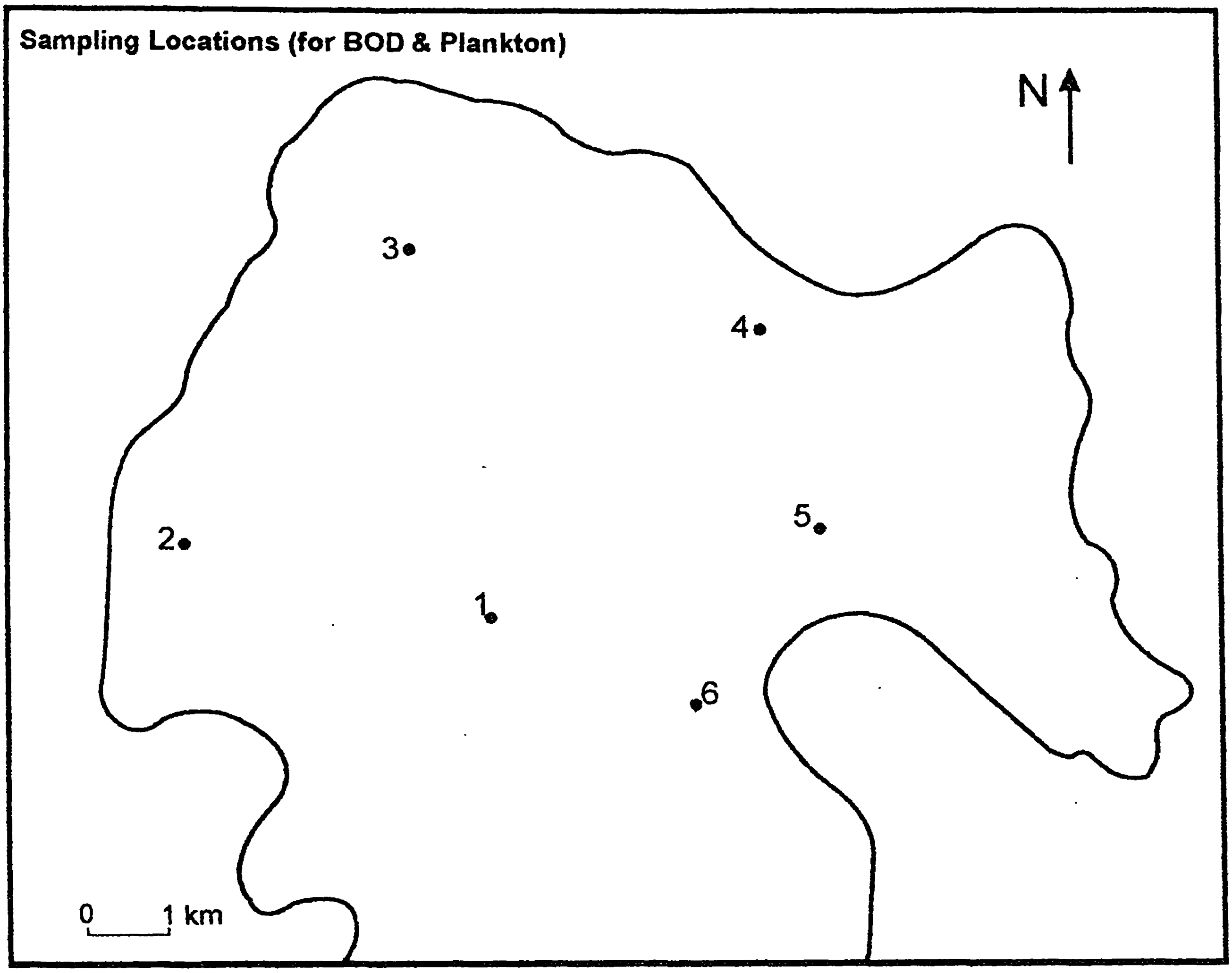

Figure 3.2 Sampling point of plankton and BOD.

CHAPTER 4

Results and Discussion

Preliminary survey was identified the habitat and most probable pollution sources of Nuwarawewa. The catchments area of the tank spared by chena cultivation at present. Paddy fields also situated around the tank.

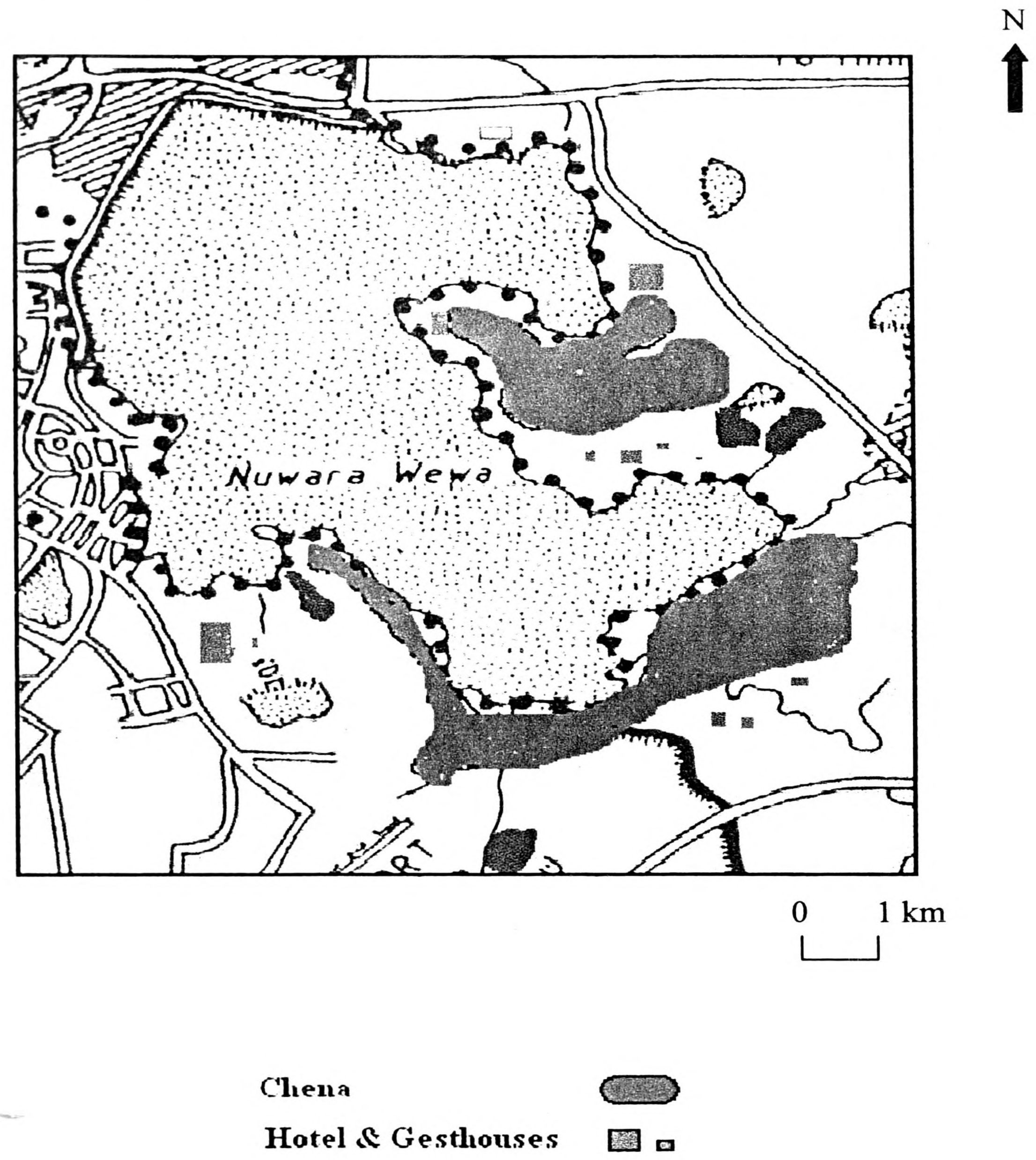

Figure 4.1 Map of the Nuwarawawa area

Organic and inorganic waste and other effluents are responsible for the variation of nutrient level in water bodies. Nutrient content in drinking water and human health has a direct relationship. Therefore measuring and evaluation of nutrient in

Nuwarawewa is essential because it is one of the highly utilized water body in Anuradhapura. The measured water quality parameters include physical and biological characteristics are given in Table 4.1.

Table 4.1 Physical parameters of Nuwarawewa

Sample no.	Sampling depth	Water Depth (m)	TDS (μS/cm)	pH	NO_3^- (mg/l)	PO_4^{3-} (mg/l)
NW1	Surface	1.25	0.4	7.84	9.9	0.03
NW2	Surface	1.6	0.4	7.97	13.2	0.09
NW3	Surface	1.4	1.2	7.98	6.2	0.07
NW4	Surface	1.2	0.4	8.22	10.7	0.36
NW5	Surface	0.7	1.2	8.40	7.7	0.07
NW6	Surface	1.3	1.2	8.18	9.5	0.03
NW7	Surface	1.75	1.2	8.06	7.7	0.25
NW8- 1	Surface	1.75	1.2	8.17	8.8	0.02
NW8-2	1	1.75	1.2	8.12	10.3	0.02
NW8-3	1.75	1.75	1.2	8.17	9.2	0.06
NW9-1	Surface	2	1.2	8.17	9.4	0.01
NW9-2	1	2	1.2	8.11	8.3	0.01
NW9-3	2	2	1.2	7.88	11.2	0.02
NW10-1	Surface	1.9	1.2	8.13	10.1	0.02
NW10-2	1	1.9	1.2	8.10	10.5	0.03
NW10-3	1.9	1.9	1.2	8.96	9.1	0.08
NW11	Surface	1.9	0.4	8.20	9.4	0.06
NW12	Surface	2	0.4	7.88	7.0	0.06
NW13	Surface	2.75	0.4	7.33	17.8	0.07
NW14	Surface	1.5	0.4	8.21	7.4	0.08
NW15	Surface	1.5	0.4	7.83	9.7	0.02
NW16	Surface	1.5	0.4	8.01	8.5	0.20
NW17	Surface	1.5	0.4	8.27	8.0	0.02
NW18	Surface	2	0.4	7.87	9.5	0.11
NW19	Surface	2	0.4	8.18	8.1	0.27
NW20	Surface	2	0.4	7.86	12.0	0.81
NW21	Surface	1.75	0.4	7.85	8.5	0.13

4.1 pH

pH is an important factor which influence the chemical, physical and biological quantity of water. pH of water depends on various factor such as the oxygen supply, decomposed organic matter and some soluble salt present in the water. The values obtained for pH in water is shown in Table 4.1. pH of water of Nuwarawewa ranges from 7.33 – 8.40, with the average being 8.03. The values indicate the alkaline nature of water, which is observed in less polluted water bodies (Wetzel and Likens 1979).

The pH of different locations of the Nuwarawewa study area is not highly varied. Fig.4.2 and Fig.4.3 show the variation of pH with phosphate and nitrate concentration.

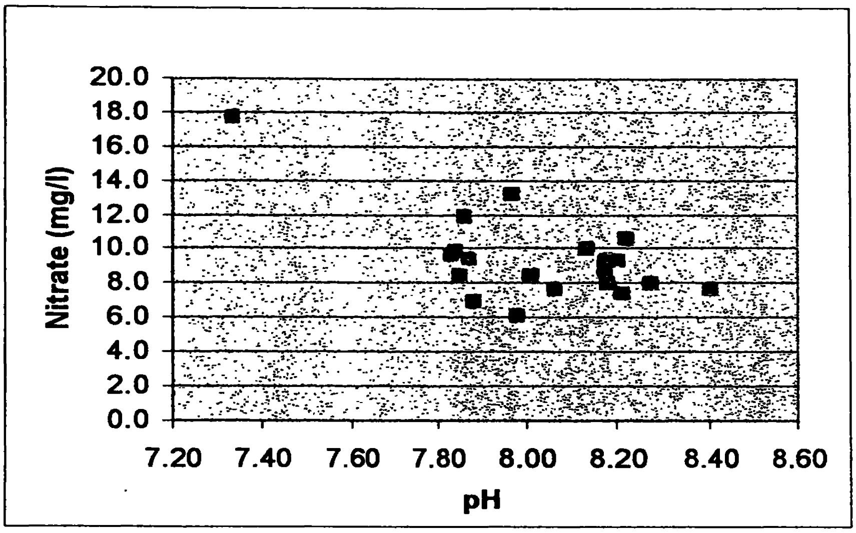

Figure 4.2 Nitrate variations with pH

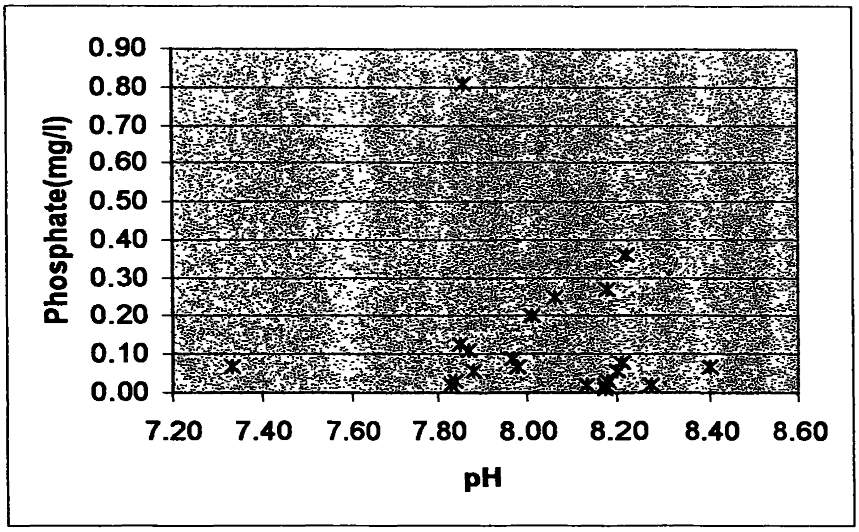

Figure 4.3 Variation of phosphate with pH

4.2 Total Dissolved Solids (TDS)

Total dissolved solids are a good general measure of the concentration of ionic substances in water. In general, fresh water has less than 1500 mg/l of TDS (Ackerman *et al.*, 1973). However TDS values are depended on many factors such as variety of climatic condition, runoff, drainage pattern and level of pollution. The value of TDS is sampling water is shown in Table 4.1. TDS of Nuwarawewa water is varied from to 0.4 – 1.20 µs/cm.

4.3 Nitrate

Nitrate and other nitrogenous compounds are essential in the life cycle of plants and animals. High concentration is however hazardous, and high levels are directly related to pollution. When the nitrate level of drinking water is higher than 45 ppm, it causes infant methomoglobinemia, tumors and cancers in stomach (Dissanayake, 1988). Figure 4.4 illustrates in spatial variation of NO_3^- in Nuwarawewa. The monitoring of nitrate levels in the tank is extremely important due to their possible effects on aquatic ecosystem. The average nitrate in the tank is being 9.41 mg/l. This value is less than the level of 45 ppm, which is the approved level of nitrate in drinking water (WHO, 1982).

Wetland conservation project, which was conducted by the Central Environmental Authority, mentioned that nitrate in Nuwarawewa varies between 0.12 – 0.15 mg/l but in the year 2004, the content has increased massively up to 6.2 – 17 mg/l. This figure express how rapidly the rate and quantity of nitrogen compound mixing with tank water. Hotels and residences around the tank, and animal husbandry activities increase the input of nitrogenous compound into the tank. Nitrate concentration in most of the sampling point is remained in 8 – 10 mg/l range. In some sampling points, nitrate level is higher than 17 mg/l. Since there is no possible explanation to this with the waste disposal or land use practices, it may be due to a non-point source pollution during the sampling period.

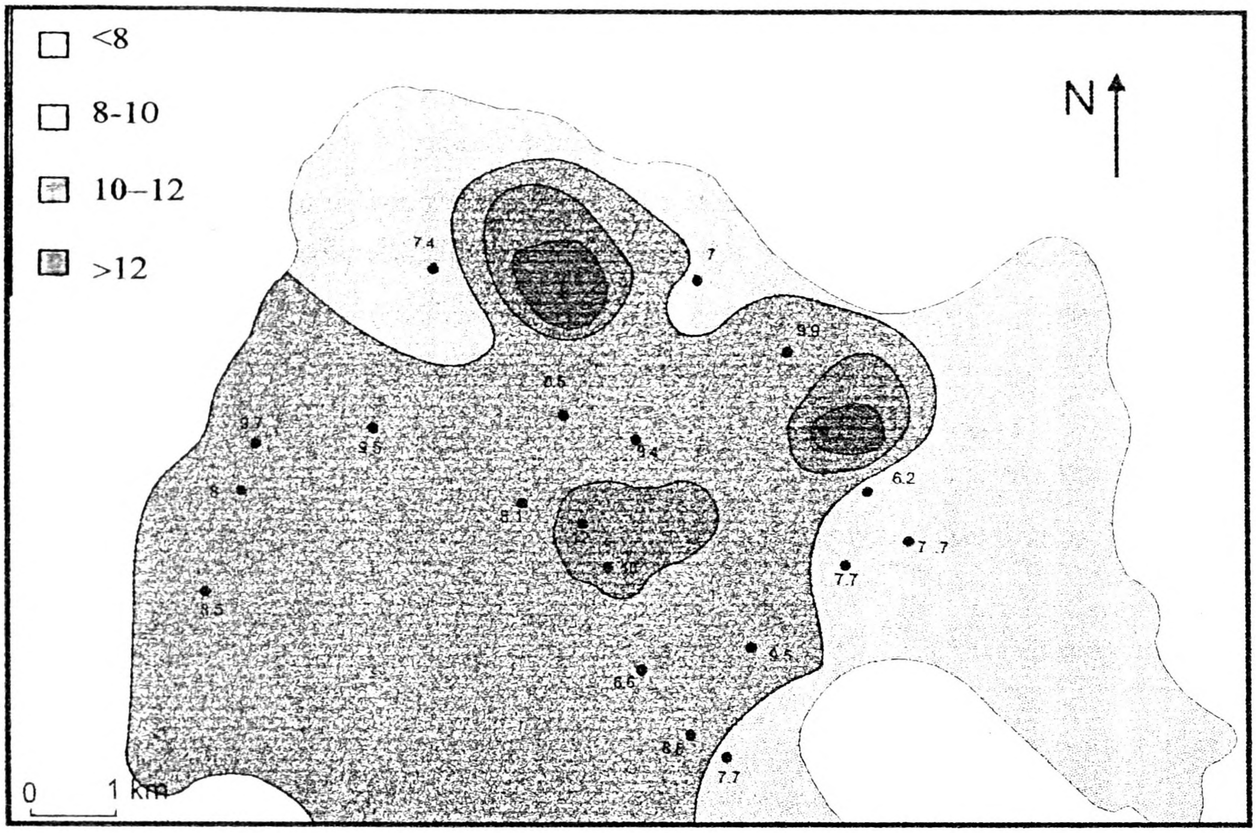

Figure 4.4 Distribution of Nitrate in Nuwarawew

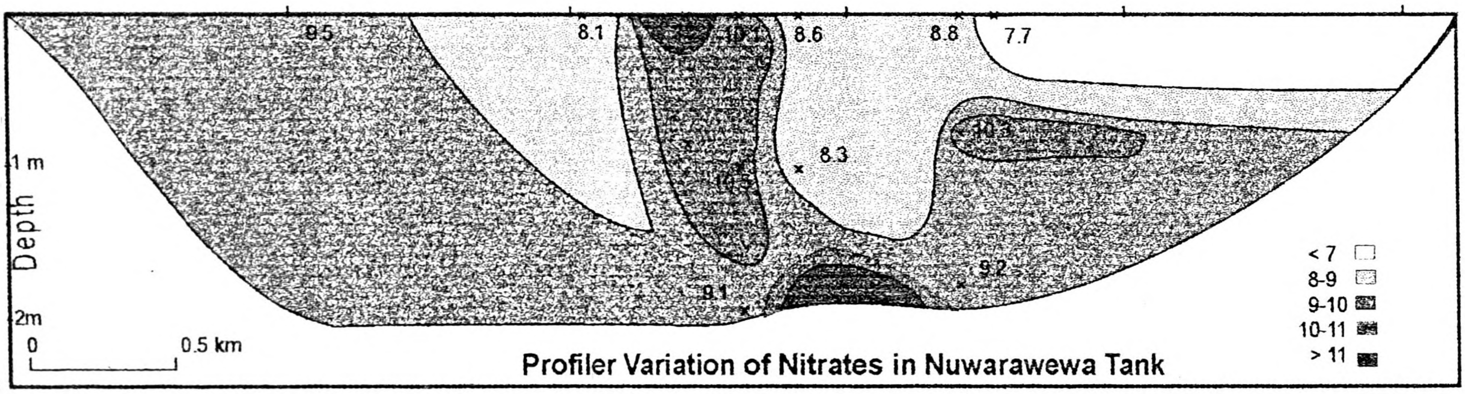

Figure 4.5 Distribution of Nitrate along the profile.

Figure 4.5 illustrates the depth variation of nitrates in the Nuwarawewa. Depth variations of sampling points are small indicating the mixing of lake water. Figure 4.2 shows the variation of Nitrate concentration with pH. Nitrate is concentrated within neutral-slightly alkaline range, but in one sampling point of the tank (point 17) high nitrate value is related to the slightly acidic pH value.

Table 4.2 Nutrient variation of some Sri Lankan tank (Silva, 1996).

Reservoir	Nitrate (mg/l)	Phosphate (mg/l)
Kotmale Oya	5.5 – 35.7	0.1 – 5.5
Rajanganaya tank	2.4	-
Kandy lake	7.76 – 8.54	0.33 – 0.18
* Nuwarawewa	6.2 – 17.8	0.02 – 0.80

*According to this study.

Table 4.2 shows the nitrate concentration in 4 man made reservoirs in Sri Lanka. The Kotmale reservoir is one of the eutrophicated reservoirs in Sri Lanka. Nuwarawewa does not indicate such a high amount of nitrate in comparison to Kotmale reservoir. The Kandy Lake shows the nitrate values of 7.76 to 8.54 ppm, which is comparable to the Nuwarawewa though somewhat higher in some sampling points. When comparing these values, it could be seen that the nitrate levels of the Nuwarawewa is higher than some other tanks and reservoirs of Sri Lanka. If nitrate levels increase with time, would tend to be accumulated in the lake and accelerate the growth of algae. Once algae die, the oxygen content become low as bacterial decomposition commenced. The decomposition process uses much of the dissolved oxygen in water and produce toxic substances in water bodies.

4.4 Phosphate

Phosphate is an essential nutrient for plant but excess phosphate can also pose serious environmental problems. When excess phosphorous in the form of phosphate enters, either from agricultural runoff or from municipal waste discharges containing phosphates, can be eutrophication or nutrient enrichment of lakes or tanks (Vallentyne, 1970).

Figure 4.6 illustrates the spatial distribution of phosphate in Nuwarawewa. Phosphate content in the tank water varies between 0.02–0.81 (mg/l) with the average of 0.13 mg/l. Phosphate concentration is higher in the middle and north-east part of the lake. Figure 4.7 illustrates the depth variation of phosphate. Accordingly phosphate concentration increases from middle of the lake to the coast. This may be due to organic and inorganic materials accumulate in the coastal strip of the tank. The figure 4.3 shows the variation of phosphate concentration with pH. According to the Wetland conservation project (1993), the phosphate concentration of Nuwarawewa was 0.18 – 0.46 (mg/l) but now it has been increased upto 0.8 mg/l.

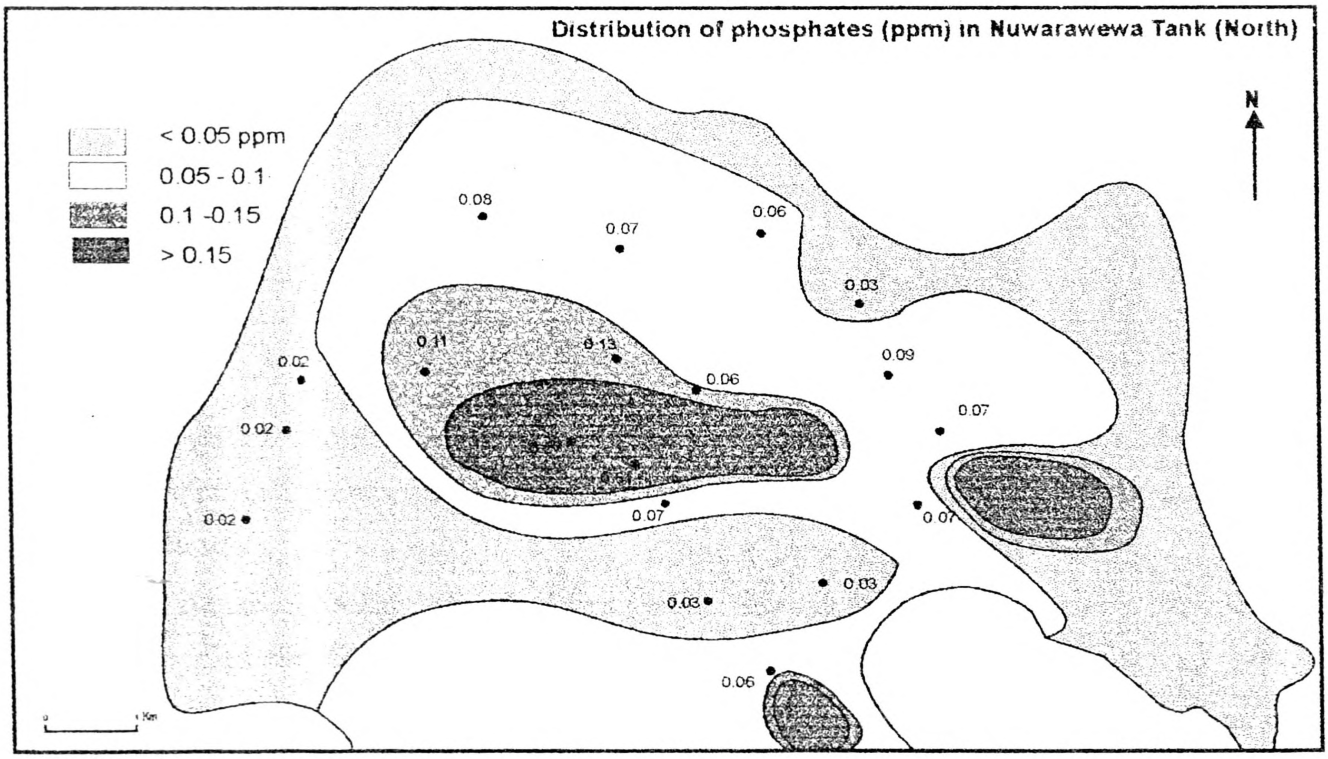

Figure 4.6 Distribution of Phosphate in Nuwarawewa.

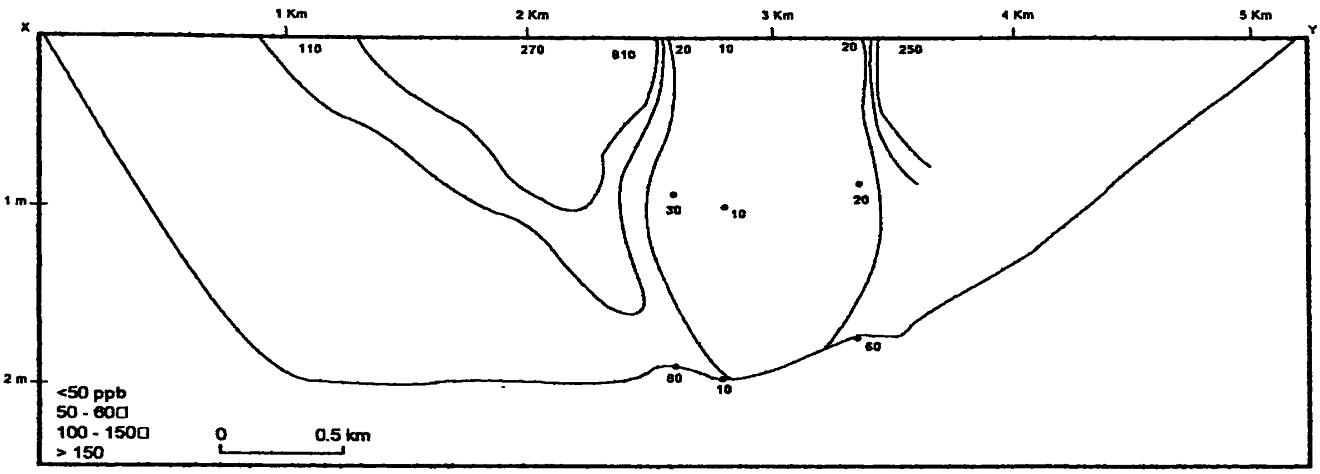

Figure 4.7 Distribution of Phosphate along the profile

4.5 Plankton

Table 4.3 Biological parameters of Nuwarawewa.

Sample No:	Surface BOD (mg/l)	Bottom BOD (mg/l)	Plankton total count
1	18	19	111
2	16	20	86
3	15	20	123
4	20	24	97
5	20	26	160
6	22	26	123

Plankton, which is a general term use for small organisms living in bodies of water, may be divided into plants (phytoplankton) and animals (zooplankton). Phytoplankton lives by absorbing carbandioxide (CO_2), nitrogen (NO_3^-), phosphorus (P) etc. from water and produce energy by photosynthesis. The small forms of phytoplankton become the main source of food for the zooplankton. The way of supporting many of the life forms in lakes has given phytoplankton the important role as the 'basic producers' of food in the ecosystem (Hasimoto, 1995). However according to table 4.3 the tank is dominated by zooplankton genus Brachionus, with species *Brachioonus falcatus* and *Keratella tropica*, most common larvae of Copipode, Cladocera make up the rest of the zooplankton. Plankton diversity of the studied tank is shown in Figure 4.8. There is a clearly variation of the plankton density within the lake. Plankton density increased when it closed to feeder canal (Yoda Ela) and adjacent to the old town. Decomposed material, sewage and other waste outlets entered mostly from these areas. As indicated in the number of plankton in the lake is increased with BOD values.

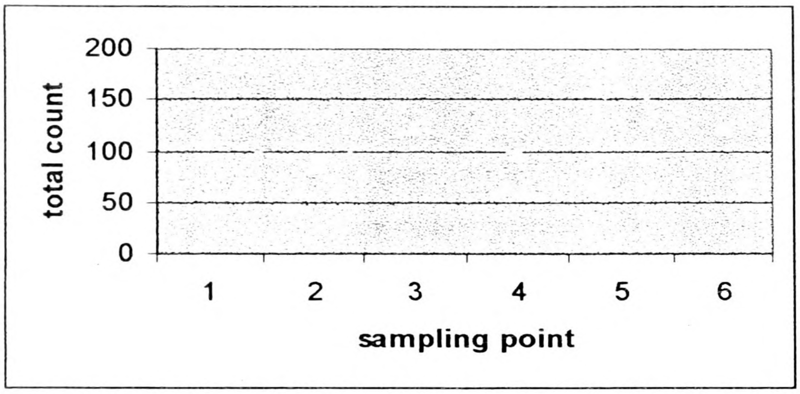

Figure 4.8 Distribution of plankton amount with sampling point

4.6 Biological Oxygen Demand

BOD is the representation of the amount of oxygen required for microbial decomposition. That is complete aerobic decay and mineralization of biodegradable organic matter present in water. Organic matter in water may derive from natural sources or by various human activities. Most of the natural organic compounds are soluble in water, but synthetic organics are insoluble in water (Wetzel, 1983). Microorganisms in a water body are dependent on the organic matter content in the water body. The microorganism density is directly proportional to the organic matter content of water (Droot, 1977).

Table 4.3 shows the BOD for 6 sampling point of the Nuwarawewa. Figure 4.9 and Figure 4.10 shows the variation of BOD values at surface and bottom but no remarkable variation were observed.

There are many waste outlets from hotels, which are directly open to the tank. The catchments area is also used for animal farming activities. The organic material quantity in the catchments area is considered to be high. All the above factors directly affect the increasing of BOD value in the lake.

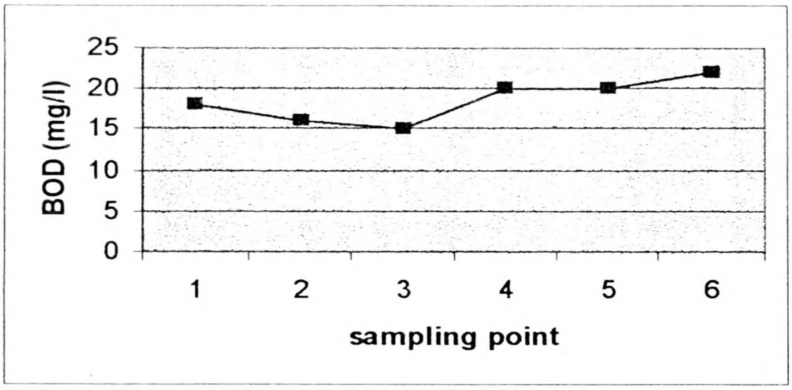

Figure 4.9 Variation of BOD with surface of the lake

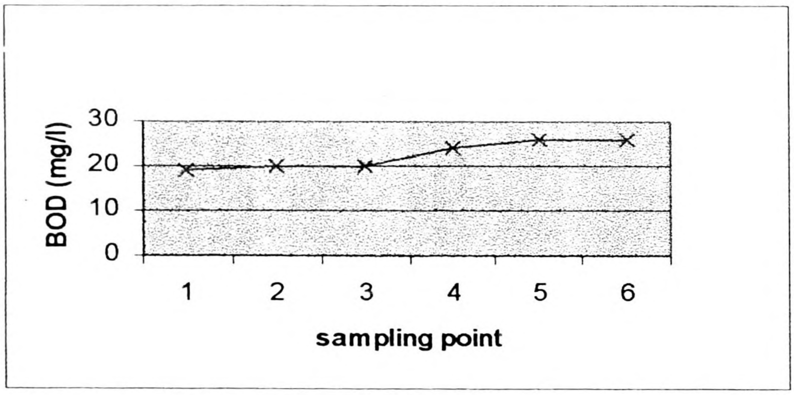

Figure 4.10 Variation of BOD with bottom of the lake

CHAPTER 5

Conclusions and Recommendation

5.1 Conclusions

According to analytical results, severe pollution is not evident in Nuwarawewa, but it must be emphasized that nutrient level in Nuwarawewa is increasing with the time, indicating an increasing tendency of pollution. According the results obtained in 1994 the NO_3^- and PO_4^{3-} values of the study tank were 0.13 mg/l and 0.32 mg/l but now it is varied to 9.41 mg/l and 0.13 mg/l, respectively, nitrate is increased 7 the factor of per year. If nitrate level is increased annually this trend, it might cause excess nourishing conditions in the lake very soon. On the other hand if nutrient such as phosphate and nitrate are increased like this, it would results the eutrophication.

Increasing trend of nutrient will lead to serious pollution of this water body. As a result, the whole ecosystem of the Nuwarawewa might be disturbed, as which affecting the ecological characteristics and human utilization. Therefore accumulation of nutrient should be controlled, particularly local administrative authorities should take immediate action to protect the lake ecosystem since the lake supplies drinking water to the general public, as well as the lake is a important for recreational activities.

5.2 Recommendations

As indicated by the present study, the Nuwarawewa is susceptible to the severe pollution in future and therefore following action need to be taken to protect this important ecosystem.

i. For the further studies, the measurements of the bacteriological, organo-chemicals and heavy metals are particularly important.

ii. Strategies should be implemented to protect the lake from point sources, which can be controlled easily. For this, a survey can be conducted to identify the major and minor effluent outfalls to the Nuwarawewa.

iii. A systematic monitoring program for water quality assessment of the Nuwarawewa should be carried out regularly.

iv. The awareness programme for the general public should be launched to educate the people in the vicinity of the lake particularly those who depends on the lake.

v. Regulating sediment loading into the tank via major inflows is important in order to control severe siltation.

vi. A proper management plan to deal with the land-use pattern and the lacustrine vegetation is essential for the protection of the lake. Monitoring of the utilization practices should be carried out as a part of the implementation of management options.

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