CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

Monitoring the water quality in the wetlands system is an important task as it shows the functionality of the wetlands. The water, after 'purification' by the wetlands, is used downstream for human recreation with bodily contact. Thus, it is important to know if the water is clean. The reasons for the poor water quality should be ascertained and perhaps the wetland functions modified to improve the 'purification' process. In the event of polluted water, it is also important to be able to warn the public of using the lake until clean water quality is restored.

3.2 Sampling Strategy

Water sampling was carried out once a month starting from March 1997 – July 2000 which could be catagorised into:

- Pre-construction of wetland cells (Phase 1)

The pre-construction of wetland cells started from March 1997 to April 1998. During this period, civil works has been commenced which included the earthwork and land clearing activities for the diversion of rivers to form the wetland cells. No planting of wetland cells was carried out.

- During Construction of wetland cells (Phase 2)

This period started from May 1998 to September 1999. This period involved planting of wetland plants in the wetland cells concurrently with the construction of weirs for inlet and outlet of the wetland cells.

- After construction of wetland cells (Phase 3)

This period started from October 1999 to July 2000. This period involved the maintenance of constructed wetlands where all the wetland cells are planted up and the vegetation in them mature. No more planting is involved except for the replacement of dead plants.

At pre-construction of wetland cells, water samples were taken from the main waterways that flow through the Project site. A total of nine sampling points were involved. The locations of the water sampling points take into consideration the proximity of the waterways to the wetland cells. This would represent sampling points in the "wetland cells" later after the construction of wetlands cell. At each sampling occasion, two separate samples were taken from the main waterways. Table 4 and Figures 7 – 16 show the water sampling locations before construction of wetland cells.

Table 4. Coordinates of Water Sampling Locations Before Construction of Wetland Cells

Sampling Location	Latitude	Longtitude
UN1	E 101° 42.064'	N 2° 58.533'
UN2	E 101° 41.990'	N 2° 58.374'
UN3	E 101° 41.910'	N 2° 58.080'
UN4	E 101° 41.882'	N 2° 57.512'
C1	E 101° 41.831'	N 2° 57.325'
C2	E 101° 41.624'	N 2° 57.000'
P1	E 101° 41.395'	N 2° 56.620'
P2	E 101° 40.979'	N 2° 55.660'
P3	E 101° 40.990'	N 2° 55.668'

Phase 2 involved sampling during planting in the completed wetland cells. A total of twenty-two (22) samples were taken during this period. Table 5 shows the number of water samples taken and their coordinates. The number of water samples taken during the construction of wetland cells is similar to that of after the construction of wetland cells. The aim of sampling after construction of wetland cells is to assess the performance of the wetlands. In Upper North wetland cells, water samples were taken from the outlet zones of each of the constructed wetland cells. Table 5 and Figures 17 - 39 show the coordinates and locations of the water sampling stations after construction of wetland cells.

Table 5. Coordinates of Water Sampling Locations After Construction of Wetland Cells

Sampling Location	Latitude	Longtitude
Upper North Arm		
UN8	E 101° 42.455'	N 2° 58.773'
UN7	E 101° 42.272'	N 2° 58.658'
UN6	E 101° 41.911'	N 2° 58.327'
UN5	E 101° 41.922'	N 2° 58.148'
UN4	E 101° 41.910'	N 2° 57.961'
UN3	E 101° 41.948'	N 2° 57.797'
UN2	E 101° 41.916'	N 2° 57.680'
UN1	E 101° 41.870'	N 2° 57.540'
Central Wetlands		
CW1	E 101° 41.733'	N 2° 57.255'
CW2	E 101° 42.003'	N 2° 57.005'
CW3	E 101° 41.613'	N 2° 57.059'
CW4	E 101° 41.710'	N 2° 56.910'
Primary Lake		
PL1	E 101° 41.622'	N 2° 56.900'
PL2	E 101° 41.289'	N 2° 56.696'
PL3	E 101° 41.281'	N 2° 56.535'
PL4	E 101° 41.305	N 2° 56.373'
PL5	E 101° 41.128'	N 2° 56.170'
PL6	E 101° 41.187'	N 2° 55.980'
PL7	E 101° 41.057'	N 2° 55.876'
PL8	E 101° 41.872'	N 2° 56.037'
PL9	E 101° 41.449'	N 2° 56.512'
PL10	E 101° 41.527'	N 2° 56.834'

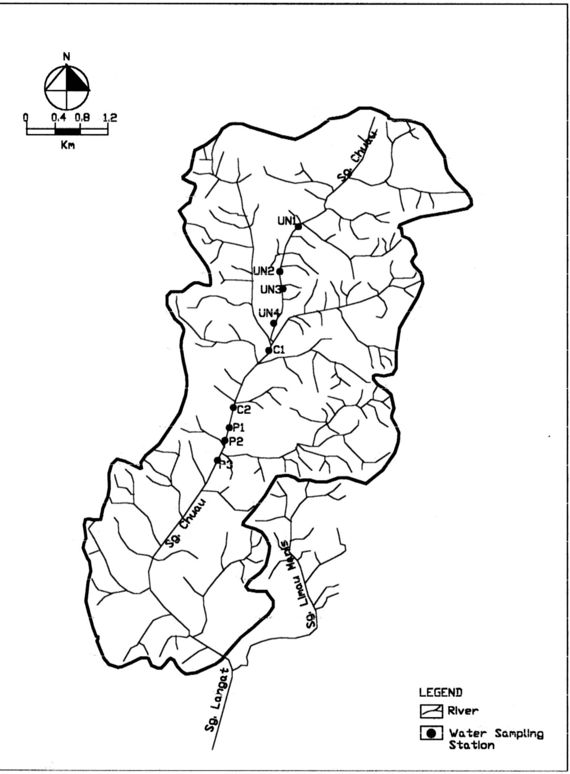

Figure 7. Water Quality Monitoring Points before Construction of Wetland Cells

Figure 8. Water Sampling Point at UN1 before Construction of Wetland Cells

Figure 9. Water Sampling Point at UN2 before Construction of Wetland Cells

Figure 10. Water Sampling Point at UN3 before Construction of Wetland Cells

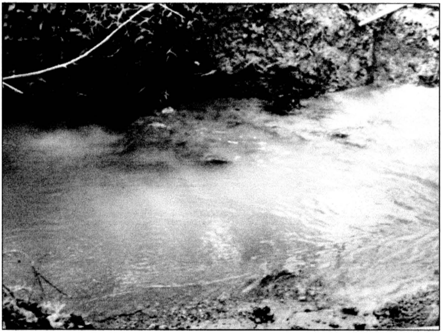

Figure 11. Water Sampling Point at UN4 before Construction of Wetland Cells

Figure 12. Water Sampling Point at C1 before Construction of Wetland Cells

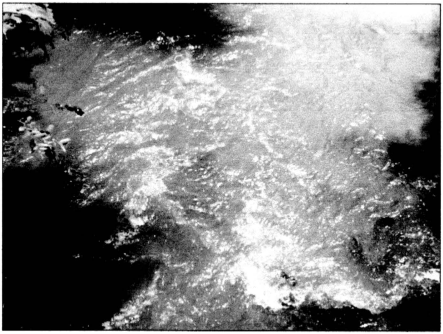

Figure 13. Water Sampling Point at C2 before Construction of Wetland Cells

Figure 14. Water Sampling Point at P1 before Construction of Wetland Cells

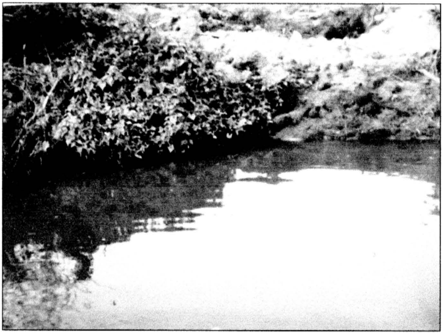

Figure 15. Water Sampling Point at P2 before Construction of Wetland Cells

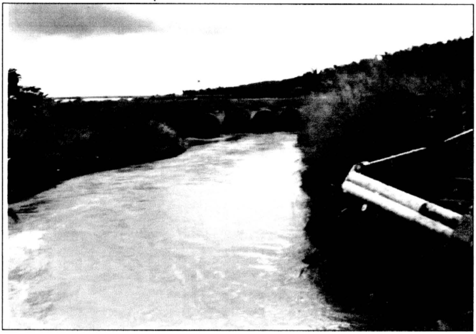

Figure 16. Water Sampling Point at P3 before Construction of Wetland Cells

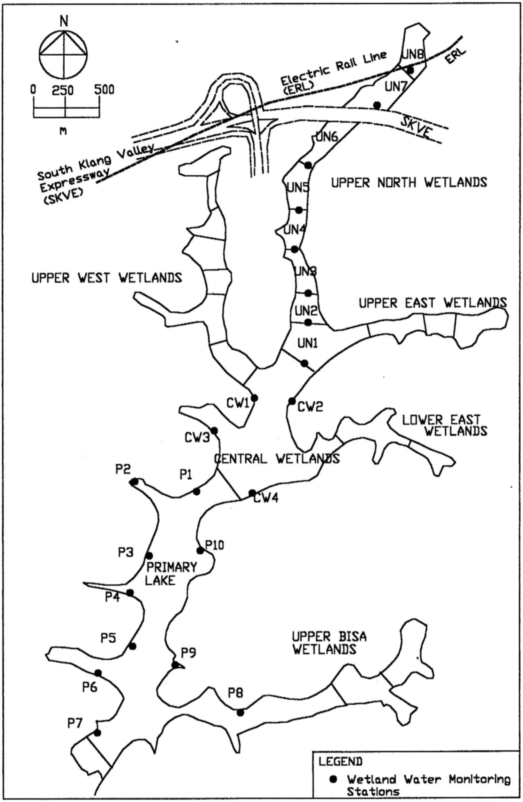

Figure 17. Water Quality Monitoring Points after Construction of Wetland Cells

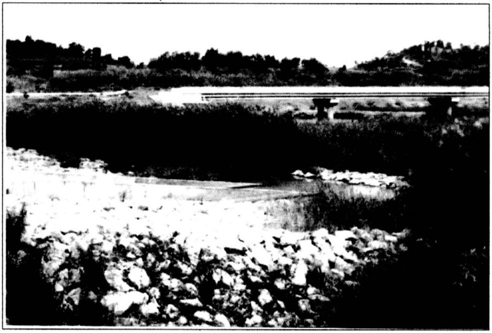

Figure 18. Water Sampling Point at UN8 after Construction of Wetland Cells

Figure 19. Water Sampling Point at UN7 after Construction of Wetland Cells

Figure 20. Water Sampling Point at UN6 after Construction of Wetland Cells

Figure 21. Water Sampling Point at UN5 after Construction of Wetland Cells

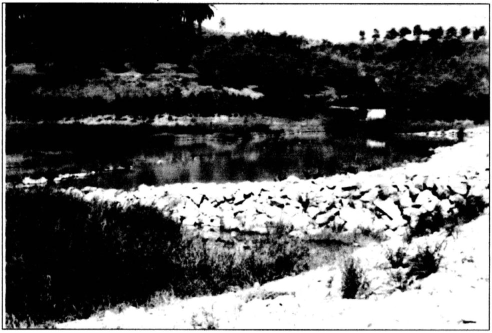

Figure 22. Water Sampling Point at UN4 after Construction of Wetland Cells

Figure 23. Water Sampling Point at UN3 after Construction of Wetland Cells

Figure 24. Water Sampling Point at UN2 after Construction of Wetland Cells

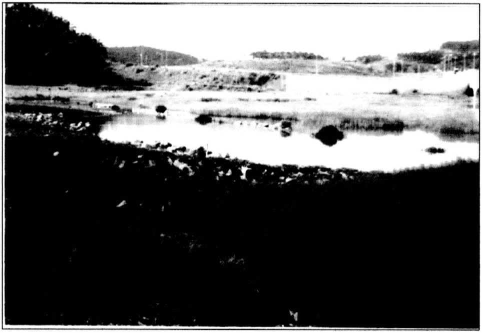

Figure 25. Water Sampling Point at UN1 after Construction of Wetland Cells

Figure 26. Water Sampling Point at CW1 after Construction of Wetland Cells

Figure 27. Water Sampling Point at CW2 after Construction of Wetland Cells

Figure 28. Water Sampling Point at CW3 after Construction of Wetland Cells

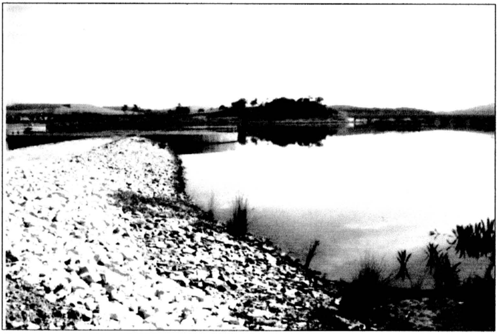

Figure 29. Water Sampling Point at CW4 after Construction of Wetland Cells

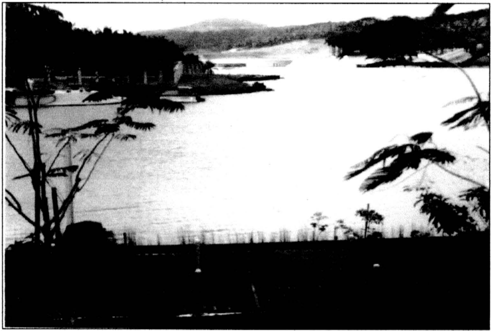

Figure 30. Water Sampling Point at PL1 after Construction of Wetland Cells

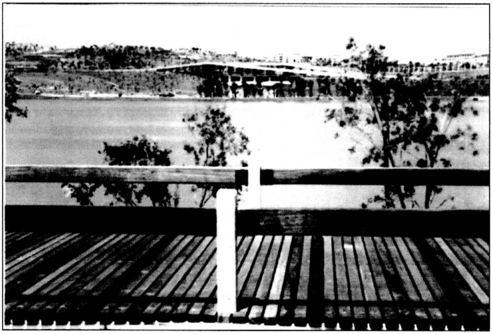

Figure 31. Water Sampling Point at PL2 after Construction of Wetland Cells

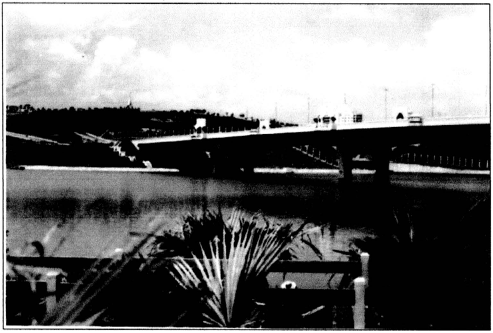

Figure 32. Water Sampling Point at PL3 after Construction of Wetland Cells

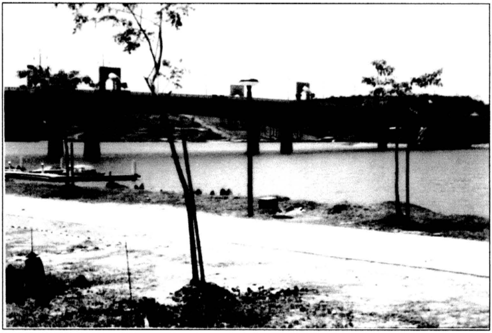

Figure 33. Water Sampling Point at PL4 after Construction of Wetland Cells

Figure 34. Water Sampling Point at PL5 after Construction of Wetland Cells

Figure 35. Water Sampling Point at PL6 after Construction of Wetland Cells

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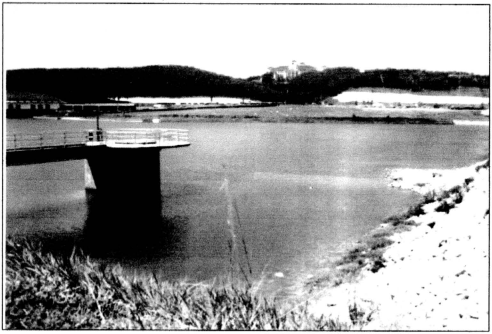

Figure 36. Water Sampling Point at PL7 after Construction of Wetland Cells

Figure 37. Water Sampling Point at PL8 after Construction of Wetland Cells

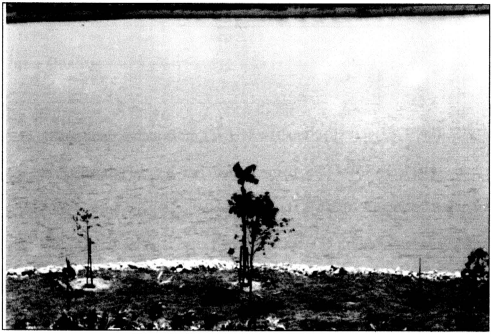

Figure 38. Water Sampling Point at PL9 after Construction of Wetland Cells

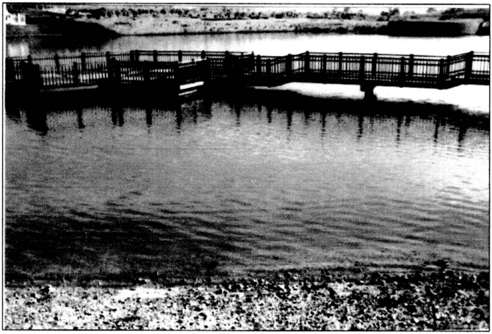

Figure 39. Water Sampling Point at PL10 after Construction of Wetland Cells

3.3 Environmental Data Collection

3.3.1 Water Quality

In this study, water quality data from the UN wetland cells (UN1 - UN8), CW and PL were used. No wetland planting has been carried out at the Primary Lake, which functions as a dam in the whole Putrajaya Wetlands System. However, water from Sg. Chuau flows into the UN wetland cells before discharging at the outlet at PL. The study period was from March 1997 till July 2000.

3.3.2 Atmospheric Parameters

Atmospheric parameters, total rainfall (mm), mean air temperature (°C), sunshine (MJm^{-2}), cloud (Oktas) for the meteorological station at Sultan Abdul Aziz Shah airport (3° 07' N, 101° 33' E) were obtained from March 1997 to July 2000 from the Malaysian Meteorological Service (MMS), Selangor.

3.4 Sampling Parameters and Methodologies

Sampling methodology was carried out using the methods recommended by Standard Analytical Methods of APHA (1995) which includes the following:

a. Grab water samples were obtained (wherever possible) approximately 1m below the water surface and close to the middle of the river. Three replicate samples were obtained for each sampling station.
b. Prewashed sampling bottles were rinsed thoroughly with river water before sampling was carried out.
c. All samples were labelled for sampling location, date and time and type of test to be conducted. Samples are kept in an ice box before delivering to the laboratory for analysis.
d. Chemical oxygen demand sampling bottle contained sulphuric acid which acts as a preservative.

Parameters for water quality analysis in this study included:

i. Physical

The physical characteristics monitored include pH and Total Suspended Solids (TSS). These are basic parameters, which provide baseline data on the quality of water in the rivers, lake and wetlands. pH was measured using HI 9023C pH/mV/°C meter in situ while TSS was done in the laboratory.

ii. Nutrients

In a water body, the degree of biological productivity, or trophic status is one of the most important aspects of water quality. Nutrient concentrations such as the phosphorus and nitrogen are the most significant factors accounting for variability in biological productivity, especially in the lakes (Malcolm *et al.*, 1998). High productivity systems or eutrophic systems, are prone to problems associated with excessive biomass production

and decay, and consequent deoxygenation of the water column and sediments (Malcolm *et al.*, 1998). In this study, the nutrient analysis was concentrated on the ammoniacal nitrogen.

iii. Biological oxygen demand

Biological oxygen demand is an indicator of water quality. Biochemical oxygen demand (BOD) and Chemical Oxygen Demand (COD) measure the capacity for consumption of oxygen by the biological and chemical constituents in the water. Dissolved Oxygen (DO) was measured to show the health of the ecosystems.

The parameters mentioned above were used to calculate the Water Quality Index (WQI) based on the Department of Environment (DOE) of Malaysia WQI which is represented by:

$$\mathbf{WQI = 0.22 * SIDO + 0.19 * SIBOD + 0.16 * SICOD + 0.15 * SIAN + 0.16 * SISS + 0.12 * SIpH}$$

Best-fit Equations for the Estimation of the Various Subindex Values

Subindex	Equation	Concentration
DO (in % saturation)	SIDO = 0 or 100 SIDO = $-0.395 + 0.030x^2 - 0.00020x^3$	for $x \leq 8$ or $x \geq 92$ for $8 < x < 92$
BOD	SIBOD = $100.4 - 4.23x$ SIBOD = $108 * e^{-0.055x} - 0.1x$	for $x \leq 5$ for $x > 5$
COD	SICOD = $-1.33x + 99.1$ SICOD = $103 * e^{-0.0157x} - 0.04x$	for $x \leq 20$ for $x > 20$
AN	SIAN = $100.5 - 105x$ SIAN = $94 * e^{-0.573x} - 5 * \|x-2\|$ SIAN = 0	for $x \leq 0.3$ for $0.3 < x < 4$ for $x \geq 4$
SS	SISS = $97.5 * e^{-0.00676x} + 0.05x$ SISS = $71 * e^{-0.0016x} - 0.015x$ SISS = 0	for $x \leq 100$ for $100 < x < 1000$ for $x \geq 1000$
pH	SIpH = $17.2 - 17.2x + 5.02x^2$ SIpH = $-242 + 95.5x - 6.67x^2$ SIpH = $-181 + 82.4x - 6.05x^2$ SIpH = $536 - 77.0x + 2.76x^2$	for $x < 5.5$ for $5.5 \leq x < 7$ for $7 \leq x < 8.75$ for $x \geq 8.75$

x = concentration in mg L^{-1} for all parameters except pH

* = multiply by

WQI = Water Quality Index

The general rating scale for Water Quality Index (WQI) % are as follows:

WQI = 80-100 - Clean Waters

WQI = 60-79 - Slightly Polluted Waters

WQI = 0 - 59 - Polluted Waters

Due to the recreational and aesthetics values associated with the Putrajaya Lake and the nature of the lake and wetlands ecosystem, the water quality parameters analysed were compared with the Class IIB – recreational use with body contact stipulated under the Proposed Interim National Water Quality Standards for Malaysia (INWQSM) (Table 6).

Table 6. Interim National Water Quality Standard for Malaysia (INWQSM)

Parameters	Units	Classes					
		I	IIA	IIB	III	IV	V
pH	-	6.5-8.5	6.5-9	6.5-9	5-9	5-9	-
DO	mg L^{-1}	7	5-7	5-7	3.5	3.0	1.0
BOD	mg L^{-1}	1	3	3	6	12	12
COD	mg L^{-1}	10	25	25	50	100	100
AN	mg L^{-1}	0.1	0.3	0.3	0.9	2.7	2.7
TSS	mg L^{-1}	25	50	50	150	300	300

Source: Annual Department of Environment (DOE) Report, 1992.

Notes:

CLASS I = conservation of natural environment water supply I – practically no treatment necessary. Fishery I – very sensitive aquatic species.

CLASS IIA = Water Supply II – conventional treatment required.
Fishery - sensitive aquatic species.

CLASS IIB = Recreational use with body contact.

CLASS III = Water Supply II – extensive treatment required.
Fishery III - common of economic value and tolerant species livestock drinking.

CLASS IV = Irrigation

CLASS V = None of the above

3.5 Laboratory Analysis

3.5.1 pH

The method used for determining pH was US EPA 150.1 (USEPA, 1983). The pH of the sample was determined electrometrically using either a glass electrode in combination with a reference potential or a combination electrode.

3.5.2 Dissolved Oxygen (DO)

The method used for determining dissolved oxygen was US EPA 360.1 (USEPA, 1983). The most common instrumental probes for determination of dissolved oxygen in water are dependent upon electrochemical reactions. Under steady-state conditions, the current or potential can be correlated with DO concentrations. Interfacial dynamics at the probe-sample interface are a factor in probe response and a significant degree of interfacial turbulence is necessary. For precision performance, turbulence should be constant.

3.5.3 Biochemical Oxygen Demand (BOD)

The method used was APHA 5210B (APHA, 1995) (Appendix 1). The method consists of filling with sample, to overflowing, an airtight bottle of the specified size and incubating it at the specified temperature for 5 days. After adding seed, dissolved oxygen was measured initially and after incubation, and the BOD was computed from the difference between initial and final DO.

3.5.4 Chemical Oxygen Demand (COD)

COD was analyzed using APHA 5220C (APHA, 1995) (Appendix 1). The mg L^{-1} COD results are defined as the milligrams of O_2 consumed per liter of sample. In this procedure, the sample was heated for two hours with a strong oxidizing agent, namely potassium dichromate. Oxidizable compounds react, reducing the dichromate ion ($Cr_2O_7^{2-}$) to green chromic ion (Cr^{3+}). Depending on the range of the test method, either Cr^{3+} or Cr^{6+} is measured.

3.5.5 Total Suspended Solids (TSS)

APHA 2540-D was used in the determination of total suspended solids (APHA, 1995). In the analysis, a well mixed sample of a known volume (200 ml) was filtered through a pre-weighed dried 0.45 μm glass a glass fiber filter membrane (Whatman GFC filter paper) using a Millipore filtration unit. The filter paper was then dried in the oven at 103 – 105 °C. The weight of the filter paper and the residue was recorded. The non-filterable residue or the total suspended solid was then calculated by the formula presented below:

$$\text{Total Suspended Solid (mg L}^{-1}\text{)} = \frac{(A - B) \times 100}{C}$$

Where,

A = [weight of filter (or filter and crucible) + residue] in mg

B = weight of filter (or filter and crucible) in mg

C = ml of sample filtered

3.5.6 Ammoniacal Nitrogen (AN)

Determination of Ammonia Nitrogen was carried out by applying the APHA-4500NH_3 B & C (Appendix 1). This method involves distillation and phenate determination. The water sample is buffered at pH 9.5 with borate buffer to decrease hydrolysis of cyanate and organic nitrogen. It is distilled into a sulfuric acid solution. The ammonia in the distillate is determined colorimetrically by phenate.

3.6 Statistical Analysis

Various statistical techniques were applied in data analyses which comprises of simple correlation, Two-way Analyses of Variance (ANOVA), Newman-Keules Test as Post Hoc Test and Multivariate Analysis.

Simple correlation analysis was used to assess the association between each of the water quality parameters and atmospheric data. Correlation coefficients near to 1.0 show a strong correlation.

Analysis of variance (ANOVA) followed by multiple range test (Newman Keul Test) was used to compare difference of water quality parameters with wetland cells and phases. A two-way analysis of variance was used to assess:

(i) Differences in water quality parameters of the three phases: Pre-construction, during construction and after construction phase.

(ii) Differences in water quality parameters of the three sites: Upper North Wetland cell, Central Wetland and Primary Lake.

(iii) Differences in water quality parameters in different seasons : dry and wet.

(iv) Differences in water quality parameters between different phases and locations.

(v) Differences in water quality parameters between different phases and seasons.

(vi) Differences in water quality parameters between different locations and seasons.

(vii) Differences in water quality parameters among phases, locations and seasons.

The Newman-Keules test was used to trace the significant difference resulting from the interaction of different phases and wetland cells for water quality parameters.

Multivariate analysis consists of method that are able to analyse complex data sets comprising of many variables (Legendre and Legendre, 1998) These techniques also permit the description of the variability of water quality data as a whole rather than the analysis of each water quality parameters independently. In contrast, conventional univariate statistical analysis like correlation and regression only enables the investigation of how pairs of variables are related.

Basically, this technique reduces the number of variables in the data set by finding linear combinations of those variables that best explain most of the observed variability (Grum *et al.*, 1997; Berzas *et al.*, 2000). Principal Component Analyses (PCA) was used to group the water quality parameters with the different wetland cells and phases. PCA is performed by using the Canonical Community Ordination (CANOCO) software version 4.0 Windows (Ter Brack and Similauer, 1998).

All statistical analysis was performed using the statistical software "Statistical Version 5". Before using the software, all data were log transformed [$\log_{10}(x+1)$] to achieve normality and homogeneity of variance before analysis (Zar, 1998). Level of significance were accepted at $p < 0.05$.